CHAPTER 10

CASHEW-GROWING SOILS

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ABSTRACT

Cashew is a major crop of India and many other countries of the world. There is great potential to expand area under this crop and exploit it commercially. Soil is a crucial factor that determines the suitability of sites for cultivation of cashew. However, a synthesized body of work on the soil information of cashew-growing soils is not available. This chapter attempts to review the available literature and present comparisons of cashew-growing soils from different parts of the world. Special focus is placed on the soils of Konkan, Maharashtra which is the region renowned for cashew production and cashewnut quality. Physical and chemical properties of cashew soils from Africa, Australia and Vietnam are compared. In India, benchmark soils as well as soils from different cashew growing states are compared. An attempt is also made to assess the carbon sequestration in cashew soils of India. With the available data on the soils of Kerala and Maharashtra, it appears that threshold limit of SOC stock (Pg million ha^{-1}) is well above the limit earlier reported for the soils of North-east India as well as Konkan which is responsible, perhaps, for maintaining the green belt of coastal ecosystem.

The distribution of clay in the subsurface play an important role in cashew tree orchards. The clay distribution gradually increased down the soil depth. Despite some early reservations, the plant available water capacity (PAWC) has emerged as a better quality parameter to adjudge soil suitability for deep-rooted agricultural crops. The PAWC values are relatively more in soils of Maharashtra than Kerala. Along with smectitic

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mineralogy in the soils of Maharashtra, it seems that the PAWC for cashew even in stress condition will be more in soils of Maharashtra than those of Kerala. It appears appropriate that a study of organoleptic parameters of consumable cashewnut in different states be compared keeping in view all the values of PAWC. Similarly, Maharashtra cashew soils showed higher delta pH than Kerala soils indicating high residual acidity. This information might be useful in exploring quality of cashewnut grown in soils of different localities.

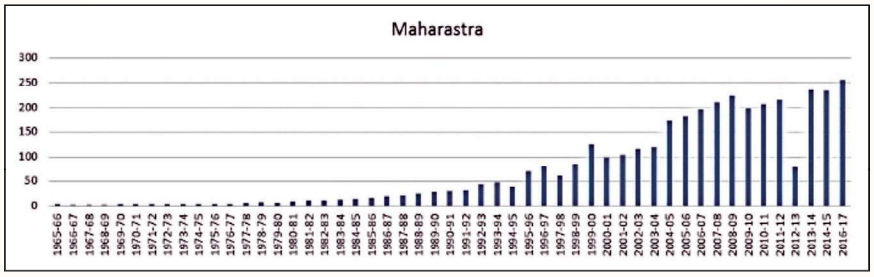
Keywords : Cashew-growing soils, soil suitability, Konkan, Kerala, carbon stock, PAWC, cashew quality, smectitic.

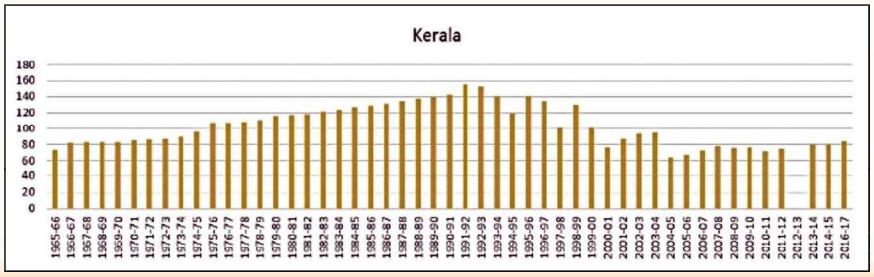
INTRODUCTION

Cashew (*Anacardium ocidentale*) is native to Brazil. It was introduced into India by Portuguese travellers in the 16th Century for afforestation and soil conservation. India was the first country in the world to exploit international trade in cashew kernels in the early part of the 20th Century. Cashew is presently grown on an area of 10.36 lakh ha with annual production of 6.71 lakh t of raw cashewnuts (Anonymous 2017, FAO 2018). Most of the area under cashew is in the east-coast and west-coast regions of the country. In India cashew is grown mainly in Maharashtra, Goa, Karnataka and Kerala along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. It is also grown to a limited extent in non-traditional areas (Chhattisgarh and Karnataka, Gujarat, Jharkhand and North-eastern hilly region). Although Andhra Pradesh has the largest area under cashew, Maharashtra ranks first in production and productivity (Table 1) (Figure 1) (Anonymous 2017).

Table 1 : Area, production and productivity of Cashew in different states/ union territories of India. *(Source: Anonymous 2017)*

Sr. No.	STATES/UTs	Area '000 ha	Production '000 MT	Productivity MT ha^{-1}
1	Maharashtra	186.20	256.61	1.38
3	Andhra Pradesh	185.57	111.39	0.60
4	Odisha	182.91	93.90	0.51
5	Karnataka	126.71	85.15	0.67
6	Kerala	87.29	83.98	0.96
7	Tamil Nadu	141.33	67.65	0.48
8	West Bengal	11.36	12.96	1.14
9	Chhattisgarh	13.70	9.33	0.68
10	Gujarat	7.22	6.50	0.90
11	Jharkhand	14.83	5.83	0.39
12	Meghalaya	8.50	5.83	0.69
13	Tripura	4.25	3.45	0.81
14	Assam	1.05	1.08	1.03
15	Nagaland	0.50	0.54	1.08
16	Manipur	0.90	0.32	0.36
18	Others	63.17	34.82	0.55
	TOTAL	**1035.49**	**779.34**	**0.75**





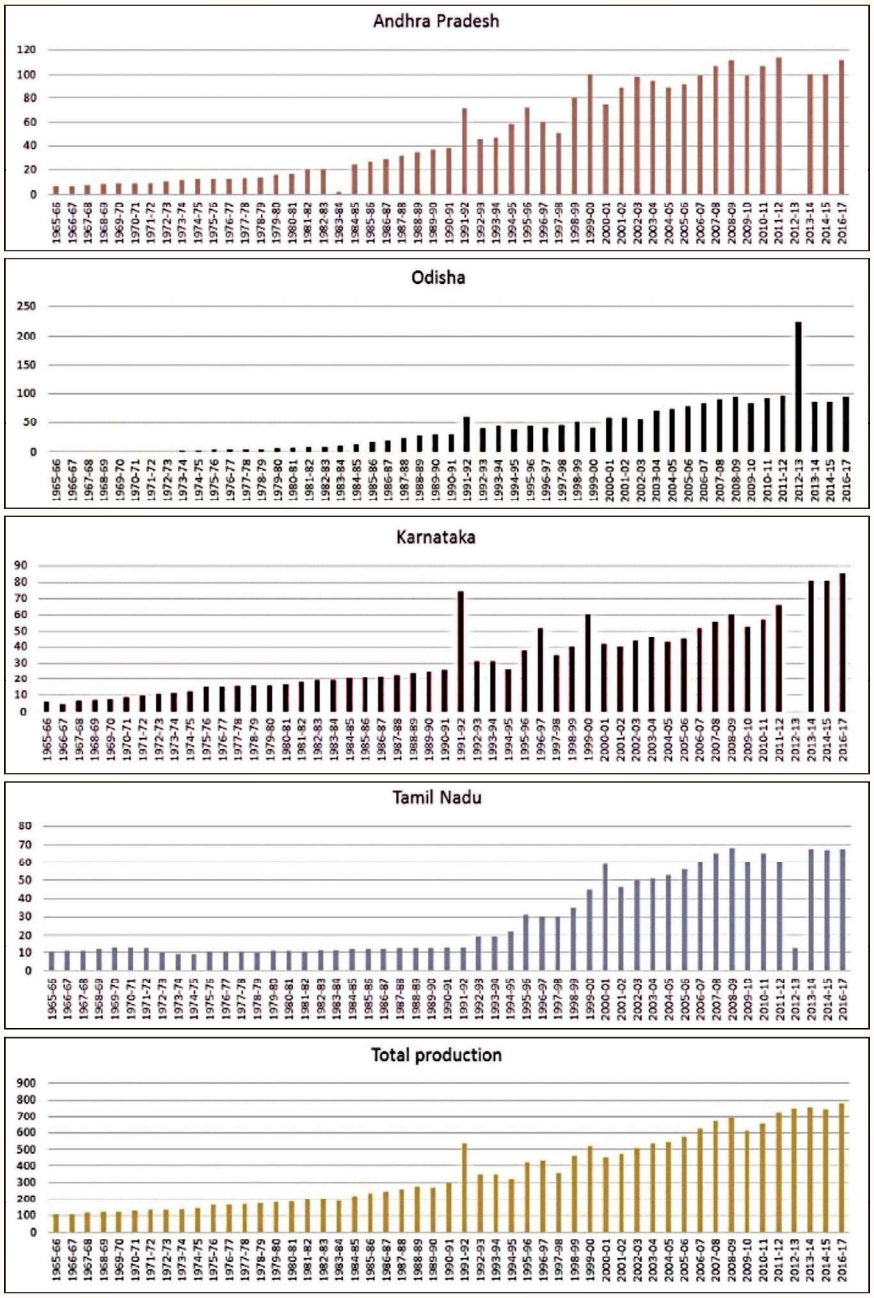


Fig. 1 : Trends in cashewnut production in major states in India (Production in million tonnes)

India requires about 12-13 lakh tons of raw cashewnuts to feed large number of cashew processing units (1,800 medium to large, and 1,850 on-farm processing units) engaging over 5 lakh workers, especially women. As India produces just 6.95 lakh tons of raw cashewnuts annually, the balance of 6.0 lakh t of raw cashewnuts is imported annually by India from the African and South East Asian countries. India exports 1.1 lakh t of cashew kernel to over 65 countries in the world. About ₹ 2,906 crore is earned as foreign exchange through export of cashew kernel, and an additional ₹ 24 crore by export of the Cashew Nut Shell Liquid (CNSL) (Bhat et al. 2010).

Traditionally, cashew has been an important crop in the coastal region (western and eastern) of the country but has recently been spreading to non-traditional areas as well. There is a great scope for expanding area under cashew in the plains of Karnataka, Chhattisgarh and non-traditional areas of Gujarat, Jharkhand, north eastern hilly region and Andaman and Nicobar Islands (Table 2) (Bhat et al. 2010). This is not clear how these authors arrived at these figures. The expansion of rubber in Tripura as an important plantation crop competing with other horticultural crops has been detailed elsewhere (Bhattacharyya et al. 1996, 2003, 2004). The methodology of that elaborate process needs to be followed. And to do that details investigation on soils and landscape need to carried out.

Table 2 : Potential area available for expansion of cashew. *(Source: Bhat et al. 2010)*

State	**Area** (million ha)
Bihar	0.25
Goa	0.1
Jharkhand	0.25
Chhattisgarh	0.5
Kerala	0.25
West Bengal	0.25
Gujarat	0.25
Tamil Nadu	0.25
NEH Region	0.5
Andhra Pradesh	1
Karnataka	1
Orissa	1
Maharashtra	1.5
Total	7.1

CASHEW IN INDIA

The cashew tree (*Anacardium occidentale*), has a long standing history as an extremely useful tree both in terms of nutrition, as well as a food taste enhancer. Considered to be a native to the northern part of South America, it is now found in many tropical countries. The English name 'cashew' is derived from the Portugese name 'caju', it is called 'acaju' in Brazil, 'merey' in Venenzuala, 'cajuil' in Spanish and 'decajou' in French. Cashew was introduced to India by the Portugese between 1563 and 1570. The Portugese people was the first to bring cashew to Goa and then spread this nutritional tree nut across the western region of India, and later to South East Asia. A Portugese missionary from Brazil brought cashew to Goa in order to stop soil erosion along with the west coast of India. It is said, that the edible value of the cashew nut was discovered by Goan prisoners exiled to the Portugese territory of Africa (Mozambique) during Goa's freedom movement in 1752. The prisoners tried them, and used them as a regular food item. Thus, the cashewnut became a part and parcel of Goan life. The local people of Goa started consuming cashewnut by the middle of the 18th century and now, it commercially ranks second to almond. Cashew now occupies amomng the nine important tree nuts in trade in the whole world (Anonymous, 2018).

In Venezuela cashew is called merey, but in all other Spanish speaking countries of Latin America it is called maranon, which may be derived from one of the first regions where the fruit was seen, viz the State of Maranhao in northern Brazil. Cashew originally belongs to Brazil, found well at home in Indian peninsular soils, and got exploited to the maximum benefit towards improving the rural economy and as a premier crop of Indian commerce. The tree establishes itself easily and by men and animals may have increased its growing area even in pre-historic times. It is likely that Spanish sailors have taken the nut to Central American countries and certain that the Portuguese brought the cashew to their territories in the East Indies and Africa. It may be assumed that cashew came to Goa, Portugals main settlement in the East Indies at a time, between 1560 and 1565. It is believed that the Portuguese brought the cashew to India, between 1563 and 1578. After India it was introduced into South-Eastern Asia and, according to Agnoloni and Giuliani

(1977), it arrived in Africa during the second half of the XVI century, first on the east coast and then on the west and lastly in the Islands. The cashew later spread to Australia and some parts of the north-American Continent. Finally, its present diffusion can be geographically located between 31 North latitude and 31 South latitude, both as the wild species and under cultivation (Ohler, 2001).

CASHEW GROWING SOILS

Cashew is grown on different types of soils (laterite, red, black and coastal sands) and experiences severe moisture stress from January to May, which adversely affects flowering and fruit set. Coconut husks buried in trenches of 1 m width, 0.5 m depth and 3.5 m length per plant, opened across the slope between two rows of cashew, helps better soil and water conservation (Saroj 2015). This not only helps conserving moisture for cashew but also in preserving soils by reducing erosion.

A large portion of cashew growing soils is reported to be acidic. Some of the major constraints to cashew production on acid soils are: i) low soil pH ii) Al, and Mn toxicity, iii) low base saturation, iv) low available P and high P fixation capacity, v) low concentrations of exchangeable calcium (Ca), magnesium (Mg) and potassium (K), reduced zinc (Zn), molybdenum (Mo) and boron (B) vi) low microbial activity (nitrification), vii) low water holding capacity (except soils in basaltic terrain) (Saroj 2015, Bhattacharyya et al. 2018)).

As has been shown in Table 3, well drained, loam to clay loam, 150-300 cm soil depth, acidic to near neutral soil reaction, non-saline with nearly 0.71 % organic carbon with high base saturation to the tune of nearly 60–65 % are ideal for cashew cultivation. It has to be remembered that cashew grows well between 200–250 m elevations above mean sea level without any water stagnation

Table 3 : Suitability criteria modified from the studies based on the cashew crop performance and yield.

Soil site characteristics		Unit	Rating				References
			Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable	
Climatic regime	Total rainfall	mm	1500-3000 987-2247 2500-3000	>3500 1000-1500 827-987 2247-3197 <2000 >4000	750-1000 601-827 3197-4926 1500-2000	<750 <601 >4926 -	Srinivasan et al (2011) Widiatmaka et al (2015) Personal communication*
	Mean temperature	°C	25-35 18-32	31-40 15-24 32-35 14-18	40-50 12-14 35-40 10-14	>50 <12 >40 <10	Srinivasan et al (2011) Personal communication*
	Mean RH	%	60-90 65-98	40-60 >90 55-85	- 40-55	- <40	Srinivasan et al (2011) Personal communication*
	Dry months	months	1-4 5.1-9.8	4-6 <1 3.9-5.1 9.8-10.5	6-8 <3.9 10.5-11.4	>8 >11.4	Srinivasan et al (2011) Widiatmaka et al (2015)
	Length of growing period	days	>210	150-210	90-150	-	Srinivasan et al (2011)
Site characteristics	Elevation (Altitude)	meter	<600 <195.6 10-250	600-900 195.6-324.4 250-350	900-1500 324.4-456.2 350-500	>1500 >456.2 >500	Srinivasan et al (2011) Widiatmaka et al (2015) Personal communication*
	Slope	%	<15 <11.9	15-33 11.9-23.1	33-50 23.1-77.4	>50 >77.4	Srinivasan et al (2011) Widiatmaka et al (2015)
	Water table	meter	>3	1-3	0.5-1	<0.5	Srinivasan et al (2011)
	Surface Rock	%	<14.5	14.5-28.8	28.8-75.5	>75.5	Widiatmaka et al (2015)

Soil charactrictics	Drainage	Qualitative class	Well to moderate well	Improper Well to moderate	well saturated poorly-drained	- Stagnant	Srinivasan et al (2011) Personal communication*
	Texture		l, sl, scl, c cl, scl, l sl, l	cl,sil,ls,s (coastal) sc, cl, sl cl	sic, (non c (swelling) c, sic, sicl sic	c (swelling) c, si, ls, s c	Srinivasan et al (2011) Widiatmaka et al (2015)
	Depth	cm	>39.7 150-300	21.1-39.7 100-150	6.6-21.1 50-100	<6.6 <50	Widiatmaka et al (2015) Personal communication*
	pH		5.0-7.3 5.4-6.4	7.3-8.0 4.0-5.0 5.1-5.4 6.4-6.9	3.0-4.0 8.0-9.5 4.6-5.1 6.9-7.7	<3.0 >9.5 <4.6 >7.7	Srinivasan et al (2011) Widiatmaka et al (2015)
	EC	dSm^{-1}	<2	2-4	4-10	>10	Srinivasan et al (2011)
	CEC	$cmol(+)kg^{-1}$	>12.40	8.54-12.40	2.56-8.54	<2.56	Widiatmaka et al (2015)
	SOC	%	>0.78	0.49-0.78	0.11-0.49	<0.11	Widiatmaka et al (2015)
	Base saturation	%	>65.7	<65.7	-	-	Widiatmaka et al (2015)
	Total N	%	>0.072	0.052-0.072	0.029-0.052	<0.029	Widiatmaka et al (2015)
	Available P	ppm	>39.69	10.84-39.69	1.02-10.84	<1.02	Widiatmaka et al (2015)
	Exchangeable K	$cmol(+)kg^{-1}$	>0.37	0.27-0.37	0.10-0.27	<0.10	Widiatmaka et al (2015)

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CLIMATE AND SOIL

Climate

Cashew tree is an evergreen plant, although a partial replacement of the leaves can occur. Owing to its sensitivity to low temperatures, its geographic distribution is confined to regions between 27 ºN and 28 ºS (Frota and Parente 1995). In spite of being a tropical fruit in origin, the cashew develops well in temperatures varying from 22 to 40ºC, although Parente et al. (1972) cite 27 ºC as the ideal average

temperature for normal development and fruit bearing. Owing to the influence of altitude on temperature, cashew plantations may be found at altitudes up to 1,000 m close to the equator. In higher latitudes and altitudes above 170 m, the yield is negatively affected (Aguiar and Costa 2002). Cashew develops well between 70% and 85% relative humidity. Trees will grow in regions where the relative humidity is 50% for a long period of time if the soil contains a good reserve of moisture or irrigation is used. In regions where the relative humidity is above 85%, fungal diseases of the leaves, flowers and fruits increase. Wind has little influence on a cashew plantation. However, at velocities of 7 m s^{-1} or higher, Aguiar and Costa (2002) reported an increase in loss of flowers and fruits and chances of trees being blown over. According to Aguiar and Costa (2002), trees are established successfully when the annual precipitation is within the range 800 to 1,500 mm, distributed over 5 to 7 months along with a 5 to 6 month drought that coincides with the flowering and fruiting phases.

Soil

In Brazil, especially in the north-east, the majority of cashew plantations grow on Quartzarenic Neosols (Quartz Sands), Latosols and Argisols (Podzolics). These are deep soils with good drainage, and with no stones or impervious layers, but with low fertility (Crisóstomo, 1991). In India, the cashew is cultivated on soil that is infertile, leached, acidic and sometimes containing excess changeable aluminium (Al) (Gunn and Coks, 1971; Falade, 1984; Badrinath et al., 1997). This may not be true as is detailed in the subsequent papargraphs that cashew-growing soils are also good fertility. Menon and Sulladmath (1982) also reported that satisfactorily prosperous plantations existed on soils that are volcanic, iron-rich, lateritic rusty, alluvial, clayey, and those with a high water table, at times subject to flooding. Since cashew requires fewer nutrients than other fruit trees many plantations are found on soils of marginal fertility (Latis and Chibiliti 1988), which may not be true. Research has shown positive responses to mineral fertilizers for cashew which is expected. (Falade, 1978;; Sawke et al., 1985 and Grundon 1999). Falade (1984) concluded that the physical and chemical characteristics of the soil influence the height of the plant as well as the diameter of the crown, and the

morphology of the root system. He concluded that light textured soils, free from stones and without an impervious layer or horizon within the top 100 cm are the best for growing cashews. Before establishing a plantation, the soil should be sampled and analysed to determine the need for soil amendments and fertilizers. In already established orchards, soil and leaf analysis provide supplementary information as to the recommendations for fertilizers and soil amendments.

The root system of the young dwarf cashew is one very well developed main root that branches many times and can grow to 10 m or more in deep sandy soils. Lateral roots develop in the upper soil layers between 15 and 32 cm deep. The length of the superficial roots may reach twice the diameter of the crown in dry-land conditions (Barros, 1995). When irrigated the lateral roots are concentrated around the wet area of soil. The characteristics of the tap and lateral roots are of importance in relation to the fertilization of cashew. Studies on the effects of topography, soil texture, stoniness and the presence of a hardened soil layer on the development of the cashew root system showed great variation in the depth of the main root and distribution in depth and length of the lateral roots (Falade 1984).

AGROCLIMATE OF CASHEW

Cashew is known as a crop of marginal lands. There are very few articles which specifically deals with cashew-growing soils in their whole perspective. This is true for most of the horticultural, plantation and spice crops. There are reports that cashew performs better in class I and II lands (USDA 1961; Mahopatra and Bhujan 1974; Anonymous 1974). Interestingly most of the cashew-growing lands do not fall in these classes, at least the best cashew –producing areas in Konkan, Maharashtra. Suitability of cashew growing areas indicate that saline and water-logged areas may not perform well (Table 3).

A. occidentale is a fast growing, hardy and drought resistant multipurpose tree species cultivated in many tropical countries. It is one of the most well- known species for its nut in the world, although all parts of the tree may not be used to its full potential. It is an important tropical tree crop and in terms of international trade

for major edible nuts it ranks second or third. It is also a well-known agroforestry species. The trees produce fruits when they are about 4 years old and maximum production is from 10 to 30 years (Anonymous 2003).

Cashew is grown in all over the tropics and also part of warm subtropics; but mostly between the Tropic of Cancer and Tropic of Capricorn. It includes Latin America (Brazil, Colombia, Cuba, Costa Rica, Dominican Republic, Guatemala, Panama, Peru, El Salvador, Venezuela); Africa (Angola Basin, Cameroon, Cape Verde Islands, Guinea-Bissau, Ivory coast, Kenya, Madagascar, Mozambique, Nigeria, South Africa, Tanzania, Uganda, Zaire, Zambia and in other African countries in small populations); Asia (India, Indonesia, Malaysia, Philippines, Sri Lanka) and also in Australia on a limited area (Mandal 2000).

Agro-climatic zoning is a powerful tool used in agricultural and environment planning of a particular region (Bhattacharyya et al 2015). India in endowed with diverse agro- climatic conditions capable of producing almost all types of agricultural production. It includes fifteen agro- climatic zones (ACZ) which have been delineated in relation to the physiographic and climatic elements, soil types and groundwater reserves to illustrate crops and their combinations (Anonymous 1989). South Konkan includes west coastal plains and the hills. This coastal strip along the Arabian Sea from the south of Mumbai all along through Goa and Kerala receives more rain and is backed by the Western Ghats' escarpment in comparison to its eastern counterpart. This is predominantly an area of rice accompanied with pulse and coconut. There is a diversified plantation economy ranging from cashew nuts and mango orchards at the foothill junctions with lowlands. Out of nine agro-climatic zones of Maharashtra, two zones are represented in south Konkan i.e. very high rainfall zone with red ferruginous soils and the Western Ghats on the basis of soil type, rainfall, and vegetation (Bhattacharyya et al. 2008).

Temperature and cashew

Temperature plays an important role in determining success and failure of cashew crop. While rating mean temperature, it has been stated that the range of 25–35 ^{o}C temperature is highly suitable (Table 3). The temperature more than 50 ^{o}C and less

than 12 °C has been considered as harmful for cashew (Srinivasan et al. 2011).

In Konkan, Maharashtra, the variation of temperature during the entire year is not very large since it is in the coastal region. The month of March, April and May are hot (32-35^0 C) which becomes relatively cool with the onset of monsoon. Night temperature is low in January, the areas within the radius of 20–25 km of coastal Konkan are pleasant during the hot months due to overall sea breezes.

Rainfall and cashew

Cashew is a typical tropical tree and therefore, it prefers humid to per humid climate (Bhattacharyya et al. 2013). However, rainfall more than 5000 and less than 600 has been referred as unsuitable for cashew cultivation (Srinivasan et al. 2011; Widiatmaka et al. 2015) (Table 3). In Konkan, Maharashtra, the rainfall is relatively more near the Western Ghats. The entire rainfall in this zone occurs during the months from June to October.

Winds and cashew

High velocity along with hot wind circulation may cause damage to cashew trees due to breakage of branches, flowers and fruit drops. During the monsoon, the wind speed is pretty high with general direction of western and south western angles. In Konkan and other coastal areas this problem is common.

Relative Humidity and Cashew

As mentioned earlier, cashew is a typical tropical fruit tree as for which it loves high humidity Therefore, the coastal regions like Maharashtra, Kerala and Orissa with high humid climate especially are preferred locations for cashew. The relative humidity less than 60 % have been reported to be unsuitable for cashew (Srinivasan et al. 2011) (Table 3). In Konkan, Maharashtra, relative humidity is high in the southern Konkan as compared to the northern counterpart. This may be one of the reasons why cashew performs better in south Konkan.

Length of growing period and Cashew

Length of growing period indirectly indicates total number of months in which the trees do not experience any moisture stress. This is calculated on the basis of

revised FAO frame work taking into account the water holding capacity of soils along with mean rainfall. Usually cashew prefers length of growing period more than 7 months. If it is less than 3 months, growing cashew will not be profitable (Srinivasan et al. 2011) (Table 3).

Elevation of land and Cashew

There are varying reports about suitability of cashew vice versa performance of cashew. It has been reported by Srinivasan et al. (2011) that the elevation less than 600 m above mean sea level is highly suitable for cashew. While Widiatmaka et al. (2015) stated that nearly 200 m and less elevation is highly suitable for cashew (Table 3). Few of the factors like water table, surface stoniness have also been correlated with cashew performance (Table 3).

SOILS

Generalities

Cashew is generally grown in all types of soils in terms of depth, colour, texture and other parameters. Usually cashew orchards suffer from poor phyto-sanitary conditions with very little agronomic management. With the advent of modern techniques and better recommendations from different research organizations, cashew is now being treated as a most important money- earning venture by the farmers. As is true, for most of the horticultural crops, there are very less information on cashew growing soils both in India and abroad (Bhattacharyya et al. 2018).

Properties of selected cashew Properties of selected cashew soils in India

Benchmark soils of India

From the database of benchmark soils in India, four were selected where cashew is being grown. Analytical data of a few benchmark soils of Karnataka, Kerala, Odisha, West Bengal and Maharashtra is shown in Tables 4 and 5. Most of the soils belong to Inceptisols, Entisols and Alfisols (Soil Survey Staff 2014). Using pedo-transfer functions (Tiwary et al. 2014), the saturated hydraulic conductivity (sHC) are found to be in the range of 3 to 6 cm hr^{-1} indicating well drained conditions of these soils. Most of the soils are sandy with less silt. Karnataka

and Odisha soils are acidic to neutral. All the soils are non-calcareous and non-sodic. Except Kerala soils, others have high base saturation and moderately high clay cation exchange capacity (clay CEC) indicating mixed and smectitic mineralogy (Table 5) (Soil Survey Staff 2014; Bhattacharyya et al. 2009).

Table 4 : Physical Properties of cashew growing Benchmark soils in India.

Depth (cm)	Particle size distribution			BD *	sHC mm hour^{-1}**
	Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
Arikunte soils (Oxic Haplustepts, Kolar, Karnataka					
0-14	83	3	14	1.4	45
14-28	29	5	66	1.5	59
28-80	39	15	46	2.1	39
Trivandrum soils (Ustoxic Dystropepts, Trivandrum district, Kerala)					
0-9	38	10	52	1.4	61
9-25	40	9	51	1.4	62
25-52	38	9	53	1.4	55
52-84	34	13	53	1.4	52
Palank soils (Typic Ustipsamments, Puri, Orissa)					
0-16	92	3.4	4.6	1.6	33
16-60	98	0.5	1.5	1.6	32
60-150	98	0.5	1.5	1.6	29
Taldangra soils (Plinthustalfs, Bankura, West Bengal)					
0-12	80	7	13	1.6	61
12-33	68	8	24	1.6	59
33-68	66	7	27	1.6	52

Table 5 : Chemical Properties of cashew- growing Benchmark soils in India.

Depth (cm)	pH (water)	OC*	$CaCO_3$	Ca	Mg	Na	K me/100g	BS %	CEC	Clay CEC	Ca/ Mg	ESP
Arikunte soils (Oxic Haplustepts, Kolar, Karnataka												
0-14	6.0	0.66	-	1.6	0.4	0.1	0.2	66	3.5	25	4	3
14-28	5.7	0.53	-	6.9	0.4	0.2	0.2	66	11.1	17	17	2
28-80	6.8	0.07	-	7.1	0.7	0.2	0.1	79	10.2	22	10	2
Trivandrum soils (Ustoxic Dystropepts, Trivandrum district, Kerala)												
0-9	4.5	1.39	-	1.7	0.4	0.1	0.2	34	6.7	13	4	1
9-25	4.5	1.10	-	1	0.2	0.1	0.2	24	5.8	11	5	2
25-52	4.8	0.41	-	0.5	0.2	0.1	0.1	23	4.0	8	3	3
52-84	5.0	0.27	-	0.2	0.1	0.1	0.1	11	4.5	9	2	2
Palank soils (Typic Ustipsamments, Puri, Orissa)												
0-16	6.8	0.14	-	1	0.5	-	-	75	2.0	43	2	-
16-60	6.9	0.09	-	0.5	0.3	-	-	80	1.0	67	2	-
60-150	7.1	0.09	-	0.5	0.3	-	-	80	1.0	67	2	-
Taldangra soils (Plinthustalfs, Bankura, West Bengal)												
0-12	4.8	0.44	-	3.2	0.8	0.2	0.2	57	7.7	58	4	3
12-33	4.8	0.31	-	4.4	1.6	0.4	0.2	60	11	47	3	4
33-68	5.3	0.24	-	4.8	1.6	0.5	0.3	61	11.9	44	3	4

*Revised organic carbon following Bhattacharyya et al (2015); soils are non-saline and non-calcareous

Cashew growing soils from Goa

The soils in Goa are clay to clay loam and are well drained as envisaged by saturated hydraulic conductivity (sHC) values (Table 6). These soils are non-calcareous, non-saline, and non-sodic. Information on clay soils indicate that these soils belong to mostly mixed mineralogy class. Except Madgaon soils, all the soils are rich in organic carbon (Table 7).

Table 6 : Physical Properties of selected cashew- growing soils in Goa.

Depth (cm)	Particle size distribution			BD *	sHC mm hour^{-1}**
	Sand (2-0.05)	Silt (0.05-0.002)	Clay (<0.002)		
Darbandora soils (Ustoxic Humitropepts), Pernum district, North Goa					
0-8	26	22	52	1.4	57
8-19	9	28	63	1.4	54
19-51	9	22	70	1.4	52
51-89	9	20	71	1.4	65
Karmeli soils (Lithic Dystropepts), Salcete, South Goa district, Goa					
0-14	30	27	43	1.4	44
14-34	22	30	48	1.4	43
Madgaon soils (Fluventic Ustropepts), North Goa, Goa					
0-18	81	8	11	1.4	53
18-46	80	7	13	1.4	49
46-73	53	18	29	1.4	45
73-107	20	22	58	1.4	46
107-128	60	13	27	1.4	46
128-148	60	13	27	1.4	45
Netravali soils (Ustoxic Dystropepts), North Goa, Goa					
0-10	24	30	46	1.4	43
10--34	13	30	57	1.4	43
34-54	11	29	60	1.4	38
54-74	12	24	64	1.4	35
SURLA soils (Typic Ustropepts), North Goa, Goa					
0-10	18	26	56	1.4	42
11--33	13	26	61	1.4	39
33-49	15	23	62	1.4	40
49-75	12	27	61	1.4	42
75-100	17	21	62	1.4	42

Table 7 : Chemical Properties of selected cashew- growing soils in Goa.

Depth (cm)	pH (water)	pH (KCl)	EC	OC*	$CaCO_3$	Ca	Mg	Na	K me/ 100g	BS %	CEC	Clay CEC	Ca/ Mg	ESP
Darbandora soils (Ustoxic Humitropepts, Pernum district, North Goa														
0-14	6.0	4.7	0	5.92	0	3.73	0.21	0.9	0.45	35	15.2	29	18	6
14-30	5.8	4.4	0.02	3.04	0	3.64	0.26	0.2	0.13	28	14.9	24	14	1
30-49	5.7	4.4	0.02	2.63	0	3.59	0.31	0.19	0.13	31	13.5	19	12	1
49-65	5.7	4.4	0.02	2.02	0	5.04	0.22	0.18	0.12	41	13.6	19	23	1
Karmeli soils (Lithic Dystropepts, Salcete, South Goa district, Goa														
0-8	5.8	4.5	0	4.64	0	2.26	0.7	0.18	0.12	26	12.7	30	3	1
8-40	5.7	4.4	0	3.82	0	1.07	0.55	0.17	0.1	16	11.8	25	2	1
Madgaon soils (Fluventic Ustropepts, North Goa, Goa														
0-18	5.4	4.3	0.06	0.77	0	1.29	0.37	0.13	0.06	53	4	32	3.7	54
18-46	5.7	4.4	0	0.38	0	1.46	0.4	0.14	0.05	50	4	31	3.4	50
46-73	5.7	4.5	0	0.62	0	2.59	1.21	0.21	0.06	52	8	27	2.7	46
73-107	5.6	4.5	0.05	0.71	0	1.75	0.47	0.15	0.05	48	5	9	3.0	47
107-128	5.8	4.8	0	0.95	0	3	0.94	0.15	0.05	63	7	24	2.3	47
128-148	5.9	4.9	0	0.97	0	3.7	0.9	0.12	0.05	66	7	27	1.7	47
Netravali soils (Ustoxic Dystropepts, North Goa, Goa														
0-10	5.7	4.9	0.18	3.56	0	2.08	1.73	0.2	0.43	37	12	26	1	2
10--34	6	5.2	0.06	1.47	0	1.85	0.32	0.2	0.18	31	8.1	14	6	2
34-54	6.2	5.5	0.04	0.72	0	4.25	1.15	0.21	0.11	68	8.4	14	4	3
54-74	6.3	5.5	0.05	0.51	0	4.42	1.38	0.2	0.13	70	8.8	14	3	2
Surla soils (Typic Ustropepts), North Goa, Goa														
0-10	5.7	4.7	0.00	3.87	0	8.64	4.73	0.18	1.29	15	25.8	46	2	1
11--33	5.9	5.0	0.00	2.57	0	7.16	4.67	0.22	2.67	15	24.2	40	2	1
33-49	5.8	5.1	0.06	1.63	0	7.04	4.44	0.21	2.09	14	21.8	35	2	1
49-75	5.7	5.0	0.08	1.44	0	8.06	3.83	0.17	1.32	13	19.5	32	2	1
75-100	5.7	5.1	0.07	1.41	0	7.14	3.85	0.15	0.94	12	17.9	29	2	1

*Revised organic carbon following Bhattacharyya et al. (2015)

Cashew growing soils from Kerala

In Kerala, the cashew growing soils were identified from the available resources judging by their elevations and information on cashew growing districts. In Pathanamthitta district, four soils were identified with its texture and organic matter content. The pH of all these soils vary from 4.6–5.3. The clay cation exchange capacity (CEC) of these soils indicate kaolinitic to mixed mineralogical class (Bhattacharyya et al 1997). In the surface, most of the soils have Ca:Mg ratio of 2–3 which increases down the depth. These soils are non-sodic as evidenced the by exchangeable sodium percentage (ESP) values. These are well drained soils with saturated and relative conductivity ranging from 5–6 cm^{-1} (Table 8).

Table 8 : Properties of selected cashew growing soils in Pathanamthitta district in Kerala. (*Source*: Anonymous 2006)

Depth (cm)	S %	Si %	C %	CF	OC* %	Extr. Iron as Fe %	pH water	pH KCl	WR		Exchangeable cations				CEC			Clay CEC	Base saturation %		Ca:Mg	ESP	sHC mm hr^{-1}
									33 kPa %	1500 kPa %	Ca	Mg	Na	K	NH_4OAc	Sum of Cations	ECEC		NH_4OAc	Sum of cations			
											cmol (+)/kg soil												
Anakkattur soils (Typic Kandiustults)																							
0-16	64	11	25	60	1.01	5.66	5.2	4	20.7	10.5	1.76	0.51	0.03	0.02	4.7	7.5	2.5	17	14	26	3.5	0.5	55
16-36	53	10	37	60	0.88	7.17	5.3	4.1	25.5	13.3	1.04	0.76	0.03	0.02	4.7	7.8	2.4	12	13	13	1.4	0.5	50
36-70	43	8	49	50	1.05	5.33	5.2	4.2	30.6	17.5	1.28	0.25	0.03	0.02	4.8	9.6	2.6	12	11	12	5.1	0.5	55
70-97	33	8	59	50	0.74	4.99	5	3.9	33.1	20.2	1.78	0.51	0.03	0.02	4.6	8.2	2.5	10	10	18	3.5	0.4	54
97-132	33	11	57	60	0.78	6.08	4.9	3.9	33.2	20.7	1.29	0.25	0.03	0.02	4.2	7.9	2	8	9	12	5.2	0.4	59
132-160	37	15	48	60	0.54	5.35	4.9	4	28.5	19.2	1.78	0.27	0.05	0.07	4.4	9.1	2	10	10	16	6.6	0.8	62
	Vallikkod soils (Typic Kandiustults)																						
0-16	70	2	28	10	0.58	2.73	4.7	4	10.1	7.1	1.25	0.50	0.12	0.25	4.7	7.5	2.5	17	45	28	2.5	2.6	60
16-41	57	3	40	0	0.52	4.17	4.8	4.2	18.6	10.2	1	0.50	0.06	0.05	4.7	7.8	2.4	12	34	21	2.0	1.3	57
41-67	56	3	42	0	0.37	2.83	4.8	4	19.5	11.3	1	0.50	0.06	0.05	4.8	9.6	2.6	12	34	17	2.0	1.3	57
67-116	51	3	46	0	0.36	3.62	4.7	3.9	20.4	12.6	1	0.50	0.05	0.07	4.6	8.2	2.5	10	35	20	2.0	1.1	57
116-150	48	1	51	0	0.43	3.27	4.8	4	20.6	12	0.75	0.50	0.04	0.05	4.2	7.9	2	8	32	17	1.5	1.0	55
150-175	53	2	46	25	0.20	2.96	4.8	4	17.8	12	0.75	0.50	0.03	0.05	4.4	9.1	2	10	30	15	1.5	0.7	55

Ittiyappara soils (Ustic Palehumults)																						
0-14	42	22	37	40	4.46	5.94	4.6	4	28.2	19.5	0.84	0.27	0.05	0.21	13.5	31.3	3.7	37	10	4	3.1	0.4	61
14-37	39	18	43	40	3.42	5.62	4.5	4.1	28.9	20	0.30	0.09	0.06	0.15	12.7	28.3	3	29	5	2	3.3	0.5	62
37-66	33	16	52	40	3.91	6.86	4.6	4.1	29.2	22.1	0.27	0.07	0.05	0.13	12.2	31.9	3.3	24	4	2	3.9	0.4	61
66-88	36	15	49	35	1.77	5.94	4.8	4.2	30.2	22.3	0.32	0.09	0.04	0.14	16.9	27.7	2.2	35	3	2	3.6	0.2	58
88-114	41	17	50	40	2.24	9.16	4.8	4.2	30	22.5	0.28	0.08	0.05	0.15	16.3	27.3	1.7	33	3	2	3.5	0.3	58
114-150	28	16	43	50	1.93	11.71	4.8	4.4	32.9	24.5	0.29	0.05	0.04	0.11	15.6	24.0	1.2	37	3	2	5.8	0.3	62
Kottangal soils (Humic Dystrustepts)																						
0-17	58	17	26	40	3.39	3.07	5.1	4.3	21.3	12.3	1.39	0.66	0.05	0.20	8.3	24.8	3.2	32	28	9	2.1	0.6	54
17-31	56	21	24	30	3.13	3.41	5.2	4.3	23.5	14.5	0.81	0.19	0.06	0.20	8.5	25.9	2.3	36	15	5	4.3	0.7	57
31-49	53	16	31	35	3.08	3.24	5	4.2	23.8	14.4	0.86	0.22	0.06	0.18	9.1	25.8	2.6	29	15	5	3.9	0.7	58
49-79	45	16	39	50	2.83	3.32	5	4.1	25.7	17.7	0.74	0.24	0.06	0.16	9.4	23.9	3	24	13	5	3.1	0.6	56
79-117	38	34	28	50	1.66	4.9	5.2	4.2	22.9	14.1	0.73	0.29	0.02	0.08	7.1	18.1	2.2	26	16	6	2.5	0.3	54

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

All the five soils are base-poor Ultisols in Kollam district suggesting requirement of more external doses of nutrients for cashew. These are clay to clay loam soils with pH ranging from 4.6 – 5.7. Clay cation exchange capacity (CEC) indicate kaolinitic mineralogical class. These are non-sodic and well drained soils (Table 9). In Kottayam district, three identified soils series vary in texture or clay loam to clay. Usually content of clay increases down the depth of soils. Soil reaction (pH) indicates acidicity. Clay cation exchange capacity (CEC) shows kaolinitic mineralogical class. These are non-sodic and well drained soils (Table 10). In Ernakulam district, three soil series were identified which are clay loam to clay in texture. There is a tendency of Cheruvalli soils to develop sodicity (Table 11). Other two soils are non-sodic. Ca and Mg ratio is relatively high and the soils are well drained (Table 11). In Kozhikode and Palakkad districts, four identified soils belong to the soil order Ultisols. These are clay loam soils with pH ranging from 4.5–5.6 (except Kairadi and Kalladikkod). Other soils are non-sodic. All these soils have very good drainage (Table 12).

Table 9 : Properties of selected cashew growing soils in Kollam district in Kerala. *(Source: Anonymous 2006)*

Depth (cm)	S %	Si %	C %	CF	OC* %	Extr. Iron as Fe %	pH water	pH KCl	WR		Exchangeable cations				CEC			Clay CEC	Base saturation %		Ca:Mg	ESP	sHC mm hr^{-1}
									33 kPa %	1500 kPa %	Ca	Mg	Na	K	NH_4OAc	Sum of Cations	ECEC		NH_4OAc	Sum of cations			
											cmol (+)/kg soil												
Kunnatur soils (Ustic Kanhaplohumults)																							
0-16	72	3	25	60	2.22	3.2	4.9	4.2	27	19.9	1.77	0.75	0.05	0.10	6.3	9.7	3.3	25	42	28	2.4	0.8	58
16-38	66	5	29	60	1.65	4.2	4.6	4.3	16	10.8	1.27	0.76	0.05	0.05	7	11.1	2.9	24	30	19	1.7	0.7	60
38-72	39	13	48	60	1.12	6.4	4.7	4.2	23.2	17.2	1.25	0.52	0.05	0.07	7.1	13.9	3.1	15	27	14	2.4	0.7	58
72-103	41	10	49	60	0.73	5.3	4.9	4.1	23.8	18.6	1.04	0.52	0.05	0.07	6.8	13.1	2.7	14	25	13	2.0	0.7	55
103-130	38	11	51	60	0.91	5.4	4.6	4.1	26.2	18.1	0.77	0.51	0.05	0.07	6.6	17.8	2.8	13	21	8	1.5	0.8	58
Mailam soils (Ustic Kandihumults)																							
0-22	52	11	37	30	0.58	2.4	4.9	4	18.8	9.6	0.72	0.43	0.21	0.27	5.2	12.4	2.2	14	31	13	1.7	4.0	55
22-55	51	10	39	20	0.66	2.36	4.7	3.9	19.9	11.7	0.62	0.39	0.30	0.25	5.9	11.3	2.4	15	26	14	1.6	5.1	58
55-82	55	10	36	25	0.88	2.4	5.3	4.2	18	10.5	1.42	0.86	0.25	0.23	5.6	11.5	2.9	16	49	24	1.7	4.5	50
82-109	48	12	40	20	1.01	3.4	5.5	4.4	19.6	12.8	0.34	0.74	0.31	0.38	6.2	14.8	1.8	16	29	12	0.5	5.0	45
109-135	48	9	44	20	0.86	3	5.7	4.7	21.5	13.6	0.58	2.90	0.28	0.56	7.4	15.1	4.3	17	58	29	0.2	3.8	42

Thrikkannamangal soils (Ustic Kanhaplustults)																							
0-14	39	15	46	35	2.57	5.94	4.7	4.1	30.1	18.3	1.5	0.75	0.10	0.46	9	21.8	4.1	20	31	13	2.0	1.1	57
14-35	34	16	50	35	2.31	6.23	4.7	4.3	32.1	18.3	0.8	0.50	0.05	0.23	7.7	21.5	4	15	20	7	1.5	0.6	56
35-67	31	12	56	40	1.85	6.66	4.6	4.1	30.7	20.3	0.8	0.50	0.04	0.33	7.5	19.4	3.8	13	22	8	1.5	0.5	57
67-103	30	6	64	40	1.36	6.97	4.8	4.3	30.4	20.8	0.8	0.50	0.05	0.28	7.7	17.4	3.3	12	21	9	1.5	0.6	54
103-152	29	5	66	40	1.08	5.86	5.1	4.3	30.9	21.4	0.5	0.50	0.03	0.25	7.6	9.3	2.8	12	17	14	1.0	0.4	49
Anayadi soils (Typic Kandiustults)																							
0-17	64	9	28	10	1.15	4.33	4.8	4.1	21.8	13.3	0.51	0.42	0.17	0.38	5.3	13.1	2.7	19	28	11	1.2	3.2	57
17-37	59	7	35	10	0.99	6.29	5.2	4.1	24.6	14.3	0.77	0.33	0.02	0.33	6.8	14.3	3.2	20	21	10	2.3	0.3	53
37-63	46	8	46	10	0.55	5.29	5.1	4	23.6	15.2	0.77	0.25	0.03	0.33	5.5	18.2	3.7	12	25	8	3.1	0.5	54
63-93	49	7	44	10	0.76	6.69	5.3	4.1	23	14.8	0.78	0.25	0.03	0.31	5.6	15.8	3.3	13	24	9	3.1	0.5	51
93-125	44	8	49	10	0.52	8.31	5.3	4	25	15.5	1.31	0.28	0.04	0.38	5.8	14.0	3.7	12	35	14	4.7	0.7	53
125-150	41	12	47	10	0.52	5.47	4.7	4.2	25.5	15.2	1.54	0.25	0.05	0.10	5.6	20.1	3.5	12	35	10	6.2	0.9	64
Kurathikkad soils (Typic Kanhaplustults)																							
0-16	47	21	32	60	1.51	7.03	4.7	4	21.6	13.8	1.56	0.56	0.02	0.04	5.3	17.2	3.5	17	41	13	2.8	0.4	60
16-33	34	22	44	60	1.02	5.06	4.9	4.1	24	17.1	1.00	0.56	0.03	0.04	4.1	17.0	2.7	9	40	10	1.8	0.7	55
33-82	37	18	46	50	0.61	8.9	5.2	4.1	24.5	18.1	0.75	0.50	0.02	0.03	4.7	15.7	2.1	10	28	8	1.5	0.4	50
82-120	31	9	61	65	0.28	9.35	5.1	4.2	27	19.1	0.78	0.30	0.03	0.03	4.9	15.7	1.7	8	23	7	2.6	0.6	52

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

Table 10 : Properties of selected cashew growing soils in Kottayam district in Kerala. *(Source: Anonymous 2006)*

Depth (cm)	S %	Si %	C %	CF	OC* %	Extr. Iron as Fe %	pH water	pH KCl	WR		Exchangeable cations				CEC			Clay CEC	Base saturation %		Ca:Mg	ESP	sHC mm hr^{-1}
									33 kPa %	1500 kPa %	Ca	Mg	Na	K	NH_4OAc	Sum of Cations	ECEC		NH_4OAc	Sum of cations			
											cmol (+)/kg soil												
Angel valley soils (Ustic Palehumults)																							
0-15	41	28	32	45	3.20	6.15	4.6	4	25.6	17	0.85	0.47	0.04	0.22	11.4	28.1	2.6	36	14	6	1.8	0.4	60
15-35	34	14	52	40	1.74	8.49	5.0	4.1	30.5	21.1	0.82	0.30	0.04	0.16	10.0	22.0	2.3	19	13	6	2.7	0.4	54
35-58	29	25	46	40	1.12	10.09	5.0	4.2	31.1	18	0.44	0.22	0.03	0.12	7.4	21.3	1.7	16	11	4	2.0	0.4	53
58-87	41	13	46	60	0.73	11.31	5.0	4.1	33.4	23	0.31	0.24	0.03	0.11	6.8	18.1	1.5	15	10	4	1.3	0.4	52
87-113	39	17	44	50	0.95	11.55	4.8	4	34	21	0.18	0.21	0.10	0.15	7.1	20.4	1.7	16	9	3	0.9	1.4	55
113-151	28	22	50	60	1.02	10.85	4.8	4	32.9	12	0.36	0.20	0.07	0.18	7.8	21.2	2.7	16	10	3	1.8	0.9	55
Chelikkuzhi soils (Ustic Kanhaplohumults)																							
0-14	58	8	34	25	2.81	1.91	4.8	4.2	19	9.8	1.12	0.09	0.00	0.17	5.5	15.9	2.3	16	25	9	12.4	0.0	73
14-44	55	8	37	15	2.94	2.03	4.9	4.2	19.9	10.1	0.27	0.00	0.03	0.16	5.3	15.0	2	14	9	3	-	0.6	-
44-79	55	9	37	20	2.26	2.23	4.8	4.2	30.9	10.3	0.93	0.11	0.08	0.12	5.4	12.6	2.1	15	23	10	8.5	1.5	67
79-96	45	10	46	25	2.40	1.98	5.0	4.2	33.3	12.3	0.74	0.34	0.00	0.21	6.5	15.8	1.3	14	20	8	2.2	0.0	54
Thiruvanchoor soils (Ustiic Kanhaplohumults)																							
0-17	36	11	53	50	2.08	3.84	4.7	3.9	23.7	13.7	0.94	0.35	0.07	0.20	8.3	15.1	2.7	16	19	10	2.7	0.8	58
17-37	34	12	54	50	1.99	3.71	4.9	3.8	22.7	12.4	0.31	0.14	0.07	0.15	8.8	16.4	2.5	16	8	4	2.2	0.8	54
37-66	27	9	64	60	1.52	3.71	4.9	3.8	26	16.1	0.20	0.08	0.07	0.22	8.3	16.6	2.5	13	7	3	2.5	0.8	54
66-91	31	11	59	60	0.73	3.99	5.0	3.9	24.8	14.8	0.52	0.18	0.07	0.17	6.1	13.1	2.5	10	15	7	2.9	1.1	54
91-130	36	13	51	55	0.84	3.2	5.1	4.1	23.9	13.9	0.71	0.19	0.06	0.11	4.2	10.4	1.8	8	25	10	3.7	1.4	54

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

Table 11 : Properties of selected cashew growing soils in Ernakulam district in Kerala. (*Source*: Anonymous 2006)

Depth (cm)	S %	Si %	C %	CF	OC* %	Extr. Iron as Fe %	pH water	pH KCl	WR		Exchangeable cations				CEC			Clay CEC	Base saturation %		Ca:Mg	ESP	sHC mm hr^{-1}
									33 kPa %	1500 kPa %	Ca	Mg	Na	K	NH_4OAc	Sum of Cations	ECEC		NH_4OAc	Sum of cations			
											cmol (+)/kg soil												
Arur soils (Ustic Kanhaplohumults)																							
0-15	30	22	48	45	2.54	3.58	4.8	4.2	30.1	21.8	0.49	0.04	0.04	0.08	7.6	16.9	1.3	16	9	4	12.3	0.5	71
15-43	30	19	51	35	2.58	3.61	4.9	4.2	30.7	22.2	1.12	0.32	0.07	0.23	8	17.6	2.5	16	22	109	3.5	0.9	57
43-86	30	19	52	45	2.21	3.98	4.8	4.2	30.9	22.9	0.94	0.41	0.07	0.24	8.2	18.2	2.8	16	20	9	2.3	0.9	56
86-127	27	18	56	55	1.86	4.78	5.0	4.1	33.3	24.2	0.77	0.53	0.07	0.23	8.2	13.5	2.4	15	20	12	1.5	0.9	52
Cheruvalli soils (Ustic Kanhaplohumults)																							
0-11	59	6	35	40	3.28	3.52	4.7	4.2	20.4	10.9	0.35	0.14	0.18	0.12	6.1	14.9	1.9	18	13	5	2.5	3.0	59
11-32	40	15	46	30	2.00	2.25	4.9	4.3	23.5	11.4	0.45	0.15	0.17	0.11	6.7	13.9	0.9	15	13	6	3.0	2.5	56
32-57	47	7	46	40	1.72	2.47	5.0	4.3	24	11.9	0.35	0.13	0.15	0.10	6.1	12.6	0.7	13	12	6	2.7	2.5	55
57-84	40	9	51	50	1.61	1.96	5.0	4.2	25.1	13.3	0.40	0.18	0.16	0.17	6.9	13.9	0.9	14	13	7	2.2	2.3	53
Ezhallur soils (Ustiic Kanhaplohumults)																							
0-13	50	9	41	35	2.59	2.85	4.8	4.1	24.5	16	0.44	0.20	0.07	0.08	6.3	12.3	1.6	15	13	6	2.2	1.1	57
13-37	43	12	45	40	2.49	3.17	4.8	4.2	27.3	16.9	0.90	0.12	0.06	0.18	6.9	12.5	2.1	15	18	10	7.5	0.9	65
39-69	42	11	48	40	2.26	3.19	4.9	4.2	28.2	18.3	0.66	0.18	0.05	0.18	6.1	13.0	1.9	13	18	8	3.7	0.8	57
69-104	35	14	51	45	1.31	3.96	4.8	4.2	26.4	18.4	0.44	0.18	0.05	0.20	6.9	10.6	1.4	14	13	8	2.4	0.7	56
104-132	36	17	47	60	0.71	4.37	5.0	4.3	24.7	18.1	0.44	0.27	0.08	0.18	7.4	9.3	1	16	13	10	1.6	1.1	53

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

Table 12 : Properties of selected cashew growing soils in Palakkad and Kozhikkode districts in Kerala. (*Source*: Anonymous 2006)

Depth (cm)	S %	Si %	C %	CF	OC* %	Extr. Iron as Fe %	pH water	pH KCl	WR		Exchangeable cations				CEC			Clay CEC	Base saturation %		Ca:Mg	ESP	sHC mm hr^{-1}
									33 kPa %	1500 kPa %	Ca	Mg	Na	K	NH_4OAc	Sum of Cations	ECEC		NH_4OAc	Sum of cations			
											cmol (+)/kg soil												
Kairadi soils (Typic Kandiustults), Palakkad																							
0-19	62	15	23	10	1.68	0.72	5.8	5.0	14.6	8.7	2.60	1.40	0.20	0.10	6.6	13.0	4.3	28	65	33	1.9	3.0	45
19-52	43	15	42	10	0.61	1.12	5.2	4.0	21.8	14	2.00	1.20	0.20	0.10	6.5	16.0	3.9	16	54	22	1.7	3.1	51
52-88	40	16	45	10	0.53	1.05	5.2	4.1	21.2	13.8	2.00	1.30	0.20	0.10	6.7	16.1	3.9	15	54	22	1.5	3.0	50
88-114	44	16	41	10	0.54	1.19	5.6	4.3	22.8	15.6	2.40	1.60	0.30	0.10	7.0	15.4	4.4	17	63	29	1.5	4.3	45
114-151	39	19	43	10	0.48	1.21	5.6	4.4	24.6	16.2	2.80	1.50	0.20	0.10	7.2	16.1	4.6	17	64	29	1.9	2.8	46
Kalladikkod soils (Typic Kandiustults), Palakkad																							
0-12	67	11	22	30	1.35	0.56	4.5	4	19.8	13.1	1.20	0.80	0.10	0.20	4.5	13.8	3.1	20	51	17	1.5	2.2	62
12-47	53	11	37	50	1.12	0.6	4.8	4.1	20.7	13.3	1.00	0.50	0.10	0.20	3.6	11.4	2.4	10	50	16	2.0	2.8	57
47-78	51	11	38	60	0.70	0.57	4.8	4.1	22.7	15.2	1.00	0.70	0.10	0.10	3.4	12.0	2.5	9	56	16	1.4	2.9	56
78-151	51	11	38	5	0.60	0.77	4.7	4	22.9	15.9	1.00	0.70	0.10	0.10	3.5	12.0	2.6	9	54	16	1.4	2.9	57
Kinalur soils (Typic Kandiustults), Kozhikkode																							
0-10	48	16	36	0	4.66	3.36	4.7	4.2	23.3	13.3	0.32	0.11	0.03	0.17	8.5	29.3	2.3	24	7	2	2.9	0.4	60
10-36	47	16	38	10	3.29	3.56	4.8	4.3	22.5	12.2	0.03	0.03	0.01	0.14	6.9	26.5	1.8	18	3	1	1.0	0.1	55
36-48	47	15	37	10	2.74	4.57	5	4.2	21.1	11.1	0.11	0.05	0.02	0.13	5.5	20.6	1.9	15	6	1	2.2	0.4	55
48-66	51	13	36	20	2.29	4.67	5.1	4.2	19.6	9.6	0.16	0.06	0.02	0.11	6.3	17.3	1.9	17	6	2	2.7	0.3	54
66-80	48	15	38	20	1.72	4.55	5.1	4	18.4	8.4	0.25	0.09	0.01	0.10	5.8	13.7	2	15	8	3	2.8	0.2	54
Perambra soils (Ustic Kanhaplohumults), Kozhikkode																							
0-12	60	10	30	0	2.49	3.78	5.1	4.3	19.7	9.7	0.71	0.27	0.01	0.08	7.7	18.4	2.1	26	14	6	2.6	0.1	55
12-30	54	13	33	5	1.54	3.68	5.1	4.3	19.8	9.8	0.09	0.07	0.00	0.05	5.3	13.9	1.3	16	4	2	1.3	0.0	52
30-60	54	10	36	25	1.41	3.94	5.2	4.4	19.2	9.2	0.18	0.10	0.01	0.05	5.6	12.9	1.4	16	6	3	1.8	0.2	52
60-87	53	10	37	25	1.01	3.71	5.3	4.3	18.1	8.1	0.22	0.10	0.01	0.03	5.1	10.8	1.3	14	7	3	2.2	0.2	51
87-116	56	9	36	20	1.00	3.66	5.3	4.3	16.7	6.1	0.31	0.10	0.02	0.03	4.7	8.9	1.2	13	10	5	3.1	0.4	52

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

Properties of selected cashew soils in Konkan Maharashtra

Cashew is grown mostly in Sindhudurg and Ratnagiri districts of South Konkan Cashew is also grown in Raigad and Thane districts in patches. Besides, there are reports on cashew in adjoining the Western Ghats in Nasik and Kolhapur districts.

In Sindhudurg district, the soils are clay loam to clay with pH ranging from 5.1–6.3. Clay cation exchange capacity (CEC) values indicate mixed to smectitic clay mineralogical class. Ca:Mg ratio is relatively high and at places exchangeable sodium percentage (ESP) values are also high. High ESP is not good for cashew. Saturated hydraulic conductivity values indicate good drainage conditions of these soils (Table 13). Ratnagiri district grows cashew in Inceptisols (Nandaon, Khed and Amboli) and Alfisols (Gavalwadi). These are clay loam to clay soils with high organic carbon (except Gavalwadi), non-calcareous, non-saline and non-sodic (Table 14).

Table 13 : Properties of selected cashew -growing soils in Sindhudurg district, Maharashtra. (*Source*: Challa et al. 1999)

Depth (cm)	Sand (2-0.05) %	Silt (0.05-0.002) %	Clay (<0.002) %	Coarse Fragments (> 2 mm)% of whole soils	OC* %	$CaCO_3$ %	EC dSm^{-1}	pH water	pH KCl	BD * Mg m^{-1}	Water retention		Exchangeable cations				CEC	Clay CEC	Base saturation NH_4OAc %	Ca:Mg	ESP	sHC mm hr^{-1}
											33 kPa %	1500 kPa %	Ca	Mg	Na	K	cmol (+)/kg soil					
Vengurla soils (Typic Haplustepts)																						
0-16	17	35	48	4	1.32	Nil	0.2	5.8	5.1	-	32.4	15.2	7	3	0.75	0.33	18	37	62	2.3	4.2	43
16-44	14	31	55	5	0.82	Nil	0.18	6.0	5.3	-	31.8	24.3	7	2	0.84	0.57	18	33	58	3.5	4.7	42
44-84	10	29	62	5	0.52	Nil	0.34	6.0	5.5	-	30.8	23	10	2	1.17	0.62	23	36	61	5.0	5.2	43
84-107	9	28	63	5	0.52	Nil	0.22	6.3	5.5	-	29.2	18.9	12	2	0.63	0.48	24	38	62	6.0	2.6	41
107-140	8	27	65	5	0.58	Nil	0.26	6.1	5.5	-	31	23.4	12	2	0.84	0.54	24	38	63	6.0	3.4	43
Malvan soils (Typic Haplustepts)																						
0-14	82	7	11	3	0.67	Nil	0.14	6.0	5.2	-	19.6	12.7	4	1	0.42	0.3	9	83	63	4.0	4.6	47
14-30	52	14	34	3	0.67	Nil	0.19	6.1	5.2	-	17.1	10.7	6	2	0.48	0.24	14	43	61	3.0	3.3	42
30-49	46	16	38	4	0.67	Nil	0.2	5.7	4.9	-	24.4	14.1	7	2	0.58	0.2	14	38	68	3.5	4.0	47
49-65	52	16	32	5	0.70	Nil	0.14	5.4	4.6	-	29.1	16.3	8	1	0.46	0.2	15	46	67	8.0	3.2	59
65+	Hard laterite																					

Ajra soils (Typic Haplustepts)																						
0-15	33	33	35	20	1.21	Nil	0.2	5.5	5.3	-	32.1	22.7	8	2	0.79	0.26	19	55	58	4.0	4.1	51
15-33	32	32	36	15	0.66	Nil	0.22	5.3	5.1	-	34.5	25.7	7	3	0.71	0.18	19	52	58	2.3	3.8	51
33-58	31	31	39	15	0.48	Nil	0.14	5.3	5.1	-	36.8	25.9	7	2	0.71	0.14	17	45	57	3.5	4.1	53
58-90	30	30	40	40	0.49	Nil	0.15	5.1	5	-	37.5	27.1	6	2	0.75	0.14	16	40	56	3.0	4.7	54
90+	Weathered Laterite																					
Verla soils (Lithic Ustorthents)																						
0-16	59	15	27	20	2.55	Nil	<0.20	4.9	4.4	-	22.4	10.7	3.87	1.98	0.21	0.11	6	24	96	2.0	3.3	57
16-36	54	14	33	35	1.10	Nil	<0.20	5.1	4.5	-	26.5	10.9	2.64	1.16	0.12	0.13	6	17	72	2.3	2.1	54
36-42+	Weathered basalt																					
Shrirange soils (Lithic Haplustepts)																						
0-16	48	15	38	5-0	1.04	Nil	<0.20	5.2	4.6	-	27.6	15.4	2.8	1.46	0.56	0.26	8	21	64	1.9	7.0	52
16-42	50	13	38	3-0	0.70	Nil	<0.20	5.0	4.4	-	28.5	16.3	1.24	0.79	0.27	0.2	6	16	40	1.6	4.4	54
42-60	Weathered basalt																					

Table 14 : Properties of selected cashew growing soils in Ratnagiri district, Maharashtra. (*Source*: Challa et al. 1999)

Depth (cm)	Sand (2-0.05) %	Silt (0.05-0.002) %	Clay (<0.002) %	Coarse Fragments (> 2 mm)% of whole soils	OC* %	$CaCO_3$ %	EC dSm^{-1}	pH water	pH KCl	BD * Mg m^{-1}	Water retention		Exchangeable cations				CEC	Clay CEC	Base saturation NH_4OAc %	Ca:Mg	ESP	sHC mm hr^{-1}
											33 kPa %	1500 kPa %	Ca	Mg	Na	K	cmol (+)/kg soil					
Nandgaon soils (Typic Haplustepts)																						
0-18	19	29	51	18	2.77	Nil	<0.20	5.7	4.9	-	26.4	21.3	14.5	4.58	0.23	0.31	26	50	77	3.2	0.9	46
18-33	19	27	55	25	-	Nil	<0.20	5.9	5	-	26.9	21.8	13.12	4.53	0.27	0.2	25	45	73	2.9	1.1	42
33-56	17	26	57	35	-	Nil	<0.20	6.1	5.2	-	28.4	23.3	14.56	6.45	0.22	0.23	29	50	75	2.3	0.8	38
56-70	Weathered Basalt																					
Gavalwadi soils (Udic Rhodustalfs)																						
0-16	33	33	34	5	0.83	Nil	0.16	8.2	6.5	-	32.7	22.7	13	2	0.52	0.3	19	56	82	6.5	2.7	20
16-47	31	32	38	5	0.43	Nil	0.16	8.2	6.6	-	33	23	10	4	0.52	0.36	17	46	87	2.5	3.0	13
47-78	30	31	34	5	0.26	Nil	N.D.	N.D.	-	-	30.5	25.2	10	3	0.5	0.18	16	48	83	3.3	3.0	-
78-100+	Hard basalt																					
Khed soils (Typic Haplustepts)																						
0-26	51	13	37	30-40	2.26	Nil	<0.20	5.4	4.8	-	28.6	16.6	8.67	3.12	0.19	0.26	20	55	61	2.8	1.0	50
26-76	48	17	36	40-60	1.48	Nil	<0.20	6.3	5.8	-	30.3	19.1	3.36	1.37	0.06	0.36	20	57	25	2.5	0.3	38
76-120+	Hard basalt																					
Amboli soils (Typic Haplustepts)																						
0-14	39	26	36	30	3.51	-	<0.20	5.5	5.0	-	36.8	28	7.7	1.48	0.75	0.48	19	54	54	5.2	3.9	53
14-30	36	25	38	30	2.61	-	<0.20	5.5	4.9	-	35.9	26	5.8	1.15	0.46	0.43	20	52	40	5.0	2.3	52
30-45	34	35	31	35	2.46	-	<0.20	5.5	4.9	-	34.1	26	5.9	1.32	0.63	0.36	19	63	43	4.5	3.3	52
45+	Weathered Basalt																					

In Raigad, four representative soils were identified which grow cashew. These are clay soils with high clay cation exchange capacity (CEC), base saturation (BS%) and Ca: Mg ratio. These are well drained soils, acidic, non-calcareous, non-saline and non-sodic (Table 15). In Thane and Palghar, three representative cashew growing soils were identified. Dahisar soils are shallow, but shows more than 50 cm depth with highly weathered basalts (Table 16). Our earlier experience with the composition of highly weathered basalt shows that these are zeolitised with high base saturation and can help in supplying necessary nutrients to trees (Bhattacharyya et al. 1993, 1999 and 2018). Other two soils viz. Thane and Haloli are moderate, deep to moderately deep, high saturation (BS%) and organic carbon. These soils are also acidic, non-saline, non-sodic and well drained.

Table 15 : Properties of selected cashew growing soils in Raigad district, Maharashtra. (*Source*: Challa et al. 1999)

Depth (cm)	Sand (2-0.05) %	Silt (0.05-0.002) %	Clay (<0.002) %	Coarse Fragments (>2 mm)% of whole soils	OC* %	$CaCO_3$ %	EC dSm^{-1}	pH water	pH KCl	BD * Mg m^{-1}	Water retention		Exchangeable cations				CEC	Clay CEC	Base saturation NH_4OAc %	Ca:Mg	ESP	sHC mm hr^{-1}
											33 kPa %	1500 kPa %	Ca	Mg	Na	K						
													cmol (+)/kg soil									
Man soils (Typic, Haplustepts)																						
0-14	32	25	44	20-0	2.46	Nil	0.4	5.8	5.3	-	25.6	17.8	14.72	6.72	0.76	0.45	30	68	77	2.2	2.6	44
14-38	29	24	47	20-30	1.91	-	1.5	5.7	5.5	-	27.1	19.3	8.3	4.99	1.7	1.43	18	38	91	1.7	9.4	44
38-70	24	24	53	40-60	1.48	-	<0.20	5.8	5.2	-	32.2	22.4	9.99	3.66	0.21	0.25	20	39	69	2.7	1.0	43
70-100	Weathered basalt																					
Mahad soils (Typic Rhodustalfs)																						
0-14	26	28	47	20-30	2.52	Nil	<0.20	5.8	5	-	33.3	20.9	13.09	4.47	0.26	0.56	27	57	69	2.9	1.0	44
14-33	24	26	51	30-40	1.44	Nil	<0.20	5.8	5	-	35.3	21	13.12	5.3	0.29	0.44	29	57	66	2.5	1.0	43
33-70	31	23	47	40-60	1.08	Nil	<0.20	6.1	5.1	-	29.5	20.5	12.35	5.28	0.38	0.57	31	67	60	2.3	1.2	40
70+	Weathered basalt																					
Sakhar soils (Udic Haplustalfs)																						
0-11	29	23	49	3.0-5.0	2.50	Nil	<0.20	6.2	5.7	-	26.3	20.4	12.75	2.6	0.12	0.7	17	36	94	4.9	0.7	42
10-33	13	30	57	-	1.32	Nil	<0.20	6.3	5.8	-	28.5	21	9.9	2.33	0.22	0.49	17	30	77	4.2	1.3	39
33-50	11	30	60	-	0.91	Nil	<0.20	6.2	5.8	-	31.3	24.7	8.8	2.5	0.22	0.39	17	29	70	3.5	1.3	39
52-90	10	27	49	-	0.77	Nil	<0.20	6.3	5.8	-	30.5	24.6	10.95	3.58	0.08	0.41	16	34	92	3.1	0.5	38
90+	Hard basalt																					
Mangaon soils (Typic Haplustepts)																						
0-17	28	26	47	15-20	1.35	-	<0.20	5.9	5	-	32.8	23.96	13.3	4.45	0.42	0.56	19	42	97	3.0	2.2	43
17-50	31	23	47	30-40	0.97	-	<0.20	6.1	5.1	-	34.35	27.82	18.52	10.52	0.43	0.48	31	66	97	1.8	1.4	39
50-82	33	19	48	40-60	0.54	-	<0.20	6.3	5.1	-	36.27	29.62	17	6.76	0.66	0.38	27	57	92	2.5	2.4	37
82-150+	Weathered basalt																					

Table 16 : Properties of selected cashew growing soils in Thane and Palghar districts, Maharashtra. (*Source*: Challa et al. 1999)

Depth (cm)	Sand (2-0.05) %	Silt (0.05-0.002) %	Clay (<0.002) %	Coarse Fragments (> 2 mm)% of whole soils	OC* %	$CaCO_3$ %	EC dSm^{-1}	pH water	pH KCl	BD * Mg m^{-1}	Water retention		Exchangeable cations				CEC	Clay CEC	Base saturation NH_4OAc %	Ca: Mg	ESP	sHC mm hr^{-1}
											33 kPa %	1500 kPa %	Ca	Mg	Na	K						
													cmol (+)/kg soil									
Thane soils (Vertic Haplustepts), Thane district																						
0-11	29	23	48	8-10	1.75	Nil	<0.20	7.3	-	-	32.7	20.6	28	12	1.55	0.24	43	90	98	2.3	3.6	24
11-35	32	20	48	8-10	1.20	Nil	<0.20	7.4	-	-	29.9	19.6	24	19	1.63	0.24	45	94	99	1.3	3.6	21
35-56	30	19	51	8-10	1.11	Nil	<0.20	7.5	-	-	31.2	24.9	26	21	1.63	0.24	50	99	97	1.2	3.2	19
56+	Weathered basalt + gravels																					
Dahisar soils (Typic Ustorthents) , Thane district																						
0-13	35	16	49	20-25	1.82	Nil	0.52	6.5	5.6	-	32.8	16.7	20	5.95	1.68	1.14	36	74	80	3.4	4.7	36
13-60	Weathered Basalt																					
Haloli soils (Vertic Haplustepts) , Palghar district																						
0-12	31	23	43	5-8	1.46	Nil	<0.20	6.9	-	-	31	25	30	10	0.73	0.3	45	106	91	3.0	1.6	30
12-28	21	29	50	5-8	1.01	Nil	<0.20	7.2	-	-	33.7	27.3	32	13	0.82	0.21	49	98	95	2.5	1.7	25
28-52	20	28	52	5-8	0.71	Nil	<0.20	7.3	-	-	31.1	21.9	30	13	0.79	0.26	45	86	98	2.3	1.8	23
52-76	21	26	53	5-8	0.70	Nil	0.2	7.4	-	-	32.5	20.4	31	14	0.94	0.27	48	91	96	2.2	2.0	22
76--	Hard basalt																					

In Nasik and Kolhapur districts of Maharashtra, four representative cashew growing soils were identified (Table 17). These are clay soils, non- calcareous, non-saline , non-sodic and well drained . These soils are very rich in organic matter and bases (BS%). Virar soils are shallow, but strike weathered basalts below the depth of 30 cm which might be a good substrate for cashew.

Table 17 : Properties of selected cashew growing soils in Nashik and Kolhapur districts, Maharashtra. (*Source*: Challa et al. 1999)

Depth (cm)	Sand (2-0.05) %	Silt (0.05-0.002) %	Clay (<0.002) %	Coarse Fragments (> 2 mm)% of whole soils	OC* %	$CaCO_3$ %	EC dSm^{-1}	pH water	pH KCl	BD * $Mg\ m^{-3}$	Water retention		Exchangeable cations				CEC	Clay CEC	Base saturation NH_4OAc %	Ca: Mg	ESP	sHC mm hr^{-1}
											33 kPa %	1500 kPa %	Ca	Mg	Na	K	cmol (+)/kg soil					
Virar soils (Typic Ustorthents), Nasik district																						
0-10	18	35	47	20-35	2.23	Nil	0.22	6.4	5.2	-	32.2	19.7	13.8	3.3	1.05	1.56	23	49	85	4.2	4.5	38
10-30	9	36	55	>35	2.08	Nil	0.15	6.3	5	-	33.3	21.4	15.6	3.63	0.67	0.6	26	47	80	4.3	2.6	39
30-60	Weathered basalt																					
Chandgad soils (Typic Haplustepts), Kolhapur district																						
0-16	20	31	50	10.0	2.55	Nil	<0.20	5.3	4.8	1.4	36.4	23.2	5.8	1.75	0.18	0.7	19	39	43	3.3	0.9	51
16-38	18	29	54	5.0	2.01	Nil	<0.20	5.4	5.2	1.31	38.5	24.7	6.19	2.25	0.39	0.64	15	28	64	2.8	2.6	49
38-66	13	29	59	5.0	1.72	Nil	<0.20	5.5	5.3	1.5	39.3	25.8	6.54	2.99	0.14	0.52	16	27	64	2.2	0.9	46
66-90	10	28	62	20.0	1.23	Nil	<0.20	5.6	5.4	1.53	42.6	26.7	5.41	2.45	0.15	0.54	14	22	63	2.2	1.1	44
90+	Weathered basalt																					

Wadkudi soils (Udic Rhodustalfs) , Kolhapur district																						
0-16	24	33	42	5	1.32	Nil	0.15	5.5	4.7	-	30.8	22.5	13	8	0.42	0.3	25	59	88	1.6	1.7	47
16-40	21	35	43	3	1.26	Nil	0.11	5.5	4.6	-	30.3	23.1	11	6	0.42	0.3	23	54	76	1.8	1.8	47
40-65	19	37	44	3	1.15	Nil	0.13	5.4	4.6	1.3	33.1	25.7	17	5	0.48	0.21	27	61	85	3.4	1.8	51
65-99	22	33	45	2	0.81	Nil	0.19	5.5	4.9	1.21	32.9	26.7	7	5	0.31	0.12	16	36	77	1.4	1.9	46
99-135	10	37	53	2	0.63	Nil	0.17	5.9	5.5	1.19	39.9	25.9	7	4	0.3	0.12	18	34	63	1.8	1.6	41
Parpoli soils (Udic Haplustalfs) , Kolhapur district																						
0-15	8	38	54	5	1.70	Nil	<0.20	5.7	4.7	-	43.8	26.7	5	2	0.62	0.7	15	27	56	2.5	4.2	44
15-35	4	39	56	3	1.59	-	<0.20	5.4	4.5	-	44.9	26	5	1	0.7	0.42	11	20	65	5.0	6.4	52
35-57	3	38	59	3	1.28	Nil	<0.20	5.4	4.5	-	40.5	23.3	5	2	0.54	0.36	13	22	61	2.5	4.2	48
57-80	6	34	61	5	1.30	Nil	<0.20	5.4	4.4	-	32.9	20.3	5	2	0.48	0.36	12	19	67	2.5	4.1	48
80+	Hard laterite																					

Properties of selected cashew soils in other parts of the world

Properties of cashew growing soils in African countries

Representative cashew growing soils in Africa are sandy (sand percentage 80-90). Eight soils described by Hartemink and Huting (2005) shows that these are moderately acidic in nature with poor organic matter content and low cation exchange capacity (CEC). (Table 18).

Table 18 : Selected properties of cashew-growing soils in African countries.
(*Source*: Hartemink and Huting 2005)

Depth (cm)	Sand (2.0-0.05 mm) %	Silt (0.05-0.002 mm) %	Clay (<0.002 mm) %	pH Soil : water (1:2.5)	Bulk density Mg m^{-3}	Organic C gkg^{-1}	Total N g kg^{-1}	Exch. Na	CEC	Clay CEC	Base saturation NH_4OAc %	ESP
								cmol (+)/kg soil				
Angola Series												
0-10	93	2	5	5.8	-	6.2	0.44	0.03	3.4	68	40	1
10-20	93	2	5	5.7	-	4.4	0.33	0.06	2.9	58	35	2
20-30	93	1	6	5.7	-	3.1	0.24	0.05	2.5	42	32	2
Botswana Series												
0-10	94	3	3	6.6	1.65	2.9	-	0.03	3.3	110	80	1
10-20	94	3	3	6.6	1.65	2.8	-	0.06	3.2	107	79	2
20-30	92	4	4	6.6	1.67	2.2	-	0.06	3.1	78	75	2
Kenya Series												
0-10	87	7	6	6.9	1.41	3.1	0.21	0.23	3.8	63	91	6
10-20	80	14	6	6.3	1.41	2.13	0.15	0.22	3.6	60	84	6
20-30	86	8	6	6.8	1.42	1.17	0.05	0.33	3.3	55	92	10
Mozambique Series												
0-10	89	5	6	6	1.47	7.0	0.67	0.08	4.1	68	86	2
10-20	89	5	6	5.9	1.47	5.9	0.51	0.08	3.8	63	77	2
20-30	90	4	6	6	1.45	4.1	0.36	0.11	3.8	63	68	3
Nambia Series												
0-10	94	3	3	7.9	-	2.6	0.25	0.05	1.5	50	100	3
10-20	94	3	3	7.9	-	2.5	0.22	0.03	1.5	50	100	2
20-30	93	3	4	7.5	-	1.7	0.08	0.03	1.6	40	100	2
Tanzania Series												
0-10	88	6	6	5.4	-	9.2	0.60	0.11	5.7	95	25	2
10-20	88	5	7	5.4	-	8.88	0.60	0.16	5.2	74	17	3
20-30	88	6	6	5.3	-	8.11	0.50	0.15	5.0	83	14	3

South Africa Series												
0-10	91	4	5	7.1	-	3.3	-	0.15	3.0	60	80	5
10-20	91	4	5	7.1	-	3.13	-	0.15	3.0	60	80	5
20-30	90	5	5	6.8	-	2.87	-	0.15	2.9	58	96	5
Zimbabwe Series												
0-10	93	3	4	5.2	-	3.6	-	0.09	1.7	43	80	5
10-20	92	4	4	5.2	-	2.2	-	0.08	1.5	38	80	5
20-30	93	2	5	4.8	-	3.2	-	0.04	1.4	28	100	3

Cashew growing soils in Vietnam

The cashew growing soils in Vietnam are acidic, and poor in nitrogen and organic carbon. Cation exchange capacity (CEC) is low suggesting the requirement of more external fertilizer application (Vinh 2005) (Table 19).

Table 19 : Selected properties of cashew-growing soils in Vietnam. (*Source*: Vinh 2005)

Depth (cm)	pH Soil: water (1:2.5)	Org. C	N	P_2O_5	K_2O	P_2O_5	K_2O	Ca^{+2}	Mg^{+2}	CEC
		%			mg $100g^{-1}$			cmol (+)/kg soil		
	White dry Sandy Bae Binh Soil (Southern Central Vietnam)									
0-18	4.67	0.398	0.020	0.007	0.018	0.470	1.51	0.10	1.80	2.00
18-30	4.60	0.402	0.200	0.017	0.018	0.520	1.12	0.74	0.58	2.03
30-50	4.60	0.387	0.016	0.011	0.019	0.460	1.21	1.04	0.83	-
50-100	4.82	0.293	0.028	0.007	0.024	0.890	1.51	1.04	0.83	-
Red dry Sandy Hong Phong Soil (Southern Central Vietnam)										
0-15	5.62	0.717	0.062	0.015	0.036	1.39	4.52	1.35	0.82	-
15-45	5.04	0.294	0.390	0.014	0.030	0.64	1.51	1.35	0.67	-
>45	4.98	0.220	0.032	0.011	0.031	0.53	1.23	0.82	0.52	-
White Grey Sandy Binh Tanh Soil (Southern Central Vietnam)										
0-15	4.95	0.468	0.054	0.012	0.012	0.530	1.51	0.10	1.80	2.00
15-30	4.52	0.389	0.036	0.007	0.012	0.320	1.12	0.74	0.58	2.03
30-55	4.25	0.300	0.027	0.006	0.012	0.270	1.21	1.04	0.83	-

Cashew growing soils in Australia

A survey report of Queensland, Australia provides detail soil information in cashew-growing areas (Table 20). Most of these soils are sandy and belong to Inceptisols. The Alfisols have more clay and are also used for cashew cultivation. These are acidic soils with low cation exchange capacity (CEC). As compared to soils of Konkan, calcium: magnesium ratio is less. Saturated hydraulic conductivity (sHC) show good drainage condition of these soils. Interestingly poorly drained Tropaquepts (Soil Survey Staff 2014) and a few other soils drainage reported (Belekar and Laut 1987) requires revisit.

Table 20 : Selected properties of cashew-growing soils in Australia.
(*Source*: Belekar and Laut 1987)

Depth	S %	Si %	C %	OC* %	pH water	pH KCl^1	Exchangeable cations				CEC NH_4OAc	Clay CEC	Base saturation %	Ca: Mg	ESP	sHC mm hr^{-1}
							Ca	Mg	Na	K			NH_4OAc			
							cmol (+)/kg soil									
Well drained brownish sands, Haplustepts (Ia)																
Top soil	78	7	15	1.27	5.7	5.3	2.19	1.01	0.17	0.16	4.06	27	87	2.17	4.2	48
Sub soil	80	6	14	0.61	5.6	4.9	0.79	0.47	0.09	0.06	2.01	14	70	1.68	4.5	48
Deep sub soil	82	5	13	0.44	5.8	5.2	0.94	0.50	0.09	0.06	2.34	18	68	1.88	3.8	46
Imperfectly drained brownish grey sands, Haplustepts (Ib)																
Top soil	91	4	5	0.61	5.2	4.8	0.32	0.22	0.13	0.03	1.21	24	58	1.45	10.8	54
Sub soil	90	5	5	0.3	5.3	5	0.19	0.18	0.11	0.03	0.84	17	61	1.06	13.2	52
Deep sub soil	89	2	9	0.34	5.3	5.1	0.14	0.63	0.10	0.03	1.41	16	64	0.22	7.1	51
Poorly drained grey sands, Tropaquepts (Ic)																
Top soil	89	5	7	0.87	5.3	5.2	0.87	0.50	0.13	0.08	2.19	31	72	1.74	5.9	53
Sub soil	92	2	6	0.24	5.5	5.5	0.19	0.11	0.06	0.03	0.68	11	57	1.73	8.8	51
Deep sub soil	98	2	0	0.04	5.6	5.5	0.06	0.05	0.03	0.01	0.25	-	60	1.20	12.0	49
Poorly drained grey sands, Tropaquepts (Ic)																
Top soil	89	5	7	0.87	5.3	5.2	0.87	0.50	0.13	0.08	2.19	31	72	1.74	5.9	53
Sub soil	92	2	6	0.24	5.5	5.5	0.19	0.11	0.06	0.03	0.68	11	57	1.73	8.8	51
Deep sub soil	98	2	0	0.04	5.6	5.5	0.06	0.05	0.03	0.01	0.25	-	60	1.20	12.0	49
Bleached sands with cemented hard pans, Troporthods (IIa)																
Top soil	93	2	5	0.64	4.8	4.4	0.06	0.15	0.11	0.03	1.13	23	31	0.40	9.7	58
Sub soil	90	2	8	0.54	5	5.1	0.03	0.06	0.08	0.02	0.59	7	32	0.50	13.5	55
Deep sub soil	87	1	12	0.38	5.2	5.1	0.07	0.31	0.12	0.12	0.83	7	75	0.23	14.5	52
Well drained brownish loams, Ustropepts (IIIa)																
Top soil	64	13	23	1.59	5.3	5	2.11	1.45	0.19	0.19	4.80	21	82	1.46	4.0	51
Sub soil	48	18	34	1.11	5.3	4.5	1.41	1.20	0.16	0.12	4.25	13	68	1.18	3.8	50
Deep sub soil	65	11	24	0.54	5.5	4.9	1.82	1.15	0.16	0.05	4.08	17	78	1.58	3.9	49

Imperfectly drained brownish loams, Ustropepts (IIIc)																
Top soil	73	9	18	1.43	5.3	4.7	1.10	0.73	0.22	0.16	3.07	17	72	1.51	7.2	52
Sub soil	74	7	19	0.78	5.5	4.4	0.89	0.34	0.26	0.06	2.98	16	52	2.62	8.7	51
Deep sub soil	90	1	9	0.38	5.8	4.9	0.54	0.33	0.18	0.02	1.39	15	77	1.64	13.0	46
Well drained, medium over fine textured, Haplustalfs (IVa)																
Top soil	59	16	25	1.71	6	6	5.33	3.80	0.29	0.13	9.65	39	99	1.40	3.0	42
Sub soil	77	6	17	0.42	6.4	5.4	1.35	1.93	0.21	0.03	3.67	22	96	0.70	5.7	36
Deep sub soil	97	1	2	0.2	6.4	6.2	0.30	0.34	0.07	0.01	0.76	38	95	0.88	9.2	38
Imperfectly drained, medium over fine textured , Haplustalfs (IVb)																
Top soil	70	11	19	1.33	5.4	4.7	1.74	1.33	0.24	0.21	4.57	24	77	1.31	5.3	50
Sub soil	72	9	19	0.64	5.5	4.5	1.59	1.56	0.25	0.07	4.63	24	75	1.02	5.4	48
Deep sub soil	67	10	23	0.37	5.8	4.9	1.25	1.57	0.49	0.06	4.38	19	77	0.80	11.2	44
Poorly drained, medium over fine textured,Tropaqualfs (IVc)																
Top soil	74	11	15	1.28	5.4	4.9	1.19	0.90	0.27	0.14	2.91	19	86	1.32	9.3	50
Sub soil	63	13	24	0.52	5.4	4.3	0.37	1.37	0.27	0.07	3.01	13	69	0.27	9.0	48
Deep sub soil	54	11	35	0.4	5.6	4.9	0.23	3.40	0.56	0.08	4.80	14	89	0.07	11.7	44
Well drained, coarse over medium textured , Haplustalfs (IVd)																
Top soil	75	8	17	0.9	5.3	4.6	0.40	0.64	0.18	0.09	2.15	13	61	0.63	8.4	50
Sub soil	76	7	17	0.24	5.5	4.6	0.14	0.61	0.08	0.06	1.62	10	55	0.23	4.9	47
Deep sub soil	64	10	26	0.32	5.5	4.3	0.17	1.53	0.19	0.11	3.33	13	60	0.11	5.7	46
Poorly drained, coarse over medium textured , Tropaqualfs (IVe)																
Top soil	74	16	10	0.65	5.5	5.1	0.35	0.43	0.18	0.06	1.21	12	84	0.81	14.8	49
Sub soil	66	15	19	0.34	5.9	5.3	0.24	1.59	0.22	0.09	2.21	12	97	0.15	10.0	42
Well drained, with thick dark topsoil, Argiustolls (Va)																
Top soil	93	2	5	0.92	5.3	4.5	1.53	0.91	0.16	0.14	3.75	75	73	1.68	4.3	53
Sub soil	53	8	39	0.6	5.5	4.8	1.50	0.89	0.17	0.05	3.43	9	76	1.69	5.0	47
Deep sub soil	73	8	19	0.34	5.9	4.7	1.22	0.88	0.29	0.03	2.72	14	89	1.39	10.7	44
Imperfectly drained with bleached A2 horizons, Paleustalfs (Vb)																
Top soil	80	8	12	0.63	5.2	4.8	0.35	0.26	0.22	0.04	1.21	10	72	1.35	18.2	53
Sub soil	83	7	10	0.2	5.3	5.5	0.15	0.20	0.10	0.02	0.69	7	68	0.75	14.5	51
Deep sub soil	51	20	29	0.4	5.5	5.4	0.36	4.83	2.31	0.14	7.72	27	99	0.07	29.9	46
Imperfectly drained without bleached A2 horizons, Haplustalfs (Vc)																
Top soil	60	15	25	0.8	4.9	4.3	0.77	0.58	1.00	0.08	3.92	16	62	1.33	25.5	56
Sub soil	65	12	23	0.59	5.1	4.6	0.42	0.44	0.12	0.04	1.67	7	61	0.95	7.2	53
Deep sub soil	68	8	24	0.37	5.4	4.9	0.27	0.84	0.12	0.08	1.77	7	74	0.32	6.8	48
Poorly drained with bleached A2 horizons, Albaqualfs (Vd)																
Top soil	92	3	5	0.56	5.1	5.1	0.17	0.17	0.15	0.03	0.84	17	62	1.00	17.9	55
Sub soil	89	4	7	0.31	5.3	5.3	0.06	0.14	0.09	0.04	0.60	9	55	0.43	15.0	51
Deep sub soil	69	6	25	0.32	5.4	5	0.23	1.33	0.24	0.08	2.44	10	77	0.17	9.8	48

S: Sand (2-0.05 mm); Si: Silt (0.05-0.002 mm); C:Clay(<0.002 mm); CF: Coarse Fragments (> 2 mm)% of whole soils; WR: Water retention;

CARBON SEQUESTRATION IN CASHEW SOILS

Carbon sequestration is the process by which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass such as tree trunks, branches, foliage, roots and soils (EPA 2010). Carbon sequestration rates depend on tree species, soil type, regional climate, and topography and management practice (EPA, 2010). Pine plantations of 90 years in the south-east of USA can accumulate 2.5Mg ha^{-1} of carbon per year. Changes in forest management result in less carbon sequestration per unit area. Changes in cropping practices, such as from conventional to conservation tillage, have been reported to sequester carbon ~ 0.1–0.3 t $acre^{-1}year^{-1}$. The above ground carbon sequestered by the mango plantation was 3.6 t ha^{-1} and it is expected to increase with increasing height and diameter at breast height. Moreover, the soil carbon sequestered by the plantation was ~29 t $ha^{-1}$and is also expected to increase with time as high litter fall and decomposition of the leaves may contribute to high organic carbon. Since there was no significant difference in nutrients added by cashew plantation compared to the adjacent land use, the plantation still serves to protect the soils against the agents of erosion namely wind and rainfall. More communities should be encouraged and assisted by the government and NGOs to adopt the use of cashew in establishing plantations and in agro-forestry programmes as they have both economic as well as environmental values.

India, Maharashtra, Konkan

Carbon stock in Konkan soils was estimated as 0.185, 0.150, 0.075 and 0.039 Pg in 0-30, 0-50, 0-100 and 0-150 cm depth of soils. Konkan represents the coastal eco-system with average rainfall of 3,000 to 4,500 mm. It is generally understood that under high rainfall region, pedogenic calcium carbonate is not found in soils as for which inorganic carbon sequestration in Konkan soils should be rare. However, there are reports of inorganic carbon in some soils of Konkan as evidenced by the value of SIC stock of 0.048, 0.080, 0.068 and 0.068 Pg in 0-30, 0-50, 0-100 and 0-150 cm depth of soils (Bhattacharyya et al. 2018). It was reported earlier that the threshold limit of SOC stock of 0.05 – 0.06 Pg million

ha^{-1} (1 Pg is 10^{15} g) should be considered as the threshold limit carrying the signature of green belt as was reported in soils of North-East as well as Konkan (Bhattacharyya et al. 2013, 2015). Roughly the cashew orchards occupy 1.8 lakh hectares in Konkan; assuming 1.0% SOC as an average limit in 0-30 cm depth of the soils where cashew is grown, the SOC stock is estimated as 0.0252 Pg. This makes the SOC stock 0.14 Pg million ha^{-1}. This is significant since it shows that the cashew orchards in Konkan are maintaining the soil health in terms of sequestering appreciably high SOC stock and should therefore be the sustainable enterprise not only from profit point of view, but also from the point of maintaining ecological balance of the otherwise fragile coastal eco-systems of Konkan.

With the available data on the soils of Kerala and Maharashtra, it appears that threshold limit of SOC stock (Pg million ha^{-1}) is well above the limit earlier reported for the soils of north east as well as Konkan to maintain the green belt of coastal ecosystem (Bhattacharyya et al. 2013, 2015) (Figure 2 & 3).

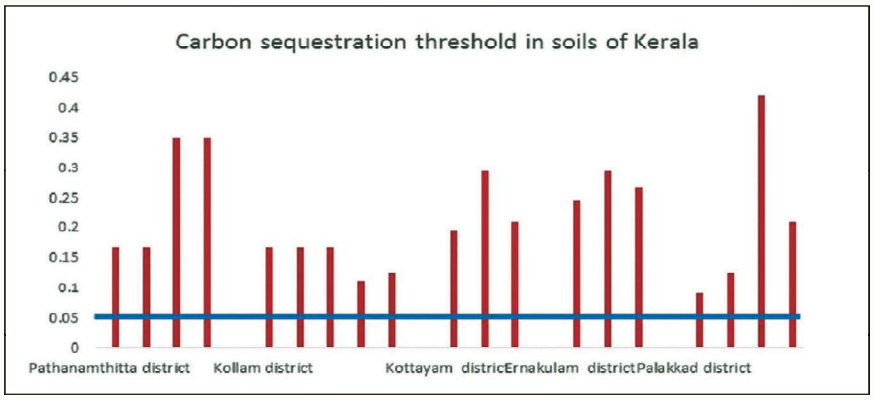


Fig. 2 : Cashew sequestration threshold in soils of Kerala (Horizontal thick line shows the minimum threshold limit of 0.05 Pg Million ha^{-1}). (Y axis is soil organic carbon threshold limit in 0.05 Pg Million ha^{-1}).

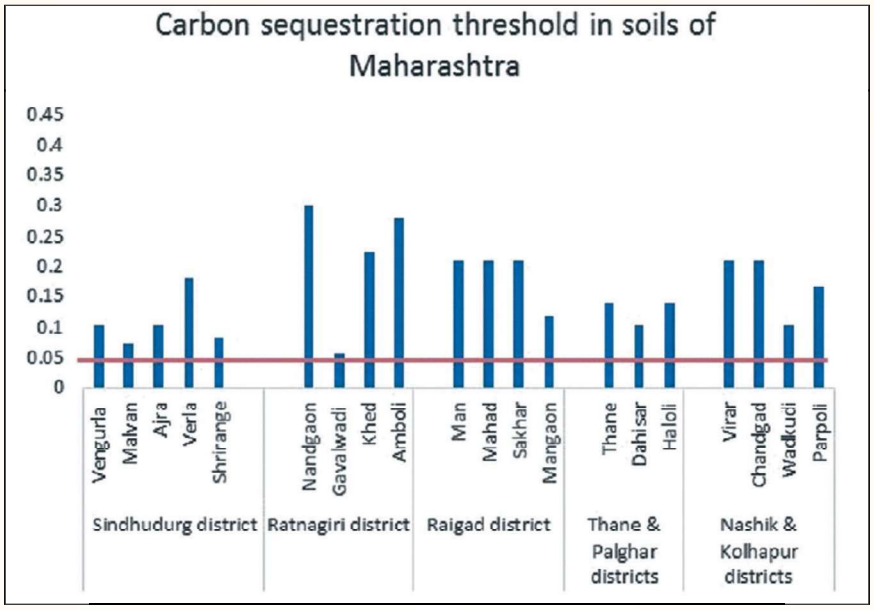
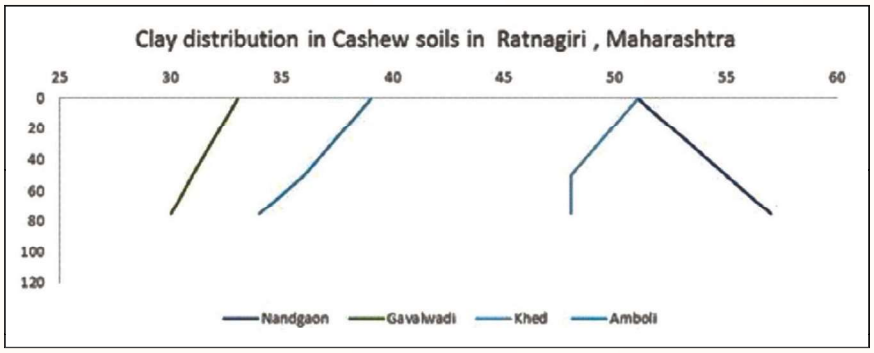


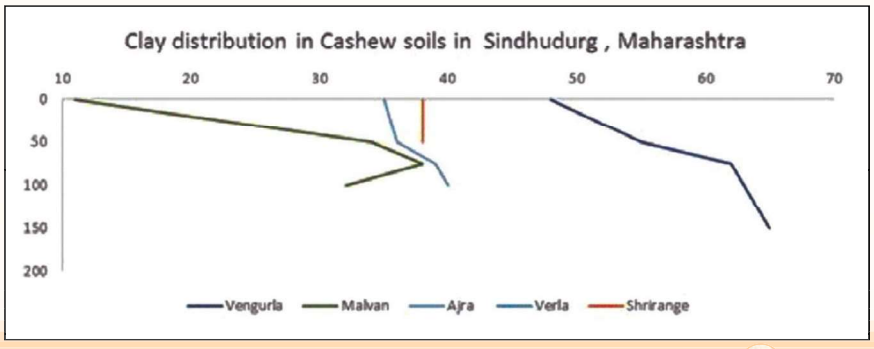
Fig. 3 : Cashew sequestration threshold in soils of Kerala. (Horizontal thick line shows the minimum threshold limit of 0.05 Pg Million ha^{-1}). (Y axis is soil organic carbon threshold limit in 0.05 Pg Million ha^{-1}).

GENERAL DISCUSSION

It is reported by the horticulturist that the cashew tree root is concentrated in 0.20% although the tap root system might go deep down the soils. These adventitious roots are the lifeline for the cashew trees since these roots absorb most of the moisture from these soils as well as nutrients. Logically therefore, the distribution of clay in the subsurface has a role to play in cashew tree orchards. The clay of soils were studied in Ratnagiri, Sindhudurg, Raigad, Thane and Palghar and in most of the cases with few exceptions, the clay distribution gradually increased down the soil depth. Similar observation is also made in the soils of Kerala (Figure 4 & 5). While studying the soil genesis in Maharashtra with special reference to the Western Ghats (Bhattacharyya et al. 1993, 1999, 2006 & 2018) and in Kerala (Chandran et al. 2004), it was observed that these soils contain minerals in clay fraction which reserves more moisture. It therefore appears that the soil clays within first 50 cm depth in Kerala, Maharashtra and

Goa can hold sufficient moisture in first 50 cm depth of soil profiles (Table 21). The concept of available water capacity (AWC) percentage has been described by a few authors as an imperfect soil parameter for soil-site suitability of horticulture crops or deep-rooted crops. Reports indicate that plant available water capacity (PAWC) is a better quality parameter to adjudge soil suitability for deep-rooted agricultural crops (Deshmukh et al. 2014). Accordingly, PAWC in cashew soils in Kerala, Maharashtra and Goa was estimated (Figure 6, 7 & 8). Figure 6 shows that the PAWC values are relatively more in soils of Maharashtra that in soils of Kerala. Earlier studies indicate that the Kerala soils have mixed clay mineralogy as compare to the smectitic mineralogy in the soils of Maharashtra. It seems therefore that the plant available water capacity for cashew even in stress condition will be more in soils of Maharashtra than in the soils of Kerala. It might influence the quality as well as quantity of nuts. It appears appropriate that a study of organoleptic parameters of consumable cashewnut in different states may be compared keeping in view all the values of PAWC.





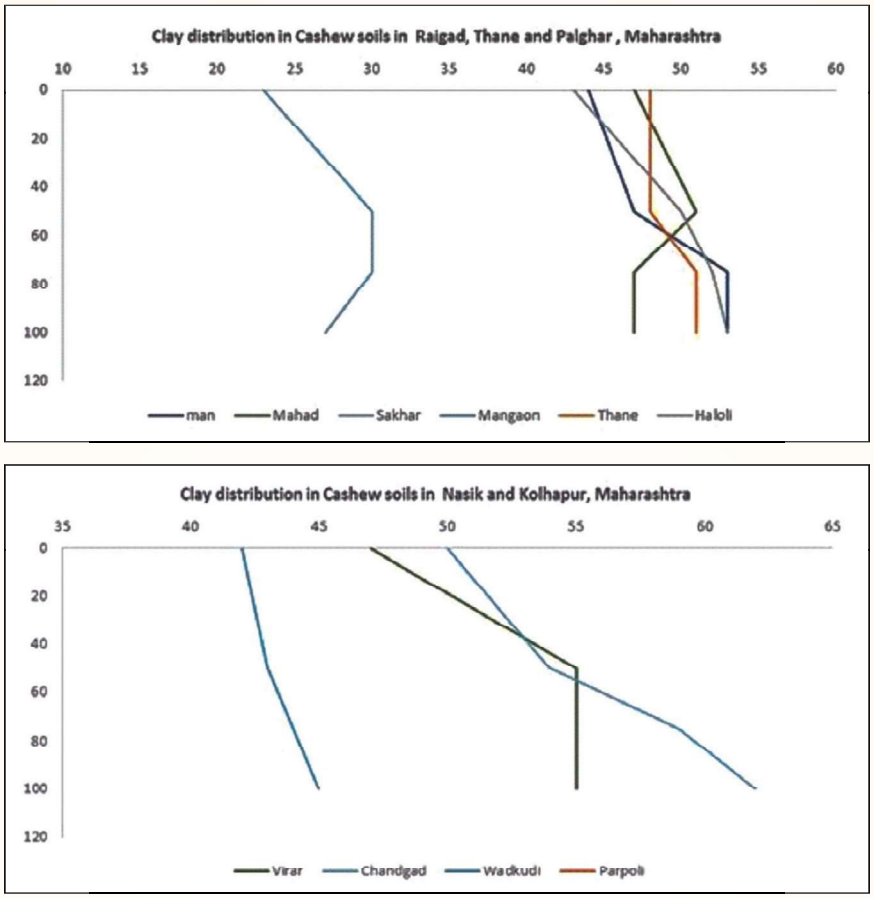
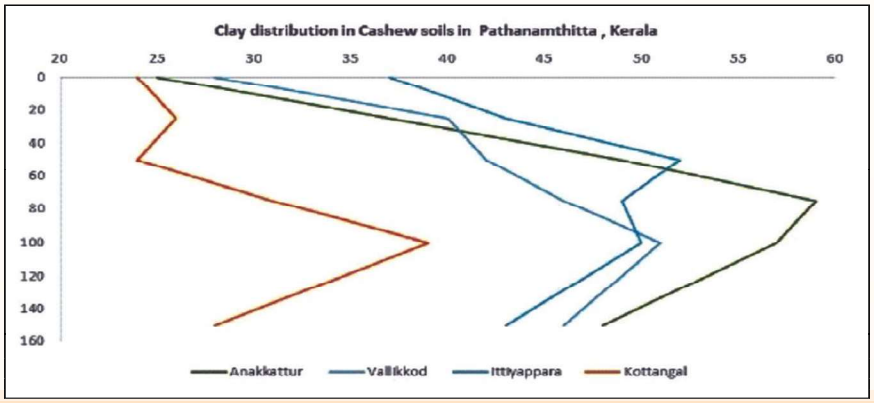
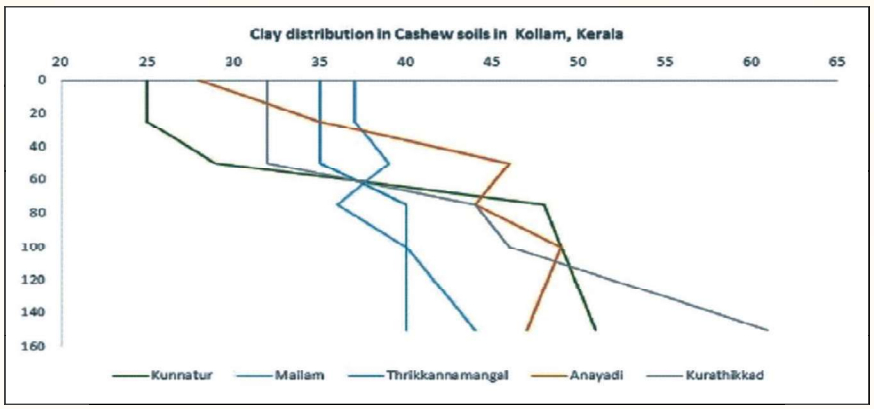
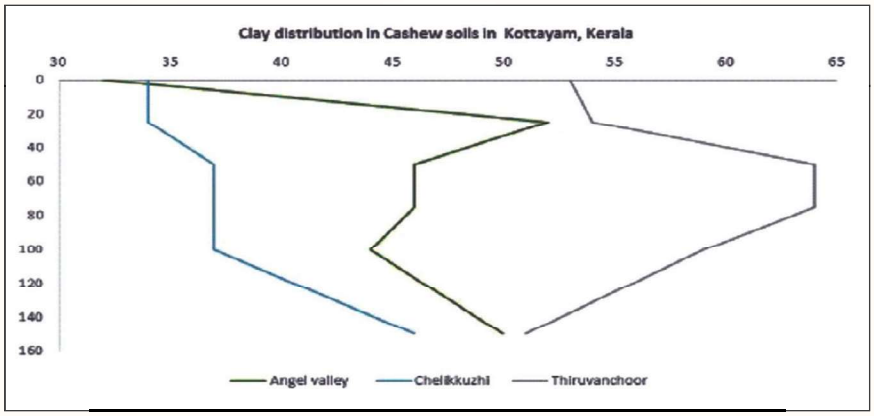
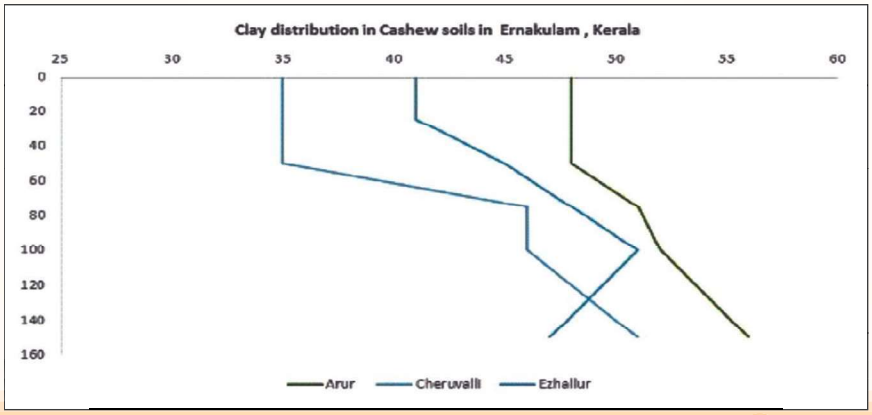


Fig. 4 : Clay distribution in cashew soils in Maharashtra.




Clay distribution in Cashew soils in Kollam, Kerala
20 25 30 35 40 45 50 55 60 65
0 20 40 60 80 100 120 140 160
Kunnatur
Mailam
Thrikkannamangal
Anayadi
Kurathikkad


Clay distribution in Cashew soils in Kottayam, Kerala
30 35 40 45 50 55 60 65
0 20 40 60 80 100 120 140 160
Angel valley
Chelikkuzhi
Thiruvanchoor


Clay distribution in Cashew soils in Ernakulam , Kerala
25 30 35 40 45 50 55 60
0 20 40 60 80 100 120 140 160
Arur
Cheruvalli
Ezhallur

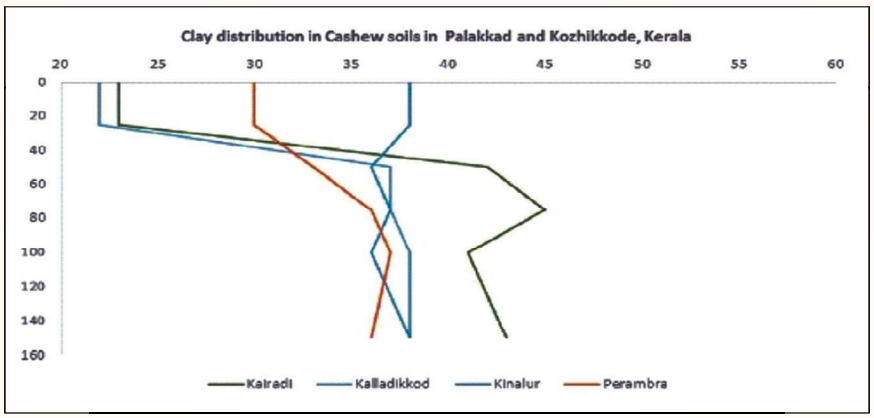


Fig. 5 : Clay distribution in cashew soils in Kerala.

Table 21 : Available water capacity (%) of soils at different depths (cm).

Soils	0-30	30-50	50-75	75-100	0-50	0-75
Pathanamthitta district						
Anakkattur	9.4	13.4	14.9	16.7	11.0	12.3
Vallikkod	10.6	12.2	13.1	13.5	11.3	11.8
Ittiyappara	12.6	14.8	15.3	15.0	13.5	14.1
Kottangal	8.5	10.3	12.3	9.6	9.2	10.2
Kollam district						
Kunnatur	8.6	12.2	14.1	14.2	10.0	11.4
Mailam	12.5	13.3	11.8	12.6	12.8	12.6
Thrikkannamangal						
Anayadi	10.2	12.7	16.1	13.5	11.2	11.9
Kurathikkad	11.0	13.1	13.1	14.6	11.8	12.3
Kottayam district						
Angel valley	12.9	14.2	11.0	13.7	13.4	13.5
Chelikkuzhi	11.1	11.7	9.5	13.1	11.4	11.5
Thiruvanchoor	15.9	17.7	18.0	16.4	16.6	17.8
Ernakulam district						
Arur	14.7	15.1	12.2	15.7	14.9	13.0
Cheruvalli	13.4	14.5	15.3	15.7	13.8	14.3

Ezhallur	13.3	14.1	14.4	15.0	13.6	13.9
Palakkad district						
Kairadi	9.7	12.7	13.3	13.0	10.9	11.7
Kalladikkod	9.9	11.4	11.4	11.4	10.5	10.8
Kinalur	11.6	11.6	11.4	11.6	11.6	11.6
Perambra	10.1	11.2	11.3	11.2	10.5	10.8
Sindhudurg district						
Vengurla	16.2	18.0	19.6	19.3	17.0	17.8
Malvan	8.9	12.6	11.2	11.2	10.4	10.6
Ajra	12.2	13.0	13.4	13.5	12.5	12.8
Verla	9.0	9.9	9.9	9.9	9.4	9.5
Shrirange	12.8	12.5	12.5	12.5	12.7	12.6
Ratnagiri district						
Nadgaon	15.5	16.4	16.4		15.8	
Gavalwadi	11.7	11.7	11.2	11.2	11.7	12.0
Khed						
Amboli	12.7	11.2	11.2	11.2	12.1	11.8
Raigad district						
Man	7.8	9.0	9.8	9.8	8.3	8.8
Mahad	13.4	9.8	9.0	9.0	12.0	11.0
Sakhar						
Mangaon	13.6	13.4	14.3	14.3	13.6	13.8
Thane and Palghar districts						
Thane	14.9	15.2	15.3	15.3	15.0	10.8
Dahisar	16.3	16.3	16.3	16.3	16.3	16.3
Haloli	14.7	15.8	16.1	16.1	15.2	15.5
Nashik and Kolhapur districts						
Virar	16.3	16.7	16.7	16.7	16.5	16.5
Chandgad	15.4	16.3	16.7	17.2	15.8	16.1
Wadkudi	12.5	13.2	13.2	12.8	12.8	12.9
Parpoli	17.5	17.8	18.0	18.1	14.2	17.8

While comparing the base saturation (sum of cations such as calcium, magnesium, potassium and sodium), we find cashew growing soils in Maharashtra are appreciably high in bases as compared to Goa and Kerala soils indicating more nutrient holding capacity of the soils of Maharashtra. This might also be one of the factors contributing better cashewnut quality in and around Maharashtra (Figure 9). Comparison of soil reaction [pH (water)], we find relatively high soil pH in Maharashtra as compared to soils of Kerala and Goa. As reported earlier regarding the presence of Ca-rich zeolites in the soils of Konkan (Bhattacharyya et al. 2018) and soils of the Western Ghats (Bhattacharyya et al. 1999), maintenance of high bases even in high rainfall (mean annual rainfall nearly 3500 mm) does not permit these Alfisols to reach the stage of Ultisols (Chandran et al. 2004; Bhattacharyya et al. 1999). It suggests that better quality of soil with relatively high base saturation as well as soil pH in the soils of Maharashtra permit maintenance of soil quality. This indirectly shows that presence of Ca-rich zeolites might be reducing soil nutrient requirements to benefit cashew farmers in Maharashtra (Figure 10).

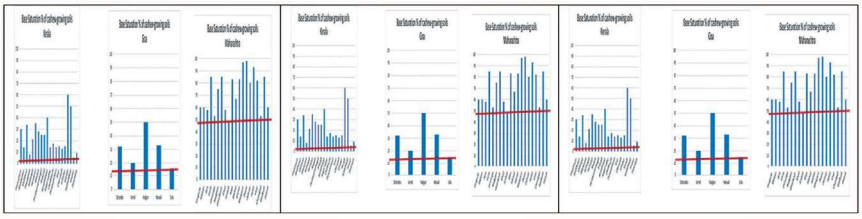


Fig. 9 : Base saturation in soils: a comparison in different states (Horizontal thick lines indicate minimum values of base saturation in three states).

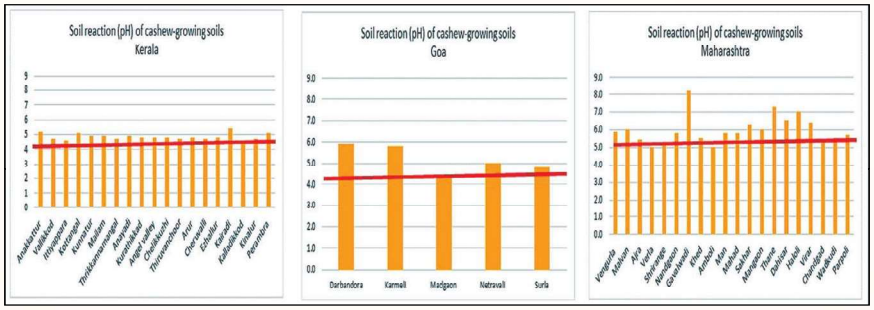


Fig. 10 : Soil reaction in cashew-growing soils : a comparison (Horizontal thick lines indicate minimum values of soil reaction , pH in three states).

A comparison of delta pH (difference between KCl pH and water pH) in cashew growing soils of Kerala and Maharashtra showed that former soils have low delta pH (Figure 11). This shows that KCl pH difference with water pH is less suggesting low residual acidity in soils of Kerala. This information might be useful in suggesting quality of cashewnut grown in soils of two different geographical locations of Kerala and Maharashtra. (Figure 11).

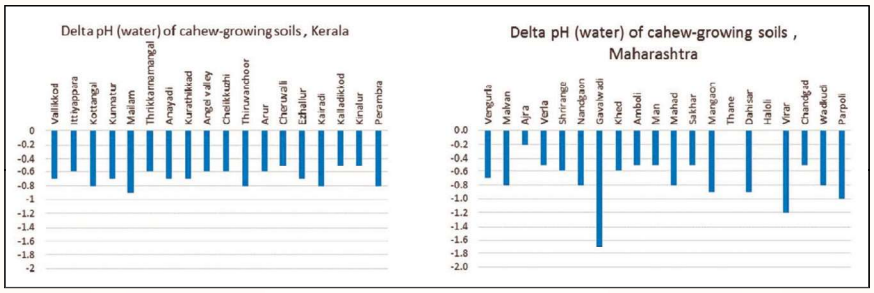


Fig. 11 : Delta pH of soils: A comparison (Horizontal thick lines indicate minimum values of delta pH in three states)

CONCLUSION

Although soils are considered important for growing crops and perennial trees, unfortunately management of these precious resources and their information to link quality of crops and fruits has been ignored. The present article is focused to document different information available in world literature on cashew soils which might be useful for soil scientists as well as horticulturist and plantation scientists in India and elsewhere.

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REFERENCES

1. Aguiar, M de J.N., and C.A.R. Costa. 2002. Exigências Climáticas. p. 21-23. *In*: L. de M. Barros (ed.) Caju. Produção: Aspectos técnicos. Embrapa Agroindústria Tropical. Fortaleza. (Frutas do Brasil, 30).

2. Anonymous (1974) Cashew, Central Plantation Crops Research Institute, India, p. 169.

3. Anonymous (1989) Agro-climatic regional planning (an overview). Planning Commission, Government of India, New Delhi, p. 144.

4. Anonymous (2003) Developing integrated production package for enhancing productivity of cashew, NATP Final report, NRCC, Puttur, DK, Karnataka, p.55.

5. Anonymous (2006) Soil Series of Kerala, NBSS Publ. No. 136, NBSS&LUP, Nagpur, pp. 136.

6. Anonymous (2003) Information About Cashewnut, http://www.hubrural.org/IMG/pdf/anacarde_danida.pdf

7. Anonymous 2017. Horticultural Statistics at a Glance – 2017. Department of Agriculture and Farmers' Welfare, Govt. of India.

8. Anonymous (2018) https://zantye.com/profile/history-of-cashew/).

9. Badrinath, MS, K Sudhir, and T Chikkaramappa (1997) Soil fertility evaluation for cashew cultivation in coastal Karnataka soils. *The Cashew*, 11: 22-23.

10. Barros L de M (1995) Botânica, origem e distribuição geográfica. p. 55–71. *In*: J.P.P de Araújo, and V.V. da Silva (ed.) Cajucultura: Modernas técnicas de produção. Embrapa-CNPAT. Fortaleza. (Frutas do Brasil, 30)

11. Belekar P and Laut P (1987) Soil family description, A soil Survey and Land Evaluation for Oil palm and Cashewnut of the Lockhart river valley, Cape York Queensland Divisional Report 87 /1 CSIRO, Institute of Natural Resource and Enviorrnment, Division of Water Resource Research, Canbera, A.C.T.

12. Bhat MG, Nagaraja KV, Rupa TR (2010) Cashew research in India, *J. Hortl. Sci.* 5: 1-16.

13. Bhattacharyya T, Pal DK, Chandran P, Ray SK, Mandal C, Telpande B (2008) Soil carbon storage capacity as a tool to prioritise areas for carbon sequestration. *Curr. Sci.*, 95: 482-494.

14. Bhattacharyya T, Pal DK, Deshpande SB (1997) On Kaolinitic and mixed mineralogy classes of shrink-swell soils. *Australian J. of Soil Res.*, 35: 1245-1252.

15. Bhattacharyya T, Sarkar D, Gangopadhyay SK, Dubey PN, Baruah U, Chamuah GS, Mukhopadhyay S, Nayak DC, Maji AK, Saxena RK, Barthwal AK, Krishna NDR, Mandal C, Sehgal J, Bhowmick KR, Singh K, Chakrabarty R, Nandi Majmdar S, Krishna Kumar AK, Sethuraj MR (1997) Soils of Tripura-I. Their taxonomy and general characteristics. *Agropedology*, 8: 47-54.

16. Bhattacharyya T, Sarkar D, Gangopadhyay SK, Dubey PN, Baruah U, Chamuah GS, Mukhopadhyay S, Nayak DC, Maji AK, Saxena RK, Barthwal AK, Krishna NDR, Mandal C, Sehgal J, Bhowmick KR, Singh K, Chakrabarty R, Nandi Majmdar S, Krishna Kumar AK, Sethuraj MR (1997) Soils of Tripura-II. Suitability for rubber. *Agropedology*, 8: 55-60.

17. Bhattacharyya T, Sarkar Dipak, Pal DK, Mandal C, Baruah U, Telpande B, Vaidya PH (2009) Soil Information System for resource management- Tripura as a case study. *Curr. Sci.*, 99: 1208-1217.

18. Bhattacharyya T, Sehgal J, Sarkar D (1996) Soils of Tripura for optimizing land use: their kinds, distribution and suitability for major field crops and rubber. NBSS Publ. 65 b (Soils of India series 6). NBSS & LUP, Nagpur, India 14 p.

19. Bhattacharyya T, Chandran P, Ray SK, Mandal C, Tiwary P, Pal DK, Maurya UK, Nimkar AM, Kuchankar H, Sheikh S, Telpande B, Kolhe A (2015) Walkley-Black recovery factor to

reassess soil organic matter: Indo-Gangetic plains and Black soil region of India case studies. *Commun Soil Sci Plant Anal,* 46: 2628–2648.

20. Bhattacharyya T, Pal DK, Mandal C, Chandran P, Ray SK, Sarkar Dipak, Velmourougane K, Srivastava A, Sidhu GS, Singh RS, Sahoo AK, Dutta D, Nair KM, Srivastava R, Tiwary P, Nagar AP, Nimkhedkar SS (2013) Soils of India: Historical perspective, classification and recent advances in knowledge: A review. *Curr. Sci.*, 104: 1308-1323.

21. Bhattacharyya T, Mandal C, Mandal DK, Jagdish Prasad, Tiwary P, Venugopalan MV, Pal DK (2015) Agro-Eco Sub-Region Based Crop Planning in the Black Soil Regions and Indo-Gangetic Plains – Application of Soil Information System, Proc.Indian Natn. Sci. Acad., 81:1151-1170. DOI: 10.16943/ptinsa/2015/v81i5/48335

22. Bhattacharyya T, Patil KD, Kasture MC, Salvi BR, Dosani AAK, Patil VK, Haldankar PM (2018) Mango-growing soils and their characteristics. IN Salvi et al. (Eds.) Advances in Mango Production Technology. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, India. Pp. 71-98.

23. Challa O, Gajbhiye KS, Velayutham (1999) Soil Series of Maharashtra, NBSS Publ. No. 79, NBSS&LUP, Nagpur, 428 p.

24. Chattopadhyay N, Hore JK, Bhattacharjya A (2015) PROSPECT OF ORGANIC CASHEW PRODUCTION IN INDIA. *Acta Hortic.* 1080, 337-341, DOI: 10.17660/ActaHortic.2015.1080.45 https://doi.org/10.17660/ActaHortic.2015.1080.45

25. Crisóstomo LA (1991) Avaliação da fertilidade em dez unidades de solo cultivadas com cajueiro nos estados de Piauí, Ceará e Rio Grande do Norte. Tese (Professor Titular). Universidade Federal do Ceará, Fortaleza.

26. Crisóstomo LA, FJ de S Santos, VH de Oliveira, B van Raij, AC de C Bernardi, CA Silva, I Soares (2003) Cultivo do cajueiro anão precoce: Aspectos fitotécnicos com ênfase na adubação e irrigação. Embrapa Agroindústria Tropical. Fortaleza. (Circular Técnica Nº 08).

27. EPA (2010) Environmental co-benefits of sequestration practices. Internet file http://www. epa. gov/sequestration/fag.html April, 2012.

28. Falade JA (1978) Effects of macronutrients on mineral distribution in cashew (*Anacardium occidentale* L). *J. Sci. Food Agri.*, 29: 81-86.

29. Falade JA (1984) Variability in soils and cashew tree size. *J. Plantation Crops,* 12: 30-37.

30. FAO 2018. Statistical Database. Food and Agricultural Organization. http://www.fao.org/faostat/en/

31. Frota PCE, JIG Parente (1995) Clima e fenologia. p. 43-54. *In*: J.P.P de Araujo, and V.V. da Silva (org.) Cajucultura: Modernas técnicas de produção. Embrapa-CNPAT, Fortaleza.

32. Grundon NJ (1999) Cashew nuts in North Queensland respond to phosphorus and sulfur fertilizers. *Better Crops International*, 13: 22-24.

33. Gunn RN, DD Coks (1971) Potentialities for Cashew in Northern Australia. *J. Austral. Inst. Agri. Sci.*, 37: 25-31.

34. Harindranath CS, Nair KM, Srinivas S, Krishnan P, Gajbhiye KS (2002) Soil Series of Goa, NBSS Publ. No. 92, NBSS&LUP, Nagpur, pp. 112 + ii

35. Hartemink AE, Huting J (2005) Sandy Soils in Southern and Eastern Africa : Extent, properties and management. In Proceedings: Management of tropical sandy soils for sustainable Agriculture, 27th Nov. – 2nd Dec., 2005 at Khon Kaen, Thailand.

36. Kalaivanan D, Rupa T R (2017) Organic cultivation of Cashew. In Improvement, Production and Processing (Eds. P.L. Saroj) pp. 295-322, Astral International Pvt. Ltd., New Delhi.

37. Kernot I (coord.) (1998) Cashew: Information kit. Queensland: Department of Primary Industries. (Agrilink series QAL 9806).

38. Krishna Moorthy V, Yadukumar N, Shankar Raj NS (2008) Handbook on organic Cashew Cultivation, Varanashi Publications, 71 p.

39. Latis T, G Chibiliti (1988) Foliar diagnosis of nutrient deficiencies in cashew: A study conducted in the Western Province of Zambia. *Revista di Agricoltura Subtropicale e Tropicale*, 82: 677-689.

40. Lindbergue Araújo Crisóstomo, Carlos Roberto Machado Pimentel, Fábio Rodrigues de Miranda, and Vitor Hugo de Oliveira1 Cashew– Dwarf Variety 3. https://www.ipipotash.org/udocs/3_Cashew_-_Dwarf_Variety.pdf, The International Potassh Institute, by CRM Pimentel accessed in June, 2018.

41. Mahopatra G, Bhujan (1974) Land selection for cahew plantation-a survey report, *Cashew Bull,* 11: 397.

42. Mandal RC (2000) Cashew Production and Processing Technology, Published by AGROBIOS (India), Jodhpur p.4.

43. Nguyen Cong Vinh (2005) Coastal sandy soils and constraints for crops in Binh Thuan Province, Southern Central Vietnam. In Proceedings : Management of tropical sandy soils for sustainable Agriculture, 27th Nov. – 2nd Dec., 2005 at Khon Kaen, Thailand.

44. Ohler JG (2001) Cashew: The World Cashew Economy, http://phalgunicashew.com/historyofcashewnut.htm.

45. Pal SK (1998) Physical Geography of India, A study in Regional Earth Sciences, Orient Longman Ltd., Hyderabad, pp.152-156.

46. Raij B van, H Cantarella, JA Quaggio, AMC Furlani (ed.) (1997) Recomendações de adubação e calagem para o Estado de São Paulo. 2nd ed. Instituto Agronômico de Campinas. Campinas. (Boletim Técnico, 100).

47. Sarkar D, Sah KD, Sahoo AK, Gajbhiye KS (2005) Soil Series of Orissa, NBSS Publ. No. 119, NBSS&LUP (ICAR), Nagpur, 254 p.

48. Saroj PL (2015) Cashew Cultivation in India: Issues and Challenges ICAR-Directorate of Cashew Research, Puttur pl.saroj@icar.gov.in, National Training on Advances in Cashew Production Technology.

49. Sawke DP, RT Gunjate, VP Limaye (1985) Effect of nitrogen, phosphorus and potash fertilization on growth and production of cashewnut. *Acta Hort.,* 108: 95-99.

50. Soil Survey Staff (2014) Keys to Soil Taxonomy. 12th Edition. USDA, USA.

51. USDA (1961) Land-Capability Classification, Soil conservation service U. S. Department of Agriculture, Washington 25, D.C., Agriculture Handbook No. 210, p.25,

52. Widiatmaka W, Ambarwulan A, Sutandi K, Murtilaksono K, Munibah, Daras U (2015) Suitable and available land for cashew (*Anacardium occidentale* L.) in the island of Lombok, Indonesia. *J. Appl. Hort.*, 17: 129-139.