Advanced Remote Sensing, 2024, 4(1), 11-27

Advanced Remote Sensing

http://publish.mersin.edu.tr/index.php/arsej

e-ISSN 2979-9104

Assessing the impact of drought on groundwater resources using geospatial techniques in Balochistan Province, Pakistan

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Cite this study: Jamil, M., Mahmood, S., Husssain, S., & Saad, M. (2024). Assessing the impact of drought on groundwater resources using geospatial techniques in Balochistan Province, Pakistan. Advanced Remote Sensing, 4(1), 11-27

Keywords
Drought
Spatial Extent
Groundwater
Geospatial technique
Balochistan

Research Article
Received: 31.12.2022
Revised: 09.12.2023
Accepted: 15.02.2024
Published: 26.02.2024

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Abstract

Globally, drought is one of the hydro-meteorological disasters causing human loss, decrease in agricultural production, loss of soil moisture and ground water table. Drought has been particularly severe in Balochistan. The ground water table has been depleted as a result of the decrease in rainfall, which has severely damaged water in tube wells and springs. The purpose of current study is to analyze the impact of drought on groundwater in Balochistan by using geospatial technique approach**.** Data is acquired through questionnaire, focus group discussion and Global positioning system (GPS). The Analysis reveals that drought has physical, economic and environmental impacts, the decline in groundwater level, the drying up of well, reservoirs, lakes and springs were terribly observed in Balochistan. Devastating drought has demolished historical fruit like apricots which were being cultivated for last 30 to 40 years. The continuous usage of solar energy modules has severely reduced the ground water level. Consequently, obvious changes have been observed in groundwater table for 20 years. The water table has reached 320 feet where it was noted 160 in 2000. Likely, it would further decline with each passing day. Water is extremely declining even though in some areas the extraction level has touched 1400 feet. Meanwhile, few areas had no availability of clean drinking water. The government should emphasize the importance of PDMA organization cooperation and the development of a strategy to help all districts in improving and solidifying their drought policies.

1. Introduction

Globally, drought is a creeping hydro-meteorological hazard with consistent precipitation scarcity [1]. It is complex natural disaster that damages numerous regions every year [2]. Severe and long-lasting impacts on environment, agricultural production and groundwater level have been incurred by drought [3]. Substantial reflectance in natural variability of environment has been observed, having concentrated possibility of occurrence in virtually all regions, regardless of precipitation or temperature [4]. Droughts are slow onset, possibility of occupying extensive region that may last for months, years and sometimes for few days [5]. Approximately, 34% of damages related to persons caused by drought and 22% economic loss dragged by others natural hazards [6]. Probably, intermittent rainfall, high temperatures, and degraded land cause drought. Therefore, decline in rainfall for longer period of time in any specific region is the main result of drought occurrence. Similarly, it may exist in all climatic zones [7].

Pakistan has been intensely affected by drought. It ranked almost fourteenth being severely damaged with drought prevalence. It is estimated that only 9% of population receive rainfall that is approximately 50 cm per year. Besides 23% receives between 20-50% rain water [8]. The rests of the population engrain estimate less than 21%. There are four sources of water and the maximum rainfall occurs in monsoon season that makes total proportion of 70-80%. Apart from that, so far Pakistan has got 79.6 mha land, which is comprised of arid and semi-arid; the composition of arid land is 70mha% and semi- arid is 88% [9]. Balochistan has been the pivot of drought. Owing to lack of rainfall the ground water decreased which has immensely debilitated water in tube wells and springs. Intermittent drought has forced people, particularly, drought hit citizens, to extract ground water as much as they could to water crops. For sake of carrying out gardening activities rich people installed solar panels while destitute people adopted pulling out of water to meet their drinking purpose out [10]. Notwithstanding, drought has not only affected water level as elaborated, it has on the other hand other impacts; the severe disasters scattered the livelihood of the people which were in the forms of livestock, agriculture and other resources [11]. The gigantic catastrophe was experienced from 1997 to 2004 by the people of Balochistan. Destroying afterward it was named as the worst disaster in the history of Baluchistan. From ministry of finance, the financial loss counted as value of 25 Billion Rupees decreased and a great loss to national exchanges and maximum economic loss of growth was experienced from 2000 to 2002 [12].

From 2010 to 2019, different parts of the world experienced drought conditions to varying degrees. The central and western parts of the United States, particularly the Great Plains, experienced severe drought conditions in 2012. This event affected agriculture, water supplies, and led to significant economic losses. Australia faced multiple droughts during this period, with the most severe being the Millennium Drought [13] extending into the early 2010s. The south-eastern part of the country, including New South Wales and Victoria, experienced prolonged dry spells, impacting water reservoirs and agricultural productivity [14]. California faced a prolonged drought during this period, leading to water shortages, decreased agricultural yields, and heightened wildfire risks. The state implemented water conservation measures to cope with the challenging conditions. Countries in the Horn of Africa, including Somalia, Ethiopia, and Kenya, faced a severe drought in 2011-2012, leading to food shortages and a humanitarian crisis. This event was exacerbated by conflict and political instability in the region. Southern Africa experienced a prolonged period of drought, affecting countries like South Africa, Zimbabwe, and Zambia. This drought had significant impacts on agriculture, water resources, and food security [15].

2. Study Area

Balochistan is one of the largest provinces located in the south-west of Pakistan. Geographically, it divided into upland, plains, deserts and coastal areas. It extends from 22°N to 32°N latitude and from 66°E to 70°E longitude (Figure 1). The total land area of Balochistan is 347,190 km^2 which is 44% of the country. The climate of Balochistan varies from semi-arid to Hyper-arid. The annual rainfall ranges from 250 mm to 350 mm and the temperatures vary from 0℃to 35 ℃ in winter while in summer it ranges up to 50 ℃. Administratively, Balochistan is divided into six divisions: Quetta, Zhob, Sibi, Nasir Abad, Kalat, and Makran, which are additionally distributed into 32 districts and 137 tehsils. Geomorphological features evince that about 80% of the area is undulating surface whereas, the remaining 20% is coastal plains. According to 2017 census, population of the study area is 12.34 million [16]. Quetta (capital city) has a population 2 million and Kech is the second populated district of the province [17]. On the other hand, district Harnai is the least populated [18].

Figure 1. Location of the study area (source: OpenStreetMap.org).

3. Methodology

In order to achieve the desired objectives, primary and secondary sources were used. Primary data was collected through questionnaire Survey and Global Positioning System (GPS). While the secondary data was acquired from Pakistan Meteorological Departments (PMD), Karachi and Satellite images were downloaded from United States Geological Survey (USGS) Geo-database. Moreover, Remote Sensing, GIS and Rain Use Efficiency Model techniques have been implemented for the accomplishment of desired objectives (Figure 2).

Primary data was collected through semi-structured questionnaire using random sampling technique, conducted in February, 2020. The questionnaire was comprised of three sections. First section was about general information, including family size, age, education, occupation, monthly income, and their socio-economic activities. The second section was about the respondent's awareness regarding drought and rainfall variability. Whereas, the third section contained questions regarding the impacts of drought on groundwater. Concurrently, GPS was used to acquire the geo-location of the surveyed sites. The depth of the groundwater table was noted based on the community perception. Moreover, in secondary data process, Rain Use Efficiency Model is applied by using vegetation parameter- extracted from satellite images- and rainfall parameter which is obtained from climate data for detecting existing drought scenario is detected. It is based on following parameters natural difference vegetation index and rainfall data (Equation 1).

$$\text{Rain Use Efficiency } model = \frac{vegetation\ data}{rainfall} \tag{1}$$

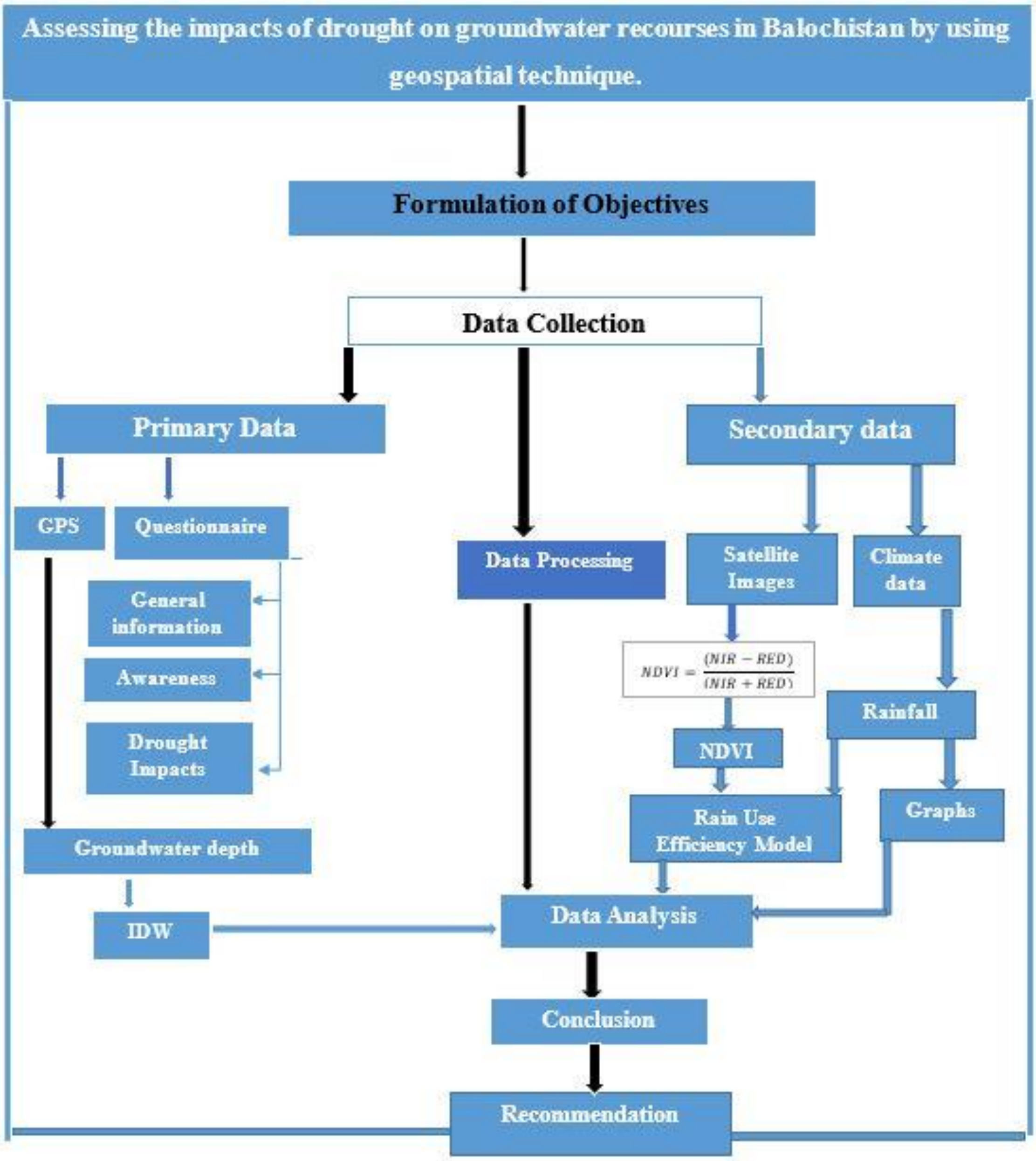

Figure 2. Research process.

4. Results

Results were obtained from the field survey performed in February 2020.

4.1. Socio-economic conditions of the studied population

Size of the surveyed population is categorised into three categories. 31.87% of respondents' families are composed of less than 10 members. Middle families, whose members are categorised from 10 -20, were 38.12% and 10.62% people had more than 20 members. However, 19.37% participants did not respond (Table 1).

Table 1. Family size of respondents in the study area.

Sample No	Family Size	Frequency	Percentage (%)
1	<10	51	31.87
2	10-20	61	38.12
3	>20	17	10.62
4	Nil	31	19.37
Total		160	100

The Table 2 portrays the respondents' age. 30% population had less than 30 years age. Secondly, 40% of surveyed population were lying in category from 30 to 50 years age and 23.12% had above 50 years. 1.87% population were further asked but did not respond.

Table 2. Age of respondents in study area.

Sample No.	Age Groups	Frequency	Percentage (%)
1	<30	48	30
2	30-50	64	40
3	>50	45	23.12
4	NIL	3	1.87
Total		160	100

Table 3 shows the income of respondents'. It was partitioned into four, because surveyed area had joint family structure less than50,000 were placed in first category, in which 32.12% population fell in. after that 35% population had monthly income from 50,000 to 100,000. And third placement were above 100,000 incomes which had 13.12% population. Remaining 18.75% did not disclose their monthly income.

Table 3. Monthly income of respondents in study area.

Serial No.	Income (PKR)	Frequency	Percentage (%)
1	<50,000	53	33.12
2	50,000-100,000	56	35
3	>100000	21	13.12
4	NIL	30	18.75
Total		160	100.00

The surveyed respondents' qualification varies from primary to higher education. Illiteracy is high – which makes almost 19.75% population had never been to school.13.12% population had got primary level education.6.25% had up to middle education. Similar respondents' ratio had been to matric level. 13.12% population had up to intermediate level education.so far the graduation level qualification is considered, approximately, 15.62% respondents had been to that stage. Only acute part of the population had crossed higher education level stage (Table 4).

Table 4. Education of the respondents in study area.

Serial No	Education	Frequency	Percentage (%)
1	Primary	21	13.12
2	Middle	10	6.25
3	Matric	8	5
4	Intermediate	21	13.12
5	Graduation	25	15.62
6	Post-graduation	13	8.12
7	Illiterate	62	19.375
Total		160	100.00

The Table 5 elaborates the respondents' occupation. Balochistan' populace formidably relies on agriculture and livestock. Therefore, 36.87% population had farming activities. Secondly, 35% respondents had their business either at small level or medium size business. The myriad business was owing to creeping drought, respondents reported. 14.37% population were involved in livestock activities.

Table 5. Occupation of the respondents in study area.

Sample No	Occupation	Frequency	Percentage (%)
1	Farming	59	36.87
3	Business	56	35
4	Livestock	23	14.375
2	Jobs	22	13.75
Total		160	100.00

Maximum number of male participants participated in field survey, which accounted for 93.12% of population. However, least female's participants were also observed taking part in that task. They were consisting of 6.87% of the population (Table 6).

Table 6. Respondents' gender in study area.

Sample No	Gender	Frequency	Percentage (%)
1	Male	149	93.12
2	Female	11	6.87
Total		160	100.00

4.2. Community awareness about drought

Community perception was assessed daring field survey. 78.75% respondents were aware of drought. Whilst, 15.65% of population had no idea of drought severity. 5.6% of respondents did not give their feedback (Table 7).

Table 7. Community perception about drought in study area.

Sample No	Community perception	Frequency	Percentage (%)
1	Yes	126	78.75
2	No	25	15.65
3	No response	9	5.6
Total		160	100.00

The Table 8 portrays the sources through which the dwellings became aware of drought.6.25% noted that increase in temperature is means about drought cognizant.6.87% population pinpointed the past experience to knowing about drought.29.37% population knew about drought by low rainfall in their rgion.8.12% respondents mentioned economics loss as source of drought familiarity.22.5 % of the population articulated the decline in groundwater table is main cause of drought prevalence. 5.62% respondents pointed out less agriculture production. Diseases in livestock were described by 6.87% population the source of acquaintance 14.37% participant's left paper unfilled.

Table 8. Sources of awareness about drought.

Sample No	How do you know about drought	Frequency	Percentage (%)
1	Temperature increase	10	6.25
2	Past experience	11	6.87
3	Low rainfall	47	29.37
4	Economic loss	13	8.12
5	Ground water table decline	36	22.5
6	Less agriculture production	9	5.62
7	Diseases in livestock	11	6.87
8	Nil	23	14.37
Total		160	100.00

The Table 9 elucidates respondents' adaptation in case of drought occurrence.15.5%popullation had adjusted the agriculture activities .25% reported that they had moved toward business .7.5% population had their jobs in case of drought situation. However, 9.37 population reported that they had moved to other protected zones. 10.62% of population declines to herding profession. Apart from that, 8.75 respondents embraced labour work owing to lack of any other breeding. Numerous respondents that accounted for 20% population had faced no charge.

These respondents had several sources of irrigation. Approximately, 18.75% of population had bored well for irrigation purpose.13.12% of population had tube well facility. 7.5% population would use canal water for irrigating their fields.4.37% respondents used to utilise open well. Besides, 6.87%population had karez system. Concluding, 28.75% of the respondents reported that they had no source for irrigation purpose (Table 10).

Table 9. Adaptation of respondents in drought.

Sample No	Adaptation	Frequency	Percentage (%)
1	Agriculture	28	15.5
2	Business	40	25
3	Jobs	14	7.5
4	Migration	15	9.37
5	Herding	17	10.62
6	Labour work	14	8.75
7	No change	32	20
Total		160	100.00

Table 10 Respondents' source of irrigation.

Sample No	Source of irrigation	Frequency	Percentage (%)
1	Bored	31	18.75
2	Tube well	53	33.12
3	Canal	12	7.5
4	Open well	7	4.37
5	Karez	11	6.87
7	No source	46	28.75
Total		160	100.00

Table 11 explains the community perception about rainfall variability.63.12% had awareness about rainfall fluctuation.30.62% of population were unaware about it and 6.25 showed no response.

Table 11. Awareness about rainfall variability.

Sample No	Knowledge about rainfall variability	Frequency	Percentage (%)
1	Yes	101	63.12
2	No	49	30.62
3	Nil	10	6.25
Total		160	100.00

Table 12 expresses the respondents' familiarity regarding rainfall variability.23.76% population reported that they had knowledge about annual rainfall variability.18.12%were aware of spatial rainfall variability. 21.25% knew about temporary rainfall. Apart from that, 36.25% never noticed any type of rainfall variability.

Table 12. Types of rainfall variability.

Sample No	Types of rainfall variability	Frequency	Percentage (%)
1	Annual	38	23.76
2	Spatial	30	18.12
3	Temporary	34	21.25
4	Nil	58	36.25
Total		160	100.00

4.3. Annual variability analysis (Rainfall)

Examining the temporal dynamics of meteorological variables in the context of changing climate is crucial for understanding climate-induced changes and suggesting feasible adaptation strategies, where rain fed drought is predominant. The graphs are showing dominant variabilities in rainfall precipitation according to different meteorological stations of particular regions.

4.3.1. Barkhan

Barkhan has a hot semi-arid climate with very hot summers and mild winters. During the 20 years Precipitation mainly falls in two distinct years 1997 and 2006 with linear trend by the slope of regression line which in this case is about −2.2016 mm/year, which is declining annually in Figure 3.

4.3.2. Dalbandin

Dalbandin has a hot desert climate with extremely hot summers and cool winters. The linear trend line is showing rainfall precipitation about -1.7756 mm/year with the declining rate in change. The climate is dry whole the year but some rain does fall in the winter annually Figure 4.

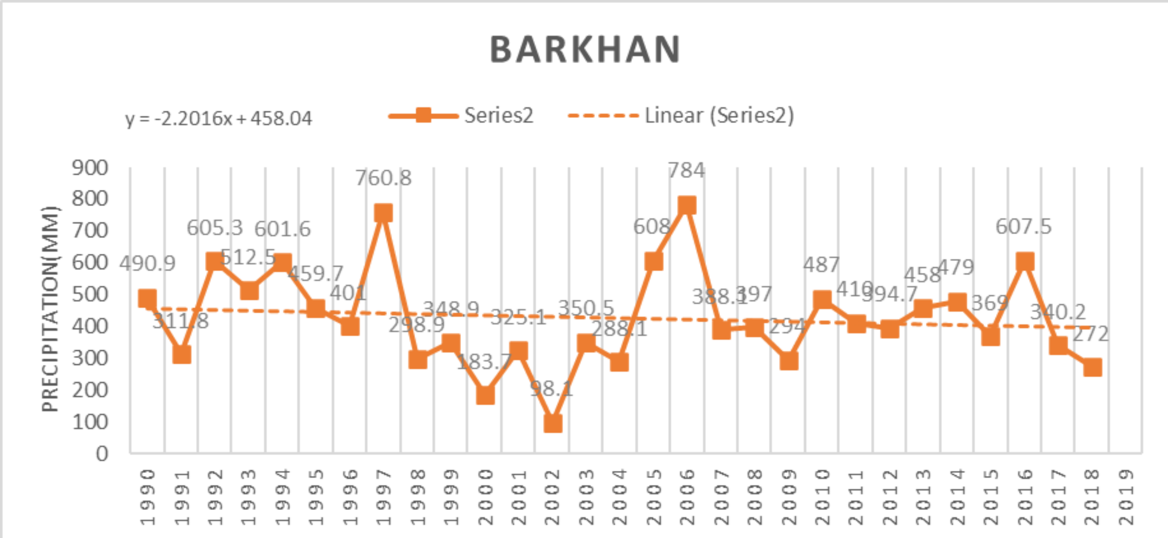

Figure 3. Rainfall pattern in Barkhan.

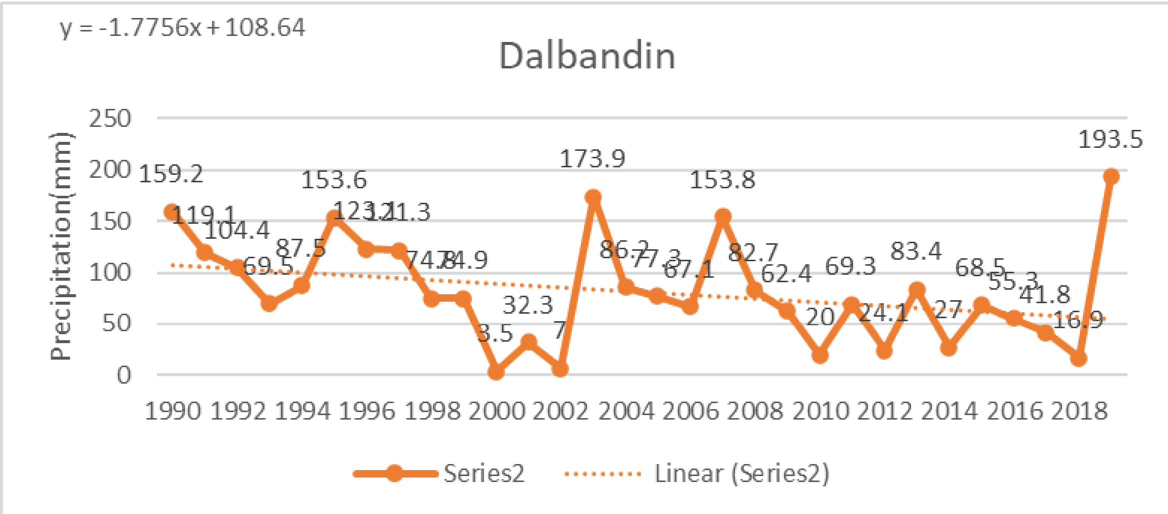

Figure 4. Rainfall pattern in Dalbandin.

4.3.3. Jivani

Jiwani has a hot desert climate with hot and humid but dry summers and warm winters. Most rainfall occurred in 1995, 1997, 2010, 2020, although there is sometimes a little rain in the monsoon season yearly as well. The regression trend line showing the rate of change of precipitation as -1.3754 mm/year in Figure 5.

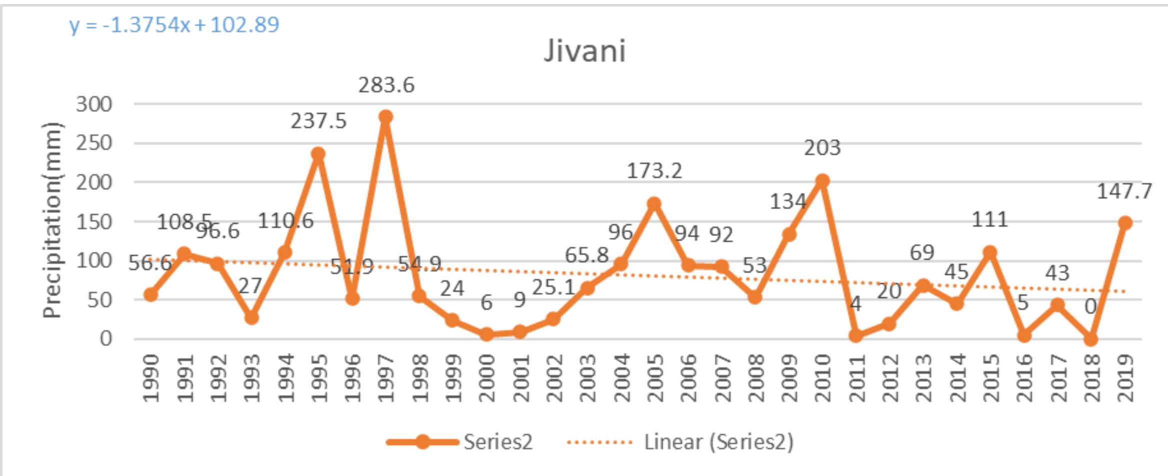

Figure 5. Rainfall pattern in Jivani.

4.3.4. Kalat

Kalat features a cold desert climate. The highest precipitation falls in 1997 about 976.9 mm/year. The linear trend line is showing the change of precipitation by regression analysis (Figure 6). The declining rate is about -6.0254 mm/year with the increase of about 302.47 mm/year.

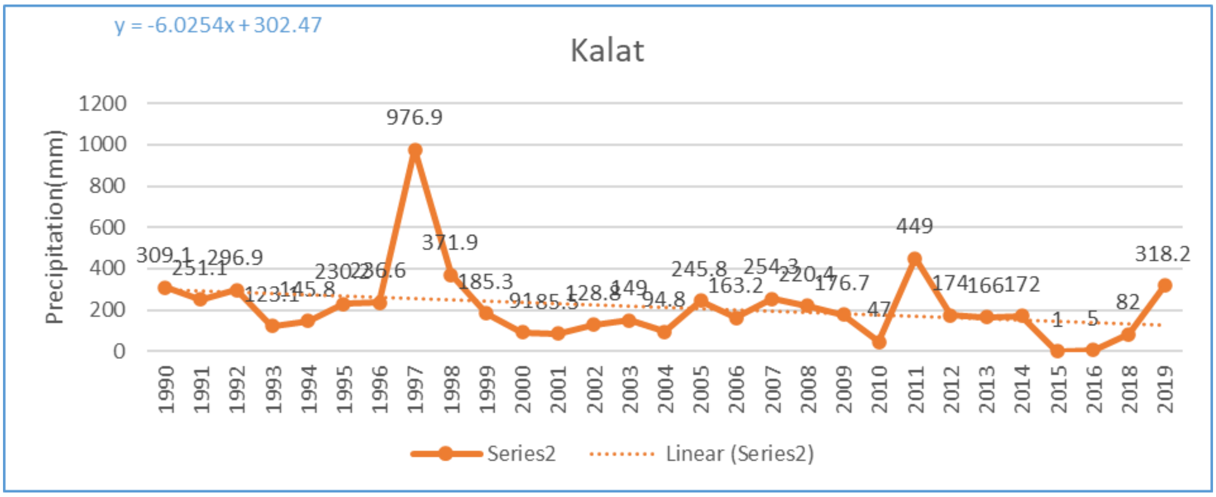

Figure 6. Rainfall pattern in Kalat.

4.3.5. Khuzdar

Khuzdar like most of Balochistan has an arid climate with very low and erratic rainfall. Unlike most parts of the province, the heaviest average rainfall comes from the Asian monsoon, though this rainfall tends to be very erratic and in many summers there is no significant rain at all. The Figure 7 showing the linear trend line of Khuzdar precipitation which is decreasing of about -2.4853 mm/year. The yearly change is showing in below figure, the highest precipitation rate was in year 1994 with the rate of 594.7 mm/year.

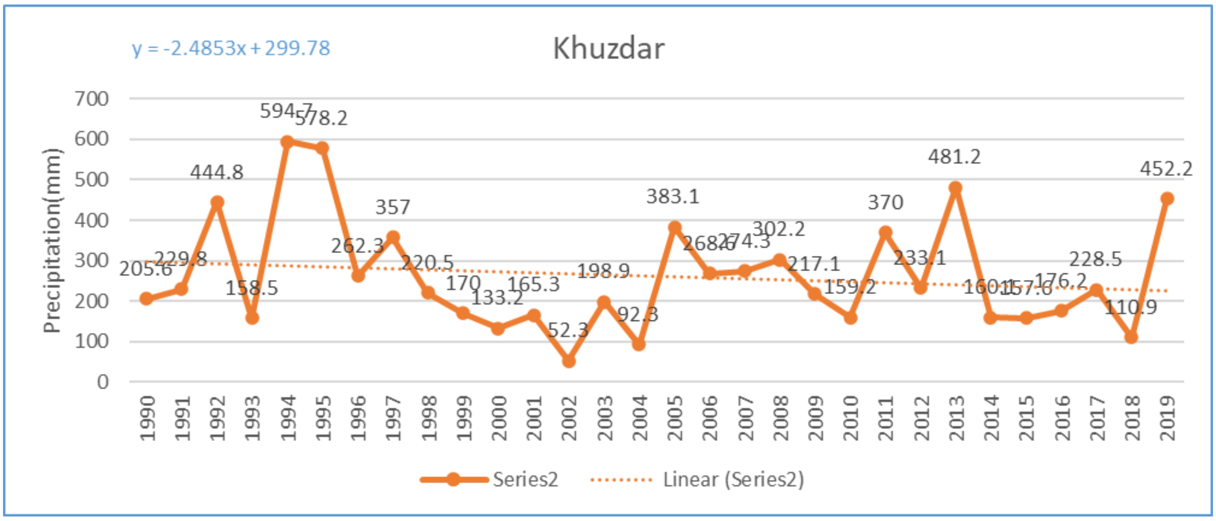

Figure 7. Rainfall pattern in Khuzdar.

4.3.6. Lasbella

Labella has hot, dry climate. Figure 8 showing the rainfall pattern in Lasbella. The highest precipitation recorded was in 2003 which is 474.6mm/year, followed by 426.1mm/year in 1994. The lowest rainfall recorded in 2002.

4.3.7. Nokkundi

Nokkundi has a hot desert with extremely hot summers and mild winters. There is virtually no rainfall whole the year. The climate is very dry there, Figure 9 showing the highest precipitation in year 2005 about 187.6 mm with the linear trend of about 0.271 mm/year.

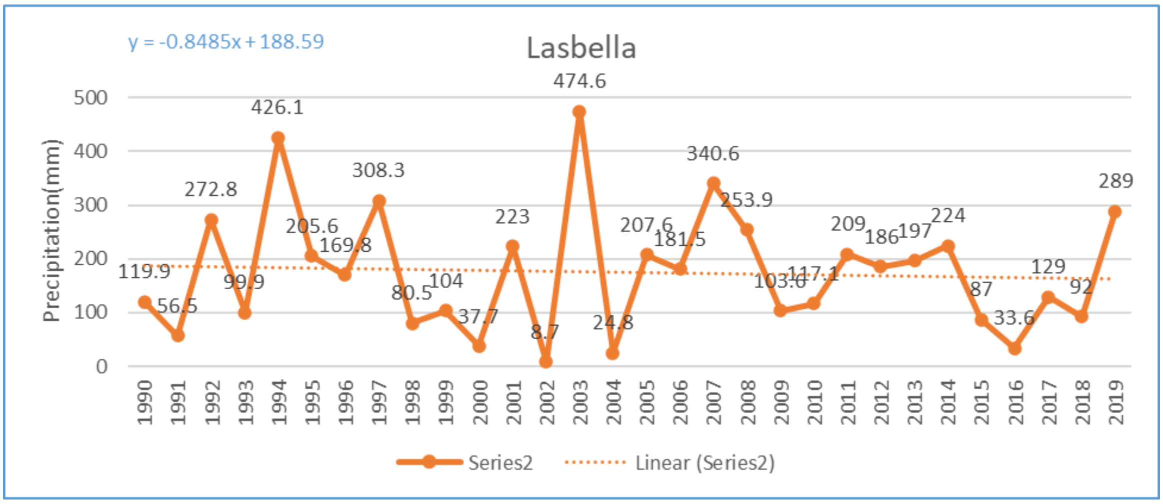

Figure 8. Rainfall pattern in Lasbella.

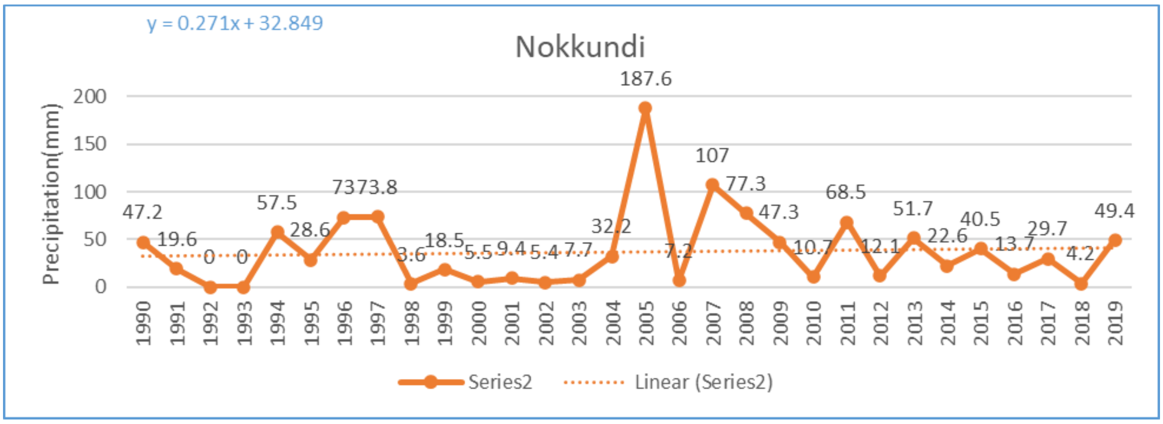

Figure 9. Rainfall pattern in Nokkundi.

4.3.8. Ormara

In Ormara, during the entire year, the rain falls for 22 days and collects up to 44mm (1.73") of precipitation. The Figure 10 showing the highest precipitation rate in year 2007, with the linear trend of about 1.5876 mm/year.

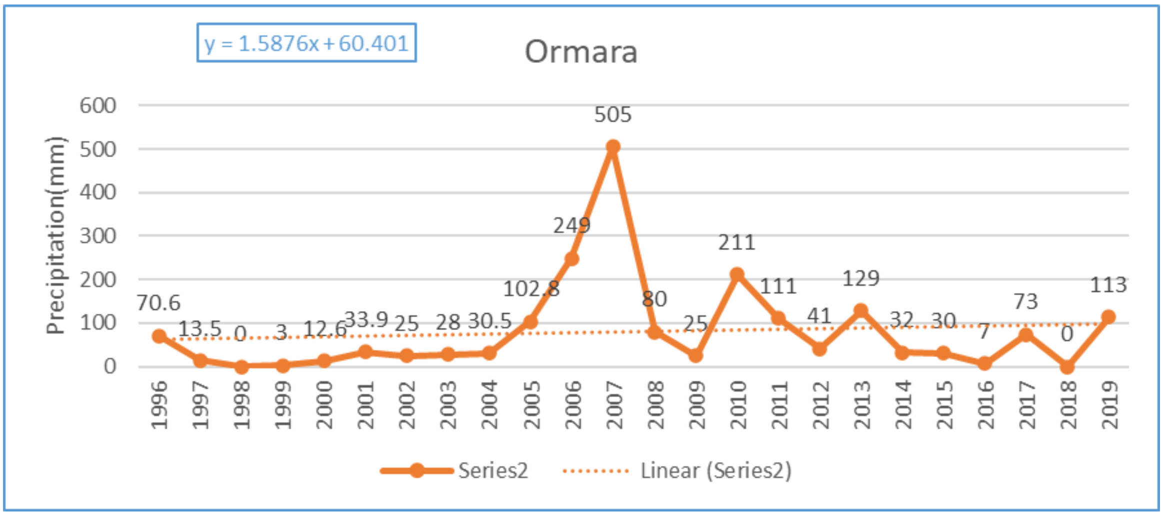

Figure 10. Rainfall pattern in Ormara.

4.3.9. Panjgur

Panjgur has a hot desert climate with hot summers and cold windy dry winters. Precipitation mainly falls in one distinct period Figure 11 showing the highest precipitation recorded 304.3 mm/year with the declining rate -1.2516 mm/year of trend line.

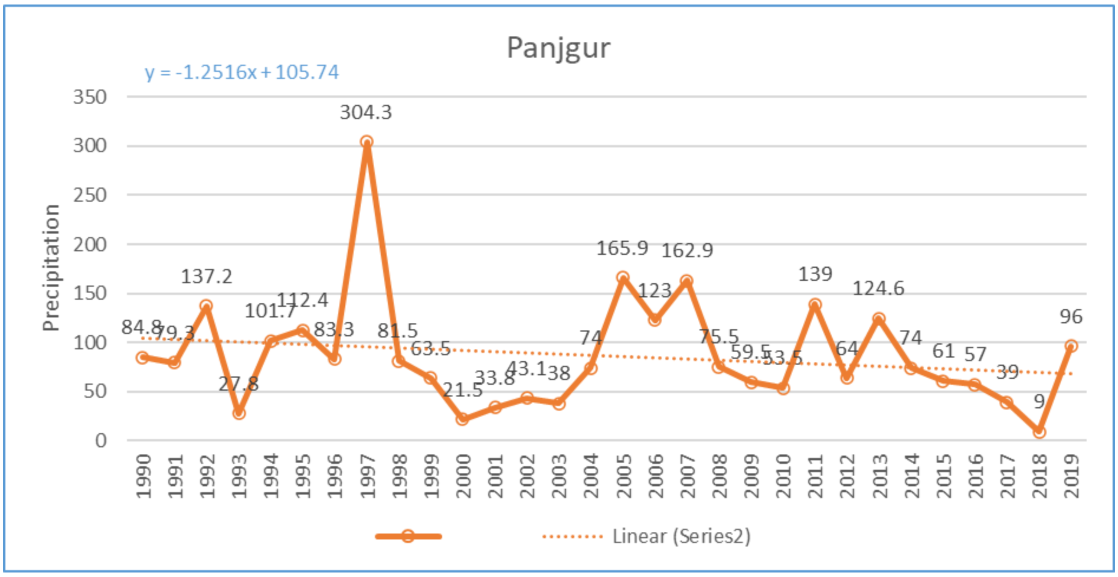

Figure 11. Rainfall pattern in Pangur.

4.3.10. Pasni

Pasni, Balochistan is conferred on balance 98.2 mm (3.9 in) of rainfall per year, or 8.2 mm (0.3 in) per month. The Figure12 showing yearly difference of precipitation. The highest precipitation falls in 2003, 2006, 2014, 2012 with the linear trend which is showing the decline in rate -0.7621 in Pasni yearly rainfall.

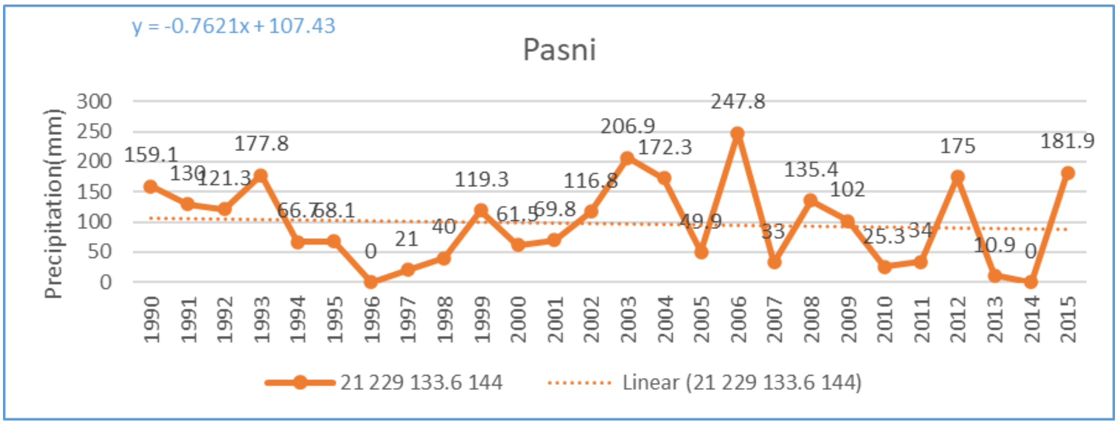

Figure 12. Rainfall pattern in Pasni.

4.3.11. Quetta

In Quetta, during the entire year, the rain falls for 34 days and collects up to 260.9mm (10.27") of precipitation. 2018 recorded the highest precipitation with value of about 513.4 mm/year (Figure 13). The declining trend line shows -1.3218 mm/year.

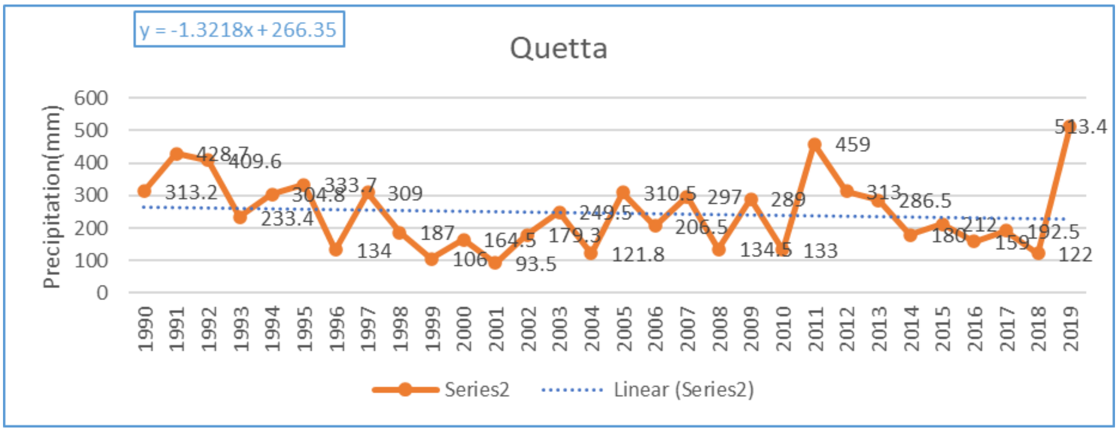

Figure 13. Rainfall pattern in Quetta.

4.3.12. Sibbi

Precipitation is light and mainly falls in two distinct periods: early spring in March and April, and during monsoon season in July and August. The Figure 14 showing the variations in precipitation recorded yearly with the linear trend line value of about 0.411 mm/year.

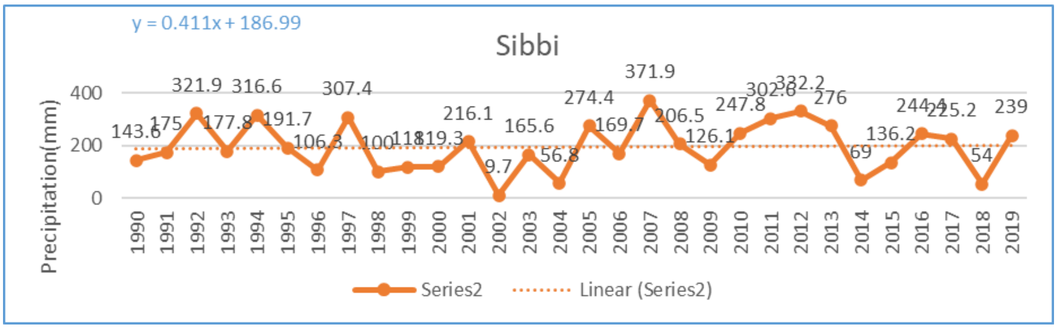

Figure 14. Rainfall pattern in Sibbi.

4.3.13. Turbat

The average amount of precipitation for the year in Turbat is 4.3” (109.2 mm). The month with the most precipitation on average is July with 1.0” (25.4 mm). The Figure 15 is showing the highest precipitation recorded yearly or variations in precipitation. 2017,2012,2008,2005 showing highest yearly value of precipitation with the decline value of -0.6752 mm/year.

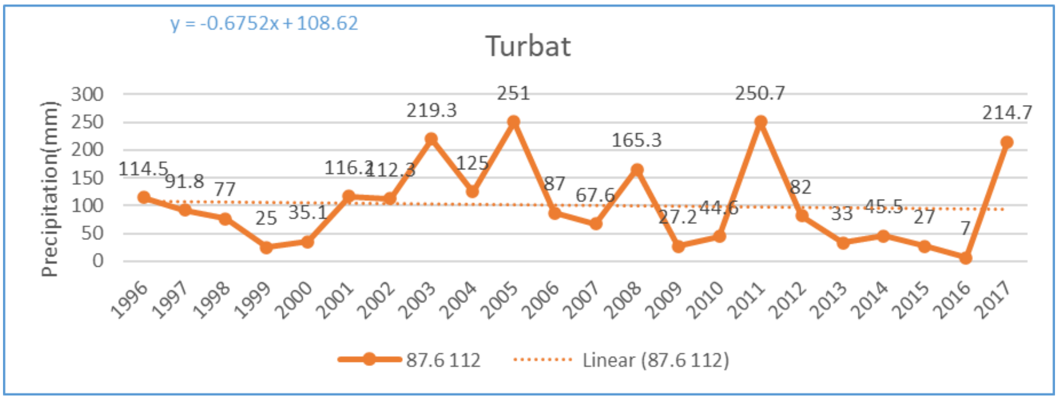

Figure 15. Rainfall pattern in Turbat.

4.3.14. Zhob

Zhob has a semi-arid climate, its rainfall being high enough to avoid the arid climate category found at lower elevations. Unlike most of Balochistan, Zhob does on occasions receive rainfall from the monsoon, though this occurs very erratically. The linear trend line in Figure 16 is showing the rate of change values -4.7832 mm/year precipitation recorded in Zhob.

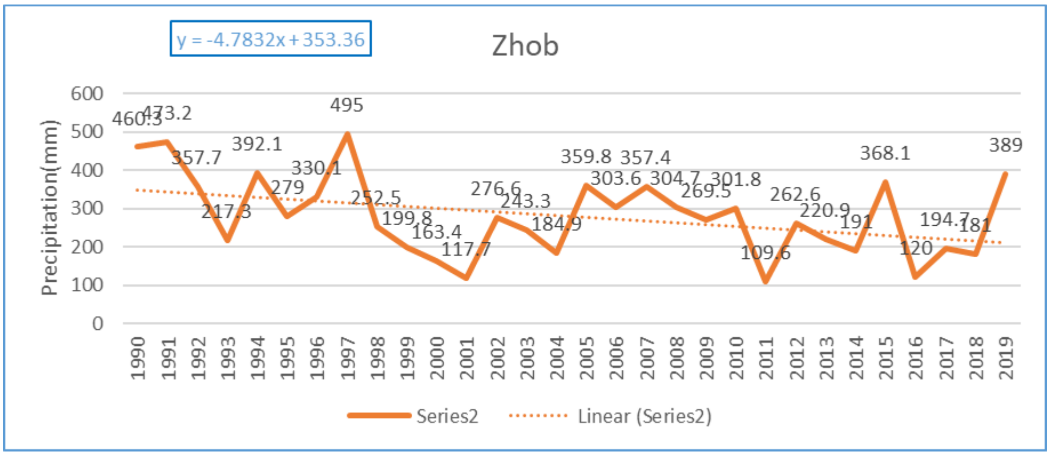

Figure 16. Rainfall pattern in Zhob.

4.4. Current drought

The Figure 17 expresses existing drought zones in Balochistan, the current drought is carried out through drought rain use efficiency model. Which is based on following parameters natural difference vegetation index and rainfall data. The current drought zones are categorised into the three classes: Extreme Drought, Moderate drought and no Drought zones. Desert areas of Balochistan are highly affected by drought. The drought hit areas which fall in extreme drought zones are Kharan districts, Panjgur, Washuk, few tehsils of Kech, many areas of Khuzdar and upland area of Zhob and Sherani district.

Conversely, Moderate drought zones are Kohlu, Sibbi, Loralai, Bolan, Killa Saifullah, Kalat, Naseerabad, Jaffrabad, Dera Murad and Musakhel. In desert areas, few regions of Awaran and Washuk lie in Moderate zones. Final class is no drought zones, also named as protected zone, where these areas are not hit by drought. And current drought status is almost protected. These protected regions are Barkhan, Dera Bugti, Harnai, few areas of Gwadar, Killa Abdullah, Quetta, Sibbi, Ziarat and many areas of Loralai. Hence, it is concluded that the rain fed areas are still in safer zones and not affected by drought. While, deficient rainfall areas with least vegetation cover are severely affected by periodic drought.

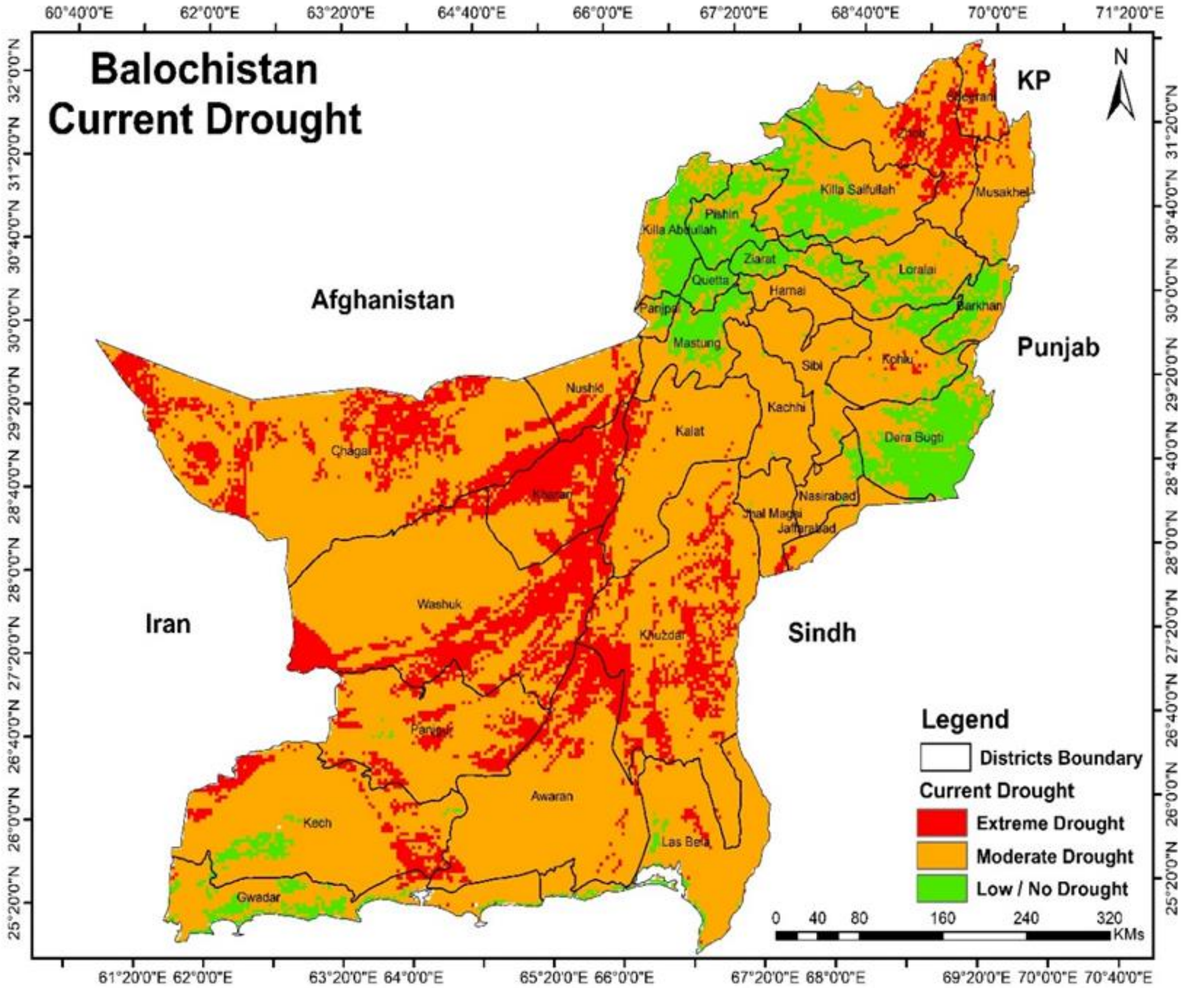

Figure 17. Current drought.

4.5. Groundwater Level

These maps show groundwater table of 2000 in Balochistan (Figure 18). Water table in plain areas of Naseerabad District, Jaffarabad, Jal Magsi, Khuzdar and Barkhan were very high, it ranged from 40 to 160 feet. Similar depth was noted in upland areas of Balochistan: Kohlu, Sherani, Sibbi, Musakhel, Kalat, Noshki. Lasbela, few areas of Khuzdar, Kalat and two lower areas of Nushki had water table from 170 to 220 feet. Furthermore, few coastal areas, Dera Bugti, and many desert areas had water level from 230 to 290 feet. Severe decline in water depth was found in desert areas of Kharan, Awaran, and Washuk which extended from 300 to 390 feet. However, extreme water decline was observed in upland areas, particularly, Quetta, Ziarat, Khuchlak where water table was 380 to 510 feet in 2000.

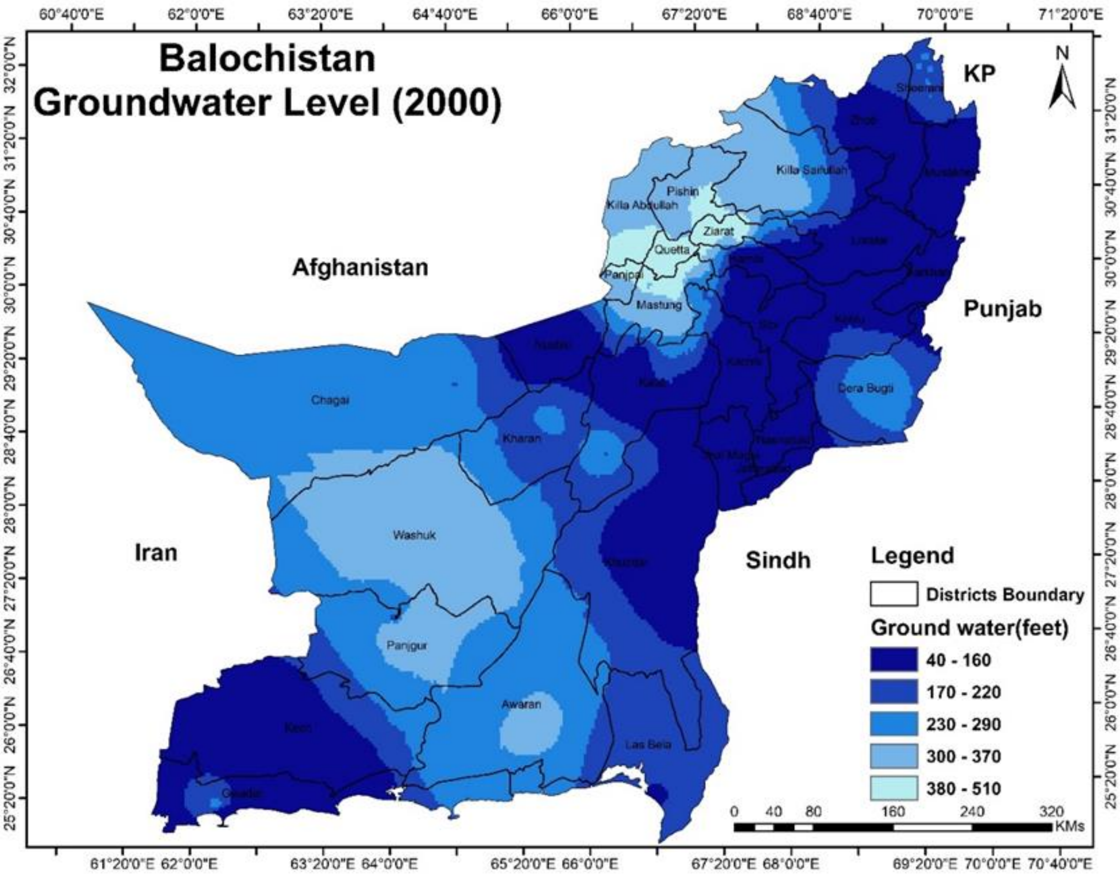

Figure 18. Groundwater table in 2000, Balochistan (Community perception).

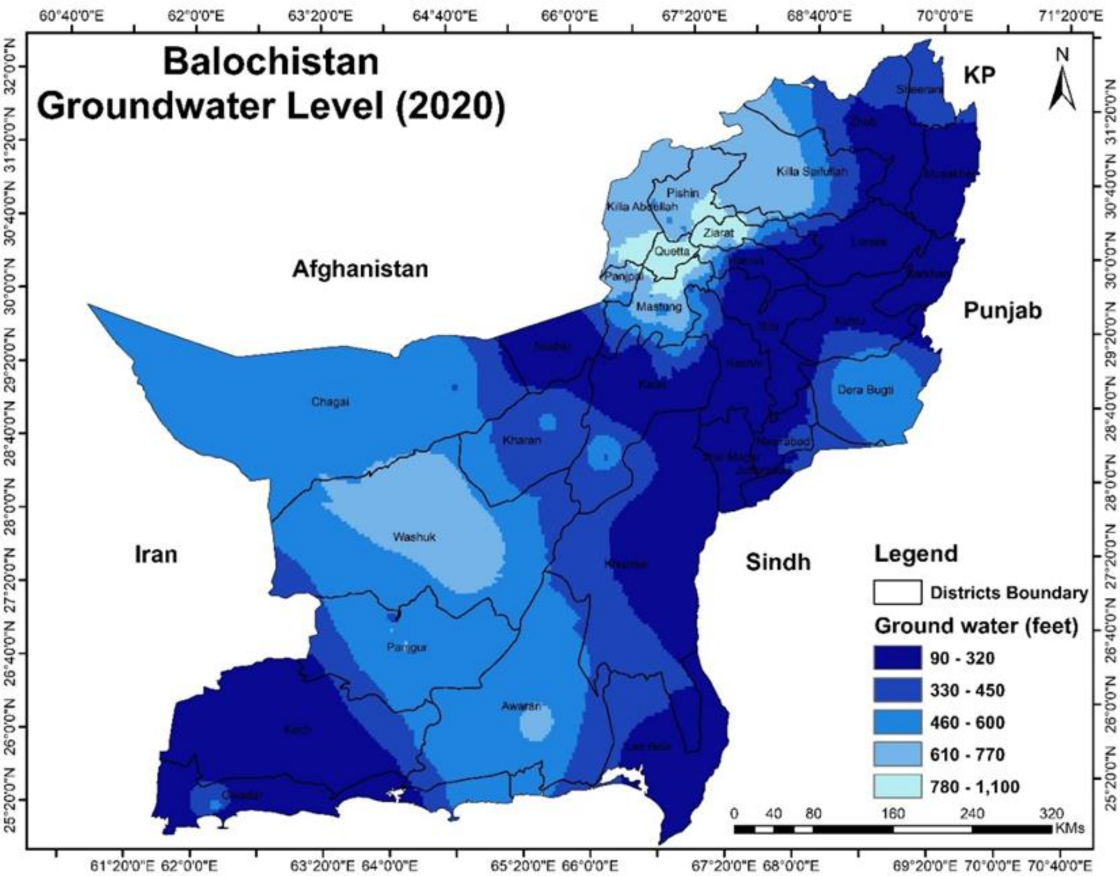

Figure 19. Groundwater table in 2020, Balochistan (Community perception).

Obvious changes have been observed in groundwater table for 20 years (Figure 19). The water table has reached 320 feet where it was noted 160 in 2000. Likely, it would further decline with each passing day, respondents reported. Besides, the table declined from 220 to 450 in many regions of Awaran, Khuzdar and Nushki districts. Each year the water table declines five meter, and shows severity level. The water depth noted in Chaghi, Washuk, Panjgur, Awaran and Dera Bugti ranges from 460 to 600. In Kharan, Pishin, Killa Saifullah and Kila Abdullah water tables ranges from 610 to 770 feet. Palpable changes occurred in Quetta, Ziarat, and Mastung where water table reached 1100. Above all, gigantic changes have been noticed in groundwater table. Water is extremely declining, even though in some areas the extraction level has touched 1400 feet. Meanwhile, few areas had no availability of clean drinking water.

4.6. Impact of drought on groundwater level

This table elaborates the source of drinking water of the dwelling of Balochistan. 17.5% respondents answered open well is main source of drinking.38.75% population utilize bore well water for drinking purpose. And 5.62% population extract water from tube well.9.37% respondents reported that they had karez availability for meeting out drinking puprpose.18.755 population use springs water and only 10% uses canal water for drinking purpose (Table 13).

Table 13. Source of drinking water.

Sample No	Source of drinking water	Frequency	Percentage (%)
1	Open well	28	17.5
2	Bore well	62	38.75
3	Tube well	9	5.62
4	Karez	15	9.37
5	Springs	30	18.75
6	Canal	16	10
Total		160	100.00

Groundwater is main source for irrigation.12.5 % respondents reported that ground water table is increasing with increased rainfall. However, major part, 60.62% responded that groundwater level is decreasing with each passing day. 16.87% population had observed no change in water table and 10 % never paid heed to water scarcity problem (Table 14).

Table 14. Perception about groundwater level**.**

Sample No	Perception about drought	Frequency	Percentage (%)
1	Increasing	20	12.5
2	Decreasing	97	60.62
3	No change	27	16.87
4	Never noticed	16	10
Total		160	100.00

4.7. Drought management

The Consequent table portrays community perception regarding drought management.30.62% respondents' suggested that drought could be managed by saving rain water. 18.75% population added that restricting pumping of underground water could surely mitigate drought .and 8.12% population further reported that less use of water would be compatible for saving groundwater. 7.5% respondents viewed maximum rainfall is the ultimate source of groundwater mounting.20% responded, the enduring management is possible through Dams construction and 15% of the population did not pay any response (Table 15).

Table 15. Community perception regarding drought management.

Sample No	Management	Frequency	Percentage (%)
1	Save rain water	49	30.62
2	Restrict pumping of underground water	30	18.75
3	Less use of water	13	8.12
4	Maximum rainfall	12	7.5
5	Construction of Dams	32	20
6	No Response	24	15
Total		160	100

Table 16 elaborates how water ought to be managed. 81.25% population reported that Dams construction is the main of source of water conservation. Only 5% population suggested the construction of barrages and 13.75% did not show any response (Table 16).

Table 16. Rainwater conservation.

Sample No	Storage of water	Frequency	Percentage
1	Dams	130	81.25
2	Barrage	8	5
3	Nil	22	13.75
Total		160	100

Apart from that, many of the respondents were reported saying that rainfall has advantages and disadvantages. Almost 45.62% population presented positive response; with increased rainfall crop production mount. Consequently, 23.75% reported that with maximum and erratic rainfall the crop and fruit production were severely affected.

5. Discussion

The analysis reveals that drought has physical, economical and environment impacts, the declining in groundwater level, the drying up of well, reservoirs, lakes and springs were terribly observed in Balochistan. Moreover, the groundwater table is declining in the province and discharge flow of wells and tube wells is severely reduced either. In many upland regions the water tables reach 1400 and receive some of the lowest rainfall, but crop production is significantly high in those location. This statistic shows that there is a probability that harvest loss in the study area can be influenced by both rainfall and other environmental variables. It is mainly because of over exploitation of land use and extensive utilization of groundwater. Many well to do families have installed solar system which provide maximum electricity to those regions. On the other hand, the indigenous people are deprived of those facilities to meet their basic requirements. Furthermore, the analysis shows abundant number of populations, which makes 36.87%, had farming and 14.37 had herding occupation in Balochistan. Only 13.75% population has jobs which is the lowest of total. Meanwhile, maximum number of the dwellings were unacquainted of drought occurrence. Similarly, 30.62% of population were unaware about rainfall variability. It is, for that reason, very pathetic that government and administrative authorities had no concern toward that creeping disaster. 29.37% population came to know about drought through decrease in rainfall. Many argued that increase in temperature was the main clue of drought looming. Others reported, economic loss, less agricultural production and decrease in groundwater table were sources through which they became aware about drought [21]. Extremely vulnerable climate changes were noticed which results in periodic drought that caused huge disturbance in the economic activities. However, this alarming condition is perpetuating because of anthropogenic activities, population growth, urbanization, temperature increase and poor water management are the main reasons for this hazard to become to become disaster [22]. Drought has global impacts, during drought, the groundwater on most small islands (<300 m in width) is completely depleted, with only large islands (>800 m) maintaining a sizeable freshwater lens for use by the local population. Of the 83 islands assessed for lens thickness during a severe drought, just over half (54%) are classified as "Highly Vulnerable" to drought, 23% are classified as "Moderately Vulnerable" to drought, and the remainder are only slightly affected by drought. it articulately manifests that drought has severe impact on groundwater [23]. Apart from that regarding the economics of agricultural groundwater extraction versus extractions for domestic wells, present illustrative findings derived from Tulare County in California (US) using a welfare maximizing approach, they found that limiting depth to groundwater is not an effective policy because agricultural opportunity costs far exceed domestic well costs. Enforcing regulation and negotiating among water user groups has transaction costs.

6. Conclusion

It is concluded from analysis that the dry condition has severely reduced the groundwater level in wells. The main source of irrigation in almost every district is groundwater. Drought has immense effect on water level decline. Meanwhile, the indiscriminate pumping of water for use of gardening and other activities has further dropped water level. The rich people have severely damaged the exact flow of underground level. Many elites have capability of installing solar system. With intensive use of solar energy panel has devastatingly declined the ground water level. Consequently, obvious changes have been observed in groundwater table for 20 years. The water table has reached 320 feet where it was noted 160 in 2000. Likely, it would further decline with each passing day. Water is extremely declining, resultantly in some areas the extraction level has touched 1400 feet. Meanwhile, few areas had no availability of clean drinking water. Devastating drought has demolished historical fruit like apricots which were being cultivated for last 30 to 40 years. The occurrence of drought has caused severe problems. The ongoing dry spell has caused the debasement of green cover and field land regions for animals, and decrease in accessibility of water for animals. This made the animals become more vulnerable and resulted in misfortunes.

Funding

This research received no external funding.

Author contributions

Muhammad Jamil: Conducted the research and prepared the initial manuscript. **Shakeel Mahmood:** Supervised the study and review the manuscript. **Saddam Hussain:** Review and updated the manuscript. **Muhammad Saad:** Review and updated the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Diaz, V., Perez, G. A. C., Van Lanen, H. A., Solomatine, D., & Varouchakis, E. A. (2020). An approach to characterise spatio-temporal drought dynamics. Advances in Water Resources, 137, 103512. https://doi.org/10.1016/j.advwatres.2020.103512
2. Himayoun, D., & Roshni, T. (2019). Spatio-temporal variation of drought characteristics, water resource availability and the relation of drought with large scale climate indices: a case study of Jhelum basin, India. Quaternary International, 525, 140-150. https://doi.org/10.1016/j.quaint.2019.07.018
3. Zhou, H., Liu, Y., & Liu, Y. (2019). An approach to tracking meteorological drought migration. Water Resources Research, 55(4), 3266-3284. https://doi.org/10.1029/2018WR023311
4. Sun, S., Lei, H., & Chang, S. X. (2019). Drought differentially affects autotrophic and heterotrophic soil respiration rates and their temperature sensitivity. Biology and Fertility of Soils, 55(3), 275-283. https://doi.org/10.1007/s00374-019-01347-w
5. Karanja, A. (2017). Analysis of temporal drought characteristic using SPI drought index based on rainfall data in Laikipia west sub-county, Kenya. Open Access Library Journal, 4(10), 80047. https://doi.org/10.4236/oalib.1103765
6. Miyan, M. A. (2015). Droughts in Asian least developed countries: vulnerability and sustainability. Weather and Climate Extremes, 7, 8-23. https://doi.org/10.1016/j.wace.2014.06.003
7. Yilmaz, B. (2019). Analysis of hydrological drought trends in the GAP Region (Southeastern Turkey) by Mann-Kendall test and innovative Şen method. Applied Ecology & Environmental Research, 17(2), 3325-3342. http://dx.doi.org/10.15666/aeer/1702_33253342
8. Khan, N., Shahid, S., Ismail, T. B., & Wang, X. J. (2019). Spatial distribution of unidirectional trends in temperature and temperature extremes in Pakistan. Theoretical and Applied Climatology, 136, 899-913. https://doi.org/10.1007/s00704-018-2520-7
9. Arshad, M., Amjath-Babu, T. S., Kächele, H., & Müller, K. (2016). What drives the willingness to pay for crop insurance against extreme weather events (flood and drought) in Pakistan? A hypothetical market approach. Climate and Development, 8(3), 234-244. https://doi.org/10.1080/17565529.2015.1034232
10. Memon, J. A., Jogezai, G., Hussain, A., Alizai, M. Q., & Baloch, M. A. (2017). Rehabilitating traditional irrigation systems: assessing popular support for Karez rehabilitation in Balochistan, Pakistan. Human Ecology, 45, 265-275. https://doi.org/10.1007/s10745-016-9890-1
11. Ahmed, K., Shahid, S., Chung, E. S., Wang, X. J., & Harun, S. B. (2019). Climate change uncertainties in seasonal drought severity-area-frequency curves: Case of arid region of Pakistan. Journal of Hydrology, 570, 473-485. https://doi.org/10.1016/j.jhydrol.2019.01.019
12. Mohsenipour, M., Shahid, S., Chung, E. S., & Wang, X. J. (2018). Changing pattern of droughts during cropping seasons of Bangladesh. Water Resources Management, 32, 1555-1568. https://doi.org/10.1007/s11269-017-1890-4
13. Leng, G., & Hall, J. (2019). Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. Science of the Total Environment, 654, 811-821. https://doi.org/10.1016/j.scitotenv.2018.10.434
14. Masih, I., Maskey, S., Mussá, F. E. F., & Trambauer, P. (2014). A review of droughts on the African continent: a geospatial and long-term perspective. Hydrology and earth system sciences, 18(9), 3635-3649. https://doi.org/10.5194/hess-18-3635-2014
15. Singh, H. (2019). Demographic changes in Balochistan. International Journal of Research in Social Sciences, 9(5), 157-171.
16. Tariq, H. H., Hamid, M., Gulzar, Q., Mir, A. W., Samad, N., Haris, M., & Khalid, M. B. (2019). Using High Resolution Stereo Imagery for Contouring: Complex Terrain Contour Mapping of Naukandi, Balochistan. National Academy Science Letters, 42, 13-17. https://doi.org/10.1007/s40009-018-0663-9
17. Ashraf, M., & Routray, J. K. (2015). Spatio-temporal characteristics of precipitation and drought in Balochistan Province, Pakistan. Natural Hazards, 77, 229-254. https://doi.org/10.1007/s11069-015-1593-1

18. Hao, L., Kang, L., Huang, H., Ye, L., Han, K., Yang, S., ... & Ma, T. (2019). Surface-halogenation-induced atomic-site activation and local charge separation for superb CO2 photoreduction. Advanced Materials, 31(25), 1900546. https://doi.org/10.1002/adma.201900546
19. Haacker, E. M., Cotterman, K. A., Smidt, S. J., Kendall, A. D., & Hyndman, D. W. (2019). Effects of management areas, drought, and commodity prices on groundwater decline patterns across the High Plains Aquifer. Agricultural Water Management, 218, 259-273. https://doi.org/10.1016/j.agwat.2019.04.002
20. Deines, J. M., Kendall, A. D., Crowley, M. A., Rapp, J., Cardille, J. A., & Hyndman, D. W. (2019). Mapping three decades of annual irrigation across the US High Plains Aquifer using Landsat and Google Earth Engine. Remote Sensing of Environment, 233, 111400. https://doi.org/10.1016/j.rse.2019.111400
21. Al Adaileh, H., Al Qinna, M., Barta, K., Al-Karablieh, E., Rakonczai, J., & Alobeiaat, A. (2019). A drought adaptation management system for groundwater resources based on combined drought index and vulnerability analysis. Earth Systems and Environment, 3, 445-461. https://doi.org/10.1007/s41748-019-00118-9
22. Barkey, B. L., & Bailey, R. T. (2017). Estimating the impact of drought on groundwater resources of the Marshall Islands. Water, 9(1), 41. https://doi.org/10.3390/w9010041
23. Martinis, S., & Twele, A. (2010). A hierarchical spatio-temporal Markov model for improved flood mapping using multi-temporal X-band SAR data. Remote Sensing, 2(9), 2240-2258. https://doi.org/10.3390/rs2092240