Characterization of Soil-Water Retention with Coarse Fragments in the Densu Basin of Ghana

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Abstract

The presence of coarse fragments can have profound impact on soil moisture retention characteristics. The study was conducted to assess the effects of coarse fragments on the moisture retention characteristics of 16 soil series, developed over five different parent materials in the Densu basin. Soil profiles were excavated at five locations, to depths within 1.5 m in the field. Undisturbed soil core samples and disturbed samples were taken in triplicates from the major genetic horizons of each soil type within the effective root depth of 1 m. Coarse fragments content of soil more than 2 mm was measured on mass basis by sieving through a 2-mm mesh. Soil moisture retention was determined using the pressure plate apparatus at suctions of pF 1 (1.0 kPa), pF 2 (10.0 kPa), pF 2.5 (33.0 kPa) and pF 3 (100.0 kPa) for the undisturbed and pF 4.2 (1500 kPa) for the disturbed samples.The volumetric moisture content between field capacity (FC) pF 2.5 (33.0 kPa) and permanent wilting pointing (PWP) pF 4.2 (1500.0 kPa) was used to evaluate the available water content (AWC) by volume and then converted to root zone available water capacity (RZAWC) in millimetres (mm) assuming an effective root depth of 1 m within the basin. Results showed that soils formed over granite and its associations have high percentage of coarse fragments while soils developed over phyllites and its associations have high clay percentage. Soil organic matter was high in the topsoil of all profiles, ranging from 0.81 to 4.44% compared with the horizons below, and the bulk density of the topsoils were less than the limiting value of 1.6 Mg m^{-3}. Site-specific moisture retention characteristics of the various soil series have been delineated. It was evident from the analyses that soils containing high clay content gave high RZAWC values compared with soils with high coarse fragments. Most of the topsoils of the profiles gave high RZAWC values compared with sub-layers with high amounts of coarse fragments. Critical water for plants establishment within the basin in the surface layer was quite favourable.

Introduction

Knowledge of soil water retention characteristics is indispensable for many soil-water related investigations. Soil moisture retention curve gives the relationship between volumetric soil moisture content and soil water pressure head. It describes the soil's ability to store or release water. Water-storage capacity is an important soil parameter in relation to soil potential and can be used to facilitate the classification of soils for irrigation purposes. Gupta & Larson (1979) stated that soil water retention especially available water is a basic soil parameter, which is influenced by many physico-chemical properties and is related to soil moisture constant, fluids movement in soils, irrigation scheduling and drainage requirement.

Tetsu *et al*. (2003) obtained water retention relations over a wide range of energy, with respect to water retained in intra-granular pores and along particle surfaces. They mentioned also that residual water in coarse textured soils occur in intra-granular pores, represent about 10% of the total soil porosity and is effectively hydraulically immobile, while the opposite is true in the case of fine textured soils. Lawless *et al.* (2008) observed in a basin of alluvial plain with soils of varying thickness over gravel beds with stones that the major source of variation of root zone available water holding capacity is the depth of the overlying soil, which may vary from 15 cm to several metres. These variations may lead to differences in optimum management and, if not considered in crop production, yield can vary substantially across soil types.

Van den Berg *et al.* (1997) have observed that detailed pressure-plate measurements of soil moisture retention curves are expensive and time-consuming. It is probably for these reasons that soil moisture release and retention characteristics are not commonly measured and are either ignored, or crudely estimated from soil texture descriptions. In view of the importance of soil moisture retention characteristics in agronomic and environmental studies, several studies have been conducted to establish relationships between soil moisture holding capacity and some physical and chemical soil parameters (Gupta & Larson, 1979; Flint & Childs, 1984; Saxton *et al.,* 1986; Vereecken *et al.*, 1989; Van den Berg *et al.*, 1997; Saxton & Rawls, 2004). Most of the aforementioned often have little quantitative soil description.

Qualitative soil descriptions are usually converted to crop-model-compatible quantitative parameters using a multi-step process. They are first converted to soil compositions, using the USDA textural triangle, for example. This induces a large degree of imprecision in the soil composition estimates. Then, these estimated compositions have to be converted to hydraulic properties using a pedotransfer function (Bouma, 1989), which further induces imprecision. In a situation where crop simulation models are very sensitive to these input parameter values and are expected to produce precise predictions, this level of imprecision is unlikely to be acceptable.

Within the Densu basin of Ghana, studies on the physical and chemical properties of soils as they affect crop growth have revealed little information on soil water retention characteristics with respect to their coarse fractions (Christiansen & Awadzi, 2000; Owusu-Bennoah *et al.*, 2000). Flint & Childs (1984) have recommended that the spatial variability in coarse fragments should be considered in site specific evaluation of water holding capacity. As a result the soil map of Ghana, classified by Boateng *et al.* (2000), and was used in land suitability assessment for different crops considering the available soil database had to employ the approach developed by FAO (1995) to estimate soil moisture values for the different soil series.

The purpose of this pioneering work in the Densu basin of Ghana is to determine the effect of coarse fragments on water retention characteristics in the basin.This will establish empirical site-specific database on moisture retention characteristics based on soil compositions and their spatial variability where hydraulic properties can be obtained by direct measurement. This will further improve the land suitability assessment by incorporating actual or reliable site-specific soil parameters.

Materials and methods

Site description

The Densu basin (Fig. 1), located in the semi-deciduous forest zone of the Eastern

Region of Ghana, covers an area of about 4160 km^2. Its geographical coordinates are between latitudes 5°20' N and 6°15' N and longitudes 0°95' W and 0°30' W. This humid tropical monsoon climate is characterised by bi-modal distribution of rainfall in a year. Average annual rainfall increases gradually from 810 mm in the south to a maximum of about 1430 mm in the northern part of the basin. The potential evapotranspiration varies between 3 and 5 mm day^{-1} in the rainy and dry seasons, respectively, and may reach an annual value of 1400 mm. The major growing season spans over April to mid-July and the minor growing season from September to mid-November. The mean air temperature is 28 °C with mean maximum and minimum temperatures of 35 °C and 25 °C, respectively. The relative humidity ranges from 60 to 95% during the year. The soil temperature regime is isothermic while the soil moisture regime is ustic, according to Soil Survey Staff (2003).

Partitioning and characterization of the basin

Most of the Densu basin is underlain by the Cape Coast granite complex, which consists largely of granites, schists and gneisses (Adu & Asiamah, 1992). A small portion of the northwest is underlain by upper Birimian rocks, while the eastern boundary is occupied partly by metamorphosed sediments of the Togo system and partly by Voltaian rocks. The upper Birrimian rocks consist mostly of volcanic rocks and greenstones including small amounts of epidiorites, diorites, amphibolites, andesites and greywackies. The Togo rocks are mainly sandstones, quartzites, shales, phyllites, quartz and sericite schists (McCallien & Burke, 1957). The major soils in the area are those developed over or in the weathering products of moderately acid rocks of granite, phyllite, quartzites and sandstones (Table 1).

Four soil sampling sites were selected to represent all the major parent materials within the basin (Fig. 1). However, for the analysis of the moisture characteristics, soils derived from colluvial materials from the four locations were grouped together in Table 1 as Location 5. Location 1, with coordinates 05°50'15.51" N; 00°23'06.75" W, is on Dansak FarmsLtd. between Nsawam and Coaltar. The soils sampled here belong to the Adawso-Bawjiasi/Nta-Ofin compound association. *Adawso* and *Bawjiasi series* occur on the upper to middle slope while *Nta* and *Ofin series* occur on the lower slope to the valley bottom. Location 2, with coordinates 06°11'32.23" N; 00°22'26.70" W, is on the research plots of the Soil Research Institute at Kukurantumi. The soils here belong to the Nankese-Koforidua/Nta-Ofin compound association. Members of this soil association include *Koforidua, Nankese, Wacri* and *Kukurantumi series* on the summits and upper slopes with *Akroso, Nta* and *Ofin series* on the middle slope to the valley bottom.

Location 3, with coordinates 06°07'24.90" N; 00°29'31.27" W, is on the seed multiplication farms of the Cocoa Services Division at Apedwa. The soils here belong to the Nzema-Bekwai/Oda compound association and Nsaba-Swedru/Nta-Ofin association. Soil types in the Nzema-Bekwai/Oda association consist of *Kobeda, Bekwai*, and *Nzema series* on the upper and middle slopes. The lower slopes to the valley bottom sites are occupied by *Kokofu, Temang* and *Oda series*. Nsaba/Swedru-Nta/Ofin association consist of *Swedru* and *Nsaba series* on the summits to upper slopes and

TABLE 1
Location, parent materials and classification of soils within the basin

Location	*Parent material*	*Ghanaian soil series*[a]	*Soil taxonomy*[b] *(2003)*	*FAO-UNESCO-ISRIC (1990)*
1	granite	Adaiso	Typic Ustipsamments	Haplic Arenosol
	granite	Akroso	Typic Hapludult	Haplic Acrisol
	granite	Adawso	Psammentic Haplustalf	Haplic Lixisol
2	granodiorite	Kukurantumi	Kanhaplic Haplustalf	Haplic Lixisol
	granodiorite	Wacri	Kanhaplic Rhodustalf	Ferric Lixisol
	granodiorite	Nankese	Kandic Paleustalf	Ferric Lixisol
	granodiorite	Koforidua	Kandic Paleustalf	Ferric Lixisol
3	phyllite	Swedru	Typic Haplustalf	Ferric Lixisol
	phyllite	Bekwai	Typic Paleudult	Ferric Acrisol
	phyllite	Nzema	Kandic Paleudalf	Haplic Acrisol
4	sandstone and shale	Bediesi	Typic Kandiustalf	Rhodic Lixisol
	sandstone and shale	Oyarifa	Typic Rhodudalf	Haplic Lixisol
	sandstone and shale	Mamfe	Typic Plinthustults	Ferric Acrisol
5(1,2,3&4**)**	colluvial	Kokofu	Udic Kandiudalf	Haplic Lixisol
	colluvial	Nta	Typic Ustifluvent	Eutric Regosol
	colluvial	Bejua	Dystric Haplustepts	Dystric Gleysol

[a]Brammer 1962; [b]Soil Survey Staff

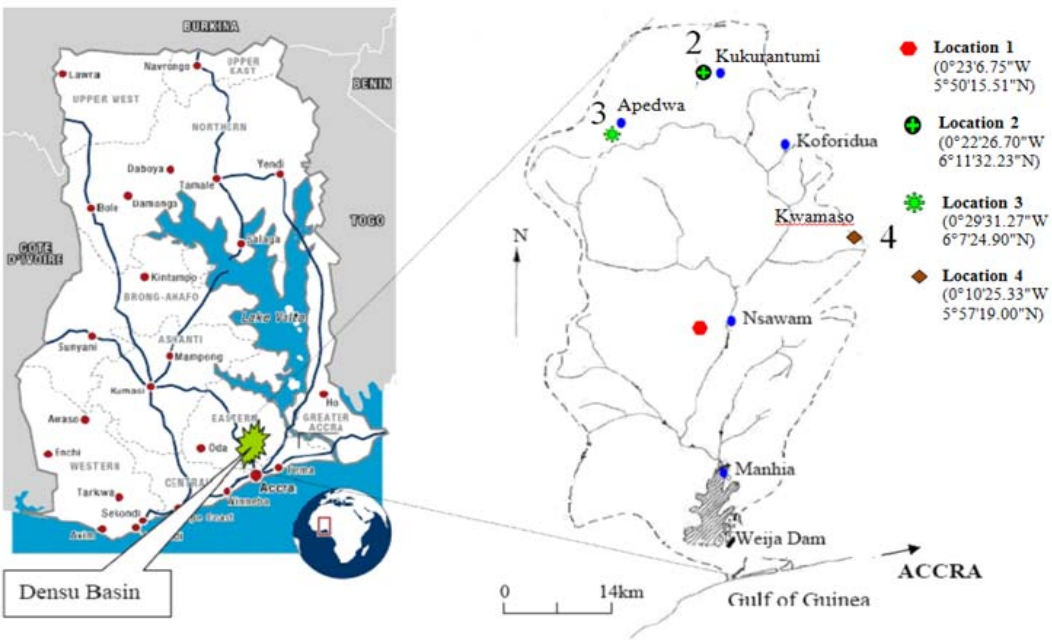

Fig.1. Map of Ghana (Adapted from: *http://www.volu.org/map.html)* showing the location of Densu basin and the sampling sites

Ofin, Densu, Kakum and *Chichiwere series* on the lower slope and valley bottom sites. Location 4, with coordinates 05°57'19.00" N; 00°10'25.33" W, is on the former plot of the Kwamoso Oil Palm Plantations between Mamfe and Adawso. Soils at this location belong to the Fete-Bediesi complex. The members of this complex include Mamfe, Bediesi and *Oyarifa series* on the upper to middle slopes with *Sutawa, Beraku* and *Bejua series* occupying the lower to valley bottom sites. The classification of the soil series in the Densu basin is as in Table 1.

Soil sampling and analysis

Soil profiles were excavated at the five locations to depth within 1.5 m in the field. The soil profiles were described according to the FAO guidelines (FAO, 1990). Undisturbed soil core samples of diameter 6 cm and height 3.5 cm were taken in triplicates from the major genetic horizons of each soil type within the effective root depth (1 m). Disturbed samples were taken from all horizons for the determination of soil texture and organic matter. Part of the disturbed soil samples were air-dried, gently crushed and passed through a 2-mm sieve. Particle size distribution (clay < 2 µm, silt 2–50 µm, sand 50–2000 µm) was determined by sieve and Sedigraph 5100 (Micrometrics Instrument Corporation). Total carbon (C) was determined by measuring the carbon dioxide evolved by igniting the soil in an induction-operating like the LECO furnace (Tabatabei & Bremner, 1970).

Soil moisture retention was determined using the pressure plate apparatus with the triplicates of samples at suctions of pF 1 (1.0 kPa), pF 2 (10.0 kPa), pF 2.5 (33.0 kPa) and pF 3 (100.0 kPa) for the undisturbed as well as the disturbed samples at pF 4.2 (1500 kPa), as described by Smith & Mullins (1991). The undisturbed core samples were trimmed to the cylinder volume, saturated in 0.1 *M* calcium chlorite ($CaCl_2$) solution for 48 hr and equilibrated at pF 1 (1.0 kPa) with pressure plate equipment. After equilibrium, the core samples were weighed, rewetted for a period of 3 hr and equilibrated at pF 2 (10.0 kPa). The process was repeated for field capacity (FC) pF 2.5 (33.0 kPa) and pF 3 (100.0 kPa). For permanent wilting point (PWP), triplicates of the disturbed samples were saturated in smaller core tubes and equilibrated at pF 4.2 (1500.0 kPa) matric potential.

Determination of dry bulk density and porosity were based on the weight of dry undisturbed samples and the values presented in averages. The initial gravimetric weights obtained were converted to volumetric weights using the determined dry bulk densities. After determining the oven dry weights of the core samples, they were then crushed gently and washed by immersion in sodium pyrophosphate and mechanically shaken, then sieved through a 2-mm mesh to separate the coarse and fine fractions of the samples. Coarse fragment content (> 2 mm) was measured on a mass basis by sieving a minimum of 500 g of soil through a 2-mm sieve. Coarse fragments are particles larger than 2 mm and smaller than 25 cm; this excludes stones and boulders. Based on an assumed mass density of coarse fragments of 2.65 Mg m^{-3}, the volumetric coarse fragments content was calculated as in Flint & Childs (1984) and Hansen *et al.* (1986). The value of the volumetric coarse fragments content was used for the determination of volumetric water content at pF 4.2 (1500.0 kPa), as shown by Van Wesemael *et al.* (1995).

The volumetric moisture content between pF 2.5 (33.0 kPa) (FC) and pF 4.2 (1500.0 kPa) (PWP) was used to calculate available water content (AWC) by volume and converted to root zone available water capacity (RZAWC) in mm assuming an effective root depth of 1 m within the basin (Hodnett *et al.*, 1995). Root zone available water capacity is the sum of available water capacity times the thickness for all layers in the root zone. This approximates the volume of water that is held in the root zone and can be used by crop plants. The RZAWC of soil is calculated from the surface to the beginning of the first root restrictive soil layer, such as bedrock or a very dense layer, or to a depth of 150 cm. However, within the basin an average effective root depth of 1 m can be used for the determination of soil moisture storage (Magier & Ravina, 1984; Hodnett *et al.*, 1995).

Results and discussion

The depths of diagnostic horizons, physical properties and percent organic matter (OM) content of the 16 soil types within the study sites are presented in Table 2. The physical soil parameters consist of the dry bulk density (Mg m^{-3}), fractions of gravel and stones (> 2000 µm), coarse sand (200–2000 µm), fine sand (50–200 µm), silt (2–50 µm), and clay (< 2 µm). From Table 2, soils developed over granite and its associates have the highest percentage of coarse sand (32–79%). Flint & Childs (1984) have shown that such spatial variability in rock fragments content should be considered in order to evaluate site specific water holding capacity. Soils developed over the phyllites and its associates have high clay percentage ranging from 27% in the top soils to about 75% in the subsoils.

Soil organic matter, which serves as a store and slow release source of soil nutrients,

TABLE 2
Physical properties and organic matter content of the soils in Densu basin

Soil name	*Depth (cm)*	*BD (Mg m^{-3})*	*Coarse sand (200–2000 µm)*	*Fine sand (50-200 µm)*	*Silt (2–50 µm)*	*Clay (<2 µm)*	*Wt. of CF (>2000 µm)*	*OM (%)*
Adaiso	0–10	1.37	72	5	15	8	53.79	1.89
	10–20	1.37	70	14	10	6	40.22	1.32
	20–60	1.50	79	6	8	6	68.51	0.42
	60–94	1.51	73	13	10	4	112.66	0.31
Akroso	0–10	1.59	49	2	9	40	2.69	0.72
	10–40	1.72	63	1	1	35	4.95	0.83
	40–70	1.73	68	2	3	27	13.13	1.46
Adawso	0–10	1.56	55	1	14	30	7.87	2.31
	10–35	1.59	53	1	11	35	89.04	1.22
	35–67	1.02	44	1	4	51	59.64	0.83
	67–97	1.47	32	1	1	66	16.65	0.43
Kukurantumi	0–15	1.43	65	10	2	23	12.14	0.81
	15–60	1.63	56	7	1	36	6.67	0.64
	60–100	1.73	42	4	2	52	7.95	0.34
	100–130	1.57	33	4	1	62	1.00	0.28
Wacri	0–15	1.24	51	15	1	33	3.83	2.53
	15–40	1.58	50	15	2	33	3.98	1.22
	40–65	1.49	46	9	1	44	4.03	1.00
	65–115	1.60	34	5	2	59	43.21	0.36

TABLE 2 con't

Soil name	*Depth (cm)*	*BD (Mg m^{-3})*	*Coarse sand (200–2000 µm)*	*Fine sand (50-200 µm)*	*Silt (2–50 µm)*	*Clay (<2 µm)*	*Wt. of CF (>2000 µm)*	*OM (%)*
Nankese	0–10	1.45	5	58	14	23	58.31	1.32
	10–40	1.48	46	4	16	34	67.29	0.69
	40–80	1.62	39	4	1	56	37.18	0.36
	80–120	1.64	31	24	1	44	7.03	0.29
Koforidua	0–12	1.04	10	46	15	29	0.29	4.25
	12–24	1.48	8	48	4	40	1.18	1.17
	24–50	1.69	9	43	5	42	7.40	0.74
	50–90	1.62	34	26	11	29	31.73	0.6
Swedru	0–7	1.36	44	5	24	27	22.75	2.89
	7–20	1.49	45	3	19	33	52.39	1.07
	20–48	1.41	26	11	9	55	52.49	0.74
	48–82	1.59	17	3	20	60	77.55	0.72
Bekwai	0–12	1.38	14	1	45	40	2.65	4.32
	12–93	1.38	10	41	13	36	>90	1.52
	93–120	1.46	6	1	18	75	13.10	0.76
	120–159	1.42	4	1	68	27	0.90	0.55
Nzema	0–8	1.13	9	1	52	38	6.24	4.44
	8–65	1.13	10	2	33	55	>90	1.72
	65–90	1.41	5	1	27	67	17.25	0.59
Bediesi	0–15	1.34	31	32	25	12	1.73	0.91
	15–35	1.33	20	37	19	24	0.00	0.67
	35–53	1.48	14	36	17	33	0.20	0.46
	53–78	1.49	9	31	17	43	0.14	0.58
Oyarifa	0–8	1.05	16	39	20	25	0.00	3.04
	8–25	1.49	11	39	18	32	0.00	1.25
	25–60	1.41	4	31	8	57	0.00	0.5
	60–110	1.33	5	23	9	63	0.00	0.41
Mamfe	0–8	1.25	48	17	26	9	2.47	2.03
	8–16	1.37	46	12	33	9	29.24	1.72
	16–28	1.63	48	13	15	24	56.95	0.45
	28–52	1.31	36	3	2	59	87.29	0.19
Kokofu	0–8	1.35	54	1	32	13	0.43	3.05
	8–30	1.51	69	1	14	16	4.17	0.97
	30–78	1.52	14	1	6	79	4.46	0.81
	78–120	1.43	16	2	23	59	25.09	0.55
Nta	0–10	1.27	72	6	15	7	0.00	1.17
	10–26	1.40	59	11	23	7	5.71	0.95
	26–39	1.59	60	5	22	13	7.77	0.34
	39–65	1.77	61	9	23	7	11.16	0.12
Bejua	0–9	1.07	24	21	45	10	0.00	2.24
	9–28	1.21	24	26	38	12	0.00	0.62
	28–50	1.54	13	23	56	8	0.00	0.53
	50-87	1–81	43	20	18	19	0.00	0.21

CF = Coarse fragments; BD = Bulk density generally was high in the topsoil of all profiles ranging from 0.81 to 4.44% compared with the horizons below in Table 2. A similar trend had been reported by Owusu-Bennoah *et al.* (2000). It also improves the soil water holding capacity (Zingore *et al.*, 2007). The low values of organic matter content in some of the topsoils may partially be due to sampling within the mid-sections of the horizons. The organic matter content within the sub-soils reduced to less than half that of the top soils in most of the profiles.

Bulk density, which measures the degree of compaction of the soils, range from 1.05 to 1.59 Mg m^{-3} for topsoils and increased with increase in soil depth. The differences could be due to the lower organic matter content in the lower layers, less aggregation, less root penetration in the sub-layers, as well as compaction caused by the weight of the over-lying layers (Foth, 1976). On the basis of bulk density all the topsoils can support crop production since their values are less than 1.6 Mg m^{-3}, which is the critical bulk density above which roots penetrate, hence, plant growth becomes inhibited (Willcocks, 1984).

Fig. 2 presents the moisture retention characteristic for both top and subsoils formed over granite parent material (*Adaiso, Akroso* and *Adawso series*). The water content at field capacity (pF 2.5) over the granite parent material with gravel varies between 9–35% by volume, and that without gravel varies between 15–38%. The volumetric moisture content at PWP (pF 4.2) with gravel varies between 3–17%, and that without gravel between 4–18%. This agrees with Flint & Childs (1984) assertion that the spatial variability in coarse fragments be considered in site specific evaluation of water holding capacity. The above, therefore, resulted in the root zone available water capacity (RZAWC) over the granite parent material with gravel as 785 mm for *Adaiso*, 1550 mm for *Akroso* and 1522 mm for *Adawso*. The RZAWC without gravel increased to 1207 mm for *Adaiso* and 1818 mm for *Adawso*. However, the decrease in RZAWC for *Akroso* to 1091 mm is not consistent with the normal trend and might be due to variability of the soil properties.

The moisture draining curves for both top and subsoils formed over granodiorite parent material (*Kukurantumi, Wacri, Nankese* and *Koforidua series*) are depicted in Fig. 3. The water content at FC over granodiorite parent material varies between 19–41% by volume for both, with and without gravel. The RZAWC with gravel is 2180 mm for *Kukurantumi*, 771 mm for *Wacri*, 1145 mm for *Nankese* and 1192 mm for *Koforidua*. The root zone available water capacity without gravel is 2203 mm for *Kukurantumi*, 1248 mm for *Wacri*, 1417 mm for *Nankese* and 1242 mm for *Koforidua*. The high water retention of the soils formed over granodiorite parent material could be attributed to the less coarse fractions and high amount of clay, and organic matter content as shown in Table 2.

Fig. 4 illustrates the moisture extraction curves for both top and subsoils formed over phyllite parent material (*Swedru, Bekwai and Nzema series*). The water content at field capacity over phyllite parent material with gravel varies between 24–45% by volume. The water content at FC without gravel varies between 30–48% by volume. The root zone available water capacity is 922 mm, 3894 mm and 1859 mm for *Swedru*, *Bekwai* and *Nzema series*, respectively. Removal of gravel from *Swedru series* doubled the RZAWC to about 1859 mm, and *Bekwai*

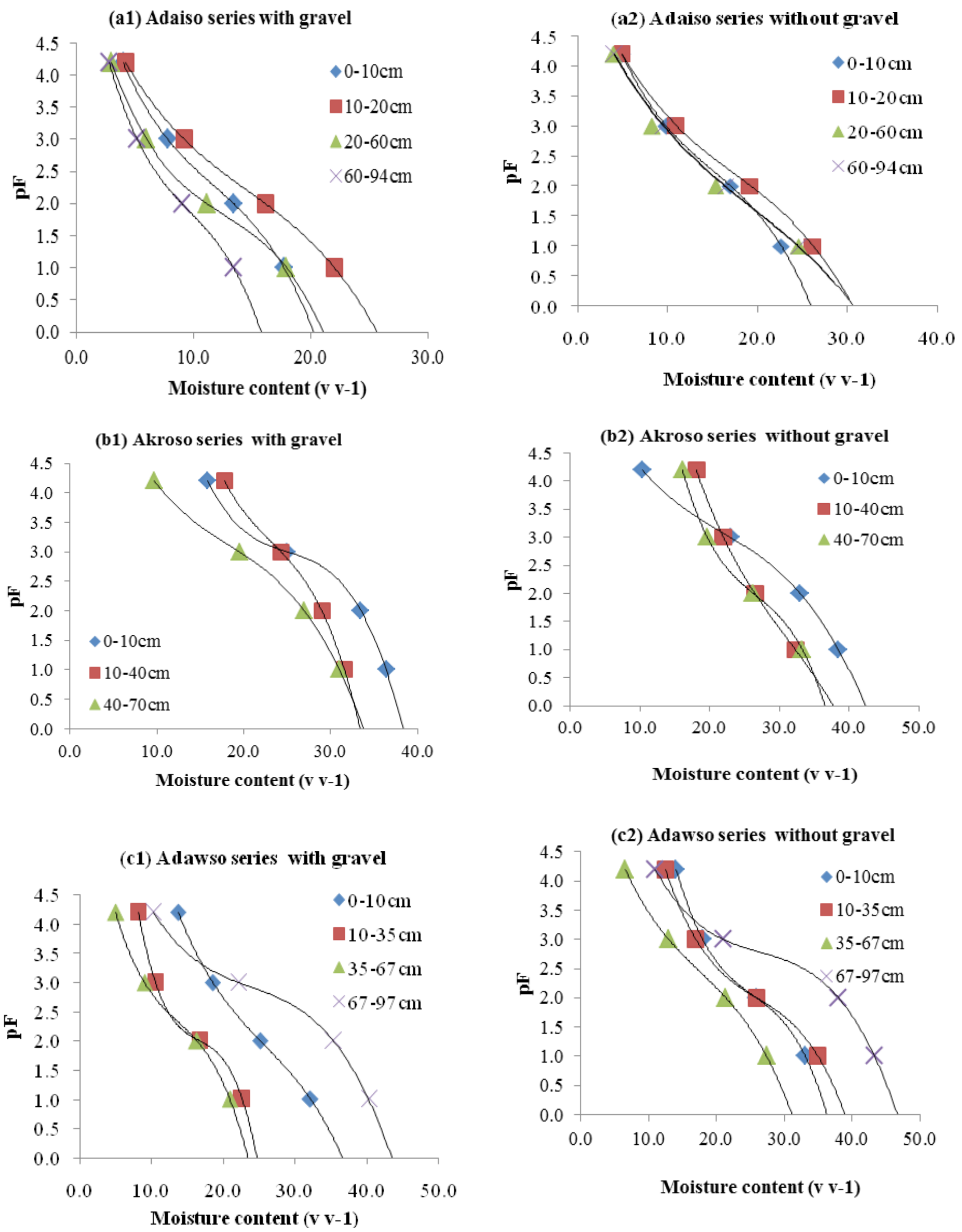

Fig. 2. Moisture characteristic over granite parent material

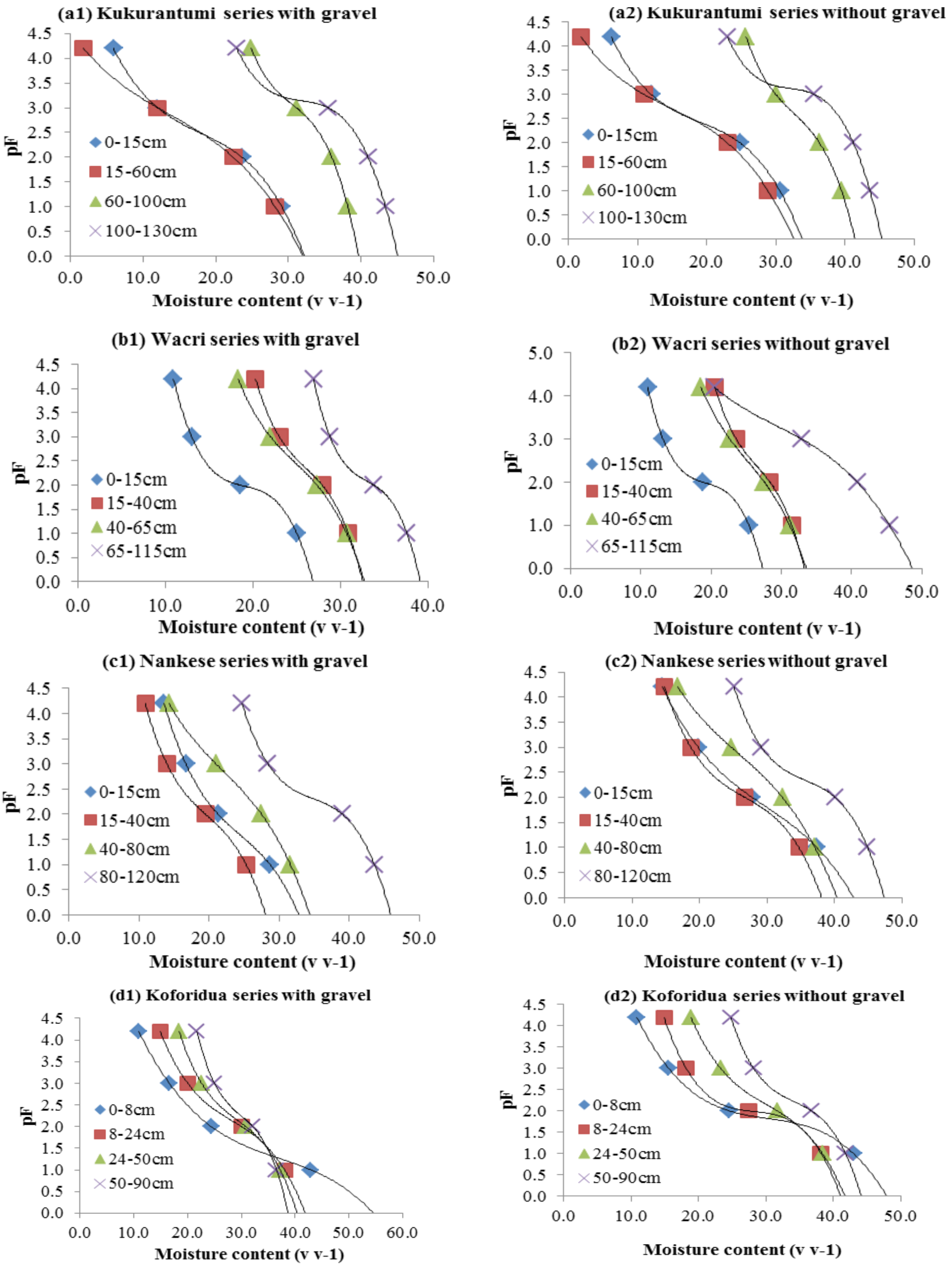

Fig.3. Moisture characteristic over granodiorite parent material

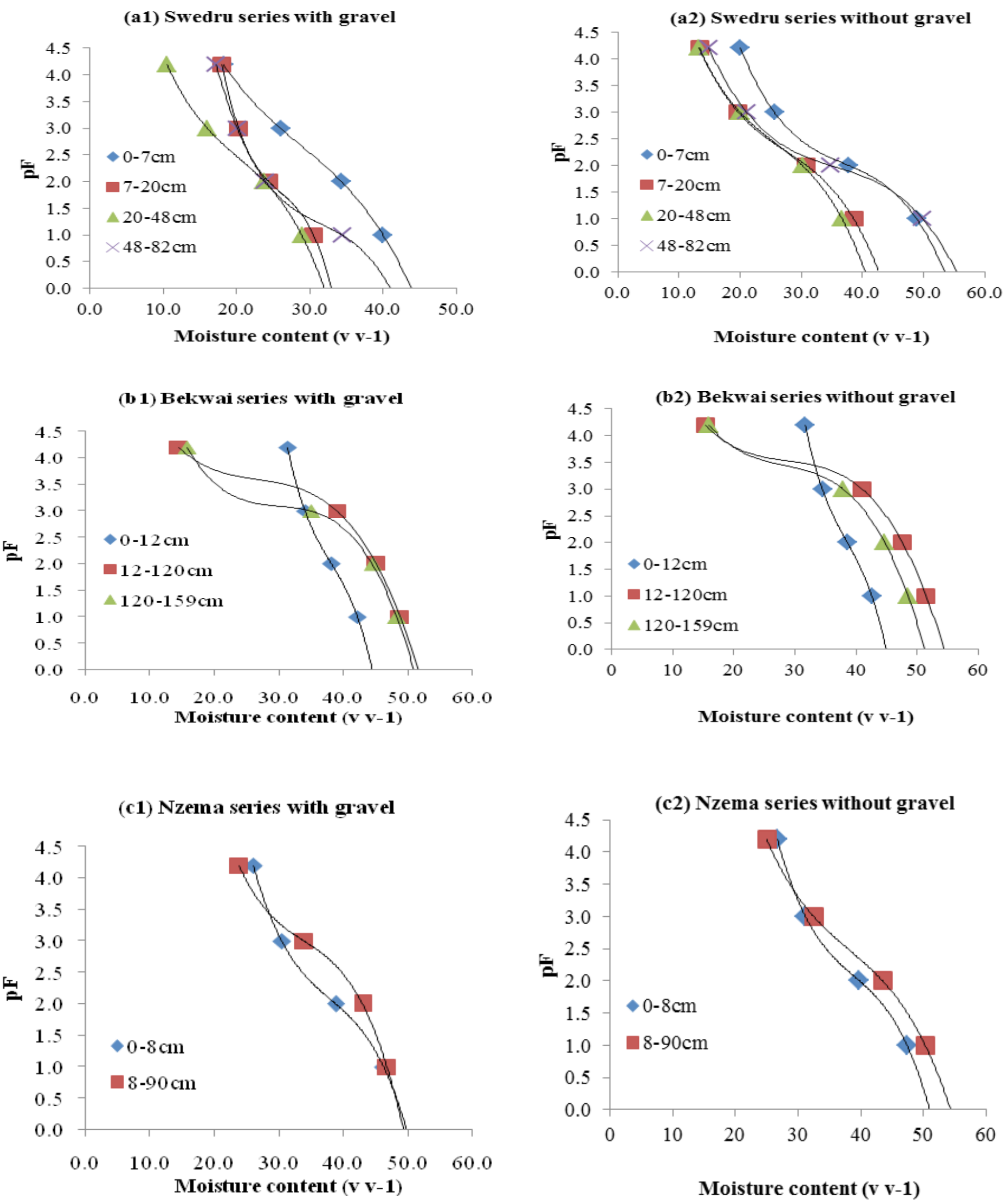

Fig. 4. Moisture characteristic over phyllite parent material

series without gravel increased to 4048 mm. The high water retention of these soils again is due to the high amount of clay content as in Table 2. However, concretionary horizons at shallow depth limited the RZAWC of *Nzema series* to 1807 mm.

The moisture retention characteristic for both top and sub-soils formed over sandstone and shale parent material (*Bediesi, Oyarifa* and *Mamfe series*) are presented in Fig. 5. The moisture content at FC here varies between 17–35% by volume for both samples with and without gravel. The root zone available water capacity is 1076 mm for *Bediesi,*1014 mm for *Oyarifa* and 660 mm for *Mamfe.* The RZAWC without gravel for *Bediesi series* increased to 1081 mm and *Oyarifa series* without gravel remained the same at1014 mm, while *Mamfe series* increased to more than double at 1682 mm. This again confirms the spatial variability of available soil water as a result of the presence of coarse fragments which have irregular layers, voids, and weathering rinds around individual fragments (Flint & Childs, 1984; Tetsu *et al*., 2003).

Fig. 6 outlines the moisture retention relationships for both top and subsoils formed over colluvial parent material (*Kokofu, Nta* and *Bejua series*). The water content at field capacity here varies between 19–41% by volume for both samples with and without gravel. The root zone available water capacity is 2142 mm for *Kokofu*, 1833 mm for *Nta* and 1753 mm for *Bejua*. The RZAWC without gravel is 2129 mm for *Kokofu*, 1627 mm for *Nta* and 1616 mm for *Bejua series*. The high water retention of the *Kokofu series* is due to the high amount of clay content compared with *Nta series,* which has lower soil water content due to high amounts of coarse sand as in Table 2.

Conclusion

The effects of coarse fragments on the moisture retention characteristics of 16 soil series developed over five different parent materials (granite, granodiorite, phyllite, sandstone/shale and colluvial) in the Densu basin in the tropical semi-deciduous forests of Ghana have been evaluated. Soils developed over granite and its associations have high percentage of coarse sand while soils developed over phyllites and its associations have high clay percentage. Generally, soil organic matter content was high in the topsoil of all profiles compared with the lower horizons. The organic matter content within the subsoils decreased to less than half that of the topsoils in most of the profiles. On the basis of bulk density, all the topsoils can support crop production because their values are less than the limiting bulk density value.

Site-specific moisture retention characteristics of the various soil series have been outlined. These described the draining curves of the soil series over the five parent materials within the basin. The root zone available water capacities for all the soils have also been analysed to inform agronomic management. It is evident from the analyses that soil series containing high clay content gave high root zone available water capacity values compared with soils with high coarse fragments. Most of the topsoils of the profiles gave high root zone available water capacity values compared with sub-layers with high amounts of coarse materials. Thus, critical water for plants establishment in the basin in the surface layer is favourable. However, the amount of available water stored throughout the root zone usually determines soil productivity. It is also evident that concretionary horizons at shallow depths

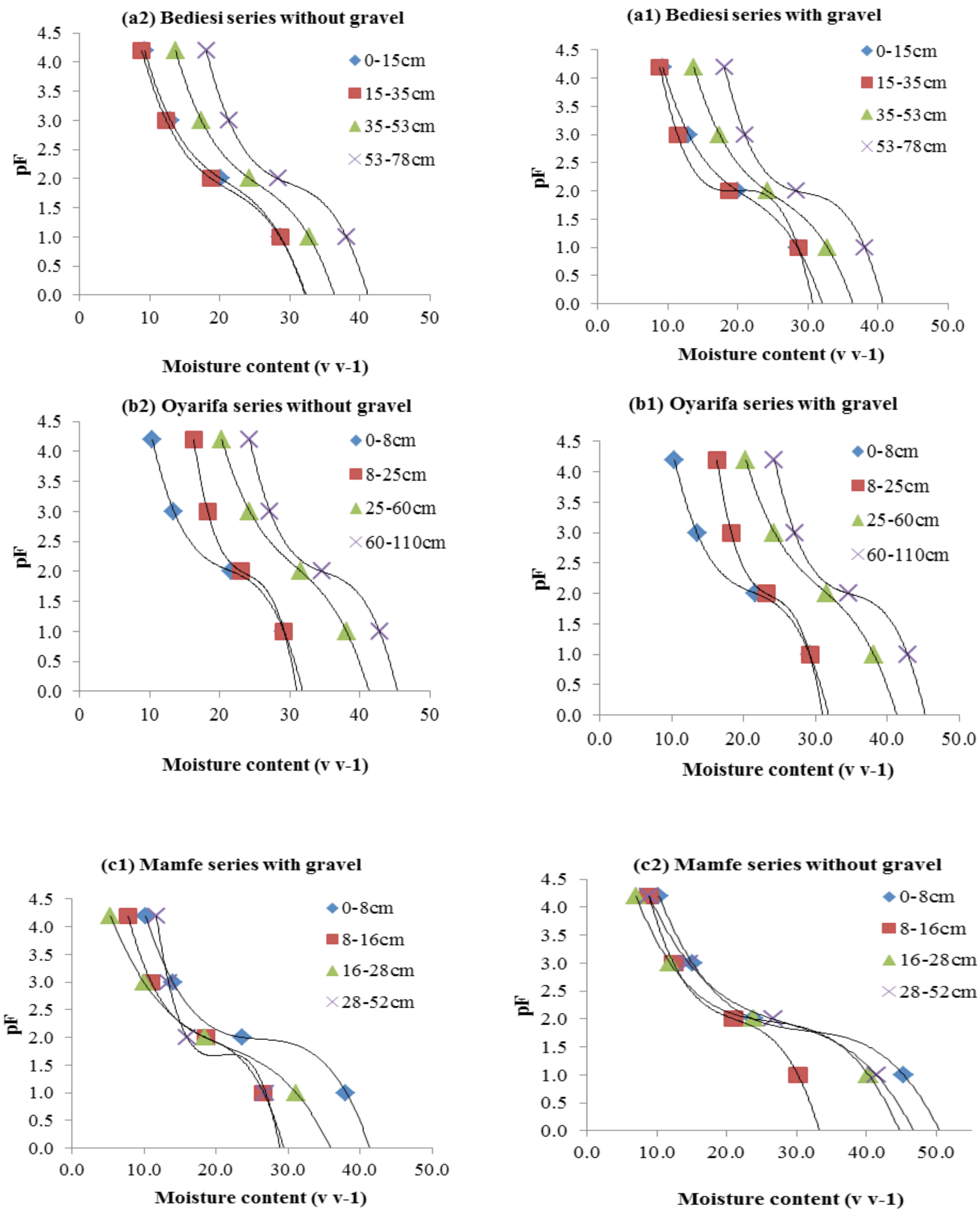

Fig. 5. Moisture characteristic over sandstone and shale parent material

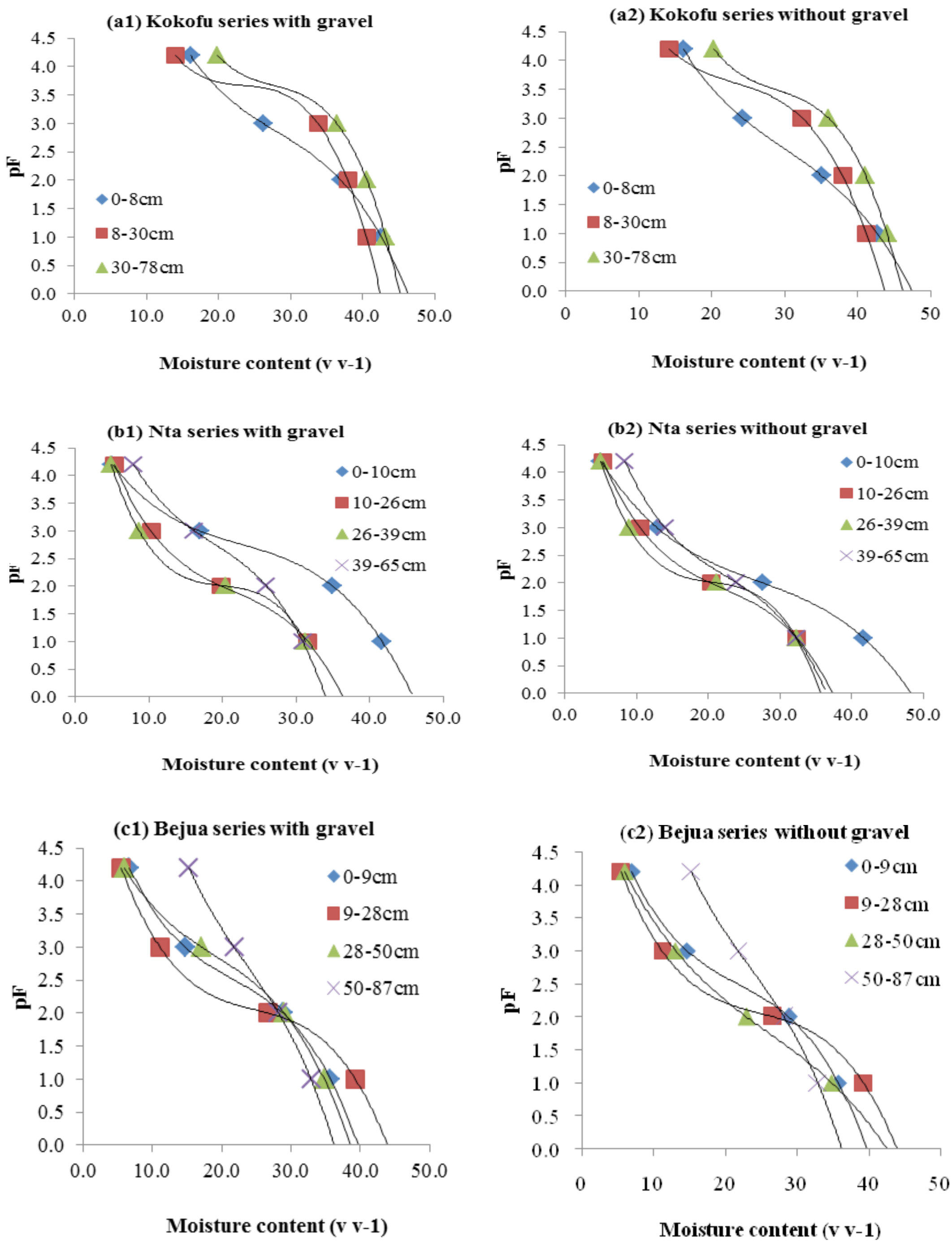

Fig. 6. Moisture characteristic over colluvial parent material

limited the RZAWC. Similar research is needed for the other agro-ecological zones within the country.

Acknowledgement

The authors are grateful to the Staff of CSIR-Soil Research Institute, Soil and Irrigation Research Centre (SIREC), Kpong, and the Ecological Laboratory, University of Ghana, for their assistance in carrying out the experiments.

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