Characterisation and classification of arecanut-growing soils of Karnataka, India

R. Vasundhara*, N.B. Prakash¹, K.S. Anil Kumar and Rajendra Hegde

ICAR-National Bureau of Soil Survey and Land Use Planning, Bengaluru-560 024, Karnataka, India
¹University of Agricultural Sciences, Bengaluru-560 065, Karnataka, India

(Manuscript Received: 04-04-2020, Revised: 04-06-2020, Accepted: 15-06-2020)

Abstract

The present investigation was carried out to characterise the soils of areca based cropping systems considering soil type and agro-climatic variability. Ten typical soil profiles were studied representing five different agro-climatic zones (ACZs) of Karnataka, namely, Tumkur and Hesarghatta (Eastern Dry Zone), T. Narasipura and Maddur (Southern Dry Zone), H D Kote and Hassan (Southern Transition zone), Mudigere and Sirsi (Hilly Zone), and Belthangady and Kumata (Coastal Zone). These pedons were studied for their morphological characteristics, physical and chemical properties. The arecanut-growing soils of Karnataka are generally deep to very deep, non-gravelly and well-drained soils. Texture ranged from sandy clay loam to clay in sub-surface. Soils of coastal and hilly zones were strongly acidic and had high organic carbon. In contrast, other sites of the southern transition zone to southern and eastern dry zone soils were near neutral to moderately alkaline with medium to high organic carbon content. Cation exchange capacity (CEC) ranged from 2.5 to 32.6 cmol (p+) kg⁻¹ and base saturation varied from 21.9 to 99.6 per cent. The major taxa of the soils identified at sub-group level of soil taxonomy were Rhodic Kanhaplustalfs, Typic Haplustalfs, Rhodic Paleustalfs, Typic Rhodustalfs, Vertic Haplustepts, Typic Haplustepts, Ustic Kanhaplohumults, Kanhaplic Haplustults and Typic Paleustults.

Keywords: Agro-climatic zone, Alfisols, arecanut, characterisation, classification, Inceptisols, Ultisols

Introduction

India is the major producer and consumer of arecanut. It is cultivated in about 4.51 lakh ha with a production of 7.47 lakh tonnes. Arecanut or betel nuts (*Areca catechu* L.) have contributed significantly for the sustainable livelihoods of millions of farmers in the country. Cultivation of palms in India also has a rich diversity and varied history and possesses its own distinct historical and economic context of development. The cultivation of arecanut can be traced back to Vedic periods and used in veterinary and ayurvedic medicines. India ranks first in arecanut production in the world. Karnataka, Kerala and Assam. Karnataka state alone contributes in terms of area and production is 2,35,770 ha, and 63.2 per cent share respectively. This crop is being cultivated in different agro-climatic regions in Karnataka (Singh et al., 2013) from Eastern dry zone to Coastal zone.

Arecanut is capable of growing in a wide variety of soils. However, well-drained soils that have very good water holding capacity are the best suitable. It thrives in areas having a well-distributed annual rainfall of 750 mm to 4500 mm, and altitude up to 1000 meters above mean sea level (MSL). It is highly sensitive to moisture deficit and should be grown with assured irrigation facilities. A temperature range of 10 °C to 40 °C is best for its growth and yield. Arecanut, a major plantation crop
of Karnataka, is occupied by hilly, coastal, southern transitional, eastern and southern dry zones. Sufficient information on the characterisation of arecanut-growing soils towards sustainability is lacking. Hence, the present study was carried out in the arecanut-growing areas of Karnataka to characterise and classify the arecanut-growing soils.

Materials and methods

Soil sampling

The soil profile samples were collected from arecanut plantations covering five different agro-climatic zones (ACZs), with varying rainfall, topography, soil type and climatic characteristics including cropping patterns. The profile samples were collected up to a depth of 150 cm or shallower depth limited by a rock or hard substratum. Two profiles from each five different ACZs of Karnataka were selected for the study based on the variability in site characteristics and productivity of arecanut. The location of profile samples collected from different ACZs and the details are shown in Table 1 and Figure 1. Soil samples were drawn for the laboratory analysis from all horizons layers to classify the physical and chemical properties. These soil samples were analysed for different parameters by following standard procedures (Table 2). Morphological properties of the soils were studied following the Soil Survey Manual (Soil Survey Staff, 2014).

Site description

The locations and site characteristics are given in Table 1. Eastern dry, Southern dry and Southern transitional zones experience hot moist semi-arid climate with average annual rainfall ranging from 750 mm to 950 mm and length of dry period >150 days. Hilly and Coastal zones have a hot, humid climate receiving an annual average rainfall between 1500 and 4500 mm with 90 days of dry period. The soil temperature regime is isohyperthermic for all the studied soils as they have a difference of less than 5°C between mean summer temperature and mean winter temperatures at a depth of 50 cm and a mean annual temperature of 22°C or higher.

Results and discussion

Morphological characteristics

The morphological characteristics of the arecanut soils are presented in Table 3. The soils were deep to very deep ranging from 112 cm to 157 cm. Soil profile P3 from T. Narasipur recorded lower depth (107 cm), and Hassan soil pedon (P6) was very deep (157 cm). The soils were reddish-brown to dark yellowish brown in colour with a hue of 2.5 YR to 10 YR, value ranging from 2 to 5 and chroma of 1 to 6. Soil colour of pedons other than southern dry zone and uplands region described as very deep.
transitional zone (Pedons 5 and Pedons 6) varied from dark brown to reddish-brown in surface and brown to dark red in sub-surface horizons. Soil pedons 5 and 6 were dark yellowish-brown to dark brown in surface and dark yellowish-brown to very dark grey in sub-surface due to high transport of soil organic carbon. Soil structure varied from weak to moderate sub-angular blocky both in surface and sub-surface horizons. Gogoi et al. (2018) also observed sub-angular blocky structure for soils of Assam.

Texture varied from sandy clay loam to clay in sub-surface. Thus, wide textural variation was observed in arecanut-growing soils: sandy loam to

Table 2. Methods of soil analysis

| Sl. No. | Parameter                     | Method and Reference                      |
|--------|-------------------------------|------------------------------------------|
| 1.     | Particle size analysis        | International pipette method, Jackson (1973) |
| 2.     | Soil reaction                 | Potentiometry, Jackson (1973)             |
| 3.     | Electrical conductivity       | Conductometry, Jackson (1973)             |
| 4.     | Organic carbon                | Wet oxidation, Walkley and Black (1934)   |
| 5.     | Cation exchange capacity      | Sarma et al. (1987)                       |
| 6.     | Bulk density                  | Core method, Jackson (1973)               |
sandy clay in P1, sandy clay to clay in P2 and P6, sandy clay loam to clay in P3 and P4, clay loam to clay in P7, clay in P5 and P8, clay loam to sandy clay in P9, sandy loam to clay in P10. Generally, heavy texture in sub-surface horizon may be due to illuviation of clay from surface horizons to sub-surface horizons. High sand and low clay content in surface soils of ferruginous soils of the semi-arid tropics was reported by Chandran et al. (2009). Clay loam to clay in texture was found in the soils of

| Horizon | Depth (cm) | Colour (moist) | Structure | Texture |
|---------|------------|----------------|-----------|---------|
| Ap      | 0-28       | Dark brown     | 7.5YR 3/4 | 1msbk   | sl      |
| Bt1     | 28-47      | Reddish brown  | 5YR 4/4   | 1msbk   | scl     |
| Bt2     | 47-63      | Reddish brown  | 5YR 4/4   | 2msbk   | sc      |
| Bt3     | 63-87      | Dark red       | 2.5YR 3/6 | 2msbk   | sc      |
| Bt4     | 87-115     | Dark red       | 2.5YR 3/6 | 2msbk   | sc      |
| Bt5     | 115-140    | Dark red       | 2.5YR 3/6 | 2msbk   | sc      |

| Horizon | Depth (cm) | Colour (moist) | Structure | Texture |
|---------|------------|----------------|-----------|---------|
| Ap      | 0-16       | Reddish brown  | 5YR 4/4   | 2msbk   | sc      |
| Bt1     | 16-36      | Reddish brown  | 5YR 4/6   | 2msbk   | sc      |
| Bt2     | 36-63      | Reddish brown  | 5YR 4/6   | 2msbk   | c       |
| Bt3     | 63-102     | Reddish brown  | 5YR 4/6   | 2msbk   | c       |
| Bt4     | 102-123    | Reddish brown  | 5YR 4/6   | 2msbk   | sc      |

| Horizon | Depth (cm) | Colour (moist) | Structure | Texture |
|---------|------------|----------------|-----------|---------|
| Ap      | 0-16       | Dark brown     | 7.5YR 3/2 | 2msbk   | scl     |
| Bt1     | 16-36      | Dark reddish brown | 5YR 3/4 | 1msbk   | sc      |
| Bt2     | 36-60      | Dark reddish brown | 5YR 3/4 | 1msbk   | sc      |
| Bt3     | 60-83      | Dark reddish brown | 2.5YR 3/4 | 2msbk | c       |
| Bt4     | 83-112     | Dark reddish brown | 2.5YR 3/4 | 2msbk | c       |
| BC      | 112-130    | Dark reddish brown | 2.5YR 3/4 | 2msbk | c       |

| Horizon | Depth (cm) | Colour (moist) | Structure | Texture |
|---------|------------|----------------|-----------|---------|
| Ap      | 0-13       | Reddish brown  | 5YR 4/4   | 2msbk   | sc      |
| Bt1     | 13-28      | Yellowish red   | 5YR 4/6   | 2msbk   | sc      |
| Bt2     | 28-47      | Yellowish red   | 5YR 4/6   | 2msbk   | sc      |
| Bt3     | 47-72      | Dark reddish brown | 5YR 3/4 | 2msbk   | scl     |
| Bt4     | 72-105     | Dark reddish brown | 5YR 3/4 | 2msbk | c       |
| BC      | 105-122    | Dark reddish brown | 5YR 3/4 | 2msbk | scl     |

| Horizon | Depth (cm) | Colour (moist) | Structure | Texture |
|---------|------------|----------------|-----------|---------|
| Ap      | 0-13       | Dark yellowish brown | 10YR 4/4 | 2msbk | c       |
| Bw1     | 13-31      | Dark yellowish brown | 10YR 3/4 | 2msbk | c       |
| Bw2     | 31-57      | Dark yellowish brown | 10YR 3/6 | 2msbk | c       |
| Bw3     | 57-89      | Dark yellowish brown | 10YR 3/6 | 2msbk | c       |
| Bw4     | 89-117     | Dark yellowish brown | 10YR 3/4 | 2msbk | c       |
| Bw5     | 117-131    | Dark yellowish brown | 10YR 3/4 | 2msbk | c       |
### P6: Hassan (Southern transitional zone)

| Horizon | Depth (cm) | Color      | Munsell Color | Soil Type |
|---------|------------|------------|---------------|-----------|
| Ap      | 0-17       | Dark brown | 10YR 3/3     | 1msbk sc  |
| Bw1     | 17-36      | Dark yellowish brown | 10YR 3/4 | 2msbk sc  |
| Bw2     | 36-57      | Dark yellowish brown | 10YR 4/4 | 2msbk sc  |
| Bw3     | 57-81      | Dark greyish brown | 10YR 4/2 | 2msbk sc  |
| Bw4     | 81-102     | Dark gray   | 10YR 4/1     | 2msbk sc  |
| Bw5     | 102-130    | Very dark gray | 10YR 3/1  | 2msbk sc  |
| Bw6     | 130-157    | Black      | 10YR 2/1     | 2msbk c   |

### P7: Mudigere (Hilly zone)

| Horizon | Depth (cm) | Color      | Munsell Color | Soil Type |
|---------|------------|------------|---------------|-----------|
| Ap      | 0-20       | Reddish brown | 5YR 4/3     | 2msbk c   |
| Bt1     | 20-54      | Reddish brown | 2.5YR 4/4   | 2msbk c   |
| Bt2     | 54-95      | Reddish brown | 2.5YR 4/4   | 2msbk c   |
| Bt3     | 95-135     | Red         | 2.5YR 5/6    | 2msbk cl  |

### P8: Sirsi (Hilly zone)

| Horizon | Depth (cm) | Color      | Munsell Color | Soil Type |
|---------|------------|------------|---------------|-----------|
| Ap      | 0-17       | Brown      | 7.5YR 4/3     | 1msbk c   |
| Bt1     | 17-44      | Brown      | 7.5YR 4/3     | 1msbk c   |
| Bt2     | 44-72      | Brown      | 7.5YR 4/2     | 1msbk c   |
| Bt3     | 72-105     | Brown      | 7.5YR 4/3     | 1msbk c   |
| Bt4     | 105-130    | Brown      | 7.5YR 5/3     | 1msbk c   |

### P9: Belthangady (Coastal zone)

| Horizon | Depth (cm) | Color      | Munsell Color | Soil Type |
|---------|------------|------------|---------------|-----------|
| Ap      | 0-16       | Brown      | 7.5YR 4/4     | 1msbk cl  |
| Bt1     | 16-36      | Strong brown | 7.5YR 4/6   | 1msbk scl |
| Bt2     | 36-65      | Strong brown | 7.5YR 4/6   | 1msbk scl |
| Bt3     | 65-105     | Strong brown | 7.5YR 4/6   | 1msbk c   |
| Bt4     | 105-130    | Yellowish red | 5YR 4/6    | 1msbk scl |
| Bt5     | 130-150    | Yellowish red | 5YR 4/6    | 1msbk sc  |

### P10: Kumata (Coastal zone)

| Horizon | Depth (cm) | Color      | Munsell Color | Soil Type |
|---------|------------|------------|---------------|-----------|
| Ap      | 0-15       | Reddish brown | 5YR 4/3     | 1msbk sl  |
| Bt1     | 15-36      | Reddish brown | 5YR 4/4     | 1msbk scl |
| Bt2     | 36-55      | Dark reddish brown | 5YR 3/4  | 1msbk cl  |
| Bt3     | 55-70      | Reddish brown | 5YR 4/4     | 1msbk c   |
| Bt4     | 70-85      | Reddish brown | 5YR 4/4     | 1msbk c   |
| Bt5     | 85-120     | Reddish brown | 5YR 4/4     | 1msbk c   |

Hilly zone soils. Prabhavati et al. (2017) reported that the soils of the hilly area generally have high clay content in sub-surface due to high degree of weathering as a result of higher precipitation, temperature and clay illuviation.

**Physicochemical properties of soil**

Data on particle size distribution (Table 4) showed that the sand content in eastern and southern dry zone soils (P1 to P4) ranged from 31.7 to 64.7 per cent within the profile. High sand content was seen at the surface horizon than the sub-surface horizon. It was due to the erosion of fine particles from higher slopes to lower under high rainfall situations. Similar findings were reported by Gogoi et al. (2018). Silt content in soil was distributed in uneven form, and it varied from 12.9 to 29.8...
The per cent clay content varied from 12.0 to 53.0 and increased with depth (P1 to P4), whereas soil pedons P6, P8, P9 and P10 showed a declining trend. Higher content of sand at the surface soil (0-30 cm) in soil pedons (P1 to P5, P7) was observed. The soil BD in different ACZs of arecanut crop, varied from 1.20 to 1.64 Mg m⁻³. In general, BD was lower in the surface layer and increased with depth, and these results are prominent in EDZ and SDZ profiles (Table 3). In STZ, HZ and CZ soil pedons, there was no regular trend in BD. Higher BD values were observed in SDZ, and EDZ soil pedons and least BD was noticed in HZ soil pedons.

The soil pH of EDZ, SDZ and STZ samples varied from neutral to strongly alkaline (7.21 to 8.59.) whereas in HZ and CZ strongly acid to slightly acid (4.99 to 5.65). High pH was observed in soil pedons P3 to P5 (Table 4). Moderate to strongly acidic soil reaction in HZ and CZ soils were mainly due to the heavy rainfall, which caused leaching of bases and thereby reducing the soil pH. Badrinath et al. (1995) reported that southern parts (CZ and HZ) of Karnataka were distributed with acidic soil, which affects crop yield. Slightly, moderately or strongly alkaline soil reaction in other areas was due to accumulation of basic salts from the weathered parent material. Electrical conductivity values indicated non-saline nature of soils of the study area.

The organic carbon content in the soils of arecanut crops ranged from 0.76 to 2.12 per cent in the surface layer. In arecanut crop, the P5 and P1 soil profiles showed higher and least organic carbon content, respectively. High organic carbon content in P5 might be due to clay mineralogy, clay fraction, and biochemical environment of the soil such as high pH favours higher production of biomass. It is very much evidenced (Table 4) that clay content of P5 soil pedons was high compared to other pedons. An overall depth-wise decreasing trend was observed for organic carbon in all zones profile (P1 to P10). The lowermost depth had the least organic carbon content compared to surface and sub-surface layers. Higher values of organic carbon were observed in surface soils. The higher build-up of soil organic carbon on surface layers under crops may be attributed to the higher accumulation of recyclable biomass. The concentration and turnover of SOC are usually highest in the surface soil (Conant et al., 2001).

Lower CEC recorded in CZ indicates better soil development while higher CEC was observed in STZ soil pedons (Table 5). CEC of soil samples ranged from 6.51 to 26.0 cmol (p+) kg⁻¹. A high range in CEC was noticed in pedon 5 (9.32 to 26.0 cmol (p+) kg⁻¹) followed by SDZ (9.28 to 21.32 cmol (p+) kg⁻¹) and EDZ (10.71 to 17.45 cmol (p+) kg⁻¹). Lower CEC was observed in HZ and CZ and ranged from 6.61 to 10.08 cmol (p+) kg⁻¹ and 6.51 to 8.7 cmol (p+) kg⁻¹, respectively. Organic carbon and clay content play a major role in influencing the CEC (Table 4). Organic carbon content decreased with depth in all soils. Still, CEC showed increasing trend indicating the mineralogy of the soils, which probably had a larger role in regulating CEC in these soils than the organic matter. Saikh et al. (1998) observed a poor correlation between CEC and organic carbon in ferruginous soils under deciduous forest and attributed this change in CEC to mineralogy. Mineralogy of soils owes to the proximity of parent material influenced by the dominance of 1:1 type of clay minerals and sesquioxides.

The distribution of exchangeable Ca²⁺, Mg²⁺, K⁺ and Na⁺ in piedmont plain soil, ranged from 0.62 to 15.6, 0.22 to 13.35, 0.01 to 2.01 and 0.01 to 0.55 mg kg⁻¹, respectively. Irrespective of the agro-climatic zone, Ca²⁺ was the dominant exchangeable cation followed by Mg²⁺, K⁺ and Na⁺. The dominance of exchangeable Ca²⁺ in the semi-arid (EDZ and SDZ pedons) soils were in agreement with the findings of earlier workers on soils of the semi-arid region (Vasundhara et al., 2018). In general, the distribution of exchangeable Na⁺ and K⁺ declined with increasing depth. In high rainfall regions (HZ and CZ pedons) small amounts of exchangeable K⁺ and Na⁺ in these soil pedons may be due to preferential losses of monovalent cations over divalent cations in leaching along with percolating water (Jenny, 1931).

CEC/clay ratio varied from 0.06 to 0.69, which indicates the type of clay minerals in different profiles. The soil profiles P2, P3, and P6 pointed to semi-active clays, whereas profiles P1, P7, P9, and P10 had sub-activity clays. P5 pointed to super...
Arecanut-growing soils of Karnataka

Table 4. Physical and chemical properties

| Horizon | Depth (cm) | Sand (%) | Clay (%) | Silt (%) | B.D (Mg m⁻³) | pH | EC (dS m⁻¹) | O.C (%) |
|---------|------------|----------|----------|----------|---------------|----|-------------|---------|
| P1: Kunigal (Fine-loamy, mixed, sub active, isohyperthermic, Rhodic Kanhaplustalfs) |
| Ap      | 0-28       | 81.3     | 12.0     | 6.7      | 1.32          | 7.64| 0.17        | 0.76    |
| Bt1     | 28-47      | 53.1     | 31.0     | 15.9     | 1.41          | 7.55| 0.14        | 0.51    |
| Bt2     | 47-63      | 57.1     | 35.4     | 7.5      | 1.52          | 7.63| 0.14        | 0.36    |
| Bt3     | 63-87      | 51.6     | 41.3     | 7.1      | 1.55          | 7.54| 0.20        | 0.23    |
| Bt4     | 87-115     | 52.0     | 40.5     | 7.5      | 1.55          | 7.42| 0.24        | 0.19    |
| Bt5     | 115-140    | 50.8     | 41.4     | 7.8      | 1.55          | 7.48| 0.14        | 0.23    |
| P2: Hesarghatta (Fine, mixed, semi-active, isohyperthermic, Typic Haplustalfs) |
| Ap      | 0-16       | 52.1     | 35.4     | 12.5     | 1.62          | 7.48| 0.37        | 1.03    |
| Bt1     | 16-36      | 46.9     | 42.8     | 10.3     | 1.19          | 7.68| 0.31        | 0.56    |
| Bt2     | 36-63      | 44.1     | 44.8     | 11.1     | 1.40          | 7.90| 0.22        | 0.44    |
| Bt3     | 63-102     | 41.7     | 45.7     | 12.6     | 1.50          | 7.99| 0.18        | 0.44    |
| Bt4     | 102-123    | 41.2     | 46.7     | 12.1     | 1.60          | 7.78| 0.15        | 0.36    |
| P3: T. Narasipura (Fine, mixed, semi-active isohyperthermic, Rhodic Paleustalfs) |
| Ap      | 0-16       | 68.7     | 23.3     | 8.0      | 1.39          | 8.40| 0.16        | 1.13    |
| Bt1     | 16-36      | 61.1     | 35.8     | 3.1      | 1.49          | 8.53| 0.13        | 0.36    |
| Bt2     | 36-60      | 51.8     | 36.4     | 11.8     | 1.55          | 8.18| 0.14        | 0.28    |
| Bt3     | 60-83      | 47.3     | 46.9     | 5.8      | 1.47          | 8.24| 0.16        | 0.24    |
| Bt4     | 83-112     | 49.3     | 46.7     | 4.0      | 1.52          | 8.39| 0.17        | 0.12    |
| Bt5     | 112-130    | 48.2     | 45.0     | 6.8      | 1.49          | 8.59| 0.28        | 0.08    |
| P4: Maddur (Clayey, skeletal mixed active isohyperthermic, Typic Haplustalfs) |
| Ap      | 0-13       | 53.3     | 37.0     | 9.7      | 1.34          | 7.89| 0.46        | 1.78    |
| Bt1     | 13-28      | 47.8     | 41.4     | 10.8     | 1.37          | 7.91| 0.18        | 0.52    |
| Bt2     | 28-47      | 45.1     | 43.6     | 11.3     | 1.44          | 7.82| 0.13        | 0.44    |
| Bt3     | 47-72      | 70.4     | 25.8     | 3.8      | 1.44          | 7.97| 0.11        | 0.48    |
| Bt4     | 72-105     | 38.5     | 45.1     | 16.4     | 1.32          | 7.85| 0.10        | 0.30    |
| Bt5     | 105-122    | 50.8     | 34.4     | 14.8     | 1.46          | 7.82| 0.11        | 0.28    |
| P5: H.D Kote (Fine, smectitic, super-active isohyperthermic, Vertic Haplustepts) |
| Ap      | 0-13       | 31.7     | 53.0     | 15.3     | 1.21          | 8.17| 0.16        | 2.12    |
| Bw1     | 13-31      | 33.7     | 46.5     | 19.8     | 1.34          | 8.30| 0.34        | 1.65    |
| Bw2     | 31-57      | 34.5     | 51.4     | 14.1     | 1.21          | 8.36| 0.30        | 1.13    |
| Bw3     | 57-89      | 31.8     | 46.9     | 21.3     | 1.33          | 8.32| 0.22        | 0.81    |
| Bw4     | 89-117     | 44.9     | 45.5     | 9.6      | 1.66          | 8.44| 0.15        | 0.57    |
| Bw5     | 117-131    | 49.1     | 38.0     | 12.9     | 1.64          | 8.10| 0.18        | 0.53    |
| P6: Hassan (Fine, mixed, semi-active, isohyperthermic, Typic Haplustepts) |
| Ap      | 0-17       | 62.8     | 35.3     | 1.9      | 1.44          | 7.32| 0.19        | 1.12    |
| Bw1     | 17-36      | 62.1     | 36.0     | 1.9      | 1.60          | 7.43| 0.20        | 0.40    |
| Bw2     | 36-57      | 61.2     | 35.9     | 2.9      | 1.36          | 7.45| 0.12        | 0.28    |
| Bw3     | 57-81      | 64.5     | 35.0     | 0.5      | 1.44          | 7.26| 0.05        | 0.32    |
| Bw4     | 81-102     | 56.8     | 42.6     | 0.6      | 1.43          | 7.23| 0.05        | 0.24    |
| Bw5     | 102-130    | 45.8     | 44.9     | 9.3      | 1.59          | 7.21| 0.04        | 0.53    |
| Bw6     | 130-157    | 45.6     | 43.9     | 10.5     | 1.34          | 7.22| 0.04        | 0.68    |
active clays, *i.e.*, smectitic type. The base saturation ranged from 33.4 to 99.6 per cent. Soils were highly base saturated except hilly and coastal soils as indicated by P7 to P10 due to high rainfall water takes bases along with it to down.

**Classification of soils**

The studied arecanut-growing soils were classified, which is presented in Table 6 as per USDA taxonomy.

Soil pedons from the eastern and southern dry zones (P1 to P4) of arecanut-growing soils were classified as Alfisols because of the presence of argillic horizon with base saturation of >35 per cent and sub-order of Ustalfs owing to the ustic moisture regimes, and this is keyed out as Rhodic Kanhaplustalfs (pedon 1), Typic Haplustalfs (pedon 2) and Rhodic Paleustalfs (pedon 3) at the great group level. Kanhaplustalfs (pedon 1) as they have a CEC of 16 cmol (+) kg⁻¹ clay or less (by NH₄OAc pH 7) in 50 per cent and its upper 100 cm is of the argillic horizon.

However, Pedon 2 and 4 in the argillic horizon did not display a hue of 2.5 YR. Hence, these pedons were logically classified as Haplustalfs at the great group level. Finally, the pedons were classified into Typic Haplustalfs at sub-group level due to the absence of lithic or paralithic contact, cracks, pumice like fragments and also due to the presence of argillic horizon with >75 percentage base saturation. Typic Haplustalfs have deep red soils and belong to Haplustalfs great group. At sub-group level, these two soils had been keyed out as Typic Haplustalfs. At the family level, the particle size class is fine (>35 % clay) with mixed mineralogy (pedon 2). And at sub-soil horizons the presence of
### Table 5. Chemical properties of arecanut-growing pedons

| Pedon no. | Depth (cm) | Exchangeable cations (cmol (p⁺) kg⁻¹) | CEC cmol (p⁺) kg⁻¹ | B S % | CEC/cm² clay |
|-----------|------------|--------------------------------------|-------------------|-------|--------------|
|           |            | Ca²⁺ | Mg²⁺ | K⁺ | Na⁺ | sum |            |               |       |              |
| **Kunigal** |            |      |      |    |     |  |            |               |       |              |
| 0-28      | 3.95       | 1.12 | 0.22 | 0.12 | 5.41 | 8.32 | 65.0 | 0.69 |
| 28-47     | 4.73       | 1.61 | 0.33 | 0.14 | 6.81 | 7.78 | 87.5 | 0.25 |
| 47-63     | 4.58       | 1.81 | 0.24 | 0.21 | 6.84 | 9.94 | 68.8 | 0.28 |
| 63-87     | 4.76       | 2.02 | 0.28 | 0.22 | 7.28 | 9.40 | 77.5 | 0.23 |
| 87-115    | 4.36       | 1.92 | 0.24 | 0.23 | 6.75 | 8.53 | 79.2 | 0.21 |
| 115-140   | 4.38       | 1.93 | 0.24 | 0.17 | 6.72 | 8.53 | 78.8 | 0.21 |
| **Hesargatta** |          |      |      |    |     |  |            |               |       |              |
| 0-16      | 9.29       | 4.5  | 0.82 | 0.11 | 14.72 | 15.44 | 95.3 | 0.44 |
| 16-36     | 4.61       | 3.91 | 0.26 | 0.22 | 9.00 | 10.8 | 83.3 | 0.25 |
| 36-63     | 6.66       | 5.65 | 0.14 | 0.36 | 12.81 | 15.34 | 83.5 | 0.34 |
| 63-102    | 12.10      | 6.36 | 0.15 | 0.42 | 19.03 | 20.30 | 93.7 | 0.44 |
| 102-123   | 6.43       | 4.29 | 0.13 | 0.29 | 11.14 | 12.31 | 90.5 | 0.26 |
| **T. Narasipura** |        |      |      |    |     |  |            |               |       |              |
| 0-16      | 4.10       | 7.44 | 0.4  | 0.21 | 12.15 | 12.2 | 99.6 | 0.50 |
| 16-36     | 4.00       | 7.19 | 0.15 | 0.21 | 11.55 | 12.2 | 94.7 | 0.34 |
| 36-60     | 3.70       | 6.65 | 0.14 | 0.31 | 10.80 | 12.74 | 84.8 | 0.34 |
| 60-83     | 5.37       | 9.78 | 0.05 | 0.42 | 15.62 | 20.09 | 77.8 | 0.46 |
| 83-112    | 5.44       | 9.71 | 0.19 | 0.37 | 15.71 | 17.50 | 89.8 | 0.37 |
| 112-130   | 6.61       | 11.68 | 0.23 | 0.47 | 11.14 | 20.95 | 90.6 | 0.45 |
| **Maddur** |            |      |      |    |     |  |            |               |       |              |
| 0-13      | 8.98       | 5.46 | 0.81 | 0.31 | 15.56 | 15.88 | 98.0 | 0.43 |
| 13-28     | 6.53       | 3.97 | 0.33 | 0.48 | 11.31 | 12.31 | 91.9 | 0.29 |
| 28-47     | 8.29       | 3.68 | 0.31 | 0.42 | 12.70 | 13.18 | 96.4 | 0.31 |
| 47-72     | 12.08      | 5.30 | 0.38 | 0.51 | 18.27 | 18.47 | 98.9 | 0.72 |
| 72-105    | 12.38      | 5.57 | 0.45 | 0.53 | 18.93 | 19.22 | 98.5 | 0.42 |
| 105-122   | 13.74      | 5.17 | 0.41 | 0.55 | 19.87 | 20.09 | 98.9 | 0.57 |
| **H D Kote** |          |      |      |    |     |  |            |               |       |              |
| 0-13      | 15.60      | 13.35 | 2.03 | 0.42 | 31.40 | 32.6 | 96.3 | 0.62 |
| 13-31     | 14.46      | 12.42 | 1.35 | 0.37 | 28.60 | 29.2 | 98.1 | 0.63 |
| 31-57     | 11.83      | 10.42 | 0.64 | 0.32 | 23.21 | 29.5 | 78.7 | 0.57 |
| 57-89     | 9.96       | 8.13 | 0.46 | 0.25 | 18.8 | 24.3 | 77.3 | 0.52 |
| 89-117    | 4.96       | 9.15 | 0.28 | 0.21 | 14.60 | 15.6 | 93.9 | 0.34 |
| 117-131   | 7.80       | 8.13 | 0.21 | 0.18 | 16.32 | 22.0 | 74.1 | 0.52 |
| **Hassan** |            |      |      |    |     |  |            |               |       |              |
| 0-17      | 6.31       | 3.708 | 0.191 | 0.46 | 10.66 | 11.6 | 92.0 | 0.34 |
| 17-36     | 6.08       | 3.35 | 0.06 | 0.50 | 9.99 | 10.8 | 92.0 | 0.30 |
| 36-57     | 6.01       | 3.58 | 0.06 | 0.30 | 9.95 | 10.9 | 91.0 | 0.30 |
| 57-81     | 5.66       | 3.77 | 0.14 | 0.16 | 9.73 | 10.4 | 94.0 | 0.30 |
| 81-102    | 5.99       | 3.76 | 0.16 | 0.14 | 10.05 | 11.3 | 89.0 | 0.27 |
| 102-130   | 9.90       | 5.15 | 0.18 | 0.24 | 15.47 | 17.9 | 87.0 | 0.39 |
| 130-157   | 11.48      | 5.45 | 0.16 | 0.29 | 17.37 | 20.6 | 84.0 | 0.46 |
| **Mudigere** |          |      |      |    |     |  |            |               |       |              |
| 0-20      | 2.76       | 0.81 | 0.17 | 0.07 | 3.81 | 9.83 | 38.8 | 0.22 |
| 20-54     | 3.70       | 0.78 | 0.04 | 0.02 | 4.54 | 8.32 | 54.6 | 0.20 |
| 54-95     | 3.48       | 0.99 | 0.04 | 0.09 | 4.60 | 8.10 | 56.8 | 0.19 |
| 95-135    | 2.65       | 0.77 | 0.04 | 0.07 | 3.53 | 7.13 | 49.5 | 0.19 |
coarse fragments >35 per cent grouped as clayey-skeletal particle size class (pedon 4).

Rhodic Paleustalfs (Pedon 3) have argillic horizon that has a clayey particle size class throughout one or more sub-horizons in its upper part. At its upper boundary, a clay increase either 20 per cent or more within a vertical distance of 7.5 cm or 15 per cent or more within a vertical distance of 2.5 cm is assigned to great group Paleustalfs and a hue of 2.5 YR or redder colour and value, moist, 3 or at least half of the argillic horizon lead to Rhodic (Table 4).

Table 6. Classification of the soils

| Agroclimatic zone | Serial no. | Location | Soil Classification |
|-------------------|------------|----------|---------------------|
| Eastern dry zone  | Pedon 1    | Kunigal  | Fine-loamy, mixed, isohyperthermic, Rhodic Kanhaplustalfs |
|                   | Pedon 2    | Hesargatta | Fine, mixed, semi-active, isohyperthermic, Typic Haplustalfs |
| Southern dry zone | Pedon 3    | T. Narasipura | Fine, mixed, semi-active isohyperthermic, Rhodic Paleustalfs |
|                   | Pedon 4    | Maddur  | Clayey, skeletal, mixed, active isohyperthermic, Typic Haplustals |
| Southern transitional zone | Pedon 5 | H D Kote | Fine, smectitic, super active isohyperthermic, Vertic Haplustepts |
|                   | Pedon 6    | Hassan  | Fine, mixed, semi-active, isohyperthermic, Typic Haplustepts |
| Hilly zone        | Pedon 7    | Mudigere | Fine, kaolinitic, sub-active, isohyperthermic, Typic Rhodustalfs |
|                   | Pedon 8    | Sirsi   | Clayey-skeletal, kaolinitic, isohyperthermic, Ustic Kanhaplohumults |
| Coastal zone      | Pedon 9    | Belthangady | Fine, kaolinitic, sub-active, isohyperthermic, Kanhaplic Haplustults |
|                   | Pedon 10   | Kumata  | Fine, mixed, sub-active, isohyperthermic, Typic Paleustults |
sub-group, respectively. Vertic Haplustepts have cracks within 125 cm of the mineral soil surface that are 5 mm or more wide through a thickness of 30 cm or more for some time in normal years, and slickensides or wedge-shaped aggregates in a layer 15 cm or more thick that has its upper boundary within 125 cm of the mineral soil surface. However, pedon 6 did not display any intergradations with other taxa or an extra shift from the central concept. This soil represented the central concept of sub-group. Hence, this pedon was logically grouped under Typic Haplustepts.

Families are differentiated with particle size, mineralogy, reaction, soil temperature and a few others. The particle size class of pedon 5 and 6 were fine having 35 to 60 per cent or more (by volume) clay. The mineralogy classes were based on the less than 0.002 mm fraction, which is smectitic for the black soils (Pedon 5) and mixed for pedons 6 and 7 are the Typic Rhodustalfs that do not have a lithic contact within 50 cm of the soil surface and have a CEC of 24 or more cmol (+) kg\(^{-1}\) clay (by 1N NH\(_4\)OAc, pH 7) in the major part of the argillic horizon or the major part of the upper 100 cm of the argillic horizon if the argillic horizon is thicker than 100 cm.

Among the arecanut-growing soils studied from the hilly and coastal zones, 3 soil profiles (Pedons 8, 9 and 10) belong to Ultisols owing to less than 35 per cent base saturation (Table 6). Pedon 8 grouped under Humults sub-order due to very high levels of soil organic carbon in the top 50 cm (>0.9 \%) and pedon 9 and 10 keyed out as Ustults at sub-order level that have an ustic moisture regime. Pedon 8 showed CEC clay ratio of <0.16 and low ECEC by clay ratio of <0.12, has kandic horizon and classified as Kanhaplohumults. Pedon 9 having Ustic sub-order that have CEC of less than 24 cmol(+)/kg\(^{-1}\) clay in 50 per cent or more of the argillic horizon as less than 100 cm thickness belongs to Kanhaplic Haplustults. Pedon 10 classified as Typic Paleustults that do not have a lithic, paralithic, or petroferric contact within 150 cm of the mineral soil surface and have 5 per cent or more skeletons on faces of peds in the layer that has showed no reduction of 20 per cent clay content. Low CEC, low bases and high clay content indicate the soils belong to hot, humid tropical origin and have a dominance of low activity clays in tropics noted by many researchers like Nair et al. (2018) and Patil and Anil Kumar (2014).

**Conclusion**

The arecanut-growing soils developed from different parent materials, climate and physiography, which made significant variations in morphological, physical and chemical properties. Higher organic carbon content at the surface horizon and declined with depth. Light soil texture in the surface, becomes heavy in sub-surface. They are deep to very deep. Very strongly acid to strongly alkaline in soil reaction with high organic carbon content belonging to Alfisols, Inceptisols and Ultisols. The CEC ranged from low to medium and exchange complex was dominated by Ca\(^{2+}\) followed by Mg\(^{2+}\), K\(^{+}\) and Na\(^{+}\) ions. The major taxa of soils identified at sub-group level of Soil Taxonomy are Rhodic Kanhaplustalfs, Typic Haplustalfs, Rhodic Paleustalfs for Eastern and Southern dry zone soils, Vertic and Typic Haplustepts for Southern transitional zones of arecanut-growings soils. Kanhaplohumults, Kanhaplic Haplustults and Typic Paleustults for hilly and Coastal zone soil.

**References**

Badrinath, M.S., Chidanandappa, H.M., Ali, H.M. and Chamegowda, T.C. 1995. Impact of lime on rice yield and available potassium in coastal acid soils of Karnataka. *Agropedology* 5: 43-46.

Chandran, P., Ray, S.K., Durge, S.L., Raja, P., Nimkar, A.M., Battacharyya, T. and Pal, D.K. 2009. Scope of horticultural land use system in enhancing carbon sequestration in ferruginous soils of the semi-arid tropics. *Current Science* 97(7): 1039-1046.

Conant, R., Paustian, K. and Elliott, E. 2001. Grassland management and conversion into grassland: Effects on soil carbon. *Ecological Applications* 11: 343-355.

Gogoi, A., Talukdar, M.C., Basumary, A. and Baruah, U. 2018. Characterisation and classification of the soils of Dorika Watershed of Assam using GIS and remote sensing techniques. *Journal of the Indian Society of Soil Science* 66(4): 341-350.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India, New Delhi, 498 p.

Jenny, H. 1931. *Behaviour of potassium and sodium during the process of soil formation*. University of Missouri Agricultural Experimental Station Research Bulletin, 162p.
Nair, K.M., Anil Kumar, K.S., Ramesh Kumar, S.C., Ramamurty, V., Lalitha, M., Srinivas, S., Arti Koyal, Parvathy, S., Sujatha, K., Shivanand, R. Hegde and Singh, S.K. 2018. Coconut-growing soils of Kerala: Characteristics and classification. *Journal of Plantation Crops* 46(2): 75-83.

Patil, S. and Anil Kumar. K.S. 2014. Characterisation and classification of soils of West Coast of Southern Karnataka. *Journal of the Indian Society of Soil Science* 62(4): 408-413.

Prabhavati, Dasog, G.S., Sahrawat, K.L., Patil, P.L and Wani. S.P. 2017. Characterisation and classification of soils from three Agro-climatic Zones of Belgavi District, Karnataka. *Journal of the Indian Society of Soil Science* 65(1): 1-9.

Saikh, H., Varadachari, C. and Ghosh, K. 1998. Changes in carbon, nitrogen and phosphorus levels due to deforestation and cultivation: A case study in Simlipal National Park, India. *Plant and Soil* 198: 137-145.

Sarma, V.A.K., Krishnan, P. and Budihal, S.L. 1987. Laboratory methods NBSS-Publ. 14, Technical Bulletin, *National Bureau of Soil Survey and Land Use Planning*, Nagpur. pp. 76-97.

Singh, G., Single, S.K. and Reddy, L.S. 2013. Check list of commercial varieties of plantation crops, Published by department of Agriculture and cooperation, Ministry of Agriculture, Krishi Bhavan, New Delhi.

Soil Survey Staff 2014. *Keys to Soil Taxonomy* (Twelveth edition), USDA, Natural Resource Conservation Service, Washington, DC.

Vasundhara, R., Chandrakala, M., Dharumarajan. S, Kalaiselvi, B., Rajendra Hegde and Singh, S.K. 2018. Characterisation and classification of soils of Madahalli micro watershed of Karnataka. *Agropedology* 28(01): 42-47.

Walkley, A. and Black, C.A. 1934. Estimation of organic carbon by chromic acid titration method. *Soil Science* 37: 29-38.