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Environmental Assessment of Climate of a Habitat Through Floristic Life-Form Spectra, a Case Study of Warangal North Forest Division, Telangana, India

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Abstract

The phytospectrum of a natural habitat, a watershed in the Godavari Valley (Telangana, India) occupied by the tropical deciduous forest, was studied. The study provided the baseline data, after laying 35 quadrats through stratified sampling to determine the floristic life-form spectra for the three distinct forest zones delimited through the remotely-sensed integrated data. The floristic spectral data thus obtained were used to compare and contrast the vegetation types within the southern tropical deciduous forest type, structured along the environmental gradients and shaped by the ecological factors. Dansereau's climate inference, using Raunkiaer's life-form proportions and their ranges provided for tropical climate, was tested whether it could be predictive of the climate of the tropical deciduous forest ecosystem. The available literature on the phytoclimates of life-forms in the tropical climate was reviewed to comprehend the diversity of the tropical forest ecosystems. The phytoclimate of the tropical deciduous forest ecosystem is phanerophytic, more precisely phanero-therophytic, underscoring the role of emerging (co-dominant) life-form through ecological succession. The study further established that the phytospectrum of Raunkiaer can effectively be used to assess the bioclimate of even the microscale sites apart from making out how the environmental factors can moderate the vegetation of a site. The study finds the phytoclimate for the life-form chamaephytes which was not realized earlier by Raunkiaer, and suggests that the floristic life-form spectra are of use for identifying the forest types, fixing their floristic affinities and change detection.

Keywords: Environmental assessment, plant life-forms, floristic spectra, Tropical deciduous forest, India, climate inference

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Introduction

The terrestrial biomes are differentiated on the basis of the dominant plant life-form[1]. Besides, the natural vegetation of a habitat can be a good indicator of its prevailing physical environment. Diverse factors like climate, geographical location (longitude and latitude), geomorphology and the nature of site disturbances *per se* determine the level of variability. However, the environment of a plant may vary daily, seasonally, vertically and horizontally[2]. Moreover, the environmental variability is not an absolute thing, even on a particular scale; rather, it is the property of interaction between the biota and the environment, in terms of both a real effect and a perpetual one[3]. This variation can be effectively biomonitored, finding suitable indicators. In view of the climate change, the environmental assessment of the climate of a natural habitat has become a necessity either for sustainability or for future ecosystem functions. At present, for assessing the effects of climate change, the life-form or plant functional type is being applied increasingly to identify the future trends in the ecosystem structure[4,5].

The study of climate in relation to life is called *bioclimatology* in which more emphasis is laid on plants in view of the fact that animals are not sedentary and reside in special niches thereby escaping the direct impact of climate. Conversely, the zooclimatic literature is meager in comparison to the studies on vegetation-atmosphere relationships[6]. Although the atmospheric events are vital to animals, the two-way interaction is lesser than with the vegetation. So, the natural vegetation remains the field indicator of the climatic conditions[7]. Employing the life-form phytospectra, efforts have been made in the past to infer the climate/phytoclimate of regions by Raunkiaer[8], McDonald[9], Ferreira[10], Cain[11], Das and Sarup[12], Meher-Homji[13], Pandey *et al*.[14], Reddy *et al*.[15], Batalha and Martins[16,17], Reddy *et al*.[18]. Meher-Homji[19] identified *ten* phytoclimate types for India, employing Raunkiaer's life-form data.

In the earlier studies of phytospectrum, there were cases of incorrect assignment of plant species to life-form categories and over-emphasizing of life-form data as stated by Cain[11]. Again, there are studies which have not fully realized the importance of all the life-forms when they have not studied the flora of a habitat throughout the year, covering all seasons. Such data are misleading when used to construct the life-form spectra and deduce the climate.

There are works producing the life-form data out of altered lands use (human-altered natural habitats) which include plantations, irrigated lands and urban areas, etc. Some of the studies, though of value in the realm of Phytogeography, demonstrated that phytospectra are good for comparisons within the geographic compass[8] and are not significant in contrasting with the adjacent places[20].

There is a need to gather and analyze the information concerning the plant communities from time-to-time to understand the changes in the structure of the local forest stands and their ability to provide the goods and services. Increased knowledge of this kind helps to augment our opportunities to maintain the integrity of the forest ecosystem, restore the degraded landscapes and assist the forest-dependent human societies shaping more stable futures for them[21]. Therefore, an attempt is made to study the life-forms of the tropical deciduous forest ecosystem in the Godavari Valley.

The objectives of the current study are: (i) to determine the life-form spectra of a watershed supporting the tropical dry deciduous forest; (ii) to procure baseline data for future floristic life-form proportions of the same habitat; (iii) to compare the floristic spectra within (at micro and meso scales) and outside (near and far) the region by means of the available data; and (iv) to infer the phytoclimate of a tropical dry deciduous forest *vis-à-vis* Dansereau[22].

Study Area

The Godavari Valley of Warangal district is located between $18^0$0' to $18^0$30' N latitudes and $80^0$0' to $80^0$43' E longitudes, covering the toposheets 65B, 3, 4, 7, 8 and 12 (1:50,000 scale). The study area covers a major part of the Warangal North Forest Division, a geographical area of 8,687.81 sq km comprising 75.96% of the total area of the district (Fig. 1).

The study area has two import aspects: (i) it has in its fold the Eturnagaram wildlife sanctuary and (ii) the *Sammakka-Saralamma [Medaram] jatara* is held once in two years in the sanctuary area which is one of the biggest human congregations (nearly one million people) for three days. The study site is 250 km inland to the east-coast of India, with prevailing dry weather. It has the mean average annual temperature of 27-29^0C

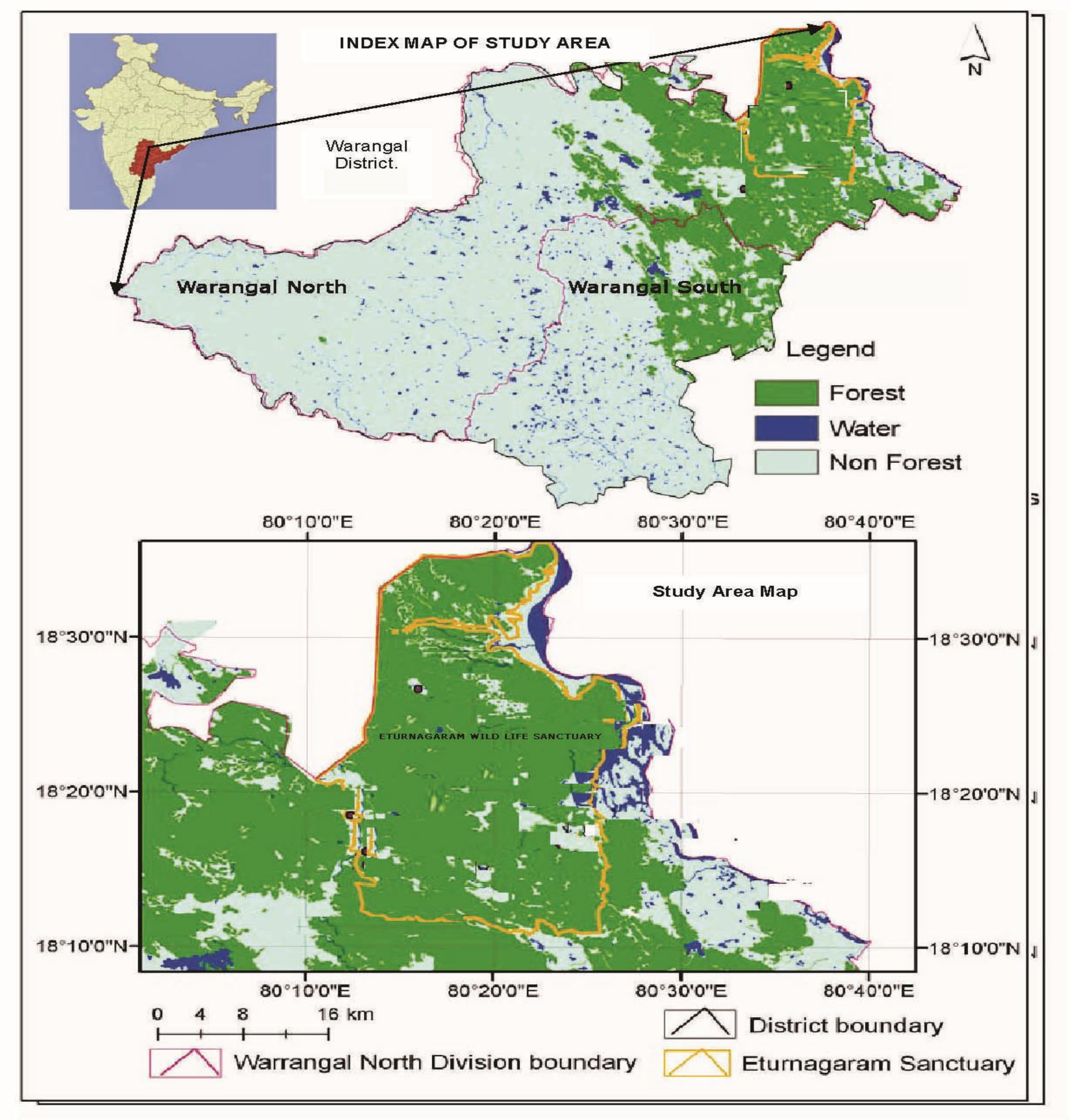

Fig. 1: The study area: Warangal North Forest Division

And receives an average annual precipitation of 1150 mm with 45 to 85 rainy days against the district average of 992 mm parallel to the slope. The rainfall increases from 800 to 1300 mm along the slope of the land. It has red earth with loamy subsoil, forest soil, black cotton soil and alluvium; the last-mentioned two soil types are found along the bank of the Godavari. As per Meher-Homji and Gupta[7], the habitat enjoys a typical tropical climate.

In the study site, the tree species occur in a continuously shifting series of combinations with a pattern, as reported elsewhere by Whittaker[23]. It is the consequence of limited floristic complement acting on the physical environment. Away from the river and along the environmental gradients, three zones can be realized (Table 1). The forest cover in the study area, accordingly, can be split into three forest zones, namely, *Tectona-*

Table 1: Physiographic Profile of the Study Area

Parameter	Forest végétation type zone		
	***Tectona-Terminalia* (TT)**	***Madhuca-Terminalia-Hardwickia* (MTH)**	***Terminalia-Hardwickia* (TH)**
Altitude (m)	100-125	150-250	250-310
Terrain	River, plain	Mountainous	Montane to plain
Soil	Forest soil, black cotton	Forest soil to Alluvium	Red earth, forest soil
Av. Temp. (^{0}C)	27	29	31
Rainfall (mm)* *	1300	1100	1000
Rainy days	85	70	55
Fire	+	++	+++
Disturbance	+	++	+++
No of quadrats laid (35)	12	11	12
Similarity index	**TT–MTH: 49.73**	–	–
	–	**MTH-TH: 47.69**	–
	–	–	**TH-TT: 48.93**

* Against the district average rainfall of 992 mm.

Note: The flowering plant species found in the study area are 325. These are those which have fallen in the 35 quadrats.

Terminalia (TT), *Madhuca-Terminalia-Haldinia* (MTH) and *Terminalia-Hardwickia* (TH). This classification is based on the integrated remotely-sensed data by Gopalkrishna[24]. The similarity index values of the three forest types are 49.73 between TT and MTH, 48.93 between TT and TH while it is 47.69 between MTH and TH.

Methods

Life-form Study

The Godavari Valley of Warangal has been surveyed floristically, covering all seasons. The life-forms of the study area are classified after Raunkiaer[8], with some necessary modifications by Gopalkrishna[24]. The proportion of each life-form represented in the flora of a particular type of vegetation is called *biological spectrum*[8,16]. Here, it is called the *floristic* life-form spectrum. Raunkiaer's life-form classification had realized five major classes based on the place of the plant's growth point (bud) during seasons with adverse conditions (cold and dry seasons), viz. phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes. Mueller-Dombois and Ellenberg[25] modified it by including the plant traits in the favourable season. Mera *et al*.[26] added a new type of life-form, the aerophyte; it is not found in the present study area. The spectra are expressed as percentages of the total number of species of the respective life-form categories.

The life-form analysis was carried out only for the study area, i.e. North Forest Division, as a watershed since Warangal district is a political and administrative unit rather than a natural habitat. The study area was sampled through stratified sampling. As many as 35 quadrats (20 × 20 m) were laid in different locations taking care of the forest vegetation type, altitude, aspect, soil and drainage (Table 1). The plant species included (fallen) in the sampling sites were recorded and their life-form nature was determined. Since the sampling sites were all strictly from the natural forest, it is presumed that the life-form proportions reflect the prevailing bioclimate. The plant specimens collected were identified and deposited in the Kakatiya University Herbarium (KUW).

Two major categories of the life-form systems can be readily distinguished, namely, physiognomic and epharmonic with the emphasis laid on the morphological structures or ecological aspects, respectively[9].

Variations in environmental gradients, soil and altitude have resulted in shaping the landscape into three different microhabitats[24]. Accordingly, the life-form phytospectra of these three forest zones are prepared (Table 2).

Results and Discussion

The normal biological spectrum (NBS) includes only the spermatophytes[9]. The Cycadophyta (Gymnosperms), also spermatophytes, are incidentally absent from the study area.

Table 2: Floristic life-form proportions in the Godavari Valley, Warangal district

Life-form	NBS*	Whole study area	Forest [zone-wise] TT	MTH	TH
1. Phanerophytes	**46**	**49.0**	**58.3**	**47.2**	**42.4**
a) Megaphanerophytes	06	1.0	1.6	0.7	1.5
b) Mesophanerophytes		17.6	22.6	21.2	22.6
c) Microphanerophytes		13.8	16.8	9.2	8.8
[MM: Meso/Microphanerophytes]	17	[31.4]	[39.3]	[30.4]	[31.4]
d) Nanophanerophytes	20	5.2	4.7	4.9	4.4
e) Stem Succulents	01	0.3	0.5	0.7	0.7
f) Epiphytes	03	0.3	0.5	0.7	0.7
g) Lianas		9.6	10.0	7.0	3.0
h) Parasites		1.2	1.6	2.8	0.7
2. Chamaephytes	**09**	**1.2**	**1.6**	**1.4**	**2.2**
3. Hemicryptophytes	**27**	**13.8**	**9.5**	**11.3**	**13.8**
4. Cryptophytes	**04**	**9.2**	**7.3**	**11.3**	**15.4**
a) Geophytes		8.0	5.3	8.5	12.4
b) Helophytes		0.6	1.0	1.4	1.5
c) Hydrophytes		0.6	1.0	1.4	1.5
5. Therophytes	**13**	**26.8**	**23.3**	**28.9**	**26.2**

***NBS**: Normal Biological Spectrum of Raunkiaer; **TT**–*Tectona-Terminalia* forest zone; MTH–*Madhuca-Terminalia-Haldinia* forest zone; **TH**–*Terminalia- Hardwickia* forest zone.

A total of 325 plant species of flowering plants (Angiospermae/Magnoliophyta) which have fallen in 35 quadrats were identified of their life-forms. These data were used to prepare the phytospectra for the whole of study area and as well the three forest types.

The physiognomic study of the present habitat revealed that all the three forest zones (Table 2) are dominated by phanerophytes (46.7%, 37.4% and 38.7% in TT, MTH and TH, respectively). The spatial heterogeneity is contrasted in the tree species diversity. There is change, though not major, in the local climate towards east as the river Godavari flows to empty of its waters into Bay of Bengal. The TT zone, which occupies the northern part of the study area, is proximate to the Godavari, at lower altitude (100 m), with relatively higher precipitation (1300 mm) and soil alluvium. This has led to the development of phanerophytes in general and more of megaphanerophytes in particular (Table 2). In contrast, the southern part of the study area has red *morum* or sandy soils, higher elevation and receives lesser rainfall (1000 mm) and harbours TH zone. In between is the MTH zone.

Although the three forest zones are predominated by phanerophytes, each zone has its own floristic specificity and life-form proportions. The phytospectrum of TH zone is closer to MTH rather than to TT in contrast to the similarity index. There was a decline in the number of phanerophytes as we moved from TT to the other two zones. The TH zone (28.7%) is closer to the NBS (i.e. 38.2%) of the area. While the nano- and mesophanerophytes are more or less in equal proportion among the three zones, the micro-to a greater extent and the mega – to a lesser extent, are higher in the TT zone (Table 2). The epiphytic phanerophytes and stem succulents, on the contrary, showed a slight increase from the TT to the TH zone, i.e. along the gradient – more mesic to dry condition.

The preponderance of cryptophytes is relatively less in TT zone (7.3%) than the TH zone (15.4%). Chamaephytes, hemicryptophytes and therophytes also showed a similar trend. However, the therophytes in the TH zone (23.3) are closer to the average value for the whole area (26.8). As one traversed from TT zone to the TH zone as the altitude, dryness and biotic disturbance increases (Table 1), the lianas and parasites have decreased.

Life-forms are units of ecological plant geography which reveal the relationship of plants to their environment. Raunkiaer[8] claimed that 'the statistics of life-forms', as biological spectra, 'give us exact numerically-expressed basis for characterizing and demarcating the plant climates'. This is to be tested further in all natural habitats. Despite the criticism, Raunkiaer's system of life-forms is still the simplest, satisfying and widely-applied to compare the phytoclimate data available for the global ecosystems and vegetation types.

Recently, van der Merwe and van Rooyen[5] wisely used the life-form spectra to establish the transitional nature of Hantam-Tanqua-Roggeveld (South Africa), distinguish the three biomes developed along the environmental gradients, and estimate the affinities amongst them.

Three types of phytospectra can be conceived, namely floristic, frequency and vegetation. The *floristic* spectrum takes-up the life-form of each species in the natural habitat while the *frequency* spectrum weighs its frequency. The *vegetation* spectrum is prepared based on individuals in each life-form class without any regard to the species[16]. Over and above, we have Raunkiaer's NBS which is the average of the life-form proportions of the global ecosystems.

Phytoclimates of the Tropics

The tropical climate is by far the most dominant climate in the Indian subcontinent[7]. The phytoclimates of the Indian tropics are not the same but different (Table 3). Either phanerophytes or therophytes usually dominate the stands of natural vegetation. The phanerophytic phytoclimate is typical of tropical habitats where the precipitation is higher and for a longer period. It is the case with the tropical climate (Table 3: examples 1, 2a, b[i]). In a typical rain forest as in Carobà, Brazil, therophytes are totally absent according to Cain *et al.*[27] (Table 3: 1a). In contrast, therophytic phytoclimate is characteristic of tropical (hot) desert[8,12,18] (Table 3: 3a-d); it is also the case elsewhere in certain parts of the Telangana region (Table 3: 2b [ii, iii]). The Jakaram Reserve Forest, also of Warangal North Forest Division abutting the southwestern part of the study area, was found tending towards the desert climate[15]. Obviously, it attained such a state within the forest division due to deforestation, mining, biotic disturbance (being proximate to the

Table 3: Climates / Forest types: the Preponderance of Life-forms and Phytoclimates in Relation to the Study Area

Habitat / Forest type	Life-form preponderanc 1 2 3 4 5	Phytoclimate	Reference
1. Tropical Climate	PH>CH≥TH>HC>CR	Phanerophytic	Raunkiaer[8]
a) Rain forest (Carobà, Brazil)	PH>CH>HC=CR	Phanerophytic	Cain *et al.*[27]
b) Tropical island (Seychelles)	PH>TH>CH>HC>CR	Phanerophytic	Raunkiaer[8]
c) Tropical coast (Simhachalam, India)	PH>TH>HC>CR>CH	Phanerophytic	Raju[33]
2. Tropical Dry Deciduous Forest:	PH>TH>HC>CR>CH	Phanerophytic	**Present study**
a) Erstwhile Hyderabad	PH>TH>HC>CH>CR	Phanerophytic	Ferreira[10]
b) Telangana, Andhra Pradesh:			
(i) Achampet	PH>TH>HC>CR>CH	Phanerophytic	Ramchandrachary[34]
(ii) Jakaram RF	TH>PH>CH>HC>CR	Therophytic	Reddy *et al.*[15]
(iii) Warangal district	TH>PH>HC>CR>CH	Therophytic	Reddy[31]
3. Tropical (hot) Desert:			
a) Central Sahara	TH>HC>CH>PH>CR	Therophytic	Raunkiaer[8]
b) California, USA	TH>PH>HC>CH=CR	Therophytic	Raunkiaer[8]
c) Lybia	TH>CH>HC>PH>CR	Therophytic	Raunkiaer[8]
d) Indian Desert:			
(i) Rajasthan	TH>CH>HC>PH>CR	Therophytic	Das and Sarup[12]
(ii) Jaisalmer	TH>PH>HC>CR>CH	Therophytic	Reddy *et al.*[18]
4. **Hot Steppe**:			
Timbuctu, Africa	CH>TH>PC>HC>CR	**Chamaephytic***	Hagerup[35]
Zwara, Lybia	CH>TH>HC>PH>CR	**Chamaephytic***	Qadir & Shetvy[36]
5. Cold Steppe:			
Pamir Mountain, USA	HC>TH>CH>CR>PH	Hemicryptophytic	Paulsen[37]
6. Savanna:			
Barinas, Venezuela	CR>TH>HC> PH> CH	Cryptophytic	Sarmiento & Monasterio[29]

CH – Chamaephytes; CR – Cryptophytes; HC – Hemicryptophytes; PH – Phanerophytes; TH – Therophytes; * Not reported by Raunkiaer[8].

settlements) and facilitated by poor soil (*morum*) and less rainfall. Although phanerophytic phytoclimate is prevalent in the region (Table 3), a shift towards therophytic phytoclimates is imminent (Table 2), driven by the increased aridity and biotic disturbance.

Floristic Spectra: Dominant and co-Dominant Life-forms

According to Cain[11], no single life-form class is associated solely with a single environmental type.

As there is no life-form exclusiveness, the harmony between the floristic structure and the environment is not complete and uniform. Consequently, the resultant vegetation is a complex of the dominant and co-dominant life-forms. As stated earlier by Raunkiaer[8], 'the plant climate in a given region may be characterized by the life-form or life-forms which, in the biological spectrum of that region, exceed the percentages of the same life-form or life-forms in the NBS'. Meher-Homji[19] may be the first person from India to assign two life-forms to indicate the prevailing phytoclimate of a habitat and it is followed by some others like Singh and Arora[28] and Reddy *et al*.[18] Accordingly, the overall life-form proportions of the study area showed (Table 2) reflect a *phanero-therophytic* climate. This better indicates the in-built trend with 3% more of phanerophytes while the therophytes more than doubled than in NBS. For Hantam-Tanqua-Roggeveld region, van der Merwe and van Rooyen[5] recognized three biomes: The Winter Rainfall Karoo and Tanqua Karoo are dominated by chamaephytes (31.1% and 43.9%, respectively) with co-dominant therophytes in the former (29.5%) and cryptophytes (24.3%) in the latter. Such a description may be of use where no single life-form exceeded more than half of the floristic composition.

Phanero-Therophytic Phytoclimate

The study area experiences 4-6 months of dry period, high rainfall and temperature. Such a tropical climate promotes good plant growth leading to the woodland development. However, therophytes (successional) were found more in store than expected in the forest gaps, openings and along the disturbance gradients like roads, footpaths, power and telephone lines, etc. while the biotic factors like human agency, livestock and even the movement of wildlife aided their spread. The recurring annual fire also predisposed the forest land for invasion by fire-prone therophytic aliens. Consequently, the therophytes (26.8%) dominated the other life-forms; they are next to phanerophytes (49%). It is interesting to note that the phanerophytes in the study site are closer in numbers of its kind in NBS of Raunkiaer whereas the therophytes became double. The phanerophytes and therophytes together constitute 65% of the life-form proportions. Conversely, the phanerophytic climate of the warm humid tropics is overlaid with the therophytic climate of a tropical desert. It is in contrast to parts of Deccan (i.e. the erstwhile Hyderabad state) which was described to have 750-1200 mm rainfall, with 5-6 dry months and *phanerophytic* phytoclimate[10] (Table 3: 2a).

Raunkiaer[8] studied in a tropical climate, including the tropical islands, hemicryptophytes find fourth place while they occupy the third position in the phytospectrum of the present study site and elsewhere (Tables 2, 3). Hemicryptophytes are characteristic of the mid-altitudes and deciduous forests[8]; this contention receives support from the present study. Furthermore, the chamaephytes are expected in higher altitudes and latitudes[11]. So, the chamaephytes are not anticipated to be high in numbers in the Godavari valley. Really, they are least found (87% less over NBS) and are outnumbered by hemicryptophytes and cryptophytes (Table 2).

Cryptophytes vis-à-vis **phytoclimate**

Raunkiaer[8] realized only four major climate types. There is no typical phytoclimate attributed to cryptophytes and here categorized into geo-, helo- and hydrophytes (Table 2). Cryptophytes are relatively fewer in number and are not a dominant life-form of any particular climate[9]. However, at least in one case (Table 3: 6, i.e. Barinas, Venezuela), Sarmiento and Monasterio[30] reported *cryptophytic climate* for a savanna with cryptophytes predominating (40%), followed by therophytes (28%). Another example is Mountain Renosterveld, South Africa[5]. The present authors are of the opinion that the past life-form studies often paid little attention to distinguish the cryptophytes from therophytes. Consequently, this category was usually under-represented. So, the current study has taken care to have a critical look at the root system of each and every monsoonal floral element. The result is a proper classification of some of these species under cryptophytes (and geophytes) which were otherwise treated as therophytes.

In the study-site, helophytes and hydrophytes were almost equal in proportion, with a trend for increase from *Tectona-Terminalia* to *Terminalia-Hardwickia* zone. Geophytes are relatively greater in proportion and increased from 5.3 in the TT zone to 12.4 in the TH zone (Table 2) along the gradients (decreasing soil moisture and increasing altitudes). *Madhuca-Terminalia-Hardwickia* zone, being in the centre, has the average value (9.2) for the entire study area. Overall, the cryptophytes were found to outclass chamaephytes.

In general, geophytes prosper well in temperate or cool (Mediterranean type) climates[8,11,14,30]. According to Cain[11], geophytes occur in fair proportion in chamaephytic phytoclimates. It is the case with Hantam-Tanqua-Roggeveld[5].

However, in the tropics, geophytes are characteristic of the Pranahita-Godavari Valley[24,31], which has a seasonal climate with the abiotic stress (drought) period in summer. They die back to underground storage organs to survive the unfavourable dry period, fire, etc. In the Godavari Valley (tropical ecosystem), geophytes are conceived as relics of the palaeoclimate, which prevailed prior to the present positioning of the Indian subcontinent. According to Zohary[32], a fraction of the flora of a place may be in discordance with the present-day climate and could be the remnant of past climate.

Singh and Arora[28] described the phytoclimate of the Ganganagar district of Rajasthan (which is proximate to the Indian desert) as of *thero-cryptophytic*. In comparison with the present site, the cryptophytes increased through hydrophytes with the added irrigation facilities like canal network.

Tropical Deciduous forest: The Phytoclimate of Dansereau

Although the Godavari Valley of Warangal district enjoys the tropical climate, the life-form proportions fall totally outside the ranges of those expected of it by Dansereau[22] for the tropical climate showed in Fig. 2; PH: **49**% < range 61-74%; CH: **1.2**% < range 6-16%; HC: **13.8**% > range 4-12%; CR: **9.2**% > range 1-5%; TH: **26.8**% > range 5-16%). The phanerophytes and chamaephytes were less than expected whereas hemicryptophytes increased slightly, therophytes to 1.7-fold and cryptophytes almost 2-fold. Conversely, Dansereau's life-form ranges, under the tropical climate, do not cover the realistic proportions of life-forms of the tropical deciduous forest. So, there is a need to carve out life-form proportion ranges for tropical deciduous forest biome within the tropical climate, with more studies of this kind in a wide range of habitats over continents to infer the phytoclimate more effectively.

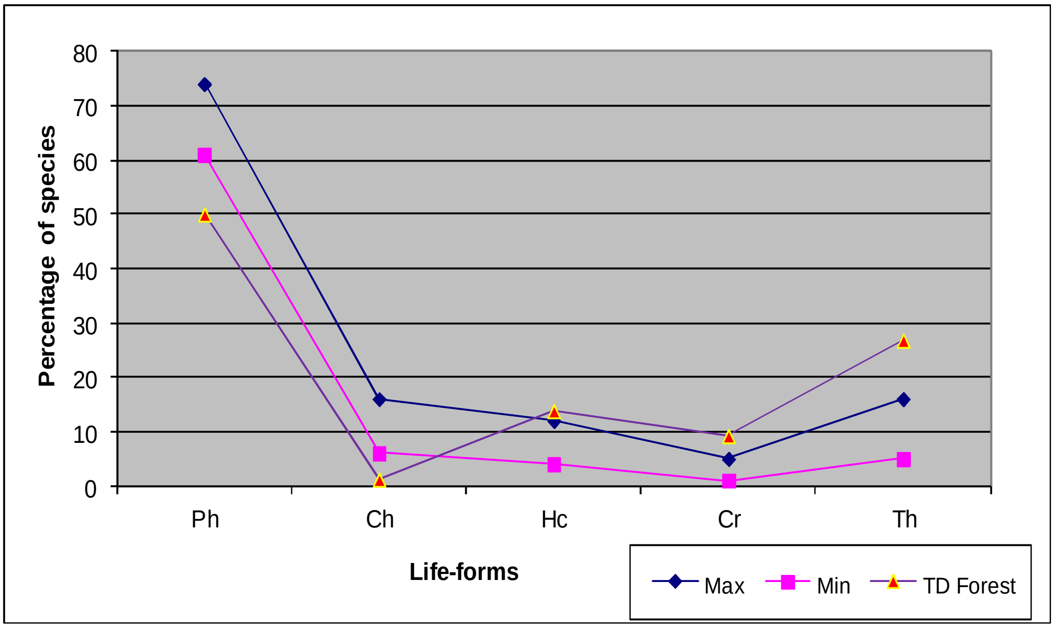

Fig. 2. Tropical Climate of Dansereau Vs. The Phytoclimate of Tropical Deciduous Forest Through Life-form Proportions

Conclusions

The floristic life-form spectra, as revealed in the present study, further demonstrates the potential use of Raunkiaer's approach to distinguish the plant communities/forest types in a forest biome, to establish the transitional and dynamic nature of biomes and the extent of their relatedness (affinities) and how the species contribution to floristic life-forms proportions are driven by the prevailing environmental gradients and ecological parameters. The review of literature of global phytospectra finds a phytoclimate for chamaephytes also which was not identified earlier by Raunkiaer or underscored by other workers of its significance.

The study also served the following purposes: (i) It provided the baseline data of the life-forms for change detection studies and determination of bioclimate in the future; (ii) It inferred, mesoscale, the phytoclimate of the watershed as phanerophytic which is truly phanero-therophytic in view of its dynamic nature and co-dominance; (ii) It helped to compare and contrast the adjacent natural strands (microscale) patterned along the environmental gradients, revealing more that is in the ecosystem store (information) than the mere forest cover; and (iv) Suggested the role of biotic factors in shaping the vegetation of a landscape by directing succession.

The extent of life-form proportions of natural habitats could be good bioindicators of environmental variation and ecological change. Therefore, the life-form spectra can be employed to know the effects of climate change. However, there is a need to discriminate the cryptophytic phytoclimates into the geophytes-dominant (cold/temperate) and the hydrophyte-dominant (aquatic/wet) ecosystems.

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