CHAPTER 1

Introduction

1.1 Introduction

India is endowed with a rich and vast diversity of natural resources, particularly soil, water, weather, agro-biodiversity and ecological regimes. India is a largely agrarian society with nearly 64 per cent of the population dependent on agriculture, although the share of agriculture in the gross domestic product has been continuously declining over the last 50 years. Crop production takes place in almost all land class types, namely, dry, semi dry, moist, sub humid and humid. Agriculture will continue to be important in India’s economy in the years to come as it feeds a large and growing population, employs a large labour force, and provides raw material to agro-based industries.
The Indian subcontinent is predominantly characterized by a tropical monsoon climate, where climatic regimes are governed mainly by the differences in rainfall both in quantity and distribution. The Indo-Gangetic Region (IGR) extends over four countries – India, Pakistan, Nepal and Bangladesh. The IGR of India occupies nearly 20% of the total geographical area of the country and encompasses five States: West Bengal, Bihar, Uttar Pradesh, Haryana and Punjab. The IGR has come into existence as a result of continuous deposition of alluvium from the hills and mountains from both sides of the Plains, i.e. the Himalayas in the north and the ranges of the Deccan Plateau in the south. It is one of the most fertile agricultural regions of the country and is also a densely populated region. Rice-wheat is the major cropping system in the IGR. With the advent of the “Green Revolution”, these two crops have come to occupy a significant area in the region, which is the “food bowl” or “food basket” of India. Rice predominates in the abundant rainfall zones of the eastern part where there is scope for growing rice under ponded water conditions during the rainy season, while irrigated rice is grown in the western part. Wheat assumes greater prominence in the western part, where it is normally grown with irrigation in winter, in rotation with rice. The IGR accounts for 53 per cent of total area under rice and wheat crops. About two-thirds increase in output of rice and wheat in the country during the last two decades has come from this region which reveals its importance in the country’s food security. During the same period, along with the spread of green revolution technology, rice-wheat crop rotation has emerged as the dominant crop sequence in the IGR.

In IGR, the climate and weather are dominated by the largest seasonal mode of precipitation in the world, due to the summer monsoon circulation. Over and above this
seasonal mode, the precipitation variability has predominant interannual and intra-seasonal components, giving rise to extremes in seasonal anomalies resulting in large-scale droughts and floods, and also short-period precipitation extremes in the form of heavy rainstorms or prolonged breaks on a synoptic scale. Further, the IGR climate is also marked by cold waves during winter and heat waves during the pre-monsoon season. Indeed, it is these extremes that have the most visible impact on human activities and therefore, receive greater attention by all sections of the society.

There are four major reasons for droughts in these areas – delay in the onset of monsoon/failure of monsoon, variability of monsoon rainfall, long breaks in monsoon and spatial variation in the persistence of monsoon rains. Even though there has been a significant increase in the application of water-conserving technologies and in water storage facilities, a recurrence of multiyear droughts result in greater impacts on agriculture today because of the rapid expansion and urbanization of the region’s population during the past several decades and the associated increased pressure on water and other natural resources. Droughts are abnormal recurring climatic events, occurring when there is a prolonged absence or deficiency or poor distribution of precipitation from the normal pattern.

To assess the drought, drought indices are normally used. Drought indices are normally continuous functions of rainfall and/or temperature, river discharge or other measurable variable. Rainfall data are widely used to calculate drought indices, because long term rainfall records are often available. Rainfall data alone may not reflect the spectrum of drought related conditions, but they can serve as a pragmatic solution in
data-poor regions. Hydrometeorological data based indices include Palmer Drought Severity Index (PDSI), Bhalme-Mooley Drought Index (BDMI), Crop Moisture Index (CMI), Agro-Hydro Potential (AHP), Standardized Precipitation Index (SPI), Surface Water Supply Index (SWSI), Reclamation Drought Index (RDI), Deciles etc.

According to a study by Nain et al. (2005), agriculture drought monitoring with crop simulation model has edge over other conventional and popular drought monitoring approach such as SPI. Crop growth and yield are determined by a number of factors such as genetic characters of crop cultivar, physical and chemical soil characteristics, weather, management practices such as date of sowing/planting, amount and time of irrigation and fertilizer application and biotic stresses. However, generally for a given area, year-to-year yield variability has been mostly modeled through weather as a predictor using either empirical or crop growth simulation approach.

With the advent of space technology, continuous availability of multi-spectral sensors on satellites, remote sensing data provide timely, accurate, synoptic and objective estimation/monitoring of crop growing conditions. Remote sensing data have certain advantage over meteorological observations for yield modeling, such as dense observational coverage, direct viewing of the crop and ability to capture effect of non-meteorological factors. A comparison of three technologies viz, meteorological indices, crop growth simulation models, remote sensing data can provide effective drought assessment tool.
1.2. Definition of the research problem

The IPCC (2001) in its Third Assessment Report (TAR) reported that under climate change the chances of occurrence of extreme droughts would increase in the Indian Subcontinent. In India, the climate and weather are dominated by the largest seasonal mode of precipitation in the world, due to the summer monsoon circulation. Over and above this seasonal mode, the precipitation variability has predominant inter-annual and intra-seasonal components, giving rise to extremes in seasonal anomalies resulting in large-scale droughts and floods, and also short-period precipitation extremes in the form of heavy rainstorms or prolonged breaks on a synoptic scale. Indeed, rainfall during a typical monsoon season is by no means uniformly distributed in time on a regional/local scale, but is marked by a few active spells separated by weak monsoon or break periods of little or no rain. Thus, the daily distribution of rainfall at the local level has important consequences in terms of the occurrence of extremes. Further, the Indian climate is also marked by cold waves during winter in the north, and heat waves during the pre-monsoon season over most parts of the country. Tropical cyclones, affecting the coastal regions through heavy rainfall, high wind speeds and storm surges, often leave behind widespread destruction and loss of life, and constitute a major natural disaster associated with climatic extremes. Indeed, it is these extremes that have the most visible impact on human activities and therefore, receive greater attention by all sections of the society. There are four major reasons for droughts in India—delay in the onset of monsoon/ failure of monsoon, variability of monsoon rainfall, long break in monsoon and areal difference in the persistence of monsoon. Almost a quarter of India’s land area is prone to drought. Areas that receive up to 60 centimeters of rainfall annually are the most
drought prone. The drought is almost directly linked to the areal variation in the
monsoon, the effect of which lasts for much longer than the actual span of the monsoon.
The most affected community is the marginal farmers, as mostly they are dependent on
rainfed agriculture.

Historical records indicate that drought occurs in any form of severity in one or
other places in the Indo-Gangetic Region of India in every year, which is the food bowl
of India. A recurrence of these multiyear droughts today would result in substantially
greater and more varies impacts because of the rapid expansion and urbanization of the
region’s population during the past several decades and the associated increased pressure
on water and other natural resources, every though there has been a significant increase in
water storage facilities and the application of water-conserving technologies. At present,
several drought indices, simulation models and modern tools such as remote sensing are
available to assess the drought climatology and several studies were conducted in India
without integrating of these.

1.3. Research Objectives

In this study, the three different approaches for characterizing the agricultural
drought conditions are compared in order to develop a rational integrated agricultural
drought assessment index with respect to rice and wheat over the study region. This
study also provides the historical drought patterns and frequency over the region using
different approaches and also the usefulness of integrated approach to agricultural
drought forecasting in terms of rice-wheat well in advance.
1.4. General agro-climatology of IGR

The IGR primarily comprises five States: West Bengal, Bihar (undivided), Uttar Pradesh (undivided), Haryana and Punjab (Fig 1.1). There are three more Indian districts – in Rajasthan and Himachal Pradesh State - that primarily fall within the IGR but outside of the five States are not considered here. Since most of the long-term data sets are available for undivided Bihar and Uttar Pradesh, here we have considered Bihar and Jharkhand as Bihar and Uttar Pradesh and Uttaranchal as Uttar Pradesh. IGR is a great crescent of alluvial soils that stretches from the delta of the Indus in the west to the Ganga-Brahmaputra delta in the east. The sediment has been deposited in rifts with the varying depth, at places reaching 4500 m.

The general slope of the ground is from west to east i.e., 200 meters above mean sea level in the west to near sea level in the east. Annual rainfall varies from 300 mm to 1600 mm increasing towards east at the rate of roughly 0.6 mm/km. Five types of moisture regimes exist in the IGR viz., arid, semi-arid, dry sub-humid, moist sub-humid and humid. Developed from huge amount of silt brought by rivers emerging from the mighty Himalayas, namely, the Indus and its tributaries, Ganga, Yamuna, Ghagra and Kosi, this region is endowed with natural resourced viz., deep productive soils, plentiful surface as well as groundwater and climate which is favorable for double and triple cropping. The Indo-Gangetic Region is bound on the north by the abruptly rising Himalayas, which feed its numerous rivers and are the source of the fertile alluvium deposited across the region by the two river systems. The southern edge of the plain is marked by the Vindhya- and Satpura Range, and the Chota Nagpur Plateau. On the west
rises the Iranian Plateau, with only the floodplain bluffs, changes in river channels and other related features of river erosion forming natural features. Two narrow terrain belts, collectively known as the Terai, constitute the northern boundary of the Indo-Gangetic Region. In the area where the foothills of the Himalayas encounter the plain, small hills known locally as ghar (meaning house in Hindi) have been formed by coarse sands and pebbles deposited by mountain streams. Groundwater from these areas flow on the surface where the plains begin, converting large areas along the rivers into swamps. The southern boundary of the plain begins along the edge of the Great Indian Desert in the state of Rajasthan, before continuing east along the base of the hills of the Central Highlands to the Bay of Bengal. The hills vary in elevation from 300 to 1200 meters and lie on a general east-west axis. The major cropping systems are rice-wheat, rice-mustard-rice, cotton-wheat, pearl millet-wheat, rice-sugarcane and maize-wheat. The crops are rice, wheat, maize, cotton, sugarcane and pearl millet. These crops are grown in large areas of IGP in rabi and kharif seasons.

The climate of the Indo-Gangetic Region is dominated by the Asian summer monsoon. The cool, dry winter is followed by a warming trend with daytime temperatures reaching as high as 45°C in June or July. The temperature rise is broken by the onset of the monsoon rains, when the daytime maximum temperature will immediately drop 5°C or more with the first rains. Summer temperatures are generally higher in the northwest part of the IGR, corresponding to later onset of the rainy season. In most of the IGR, winter temperatures is very low allowing production of wheat, potatoes and other cool season crops where irrigation is possible. Annual precipitation varies from 400 mm in western IGR to 1600 mm in eastern India.
Within the IGR, Indo-Gangetic Plain (IGP) is homogenous in topography, in the west the elevation of the IGP is 150-300 m whereas in the east it is generally less than 50 m. The Planning Commission, Government of India (1979) divided the country into 15 broad agro-climatic zones based on physiography and climate. Four of these broad agro-climatic zones fall in this IGR.

They are

1. Lower Gangetic Region – ACR III (West Bengal)
2. Middle Gangetic Region – ACR IV (Bihar and Eastern Uttar Pradesh)
3. Upper Gangetic Region – ACR V (Western Uttar Pradesh)
4. Trans-Gangetic Region – ACR VI (Haryana, Punjab, Rajasthan)

The general agro-climatic characteristics (Ghosh, 1991; Basu and Guha, 1996; Narang and Virmani, 2001) of these four regions are summarized as follows,

**Lower Gangetic Region:** This zone experiences a sub-humid to humid and sub-tropical climate. It receives 1200-1600 mm annual rainfall. The soils are perfectly suited for rice cultivation and rice constitutes the main staple food of the people. Rice is grown primarily as a rainy season crop under long-duration flooded conditions. It also constitutes the marshy saline bog lands where hardly any farming is possible. This region consists of the following zones;
ACZ D1—Old and New Alluvial Zone: This Zone lying on the east of the Ganges River constitutes the traditional rice-growing zone of this region. This zone experiences a sub-humid to humid and sub-tropical climate. Rice is grown primarily as a rainy season crop under long-duration flooded conditions. The soils are ideally suited for rice
cultivation and rice constitutes the main staple food of the people. Wheat is a recent entrant into West Bengal. Prior to the era of HYVs, hardly any wheat was cultivated in West Bengal. But since the advent of HYVs in the late 1960s, because of their short duration and photoperiod-insensitive nature, a sizeable area in West Bengal is now sown to wheat, particularly this zone, which enjoys comparatively cool winters. This makes wheat cultivation a successful economic proposition.

**ACZ D2—Laterite and Red Soil Zone:** This zone constitutes the major rice growing component of West Bengal and lies on the western side of the Ganges River. It accounts for the maximum area of rice in the State. Very little area has come to be occupied by wheat; perhaps because of (i) low soil water holding capacity and little opportunity for irrigation, and (ii) a comparatively higher temperature regime (warmer winters with no or very little chilling period).

**ACZ D3—Coastal Saline Soil Zone:** Being coastal saline zone, it has hardly any sizeable cultivated area. In fact, it constitutes the marshy saline bog lands of West Bengal where hardly any farming is possible.

**Middle Gangetic Region:** It has an annual rainfall of 1000-1200 mm, of which 85-90% received during the monsoon months of June-September and this zone experiences a sub-humid, sub-tropical climate. Eastern Uttar Pradesh is considered as naturally the most-suited rice-growing area in the IGR and rice is also the primary staple food of the people living here. The soils of south Bihar zones are well drained and water availability is high and is comparatively free from recurring floods except on the eastern flank where floods occur once in every 2-4 years. This region consists of the following zones;
ACZ C1—Eastern Plain Zone: This zone lies between the Saryu and Ganges Rivers in the Central IGR. It has an annual rainfall of 1000–1200 mm, of which 85–90% is received during the monsoon months of June-September/October and is also endowed with good soils. This zone constitutes a major traditional rice-growing area of the IGR. The density of rice area is quite high and extent of rice cultivation well spread, except in the southwest.

ACZ C2—North-Eastern Plain Zone: This zone lies north of the River Saryu and between the Rivers Gandak and Ghaghra. The area enjoys a subhumid, sub-tropical climate. The monsoon season lasts from June–September. The annual rainfall of 1000–1200 mm or more and low flood intensity accounts for rice cultivation on an extensive scale in this zone. In fact, Eastern Uttar Pradesh, with copious rainfall and heavy to medium heavy textured soils, is considered as naturally the most-suited rice-growing area in the IGR. Therefore, the intensity of rice cultivation is very high in this region and rice is also the primary staple food of the people living here.

ACZ C3—South Bihar Alluvial Plain Zone: This zone lies to the south of the Ganges River with the Sone River forming its major tributary on the southern flank. It is comparatively free from recurring floods except on the eastern flank where floods occur once in every 2–4 years. The soils of this zone are well drained and water availability is high. Rice cultivation is concentrated along the Sone and Ganges Rivers; with the intensity decreasing in flood-prone areas.

ACZ C4—North-West Alluvial Plain Zone: This zone lies on the east of the River Gandak and north of the Ganges River, at an elevation of 50–100 m (msl). It has an annual rainfall of about 1200 mm but it is most frequently flooded. Deep water paddy in
the flood-prone areas and upland rainfed paddy at upper elevations, besides transplanted paddy are major rice-based cropping features of this zone. High frequency of floods (once every year or every 2 years) makes growing of most other crops a risky proposition and the predominance of paddy in this region is, therefore, inevitable.

**ACZ C5—North-East Alluvial Plain Zone:** This zone constitutes, along with the North-West Alluvial Plain Zone, the second most severely affected flood-prone area of the state after the North-West Alluvial Plain Zone ACZ C4. This is inundated almost regularly every year by high floods of the Kosi and Ganges Rivers and their Himalayan tributaries. Accordingly, even though agro-climatically suitable for rice production, the intensity of rice area here is comparatively low.

Sizeable area of wheat is cultivated in the Middle-Gangetic Plains Region, as well. But this is largely concentrated in eastern Uttar Pradesh. The density of wheat cultivation tends to thin out from the west to the east of the region. The state of Bihar, though showing sizeable area under wheat, has a comparatively thinner spread of area in the north-eastern and southern flanks. Agro-climatically, the Bihar IGR region has mild winters and, therefore, has a rather shorter wheat-growing span. In fact, the growing season of wheat tends to be shorter by almost 30–35 days as compared with that of the Trans-Gangetic/ Western Uttar Pradesh regions. The abrupt rise of temperatures in spring which often causes terminal heat stress, further curtails the growing period. This enforced maturity results in imperfectly developed or incompletely filled grains. In spite of these handicaps, because wheat has a stable performance (though at lower yield levels) and as it fits very well in the 2-crops-a-year rice-based system, it is cultivated extensively in the
entire Middle-Gangetic Plains Region. Of course, the area intensity fluctuates in response to the water availability resource and the time of planting available.

*Upper Gangetic Region:* It has an annual rainfall of 800-1200 mm. It possesses an extensive network of irrigation facilities and soils are deep alluvial, medium to heavy textured but are easily ploughable. The favourable climate and soil and the availability of ample irrigation facilities make growing of rice a natural choice for the area. This region consists of the following zones;

**ACZ B1—Western Plain Zone:** This zone constitutes the western-most districts of Uttar Pradesh, the most fertile zone of the state. It constitutes the sugarcane belt of Uttar Pradesh. Agro-climatically, it is well endowed with a congenial climate, possesses an extensive network of irrigation and abundant underground water reserve (due to high recharge from the Yamuna and Ganges Rivers and their tributaries coming from the Himalayas). In spite of all these favorable factors, it has, however, very minimal area of rice and that too confined mostly to district Saharanpur. This area has a large number of sugar factories, both in the organized and unorganized (farmer-owned unrefined sugar manufacturing units) sectors. Further, as sugarcane is the most popular crop, there is little scope for rice which competes with sugarcane for labor, capital and intensive field care.

**ACZ B2—Mid-Western Plain Zone and ‘Bhabar and Tarai Zone’:** This area constitutes the sub-humid zone. It has an annual rainfall of 1000–1200 mm and also enjoys ample irrigation resources. The underground water-table is shallow and can be easily exploited. Soils too are comparatively heavy permitting successful cultivation of rice. Rice constitutes a major crop of the area, only next to wheat.
**ACZ B3—Central Plain Zone:** It has an annual rainfall of 800–1200 mm and is liberally sourced by the Ganges and Yamuna Rivers and their tributaries. Soils are deep alluvial, medium to medium heavy textured but are easily ploughable. The favorable climate and soil, and the availability of ample irrigation facilities make growing of rice a natural choice for the area. This zone has a sizeable area of rice though its scatter is generally more widespread.

**ACZ B4—South-Western Semi-Arid Zone:** This zone constitutes relatively the driest parts of Uttar Pradesh. The area has mostly a rainfed farming type of environment and, therefore, accounts for a minimal area of rice.

This region, besides receiving ample winter rains (80–100 mm), also enjoys abundant irrigation water availability. It has deep, well-drained alluvial fertile soils. The region has a well-developed infrastructure; like rail, roads, transport, communications, electricity, a vast network of canal and tubewell-based irrigation systems, and an easy access to markets. Fertilizers and other inputs, a fairly high level of agro-technology and credit are readily available. In Western Uttar Pradesh, and in Tarai regions the main competition to wheat comes from sugarcane, while in the dry zone, low water requiring crops like canola and mustard, winter legumes such as chickpea, mixed crops, etc. are cultivated during *rabi*.

**Trans-Gangetic Region:** Agroclimatologically, this zone falls in the low rainfall zone of 400-800 mm. But this zone has the unique advantage of enjoying the highest irrigation intensity in the country, with more than 94 % of net area sown being irrigated through a network of perennial canals and tubewells. Groundwater reserves are being fully exploited with the result that this area is showing a sharp decline in groundwater-table,
averaging 20 cm per annum (Narang and Gill, 1994). This region consists of the following zones:

**ACZ A1—Central Plain Zone:** Agro-climatologically, this zone falls in the low rainfall zone of 400–800 mm. But this zone has the unique advantage of enjoying the highest irrigation intensity in the country, with more than 94% of net area sown being irrigated through a network of perennial canals and nearly 0.8 million tubewells. Groundwater reserves are being fully exploited with the result that this area is showing a sharp decline in groundwater-table, averaging 20 cm per annum (Narang and Gill 1994). Overall congenial growing conditions (bright sunshine duration of 13–14 hrs or more) during most of the active growth period of rice and a continuous replenishment of irrigation water. The farmers grow rice on light sandy loam/loam textured soils found on more than half of this zone. It requires 1500 mm of irrigation water applied over 100–110 day active crop growing phase besides the 330 mm average normal effective rain received during the growing season (Narang and Gulati 1992). The water application consists of scheduling 20–25 cm water at land preparatory tillage, puddling and transplanting. Water is then kept ponded for about two weeks. It is followed subsequently by fresh irrigations applied 1–2 days after the surface water has seeped in and the soil surface develops hair-size cracks. This process is repeated 20–30 times during the life-cycle of the crop. Irrigation is discontinued about 2–3 weeks prior to harvest. In fact, the “Green Revolution” which originated at Ludhiana, has spread rapidly engulfing the whole Central Plain Zone endowed with good canal and tubewell, fresh water resource.

**ACZ A2—Western Plain Zone:** In this zone rice competes with cotton, which is another major cash crop of the area. Tubewell water use is moderate, as the underground water is
mostly brackish; and, therefore, soils at places are saline and alkali with an impeded drainage. Cotton and other oilseeds/pulse grains can no longer be grown. Farmers are shifting to rice cultivation. This shift in cropping pattern is causing considerable concern for the sustainability of cotton production in the area.

**ACZ A3—Sub-Montane Undulating Zone and Undulating Plain Zone:** There is a sizeable area of rice in this undulating plain zone of the sub-montane tract, soils get enriched with good sedimentation of silt and clay during the rainy season. Availability of canal and tubewell irrigation supplemented by rain makes large-scale growing of rice quite feasible and rice area has virtually spread to occupy all of the plain land available in the Undulating Plain Zone.

**ACZ A4—Eastern Zone:** This zone includes the very fertile eastern districts of Haryana. This area is famous for Basmati rice production. The area, being generally short of groundwater resources (due to poor and marginal quality water) is generally dependent on canal water and rainfall for sustaining rice. Therefore, rice is normally planted with the onset of the monsoon; this comparatively late planting makes this area suitable for growing of Basmati rice, which requires a steadily falling temperature regime with comparatively cool nights, and high relative humidity during the reproductive and grain development phase. These environmental conditions are considered to improve the quality of Basmati rice in terms of its aroma, cooking quality, less breakage of slender-long grains during milling and polishing.

**ACZ A5—Western Zone:** This zone constitutes the south-western arid parts of Haryana state interspersed with desert-like soils, sand dunes, scarce water availability, highly brackish (poor quality) waters and limited canal irrigation resource. Thus, rice area in this
zone is nominal as rice growing is limited to certain pockets only, where, besides canal water, some supplemental tubewell irrigation water is also available.

Wheat cultivation is widespread in this agroclimatic region, because it receives good winter rains (100–110 mm) and is well endowed with a very comprehensive irrigation system of tubewells and canals. Besides, this region enjoys long bright sunshine-hour duration (10–12 hrs/day) and low temperatures appropriate for vernalization and good seed-set in wheat. Fertilizer and herbicide use is widespread; mechanization (tractorized land preparation, harvesting, threshing and transportation of produce) is extensive; and basic infrastructure of rail, road, transport, communications, electricity supply, etc., are adequate. The farmers of the region too are very progressive, entrepreneur-minded, receptive to the adoption of new innovative technologies and adept in managerial skills. Since the introduction of high-yielding varieties (HYVs) of wheat from the late 1960s and rice from early 1970s, the farmers of the region have maintained an uninterrupted lead of ever increasing yields of wheat and rice in India.

According to Mandal et al. (1999), this region is divided into 18 agro-ecological sub-zones. This agro-ecological zone map is based on the superimposition of three basic maps viz., soil-physiography, bioclimate and length of growing period (Fig. 1.2). The detailed agro-ecological characteristics of each of sub-division are narrated in Table 1.1.
Fig. 1.2: Agro-ecological sub-region map of IGR
<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Agro-ecological region</th>
<th>Agro-ecological sub-region and Length of Growing Period (LGP)</th>
<th>Representative stations</th>
<th>Latitude (°N) Longitude (°E) Altitude (m)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Western Plain, hot arid eco-region M9E1</td>
<td>South-Western Punjab Plain, hot typic-arid ESR with deep, loamy desert soils, low AWC and LGP 60-90 days (M9E12)</td>
<td>Hisar</td>
<td>29.10,75.44, 215</td>
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<td>2</td>
<td>Northern Plain N8D2</td>
<td>North Punjab Plain, hot semi-arid ESR with deep loamy alluvium-derived soils, medium AWC and LGP 90-120 days (N8Dd3)</td>
<td>Ludhiana</td>
<td>30.56,75.52, 247</td>
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<td></td>
<td></td>
<td>Ganga Yamuna Doab, Rohilkhand and Avadh plain, hot moist semi-arid ESR with deep, loamy alluvium-derived soils, medium to high AWC and LGP 120-150 days (N8Dm4)</td>
<td>Allahabad Kanpur</td>
<td>25.27,81.44, 98 26.26,80.22, 126</td>
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<td></td>
<td></td>
<td>Madhya Bharat Plateau, hot, moist semi-arid ESR with deep loamy and clayey mixed Red and Black soils, medium to high AWC and LGP 120-150 days (N6Dm4)</td>
<td>Jhansi</td>
<td>25.27, 78.35, 251</td>
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<tr>
<td>3</td>
<td>Northern Plain, hot subhumid (dry) N8C3</td>
<td>Punjab and Rohilkhand Plains, hot dry/moist subhumid transitional ESR with deep, loamy to clayey alluvium-derived soils, medium AWC and LGP 120-150 days (N8(Cm)Cd4)</td>
<td>Karnal</td>
<td>29.28, 77.44, 239</td>
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<td></td>
<td></td>
<td>Rohilkhand, Avadh and south Bihar Plains, hot dry sub humid ESR with deep loamy alluvium-derived soils, medium to high AWC and LGP 150-180 days (N8Cd5)</td>
<td>Lucknow Faizabad</td>
<td>26.52, 80.56, 111 26.47, 82.08, 133</td>
</tr>
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<td>4</td>
<td>Transitional AER</td>
<td>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)</td>
<td>Hazaribagh</td>
<td>23.59,85.22, 611</td>
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<td>5</td>
<td>Eastern Plateau and Eastern Ghats, hot subhumid J23C3(4)</td>
<td>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)</td>
<td>Dhanbad</td>
<td>23.47, 86.30, 156</td>
</tr>
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<td>6</td>
<td>Eastern Plain, hot subhumid (moist) O8C4</td>
<td>North Bihar and Avadh Plains, hot dry to moist subhumid transitional EST with deep, loamy alluvium-derived soils, low to medium AWC and LGP 180-210 days (O8Cd/Cm6)</td>
<td>Pusa Purnea Gorakhpur</td>
<td>25.39, 84.40, 52 25.46, 87.28, 38 26.45, 83.25, 78</td>
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<td></td>
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<td>Foothills of Himalayas, warm to hot moist subhumid ESR with deep loamy to clayey Tarai soils, high AWC and LGP 180-210 days (B10Cc6)</td>
<td>Bahraich</td>
<td>27.34,81.36, 124</td>
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<td>7</td>
<td>Western Himalayas, warm subhumid</td>
<td>Kumaun Himalayas, warm moist to dry subhumid transitional ESR with medium to deep loamy to clayey</td>
<td>Tehri Garhwal</td>
<td>30.52,78.02, 1600</td>
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</tbody>
</table>

Table 1.1: Agro-ecological sub-regions of Indo-Gangetic States (Contd....)
<table>
<thead>
<tr>
<th>Region</th>
<th>Description</th>
<th>Length (days)</th>
<th>Location</th>
<th>Status</th>
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<tr>
<td>A15C(BA)4(5)</td>
<td>Brown Forest and Podzolic soils, medium AWC and LGP 150-210 days (A15Cd/Cm6)</td>
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<td>14.4</td>
<td>Kumaun Himalayas, warm humid to per humid transitional ESR with shallow to medium deep loamy red and yellow soils, low AWC and LGP 270-300 days (A3BA9)</td>
<td></td>
<td></td>
<td>Not Considered</td>
</tr>
<tr>
<td>14.5</td>
<td>Foothills of Kumaun Himalayas (Subdued), warm moist subhumid ESR with medium to deep, loamy Tarai soils, medium AWC and LGP 270-300 days (A10A9)</td>
<td></td>
<td></td>
<td>Not Considered</td>
</tr>
<tr>
<td>8</td>
<td>Assam and Bengal Plain, hot subhumid to humid Q8C(BA)5</td>
<td>15.1</td>
<td>Bengal basin and north Bihar Plain,</td>
<td>Asansol, Krishnanagar, Dumka</td>
</tr>
<tr>
<td>9</td>
<td>Eastern Himalayas, warm perhumid C11A5</td>
<td>16.1</td>
<td>Foot-hills of Eastern Himalayas,</td>
<td>Not Considered</td>
</tr>
<tr>
<td>16.2</td>
<td>Darjeeling, warm perhumid ESR with shallow to medium deep loamy brown and red hill soils, low to medium AWC and LGP 300 days (C11A10)</td>
<td></td>
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<tr>
<td>10</td>
<td>Eastern Coastal Plain, hot subhumid to semi-arid S7CD2-5</td>
<td>18.5</td>
<td>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)</td>
<td>Not Considered</td>
</tr>
</tbody>
</table>

Table 1.1: Agro-ecological sub-regions of Indo-Gangetic States