

Status of Farm Mechanization in India, 01 Jan 2000

Agro-Ecological Zones, their Soil Resource and Cropping Systems

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ABSTRACT

India is gifted with heterogeneous landforms and variety of climatic conditions such as the lofty mountains, the raverine deltas, high altitude forests, peninsular plateaus, variety of geological formations endowed with temperature varying from arctic cold to equatorial hot, and rainfall from extreme aridity with a few cms (<10 cm) to perhumid with world's maximum rainfall (1120 cm) of several hundred cms. This provides macro relief of high plateau, open valleys, rolling upland, plains, swampy low lands and barren deserts. This varying environmental situations in the country have resulted in a greater variety of soils. Therefore, the systematic appraisal of agro-ecological regions has tremendous scope in grouping relatively homogenous regions in terms of soil, climate and physiography and conducive moisture availability periods (length of growing season) in planning appropriate land use.

Depending upon the soil, bioclimatic type and physiographic situations, the country has been grouped into 20 agro-eco regions (AER) and 60 agro-eco subregions (AESR). Each agro-eco subregion has further been classified into agro-eco unit at district level for developing long term land use strategies. The constraints and potentials with appropriate ameliorative measures have been described and suggested for each region for better understanding and adoption for formulating the plans to suggest crop/cropping system which will help in minimizing the deterioration of land quality controlled by soil physical conditions, nutrient availability and organic carbon pool.

1. INTRODUCTION

The soil, water, climate, flora and fauna constitute the basic natural resources and the national treasure of any country. The soil is the most important among them. It is the basic source to produce food, fodder, fuel and fiber - the necessities of the human being. The agriculture and the other allied activities and in turn the prosperity and economic growth of a country depend on the soil resource. It is, therefore, important to understand the inherent potential and limitations of soil for managing it for sustained production.

India is gifted with heterogeneous landforms and variety of climatic conditions such as the lofty mountains, the raverine deltas, high altitude forests, peninsular plateaus, variety of geological formations endowed with temperature varying from arctic cold to equatorial hot, and rainfall from extreme aridity with a

few cms (<10 cm) to perhumid with world's maximum rainfall (1120 cm) of several hundred cms. This provides macro relief of high plateau, open valleys, rolling upland, fertile plains, swampy low lands and barren deserts. These varying environmental situations in the country have resulted in a greater variety of soils compared to any other part of the world. Therefore, the systematic appraisal of agro-ecological regions encompassing relatively homogenous regions in terms of soil, climate and physiography and conducive moisture availability periods i.e. length of growing period (LGP) will help in planning of appropriate land use.

Concept

Agro-climatic zone is a land unit in terms of major climate, superimposed on length of growing period (moisture availability period) (FAO, 1983) whereas an agro-ecological zone is the land unit carved out of agro-

climatic zone superimposed on landform which acts as modifier to climate and length of growing period.

Need

- To assess yield potentialities of different crops, crop combination in agroecological regions/zones.
- To formulate future plan of action involving crop diversification.
- To disseminate agricultural research and agro-technology to other homogenous areas.
- To determine the crop suitability for optimization of land use in different agro-ecological regions/zones.

Methodology

The methodology used in delineation of agro-ecological region is shown in Fig. 1. Four basic maps i.e. soil, physiography, length of growing period (LGP) and bioclimate are required to delineate agro-ecological regions (AER) (Sehgal et al. 1992) (Fig.2 and legend Table 2) agro-ecological subregion (AESR) and agro-ecological zone at state and agro-ecological unit at watershed level. The criteria used at different levels of Agroecological zoning exercise is shown in Table 1.

The nomenclature used in describing AER may be denoted from, the ‘Key to map symbol’ see Fig 2. For the sake of clarity, it is described for a case, “**A13Eh1**”

- A** = Physiographical region (Western Himalayas);
- 13** = Soil scape (shallow skeletal soil)

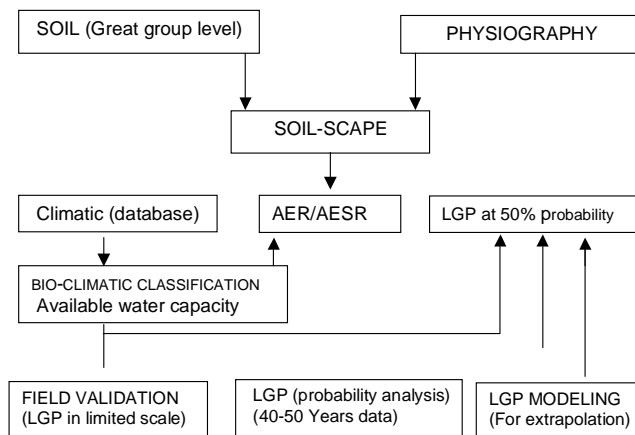


Fig. 1. Schematic diagram showing methodology used for Agro-Ecological Regions

AER/AESR = Agro Ecological Region/ Agro-Ecological Subregions
LGP = Length of Growing Period

Eh = Hyper (Arid) bioclimatic zone; **1** = Length of Growing Period (<60 days)

Thus the whole unit is read as Western Himalayas, shallow skeletal soils, hyper arid climate with LGP<60 days.

Each agro-ecoregion has been grouped into Agro-eco subregions (AESR) and described in subsequent pages incorporating details about the climate, soils, area,

Table 1. Criteria used for agro-ecological delineation (Mandal et al. 1999)

Sr. No.	Level	Criteria used			
		Soil	Physiography	Bioclimate	LGP*
1.	Agro-ecological Regions of India (AER) (20 AER) (For resource planning at national level)	Great group association (1:7 m scale)	Broad 15 divisions	Arid, Semiarid, Subhumid, Humid, Per humid (After Thornthwaite and Mather, 1955 and Penman PE)	<90 days; 90-150; 150-210; >210
2.	Agro-ecological sub-regions of India (60 AESR) (for resource planning at regional level).	Sub group association (1:1 m scale)	Sub division of major physiography	Arid/typic arid/hyper arid semiarid/ semi arid dry/semi arid moist sub humid/dry/moist humid, perhumid	<60 (with 30 days interval) to >330 days
3.	Agro-ecological zones at state level (for resource planning at state level)	Soil family association (1:250,000 scale)	Landform	Bioclimate computation based on subdivision level rainfall data	LGP isolines with 15 days interval
4.	Agro-ecological unit at district level (for resource planning at district level)	Soil series association (1:50,000 scale)	Geomorphic Unit	Bioclimate computation based on rainfall at block level	LGP isolines with 7 days or 10 days interval
5.	Agro-ecological unit at watershed level	Soil phase (1:5,000 scale)	Details of geomorphic units	Effective rainfall at unit level	LGP based on AWC (soil unit)*

*LGP= Length of Growing Period; AWC= Available Water Capacity

*<90 days : Feasible for single short duration crop

90-150 days : Suitable for one medium duration crop or single short duration crop plus relay crop

>210 days : Feasible for double cropping

Table 2. Descriptive Legend of AER and AESR

- 1. Western Himalayas, cold arid eco-region (A13E1)**
 - 1.1 Eastern aspect of Ladakh Plateau, cold, hyper-arid eco-subregion (ESR) with shallow skeletal soils, very low AWC and LGP <60 days (A13Eh1).
 - 1.2 Western Aspect of Ladakh Plateau and north Kashmir Himalayas, cold to cool, typic-arid ESR with shallow, loamy-skeletal soils, low AWC and LGP 60-90 days (A13Et2)
- 2. Western Plain, Kachchh and part of Kathiawar Peninsula, hot arid eco-region (M9E1)**
 - 2.1 Marusthali hot, hyper arid ESR with shallow and deep sandy desert soils very low AWC and LGP < 60 days (M9Eh1).
 - 2.2 Kachchh Peninsula (Great Rann of Kutch as inclusion), hot hyper-arid ESR with deep loamy saline and alkali soils, low AWC and LGP <60 days (L12Eh1)
 - 2.3 Rajasthan Bagar, North Gujarat Plain and South-Western Punjab Plain, hot typic- arid ESR with deep, loamy desert soils (inclusion of saline phase), low AWC and LGP 60-90 days (M9Et2).
 - 2.4 South Kachchh and North Kathiawar Peninsula, hot arid ESR with deep loamy saline and alkali soils, low AWC and LGP 60-90 days (L12Et2).
- 3. Deccan plateau, hot arid ecosubregion (K6E2)**
 - 3.0 Karnataka Plateau (Rayalseema as inclusion), hot arid ESR with deep loamy and clayey mixed Red and Black soils, low to medium AWC and LGP 60-90 days (K6Et2).
- 4. Northern Plain (and Central Highlands) including Aravallis, hot semi-arid ecoregion (N8D2)**
 - 4.1 North Punjab Plain, Ganga-Yamuna Doab and Rajasthan Upland, hot semi-arid ESR with deep loamy alluvium-derived soils (occasional saline and sodic phases), medium AWC and LGP 90-120 days (N8Dd3).
 - 4.2 North Gujarat Plain (inclusion of Aravalli range and east Rajasthan Uplands), hot dry semiarid ESR with deep loamy Gray Brown and alluvium-derived soils, medium AWC and LGP 90-120 days (P14Dd3).
 - 4.3 Ganga Yamuna Doab, Rohilkhand and Avadh Plain, hot moist semi-arid ESR with deep, loamy alluvium-derived soils (sodic phase inclusion), medium to high AWC and LGP 120-150 days (N8Dm4).
 - 4.4 Madhya Bharat Plateau and Bundelkhand Uplands, hot, moist semi-arid ESR with Deep loamy and clayey mixed Red and Black soils, medium to high AWC and LGP 90-120 days (N6Dm4).
- 5. Central (Malwa) Highlands, Gujarat plains and Kathiawar Peninsula Ecoregion (I5 D2)**
 - 5.1 Central Kathiawar Peninsula, hot, dry semiarid ESR with shallow and medium loamy to clayey black soils (deep black soils as inclusion) medium AWC and LGP 120-150 days (L4Dd3)
 - 5.2 Madhya Bharat Plateau, Western Malwa Plateau, Eastern Gujarat Plain, Vindhyan and Satpura range and Narmada Valley, hot moist semi-arid ESR with medium and deep, clayey Black soils (shallow black soils as inclusions), medium to high AWC and LGP 120-150 days (I5Dm4).
 - 5.3 Coastal Kathiawar Peninsula, hot moist semi-arid ESR with deep loamy coastal alluvium-derived soils (saline/phases inclusion), low to medium AWC and LGP 120-150 days (L7Dm4)
- 6. Deccan Plateau, hot semi-arid eco-region (K4D2)**
 - 6.1 South Western Maharashtra and North Karnataka Plateau, hot dry semi-arid ESR with shallow and medium loamy Black soils (deep clayey Black soils as inclusion), medium to high AWC and LGP 90-120 days (K4Dd3).
 - 6.2 Central and Western Maharashtra Plateau and North Karnataka Plateau and North Western Telangana Plateau, hot moist semi-arid ESR with shallow and medium loamy to clayey Black soils (medium land deep clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K4Dm4)
 - 6.3 Eastern Maharashtra Plateau, hot moist semi-arid ESR with medium land deep clayey Black soils (shallow loamy to clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K5Dm4).
 - 6.4 North Sahyadris and Western Karnataka Plateau, hot dry subhumid ESR (K4Cd5).
- 7. Deccan Plateau (Telangana) and Eastern Ghats, hot semi-arid ecoregion (K6D2)**
 - 7.1 South Telangana Plateau (Rayalseema) and Eastern Ghat, hot dry semi-arid ESR with deep loamy to clayey mixed Red and Black soils, medium AWC and LGP 90-120 days (K6Dd3).
 - 7.2 North Telangana Plateau, hot moist semi-arid ESR with deep loamy and clayey mixed Red and Black soils, medium to very high AWC and LGP 120-150 days (K6Dm4).
 - 7.3 Eastern Ghat (South), hot moist semi-arid/dry subhumid ESR with medium to deep, loamy to clayey mixed Red and Black soils, medium AWC and LGP 150-180 days (H6Dm/Cd5).
- 8. Eastern Ghats and Tamil Nadu Uplands and Deccan (Karnataka) Plateau, hot semiarid eco-region (H1D2)**
 - 8.1 Tamil Nadu Uplands and Leeward Flanks of South Sahyadris, hot dry semi-arid ESR with moderately deep to deep, loamy to clayey, mixed Red and Black soils, medium AWC and LGP 90-120 days (H6Dd3).
 - 8.2 Central Karnataka Plateau, hot moist semi-arid ESR with medium to deep Red loamy soils, low AWC and LGP 120-150 days (K1Dm4).
 - 8.3 Tamil Nadu Uplands and Plains, hot moist semi-arid ESR with deep red loamy soils, low AWC and LGP 120-150 days (H1Dm4).
- 9. Northern Plain, hot subhumid (dry) eco-region (N8C3)**
 - 9.1 Punjab and Rohilkhand Plains, hot dry/moist subhumid transitional ESR with deep, loamy to clayey alluvium-derived (inclusion of saline and sodic phases) soils, medium AWC and LGP 120-150 days (N8Cm/Cd4).
 - 9.2 Rohilkhand, Avadh and south Bihar Plains, hot dry subhumid ESR with deep loamy alluvium-derived soils, medium to high AWC and LGP 150-180 days (N8Cd5).
- 10. Central Highlands (Malwa and Bundelkhand), hot subhumid (dry) eco-region (I6C3(4))**
 - 10.1 Malwa Plateau, Vindhyan Scarpland and Narmada Valley, hot dry subhumid ESR with medium and deep clayey Black soils (shallow loamy Black soils as inclusion), high AWC and LGP 150-180 days (15Cd5).
 - 10.2 Satpura and Eastern Maharashtra Plateau, hot dry subhumid ESR with shallow and medium loamy to clayey Black soils (deep clayey Black soils as inclusion), medium to high AWC and LGP 150-180 days (K4Cd5).
 - 10.3 Vindhyan Scarpland and Bundelkhand Plateau, hot dry subhumid ESR with deep loamy to clayey mixed Red and Black soils, medium to high AWC and LGP 150-180 days (I6Cd5)
 - 10.4 Satpura range and Wainganga Valley, hot moist subhumid ESR with shallow to deep loamy to clayey mixed Red and Black soils, low to medium AWC and LGP 180-210 days (K6Cm6).

(Table 2 contd . . .)

(Table 2 concluded)

- 11. Chattisgarh/Mahanadi Basin Agro-eco-region (J3 C3)**
 11.0 Moderately to gently sloping Chattisgarh/Mahanadi Basin, hot moist/dry subhumid transitional ESR with deep loamy to clayey Red and Yellow soils, medium AWC and LGP 150-180 days (J3Cd/Cm5).
- 12. Eastern Plateau (Chhotanagpur) and Eastern Ghats, hot subhumid eco-region (J23C3(4))**
 12.1 Garjat Hills, Dandakaranya and Eastern Ghats, hot moist subhumid ESR with deep loamy Red and Lateritic soils, low to medium AWC and LGP 180-210 days (J2Cm6)
 12.2 Eastern Ghats, hot moist subhumid ESR with medium to deep loamy Red and Lateritic soils, medium AWC and LGP 180-210 days (H2Cm6).
 12.3 Chhotanagpur Plateau and Garjat Hills, hot, dry subhumid ESR with moderately deep to deep loamy to clayey Red and Lateritic soils, medium AWC and LGP of 150-180 days (J2Cd5)
- 13. Eastern Plain, hot subhumid (moist) ecoregion (O8C4)**
 13.1 North Bihar and Avadh Plains, hot dry to moist subhumid transitional ESR with deep, loamy alluvium-derived soils, low to medium AWC and LGP 180-210 days (O8Cd/Cm6).
 13.2 Foothills of Central Himalayas, warm to hot moist subhumid ESR with deep loamy to clayey Tarai soils, high AWC and LGP 180-210 days (B10Cm6).
- 14. Western Himalayas, warm subhumid (to humid with inclusion of perhumid) ecoregion [A15C(BA)4(5)]**
 14.1 South Kashmir and Punjab Himalayas, cold and warm by dry semi-arid/dry subhumid ESR with shallow to medium deep loamy Brown Forest and Podzolic soils, low to medium AWC and LGP 90-120 days (A15Dd/Cd3).
 14.2 South Kashmir and Kumaun Himalayas, warm moist to dry subhumid transitional ESR with medium to deep loamy to clayey Brown Forest and Podzolic soils, medium AWC and LGP 150-210 days (A15Cd/Cm6).
 14.3 Punjab Himalayas, warm humid to perhumid transitional ESR with shallow to medium deep loamy brown forest and podzolic soils, low to medium AWC and LGP 270-300+ days (A15BA9)
 14.4 Kumaun Himalayas, warm humid to perhumid transitional ESR with shallow to medium deep loamy Red and Yellow soils, low AWC and LGP 270-300+ days (A3B/A9).
 14.5 Foothills of Kumaun Himalayas (Subdued), warm moist subhumid ESR with medium to deep, loamy arai soils, medium AWC and LGP 270-300 days (A10A9).
- 15. Assam and Bengal Plain, hot subhumid to humid (inclusion of perhumid) eco-region (Q8C(BA)5).**
 15.1 Bengal basin and North Bihar Plain, hot moist subhumid ESR with deep loamy to clayey alluvium-derived soils, medium to high AWC and LGP 210-240 days (O8Cm7).
 15.2 Middle Brahmaputra Plain, hot humid ESR with deep, loamy to clayey alluvium-derived soils, medium AWC and LGP 240-270 days (Q8B8).
 15.3 Teesta, lower Brahmaputra Plain and Barak Valley, hot moist humid to perhumid ESR with deep, loamy to clayey alluvium-derived soils, medium AWC and LGP 270-300 days (Q8A9).
 15.4 Upper Brahmaputra Plain, warm to hot perhumid ESR with moderately deep to deep loamy, alluvium-derived soils, medium AWC and LGP 300 days (Q8A10).
- 16. Eastern Himalayas, warm perhumid eco-region (C11A5)**
 16.1 Foot-hills of Eastern Himalayas (Bhutan foot-hills), warm to hot perhumid ESR with shallow to medium, loamy-skeletal to loamy Tarai soils, low to medium AWC and LGP 270-300 days (C10A9).
- 16.2 Darjeeling and Sikkim Himalayas, warm perhumid ESR with shallow to medium deep loamy Brown and Red Hill soils, low to medium AWC and LGP 300 days (C11A10).**
- 16.3 Arunachal Pradesh (Subdued Eastern Himalayas), warm to hot perhumid ESR with deep, loamy to clayey Red Loamy soils, low to medium AWC and LGP 300 days (C1A10).**
- 17. North-eastern Hills (Purvachal), warm perhumid eco-region (D2A5).**
 17.1 Meghalaya Plateau land Nagaland Hill, warm to hot moist humid to perhumid ESR with medium to deep loamy to clayey Red and Lateritic soils, medium AWC and LGP 270-300+ days (D2A9).
 17.2 Purvachal (Eastern Range), warm to hot perhumid ESR with medium to deep loamy Red and Yellow soils, low to medium AWC and LGP 300 days (D3A10).
- 18. Eastern Coastal Plain, hot subhumid to semiarid ecoregion (S7Cd2-5)**
 18.1 South Tamil Nadu Plains (Coastal), hot dry semi-arid ESR with deep, loamy to clayey, alkaline Coastal and deltaic alluvium-derived soils, medium AWC and LGP 90-120 days (S7Dd3).
 18.2 North Tamil Nadu Plains (Coastal), hot moist semi-arid ESR with deep, clayey and cracking Coastal land Deltaic alluvium-derived soils, high AWC and LGP 120-150 days (S7Dm4).
 18.3 Andhra Plain, hot dry subhumid ESR with deep, clayey Coastal and Deltaic alluvium-derived soils, low to medium AWC and LGP 150-180 days (S7Cd5).
 18.4 Utkal Plain and East Godavari Delta, hot dry subhumid ESR with deep, loamy to clayey Coastal and deltaic alluvium-derived soils, medium AWC and LGP 180-210 days (S7Cd6).
 18.5 Gangetic Delta, hot moist subhumid to humid ESR with deep, loamy to clayey Coastal and deltaic alluvium-derived soils, medium AWC and LGP 240-270 days (S7Cm7).
- 19. Western Ghats and Coastal Plain, hot humid-perhumid eco-region (E2BA5)**
 19.1 North Sahyadris and Konkan Coast, hot humid ESR with medium to deep loamy to clayey mixed Red and Black soils, medium to high AWC and LGP 210-240 days (E6B8).
 19.2 Central and South Sahyadris, hot moist subhumid to humid transitional ESR with deep, loamy to clayey Red and Lateritic soils, low to medium AWC and LGP 210-270 days (E2Cm/B7(9)).
 19.3 Konkan, Karnataka and Kerala Coastal plain, hot humid to per humid transitional ESR with deep, clayey to loamy acidic coastal alluvium-derived soils, low AWC and LGP 240-270 days (R7A(B8(7))).
- 20. Islands of Andaman-Nicobar and Lakshadweep, hot humid to perhumid island ecoregion (T1A(B)5/T1B(A)5)**
 20.1 Andaman and Nicobar group of Islands, hot perhumid ESR with shallow to medium deep, loamy to clayey Red and Yellow and Red Loamy soils, low to medium AWC and LGP 300 days (T3A10).
 20.2 Level Lakshadweep and group of Island, hot humid ESR with shallow to medium deep loamy to sandy Black, sandy and Littoral soils, low to medium AWC and LGP 240-270 days (U16B8).

and districts, land use and constraints.

Agro-eco subregions superimposing with randomly selected districts meant for developing mechanization

strategy for long term basis are depicted in Fig 3 and Table 3.

The characteristics of different agro-subregions with

Table 3. Randomly selected (120) districts meant for Long Term Mechanisation Strategy with agro-eco region/subregion

No. of Districts	Location of FIM Centre (SAU/ICAR Institute)	State	District	Agro-eco subregion (Fig 3)*	Agro-climatic zone (Fig 4)**
1	2	3	4	5	6
4	A.A.I., Allahabad	Uttar Pradesh	Varanasi	4.3	4
		Uttar Pradesh	Lalitpur	4.4	4
		Uttar Pradesh	Kanpur Dehat	4.3	4
5	A.A.U., Jorhat	Uttar Pradesh	Mirzapur	11.0	4
		Assam	Jorhat	15.4	2
		Assam	Dibrugarh	15.4	2
		Assam	Dhemaji	15.4	2
6	M.P.U.A.T., Udaipur	Assam	Sibsagar	15.4	2
		Assam	Golaghat	15.4	2
		Rajasthan	Udaipur	4.2	8
		Rajasthan	Jalore	2.3	14
		Rajasthan	Chittorgarh	5.2	8
6	O.U.A.T., Bhubaneswar	Rajasthan	Sirohi	2.3	8
		Rajasthan	Banswara	5.2	8
		Rajasthan	Kota	5.2	8
		Orissa	Sonpur	12.1	7
		Orissa	Angul	12.1	7
		Orissa	Ganjam	12.2/18.5	7
5	A.N.G.R.A.U., Hyderabad	Orissa	Nayagarh	12.2	7
		Orissa	Khurda	12.2	11
		Orissa	Jagatsinghpur	18.5	11
		Andhra Pradesh	Rangareddi	7.2	10
		Andhra Pradesh	Kurnool	7.1	10
5	B.A.U., Ranchi	Andhra Pradesh	Medak	7.2	10
		Andhra Pradesh	Nalgonda	7.2	10
		Andhra Pradesh	Warangal	7.2	10
		Bihar	Ranchi	12.3/11.0	4
		Bihar	Dumka	12.3	7
8	C.I.A.E., Bhopal	Bihar	Dhanbad	12.3	7
		Bihar	Deoghar	12.3	7
		Bihar	Gumla	11.0	7
		Madhya Pradesh	Nimar (Khandwa)	5.2	9
		Madhya Pradesh	Seoni	10.4	8
		Madhya Pradesh	Sehore	10.4	8
		Madhya Pradesh	Chhindwara	10.4	8
		Madhya Pradesh	Damoh	10.0/10.3	8
5	G.A.U., Ahmedabad	Madhya Pradesh	Bhopal	10.1	8
		Madhya Pradesh	Vidisha	10.1	8
		Madhya Pradesh	Raisen	10.1	8
		Gujarat	Rajkot	2.4	13
		Gujarat	Banaskantha	2.3	13
		Gujarat	Ahmedabad	4.2	13
		Gujarat	Valsad	19.1	13
6	G.B.P.U.A.T., Pantnagar	Gujarat	Vadodara	5.2	13
		Uttar Pradesh	Almora	14.5	1
		Uttar Pradesh	Bageshwar	14.2	1
		Uttar Pradesh	Bijnor	9.1	5
		Uttar Pradesh	Baghpat	4.1	5
		Uttar Pradesh	Muzaffarnagar	9.1/4.1	5
		Uttar Pradesh	Nainital	14.5	1

(Table 3 contd . . .)

(Table 3 contd . . .)

1	2	3	4	5	6
4	C.C.S.H.A.U., Hissar	Haryana	Bhiwani	2.1	6
		Haryana	Faridabad	4.1	6
		Haryana	Kaithal	4.1	6
		Chandigarh	Sonipat	4.1	6
2	Ch.S.K.K.V.V., Palampur	Himachal Pradesh	Kangra	14.3/14.2	1
		Himachal Pradesh	Una	14.2	1
9	I.C.A.R. Res. Complex for NEH Region, Umiam (Meghalaya)	Manipur	Imphal	17.2	2
		Mizoram	Aizawl	17.2	2
		Meghalaya	Jaintia Pahar	17.1	2
		Meghalaya	East Khasi Hills	17.1	2
		Tripura	West Tripura	17.2	2
		Nagaland	Mon	17.1	2
		Arunachal Pradesh	Tawang	16.3	2
		Arunachal Pradesh	West Kameng	16.3	2
		Arunachal Pradesh	East Siang	16.3	2
2	I.I.S.R., Lucknow	Uttar Pradesh	Lucknow	9.1/4.3	8
		Uttar Pradesh	Bara Banki	9.1	5
5	I.I.T., Kharagpur	West Bengal	Bankura	12.3/15.1	2
		Sikkim	West Sikkim	16.2	2
		West Bengal	Hooghly	1615.1.2	3
		West Bengal	Midinipur	15.1/12.3	3
		West Bengal	Bardhaman	15.1/12.3	2
5	J.N.K.V.V., Jabalpur	Madhya Pradesh	Umeria	10.3	7
		Madhya Pradesh	Katni	10.1	8
		Madhya Pradesh	Jabalpur	10.1	8
		Madhya Pradesh	Rewa	10.3	8
		Madhya Pradesh	Korba	11.0	7
4	K.A.U, Thrissur	Kerala	Idukki	19.2	12
		Kerala	Pathanamthitta	19.2	12
		Kerala	Kollam	19.2/19.3	12
		Kerala	Alappuzha	19.3	12
4	M.P.K.V., Pune	Maharashtra	Thane	19.1/19.3	12
		Maharashtra	Raigarh	19.1/19.3	12
		Maharashtra	Pune	6.4/6.1	9
		Maharashtra	Satara	6.4/6.1	9
5	N.D.U.A.T., Faizabad	Uttar Pradesh	Balia	9.2/13.1	4
		Uttar Pradesh	Gonda	13.1	4
		Uttar Pradesh	Mau	9.2/13.1	4
		Uttar Pradesh	Basti	13.1	4
		Uttar Pradesh	Gorakhpur	9.1/14.2	4
4	P.A.U., Ludhiana	Punjab	Gurdaspur	9.1/14.2	6
		Punjab	Mansa	2.3	6
		Punjab	Ludhiana	4.1/9.1	6
		Punjab	Nawashehar	9.1	6
3	P.D.K.V., Akola	Maharashtra	Yavatmal	6.3	9
		Maharashtra	Akola	6.3	9
		Maharashtra	Amravati	6.3/10.2	9
6	R.A.U., Pusa, Samastipur	Bihar	Lakhi-serai	13.1	4
		Bihar	Madhubani	13.1	4
		Bihar	Samastipur	13.1	4
		Bihar	Katihar	13.1	4
		Bihar	Vaishali	13.1	4
		Bihar	Siwan	13.1	4
3	S.K.U.A.S.T., Jammu	J & K	Udhampur	14.2/14.1	1
		J & K	Kathua	14.2	1
		J & K	Jammu	14.2	1

(Table 3 contd . . .)

(Table 3 concluded)

1	2	3	4	5	6
8	T.N.A.U., Coimbatore	Tamil Nadu	Namakkal	8.3	10
		Tamil Nadu	Nilgiris	19.2	12
		Tamil Nadu	Tiruvanamalai	8.3	10
		Tamil Nadu	Coimbatore	8.1	10
		Tamil Nadu	Tuticorin	8.1	11
		Tamil Nadu	Erode	8.3	10
		Tamil Nadu	Salem	8.3	10
		Pondicherry	Karaikal	18.2	11
6	U.A.S., Raichur	Karnataka	Haveri	6.4	10
		Karnataka	Belgaum	6.4	10
		Karnataka	Gadag	6.4	10
		Karnataka	Dharwad	6.4	10
		Karnataka	Chitradurga	8.2/3	10
		Goa	Goa	19.2/19.3	12

*NBSS&LUP, Nagpur; **Planning Commission, New Delhi

major soil groups are given in Table 4. Appropriate Indian nomenclature of major soil great groups is indicated in Table 5.

2. COLD ARID ECOREGION WITH SHALLOW SKELETAL SOILS (A13 E1)

It represents the area of the north-western Himalayas, covering Ladakh and Gilgit districts (Fig.2) with an area of 15.2 m ha, occupying 4.7 per cent of the total geographical area (329 m ha) of the country. The region is subdivided into 1.1 and 1.2 subregions (Table 2 and Fig. 3).

Agro-Climate: This region is characterized by mild summer and severe winter with mean annual temperature of less than 8°C and mean annual rainfall of less than 150 mm. The precipitation covers less than 15 per cent of the mean annual PET¹. The area qualifies for **aridic** soil moisture and **cryic** soil temperature regime with LGP² of less than 90 days in a year.

Soils: The skeletal and calcareous soils occur on gently sloping to almost level valleys. They are alkaline in reaction and low to medium in organic matter content. They are classified into Great Groups of **Cryorthents** and **Cryorthids**. The area is dominantly represented by Ladakh series, classified as Typic **Cryorthent**.

The higher northern part of the plateau remains under permanent snow cover.

Land Use: The ecoregion shows sparse forest trees. The area under non-agricultural uses, (including culturable fallows), accounts for 11.1 per cent, current fallow 1.2 per cent, and the net sown area 2.5 per cent.

The major part of cultivated area is under vegetables.

However, the production per unit area is low. The millets, wheat, fodder, pulses and barley are next in order and their yield ranges from 400 to 700 kg/ha. Among the cultivated fodders, the production of alfa-alfa is more dependable (Fig. 5). Apple and apricot are the major fruit crops grown in the area. Among the livestock, mule dominates, while sheep, goat and yak stand next in order. This zone is known for grazing (by pashmina goats).

Constraints

- Severe climatic conditions, especially cryic temperature regime which acts as a thermal pan for plant growth.
- Narrow crop growing period limits agriculture to valleys during thawing period which coincides with the scanty rains.
- Shallow, sandy and gravelly/bouldery soils.
- Moderately to highly calcareous nature of soils which poses nutrient imbalance for normal crop production.

3. HOT ARID ECOREGION WITH DESERT AND SALINE SOILS (M9E1)

The western Plain (Kachchh and part of Kathiawar peninsula), hot and arid agro-ecoregion, covers south-western parts of the States of Punjab and Haryana, western parts of Rajasthan, Kachchh peninsula and northern part of Kathiawar peninsula in Gujarat State. The area accounts to 31.9 m ha, representing 9.78 per cent of the total geographical area of the country. The region is divided into 2.1, 2.2, 2.3 and 2.4 ecosubregion (Fig.3)

Agro-Climate: The region is characterized by typical hot summer and cool winter (arid). The mean annual

¹PET = Potential Evapotranspiration

²LGP = Length of Growing Period

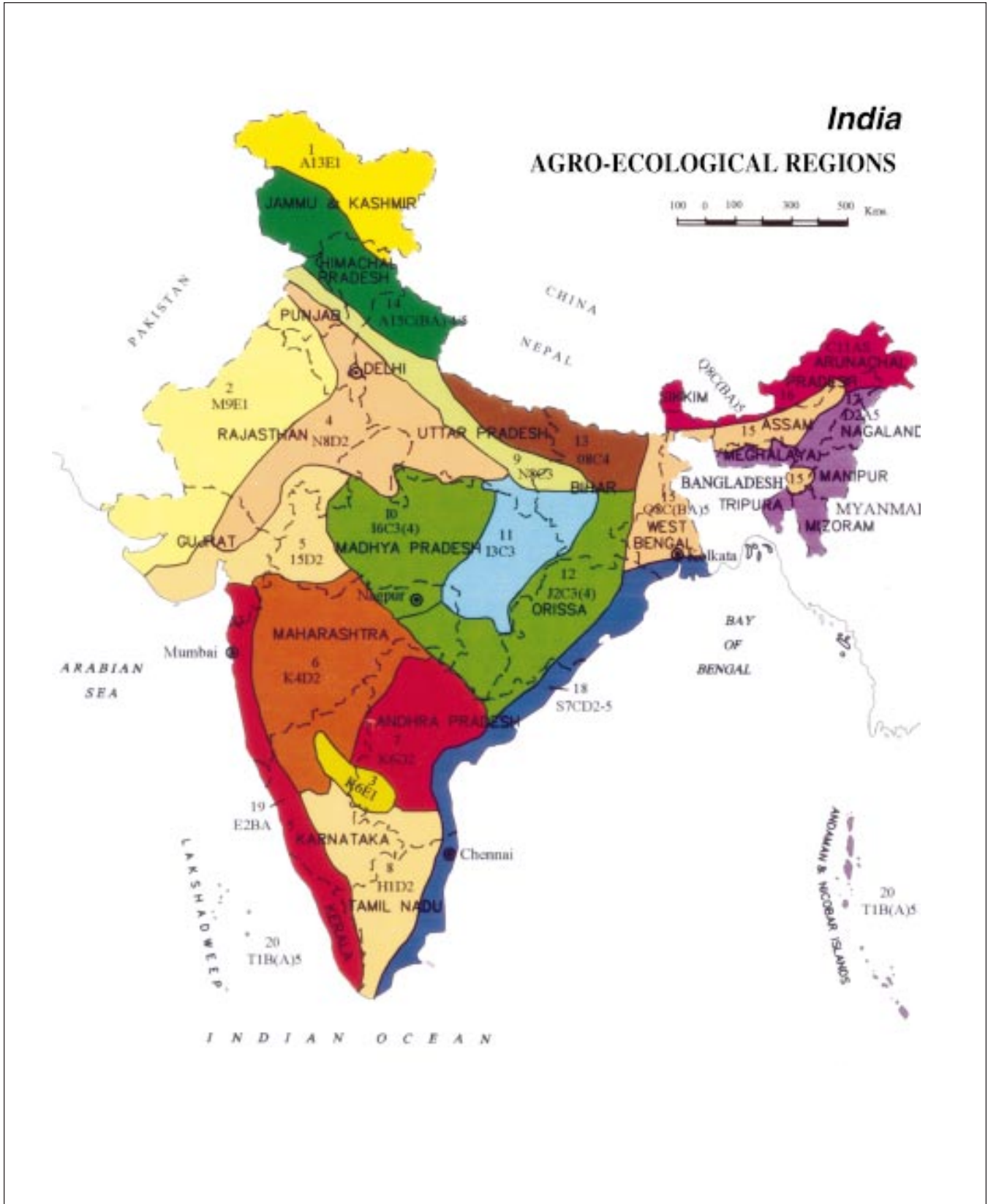


Fig. 2. Agro-Ecological Regions of India (20 AER, briefly described in Table 2)

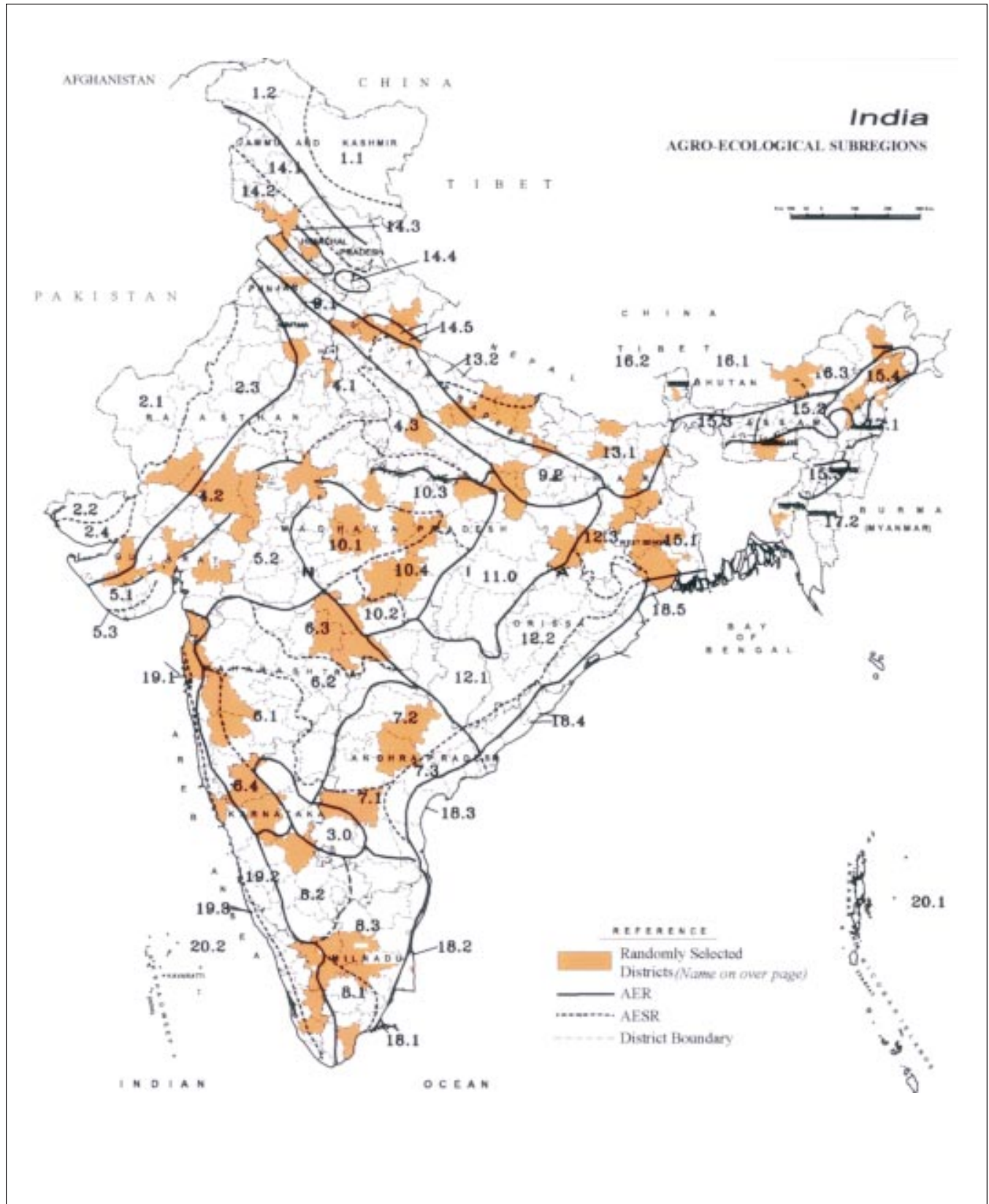


Fig. 3. Map showing AESR and randomly selected districts for long term mechanisation strategy (Refer Table 3)

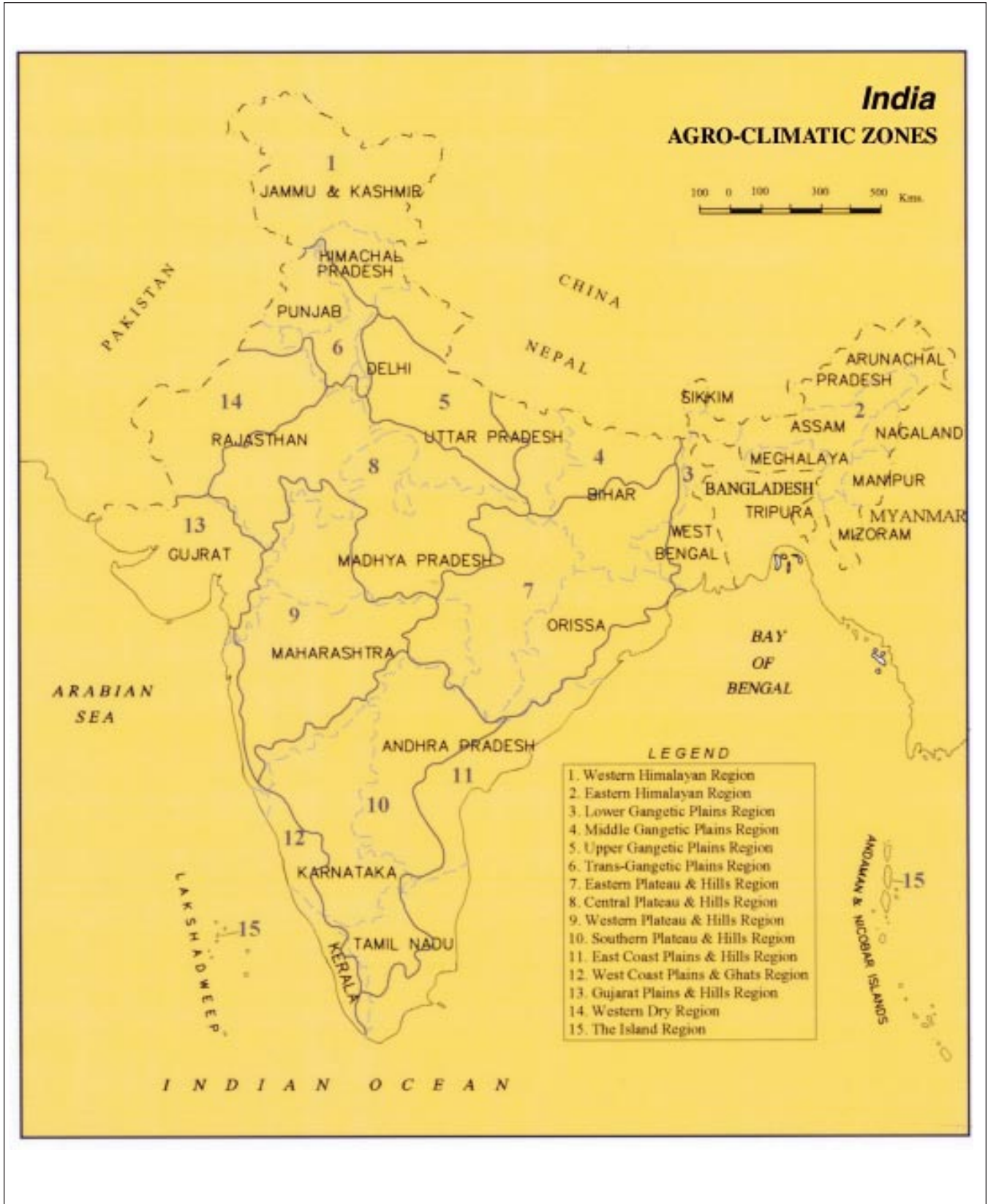
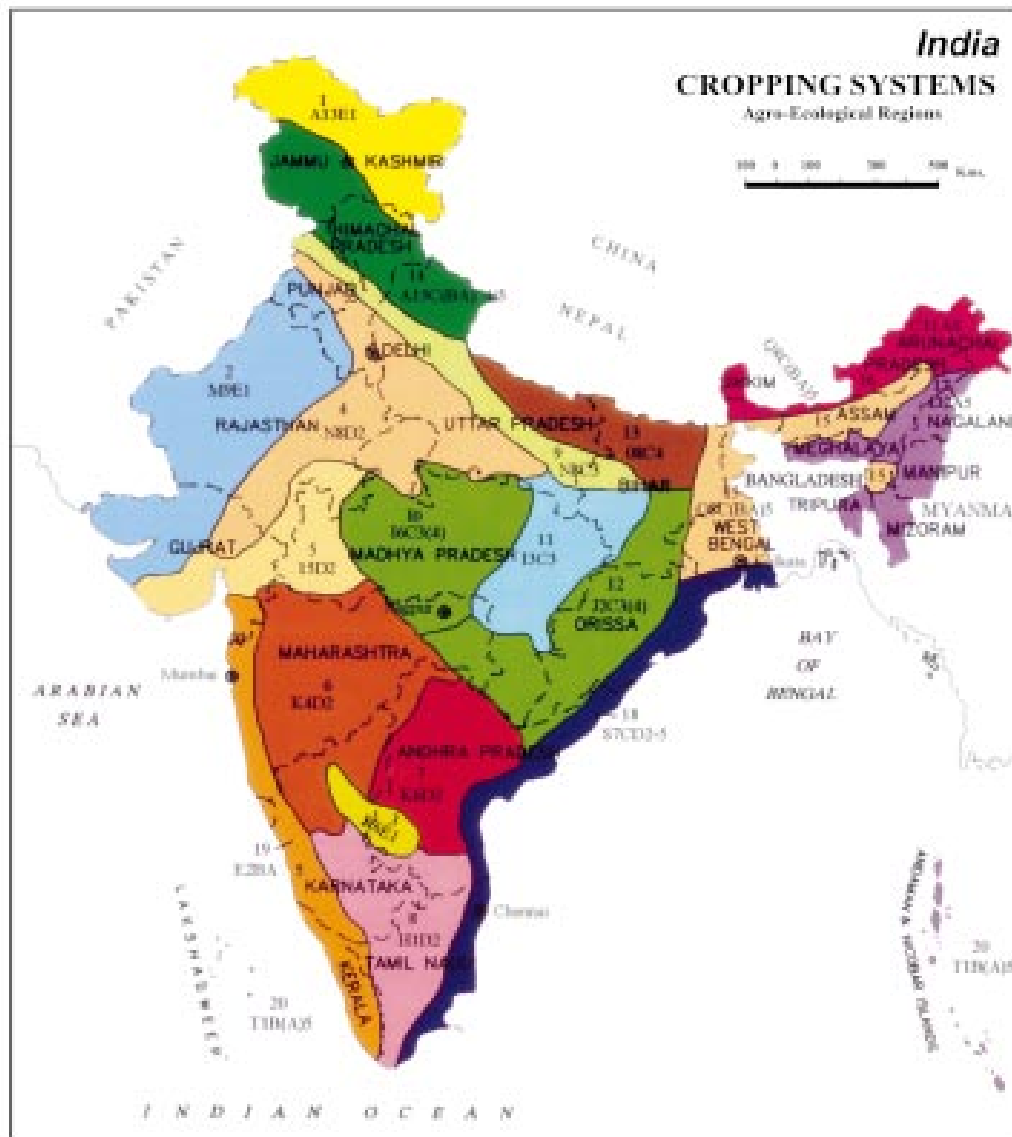


Fig. 4. Agro-climatic Zones of Planning Commission



LEGEND

 Sparse forest trees with vegetables, millet, wheat and fodder	 Paddy, pulses, groundnut
 Thorny forest with pearl millet and fodder	 Paddy, maize, pigeonpea and moong
 Thorny forest, pearl millet sorghum and sunflower	 Wheat, millet, maize, rice and horticultural crops
 Wheat, paddy, maize, pulses	 Paddy, jute, tea and horticultural crops
 Sorghum pearl millet, pigeonpea and groundnut	 Millets, potato, mustard, sesamum and pulses
 Paddy, maize, barley, pigeonpea, paddy and groundnut	 Millets, maize and potato, paddy and jute
 Millets, pulses and oilseeds	 Paddy, coconut, blackgram, sunflower and groundnut
 Paddy, maize, barley, pigeonpea and jute	 Paddy, tapioca, coconut and spices
 Paddy, sorghum, pigeonpea and soybean	 Paddy, coconut, arecanut, oil palm, pineapple, Tapioca and pepper (intercultivation)
 Paddy, millets, pigeonpea, moong and blackgram	

Fig. 5. Map showing cropping systems in different AER

precipitation is less than 400 mm. It is just adequate to cover 15-20 per cent of annual PET demand (1500 and 2000 mm). This results in large deficit of water (1500-1800 mm) throughout the year. The ecosystem represents **aridic** soil moisture and **hyperthermic** soil temperature regimes with an annual LGP of less than 90 days.

Soils: The dominant soils representing the area are gently to very gently sloping **Torripsamments**, **Camborthids** and **Calciorthids**, interspersed with level to very gently sloping **Salorthids** and **Natrargids**. The sandy soils, represented by Thar series (**Torripsamments**), are moderately calcareous and alkaline in reaction. In addition, Pali (**Camborthids**), Lakhpat (**Natrargids**) and Nihalkhera (**Calciorthids**) series occur in order of their extent of distribution.

Land Use: The area is under rainfed Mono-cropping (traditional) agriculture. The resistant and short duration rainy season crops, such as pearl millet, 'chari' (fodder), and pulses are grown in non-saline areas (Fig.5). The yields are low under average management practices. In areas favoured by availability of irrigation water, cotton, sugarcane, mustard, gram and wheat are grown.

The natural vegetation comprises sparse, sporadic tropical thorn forest. Recent statistics show that the forest area in the region is drastically reduced from 15 to almost 1 per cent.

Constraints

- Erratic and scanty rainfall leading to high water deficit.
- Soil salinity leading to frequent physiological droughts.
- Acute droughtiness at the time of grain formation.
- Nutrient imbalance, especially for N, P Zn and Fe.

4. HOT ARID ECOREGION WITH RED AND BLACK SOILS (K6 E1)

It comprises a part of the Deccan plateau that includes the districts of Bellary, SW parts of Bijapur and Raichur of Karnataka and Anantapur of Andhra Pradesh. The region covers an area of 4.9 m ha, representing 1.5 per cent of the total geographical area of the country (Fig.3).

Agro-Climate: The climate is characterized by hot and dry summer and mild winter. The rainfall is erratic and ranges from 400 to 500 mm. It covers about 20 to 25 per cent of the annual PET demand of 1800 to 1900 mm. The region experiences severe drought conditions almost throughout the year with gross annual water deficit of 1500-1600 mm. The LGP is of less than 90 days. The area qualifies the **aridic-ustic** soil moisture and **isohyperthermic** soil temperature regimes.

Soils: The soils are represented by gently sloping

shallow and medium red loamy (**Rhodustalfs**, **Haplustalfs**, **Ustropepts**) and level to very gently sloping, deep, clayey black soils of **Pellusterts** and **Ustropepts**. The dominant Red (loamy) soils, represented by **Garnimitta** series (**Typic Rhodustalfs**) are slightly acidic and noncalcareous. The subdominant deep, clayey black soils represented by Raichur series (**Typic Pellusterts**) are slightly alkaline and calcareous in nature.

Land Use: The traditional practice is rainfed farming which includes fallowing the land in rainy season and growing of crops in the post-rainy season on residual soil moisture. However, some farmers do grow pearl millet, with limited risk during the rainy season. The common post-rainy season crops are sorghum and safflower (Fig.4). The yields under traditional, management practices are very low. Groundnut, sunflower, sugarcane and cotton are intensively grown under irrigated conditions wherever feasible. The natural vegetation of the area comprises tropical thorn forest.

Constraints

- High runoff and erosion hazard during stormy cloud bursts.
- Prolonged dry spells during crop growing period resulting in occasional crop failure.
- Narrow range of workable soil moisture in Black soils.
- Subsoil sodicity affecting soil structure, drainage and oxygen availability, especially in subdominant Black soils.
- High subsoil density in Red loamy soils limiting effective rooting depth.

5. HOT SEMI-ARID ECOREGION WITH ALLUVIUM-DERIVED SOILS (N8 D2)

It constitutes the parts of Gujarat, northern plains and central highlands covering an area of 32.3 m ha and representing 9.8 per cent of the total geographical area of the country. The region is further divided into 4.1, 4.2, 4.3 and 4.4 ecosubregions (Table 4 and Fig. 3).

Agro-Climate: The climate of the region is characterized by hot and dry summer and cool winter. The annual precipitation ranges from 500 to 1000 mm with an increasing trend from west to east. It covers 35 to 42 per cent of the mean annual PET demand (1400 and 1900 mm). Annual water deficits of 700-1000 mm. The LGP ranges between 90 and 150 days. The soil moisture regime is **typic-ustic** and the soil temperature regime is **hyperthermic**. The parts of Bundelkhand region comprising the districts of Banda, Hamirpur, Jhansi, Jalaun (Orai) and Datia are subjected to occasional and acute droughtiness.

Soils: The soils are moderately to gently sloping, coarse to fine loamy, great group of **Ustochrepts** and **Natrustalfs**, grading through gently to very gently sloping great groups of **Ustochrepts** and **Ustipsammets** to nearly level **Ustifluvents**. In the northern part of the region, the terrain is frequently interrupted by stable sand dunes. The soils of the regions are dominantly represented by Kanjili series classified as **Ustochrepts** and occasionally by Chomu and Zarifa Viran and Ghabdan series. The Chomu soils are sandy (**Ustipsammets**), the Zarifa-Viran soils are fine loamy and highly sodic (**Natrustalfs**) and the *Ghabdan soils are fine loamy, highly sodic (**Salic Natrustalfs**).

Land use: Almost 65 per cent of the region is under irrigated agriculture. The remaining part is under traditional rainfed agriculture. In northern plain, the droughty climate is overcome by introducing tubewell irrigation and the area is intensively cultivated for both kharif and rabi crops, such as rice, millets, maize, pulses, berseem, wheat, mustard and sugarcane. The moderately high yields of wheat and paddy are obtained with irrigated. In some parts of central highlands, like Bundelkhand, less than 25 per cent of the net cropped area is under irrigation, while the rest is under rainfed agriculture. The predominant kharif crops grown under rainfed agriculture are jowar, pigeonpea and soybean (Fig.5), while rabi crops, such as pulses (gram), lentil and wheat are grown on residual moisture with one or two protective irrigations at critical stages of crop growth. In Chambal catchment, the cropping pattern has undergone drastic change replacing millets by wheat, cotton and sugarcane after the introduction of irrigation. The natural vegetation comprises tropical dry deciduous and thorn forests.

Constraints

- Coarser soil texture and low plant available water capacity (AWC).
- Over exploitation of groundwater, resulting in lowering of groundwater table in some areas
- At places, imperfect drainage conditions lead to spread of surface and subsurface soil salinity and/or sodicity.

6. HOT SEMI-ARID ECOREGION WITH MEDIUM AND DEEP BLACK SOILS (I5D2)

The ecoregion covers the Central highlands (Malwa), Gujarat plains and Kathiawar peninsula, western parts of Madhya Pradesh, south-eastern parts of Rajasthan and Gujarat States. It covers an area of 17.6 m ha, representing 5.4 per cent of the total geographical area

of the country. The agro-ecoregion is divided into 5.1, 5.2, 5.3 ecosubregion. (Table 4 and Fig 3).

Agro-Climate: The climate of the region is characterized by hot and wet summer and dry winter. The annual precipitation in the region ranges from 500 to 1000 mm. It covers 40 to 50 per cent of the annual PET demand (1600 to 2000 mm) resulting in gross annual water deficit of 800 to 1200 mm. The LGP ranges from 90 to 150 days in a year. The dominant soil moisture regime in the area is **typic-ustic**. The soil temperature regime is **hyperthermic** and **Isohyperthermic** (in coastal area of Kathiawar peninsula).

The parts of the district Banswara (Rajasthan), Jhabua, Dhar (M.P.) and Panchmahal (Godhra), Bhavnagar, Amreli (Gujarat) are subject to drought hazard once in three years. The frequent inter drought spells of lead to crop failure and the region thus earmarked as drought-prone area.

Soils: The dominant soils, representing the region are gently to very gently sloping deep, loamy to clayey **Ustochrepts** and nearly level to very gently sloping deep Black soils (**Chromusterts**). The Kathiawar peninsula and the coastal areas are represented by **Salorthids**. The dominant soils of the Malwa plateau are largely typifying by **Sarol** and **Kamliakheri** series. They are clayey, slightly alkaline, calcareous with characteristic swell-shrink properties.

Land Use: Dryland farming is the common practice in the region. The Kharif crops usually cultivated in the area are sorghum, pearl millet, pigeonpea, groundnut, soybean, maize and pulses (Fig 5). The common Rabi crops are sorghum, safflower, sunflower and gram. Wheat is grown under irrigated conditions. The natural vegetation comprises dry deciduous forest.

Constraints

- The intermittent dry spell periods.
- Imperfect drainage limits optimum root ramification and oxygen availability in low-lying areas.
- Salinity and alkalinity hazards under irrigated agriculture.
- Severe salinity and seasonal inundation by sea water in the Kathiawar coast resulting in crop failure.

7. HOT SEMI-ARID ECOREGION WITH SHALLOW AND MEDIUM (DOMINANT) BLACK SOILS (K4 D2)

The agro-ecoregion with hot, semi-arid climate covers the Deccan plateau, comprising most of the central and western parts of Maharashtra, northern parts of Karnataka and western parts of Andhra Pradesh. It

*Due to subsidence of groundwater table and leaching of salts due to tubewell irrigation, the soil has since been changed from Salic Natrustalf to Typic Natrustalf.

spreads over 31.0 m ha, representing 9.5 per cent of the total geographical area of the country. It is divided into 6.1, 6.2, 6.3 and 6.4 ecosubregion (Table 4 and Fig 3).

Agro-Climate: The climate is characterized by hot and humid summer and mild and dry winter. The mean annual precipitation, ranging between 600 and 1000 mm, covers about 40 per cent of annual PET demand (1600 and 1800 mm). This results in gross annual deficit of 800 to 1000 mm of water. The LGP ranges from 90 to 150 days. A part of the region, comprising the districts of Ahmednagar, Bid, Solapur, Sangli (eastern parts), Satara (eastern parts), Osmanabad and Latur in Maharashtra state, and Bidar, Gulbarga, Bijapur and Dharwad in Karnataka State constitutes drought-prone areas. Severe drought spells repeat once in three years. The moisture availability mostly remains as submarginal. The LGP extends over 90 days or less at places leading to severe crop failure. The area is classified as **Ustic Soil Moisture**, and (iso) **hyperthermic** soil temperature regimes.

Soils: The soils are represented by moderately to gently sloping **Ustorthents** and **Ustropepts**, grading to level to very gently sloping **Chromusterts/Pellusterts** in valleys. They are classified as Pargaon, Sawargaon and Barsi series. The Pargaon soils are shallow, loamy skeletal and highly calcareous in nature. The Sawargaon and Barsi soils, however, are clayey, calcareous and moderately alkaline showing marked swell-shrink properties.

Land Use: The traditional practice is rainfed agriculture. The sorghum, pigeonpea and pearl millet are major kharif season crops (Fig 5). The drought-prone districts of the region, interestingly, have bimodal rainfall distribution. Therefore, crops are grown during September/October on stored residual soil moisture since there is a significantly long dry period during the first phase of the rains. The post-rainy season crops grown on residual soil moisture are mainly sorghum, safflower and sunflower. Cotton and groundnut are grown under irrigated conditions. The natural vegetation in the region comprises tropical, dry deciduous and thorn forests.

Constraints

- Prolonged dry spells adversely affect the crop growth and lead to crop failure in some years.
- High runoff during stormy cloud bursts in the rainy season result in heavy soil loss.
- Deficiency of N, P and Zn leads to nutrient imbalance.

8. HOT SEMI-ARID ECOREGION WITH RED AND BLACK SOILS (K6 D2)

The agro eco-region with hot, semi-arid climate and supporting Red and Black soils covers the parts of the

Deccan plateau (Telangana) and major parts of eastern Ghats of Andhra Pradesh. It occupies an area of 16.5 m ha, representing 5.2 per cent of the total geographical area of the country. It is subdivided into 7.1, 7.2 and 7.3 eco-subregion (Table 4 and Fig 3).

Agro-Climate: The climate is characterized by hot and moist summer and mild and dry winter. The mean annual rainfall, ranges from 600 to 1100 mm and covers about 40 per cent of annual PET demand, resulting in gross deficit of 700-800 mm of water. The LGP ranges from 90 to 150 days. The area, covering the districts of Nalgonda, Mahbubnagar, Kurnool, Prakasam, Nellore and Cuddapah, are recognized as drought-prone. The soil moisture regime is **ustic** and soil temperature regime is **isohyperthermic**.

Soils: The soils in the region are of moderately to gently sloping **Ustorthents** and **Rhodustalfs** (Red soils), grading through gently to very gently sloping **Ustropepts**, to nearly level **Chromusterts/Pellusterts** (Black Cotton soils). The Black Cotton soils are represented by **Kasireddipalli** series. These are clayey, calcareous and strongly alkaline in reaction showing remarkably swell and shrink phenomena on wetting and drying. They have high production potential. However, they have high management problems also. The Red soil represented by Patancheru series (Rhodustalfs), are non-calcareous and neutral in reaction.

Land Use: Rainfed agriculture is the traditional practice. The major Kharif crops grown in the area are sorghum, cotton, pigeonpea, rice, groundnut and castor (Fig 5). The crops grown on stored/residual soil moisture during post-rainy season are sorghum, sunflower, safflower and some oilseeds. At places rice is cultivated under irrigation in rabi season. The natural vegetation comprises tropical, dry deciduous and thorn forests.

Constraints

- High runoff during rainy season leads to severe soil and nutrient loss both in the Red and Black Soil areas.
- Under irrigated agriculture, unjudicious use of irrigation water and imperfect drainage conditions result in high groundwater table leading to subsoil salinity and sodicity, especially in the Black soil areas.
- Deficiency of N, P and Zn in soils results in nutrient imbalance.
- Frequent droughtiness results in crop failure in some years.

9. HOT SEMI-ARID ECOREGION WITH RED LOAMY SOILS (H1D2)

The agro-ecoregion with hot, semi-arid climate and Red loamy soils, covers eastern Ghats, southern parts of Deccan plateau, Tamil Nadu uplands, and western

parts of Karnataka. It has an area of 19.1 m ha, representing 5.8 per cent of the total geographical area of the country. It is divided into 8.1, 8.2 and 8.3 ecosubregions (Table 4 and Fig 3).

Agro-climate: The climate of the region is characterized by hot and dry summer and mild winter. It receives an annual rainfall of 600 to 1000 mm. The western parts of the region falling in Karnataka receive about 70 per cent of the rainfall during June to September. The eastern parts receive rains during October to December. The area experiences the annual water deficit of 400 to 700 mm. The LGP ranges from 90 to 150 days. The soil moisture regime is **ustic** and soil temperature regime is **isohyperthermic**.

Soils: The major soils of the area are of moderate to gently sloping **Ustorthents** and **Ustropepts**, grading to gently to very gently sloping **Rhodustalfs** and **Plinthustalfs**. They are represented by **Tyamagondalu** and **Palathurai** series. Tyamagondalu soils are noncalcareous and slightly acidic in nature, while Palathurai soils are calcareous and moderately alkaline in reaction. Both are low in cation exchange capacity.

Land Use: The rainfed agriculture is the traditional practice in the region. The millets, pulses, and groundnut are cultivated in kharif season (Fig 5), while sorghum and safflower are grown in rabi season. Rice is cultivated under irrigation. At places sugarcane and cotton are also grown under irrigated conditions. The natural vegetation comprises tropical, dry deciduous and thorn forests.

Constraint

- High runoff that results in severe soil erosion.
- Coarse soil texture and low to medium PAWC¹, resulting in severe droughtiness during the crop growing period.
- Nutrient imbalance, resulting from deficiency of N, P and Zn.

10. HOT SUBHUMID (DRY) ECOREGION WITH ALLUVIUM-DERIVED SOILS (N8C3)

The agro-ecoregion with hot, subhumid (dry) climate and alluvium-derived soils covers a part of the northern Indo-Gangetic Plain, including piedmont Plain of the western Himalayas. It occupies an area of 12.1 m ha, representing 3.7 per cent of the total geographical area of the country. The ecoregion is divided into 9.1 and 9.2 ecosubregions (Table 4 and Fig 3).

Agro-Climatic: The agro-climate of the region is characterized by hot summer and cool winter. It receives an annual rainfall of 1000 to 1200 mm; 70 per cent of which is received during July to September. The rainfall

covers about 70 per cent of the annual PET demand of 1400 to 1800 mm and leaves an annual water deficit of 500 to 700 mm. The region has LGP of 150 to 180 days. It experiences dry period from February to June with mean annual temperature of more than 22°C, and thus qualifies for **ustic** soil moisture and **hyperthermic** soil temperature regime. The areas adjacent to foot-hills are relatively cooler and experience thermic soil temperature regime. The district of Gaya (Bihar) is drought-prone.

Soils: The soils of the region are generally deep and loamy. They have developed on alluvium. The dominant soilscapes, representing the northern plain, constitute gently to very gently sloping **Ustochrepts**, **Haplustalfs** and **Eutrochrepts** and gently to moderately sloping **Ustifluvents**.

The soils of Basiaram series (**Eutrochrepts**) are very gently sloping and that of Shajadapur (**Ustochrepts**), Gurudaspur (**Haplustalfs**) and Itwa series (**Ochraqualfs**) are nearly level dominating the area. In general, they are neutral in reaction and have moderate clay and low organic carbon content. Itwa soils are sodic in their subsurface.

Land Use: Traditionally the rainfed and irrigated agriculture is common. The crops grown are rice, maize, barley, pigeonpea and jute in kharif season (Fig 5), and wheat, mustard and lentil in rabi season. Sugarcane and cotton are grown at places under irrigated conditions. The natural vegetation comprises tropical dry deciduous forests.

Constraint

- An injudicious use of irrigation water may lead to waterlogging and salinity hazards.

11. HOT SUBHUMID ECOREGION WITH RED AND BLACK SOILS (16 C3/4)

The agro-ecoregion with hot, subhumid climate and Red and Black soils covers part of Malwa plateau and Bundelkhand uplands including Baghelkhand plateau, Narmada valley, Vindhyan scarplands and northern fringe of Maharashtra plateau, encompassing some districts of Madhya Pradesh. It covers an area of 22.3 m ha representing 5.8 per cent of the total geographic area of the country. The ecoregion is subdivided into 10.1, 10.2, 10.3 and 10.4 ecosubregion (Table 4 and Fig 3).

Agro-Climatic: The climate of the region is characterized by hot summer and mild winter. The precipitation shows an increasing trend towards east. The mean annual rainfall ranges between 1000 and 1500 mm covering about 80 per cent of the mean annual PET (1300-1600 mm). The region remains fairly dry during

¹ PAWC = Plant available water capacity

the post-rainy period with water 500-700 mm deficit mounting to the winter rains of around 30 per cent probability is commonly observed.

Dry period occurs from February to May suggesting **typic ustic** soil moisture regime. The mean annual soil temperature of more than 22°C thus qualifies the area for **hyperthermic** soil temperature regime. The LGP ranges from 150-180 days.

The districts of Balaghat, Seoni, Mandla, Bhandara, Chhindwara are relatively more humid showing the LGP ranging from 180 to 210 days in a year. Consequently SMCS¹ remains moist for a longer period qualifying the area for **udic Ustic** soil moisture regimes.

Soils: The soils are largely medium. The deep black soils are interspersed with patches of Red soils. The soils representing the region are typified by moderately to gently sloping **Ustorthents**, gently to very gently sloping **Ustochrepts** and **Haplustalfs**, and very gently sloping to nearly level **Chromusterts**.

The dominant soil series of region are Marha, Kheri and Linga (**Chromusterts**) occurring in association with the moderately deep soils of Kamliakheri series (**Ustochrepts**). They are calcareous, slightly alkaline, montmorillonitic and have high swell-shrink potential. The red soils generally occur on ridges and on pediment surfaces. They are shallow to moderately deep, clayey, neutral to slightly acidic in nature and are represented by Dumra series (**Udic Haplustalfs**) occurring on gently to very gently sloping pediment surface in Bundelkhand region.

Land use: Rainfed agriculture is the common practice. Rice, sorghum, pigeonpea and soybean are common grown kharif crops. Gram, wheat and vegetables are common rabi season crops. Kharif cropping is totally rainfed, whereas Rabi cropping is partly irrigated at critical stages growth. However, rich farmers grow rice, wheat and gram and, at places, cotton using irrigation facilities. The natural vegetation comprises tropical moist deciduous forest.

Constraints

- Cracking clayey soils having narrow workable moisture conditions.
- Dry tillage and inter-tillage practices are difficult to perform.
- Risk of inundation of the cropped areas during rainy season and risk of acute droughtiness due to prolonged dry spells in Kharif season leading to crop failure at places.
- Soil loss due to heavy runoff during rainy season

- resulting in stagnation of water and poor germination.
- Deficiency of N, P and Zn resulting in nutrient imbalances.

12. HOT SUBHUMID ECOREGION WITH RED AND YELLOW SOILS (J3 C3)

The agro-ecoregion, with hot, subhumid climate and supporting red and yellow soils, comprised of eastern plateau. It covers Chhattisgarh region and southwest highlands of Bihar State. It occupies an area of 14.1 m ha, representing 4.3 per cent of the total geographical area of the country.

Agro-Climate: The climate of the area is characterized by hot summers and cool winters. The annual rainfall is 1200 to 1600 mm; of which 70-80 per cent is received between July to September. It meets about 60 per cent of annual PET demand (1400 to 1500 mm) resulting in an annual water deficit of 500 to 700 mm. The water balance shows that PET exceeds the precipitation from October to June. The soils remain dry from December to May/June suggesting **typic Ustic** soil moisture regime. The mean annual soil temperature of more than 22°C qualifies for **hyperthermic** soil temperature regime. The LGP ranges between 150 and 180 days in a year.

Soils: The dominant soils in the area are represented by moderately to gently sloping **Ustorthents** and **Ustochrepts** which grade to gently to very gently sloping **Haplustalfs**, **Rhodustalfs** and **Plinthustalfs**. They are classified as Ghatapara, Chhal and Ekma series. They are deep loamy non-calcareous and neutral to slightly acidic in reaction.

Land Use: Rainfed agriculture is the traditional farming with cultivation of rice, millets, pigeonpea, moong (green peas) and blackgram ('urid') in kharif season (Fig 5). At places wheat and rice are cultivated under irrigated conditions during rabi season. The natural vegetation comprises tropical moist deciduous forest.

Constraints

- The soils are susceptible to severe water erosion hazard.
- Partial waterlogging in early stages of crop growth and seasonal droughtiness during advance stage crop growth.
- Subsoil gravelliness and coarse texture, at places, reduce AWC.
- Deficiency in N, P and micronutrients, such as Zn and B, causes nutrient imbalances.

¹SMCS = Soil moisture control section

13. HOT SUBHUMID ECOREGION WITH RED AND LATERITIC SOILS (J2 C 3/4)

The agro-ecoregion constitutes Chhotanagpur Plateau of Bihar, western parts of West Bengal, eastern Ghats (Dandakaranya and Garhjat hills) of Orissa and Bastar Region of Chhattisgarh. It occupies an area of 26.8 m ha, representing 8.2 per cent of the total geographical area of the country. It is divided into 12.1, 12.2 and 12.3 ecosubregion (Table 4 and Fig 3)).

Agro-Climate: The climate of the region is characterized by hot summers and cool winters. The area receives an annual rainfall of 1000-1600 mm which covers about 80 per cent of the PET leaving deficit of 500 to 700 mm of water per year. The water balance shows a prolonged dry period from December to May (more than 90 days in a year). As such the area, in general, qualifies for **Typic Ustic** soil moisture regime. The mean annual soil temperature of more than 22°C qualifies the area for **hyperthermic** soil temperature regime. The LGP varies from 150 to 180 days and at places it is 180 to 210 days.

Soils: The dominant soils of the area are represented by gently to very gently sloping **Ustochrepts**, **Haplustalfs**, **Plinthustalfs**, **Paleustalfs**, **Haplustults** and **Rhodustalfs**. The soils of Pusaro, Bhubaneswar and Chougel series are observed largely in the region. They are fine loamy to clayey, non-calcareous, slightly to moderately acidic and have relatively low cation exchange capacity. The soils are generally shallow on the ridges and plateaus and are under forest cover. The soils in valleys are deep and are generally cultivated.

Land use: Rainfed farming is the traditional practice with cultivation of rice, pulses (moong, blackgram and pigeonpea) and groundnut (Fig 5). In rabi season, rice (at places) and wheat are cultivated mostly under irrigated condition. The natural vegetation comprises tropical dry and moist deciduous forests.

Constraints

- The soils are susceptible to severe erosion hazard.
- Seasonal droughtiness limits optimum crop yields.
- Subsoil graveliness and coarse soil texture results in low AWC.
- Deficiency of N, P and some micronutrients, such as Zn and B causes nutrient imbalances.
- The soils are subject to moderate to high P fixation (especially the Red and Lateritic soils).

14. HOT SUBHUMID (MOIST) ECOREGION WITH ALLUVIUM-DERIVED SOILS (08 C4)

The agro-ecoregion, comprising eastern plains covers north-eastern Uttar Pradesh and Northern Bihar including foothills of Central Himalayas. It occupies an

area of 11.1 m ha, representing 3.4 per cent of the total geographical area of the country. The ecoregion is divided into 13.1 and 13.2 ecosubregions (Table 4 and Fig 3).

Agro-Climate: The climate of the region is characterized by hot, wet summer and cool, dry winter. The area receives an annual rainfall of 1400-1800 mm which exceeds the mean annual PET demand (1300 and 1500 mm). The area experiences a small seasonal water deficit of 400 to 500 mm during February to May. The LGP ranges from 180 to 210 days in a year. The soil moisture control section (SMCS) either as a whole or in parts remains dry from middle of January till May. (about 120-150 cumulative days) qualifying the area for **udic**, **Ustic** soil moisture regimes.

The northern fringe of the region comprising piedmont plain or the foothills of central Himalayas where SMCS does not get dry for as long as 90 or more days in a year qualifies the area of **Udic** soil moisture regime. The mean annual soil temperature of more than 22°C qualifies the area for **hyperthermic** soil temperature regime.

Soils: The soils in the area are represented by level to very gently sloping alluvium-derived soils, such as **Ustifluvents**, **Ustochrepts**, and **Eutrochrepts**. These occur in association with level to very gently sloping, imperfectly drained, **Aquic Hapludalfs**, and at some places **Haplustalfs**. The soils of Kesarganj and Sabour series, are calcareous and moderately alkaline in reaction. They show different degree of profile development from A-C soils (in the flood plains) to A-Bt-C soils (on stable terraces). The Tarai soils occur on piedmont plain at the foothills of central Himalayas represented by Haldi series occurring extensively in Tarai areas adjoining Pantnagar University. The soils are deep, loamy and high in organic matter content and are classified as **Typic Hapludolls**.

Land use: Rainfed agriculture with cultivation of rice, maize, pigeonpea, moong are common in kharif season (Fig 5). In post-rainy (rabi) season, wheat, lentil, pea, sesamum, and at places, groundnut is grown on residual soil moisture with one or two protective irrigations at critical stages. The important cash crops such as sugarcane, tobacco, chillies, turmeric, coriander and potato are usually grown with supplemental irrigation. The natural vegetation comprises tropical moist deciduous and dry deciduous forests.

Constraints

- Flooding and imperfect drainage conditions limit soil aeration.
- Salinity and/or sodicity, occurring in patches, affect crop yields.

- Deficiency of N, P and Zn results in nutrient imbalances.

15. WARM SUBHUMID TO HUMID WITH INCLUSION OF PERHUMID ECOREGION WITH BROWN FOREST AND PODZOLIC SOILS (A15 C (BA) 4/5)

The agro-ecoregion comprising western Himalayas, covers Jammu and Kashmir, Himachal Pradesh and north-western hilly areas of Uttar Pradesh. It occupies an area of 21.2 m ha, representing 6.3 per cent of the total geographical area of the country. The ecosubregion is divided into 14.1, 14.2, 14.3, 14.4 and 14.5 ecosubregion (Table 4 and Fig 3).

Agro-Climat: The region represents warm subhumid to cool humid (with inclusion of perhumid) ecosystem. and is characterized by mild summer and cold winter. The mean annual soil temperature, in general, varies from 12°C to 20°C qualifying for Mesic/Thermic soil temperature regime. In contrast, Lahul Spiti area has cryic-mesic soil temperature regime, where the mean winter soil temperature (MWST) declines below freezing point forming thermal pan for crop growth. The precipitation shows an increasing trend from West to East. The rainfall in general varies from 1000-2000 mm. It is more than 2000 mm in parts of Himachal and Uttar Pradesh comprising Humid and Perhumid pockets in the region. Since PET demand is low, precipitation exceeds PET in most of the months.

The soil moisture control section (SMCS) in most of the areas does not remain dry, either wholly or in parts for as long as 45 consecutive days and/or 90 cumulative days in a year, qualifying it for **Udic** soil moisture regime. However, in the extreme western part of the region, SMCS remains dry for as long as 90-120 days in a year qualifying for **udic-ustic** soil moisture regime.

Soils: The major soils occurring in the region are shallow to deep, medium having high organic matter content, and weak (A-C) to well developed (A-Bt-C) horizons. They are classified as Brown Forest and Podzolic Soils belong to the great groups of **Eutrochrepts**, **Hapludalfs**, **Haplustalfs**, **Hapludolls**, **Haplohumults**, and **Haplaquepts**. Some such soils are classified as Gogji-Pather, Wahthora and Kullu series. They are fine loamy, neutral in reaction and have 50 per cent or more base saturation. Tarai soils (Nainital and Garhwal districts) are deep, loamy, neutral to mildly alkaline moderately base saturated soils high in organic matter and typically represented by Haldi series.

Land use: Rainfed farming is the traditional practice in the valleys and on terraces. The common crops grown are wheat, millet, maize and rice. The terraced uplands are cultivated for paddy and/or horticultural plantation

crops, like apples (Fig 5). The natural vegetation comprises Himalayan moist temperate, subtropical pine and sub-alpine forests.

Constraints

- Severe climate, especially cryic/frigid temperature regime, in northern high altitude permits limited choice of crops.
- Deforestation and excessive slopes favour soil erosion.
- Soil degradation, results in common landslides.
- Imperfect drainage conditions in valleys limits the choice of crop.
- Soil acidity, especially in Kangra and Manali areas of Himachal Pradesh
- Droughtiness is experienced especially in the lower hills due to excessive runoff and coarser soil texture.

16. HOT SUBHUMID (MOIST) TO HUMID (INCLUSION OF PERHUMID) ECOREGION WITH ALLUVIUM-DERIVED SOILS (Q8 C(BA)5)

The agro-ecoregion, comprising the plains of the Brahmaputra and the Ganga Rivers, covers parts of the States of Assam and West Bengal. The region occupies an area of 12.1 m ha, representing 3.7 per cent of the total geographical area of the country. It is divided into 15.1, 15.2, 15.3 and 15.4 ecosubregion (Table 4 and Fig 3).

Agro-Climat: The climate of the area is characterized by hot summer and mild to moderately cool winter. The intensity of precipitation increases in northern and eastern parts of (Bengal basin and Teesta-Brahmaputra Plain) as compared with the southern parts (Ganga Plain). The rainfall in Ganga Plain ranges between 1400 and 1600 mm; in Barak Basin (Tripura Plain) and Teesta-Brahmaputra Plains from 1800 to 2000 mm. The water balance shows that P exceeds PET from June to October followed by a period of utilization till mid-February in most of the years. The SMCS remains partly dry for as long as 90 cumulative days qualifying the area for **udic-ustic** soil moisture regime.

The water balance in Teesta Valley, Barak Brahmaputra Valley and Kushiara Valley (Tripura Plain) indicate that P exceeds PET in most of the months in a year. The SMCS in the area does not remain dry for as long as 90 cumulative days qualifying the area for Udic moisture regime. The LGP, in general, is more than 210 days in a year. The soil moisture and temperature regimes are **udic-ustic** (to **Udic**) and **Hyperthermic**, respectively.

Soils: The soils are represented by level to very gently sloping **Haplaquepts**, **Haplaqualfs**, **Dystrochrepts**, **Eutrochrepts**, **Fluvaquents**, **Hapludalfs**. The soils of

the Jaihing, Kanagarh and Jorhat series, classified as Dystrochrepts, Fluvaquents and Haplaquepts, respectively are slight to strongly acidic and general have low to moderate base saturation.

Land Use: In view of the high rainfall, the rice based cropping system is common in the Brahmaputra, Teesta and Ganga Plains. The rice and jute are main crops grown in rainy season under rainfed condition. In northern foothills of eastern Himalayas, encompassing Teesta and Brahmaputra regions, plantation crops, such as tea and horticultural crops like pineapple, citrus and banana are grown (Fig 5). Rice, jute, pulses, oilseeds (mustard) are grown on stored/residual soil moisture in rabi season. Very recently, considerable areas in Ganga and Teesta Plains have been brought under irrigation to cultivate rice, wheat, and sugarcane during the rabi season. The natural vegetation comprises tropical moist and dry deciduous forests.

Constraints

- Flooding and waterlogging
- Excessive leaching of bases and nutrients, resulting in low base status soils, especially in the Brahmaputra (Assam) Plain.
- Soil acidity (results in plant nutrient fixation, especially P) leads to nutrient imbalances.

17. WARM PERHUMID ECOREGION WITH BROWN AND RED HILL SOILS (C11 A5)

The eastern Himalayan agro-ecoregion encompasses northern hilly parts of West Bengal, northern parts of Assam, Arunachal Pradesh and Sikkim States. It occupies an area of 9.6 m ha, representing 2.9 per cent of the total geographical area of the country. The ecoregion is divided into 16.1, 16.2 and 16.3 ecosubregions (Table 4 and Fig 3).

Agro-Climate: The climate of the region is characterized by warm summer and cool winter. The annual rainfall is 2000 mm. The area experiences short period of water stress during post-rainy period because of seasonal water deficit. The water balance shows the longest LGP (more than 270 days) in a year. The region is classified as **Udic** soil moisture regime. In view of severe heterogeneity of elevations in the region, solar isolation, PET and soil temperature regimes are much variable.

The soil temperature regime at elevation of >1500 m is **Thermic**, and at elevation of >3000 m is **Mesic** (in most of Darjeeling, Sikkim Himalayas and Arunachal Pradesh). The lower elements of topography, like valleys have **Hyperthermic** soil temperature regime.

Soils: The dominant soils in the region vary from shallow to moderately shallow, loamy, Brown Forest to

deep, organic matter rich soils with moderate to low base status. These soils belong to Great Groups of **Haplumbrepts, Dystrochrepts, Hapludalfs, Paleudults, Hapludolls, Argiudolls**, etc. The soils of Germotali series, classified as **Hapludalfs** are moderately acid and have about 50 per cent bases in the exchange complex.

Land use: In general, Jhum cultivation is the traditional farming. It is practiced with mixed cropping on the steep slopes under rainfed condition at an interval of 3-4 years. Another type of traditional practice is the cultivation of millets on upland terraces and potato, maize, millets and paddy in valleys. In the lower valleys, rice, maize, millets, potato, sweet potato, mustard, sesamum and pulses are grown under rainfed as well as irrigated conditions. At places cotton, mesta and sugarcane are also grown both under rainfed and irrigated conditions. In the hilly areas, vegetables and plantation crops like tea, and medicinal plants, and horticultural crops like pineapple, citrus, apple, pear, peach, banana are grown on terraces. The natural vegetation comprises subtropical pine forest and temperate wet evergreen forests, subalpine forest, etc.

Constraints

- Severe climatic conditions restrict the choice of crops.
- Steeply sloping landforms encourage heavy runoff resulting in severe erosion hazards.
- Deforestation for shifting cultivation leads to severe soil degradation problem.
- High rainfall leading to intense leaching results in soils with poor base status.
- Excessive moisture leading to water stagnation in valleys during (post) monsoon period limits the choice of crop.
- Low temperature during post-monsoon period limits the cultivation of second arable crops. Monocropping is therefore commonly practiced in these regions.

18. WARM PERHUMID ECOREGION WITH RED AND LATERITIC SOILS (D2A5)

The north-eastern hills (Purvachal) agro-ecoregion comprises hilly States of Nagaland, Meghalaya, Manipur, Mizoram and southern Tripura. The region covers an area of 10.6 m ha, representing 3.3 per cent of the total geographical area of the country. The agro-ecoregion is divided into 17.1 and 17.2 ecosubregion (Table 4 and Fig 3).

Agro-Climate: The agro-climate of the region is characterized by warm summer and cool winter. The annual precipitation varies from 2000 to 3000 mm which exceeds the PET in most of the months. The moisture index (IM) exceeds 100 per cent suggesting perhumid

ecosystem in the region. The water balance shows that the region experiences only a short water deficit of 100-150 mm during the post-monsoon period. LGP exceeds 270 days in a year. The area represents **Udic** soil moisture regime. The soil temperature regime varies from **Hyperthermic** in valleys to **Thermic** in higher topographic positions.

Soils: The major soil formations in the area include shallow to very deep, loamy, Red and Lateritic and red and Yellow soils. They are classified as **Dystrochrepts**, **Hapludults**, **Paleudults**, **Hapludalfs** and **Rhodustalfs**. At places **Haplumbrepts** and **Hapludolls** are also observed. The soils of **Dialong** series typifying **Hapludalfs** are strongly acidic in reaction and have moderate bases on the exchange complex.

Land use: Jhum cultivation is the traditional farming. Rice is the dominant crop grown in valleys and on hill terraces. Millets, maize and potatoes are cultivated on terraces at higher altitudes, while rice and jute are grown in small under rainfed condition (Fig 5).

Oilseeds (mustard) and pulses (blackgram, greengram, lentil) are cultivated in valleys as post-rainy season crops. Hill terraces are also used for plantation crops, such as, tea, coffee, rubber and horticultural crops, like oranges, pineapple, etc. The natural vegetation comprises wet evergreen and tropical moist deciduous forests.

Constraints

- Deforestation and shifting cultivation result in severe soil erosion hazard.
- Excessive rainfall leading to leaching results in depletion of nutrients rendering soils poor in base status.
- Low temperature in post-rainy period limits the introduction of a wide variety of crops.
- Small to marginal land holdings limit the introduction of modern implements.

19. HOT SUBHUMID TO SEMI-ARID ECOREGION WITH COASTAL ALLUVIUM-DERIVED SOILS ((S7 CD2-5)

The agro-ecoregion comprises the south-eastern coastal plain, extending from Kanyakumari to Gangetic Delta. The region covers an area of 8.5 m ha, representing 2.6 per cent of the total geographical area of the country. It is divided into 18.1, 18.2, 18.3, 18.4 and 18.5 eco subregion (Table 4 and Fig 3).

Agro-Climatic: The Eastern Coast extending from Kanyakumari to Gangetic delta experiences wide range of climate conditions. The coastal parts between Kanyakumari and south of Thanjavur (Tamil Nadu) and between north of Madras and west Godavari (Andhra

Pradesh) receive the rainfall of 900 to 1100 mm, of which about 80 per cent in October to December. The PET in this area varies between 1700 to 1800 mm. The annual deficit of water is 800 to 1000 mm. The LGP ranges from 90 to 150 days. This area represents semi-arid climatic conditions.

The remaining part of eastern coast, that lies between Nagapattinam and Madras (Tamil Nadu) and extending to north-western part of coastal strip, including parts of north-western Godavari (Andhra Pradesh), Orissa and West Bengal, receives 1200 to 1600 mm of rainfall of which 80 percent is received as during June to Sept. The PET varies between 1400 to 1700 mm. The annual deficit of water is 600 to 800 mm. The LGP is much higher than the southern parts and varies from 150 to 210 days or more in a year. The area represents a subhumid (moist) climatic type.

The mean annual soil temperature is higher than 22°C and the difference between mean summer and mean winter soil temperatures is less than 5°C. Therefore, the soil temperature regime is **Isohyperthermic**. Hence, the bio-climatic variations in the ecosystem extend from semi-arid to subhumid, and the length of growing period ranges from 90 to 210 days. The region has been grouped in one agro-ecosystem because of maritime climatic influences and limited area.

Soils: The soils of **Haplaquepts**, **Halaquepts**, **Ustifluvents**, **Pellusterts** occur on level to very gently sloping topography and **Ustropepts**. Motto (**Haplaquepts**) and Kalathur (**Pellusterts**) series are slight to moderately sodic. Both are clayey in nature but have marked differences in their cation exchange capacity, suggesting differences in clay mineralogy. The Kalathur soils have high swell-shrink potential.

Land Use: Both rainfed and irrigated agriculture are practiced in the region. The lead crop cultivated in the area, both in kharif and rabi season, is rice. Coconut is a dominant plantation crop of the region. In some parts, pulses, such as blackgram and lentil, and oilseed crops, such as sunflower and groundnut are cultivated after rice (on residual moisture) (Fig 5). Besides agriculture, raising of coastal and brackish water fisheries are important economic activities of the coastal people.

Constraints

- Imperfect to poor drainage conditions and limiting oxygen availability adversely affect crop yield.
- Soil salinity (and sodicity at places) resulting from poor drainage conditions adversely affect crop production.
- The area is prone to cyclone during monsoon and retreating monsoon periods.

20. HOT HUMID PERHUMID ECOREGION WITH RED, LATERITIC AND ALLUVIUM-DERIVED SOILS (E2 B/A5)

The agro-ecoregion comprises Sahayadris, western coastal plains of Maharashtra, Karnataka and Kerala States, including Nilgiri hills of Tamil Nadu. The region occupies an area of 11.1 m ha, representing 3.6 per cent of the total geographical area of the country. It is divided into 19.1, 19.2 and 19.3 eco subregions (Table 4 and Fig 3).

Agro-Climate: The climate is characterized by hot and humid summer and warm winter. The mean annual temperature varies between 25°C and 28°C. The mean summer and winter soil temperatures differ by less than 5°C. The mean annual rainfall exceeds 2000 mm in most of the areas. The water balance shows that rainfall exceeds PET demand (1400-1600 mm) in most of the months, except seasonal deficit of 300 to 400 mm during February to mid-April. The region is represented by a longer LGP ranging between 150 and 210 days. At places it exceeds 210 days in a year. The soils of the area qualify for **Udic** moisture and **Isohyperthermic** temperature regimes.

Soils: The major soils of the region include Red and Laterite Soils along the leeward flank of Sahyadris and the alluvium-derived soils in the coastal plains. These soils belong to the great groups of **Dystropepts**, **Eutropepts**, **Hapludults**, **Haplaquepts** with localized **Haplorthox** as per Soil Taxonomy of 1975.

The soils of Trivandrum and Kunnamangalam series, typifying **Dystropepts** and **Haplorthox** are very deep, clayey, strongly to moderately acidic in nature and poor in base saturation. Because of the dominance of Kaolinite (1:1 type) clay mineral, the soils are low in retentive capacity, suggesting poor inherent fertility.

Land Use: The area is intensively cultivated for rice, tapioca, coconut and spices. The natural vegetation comprises tropical moist deciduous forests.

Constraints

- Excessive leaching that leads to depletion of plant nutrients and bases.
- Waterlogging, resulting from imperfect drainage conditions affects crop growth in the coastal plains.
- Steep slopes, causing runoff, leads to severe soil erosion.
- Inundation of land area results in localised saline marshes.

21. HOT HUMID PER HUMID ISLAND ECOREGION WITH RED LOAMY AND SANDY SOILS (T1 A/B5 & T1 B/A5)

The agro-ecoregion comprises the group of islands of Andaman and Nicobar in the east and that of

Lakshadweep in the west. The region covers an area of 0.8 m ha, representing 0.3 per cent of the total geographical area of the country. It is divided into 20.1 and 20.2 ecosubregions (Table 4 and Fig 3).

Agro-Climate: The climate is typified by tropical conditions with little difference between mean summer and mean winter temperatures. The annual rainfall of these two far-seated areas varies from 1600 to 3000 mm. The Lakshadweep Islands receiving 1600 mm rainfall representing humid climate, and the Andaman-Nicobar group of Islands receiving 3000 mm rainfall representing perhumid climate. The rainfall covers the entire annual PET demands, except for small seasonal water deficit of 300-400 mm during the post-monsoon period (January to March). However, real deficit is realized only for a short period during February and March. The LGP is more than 210 days which is long enough to support double cropping system and plantation crops grown in the area. The area experiences **Udic** soil moisture and **Isohyperthermic** soil temperature regime.

Soils: The soils of the Andaman and Nicobar Islands (in the East) greatly differ from those of Lakshadweep Islands (in the West). The former show medium to very deep, Red loamy soils including marine alluvium-derived soils along the coast. They qualify for the Great Groups of **Hapludalfs**, **Dystropepts**, **Eutropepts** and **Sulfaquents** (along the coast). The soils have low to medium AWC. The soils of Lakshadweep Group of Islands, on the other hand, are highly calcareous and sandy in nature (**Udipsamments**). In spite of significant soil differences, the two islands have been maintained in one region in view of other agro-climatic considerations. The soils of Ahargaon, Dhanikhari and Garacharma series typify the dominant soils observed in the Andaman and Nicobar Islands. These are slightly to strongly acidic in nature and are moderate to low (40-70%) in base saturation.

Land Use: The natural vegetation comprises tropical rain (evergreen) and littoral and swamp forests. About 2/3 of the Andaman is under native forest and agriculture is confined only to specific areas around habitations, where the dominant crop grown is rice. In general, the land use is dominated by plantation crops, such as coconut, arecanut, oilpalm with or without intercultivation of pineapple, tapioca and pepper.

In Lakshadweep, rice is mainly grown under lowland conditions. Coconut is the main plantation crop with high yield. Besides agriculture, marine fishery is an important means of subsistence for the people.

Constraints

- Degradation of the tropical rain-forest ecosystem leads to severe soil erosion hazard. With the clearing

of rain forests, the ecosystem is disturbed resulting in severe soil erosion. Simultaneously economic interest to protect tropical rain-forest demands introduction of sustainable plantation crops (oilpalm) by using technology, which may ensure maintaining the ecosystem. It may demand deforestation in strips

followed by plantation of oilpalm to provide protection against erosion.

- Inundation of coastal areas leads to saline marshes and consequently formation of acid sulphate soils.
- Gradual increase in areas under mangroves suggests increase in degradation of the coastal areas.

Table 4. Location and characteristics of different subregions with major soil groups (Velayutham *et al.* 1999)

Agro-ecosub-region/region	Area m ha LGP (days)	Breif Description	Distribution States/Districts	Major Soil Groups	Rainfall (PET mm) [Mean Temp. (°C)]
1	2	3	4	5	6
1.1 A13Eh1	6.4 (<60)	Western Himalayas (Ladhakh Plateau), cold arid ecosystem with shallow skeletal soils and GP less than 60 days	J&K: Ladhak (Leh)	Cryorthents, Cryorthids	100-150 (700-800) 9-11°C
1.2 A13Et2	8.8 (60-90)	Western Himalayas (Western Aspect Ladakh Plateau), cold arid ecosystem with shallow skeletal soils and LGP 60-90 days	J&K: Ladhak, Gilgit; HP: Lahul & Spiti valleys	Cryorthents, Cryorthids	300-800 (700-800) 2-8°C
2.1 M9Eh1	12.3 (<60)	Western Plain, hot arid ecosystem with desert soils and GP less than 60 days	Rajasthan: Bikaner, Jaisalmer, Barmer, Jodhpur (50%) and Ganganagar Punjab: Faridkot	Torripsamments, Calciorthids, Camborthids	100-300 (1700-2000) 25-28°C
2.2 L12Eh1	2.0 (<60)	Kachchh Peninsula, hot arid ecosystem with saline and alkali soils and LGP less than 60 days	Gujarat: Lakhpat, Banni Great Rann of Kutch	Salorthids, Natrargids, Camborthids, Torripsamments	<300 (1800-1900) 25-27°C
2.3 M9Et2	11.5 (60-90)	Western plain (Rajasthan Bagar, Punjab and Haryana Plains), hot arid ecosystem with desert soils and GP 60-90 days	Punjab: Bathinda, Firozpur and Faridkot Haryana: Sirsa, Hissar, Bhiwandi* Mahendragarh (Narnaul) Rajasthan: Churu, Jhun- jhunun, Sirohi, Jalore, Eastern half of Jodhpur and Ganganagar Gujarat: Bansaskantha (Palanpur)	Camborthids, Calciorthids, Torripsamments Natrargids, Salorthids	<300-450 (1800-1900) 24-27°C
2.4 L12Et2	6.1 (60-90)	Kachchha and Kathiawar Peninsula, hot arid ecosystem with saline-alkali soils, and GP 60-90 days	Gujarat: Bhuj including Rapar, Adesar, Anjar, Kandla talukas, Northern part of Jamnagar district	Camborthids, calciorthids, Natrargids, Halaquepts	400-500 (1800-1900) 26-27°C
3 K6Et2	(4.9)	Deccan (Karnataka) Plateau, hot arid ecosystem with mixed Red and Black soils and GP 60-90 days	Karnataka: Bellary and Southern Raichur, Bijapur, Northern Chitradurga and Tumkur AP: Anantpur	Rhodustalfs Haplustalfs Paleusterts Chromusterts Ustrophepts	400.500 (1800-1900) 27-28°C

(Table 4 contd . . .)

(Table 4 contd . . .)

1	2	3	4	5	6
4.1 N8Dd3	11.8 (90-120)	Northern (Punjab) Plain, (Ganga Yamuna Doab and East Rajasthan Upland), hot semi-arid ecosystem with alluvium-derived soils and GP 90-120 days.	Punjab: Amritsar, Kapurthala, Northern Ferozpur and Faridkot, Sangrur, Ludhiana (Western), Patiala (Southern) U.P.: (W.Part), Ghaziabad, Bulandshahr, Aligarh, Mathura, Etah, Agra, Mainpuri, Moradabad (S.Part) Rajasthan: Alwar, Bharatpur, Jaipur, Sawai-Madhopur, Dhaulpur	Ustochrept, Ustipsamments, Haplustalfs, Natrustalfs	600-800 (1400-1800) 25-26°C
4.2 P14Dd3	7.6 (90-120)	Gujarat Plain (Aravalli range, East Rajasthan Upland and West Gujarat Plain), hot semi-arid ecosystem with Grey brown and alluvium-derived soils and GP 90-120 days	Rajasthan: Ajmer, Tonk, Bhilwara, Udaipur , Dungarpur Gujarat: Sabarkantha (Himmatnagar) Mehsana, Ahmedabad , Surendranagar, part of Bhuj (Radhanpur)	Ustorthents, Ustochrepts, Fluventic Ustochrepts	500-850 (1400-1700) 25-27°C
4.3 N8Dm4	6.9 (120-150)	Northern Plain (Ganga Yamuna doab, Rohitkhand and Avadh plain) hot semi-arid ecosystem with alluvium-derived soils and GP 120-150 days	U.P.: Bandaun, Shajahanpur (S.Part) Fatehgarh, (Farukkabad), Hardoi, Unnao, Etawah, Kanpur , Orai, Jalaun), Rai Bareilly, Fatehpur, Bela (Pratapgarh), Jaunpur, Allahabad, Western part of Varanasi , M.P.: Bhind	Ustochrepts, Ustorthents, Halaquepts, Natrustalfs	700-900 (1400-1600) 24-25°C
4.4 I6Dm4	5.9 (120-150)	Central Highlands (Madhya Bharat and Bundelkhand Uplands), hot semi-arid ecosystem with mixed Red and Black soils and GP 120-150 days	M.P.: Morena, Gwalior, Datia, Shivpuri U.P.: Lalitpur	Ustochrepts, Chromusterts, Ustorthents	800-1000 (1400-1600) 24-25°C
5.1 L4Dd3	2.7 (90-120)	Kathiawar Peninsula, hot semi-arid ecosystem with deep black soils (shallow and medium black soils as inclusion and GP 90-120 days)	Gujarat: Northern part of Junagadh, Amreli, Rajkot and Western part of Bhavnagar	Ustorthents, Ustochrepts, Chromusterts, Salorthids	600-700 (1700-2000) 24-25°C
5.2 I5Dm4	14.0 (120-150)	Central Highlands (Madhya Bharat Plateau, W. Malwa Plateau, E. Gujarat Plain, Vindyan range, Narmada Valley, Satpura range hot semi-arid ecosystem with deep Black soils (shallow and medium black soils as inclusions) and GP 120-150 days.	Rajasthan: Bundi, Chittourgarh , Banswara , Kota , Jhalawar M.P.: Ujjain, Ratlam, Jhabua, Indore, Dhar, Dewas, Khandwa (East Nimar), Khargone (West Nimar), Mandasaur Gujarat: Panch Mahal (Godhra), Kheda, Vadodara , Bharuch, Surat (N. Part)	Ustochrepts, Chromusterts, Pellusterts	800-1000 (1500-1800) 24-25°C
5.3 I7Dm4	0.9 (120-150)	Kathiawar Peninsular (coast), hot semi-arid ecosystem with deltaic alluvium-derived soils and GP 120-150 days	Gujarat: Coastal parts of Junagadh, Amreli and Bhavnagar, Diu (Daman & Diu)	Halaquepts, Haplaquepts, Ustrophepts, Chromusterts	500-800 (1800-1900) 26-27°C

(Table 4 contd . . .)

(Table 4 contd . . .)

1	2	3	4	5	6
6.1 K4Dd3	7.6 (90-120)	Deccan (Western Maharashtra), Plateau, hot semi-arid ecosystem with Black soils medium and deep Black soils as inclusion) and GP 90-120 days	Maharashtra: Eastern half of Pune, Satara and Sangli, Solapur, Osmanabad, Bid, Ahmadnagar Karnataka: Bijapur (N. Part), Raichur and Dharwad (E. Part)	Ustorthents, Ustrophepts, Chromusterts	600-750 (1500-1800) 26-27°C
6.2 K4Dd4	12.6 (120-150)	Deccan (W. Maharashtra), Northern Karnataka Plateau), hot semiarid ecosystem with shallow Black soils (deep and medium Black soils as inclusion) and GP 120-150 days	Maharashtra: Dhule, Nasik, Jalgaon (W. Part), Aurangabad, Northern hilly part of Ahmadnagar, Jalna, Parbhani, Nanded, Latur	Ustorthents, Ustrophepts, Chromusterts	700-1000 (1700-1900) 26-27°C
6.3 K5Dm4	5.4 (120-150)	Deccan (NW. Maharashtra) Plateau, hot semi-arid ecosystem with deep Black soils (shallow and medium black soils as inclusion) and GP 120-150 days	Maharashtra: Jabalpur (E. Part), Buldhana, Akola, Amravati, Yavatmal	Ustorthents, Chromusterts, Ustochrepts	800-1100 (1600-1800) 26-27°C
6.4 K4Cd5	5.4 (150-180)	Deccan (W. Maharashtra and Karnataka), Plateau, hot dry subhumid ecosystem with shallow black soils (medium and deep black soils as inclusions) and GP 150-180 days	Maharashtra: Western parts of Pune, Satara and Sangli, Kolhapur (E. Part) Karnataka: Belgam, Dharwar , Eastern part of Uttar Kannad (Karwar), Gadag	Ustorthents, Ustrophepts, Chromusterts, Pellusterts	(1600-1700) 1100-1200 24- 25°C
7.1 K6Dd3	3.9 (90-120)	Deccan (Telengana) Eastern Ghat) Plateau hot semi-arid ecosystem with mixed red and black soils and GP 90-120 days and GP 90-120 days	A.P.: Cuddapah, Kurnool Maharashtra: Satara and Sangli, Solapur, Osmanabad, Bid, Ahmadnagar	Ustorthents, Rhodustalfs, Ustrophepts, Chromusterts, Pellusterts	700-750 (1800-1900) 28-29°C
7.2 K6Dm4	9.2 (120-150)	Deccan (Telengana, Plateau, hot semi-arid ecosystem with mixed red and black soils and GP 120-150 days and GP 90-120 days	A.P.: Karimnagar, Rangareddi , Hyderabad, Warangal , Khammam, Mahboobnagar, Nalgonda , Sangareddi, Medak	Rhodustalfs, Haplustalfs, Pellusterts, Ustrophepts, Chromusterts, Pellusterts	700-1000 (1600-1800) 25-29°C
7.3 H6Dm/Cd5	3.4 (150-180)	Eastern Ghat, hot, moist semi-arid dry subhumid ecosystem with mixed red and black soils and GP 150-180 days and GP	A.P.: Western parts (highlands) of Eluru (W. Godavari and Krishna (machillipatnam) Guntur and Ongole (Prakasam) and Nellore (NE parts)	Haplustalf, Ustrophepts, Chromustert, Pellustert, Rhodustalfs	800-1000 (1500-1800) 24-25°C
8.1 H6Dd3	3.7 (90-120)	Eastern Ghat (TN uplands and SE Sahyadris), hot semi-arid ecosystem with mixed red and black soils and GP 90-120 days	T.N.: Coimbatore , Anna (Dindigul), Madurai, Kamrajar (Virudunagar), Tirunelveli, Kanyakumari (Non-Coastal part)	Chromusterts, Pellusterts, Haplustalfs, Ustrophepts, Ustorthents, Ustifluvents	800-1100 (1500-1800) 28-29°C
8.2 K1Dm4	6.5 (120-150)	Deccan (Karnataka) Plateau, hot semi-arid ecosystem with red loamy soils and GP 120-150 days	Karnataka: Eastern part of Shimoga and Chikmangalur, Hassan, Mysore, Mandya, Bangalore, Chitradurga (S. Part), Kolar, Tumkur	Haplustalfs, Rhodustalfs, Pellusterts, Chromusterts, Ustrophepts	600-900 (1600-1800) 26-29°C

(Table 4 contd . . .)

(Table 4 contd . . .)

1	2	3	4	5	6
8.3 H1Dm4	8.9 (120-150)	Eastern Ghat (T.N. Uplands), hot semi-arid ecosystem with Red Loamy soils and GP 120-150 days	A.P.: Chittoor T.N.: North Arcot (Vellore), Dharamapuri, Salem, Arcot (Cuddalore), Chengalpattu (Kanchipuram), Periyar (Erode), Tiruchhirapalli, Pudukottai and Tuticorin (Non-Coastal plains and Uplands)	Haplustalfs, Rhodustalfs, Pellusterts, Ustropepts, Ustorthents, Chrmusterts	550-1000 (1400-1600) 23-25°C
9.1 N8Cd/cm4	3.9 (120-150)	Northern Plain (Punjab and Rohilkhand Plains), hot dry subhumid ecosystem with alluvium-derived soils and GP 120-150 days	Punjab: Southern part of Gurdaspur, Hoshiarpur, Jalandhar, Rupnagar, Northern part of Ludhiana and Patiala Union Territory of Chandigarh Haryana: Ambala U.P.: Saharanpur, Bijnor , Moradabad (N. Part), Eastern part of Muzaffarnagar	Haplustalfs, Rhodustalfs, Pellustalfs, Ustorthents	700-1000 (1700-2000) 28-29°C
9.2 N8Cd5	8.3 (150-180)	Northern (Rohilkhand Plain, Avadh Plain and S. Bihar Plain), hot dry subhumid ecosystem with alluvium-derived soils and GP 150-180 days	U.P.: Rampur, Bareilly, Pilibhit, Northern part of Shajahanpur, Southern part of Lakhimpur (Kheri), Sitapur, Lucknow, Barabanki, Faizabad, Sultanpur, Azamgarh, Balia, Ghazipur, Eastern part of Varanasi Bihar: Bhojpur (Ara), Rohtas (Sasaram), Jahanabad, Patna, Bihar-Sariff (Nalanda), Aurangabad, Gaya, Nawada	Ustochrepts, Ustifluvents, Natrustalfs	700-1000 (1300-1500) 24-26°C
10.1 I5Cd5	8.1 (150-180)	Central Highlands (Malwa Plateau, Bundelkhand uplands) hot dry subhumid ecosystem with deep black soils (shallow and medium black soils as inclusion) and GP 150-180 days	M.P.: Guna, Sagar, Bhopal , Damoh , Vidisha , Rajgarh, Shajapur, Sehore , Raisen , Western parts of Jabalpur , Narsimpur and Hoshangabad	Ustochrepts, Halaquepts, Natrustalfs, Haplustalfs, Ochraqualfs, Haplaquepts, Ustorthents	1000-1200 (1300-1500) 25-26°C
10.2 K5Cd5	2.8 (150-180)	Deccan (Satpura) Plateau, hot dry subhumid ecosystem with deep black soils (shallow and medium deep black soils as inclusion) and GP 150-180 days, parts of Jabalpur, Narsimpur	M.P.: Betul Maharashtra: Wardha, Nagpur	Ustochrepts, Chromusterts, Ustorthents, Rhodustalfs, Haplustalfs	1000-1500 (1400-1600) 24-26°C
10.3 I6Cd5	5.8 (150-180)	Central Highlands (Vindhyan Scarpland and Bundelkhand Upland), hot dry subhumid eco-system with mixed Red and Black soils and GP 150-180 days	M.P.: Tikamgarh, Chhatarpur, Panna, Satna, Rewa , Sidhi, Shahdol	Ustorthents, Ustochrepts, Chromusterts, Haplustalfs, Rhodustalfs	1000-1200 (1300-1500) 25-26°C

(Table 4 contd . . .)

(Table 4 contd . . .)

1	2	3	4	5	6
10.4 K6Cm6	5.6 (180-210)	Deccan (Satpura range and Maharashtra) Plateau, hot moist subhumid ecosystem with Red and Black soils and GP 180-210 days	M.P.: Chhindwara, Seoni, Mandla, Balaghat, Eastern parts of Jabalpur, Narsimpur and Hoshangabad Maharashtra: Bhandara	Ustochrepts, Chromusterts, Ustorthents, Haplustalfs, Paleustalfs Plinthustalfs	1000-1200 (1400-1500) 25-26°C
11 J3(Cd/Cm)5	14.1 150-180	Eastern (Baghelkhand and Chhotanagpur) Plateau, hot dry and moist subhumid ecosystem with Red and Yellow soils and GP 150-180 days	U.P.: Mirzapur Bihar: Palamu (Daltonganj), Hazaribag, Gumla, Lohardaga M.P.: Ambikapur, Bilaspur, Raigarh, Raipur, Rajnangaon, Durg	Ustorthents, Ustochrepts, Haplustalfs, Rhodustalfs	1100-1500 (1400-1600) 24-25°C
12.1 J2Cm6	17.6 (180-210)	Eastern (Gujarat Hills, Dandakaranya) Plateau, hot moist subhumid ecosystem with Red and Lateritic soils and GP 180-210 days.	Maharashtra: Chandrapur, Gadchiroli M.P.: Bastar (Jagdalpur) Orissa: Koraput, Kalahandi (Bhiwanipatna), Phulbani, Bolangir, Sambalpur, Sundergarh, Dhenkanal, Mayurbhanj (Baripada)	Ustochrepts, Ustorthents, Haplustalfs, Rhodustalfs, Chromusterts, Haplaquept, Plinthustalfs	1200-1600 (1400-1600) 25-28°C
12.2 H2Cm6	(3.3) 180-210	Eastern Ghat, hot moist subhumid ecosystem with Red and Lateritic soils and GP 180-210 days	A.P.: Western highlands of Vishakhapatnam, Vizianagram Orissa: Western highlands of Ganjam (Chhatrapur), Puri (Bhubaneswar), Cuttack and Baleshwar (Non-Coastal part)	Haplustalfs, Ustochrepts, Haplaquepts, Ustifluvents, Plinthustalfs, Rhodustalfs, Haplustalfs, Ustorthents, Chromusterts	1400-1700 (1400-1600) 26-27°C
12.3 J2Cd5	5.6 (150-180)	Eastern (Chhotanagpur) Plateau and Gujarat Hills hot dry subhumid ecosystem with Red and Lateritic soils and GP 150-180 days	Bihar: Dumka, Devghar, Giridih, Dhanbad, Ranchi, Singhbhum (Chaibasa) West Bengal: Western parts of Birbhum, Bankura, Bardhaman and Medinipur (Siuri, Simlapal, Asansol, Jhargram subdivision, respectively), Puruliya Orissa: Kendujhargarh (Kendujhira)	Ustorthents, Haplustalfs, Rhodustalfs, Haplustulfs, Haplaquepts, Ustochrepts, Ochraqualf	(1400-1600) 25-27°C 1200-1600
13.1 O8Cd (cm)6	9.9 (180-210)	Eastern (North Bihar and Avadh) Plain, hot dry to moist subhumid ecosystem with alluvium-derived soils and GP 180-210 days	U.P.: Bahraich, Gonda, Gorakhpur and Deoria Bihar: Paschim Champaran (Bettiah) Purab Champaran (Motihari), Gopalganj, Siwan, Sitamari, Muzaffarpur, Chhapra (Saran), Madhubani, Darbhanga, Samastipur, Saharsa, Begusarai, Munger, Khagaria, Sahibganj, Bhagalpur, Katihar, Madhepura, Purnia, Hazipur, Godda	Paleustalfs, Haplustalfs, Ustorthents, Ustochrepts, Haplaquepts, Haplaquents, Udifluvents, Pssamaquents	1200-1500 (1400-1600) 25-26°C

(Table 4 contd . . .)

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1	2	3	4	5	6
13.2 B10Cm6	1.2 (180-210)	Central Himalayas, Warm to hot moist subhumid ecosystem with Tarai soils and GP 180-210 days	U.P.: Foothills in Kheri and Bahraich, Pilibhit, Gonda , Basti, Gorakhpur	Ustifluvents, Ustochrepts, Haplustalfs, Hapludalfs, Haplaquolls, Utochrepts	1200-1500 (1400-1700) 24-25°C
14.1	A15Dm (Cd)3 (6.0) 90-120	Western (Kashmir) Himalayas, warm semi-arid to dry humid ecosystem with skeletal soils and GP 90-120 days	J&K: Tribal Territory, Chilas, Gilgitwazarat, Srinagar (N. Part), Udampur (N. Part), Baramulla (N. Part) H.P.: Northern parts of Chamba, Kullu, major southern part of Lahul and Spiti (Keylong), Kalpa (Kinnaur)	Hapludolls, Haplaquepts, Fluvaquents, Udifluvents, Eutrochrepts, Haplustalfs, Udorthents	1400-1500 (1400-1600) 20-24°C
14.2 A15Cd (cm)6	12.7 (180-210)	South Kashmir & Kumaun Himalayas, warm to hot dry to moist subhumid ecosystem with Brown Forest and Podzolic Soils and GP 180-210 days	J&K: Muzaffarabad, Baramulla (S. Part), Punch, Mirpur, Srinagar (S. Part), Anantnag, Riiasi , Jammu, Udampur (S. Part), Kathua Punjab: Northern wedge (Siwalik foothills) of Gurdaspur and Hoshiarpur H.P.: Southern part of Chamba, Una (Hamirpur), Solan, Bilaspur, Nahan, Kullu (S. Part), Dharamshala (S. Part) U.P.: Dehradun (S. Part), Southern part of Narendranagar (Tehri Garhwal), Gopeshwar (Chamoli), Almora, Pithoragarh	Eutrochrepts, Ustorthents, Hapludalfs, Hapludolls, Argiudolls, Udifluvents, Haplaquepts	500-600 (800-900) 8-10°C
14.3 A15 (B/A)9	1.0 (270-300)	Punjab Himalayas, warm humid and perhumid ecosystem with brown forest and Podzolic soils and GP 270-300* days	H.P.: Dharamsala, Mandi, Shimla, Bilaspur	Hapludalfs, Eutrochrepts, Udorthents, Dystochrepts	600-1300 (800-1000) 15-20°C
14.4 A3 (B/A)9	0.5 (270-300)	Kumaun Himalayas, warm perhumid to perhumid ecosystem with red and yellow soils and GP 270-300 days	U.P.: Dehradun (N. Part), Uttar Kashi (S. Part), Tehri Garhwal (N. Part)	Ustorthents, Udorthents, Eutrochrepts, Dystochrepts, Hapludalfs	2000-2500 (800-1000) 3-30°C
14.5 A10B (A)9	0.9 (210-240)	Foothills of Kumaun Himalayas (subdued), warm perhumid/perhumid ecosystem with Tarai soils and GP270-300 days	U.P.: Pauri Garhwal, Nainital	Hapludolls, Eutrochrepts	2000-2600 (800-1000) 14-15°C
15.1 08Cm7	5.2 (210-240)	Eastern plain (Ganga Plain) hot moist subhumid ecosystem with alluvium-derived soils and GP 210-240 days	West Bengal: West Dinajpur (Balurghat), Maldah, Murshidabad (Behrampur), Krishnanagar, Hoogli, North 24-Parganas, Howrah Calcutta: Eastern parts of Medinipur, Bankura, Bardhaman and Birbhum	Ustochrepts, Eutrochrepts, Ochraqualfs, Haplaquepts, Ustifluvents, Haplustalfs, Dystochrept, Udifluvents	1300-1600 (1400-1600) 25-26°C

(Table 4 contd . . .)

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1	2	3	4	5	6
15.2 Q8B8	3.2 240-270	Bramhaputra plain, hot humid ecosystem with alluvium-derived soils and GP 240-270 days	Assam: Barpeta, Kamrup, Nalbari (S. Part), Darrang (Mangaldoi), Sonipur (Tezpur), Nagaur	Haplustalfs, Ustochrepts, Ustorthents, Udifluvents, Udipsammments, Haplaquepts	1600-2000 (1400-1600) 24-26°C
15.3 Q8A9	1.4 (270-300)	Assam and Bengal Plain (Teesta Valley and Barak valley), hot perhumid ecosystem with alluvium derived soils and GP 270-300 days	West Bengal: Jalpaiguri (Plain), Koch Bihar Assam: Goalpara, Dhubri, Kokrajhar (Plain), Silchar, Karimgunj Tripura: Northern part of Dharmanagar	Haplaquepts, Udifluvents, Hapludalfs, Fluvaquents	2000-3200 (1400-1600) 24-25°C
15.4 Q8A10	2.3 (>300)	Assam and Bengal Plain (Upper Bramhaputra Valley), warm to hot perhumid ecosystem with alluvium-derived soils and GP >300 days	Assam: Jorhat, Golaghat, Sibsagar, Dibrugarh, Northern plain of Kabir Anglong, Northern Lakhimpur	Dystochrept, Kandihumult, Haplohumults, Hapludalfs, Fluvaquents, Haplaquepts	2500-3000 (1400-1600) 23-24°C
16.1 C10A9	0.3 (>300)	Eastern Himalayas, warm perhumid ecosystem with Tarai soils and GP >300 days	West Bengal: Foothills of Siliguri and Jalpaiguri Assam: Foothills of Kokrajhar, Barpeta, Nalbari and Darrang (Mangaldoi)	Umbrepts, Dystochrepts, Udorthents	2600-3000 (800-1000) 23-24°C
16.2 C11A10	1.1 (>300)	Eastern Himalayas (Darjeeling & Sikkim), Sikkim, warm perhumid ecosystem with Brown and Red hill and Podzolic soils and GP more than 300 days	West Bengal: Darjiling (subdivision of Darjeeling district) Sikkim: North, South, East and West Sikkim	Udorthents, Dystochrepts, Haplumbrepts, Eutrochrepts	2500-3000 (800-900) 13-15°C
16.3 C1A10	8.2 (>300)	Eastern Himalayas (Arunachal Pradesh), warm to hot perhumid ecosystem with Red loamy soils and GP more than 300 days	Arunachal Pradesh: Bomdila (W. Kameng), Seppa (East Kameng), Lower Subansiri (Zirol, Upper Subansiri (Daporijo), W. Siang (Along), E. Siang (Pasighat), Dibang Valley (Anini), Lohit (Tezu)	Udorthents, Hapludalfs, Dystochrepts, Paleudalfs, Haplumbrepts	>3000 (800-1000) 15-25°C
17.1 D2A9	5.1 270-300	Eastern range (Meghalaya Plateau and Nagaland hill), warm to hot perhumid ecosystem with red and lateritic soils and GP 270-300 days.	Meghalaya: W. Garo hills (Tura), E. Garo hills, E. Khasi hill (Shillong), Nongstain, Jowai Assam: N. Cachchar (Haflong), Karbi-Anglong (Diphu) Nagaland: Kohima, Phek, Zunhebphoto, Eastern part of Wokha Mokakchung, Thensung, Mon. Arunachal Pradesh: Tirup (Khonsa)	Dystochrepts, Hapludults, Hapludalfs, paleudalfs, Paleudults, Hapludolls	>2500 (1400-1600) 16-24°C

(Table 4 contd . . .)

(Table 4 contd . . .)

1	2	3	4	5	6
17.2 D3A10	5.5 (>300)	Eastern range (Purvachal), warm to hot perhumid ecosystem with Red and Yellow soils and GP more than 300 days	Manipur: Senapati (Karong), Ukhrul, Imphal, Churachandpur, Tamenglog, Thoubal (Chandel) Mizoram: Aizwal, Lunglie, Lawngtlai Tripura: W. Agartala, Dharmanagar (N. Part), Udaipur (S. Part)	Dystrochrept, Hapludalfs, Hapludults, Paleudalfs	>3000 (1400-1600) 16-25°C
18.1 S7Dd3	0.5 (90-120)	East (TN) Coastal Plain, hot semi-arid ecosystem with coastal and deltaic alluvium-derived soils and GP 90-120 days	T.N.: Coastal plains of Pudukkottai, Ramnathapuram, Tuticorin, Tirunelveli and Kanniyakumari	Haplustalfs, Rhodustalfs, Ustorthents, Ustifluvents, Ustipsamments, Chromusterts, Ustrophepts	900-1000 (1800-1900) 27-28°C
18.2 S7Dm4	1.6 (120-150)	East Coastal (TN) Plain, hot moist semiarid ecosystem with Coastal and deltaic alluvium-derived soils and GP 120-150 days.	T.N.: Madras, Coastal plain of chengal Pattu, Cuddalore, Thanjavur, Karaikal and Pondicherry (U.T.)	Ustrophepts, Chromusterts, Paleusterts, Ustifluvents, Ustipsamments	1200-1400 (1600-1800) 28-29°C
18.3 S7Cd5	2.0 150-180	Eastern Coastal (Andhra) Plain, hot dry subhumid ecosystem with coastal and deltaic alluvium-derived soils and GP 150-180 days	A.P.: Coastal plain of W. Godavari, Krishna and Guntur, Prakasham and Nellore	Ustifluvents, Ustrophepts, Chromusterts, Paleusterts, Rhodustalfs, Ustorthents, Haplustalfs	900-1100 (1700-1800) 28-29°C
18.4 S7Dd6	3.2 (180-210)	Eastern Coastal (Utkal) Plain, hot dry subhumid ecosystem with coastal and deltaic alluvium- derived soils and GP 180-210 days	A.P.: Srikakulam, Coastal plains of E. Godavari (Kakinada) Vishakhapatnam, Vizianagaram Orissa: Coastal plain of Ganjam, Puri and Cuttack	Halaquepts, Fluvaquents, Haplaquepts, Ustifluvents, Ustochrepts, Haplustalf, Chromusterts	1200-1500 (1600-1700) 26-27°C
18.5 S7Cm8	1.2 (240-270)	Eastern Coastal (Ganga) Plain, hot moist subhumid ecosystem with Coastal and deltaic alluvium-derived soils with GP 240-270 days	Orissa: Coastal plain of Baleshwar West Bengal: Coastal plains of Medinipur (Contai subdivision) and South 24-Parganas (including Sundarban) Sagar Island	Halaquepts, Fluvaquents, Haplaquepts, Eutrochrepts, Ochraqualfs, Tropaquepts	1600-1800 (1400-1600) 26-27°C
19.1 E6B6	2.2 180-210	Western Ghat (Sahyadris) hot humid ecosystem with mixed red and black soils and GP 180-210 days with GP 90-120 days	Gujarat: Southern part of Surat, Dang, Valsad, Daman (Daman & Diu), and U.T. of Dadra Nagar Haveli Maharashtra: Thane, Bombay, Alibagh (Kulaba)	Ustorthents, Ustrophepts, Chromusterts, Halaquepts, Fluvaquents, Ustipsamments	1600-2000 (1400-1600) 27-28°C

(Table 4 contd . . .)

(Table 4 concluded)

1	2	3	4	5	6
19.2 E2Cm (B)7(8)	6.9 (210-270)	Western Ghat (Sahyadris) hot, moist subhumid to humid and per humid ecosystem with red and lateritic soils and GP 210-270 days	Maharashtra: Ratnagiri, Sindhudurg, Dang, Hilly parts of Kolhapur Goa: Panaji Karnataka: Western parts of Uttar Kannad (Karwar), Shimoga and Dakshin Kannad (Mangalore), Western parts of Chikmangalore and Kadagul (Madikari) Kerala: Cannanore (Hilly part), Wayanad (Kottapadi), uplands of Kozhikode (Calicut), Highlands of Malappuram, Palghat and Ernakulam, Kottayam, Pattanamtitta , Quilon and Trivandrum, Idukki T.N.: Udagamandalam (Nilgiri), Uplands of Trichur	HaplustalFs, Ustrophepts, Rhodulstalfs, Tropoflluvents. Udorthents, Hapludalfs, Dystrophepts, Haplorthox	2000-3000 (1400-1800) 27-28°C
19.3 R7A(B)8(7)	2.0 (240-270)	West Coastal plain, hot perhumid ecosystem with coastal alluvium-derived soils and GP 240-270 days	Maharashtra: Narrow coastal strip of Ratnagiri, Sindhudurg and Union Territory of Goa Karnataka: Narrow coastal strip of Karwar, Mangalore Kerala: Western half of Cannanore, narrow coastal strip of Malappuram, Calicut, Trichur and Ernakulam, Aleppy, Quilon and Trivandrum	Ustrophepts, Tropaquepts, Troposamments, HaplustalFs, Haplusdalfs, Toporthents, Dystrophepts	>3000 (1400-1700) 27-28°C
20.1 T3A10	0.8 (>300)	Eastern highlands (Andaman Nicobar Group of Islands), hot perhumid ecosystem with Red loamy soils and GP more than 300 days	Andaman & Nicobar Islands group	Troporthent, Eutrophepts, Tropaquepts, Haplichy-draquents, Humitrophepts, Troposamments Ustifluvents	>300 (1400-1600) 27-28°C
20.2 U16B8	003 (240-270)	Western highlands, hot humid ecosystem with sandy and littoral soils and GP 240-270 days	Lakshadweep group of Islands	Ustipsamments, Udifluvents	1600-2000 (1400-1600) 26-27°C

Note: *District shown with **bold letters** indicate randomly selected districts for long term mechanization strategy.

22. CONCLUSION

Food security remains a persistent and overbearing problem for a large proportion of world population in general and Indian population in particular. It has immediate consequence on soil in terms of determining survival strategies of small and marginal farmers in view of declining productivity, loss of surface soil mass and soil degradation. Global environmental problem such as land degradation, desertification, loss of biological diversities and climate change would dominate overall

objective of soil study in the current 21st century. Soil is the most essential resource for sustained quality of human life and related activities, therefore, soil resource and agro-ecology based agricultural development should be the strategy for exploiting renewable resources on which our nation must built and grow to fulfill all the cherished dreams. Therefore, following steps should be taken by the scientific community for conserving the precious soil resources for sustained food production.

- Assessment of soil resource in terms of its capabilities

Table 5. The extent, distribution of the different soil classes in “Soil Map of India” and their equivalents according to the new USDA system

Sr. No.	Indian nomenclature to major groups (Area Km ²)	Distribution (States)	Equivalent soil great groups of major soils USDA system of classification
1.	Red loamy soil (2,13,271)	Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Madhya Pradesh, Orissa	Paleustalfs Rhodustalfs Haplustalfs
2.	Red sandy soils (3,30,590)	Tamil Nadu, Karnataka, Andhra Pradesh	Haplustalfs Rhodustalfs
3.	Laterite soils	Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Orissa, Maharashtra, Goa, Assam	Plinthaquults Plinthaquults
4.	Red and yellow soils (4,03,651)	Madhya Pradesh, Orissa	Haplustults Ochraqults
5.	Shallow black soils (31,532)	Maharashtra	Ustorthents Ustopepts
6.	Medium black soils (4,30,383)	Maharashtra, Madhya Pradesh, Gujarat	Pellusterts Chromusterts
7.	Deep black soils (1,12,060)	Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Gujarat	Pellusterts Chromusterts Pelluderts
8.	Mixed red and black soils (1,62,255)	Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh	Association of Alfisols and Vertisols
9.	Coastal alluvium soils (54,403)	Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra, Gujarat	Haplaquents
10.	Coastal sands (4,534)	Orissa	Ustipsamments
11.	Deltaic alluvium soils (87,045)	Tamil Nadu, Andhra Pradesh, Orissa, West Bengal	Quartzipsamments Tropaqualfs
12.	Alluvial soils Khaddar (recent alluvium) Hangar (old Alluvium) (3,56,720)	Uttar Pradesh, Punjab, Bihar, West Bengal, Assam	Haplaquents Ustifluvents
13.	Alluvium soils (highly calcareous) (13,611)	North-Eastern, Uttar Pradesh, Bihar	Haplustalfs Calciorthents
14.	Calcareous sierozemic Soils (45,080)	Punjab	Calciorthids
15.	Grey brown soils (1,01,572)	Gujarat, Rajasthan	Calciorthids
16.	Desert soil Rhegosolic (1,54,423)	Rajasthan	Calciorthids, Psamments
17.	Desert soils Lithosolic	–	Lithic Entisols
18.	Terai soils (28,919)	Uttar Pradesh, Bihar, West Bengal	Haplaquolls
19.	Brown hill soils (over sandstones and shales) (81,242)	Uttar Pradesh, Bhutan, Sikkim, Himachal Pradesh	Palehumults
20.	Sub-mountain soils (Podsollic) (76,695)	Uttar Pradesh, Jammu & Kashmir	Hapludalfs
21.	Mountain meadow soils (59,790)	Kashmir including Ladakh	Cryoborolls Cryochrepts
22.	Saline and alkali (17,377)	Uttar Pradesh, Punjab, Maharashtra, Karnataka, Tamil Nadu	Salorthids, salargids, Natrargids
23.	Peaty and saline peaty soils (2,720)	Kerala	Histosols
24.	Skeletal soils (79,151)	Madhya Pradesh	Lithic Entisols
25.	Glaciers and eternal snow (29,335)	Uttar Pradesh, Kashmir	Lithic Entisols

Source: *Natural Resource Management for Agricultural Production in India* – J.S.P. Yadav and G.B. Singh (Eds.) Indian Society of Soil Science, 2000.

- for various agricultural and non-agricultural uses.
- Soil and climatic based crop specific land suitability evaluation.
- Evaluation of efficiency of agricultural input and their improvement.
- Controlling soil degradation through monitoring at benchmark sites.
- Restoring soil health through appropriate and cost effective techniques keeping in view of environmental degradation problems.

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