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APPLICATION OF HOLDRIDGE LIFE ZONES (HLZ) IN PAKISTAN

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Abstract

Classification of an ecosystem is important in understanding climate change. This paper examines and juxtaposes the existing systems used in Pakistan with the contemporary global systems and tessellates that the two are not congruent. We propose application of Holdridge life zone (HLZ) classification system in Pakistan which has not yet been determined. This opens a new outlook and helps understanding climate change in Pakistan while aligning it with the globally accepted uniform system. There is no single classification system in Pakistan that could be regarded as universally accepted. Previous classifications have done to fulfill specific objectives. It is accepted that three key factors of HLZ have to be taken into account to reach a meaningful interpretation of climate *viz a viz* vegetation i.e. $T_{Bio,}$ P_{Ann} and PET ratio. In this paper a new biome map of Pakistan at 0.5° Spatial resolution has been extracted based on HLZ model. We investigated 38 worldwide classes and acknowledge the existence of 26 in Pakistan including 5 classes from the Tropical Zones. We find that the extracted map is in line with the ground reality as well as the previous studies done on the subject. This study opens up a new era to empirically capture impacts of climate change on shifts in vegetation zones of Pakistan. HLZ provides an opportunity for spatial modeling of the climate change influence on vegetation pattern.

Key words: Life zone, Climate change, Forest type

Introduction

Earliest vegetation maps of the world drawn in 1855 by Augustin revealed that the forest types were located in belts of Life Zones (Roy *et al*., 2006). A Life Zone is a grouping of basic natural units having regions with similar plant and animal growth within a definite range of climatic conditions. Two different vegetation communities having identical climatic conditions, flora and fauna may be entirely different however the general life-form can still be the same. Researchers have also mapped and classified forests historically by Forest cover types. The concept is similar to "biome" but the later does not synchronize well with the climatic parameters. An adequate climate based classification system must fulfill four principles i.e. data manipulation, wieldy to apply, directed toward limited, well defined objectives based on atmospheric parameters, and fulfils meteorological principles (Essenwanger, 2001).

The concept of life zone has been used since the start of 21st century across the world. Local attempts made in many countries showed 19 life zones in India (Roy *et al*., 2006), 20 in Africa (Velarde *et al*., 2005), 38 in the US (Lugo *et al*., 1999), and 26 in China (Yue *et al*., 2001). Three complete and three transitional life zones were recognized at Saint Lucia (Isaac & Bourque, 2001). Similarly 18 biomes were mapped in Australia based on HLZ model (Jia *et al*., 2012).

A comparable system in Pakistan that corresponds to some accepted system is needed due to the tremendous importance of climate change since 1992. The climatic boundaries of Pakistan lie between 23.69 -36.9^{o}NL and 60.87-75.38^{o}EL and extend from Arabian Sea to Himalayas having great climatic and floral variations and many classification systems have attempted to capture this variability. These are based on different criteria, e.g. climatic zones, agro-ecological zones, aridity zones, cropping zones coupled with administrative units none having consensus. To fill this gap we propose application of Life Zone Classification specific to Pakistan that tessellates with the ongoing discourses on climate change research.

Material and Methods

Historical classification of Life zones: Major plant formations of the world have historically been reported to be dependent on drought and heat tolerance of the dominant species (Watson *et al*., 1995; Roy *et al*., 2006). Life Zone was further introduced by Merriam in 1889 finds similarity in flora and fauna additionally found it to correspond with altitude and latitude. Wladimir Koppen, in 1884, devised Koppen climate classification system and was updated several times (Koppen, 1884). The system was based on the concept that native vegetation is the best expression of climate. Earth was divided into 5 main groups denoted with symbols A to E having several subdivisions. The classification combines the average annual and monthly temperatures and seasonal variations of precipitation with reference to the native vegetation (Peel *et al*., 2007). Beard (1944) made further amendments on the basis of plant associations, formations and formation series. Trewartha (1968, 1980) redefined the areas of the broad climatic groups of Koppen by adjusting the vegetation types of the world especially in USA wherein dissimilar vegetation regions were previously grouped together.

In a parallel approach Holdridge (1947, 1967) formulated Life Zone classification system which was independent of the vegetation patterns and was entirely based on three equivalently weighted climatic factors of Mean Annul Bio-temperature (T_{Bio}), Mean Annual Precipitation (P_{Ann}) and Potential Evapo-Transpiration (PET) represented as a two dimensional set of hexagons arranged in a triangular frame each having six micro triangles representing local environments as shown in the Holdridge Life Zone Scheme (Table 2). The scheme represents hundreds of vegetation associations including local variants and is followed globally (Watson *et al*., 1995). It was found that the life zones are influenced by the growing season length and temperature variations (Rawson & Macpherson, 2000). Therefore base temperatures below freezing point were substituted to 0 C assuming that vigorous growth cannot be maintained below 0 C (Holdridge & Grenke, 1971; Jia *et al*., 2012). Thornthwaite (1948) also devised a system based on water balance in which Potential Evapo-transpiration Ratio (PET) was introduced having following formula:

$$PETi\ (0) = 1.6(10Ti/J)c \qquad (1)$$

At latitudes other than 0°

$$PETi(L) = KPTi\ (0) \qquad (2)$$

where, K is a constant for each month of the year varying as a function of latitude

Ii = Heat Index = (*Ti*/5)1.514
Ti = Mean monthly temperature
J = Annual temperature efficiency index

$$J = \sum i = 112(l) \qquad (3)$$

C is an exponent calculated as
$c = 0.000000675J3 – 0.0000771J2 + 0.01792J + 0.49239$

Box (1981) extended Holdridge Classification System to accurately predict the coexistence of plant growth forms and the dominant plant species (Watson *et al*., 1995). International Institute for Applied Systems Analyses (IIASA), in 1989, developed a vector based dataset of HLZ at 0.5° spatial resolution and mapped 38 life zones across the world (Anon., 2002).The three parameters used were from global historical records of at least five years between 1930 and 1960 (Leemans, 1990). The Global Ecological Zoning (GEZ) by Food and Agriculture Organization of the United Nations in the Forest Resources Assessment is widely consulted (Jia *et al*., 2012). The two tiered hierarchy of this classification follows Koppen-Trewartha 1968 version with addition of a distinct class of Mountain systems. The boundaries of the GEZ were delineated discretely for 10 regions covering the entire terrestrial earth by using their existing source maps of multiple origins (Anon., 2010).

Classification of vegetation/climate in Pakistan: Champion (1935) surveyed the forest types of the Indian subcontinent and later, with Khattak (1962-63), revisited the same to classify the Forest Types of Pakistan following the Beards classification(Champion *et al*., 1965). Floristic groups were assembled into physiognomic groups. Major Forest Types were consequently identified into 9 groups (Table 1). Pakistan Agriculture Research Council (PARC),in collaboration with Pakistan Forest Institute and Soil Survey of Pakistan (1987) defined 18 Agro-Ecological-Zones in which individual inventories encompassing multiple factors were incorporated including parent material, temperature, precipitation, vegetation and administrative units (Khan, 2004). It also delineated 10 other agro-ecological zones by incorporating physiography, climate, soil and agricultural land use. Similarly Agro climates of Pakistan were classified which addressed the issue of climate change in Pakistan (Chaudhary & Rasul, 2004). The reference crop evapo-transpiration (ET°) was used instead of PET to better characterize agricultural crops by modifying Thornthwaite method for estimation of moisture in the atmosphere (Zahid & Rasul, 2011) however, This work remained focussed on agricultural crops (Chaudhary & Rasul, 2004). A conference proceeding in Ohio presented different classes for climates of Pakistan. Geographical location, rough topography, proximity to sea level, soil content and vegetation cover were considered critical parameters. Five macro-regions covering 18 meso and 46 micro climates were identified based on temperature (i.e. Hot, Warm, Mild, Cool and Cold) and precipitation (i.e. arid, semi-arid, sub humid and humid) (Khan, *et al*., 2010). According to Forest resources assessment by FAO the GEZ of Pakistan comprises mainly of Tropical/ Subtropical Deserts, Subtropical Steppe and Subtropical Mountain systems (Anon., 2010). HLZ of Pakistan has not yet been determined however Qadir *et al*., (1966) reported Karachi in “Sub-tropical desert bush” (Parveen *et al*., 2007).

Results and Discussion

There is no single classification system in Pakistan that could be regarded as universally accepted. Previous classifications have been done to fulfill specific objectives. The difficulty in devising an appropriate system is that available is not uniform since vegetation is distributed unevenly in intricate spatial mosaics. Regional biodiversity can be characterized by species richness, taxic diversity and functional diversity (Watson *et al*., 1995). HLZ provides an opportunity for spatial modeling of the climate change influence on vegetation patterns (Watson *et al*., 1995).

HLZ is considered to be the most adequate global classification system having regional implications (Jia *et al*., 2012). This is also due to its floating nature and the co-variance of the key climatic parameters in the Life Zone Classification scheme (Fig. 1). Different zones provide different vegetation and thus are helpful in understanding the scientific explanation of the vegetation (Khan *et al.,* 2014).

Table 1. Classification of climate/vegetation in Pakistan.

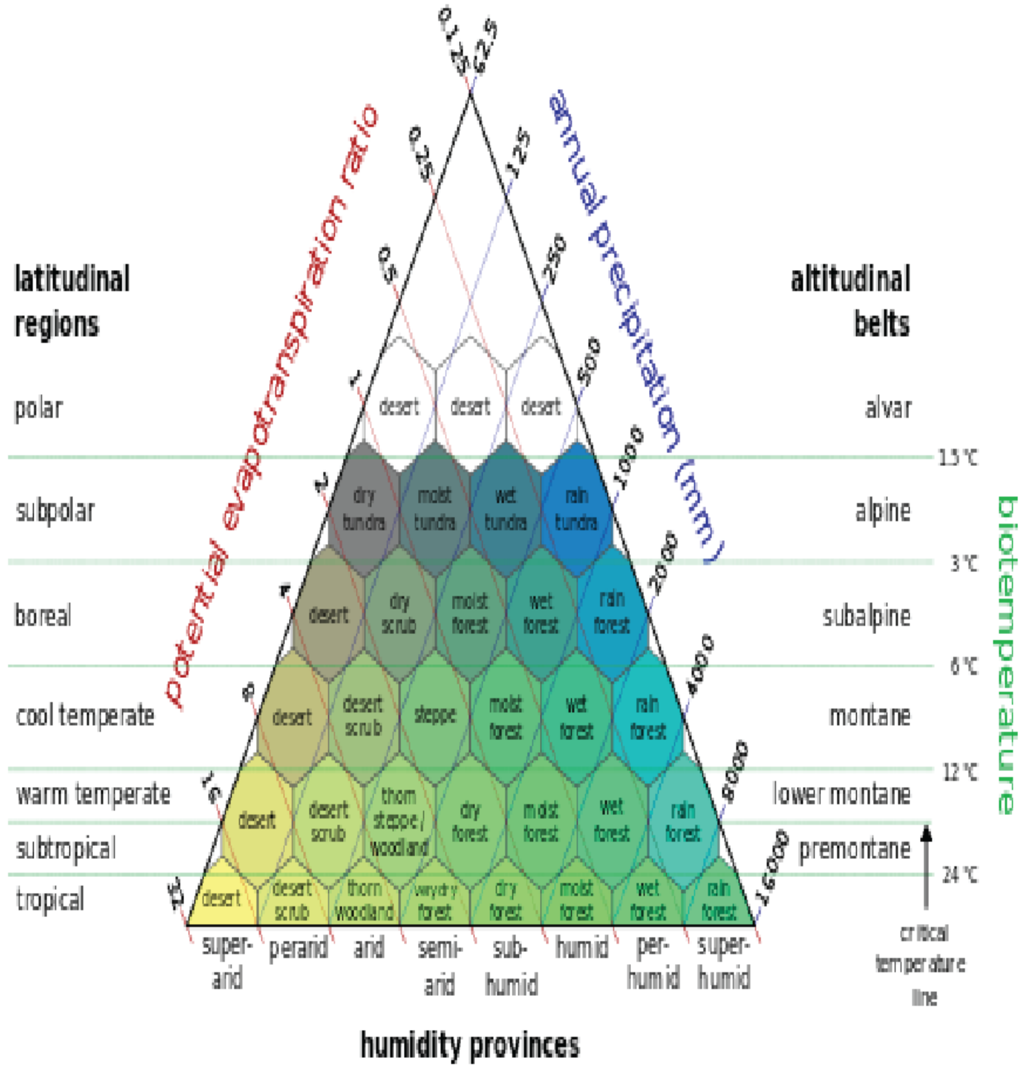
Classification System	Major divisions	Subdivisions
Forest Types of Pakistan	*Tropical forest*	Littoral and swamp forest
(Champion, Seth and Khattak) 1962-63		Dry deciduous forest
		Thorn forest
	Montane subtropical forest	Dry subtropical broadleaved forest
		Subtropical pine forest
	Montane Temperate Forest	Himalayan moist temperate forest
		Himalayan dry temperate forest
	Sub-Alpine Forest	*Sub-Alpine Forest*
	Alpine Scrub Forest	*Alpine Scrub Forest*
Agro Ecological Zones of Pakistan	*Snow Desert Region*	-
(PARC, PFI and Soil Survey of Pakistan)	*Dry Cold Temperate Continental Winter Rains Region*	Alpine Scrub high to very high altitudinal montane zone
1987		Sub-Alpine Scrub Forest high to very high altitudinal montane zone
	Dry Cool Temperate Continental Winter Rains Region	Juniperus, moderately high to high altitudinal montane zone
		Pinus gerardiana, moderately high to high altitudinal montane zone
	Dry Temperate Continental Winter Rains Region	*Olea-Pistacia*, low to moderately high altitudinal montane zone
		Quercus ilex, low to moderately high altitudinal montane zone
	Semi-Arid Warm Subtropical Continental winter/monsoon rains region	*Olea-Acacia modesta,* low altitudinal montane/Plateau zone
		Olea-Acacia senegal, low altitudinal montane zone
	Semi-Arid Hot Subtropical Continental winter/monsoon rains region	*Acacia-Prosopis-Zizyphus*, low altitudinal piedmont/ loess plains zone
	Arid Hot Subtropical Continental winter rains region	Salvadora- Nannorrhops, low altitudinal montane zone
	Arid Hot Subtropical Continental monsoon/ winter rains region	*Acacia senegal-Salvadora-Capparis*, low altitudinal montane zone
		Acacia jacquementii-Salvadora-Capparis, low altitudinal montane zone
	Very Arid Hot Subtropical Continental winter rains region	*Haloxylon salicornicum-Rhazya*, low altitudinal intermontane piedmont plains zone
		Haloxylon persicum, low altitudinal intermontane sandy desert zone
		Alhagi desmostachya, low altitudinal intermontane plains zone
		Olea-dry chirpine, low altitudinal montane zone

Table 1. (Cont'd).

Classification System	Major divisions	Subdivisions
	Sub-humid warm subtropical continental monsoon	*Olea*-dry chirpine, low altitudinal piedmont plains zone
		Moist Blue Pine, moderately high to high altitudinal montane zone
	Humid Cool Temperate Continental Monsoon/ Winter Rains Region	Mixed Coniferous, moderately high to high altitudinal montane zone
	Humid Cool Temperate Continental Monsoon/ Winter Rains Region	Moist Chir Pine, low to moderately high altitudinal montane zone
	Humid moderately cool SubTropical continental Monsoon/ Winter rains region	*Calligonum*, sandy desert zone
	Humid moderately cool SubTropical continental Monsoon/ Winter rains region	*Capparis-Suaeda-Tamarix,* piedmont plains zone
		Salvadora, piedmont plains zone
	Arid Hot Subtropical Continental Monsoon rains region	*Prosopis-capparis*, Subrecent river/ piedmont plains zone
		Tamarix- phoenix dactyllifera, river plains zone
		Acacia-populus, Recent river plains zone
		Salvadora-prosopis, subrecent/ old river plains zone
	Semi-Arid Hot Subtropical Continental Monsoon rains region	*Salvadora-Calligonum*, sandy desert zone
	Semi-Arid Hot Subtropical Continental Monsoon rains region	*Butea*, piedmont plains zone
	Sub-humid Warm Subtropical Continental monsoon rains region	*Butea*, river plains zone
	Sub-humid Warm Subtropical Continental monsoon rains region	*Avicennia,* tidal flats zone
	Arid Warm Tropical Maritime monsoon/Winter rains region	*Suaeda-salsola*, estuarine plains zone
	Arid Warm Tropical Maritime monsoon/Winter rains region	*Acacia senegal*-Calligonum, sandy desert zone
	Arid Warm Tropical Maritime Monsoon rains region	*Acacia senegal,* river plains zone
	Arid Warm Tropical Maritime Monsoon rains region	*Acacia jacquemontii*, montane zone
	Arid Warm Tropical Maritime winter rains region	*Suaeda-salsola*, piedmont plains zone
	Arid Warm Tropical Maritime winter rains region	Humid
Agro Climatic Zones of Pakistan (Dr. Qamaruzzaman ch.) 2004	*Humid*	Wet-Subhumid
	Humid	Dry-Subhumid
	Sub-humid	Wet-SemiArid
	Semi-Arid	Dry-SemiArid
	Semi-Arid	Arid
	Arid	
	Arid	

Table 2. Proposed Classification system in Pakistan.

Classification System	*Major divisions*	Subdivisions
HLZ	*Polar*	Polar Desert
	Sub-Polar	Polar dry tundra
		Polar moist tundra
		Polar rain tundra
		Polar wet tundra
	Boreal	Boreal Desert
		Boreal moist forest
		Boreal wet forest
		Boreal Dry Bush
	Cool	Cool temperate desert bush
		Cool temperate moist forest
		Cool temperate steppe
	Warm	Warm Temperate desert
		Warm Temperate desert bush
		Warm Temperate dry forest
		Warm Temperate thorn steppe
	Syb-Tropical	Sub-Tropical desert
		Sub-Tropical desert bush
		Sub-Tropical dry forest
		Sub-Tropical thorn steppe
		Sub-Tropical moist forest
	Tropical	Tropical desert
		Tropical desert bush
		Tropical dry forest
		Tropical thorn steppe
		Tropical very dry forest



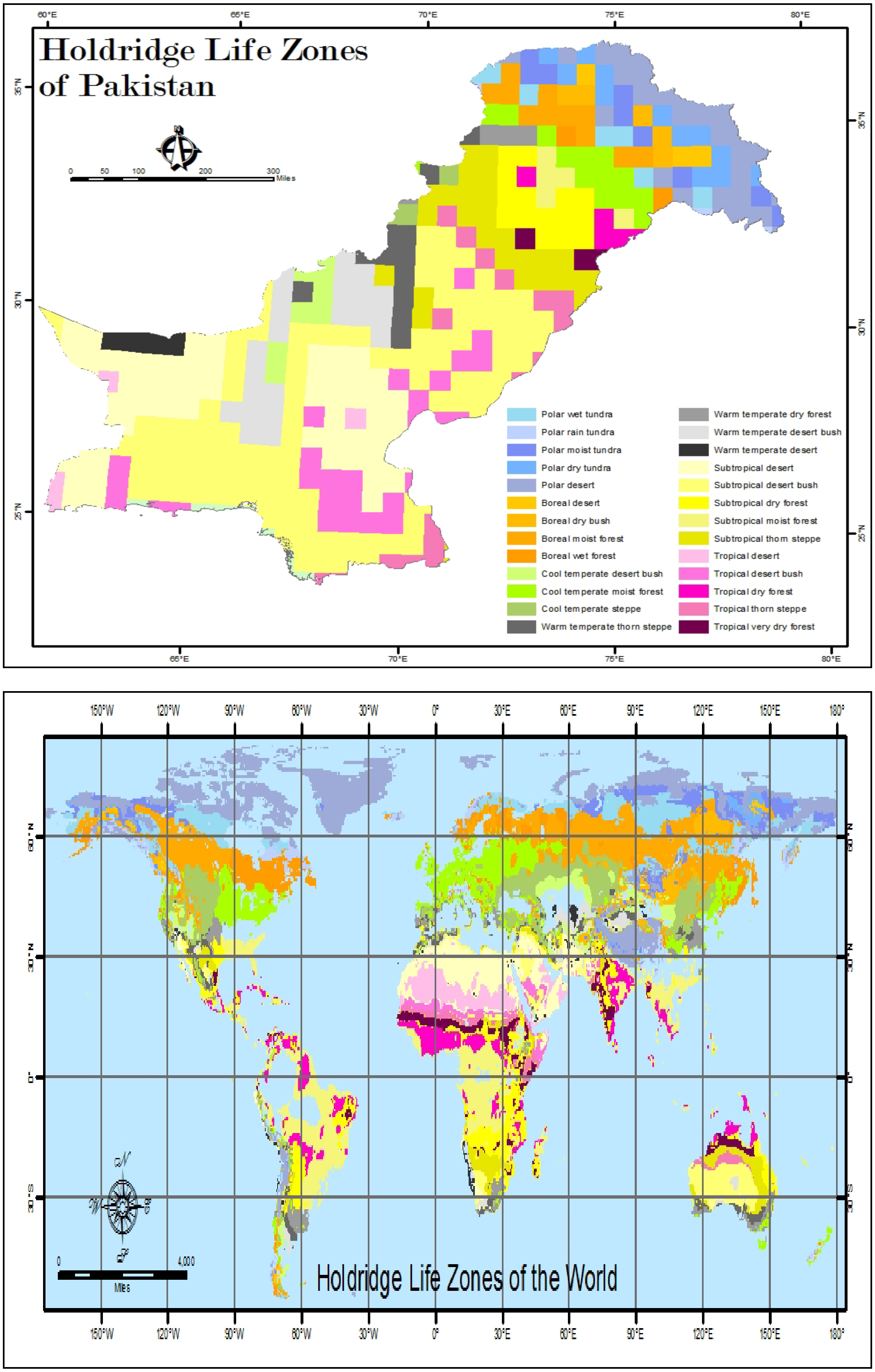


Fig. 1. Proposed Holdridge Life Zones of Pakistan.

Koppen classification system on the other hand takes into account vegetation as the decisive factor in the classification of a climate. However in a region like Pakistan Koppen classification is less practical due to irregular distribution of vegetation types (Bharucha & Shanbagh, 1956). This classification is based more or less on the interactions of vegetation with climate rather than solely on meteorological data however recent studies have revealed that plant distribution is dependent more on the climate (Chaudhary & Rasul, 2004). Koppen had to repeatedly revise the system due to its imperfection in correlation with vegetation as is mainly based on facts and observations thus resulted in a lot of dislocations. Some important climatic factors, like PET have been totally ignored in most of the regions and it is always difficult to tell the nature of moist and dry climate only with precipitation (Khan *et al*., 2010). Koppen's-Trewartha lettered symbols as followed by GEZ of FAO are difficult to characterize forests of Pakistan and since it delineates sharp boundaries of vegetation zones that do not exsit here due to periodical changes.There are gradual transitions that occur in micro-climatic zones with time, therefore the classes are supposed to be floating in nature (Isaac & Bourque, 2001;Yue *et al*., 2001). Champion (1965) classified forest types of Pakistan referring to a unit of vegetation that differentiate regions parallel to soil of medium depth and fertility as the climatic climax. Uncertainties remain in the differentiation of various forests (Champion *et al*., 1965). As two vegetation types do not always reflect single site conditions. Thus, a Deodar forest may not be a sign of xeric conditions; similarly the blue pine forest is not always found in Mesic habitat type (Kotar & Burger, 1999).

HLZ provide the most extensive and logical sequence of classification in Pakistan even at the global scale at 0.5° spatial resolution. After extraction of Pakistan's map from the global HLZ (Table 2) the computer generated Fig. 1 which revealed that the classes of vegetation zone represent similar vegetation types that are on ground and also to those observed in the previous studies as shown in Table 2. It revealed that all the global divisions of HLZ as shown in Figure 1 are available in Pakistan; out of the 38 global sub divisions 26 exist in Pakistan. Polar and Boreal Zones are restricted to the northern areas followed by the Cool and Warm Temperate in the northern reaches of the provinces of Khyber Pakhtunkhwa, Punjab and Baluchistan regions. Most of the regions in Punjab, Baluchistan and Sindh fall in the subtropical zones as desert, desert bush and thorn steppe. It is for the first time that Tropical division as defined by HLZ has been identified in Pakistan though the 5 sub divisions (Fig. 1 and Table 2) are mainly dispersed in the Southern regions along the sea coast and the extreme drier end namely tropical desert, tropical desert bush, tropical dry forest, tropical thorn steppe and tropical very dry forest. This study also confirms that wet and rain forests do not exist in Pakistan (Chaudhry, 1961). Parveen *et al*., (2007) referred to Qadir *et al*., (1966) also have determined the bio-climate of Karachi by Holdridge's system.

Conclusion

Continuous monitoring of data can help monitor if any changes are taking place due to climate change. The map at Figure 1 provides basis to understand climate change in Pakistan. In this paper we applied the HLZ model to extract a new map at 0.5 spatial resolution for Pakistan. A comparison of this map with the past studies reveals that it has good accuracy and does not conflict with the ground reality.

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