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Soil heterogeneity: A comparative assessment of soils from two different AESR, southern India

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ABSTRACT

A comparative study was carried out to assess the nature and characteristics of soils from two agro-ecological sub regions (AESU and AESR) from two states of South India. Using sentinel-2 satellite data, google imagery and top sheet, a detailed soil survey was taken up in AESU and AESR. Major soils from upland as well as from lowlands were compared to assess the soils heterogeneity. Results showed that there was a high heterogeneity between properties of soils AESU and AESR. Variability existed in climatic conditions (tropical humid region in AESU and semiarid condition in AESR), physiographic (valley plain to gently, very gently, moderate, steep and very steep slopes in AESU and levelled to gently and very gently slopes in AESR), geology (charnockite and granite gneiss in AESU whereas granite gneiss in AESR), land use (rubber, paddy, coconut in AESU and paddy, mango, pigeon pea, groundnut in AESR), soil classification (Ultisols and Alfisols in AESU whereas Alfisols and Inceptisols in AESR) and land capability (soil and water conservation measures must in AESU and slope was manageable with agronomic management practices in AESR). Soils varied in texture (clay, sandy clay and clay loam in AESU whereas sandy clay loam to sandy loam in AESR), consistency and depth of soils (shallow to very deep in AESU and shallow to deep in AESR). Clay content (32.9 to 63.5%) was dominant fraction in AESU whereas sand (52.1 to 72.1%) was in AESR. Soil acidity (strongly acid to very strongly acid) was a major problem (both hydrogen and aluminium saturation) in AESU whereas slightly acidic to neutral and slightly alkaline in AESR. Organic carbon content was high (up to 25.9 gkg^{-1}) in AESU whereas it was up to 10.0 gkg^{-1} in AESR. Base saturation was <35% in AESU and >75% up to 100% in AESR. Calcium carbonate equivalent is >5% in AESR and not a problem in AESU. CEC was low (<12 cmol (p+) kg^{-1}) in AESU and good (>12 cmol (p +) kg^{-}1) in AESR.

Key words: Soils, heterogeneity, morphological, physical, chemical, agro-ecological sub-regions (AESR), southern India

INTRODUCTION

Heterogeneity can be defined based on two components: the system property of interest and its complexity or variability. A system property can be anything that is of ecological interest, e.g., soil nutrients or other soil properties. Complexity refers to qualitative or categorical descriptors of this property, while variability refers to quantitative or numerical descriptors of the property. Heterogeneity is thus defined as the complexity and/or variability of a system property in space and/or time. Soils are formed from parent materials through physical, chemical, biological soil forming processes at particular climate and landscape. All these components have an impact on soil heterogeneity in their, morphological, physical and chemical properties at spatial and temporal scale (Wang *et al.,* 2007; Lin *et al.* 2005). Earlier investigations reported the relationship between spatial heterogeneity soil characteristics and the environmental factors in various landscapes (Gallardo, 2003; Sauer *et al.* 2006). There is a relationship between variability of soil properties and topographic factors viz., slope gradient, elevation and aspect. In the present study, the spatial heterogeneity of soil physical, chemical and morphological properties were compared between two agro-ecological sub regions (AESR). AESR from southern Indian state Andhra Pradesh and agro-ecological sub-unit (AESU) from Kerala state were selected, with the objective to know the heterogeneity in soil morphological, physico-chemical properties.

MATERIALS AND METHODS

Study area

Agro-ecological zone foot hills and high hills; Agro ecological sub units (AESU) 12 and 14 are southern and central foot hills and southern high hills, respectively. Elamdesam

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block (north latitudes 9^0 46' 38.2" and 10^0 2' 18.14" and east longitudes 76^0 42' 59.49" and 76^0 53' 46.99") was selected which is divided in to seven panchayats and eight villages for this study. Geology of the area is charnockite and granite gneiss of the Archaen age. Rainfall ranges from 3462 mm to 3602 mm and mean annual temperature varies between 22 ^oC to 27 ^oC.

AESR 7.1 is South Telangana Plateau (Rayalseema) and Eastern Ghat, hot, dry semi-arid eco-sub region. In this AESR, Rayachoty mandal was selected which lies between north latitudes 13^o 59' 45.28"and 14^o 7' 12.263" and east longitudes 78^o 35' 24.85" and 78^o 54' 5.608". It is divided in to seventeen villages. The mean annual rainfalls is 638 mm and mean annual temperature varies between 23 ^oC to 34 ^oC. Geology of Rayachoty mandal was granite-gneiss. A detailed soil survey was carried out at 1:10,000 scale in both the selected blocks and mandal using Survey of India toposheet (1:50,000 scale), sentinel-2 satellite data and google imagery. Soils were excavated or dug to a depth of hardrock (maximum two meter) in the selected slope both in upland and lowlands. Soil site characteristics and morphological properties were noted down. Selected master profile samples as well as surface soils (0 to 20 cm) were processed and analysed for their physical and chemical properties. Particle size analysis was carried out by International Pipette Method. Gravel content was determined by gravimetry method (Govindarajan and Koppar, 1975). Soil pH, electrical conductivity (1:2.5 soil: water ratio) and organic carbon were determined by adopting standard procedures (Jackson, 1973). Cation exchange capacity was determined by neutral normal ammonium acetate method (Schollenberger and Dreibelbis, 1930) and calcium carbonate equivalent (%) by Piper method (1966). The soils were classified according to soil taxonomy (Soil Survey Staff, 2003).

RESULTS AND DISCUSSION

In AESU 12 and 14, slope varied from leveled (0 to 1%) to very steep slope (>33%) where as in AESR 7.1, slope varied from leveled to gently sloping (3-5%). In both AESU and AESR soils moisture regime was Ustic and soil temperature regime was Iso-hyperthermic (Chandrakala *et al.* 2017 and Chandrakala *et al.* 2019b). Mean annual temperature was 27.5 ^oC in AESU and it varied between 23 ^oC to 34 ^oC in AESR. Mean annual precipitation was 3911.7 mm in AESU and 638 mm in AESR. Soil moisture was adequate in AESU and deficient in AESR. Length of growing period was 41 weeks and length of dry period was 2.5 months in AESU whereas LGP was 145 days and remaining days were drier in AESR (Fig. 1 and 2).

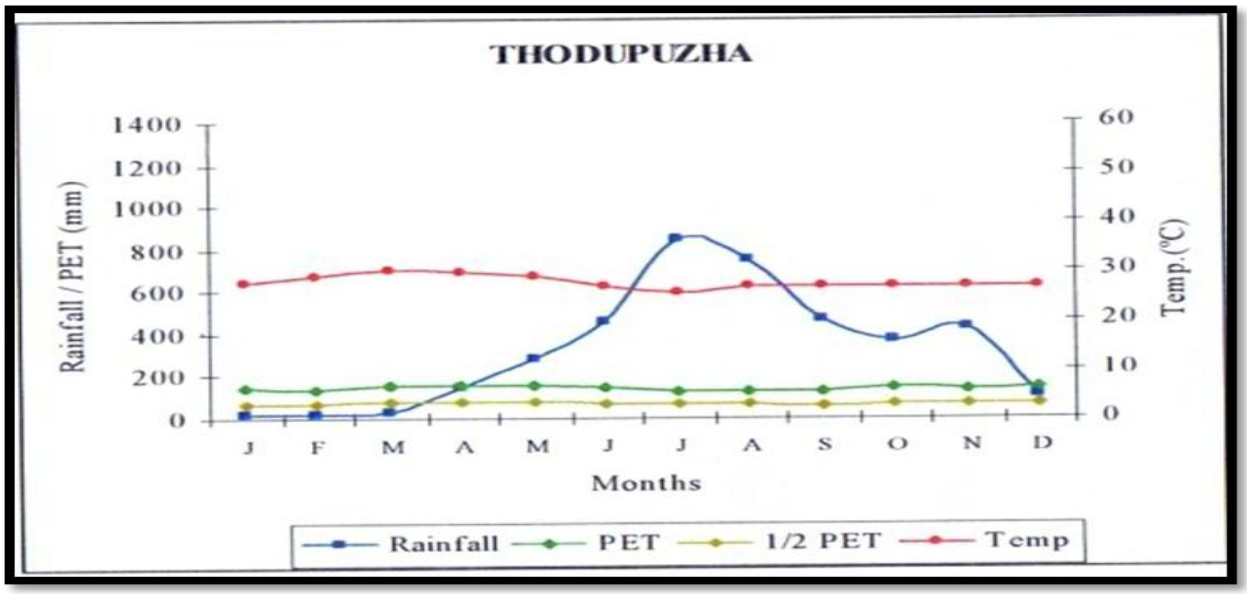

Fig.1: Water balance diagrams of Elamdesam block, Thodupuzha taluk, Idukki district, AESU, Kerala

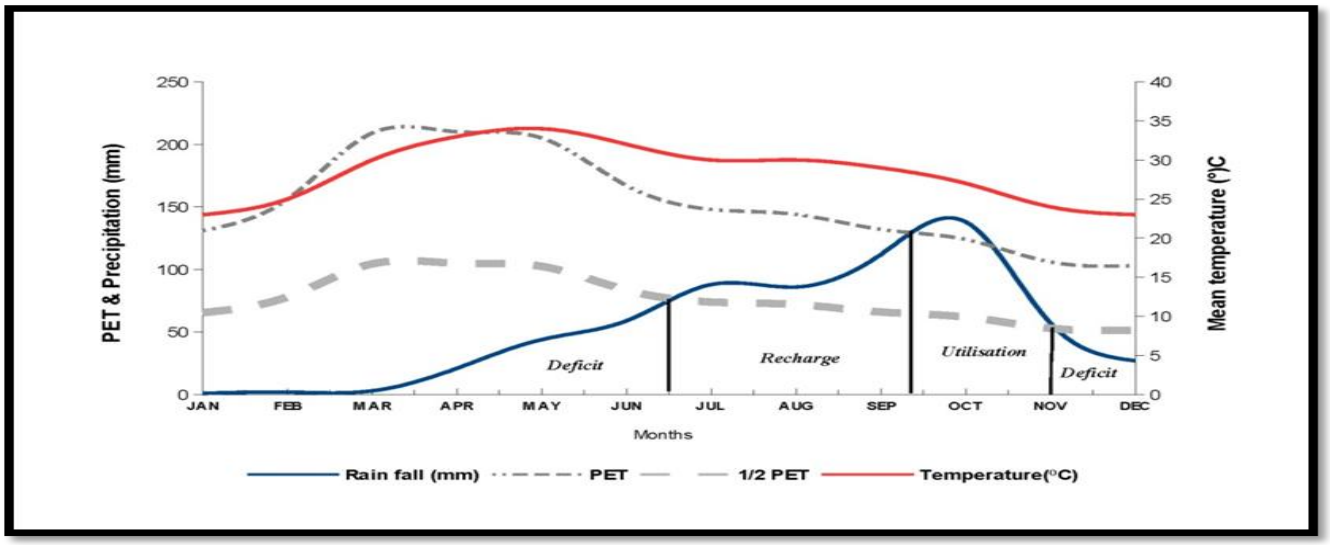

Fig. 2: Water balance diagram of Rayachoty mandal, YSR Kadapa district, AESR, Andhra Pradesh

Soil morphological properties

Soils in AESU 12 and 14 (Table 1) were comparatively deeper (up to 210+ cm) than AESR 7.1 (maximum 155 cm) which showed that soils were well developed in AESU 12 and 14 (Chandrakala *et al.* 2018b) which may be due to the favorable soil forming factors (climate, temperature and rainfall) resulting in deeper soils in AESU.

Table 1: Morphological features of major soils of different AESR, Southern India

Series	Depth cm	Horizon	Colour (moist)	Texture	Structure	Consistence	Coarse fragments	Special features
AESU 12 and 14								
Uplands								
Vellanchara	0-16	Ap	5YR 5/6	Sc	m1sbk	l, fr, s, p	-	-
	16-35	Bt1	5YR 5/6	Sc	m2sbk	s, fi, vs, vp	-	T tn p
	35-57	Bt2	5YR 5/6	Cl	m2sbk	s, fi, vs, vp	20-30	T tn p
	57-96	Bt3	2.5YR 4/6	C	m2sbk	s, fi, vs, vp	10-15	T tn p
	96-125	Bt4	2.5YR 4/6	Cl	m2sbk	s, fi, vs, vp	10-15	T tn p
	125-151	Bt5	2.5YR 4/6	Sc	m2sbk	s, fi, vs, vp	20-25	T tn p
	151-177	Bt6	2.5YR 4/6	C	m2sbk	s, fi, vs, vp	-	T tn p
	177-210+	Bt7	2.5YR 3/6	Cl	m2sbk	s, fi, vs, vp	-	T tn p
Lowlands								
Karimannoor-2	0-11	Ap	10YR 4/3	Sc	m1sbk	s, fr, s, p		-
	11-27	BW1	10YR 4/4	Cl	m2sbk	s, fr, s, p		-
	27-41	BW2	10YR 4/4	Scl	m2sbk	s, fr, s, p		-
	41-54	Bt1	10YR 4/6	C	m2sbk	s, fr, s, p		T tn p
	54-70	Bt2	10YR 4/6	C	m2sbk	s, fr, s, p		T tn p
	70-81	Bt3	10YR 5/6	Sc	m2sbk	s, fr, s, p		T tn p
	81-95	BC	10YR 4/1	C	m2sbk	s, fr, vs, vp		-
AESR 7.1								
Uplands								
Kumarapalli	0-14	Ap	2.5YR4/6	Sl	m1sbk	fr, so, po	25	-
	14-40	Bt1	2.5YR4/4	Scl	m2sbk	fr, s, p	35	T tn p
	40-63	Bt2	2.5YR4/4	Scl	m2sbk	fr, s, p	50	T tn p
	63-81	BC	2.5YR5/6	Sl	m2sbk	fr, ss, sp	30	T tn p
Lowlands								
Duganvandlapalli	0-15	Ap	10YR4/1	Scl	m2sbk	fr, ss, sp	-	-
	15-40	Bw1	10YR5/3	Scl	m2sbk	fr, ss, sp	-	-
	40-80	Bw2	10YR6/4	Scl	m2sbk	fr, ss, sp	-	-
	80-125	Bw3	10YR4/4	Scl	m2sbk	fr, ss, sp	-	-
	125-155	Bw4	10YR4/3	Scl	m2sbk	fr, ss, sp	-	-

Argillic (Bt) and Kandic horizons were found in both upland as well as in lowlands of AESU 12 and 14 which may be due to the clay illuviation whereas in AESR 7.1 Bt horizon was present in uplands and in lowlands Cambic horizon was identified. This variation in amount and nature of clay illuviation and horizonation may be due to differences in landforms, physiography and topographycal features of the land. The surface soil color was red (2.5YR 4/6M) in uplands of AESR 7.1 and yellowish red (5YR 5/6M) in AESU 12 and 14. This difference in color may be due to the parent material particularly iron containing nodules and their oxidation and reduction upon alternate wetting and drying during wet and dried condition in AESU. Consistency of soils varied firm to friable, sticky to very sticky and plastic to very plastic in AESU 12 and 14 whereas in AESR 7.1 soils were friable and slightly sticky to sticky and slightly plastic to plastic which might be due to the clay dominant fraction in AESU whereas sand content was dominant fraction in AESR (Chandrakala *et al.* 2018b). Gravel content was more (> 35%) in soils of AESR 7.1 compared to AESU which makes soils having low water holding capacity and low nutrients reserve (Table 1) for crop production hence these soils required frequent irrigation and external nutrients supply for better crop production and productivity.

Soil physico-chemical properties

Sand content (Table 2) was more (>50%) and clay content was less (<35%) in soils of AESR 7.1, whereas clay content was more (>35% to up to 63.5%) in AESU 12 and 14 which may be due to the highly weathered soils in AESU (Jena *et al.* 2016) and under weathering in AESR 7.1 due to comparatively less congenial climatic condition for physical and chemical soil

Table 2: Physical and chemical properties of major soils of different AESR, southern India

Depth (cm)	Particle size distribution (% of <2 mm)			Organic Carbon (gkg^{-1})	pH	EC ($d\ m^{-1}$)	Exchangeable bases (cmol (p+) kg^{-1})				CEC	CEC/ Clay (%)	B.S (%)	CCE (%)
	Sand	Silt	Clay				Ca	Mg	Na	K				
AESU 12 and 14														
Uplands**:** Vellanchara (Clayey kaolonitic isohyperthermic family of Ustic Kandihumults)														
0-16	53.4	10.8	35.8	15.9	5.22	0.05	0.97	0.12	0.05	0.10	5.94	0.17	21	
16-35	47.5	16.8	35.6	12.3	5.42	0.02	0.70	0.00	0.04	0.04	4.75	0.13	17	
35-57	42.8	17.3	39.9	9.9	5.11	0.02	0.42	0.00	0.03	0.02	4.86	0.12	10	
57-96	44.6	13.9	41.5	9.1	4.87	0.02	0.32	0.00	0.03	0.02	4.10	0.10	9	
96-125	44.7	15.9	39.5	9.1	4.89	0.02	0.32	0.00	0.02	0.02	4.00	0.10	9	
125-151	55.8	6.6	37.6	7.9	4.85	0.02	0.11	0.00	0.02	0.02	3.35	0.09	5	
151-177	38.9	17.5	43.6	5.9	4.81	0.02	0.10	0.00	0.02	0.02	3.78	0.09	4	
177-210	40.7	21.3	38.0	5.1	5.23	0.01	0.13	0.00	0.02	0.02	2.48	0.07	7	
Lowlands: Karimannoor-2 (Fine, mixed, acid, isohyperthermic sub-active family of Oxyaquic Haplustepts)														
0-11	45.5	16.5	38.1	11.9	4.9	0.04	1.86	0.63	0.07	0.12	9.08	0.24	30	
1-27	42.6	19.8	37.5	13.9	4.16	0.15	1.17	0.15	0.25	0.05	8.57	0.23	19	
27-41	47.8	19.2	32.9	13.5	4.42	0.07	0.76	0.14	0.15	0.03	7.45	0.23	14	
41-54	39.2	19.1	41.7	9.9	5.3	0.03	1.72	0.66	0.05	0.04	7.14	0.17	35	
54-70	40.5	15.0	44.5	8.0	5.33	0.03	1.65	0.85	0.03	0.05	7.55	0.17	34	
70-81	47.4	11.5	41.1	8.3	5.33	0.03	1.56	0.88	0.15	0.07	6.53	0.16	41	
81-95	17.9	18.6	63.5	25.9	4.77	0.06	1.97	1.09	0.13	0.12	16.22	0.26	20	
AESR 7.1														
Uplands: Kumarapalli (Loamy-skeletal mixed isohyperthermic Typic Haplustalfs)														
0-14	72.2	17.3	10.5	4.6	6.61	0.03	3.34	1.30	0.02	0.05	5.90	0.56	79.82	
14-40	58.5	17.1	24.4	4.2	6.54	0.03	7.37	2.78	0.04	0.06	11.80	0.48	86.96	
40-63	53.5	19.7	26.9	2.2	6.71	0.05	9.59	2.34	0.06	0.07	13.00	0.48	92.74	
63-81	66.5	13.8	19.7	3.2	8.18	0.11	-	-	0.04	0.05	13.80	0.70	100	
Lowlands: Duganvandlapalli (Fine Loamy mixed isohyperthermic (calcareous) Typic Haplustepts)														
0-15	55.5	24.4	20.1	10.0	8.76	0.28	-	-	0.76	0.97	12.50	0.62	100	4.34
15-40	54.5	25.5	20.0	2.9	9.01	0.30	-	-	1.52	0.92	14.10	0.70	100	3.17
40-80	55.8	20.6	23.6	2.2	9.36	0.36	-	-	2.36	0.40	14.30	0.60	100	9.98
80-125	52.1	24.9	23.0	2.2	9.45	0.36	-	-	2.49	0.42	15.90	0.69	100	6.58
125-155	56.0	22.1	21.9	1.4	9.39	0.35	-	-	3.40	0.62	17.50	0.80	100	4.93

forming processes in AESR. The subsurface had more clay content than surface due to the clay illuviation coupled with upward movement of coarser soil particles due to surface erosion of clay (Chandrakala *et al.,* 2021). Organic carbon content was very high (>10.0 gkg^{-1} and up to 25.9 gkg^{-1}) in soils of AESU 12 and 14 whereas which was low (1.4 to 10.0 gkg^{-1}) in AESR 7.1 which may be due to the land use difference in AESU 12 and 14 rubber plantation and paddy in lowlands. Addition of rubber leaf litter and paddy roots add organic matter (Chandrakala *et al.* 2017 and Chandrakala *et al.* 2019a). In AESR addition of organic matter to soil was less recording 10.0 gkg^{-1} organic carbon in surface soils in lowlands which was under paddy cultivation (Chandrakala *et al.,* 2021). Soils of AESU 12 and 14 were strongly acid (pH 5.0-5.5) to very strongly acid (4.5 to 5.0) in reaction whereas in AESR 7.1 neutral (pH 6.5-7.3) to strongly alkaline (pH >8.4) and very strongly alkaline. The higher saturation of aluminum (KCl exch. Al was 0.06 to 0.29 meq/100g), hydrogen (upto 0.45 meq/100g) and $BaCl_2$ acidity (5.7 to 9.02 meq/100g) in AESU 12 and 14 whereas calcium carbonate accumulation (31.7 to 99.8 gkg^{-1}) in lowlands of AESR 7.1 resulted in acidic and alkaline reaction, respectively. Soils were non saline in both the AESU and AESR but still electrical conductivity was little more in AESR 7.1 which may be due to higher exchangeable calcium, magnesium, sodium (0.02 to 3.40 cmol (p+) kg^{-1}) and potassium (0.05 to 0.97 cmol (p+) kg^{-1}) saturation in AESR. CEC was low in AESU 12 and 14 which may be due to low activity of clay though amount of clay was higher. The low CEC was due to dominance of clay minerals with low CEC and presence of hydrous oxides of iron and aluminium in the soils (Sarkar *et al.* 2002). Base saturation (BS) was less than 35% in AESU 12 and 14 which may be due to the soils are highly weathered and low cations (exch. Ca, Mg, Na and K) content particularly low bases reserve due to leaching of bases by the heavy rainfall hence these soils were classified as Ultisols in uplands and Inceptisols in lowlands (Chandrakala *et al.* 2017). In AESR 7.1 soils were having >35% BS and also 100 % hence were classified as Alfisols in uplands and Inceptisols in lowlands (Chandrakala *et al.* 2019b).

Soil fertility status

Generally surface soils had more available nutrients as compared to subsurface (Table 3) which may be due to application of nutrients and organic matter to surface soils during crop production. Available phosphorus content was higher (35.6 kg ha^{-1} in surface) in AESU compared to AESR, which may be due to successive application of phosphorus fertilizer for paddy cultivation resulting slight building of P. It also might be due to higher decomposition of native soil P by organic acids released during the decomposition of rubber leaf litter and paddy roots and organic manure mediated complexation of cations responsible for fixation of P in soil (Sushma *et al.,* 2007). The available potassium content was higher (237 kg ha^{-1} in surface) in AESR compared to AESU which may be due to the K bearing minerals present in AESR (Chandrakala *et al.*, 2018a). The available sulphur content was more (9.1 to 14.2 in surface) in AESU compared to AESR which might be due to fine texture soils. The available calcium and magnesium contents were higher in AESR as compared to AESU which might be due to higher rainfall in AESU causes leaching of bases to sub-surfaces. Available iron content was more in AESU compared to AESR due to inherent soil capacity by the presence of iron bearing pyrites in AESU. Available zinc, copper and boron contents were more in AESU as compared to AESR due to higher organic mattes present in the AESU.

High soil heterogeneity existed in between AESU and AESR of southern India. Ultisols and Inceptisols were dominant in AESU whereas Alfisols and Inceptisols in AESR. The nature and amount of sand, clay and organic carbon contents highly differed. Soil texture, consistency, color, pH, BS, CEC, CCE also differed between AESU and AESR. The study helps to assess the heterogeneity in soil properties and further to take up suitable land use options with best soil and water conservation measures for better crop production and productivity.

Table 3: Fertility status of major soils of different AESR, southern India

Series	Depth (cm)	P (kg ha^{-1})	K (Kg ha^{-1})	S (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
AESU 12 and 14											
Uplands											
Vellanchara	0-16	7.0	77	9.2	132.6	18.8	9.4	12.0	1.1	4.7	0.29
	16-35	4.0	29	7.5	78.9	6.6	4.7	1.6	0.2	3.6	0.35
	35-57	2.0	21	11.7	38.4	5.8	3.3	0.7	0.2	2.8	0.19
	57-96	2.0	13	15.8	23.9	4.0	3.6	0.2	0.2	2.3	0.23
	96-125	0.24	19	24.2	29.6	4.4	4.0	0.4	0.2	2.4	0.35
	125-151	2.0	17	17.5	15.6	3.8	4.5	2.4	0.3	2.4	0.17
	151-177	2.0	16	10.8	15.6	5.2	3.4	0.6	0.3	2.3	0.39
	177-210+	0.72	12	20.0	19.3	4.9	3.4	0.8	0.2	2.1	0.33
Lowlands											
Karima-nnoor-2	0-11	35.6	101	14.2	372.8	77.0	15.5	17	1.3	1.6	1.03
	11-27	18.5	43	10.8	234.7	17.7	13.1	3.6	0.71	1.7	0.79
	27-41	11.9	24	14.2	152.4	16.5	7.8	1.6	0.7	1.5	0.51
	41-54	7.9	35	13.3	344.4	80.7	6.4	3.6	0.6	1.1	0.55
	54-70	6.9	44	15.0	329.3	103.7	7.2	4.7	0.5	1	0.68
	70-81	5.5	62	12.5	312.8	106.5	9.3	3.9	0.3	0.7	0.48
	81-95	18.2	104	19.2	393.4	132.1	70.6	12.3	0.5	1.5	0.25
AESR 7.1											
Uplands											
Kumarapalli	0-14	3.0	37	8.33	-	-	6.4	8.0	0.3	0.7	0.30
	14-40	2.0	42	4.16	-	-	4.0	11.6	0.1	1.2	0.33
	40-63	5.0	50	5.0	-	-	4.3	5.8	0.1	1.2	0.49
	63-81	5.0	33	1.66	-	-	2.8	1.5	0.1	0.4	0.17
Lowlands											
Duganvan-dlapalli	0-15	9.0	237	10.0	-	-	1.7	1.5	0.2	1.2	0.29
	15-40	5.0	244	10.8	-	-	3.1	0.6	0.2	0.9	0.27
	40-80	1.0	130	6.7	-	-	1.4	0.6	0.0	0.6	0.55
	80-125	8.0	141	10.8	-	-	0.6	1.6	0.0	0.9	0.12
	125-155	2.0	125	11.7	-	-	0.9	1.1	0.0	0.7	0.16

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