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CLASSIFICATION AND ASSESSMENT OF ARIDITY OVER PAKISTAN PROVINCES (1960-2009)

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Abstract

Due to rapid growth of population, massive deforestation and anthropogenic activities, noticeable change in climate conditions is being observed in Pakistan. Increased aridity due to climate change is a growing environmental problem of the agricultural country like Pakistan. It is essential to assess and monitor aridity to combat the probable land degradation and drought desertification. Identification of arid and semi arid regions on climatic basis is the first essential step in any project of land reclamation for agricultural and other purposes. A geographic information system is used in this paper for the assessment of aridity in Pakistan from long term climatic data of fifty years (1960-2009) collected from fifty four stations situated in the country. In the delineation of climatic zones and delimitation of their boundaries, five well known aridity models *viz*. De Martonne Aridity index, Erinc Aridity index, Thornthwaite Precipitation Effectiveness index, UNESCO Aridity index and Thornthwaite Moisture index are utilized for this purpose. The study shows that southern parts of the country are dry and more vulnerable to drought while the northern parts have variable types of climate. Almost 75 to 85% of the total area of the country is arid in which most part lies in the south while less than 10% area is humid lies in the north of the country. This study will be a good predicator for agricultural scientist, agronomist and hydrologist to plan according the climate of the region.

Keywords: Aridity; Climate Change; Geographic Information System; Moisture Index, Vulnerable

Introduction

Increased in aridity, dryness and desertification have become a major environmental problem affecting the living conditions of the people in the affected region in many countries of the world (Tabari., et al.,2014). Once the aridity or dryness of an area increased beyond a certain level it becomes difficult to recover. In recent years, much interest has been evinced in the study of arid and semi arid regions with special reference to their reclamation for the purpose of human settlement and agricultural production. In any such reclamation project on broad scale, it is essential as a first step to identify the climate of different regions and delimit their boundaries. Arid or humid climate of a region depends on whether or not the precipitation (water supply) is sufficient to meet its water requirement. In the context of climatic classification by water requirement is meant that the total water required for the maximum evapotranspiration.

Desertification refers to land degradation is among the most complex of environmentally and socio-economic threatening events in which climate may have a role. In the process of land degradation, dry land areas become much less biologically productive. Desertification is defined as "land degradation cause by various factors including climatic variations and human activities in arid, semi arid and dry sub-humid areas" (UNEP, 1994). Expansion and contraction of aridity may depend upon inter-annual variations of precipitation in the country. This generally results reducing in livelihood opportunities for human especially for the production of crops and livestock.

Dry lands are classified on the basis of aridity defined as where the water deficit occurs to some extent throughout the hydrological year. According to UNEP, (1997) report, 6.1 billion ha, which is 47% of all land area comprises of dry land environment. Approximately 84% of this area falls within the arid, semi arid and dry sub humid climates which are inherently vulnerable to desertification. Millennium Ecosystem Assessment report (MEA, 2005) estimates that almost 10 to 20% of the susceptible dry lands is believed to have already undergone land degradation. It is estimated that livelihood of almost one billions people in over 100 countries area at risk from desertification and over 250 millions are directly affected (UNCCD,2006). Desertification threatens the sustainability of land, and is believed to be one of the most serious global environmental problems. The consequences of desertification and aridity may expand in the future as a projected 2.0°C to 4.5°C rise in global average temperature and increase in land areas affected by droughts area expected by the year 2100 (IPCC,2007). Agriculture is the backbone of the country which not only fulfils the food requirement of the country but also help to earn foreign exchange. According to GoP (2008) survey, the total cultivable area is 34.54Mha (39.3 percent of total land area), of which only 23.38Mha area is under cultivation while remaining 11.16Mha is being used with low potential rangelands. An area of only 4.22Mha (4.8 percent of the total land area) is under forest cover.

Pakistan is a country which has diversified ecological and climatical zone, topography and agricultural resource base. The agriculture land of Pakistan has potential to produce all types of crops. About 17 percent of the cultivated area is rainfed and depends on rainfall for crop production. Agriculture is mostly relying on rainfall in potowar plateau, northern mountains and northeastern plains which is forming the largest contiguous block of dry land farming in Pakistan (GoP, 2006).

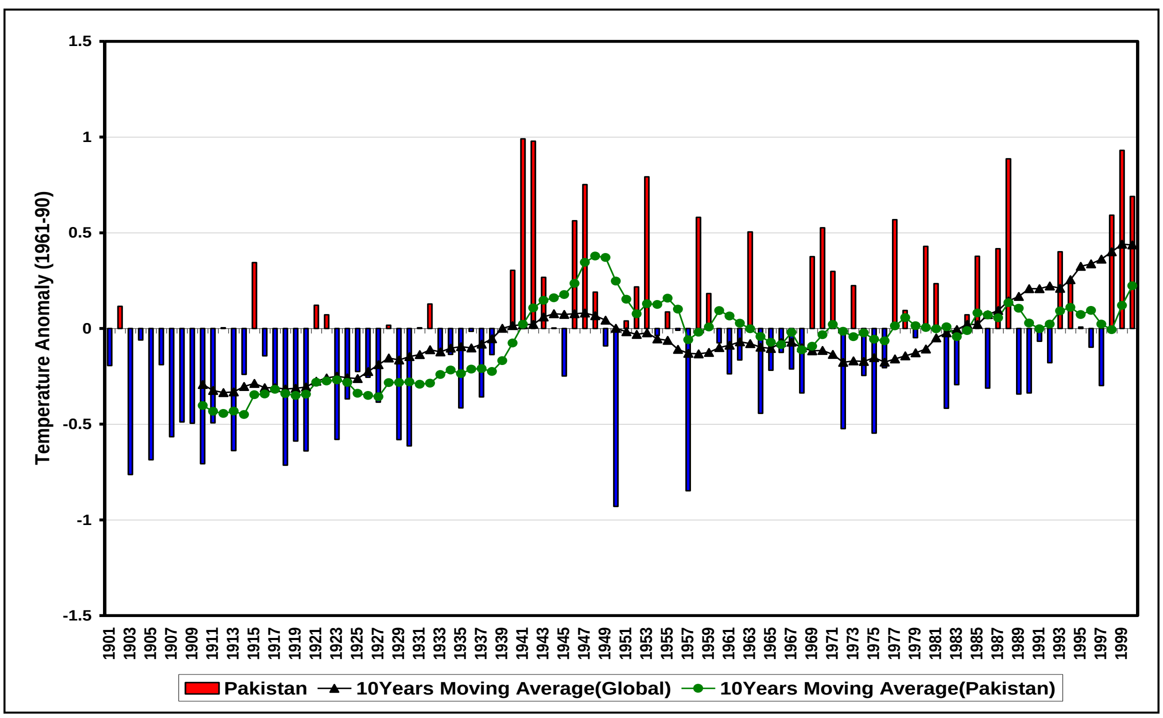

Fig-1: Global and Pakistan Air Temperatures Anomaly obtained from CRU

Almost two third part of Pakistan is arid to semi arid and there is large spatial variability in the temperature in that area (Chaudhary and Rasul, 2004). It was revealed by conducting study on climatical normals of Pakistan, 1931-60 and 1961-90, that there was cooling over northern and southeastern Pakistan due to increase in monsoon cloudiness and rainfall (Kruss et al, 1992). Afzaal et.al, (2009) observed that the temperatures have been rising at the rate of 0.06°C per decade and the total change in temperature has been 0.64°C over the period showing the warming trend in the country.

Climate of Study Area

Pakistan lies in the west of south Asia between 23°39′N-37°01′N latitude and 60°49′E-77°40′E longitude comprising of Indus agricultural plains to western high lands. The total geographical area of Pakistan is 79.6 million hectares (Mha). Due to complex topography and latitudinal variation, Pakistan experiences tropical to subtropical types of climate. Pakistan experience four distinct types of climate during the year.(i) moist winter season from December to March,(ii) the pre-monsoon hot summer season from April to June, (iii) the rainy monsoon season from July to September,(iv) the post monsoon dry season from October to November. Average temperature of the country ranges from 12°C to 20°C during winter and 19°C to 35°C in summer. The highest maximum temperature reaches upto53°C in the south and lowest minimum reaches upto-24°C in the extreme north of the country. The average relative humidity for the whole year ranges from 20% to 58% with a maximum in August and minimum in May.

There are two sources of rainfall i.e. monsoon (July to September) and Western depression (December to march). Annual average area weighted rainfall varies 30mm to 400mm from south to north. South parts of the country are highly vulnerable to drought and aridity. The dry season in the country begins by the mid of September and continues till start of December and April to mid of June. The longest dry periods are normally observed in south of the country especially in southwestern parts where it remains from April to November. Pakistan receives 60 to 65% of rainfall during monsoon season which is not only helpful to lift water table but also the water demands of crops. Northeastern mountains and sub mountainous plains of the north part receive more than 1700mm annual precipitation of which the major share (over 1000mm) comes from monsoon. South parts receive very low amount of precipitation and have high temperature than the north parts of the country. Low elevation plains of southwest Balochistan accumulate only 30mm of precipitation on an average during the whole year. Water requirement and evaporation rate is very high in south parts of the country.

However monsoonal rainfall plays a vital role to compensate it to some extent. Annual amount of rainfall in rainfed area of northern parts of the country varies from 900mm to 1800mm which not only fulfills the water requirement for *Rabi* crops but also the *Kharif* crops (Adnan and Khan, 2009).

Materials and Methods

The aridity maps are prepared by incorporating the aridity measuring indices in Geographic Information System (GIS). This tool is very helpful for classification and assessment of aridity of an area. For aridity mapping of Pakistan, climatic data of meteorological parameters of temperature, humidity, precipitation and Reference Crop evapotranspiration (PET) for fifty years (1960-2009) of fifty four climatic stations was accessed in and around the country. The data used in this research is taken from Pakistan Meteorological Department (PMD). The location of the climatic stations is shown in figure-2.

Fig- 2: Location of climatical stations in and around Pakistan

ET_0 was calculated by modified Penman–Monteith method. The selection of a particular method for the determination of ET_0 depends upon the type of meteorological data available for the given region and the accuracy desired in the computation of water needs.

Modified Penman–Monteith method.

FAO- Penman equation gives best result than the rest method not only for arid climate but also for humid climate. This method shows the minor deviations from the actual evapotranspiration data in Pakistan throughout the year (Rasul, 2009).The recommended method is said to overcome shortcomings of the previous FAO–Penman method and provides results that are more consistent. According to Penman–Monteith combination equation, ET_0 can be expressed as

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where ET_o is the reference evapotranspiration ($mmday^{-1}$); R_n:net radiation at the crop surface ($MJm^{-2}day^{-1}$); G: soil heat flux density ($MJ\ m^{-2}day^{-1}$); T:mean daily temperature at 2 m height (°C); u_2:wind speed at 2 m height (ms^{-1}); e_s:saturation vapor pressure (kPa); e_a:actual vapor pressure (kPa); e_s-e_a :saturation vapor pressure deficit (kPa); Δ:slope of vapor pressure curve ($kPa°C^{-1}$); γ: psychrometric constant ($kPa°C^{-1}$)=0.665 $x10^{-3}$ P, where P is atmospheric pressure (kPa).

Reddy and Reddy (1973) suggested some modifications to Thornthwaite's scheme (1948) to develop more homogeneous types-hereafter called" Modified Thornthwaite's Approach". In this method, the soil term was eliminated in the computation of moisture index using the potential evapotranspiration (PET) and rainfall (P). Here in this research investigation, reference crop evapotranspiration (ET_o) is used instead of PET hoping for better results in relation to natural vegetation.

Inverse Distance Weighted Average (IDWA)

IDWA is an averaging procedure. It gives each neighbouring station a weight which is proportional to a power of the inverse of the station distance. Thus, closer stations have more weight in the averaging procedure than stations that are further away. If the power exponent is large, closer stations get much more weight than stations that are further away. Therefore, with an increasing power exponent, IDWA converges to nearest neighbour interpolation. On the other hand, the smaller the exponent is, the further reaches the influence of each station. For exponents close to zero, the interpolated field becomes the area average with small spikes at station locations. Note that if a station is very close to the grid point it gets nearly all the weight. If a grid point and station are at exactly the same location IDWA is not defined because of division by zero.

There are two fundamental theoretical disadvantages with IDWA. The first is that the theoretical continuous climate surface has locations (the stations themselves) where it is not differentiable. However, from a practical point of view this should not be taken too seriously.
The second disadvantage is that the distribution of weights to the neighbouring stations depends only on the ratios of distances. This means, that scales do not play a role. IDWA does not distinguish the case where one station is 10m and the other 30m away from the case where one station is 100km and the other is 300km away. However, from a climatical point of view there is a tremendous difference which should be taken into account.

ArcGis 9.3 was used for aridity mapping of Pakistan and area of each aridity index was calculated along with its minimum maximum, mean and standard deviation. Five aridity indexing indices namely De Martonne's Aridity Index, Thornthwaite's Precipitation Effectiveness Index, Thornthwaite's Moisture Index, UNESCO Aridity Index and Erinc Aridity Index indices are used and interpolation is done by IDWA Method. Description of each model is as follows;

De Martonne's Aridity Index.

De Martonne's (1926) proposed a method for calculating aridity index (AI) of an area using the following equation;

$$AI = [P/(T+10) + 12p/(t+10)]/2 \qquad \textbf{(1)}$$

where

P is the mean annual precipitation in mm; T is the mean annual temperature in °C

p the precipitation of the driest month in mm; and t the mean temperature of the driest month in °C.

According to the AI values, De Martonne classified the climate into six groups namely, arid, semi arid, dry sub humid, humid and very humid. De Martonne classification of aridity index is shown in table-1.

Table 1: the classification of the dryness based on De Martonne's Aridity Index

S.NO.	AI Values	Climate Class
1	≤ 5	**Arid**
2	5-12	**Semi-arid**
3	12-20	**Dry Sub-humid**
4	20-30	**Wet Sub-humid**
5	30-60	**Humid**
6	≥ 60	**Very Humid**

Thornthwaite's PrecipitationEffectiveness Index.

Thornthwaite (1931) classified the climatic region into different classes based on the precipitation effectiveness index (PE), which is computed from the monthly values of precipitation and temperature. The index is given as;

$$PEIndex = \sum_{1}^{n=12} 115 \times (P/(T-10))^{10/9} \qquad \textbf{(2)}$$

where

P is the Monthly precipitation in inches;T is the mean temperature in °F; and n = months=12.

The classification of the climatic regions based on Thornthwaite's Precipitation Effectiveness into six groups namely, arid, semi arid, dry sub humid, humid and very humid. given in Table-2.

Table 2: The classification of the climatic regions based on Thornthwaite's Precipitation Effectiveness Index

S.NO.	PE Index	Climate Class
1	< 16	**Arid**
2	16-31	**Semi-arid**
3	32-63	**Dry Sub-humid**
4	64-99	**Wet Sub-humid**
5	100-127	**Humid**
6	≥ 128	**Very Humid**

Thornthwaite's Moisture Index

The criteria described in modified Thornthwaite approach (1948), adopted by Reddy and Reddy (1973) for climatic classification of India and some parts of Africa was employed to classify various climatic features of Pakistan. The same weights are given both for humid and arid-terms and uniform limits are used on both wet and dry sides of the scale, as in modified Thornthwaite approach (Reddy and Reddy, 1973). Moisture index is defined as using the mean annual rainfall and mean annual potential evapotranspiration as;

$$I_m = \frac{(R - ET_o)}{ET_o} \times 100 \qquad (3)$$

Where I_m is moisture index in percentage; R is the Mean Annual rainfall in mm; and ET_o is the Mean Annual Potential Evapotranspiration in mm.

The negative and positive values of I_m respectively refer to dry and wet zones. Reddy & Reddy, (1973) defined the moisture limits for broad climatic zones into eight groups namely, Hyper arid, arid, dry semi-arid, wet semi-arid, dry sub-humid, wet sub-humid, humid and very humid as shown in table-3

Table 3:Broad Scale Climatic Zones on the Basis of Moisture Index

S.No.	Moisture Index (Im, %)	Climate Class	
1	<-90	Hyper Arid	
2	-90 to -80	Arid	
3	-79 to -56	Dry	Semi Arid
4	-55 to -26	Wet	
5	-25 to 0	Dry	Sub-Humid
6	1 to 20	Wet	
7	21 to 50	Humid	
8	>50	Very Humid	

UNESCO Aridity Index

The UNESCO (1979) proposed a method for aridity mapping from the ratio of precipitation (P) to potential evapotranspiration (PET), i.e.

$$AI = \frac{P}{ET_o} \quad \textbf{(4)}$$

Where AI is the aridity index; P is the precipitation(mm); ET_o is the potential evapotranspiration by penmen's formula; (mm)

Five climatic zones namely, Hyper arid, arid, semi arid, dry sub humid and humid are proposed by UNESCO Aridity index as shown in table-4.

Table 4:The classifications of the climate region based on UNESCO Aridity Index

S.NO.	AI VALUES	CLIMATE CLASS
1	≤ 0.03	**Hyper Arid**
2	0.03-0.2	**Arid**
3	0.2-0.5	**Semi-arid**
4	0.5-0.65	**Dry Sub-humid**
5	>0.65	**Humid**

The UNESCO system is attractive in that it is very simple conceptually as well as operationally. It is totally based on the two main parameters that define aridity. Warm arid region have low precipitation (P) and high evapotranspiration rate (ET_o) therefore they have low value of aridity index. For hyper arid region, the value will less than equal to 0.03 while for humid region its will be greater than 0.65.

Erinc Aridity Index

Erinc (1996) calculated aridity index by taking the ratio of total annual rainfall (P) to the annual mean maximum temperature (T_{max}) as shown;

$$I_m = \frac{P}{T_{\max}} \quad \textbf{(5)}$$

where

I_m is the aridity index; P is the annual total precipitation (mm); T_{max} is the mean annual maximum temperature (°C)

Six climatic zones namely, hyper arid, arid, semi arid, dry sub humid, humid and very humidare proposed by Erinc Aridity index as shown in table-5.

Table 5:The classifications of the climate region based on Erinc Aridity Index

S.NO.	I_M Values	Climate Class
1	< 8	**Hyper Arid**
2	8-15	**Arid**
3	15-23	**Semi-arid**
4	23-40	**Dry Sub-humid**
5	40-55	**Humid**
6	> 55	**Very Humid**

Results and Discussion

The aridity maps prepared by using De Martonne's Aridity Index, Thornthwaite's Precipitation Effectiveness Index, Thornthwaite's Moisture Index, UNESCO Aridity Index and Erinc Aridity Index indices show that most of the southern parts of the country is arid to hyper arid where as northern parts lies between semi arid to very humid zone (Fig-2). This analysis shows that the climate of northern parts is quite variable where as the southern parts is almost same. The reason in the variability of the climate in the northern parts is that this region received rainfall in summer due to monsoon winds (July to September) and winter due to western disturbances (December to March). Southern parts of the country receive most of the rainfall in monsoon season while a meager amount of rainfall in winter. This monsoonal rainfall brings relief to moisture stress to some extent but due to low elevation, higher evapotranspiration and day time temperature, dry climate exists throughout the year. Therefore, agriculture activity does not depend on rainfall and proper irrigation is required which may be in the form of canals, river and tube wells. Although monsoon rainfall bring a bit relief to overcome the moisture stress to some extent during its period however after that it makes difficult for the agricultural to sustain in this climate.

The total annual mean temperature and evapotranspiration in the south of the country is very much higher than that of north. Whereas, the amount of rainfall is very low in southern parts as compare to northern parts of the country. Because of this, the gap between evapotranspiration and rainfall cause dryness in the region i.e. greater the difference between these two greater will be the aridity of a region. Climate of arid and hyper arid zone is very dry in nature. Due to this dry nature, relatively low rainfall and massive deforestation, the vegetable cover of the areas has decreased distinctively. If this trend continued, the area might become almost desolate. A decrease in rainfall has caused lowering of the ground water which bring drought like conditions to this part of the country and it has serious impacts on the agricultural sector. This is quite unfortunate for our agriculture that evaporative demand and water requirement for crops in whole southern parts of the country is very high as compare to northern parts and it is very difficult to carry out the agricultural activity in these regions.

Climate variability and change profoundly influence social and natural environments throughout the world, with consequent impacts on natural resources and industry that could be large and far-reaching. Climate change due to global warming not only started to impact the weather pattern but also influence the agriculture sector in Pakistan. Pakistan is an agriculture whose majority of the population depends upon agriculture. Glaciers are the big fresh water sources for Pakistan which fulfills the water demands in the agriculture land while rainfall fulfills the water requirement of the barani areas. An increase in temperature was observed in the country especially during the last few decades which accelerate snow melting on glaciers.The increased rate of glacial melting in Himalayas has caused vast lakes to develop, and if these lacks outburst, these can inundate towns and villages below. There is high level of confidence that recent regional changes (rising tendency) in temperature have discernable impacts on precipitation, evaporation, stream flow, runoff and other elements of hydrological cycles (Elshamy et al., 2006). Evaporation rate and water requirement of crops are very high and continuously increasing due to increase in temperature especially the southern parts of the country. ENSO is responsible for major fluctuations in weather systems and ultimately the changes in climatic patterns of the region (Srinivas and Kumar, 2006). El Nino phenomena suppress monsoon rainfall activity over Pakistan. La Nina phenomena have a negative impact on winter precipitation over Pakistan. recent history's worst drought (1998-2001) over Pakistan and most of South Asia is linked with La Nina phenomena (Chaudhry et al., 2001).

Thornthwaite's Moisture Index method gives the detail range of zoning of region than the rest of the method and it is a best index to determine the aridity of a region because of the two most important parameters rainfall and evapotranspiration are incorporated in it. These are the two predictor to calculate the water balance and water requirement of crops in a region.

Fig-3(a-e) shows that five indices depict that climate of southern Pakistan is said to be dry as the whole region experiences arid to hyper arid climate and there is no variability in the climate throughout the year. Sindh, Balochistan and southern Punjab experience dry and invariable climate. The climate of northern Pakistan is quite variable i.e. lies between arid to humid as compare to southern Pakistan. The area of Gilgit-Baltistan lies in extreme north of the country experiences arid climate but this climate varies through out the year. This region comes under humid climate during winter (December to March). Due to low temperature, snow covered mountains and high elevation makes this area quite sustainable to carry out the agriculture activity.The sub-mountainous region of Azad Kashmir, north eastern Punjab, and Upper Khyber Pukhtoonkhwa experience humid climate. This is the region which is always under the influence of monsoonal activity along with the western disturbances in winter. In this region there is more interaction of easterly and westerly winds which some time bring heavy rainfall and cause flash floods. Because of the complex topography of this region and low temperature keep this region in humid belt. But some time due to lack of rainfall most of the reservoirs remain unfilled and this region comes under drought. Normally, People living in this region rely on rainfall for their agricultural activity and lack of rainfall not only creates problem to carry agricultural activity but also the strongly affect the livelihood of people. Most parts of humid zone are rainfed in which agricultural activity totally depends on rainfall. However in some humid regions, supplementary irrigation is also used to trounce the water requirement for crops.

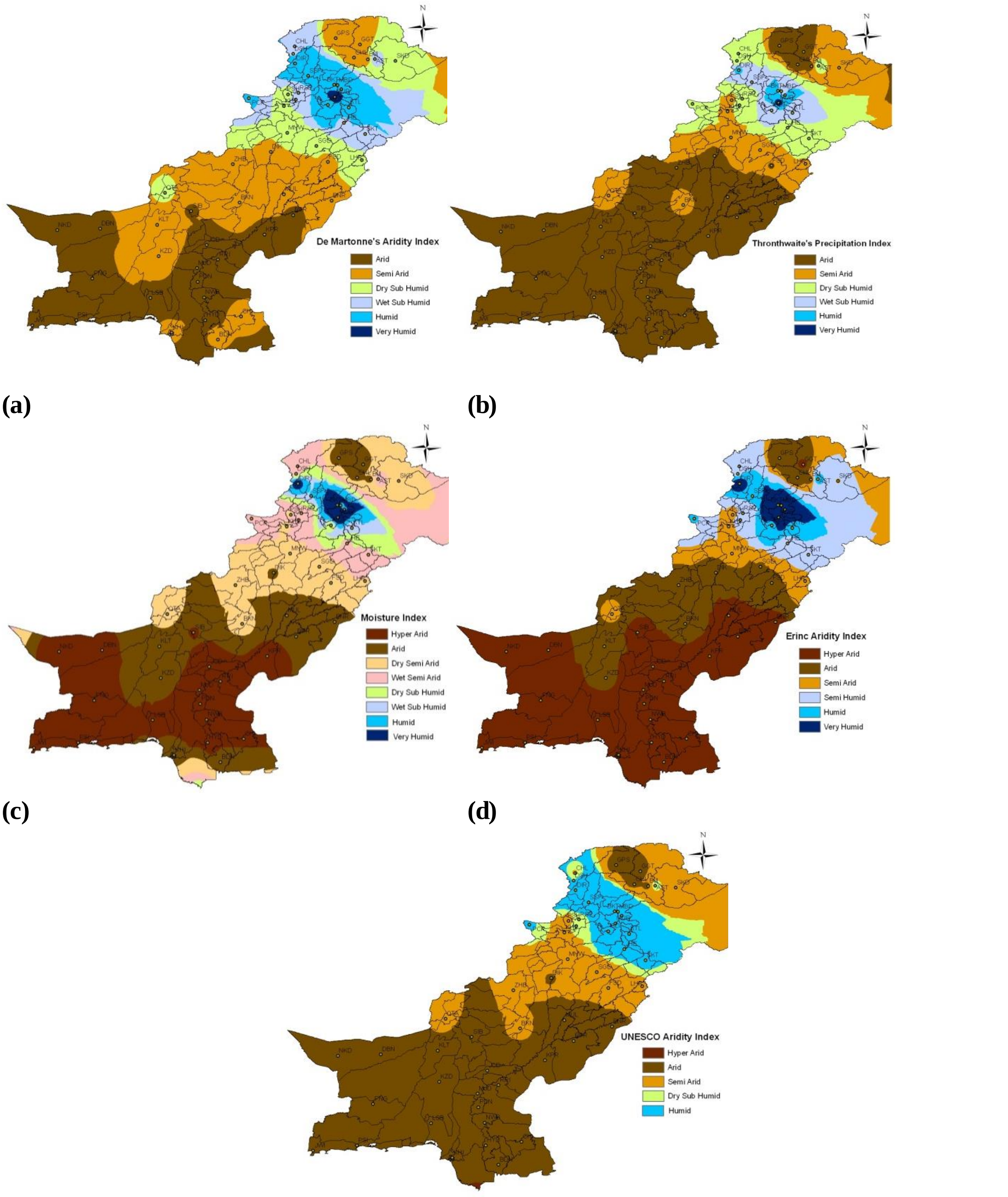

Fig-3: Classifications of the climate region based on different indices (a)DeMartonne's Aridity Index (b) Thornthwaite's Precipitation Effectiveness Index (c) Thornthwaite's Moisture Index (d) UNESCO Aridity Index (e) Erinc Aridity Index

The statistics obtained by using five different indices are shown in table-6. The minimum AI values obtained in the south of Pakistan which show that the area is arid to hyper arid and the climate is very much dry. The analyses show that the driest place of Pakistan is Nokkundi; which has annual amount of rainfall less than 33mm. The maximum AI values are observed in the north of the country show that the climate of that region is between humid to very humid. . Murree, the most humid place of Pakistan also lies in this region where annual amount of rainfall is greater than 1900mm.

Table 6: statistics of aridity index (AI) Values obtained by different indices

	AI values obtained by different indices				
	De-Martonne's Aridity Index	**Thornthwaite's Precipitation Effectiveness Index**	**Thornthwaite's Moisture Index**	**UNESCO Aridity Index**	**Erinc Aridity Index**
Min	1.50	1.96	-97.07	0.03	1.65
Max	80.65	148.58	116.49	2.16	114.36
Mean	17.03	28.72	-57.73	0.42	20.72
Standard Deviation	σ=17.90	σ=32.81	σ=50.30	σ=0.50	σ=22.94

Using different aridity indices, Geographic information system (GIS) applied to calculate the percentage of demarcated area more precisely in Pakistan as shown in table-7. It was observed that the climate of 74.73% to 88.38% of the area lies between semi arid to hyper arid. 2.33% to 12.96% area demarcated as dry sub humid, 1.23 % to 6.18% is wet sub humid, 0.88% to 5.90% is humid and 0.07% to 2.22% is very humid. Standard deviation values obtained by different indices (table-5) represents sub humid to very humid range. Therefore it can be said that the climate of Pakistan is mostly arid type except few areas in the north which are sub humid to very humid.

Table 7: Percentage of Area demarcated obtained by different indices

Climate		Percentage of Area demarcated by different aridity indices				
		De-Martonne's Aridity Index	Thornthwaite's Precipitation Effectiveness Index	Thornthwaite's Moisture Index	UNESCO Aridity Index	Erinc Aridity Index
Hyper Arid		-----	-----	34.06	0.13	52.34
Arid		38.62	69.83	28.83	64.68	23.63
Semi Arid	Dry	36.11	16.84	22.51	23.70	8.90
	Wet			8.27		
Sub-Humid	Dry	12.96	8.84	2.33	3.18	9.85
	Wet	6.18	3.53	1.23	----	----
Humid		5.90	0.88	1.55	8.31	3.05
Very Humid		0.23	0.07	1.23	-----	2.22

Sustainable measures like under ground canals or water channel in the form of kareez, integrated micro watershed management for the promotion in situ moisture conservation and rapid forestation should be taken in the region to handle the situation. Environmental and Sustainable development of natural resources have to be more expedited. People living in rural areas, Local farmers have to be educated about the new techniques of farming to preserve water and social awareness should be developed about deforestation and its environmental consequences.

Conclusion

This study provides a preliminarily idea about the climate of Pakistan is mostly arid in nature. It is revealed that almost 74.73% to 88.38% of the area possess semi arid to hyper arid climate while 0.07 % to 12.96% area demarcated as dry sub humid to very humid. The results show that the climate of whole southern Pakistan is arid to extremely arid. In Southern parts, evapotranspiration rate is very high and mostly crops are remained under water stress till reaching to maturity. So, Agricultural activity depends on proper irrigation rather than rainfall. It is conclude that southern parts are most vulnerable to drought. Northern parts of the country have variable types of climate.i.e dry semi arid to very humid. Most of the rainfed regions also come under the humid zone and agriculture commodities of this region depends upon rainfall.

Sometimes shortage of rainfall damages the agro-socioeconomic activity of this region. This area is always remained under threat of drought. It is already predicted that the temperature are increasing in the country and this increase in northern parts especially humid regions, may increase evapotranspiration. This situation can be very helpful for strong convection, because of this; frequency of extreme event would be more in these regions that may cause flash flood. Increase in evapotranspiration, may increase the water requirements of the crops and decrease the soil moisture which may alter the amount of water availability in the soil due to which the plants roots may be damaged. The results will be useful in future for planning, designing and operating irrigation system and crop planning too.

Recommendation

This study provides a contemporary view of future water requirement of this region in view of global warming. More emphasis is needed to develop technologies for reducing the water losses in future and conservation of rainwater and development of crop varieties requiring less water. Sustainable measures like under ground canals or water channel in the form of kareez, integrated micro watershed management for the promotion in situ moisture conservation and rapid forestation should be taken in the region to handle the situation. New varieties of Drought tolerant crops like cotton, sorghum etc should be cultivated in drought prone areas of the country.

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