Climate Change And Agriculture

About the Book

Rainfed agriculture is gaining importance throughout the globe in view of its inherent problem of low or sparse rainfall which is accentu ted further by climate change. To sustain agriculture and ther related activities, we need to know more about the soils and other natural resources including plants, insects and other biological elements which are experiencing climatic stress due to global warming.

On the basis of expertise by a team of leading scientists from national and international organizations, the 16 chapters of this book discuss the issues and priorities for agricultural and related managements. Covering areas such as north-eastern Himalayas, semi-arid tropics, eastern and north-eastern India and the Indo-Gangetic Plains with an overall global scenario of the rainfed agriculture, this book will be necessary for both the academics and policy makers in understanding natural resources and their management for sustainable agriculture.

SP Pvt Ltd

Studium Press (India) Pvt. Ltd.
4735/22, 2nd Floor Prakash Deep Building (Near PNB),
Ansari Road, Darya Ganj, New Delhi-110002
Phone: +91-11-43240200-15 (15 lines)
Fax: +91-11-43240215
E-mail: studiumpress@gmail.com
Website: http://www.studiumpress.in

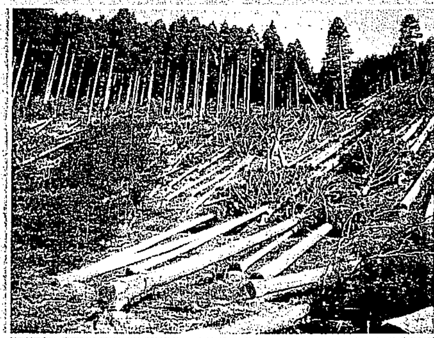
ISBN 93-80012-40-3
9 789380 012407

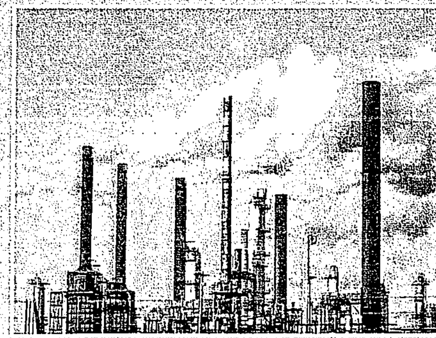
Bhattacharyya
Pal
Sarkar
Wani

Climate Change And Agriculture

SP Pvt Ltd

Climate Change
And Agriculture





SP Pvt Ltd

T Bhattacharyya
D K Pal
Dipak Sarkar
S P Wani

Climate Change And Agriculture

Editors

T. Bhattacharyya
D.K. Pal
Dipak Sarkar
S.P. Wani

2013

Studium Press (India) Pvt. Ltd.

1

Rain-fed Agriculture, Area and Extent

T. Bhattacharyya[1], D.K. Pal[2], S.P. Wani[2] and K.L. Sahrawat[2]

ABSTRACT

Rainfed areas, although vary from region to region, are important in terms of agriculture since most of the poor communities live in these areas. Rainfed agriculture (RFA) is fragile due to climatic vagaries. More than 90 per cent area comes under RFA in the sub-Saharan Africa; the corresponding figures are 90 per cent, 60 per cent, 65 per cent and 75 per cent for Latin America, South-Asia, East-Asia and Near-East North Africa, respectively. RFA in India has been estimated as 90 m ha. In view of more than 50 per cent geographical area in India experiencing relatively dry climate, the management of these locations requires special attention for better crop productivity. This is more so in view of the climate change and its influence in arid and semi-arid climate causing soil degradation in terms of low organic carbon, formation of pedogenic calcium carbonate and sub-soil sodicity. To circumvent such adverse situation, proven management techniques including agro-forestry may form the strategic plan to make degraded soils resilient by reducing the rate of formation of calcium carbonate and by enhancing the organic carbon sequestration of Indian soils. The most unfavourable natural endowment is the climatic adversity and this will ever demand for extra resources to support targetted yield in the Indian agriculture and thus may retard the pace of rehabilitation programme required to restore the soil productivity. Research endeavours for maintaining health of soils in this area should be a part of national agenda. In absence of such programme, deforestation will continue to encroach upon the area under agriculture and obviously this may affect the natural resources, which are so vital for human sustenance in tropical world.

[1] National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur-440 033.
[2] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh.
Corresponding author: E-mail: tapas11156@yahoo.com

Keywords: Dry lands, Agriculture, Rehabilitaton.

1. INTRODUCTION

Despite increase in food production due to modern agricultural managements, many parts of the world continue to face food insecurity. About 60% of the world's population facing food insecurity resides in South Asia and sub-Saharan Africa. Most of these areas are rain-fed and there are several challenges in terms of area, extent and future perspective to improve the livelihood. Rain-fed areas vary from region to region and yet these are the zones where food is produced mostly for the poor communities. Rain-fed agriculture in the SAT (Semi-Arid Tropics) area is fragile in view of spatial and temporal variation of rainfall. The total rainfall in these areas is received within a short span of three to five months (Wani *et al.*, 2004). Besides, as the rainfall is of high intensity and only for short duration, huge amount of soil erosion and often flash flooding occur. It has been established that SAT induces formation of pedogenic calcium carbonate (PC) with concomitant sub-soil sodicity, making the soil extremely impervious to air and rain water, which in turn leads to flooding (Bhattacharyya *et al.*, 2004; Pal *et al.*, 2000, 2006).

It has been reported that there is increased frequency of extreme events like drought, floods, and hurricanes due to climate change. Many scenarios indicate losses of rain-fed production area (10–20%) that is expected to affect nearly 1.2 billion people by 2080 (IIASA, 2002). Climate change has been reported to adversely affect the water availability and food production, and as a result land degradation, poverty and food insecurity are expected to grow to menacing proportions (Wani *et al.*, 2009; 2011).

2. RAIN-FED AGRICULTURE: BACKGROUND

Hunger, poverty, and vulnerability of livelihoods to natural and other disasters will continue to be extremely important factors in the rural tropical areas of Africa and Asia. These challenges are further influenced by climate aberration, population growth, degrading natural resources, poverty, and other health related problems (Walker, 2010). The majority of poor in developing countries live in rural areas. Their livelihoods depend on agriculture and over-exploitation of the natural resource base makes the situation only worst. The importance of rain-fed agriculture centers on a disproportionate food distribution between men and women (WHO, 2000). It has been reported that every one per cent increase in agriculture yield translates to a 0.6% to 1.2% decrease in the percentage of absolute poor (Thirstle *et al.*, 2002). On an average, agriculture in the sub-Saharan Africa constitutes 35% of the Gross

Domestic Produce (GDP) and employs 70% of the total population and more than 95% of the agriculture area is under rain-fed (Wani *et al.*, 2011).

In Africa and South Asia, agriculture will continue to remain the backbone of economy in future. Most of the poor people are farmers and landless labourers. Therefore, the strategies have to focus on generating more income to reduce poverty and its related problems. Substantial gains in land, water, and labour productivity along with the careful natural resource management are essential to combat soil degradation, maintain sustainable crop production, and ultimately to bring better lifestyle to the rural poor.

3. AREA AND EXTENT

Rain-fed agriculture produces most food for poor communities for the developing countries. It is important to note that in sub-Saharan Africa more than 95% area is rain-fed. In Latin America, the corresponding figure is 90% and in South Asia, East Asia and near East and North Africa the figures are 60%, 65%, and 75%, respectively (Table 1).

Table 1: Global and continent-wise area and percentage of total arable land.

Continent Regions	*Total arable land (million ha)*	*Rain-fed area (million ha)*	*% of rain-fed area*
World	1551.0	1250.0	80.6
Africa	**247.0**	**234.0**	**94.5**
Northern Africa	28.0	21.5	77.1
Sub-Saharan Africa	218.0	211.0	96.7
America	**391.0**	**342.0**	**87.5**
Northern America	253.5	218.0	86.0
Central America and Caribbean	15.0	13.5	87.7
Southern America	126.0	114.0	90.8
Asia	**574.0**	**362.0**	**63.1**
Middle East	64.0	41.0	63.4
Central Asia	40.0	25.5	63.5
Southern and Eastern Asia	502.0	328.0	65.4
Europe	**295.0**	**272.0**	**92.3**
Western and central Europe	125.0	107.5	85.8
Eastern Europe	169.0	164.0	97.1
Oceania	**46.5**	**42.5**	**91.4**
Australia and New Zealand	**46.0**	**42.0**	**91.3**
Other Pacific Islands	**0.57**	**0.56**	**99.3**

Source: FAO, AQUASTAT: FAO's information system on water and agriculture.

Out of 142 m ha of the net sown area in India, irrigated (rain-fed) agriculture is practiced in over 90 m ha. Nearly 67 m ha of rain-fed area falls in the mean annual precipitation range of 500–1500 mm. Productivity and stability in rain-fed areas are low. Although rain-fed agriculture occupies about 63 percent of the total cropped area in India, it contributes only 45 percent of the country's agricultural production. Major rain-fed crops grown in India comprise coarse grains, particularly pearl millet and sorghum, pulses, oilseeds and cotton. Not only are the yields of these crops low (average yield of coarse grains being just about 880 kg ha^{-1}), but also the technology transfer gap is very wide. The region is characterized by erratic and often low rainfall, low soil fertility and harsh temperature regime (Kaul and Mittal, 1998). Later estimate showed that the area under dry land agriculture in India is 100–105 m ha, of which Alfisols, Vertisols and Entisols occupy 30, 35 and 10 per cent, respectively (Virmani *et al.*, 1991), besides some areas under Inceptisols.

In India, rain-fed areas include part of sub-humid dry (SHD), semi-arid moist (SAM), semi-arid dry (SAD) and arid bioclimatic systems (Table 2). Recent studies have shown that nearly 155.8 m ha of the country requires priority for better natural resource management in the form of organic carbon sequestration to bring back the soils to normal state (Bhattacharyya *et al.*, 2008). Earlier, it was stated that arid and semi arid areas are called dry lands (Sehgal and Sharma, 1994). Our recent observation indicates that there are areas under subhumid bioclimatic systems which also experience drought and should therefore be included in the dry tracts of the country (Bhattacharyya *et al.*, 2000, 2008).

Table 2: Different bioclimatic systems as part of rain-fed agriculture in India.

Bioclimatic system	*Mean annual rainfall (MAR) (mm)*
SHM	> 1100
SHD	1000–1100
SAM	850–1000
SAD	550–850
Arid	<550

Source: Bhattacharyya *et al.*, 2006.

In the dry ecosystem, climatic variability (in terms of mean annual rainfall (MAR) and mean annual temperature (MAT)) results in the magnitude in the regressive pedogenic processes (Pal *et al.*, 2000, 2006, 2011). This modifies the physical, chemical and biological properties of soils resulting in an interannual variability in crop yields. The water deficit in soils is unfavourable for the growth and development of rain-fed crops and often produce low crop yield (Singh and Subba Rao Reddy, 1988). The effective cropping season is restricted, both by quantity and distribution of rainfall, thereby setting the limits on the choice of crops, cultivars and cropping systems. Besides, the knowledge on soils and their

modifiers (zeolites, gypsum, calcium carbonate, palygorskite) for each AESR is necessary as the presence of modifiers immensely affect the soil-water relations (Bhattacharyya *et al.*, 1993, 1999, 2004, 2006, 2011; Pal *et al.*, 2006), especially for post rainy season crops that are grown on conserved rain water.

In India, out of 60 agro eco-subregion (AESRs) (Velayutham *et al.*, 1999), 27 AESRs represent relatively dry tracts, showing arid, semi-arid, sub-humid bio climates covering an area of 179.6 m ha (nearly 55% total geographical area of the country) (Table 3). Table 4 indicates datasets for representative soils from these AESRs for the first 30 cm depth.

Table 3: Description of agro-ecological regions (AER) and subregions of India.

Sl. no.	*AER and sub-region no.*	*Description*	*Location (state and districts)*	*Area, m ha (% of TGA)*
2. Western Plains, Hot Arid Ecoregion, LGP <60 days				
1.	2.1	Marusthali plains, hot hyper-arid, very low AWC, LGP <60 days	*Punjab*: Southern part Ferozepur *Rajasthan*: Hanumangarh and Ganganagar	12.3 (3.7)
2.	2.3	Kachch Peninsula, hot hyper-arid	*Punjab*: Muktasar, Bathinda, Central Ferozepur low AWC and LGP <60 days and South Faridkot *Haryana*: Bhiwani, Hisar, West Mahendragarh	11.5 (3.5)
3. Deccan Plateau, Hot Arid Ecoregion				
3.	3.1	Karnataka Plateau, hot arid with moderately well drained, clayey mixed black and red soils, LGP 90–120 days	*Karnataka*: Bijapur, Dharwad, Raichur, Bellary, Chitradurga	2.79 (0.9)
4.	3.2	Karnataka Plateau, hot arid with moderately well drained, loamy mixed red soils, LGP <90 days	*Karnataka*: Tumkur, Cuddapah *Andhra Pradesh*: Ananthapur	2.11 (0.6)
4. Northern Plains, Hot Semi-Arid Ecoregion, LGP 90–150 days				
5.	4.1	North Punjab Plain, Ganga–Yamuna Doab, hot semi-arid, medium Moga, Faridkot and Ferozepur, AWC, LGP 90–120 days	*Punjab*: Amritsar, Kapurthala, Sangrur, Patiala *Haryana*: Kurukshetra, Kaithal, Karnal, Jind, Sonepat, Panipat, Rohtak, Faridabad, Gurgaon, Mahendragarh, Rewari	11.8 (3.5)

Table 3: *(Contd...)*

Table 3: (*Contd...*)

Sl. no.	*AER and sub-region no.*	*Description*	*Location (state and districts)*	*Area, m ha (% of TGA)*
			Uttar Pradesh: Meerut, Ghaziabad, Bulandshahr, Aligarh, Mathura, Etah, Agra, Mainpuri, Firozabad, West Muzafarnagar, South Moradabad and South Etawah	
6.	4.2	North Gujarat Plain (inclusive of Aravalli range and Eastern Rajasthan Uplands) hot, dry semi-arid eco-subregion	*Gujarat*: Sabarkantha (Himmatnagar), eastern Mahesana, Ahmadabad, Surendranagar (eastern parts) and northern tips of Bhavnagar and Rajkot *Rajasthan*: Tonk, Ajmer, Udaipur, Bhilwara, Durgarpur, Rajsamand and Chiiaurgarh (Western parts) northern half of Bundi	7.6 (2.3)
7.	4.3	Ganga–Yamuna Doab, Rohilkhand and Avadh Plain, hot moist semi-arid, medium to high AWC, LGP120–150 days	*Uttar Pradesh*: Budaun, Hardoi, Farrukhabad, Kanpur, Unnao, Western Varanasi, Etawah, Southern Shahjahanpur, Raebareli, Allahabad, and Pratapgarh *Madhya Pradesh*: Bhind	6.9 (2.0)
8.	4.4	Madhya Bharat Pathar and Bundelkhand Uplands, hot, moist semi-arid eco sub-region	*Uttar Pradesh*: Jhansi, Hamirpur, Lalitpur, Banda; *Madhya Pradesh*: Shivpuri, Gwalior, Morena, Datia and northern tips of Guna and Sagar	5.9 (1.7)
5. Central (Malwa) Highlands, Gujarat Plains and Kathiwar, Peninsula Eco-region				
9.	5.1	Central Kathiwar Peninsula, hot, dry semi-arid eco-subregion	*Gujarat*: Rajkot (southern parts), Amreli, Junagadh, and Bhavnagar and parts of Ahmadabad	2.7 (0.8)
10.	5.2	Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujarat Plain, Vindhyan and Satpura range and Narmada valley, hot, moist semi-arid eco-region	*Madhya Pradesh*: Jhabua, Ratlam, Mandsaur, Ujjain, Indore, Dewas, East Nimar, West Nimar, and Dhar, parts of Rajgarh and Shajapur *Gujarat*: Godhra (Panchmahal). Bharuch, Vadodara, Kheda, and Surat (North and Central part); *Rajasthan*: Bundi (south), Kota, Banswara, Chittorgarh and Jhalawar, Baran	14.0 (4.3)
11.	5.3	Coastal Kathiwar Peninsula, hot, moist semi-arid eco sub-region	*Gujarat*: Coastal parts of Junagadh, Amreli and Bhavnagar *U.T.*: Daman and Diu	0.9 (0.3)

Table 3: (*Contd...*)

Table 3: (*Contd...*)

Sl. no.	*AER and sub-region no.*	*Description*	*Location (state and districts)*	*Area, m ha (% of TGA)*
6. Deccan Plateau, Hot semi–arid Eco–region				
12.	6.1	South Western Maharashtra and North Karnatak Plateau, hot, dry, semi-arid eco-subregion	*Maharashtra*: Ahmadnagar (south and central), Bid, Solapur, Sangli, Satara and Pune (eastern part), Osmanabad, parts of Latur *Karnataka*: Bijapur (Northern Part), raichur (NE Part)	7.6 (2.3)
13.	6.2	Central and westrn Maharshtra Plateau and North Karnataka Plateau and Nort Westtern Telangana Plateau, hot, moist semi-arid ecoregion	*Maharashtra*: Nashik, Dhule, Aurangabad, Jalna, Nanded Parbhani, Northern hilly part of Ahmadnagar, Jalgaon (Western Part); *Karnataka*: Bidar, Gulbarga; *Andhra Pradesh*: Nizamabad and Adilabad	12.6 (3.8)
14.	6.3	Eastern Maharashtra Plateau, hot, moist semi-arid ecosubregion	*Maharashtra*: Buldhana, Akola, Amravati Yavatmal and Jalgaon (Eastern parts)	5.4 (1.6)
15.	6.4	North Sahyadris and Western Karnataka Plateau, hot, dry subhumid eco-subregion	*Maharashtra*: Kolhapur (eastern parts) and Western parts of Satara, Sangli and Pune; *Karnataka*: Belgaum and Dharwad (Uttar Kannad–eastern part)	5.4 (1.6)
7. Deccan (Telangana) Plateau and Eastern Ghats, Hot Arid Ecoregion				
16.	7.1	South Telangana Plateau (Rayalseema) and Eastern Ghat, hot, dry semi-arid eco-subregion	*Andhra Pradesh*: Cuddapah, Kurnool	3.9 (1.2)
17.	7.2	North Telangana Plateau, hot, moist semi-arid eco-subregion	*Andhra Pradesh*: Karimnagar, Warangal, Rangareddy, Mahabubnagar, Nalgonda, Khammam, Sangareddy and Hyderabad	9.2 (2.8)
18.	7.3	Eastern Ghat (South), hot, moist semi-arid/ dry–subhumid eco-subregion	*Andhra Pradesh*: Northern parts of West Godavari and Krishna (Machlipatnam), non coastal parts of Guntur, Prakasam and Nellore	3.4 (1.0)
8. Eastern Ghats, TN Uplands and Deccan (Karnataka) Plateau, Hot, Semi-arid Ecoregion				
19.	8.1	Tamil Nadu Uplands and Leeward Flanks of South Sahyadris, hot, dry semi-arid eco-subregion	*Tamil Nadu*: Coimbatore, Madurai, Thirunelveli, Dindigal (Anna), Virudnagar (Kamrajar) and Tuticorin, Nagercoil (Kanyakumari) (Non-coastal parts)	3.7 (1.1)

Table 3: (*Contd...*)

Table 3: *(Contd...)*

Sl. no.	*AER and sub-region no.*	*Description*	*Location (state and districts)*	*Area, m ha (% of TGA)*
20.	8.2	Central Karnataka Plateau, hot, moist semi-arid eco-subregion	*Karnataka*: Hassan, Tumkur, Bangalore, Mysore, Mandya, Kolar, Chickmangalur, eastern parts of Shimoga, central and southern Chitradurga	6.5 (2.0)
21.	8.3	Tamil Nadu Uplands and Plains, hot, moist semi-arid eco-subregion	*Andhra Pradesh*: Chittor *Tamil Nadu*: North Arcot, South Arcot, Dharampuri, Periyar (Erode), Salem, Tiruchirapalli, Pudukottai, Sivaganga, Chengalpattu, Non-coastal parts of Ramnathpuram and Turicorin, Thanjavur	8.9 (2.7)
9. Northern Plains, Hot Sub-humid (Dry) Ecoregion, LGP 120–180 days				
22.	9.1	Punjab and Rohilkhand Plains, hot/dry moist sub-humid transition, medium AWC and LGP 120–150 days	*Jammu and Kashmir*: Southern parts of Jammu (R.S. Pura) and Kathua; *Himachal Pradesh*: Parts of Kangra, Una and Bilaspur; *Punjab*: Gurdaspur, Hoshiarpur, Rupnagar, Nawashahar, northern parts of Amritsar, Kapurthala, Jalandhar, Ludhiana and Patiala, Chandigarh and Union Territory *Haryana*: Ambala, Yamuna Nagar, northern parts of Kurukshetra, Karnal *Uttar Pradesh*: Saharanpur, Bijnaur, N–E Muzaffar Nagar, Northern Muradabad, West Rampur, S–W Nainital	3.9 (1.2)
23.	9.2	Rohilkhand, Avadh and south Bihar Plains, hot dry sub-humid, medium to high AWC and LGP 150–180 days	*Uttar Pradesh*: Barielly, Pilibhit, Sitapur, Bara Banki, Sultanpur, Azamgarh, Ghazipur, Lucknow (north), southern parts of Nainital, Mau (south), Faizabad and Balia, Rampur, northern parts of Shahjahanpur; *Bihar*: Bhojpur (Ara), Rohtas (Sasaram), Aurangabad, Gaya, Jahanabad, Nalanda, Patna, Nawada	8.3 (2.5)
10. Central Highlands (Malwa, Bundelkhand and Eastern Satpura Range), Hot, sub-humid (dry/moist) Eco-region				
24.	10.1	Malwa Plateau, Vindhyan Scarpland and Narmada valley, hot, dry subhumid eco-subregion	*Madhya Pradesh*: Guna, Rajgarh, Raisen, Sagar, Bhopal, Sehore, Shajapur, Hoshangabad, Jabalpur, Narsihapur, Vidisha and Damoh (south and central), Dewas (east)	8.1 (2.5)

Table 3: *(Contd...)*

Table 3: *(Contd...)*

Sl. no.	*AER and sub-region no.*	*Description*	*Location (state and districts)*	*Area, m ha (% of TGA)*
25.	10.2	Satpura and Eastern Maharashtra Plateau, hot, dry subhumid eco-subregion	*Madhya Pradesh*: Betul *Maharashtra*: Wardha and Nagpur and northern parts of Chandrapur	2.8 (0.8)
26.	10.3	Vindhyan Scarpland and Bagelkhand Plateau, hot dry-sub-humid eco-subregion	*Madhya Pradesh*: Tikamgarh, Chhatrapur, Panna, Satna, Rewa, Sidhi and Shahdol	5.8 (1.8)
27.	10.4	Satpura range and Wainganga Valley, hot, moist–subhumid eco-subregion	*Madhya Pradesh*: Chhindwara, Seoni, Mandla, Balaghat, south-eastern parts of Jabalpur; *Maharashtra*: Bhandara	5.6 (1.7)

4. RAIN-FED AGRICULTURE: INDIAN SCENARIO

Current arid and semi-arid environments prevailing in central and southern Peninsular India are a part of global warming phenomena (Eswaran and van den Berg, 1992). It is in this respect that tropical soils of the Indian subcontinent require immediate attention for better carbon management. In view of larger aerial extent and the specific soil property, the semi-arid tracts and other drier tracts in the subhumid ecosystem of India offers a better scope for carbon sequestration. Effective carbon management thus can help not only in building up the SOC (soil organic carbon) stock to a level of 10.5 Pg from the existing 2.9 Pg (Bhattacharyya *et al.*, 2000) but also to dissolve the SIC (soil inorganic carbon *i.e.*, $CaCO_3$) stock to the tune of 1.9 Pg much to the benefit of soil physical conditions (Pal *et al.*, 2011) and in providing calcium nutrition to growing plants. Such management interventions will bring back the soil productivity of the vast area under semi-arid tract and will also keep the impending climatic hazards of the major geographical area of the country at bay. Forest ecosystem in hills and mountainous areas is the most conducive soil-climatic environment for higher accumulation of SOC. Such environment exists in other physiographic regions. Encroaching such areas for agricultural activity to produce more food grains will make the soil unhealthy by decomposition of OC due to increase in soil temperature as a result of removal of permanent vegetation cover. It has been reported that clearing rain forest considerably alters microclimate and results in solar radiation reaching ground level during day (Dalal and Canter, 2000). Measurement of changes in micro-climate shows that soil temperature increases by as much as 3°C to a depth of first 20 cm, which can increase the rates of organic matter decomposition and its loss from the soil environment. Soils under arid and semi-arid climates, irrespective

Table 4: Selected soil properties representing the drier tracts of agro-ecological subregions of India

Sr. no.	AESRs	Soil series	Soil classification[1]	Soil properties (0–30 cm)								
				pH (water)	EC[2] (d Sm^{-1})	SOC[3] (%)	$CaCO_3$ (%)	CEC[4] (cmol (p+) kg^{-1})	BS[5] (%)	ESP[6]	B.D.[7] (Mgm^{-3})	H.C.[8] ($cmhr^{-1}$)
1	1.1	Ladakh II	Typic Cryorthents	8.6	0.3	0.12	1.5	1.0	NA[9]	NA	NA	NA
2	1.1	Ladakh III	Typic Cryorthents	8.5	0.3	0.12	0.8	3.3	NA	NA	NA	NA
3	1.2	Kibber	Typic Cryochrepts	7.7	1.0	2.50	0.0	10.6	96	NA	NA	NA
4	2.1	Chirai	Typic Camborthids	8.1	0.1	0.10	5.9	6.4	96	7	1.48	NA
5	2.1	Pai	Typic Camborthids	8.4	<0.2	0.22	0.0	NA	NA	NA	NA	NA
6	2.2	Amliara	Fluventic Comborthids	8.1	<0.2	0.50	1.5	NA	NA	NA	NA	NA
7	2.2	Balasar	Typic Torripsamments	9.2	<0.2	0.08	22.6	NA	NA	6	NA	NA
8	2.3	Hisar	Typic Ustochrepts	8.0	0.3	0.15	0.2	NA	NA	NA	NA	NA
9	2.3	Jaitaran	Typic Camborthids	8.3	0.2	0.36	NA	NA	NA	NA	NA	NA
10	2.4	Bhola	Vertic Ustochrepts	8.4	1.5	0.65	18.3	37.5	98	4	1.70	NA
11	2.4	Semla	Udic Haplusterts	8.7	0.7	0.70	21.2	55.0	98	4	1.80	NA
12	3	Jamakhandi	Typic Paleustalfs	8.3	NA	1.10	1.1	20.0	70	2	1.58	NA
13	3	Sollapuram	Sodic Haplusterts	8.4	NA	0.55	17.0	59.0	89	10	1.40	0.35
14	4.1	Zarifa Viran	Typic Natrustalfs	10.3	8.1[10]	0.30	0.8	12.0	100	95	1.46	NA
15	4.1	Shergarh	Typic Ustipsamments	8.2	0.2	0.12	2.8	3.3	80	3	NA	NA
16	4.2	Baland	Typic Haplustepts	8.5	0.2	0.50	4.0	22.0	90	2	NA	NA
17	4.2	Kajlodiya	Typic Haplustepts	8.5	0.3	0.30	0.0	16.7	89	15	NA	NA
18	4.3	Nagariya	Typic Haplustepts	9.0	0.2	0.32	1.3	3.8	95	26	NA	NA
19	4.3	Bijaipur	Udic Ustochrepts	6.8	NA	0.15	NA	6.1	98	6	NA	NA
20	4.4	Haripur	Vertic Ustochrepts	7.8	0.2	0.42	1.4	14.0	NA	NA	NA	NA
21	4.4	Singpura	Typic Ustochrepts	7.7	0.2	0.30	NA	18.0	99	3	NA	NA

Table 4: *(Contd...)*

Table 4: *(Contd...)*

Sr. no.	AESRs	Soil series	Soil classification[1]	Soil properties (0–30 cm)								
				pH (water)	EC[2] (d Sm^{-1})	SOC[3] (%)	$CaCO_3$ (%)	CEC[4] (cmol (p+) kg^{-1})	BS[5] (%)	ESP[6]	B.D.[7] (Mgm^{-3})	H.C.[8] ($cmhr^{-1}$)
22	5.1	Gondal	Lithic Ustorthents	7.5	0.3	0.14	NA	35.3	98	1	NA	NA
23	5.1	Kagwad	Lithic Haplustepts	8.2	0.3	0.38	1.6	55.1	99	1	NA	NA
24	5.2	Haldhar	Chromic Haplusterts	7.5	0.1	0.24	1.0	44.5	95	1	NA	NA
25	5.2	Jalalpur	Typic Haplusterts	8.3	0.7	0.48	3.1	44.0	NA	NA	1.35	NA
26	5.3	Khuntwada	Vertic Haplustepts	8.8	0.2	0.66	10.0	86.0	91	10	NA	NA
27	5.3	Lilvan	Vertic Haplustepts	7.5	0.2	0.45	3.4	52.7	76	0	NA	NA
28	6.1	Talegaon	Typic Haplusterts	7.7	0.2	0.39	1.0	44.0	92	NA	NA	NA
29	6.1	Sirasgaon	Typic Haplusterts	7.9	0.3	0.42	8.9	48.0	95	NA	1.42	NA
30	6.2	Annapur	Fluventic Haplustepts	7.9	0.3	0.34	4.9	31.0	72	NA	NA	NA
31	6.2	Torkewadi	Lithic Ustorthents	7.9	0.6	0.51	NA	41.2	100	NA	NA	NA
32	6.3	Jambha	Typic Haplusterts	8.6	0.2	0.46	2.0	53.0	100	0	1.75	NA
33	6.3	Loni	Typic Haplusterts	6.3	0.6[10]	0.85	5.0	61.0	103	1	1.30	3.3
34	6.4	Achmati	Sodic Haplusterts	8.6	0.2	1.23	13.7	63.2	111	8	NA	NA
35	6.4	Nimone	Typic Haplusterts	8.1	0.3	0.48	5.0	56.7	85	NA	1.60	NA
36	7.1	Rayadurg	Ustic Haplargids	8.8	NA	0.52	NA	NA	NA	NA	NA	NA
37	7.1	Kurnool	Vertic Haplustepts	9.4	0.0	0.62	17.6	50.0	NA	29	NA	NA
38	7.2	Kasireddipalli	Sodic Haplusterts	7.8	0.3[10]	0.52	6.0	50.0	95	3	1.60	0.7
39	7.2	Chitkul	Vertic Haplustepts	7.7	0.0	0.80	2.0	25.0	102	3	NA	NA
40	7.3	Peddapuram	Rhodic Paleustalfs	5.6	0.1	0.25	NA	3.6	43	4	NA	NA
41	7.3	Nuzvid	Typic Paleustalfs	6.3	NA	0.37	NA	5.8	81	0	NA	NA
42	8.1	Coimbatore	Vertic Ustropepts	8.7	NA	0.37	8.0	45.0	94	14	NA	NA

Table 4: *(Contd...)*

Table 4: (*Contd...*)

Sr. no.	AESRs	Soil series	Soil classification[1]	pH (water)	EC[2] (d Sm^{-1})	SOC[3] (%)	$CaCO_3$ (%)	CEC[4] (cmol (p+) kg^{-1})	BS[5] (%)	ESP[6]	B.D.[7] (Mgm^{-3})	H.C.[8] ($cmhr^{-1}$)
				Soil properties (0–30 cm)								
43	8.1	Kovilpatti	Gypsic Haplusterts	8.0	0.4	0.36	4.8	60.4	105	1	1.20	2.9
44	8.2	Tyamagondalu	Kandic Paleustalfs	5.3	NA	0.48	NA	5.8	83	3	1.50	NA
45	8.2	Channasandra	Fluventic Haplustepts	6.6	NA	0.68	NA	7.5	98	5	1.70	NA
46	8.3	Sivagangai	Rhodic Paleustalfs	5.9	0.0	0.42	NA	8.9	66	NA	NA	NA
47	8.3	Salur	Vertic Haplustepts	8.0	0.4	0.51	1.2	19.5	99	4	NA	NA
48	9.1	Berpura	Udic Ustochrepts	8.3	<0.2	0.27	NA	NA	NA	NA	NA	NA
49	9.1	Shahazadpur	Udic Ustochrepts	6.7	<0.2	0.22	NA	NA	NA	NA	NA	NA
50	9.2	Basiaram	Udic Ustochrepts	7.4	0.4	0.34	tr	7.0	92	10	1.22	NA
51	9.2	Sarthua	Vertic Endoaqualfs	6.7	0.3	0.38	NA	17.5	76	8	NA	NA
52	10.1	Kheri	Typic Haplusterts	7.5	0.4[10]	0.60	4.0	47.9	94	1	1.40	2.8
53	10.1	Jamra	Chromic Haplusterts	8.0	0.3	0.73	1.7	42.0	95	3	1.70	NA
54	10.2	Linga	Udic Haplusterts	7.9	0.4[10]	0.85	7.2	64.5	85	1	1.40	2.6
55	10.2	Sukali	Typic Ustochrepts	7.9	0.5	0.29	5.5	32.0	NA	NA	NA	NA
56	10.3	Sundra	Chromic Haplusterts	8.5	NA	0.65	0.6	36.0	NA	5	1.70	NA
57	10.3	Marha	Chromic Haplusterts	8.0	<0.2	0.40	NA	50.0	100	2	1.70	NA
58	10.4	Sagar	Typic Haplustepts	6.5	0.1	0.85	NA	43.0	94	1	NA	NA
59	10.4	Gondatola	Typic Rhodustalfs	5.0	0.0	1.00	0.0	15.8	56	NA	NA	NA
60	11	Bichanpur	Chromic Haplusterts	7.1	<0.2	0.74	1.5	41.8	99	1	1.70	NA
61	11	Hitekusa	Typic Haplustalfs	5.5	0.2	0.91	NA	10.0	83	2	1.62	NA
62	12.1	Gadchiroli	Typic Haplustolls	5.9	0.1	1.40	NA	12.6	85	0	1.75	NA
63	12.1	Bawanpuri	Chromic Haplusterts	5.8	0.2	0.67	NA	18.0	89	4	1.70	NA

Table 4: (*Contd...*)

Table 4: (*Contd...*)

Sr. no.	AESRs	Soil series	Soil classification[1]	pH (water)	EC[2] (d Sm^{-1})	SOC[3] (%)	$CaCO_3$ (%)	CEC[4] (cmol (p+) kg^{-1})	BS[5] (%)	ESP[6]	B.D.[7] (Mgm^{-3})	H.C.[8] ($cmhr^{-1}$)
				Soil properties (0–30 cm)								
64	12.2	Bhubneswar	Typic Halaquepts	4.8	NA	0.55	NA	6.7	37	5	1.59	NA
65	12.2	Motto	Vertic Haplustalfs	7.0	1.4	0.66	NA	17.0	100	26	1.45	NA
66	12.3	Pusaro	Typic Paleustalfs	4.9	NA	0.24	NA	8.7	62	1	1.70	NA
67	12.3	Phulkusma	Typic Haplustalfs	5.9	NA	0.36	NA	12.0	78	6	NA	NA
68	13.1	Baratol	Typic Haplustepts	5.8	0.5	0.58	2.8	23.8	70	2	NA	NA
69	13.1	Hirapatti	Fluventic Haplustepts	7.9	0.6	0.84	3.8	8.5	95	8	NA	NA
70	13.2	Bahraich	Typic Udifluvents	8.8	0.2	0.60	4.4	19.4	94	4	NA	NA
71	13.2	Kesarganj	Typic Udifluvents	9.1	0.3	0.68	6.1	8.8	85	15	NA	NA
72	14.1	Bathal	Typic Cryorthents	7.9	0.1	0.25	NA	3.3	NA	NA	NA	NA
73	14.1	Kalpa	Typic Dystrudepts	5.7	0.2	0.02	NA	14.3	NA	NA	NA	NA
74	14.2	Ropri	Typic Udorthents	7.2	0.2	1.12	NA	8.2	72	4	NA	NA
75	14.2	Dehra	Dystric Eutrudepts	6.2	0.8	0.32	NA	10.5	61	1	NA	NA
76	14.3	Mataur	Dystric Eutrochrepts	6.7	<0.2	0.43	NA	7.9	78	NA	NA	NA
77	14.3	Rajpura	Typic Paleudalfs	6.0	NA	0.53	NA	10.5	96	9	NA	NA
78	14.4	Gajeli	Typic Dystrudepts	6.5	0.2	1.35	NA	3.8	NA	6	NA	NA
79	14.4	Tayari	Typic Udorthents	6.5	0.1	1.45	NA	5.5	79	13	NA	NA
80	14.5	Haldi	Typic Hapludolls	7.1	NA	0.69	NA	7.6	87	6	1.49	NA
81	14.5	Nainital	Typic Endoaquolls	7.6	NA	3.00	NA	25.6	100	1	1.44	NA
82	15.1	Amarpur	Typic Ustochrepts	7.1	NA	0.40	NA	10.8	74	NA	NA	NA
83	15.1	Anantpur	Typic Endoaqualfs	5.9	0.3	0.33	NA	16.1	68	7	NA	NA
84	15.2	Morigaon	Typic Fluvaquents	5.9	NA	0.69	NA	3.6	92	5	NA	NA

Table 4: (*Contd...*)

Table 4: *(Contd...)*

Sr. no.	*AESRs*	*Soil series*	*Soil classification*[1]	*Soil properties (0–30 cm)*								
				pH (water)	*EC*[2] *(d Sm^{-1})*	*SOC*[3] *(%)*	*$CaCO_3$ (%)*	*CEC*[4] *(cmol (p+) kg^{-1})*	*BS*[5] *(%)*	*ESP*[6]	*B.D.*[7] *(Mgm^{-3})*	*H.C.*[8] *($cmhr^{-1}$)*
85	15.2	Barbhagia	Typic Epiaquents	6.3	NA	0.90	NA	13.7	96	6	NA	NA
86	15.3	Bongaigaon	Typic Endoaquepts	6.1	NA	1.01	NA	5.7	47	5	NA	NA
87	15.3	Jogighopa	Typic Psammaquents	5.9	NA	0.75	NA	5.9	53	5	NA	NA
88	15.4	Sonari	Oxyaquic Dystrudepts	4.9	NA	0.54	NA	9.2	36	4	NA	NA
89	15.4	Amguri	Dystric Eutrudepts	5.6	NA	1.30	NA	9.5	61	5	NA	NA
90	16.1	Darrang	Typic Endoaquepts	5.6	NA	1.00	NA	8.2	55	3	NA	NA
91	16.1	Dhansiri	Typic Psammaquents	6.5	NA	0.32	NA	3.5	54	6	NA	NA
92	16.2	Rayong	Fluventic Haplustepts	4.3	NA	3.60	NA	16.0	45	1	NA	NA
93	16.2	Maniram	Typic Hapludolls	5.4	NA	2.77	NA	11.6	63	0	NA	NA
94	16.3	Longsom	Typic Dystrudepts	5.5	NA	1.47	NA	11.3	61	2	NA	NA
95	16.3	Wakka	Lithic Udorthents	5.4	NA	3.22	NA	10.8	19	2	NA	NA
96	17.1	Mawlyndair	Humic Dystrochrepts	4.6	NA	3.70	NA	6.1	20	3	NA	NA
97	17.1	Lailad	Typic Kanhaplohumults	5.8	NA	1.65	NA	9.8	43	2	NA	NA
98	17.2	Longol–5	Typic Dystrudepts	4.7	NA	1.99	NA	31.8	19	1	NA	NA
99	17.2	Longol–6	Typic Kandiudults	4.4	NA	1.66	NA	15.1	16	2	NA	NA
100	18.2	Kalathur	Sodic Haplusterts	9.4	0.4	0.57	8.3	41.6	103	18	NA	NA
101	18.2	Thirunallar	Typic Haplusterts	7.6	0.2	0.85	2.4	33.3	NA	6	NA	NA
102	18.3	Kovvur	Aquic Haplustepts	7.9	NA	0.57	NA	11.9	86	5	NA	NA
103	18.3	Kaveli	Typic Ustipsamments	6.9	NA	0.13	0.6	1.4	109	15	NA	NA
104	18.4	Srikakulam	Typic Haplustalfs	6.1	0.1[10]	0.64	NA	7.9	60	3	NA	NA
105	18.4	Suryapet	Fluventic Haplustepts	7.9	0[10]	0.50	NA	17.2	90	4	NA	NA
106	18.5	Rantrapur	Typic Haplustalfs	6.6	0.6	0.14	NA	6.1	74	2	NA	NA
107	18.5	Sagar	Vertic Endoaquepts	6.4	4.2[10]	0.96	2.2	19.9	81	16	1.14	0.4
108	19.1	Pati	Lithic Ustorthents	6.3	<0.2	1.61	NA	41.2	76	1	NA	NA
109	19.1	Tinoda	Typic Haplustepts	5.6	<0.2	2.06	NA	42.2	78	1	1.60	NA
110	19.2	Chimpukkad	Ultic Haplustalfs	4.4	0.2	0.39	NA	5.4	38	0	NA	NA
111	19.2	Karinganthode	Ultic Paleustalfs	5.2	0.0	0.90	NA	10.1	49	0	NA	NA
112	19.3	Palghar	Vertic Halaquepts	7.2	5.9	0.73	3.4	46.9	93	41	NA	NA
113	19.3	Virthan	Entic Haplusterts	8.0	0.4	1.38	3.8	38.3	87	1	1.27	NA
114	20.1	Basanthipur	Typic Tropudalfs	5.0	NA	1.68	NA	22.7	63	1	NA	NA
115	20.1	Govindpur	Typic Tropudalfs	5.1	NA	1.81	NA	21.1	87	2	NA	NA
116	20.2	Kavaratti	Typic Ustipsamments	8.4	NA	0.91	86.3[11]	3.0	100	14	NA	NA
117	20.2	Andrott	Typic Troporthents	8.3	NA	1.02	78[11]	2.4	100	5	NA	NA

Table 4: (*Contd...*)

[1]Soil Taxonomy (Soil Survey Staff 2006); [2]EC: Electrical conductivity; [3]SOC: Soil organic carbon; [4]CEC: Cation exchange capacity; [5]BS: Base saturation; [6]ESP: Exchangeable sodium percent; [7]B.D. Bulk density; [8]HC: Saturated hydraulic conductivity; [9]NA: not available; [10]Value for ECe (Electrical conductivity of saturation extract; [11]$CaCO_3$ is contributed by shells which are marine in nature. (Source: Bhattacharyya *et al.*, 2011)

of physiographic regions, are impoverished in OC despite their ability to interact with organic matter in binding OC in terms of clay-organic complex. Sequestration of OC in soils of these climates is not possible due to high temperature and less rainfall, impairing the possibility of vegetative cover over the land.

In the present scenario of differing climatic parameters such as the increase in temperature and reduction in annual rainfall in some areas of the country, sequestration of OC will continue to remain as a potential threat for tropical soils of Indian subcontinent (Jenny and Raychaudhari, 1960; Sombroek *et al.*, 1993). Therefore, the arid climate will continue to remain as a bane for Indian agriculture as this will cause soil degradation in terms of depletion of OC, formation of pedogenic $CaCO_3$ with the concomitant development of sodicity (Velayutham *et al.*, 2000; Eswaran and Van der Berg, 1992; Balpande *et al.*, 1996). To combat such situation, the restoration of OC balance and efforts to enlarge the soil carbon pool by appropriate management techniques and encouragement of agro-forestry should form the strategic perspective to sustain the soil health of Indian soils (Bhattacharyya *et al.*, 2004). The most unfavourable natural endowment is the climatic adversity and this will ever demand for extra resources to support targeted yield in the Indian agriculture and thus may retard the pace of rehabilitation programme required to restore the soil productivity. Despite this fact research attention for soils of arid climates sponsored through national agenda needs to be an immediate concern. In the absence of such programme, deforestation will continue to increase in area under agriculture and obviously this may affect the natural resources.

REFERENCES

Balpande, S.S., Deshpande, S.B. and Pal, D.K. (1996). Factors and processes of soil degradation in Vertisols of the Purna Valley, Maharashtra, India. *Land Degradation and Development*, **7:** 313–324.

Bhattacharyya, T., Pal, D.K., Chandran, P., Mandal, C., Ray, S.K., Gupta, R.K. and Gajbhiye, K.S. (2004). Managing Soil carbon stocks in the Indo-Gangetic Plains, India, Rice–Wheat Consortium for the Indo-Gangetic Plains, New Delhi-110012, India. p. 44.

Bhattacharyya, T., Pal, D.K. and Deshpande, S.B. (1993). Genesis and transformation of minerals in the formation of red (Alfisols) and black (Inceptisols and Vertisols) soils on Deccan basalt. *Journal.* of *Soil Science.*, **44:** 159–171.

Bhattacharyya, T., Pal, D.K. and Srivastava, P. (1999). Role of zeolites in persistence of high altitude ferriginous Alfisols of the Western Ghats, India. *Geoderma*, **90:** 263–76.

Bhattacharyya, T., Pal, D.K., Lal, S., Chandran, P. and Ray, S.K. (2006). Formation and persistence of Mollisols on Zeolitic Deccan basalt of humid tropical India. *Geoderma*, **136:** 609–620.

Bhattacharyya, T, Pal, D.K., Chandran, P., Ray, S.K., Mandal, C. and Telpande, B. (2008). Soil carbon storage capacity as a tool to prioritise areas for carbon sequestration. *Current Science*, **95:** 482–494.

Bhattacharyya, T., Ray, S.K., Sarkar, Dipak., Balbuddhe, D.V., Dasgupta, D., Chandran, P., Tiwari, P., Mandal, C., Nimje, A.M., Deshmukh, R.R., Telpande, B.A., Lokhande, M.A., Wadhai, K.N., Dongre, V.T., Thakre, S.W., Likhar, C.K., Sheikh, S.M., Aggrawal, P.K., Pathak, H., Venkateshswarlu, B., Rao, V.U.M., Soora, Naresh Kumar and Singh, A.K. (2011). Soil resource information of different agro-eco subregions of India for crop and soil modelling. National Project on Climate change (ICAR Network Project), National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra, India. p. 302.

Bhattacharyya, T. (2011a). Carbon capture and storage: Role of soil as substrate. Indian Society of Soil Science Newsletter, No. 31 (www.isss.india.org). pp. 1–2.

Dalal, R.C. and Canter, J.U. (2000). Soil organic matter dynamics and carbon sequestration in Australian tropical soils. pp. 283–314, (Lal, R., Kimble, J.M. and Stewart, B.A. *Eds.*). Boca Ratan.

Eswaran, H. and Van den, Berg. (1992). Impact of building of atmospheric CO_2 on length of growing season in the Indian sub-continent. *Pedologie*, **42:** 289–296.

IIASA. (2002). Climate change and agricultural vulnerability. Special report for the UN World Summit on Sustainable Development, Johannesburg (http://www.iiasa.ac.at/Research/LUC/JB–Report.pdf).

Jenny, H. and Raychaudhari, S.P. (1960). *Effect of climate and cultivation on nitrogen and organic matter reserves in Indian soils*, ICAR, New Delhi, India. p. 126.

Karl, F.L. and Mittal, J.P. (*Eds.*). (1998). National Agricultural Technology Project. Main document, Indian Council of Agricultural Research, New Delhi, India.

Pal, D.K., Dasog, G.S., Vadivelu, S., Ahuja, R.L. and Bhattacharyya, T. (2000). Secondary calcium carbonate in soils of arid and semi-arid regions of India. pp. 149–85, *In: Global climate change and pedogenic carbonates* (Lal, R., Kimble, J.M., Eswaran, H. and Stewart, B.A. *Eds.*). Boca Raton, Florida: Lewis Publishers.

Pal, D.K., Bhattacharyya, T., Ray, S.K., Chandran, P., Srivastava, P., Durge, S.L., and Bhuse, S.R. (2006). Significance of soil modifiers (Ca–zeolites and gypsum) in naturally degraded Vertisols of the Peninsular India in redefining the sodic soils. *Geoderma*, **136:** 210–228.

Pal, D.K., Bhattacharyya, T., and Wani, S.P. (2011). Formation and management of cracking clay soils (Vertisols) to enhance crop productivity: Indian Experience. pp. 317–343, *In: World soil resources and food security* (Lal, R., Francis Sewart, B.A. and Taylor, *Eds.*).

Sehgal, J.L. and Sharma, J.P. (1994). Soil and climatic resource characterization of dryland eco-system in India for sustainable agriculture, Bulletin No. 6. pp. 12–25, *In: Soil management for sustainable agriculture in dryland areas*, Indian Society of Soil Science, New Delhi.

Singh, R.P. and Subba Reddy, G. (1988). *In: Drought research priorities for the dryland tropics* (Bidinger, F.R. and Johansen, C. *Eds.*) ICRISAT, Patancherua, Andhra Pradesh, 502324, India.

Soil Survey Staff. (2006). *Keys to soil taxonomy*. 10th Ed. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Services.

Sombroek, W.G., Nachtergache, F.O. and Hable, A. (1993). Amounts, dynamics and sequestrations of carbon in tropical and subtropical soils. *Ambio*, **22:** 417–427.

Thirtle, C., Beyers, L. and Lin, L. *et al.* (2002). The impact of changes in agricultural producitivity on the incidence of poverty in developing countries. DFID Report No. 7946. London: Department of International Development (DFID).

Velayutham, M., Mandal, D.K., Mandal, C. and Sehgal, J. (1999). *Agro-ecological subregions of India for Development and Planning*, NBSS and LUP, Nagpur Publication pp. 35–452.

Velayutham, M., Pal, D.K. and Bhattacharyya, T. (2000). Organic carbon stock in soils of India. pp. 71–96, *In: Global climate change and tropical ecosystems* (Lal, R., Kimble, J.M. and Stewart, B.A. *Eds.*). Lewis Publishers, Boca Raton, Florida, USA.

Virmani, S.M., Pathak, P. and Singh, R. (1991). Soil-related contraints in dry land crop production in Ultisols, Alfisols and Entisols of India, Bulletin on Soil-Related constraints in crop production. *Journal of the Indian Society of Soil Science*, **15:** 80–95.

Welter, T. (2010). Challenges and opportunities for agricultural R and D in the semi-arid tropics. Internal document for strategic planning, Patancheru, Andhra Pradesh, India: ICRISAT.

Wani, S.P., Balloli, S.S. and Kesava Rao, A.V.R. *et al.* (2004). Combating drought through integrated watershed management for sustainable dryland agriculture. pp. 39–48, *In: Regional Workshop on Agricultural Drought Monitoring and Assessment using Space Technology*, 4 May 2004, Hyderabad, India: National Remote Sensing Agency (NRSA).

Wani, S.P., Rockstrom, Johan, Venkateswarlu, B. and Singh, A.K. (2011). New Paradigm to unlock the potential of rain-fed agriculture in the semi-arid tropics. *In: World soil resources and food security* (Lal, R. and Stewart, B.A. *Eds.*). CRC Press, Boca Raton. pp. 419–70.

Wani, S.P., Sreedevi, T.K. and Rockstrom, J. (2009). Rain-fed agriculture–past trend and future prospects. pp. 1–35, *In: Rain-fed agriculture: Unlocking the potential* (Wani, S.P., Rockstrom, J. and Oweis, T. Eds.). Comprehensive Assessment of Water Management in Agriculture Series. Wallingford, UK: CAB International.

World Health Organization (WHO) (2000). Gender, Health and Poverty. Factsheet no. 25, http://www.who.int.int/mediacenter/factsheets/fs251/enl.

2

Soils of North-Eastern Region and their Management for Rain-fed Crops

M. Datta[1]

ABSTRACT

Agriculture which is of CDR system (Complex, Diverse and Risk Prone), becomes the mainstay of livelihood among the farming community of NE (North East) region. The agricultural practices in the region are broadly of two distinct types viz., settled farming practised in the plains, valley / foot hills and terraced slopes and shifting cultivation in the hill slopes. The agriculture in the north east India is basically subsistence oriented. This is partly due to lack of soil moisture and sufficient irrigation facilities. The total cultivable land in NE India is 28.41 per cent of the total geographical area (TGA) and out of which only 18.75% is net sown area. The cropping pattern in the region with the exception of Sikkim is characterized by predominance of rice as the lead crop. In Sikkim, the dominant crop is maize. Many indigenous farming systems are existing in North Eastern Hill region and performing well from the point of view of resource conservation and maintenance of ecological balance. The soils of the North Eastern Region have developed in situ on different types of rocks of geological ages starting from Paleozoic to recent formation. According to old soil classification, there are 5 types of soils viz. red loamy, alluvial, mountain, laterite, red and yellow and terai. now USDA classification indicated that the soils of the region belong to we 5 orders, 22 great groups and 45 sub groups. The agroclimatic zones in NE India vary from Alpine to mild tropical with an average annual rainfall of more than 2000 mm. But 80% of the rainfall comes between late June and late September. In some years, rainfall varies within the region, some areas of it receiving surplus and some other areas receiving deficient rainfall. Thus, it is realized that presence of irrigational facilities are necessary even in the growing period of the kharif crops. The management options to address the

[1] ICAR Research Complex for NEH Region, Lembucherra, Tripura, 7990210, India. *Corresponding author* E-mail: mdatta2@rediffmail.com/mdatta54@gmail.com