HYDROLOGICAL AND METEOROLOGICAL DROUGHT AND TREND ANALYSIS IN AFGHANISTAN AND THEIR IMPLICATIONS ON TRANSBOUNDARY RIVERS

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ABSTRACT

HYDROLOGICAL AND METEOROLOGICAL DROUGHT AND TREND ANALYSIS IN AFGHANISTAN AND THEIR IMPLICATIONS ON TRANSBOUNDARY RIVERS

Afghanistan as a landlocked country located within central and southwestern Asia has an arid to semi-arid climate. Most of the people are involved in agricultural activities and major part of the country's gross domestic product depends on agriculture, but the country has the lowest water storage capacity. Consecutive periods of droughts and rapid snowmelt due to climate change have made it more challenging for convenient water resources management practices. Other major concern is transboundary water that flows to downstream countries without any sharing agreement rather than one on the Helmand River. Therefore, this study first aims to investigate the historical hydrological and meteorological drought characteristics across the whole country using Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) for meteorological drought analysis for a period 1979-2019, and Streamflow Drought Index (SDI) is used for hydrological drought analysis using two different time series (1960-1979 and 2008-2020) from 55 hydro-meteorological stations. Missing streamflow data in four stations across four transboundary River Basins (RBs) of the country is modeled using Remote Sensing (RS) techniques via Landsat satellite imagery time series data from 1988 to 2021, and which is the novelty of this study. Afterwards, trends in streamflow, precipitation and temperature are examined using Mann-Kendall's and Sen's slope statistical tests. A four decadal countrywide drought maps are also generated. Finally, the effects of droughts and trends on transboundary rivers in the country are investigated. Data from (55) ground stations is used for this purpose in this study.

ÖZET

AFGANİSTAN İÇİN HİDROLOJİK VE METEOROLOJİK KURAKLIK VE EĞİLİM ANALİZİ VE BUNLARIN SINIR AŞAN NEHİRLER ÜZERİNE MUHTEMEL ETKİLERİ

Afganistan, Asya kıtasının orta-güneybatısında bulunan ve yarı-kurak iklime sahip karasal bir ülkedir. Nüfüsunun büyük çoğunluğun tarım ile uğraşmasına ve ülkenin gelirinin çoğunun zirai ürünlerden olmasına rağmen ülkenin su kaynağı kapasitesi düşüktür. İklim değişikliği nedeniyle arda arda kuraklıklar ve ani kar erimeleri su kaynakları yönetimini daha da zor hale sokmuştur. Diğer bir problem, Helmand Nehri dışında, sınır aşan suları ortak kullanan komşu ülkeler arasında bir antlaşmanın olmamasıdır. Bu nedenle, bu çalışmanın ilk amacı, Standart Yağış İndisi (SPI) ve Rekonans Kuraklık İndisi (RDI) ile, 1979-2019 periyodu için, meteorolojik kuraklık ve 55 hidro-meteorolojik istasyondan elde edilen iki farklı zaman serisi (1960-1979) ve 2008-2020) için, Akış Kuraklık İndisi (SDI) ile hidrolojik kuraklık analizlerinin bütün ülke için araştırılması olmuştur. Çalışmanın orijinalliğini, uzaktan algılama (RS) teknikleri ile, Landsat 1988-2021 uydu görüntü zaman serileri ile beraber kullanarak, sınır aşan nehir havzalarındaki dört istasyon için eksik akış verilerinin tamamlanması oluşturmuştur. Daha sonra, Mann-Kendall ve Sen'eğim istatistiksel testlerin kullanılmasıyla akış, yağış ve sıcaklık eğilimleri incelenmiştir. Son kırk yıla ait ülkenin kuraklık haritaları üretilmiştir. Kuraklık ve eğilimlerin sınıraşan nehirler üzerine olan etkileri araştırılmıştır. Ellibeş (55) istasyondan elde edilen veriler bu amaç için kullanılmıştır.

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LIST OF ABBREVIATIONS

AINC	Afghanistan Initial National Communication
AMHG	At-Many-stations Hydraulic Geometry
AMSR-E	Advanced Microwave Scanning Radiometer
ANDMA	Afghanistan National Disaster Management Authority
ANDS	Afghanistan National Development Strategy
ANN	Artificial Neural Network
ARD	Analysis Ready Data
C	Calibration
CPC-RFE	Climate Prediction Centre Rainfall Estimate
CA	Central Asian
CRU	Climatic Research Unit
CZI	China-Z Index
DI	Deciles Index
DHMA	Disaster Management and Humanitarian Affairs
DPI	Discrepancy Drought Index
DrinC	Drought Index Calculator
EDI	Effective Drought Index
EO	Earth Observation
ERA-40	ECMWF Re-Analysis
ERTS	Earth Resources Technology Satellite
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEE	Google Earth Engine
GPCC	Global Precipitation Climatology Center
GSMaP_MVK	Global Satellite Mapping of Precipitation Microwave-IR Combined Product
HMNDP	High-Level Meeting on National Drought Policy
HRWT	Helmand River Water Treaty

HYMEP	Hydro-Meteorological Information Management Project
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
JDI	Joint Deficit Index
JICA	Japan International Cooperation Agency
LTS	Landsat Time Series
M	Measurement
MAE	Mean Absolute Error
MAIL	Ministry of Agriculture, Irrigation and Livestock
MCZI	Modified China-Z Index
MEW	Ministry of Energy and Water
MFA	Ministry of Foreign Affairs
MODIS	Moderate Resolution Imaging Spectroradiometer
MK	Mann-Kendall
MSS	Multispectral Scanning System
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NEPA	National Environmental Protection Agency
NIR	Near Infrared
NS	Nash-Sutcliffe efficiency
OLI	Operational Land Imager
PDSI	Palmer Drought Severity Index
PN	Percent of Normal
Q	Discharge
r	coefficient of correlation
RB	River Basin
RBM	River Basin Management
RDI	Reconnaissance Drought Index
RMSE	Root Mean Square Error
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service

SDI	Streamflow Drought Index
SHI	Standardized Hydrological Index
SPEI	Standardized Precipitation Evapotranspiration Index
SPSI	Standardized Precipitation-Streamflow Index
SR	Surface Reflectance
SRI	Standardized Runoff Index
SSI	Standardized Streamflow Index
SPI	Standardized Precipitation Index
SWAT	Soil Water Assessment Tool
SWOT	Surface Water and Ocean Topography
SWSI	Streamflow Water Supply Index
TA	Top of the Atmosphere
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TMPA	Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis
TRMM	Tropical Rainfall Measuring Mission
UNFCCC	United Nations Framework Convention on Climate Change
UNWC	United Nations Convention on the Non-navigational Uses of International Watercourses
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VCI	Global Vegetation Condition Index
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

1.1. Drought

Drought is a natural extreme event, which has different spatial and temporal characteristics. It is defined as a period of abnormally dry weather with a duration to result in a critical hydrological imbalance (IPCC, 2014). Palmer (1965) has defined drought as a ‘‘meteorological anomaly characterized by a prolonged and abnormal moisture deficiency’’. Yet, there is not a single definition for drought to be accepted by all (Tsakiris et al., 2013). Droughts are recognized when there is no precipitation over a long period of times, however, their extent, onset, and end is hard to determine (Vicente-Serrano et al. 2010). Further, it happens in any region with any climate whether it has less or more rainfall (Wilhite et al., 2014). Therefore, understanding and monitoring drought is very difficult (Lawal et al., 2021). Studies of drought impacts in recent years show that drought-related events are increasing, while reasons for increased vulnerability are more demand for food due to population growth, inaccessibility to water, especially in semi-arid and arid regions, and economic and industrial growth. Briefly, impacts of drought are likely to increase in the future as society’s demands on water and other environmental requirements (Wada et al., 2011). Also, deficit in the spatio-temporal inconsistency of supply and demand of water is expected to become harsh in case of warm climate (Huang et al., 2014; Raja et al., 2018). Moreover, conflicts between water users have emerged, and worldwide drought has been a stressor for international relations in transboundary rivers (Stahl, 2005; Stahl, 2008) and is expected to continue to be so in the future (De Stefano et al., 2012). Although droughts occur everywhere, it is important to note that, in general, the most severe consequences of drought for humans occur in arid or semi-arid regions where the availability of water is already low under normal conditions, the demand often is close to or even exceeds the natural availability and society often lacks the ability to adapt to the drought hazard (Dai, 2011). Therefore, drought management is and will increasingly be crucial. Yet, knowledge on drought frequency and its severity plays vital role not just in water resources management, but for other social, economic, and environmental implications of a region as well.

To analyze spatial and temporal severity of drought, various indices are usually employed. Some popular drought indices to quantify magnitude of meteorological drought are Standardized Precipitation Index (SPI) (McKee, 1993), Reconnaissance Drought Index (RDI) (Taskiris and Vangelis, 2005), Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010), Palmer Drought Severity Index (PDSI) (Palmer, 1965), Deciles Index (DI) (Gibbs and Maher, 1967), and Effective Drought Index (EDI) (Byun and Wilhite, 1999). Hydrological drought that represents deficit in streamflow is measured by other relevant indices, of which, Streamflow Drought Index (SDI) (Nalbantis and Tsakiris, 2009), Standardized Runoff Index (SRI) (Shukla and Wood, 2008), Standardized Streamflow Index (SSI) (Vicente-Serrano et al., 2012) can be named for their extensive use in studies among others.

While drought severity, duration, and intensity are anticipated to increase in the future (Bisht et al., 2019), arid and semi-arid regions may be substantially affected (IPCC, 2018). Afghanistan, with semi-arid and arid climate has already started to face more drought events in recent decades. Some regions were hit severely by drought in 1999, 2000, 2001, 2005, 2007, 2010, 2016, and 2017. Further, droughts are expected to be the norm that may result in desertification, land degradation, and severe soil erosion in Afghanistan (Rousta et al., 2020).

In addition to assessment of drought conditions in a region, it is important to evaluate tendencies in hydrologic and climatic variables (e.g., streamflow, rainfall, and temperature) so that to understand their patterns in terms of spatial and temporal extent. Knowledge about the magnitude of these variables is also necessary in studies associated with drought. Therefore, Mann-Kendall non-parametric test to detect trends in hydro-meteorological variables and Sen’s slope estimator to compute their magnitude are the widely-used methods among others in the literature (e.g., Yue et al., 2002; Tyralis et al., 2018; Kisi et al., 2018; Bawden et al., 2014; Adnan et al., 2018; Wu et al., 2016; Teegavarapu, 2019; Simsek, 2021; Aher and Yadav, 2021; Güçlü, 2018; Li et al., 2021; Pervin and Khan, 2021)

As four River Basins (RBs) of Afghanistan are transboundary and recent climate change has exacerbated both spatial and temporal variations in river flows, studying the impact of hydrological and meteorological droughts along with trends in hydro-meteorological variables on these rivers seems rational so that to inform policymakers and key decision-makers involved in transboundary water negotiation and bilateral treaties. Most importantly, transboundary water has created disputes with neighboring countries as most of Afghanistan's rivers flow toward its downstream countries. Hence, this study will contribute scientifically to address historical and current conditions in transboundary river flows as well.

The overall objective of this study is to assess and analyze the spatio-temporal variability of historical hydrological and meteorological drought and detect trends in hydro-meteorological variables across all five RBs of Afghanistan. Meteorological drought is studied for the period 1997-2019, and hydrological drought is studied for two different periods (1960-1979 and 2008-2019). Besides, missing streamflow in strategic transboundary stations is estimated using state-of-the art remote sensing technique from 1988 to 2019, which represents the novelty of this research. In recent years, Japan's International Cooperation Agency (JICA) assisted MEW to perform precipitation gap-filling from 1979 to 2008 through Project on Capacity Enhancement of Hydro-Meteorological Information Management (HYMEP), which is also used in this study. Two meteorological indices such as Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) are employed as well-known and widely used indices in meteorological drought monitoring. Furthermore, hydrological drought is analyzed using Streamflow Drought Index (SDI) and Standardized Streamflow Index (SSI). Afterwards, Mann-Kendall test is performed to detect trends in streamflow, rainfall, and temperature, and then Sen's slope estimator is used to quantify magnitudes of detected trends. Finally, the implications of droughts and trends will be considered on transboundary rivers.

Rainfall and temperature data of 55 meteorological stations obtained from Ministry of Energy and Water (MEW) representing all five RBs is used (Figure 1.1) for meteorological and hydrological drought analysis. Rainfall and temperature gap-fill data for a period 1979-2008 processed by MEW is also used. Drought Index Calculator (DrinC) is used for SPI, RDI, SSI, and SDI computation.

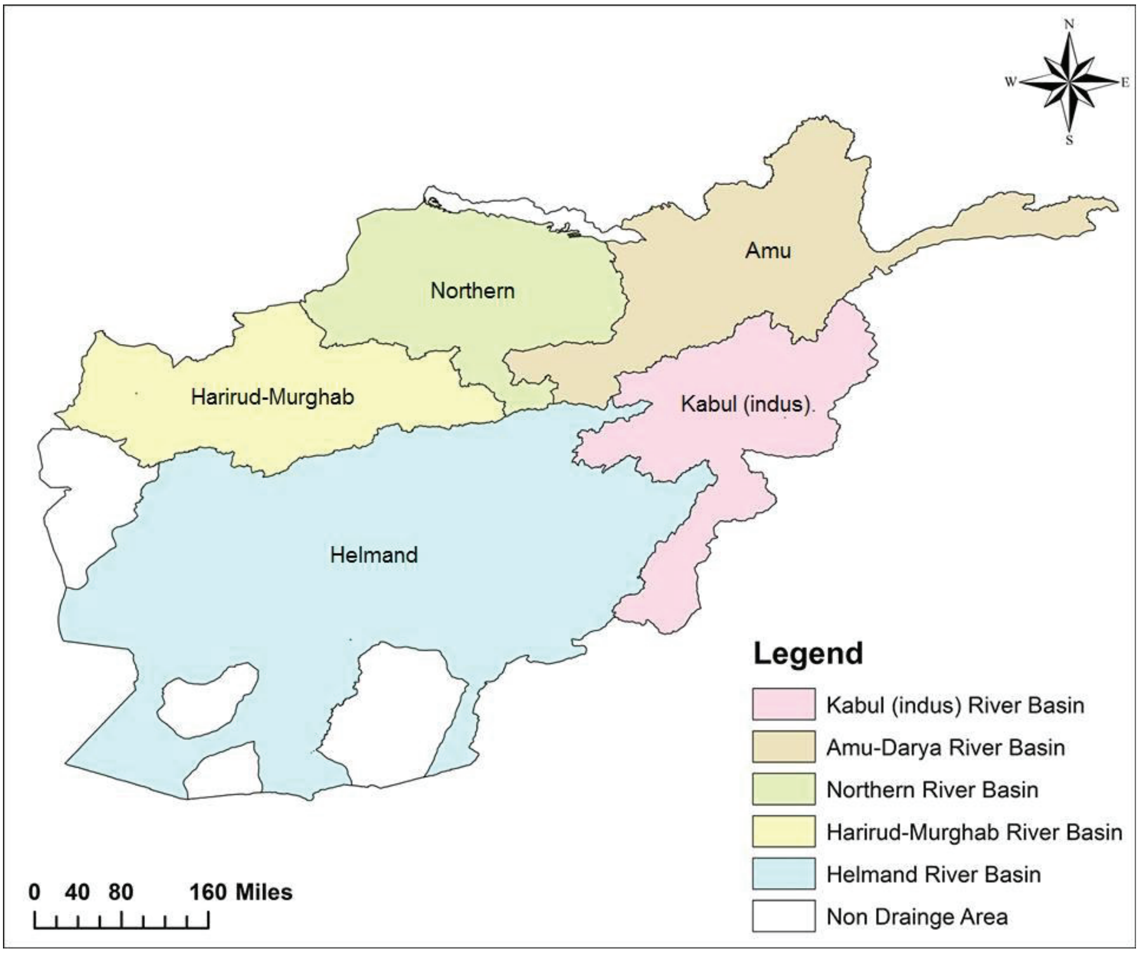


Figure 1.1. River Basin Map of Afghanistan

1.2. Background

Afghanistan as a landlocked mountainous country for a long time suffers from lack of water resources management and necessary water resources infrastructure to store water. Basically, the country sees its economic sustainability in the management of water resources, which represents a strong view in this regard. Also, the need for hydropower generation is another demand that Afghanistan is looking for reserving water. Hence, there are some efforts undertaken for the improvement of water resources sector in the last few years. The water availability per capita per year is more than 2000 m^3, however, the storage capacity is just 80 m^3 per capita per year (Saffi and Kohistani, 2013). The total annual volume of renewable water resources is 75 billion m^3 out of which 18 billion m^3 is ground water and 57 billion m^3 is surface water with a total annual water withdrawal of about 20.3 billion m^3 (Ahmad and Wasiq, 2004; JICA, 2011). Another fact to present is that around 80% of this country's water comes from snowmelt of the glaciers in the Hindu Kush mountains (Mahmoodi, 2008; and Walters and Groninger, 2014).

The country is divided into five hydrological River Basins (RBs), which are Amu RB, Harirud-Murghab RB, Helmand RB, Kabul RB, and Northern RB. Out of these five RBs, four are transboundary such as Amu, Harirud-Murghab, Helmand, and Kabul RBs. About 90% of Afghanistan's water is shared with neighbors (i.e., Pakistan, Tajikistan, Uzbekistan, Turkmenistan, and Iran). Some mistrusts and disputes exist with the neighboring countries on shared water, especially with Pakistan and Iran that have relatively less water availability than Afghanistan. Therefore, this study will be a startup for a better policy framework design towards management of transboundary rivers taking droughts and climatic trends into account.

Afghanistan had a relatively good hydrological and meteorological networks for measuring river flows, precipitation, and temperature. The hydrological stations were installed across the country by the United States Geological Survey (USGS) in early 1950s that were operational until late 1970s. However, these networks were destroyed in 1979 by the Soviet invasion and all the data collection process was stopped until after 2001. They USGS then helped the MEW to reinstall some of the stations again. Later in 2008, MEW started collecting hydro-meteorological data while it is still not available in a public domain, it is rather accessible through a process of applying formally.

There exist several governmental institutions that are directly or indirectly involved to respond to drought events, make preparations for such events or provide predictions on drought occurrence, which are the MEW, the Office of the State Minister for Disaster Management and Humanitarian Affairs (DMHA), Afghanistan National Disaster Management Authority (ANDMA), Ministry of Agriculture, Irrigation and Livestock (MAIL), and the National Environmental Protection Agency (NEPA) from which DMHA and ANDAMA are responsible to oversee all aspects of strategies, policies and operations related to disaster risk reduction. MEW's responsibility is to develop policies and strategies regarding water resources and to forecast drought events, also develop drought mitigation measures, and the MAIL is responsible to stockpile food for such events. Still, the national drought policy is not finalized to the best of our knowledge.

1.2.1. Climate and Geographic Location

Afghanistan is a mountainous landlocked country while its climate is classified as arid in the south and southwest and semi-arid in the north and northeast. Temperature is ranging from +50 °C in summer season in the desserts (south and southwest) to -50 °C in winter season in mountains (north and northeast) (Habib et al., 2013). Based on this significant difference in the climate, the rainfall and water resources have quite diverse spatial distribution across the country. The precipitation ranges from 52 mm at Zaranj in southwest and 992 mm at North Salang in northeast (Habib et al., 2013). The Afghanistan National Development Strategy (ANDS, 2008) reports the annual average precipitation in Afghanistan as 250 mm, but Ahmad and Wasiq (2004) indicate it to be 227 mm, whereas JICA (2011) reports it as 300 mm that ranges from 75 mm in the southwest to 1270 mm in the northeast. The rate of evapotranspiration extends to 1,800 mm in the south and southwest plains and in the north and northeast plains, it ranges from 1,200 to 1,400 mm (ANDS, 2008). Mean annual temperature in the country has increased by 0.6 °C from 1960 to 2008 at a rate of 0.13 °C in average (AINC, 2015). Furthermore, the climate projections from 2008 to 2090 indicate that there will be an increase of 1.4 to 4.0 °C till 2060s, and 2.0 to 6.2 °C until 2090s (AINC, 2015).

1.2.2. A Brief Look to Afghanistan's Water Resources

Afghanistan's total annual renewable water resources are reported with some different values such as 84 billion m^3 by Favre and Kamal (2004), 75 billion m^3 by Ahmad and Wasiq (2004), Mahmoodi (2008), JICA (2011), Saffi and Kohistani (2013), and Habib (2014) out of which 57 billion m^3 is surface and 18 billion m^3 is ground water. Shroder and Ahmadzai (2016) have provided a range of 55 to 84 billion m^3 for the annual potential of water in the country. The total annual water withdrawal is about 20.3 billion m^3 (Ahmad and Wasiq, 2004; and JICA, 2011). Although, the water availability per capita is more than 2000 m^3 per year (Ragab and Prudhomme, 2002), the water storage capacity is just 80 m^3 per capita per year (Saffi and Kohistani, 2013). On the other hand, Afghanistan Initial National Communication (AINC, 2015) to the United Nations Framework Convention on Climate Change (UNFCCC) reported the overall availability of water to be 2,775 m^3 per capita per year in theory. Hence, Afghanistan is not a water scarce or water stressed country based on the (1989) indicator. However, because of limited water storage infrastructure, most of its water flow to downstream neighbors.

Afghanistan's most of the precipitation is in the form of snow, and almost 80 percent of the water resources are from snow that originates in higher altitudes of Hindu Kush Mountains of above 2,000 meters. The snowfall accumulates in these mountains during the winter and then it starts melting from spring and continues during summer, which feds all major rivers during the year. Due to recent climate changes, the rapid snowmelt occurs early in spring that results in flash floods and most importantly, large amount of water crosses borders because of limited storage infrastructure along transboundary rivers. The inadequate water storage infrastructure including for flood mitigation has created serious challenges for water security and economic growth as majority of country's population solely rely on agriculture and irrigation. Below average precipitation and increase in temperature are among other concerns as well. Moreover, the spatial distribution of water resources is another challenge, for example, an RB that holds more water does not necessarily account for more irrigated land and population and vice versa for another RB. Table 1.1 indicates the contribution of surface water with respect to RBs. In fact, water consumption in the country is only 33% of available surface water (ANDS, 2008).

Table 1.1. Annual discharge of Afghanistan's river basins (modified from Favre & Kamal 2004; and Shroder & Ahmadzai 2016).

River Basin	Land Area (%)	Total Annual Discharge (km3)	Total Annual Flow (%)
Amu Darya	14	45.4 - 48.1	57
Harirud-Murghab	18	2.3 - 3.06	4
Helmand	43	9.13 - 17.66	11
Kabul (Indus)	12	18.2 - 20.9	26
Northern	13	1.67 - 1.81	2
Total	100	80.3 - 87.93	100

It is stated earlier that due to the lack of infrastructure for water resources storage in Afghanistan, most of the water is flowing to the neighboring countries as four RBs out of five are transboundary. The water of Amu RB is shared with the Central Asian (CA) countries like Turkmenistan, Uzbekistan, and Tajikistan, the Kabul River is flowing to Pakistan, water from Harirud-Murghab Rivers is flowing to Iran and Turkmenistan, and the longest and important river of the country, Helmand River is flowing to Iran. Two other rivers from the Helmand RB namely Farah Rud and Khash Rud also flows to Iran. Even Afghanistan is not a water stressed country as per the Falkenmark (1989) indicator, which states that a country is not water stressed if the water availability per capita per year is more than 1700 m^3, but the water storage capacity is about 80 m^3/capita/year (Favre and Kamal, 2004) but as per AINC (2015), it is indicated to be 140 m^3/capita/year which is still very low. Moreover, the climate change that has resulted in a rapid snowmelt, has also raised concerns while most of the water comes from the snowmelt. There will be a 10% decrease in the total annual precipitation during the next 50 years in Afghanistan (Vining and Vecchia, 2007) due to the climate change. In addition, Afghanistan has already suffered some periods of drought from which four consecutive years of drought caused many damages that was from 1998 to 2001. Indeed, the need of Afghanistan for the hydroelectric generation, food security and stable economy solely depends on water resources development and management. There will be a higher demand of water for irrigation in the future with the population growth and with development of the available arable farming. Further, since more than 50% of the country's Gross Domestic Product (GDP) relies on agriculture (Hayat and Baba, 2017), it makes sense that water resources infrastructure is crucial for overall development of the country. The different policies and strategies in place for water resources management in neighboring countries make the situation more challenging as there is not a common consensus on the rational use and share of water. Taking all these concerns into consideration, the following major problems currently exist in relation to water resources management in the country:

1. Limited climatic and hydrologic studies with limited coverage area exist.
2. Streamflow measurement is not available for the period 1979-2008 across the whole country.
3. Due to the missing streamflow measurement along rivers network (1979-2008), and inaccessibility to recently observed streamflow data (2008-2019) publicly, hydrological drought is not examined that can represent a country level study.

4. Countrywide meteorological drought studies are not available that use ground observed long-term rainfall data or they are very limited in terms of area, in-situ gauging data, and timeframe coverage.
5. There are limited climatic and hydrologic trend studies.
6. Country Drought Policy is not developed yet.
7. Transboundary Water Policy is under development, but not finalized yet.
8. Lack of knowledge on interrelations of climate change, droughts, trends, transboundary water, and water and food security.

Since the availability of water resources is a vital factor for the ecosystem, environment, food security, economy, and livelihood of a society, especially in areas where most of the people rely on agricultural activities, a comprehensive study on drought characterization is necessary. This is true for Afghanistan where about 80% of the population relies on agricultural activities in the country (Mahmoodi, 2008) that accounts for 50% the Gross Domestic Product (GDP) of the country (Hayat and Baba, 2017). Hence, the issue of drought has received a considerable attention in the country as it has been suffering some periods of droughts since late 1990s. Most importantly, the rapid melting of glaciers due to the climate change that as per Favre and Kamal (2004) and Mahmoodi (2008) accounts for 80% of the total precipitation, exacerbates the water shortage with the existing weak water storage infrastructures. Further, majority of the population resides in rural areas that merely depends on agriculture and livestock that makes 80% of the country's total population (Mahmoodi, 2008). That is why most of the water is used for agricultural purposes with traditional irrigation practices such as flood irrigation which wastes more water that is not recommended as a good and efficient irrigation practice at this modern era. In 2009, from a total of 7.7 million hectares of the country's arable land, only 3.2 million hectares was cultivated, making less than half of the available area (Torell and Ward, 2010). Hence, if the total arable land is used, the irrigation water demand will be increased to more than 100% of what is required for 3.2 million hectares.

1.2.3. Transboundary Rivers and Their Water Resources Potential

Afghanistan is divided into five RBs (Figure 1.1), out of which four are transboundary. About 90% of Afghanistan's surface water is transboundary and it is upstream country in many cases (Favre and Kamal 2004), but there is an exceptional case in the Kabul RB that both Afghanistan and Pakistan are upstream and downstream to each other (Vick, 2014; Saeed et al., 2017). The country's water still flows to neighboring countries for many years without any legal treaties rather than Helmand River Water Treaty (HRWT 1973) with Iran. According to the Afghanistan's National Development Strategy (ANDS, 2008), the Ministry of Energy and Water (MEW) of Afghanistan has already begun some large infrastructure projects and even some of the dams and canals have been completed. An example of the recently completed projects is the Salma Dam project on Harirud river with a capacity of 1,015 million m^3 (Thomas & Warner 2015), completed in June 2016. Shah wa Arus concrete gravity dam for irrigation and hydropower purpose is another major project in the Kabul RB located in Shakrdara district, started in 2012 that will finish shortly as per MEW. Moreover, government of Afghanistan had announced 21 dam projects in 2016 for which feasibility studies and surveys had started. Besides, Afghanistan is still pushing for unilateral resource capture to adopt hegemonic mechanisms (Thomas & Warner 2015). In addition, according to many of the Afghan parliament members who played important role in transboundary waters decision-making process, delaying negotiations with neighbors and continuing development of water resources would be in the best interest of Afghanistan until the country come to the table with a hydro-hegemony status (Thomas et al., 2016). Thus, it can be said that the country is reluctant to make any negotiations currently.

To sum up, the ANDS (2008) in water sector's strategy insists on the storage and control of water so that the country can be prepared for the periods of drought due to the climate change. Currently, the MEW has prepared a draft of the Trans-Boundary Water Policy, which is at the Ministry of Foreign Affairs (MFA) now (DURAN 2015). According to our knowledge, the policy is not finalized yet. Also, the Afghan government expects that managing water resources will significantly help poverty reduction in the country as well, which is the biggest challenge for the country at the time being. Finally, Afghanistan is serious to manage its water resources whether it is for irrigation development, hydropower generation, poverty reduction, sustainability, future needs during drought or even future drinking water purposes.

1.3. Research Objectives

The general objective of this study is to analyze the countrywide historical hydrological and meteorological drought, examine trends in these variables, and relate their impacts on transboundary water using available in-situ gauging stations data. The research consists of four sub-objectives, which are:

1. To estimate missing river discharge from 1988 to 2021 using Landsat satellites Surface Reflectance (SR) time series products as proxy for streamflow measurement. Indeed, this sub-objective represents the novelty of this research.
2. To identify drought prone areas across the country and examine drought frequencies.
3. To observe the decadal anomalies in rainfall, temperature, and streamflow.
4. To generate countrywide historical drought maps for a period of 41 years.

1.4. Significance of Research

Most of Afghanistan's water flows to downstream neighboring countries without any water sharing treaty rather than one with Iran. Understanding long term drought frequencies in hydrological and meteorological variables along with knowledge on trends in these variables will address some essential scientific insights and statistics to water resources managers, policymakers, and lawmakers. This research also employs a state-of-the-art method for estimating missing river discharge data for the period (1988-2021) using multiple Landsat satellites Remote Sensing (RS) data for the first time. It will contribute to more advance methods in RS to estimate river discharge in areas where ground gauged discharge data does not exist or missing, especially for a long time and before 2000s while no other optical sensors existed. In recent years, RS techniques are employed by some authors (e.g., Tarpanelli et al., 2013; Tarpanelli et al., 2017; Hashimoto and Oki, 2013; Moramarco et al., 2019; Tourian et al., 2017), which shows an interest and vitality in river discharge estimation remotely with different RS methods.

Hence, this study is expected to provide further contribution to this scientific field and to facilitate further advanced investigations in river discharge modelling.

1.5. Thesis Framework

CHAPTER 1. Introduction presents a brief information about the topic, research background, research problems, thesis objectives, significance of the thesis, and thesis framework.

CHAPTER 2. Literature review presents comprehensive review relevant studies and methodologies used in hydrological and meteorological drought analysis, trend analysis, effects of droughts and climatic trends on transboundary rivers, and discharge estimation in rivers using RS techniques.

CHAPTER 3. Meteorological drought presents historical meteorological drought analysis of all five RBs covering the entire country that consists of rainfall and temperature data from (55) meteorological stations.

CHAPTER 4. Drought mapping provides historical drought maps for the entire country based on SPI and RDI indices for the period 1979 to 2019.

CHAPTER 5. River discharge modelling using remote sensing data presents a state-of-the-art methodology for river discharge prediction in Afghanistan's transboundary rivers for the period 1988-2021.

CHAPTER 6. Hydrological drought presents the historical hydrological drought analysis of all five RBs across the whole country for two sets of in-situ streamflow time series (historical and new) data from 55 gauging stations.

CHAPTER 7. Climatic and hydrologic trends present the study of historical temperature, rainfall, and hydrological trends across the country for a period of four decades (1979-2019).

CHAPTER 8. Drought and trends impact on transboundary rivers presents a discussion on the existing issue in Afghanistan's transboundary water management and water sharing, impacts of historical droughts and climatic trends on transboundary rivers.

CHAPTER 9. Research summary and recommendations represent the overall findings of the research with summary points and provides recommendations for future studies in related topic.

CHAPTER 2

LITERATURE RVIEW

2.1. Drought Phenomenon in the 21st Century

Drought has become one of the serious challenges in today's water resources management field, which is also an important component of the climate system. It is a natural aspect of climate that occurs in virtually all climatic routines whether the region has low or high precipitation (Mishra and Singh, 2010). Considering its temporal extent, drought frequency is the ratio between the number of drought events and the number of years of a study period (Tan et al., 2015). Furthermore, drought is both disaster and hazard; a disaster because it is a failure in the precipitation regime; a hazard because it is a natural variable of the climatic system that has an uncertain occurrence (Paulo et al., 2012). Both climate change and increase in the world's population will result in a higher demand of fresh water in the future along with the higher demand of food, especially in the 21st century. If a drought event occurs, it will even add an extra challenge to the existing problem. Drought will be more frequent with severe issues under these consequences, (a) increasing population at a faster rate, thus leading to increased demand of water; (b) limited or uncertain water supplies that are mainly due to the change in the climatic factors like increase in the temperature; and (c) extreme precipitation regimes (Smith and Katz, 2013; Trenberth et al., 2015). Concerns exist that global warming may exacerbate hydrological and meteorological systems, and what are the best practices for the adaption of mitigation measures. Thus, precise efforts are needed for drought investigations to be prepared for its occurrence in advance.

In recent years, there has been an increasing interest in the investigation of drought across the globe due to climate change, particularly in arid and semi-arid regions where people suffer from water shortages. Regions that are more vulnerable to drought, especially with arid and semi-arid climate, with growing populations, and growing water demands, need to monitor their drought vulnerability constantly to ensure water security

(Wood and Sheffield, 2012). Hence, drought management is not being treated based on crisis-response perspective now, but on risk-based perspective (Wilhite, 2014).

Nevertheless, since its start and end are difficult to determine (Vicente-Serrano et al., 2010; Tsakiris, 2017; Paulo et al., 2012) and because in different regions and at different periods of time, the water shortage is due to a considerable spatial and temporal variability (Zarch et al., 2015), drought should be studied based on a specific location and specific period case. Mishra and Singh (2011) have presented six different components of drought modeling viz., spatio-temporal drought analysis, probabilistic characterization of droughts, climate change impact on droughts, land data assimilation systems, drought forecasting, and drought management, which indicates that drought study is not a stand-alone effort. Even it is impossible to prevent the occurrence of a drought event, a preparedness and adoption of mitigation plans may smoothly convey the event to a risk rather than a disaster, however. Thus, there is still a need to conduct more in-depth studies on drought in different climatic regions of the world or where drought analysis has not been studied.

It is impossible to avoid drought, but there are ways to mitigate its harmful effects (Smakhtin and Schipper 2008). Drought occurs in almost all climatic systems as it stands for climate’s natural and recurring feature (Zarch et al. 2015), and it is fast becoming one of serious natural hazard around the world. On one hand, drought is a long-term phenomenon, on the other hand, it allows a time frame for resistance against it and other mitigation preparations (Tsakiris, 2017). For this reason, a High-Level Meeting on National Drought Policy (HMNDP) was held in Switzerland in 2013 which was organized by the World Meteorological Organization (WMO), Food and Agriculture Organization of the United Nations (FAO), and the Secretariat of the United Nations Convention to Combat Desertification (UNCCD), urging all countries to develop and implement national drought policies to survive (Sivakumar et al., 2014). Recently, many researchers around the world have shown an increased interest in studies related to drought and trends in both precipitation and temperature, especially in arid and semi-arid regions. Also, attentions have been paid on how to well monitor and detect drought and trends using various scientific formulations and techniques. Scientists concentrate on how to analyze, formulate, and determine these natural adverse events. Policy makers try to construct efficient frameworks to confront them so that to persist. Then, drought indices supply information to decision makers on drought severity and are helpful to be used to trigger drought contingency plans in case of their availability (Morid et al., 2006).

Generally, a drought event may cause environmental, social, or economic issues based on its features. Still, it doesn't create problems related to the availability of water resources in a country only, but also causes disputes among the countries that share waters. A better knowledge of hydrological drought might facilitate resolutions to settle conflicts over transboundary waters between countries. Thus, investigation of the hydrological drought is essential in a country like Afghanistan that shares four out of its all five River Basins (RBs). Indeed, due to the lack of scientific data and some unclear political issues, the transboundary water resources policy is still in a draft state in the Ministry of Energy and Water (MEW) of Afghanistan that needed to be finalized years before as most of the country's water flow out to neighbors without any legal agreement rather than one with Iran.

2.2. Drought Classification

Drought is generally categorized as hydrological, meteorological, agricultural, and socio-economic (Wilhite and Glantz, 1985; American Meteorological Society, 1997; Mishra and singh, 2010; Sheffield and Wood, 2011); and drought indices can be employed as indicators to quantify the drought severity (Mishra and Singh, 2010). In addition to these four types, Sheffield and Wood (2011) introduced regional and ecological droughts in order to focus on the environmental impacts of drought concerning ecology rather than the socio-economic impacts. Meteorological drought is associated with precipitation deficits, hydrological drought is linked to streamflow in rivers, lakes and reservoirs, and groundwater shortages, agricultural drought is related to lack of moisture in the soil, and socio-economic drought is the situation where demand of water is higher than its supply. According to literature, different types of droughts are summarized as:

- A meteorological drought occurs when there is a significant deviation from the mean precipitation in a region over an extended period; precipitation data are used to identify and analyze this type of drought (Mishra and Singh, 2010; Sheffield and Wood, 2011).

- Hydrological drought refers to a period of deficiency in the supply of surface and sub-surface water of a given water resource management system (Panu and Sharma, 2002; Mishra and Singh, 2010; Sheffield and Wood, 2011). The following datasets are used to analyze hydrological droughts: streamflow, lake and reservoir levels, and groundwater levels (Mishra and Singh, 2010; Sheffield and Wood, 2011).
- Agricultural drought is defined as a period of soil moisture deficiency leading to a reduction in the moisture supply available for crops and other types of vegetation (Panu and Sharma, 2002; Sheffield and Wood, 2011); this type of drought is driven by meteorological and hydrological droughts (Sheffield and Wood, 2011). Several drought indices have been used to study agricultural drought, featuring a combination of hydrometeorological variables such as precipitation, soil moisture, and temperature (Mishra and Singh, 2010).
- Socio-economic drought refers to a combination of meteorological, hydrological, and agricultural droughts which result in adverse social and economic impacts on humans. This type of drought differs from those in the other three categories due to its direct link to the relationship between supply and demand for a given economic good (e.g., water): when the demand for water exceeds the supply, the result is a socio-economic drought (Mishra and Singh, 2010; Sheffield and Wood, 2011).
- Groundwater drought is defined as a lack of groundwater recharge over a prolonged period because of low precipitation and high evapotranspiration. This type of drought is mainly associated with low groundwater heads, small groundwater gradients, low groundwater storage, and low well yields (shallow wells may even dry up) (Van Lanen and Peters, 2000; Mishra and Singh, 2010). Groundwater levels and gradients are used to quantify the effects of this kind of drought (Van Lanen and Peters, 2000).
- Regional drought is defined as a period during which more than 70% of a given area (within a larger region) is affected by drought (Fleig et al., 2011).
- Ecological drought measures the impacts of drought on ecosystems, and it is caused by a reduction in soil moisture due to low precipitation (causing a reduction in evapotranspiration), which adversely affects local vegetation (Sheffield and Wood, 2011).

Indeed, drought and aridity are two different words, drought is a temporarily natural imbalance of water due to less or insufficient precipitation, while aridity is a natural environmental imbalance in the availability of water (Tsakiris et al., 2013).

2.3. Drought Monitoring

Since the occurrence and consequence of drought is anticipated to exacerbate under climate change, there is an increase demand for firm and extensive monitoring of drought to support planning and mitigation of drought impacts (Halwatura et al., 2017; Zhou et al., 2022a). To characterize drought, we need to know its spatial and temporal extent along with its severity or intensity (Vangelis et al., 2013). Also, to tackle drought, first we need to monitor and oversee its impact on a specific region over a period and then take some necessary mitigation measures. Additionally, information about some primary variables such as streamflow or discharge, precipitation and temperature are needed so that to quantify hydrological and meteorological droughts. This data is then incorporated into some indicators for measuring the intensity of drought. Basically, drought indices are the most powerful tools for observing numerous types of drought events (Zhou et al., 2022b). Therefore, different kind of indices have been introduced for drought monitoring including meteorological drought indices such as Standardized Precipitation Index (SPI) introduced by McKee et al. (1993) in the USA, Standardized Precipitation Evapotranspiration Index (SPEI) proposed by Vicente-Serrano et al. (2010) in Spain, Palmer Drought Severity Index (PDSI) developed by Palmer (1965) in the USA, Deciles Index (DI) developed by Gibbs and Maher (1967) in Australia, Percent of Normal (PN) described by Willeke et al. (1994), China-Z Index (CZI) a drought index (Ju et al., 1997) that was introduced to the National Meteorological Centre of China (Wu et al., 2001), modified CZI (MCZI), Effective Drought Index (EDI) proposed by Byun and Wilhite (1999), Z-Score, and Reconnaissance Drought Index (RDI) was proposed by Tsakiris and Vangelis (2005) in Greece. Further, hydrological drought indices namely Surface Water Supply Index (SWSI) developed by Shafer and Dezman (1982) in USA, Streamflow Drought Index (SDI) introduced by Nalbantis and Tsakiris (2009) in Greece, Standardized Runoff Index (SRI) developed by Shukla and Wood (2008) in United States, Standardized Hydrological Index (SHI) proposed by Sharma and Panu (2010) in Canada, and Standardized Streamflow Index (SSI) by Vicente-Serrano et al. (2012) in Spain.

Additionally, there are some indices that detect both hydrological and meteorological droughts together like Standardized Precipitation-Streamflow Index (SPSI) proposed by Rad et al. (2017) in Iran, and Joint Deficit Index (JDI) introduced by Kao and Govindaraju (2010) in USA. The indices are helpful for contextualization of a simple communication among all stakeholders about the data and information related to the drought severity (Tsakiris et al., 2013). It is worth noting that more than 150 drought indices for meteorological, hydrological, agricultural, and socioeconomic droughts monitoring exist according to Halwatura et al. (2017). There is not an index to be appropriate universally (Morid el al., 2006) as some of them have been introduced for a particular geographic location in the world, but SPI is regarded as the main meteorological drought index by the World Meteorological Organization (WMO) in 2009 to be used for drought monitoring (Hayes, 2011). Still, there exist complexities to well monitor and assess drought especially in the data scarce areas around the globe.

The knowledge of remote sensing has also been employed for drought monitoring in recent decades, which is a useful tool particularly in regions where required observed data is scarce or variety of data components are required not available from the ground observation stations. At the end of the 20th century, a paradigm shift occurred in drought monitoring, synchronous with developments in earth observation and remote sensing technologies viz. launch of the Landsat satellite in 1972 (West et al., 2019). Satellite-based sensors are now capable to get direct and indirect measurements of majority of the hydrological and meteorological components including river levels, total water storage, precipitation, snow, and soil moistures (Sheffield and Wood, 2011). Furthermore, recent global and near-real time observations of remote sensing advances have facilitated drought characterization extensively, particularly in regions with limited gauging stations (Jiao et al., 2019).

2.4. Meteorological Drought and Indices

A general approach to characterize and quantify meteorological drought events, numerous indices have been developed. Drought indices are helpful in drought characterization and quantification such as its severity, frequency, intensity, and duration and therefore, provide decision-makers a method to assess drought events and to consider necessary mitigation measures for their adverse impacts (Mishra and Singh, 2010; Singh et al., 2019). Meteorological drought indices are thoroughly reviewed in literature (e.g., Sheffield and Wood, 2011; Heim, 2002; Mishra and Singh, 2010; Kchouk et al., 2021). The frequently used meteorological drought indices include SPI (McKee et al., 1993), RDI (Tsakiris et al., 2007), SPEI (Vicente-Serrano et al., 2010), and PDSI (Palmer, 1956). Moreover, various studies have been investigated meteorological drought in arid and semi-arid regions (e.g., Tayfur, 2021; Zhang et al., 2021; Ben Mhenni et al., 2021) including application of newly developed indices. As a matter of fact, SPI and RDI are the two prevailing meteorological drought indices throughout the years, which are used by a large number of authors (e.g., Halwatura et al., 2017; Singh et al., 2019; Huang et al., 2017; Syed et al., 2022; Vangelis and Tsakiris, 2013; Mohammed and Scholz, 2017; Zarch et al., 2015; Vergni et al., 2021; Jena et al., 2020; Wei et al., 2021; Fatawu et a., 2021; Abdelmalek and Nouiri, 2020; Rani et al., 2022).

2.4.1. Standardized Precipitation Index (SPI)

The SPI is one of the mostly used index in the world that is generally applied for meteorological drought monitoring based on some defined numerical values as shown in Table 2.1 The index is introduced by McKee et al. (1993) in the USA which has now gained a lot of popularity and acceptance around the globe. Many researchers have regarded the SPI as a good and easy tool for drought monitoring, for example, Wu et al. (2001) used it for arid and humid regions in China, Surendran et al. (2017) applied SPI for a semi-arid region in India, Onuşluel Gül et al. (2022) investigated drought behavior in Thracian, Aegean and Mediterranean transects of Turkey's major river basins using SPI, Prajapati et al. (2021) used SPI to characterize drought in Marathwada region of Maharashtra, India, Zerouali et al. (2021) applied SPI to examine spatial and temporal drought pattern for the period 1972 to 2010 in the Oued Sebaou basin, Algeria. Besides, Cheval (2015) asserted that in many developing and developed countries, SPI is the most preferable index for meteorological drought monitoring. Most importantly, WMO has also recommended application of SPI as a suitable drought monitoring index for all regions with different climatic conditions.

Still being dominant in meteorological drought analysis, SPI is recently used by Wossenyeleh et al. (2022) in Ethiopia, Rahmani and Fattahi (2021) in Midlands UK, Fahimirad and Shahkarami (2021) in Iran, Waseem et al. (2021) in Punjab, Pakistan, Yildirim and Rahman (2021) in Australia, Kchouk et al. (2021) and Gumus et al. (2021) in Southern Anatolia Project region, Turkey.

Table 2.1. SPI Drought Classification

Description of State	Criterion
Extremely wet	$SPI \geq 2.0$
Very wet	$1.5 \leq SPI < 2.0$
Moderately wet	$1.0 \leq SPI < 1.5$
Near normal	$-1.0 \leq SPI < 1.0$
Moderately dry	$-1.5 \leq SPI < -1.0$
Severely dry	$-2.0 \leq SPI -1.5$
Extremely dry	$SPI < -2.0$

2.4.2. Reconnaissance Drought Index (RDI)

This index is proposed by Tsakiris and Vangelis (2005). RDI is among one of the widely used index in meteorological drought studies, which utilizes potential evapotranspiration as input in addition to precipitation, and this characteristic differentiates RDI from SPI. Still, the performance of RDI and SPI is usually similar and may be used to detect various drought conditions effectively. RDI is used in various drought studies, for example, Adnan et al. (2018) used the RDI to monitor various drought conditions in Pakistan. Shah et al. (2013) employed RDI to monitor meteorological drought conditions Bhavnagar District of India from 1971 to 2010.

Recently Reconnaissance Drought Index (RDI) has also been used widely. For specifed reference periods, RDI in standardized form is derived from the same procedure initially, which is used for SPI calculation. More precisely, the normal distribution is acquired in RDI calculation by fitting the gamma probability density function to the given frequency distribution of αk. The magnitude of drought for a specific location is presented by RDI, which is dependent on the probability of drought event occurrence (Tigkas 2008; Tsakiris et al. 2007). The classification of RDI is like SPI as shown in Table 2.2.

Table 2.2. RDI Drought Classification

Category	RDI Value
Extremely wet condition	2.0 and above
Very wet condition	1.5 to 1.99
Moderately wet condition	1.0 to 1.49
Near normal condition	−0.99 to 0.99
Moderately dry condition	−1.49 to −1.0
Severely dry condition	−1.99 to −1.5
Extremely dry condition	−2.0 and less

2.5. Hydrological Drought

Hydrological drought is defined as a considerable decrease in water availability in earth phase of the hydrological cycle (Nalbantis and Tasakiris, 2009). Hydrological drought needs a separate assessment and characterization from meteorological drought because there is no direct spatial or temporal relationship between hydrological drought and climate usually (Wu et al., 2017; Vicente-Serrano et al., 2012; Wu et al., 2016). Therefore, several indices have been developed and proposed in the literature for this purpose. Standardized Streamflow Index (SSI), Standardized Runoff Index (SRI), and Streamflow Drought Index are used to characterize spatio-temporal hydrological drought events (Vicente-Serrano et al., 2012; Shukla and Wood, 2008; Nalbantis and Tsakiris, 2009)

2.5.1. Streamflow Drought Index (SDI)

It is worth mentioning that the SDI is employed here because the index is accepted as an effective tool to detect hydrological drought (e.g., Tabari et al., 2013; Gumus and Algin, 2017). Moreover, SDI is recently used by Altın et al. (2020) in Eastern Mediterranean part of Turkey, Abbas and Kousar (2021) in Pakistan’s Upper Indus Basin from 1991 to 2017, Prajapati et al. (2021) in India’s Marathwada region from 2000 to 2014, Minea et al. (2021) in eastern Romania, Rahmani and Fattahi (2021) in Midlands UK, Fahimirad and Shahkarami (2021) in Iran, Simsek (2021) across Mediterranean

Basin, Turkey to calculate characteristics of hydrological drought. All these studies strengthen the suitability and use of the SDI for hydrological drought examination.

2.6. Trends in Climatic Parameters

Climate change in recent decades is one of the serious challenges around the globe. In recent years, there has been a reduction in food security because of increase in temperature, variation in rainfall patterns, and increase in extreme climatic conditions (IPCC, 2019). In other words, an increase in temperature, fast variation of the hydrological cycle, and increase the occurrence and intensity of extreme weather events in different geographical locations around the world are evidence of the climate change (IPCC, 2021). According to two scenarios presented by NEPA and UNEP (2016), the mean temperature increase over Afghanistan are 1.4 °C and 2 °C until 2050, 2.6 °C and 6.3 °C until 2100 respectively.

Many climate change studies across the world are available that investigate different climatic variables affecting environment in various aspects. The effects are particularly crucial for agriculture in regions where most of the population depend on it, especially regarding the study area of this research. A decrease in precipitation and increase in temperature may hamper the crop production drastically and result in socio-economic anomalies. Moreover, the spatial and temporal inconsistencies of climatic variables can also hinder normal human activities even with no decrease and increase in precipitation and temperature, respectively.

To understand the spatio-temporal variations of hydroclimatic variables, it is necessary to perform trend test to see the changes in the status of precipitation, temperature, and streamflow. In climate change studies, trend analysis is usually used by researchers to examine the spatial and temporal patterns of climatic variables. One of the commonly used nonparametric test for detecting trends in hydroclimatic time series is the Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). Moreover, several studies have used the non-parametric Kendall's tau-based Theil-Sen estimator that is known as Sen's (1968) slope estimator to estimate spatial pattern of the linear trend along with the non-parametric Mann-Kendall test (Qian et al., 2019). For example, Aher and Yadav (2021) studied seasonal, monthly, and annual rainfall pattern in India's semi-arid regions of the Godavari basin from 1871 to 2016 using Mann-Kendall test and Sen's slope estimator, Kwawuvi et al. (2022) examined spatio-temporal variations of rainfall in the Oti River Basin of West Africa for the period 1981-2010 for observed, and 2021-2050 for predicted employing Mann-Kendall test and Sen's slope to estimate magnitude of the trend, Gocic and Trajkovic (2013) examined annual and seasonal trends from 1980 to 2010 using Mann-Kendall and Sen's methods, Pervin and Khan (2022) assessed temporal trends in temperature and rainfall for 1990-2020 period in Chattogram city, Bangladesh, applying Sen's method and Mann-Kendall statistical test.

2.6.1. Mann-Kendall Test

Proposed by Mann (1945) and Kendall (1975), Mann-Kendall is a nonparametric trend test that has been proven to be used widely to detect trends in hydro-meteorological time series (Tyralis et al., 2018). The logic behind using non-parametric statistical tests is that compared with parametric test, the non-parametric tests are considered more applicable for data that is non-normally distributed, which is the case in hydro-meteorological times series (Yue et al., 2002).

The MK test is used in many hydro-meteorological studies including Yacoub and Tayfur (2020) for observing trends in precipitation for a period 1919-2016 across Mauritania, Kisi et al. (2018) for assessing streamflow in the Black Sea Region of Turkey, Bawden et al. (2014) for hydrological trends detection in the Athabasca River region in Canada, Adnan et al. (2018) for precipitation and temperature trends analysis in Pakistan, Wu et al. (2016) to calculated trends in SSI and SPI time series in Jinjiang River Basin, Chin, and Simsek (2021) to observe monotonic trends in streamflow across the Mediterranean Basin in Turkey. A detailed list of studies that have applied the MK test on hydroclimatic variables is available in Teegavarapu (2019). In fact, most recent studies regarding MK test can be referred to (Rani et al., 2022).

2.6.2. Sen's Slope Estimator

Developed by Sen (1986), an estimator of the magnitude of a trend's slope in a time series data. Sen's median slopes method provides a robust estimation of the tendency. The slope calculated in this method represents a change in the distribution of values given in a time-period to see whether it is increasing or decreasing. Indeed, it calculates the variance between the sign of observed data and estimated data (Deb and Sil, 2019).

Sen's slope estimator is still a prominent test in hydro-meteorological studies across the world and has been recently used by many researchers including (Simsek, 2021; Deb and Sil, 2019; Mondol et al., 2021; Rosmann et al., 2016; Umar et al., 2018; Zhang et al., 2022; Harka et al., 2021; Deng et al., 2017; Yacoub and Tayfur, 2020). Sen's slope test determines the magnitude of trend (change per unit time) of linear time series (Sen 1968). The function of linear trend presented by f(t), slope and constant of the equation is marked as M and C, respectively (Eqs. 1 and 2). The magnitude of trend is estimated by this method:

$$f(t) = M(t) + C \quad (1)$$

$$Q = \text{median } (5)\ Xi - Xj \ / \ ti - tj \quad (2)$$

The data values are presented as xi and xj at time ti and tj (i>j), respectively (Eq. 2). The Mann–Kendall test is used to determine the linear trend significance (at 95% level) of annual precipitation, temperature, and multiple drought indices.

2.7. Remote Sensing (RS) and Water Resources

In-situ measurements with adequate spatio-temporal coverage is the best practice to observe water resources. These measurements are limited or do not exist in most regions of developing countries. In recent years, satellite-based observations have proven to assist limited ground-based water resources monitoring systems with useful amount of information (Kansakar and Hossain, 2016; Zhang and Gao, 2016; Biswas and Hossain, 2018; Sheffield et al., 2018) called remote sensing. Remote sensing is the science of acquiring information regarding an area or object without any physical contact. Near infrared or visible (NIR or VIS) imagery is often used to estimate water bodies (Gao, 2015; Govender et al., 2007). Furthermore, satellite-based sensors can directly or indirectly measure almost all components of the hydrological cycle (McCabe et al., 2017; Zhang et al., 2016). These all advancements in remote sensing provide platforms for researchers to perform water resources studies on different extents, especially in regions with lack of in-situ water resources data.

Satellite altimetry was initially intended to observe sea level rises and surface of sea since 1990s Indeed, satellite altimetry has proven to be valuable for water level changes of reservoirs, lakes, and rivers (Schwatke et al., 2020). Several satellite data are used over the last few years in water resources and climatic studies in many regions of the world that have proven to be able to manage water resources in various aspects with the availability of data from various sensors and wavelengths and with a broad range of spectral and spatio-temporal resolutions (Govender et al., 2007). For example, simple approach to calculate volume variances of reservoirs and lakes is relied on the combination of surface area from optical images and water levels from satellite altimetry (Schwatke et al., 2020).

2.8. Role of Remote Sensing in Hydrological Studies

In hydrological studies, both spatial and temporal extent of data is important. Further, we usually need consistent and a longer period data to carry these studies. While the collection, archiving, and distribution of river streamflow are limited and a decline in river gauging stations exist (Hannah et al., 2011; Dixon et al., 2020), there may be no data available for some locations of interest either. In addition, due to rationalization of priorities of organizations that are involved in water resources development, it is difficult to operate and maintain considerable number of hydrological observation stations mainly in inaccessible areas (Alsdorf and Lettenmaier, 2003). This has resulted in the decline of about 75 percent in the annual monitoring of streamflow worldwide since 1970 (Sneeuw et al., 2014; Tourian et al., 2013). Further, time and cost limitations are other factors that may restrict hydrological experiments and studies. Therefore, to overcome these obstacles, knowledge of remote sensing (RS) is getting more and more attention day by day. Employing RS eliminates many existing restrictions regarding various hydrological variables. Satellite RS has been used in hydrological studies for many years. A major focus of RS research in hydrology has been to develop approaches for estimating hydro-meteorological states and fluxes (Schmugge et al., 2002). The primary set of state variables include land surface temperature, near-surface soil moisture, snow cover/water equivalent, water quality, landscape roughness, land use and vegetation cover. RS, particularly from various satellites in various spectral bands, can provide information on catchment characteristics (e.g., landcover, land use, slope, vegetation), from which the parameters of hydrological models can be gathered (Schultz and Engman, 2012). The upcoming Surface Water and Ocean Topography (SWOT) satellite mission will characterize the global surface water budget by measuring spatial and temporal water storage changes in reservoirs, lakes, and large rivers (Durand et al., 2010). SWOT is scheduled to launch in November 2022 on a SpaceX Falcon 9 rocket, according to NASA. Hence, the free and without borders availability of the most of remote sensing data is appreciated. Satellite radar altimetry has been also used in the literature for studying changes in water storage.

The recent developments in RS hydrology, especially over the past 10 years, have proved that hydraulic variables can be measured from orbiting satellite sensors with reliability (Huang et al., 2018a). Most satellite RS uses one of the two kinds of sensors viz. passive and active. Passive sensors detect natural radiation (from the sun) that is emitted or reflected by an object, whereas active sensors emit energy to scan objects, and then detect and measure the radiation that is reflected or backscattered from the target. Hence, imagery data acquired by instruments that measure reflectance from the sun is called optical sensor, which is collected during the sunlight and when there is no cloud. On the other hand, radar altimeter that obtains data via instruments, which emit radar signal towards an object and measure the reflected energy from that object at any time (day and night) is called active sensor. Different sensor types and frequencies in the electromagnetic spectrum can provide different information about water cycle variables (Tang et al., 2009). In addition to electromagnetic sensors, hydrologists are now using microgravity sensors to measure space-time variations in total terrestrial water storage (Tapley et al., 2004). In summary, while satellite remote sensing techniques can, depending on the orbital characteristics of the platform, make continuous and up-to-date measurements with wide regional coverage, they still rely on in situ observations for algorithm development and validation.

2.8.1. River Discharge Estimation Using Different Remote Sensing Techniques

Remotely sensed data is getting more attention in streamflow measurement, especially in inaccessible and remote areas or where gauging networks do not exist. Access to gauging data is decreasing in recent years (Vorosmarty et al., 1999; IAHS, 2001; Calmant and Seylerm, 2006) because many countries do not share this kind of data (Durand et al., 2010). Moreover, despite of the existing ground-based streamflow gauging networks, they may not provide enough spatial coverage for scientific studies (Bjerklie et al., 2005). Hence, in contrast to ground observed data, RS facilitates an unlimited coverage of rivers and other water bodies (Sichangi et al., 2018). As a result, different novel methods have been recently developed for the estimation of river discharge using remotely sensed techniques as summarized by Sichangi et al. (2018). Yet, it is impossible to measure river discharge directly from the remotely sensed measurement, but to use some proxies as explained by numerous researchers (e.g., Tarpanelli et al., 2017; Bjerklie, 2007; Van Dijk, 2016; Brankenridge, 2007) with different methodologies and tools.

Remote sensors operate based on some physical principles, observing the electromagnetic characteristics of Earth surfaces either with optical sensors (reflected energy), passive microwave sensors (emitted energy) or active sensors (scattered energy), which provide variety of information about land properties (Joshi et al., 2016). the use of remote sensing by satellite for streamflow analyses can be categorized into techniques based on satellite altimetry, synthetic Aperture Radar (SAR), and optical images (Ahmad and Kim, 2019). Applying optical, altimetry, and SAR data in surface water modelling, these articles can be referred (e.g., Musa et al., 2015; Huang et al., 2018a). Indeed, river discharge can be retrieved using optical and radar imaging sensors onboard satellites that provide river width measurements (Smith and Pavelsky, 2008), radar altimetry, which measures water height (Tourian et al., 2013), and water velocity (Tarpanelli et al., 2015). These RS observations may be converted to river discharge via hydraulic equations or statistical relations (Zakharova et al., 2020).

Investigating river discharge estimation by optical sensors, Brakenridge and Anderson (2006) used MODIS data for flood detection and characterization acknowledging that MODIS data can be also used for discharge estimation. Further, Tarpanelli et al. (2013) applied a 7-year time series of daily MODIS data in four stations along the Po River in Italy to estimate discharge. Likewise, Van Dijk et al. (2016) evaluated monthly discharge of more than 8000 gauging stations all over the world using optical MODIS and passive microwave remotely sensed data. Sichangi et al. (2016) used MODIS and multiple satellite altimetry data to estimate daily discharge in large rivers. Gleason and Smith (2014) used the At-Many-stations Hydraulic Geometry (AMHG) approach to estimate river discharge (Q) solely from remotely sensed observations of river width using Landsat imagery data.

Radar altimetry is one of the methods that provides complementary information about river streamflow by scrutinizing hydraulic variables such as width, slope, and surface water elevation (Brakenridge et al., 2006; Bjerklie et al., 2005). This method is based on the principle of a microwave pulse's echo that is transmitted by the altimeter and then reflected by water surface. Indeed, various satellite radar altimetry missions can help to retrieve river stage and discharge information for instance TOPEX/Poseidon, JASON, Geosat, Seasat, CryoSat, ERS, Sentinel, and ENVISAT that carry radar altimeters. Despite of development of the satellite altimetry for measuring ocean level changes, it has been shown a promising source of data for large rivers (Tarpanelli et al., 2013). For example, Jasinski et al. (2001) used river stage data from TOPEX/Poseidon satellite altimetry data to assess discharge ratings in several locations of the Amazon basin by comparing altimetry data with stage and discharge measured at the existing gaging stations. Leon et al. (2006) derived a stage-discharge relationship using ENVISAT altimetry data for the upper Negro River in the Amazon Basin. Schneider et al. (2018) evaluated the potential of Cryosat-2 for measuring the water level on the Po River in Italy and compared the Cryosat-2 observation errors with the in-situ measurements. Huang et al. (2018b) observed variations in water levels in the Brahamaputra River in India using the Jason-2, 3, and ENVISAT altimetry data. Some other studies have also demonstrated satellite altimetry to be capable of discharge estimation in rivers as mentioned by Tarpanelli et al. (2017). In brief, radar altimetry missions have different temporal resolutions that ranges from 10 days for TOPEX/Poseidon and JASON to 35 days for ERS-2 and ENVISAT (Calmant and Seyler, 2006).

The ratio of the Advanced Microwave Scanning Radiometer (AMSR-E) passive microwave brightness temperature or Moderate Resolution Imaging Spectroradiometer (MODIS) 4 Global satellite-based measurement of river and reservoir dynamics near-infrared reflectance between a wet measurement grid cell and its nearby dry calibration grid cell has become a useful tool that can be trained using in situ data and used as a simple and computationally efficient approach to predict river discharge (Brakenridge et al., 2012; Brakenridge et al., 2007; Revilla-Romero et al.; 2014 Tarpanelli et al., 2013; Van Dijk et al., 2016; Hou et al., 2018; Li et al., 2019; Tarpanelli et al., 2019; Tarpanelli and Domeneghetti, 2021). A simpler automated statistical method that can be readily applied globally and provide near real-time information even also at ungauged reaches is required. Regarding river discharge estimation by optical sensors, MODIS data is used by Brakenridge and Anderson (2006) for flood detection and characterization where they have admitted that MODIS data can also be used for discharge estimation. Following this concept, Tarpanelli et al. (2013) applied a 7-year time series of daily MODIS data in four stations along the Po River in Italy. They acquired the surface reflectance values for two pixels named in land (C: Calibration) and in water (M: Measurement) pixels from each individual image to have a time series of the C/M ratio. Then the observed discharge and velocity was collected for the same date of the satellite passed from the stations. Finally, the agreement between filtered C/M and observed Q time series was evaluated via Root Mean Square Error (RMSE), Nash-Sutcliffe efficiency (NS), coefficient of correlation (r), Mean Absolute Error (MAE), and 10^{th}, 50^{th}, and 90^{th} percentiles of the absolute error distribution. Van Dijk et al. (2016) evaluated monthly discharge of more than 8,000 gauging stations all over the world using optical MODIS and passive microwave remotely sensed data. Further, Sichangi et al. (2016) used MODIS and multiple satellite altimetry data to estimate daily discharge in large rivers. Gleason and Smith (2014) used the At-Many-stations Hydraulic Geometry (AMHG) approach to estimate river discharge (Q) solely from remotely sensed observations of river width using Landsat imagery data. In another study, Tarpanelli et al. (2018) used imagery data from multiple optical sensors and combined it with radar altimetry via Artificial Neural Network (ANN) to estimate discharge in the Po and Niger rivers. The combination of active and passive satellites data for flow measurements seems to be a better and a new way to reduce some existing constraints especially for the regions where there are no gauging sites or where in situ data is inaccessible. In fact, studies conducted by Tarpanelli et al. (2013) and Hirpa et al.

(2013) describe that variation in surface reflectance can be used as a proxy for the river discharge estimation. All these studies show a promising environment for a potential to indirectly estimate streamflow in rivers via remote sensing.

Moreover, estimation of river discharge from hydraulic characteristics acquired from remotely sensed data is provided in the literature (e.g., Roux and Dartus, 2006; Brakenridge et al., 2006; Bjerklie et al., 2005; Bjerklie et al., 2003; Tarpanelli et al., 2021; Van Dijk et al., 2016; Bjerklie et al., 2018; Sichangi et al., 2016; Hashimoto and Oki, 2013). Yet, efforts have been underway to evaluate the application of various algorithms to estimate discharge in rivers from remote observations of the river channel (Bonnema et al., 2016; Durand et al., 2016). For instance, Durga Rao et al. (2020) developed a genetic algorithm to estimate river discharge via RS coupled with hydraulic geometry in four rivers in India. Hence, studies conducted by Hirpa et al. (2013) and Tarpanelli et al. (2013) indicate that variation in surface reflectance can be used as a proxy for the river discharge estimation. All these studies show a promising environment for a potential to indirectly estimate streamflow in rivers via remote sensing.

Most water flux estimation method use regression-based relationships between remotely measured inundated area and in-situ measured discharge to predict fluxes (e.g., Smith, 1997). Although satellite data will probably never replace traditional ground-based gauges, remote sensing represents a valuable supplementary source of earth observation that is able to provide useful information for hydrological analysis and for river monitoring (Domeneghetti et al., 2018).

2.8.1.1. C/M Method

The C/M method is widely used to monitor river discharge (Tarpanelli, Brocca, et al., 2013). The principle of this method is that the reflectance ratio between the benchmarked area and the inundated area is correlated with river discharge. Brakenridge et al. (2007) initially used Advanced Microwave Scanning Radiometer for EOS the Earth Observing System data at 37 GHz to globally infer river discharges based on the ratio between the brightness temperature measured for a pixel unaffected by the river and a pixel centered over the river itself. This procedure has been implemented worldwide within the “Global Flood DetectionSystem”. Subsequently, the MODIS sensor was used to estimate river discharge successfully (Tarpanelli,Brocca, et al., 2013; Van Dijk et al., 2016). The researchers exploited different behaviors of water and landin the NIR band by computing the ratio (C/M) of the MODIS NIR band reflectivity value between two pixels:one located within the river (M) and one outside the river (C) to estimate river discharge. The C/M method issimple and robust and thus has been used widely. However, due to the width and variability of small rivers channel (widths less than 100 m), this method cannot accurately monitor its discharge using Landsat images.

2.8.1.2. Optical Sensors

In another study, Tarpanelli et al. (2018) used imagery data from multiple optical sensors and combined it with radar altimetry via Artificial Neural Network (ANN) to estimate discharge in the Po and Niger rivers. The combination of active and passive satellites data for flow measurements seems to be a better and a new way to reduce some existing constraints especially for the regions where there are no gauging sites or where in situ data is inaccessible.

2.8.1.3. Surface Reflectance in Near Infrared (NIR) Bands

Tarpanelli et al. (2013) applied a 7-year time series of daily MODIS data in four stations along the Po River in Italy. They acquired the surface reflectance values for two pixels named in land (C: Calibration) and in water (M: Measurement) pixels from each individual image to have a time series of the C/M ratio. Then the observed discharge and velocity was collected for the same date of the satellite passed from the stations. Finally, the agreement between filtered C/M and observed Q time series was evaluated via Root Mean Square Error (RMSE), Nash-Sutcliffe efficiency (NS), coefficient of correlation (r), Mean Absolute Error (MAE), and 10^{th}, 50^{th}, and 90^{th} percentiles of the absolute error distribution.

2.8.2. Application of Landsat Imagery Data in Hydrology

The National Aeronautics and Space Administration (NASA) of the United States (US) launched the first civilian Erath observation satellite on July 23, 1972, called Earth Resources Technology Satellite (ERTS-1), which was later renamed Landsat 1. In January 2008, NASA and USGS released the Landsat archive as a free and open access imagery data via internet based on a new Landsat Data Distribution Policy (Woodcock et al., 2008), which led to a dramatic utilization in Landsat imagery data (Wulder et al., 2016) in different earth science studies. In addition to other fields, Landsat data is in a continuous use for water resources and climate change studies (Wulder et al., 2016). Landsat imagery data has higher spatial resolution (30 m) with low temporal resolution of 16 days. Still, it is the longest mission in Earth Observation (EO) studies that can be relied on, especially in places where in-situ data does not exist. Landsat is a three-generation mission i.e., Landsat 1, 2, and 3 are first generation, Landsat 4 and 5 are second generation, and Landsat 7, 8, and 9 are third generation. Recently, the United States Geological Survey (USGS) has released a new dataset, called Landsat Analysis Ready Data (ARD), which is designed specifically for facilitating time series analysis. Landsat Time Series (LTS) has been widely used for a variety of time series analysis for monitoring environmental change (Zhu, 2017) including surface water dynamics (Pekel et al., 2016; Tulbure et al., 2013).

Landsat 1, which had a Multispectral Scanning System (MSS) on board in four spectral bands with a spatial resolution of 80 m, providing a worldwide coverage at a temporal resolution or repeat cycle of 16 days. Landsat 2 and 3 were then launched in January 1975 and March 1978 having four and five spectral bands respectively. With the launch of Landsat 4 in July 1982, it had a new sensor onboard called Thematic Mapper (TM) having 7 spectral bands in addition to the to the MSS sensor that had 4 spectral bands, with a repeat cycle of 16 days and spatial resolution of 30 m. Landsat 5 was then launched in March 1984 having both TM and MSS sensors and the same spectral bands, repeat cycle and spatial resolution as Landsat 4. The Landsat 6 however did not achieve orbit, which was launched in October 1993 and thus failed. Later in April 1999, Landsat 7 with an Enhanced Thematic Mapper Plus (ETM+) was launched that is still active. The ETM+ sensor of this satellite has eight spectral bands, including a pan and thermal band with a 30 m spatial resolution and 16 days repeat cycle around orbit. Landsat 8 was lastly launched in February 2013 with an Operational Land Imager (OLI) sensor having 9 spectral bands and a Thermal Infrared Sensor (TIRS) having two spectral bands, which is still orbiting. Lastly, Landsat 9 was launched in September 2021, which carries two instruments such as OLI-2 with 9 spectral bands and TIRS-2 with two spectral bands. Tables 2.3, 2.4, and 2.5 represents spectral bands' properties onboard Landsat 5, 7, and 8, respectively.

Table 2.3. Landsat 5 Technical Specifications

Landsat 5	Resolution (meters)	Wavelength (micrometers)
Band 1 (Blue)	30	0.45 – 0.52
Band 2 (Green)	30	0.52 – 0.60
Band 3 (Red)	30	0.63 – 0.69
Band 4 (NIR)	30	0.76 – 0.90
Band 5 (SWIR1)	30	1.55 – 1.75
Band 6 (Therma1)	120 (30)	10.40 – 12.50
Band 7 (SWIR2)	30	2.08 – 2.35

Table 2.4. Landsat 7 Technical Specifications

Landsat 7	Resolution (meters)	Wavelength (micrometers)
Band 1 (Blue)	30	0.45 – 0.52
Band 2 (Green)	30	0.52 – 0.60
Band 3 (Red)	30	0.63 – 0.69
Band 4 (NIR)	30	0.77 – 0.90
Band 5 (SWIR1)	30	1.55 – 1.75
Band 6 (Therma1)	60 (30)	10.40 – 12.50
Band 7 (SWIR2)	30	2.09 – 2.35
Band 8 (Panchromatic)	15	0.52 – 0.90

Table 2.5. Landsat 8 Technical Specifications

Landsat 8	Resolution (meters)	Wavelength (micrometers)
Band 1 (Coastal aerosol)	30	0.43 – 0.45
Band 2 (Blue)	30	0.45 – 0.51
Band 3 (Green)	30	0.53 – 0.59
Band 4 (Red)	30	0.64 – 0.67
Band 5 (NIR)	30	0.85 – 0.88
Band 6 (SWIR1)	30	1.57 – 1.65
Band 7 (SWIR2)	30	2.11 – 2.29
Band 8 (Panchromatic)	15	0.50 – 0.68
Band 9 (Cirrus)	30	1.36 – 1.38
Band 10 (TIRS1)	100	10.6 – 11.19
Band 11 (TIRS2)	100	11.50 – 12.51

Regarding the usage of Landsat imagery data in hydrology, it has already been used in many various areas of hydrology. Coskun and Alparslan (2009) used the Landsat 5 TM satellite data to assess the quality of water in Omerali Reservoir in relation to the population increase and land use in Istanbul, Turkey. Anderson et al. (2012) utilized the Landsat thermal imagery data to observe evapotranspiration. In another study, Mueller et al. (2016) mapped the extent of surface water across Australia using a 27-year times series of Landsat imagery data from 1987 to 2014. Moreover, Feyisa et al. (2014) offered a new water bodies extraction index using the Landsat data to map surface water bodies in New Zealand, Ethiopia, South Africa, Switzerland, and Denmark. Bjerklie et al. (2018) used Landsat Dynamic Surface Water Extent (DSWE) product to measure the water surface area in the river reach so that this data coupled with radar altimetry measurements and hydraulic relations can provide river discharge estimation. Later, Durga Rao et al. (2020) used Landsat imagery data to estimate river width as part of the effort to estimate river discharge using satellite data. Zakharova et al. (2020) also used Landsat 8 images to assess the channel width variations in a study to estimate river discharge through satellite altimetry in western Siberia. These studies are just few examples of many other that employ Landsat RS data in hydrological studies.

Application of remote sensing in river discharge estimation has been an interesting subject matter for scientists especially since last decade. researchers have used Surface Reflectance (SR) (e.g., Tarpanelli et al., 2017; Brankenridge, 2007; Tarpanelli et al., 2017) Two types of reflectance are commonly computed within remote sensing. One form of reflectance is top-of-the-atmosphere reflectance (TA). The sun's angle of elevation, length between the Sun and the Earth, and exoatmospheric irradiance from the sun can be addressed by calculating TA, which gives the amount of reflected radiation that is being received by a sensor at the top of the atmosphere (Young et al., 2017). The second form of reflectance that is commonly derived from TA is SR. Converting TA data to SR aims to minimize how electromagnetic radiation is impacted by particles such as atmospheric aerosols, water vapor, and gases (Young et al., 2017). The process of attempting to remove the effects of the atmosphere to determine surface characteristics is termed atmospheric correction (Vermote and Kotchenova, 2008).

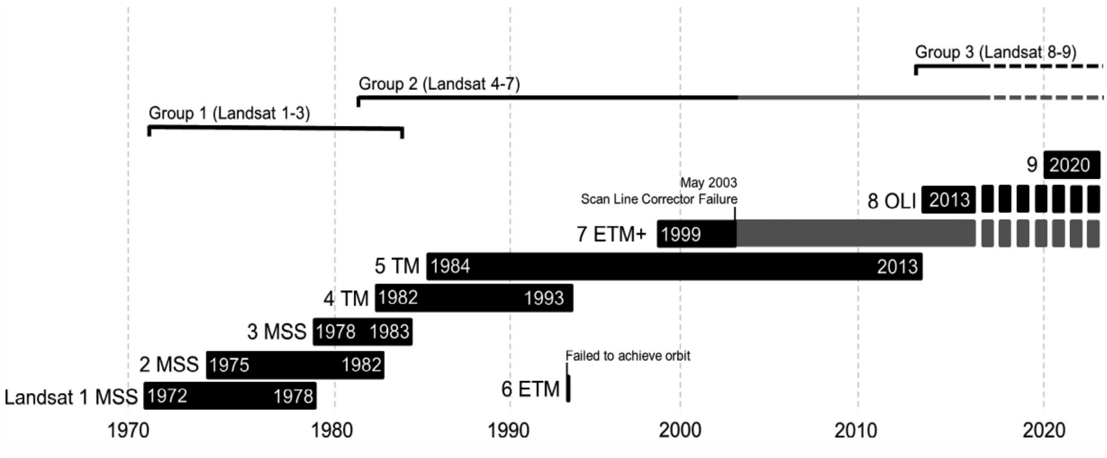


Figure 2.1. A timeline of Landsat satellites and sensors
(Source Young et al., 2017)

2.8.3. Application of Moderate Resolution Imaging Spectroradiometer (MODIS)

Moderate Resolution Imaging Spectroradiometer (MODIS) is a mid-resolution optical sensor aboard Terra and Aqua satellites launched in 1999 and 2002 respectively. MODIS has 36 spectral bands of which, bands 1 and 2 in red and near-infrared wavelengths have a spatial resolution of 250 m and bands 3-7 in green, blue and the mid-infrared wavelengths have a spatial resolution of 500 m. Moreover, MODIS has high temporal revisit up to two observations per day for every point on earth, which makes it useful to measure surface water changes. Nonetheless, the capabilities of MODIS are limited by relatively low spatial resolution and cloud contamination. At a spatial resolution of 250-500 m, water bodies less than a pixel cannot be detected by MODIS. Additionally, floods regularly happen at the same time as cloud-borne rainfall events, which limits the amount of available data for peak flows.

2.9. Google Earth Engine (GEE)

To compute a large amount of satellite imagery data with high spatial and temporal characteristics, we need appropriate tools and resources. In addition, analyzing bulk amount of satellite data may require long period for researchers to complete. Hence, in the last decade, advances in RS technology and machine learning platforms for example the development of Google Earth Engine (GEE), has made access to high quality remote sensing data and powerful computation methods presented to researchers (Gorelick et al. 2017), which is developed by Google in 2010. Multi-petabyte archive of georeferenced datasets can be combined in the GEE catalog that includes images from Earth observing satellites and airborne sensors (e.g., Landsat and MODIS), weather and climate datasets, as well as digital elevation models (Gorelick et al., 2017). In fact, GEE can eliminate many obstacles such as storage, processing, and visualization of large datasets and offer a ready-to-use RS product. Moreover, GEE is a platform that provides access to satellite imagery features, accompanied by algorithms as well as cloud computing for processing global-wide time-series data (Kumar and Mutanga, 2018; Gorelick et al., 2017). It provides large-scale cloud computing capabilities and high-performance computing resources, thus enables researchers to access and analyze mega-file data (Gorelick et al., 2017). It is an innovative cloud-based geospatial information platform that can utilize Landsat dataset to process large amount of RS data (Mutanga and Kumar, 2019). Different from the other remote sensing computer systems, GEE does not require the large file downloads from a huge volume of dataset collections or processing capabilities. With cloud computing capabilities, GEE can derive and analyze big datasets such as remote sensing data for a large area over a longer time. The numerous built-in codes that allow users to process, classify, and generate desired products with minimal effort is another advantage of the GEE (Gorelick et al., 2017). Thus, the acquisition and analysis of Landsat data can be simplified with GEE.

The GEE is a broad platform that addresses the challenges of computing geospatial data for various purposes on Earth studies including water resources and hydrology to collect, analyze, and visualize satellite data. There is no need to download, process, store, or disseminate large amount of data on servers because the GEE catalog is updating satellite data on a continuous manner (Gorelick et al., 2017). GEE platform computing has gained more attention in recent years because of its capability to perform substantial calculations within minutes that couldn't be done in other RS data processing platforms yet. Thus, GEE is used by numerous researchers for water resources and hydrological studies around the world. For example, Sun et al. (2020) used time series Landsat data via GEE so that to obtain the annual variations of the Yangtze River islands during 1986-2017 in China. Amani et al. (2021) analyzed Landsat imagery data in GEE cloud platform to observe wetland changes from 1984 to 2020 in Alberta, Canada. Chen et al. (2021) employed GEE to assess the inland watercolor for water quality analyzes through SR products of Landsat 8 time series for 2015 in China.

2.10. Climate Change and Transboundary Water Sharing Complications

Water resource management is currently facing two main challenges such as transboundary water basin management and water security in both developing and developed countries (Kansakar and Hossain, 2016). Currently, there are 310 recognized international transboundary river basins that cover almost half of the land surface

(McCracken and Wolf, 2019), while about 40 percent of the world's population depend on the water resources of these shared river basins (World Bank 2019; UNEP 2016). Besides, due to the hydro-meteorological anomalies in transboundary river basins, there will be more stress on these rivers (Munia et al., 2020). Thus, responsible institutions and policymakers may adopt robust mechanisms to ensure water security and sustainability. Also, due to insufficient coverage of hydro-meteorological stations for observing spatio-temporal extent of data, up to date assessment of climate change over transboundary rivers has gained attention due to both food and water security. Hence, to understand the status quo of climate impact on transboundary rivers, especially due to drought, hydrological variability, and temperature, a literature review and case studies are presented.

Disputes over transboundary river basins will be more common with increase in demand due to different factors including economic growth and population increase. Therefore, adaptation to these shared water resources, which's quantity is affected by climate change is the first and necessary step towards cooperation and sustainability. That is why, the UNECE (2009) Guidance on Water and Climate Adaptation is described as an essential tool that provides countries with instruction to adapt to climate change in water. The Guidance explains adaptation measures and steps that are required to develop a climate-proof water strategy, more specifically in a transboundary context. As the primary audience of this Guidance are policymakers, managers, and decision-makers for transboundary waters, it is a roadmap for climate adaptation and coping strategies.

As the climate change will probably affect the seasonal and regional rainfall quantity and spatio-temporal characteristics based on the hydrological projections (Schneider et al., 2013), it is essential for the riparian states to set forward for cooperation and adaptation of the new normal. Under these situations, allocation of stressed water resources between upstream and downstream will be challenging and critical (Renzetti and Dupont, 2017).

There are numerous studies that have analyzed spatial and temporal variations and issues in transboundary rivers because of climate change. For instance, Munia et al. (2020) used four global hydrological models together to determine impact of climate driven factors on transboundary water stating that in the year 2050, many people will be staying in upstream areas of river basins to make sure they receive the required water for survival. Therefore, bilateral water treaties have significant role in these regions (Munia et al. 2020).

2.11. Drought and Climatic Trends Related Studies in Afghanistan

Based on conflicts and instabilities for the last four decades in Afghanistan, there is scarcity of ground observed data in relevance to hydrology and meteorology. For this reason, there are some limited scientific investigations in recent years in different disciplines of water resources engineering that can be counted on as a reasonable start. Hence, as a brief review of the literature, we will provide a brief insight to the studies that are mainly devoted to climate change, drought and trend analysis, and transboundary water resources concerning the topic of this research.

Rousta et al. (2020) studied drought conditions in Afghanistan using vegetation coverage through satellite datasets such as MODIS, LST, and TRMM applying SPI, NDVI, and VCI indices for a period 2001-2018.

2.11.1. Hydrological Drought Studies

In a study, Goes et al. (2015) modelled the flow in the Helmand RB (one of the largest basins in Afghanistan) so that to fill the gap where ground data on river discharge does not exist from 1980s to 2008 in addition to an overview of water resources in the basin. They simulated flow from 1952 to 2012 in the basin via satellite gridded precipitation data with a 2.5° resolution adopting the Soil Water Assessment Tool (SWAT) rainfall-runoff modelling tool. Roodari et al. (2021) investigated hydrological drought behavior in the Helmand RB using observed and modelled streamflow data of 6 stations from 1970 to 2006.

2.11.2. Meteorological Drought Studies

Several studies have been conducted for meteorological drought investigation in Afghanistan since last decade. Roodari et al. (2021) analyzed spatial and temporal patterns of drought across Helmand RB from 1970 to 2006 using the SPI and SPEI. The gridded precipitation and temperature data from the Climatic Research Unit (CRU) was used in this study where daily precipitation and temperature were downscaled from the monthly time series.

Applying remotely sensed climatic data, Qutbudin et al. (2019) studied meteorological drought characteristics from 1901 to 2010 in Afghanistan through Standardized Precipitation Evapotranspiration Index (SPEI) using a 50-year sliding window with a 10-year interval. They utilized 0.5° grid resolution rainfall and temperature data from Global Precipitation Climatology Center (GPCC) and Climate Research Unit (CRU) respectively using 281 grid points covering entire country to see the effect of drought on rice, corn, and wheat. Muhammad et al. (2017) studied drought for a period of 45 years from 1957 to 2002 using Palmer hydrological drought index (PHDI), Palmer moisture anomaly index (Z-index), and Palmer drought severity index (PDSI) in Amu River Basin. In this study, they have obtained the daily temperature and precipitation data from the ERA-40 satellite with a 0.5° spatial resolution. Moreover, data about the water-holding capacity of the soil was acquired from the soil map of Afghanistan that was prepared by the USDA Soil Conservation Service (USDA-SCS). The importance of this research was that the authors applied Palmer's model with snowmelt and without snowmelt to describe and detect droughts in the past in the Amu River Basin, where both models revealed droughts for the years 1970 – 1971 and 2000 – 2001.

Alami et al. (2018) studied meteorological drought in the Helmand RB in four different stations over a monthly ground recorded precipitation data for a period of 37 years (1979-2015) in Afghanistan where they used SPI, PN, and Deciles to detect drought. Different drought conditions were identified based on the drought classification of the indices in 1985, 1987, 1994, 1997, 1999, 2000, 2001, 2002, 2003, and 2004 with an extreme drought condition in 2001 for all four stations which is also reported as national drought in other literatures. In another study, Alami et al. (2017) recommended the application of gamma-SPI, log-SPI, and Deciles to be suitable tools for drought monitoring in the Kabul RB in Afghanistan. This research has used SPI, PN, CZI, and Deciles over a monthly precipitation data of 38 years period from 1979 to 2016 in four stations. Further, Tayfur (2021) investigated meteorological drought in Kabul River Basin from 1979 to 2016 using a newly developed drought index called Discrepancy Drought

Index (DPI). Based on the findings of this study, severe droughts occurred during 2000 and 2001 in most parts of the basin.

2.11.3. Climate Related Studies

Aich et al. (2017) analyzed past (1951 to 2010) and future (2010 to 2100) climate change in Afghanistan using remotely sensed meteorological data. They used the Global Soil Wetness Project Phase 3 (GSWP3) reanalysis data with a grid of 0.5 x 0.5° to analyze the climate change in the past, also, the monthly ground observed data was used for validity of the obtained satellite data. For the future climate projects, data from the Coordinated Regional Downscaling Experiment for South Asia (CORDEX-SA) was used with a grid of 0.5 x 0.5° in order to perform the modelling. According to the results of this research, it was found that the temperature over the entire country was increased by 1.8 °C with a lowest of 0.6 °C in the Hindu Kush region, and a highest of 2.4 °C in the east from 1951 to 2010. Also, in the glacier area located in the northeast of Afghanistan, the temperature increment was observed to be between 0.3 and 0.7 °C.

Shokory et al. (2017) studied the variations in rainfall and trends in temperature for a short period from 2006 to 2013 in the Kabul RB. They used ground data collected from 49 stations having temperature, precipitation, and relative humidity values. In terms of usage of remotely sensed data for hydrological studies in data sparse areas like Afghanistan, Ghulami et al. (2017) evaluated the performance of four gridded precipitation datasets namely Global Satellite Mapping of Precipitation Microwave-IR Combined Product (GSMaP_MVK V5), Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources, Monsoon Asia (APHRODITE MA V1101), Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA V7), and Climate Prediction Centre Rainfall Estimate (CPC-RFE 2.0) in the Kabul RB in Afghanistan. They also validate the satellite data with a ground observation data of 9 gauging stations for a period of 4 years from 2004 to 2007. A conclusion was then made that in regions where there is lack of spatial and temporal precipitation data, satellite-based precipitation data is suitable to fill the gap.

2.12. Transboundary Water Related Studies in Afghanistan

Considering transboundary water related issues in Afghanistan, some studies that comprises general hydro-political, strategy and policy making topics are published. However, scientific studies are still a few in their extent, while the importance of technical analyses plays vital role in addition to political, hydro-hegemony, water sharing treaties, and cooperation point of views. Currently, Afghanistan has only one legal treaty over Helmand River water sharing with Iran (Hayat and Elci, 2017). An insight of the 1973 Helmand River Water Treaty (HRWT) with Iran is provided calling both the Afghan (upstream) and Iranian (downstream) sides for a tactful coordination on transboundary water sharing in this article where an initial strategic framework is further offered to be adopted for transboundary water resources management in Afghanistan for mitigating current disputes over shared waters with other neighbors as well, and this to be a step towards development of transboundary water policy by government. Thomas and Varzi (2015) examined the soundness of the 1973 HRWT reporting flaws in terms Integrated Water Resources Management (IWRM) and River Basin Management (RBM) in the treaty claiming that the treaty is not viable in terms of transboundary water resources development neither for upstream nor for downstream state. Acquah and Ward (2017) developed an economic optimization framework for Afghanistan's transboundary RBs for facilitation of possible water sharing agreements. Mianabadi et al. (2020) used satellite data to analyze precipitation trends in Helmand/Hirmand transboundary RB to propose a solution to the conflict between Afghanistan and Iran in a limited context. In a recent study concerning Helmand water treaty between Afghanistan and Iran, Loodin and Wolf (2022) examined that whether based on sustainability, equity, and responsibility criteria, Islamic water management principles are the driving force to the possible revision of Helmand River Water Treaty between Afghanistan and Iran or not. Thomas and Warner (2015) on the other hand focused on the hydro-political issues of Harirud transboundary RB shared by Afghanistan, Iran, and Turkmenistan explaining the hydro-hegemon state of Afghanistan. They conclude that the country is still not able to have full control over its water even some efforts are undertaken for its control. In another paper by Nagheeby and Warner (2018), they provide their argument that how the riparian states in Harirud RB may interact and what is the geopolitical side of hydropolitics in this RB. Examining the transboundary water of Kabul RB that is shared with Pakistan, Vick (2014) believed that the 1997 United Nations Convention on the Non-navigational Uses of International Watercourses (1997 UNWC) adoption may result in a better negotiation for the water sharing agreement between Afghanistan and Pakistan. Vick then recommended continuous dialogues and capacity building of the associated institutions to create an environment of coordination rather than the current mistrusts. Taraky et al. (2021) also studied the Kabul transboundary river basin in the framework of flood risk mitigation taking future climate change into consideration and how conflicts might be solved through continuous cooperation and data sharing. Furthermore, Panikkar et al. (2019) presents solutions for transboundary water cooperation of Kabul RB as results of an environmental diplomacy workshop held between Afghanistan and Pakistan. Akhtar and Iqbal (2017) discussed framing of a policy based on hydrological trend analysis in Kabul RB, and how Afghanistan and Pakistan may cooperate as upstream and downstream countries respectively. Atef et al. (2019) introduced a decision support tool to present to decision makers all demands in the basin, benefits of river basin development, and possible investments to convey negotiations between Afghanistan and Pakistan to a win-win situation. Lastly but not the least, Nori (2020) studied Afghan government's law, regulations, and policies to propose a viable solution for managing transboundary waters taking engagement of all stockholders into account.

There are some articles that mainly focus on Helmand River water sharing issues with Iran that only explain problems in downstream, but not in upstream. For example, Mianabadi et al. (2021) described the ''no-harm'' principle, citing it as a customary international law and linked it with economic, environmental, and health problems in downstream due to the construction of Kamal Khan dam constructed over Helmand River upstream in Afghanistan, which is a late upstream developer discussed earlier. However, the equitable and reasonable principle is not fully covered in this article that may also could describe the reasonable use of water by both countries based on the needs and the area of the basin shared in terms of percentages between these two. On the contrary, some other articles present issues regarding water resources management, hurdles against economic development related to agriculture, need for hydropower generation constructing dams, adopting climate change, providing water for drinking purposes, and enhancing irrigation networks for food security. For instance, Ahmadzai and McKinna (2018) express that while Afghanistan has ample water resources and which can recover economy and generate hydropower energy with about 23,000 MW capacity for the people with poverty and no access to basic needs, just 30-38 percent of the population have access to electricity. This article further analysis Afghanistan's transboundary water in terms of social, legal, environmental, political, economic, and technological factors urging for reasonable negotiations on water sharing treaties and regional cooperation.

2.13. Research Gap

This study specifically focuses on analyzing historical hydrological and meteorological drought along with examining trends in the climatic variables, also determining implications of droughts and trends on transboundary rivers encompassing entire country of Afghanistan. Unlike other studies that have focused on a specific small area and using satellite and reanalysis data, this study uses a long-term ground observed hydro-meteorological data for quit a long period of 41 years. In fact, there is a gap in streamflow data coverage from 1979 to 2008 due to the war and instability in the country. And that is why, there is not a single study that models or estimates the missing streamflow in transboundary rivers.

Due to lack of ground observed hydrological and meteorological data, also limited access to this data, very few studies exist regarding hydro-meteorological drought studies in Afghanistan. Most importantly, streamflow data does not exist from 1979 to 2008 in any station across the rivers so that hydrological drought can be studied. Also, there are very few drought and trend related studies that have used observed climatic data, rather most of the studies have employed reanalysis and satellite data. Therefore, in-situ, reanalysis, and remotely sensed modeled hydro-meteorological data is used making this research unique among other drought analyses and climatic studies in Afghanistan.

2.14. Summary and Conclusion

After reading all drought and transboundary water related literature for Afghanistan, it can be concluded that: 1, any hydrological drought analysis has not been undertaken yet in the country. 2, meteorological drought is studied for a limited number of stations in some RBs but not for the entire country, and the indices used are based on one input as precipitation. 3, there is just one study focused on precipitation and temperature trends, but the authors have used satellite data, not the ground observed meteorological data. 4, the link between drought and transboundary water is not studied yet which is the most important issue for Afghanistan. 5, no research has been conducted yet to calculate a missing streamflow data of about 18 years along the transboundary rivers that is a paramount for Afghanistan's transboundary rivers and drought. Therefore, this research will fill all the gaps mentioned above so that to facilitate a foundation of knowledge regarding drought and transboundary water related issues in Afghanistan for policy makers, public institutions, and academicians. Moreover, this research is also aimed to contribute to the knowledge regarding long period missing hydrological data and to provide some scientific thoughts on how drought and transboundary water are associated. Therefore, this study may not just be beneficial for Afghanistan, but everywhere in the world for similar cases. For you further pursual.

CHAPTER 3

METEOROLOGICAL DROUGHT

3.1. Introduction

Meteorological drought has a direct connection with the climate change, where climate change is inevitable. To mitigate the adverse impacts of meteorological drought, there is a need for studying its characteristics and onsets. Further, countries need to prepare strategies and policies to combat drought events.

The daily recordings for meteorological (rainfall, temperature, wind, and relative humidity) and hydrological (streamflow) observations started back in 2008 in most of the newly installed stations across RBs as the property of MEW. The meteorological data gap from 1979 to 2008 was then filled via JICA's effort with collaboration of MEW for reconstruction of time series data. Thus, the rainfall and temperature data analyzed in this thesis can be divided into two types in terms of length of the record; (1) in-situ time-series that start in 2008 and ending in 2020 (Table x) and (2) reanalysis satellite data processed, and quality controlled by MEW with collaboration of JICA in 2018.

We have used two widely used meteorological drought indices in this section of our study such as SPI and RDI to detect historical spatial and temporal drought events across Afghanistan from 1979 to 2019. The SPI requires precipitation data as a single input, which is still a paramount index in meteorological studies. This index is recently used by several researchers around the globe (e.g., Onuşluel Gül et al., 2022)

Precipitation data from 55 meteorological stations (Tables 3.1, 3.2, 3.3, 3.4, and 3.5) across all five RBs of the country for a period of 41 years is used for meteorological drought detection.

In this research, one univariate and one multivariate well known and widely used indices such as SPI and RDI are used to characterize past meteorological drought events in Afghanistan. For hydrological drought analysis, two commonly used indices such as SDI and SSI are used. Further, Mann-Kendall and Sen's tests are performed to see past trends in precipitation and temperature across the country. Moreover, historical drought maps showing vulnerable basins and sub-basins across the country are generated. Finally, implications of drought events and hydrological trends on transboundary rivers are investigated.

Table 3.1. Amu RB Meteorological Stations

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Ahangaran	34.833	67.982	2379	Amu	Upper Kunduz	Bamyan
Baghlan	36.109	68.672	540	Amu	Lower Kunduz	Kunduz
Balay-i-Kelagai	35.741	68.755	749	Amu	Lower Kunduz	Kunduz
Bamyan	34.823	67.825	2507	Amu	Upper Kunduz	Bamyan
Dasht-i-Safid	35.317	67.906	1604	Amu	Upper Kunduz	Kahmard
Doshi	35.604	68.691	847	Amu	Lower Kunduz	Andarab
Faizabad	37.110	70.557	1180	Amu	Kokcha	Kokcha
Gerdab	36.361	68.863	475	Amu	Lower Kunduz	Kunduz
Keshem	36.933	70.050	808	Amu	Kokcha	Keshem
Khwajaghar	37.069	69.487	488	Amu	Taluqan	Kokcha
Nazdik-i-Jurm	36.926	70.858	1438	Amu	Kokcha	Kokcha
Nazdik-i-Taluqan	36.635	69.737	1008	Amu	Taluqan	Farkhar

Table 3.2. Harirud-Murghab RB Meteorological Stations

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Cheldukhtaran	35.121	62.316	773	Harirud-Murghab	Harirod Murghab	Murghab
Dawlatyar	34.547	65.754	2435	Harirud-Murghab	Upeper Harirud	Harirud
Nazdik-i-Herat	34.421	62.449	1140	Harirud-Murghab	Upeper Harirud	Harirud
Pul-i-Hashemi	34.341	61.937	865	Harirud-Murghab	Lower Harirud	Harirud
Rabat-i-Akhund	34.260	62.944	1183	Harirud-Murghab	Lower Harirud	Harirud
Shinya	34.508	65.669	2407	Harirud-Murghab	Upeper Harirud	Harirud
Torghundi	35.253	62.283	673	Harirud-Murghab	Lower Harirud	Murghab

Table 3.3. Helmand RB Meteorological Stations

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Adraskan	33.637	62.263	1339	Helmand	Lower Helmand	Helmand
Farah	32.364	62.062	651	Helmand	Farah Rod	Farah
Gardandiwal	34.500	68.213	2739	Helmand	Upper Helmand	Helmand
Gardiz	33.594	69.229	2299	Helmand	Upper Jilga	Jilga
Lashkargah	31.583	64.355	773	Helmand	Middle Helmand	Helmand
Nazdik-i-Adraskan	33.704	62.280	1382	Helmand	Lower Helmand	Helmand
Nazdik-i-Gardandiwal	34.582	68.171	3066	Helmand	Upper Helmand	Helmand
Nazdik-i-Kandahar	31.615	65.576	971	Helmand	Arghandab	Arghandab
Tarnak	31.560	65.843	1019	Helmand	Arghandab	Arghandab
Waras	34.225	66.920	2498	Helmand	Upper Helmand	Helmand

Table 3.4. Kabul RB Meteorological Stations

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Asmar	34.915	71.202	832	Kabul	Kunar	Kunar
Bagh-i-Lala	35.152	69.221	1698	Kabul	Ghorband	Salang
Bagh-i-Omomi	35.149	69.288	1587	Kabul	Ghorband	Shutul
Chaghasarai	34.909	71.129	847	Kabul	Kunar	Pich
Doabi	35.348	69.619	2059	Kabul	Panjshir Balayi	Dara-i-Hazara
Estalef	34.828	69.078	1821	Kabul	Kabul Balayi	Estalef
Keraman	35.284	69.657	2232	Kabul	Panjshir Balayi	Dara-i-Hazara
Naghlo	34.637	69.717	998	Kabul	Kabul Payini	Kabul
Nawabad	34.820	71.120	796	Kabul	Kunar	Kunar
Omarz	35.376	69.641	2042	Kabul	Panjshir Balayi	Panjshir
Payin-i-Qargha	34.553	69.036	1970	Kabul	Kabul Wasati	Paghman
Pul-i-Behsod	34.442	70.460	555	Kabul	Kabul Payini	Kabul
Pul-i-Kama	34.469	70.557	558	Kabul	Kabul Payini	Kunar
Pul-i-Qarghayi	34.547	70.242	643	Kabul	Laghman	Laghman
Qala-i-Malek	34.577	68.970	2211	Kabul	Kabul Wasati	Paghman
Sultanpor	34.416	70.296	686	Kabul	Kabul Payini	Surkh Rod
Tang-i-Gulbahar	35.159	69.289	1625	Kabul	Ghorband	Panjshir
Tang-i-Sayedan	34.409	69.104	1870	Kabul	Kabul Wasati	Maidan

Table 3.5. Northern RB Meteorological Stations

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Asiabad	36.189	65.955	657	Northern	Sar-i-Pul	Sar-i-Pul
Dara-i-Zhwandon	36.167	68.072	1440	Northern	Khulm Aibak	Samangan
Dawlatabad	36.418	64.883	404	Northern	Shirin Tagab	Faryab
Doshqadam	34.975	66.526	2241	Northern	Upper kunduz	Bamyan
Nazdik-i-Nayak	34.743	66.994	2613	Northern	Upper kunduz	Bamyan
Nazdik-i-Sar-i-Pul	36.158	66.103	760	Northern	Sar-i-Pul	Sar-i-Pul
Sayad	36.537	67.812	715	Northern	Khulm Aibak	Samangan
Tang-i-Tashqurghan	36.659	67.695	516	Northern	Khulm Aibak	Samangan

3.2. Data Sources and Acquisition

Meteorological data such as precipitation and temperature for a period of 41 years (1979-2019) is acquired from the Ministry of Energy and Water (MEW). The data is divided into two parts such as reanalysis satellite data from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center's (NCDC) Operational Model Archive and Distribution System (NOMADS) and in-situ data from meteorological stations installed and operated by the MEW. The MEW professionals have used the NOAA GRIdded Binary2 or General Regularly distributed Information in Binary2 (GRIB2) version of the data, which is a standard WMO format for collecting, exchanging, and archiving gridded data. Further, this data (1979-2009) is validated using ground observed data for the period 2011-2013 and quality controlled. Still, this data is provided under strict processes to users and is not available in any public domain.

3.3. Study Area

The study area encompasses the entire country of Afghanistan. According to hydrological characteristics, the country is divided into five major RBs (Figure 3.1). It is located between central and south-west Asia, and between 60° 40' 46'' to 74° 51' 52'' E and 29° 18' 20'' to 38° 18' 13'' N, with a total area of about 652,000.00 km^2. Afghanistan has borders with Pakistan in the east and south, China in the north-east strip, Iran in the west, and in the north with Tajikistan, Uzbekistan, and Turkmenistan. Average annual precipitation is 270 mm where precipitation varies from 89 to 846 mm in the high altitudes of northern areas, while it is from 16 mm to 209 mm in arid south-western region. The overall average temperature is -2°C in January, while it is 32°C in July, and extreme temperature of minimum -50°C and maximum 50°C. The maximum, minimum, and average elevations of the RBs above sea level (ASL) are: (a) Amu RB 7,492, 404, and 2,906 m; (b) Harirud-Murghab 3,887 , 652 , and 1,369 m; (c) Helmand RB 4012 , 492 , and 1,852 m; (d) Kabul RB 4,535 , 414 , and 2,653 m; (e) Northern RB 4,024 , 404 , and 2,456 m respectively.

Meteorological data from 55 in-situ gauging stations, distributed over whole Afghanistan were obtained. The distribution of stations across all five RBs and related specifications are shown in Figure 3.2.

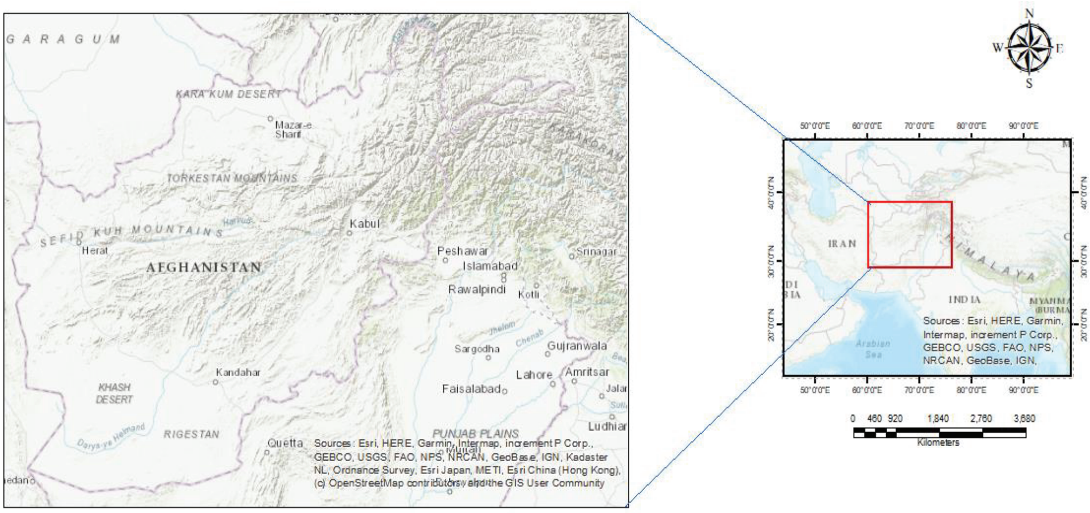


Figure 3.1. Study Area Map (Afghanistan)

3.4. Methods and Materials

In this study, daily rainfall and temperature data for the period 1979-2019 (forty-one year) collected from 55 meteorological stations across all five RBs was used for meteorological drought characterization in Afghanistan. The drought index calculator (DrinC) software developed by Tigkas et al. (2015) was employed and the data was rearranged based on the hydrological year (October – September). DrinC computes the drought indices by considering the meteorological data to be of long-term datasets (at least 35 years). The software calculates the indices in the form of RDI, SPI, Deciles, and SDI, which leads to the analysis of drought magnitude in terms of severity for an area. Furthermore, it enables monitoring of drought, along with spatial distribution assessment and investigation of drought and other climatic conditions.

3.4.1. SPI

The SPI is dependent on equal probability transformation of accumulated data of monthly precipitation into a standard normal variable. The index main work at different monthly precipitation time scale data series (1, 3, 6, 9, 12, 24 months). McKee et al. (1993) defined the basic criteria of SPI to characterized different standard of drought and wet conditions: near normal (0 to 0.99)

$$SPI = \frac{x_{ij} - x_{im}}{\sigma} \tag{3}$$

Where x_{ij} is the monthly or seasonal precipitation at ith rain gauge station and jth observation, x_{im} represents the long-term precipitation mean and is its standard deviation.

$$\text{for } 0.0 < H(x) \leq 0.5$$

$$z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right), \tag{4}$$

$$t = \sqrt{\ln\left(\frac{1}{\left(H(x)\right)^2}\right)}$$

for $0.5 < H(x) < 1.0$

$$z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \quad (5)$$

$$t = \sqrt{\ln\left(\frac{1}{\left(1 - H(x)\right)^2}\right)}$$

where $c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$, and $d_3 = 0.001308$

In this method, a time series of monthly precipitation data (generally a continuous period of at least 30 years) is first fitted to a probability distribution, then transformed into a normal distribution to detect wet and dry conditions (McKee et al. 1993) as greater than mean (zero) SPI values represent no drought conditions and smaller than mean (zero) values show drought conditions as presented in Table 4. Considering the drought classification of the SPI, it is randomly divided into near normal (0.99 > SPI > −0.99), moderately dry (−1.0 > SPI > −1.49), severely dry (−1.5 > SPI > −1.99), and extremely dry (SPI < −2.0) (Morid et al., 2006). The SPI is flexible to used different time scales (e.g., 1, 3, 6, and 12 months).

Table 3.6. Classification of Meteorological Drought Based on SPI

Description of State	Criterion
Extremely wet	$SPI \geq 2.0$
Very wet	$1.5 \leq SPI < 2.0$
Moderately wet	$1.0 \leq SPI < 1.5$
Near normal	$-1.0 \leq SPI < 1.0$
Moderately dry	$-1.5 \leq SPI < -1.0$
Severely dry	$-2.0 \leq SPI -1.5$
Extremely dry	$SPI < -2.0$

3.4.2. RDI

RDI is capable to assess the drought severity (Vangelis et al., 2013). It can be described in standardized (RDI_{st}), initial value (α_k), and normalized (RDI_n) forms (Zarch et al., 2015). The initial value (α_k) of RDI is usually calculated for the i-th year in a time basis of k consecutive months as follows:

$$\alpha_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} \mathrm{PET}_{ij}} \quad , i = 1(1)N \text{ and } j = 1(1)k \tag{6}$$

Where P_{ij} and PET_{ij} are the precipitation and potential evapotranspiration of the j-th month of the i-th year and N is the total number of years of the available data. The values of follow satisfactorily both the lognormal and the gamma distributions in a wide range of locations and different reference periods, in which they were tested (Tigkas, 2008; Tsakiris et al., 2008). If lognormal distribution is applied, we can use the following equation for the RDI_{st} calculation:

$$RDI_{st}^{(i)} = \frac{y^{(i)} - \bar{y}}{\hat{\sigma}_y} \tag{7}$$

in which $y^{(i)}$ is the ln ($\alpha_k^{(i)}$), $\bar{y}$ is its arithmetic mean and $\hat{\sigma}_y$ is its standard deviation.

Moreover, RDI_{st} can be calculated applying the pdf of the gamma distribution in case if the gamma distribution is used, that is (Vangelis et al., 2013):

$$g(x) = \frac{1}{\beta^{\gamma}\Gamma(\gamma)} x^{\gamma-1} e^{-x/\beta}, \text{for x} > 0 \tag{8}$$

For computation of the normalized (RDI_n), the following formula is used:

$$RDI_{n(k)}^{(i)} = \frac{\alpha_k^{(i)}}{\bar{\alpha}_k} - 1 \tag{9}$$

In the above formula, $\bar{\alpha}_k$ is the arithmetic mean of α_k values.

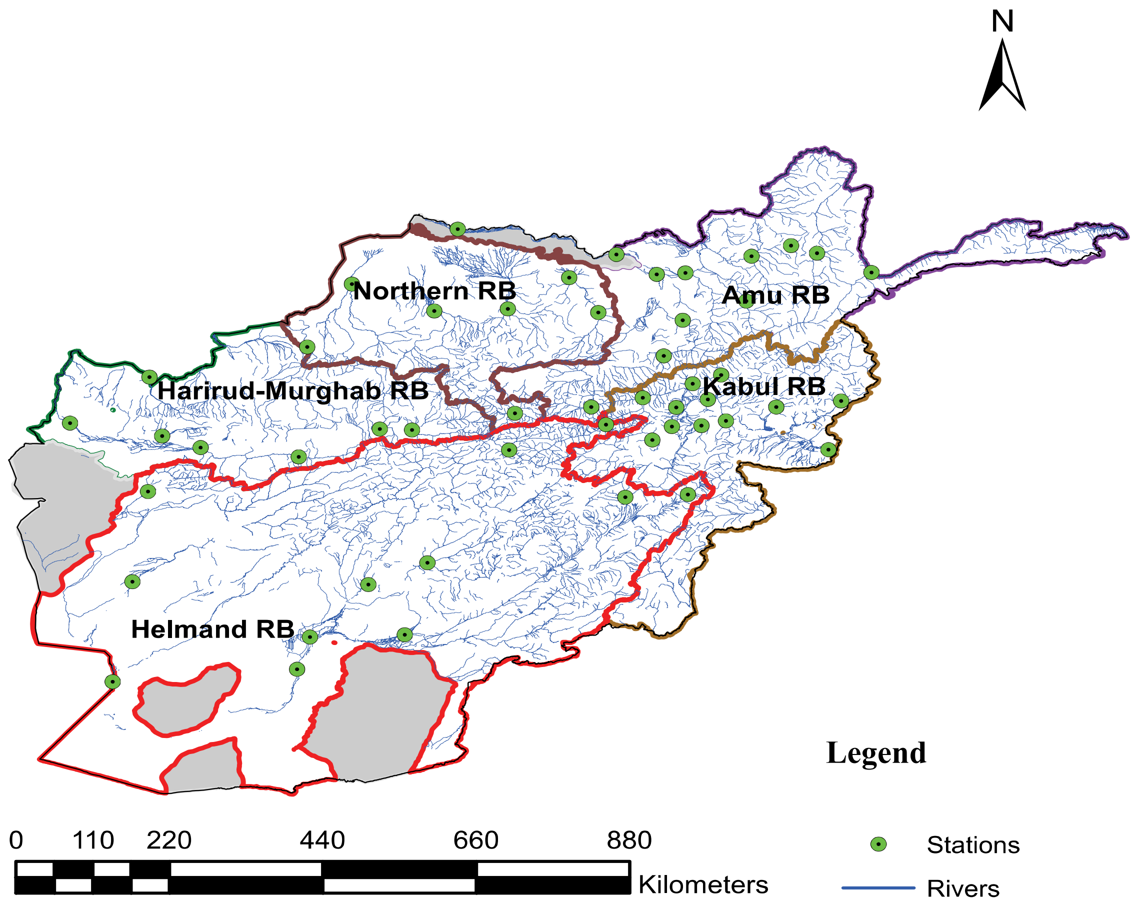


Figure 3.2. Location Map of Meteorological Stations

3.5. SPI Results

Results from the SPI analysis represents historical dry and wet conditions across different RBs with different categories of near normal, moderately, very, or extremely. The observed historical drought events and magnitude of severity with respect to each river basin according to SPI computation are explained separately. Moreover, Detailed RDI results for all stations within the study period are provided in APPENDEX A.

3.5.1. SPI Results for Amu RB

The analysis consists of annual SPI drought detection for all stations under study in the Amu RB. The results of extreme and severe drought magnitude for all stations are summarized in Tables 3.7 and 3.8. Moreover, graphical representation of the SPI results with respect to each station is presented in Figure 3.3.

According to SPI, considerable dry events in the Amu RB based on hydrological years are:

- **Extremely Dry:** Extreme drought events occurred in many stations of the basin in 1999, 2000, 2016, and 2017 with a one station extreme drought in 1985 (Gerdab) and two stations in 2010 (Bamyan and Faizabad).
- **Severely Dry:** Severe droughts happened in 1985 in three stations (Khwajaghar, Faizabad, and Baghlan), in 1999 in one station (Ahangaran), in 2005 in two stations (Bala-i-Kelagai and Nazdi-i-Taluqan), in 2008 in one station (Khwajaghar), in 2013 in two stations (Dasht-i-Safid and Nazdik-i-Jurm), in 2016 in one station (Doshi), in 2017 in two stations (Ahangaran and Nazdik-i-Jurm), and in 2019 in one station (Dasht-i-Safid).
- **Moderately Dry:** Moderate drought occurred in 1999 in one station (Faizabad), in 2002 in one station (Nazdik-i-Taluqan), in 2003 in one station (Gerdab), in 2005 in two stations (Doshi and Gerdab), in 2007 in four stations (Nazdik-i-Taluqan, Baghlan, Faizabad, and Nazdik-i-Jurm), in 2010 in two stations (Ahangaran and Nazdik-i-Jurm), in 2011 in two stations (Bamyan and Ahangaran), in 2012 in one station (Bamyan), in 2013 in one station (Ahangaran), in 2014 in one station (Dasht-i-Safid), in 2015 one station (Bala-i-Kelagai), in 2016 in one station (Gerbad), in 2017 in two stations (Doshi and Gerdab), in 2019 in one station (Keshem).
- **Near Normal:** Years 1979, 1980, 1981, 1983, 1986, 1987, 1988, 1989, 1990, 1992, 1993, 1994, 1996, 2002, 2003, 2006, and 2009 were observed by most of the stations as close to normal years.
- **Moderately Wet:** Hydrological years i.e., 1981 detected as moderate by two stations (Baghlan and Ahangaran), by five stations (Baghlan, Gerdab, Nazdik-i-Jurm, Keshem, and Dasht-i-Safid) in 1982, by three stations (Keshem, Khwajaghar, and Nazdik-i-Jurm) in 1984, by one station (Faizabad) in 1989, by one station (Bamyan) in 1990, by six stations (Doshi, Baghlan, Keshem, Bamyan, Khwajaghar, and Gerdab) in 1991, by one station (Doshi) in 1993, by four stations (Nazdik-i-Jurm, Bala-i-Kelagai, Gerdab, and Baghlan) in 1995, by three stations (Dasht-i-Safid, Ahangara, and Baghlan) in 1997, by six stations (Nazdik-

i-Taluqan, Keshem, Khwajaghar, Bamyan, Baghlan, and Ahangaran) in 2004, by three stations (Ahangaran, Bamyan, and Keshem) in 2006, by one station (Bamyan) in 2008, and by two stations (Doshi and Khwajaghar) in 2018.

- **Very Wet:** Stations that detected very wet conditions across the basin are: Ahangaran in 1990, Nazdi-i-Jurm and Faizabad in 1991, Gerdab in 1992, Bala-i-Kelagai in 1993, Nazdik-i-Taluqan and Keshem in 1995, and Bamyan, Nazdik-i-Taluqan, and Khwajaghar in 1997.
- **Extremely Wet:** We have just a few cases for the extremely wet conditions that are viz. Faizabad station in 1982, Doshi station in 1983, and again Faizabad station in 1997.

Table 3.7. Extreme Drought Events in Amu RB based on SPI

Year	Station										
	Baghlan	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Faizabad	Gerdab	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1985	-	-	-	-		-	-2.16	-	-	-	
1999	-	-	-	-	-2.08	-	-	-	-	-	-2.19
2000	-2.13	-	-	-	-2.82	-	-2.71	-2.32	-2.42	-	-2.00
2010	-	-	-2.13	-	-	-2.29	-	-	-	-	-
2016	-2.01		-2.26	-2.95	-	-	-	-	-	-	-
2017	-2.09	-2.10	-2.10	-2.03	-	-	-	-2.10	-	-	-
2019	-	-	-	-	-	-	-	-	-	-2.20	-

Table 3.8. Severe Drought Events in Amu RB based on SPI

Year	Station									
	Ahangaran	Baghlan	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1985	-	-1.52	-	-	-	-	-	-	-	-
1999	-1.60	-	-1.57	-	-	-	-	-1.73	-	-
2000	-	-	-	-	-	-	-	-	-1.66	-1.95
2005	-	-	-	-	-	-	-	-	-	-1.70
2008	-	-	-	-	-	-	-	-1.59	-	-
2013	-	-	-	-	-1.82	-	-	-	-1.63	-
2015	-	-	-	-	-1.51	-	-	-	-	-
2016	-	-	-	-	-	-1.67	-1.62	-	-	-
2017	-1.63	-	-	-	-	-	-	-1.91	-1.83	-
2018	-	-	-	-1.68	-1.91	-	-	-	-	-
2019	-	-	-		-1.71	-	-	-	-	-

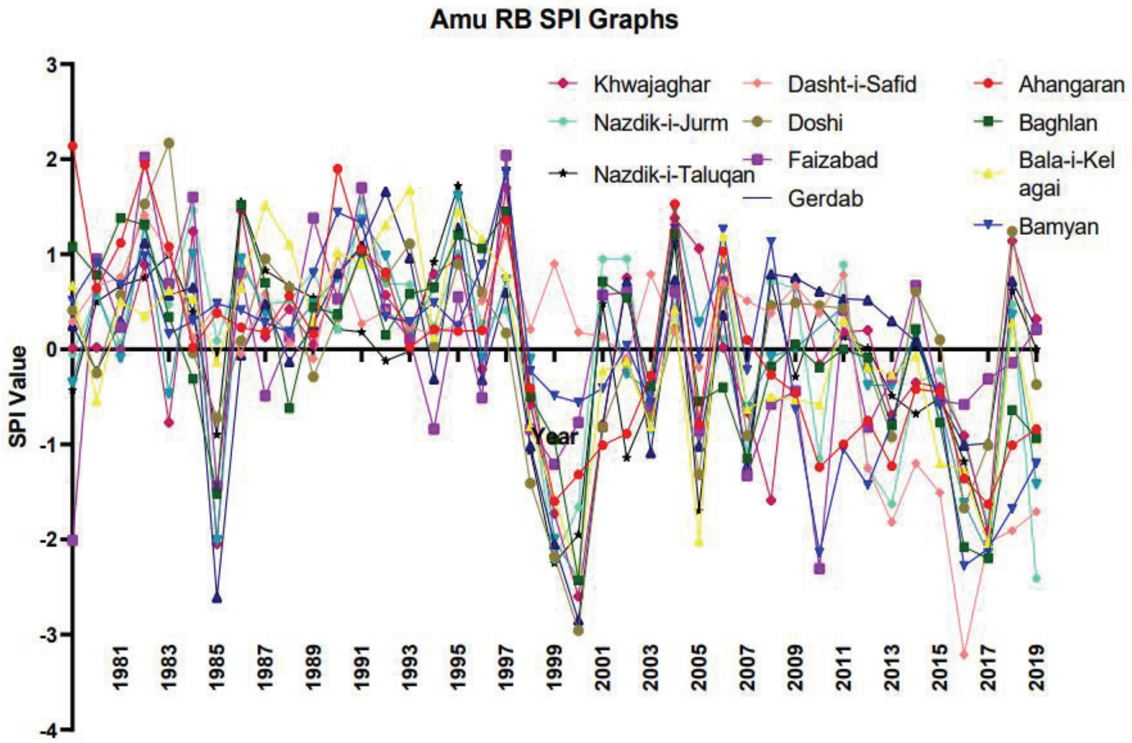


Figure 3.3. SPI Drought Graphs for Amu RB Stations

3.5.2. SPI Results for Harirud-Murghab RB

The analysis consists of annual SPI drought detection for all stations under study in the Harirud-Murghab RB. The results of extreme and severe drought magnitude for all stations are summarized in Tables 3.9 and 3.10. Moreover, graphical representation of the SPI results with respect to each station is presented in Figure 3.4.

- **Extremely Dry:** In this basin, droughts with extreme magnitude were observed in 1999 and 2000 by majority of the studied stations. Two more extreme events were recorded by Rabat-i-Akhond in 2008 and Pul-i-Hashemi in 2017.
- **Severely Dry:** Severe drought events were observed in in Dawlatyar and Shinya stations in 1984, Rabat-i-Akhond in 1999, Pul-i-Hashemi station in 2003, Pul-i-Hashemi, Cheldukhtaran, and Nazdik-i-Herat stations in 2005, and Torghundi station in 2007.
- **Moderately Dry:** Drought years with moderate classification were detected in 2003 in Rabat-i-Akhond and Cheldukhtaran stations, in 2005 in Torghundi and Dawlatyar stations, in 2007 in Torghundi and Shinya stations, in 2008 in Shinya

station, in 2010 in Torghundi, Dawlatyar, and Shinya stations, in 2012 in Rabat-i-Akhond station, in 2016 in Shinya station, and in 2017 in Rabat-i-Akhon, Cheldukhtaran, and Nazdik-i-Herat stations.

- **Near Normal:** 1979 and 1980 were normal years for all covered stations. 1983 was normal for Cheldukhtaran, Nazdik-i-Herat, Pul-i-Hashemi, Rabat-i-Akhond, and Torghundi stations. Further, 1985, 1986, 1987, 1988, 1989, 1993, 1994, 1995, 1996, 1997, 1998, 2002, 2004, 2011, 2012, 2013, 2014, 2015, and 2016 were normal years for all stations except for Cheldukhtaran in 1986 and 1988, Torghundi in 1995, Rabat-i-Akhond in 2012, and Shinya in 2016. Three stations i.e., Torghundi, Dawlatyar, and Shinya recorded normal year in 2003.
- **Moderately Wet:** Year 1981 was classified as moderately wet by Cheldukhtaran, Nazdik-i-Herat, Pul-i-Hashemi, Rabat-i-Akhond, and Torghondi stations, in 1988 by Pul-i-Hashemi station, 1989 by Dawlatyar, Rabat-i-Akhond, Shinya, and Torghondi stations, 1991 and 1992 by all stations under study, in 1995 by Torghundi stations, in 2006 by Shinya and Dawlatyar stations, in 2009 by Cheldukhtaran station, in 2018 by Nazdik-i-Herat and Shinya stations.
- **Very Wet:** This condition was detected by Dawlatyar and Shinya stations in 1982, and by Shinya station in 1990.
- **Extremely Wet:** For this classification, we have just observed two events, one in 1990 by all stations except Shinya, and the second in 2018 just for Cheldukhtaran station.

Table 3.9. Extreme Drought Events in Harirud-Murghab RB based on SPI

Year	Station					
	Cheldukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Shinya	Torghundi
1999	-	-2.68	-2.53	-2.31	-2.51	-
2000	-2.49	-2.19	-2.37	-2.31	-	-2.10
2017	-	-	-	-2.19	-	-

Table 3.10. Severe Drought Events in Harirud-Murghab RB based on SPI

Year	Station						
	Celdukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Rabat-i-Akhund	Shinya	Torghundi
1984	-	-1.63	-	-	-	-1.51	-
1999	-1.78	-	-	-	-1.55	-	-
2000	-	-	-	-	-	-1.93	-
2005	-	-	-1.53	-1.65	-	-	-
2017	-	-	-	-	-	-	-1.73

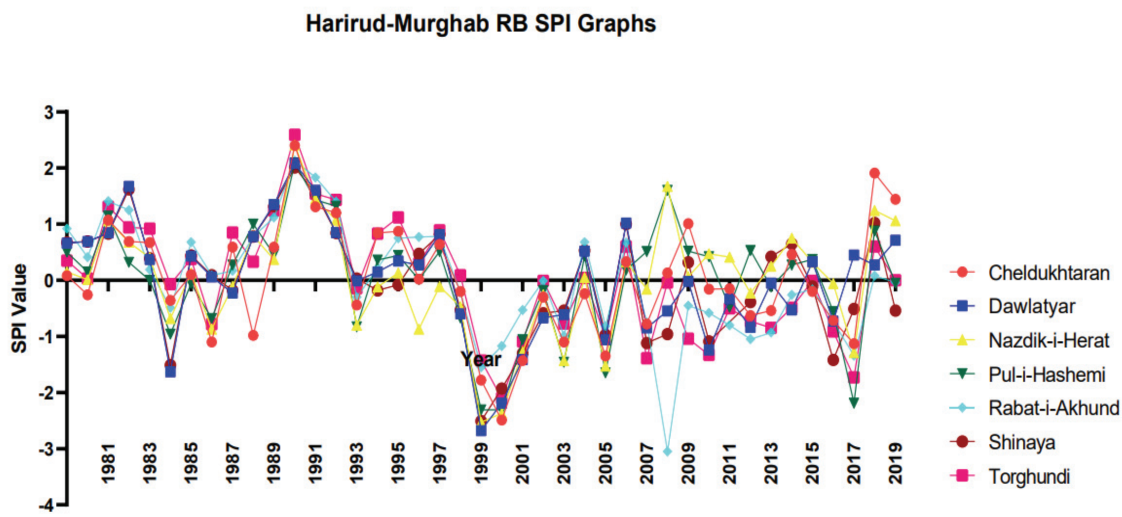


Figure 3.4. SPI Drought Graphs for Harirud-Murghab RB Stations

3.5.3. SPI Results for Helmand RB

The analysis consists of annual SPI drought detection for all stations under study in the Helmand RB. The results of extreme and severe drought magnitude for all stations are summarized in Tables 3.11 and 3.12. Moreover, graphical representation of the SPI results with respect to each station is presented in Figure 3.5.

- **Extremely Dry:** The extreme drought events occurred in this basin were hydrological years 1999 and 2000 for majority of the studied stations. Also, 2001 for Gardiz, 2003 for Nazdik-i-Kandahar and Gardiz, 2011 for Gardandiwal, and 2017 for Farah and Gardandiwal stations.
- **Severely Dry:** Severely dry events were recorded in 1998 in all stations covered by this study. In addition, Farah and Lashkargah in 1999, Tarnak, Lashkargah, Gardiz, and Farah in 2000, Nzadik-i-Gardandiwal and Waras in 2001, Lashkargah in 2003, Nazdik-i-Adraskan in 2005, Nazdik-i-Adraskan in 2007, Adraskan, Tarnak, and Nazdik-i-Adraskan in 2017 observed severe droughts.
- **Moderately Dry:** This classification of drought was detected in in Lashkargah, Adraskan, Nazdik-i-Gardandiwal, Nazdik-i-Adraskan and Waras stations in 1984. In Waras station in 1998, Nazdik-i-Kandahar in 2000 and in majority of the stations in 2001. Further, in Nazdik-i-Gardandiwal, Waras, and Gardandiwal stations in 2002, in Farah, Tarnka, Nazdik-i-Garadandiwal, and Waras stations in 2003, and in majority of the stations in 2005. Finally, Farah station in 2009, Adraskan station in 2015, Gardandiwal, Nazdik-i-Kandahar, and Nazdik-i-Adraskan stations suffered moderate drought.
- **Near Normal:** Hydrological years 1979, 1980, 1983, 1885, 1986, 1987, 1988, 1993, 1994, 1995, 1996, 1997, and 2006 were categorized as near normal in terms of drought for most of the stations investigated in this study.
- **Moderately Wet:** The moderate wet conditions were observed in 1981 in Gardandiwal, Gardiz, Tarnka, and Nazdik-i-Kandahar, in 1982 in Nazdik-i-Kandahar and Tarnka, in 1992 in Farah, Adraskan, and Nazdik-i-Adraskan, in 1997 in Nazdik-i-Kandahar, Tarnak, and Lashkargah, in 2004 in Farah, Lashkargah and Gardandiwal, in 2006 in Tarnak and Gardandiwal, in 2008 in Adraskan, in 2012 in Nazdik-i-Gardandiwal, in 2013 Nazdik-i-Gardandiwal, in 2014 in Adraskan, Nazdik-i-Adraskan, and Waras, in 2015 in Gardiz and

Nazdiki-Gardandiwal, in 2018 in Gardiz and Lashkarga, and finally in 2019 in Gardandiwal stations.

- **Very Wet:** This type of the SPI category was recorded in Gardiz and Gardandiwal stations in 1982, in Gardandiwal, Lashkargah and Adraskan stations in 1990, in Gardandiwal station in 1991, in Farah station in 1995, in Tarnak station in 1997, in Tarnka and Nazdik-i-Kandahar stations in 2004, in Nazdik-i-Adraskan station in 2008, in Gardiz, Waras, and Lashkargah stations in 2013, in Nazdik-i-Gardandiwal and Waras stations in 2015, in Adraskan and Lashkargah stations in 2018, and Nazdik-i-Gardandiwal, Gardiz, and Waras stations in 2019.
- **Extremely Wet:** The extreme conditions in terms of degree of wetness were identified in 1990 in Nazdik-i-Kandahar, Farah, and Tarnak, in 1991 in Nazdik-i-Adraskan, and in 2018 in Farah, Nazdik-i-Gardandiwal, and Nazdik-i-Adraskan stations.

Table 3.11. Extreme Drought Events in Helmand RB based on SPI

Year	Station									
	Adraskan	Farah	Gardandiwal	Gardiz	Lashkargah	Nazdik-i-Adraskan	Nazdik-i-Gardandiwal	Nazdik-i-Kandahar	Tarnak	Waras
1999	-2.07	-2.63	-2.15	-2.77	-	-2.04	-2.18	-2.29	-2.35	-2.03
2000	-2.22	-	-2.01	-	-	-2.18	-2.07	-	-	-2.65
2003	-	-	-	-	-	-	-	-2.36	-	-
2017	-	-	-	-	-2.74	-	-	-	-	-

Table 3.12. Severe Drought Events in Helmand RB based on SPI

Year	Station						
	Adraskan	Farah	Gardandiwal	Gardiz	Lashkargah	Nazdik-i-Gardandiwal	Tarnak
1999	-	-1.79	-	-	-1.76	-	-
2000	-	-1.52	-	-1.84	-1.72	-	-1.50
2001	-	-	-	-1.95	-	-1.60	-
2003	-	-	-	-1.96	-1.84	-	-
2010	-	-	-1.70	-	-	-	-
2011	-	-	-1.98	-	-	-	-
2017	-1.88	-	-	-	-	-	-1.72

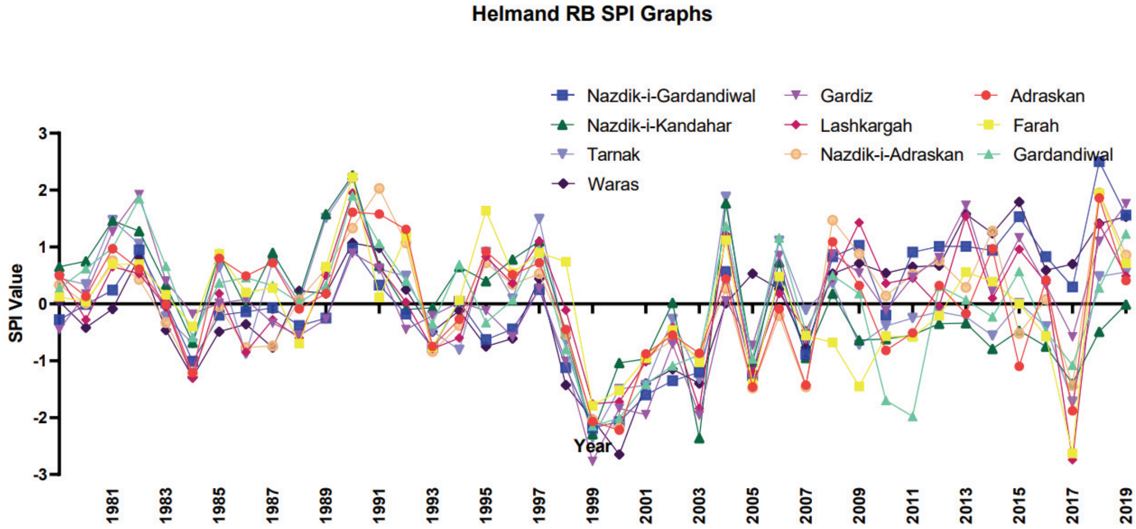


Figure 3.5. SPI Drought Graphs for Helmand RB Stations

3.5.4. SPI Results for Kabul RB

The analysis consists of annual SPI drought detection for all stations under study in the Kabul RB. The results of extreme and severe drought magnitude for all stations are summarized in Tables 3.13 and 3.14. Moreover, graphical representation of the SPI results with respect to each station is presented in Figure 3.6.

- **Extremely Dry:** Periods of extreme droughts detected in Kabul RB were in 1999 by all stations and in 2000 and 2001, by half of the stations. Moreover, extreme events were detected in 2003 by Sultanpur and Chaghasarai, and in 2011 by Doabi stations.
- **Severely Dry:** Severe drought hit years in the basin were seen by Istalif, Asmar, Doabi, Omarz, and Gulbahar stations in 2000, by majority of the stations in 2001, by Asmar, Pul-i-Behsod, Pul-i-Qarghay, Pul-i-Kama and Naghlo stations in 2003, by Estalif station in 2016, and by Estalif and Naghlo stations in 2017.
- **Moderately Dry:** This category was detected in 1985 by Keraman and Omarz, in 1996 by Bagh-i-Omomi and Bagh-i-Lala, and by majority of the stations in 1998. Following, Pul-i-Kama, Pul-i-Behsod, Sultanpur, and Naghlo stations in 2000, Sultanpur, Tanga-i-Gulbahar.

- **Near Normal:** 1979, 1980, 1981, 1983, 1984, 1986, 1988, 1989, 1992, 1993, 1994, 1995, 1996, 1997, 2004, 2007, 2008, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, and 2019 were observed as near normal years in majority of the stations.
- **Moderately Wet:** Stations such as Pul-i-Kama and Sultanpur in 1980, Doabi and Chaghasarai in 1982, Pul-i-Kama, Sultanpur, Pul-i-Qarghay, Pul-i-Behsod, in 1987, Pul-i-Qarghay, Tanga-i-Gulbahar, and Doabi in 1990, Istalif, Keraman, and Omarz in 1991, Doabi and Naghlo in 1997, Keraman in 2004, Payin-i-Qargha in 2006, Nawabad, Tanga-i-Gulbahar, Chaghasarai, Omarz, and Doabi in 2008, Tanga-i-Gulbahar in 2011 and 2012, Omarz, Tanga-i-Sayedan, and Tanga-i-Gulbahar in 2013, Nawabad, Chaghasari, Keraman, and Tanga-i-Gulbahar in 2014, Payin-i-Qargha, Tanga-i-Gulbahar, Tanga-i-Sayedan, and Omraz in 2015, Chagahsari in 2017, Payin-i-Qargha and Nawabad in 2018, and Sultanpur and Pul-i-Kama in 2019 recorded moderate drought.
- **Very Wet:** These conditions were detected in 1982 in Asmar, Istalif, Nawabad, Bagh-i-Omomi, Payin-i-Qargha, Bagh-i-Lala, Sultanpur, Tanga-i-Sayedan, and Naglo stations. Further, in 1990 in Sultanpur, Pul-i-Behsod, and Naghlo, Tanga-i-Sayedan, in 1991 Doabi, in 2004 Doabi and Omarz, in 2006 Tanga-i-Sayedan, Qala-i-Malik, Pul-i-Kama, and Pul-i-Qarghay, in 2008 Pul-i-Qarghay, Tanga-i-Sayedan, and Keraman, in 2018 Chagahsarai, Asmar, and Tanga-i-Gulbahar, and finally in 2019 in Asmar, Bagh-i-Lala, Chaghasarai, Nawabad, and Tanga-i-Gulbahar stations.
- **Extremely Wet:** Extreme wet category was observed in Pul-i-Kama station in 1982, in Qala-i-Malik, Istalif, Tanga-i-Sayedan, Naglo, and Payin-i-Qargha stations in 1990, in Sultanpur, Pul-i-Qarghay, Pul-i-Kama, Pul-i-Behsod, Omarz, Naghlo, Keraman, and Doabi stations in 2006, and in Bagh-i-Omomi and Bagh-i-Lala stations in 2018.

Table 3.13. Extreme Drought Events in Kabul RB based on SPI

Year	Station																
	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Chaghasarai	Doabi	Keraman	Naghlo	Nawabad	Omarz	Payin-i-Qargha	Pul-i-Behsod	Pul-i-Kama	Pul-i-Qarghay	Qala-i-Malik	Sultanpur	Tanga-i-Gulbahar	Tanga-i-Sayedan
1999	-2.56	-2.30	-2.44	-2.67	-2.28	-	-	-2.80	-2.32	-2.27	-2.91	-2.96	-2.90	-2.15	-2.63	-2.00	-2.17
2000	-	-2.51	-2.67	-	-2.02	-	-	-2.03	-2.02	-2.50	-	-	-2.07	-2.39	-	-2.18	-2.40
2001	-2.08	-	-	-2.17	-	-	-2.82	-2.26	-	-2.30	-	-	-	-2.19	-	-2.03	-2.21
2003	-	-	-	-2.06	-	-	-	-	-	-	-	-	-	-	-2.09	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.14. Severe Drought Events in Kabul RB based on SPI

Year	Station													
	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Chaghasarai	Doabi	Estalif	Keraman	Naghlo	Nawabad	Omarz	Pul-i-Behsod	Pul-i-Kama	Pul-i-Qarghay	Sultanpur
2000	-1.87	-	-	-1.94	-1.97	-1.76	-	-	-	-	-	-	-	-
2001		-1.71	-1.78		-1.52	-	-1.64	-	-	-1.60	-1.88	-1.76	-1.90	-
2003	-1.78	-	-	-	-	-	-	-1.51	-1.93		-1.60	-1.60	-1.62	-
2016	-	-	-	-	-	-1.60	-	-	-	-	-	-	-	-
2017	-	-	-	-	-	-1.65	-	-1.70	-	-	-	-	-	-

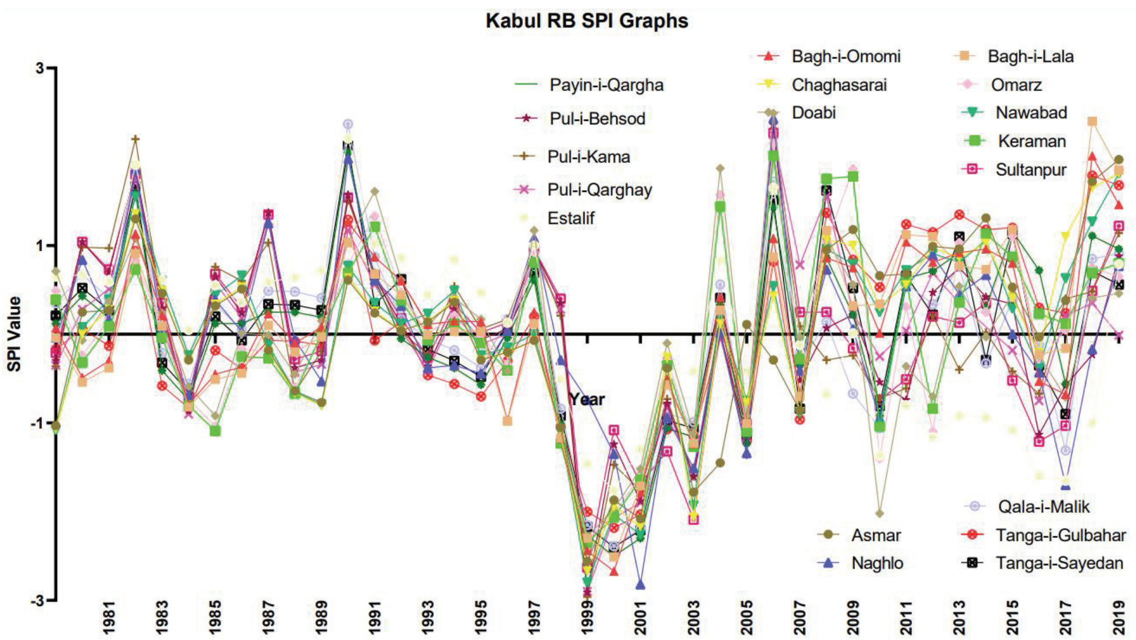


Figure 3.6. SPI Drought Graphs for Kabul RB Stations

3.5.5. SPI Results for Norther RB

The analysis consists of annual SPI drought detection for all stations under study in the Northern RB. The results of extreme and severe drought magnitude for all stations are summarized in Tables 3.15 and 3.16. Moreover, graphical representation of the SPI results with respect to each station is presented in Figure 3.7.

- **Extremely Dry:** Extreme drought events were recorded in 1999 and 2000 by majority of the studied stations. Another extreme drought event was recorded in 2010 in Tanga-i-Tashqurghan station.
- **Severely Dry:** Severe drought was seen in 1985 in Sayad, in 1998 in Dawlatabad, in 1999 in Tanga-i-Tashqurghan, in 2003 in Nazdik-i-Saripul, in 2005 in Nazdik-i-Saripul, 2010 in Tanga-i-Tashqurghan, Doshqadam, and Sayad, in 2012 in Doshqadam, and in 2017 in Asiabad and Tanga-i-Tashqurghan stations.
- **Moderately Dry:** This classification of drought was recorded in Dawlatabad station in 1981, in majority of the stations in 1985, in Dara-i-Zhwandon station in 1995, in Doshqadam and Dawlatabad stations in 1999, in Doshqadam, Tanga-i-Tashqurghan, and Dawlatabad stations in 2000, in majority of the stations in 2001, in Nazdik-i-Nayak station in 2002, in majority of the stations in 2003, in half of the studied stations in 2005, in Dara-i-Zhwandon, Nazdik-i-Saripul, sayad, Nazdik-i-Nayak, and Asiabad stations in 2007, in Doshqadam station in 2009, in Asiabad, and Nazdik-i-Saripul stations in 2010, in Tanga-i-Tashqurghan station in 2012, in Doshqadam station in 2014 and 2015, in Nazdik-i-Saripul and Doshqadam stations in 2017, and in Tanga-i-Tashqurghan and Doshqadam stations in 2019.

Table 3.15. Extreme Drought Events in Norther RB based on SPI

Year	Stations				
	Dara-i-Zhwandon	Nazdik-i-Nayak	Nazdik-i-Saripul	Sayad	Tanga-i-Tashqurghan
1999	-2.77	-2.55	-2.25	-2.47	-
2000	-2.46	-2.17	-2.04	-	-
2010	-	-	-	-	-2.23

Table 3.16. Severe Drought Events in Norther RB based on SPI

Year	Stations						
	Asiabad	Dawlatabad	Doshqadam	Nazdik-i-Nayak	Nazdik-i-Saripul	Sayad	Tanga-i-Tashqurghan
1985	-	-	-	-	-	-1.51	-
1998	-	-1.56	-	-	-	-	-
1999	-1.94	-	-	-	-	-	-1.86
2000	-1.92	-	-	-	-	-1.77	-
2001	-	-	-	-1.63	-	-1.57	-
2005	-	-	-	-	-1.56	-	-
2010	-	-	-1.85	-	-	-1.89	-
2012	-	-	-1.92	-	-	-	-
2017	-1.60	-	-	-	-	-	-1.79

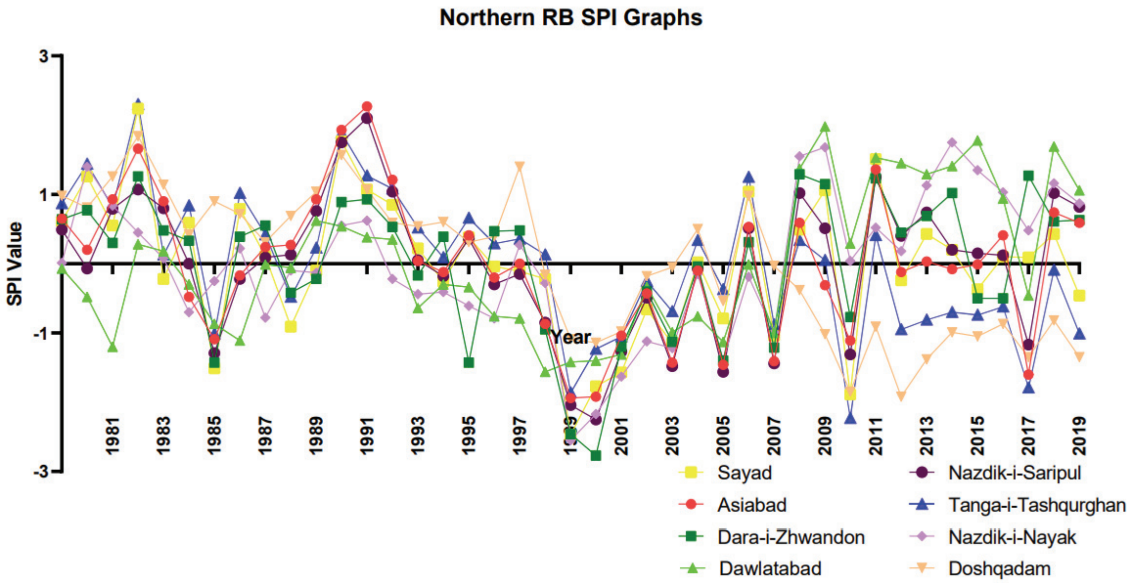


Figure 3.7. SPI Drought Graphs for Northern RB Stations

3.6. RDI Results

Results from the RDI index were most likely as SPI. Therefore, the extreme and severe drought episodes based on RDI with respect to each RB are presented in tabulated and graphical forms. Detailed RDI results for all stations within the study period are provided in APPENDEX A.

3.6.1. RDI Results for Amu RB

Table 3.17. Extreme Drought Events in Amu RB based on RDI

Year	Station										
	Baghlan	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Faizabad	Gerdab	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1985	-	-	-	-		-	-2.16	-	-	-	
1999	-	-	-	-	-2.08	-	-	-	-	-	-2.19
2000	-2.13	-	-	-	-2.82	-	-2.71	-2.32	-2.42	-	-2.00
2010	-	-	-2.13	-	-	-2.29	-	-	-	-	-
2016	-2.01		-2.26	-2.95	-	-	-	-	-	-	-
2017	-2.09	-2.10	-2.10	-2.03	-	-	-	-2.10	-	-	-
2019	-	-	-	-	-	-	-	-	-	-2.20	-

Table 3.18. Severe Drought Events in Amu RB based on RDI

Year	Station									
	Ahangaran	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Gerdab	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1985	-	-	-	-	-	-	-1.59	-1.60	-	-
1999	-1.64	-	-	-	-	-1.98	-1.93		-	-
2000	-	-1.81	-	-	-	-	-	-	-	-
2005	-	-1.54	-	-	-	-	-	-	-	-1.76
2007	-	-	-	-	-	-1.50	-	-	-	-1.61
2012	-	-	-	-	-	-	-	-	-1.64	-
2013	-	-	-	-1.83	-	-	-	-1.59	-1.73	-
2015	-	-	-	-1.69	-	-	-	-	-	-
2016	-	-1.52	-	-	-1.61	-	-1.62	-	-	-
2017	-1.62	-	-	-	-	-	-	-1.52	-1.92	-1.83
2018	-	-	-1.63	-1.91	-	-	-	-	-	-
2019	-	-	-	-1.72	-	-	-	-	-	-

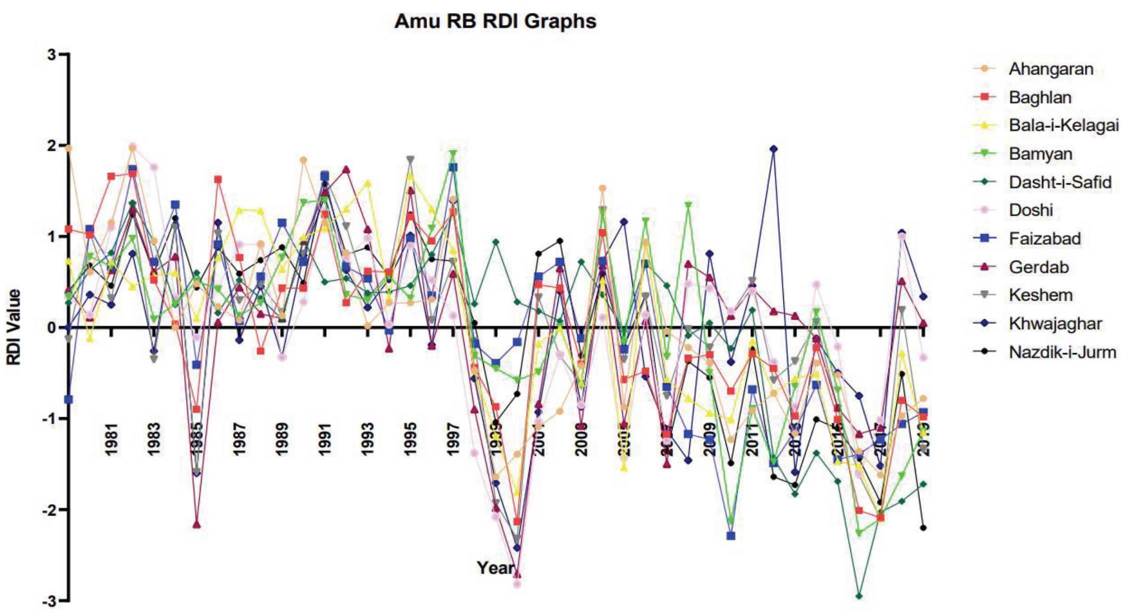


Figure 3.8. RDI Drought Graphs for Amu RB Stations

3.6.2. RDI Results for Harirud-Murghab RB

Table 3.19. Extreme Drought Events in Harirud-Murghab RB based on RDI

Year	Station					
	Cheldukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Rabat-i-Akhund	Torghundi
1999	-	-2.73	-2.08	-2.31	-	-
2000	-2.46	-2.35	-	-2.33	-	-2.00
2008	-	-	-	-	-2.88	-
2017	-	-	-	-2.16	-	-

Table 3.20. Severe Drought Events in Harirud-Murghab RB based on RDI

Year	Station						
	Cheldukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Rabat-i-Akhund	Shinya	Torghundi
1984	-	-1.67	-	-	-	-	-
1999	-1.80	-	-	-	-1.54	-1.76	-
2000	-	-	-1.96	-	-	-	-
2001	-1.48	-1.53	-	-	-	-	-
2005	-	-	-	-1.68	-	-	-
2010	-	-	-	-	-	-1.56	-
2016	-	-	-	-	-	-1.77	-
2017	-	-	-1.89	-	-	-	-1.75

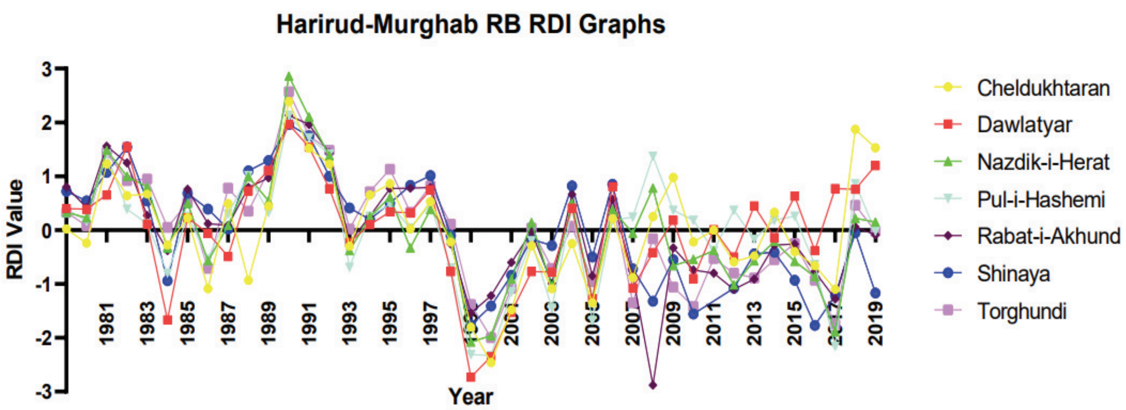


Figure 3.9. RDI Drought Graphs for Harirud-Murghab RB Station

3.6.3. RDI Results for Helmand RB

Table 3.21. Extreme Drought Events in Helmand RB based on RDI

Year	Station								
	Adraskan	Farah	Gardandiwal	Gardiz	Lashkargah	Nazdik-i-Adraskan	Nazdik-i-Gardandiwal	Nazdik-i-Kandahar	Tarnak
1999	-2.03	-	-2.07	-2.71	-	-	-2.16	-2.15	-2.21
2000	-2.22	-	-	-	-	-2.16	-2.08	-	-
2003	-	-	-	-	-	-	-	-2.21	-
2017	-	-2.44	-	-	-2.77	-	-	-	-

Table 3.22. Severe Drought Events in Helmand RB based on RDI

Year	Station							
	Adraskan	Farah	Gardandiwal	Gardiz	Lashkargah	Nazdik-i-Adraskan	Nazdik-i-Gardandiwal	Tarnak
1999	-	-1.75	-	-	-1.72	-1.99	-	-
2000	-	-1.55	-1.98	-1.85	-1.73	-	-	-
2001	-	-	-	-1.94	-	-	-1.61	-
2003	-	-	-	-1.94	-1.72	-	-	-
2005	-1.50	-	-	-	-	-1.51	-	-
2007	-1.53	-	-	-	-	-1.53	-	-
2010	-	-	-1.76	-	-	-	-	-
2011	-	-	-1.93	-	-	-	-	-
2017	-1.81	-	-	-	-	-	-	-1.86

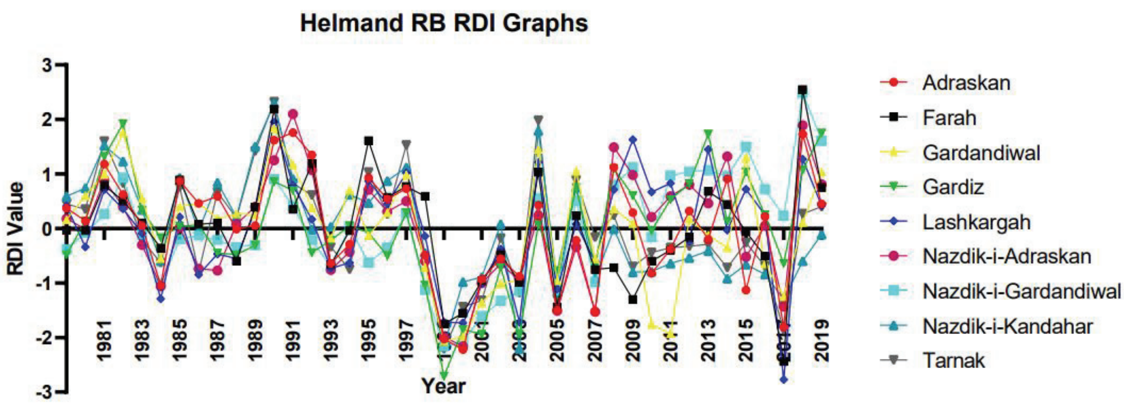


Figure 3.10. RDI Drought Graphs for Helmand RB Stations

3.6.4. RDI Results for Kabul RB

Table 3.23. Extreme Drought Events in Kabul Kabul RB based on RDI

Year	Station								
	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Doabi	Keraman	Naghlo	Payin-i-Qarghay	Pul-i-Kama	Pul-i-Qarghay
1999	-2.33	-2.40	-2.35	-2.08	-2.31	-	-2.23	-2.75	-2.83
2000		-2.64	-2.60	-	-2.11	-	-2.47	-	-2.11
2001	-2.05	-	-	-	-	-2.71	-2.28	-	-
2010	-	-	-	-2.24	-	-	-	-	-

Table 3.24. Severe Drought Events in Kabul RB based on RDI

Year	Station							
	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Doabi	Keraman	Naghlo	Pul-i-Kama	Pul-i-Qarghay
2000	-1.86	-	-	-1.88	-	-	-	-
2001	-	-1.82	-1.74	-	-1.74	-	-1.70	-1.91
2003	-1.81	-	-	-	-	-1.57	-1.57	-1.68
2017	-	-	-	-	-	-1.72	-	-

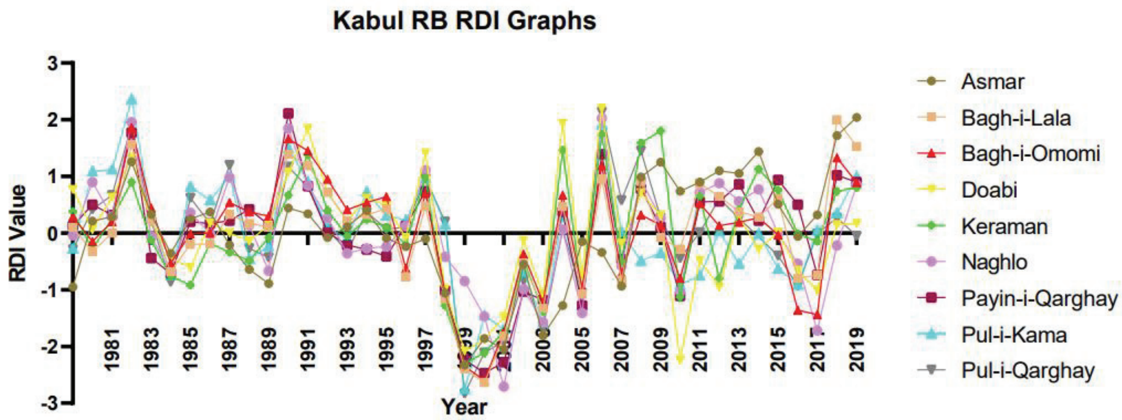


Figure 3.11. RDI Drought Graphs for Kabul RB Stations

3.6.5. RDI Results for Northern RB

Table 3.25. Extreme Drought Events in Northern RB based on RDI

Year	Station				
	Dara-i-Zhwandon	Nazdik-i-Nayak	Nazdik-i-Sari Pul	Sayad	Tanga-i-Tashqurghan
1999	-2.31	-2.81	-2.00	-	-
2000	-2.62	-2.46	-2.20	-	-
2010	-	-	-	-2.35	-2.22

Table 3.26. Severe Drought Events in Northern RB based on RDI

Year	Station						
	Dara-i-Zhwandon	Dawlatabad	Doshqadam	Nazdik-i-Nayak	Nazdik-i-Sari Pul	Sayad	Tanga-i-Tashqurghan
1998	-	-1.53	-	-	-	-	-
1999	-	-	-	-	-	-1.78	-
2001	-	-	-	-1.73	-	-	-
2005	-	-	-	-	-1.52	-	-
2007	-	-	-	-	-1.50	-	-
2010	-	-	-1.82	-	-	-	-
2012	-	-	-1.88	-	-	-	-
2015	-1.58	-	-	-	-	-	-
2017	-	-	-	-	-	-	-1.89

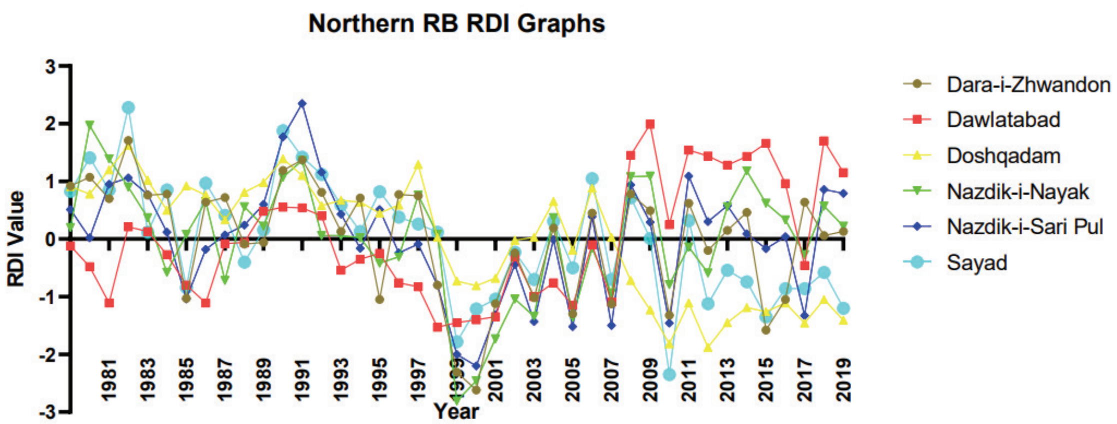


Figure 3.12. RDI Drought Graphs for Northern RB Stations

3.7. Rainfall Anomalies (1979 – 2019)

The spatio-temporal distribution of rainfall across five RBs varies, and the climate change plays a vital role in these anomalies. The maximum and minimum annual rainfall recorded in the study period based on 55 rain gauges in Amu RB was 663.65 and 103.32 mm, in Harirud-Murghab RB 636.48 and 34.12 mm, in Helmand RB 792.25 and 15.95 mm, in Kabul 809.24 and 38.74 mm, and Northern RB 845.95 and 48.55 mm respectively. The maximum average, minimum average, and average rainfall for the study period across the country based on the 55 rain gauge data was 749.51, 48.14, and 269.79 mm. From the annual rainfall data, we detected many low rainfall events starting from the hydrological year 1999 i.e., 5 stations recorded 14 annual rainfall events less than 50 mm in Helmand RB, 6 stations recorded 15 annual rainfall events less than 150 mm in Amu RB, 6 stations recorded 16 annual rainfall events less than 100 mm in Harirud-Murghab RB, 11 stations recorded 22 annual rainfall events less than 100 mm in Kabul RB, and 4 stations recorded 16 annual rainfall events less than 100 mm in Northern RB. Therefore, it can be clearly stated that from the fiver RBs, Helmand which is also the largest all RBs in the country, suffers from decreasing rainfall in terms of both spatial and temporal extents in comparison to other RBs.

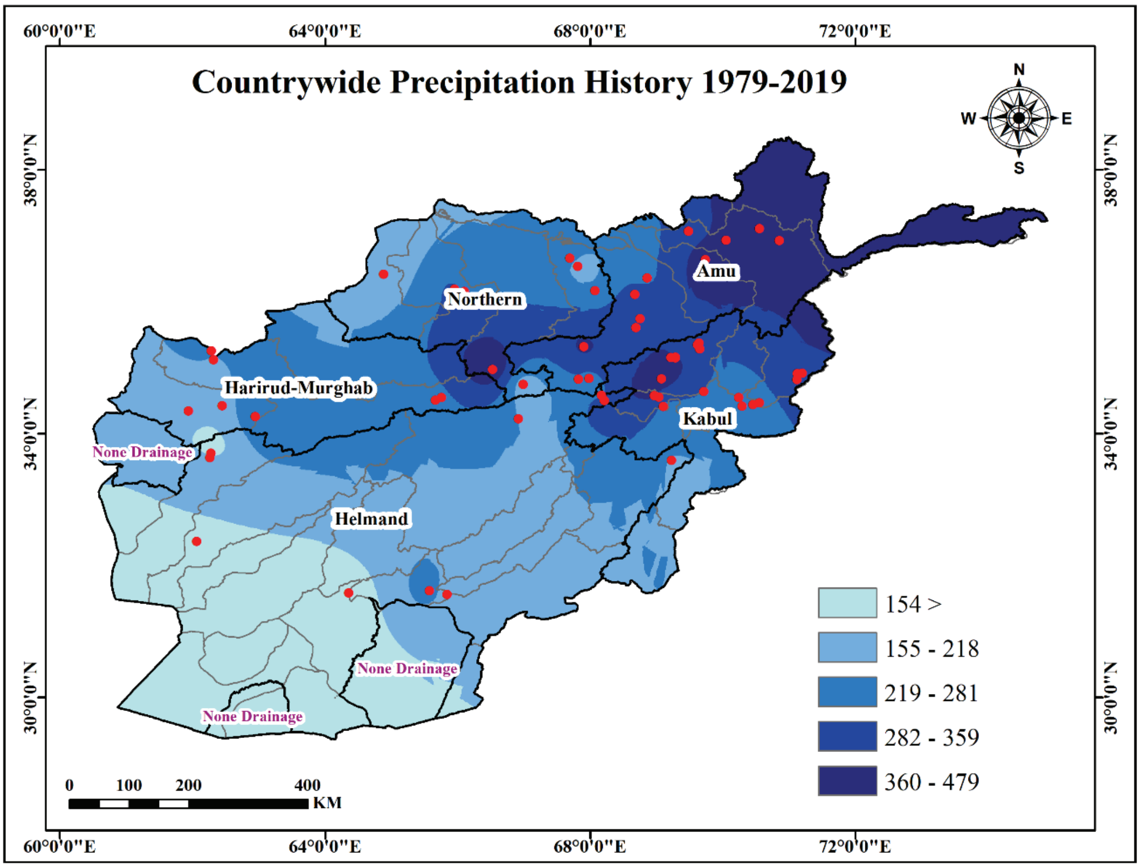


Figure 3.13. Precipiation History of Afghanistan from 1979 to 2019 based on 55 Stations Data

Table 3.27. Decades Precipitation History in Afghanistan

Decade	River Basin				
	Amu	Harirud-Murghab	Helmand	Kabul	Northern
	P, mm/yr	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*
1979 - 1988	378.05	251.84	219.97	337.35	277.83
1989 - 1998	387.10	290.10	238.28	335.62	276.57
1999 - 2008	315.48	171.76	154.36	257.19	193.88
2009 - 2018	294.09	201.36	213.16	345.00	239.85

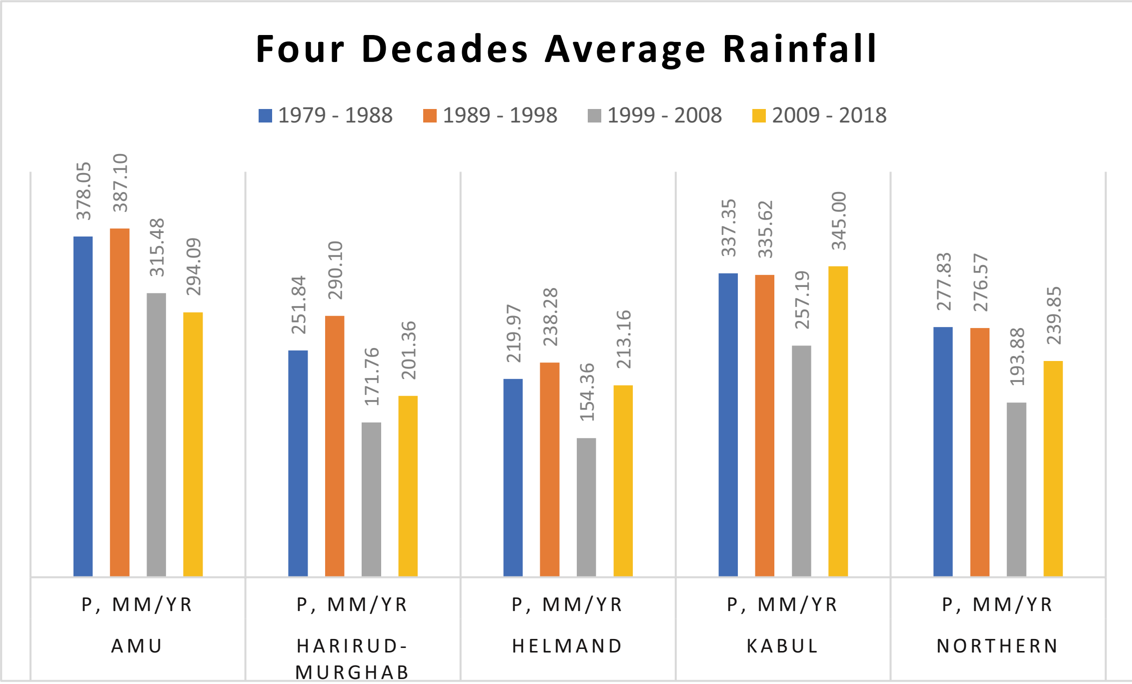


Figure 3.14. A Representation of Decadal Rainfall Comparison in Afghanistan

Table 3.28. Four Decades Minimum, Maximum, and Average Rainfall with respect to RBs based on 55 Stations Data

Period	River Basin					
	Amu	Harirud-Murghab	Helmand	Kabul	Northern	Countrywide Average
1979-2019	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*	*P, mm/yr*
Maximum	663.65	636.48	792.25	809.24	845.95	749.51
Minimum	103.32	34.12	15.95	38.74	48.55	48.14
Average	342.02	229.26	208.42	322.38	246.86	269.79

3.8. Temperature Anomalies (1979 – 2019)

Temperature increase directly affects evapotranspiration rate, which will also intensify drought events. Therefore, understanding temperature variations are essential in drought studies. Even detailed analysis of temperature trends across Afghanistan is provided in chapter 7, here we just provide some general data and countrywide average temperature mapping as shown in Figure 3.7. Moreover, the decadal variations in the average temperature on each RB level show a rise in the last four decades, especially for the last two decades of 1999-2008 and 2009-2018. In the Amu RB, the decadal average temperature is 12.17, 12.28, 13.42, and 14.39 °C for the periods 1979-1988, 1989-1998, 1999-2008, and 2009-2018, respectively. In Harirud-Marghab RB, it is 11.77, 11.63, 12.51, and 14.16 °C for the periods 1979-1988, 1989-1998, 1999-2008, and 2009-2018, respectively. Furthermore, the average decadal temperature for the 1979-1988, 1989-1998, 1999-2008, and 2009-2018 periods in the Helmand RB is 15.97, 15.85, 16.4, and 16.34 °C, respectively. In the Kabul RB, the decadal average temperature shows a rise from one decade to the other and it is 13.57, 13.58, 14.51, and 15.24 16 °C for the periods 1979-1988, 1989-1998, 1999-2008, and 2009-2018, respectively. Finally, the Northern RB has an average temperature of 11.84, 11.84, 12.7, and 15.34 °C for the periods 1979-1988, 1989-1998, 1999-2008, and 2009-2018, respectively. These decadal average figures in temperature clearly indicate a significant rise in temperature across the whole country even in the different stations with higher altitudes.

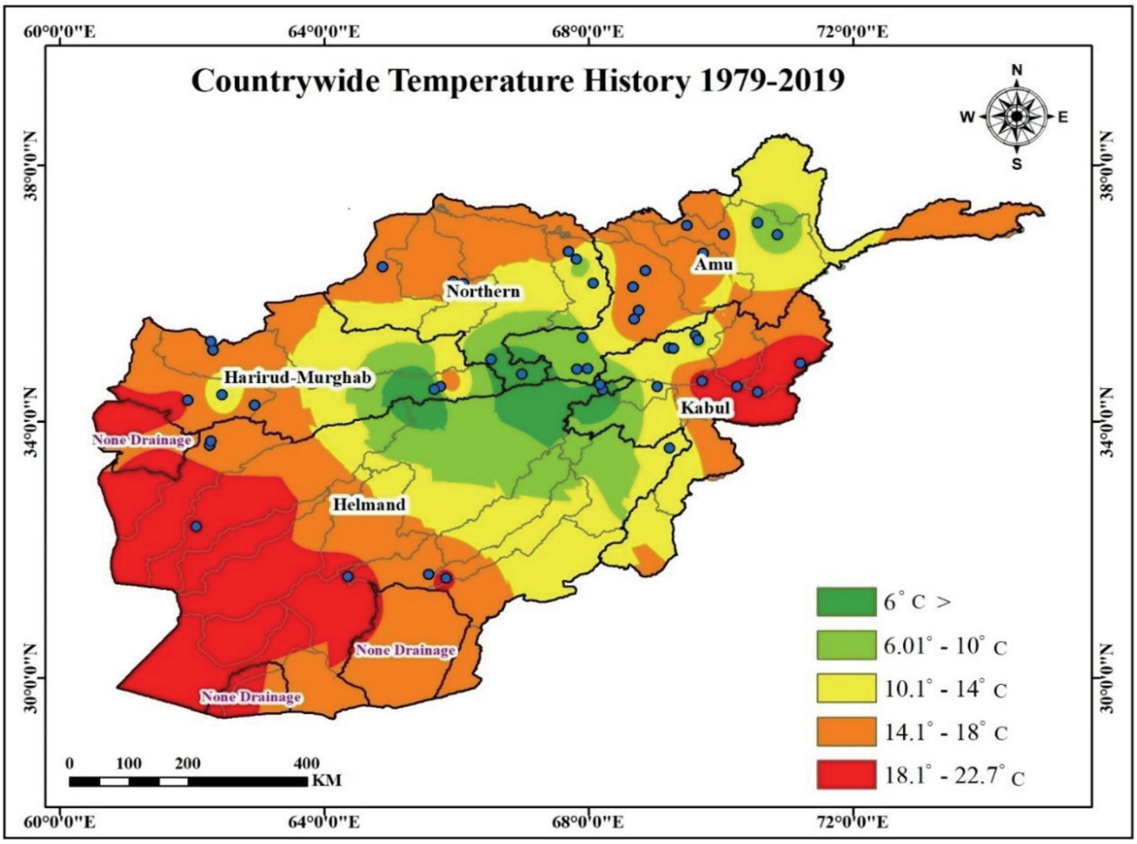


Figure 3.15. Average Temperature History of Afghanistan from 1979 to 2019

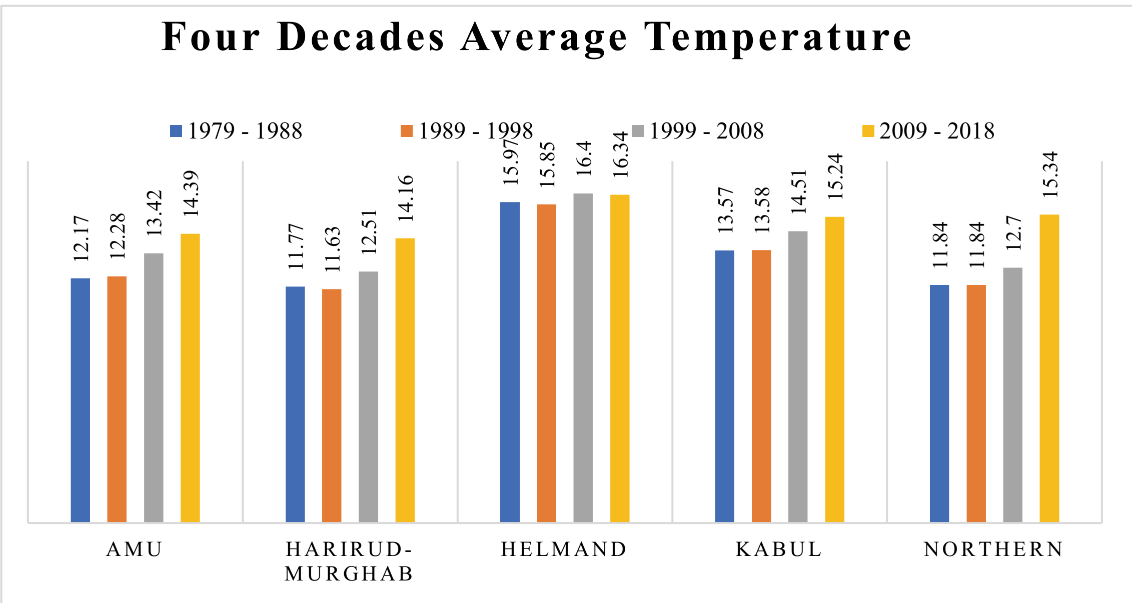


Figure 3.16. A Representation of Decadal Average Temperature Comparison in Afghanistan

Table 3.29. Four Decades Average Temperature Values with respect to RBs

Decade	River Basin				
	Amu	Harirud-Murghab	Helmand	Kabul	Northern
	T, ℃	*T, ℃*	*T, ℃*	*T, ℃*	*T, ℃*
1979 - 1988	11.83	11.77	14.26	14.85	10.38
1989 - 1998	12.07	11.63	14.31	14.90	10.36
1999 - 2008	13.26	12,51	14.89	15.92	11.30
2009 - 2018	14.56	14.16	14.90	16.75	14.65

CHAPTER 4

DROUGHT MAPPING

4.1. Country Drought Mapping (1979 – 2019)

According to the SPI and RDI analyses, drought maps were generated using ArcGIS software so that the spatial extent of drought with respect to time during the study period 1979 – 2019 across the country can be explained using mapping. These drought maps will help institutions and interested users to have basic knowledge of the drought history in the country. Thus, Figures 4.1 to 4.82 represent drought extent with respect to covered gauging stations based on SPI and RDI drought indices. Based on these drought maps, one can acknowledge that many drought events start to occur from 1999 and then happening frequently especially in the south, west and south-west regions of the country.

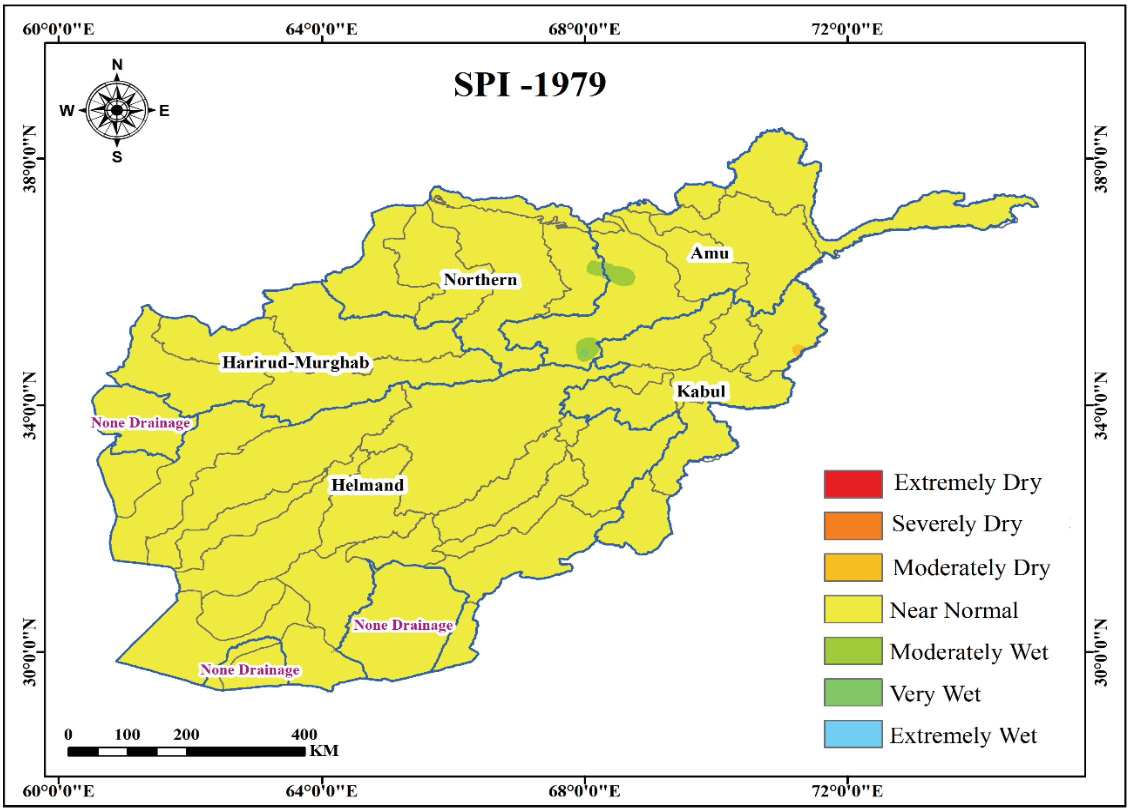


Figure 4.1. 1979 SPI Map

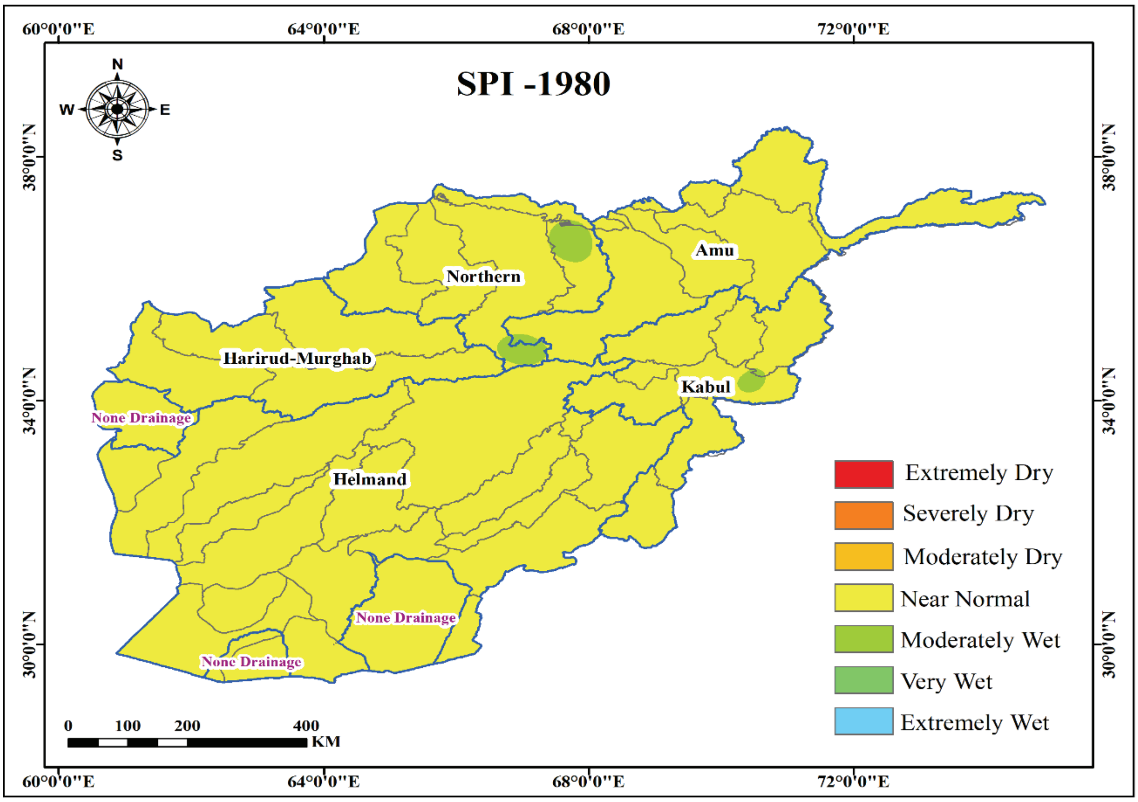


Figure 4.2. 1980 SPI Map

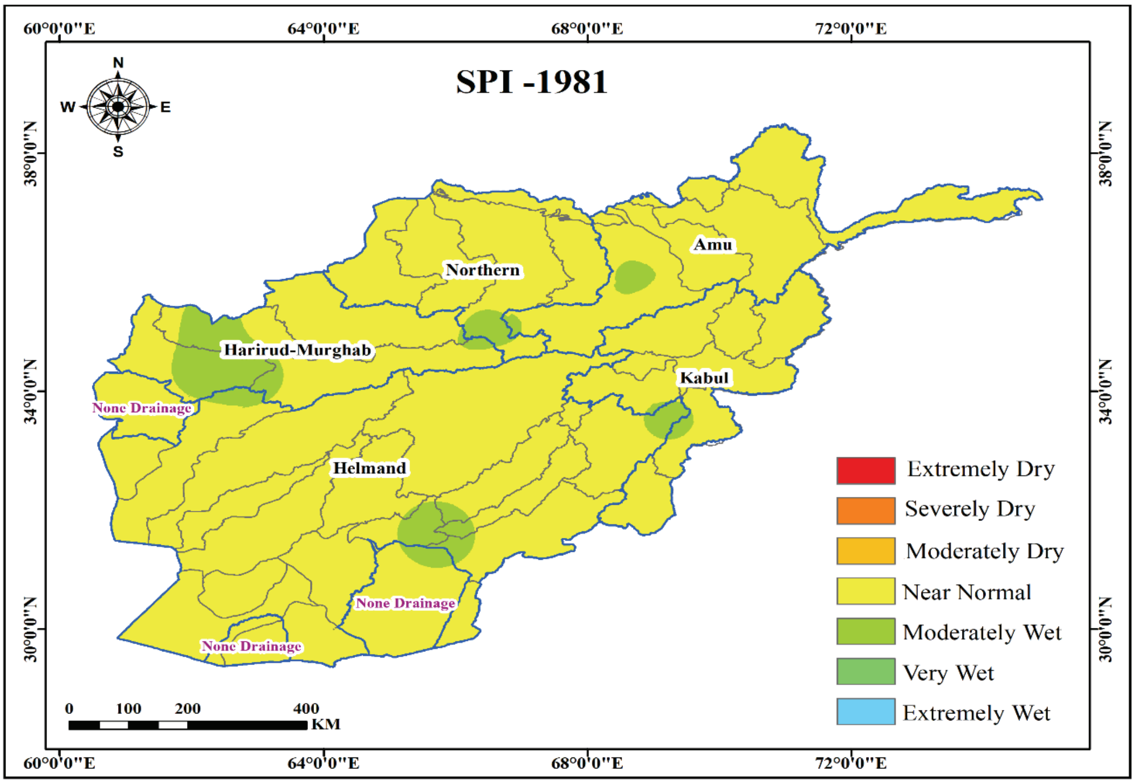


Figure 4.3. 1981 SPI Map

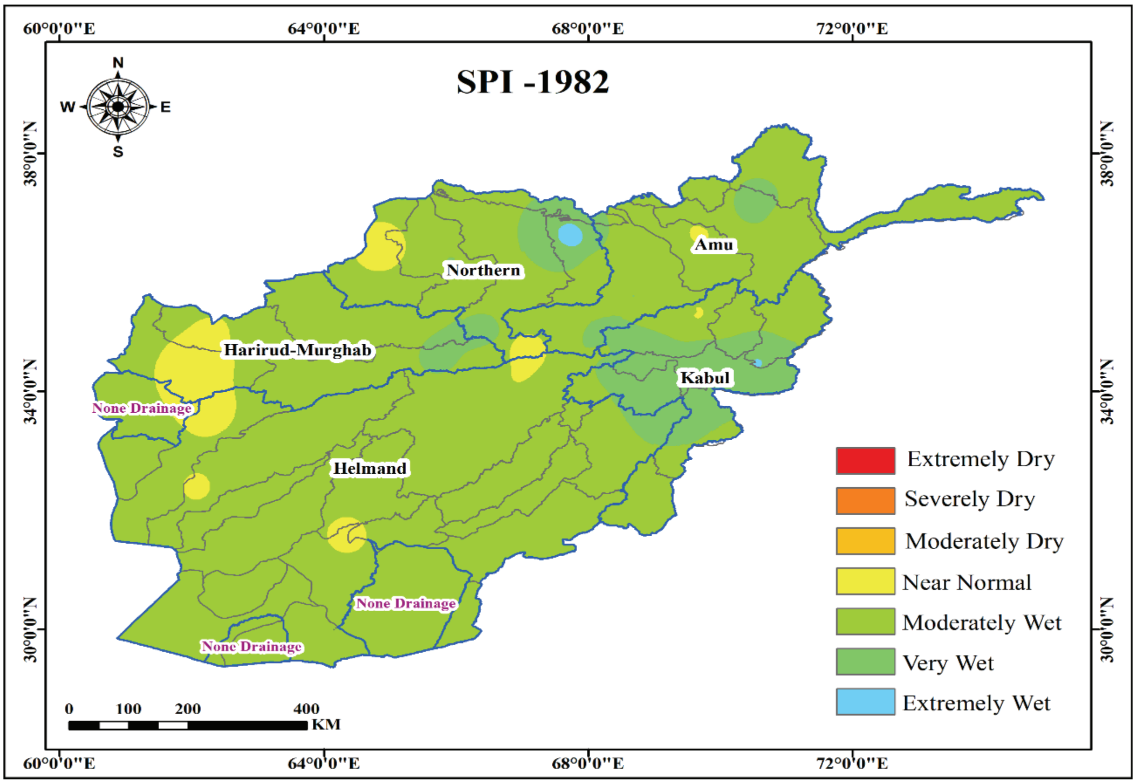


Figure 4.4. 1982 SPI Map

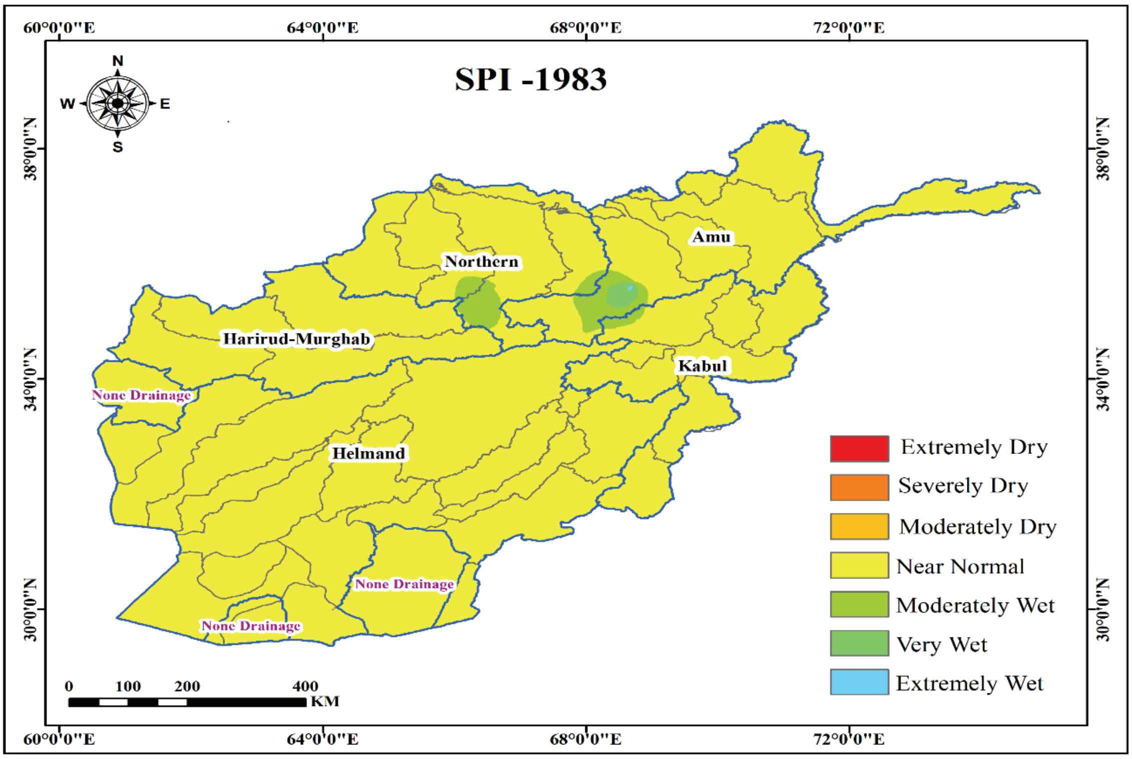


Figure 4.5. 1983 SPI Map

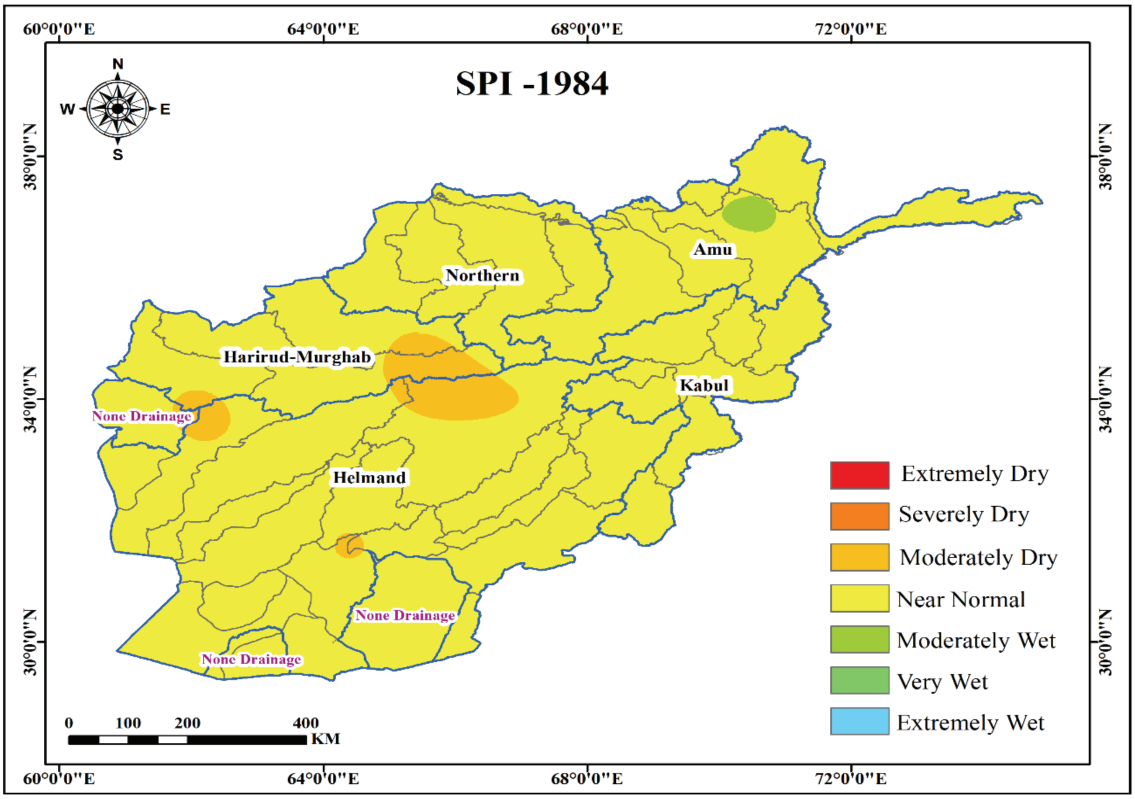


Figure 4.6. 1984 SPI Map

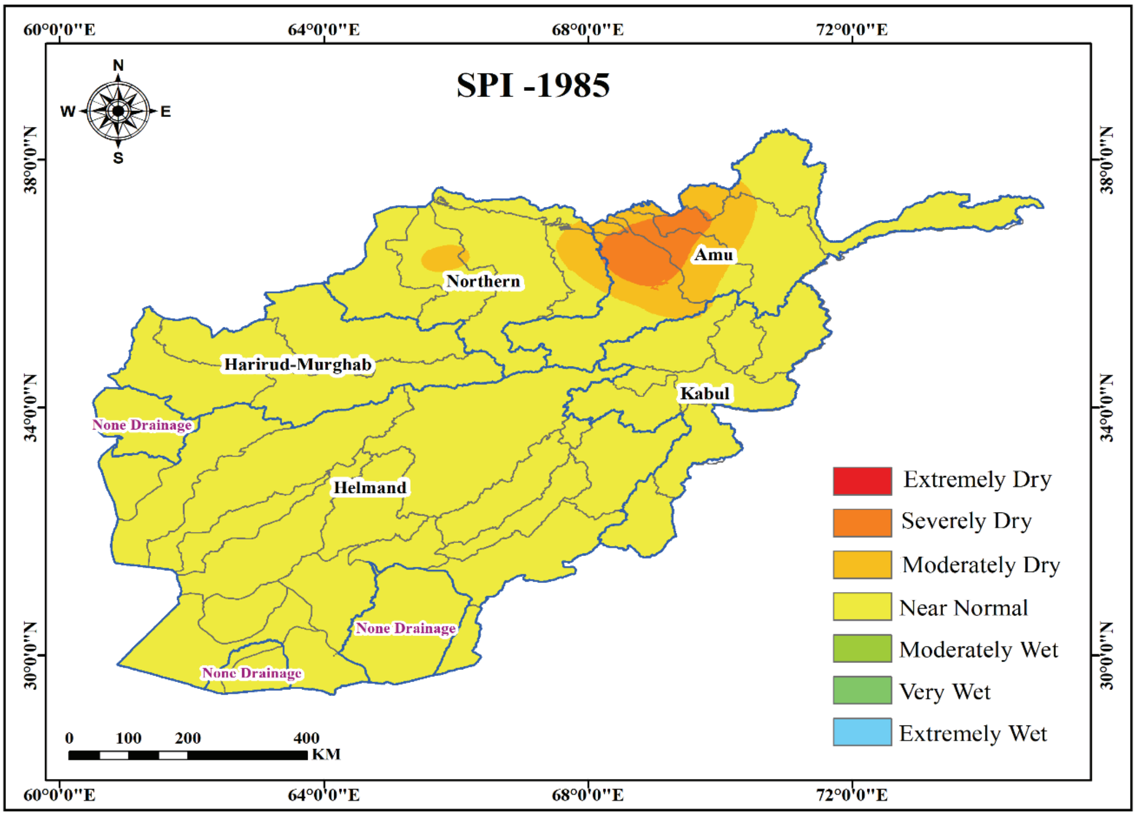


Figure 4.7. 1985 SPI Map

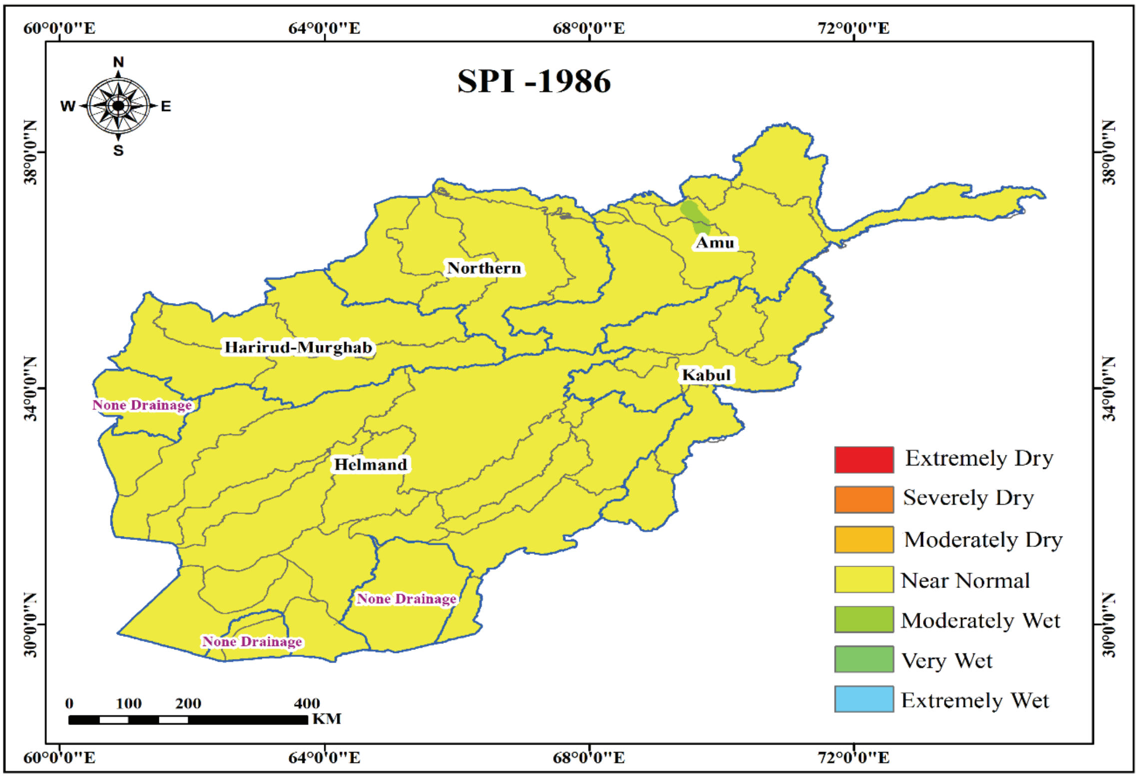


Figure 4.8. 1986 SPI Map

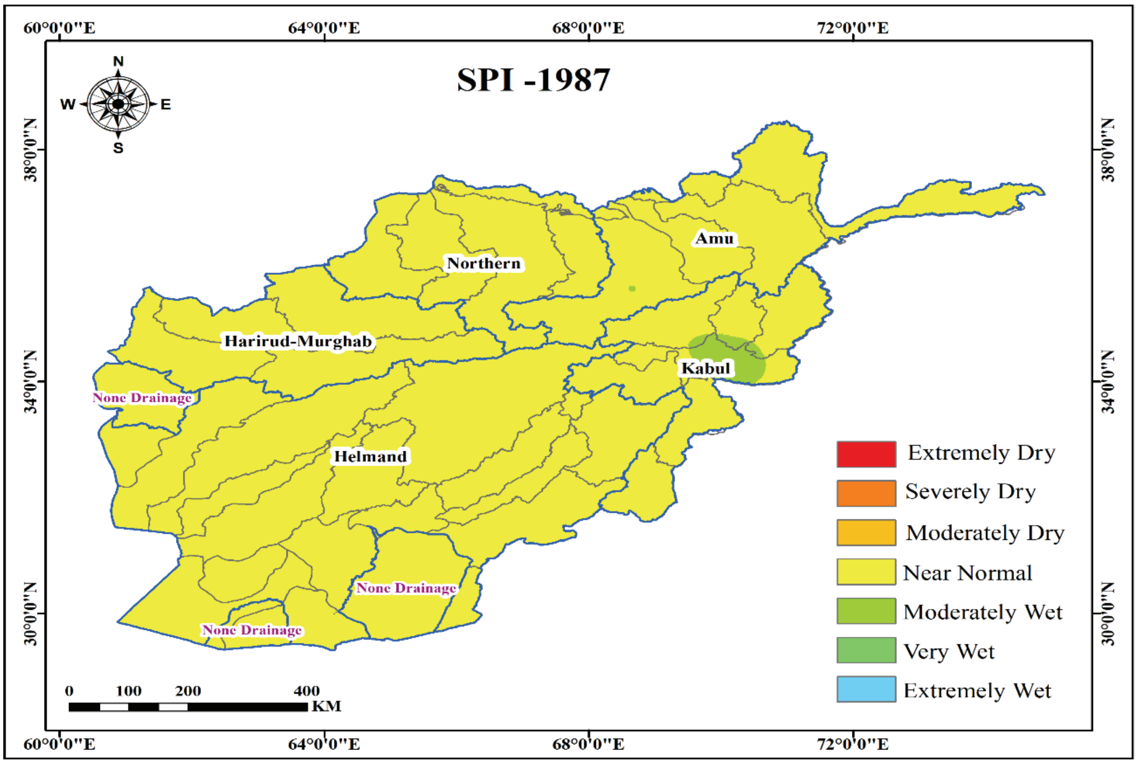


Figure 4.9. 1987 SPI Map

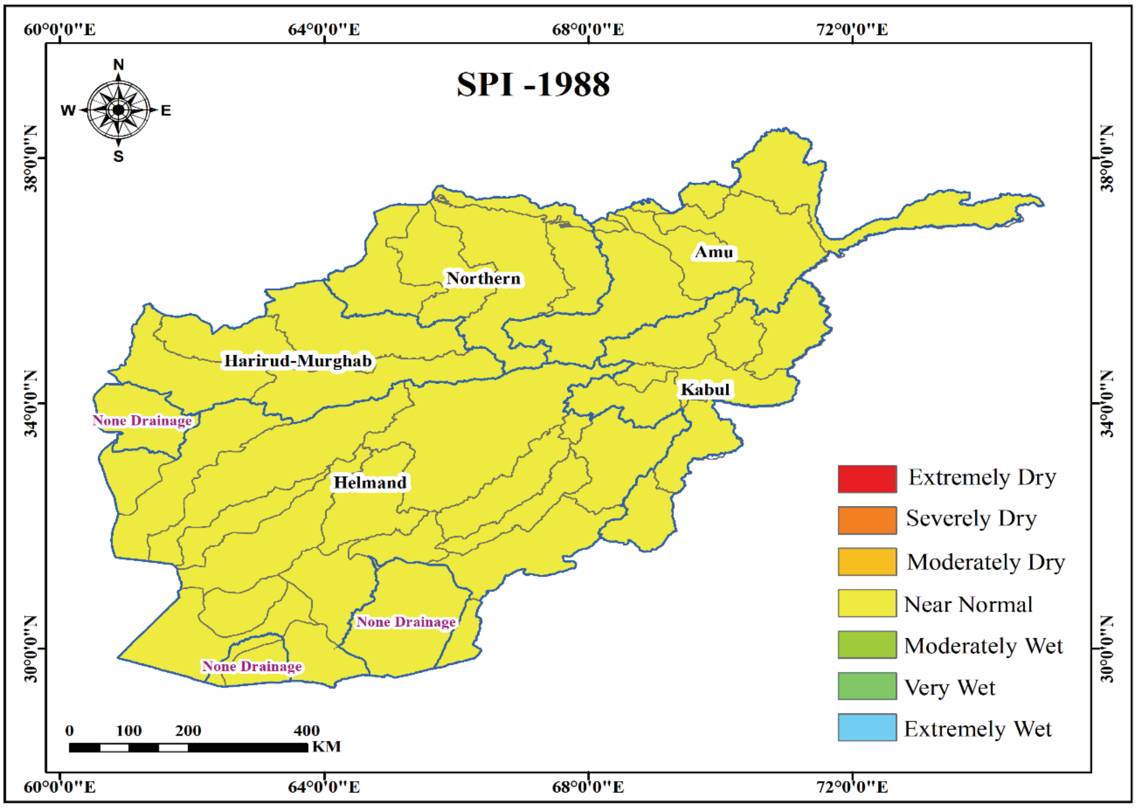


Figure 4.10. 1988 SPI Map

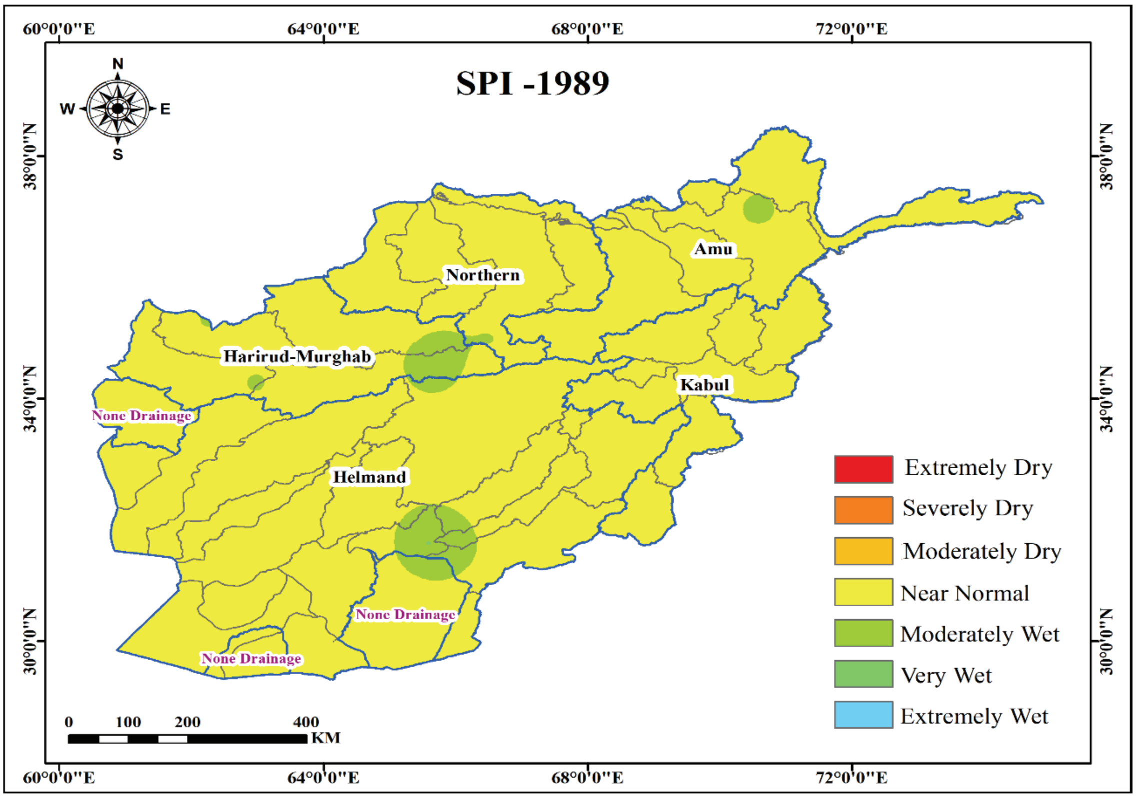


Figure 4.11. 1989 SPI Map

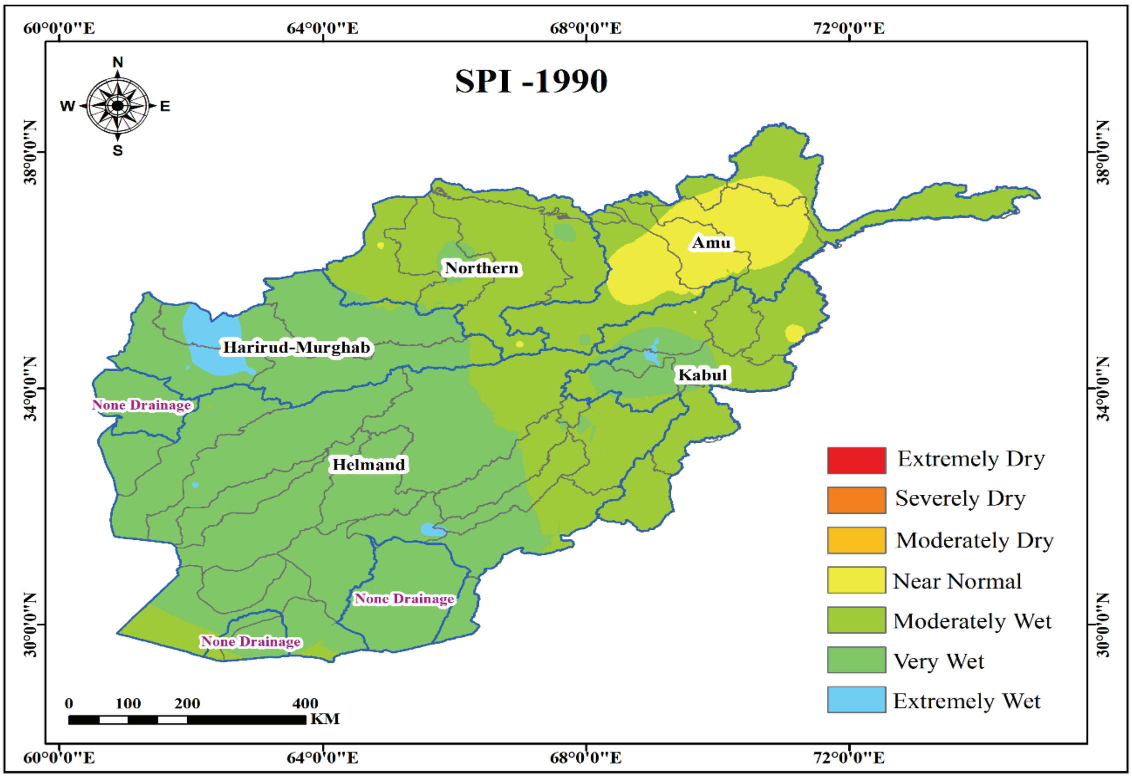


Figure 4.12. 1990 SPI Map

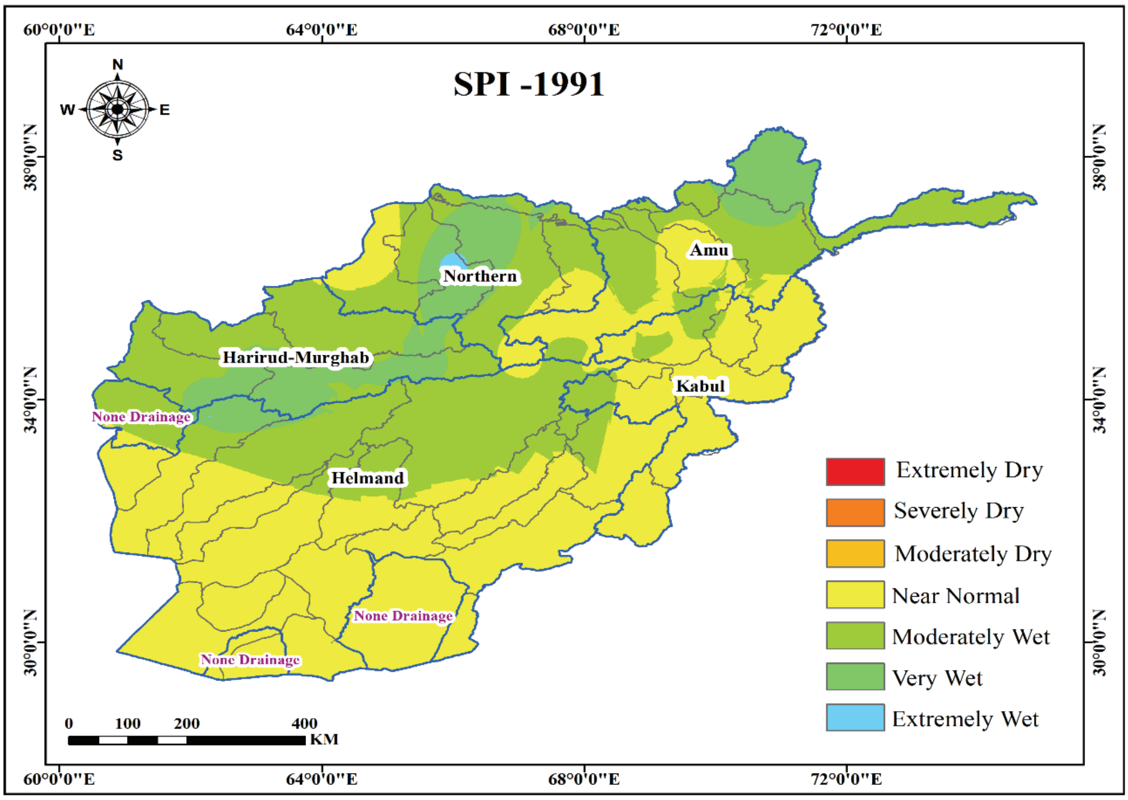


Figure 4.13. 1991 SPI Map

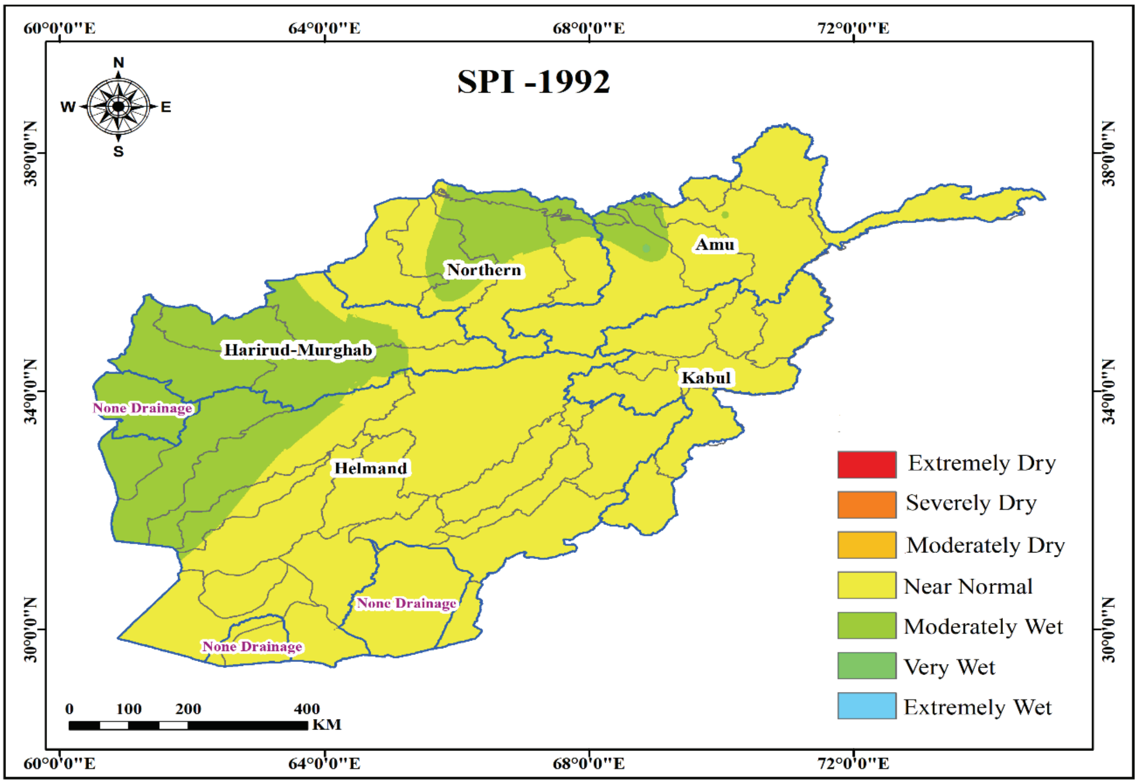


Figure 4.14. 1992 SPI Map

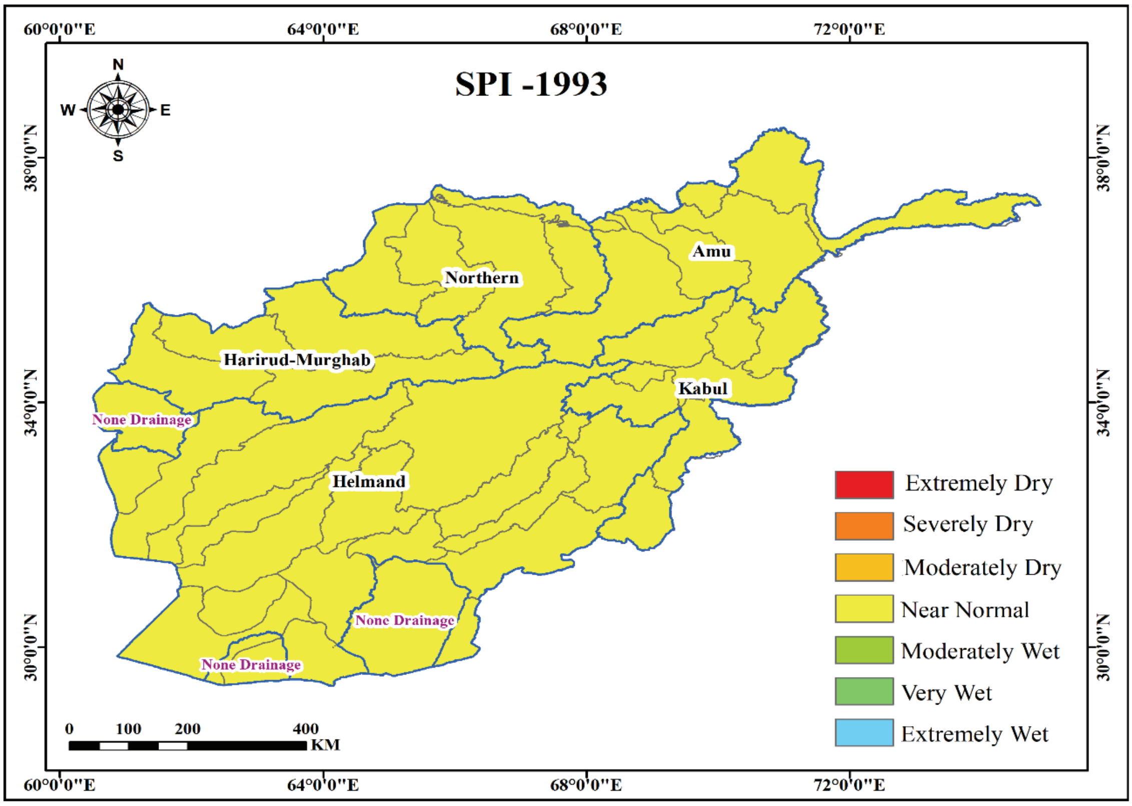


Figure 4.15. 1993 SPI Map

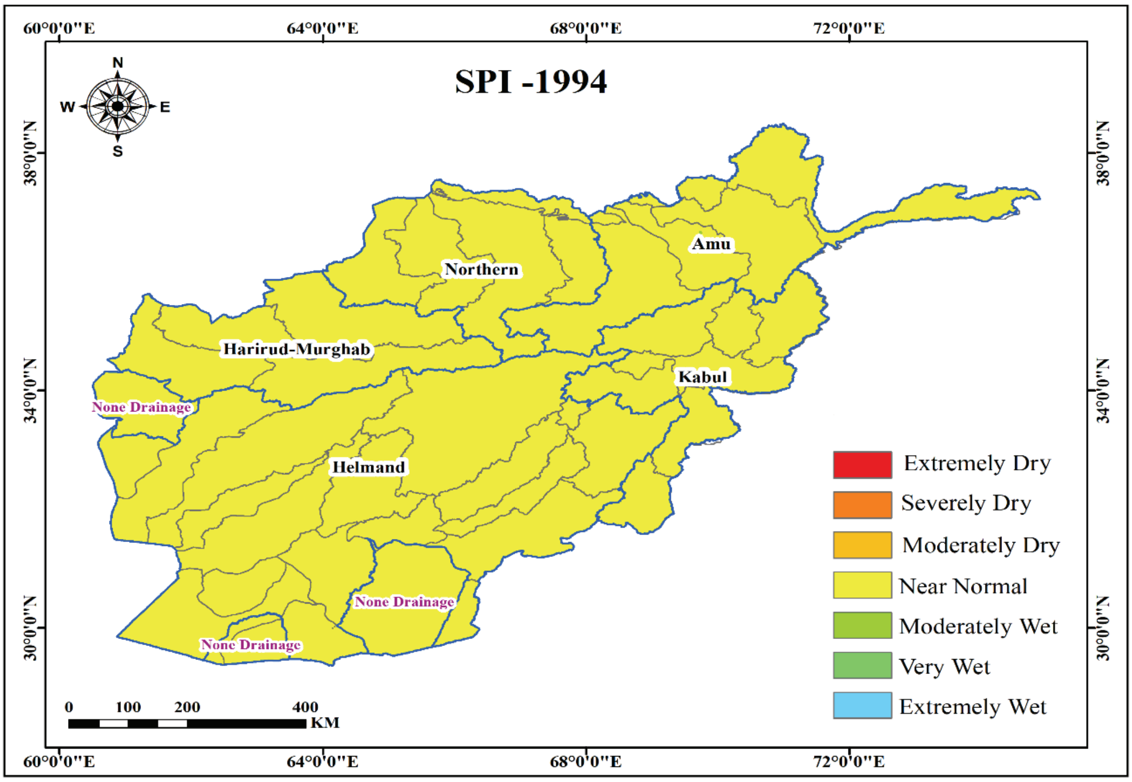


Figure 4.16. 1994 SPI Map

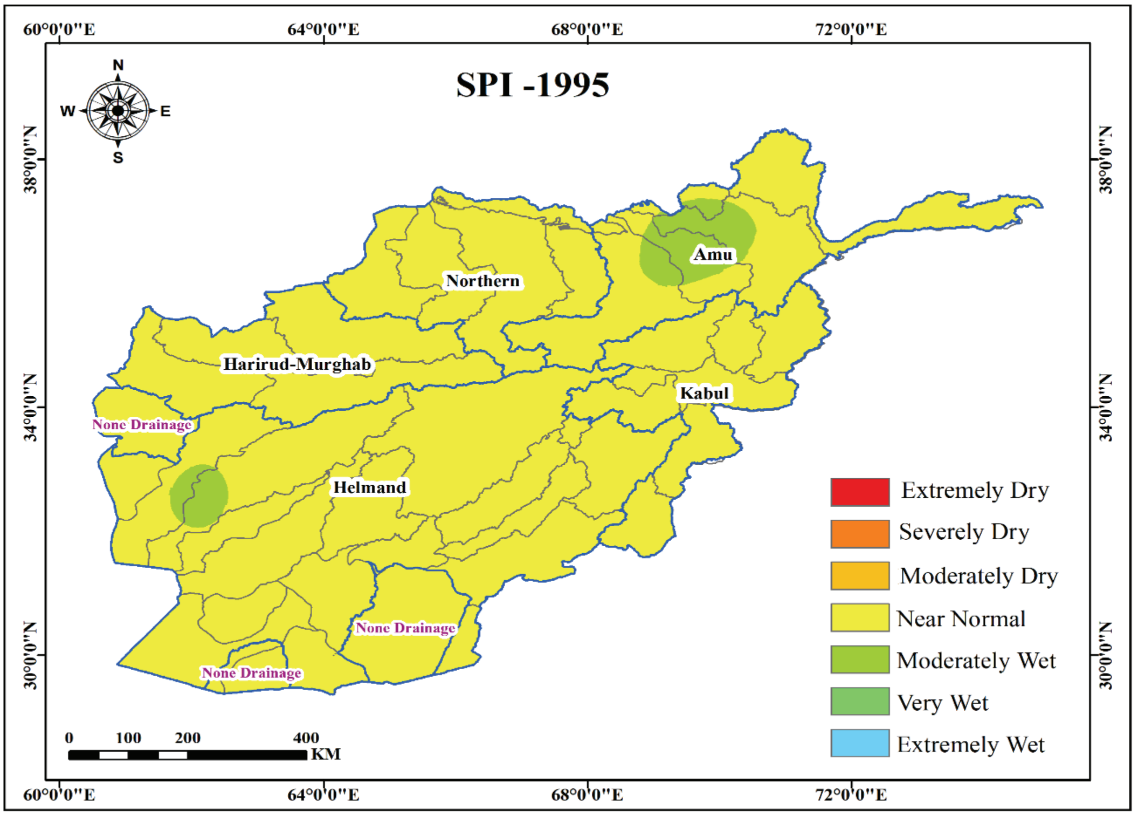


Figure 4.17. 1995 SPI Map

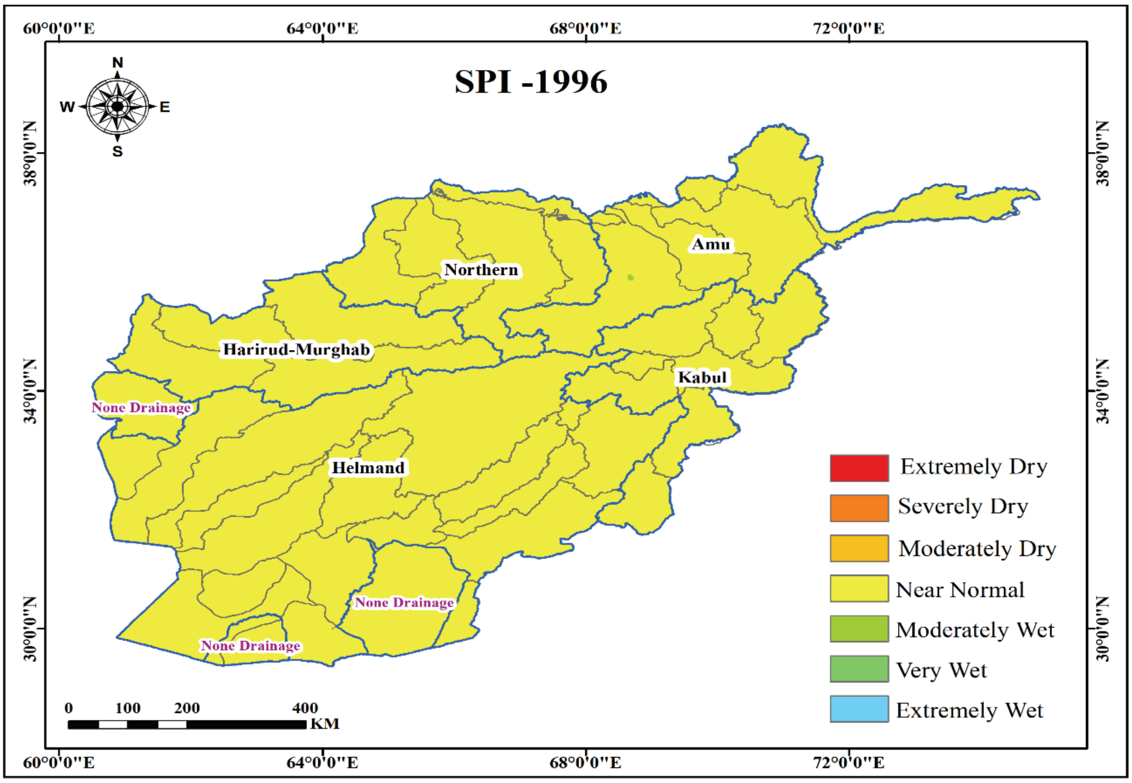


Figure 4.18. 1996 SPI Map

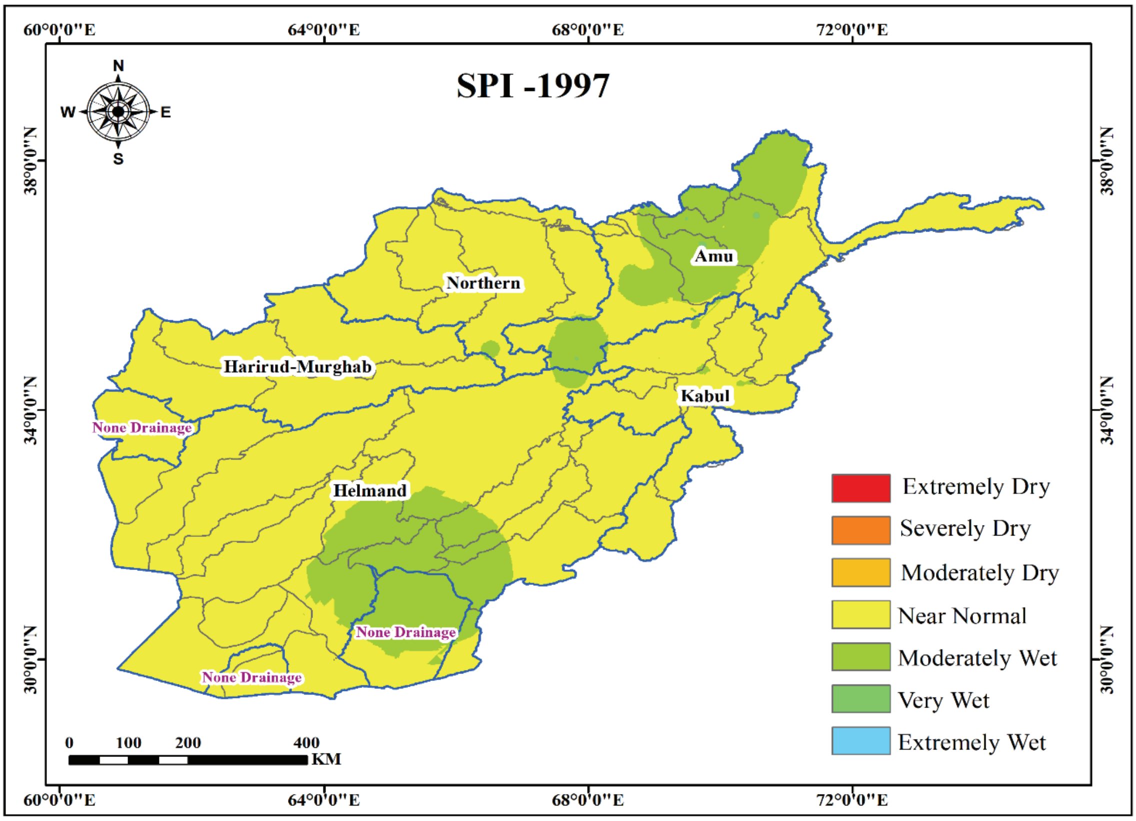


Figure 4.19. 1997 SPI Map

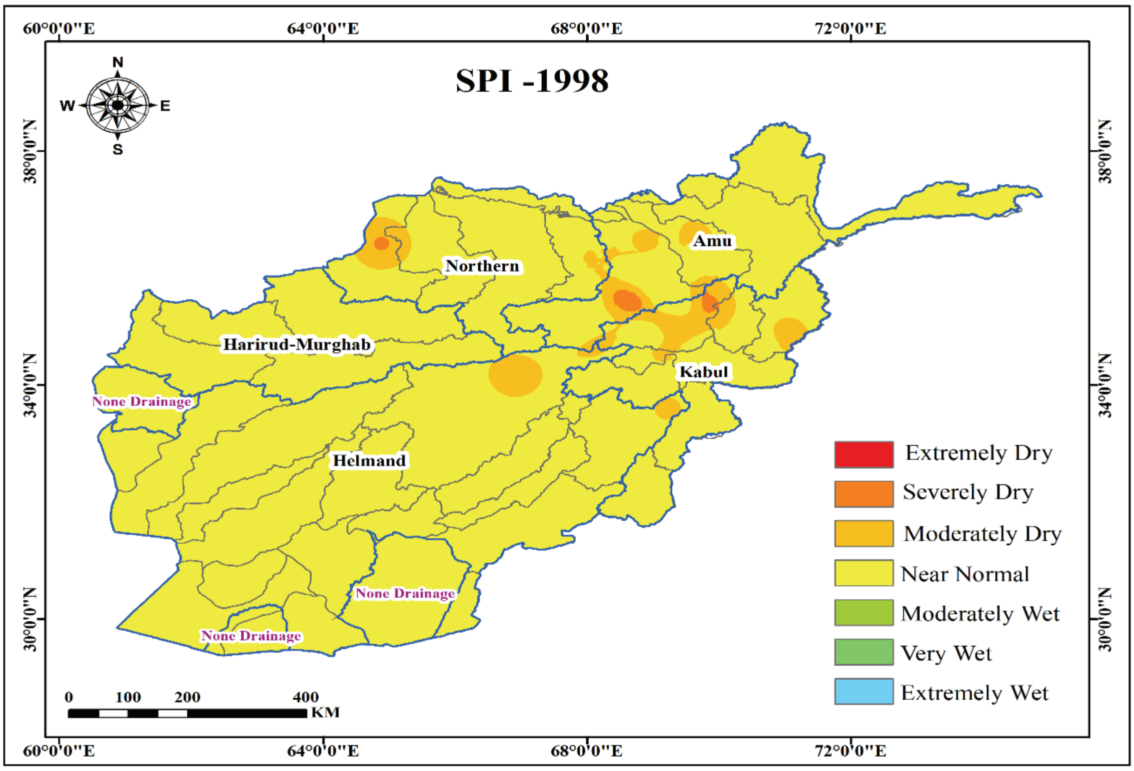


Figure 4.20. 1998 SPI Map

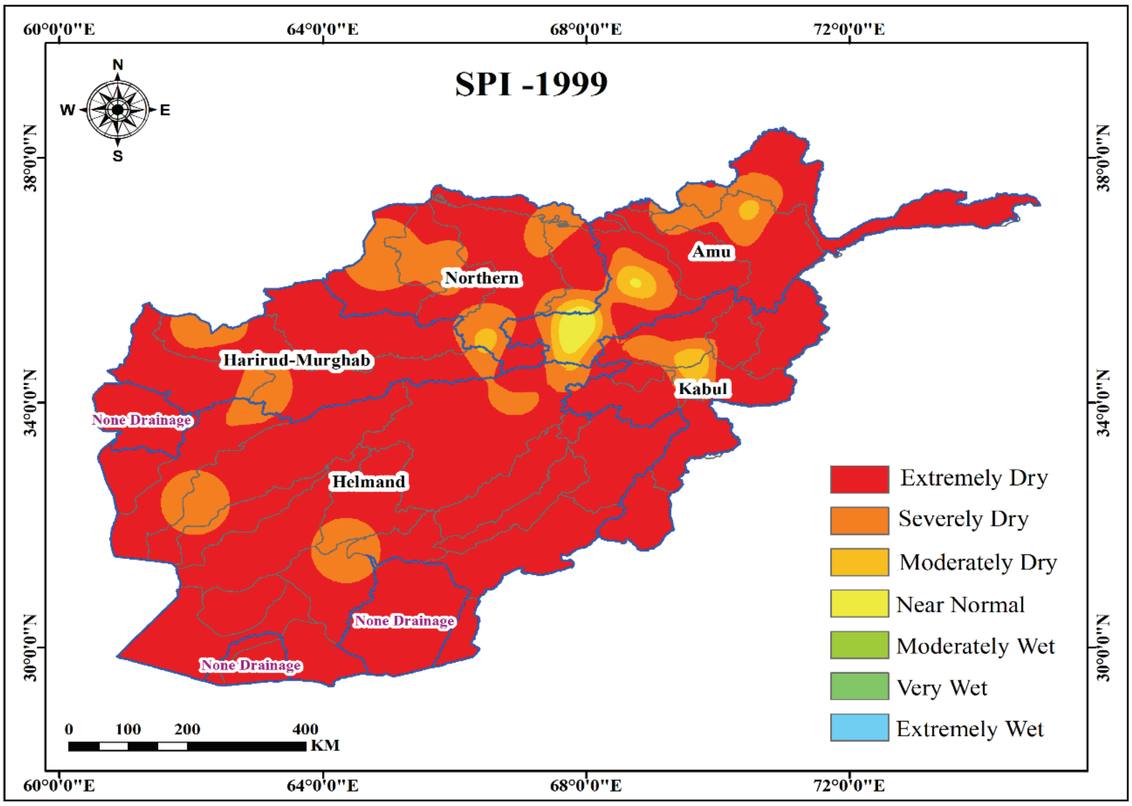


Figure 4.21. 1999 SPI Map

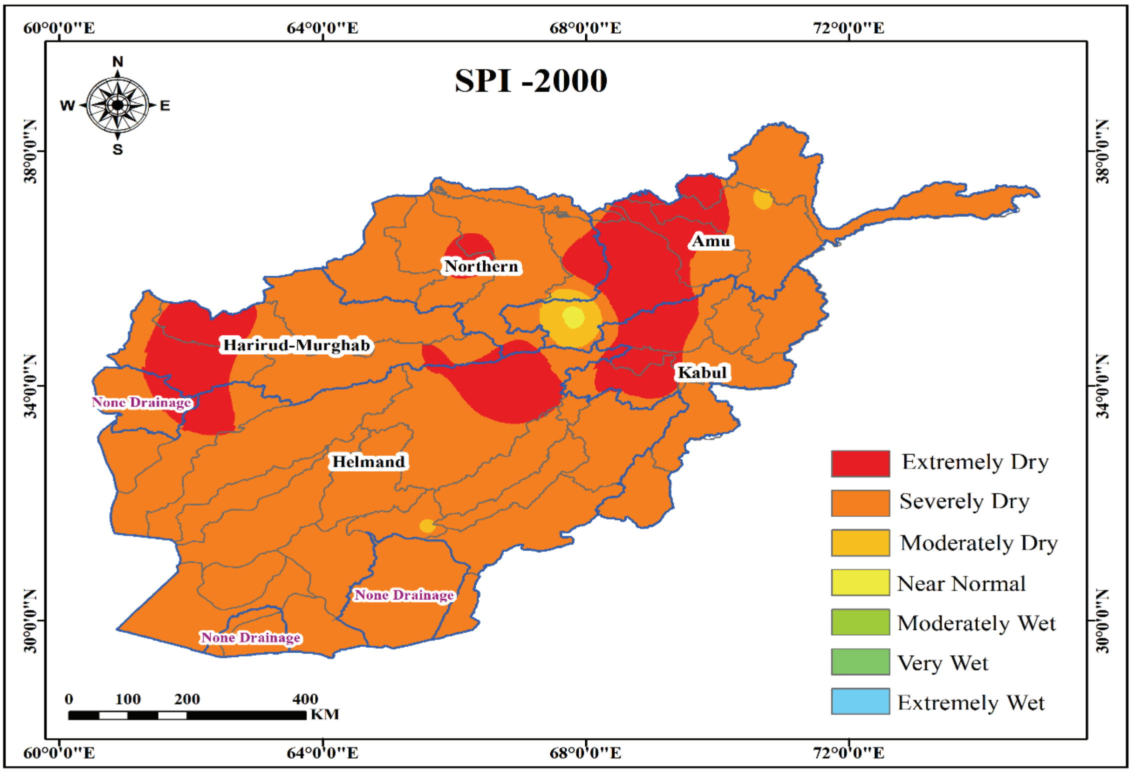


Figure 4.22. 2000 SPI Map

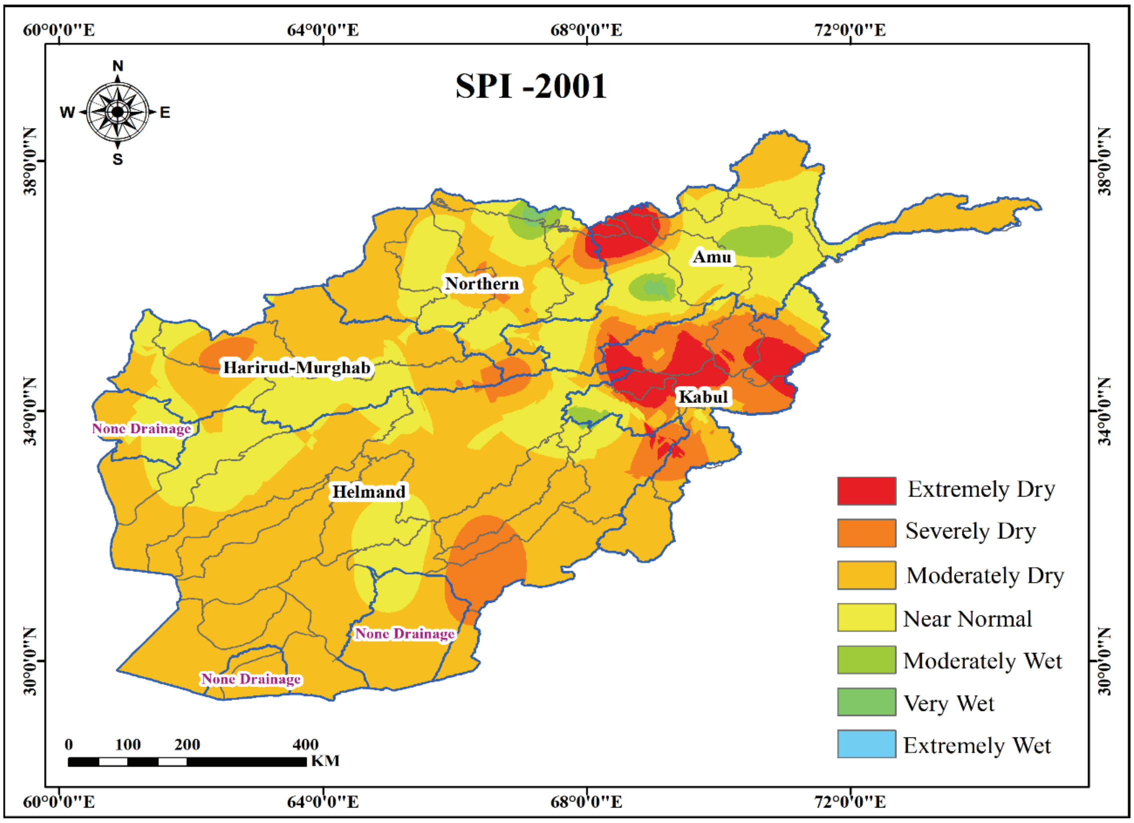


Figure 4.23. 2001 SPI Map

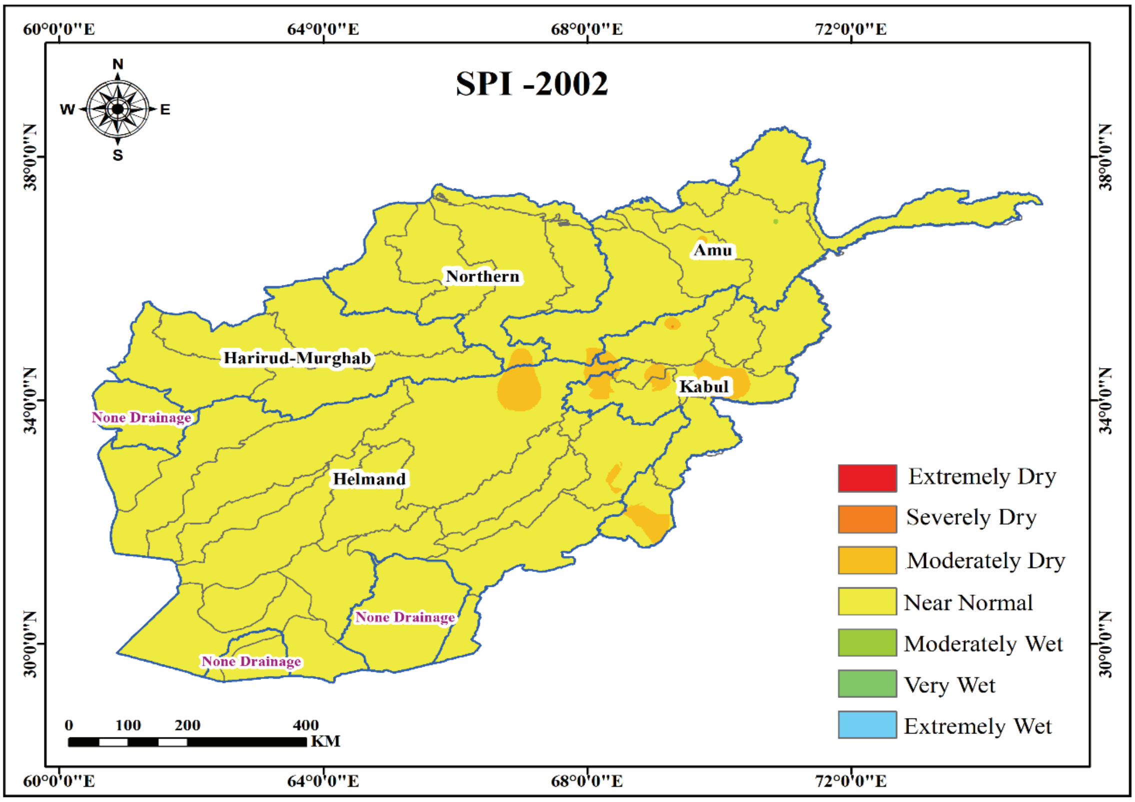


Figure 4.24. 2002 SPI Map

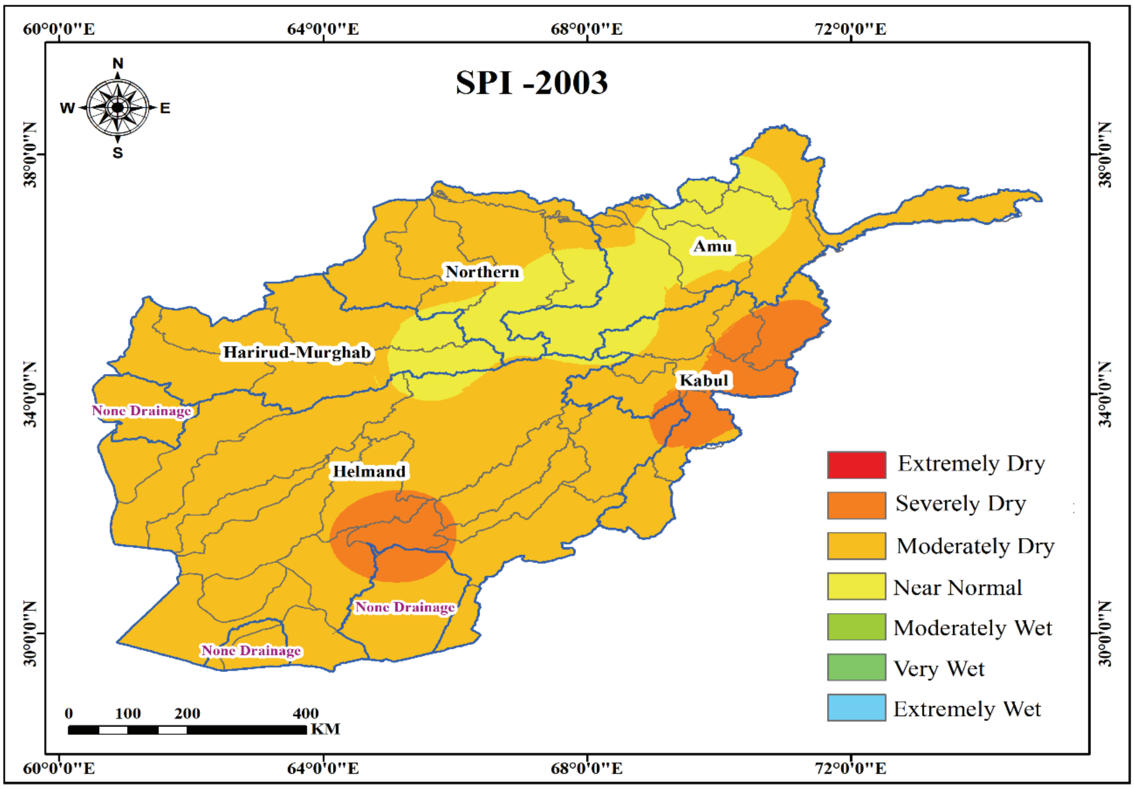


Figure 4.25. 2003 SPI Map

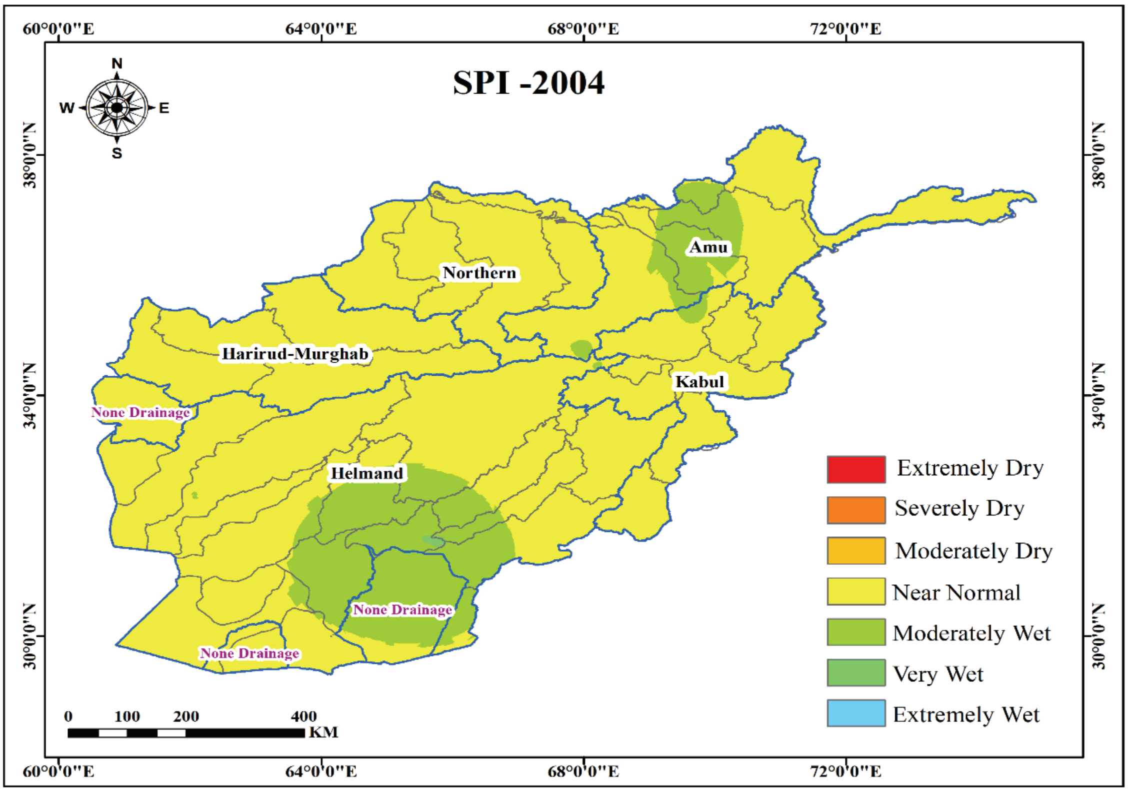


Figure 4.26. 2004 SPI Map

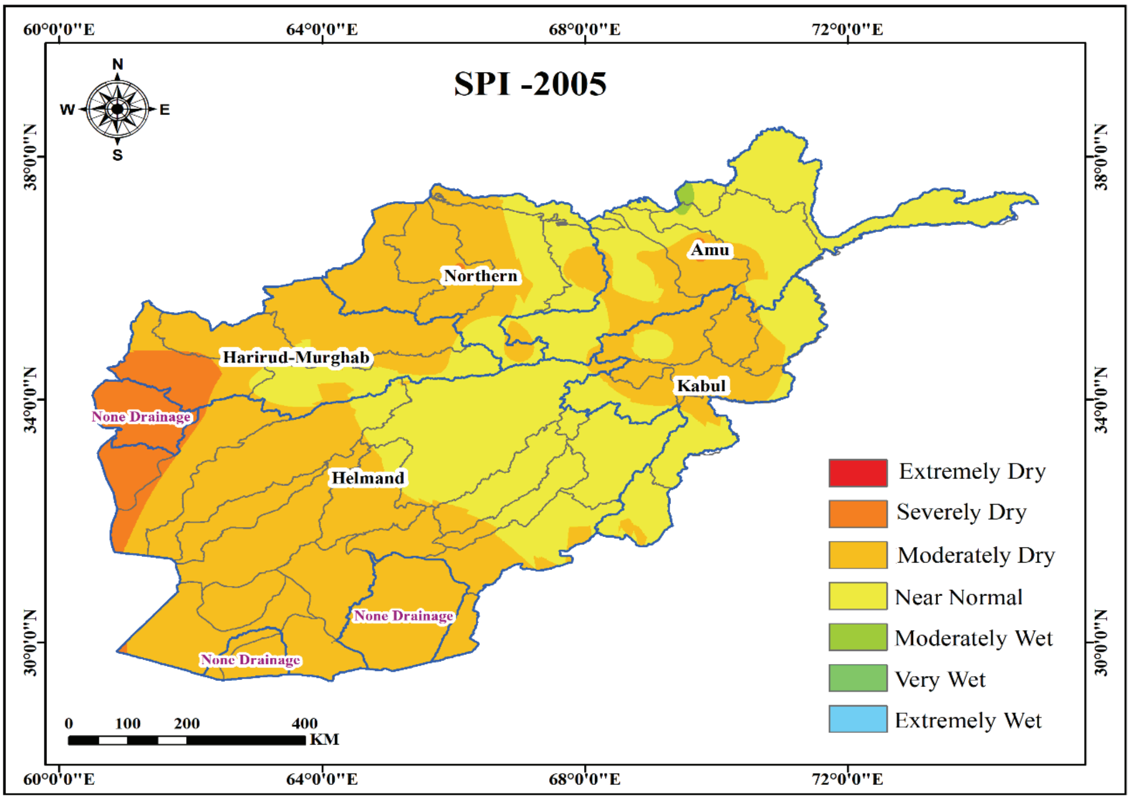


Figure 4.27. 2005 SPI Map

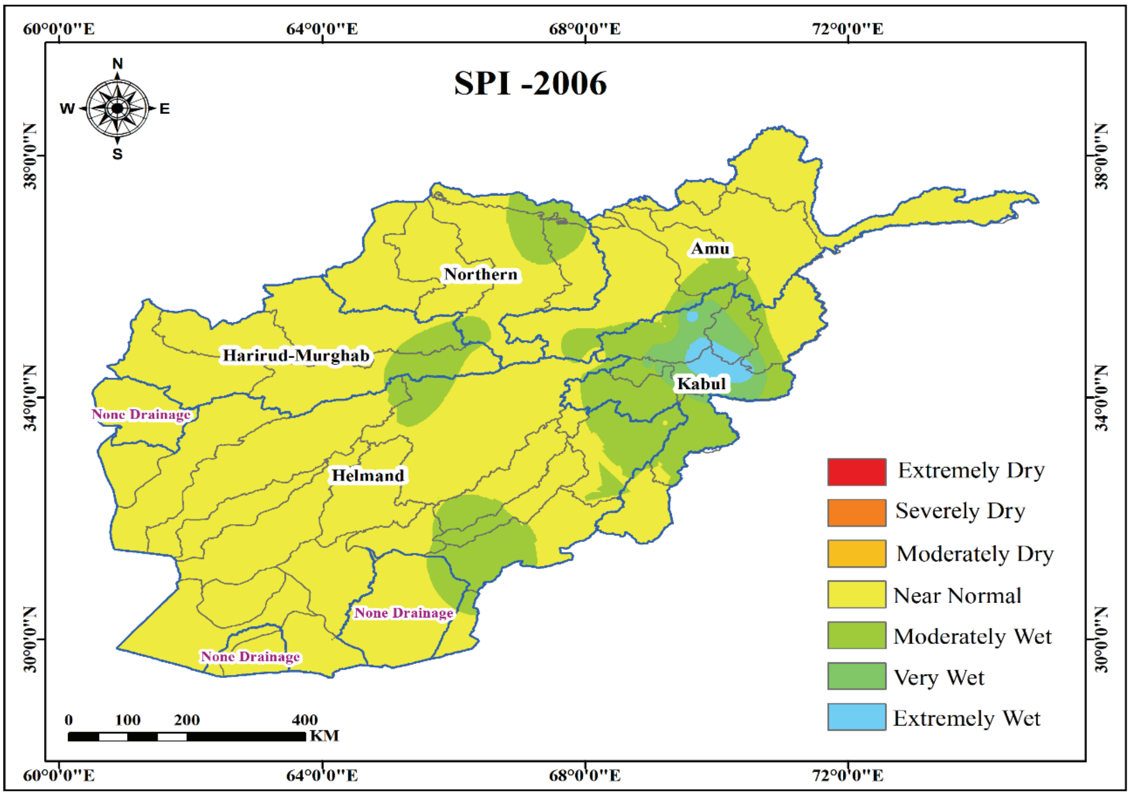


Figure 4.28. 2006 SPI Map

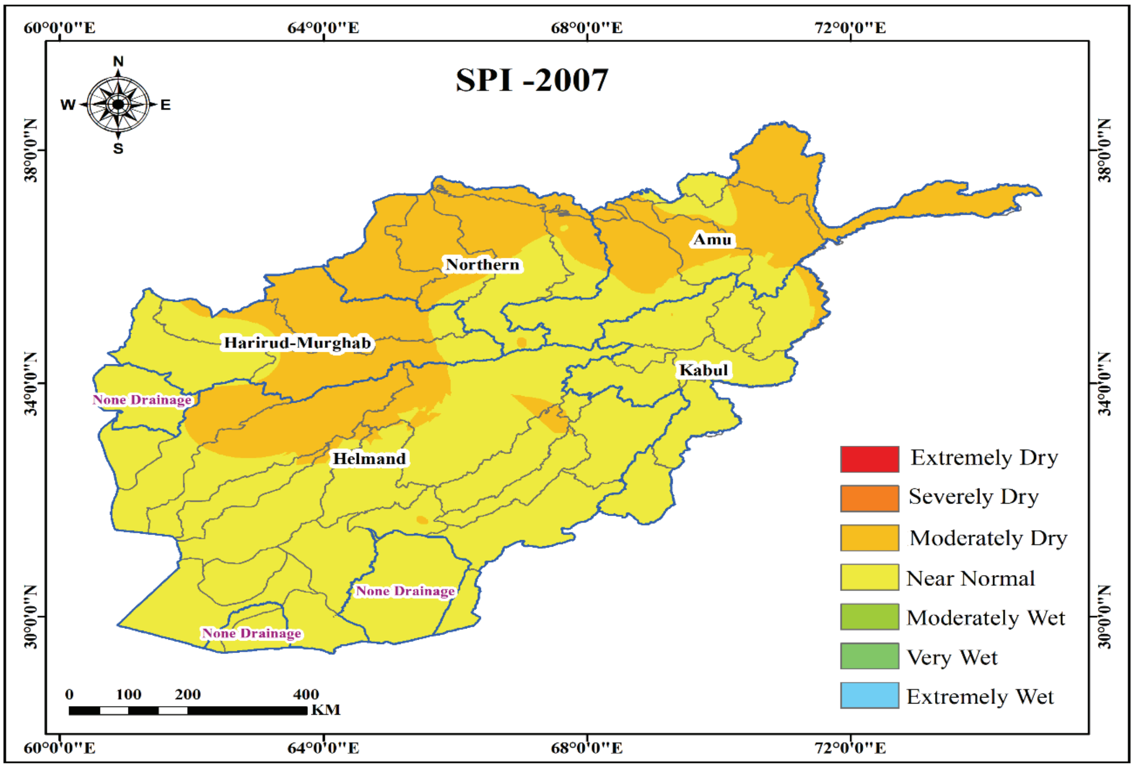


Figure 4.29. 2007 SPI Map

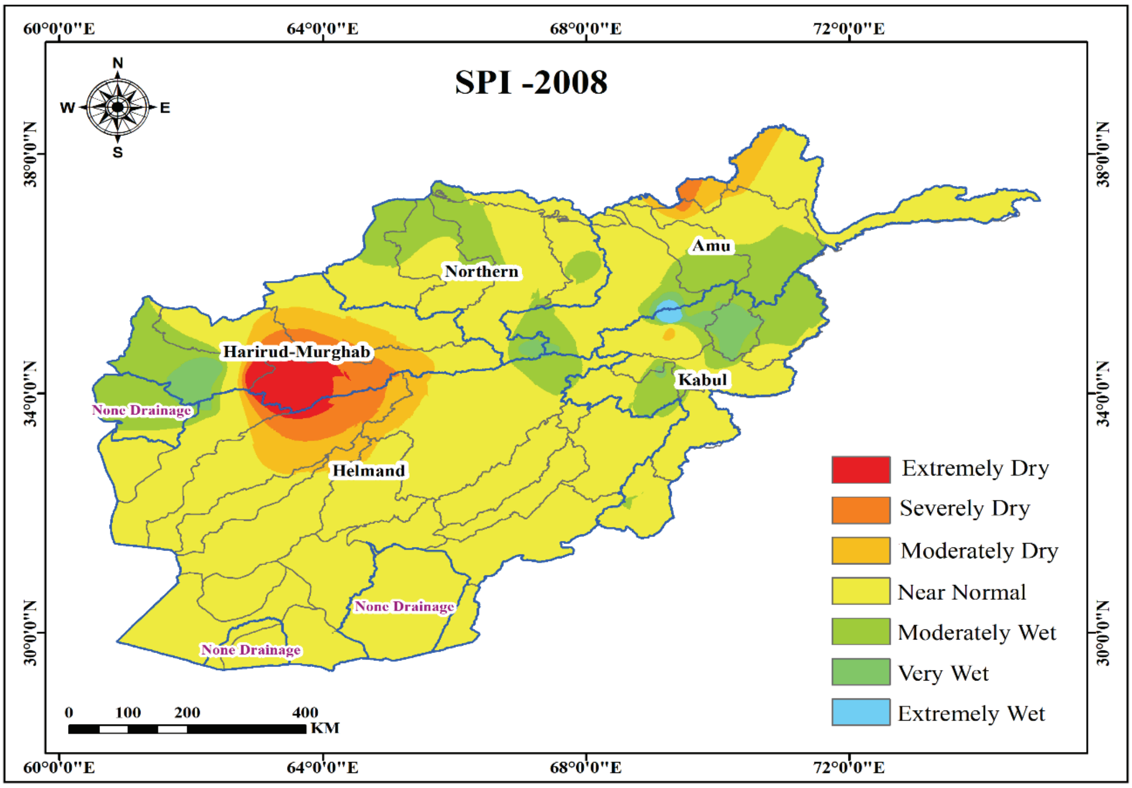


Figure 4.30. 2008 SPI Map

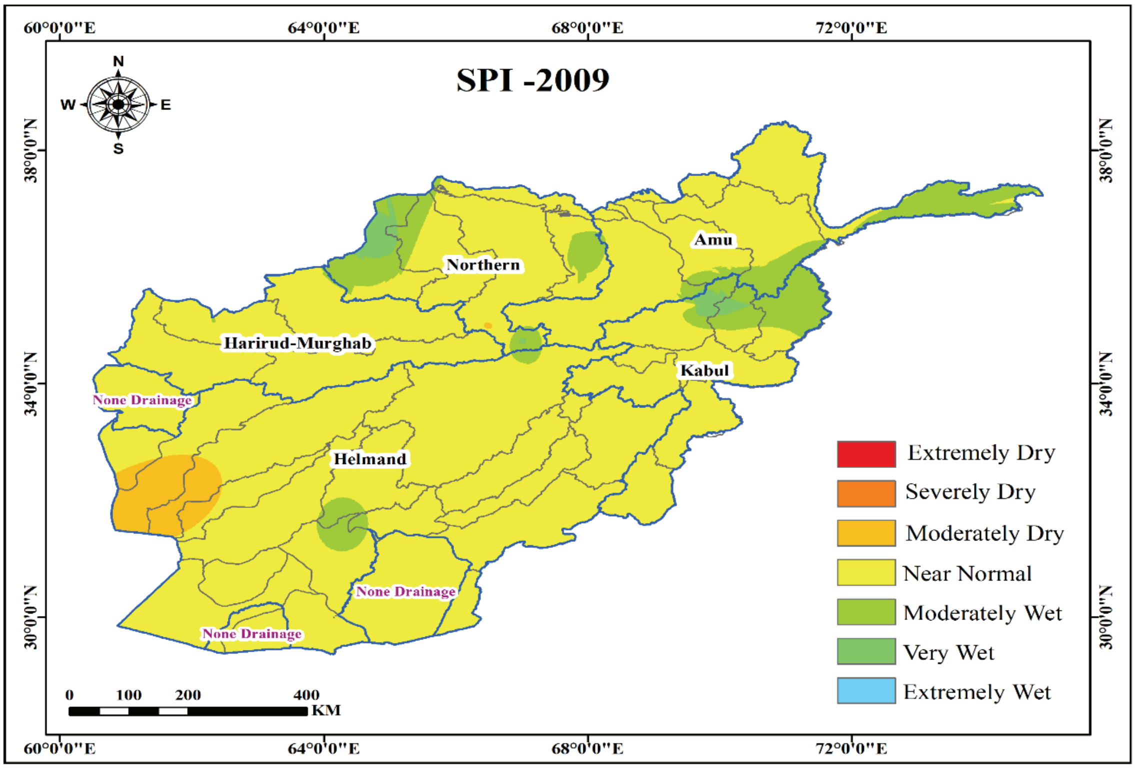


Figure 4.31. 2009 SPI Map

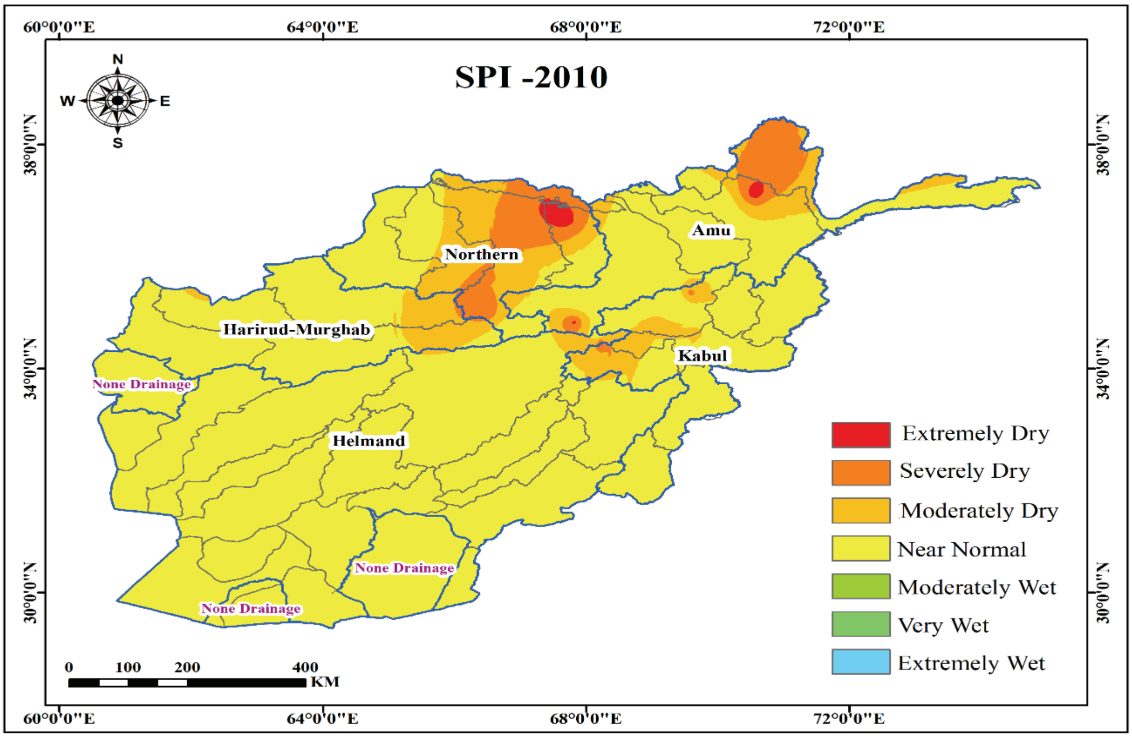


Figure 4.32. 2010 SPI Map

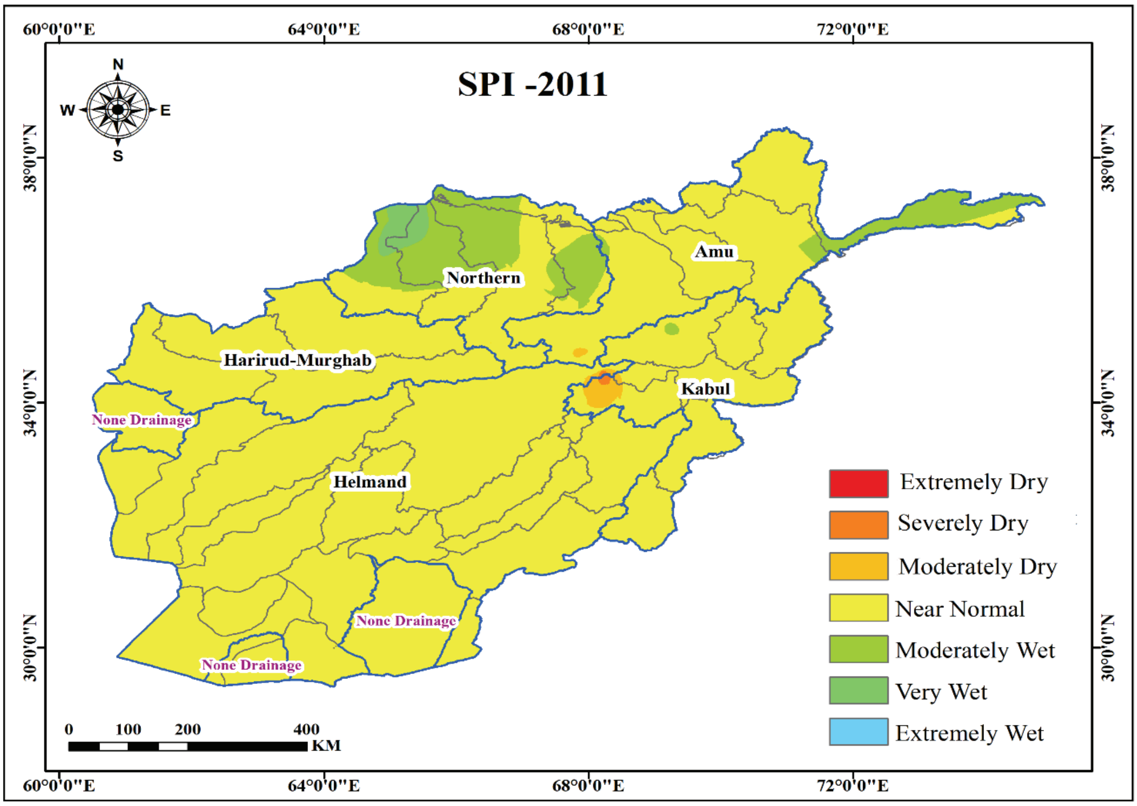


Figure 4.33. 2011 SPI Map

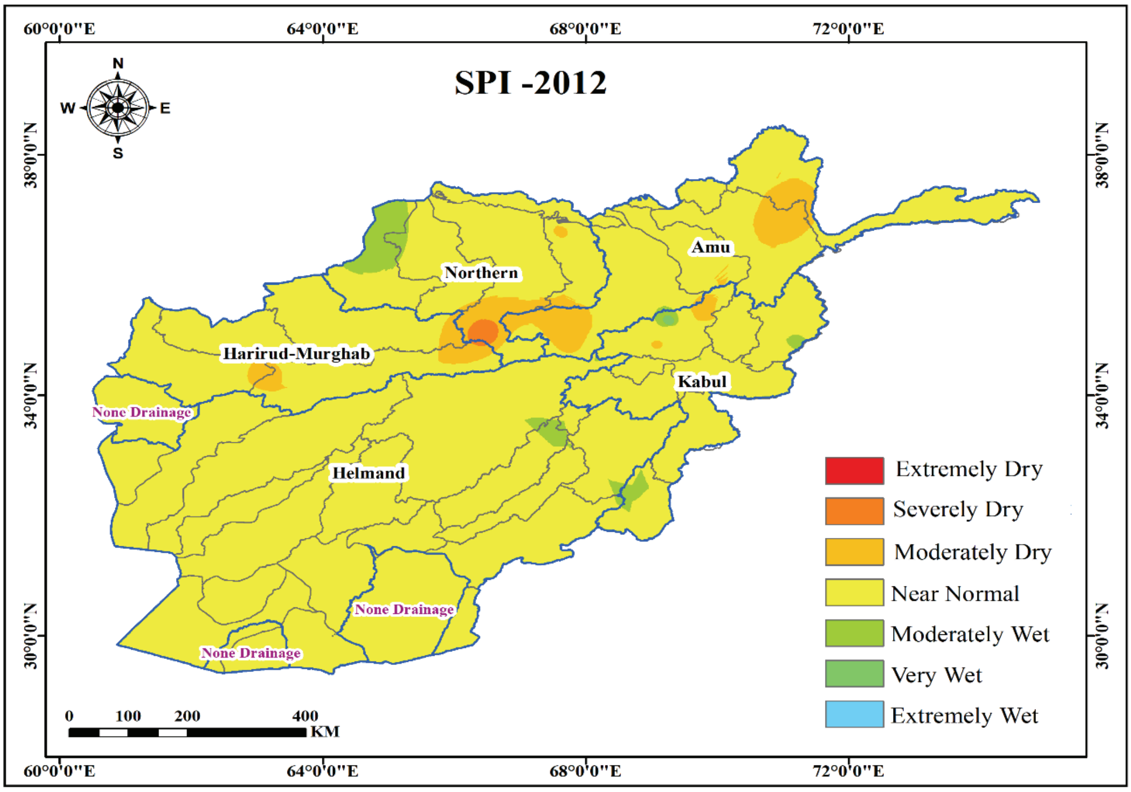


Figure 4.34. 2012 SPI Map

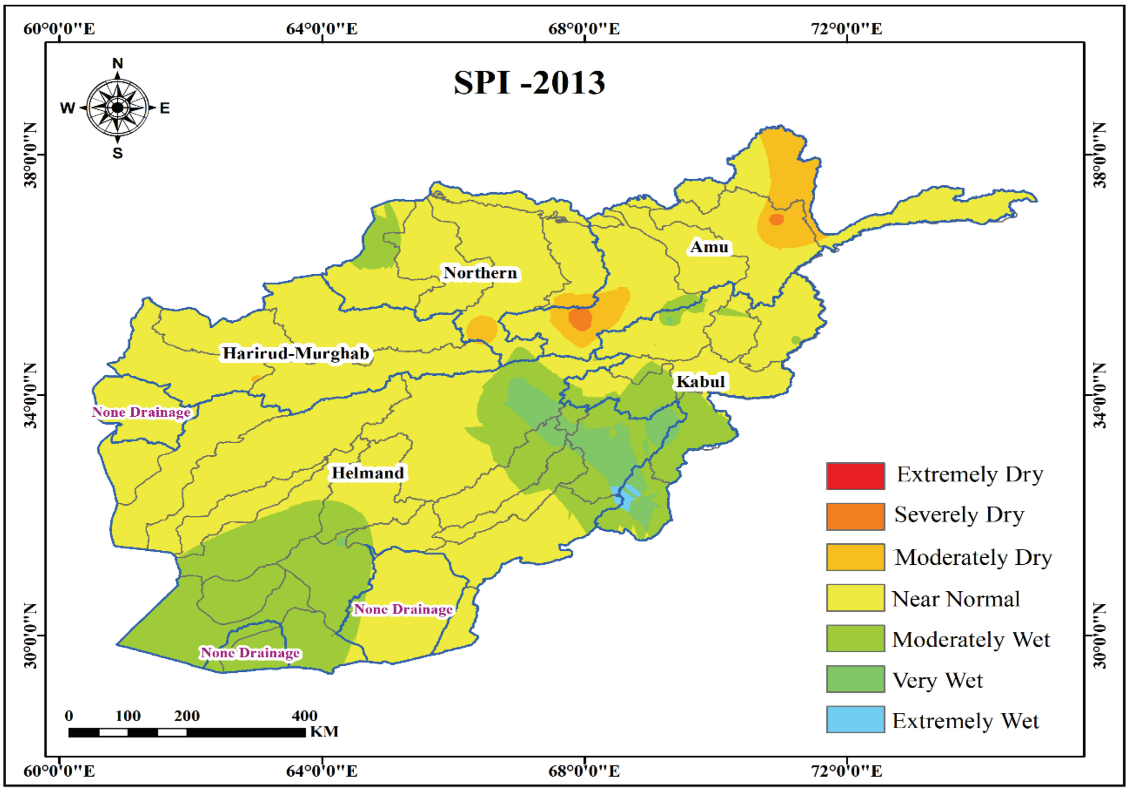


Figure 4.35. 2013 SPI Map

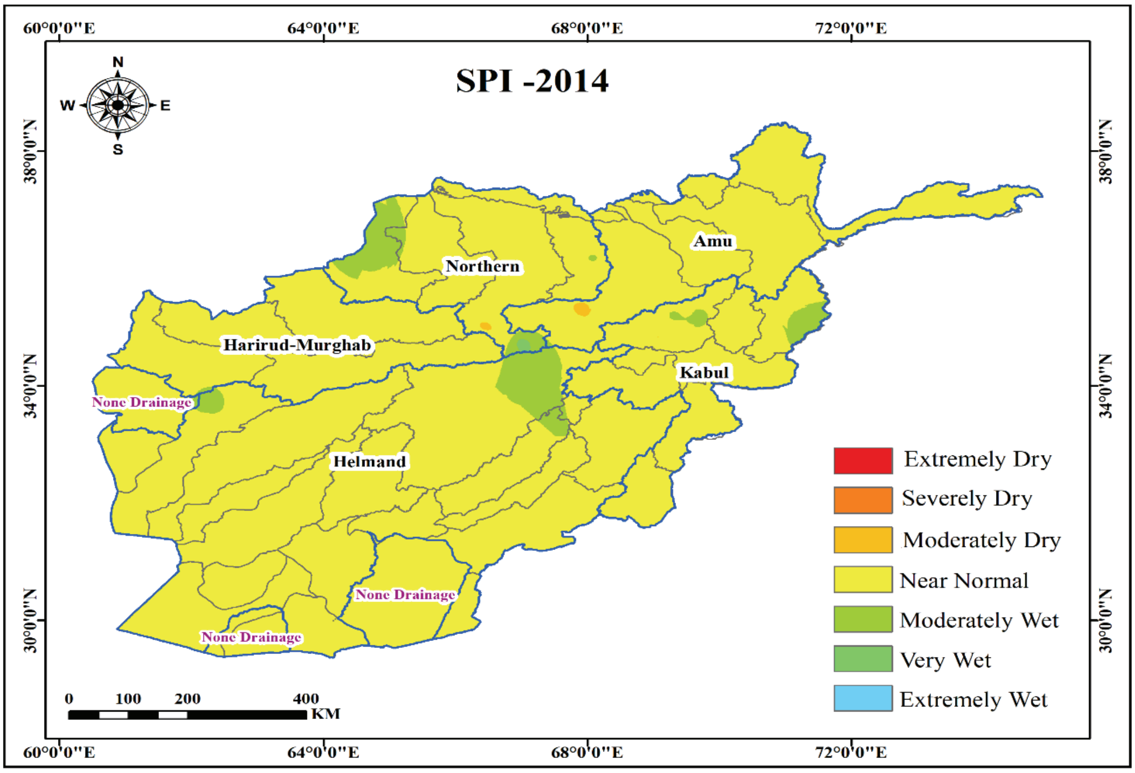


Figure 4.36. 2014 SPI Map

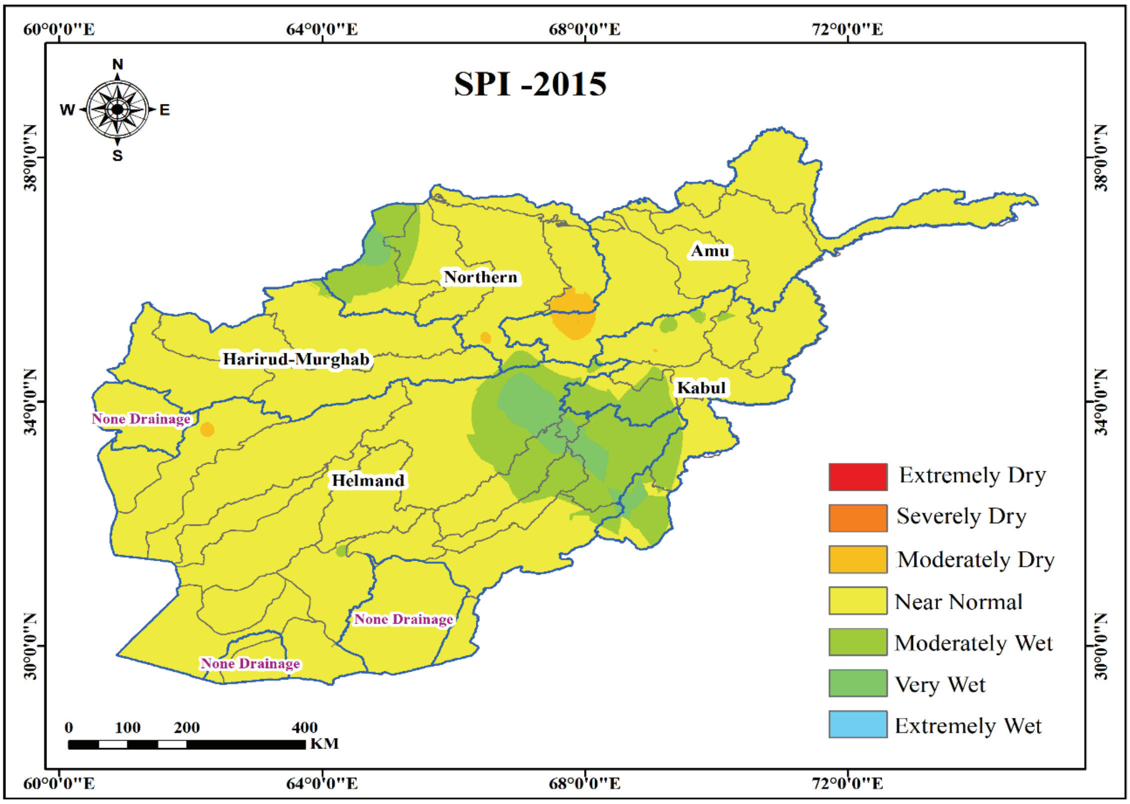


Figure 4.37. 2015 SPI Map

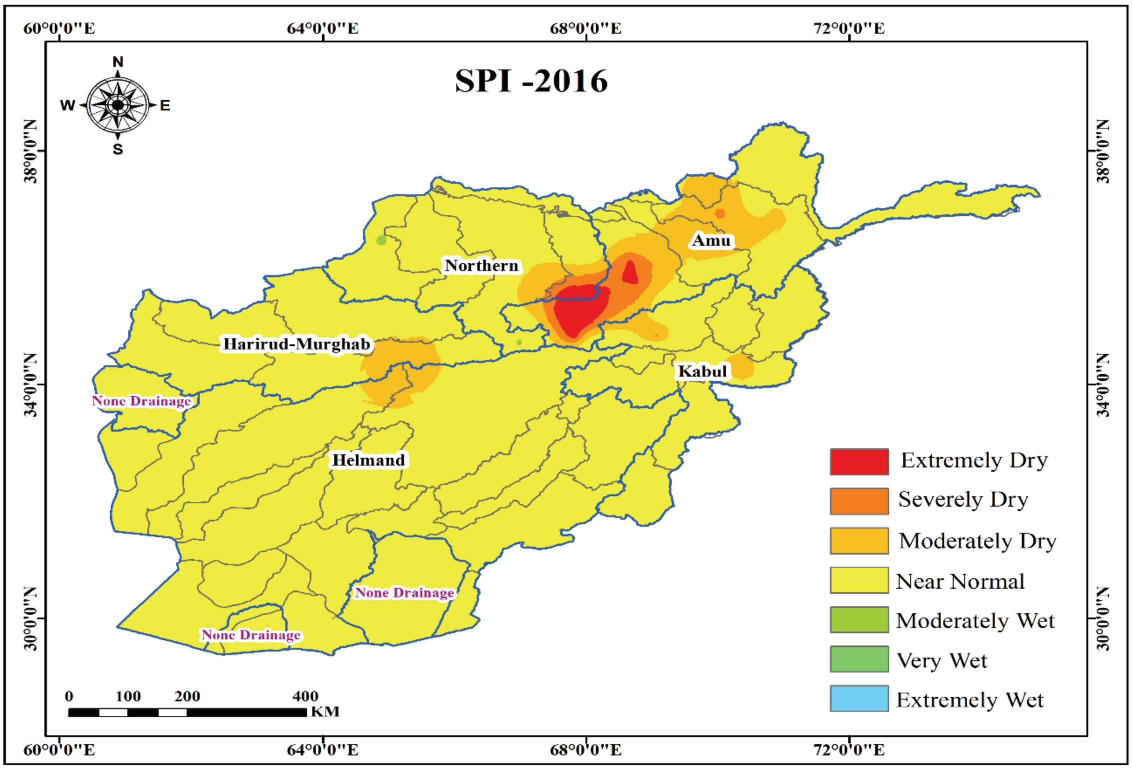


Figure 4.38. 2016 SPI Map

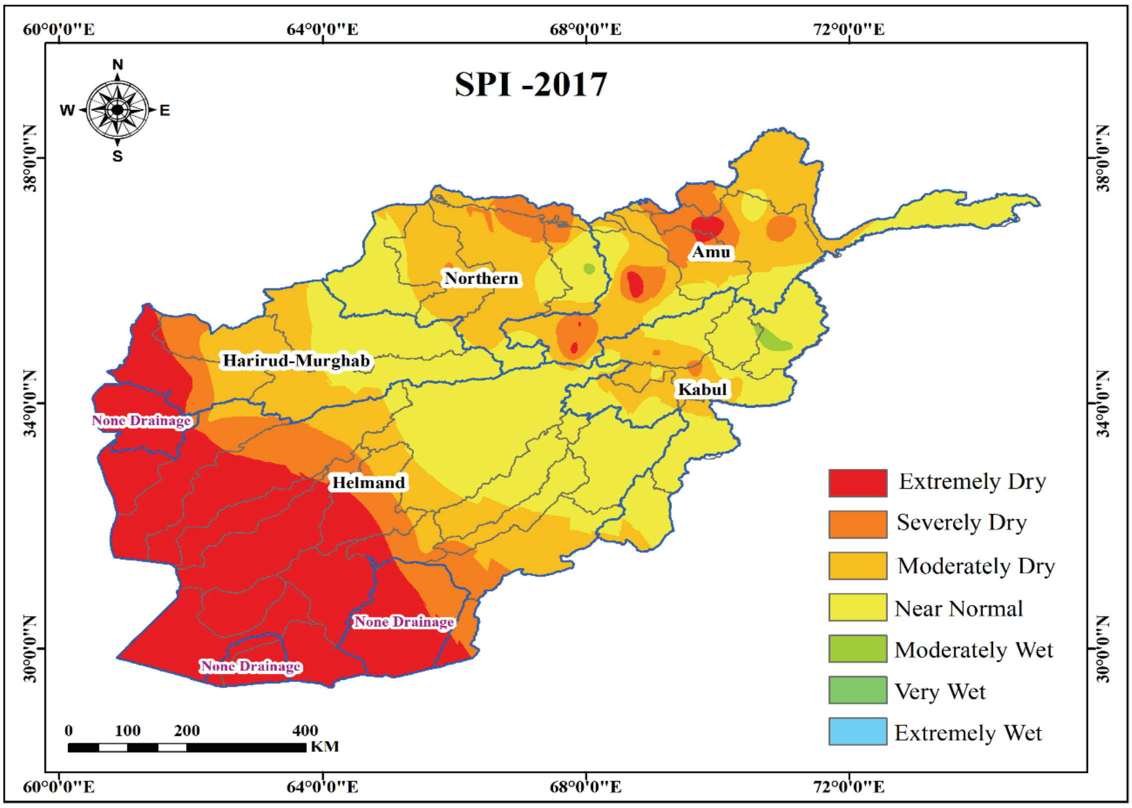


Figure 4.39. 2017 SPI Map

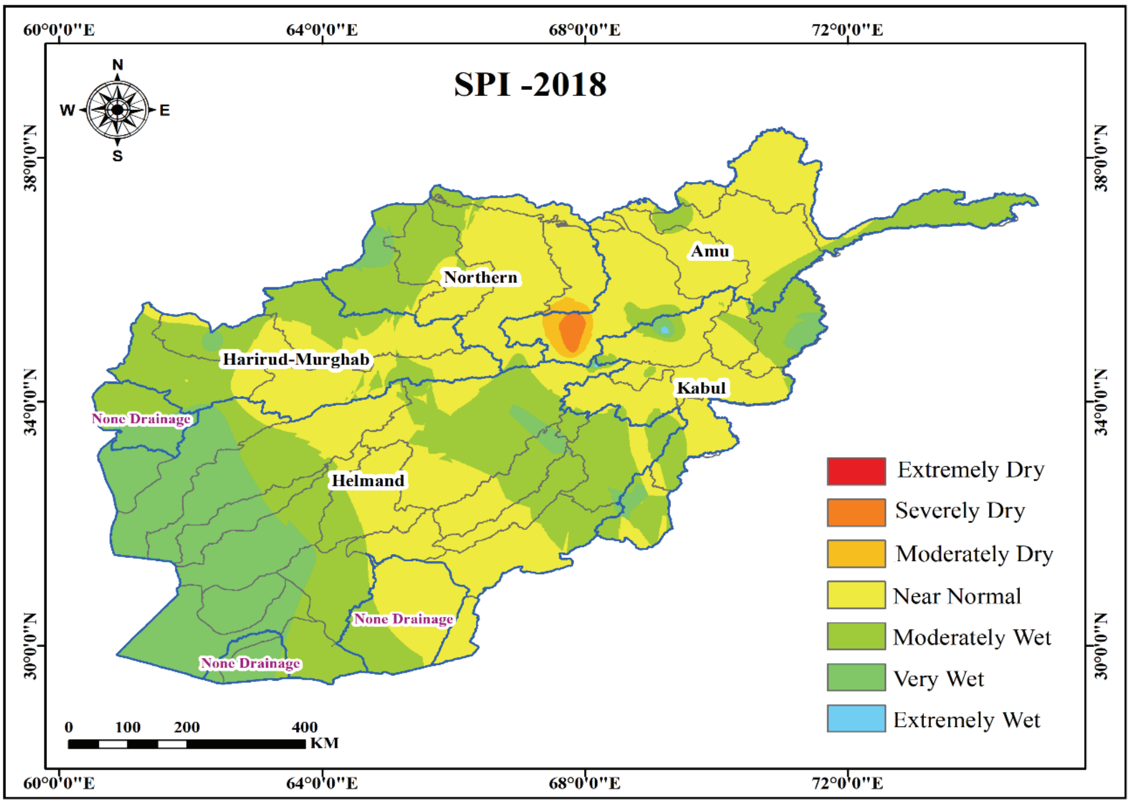


Figure 4.40. 2018 SPI Map

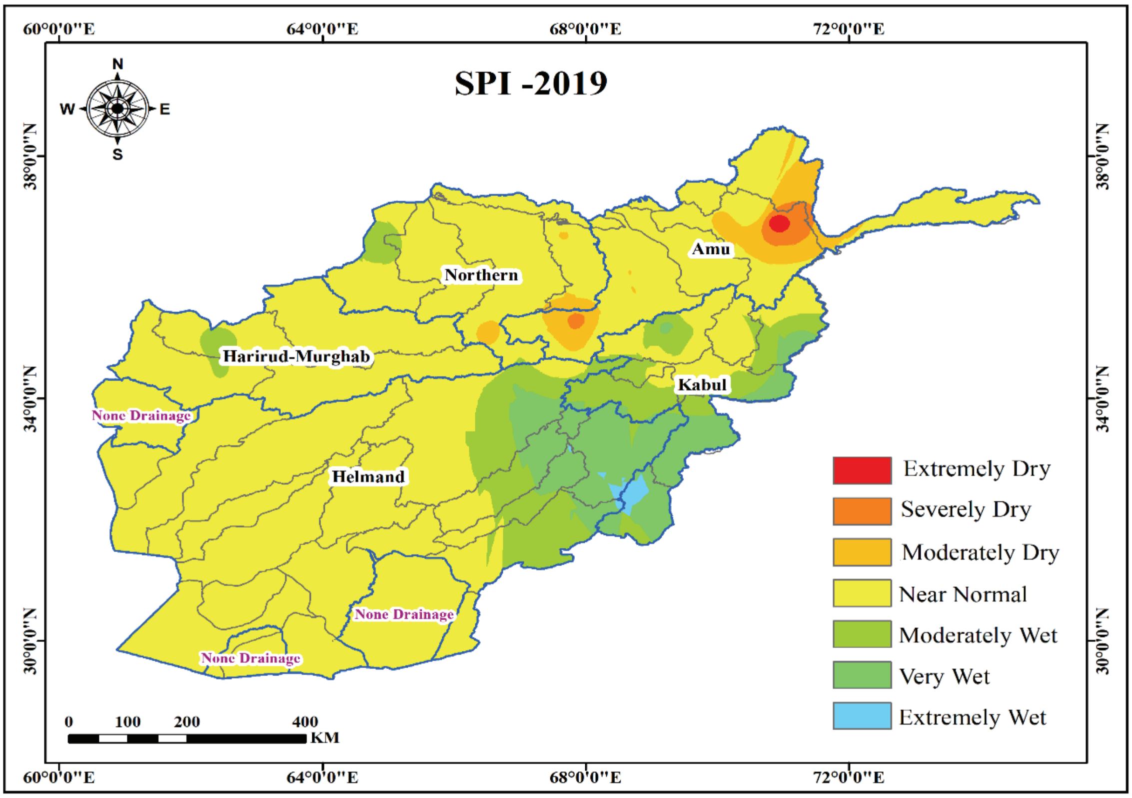


Figure 4.41. 2019 SPI Map

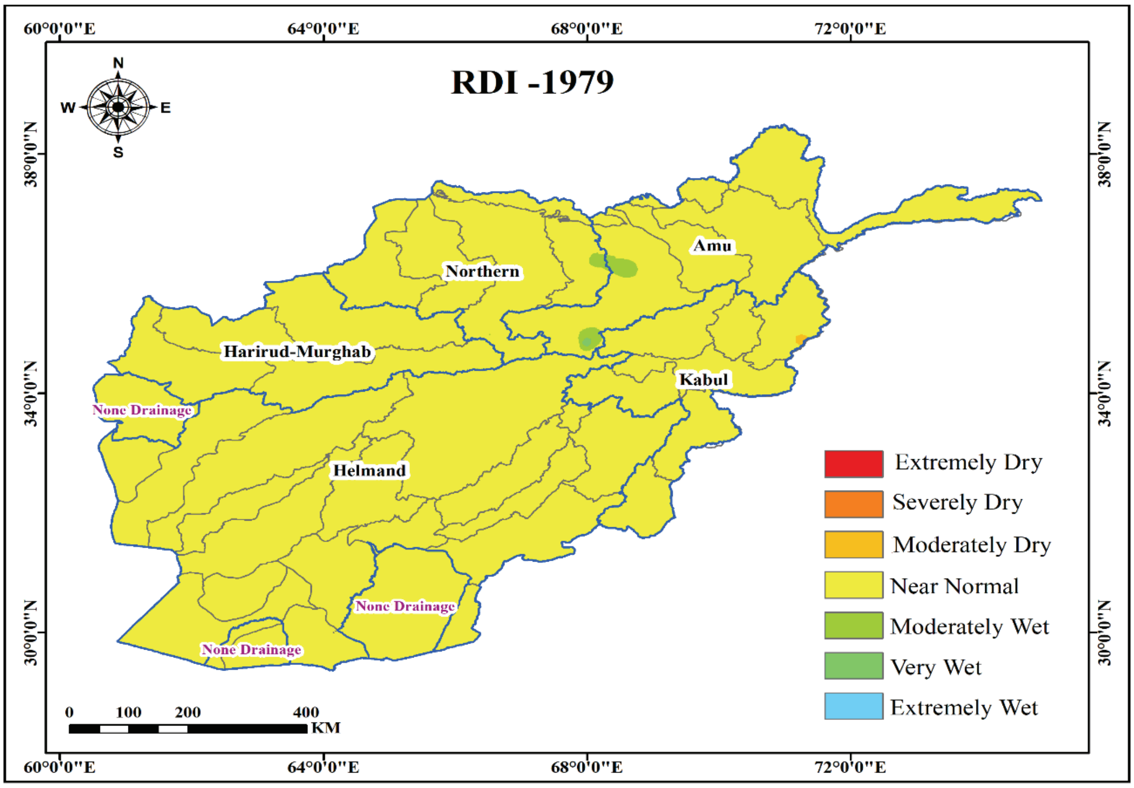
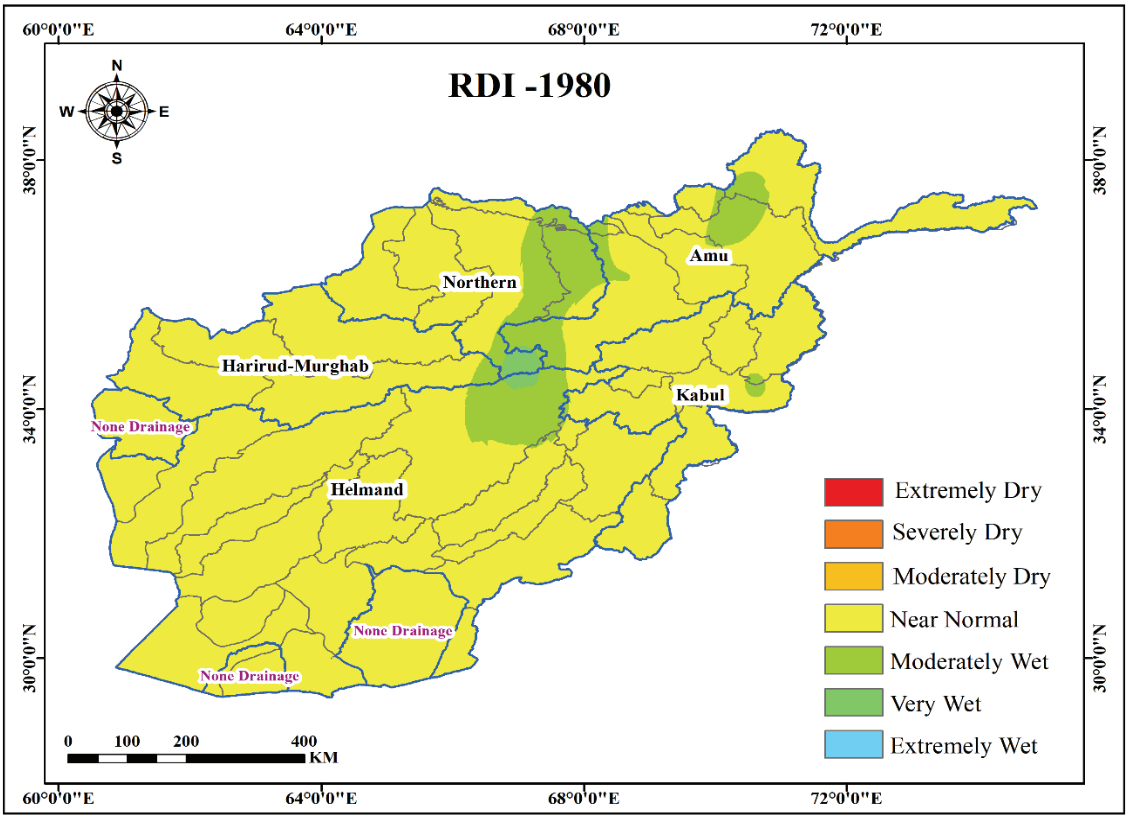


Figure 4.42. 1979 RDI Map



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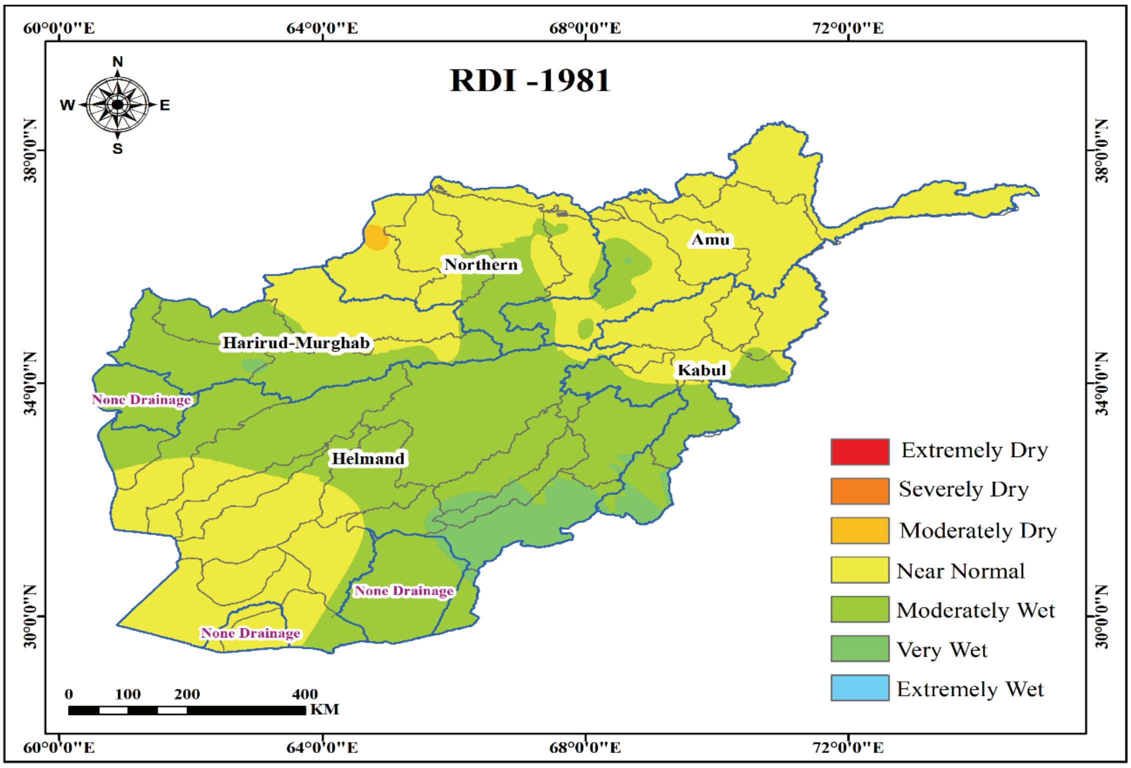

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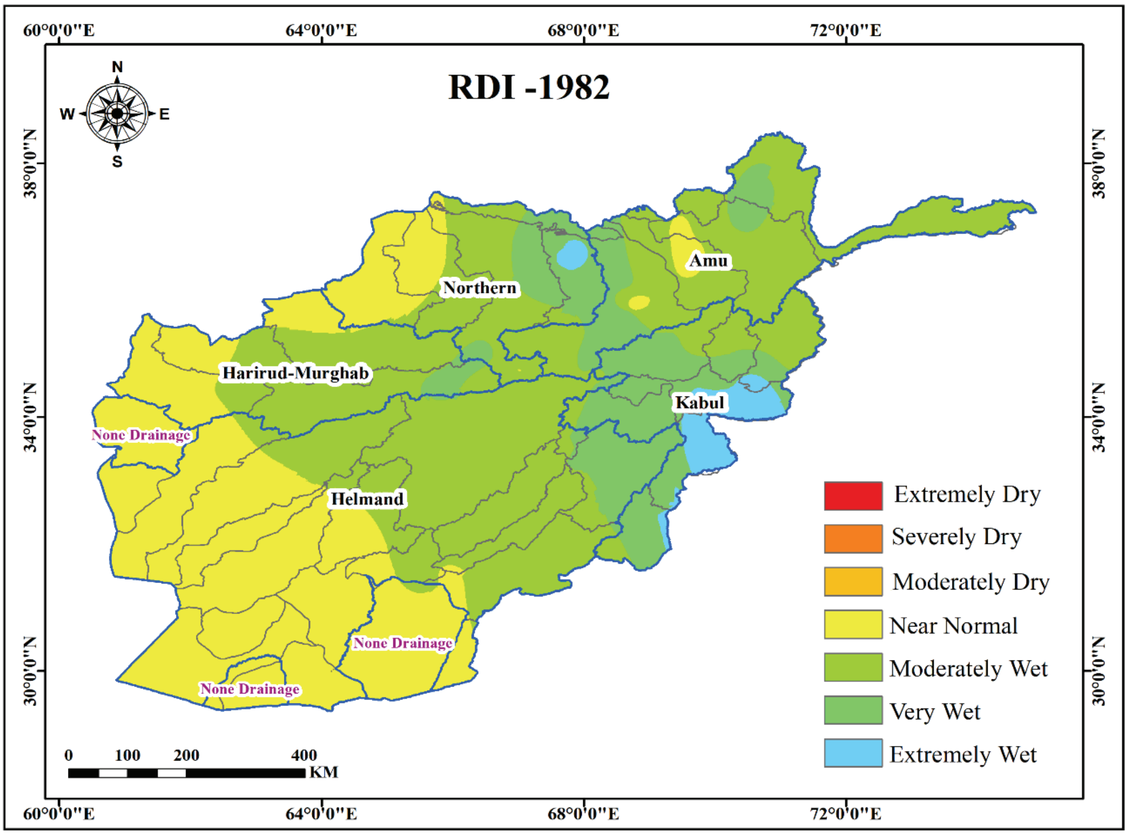

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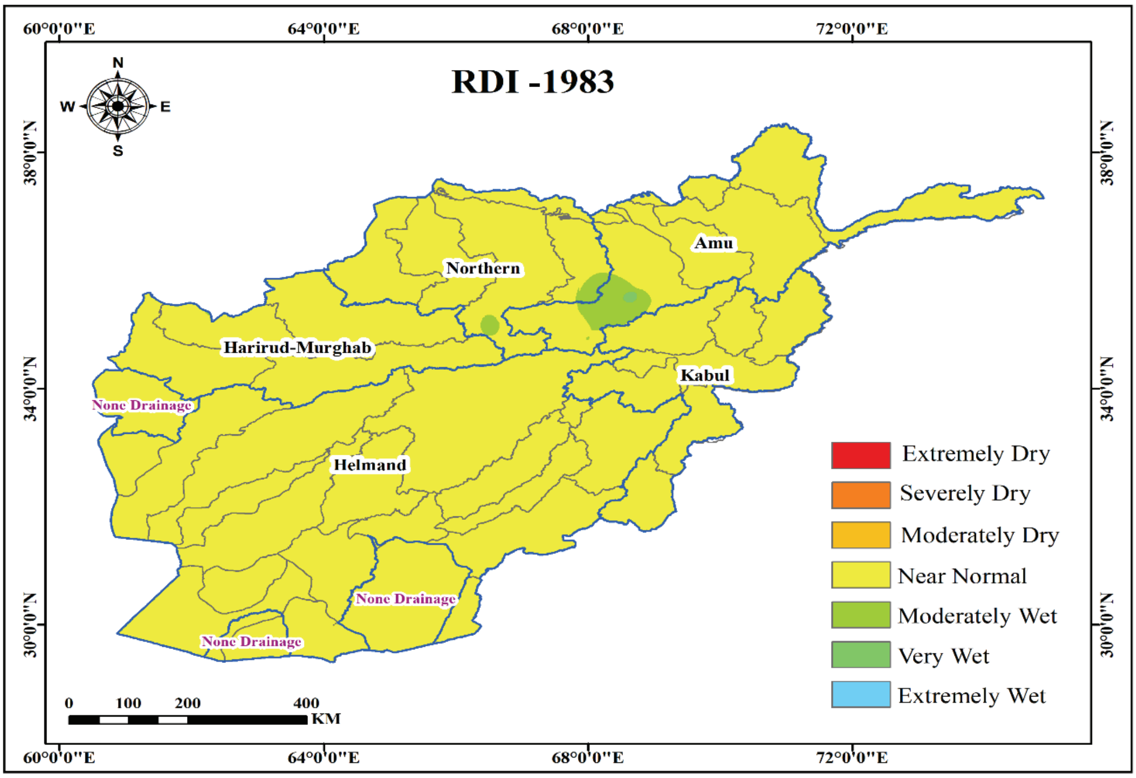

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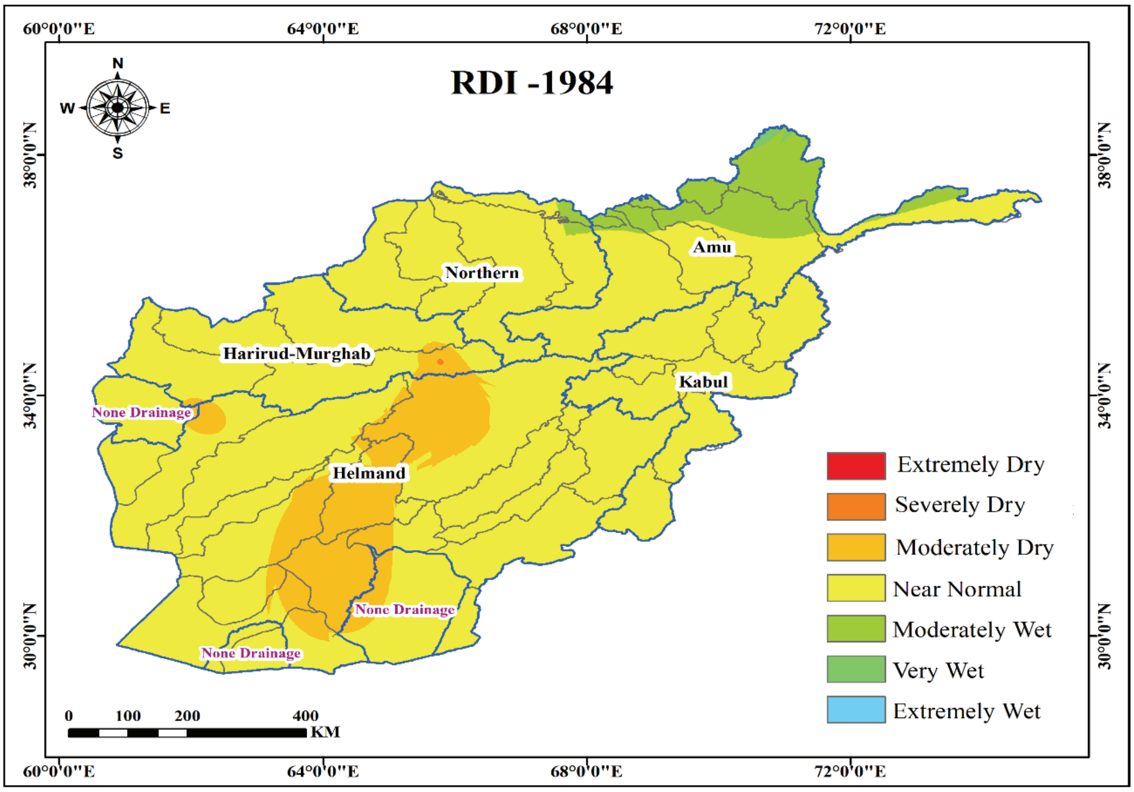
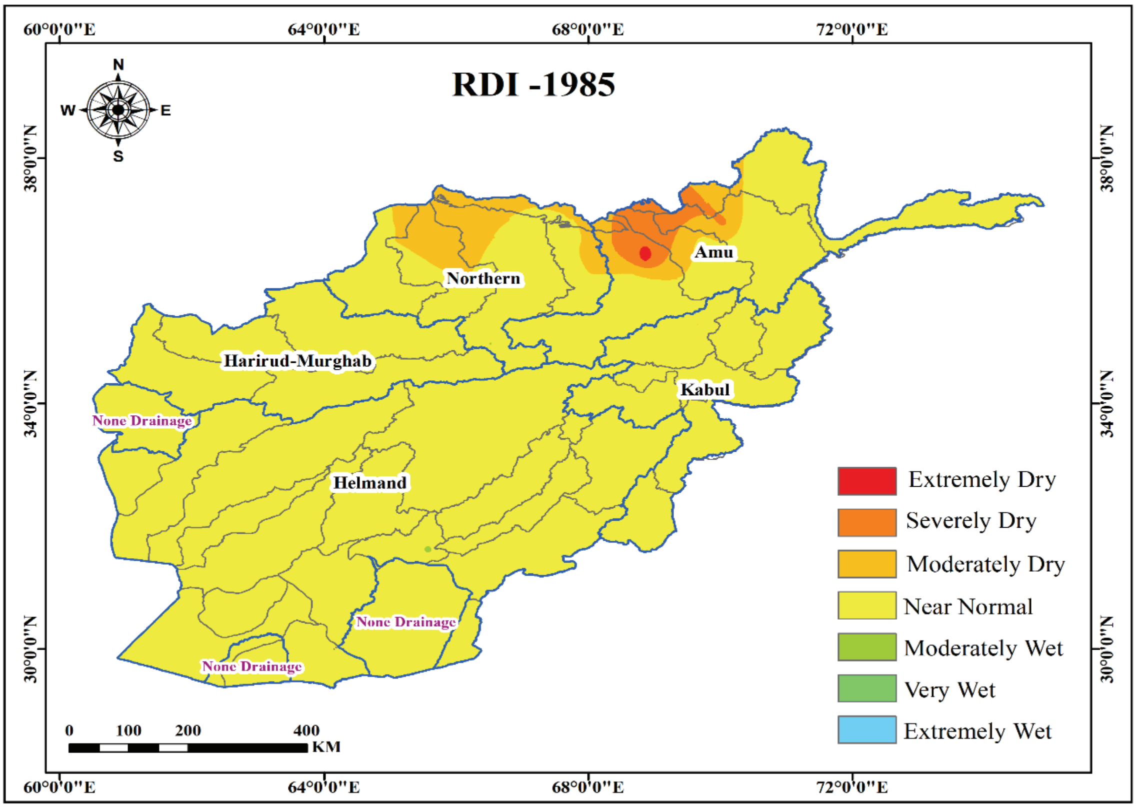


Figure 4.47. 1984 RDI Map



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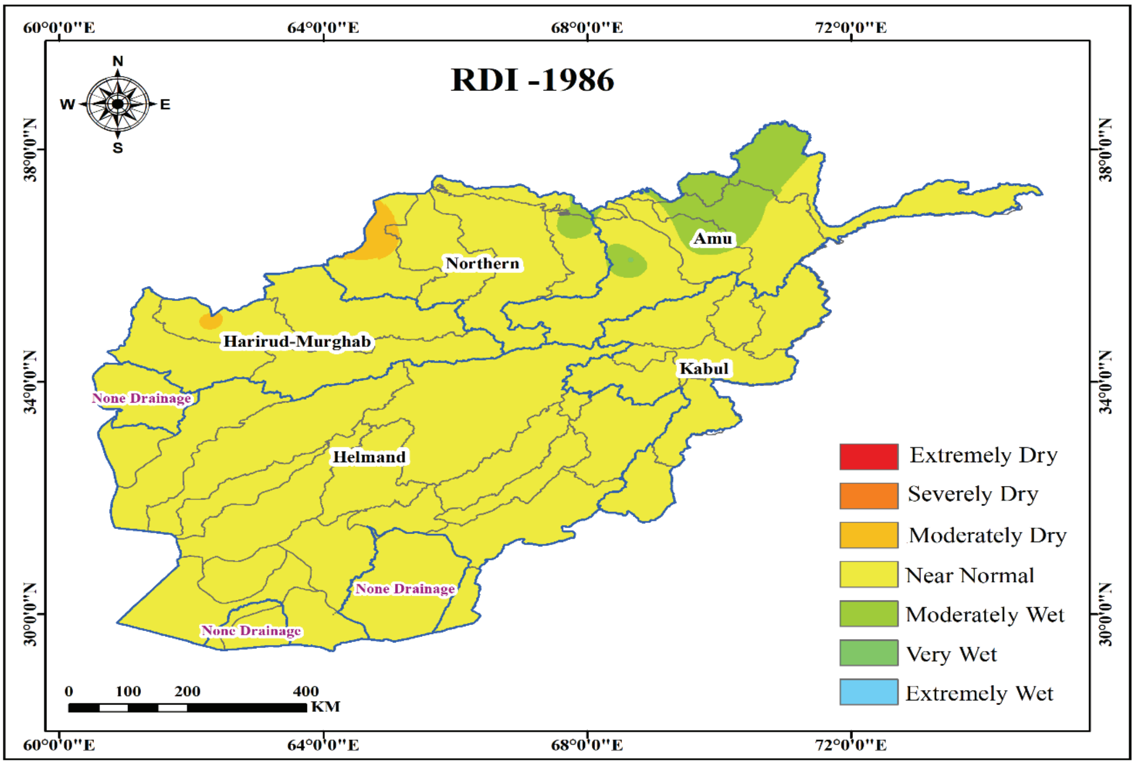

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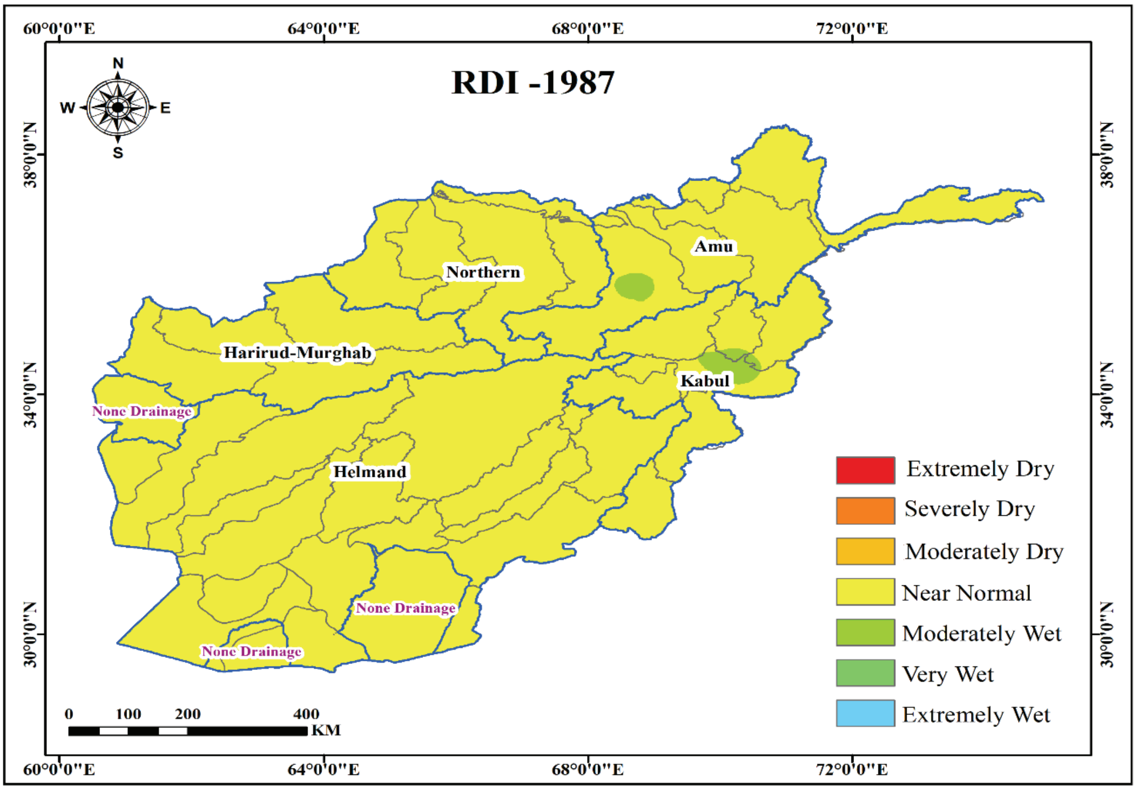

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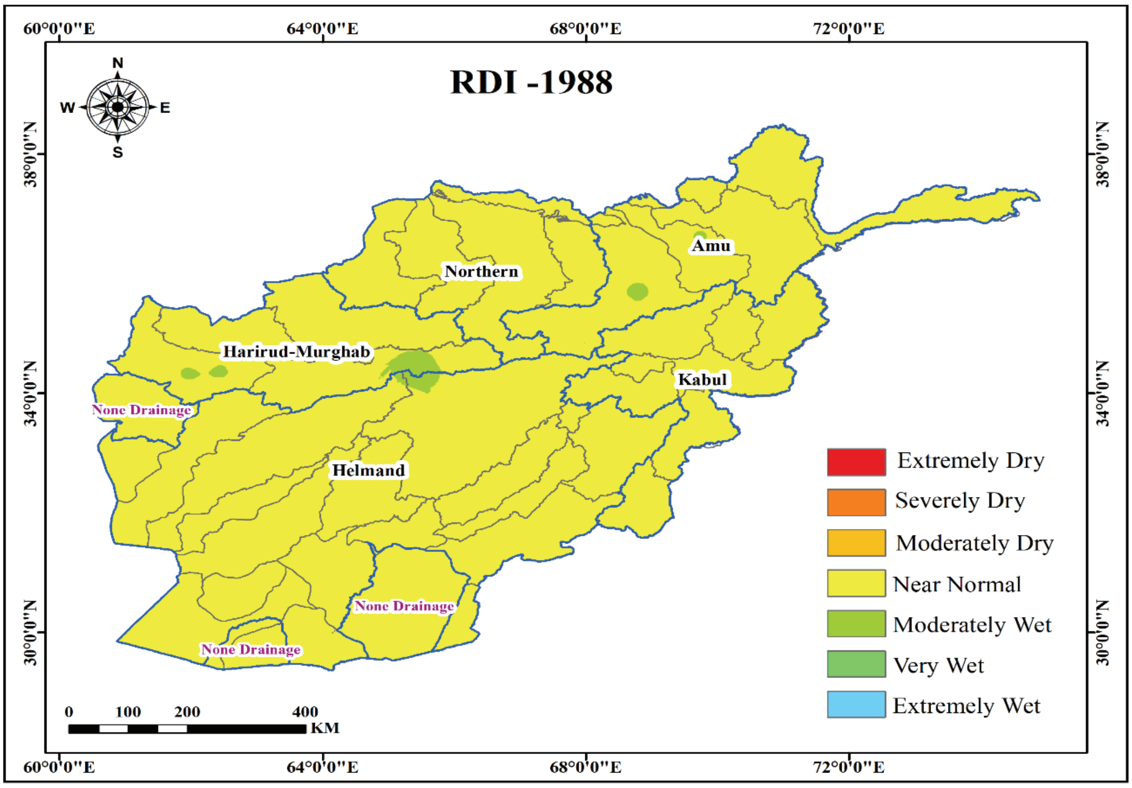


Figure 4.51. 1988 RDI Map

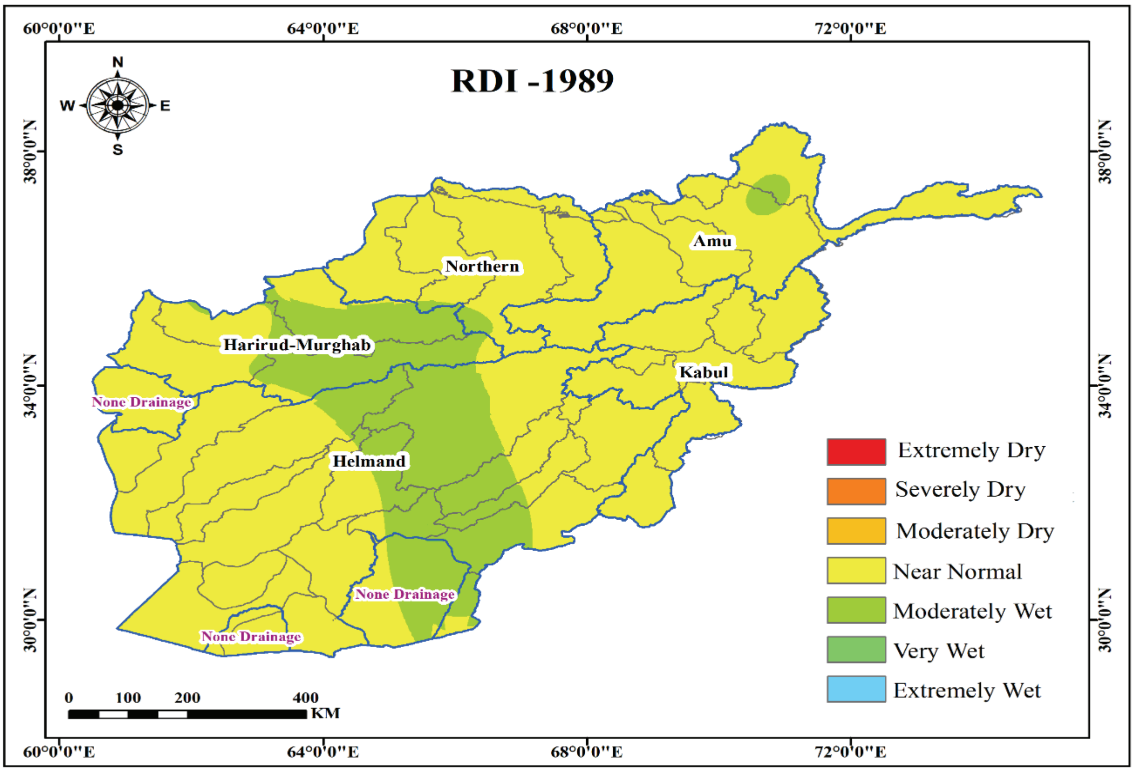


Figure 4.52. 1989 RDI Map

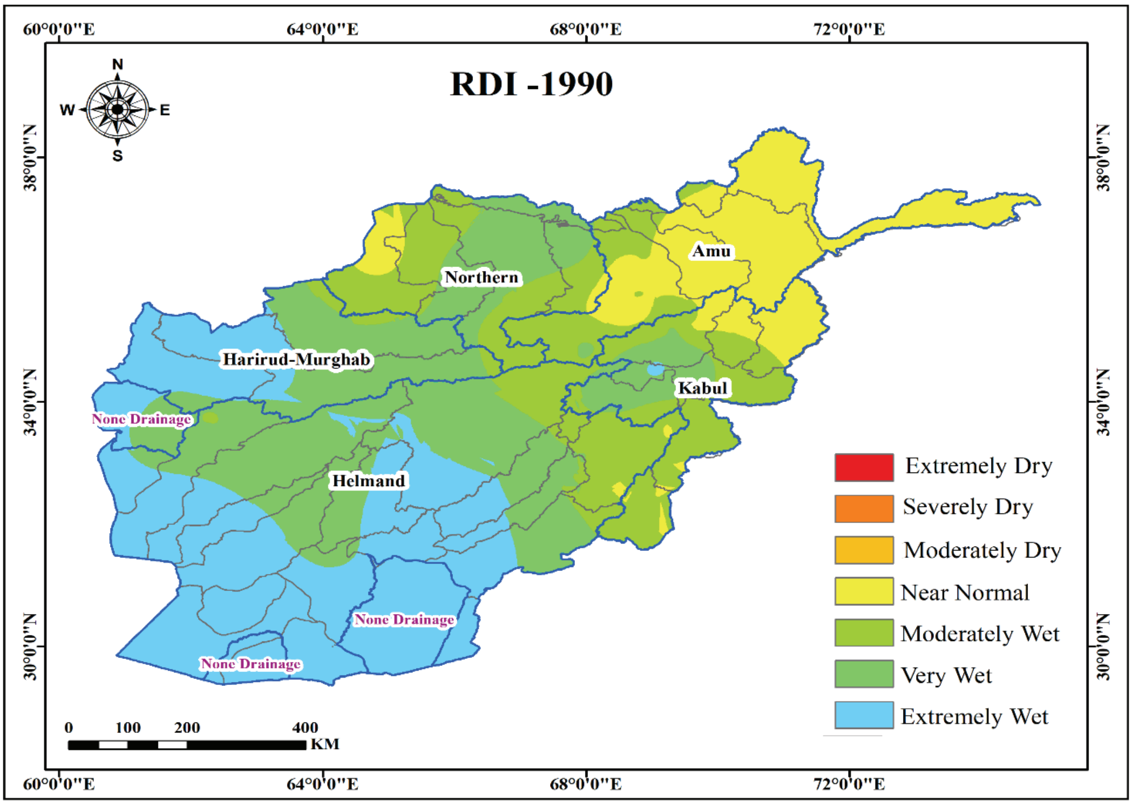
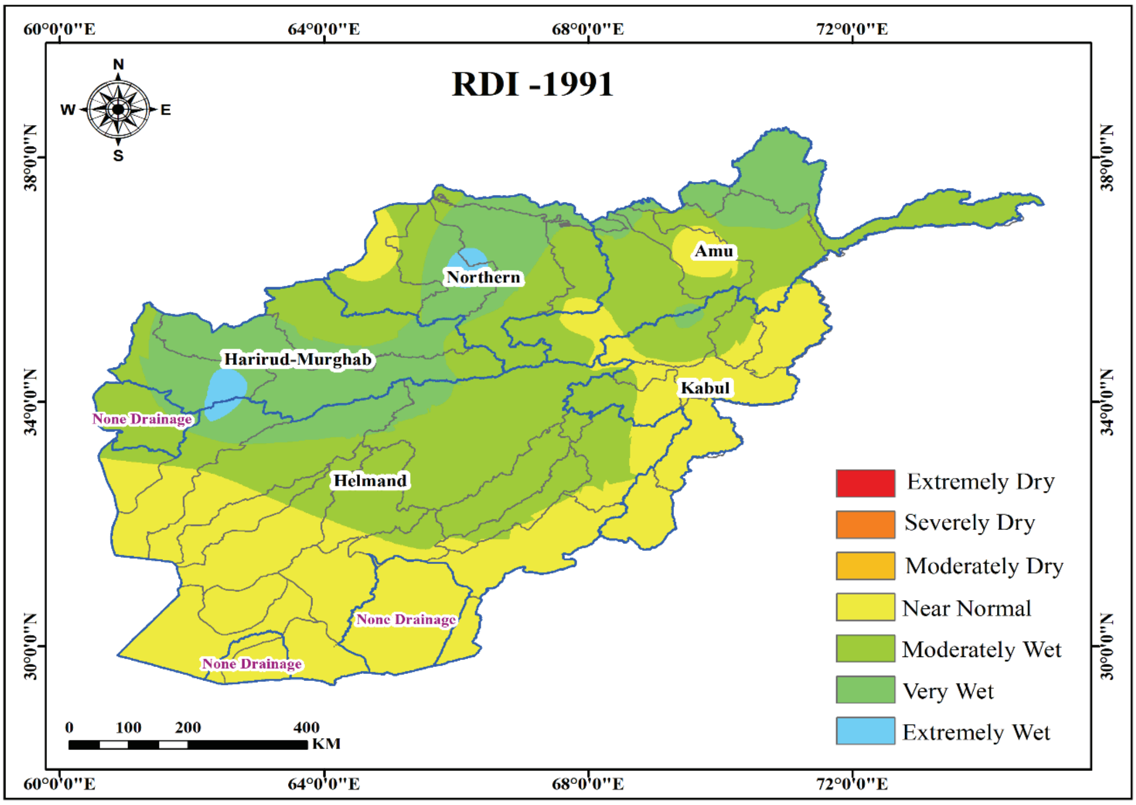


Figure 4.53. 1990 RDI Map



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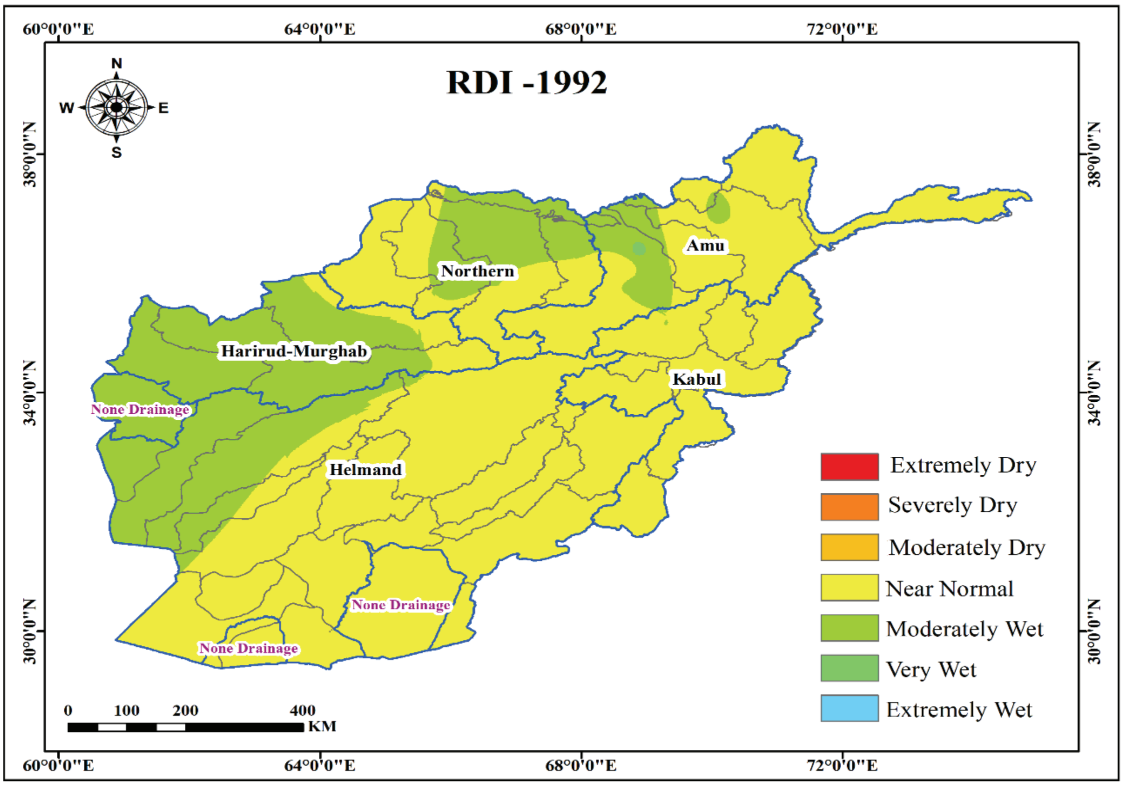

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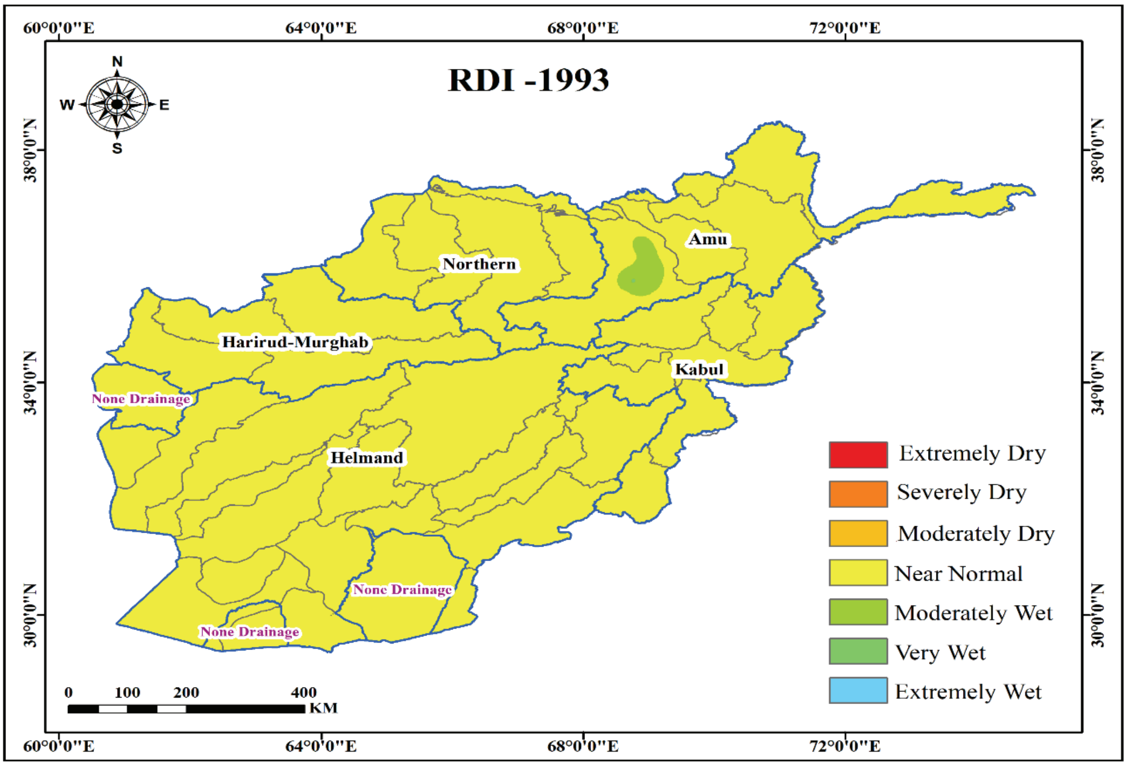

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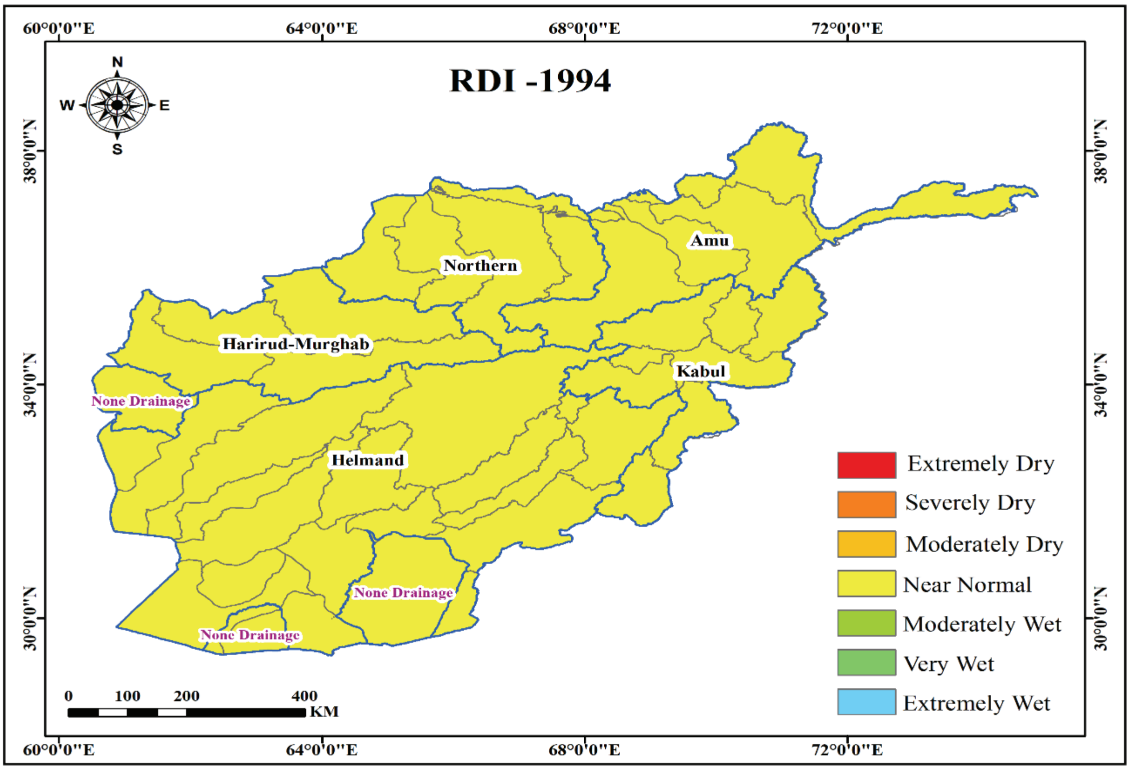
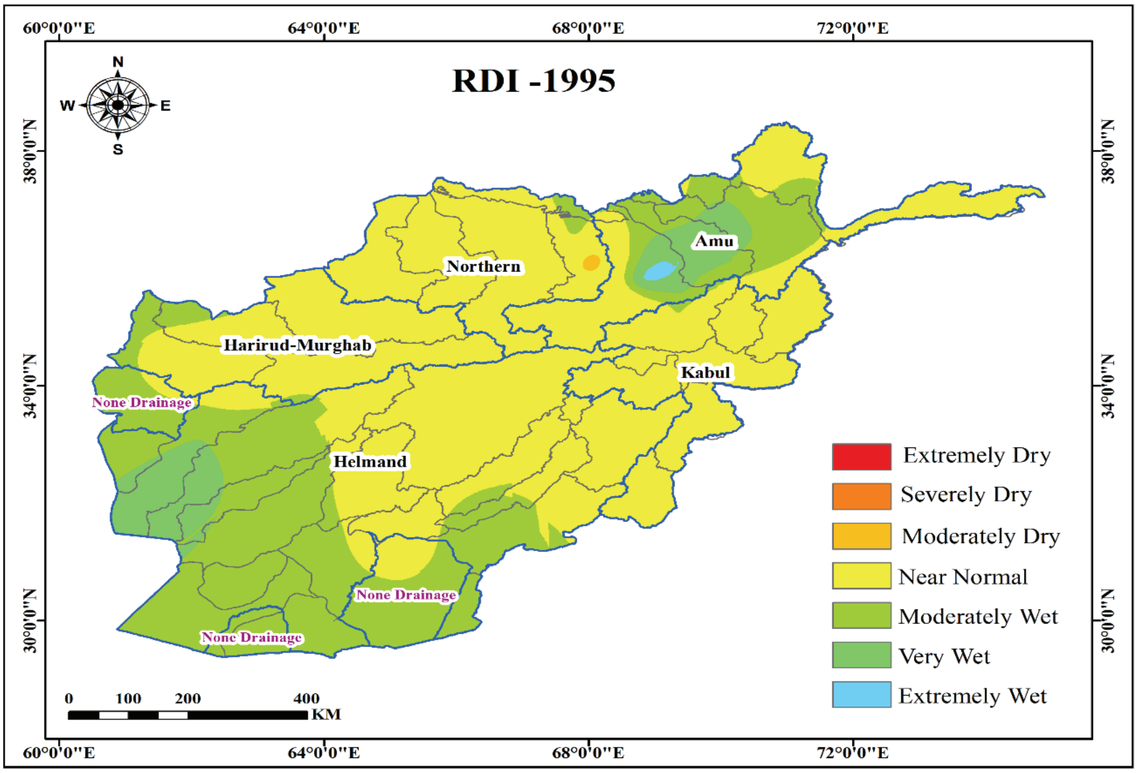


Figure 4.57. 1994 RDI Map



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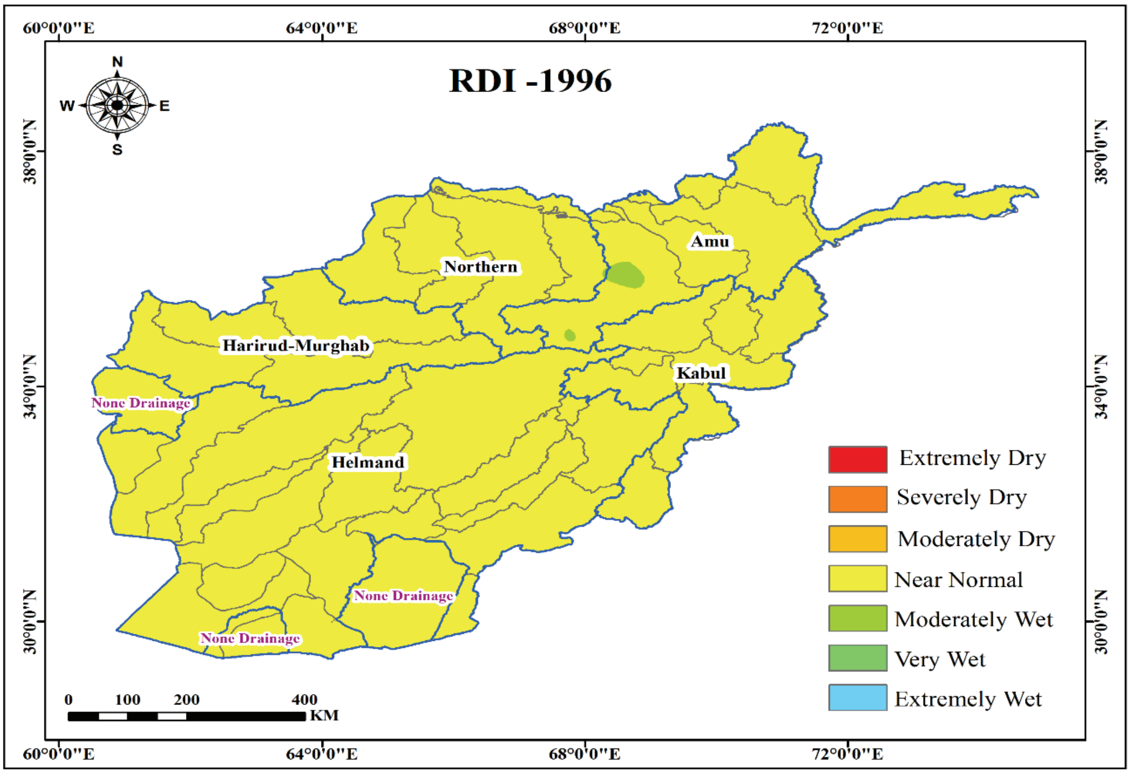

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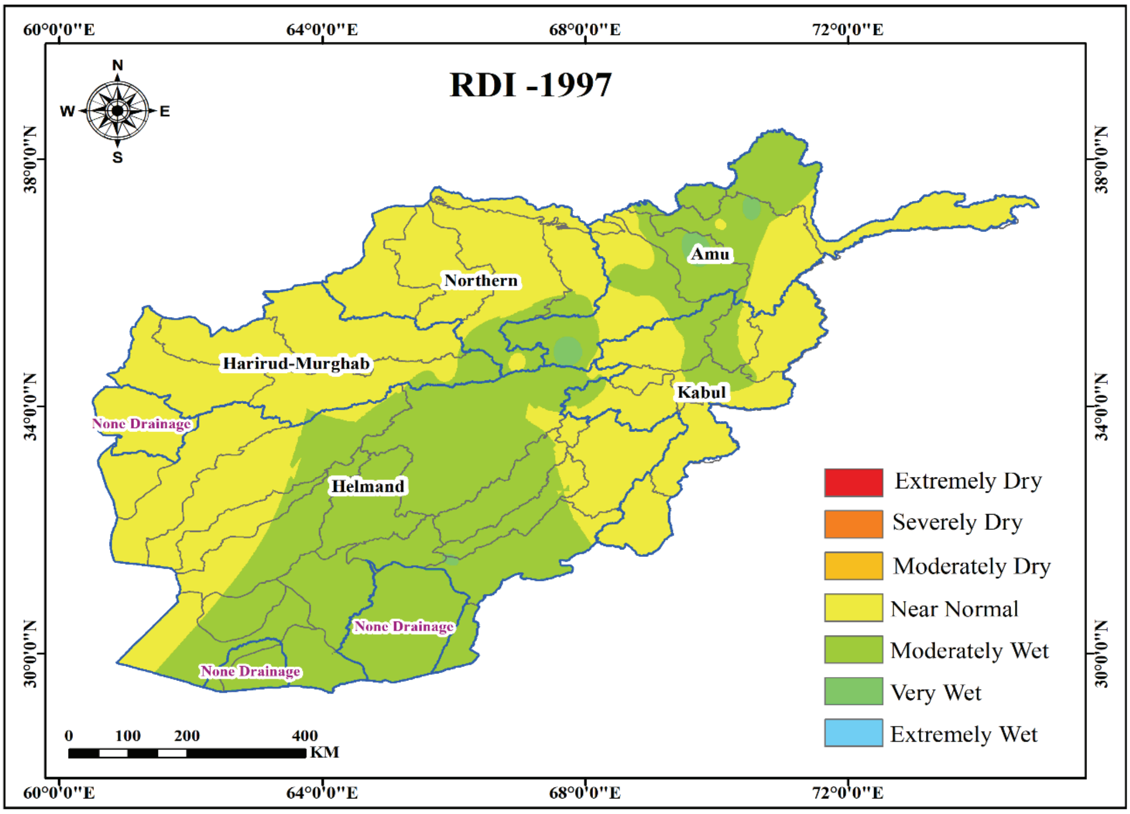

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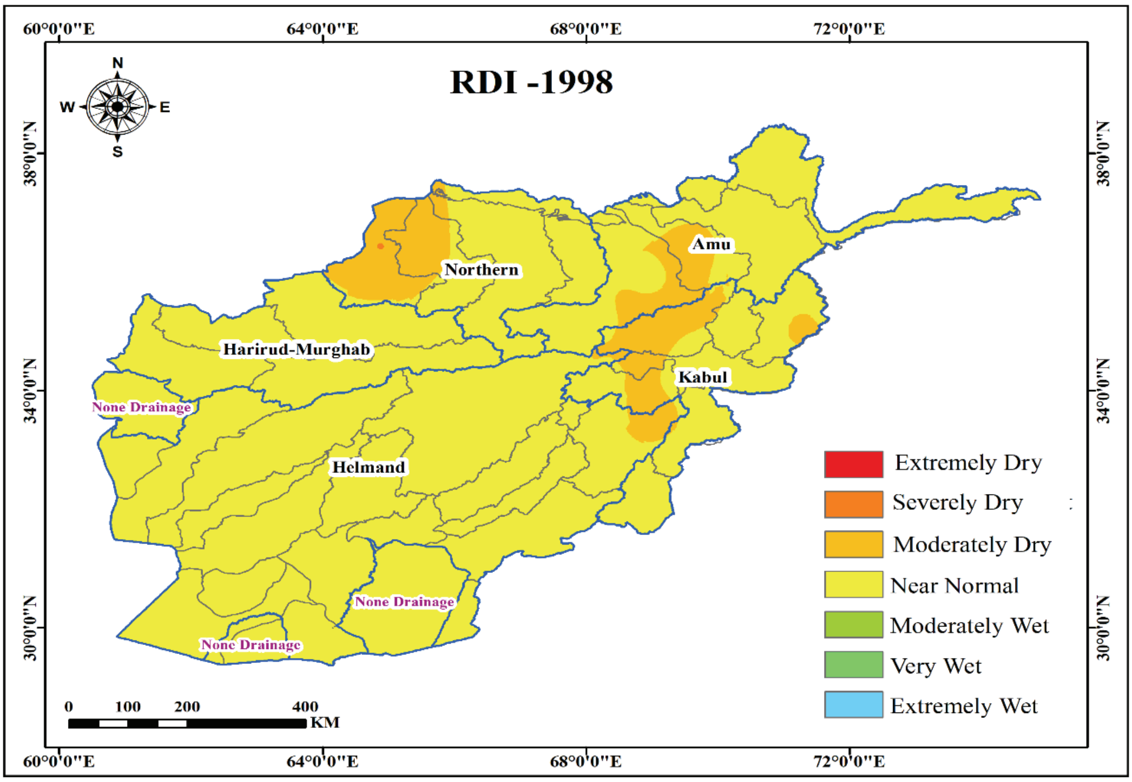


Figure 4.61. 1998 RDI Map

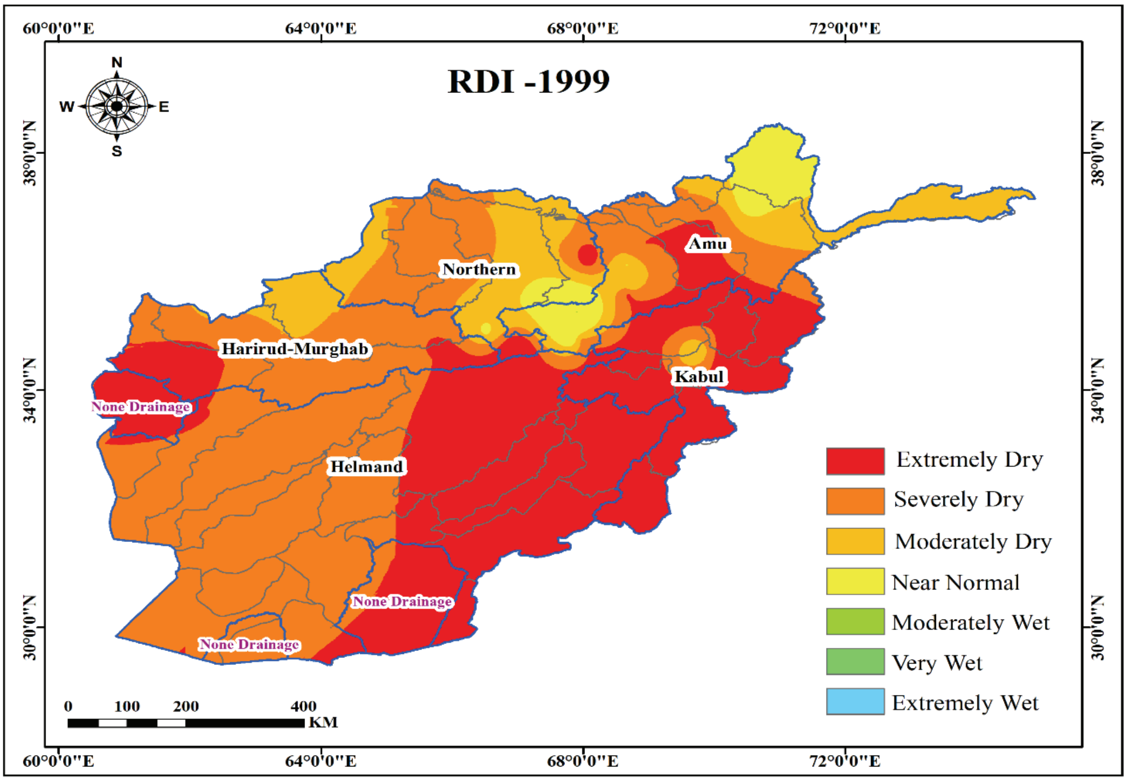
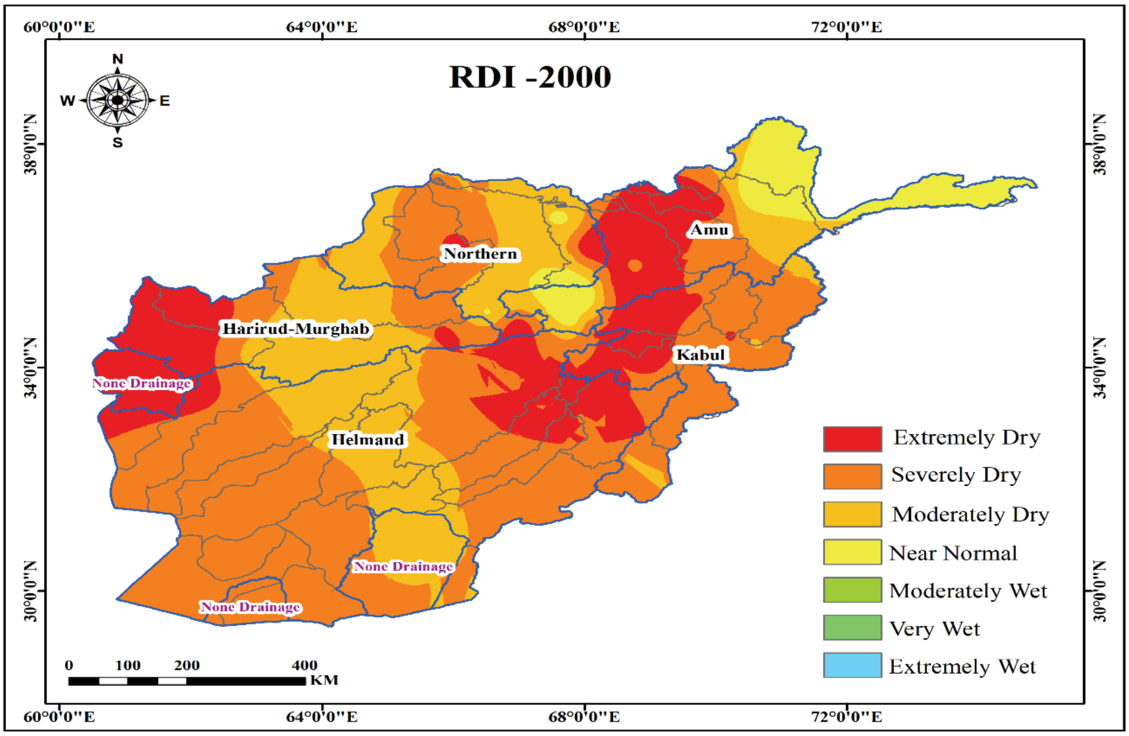


Figure 4.62. 1999 RDI Map



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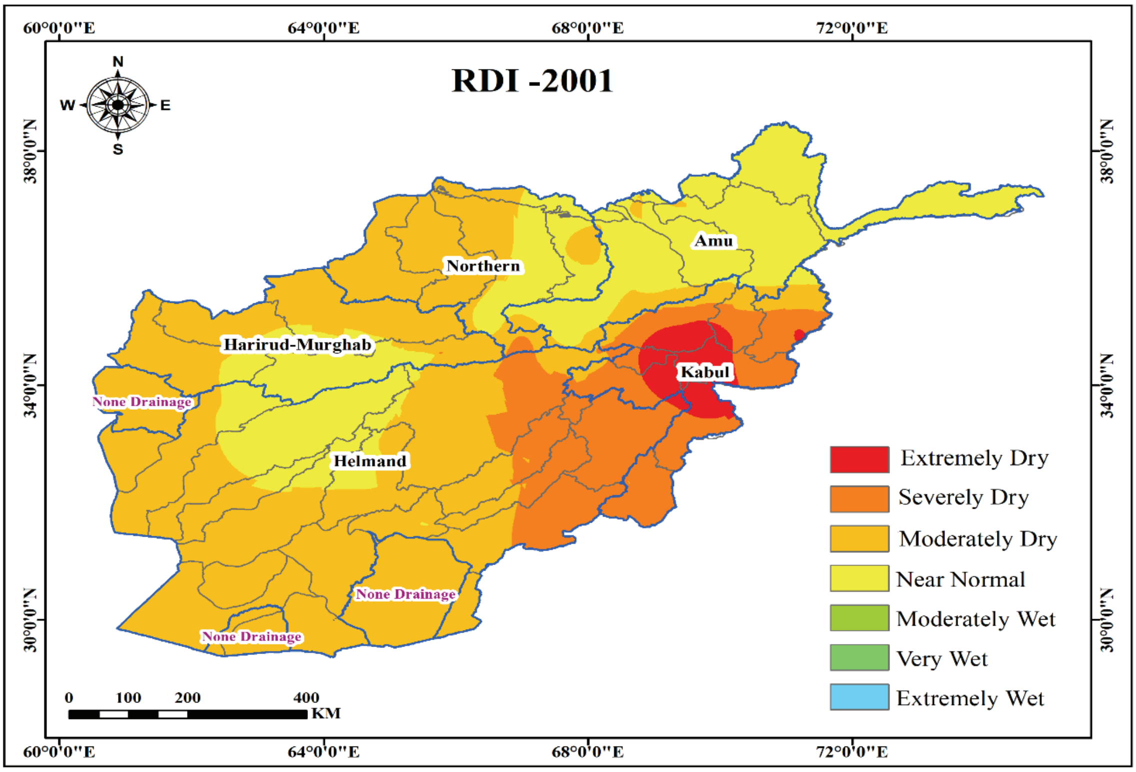

Figure 4.64. 2001 RDI Map

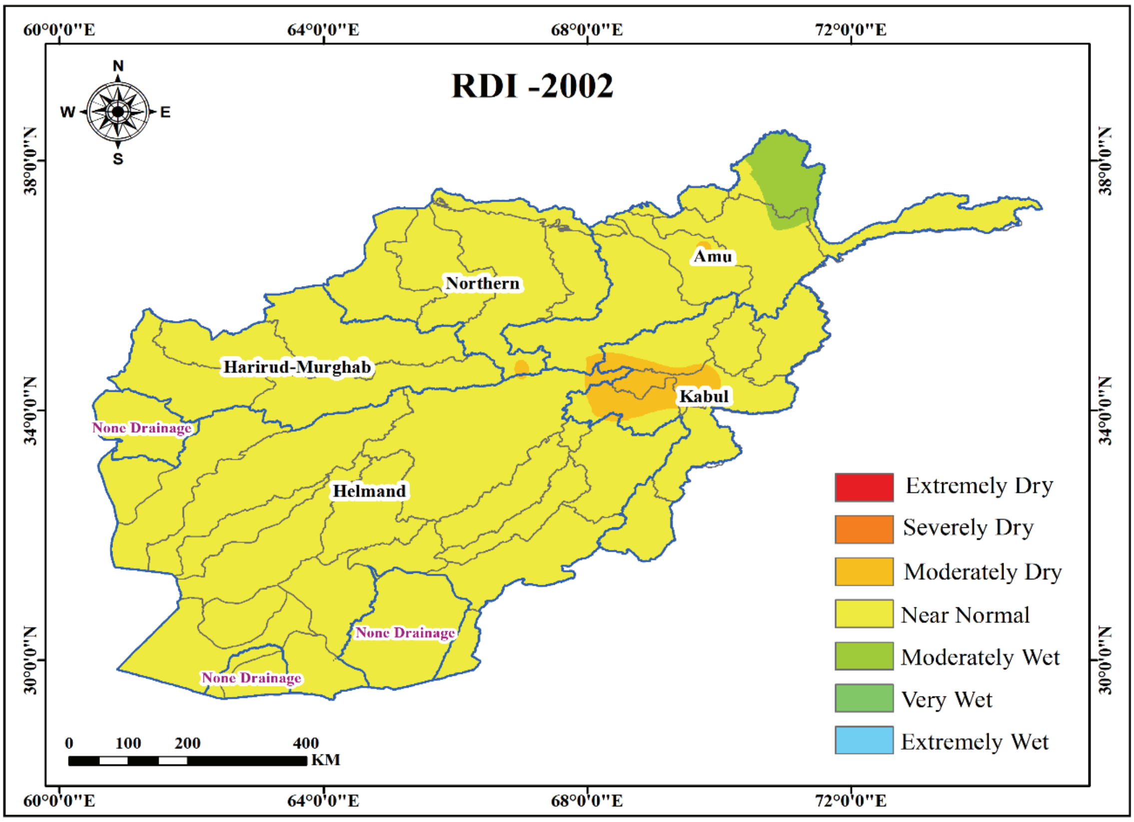

Figure 4.65. 2002 RDI Map

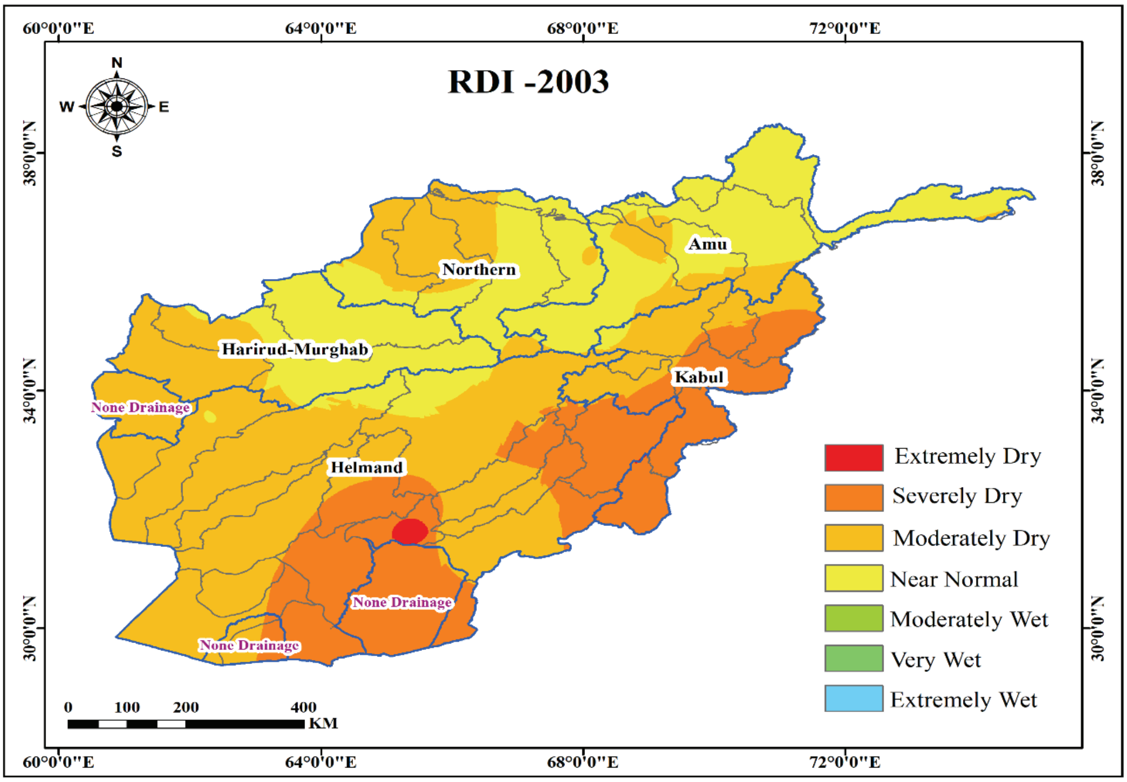

Figure 4.66. 2003 RDI Map

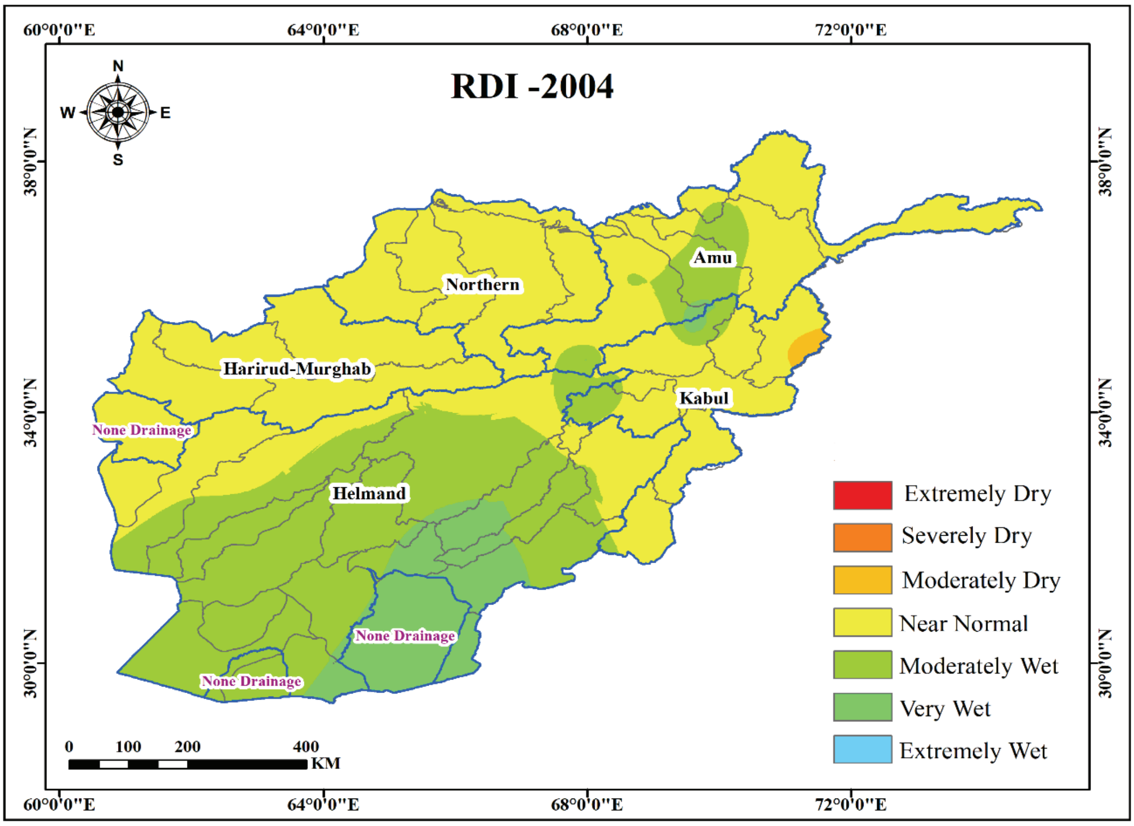

Figure 4.67. 2004 RDI Map

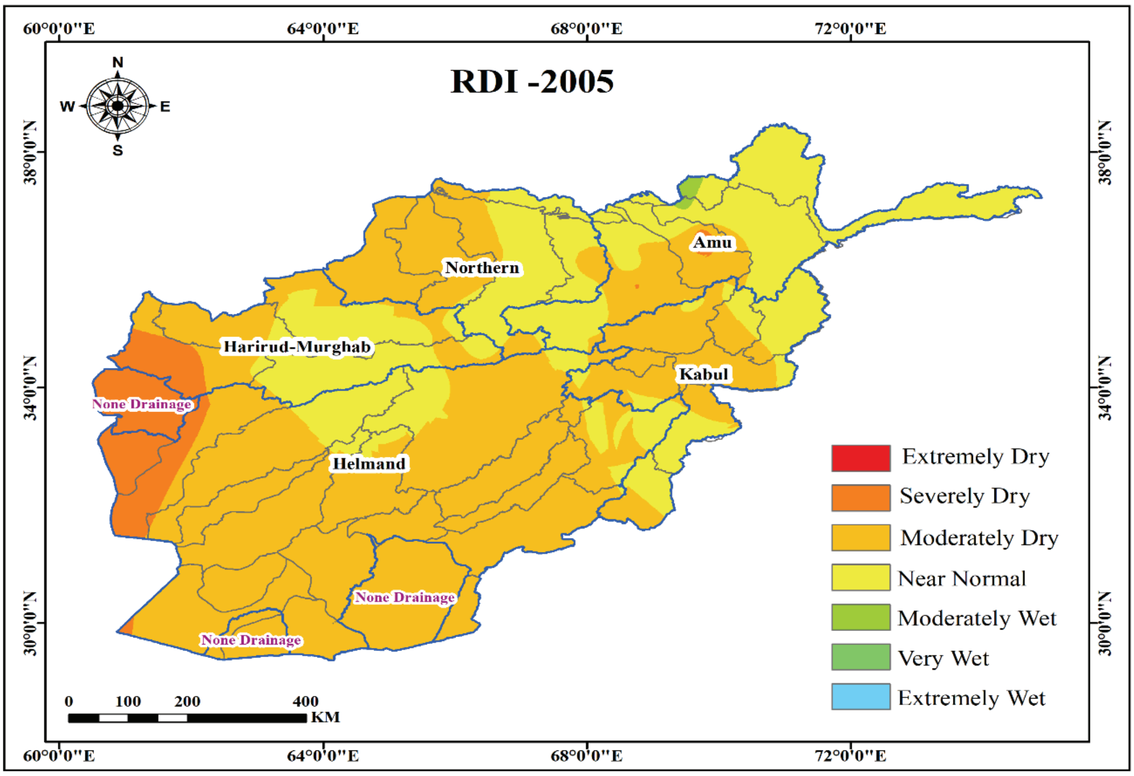

Figure 4.68. 2005 RDI Map

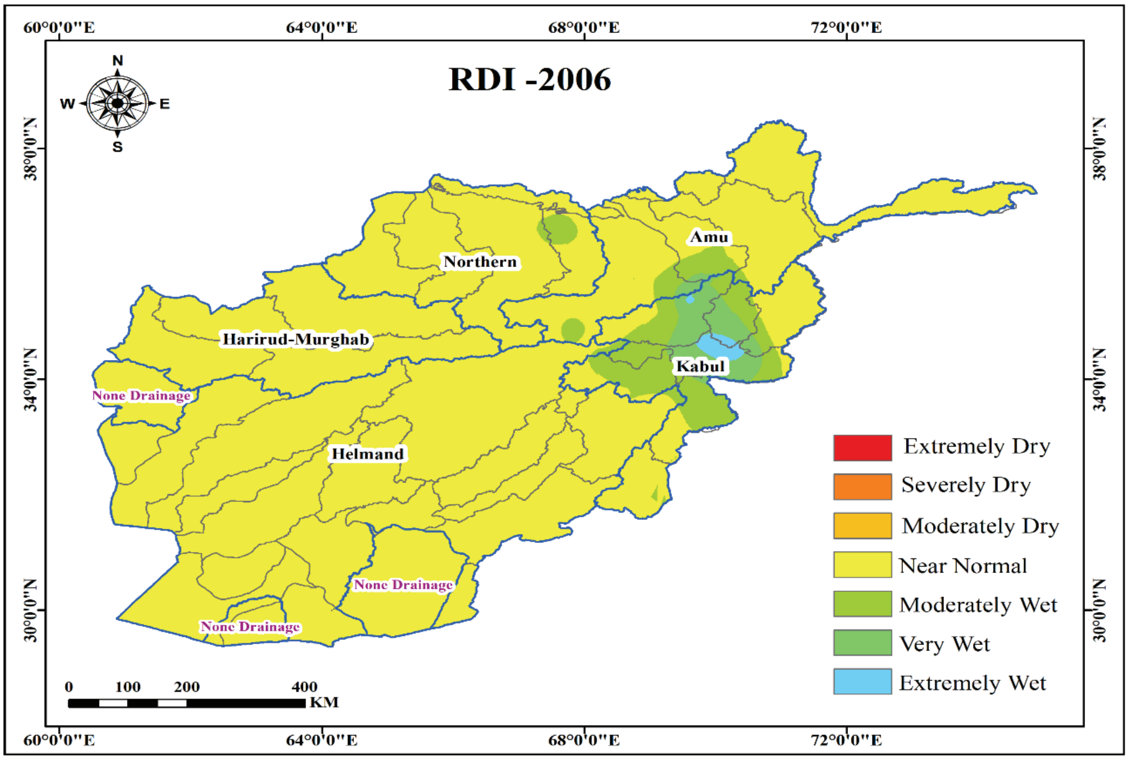

Figure 4.69. 2006 RDI Map

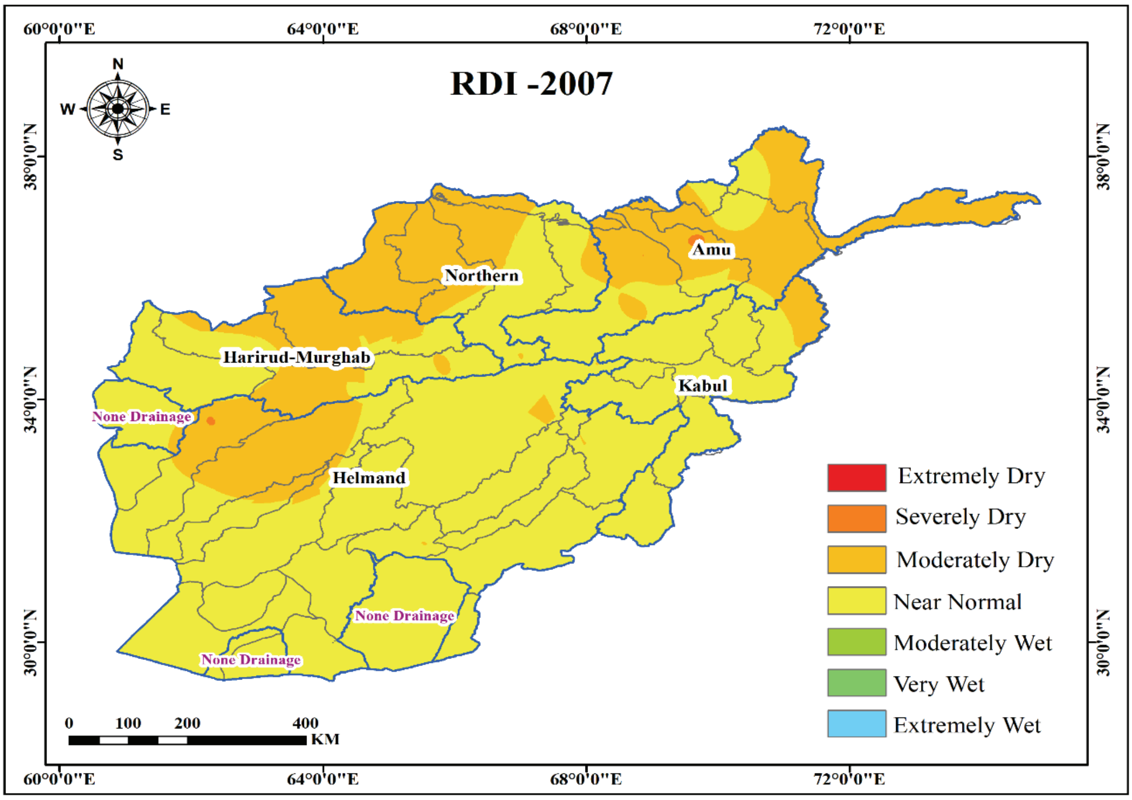

Figure 4.70. 2007 RDI Map

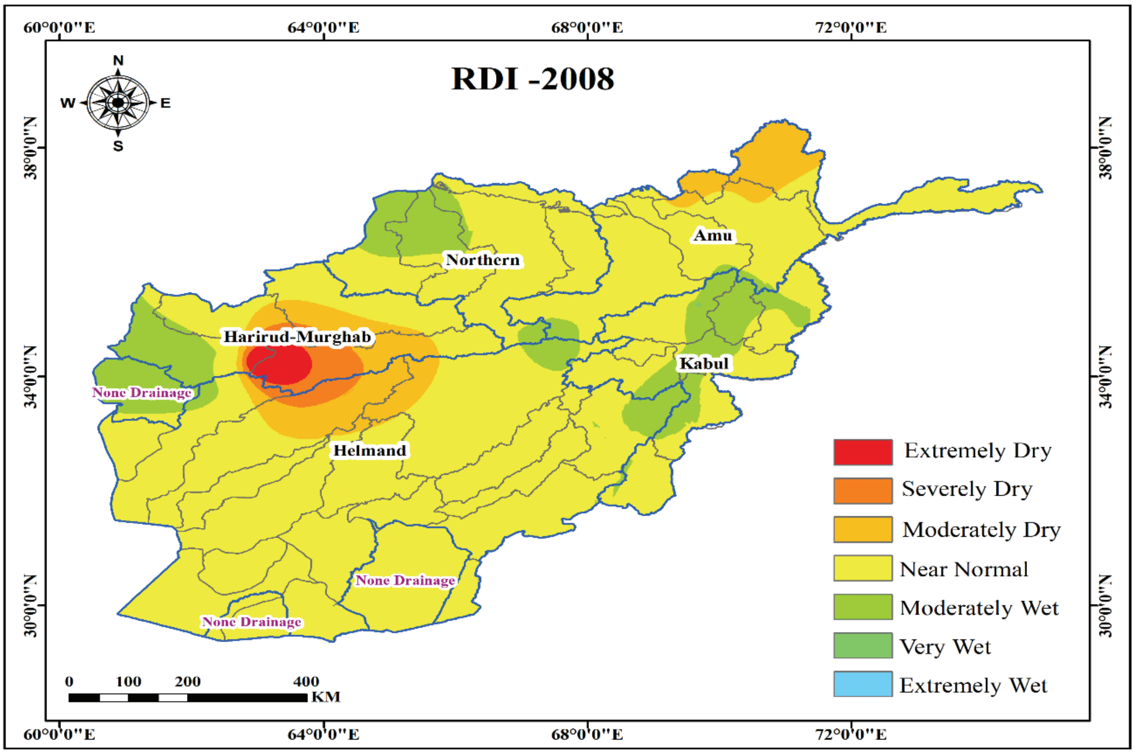

Figure 4.71. 2008 RDI Map

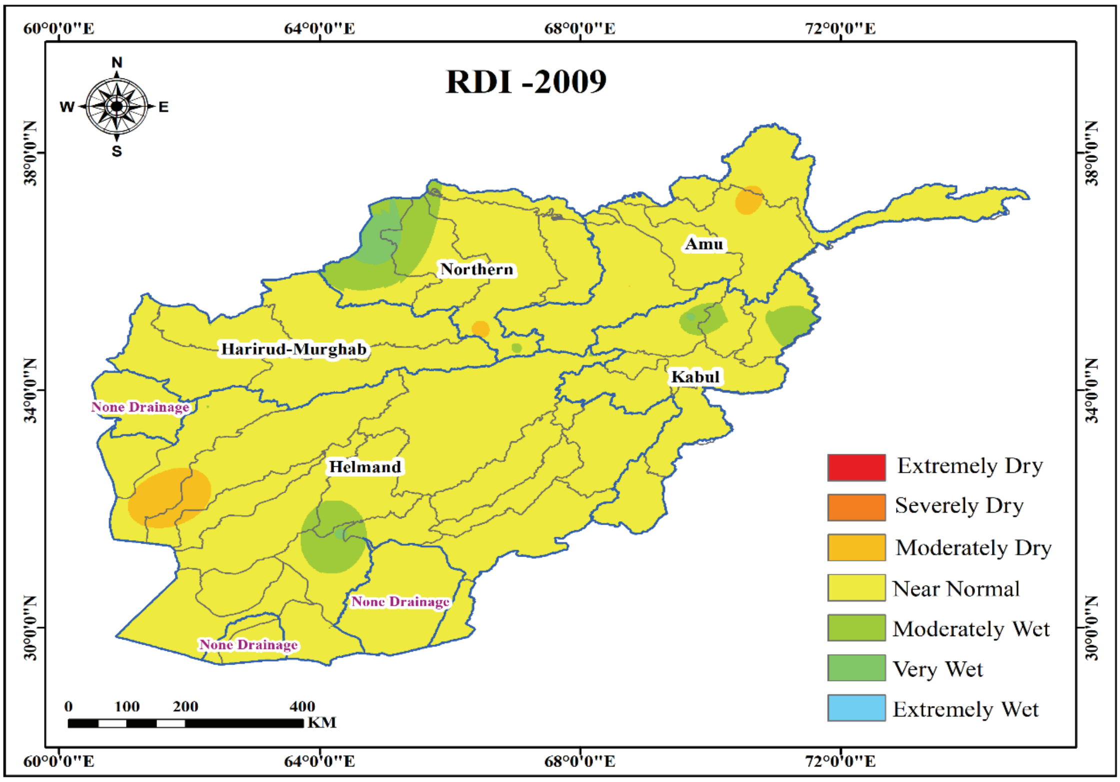

Figure 4.72. 2009 RDI Map

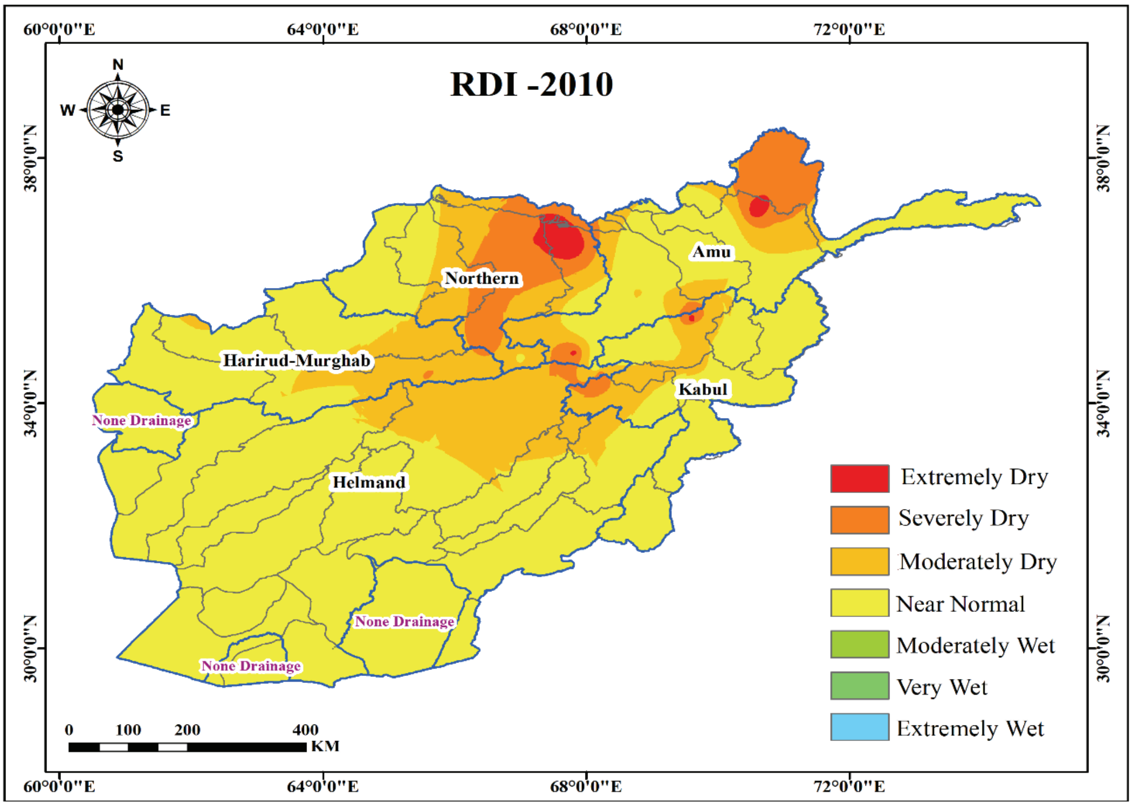

Figure 4.73. 2010 RDI Map

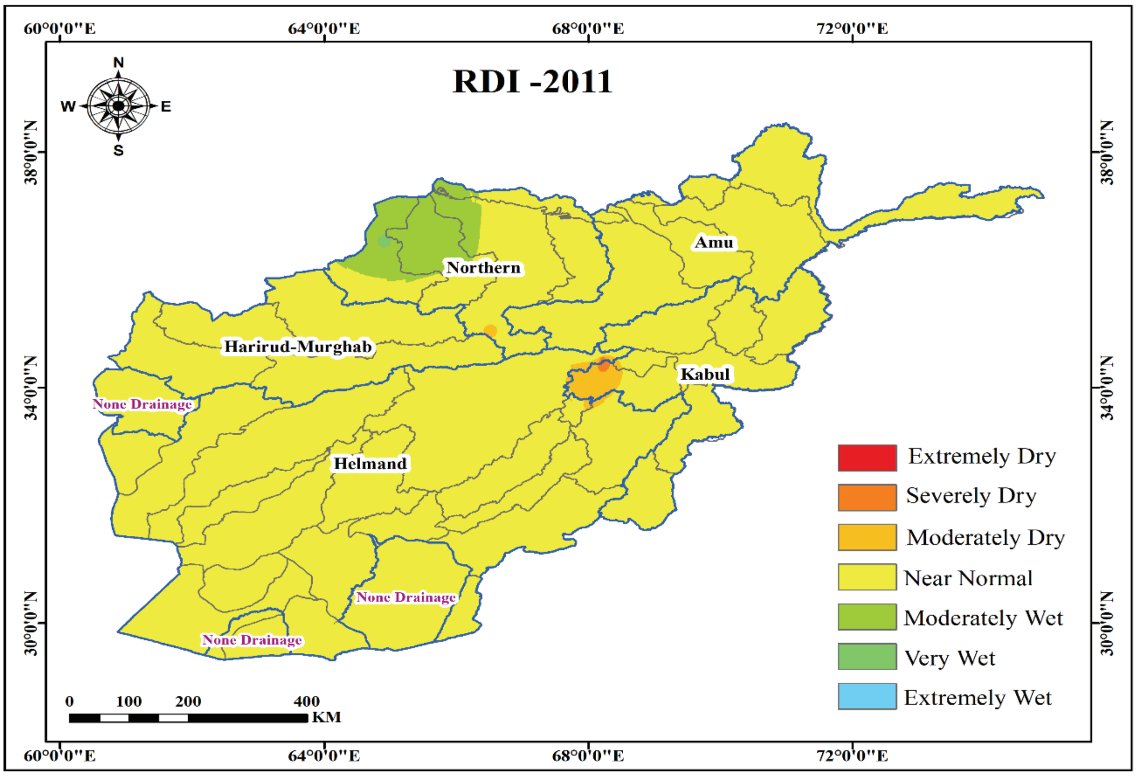

Figure 4.74. 2011 RDI Map

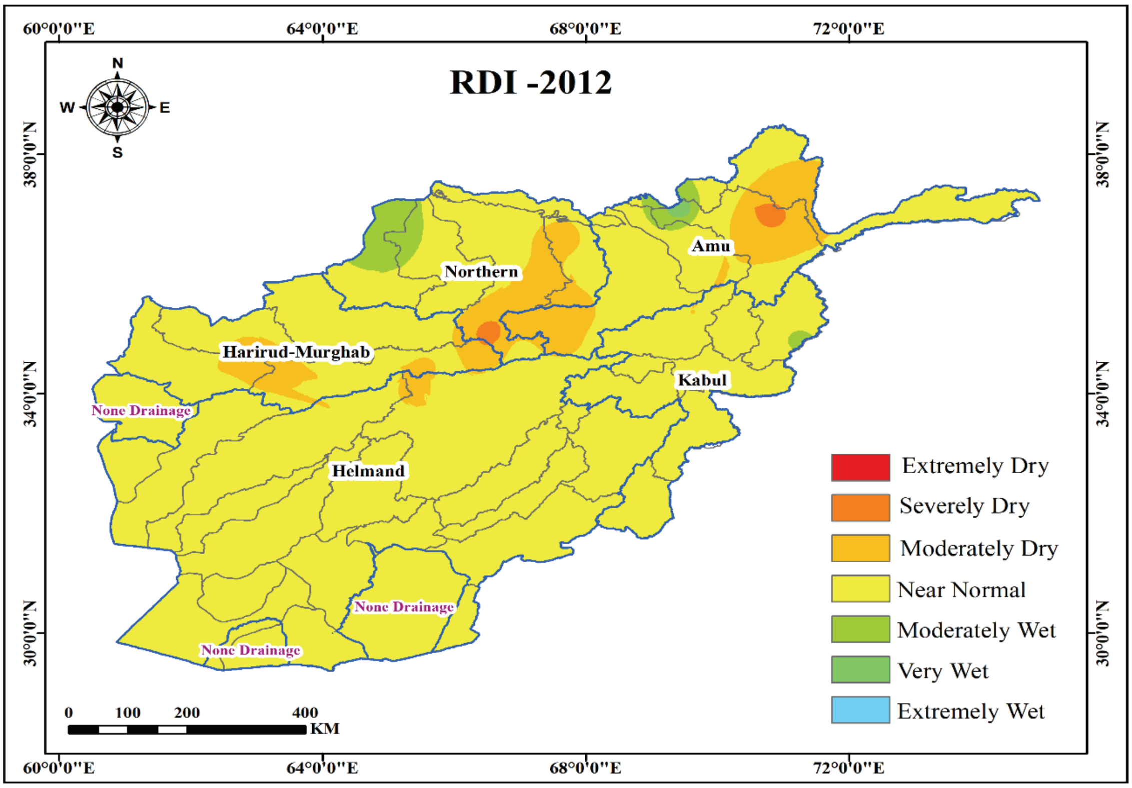

Figure 4.75. 2012 RDI Map

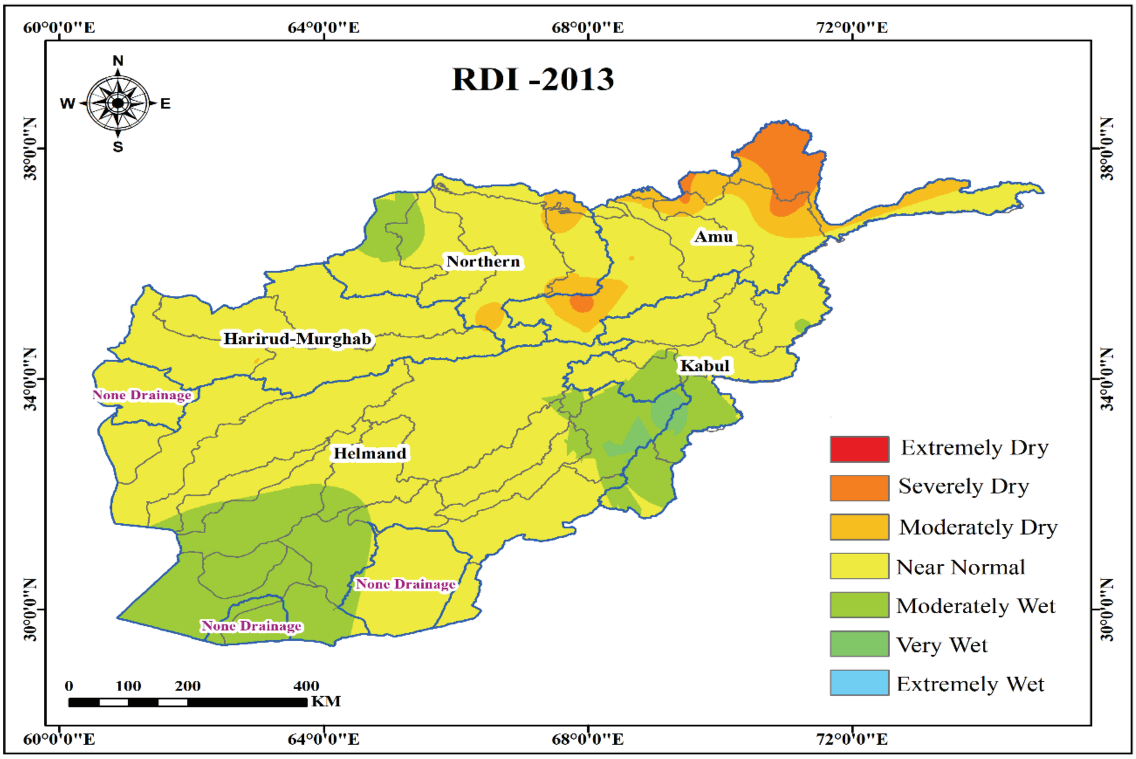

Figure 4.76. 2013 RDI Map

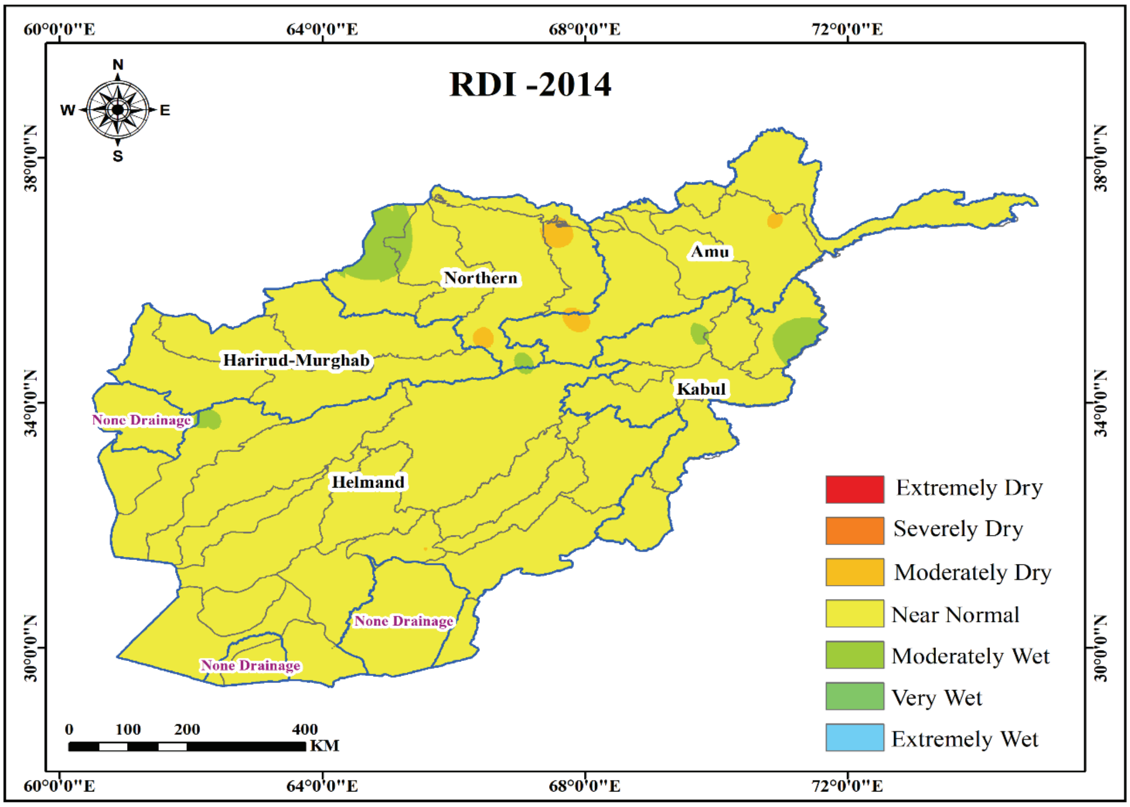

Figure 4.77. 2014 RDI Map

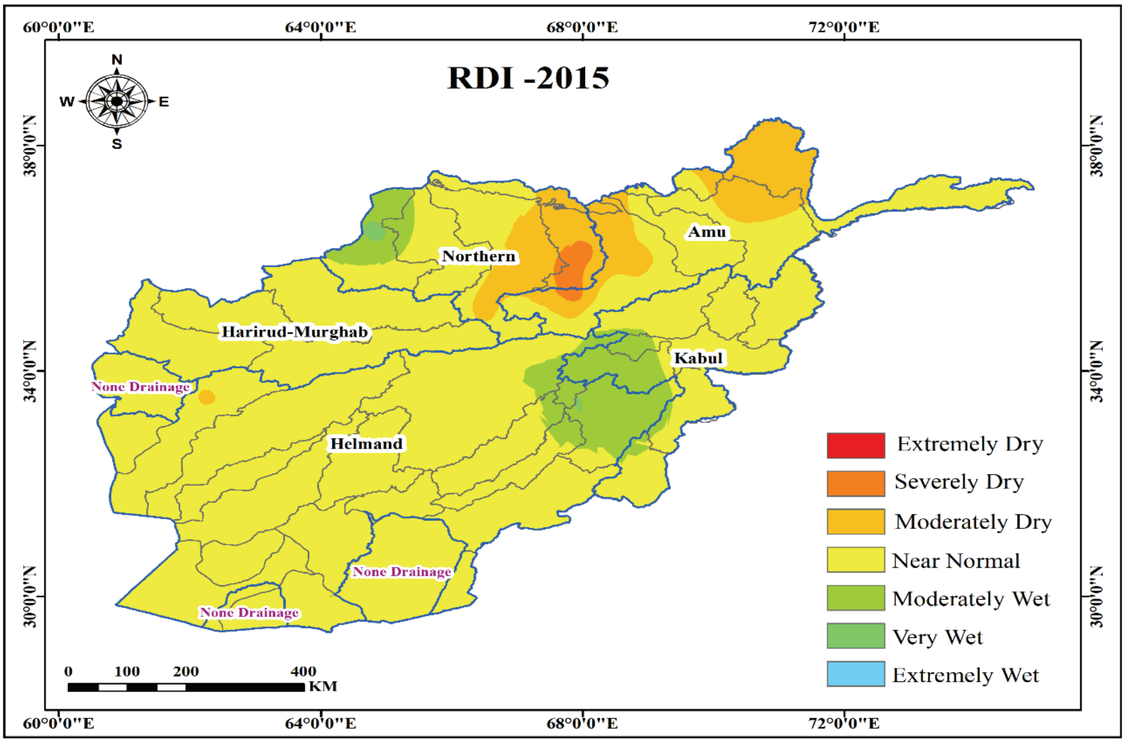

Figure 4.78. 2015 RDI Map

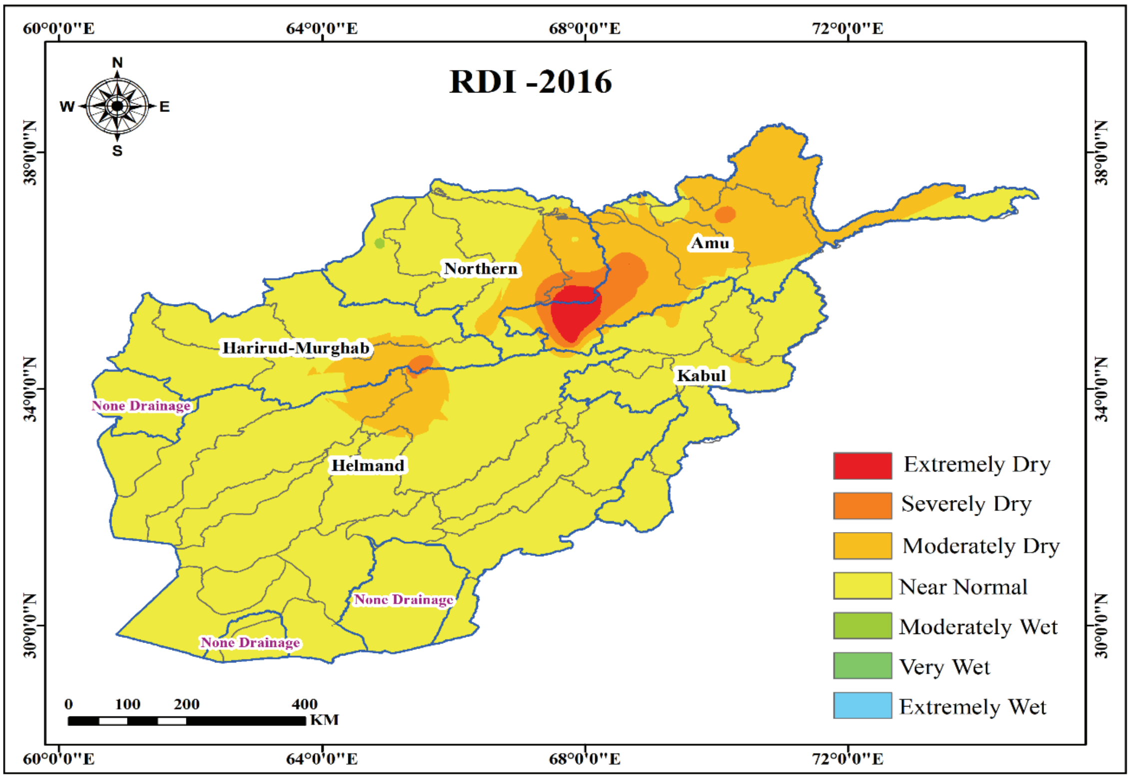

Figure 4.79. 2016 RDI Map

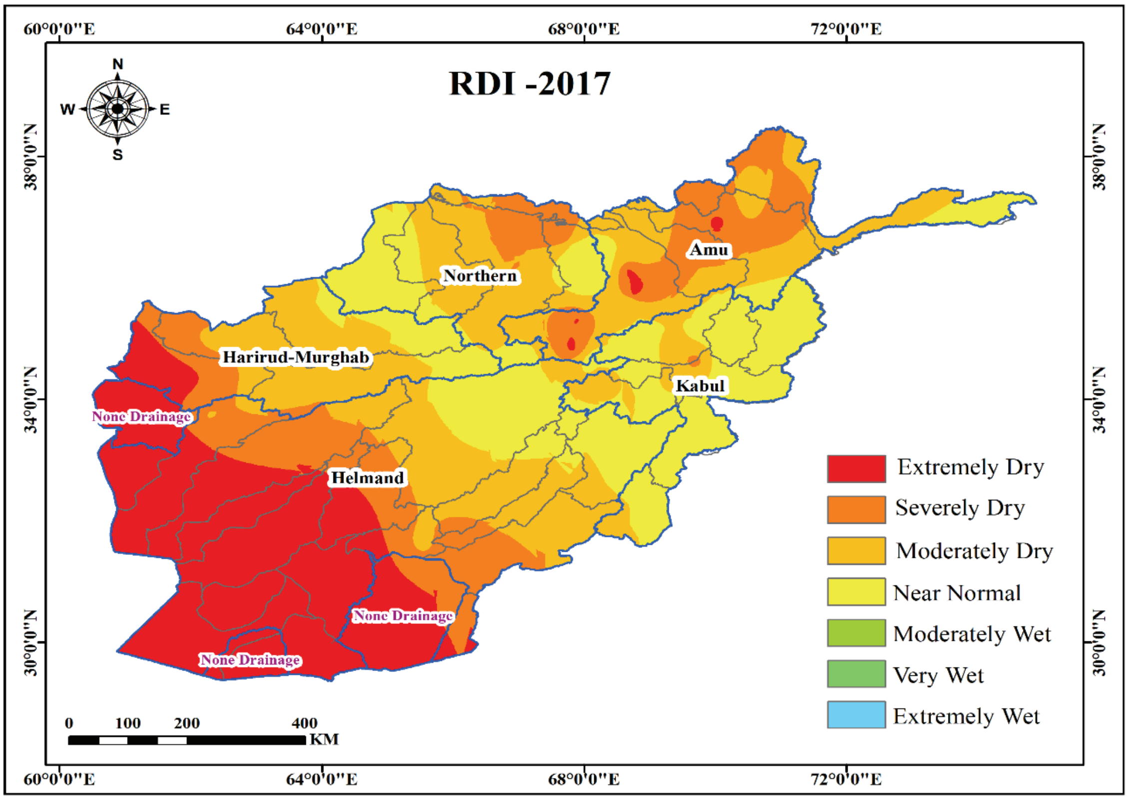

Figure 4.80. 2017 RDI Map

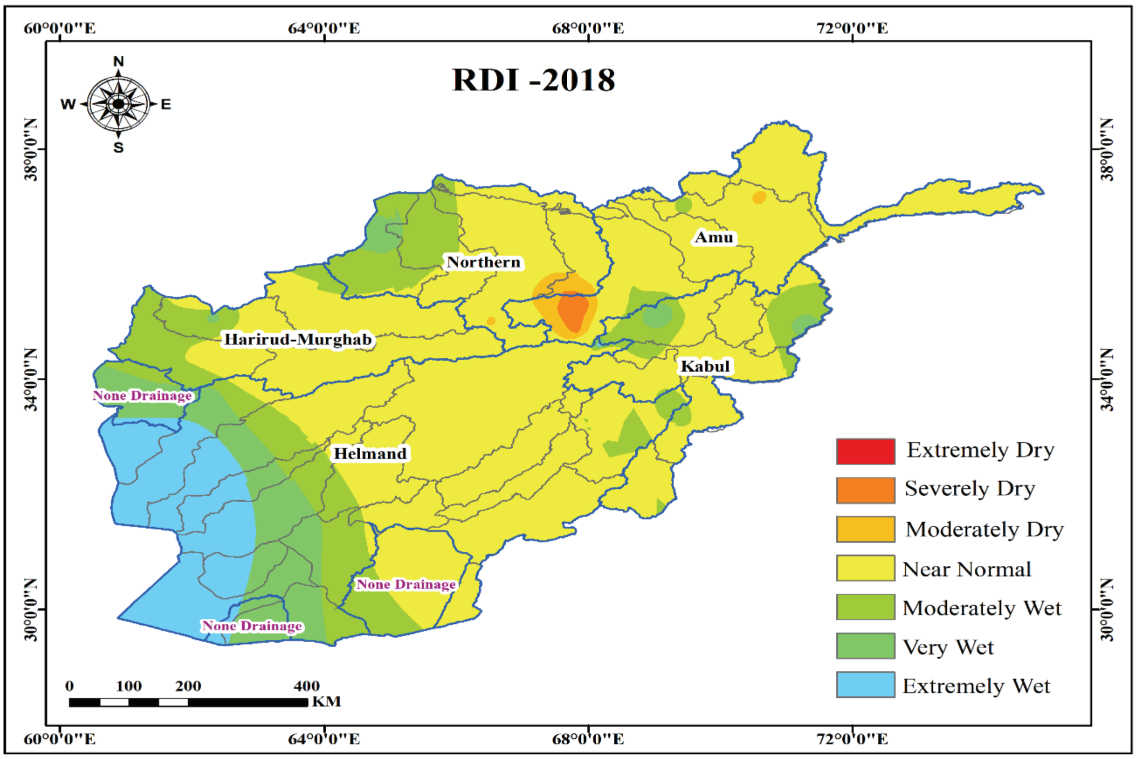

Figure 4.81. 2018 RDI Map

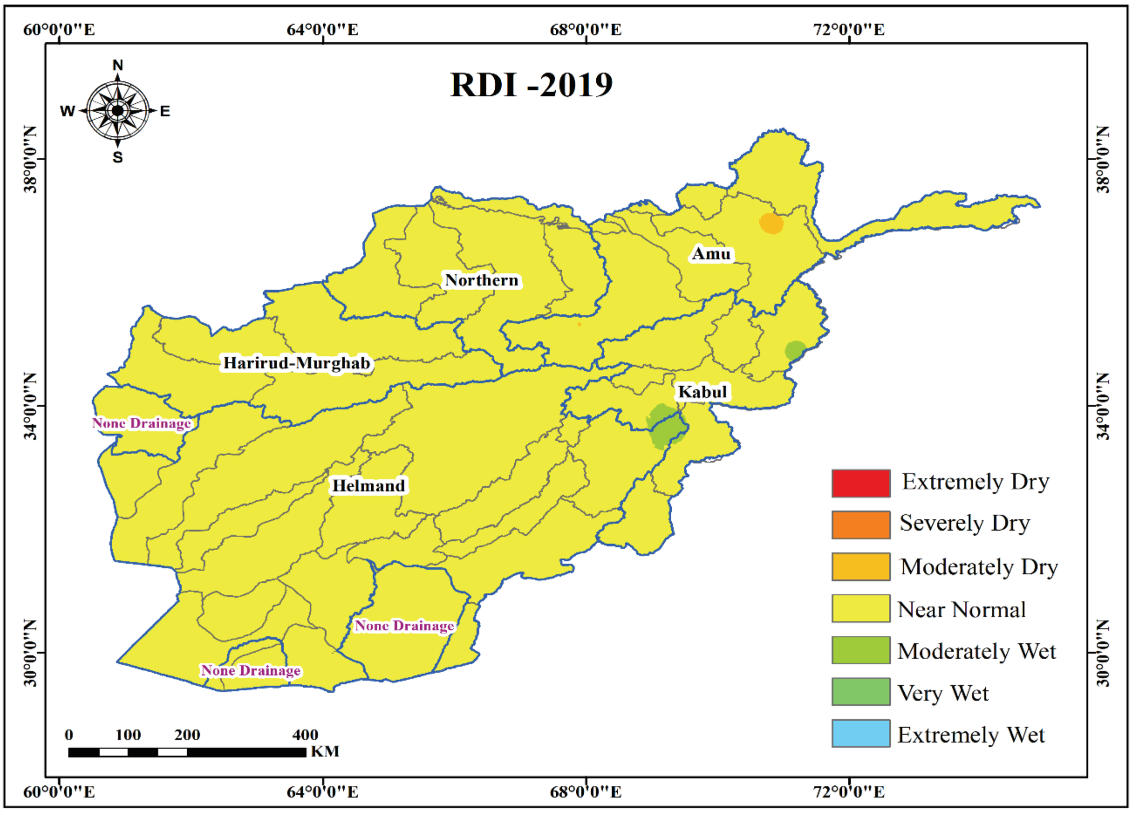

Figure 4.82. 2019 RDI Map

4.2. Discussion and Conclusion

In present study, a forty-one-year historical cumulative monthly rainfall and temperature data across whole Afghanistan through 55 meteorological stations was examined meteorological drought characterization using time scales of 12 months. Stations across all five RBs were selected to represent the best spatial coverage and based on the availability of the corresponding data. The meteorological data used was a combination of in-situ and reanalysis satellite data processed and quality controlled by the MEW professionals. Two well-known meteorological drought analysis indices such as SPI and RDI were used to characterize historical drought in the country while indices showed a good correspondence between each other for the annual scale time series. There were some extreme, severe and moderate dry events detected by both SPI and RDI. However, there were slight differences in some cases between SPI and RDI, while much stronger severity is presented by RDI, which indicate that the ET_0 as additional input to this index in comparison to that of SPI has effect on drought analysis in regions of arid climate. Extreme and severe droughts were observed in 1999 and 2000 across the whole country according to both SPI and RDI. Moreover, an extreme drought event was detected in some parts of the Kabul RB along with severe drought covering entire basin and a part of the Helmand RB in 2001. Moderate drought had occurred almost across the whole country in the same year with an exception in some regions on the Amu RB. Further, moderate drought events started to occur with a frequency of 3 to 5 years. For example, another moderate drought that hit the whole country was in 2003 and 2005 was moderate drought for the most parts of the country. 2007 was a moderate drought for some parts of the Harirud-Murghab, Amu, Helmand, and Northern RBs which also indicates a spatial variation in rainfall. 2010 was another episode of extreme drought in two stations of Northern and Amu RBs and severe and moderate drought in the most parts of the Northern RB. In addition, Severe and moderate drought was observed in some stations of the Kabul, Harirud-Murghab, and Amu RBs as per SPI and severe drought is extended to the Helmand RB based on RDI. Moderate drought was detected in some stations in Harirud-Murghab, Norther, and Amu RBs by SPI, and RDI detected moderate drought in some other stations as well. 2013 was severe and moderate drought for some areas of the Amu and Northern RBs, while this year was a moderately wet year for some parts of the Helmand and Kabul RBs, which is another example of the spatio-temporal variabilities of the rainfall due to the climate change. In 2016, an extreme drought hit a smaller area of the Northern and Amu RBs. In fact, moderate drought coverage of the RDI in Helmand, Amu, Norther, and Harirud-Murghab RBs was more than that of SPI in this year. 2017 was a year when extreme drought episode hit the west and south-west parts of Afghanistan at most in Harirud-Murghab and Helmand RBs. Still, moderate drought happened in many stations in all RBs in the same year, where the coverage of RDI was spatially wider than SPI.

While comparing SPI to RDI, the 1999 was extreme drought covering almost the whole country. In contrast, this year was classified as severe drought in half of the Helmand and severe and moderate drought from most regions of the Harirud-Murghab, Northern, and Amu RBs with extreme drought in Kabul RB, upper Helmand RB, and smaller areas of the rest of the RBs as per RDI calculations. Further, the extreme drought event in 2000 detected by SPI and RDI were almost the same areas in all RBs, but SPI classified this year to be a severe drought year for the rest of the RBs while RDI detected moderate drought areas in all RBs as well. In 2001, extreme drought was just observed in the Kabul RB by RDI, but SPI indicated a smaller area of extreme drought in the Amu RB too. Also, the spatial coverage of severe drought as per RDI was more than SPI in the same year. On one hand, 2003 was example of another drought year that RDI's severe drought had larger coverage in Helmand and Kabul RBs in comparison to the SPI's drought coverage in severe magnitude. On the other hand, SPI's moderate drought coverage was larger than RDI in this year. In 2005, the RDI moderate drought coverage was larger than SPI with similar severe drought coverage across the country. Also, 2007 had the same moderate drought coverage for both SPI and RDI. Furthermore, the 2008 extreme drought that hit the central Harirud-Murghab RB was observed by both RDI and SPI where SPI's spatial extent was more than RDI and severe and moderate droughts were detected by both indices in the same year in central and southern regions of the Harirud-Murgha RB and northern regions of the Helmand RB. Another significant difference between RDI and SPI was the 2010 extreme and severe drought episodes observed by RDI in some regions of the Amu, Helmand, Harirud-Murghab, Northern, and Kabul RBs, but near normal in Helmand RB and with less coverage of extreme and severe droughts in the other four RBs. Moreover, RDI detected severe drought in the Northern RB and moderate drought in the Northern and Amu RBs in 2015, however, SPI recorded those RBs to be a near normal drought regions for that year. The extreme drought of 2016 in smaller regions of the Amu and Northern RBs were observed by both indices, but the extent of RDI's severe drought was larger than SPI in Amu and Northern RBs. Hydrological year 2017 recorded another wider extreme drought event in western and south-western Afghanistan mainly in Helmand and Harirud-Murghab RBs and some smaller areas in the Amu RBs too. Severe and moderate droughts were detected in most of the regions of Helmand, Harirud-Murghab, Northern, and Amu RBs after the extreme droughts by both drought indices. However, the extent of these two events was larger based on the RDI computations than SPI. Lastly, SPI observed extreme drought in some smaller regions in 2019 in the Amu RB, but RDI classified those regions as normal drought hit regions.

Drought graphs were produced for each station under study and the graphical comparison of the SPI and RDI are shown for more details. Also, tabulated extreme, sever, and moderate drought events with respect to each RB is provided notifying users and readers about the significant drought events and their spatial and temporal characteristics. In addition to that, maximum, minimum, and average rainfall on both country and basin level are shown so that one can see the decadal rainfall anomalies in the last four decades. The maximum annual rainfall recorded in the period 1979-2019 in the Amu, Harirud-Murghab, Helmand, Kabul, and Northern RBs was 663.65, 636.48, 792.25, 809,24, and 845.95 mm respectively. Minim annual rainfall in these five RBs was 103.32, 34.12, 15.95, 38.74, 48.55, and 48.14 respectively. Furthermore, average annual rainfall was recorded to be 342.02, 229.26, 208.42, 322.38, and 246.86 in the Amu, Harirud-Murghab, Helmand, Kabul, and Northern RBs, respectively. The maximum average, minimum average, and average annual rainfall on a country level recorded in 55 stations in five RBs across the country was 749.51, 48.14, and 269.79 mm, respectively. The average annual rainfall for the 1979-1988 decade in the Amu, Harirud-Murghab, Helmand, Kabul, and Northern RBs was 378.05, 251.84, 219.97, 337.35, and 277.83 mm, respectively. The 1989-1998 decade recorded the average annual rainfall in these five RBs to be 387.10, 290.10, 238.28, 335.62, and 276.57, respectively. Moreover, 315.48, 171.76, 154.36, 257.19, and 193.88 mm was the average rainfall recorded in the 1999-2008 decade in Amu, Harirud-Murghab, Helmand, Kabul, and Nortern RBs, respectively. Finally, the 2009-2018 decade's average annual rainfall depth was 294.09, 201.36, 213.16, 345.00, and 239.85 mm in the order of RBs mentioned earlier, respectively.

From the above discussion, we can conclude that SPI and RDI are widely used and useful meteorological drought indices that are able to detect drought events based on the different timescales. In this study, we just considered a 12-month time scale for these two indices to investigate drought on a country level. Still, these two indices behave differently in some cases and in some regions with different climates such as arid and semi-arid in our case. The country started to suffer from frequent droughts since 1999 as this year was the first extreme drought event across the entire country according to SPI, but extreme and severe drought year as per RDI. Year 2000 record extreme drought by several stations and severe by many of the studied stations. Extreme drought events were seen in few stations just in the Kabul and Amu RBs and several moderate drought events across the whole country. In 2003 and 2005, severe and moderate drought episodes hit most parts of the country again. Year 2007 was a moderate drought wave in some parts of the northern and western Afghanistan, while in 2010 some areas in central and north-east were hit by extreme and severe drought. The western and south-western parts of the country in Helmand and Harirud-Murghab RBs suffered another extreme drought event in 2017 after 1999 and 2000. We can conclude that after 1999, rather than those extreme, severe, and moderate drought events explained here, the entire country the entire country has been suffering the near normal drought almost every year. The decadal annual rainfall values in each RB indicate that rain fall has decreased in the last two decades with a significant decline in the 1999-2008 decade in all five RBs.

CHAPTER 5

RIVER DISCHARGE MODELLING USING REMOTE SENSING DATA

5.1. Introduction

Afghanistan's in-situ hydrological data does not exist from 1979 to 2008 because the hydrological network was totally disabled due to the Soviet invasion, war and instability. To fill in the gap in streamflow, especially in transboundary rivers, this part of the research opted a novel RS method using Landsat time series for a longer period to model river discharge in four locations of the country's transboundary rivers. Most of the procedures follow the methodology proposed by Tarpanelli et al. (2013) for MODIS data with a difference with using Landsat time series and a longer period. The Landsat SR from the NIR band time series is used as proxies representing river discharge. Pixel based SR values from water and land locations are generated through GEE cloud computing platform due to the huge amount of Landsat time series data encompassing Landsat 5, 7, and 8 satellites.

5.2. Data Acquisition and Processing

To estimate river discharge in four critical gauging stations along four different transboundary rivers, we retrieved SR data from the Landsat imagery namely Landsat 5, 7, and 8 with different periods of operation in orbit (See Figure 5.1). In fact, Landsat 5 captured images from Earth with a TM sensor from 1984 to 2013. Landsat 7 was launched in 1999, which is still operational with ETM+ sensor, but its scan line corrector has been failed since 2003. Landsat 8 started its mission in 2013 with an OLI sensor that is operating since then. Hence, SR products from the NIR bands of Landsat 5 (Band 4, 0.76 μm–0.90 μm), Landsat 7 (Band 4, 0.77 μm –0.90 μm), and Landsat 8 (Band 5, 0.85 μm –0.88 μm) for a period 1988-2021 is obtained using GEE a cloud computing platform.

The temporal resolution is 16 days with one station (Dakah in Kabul RB) in 8 days as tow paths (151 and 152) and passage of the Landsat satellites covering all four locations is i.e., 05:00 to 06:30 local time. A Java code is developed to obtain pixel wise SR values from the Landsat time series.

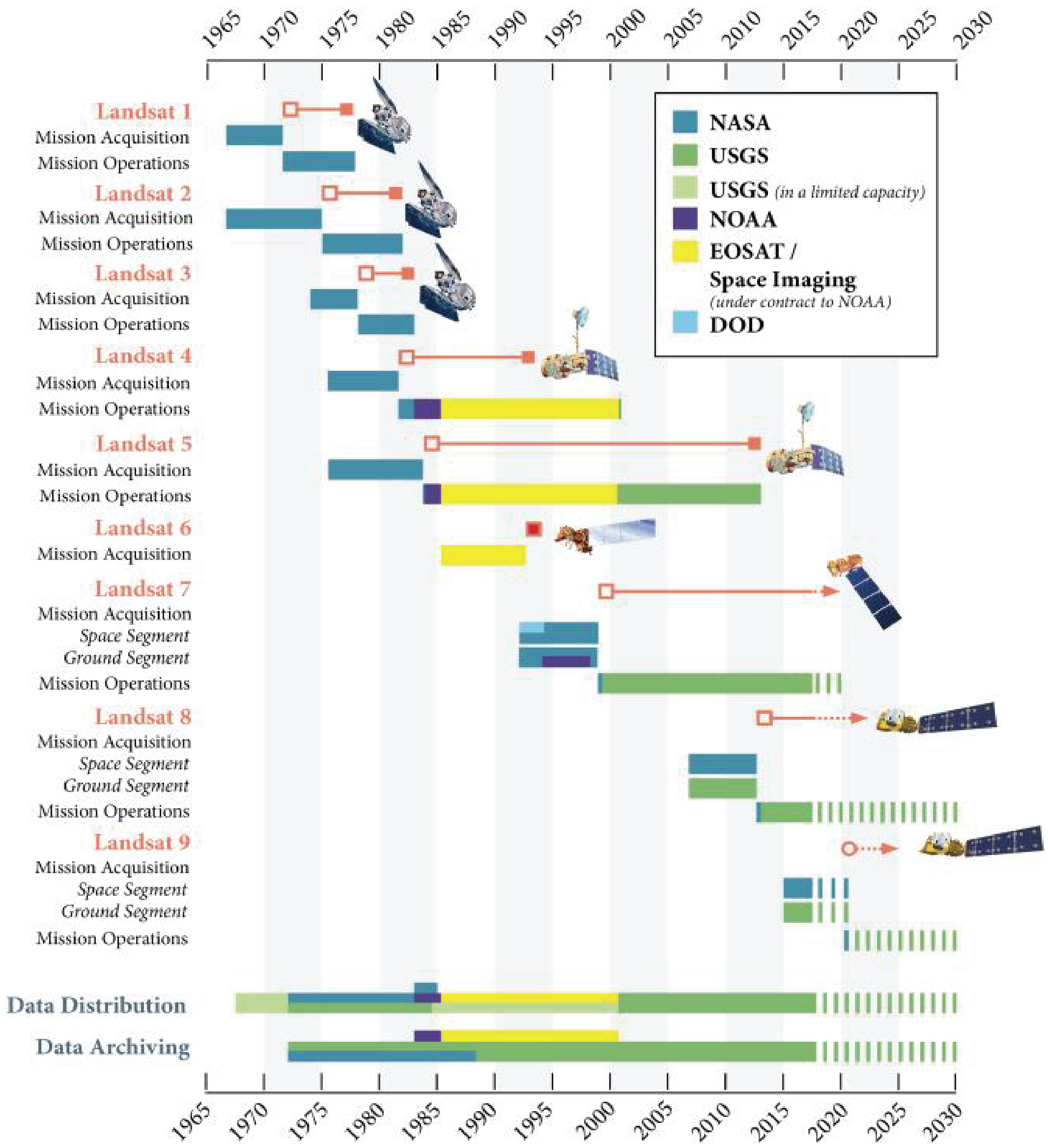

Figure 5.1. Landsat Satellites Mission Operation Periods

5.3. Study Area

Four stations across four transboundary RBs explained in Table 5.1 and shown in Figure 5.2 represent the study area. First location is close to Khwajaghar in-situ gauging station in Kokcha river, Amu RB, second location is close to Tirpul gauging station in Harirud river, Harirud-Murghab RB, third location is close to Khwabgah gauging station in Helmand River, Helmand RB, and the fourth location is close to Dakah gauging station in Kabul River, Kabul RB. These all are the last within country stations along these rivers that can be used to measure the flow going out of the country.

Landsat 5, 7, and 8 footprints WRS-2 path/row encompasses Khwajaghar at path 153, row 34, Tir Pul at path 158, row 36, Khwabgah at path 157, row 39, and Dakah at paths 151 & 152, and row 36 accordingly.

Table 5.1. Specifications of four Hydrological Stations

River Basins	Stations	Station ID	Geographical Location		Drainage Area (km^2)
			Latitude (N)	Longitude (E)	
Helmand RB	Khwabgah	4-0.0002M	30° 48'	61° 46'	159,099.00
Kabul RB	Dakah	1-0.000-1M	34° 14'	71° 02'	67,370.00
Harirud-Murghab RB	Tir Pul	8-0.000-1M	34° 36'	61° 16'	31,760.00
Amu RB	Khojaghar	15-0.000-1M	37° 05'	69° 28'	20,646.00

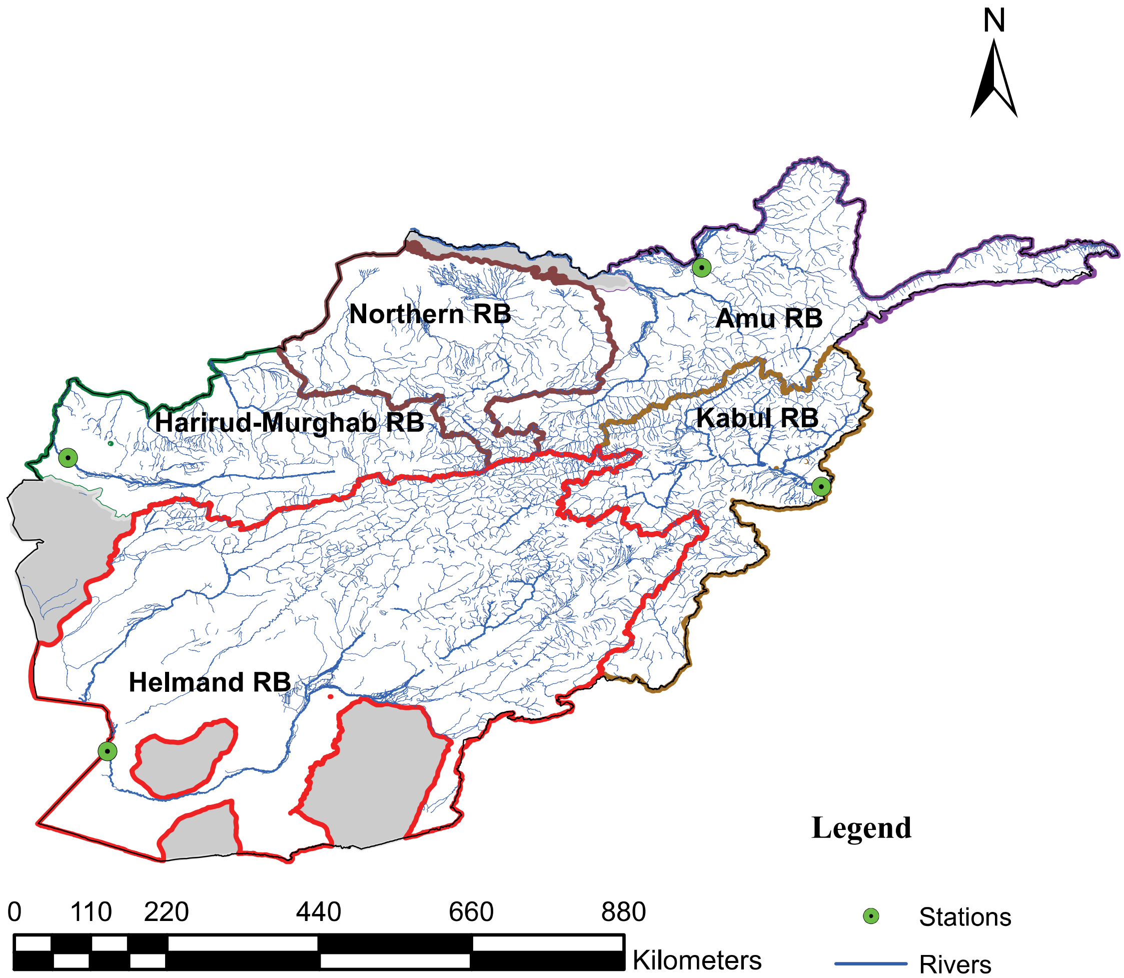

Figure 5.2. Studay Area of Four Transboundary Stations

5.4. Materials and Methods

This specific part of the study focuses on modelling missing river discharge in four critical points along the four transboundary rivers located in four transboundary RBs. The Landsat time series imagery data of three Landsat mission satellites such as Landsat 5 TM, 7 ETM+, and 8 OLI images between January 1988 and December 2021 were acquired from the Level-1 Precision and Terrain (L1TP) in the GEE platform using Java script (see Figure 5.3). Selection of Landsat imagery products viz. SR among the available satellites was mainly based on the concerned study period, especially the period before year 2000 while other satellites and radar altimetry couldn’t be used for this purpose. Indeed, the SR products MODIS onboard Terra and Aqua satellites after year 2000 were also evaluated, but due to their spatial resolution, the results were not satisfactory for discharge modeling. The Landsat images have been already atmospherically corrected using Landsat Surface Reflectance Code (LaSRC) and Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). Technically, LEDAPS is an algorithm that is used for SR atmospheric corrections (Mattiuzzi, & Atzberger, 2015). A total of 3,806 Landsat images were acquired initially for the study time-period. Then, the pixel wise SR products for land (the pixel to be totally in land even during floods) and water (the pixel to be totally in water even in low flow time) were processed from each Landsat image making a total of 7,612 values. Near Infrared (NIR) bands are opted to acquire SR products because in the NIR region reflectance values of common land cover types (such as bare or vegetated soils), have extremely higher values than water pixels (Tarpanelli et al., 2013). Hence, in any given area, during a flood event, water surface increases causing a decrease in the NIR reflectance value of the area detected by the satellite, which enables discharge estimation calculations (Tarpanelli et al., 2013). The analysis process of discharge modeling is summarized in the following ten stages.

1. Four locations along the four transboundary rivers (Amu, Harirud, Helmand, and Kabul) close to borders where the last in-situ gauges are located were selected.
2. The locations were selected so that a Landsat image's 30 x 30 m pixel is completely in water all the time during the year representing in-water pixels.
3. In addition to the four in-water pixels, four locations were chosen to represent in-land pixels to be used for calibration purpose, and these pixels will remain dry even in floods and river overflows.
4. The water and land pixels were named M and C respectively. These pixels represent SR values of land and water.
5. The NIR bands in the wavelength range of 0.76 – 0.90 μm (bands 4 in Landsat 5 and 7, band 5 in Landsat 8) were used to extract the SR products because in the NIR region reflectance values of land pixels have significantly higher readings than water pixels (Tarpanelli et al., 2013).
6. SR values of Landsat series from 1988 to 2021 were obtained through GEE, and a code was developed for this purpose. Indeed, SR data before 1988 for the study locations were not appropriate to be used, that is why, we have not recovered the missing data from 1997 to 1988.
7. To calculate the C/M ratio, the SR values for the land points in each observation were divided by the water points SR values.

8. To reduce the amount of noise in the C/M times series distribution, an exponential filter C/M* was applied as shown in Figure 5.4 (for more details, refer to Tarpanelli et al., 2013).
9. A linear regression analysis between each pair of monthly C/M * data and the existing in-situ river discharge data with respect to each location was then performed to assess their relationship and the correlation among these variables was also tested.
10. The data is then validated and lastly, discharge simulation is performed for the targeted results.

The JavaScript/code for Landsat SR products of this study is provided in APPENDEX B.

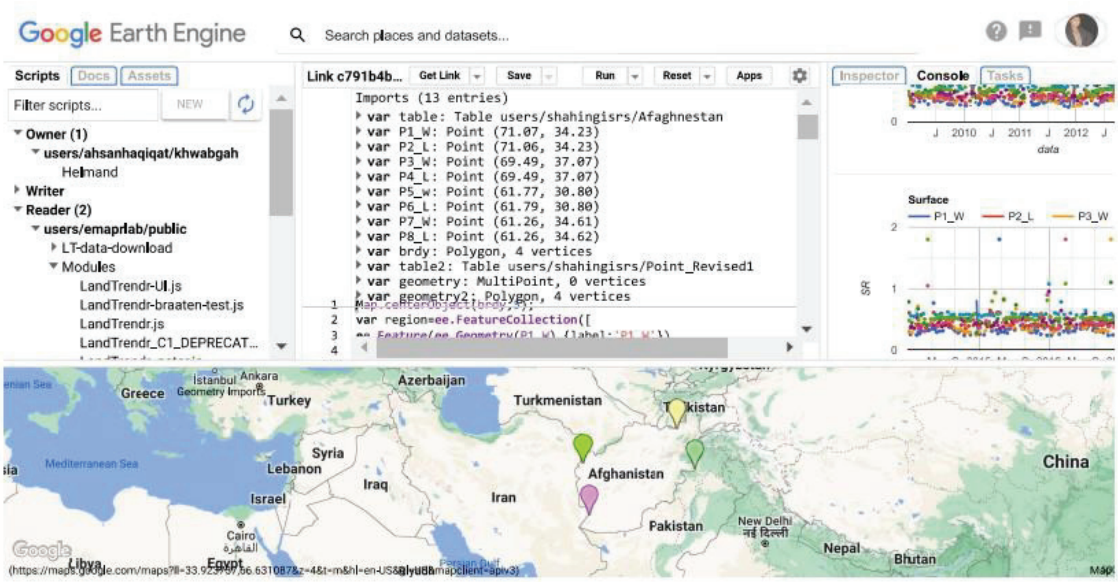

Figure 5.3 . A Screenshot of GEE RS Data Cloud Computing Platform

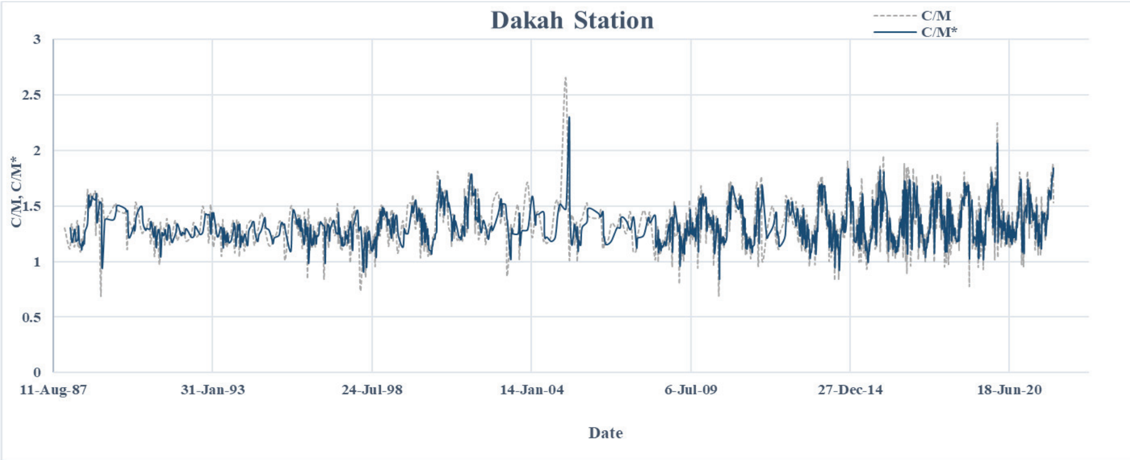

Figure 5.4. C/M and C/M* Graphs

5.5. Results

After running the developed code in the GEE cloud platform, SR products from the Landsat series were acquired and a linear regression analysis between C/M* and discharge time series was employed. The relationship between in-situ discharge and satellite time series enabled us to validate Landsat SR time series for modeling the missing discharge from 1988 to 2021. The correlation coefficient (r) between in-situ (which are available from 2008 to 2019) and C/M* time series in Khwajaghar station (in Amu RB) was 0.53, Tir Pul station (in Harirud-Murghab RB) 0.79, Khwabgah station (in Helmand RB) 0.39, and Dakah station (in Kabul RB) 0.65, which means that one station had very strong correlation coefficient, two strong correlation coefficient, and one station a moderate correlation coefficient that was Khwabgah station in Helmand RB (Table 5.2). According to linear regression analysis, each station was treated separately with the appropriate regression formula, the data was validated for a period of 10 years, and then the discharge was simulated in each station as per the related linear regression formulas as indicated in Figures 5.5 to 5.16.

Table 5.2. Correlation between in-situ discharge and C/M* time series

River Basin	River	Station	*r* between C/M* & *in-situ* Discharge
Amu	Kokcha	Khwajaghar	0.53
Harirud-Murghab	Harirud	Tirpul	0.79
Helmand	Helmand	Khwabgah	0.39
Kabul	Kabul	Dakah	0.65

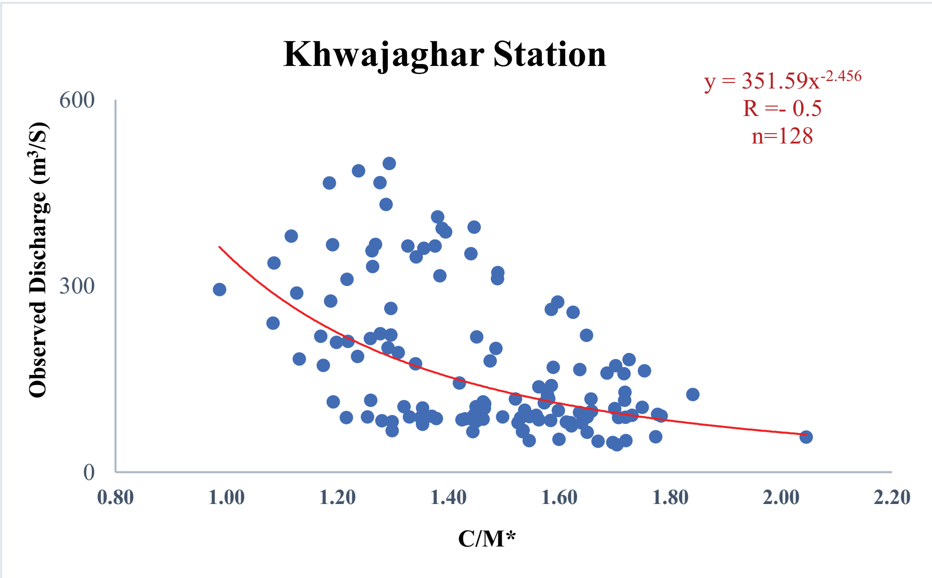

Figure 5.5. Linear Regression between in-situ Discharge and C/M* in Amu RB

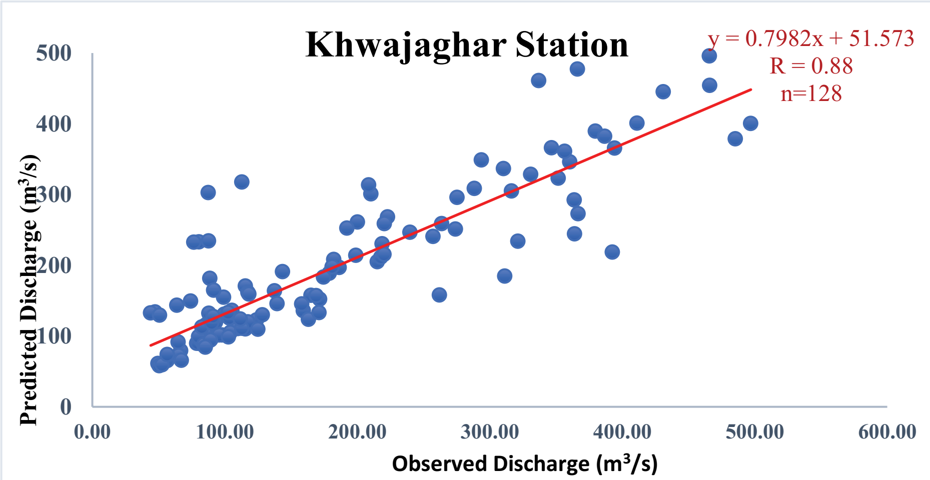

Figure 5.6. Linear Regression between in-situ and Predicted Discharge in Amu RB

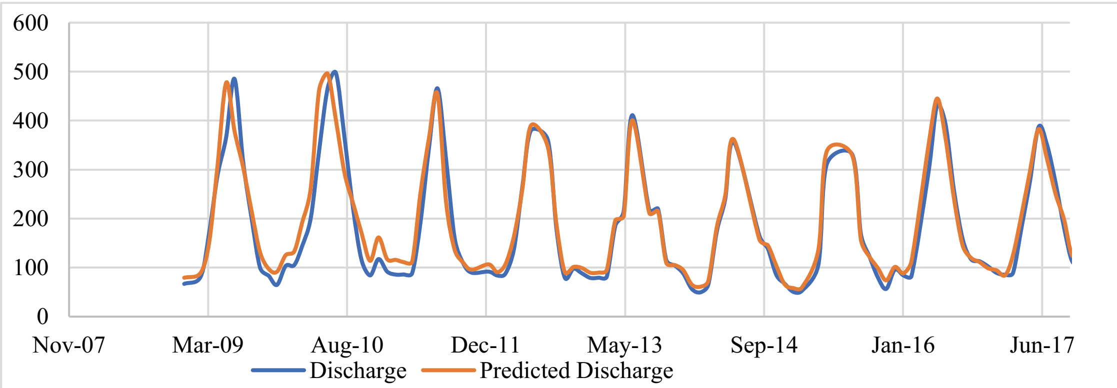

Figure 5.7. Observed Vs. Predicted Discharge in Khwajaghar Station

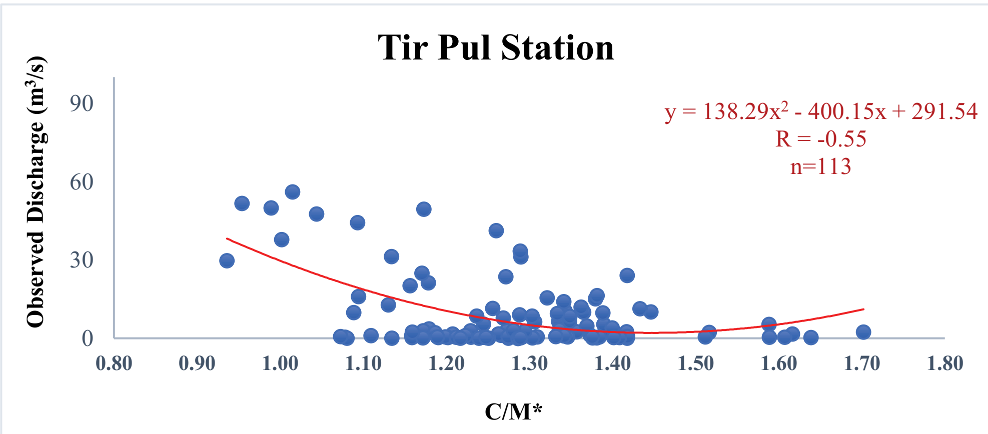

Figure 5.8. Linear Regression between in-situ Discharge and C/M* in H-M RB

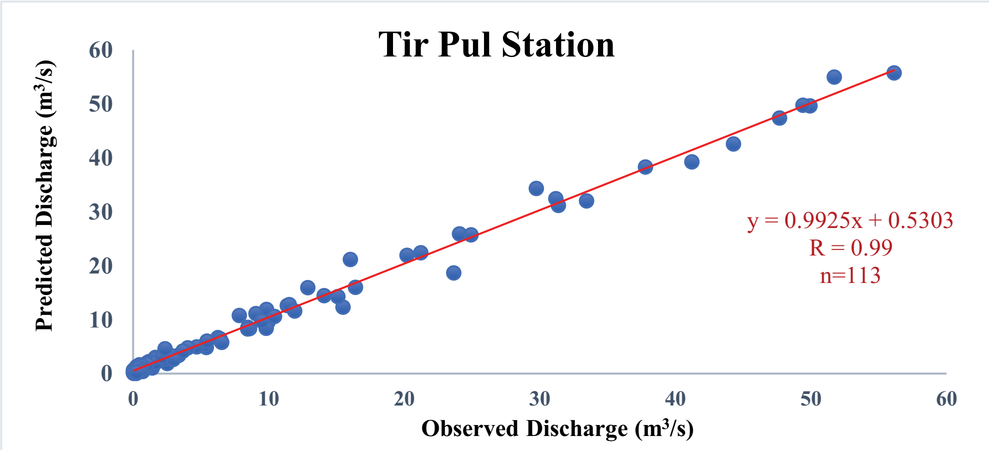

Figure 5.9. Linear Regression between in-situ and Predicted Discharge in H-M RB

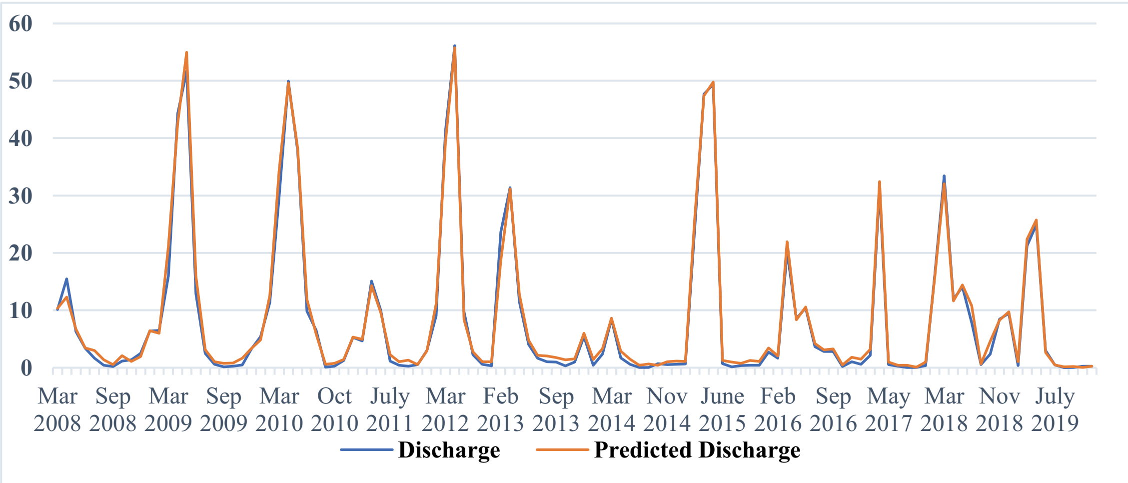

Figure 5.10. Observed Vs. Predicted Discharge in Tirpul Station

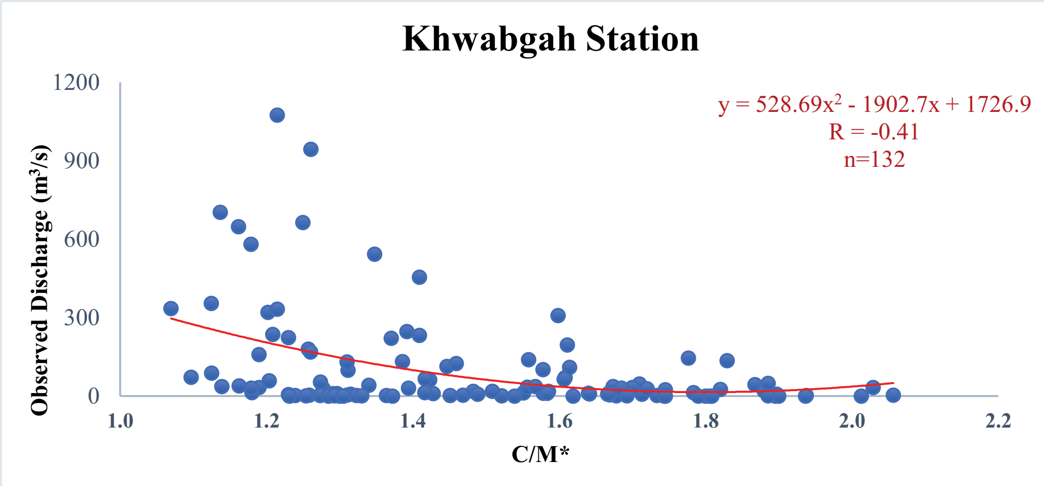

Figure 5.11. Linear Regression between in-situ Discharge and C/M* in Helmand RB

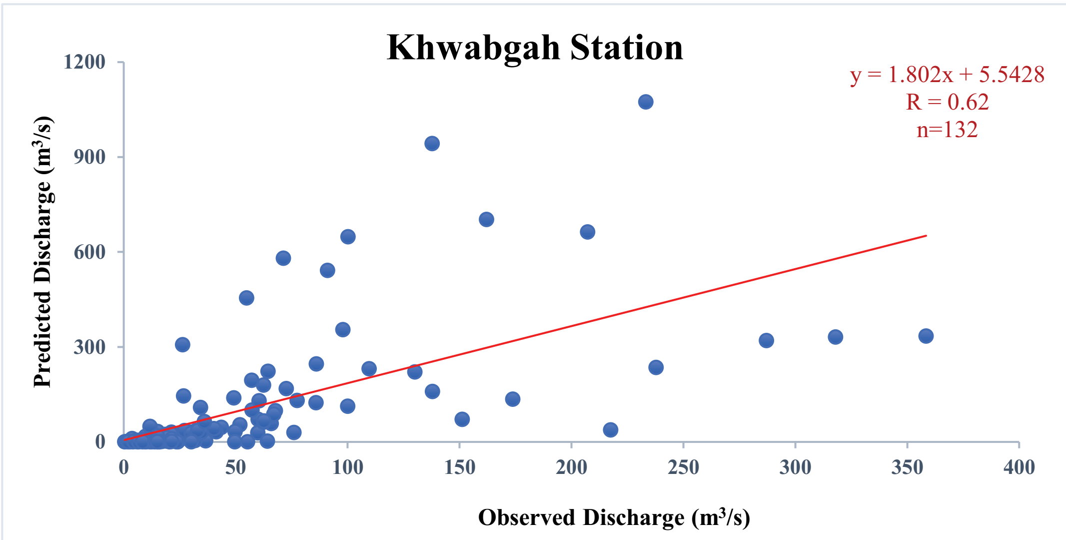

Figure 5.12. Linear Regression between in-situ and Predicted Discharge in Helmand RB

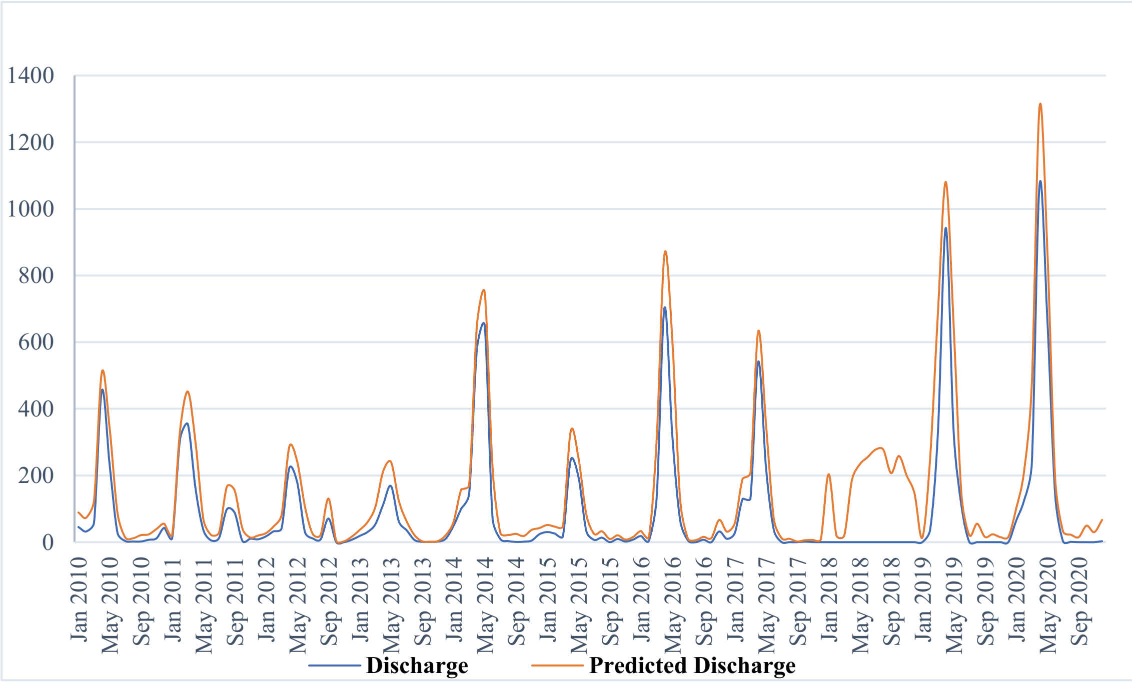

Figure 5.13. Observed Vs. Predicted Discharge in Khwabgah Station

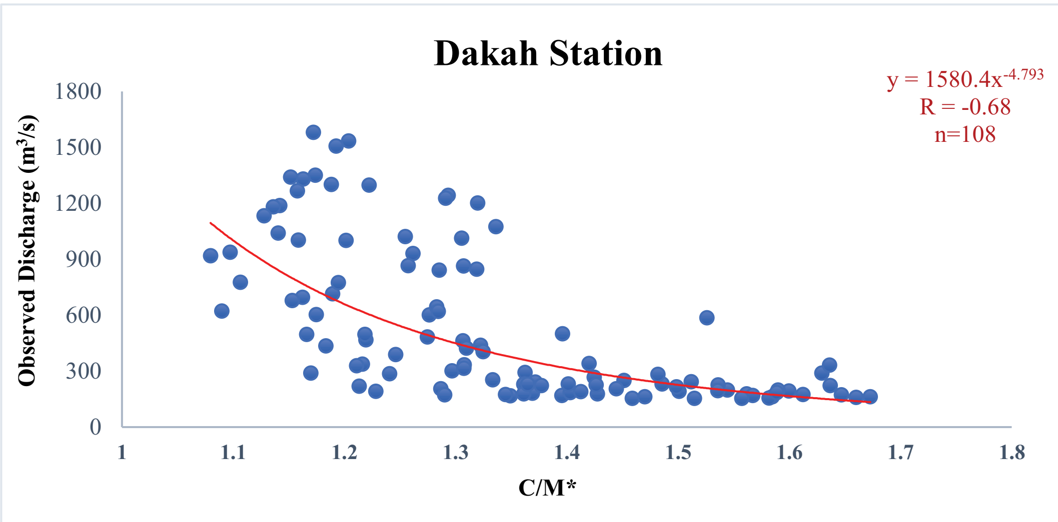

Figure 5.14. Linear Regression between in-situ Discharge and C/M* in Kabul RB

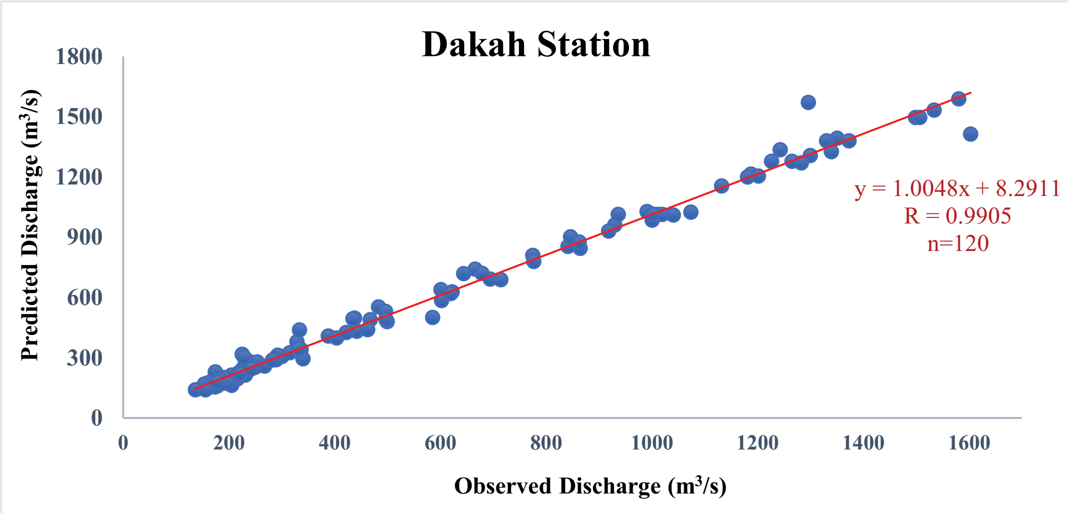

Figure 5.15. Linear Regression between in-situ and Predicted Discharge in Amu RB

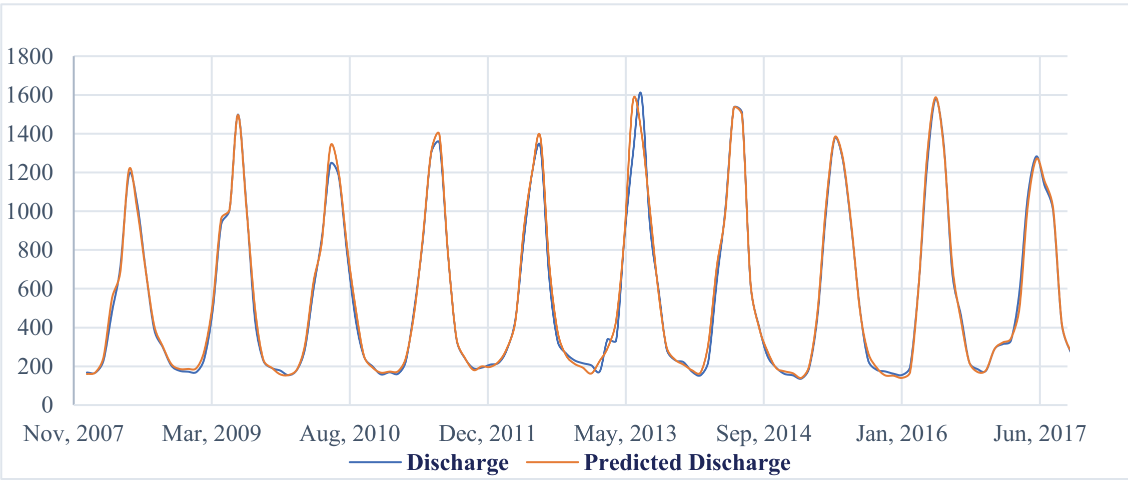

Figure 5.16. Observed Vs. Predicted Discharge in Dakah Station

5.6. Discussion and Conclusion

The in-situ hydrological (river streamflow) data in two-time intervals from 1950/1960 to 1968/1969 and then from 2008/2009 to present is available and the MEW is the responsible body for monitoring, collecting, storing, and processing this data. A gap exists for the period 1979 – 2008 in river streamflow measurement across the entire country. Hence, to fill-in the gap between the two periods mentioned earlier, a novel RS technique was employed in this study. In fact, due to the unavailability of RS data (Landsat SR products) from 1979 to 1987, the discharge gap between 1988 to 2008 was filled in four transboundary RBs of the country. In addition, the discharge modelling in these four gauging stations was extended till end of 2020, which means discharge was estimated for a period 1988-2021.

The correlation coefficient in two stations such as Tirpul and Dakah between C/M* and observed discharge was 0.79 and 0.65 respectively. But the correlation coefficient in Khwajaghar and Khwabgah stations between C/M* and observed discharge was 0.53 and 0.39 that was low than the other two stations may be due to shallow water in the rivers during the Landsat visit. Still, there was not any other available satellite to rely on during the period of study and because of the width of these rivers around 100 to 200 m maximum. The modeled discharge data for the four stations across four transboundary RBs of the country is provided in APPENDEX D.

CHAPTER 6

HYDROLOGICAL DROUGHT

6.1. Introduction

Human activities such as water withdrawal, irrigation, urbanization, changes in land use and land cover, and particularly reservoir operation have adverse impacts on hydrological drought (Van Loon et al., 2016). The relationship of human activities and hydrological drought is important research field as highlighted by the International Association of Hydrological Science in the recent scientific decade of 'Panata Rhei' (Montanari et al., 2013). Hence, examining the long-term evolution patterns of hydrological droughts is of vital significance that may have impact by infrastructures made by human (Yu et al., 2019).

Streamflow drought occurs when there is considerable low streamflow condition in reference to a normal flow taking the spatial and temporal characteristics of a region into account (Van Loon, 2013). Hydrological drought characteristics in a region are mainly governed by regional climatic factors. Drought indicator can be computed on different time intervals to characterize drought severity in various streamflow regimes and climatic conditions (Wang et al., 2015; Fleig et al., 2006; Van Loon, 2013). Therefore, selection of drought analysis indices should be based on long-term available streamflow data and the ability of index itself as well so that to precisely detect spatio-temporal variability of a hydrologic drought event.

6.2. Data Acquisition

River discharge data consist of two different timeframes (1950/1960 – 1978/1979 and 2008/2009 – 2019) is obtained from the MEW. The first set of in-situ streamflow data is called historical data collected from the USGS installed stations, and the second set of data is collected from newly installed in-situ gauging stations by MEW, which is also called new data. In addition, streamflow data from four stations across transboundary RBs, which was modeled from 1988 to 2021 was also used hydrological drought analysis process.

6.3. Study Area

The study area encompasses the whole country of Afghanistan as already explained in Chapter 3. Streamflow data of 52 hydrological in-situ stations was used from all five RBs as detailed in Tables 6.1 to 6.5.

Table 6.1. Specifications of Hydrological Stations in Amu RB

Station	Latitude	Longitude	Altitude (m)	River Basin	Sub-River Basin	River
Ahangaran	34.833	67.982	2379	Amu	Upper Kunduz	Bamyan
Baghlan	36.109	68.672	540	Amu	Lower Kunduz	Kunduz
Balay-i-Kelagai	35.741	68.755	749	Amu	Lower Kunduz	Kunduz
Bamyan	34.823	67.825	2507	Amu	Upper Kunduz	Bamyan
Dasht-i-Safid	35.317	67.906	1604	Amu	Upper Kunduz	Kahmard
Doshi	35.604	68.691	847	Amu	Lower Kunduz	Andarab
Faizabad	37.110	70.557	1180	Amu	Kokcha	Kokcha
Gerdab	36.361	68.863	475	Amu	Lower Kunduz	Kunduz
Keshem	36.933	70.050	808	Amu	Kokcha	Keshem
Khwajaghar	37.069	69.487	488	Amu	Taluqan	Kokcha
Nazdik-i-Jurm	36.926	70.858	1438	Amu	Kokcha	Kokcha
Nazdik-i-Taluqan	36.635	69.737	1008	Amu	Taluqan	Farkhar

Table 6.2. Specifications of Hydrological Stations in Harirud-Murghab RB

Station	Latitude	Longitude	Elevation (m)	River Basin	Sub-River Basin	River
Cheldukhtaran	35.121	62.316	773	Harirud-Murghab	Harirod Murghab	Murghab
Dawlatyar	34.547	65.754	2435	Harirud-Murghab	Upeper Harirud	Harirud
Nazdik-i-Herat	34.421	62.449	1140	Harirud-Murghab	Upeper Harirud	Harirud
Pul-i-Hashemi	34.341	61.937	865	Harirud-Murghab	Lower Harirud	Harirud
Rabat-i-Akhund	34.260	62.944	1183	Harirud-Murghab	Lower Harirud	Harirud
Shinya	34.508	65.669	2407	Harirud-Murghab	Upeper Harirud	Harirud
Torghundi	35.253	62.283	673	Harirud-Murghab	Lower Harirud	Murghab

Table 6.3. Specifications of Hydrological Stations in Helmand RB

Station	Lat.	Long.	Elev. (m)	River Basin	Sub-River Basin	River
Adraskan	33.63	62.26	1339	Helmand	Lower Helmand	Helmand
Farah	32.36	62.06	651	Helmand	Farah Rod	Farah
Gardandiwal	34.50	68.21	2739	Helmand	Upper Helmand	Helmand
Gardiz	33.59	69.22	2299	Helmand	Upper Jilga	Jilga
Lashkargah	31.58	64.35	773	Helmand	Middle Helmand	Helmand
Nazdik-i-Adraskan	33.70	62.28	1382	Helmand	Lower Helmand	Helmand
Nazdik-i-Gardandiwal	34.58	68.17	3066	Helmand	Upper Helmand	Helmand
Nazdik-i-Kandahar	31.61	65.57	971	Helmand	Arghandab	Arghandab
Tarnak	31.56	65.84	1019	Helmand	Arghandab	Arghandab
Waras	34.22	66.92	2498	Helmand	Upper Helmand	Helmand

Table 6.4. Specifications of Hydrological Stations in Kabul RB

Station	Latitude	Longitude	Elevation (m)	River Basin	Sub-River Basin	River
Asmar	34.915	71.202	832	Kabul	Kunar	Kunar
Bagh-i-Lala	35.152	69.221	1698	Kabul	Ghorband	Salang
Bagh-i-Omomi	35.149	69.288	1587	Kabul	Ghorband	Shutul
Chaghasarai	34.909	71.129	847	Kabul	Kunar	Pich
Doabi	35.348	69.619	2059	Kabul	Panjshir Balayi	Dara-i-Hazara
Estalef	34.828	69.078	1821	Kabul	Kabul Balayi	Estalef
Keraman	35.284	69.657	2232	Kabul	Panjshir Balayi	Dara-i-Hazara
Naghlo	34.637	69.717	998	Kabul	Kabul Payini	Kabul
Nawabad	34.820	71.120	796	Kabul	Kunar	Kunar
Omarz	35.376	69.641	2042	Kabul	Panjshir Balayi	Panjshir
Payin-i-Qargha	34.553	69.036	1970	Kabul	Kabul Wasati	Paghman
Pul-i-Behsod	34.442	70.460	555	Kabul	Kabul Payini	Kabul
Pul-i-Kama	34.469	70.557	558	Kabul	Kabul Payini	Kunar
Pul-i-Qarghayi	34.547	70.242	643	Kabul	Laghman	Laghman
Qala-i-Malek	34.577	68.970	2211	Kabul	Kabul Wasati	Paghman
Sultanpor	34.416	70.296	686	Kabul	Kabul Payini	Surkh Rod
Tang-i-Gulbahar	35.159	69.289	1625	Kabul	Ghorband	Panjshir
Tang-i-Sayedan	34.409	69.104	1870	Kabul	Kabul Wasati	Maidan

Table 6.5. Specifications of Hydrological Stations in Northern RB

Station	Latitude	Longitude	Elevation (m)	River Basin	Sub-River Basin	River
Asiabad	36.189	65.955	657	Northern	Sar-i-Pul	Sar-i-Pul
Dara-i-Zhwandon	36.167	68.072	1440	Northern	Khulm Aibak	Samangan
Dawlatabad	36.418	64.883	404	Northern	Shirin Tagab	Faryab
Doshqadam	34.975	66.526	2241	Northern	Upper kunduz	Bamyan
Nazdik-i-Nayak	34.743	66.994	2613	Northern	Upper kunduz	Bamyan
Nazdik-i-Sar-i-Pul	36.158	66.103	760	Northern	Sar-i-Pul	Sar-i-Pul
Sayad	36.537	67.812	715	Northern	Khulm Aibak	Samangan
Tang-i-Tashqurghan	36.659	67.695	516	Northern	Khulm Aibak	Samangan

6.4. Methodology

Like meteorological drought monitoring, hydrological drought is also examined through some indices. Thus, a prevailing drought index called SDI was employed for historical hydrological drought analysis.

6.4.1. Streamflow Drought Index (SDI):

Proposed by Nalbantis and Tsakiris (2009), in this method, it is assumed that a monthly series of streamflow volumes over a given period $Q_{i,j}$ with 'i' impliying the hydrological year and 'j' the rank of the month in that hydrological year (j=1 for October and j=12 for September). Therefore, we obtain:

$$V_{i,k} = \sum_{j=1}^{3k} Q_{i,j} \quad i = 1, 2, \dots \quad j = 1, 2, \dots, 12 \quad k = 1, 2, 3, 4 \tag{10}$$

In the above equation, $V_{i,k}$ is the cumulative streamflow volume for the i-th hydrological year and the k-th reference period, $k = 1$ for October-December, $k = 2$ for October-March, $k = 3$ for October-June, and $k = 4$ for October-September.

The SDI is defined according to the cumulative streamflow volumes $V_{i,k}$ for each reference period of the i-th hydrological year as:

$$\mathrm{SDI}_{i,k} = \frac{V_{i,k} - \bar{V}_k}{s_k} \quad i = 1, 2, \ldots, \quad k = 1, 2, 3, 4 \tag{11}$$

Where $\bar{V}_k$ is the mean and s_k is the standard deviation of the cumulative streamflow volumes of reference period k as these are calculated over a long period of time. Even other values can be used, the truncation level is set to $\bar{V}_k$ in this context. In the following Table 6.6, the hydrological drought is classified based on the SDI:

Table 6.6. Hydrological Drought Classification based on SDI

State	Description	Criterion	Probability (%)
0	Non-drought	SDI ≥ 0.0	50
1	Mild drought	$-1.0 \leq$ SDI < 0.0	34.1
2	Moderate drought	$-1.5 \leq$ SDI < -1.0	9.2
3	Severe drought	$-2.0 \leq$ SDI < -1.5	4.4
4	Extreme drought	SDI < -2.0	2.3

6.5. SDI Results

The hydrological drought based on the SDI analysis results are in two different time series datasets called as historical and new discharge data respectively. The data for each station differs from another with respect to time. Each station has different timeframes with some just with new discharge data. Therefore, the results are presented accordingly as shown in Tables 6.7, 6.8, 6.9, 6.10, 6.11, and 6.12. Following are some extreme, severe, and moderate hydrological drought events that occurred across the RBs based on a 12 month or annual time step because the monthly analysis is beyond the scope of this study.

Extreme Drought Events: Extreme events occurred in 2007 in Gerdab station and in 2011 in Ahangaran station in Amu RB. In Helmand RB, the extreme hydrological drought episodes were observed in 1962 and 1970 in Farah station, in 1971 in Khwabgah station, in 2012 in Waras station, and in 2018, in Gardiz, Lashkargah, and Nazdik-i-Kandahar stations. In Kabul RB, extreme hydrological drought was detected in 1971 in Bagh-i-Lala, Bagh-i-Omomi, Pul-i-Qarghai, and Sultanpur stations, in 1977 in Bagh-i-Omomi, Omarz, and Tanga-i-Gulbahar stations, in 2006 in Payin-i-Qargha stations, in 2008 in Tanga-i-Gulbahar station, in 2011 in Chaghasarai station, and in 2018 in Tanga-i-Sayedan station. indeed, extreme droughts were not observed in Harirud-Murghab and Northern RBs for the study period.

Severe Drought Events: Severe drought episodes were detected in the Amu RB in 1971 in Baghlan and Gerdab stations, in 1972 in Khwajaghar and Nazdik-i-Jurm stations, in 1974 in Doshi and Khwajaghar stations, in 2008 in Baghalan station, in 2009 and 2011 in Faizabad station, in 2012 in Keshem, and in 2020 in Khwajaghar stations. Further, these kinds of events were detected in Harirud-Murghab RB in 1971 and 2015 in Dawlatyar station, in 2010 and 2012 in Nazdik-i-Herat and Rabat-i-Akhond stations respectively. In the Helmand RB, severe drought was just detected in 1971 in Farah, Nazdik-i-Adraskan, and Waras stations. Moreover, severe drought in the Kabul RB was observed in 1970 in Pul-i-Qarghai and Tanga-i-Sayedan stations, in 1971 in Chaghasarai, Naghlo, and Tanga-i-Sayedan staions, in 1974 in Payin-i-Qargha and Sultanpur stations, in 1977 in Bagh-i-Lala and Naghlo stations, in 2011 in Boabi stations, in 2013 in Naghlo, and in 2018 in Bagh-i-Lala and Naghlo stations. Also, severe drought hit just Dara-i-Zhwandon station in 2019 in the Northern RB.

Moderate Drought Events: Amu RB suffered moderate droughts in 1971 in Doshi and Khwajaghar stations, in 1974 in Baghlan, Gerdab, and Keshem stations, in 1977 in Doshi station, in 1978 in Baghlan station, in 2008 in Gerdab station, in 2009 in Dasht-i-Safid station, in 2011 in Dasht-i-Safid and Gerdab stations, in 2013 in Keshem station, in 2014, 2017, and 2018 in Nazdik-i-Jurm station, and in 2020 in Dasht-i-Safid station. In Harirud-Murghab RB, moderate drought was observed in Rabat-i-Akhond station in 1966, in Dawlatyar station in 1970, in Rabat-i-Akhond station in 1971, in Shinya station in 2010, 2011, and 2012, in Dawlatyar station in 2012, in Rabat-i-Akhond station in 2013, in Dawlatyar, Pul-i-Hashemi, and Shinya stations in 2018, and in Torghundi station in 2010. In Helmand RB, moderate drought was seen in 1955 in

Nazdik-i-Kandahar station, in 1958 and 1963 in Farah station, in 1966 in Nazdik-i-Kandahar station, in 1970 in Nazdik-i-Adraskan station, in 1971 in Gardandiwal and Nazdik-i-Gardandiwal stations, in 1974 in Gardiz and Tarnak stations, in 1977 in Adraskan and Nazdik-i-Kandahar stations, in 1979 in Nazdik-i-Gardandiwal station, in 2010, 2011, and 2012 in Adraskan station, in 2012, 2013, and 2015 in Khwabgah station, in 2013 in Nazdik-i-Adraskan station, in 2015 in Nazdik-i-Kandahar station, in 2017 in Lashkargah station, and in 2018 in Farah, Gardandiwal, Nazdik-i-Adraskan, and Nazdik-i-Gardandiwal stations. In Kabul RB, moderate drought episodes were observed in 1962 in Chaghsarai and Pul-i-Qarghai stations, in 1964 in Asmar station, in 1970 in Bagh-i-Lala and Sultanpur stations, in 1971 in Omarz, Payin-i-Qargha, Pul-i-Kama, and Tanga-i-Gulbahar stations, in 1974 in Bagh-i-Omomi, Naghlo, Pul-i-Kama, Tanga-i-Gulbahar, and Tanga-i-Sayedan, in 1975 and 1976 in Omarz station, in 1977 in Pul-i-Kama, Pul-i-Qarghai, Sultanpur, and Tanga-i-Sayedan stations, in 2007 in Pul-i-Qarghi station, in 2008 in Nawabad station, in 2012 in Chaghasarai station, in 2013 in Asmar, Pul-i-Qarghai, and Tanga-i-Gulbahar stations, in 2014 in Pul-i-Kama station, in 2015 in Pul-i-Behsod station, in 2016 in Keraman station, in 2018 in Bagh-i-Omomi and Estalif astations, and in 2020 in Keraman station. Further, these types of droughts were detected in the Northern RB in 1974 in Dawlatabad, in 2012 in Dara-i-Zhwandoon, in 2017 and 2019 in Asiabad stations.

Comparison of hydrological and meteorological drought events is challenging in this study due to three reasons: First, the first set of hydrological time series are until 1979, which cannot be compared with meteorological time series as they are from 1979 to 2019; Second, most of the precipitation in Afghanistan is in the form of snowfall and most of the perennial rivers are fed during the year by packs of snowmelt stored on the high altitudes of the mountains; and Third, monthly meteorological and hydrological analysis was not performed in this study, which may have presented some promising results, and this kind of analysis was beyond the scope of the study. That is why, in most cases, hydrological drought events do not follow the meteorological drought paths in this study.

However, after precisely examining these two series, there were some cases that meteorological drought happened in the same year and or was followed by hydrological drought. For instance, in the Nazdik-i-Jurm station of Amu RB, a severe drought occurred in 2017, where a moderate hydrological drought happened in this year as well and was extended to 2018. An extreme meteorological drought event in 2017 in the Harirud-Murghab RB's Pul-i-Hashemi was followed by a moderate hydrological drought event in 2018. Furthermore, an extreme meteorological drought in 2017 in the Lashkargah station of Helmand RB was followed by an extreme hydrological drought in 2018 in the same station. In addition, a moderate hydrological drought in Nazdik-i-Adraskan station in 2018 succeeded moderate meteorological drought of 2017 in the Helmand RB. In the Kabul RB, a severe meteorological drought in 2017 was followed by severe hydrological drought in 2018 in the Naghlo station, and another severe moderate meteorological drought in 2017 was followed by mild hydrological drought in 2017 and moderate hydrological drought in 2018 in the Estalif station.

Table 6.7. Extreme Hydrological Drought Events in Afghanistan as per SDI Index

Station	Year										
	1962	1970	1971	1977	2006	2007	2008	2010	2011	2012	2018
Ahangaran	-	-	-	-	-	-	-	-	-2.7	-	-
Gerdab	-	-	-	-	-	-2.4	-	-		-	-
Dawlatyar	-	-	-1.5	-	-	-	-	-	-1.7	-	-
Nazdik-i-Herat	-	-	-	-	-	-	-	-1.5	-	-	-
Pul-i-Hashemi	-	-	-	-	-	-	-	-	-	-	-
Farah	-2.6	-2	-	-	-	-	-	-	-	-	-
Gardiz	-	-	-	-	-	-	-	-	-	-	-2.7
Khwabgah	-	-	-2.2	-	-	-	-	-	-	-	-
Lashkargah	-	-	-	-	-	-	-	-	-	-	-2.4
Tarnak	-	-	-	-	-	-	-	-	-	-	-2.7
Waras	-	-	-	-	-	-	-	-	-	-2.2	-
Asmar	-	-	-	-	-	-	-	-	-	-	-
Bagh-i-Lala	-	-	-2.9	-	-	-	-	-	-	-	-
Bagh-i-Omomi	-	-	-3	-2.1	-	-	-	-	-	-	-
Chaghasarai	-	-	-	-	-	-	-	-	-2.6	-	-
Doabi	-	-	-	-	-	-	-	-	-	-	-
Estalif	-	-	-	-	-	-	-	-	-	-	-
Keraman	-	-	-	-	-	-	-	-	-	-	-
Naghlo	-	-	-	-	-	-	-	-	-	-	-
Nawabad	-	-	-	-	-	-	-	-	-	-	-
Omarz	-	-	-	-2	-	-	-	-	-	-	-
Payin-i-Qargha	-	-	-	-	-3.1	-	-	-	-	-	-
Pul-i-Behsod	-	-	-	-	-	-	-	-	-	-	-
Pul-i-Kama	-	-	-	-	-	-	-	-	-	-	-
Pul-i-Qarghay	-	-	-2.2	-	-	-	-	-	-	-	-
Sultanpur	-	-	-2.4	-	-	-	-	-	-	-	-
Tanga-i-Gulbahar	-	-	-	-2.2	-	-	-2.1	-	-	-	-
Tanga-i-Sayedan	-	-	-	-	-	-	-	-	-	-	-2.2

Table 6.8. Severe Hydrological Drought Events in the Amu RB

Station	Year							
	1971	1972	1974	2008	2009	2011	2012	2020
Ahangaran	-	-	-	-	-	-	-	-
Baghlan	-1.62	-	-	-1.58	-	-	-	-
Bamyan	-	-	-	-	-	-	-	-
Dasht-i-Safid	-	-	-	-	-	-	-	-
Doshi	-	-	-1.53	-	-	-	-	-
Faizabad	-	-	-	-	-1.76	-1.74	-	-
Gerdab	-1.63	-	-	-	-	-	-	-
Keshem	-	-	-	-	-	-	-1.66	-
Khwajaghar	-	-1.72	-1.69	-	-	-	-	-1.82
Nazdik-i-Jurm	-	-1.86	-	-	-	-	-	-

Table 6.9. Severe Drought Events in the Harirud-Murghab RB

Station	Year			
	1971	2010	2012	2015
Dawlatyar	-1.53	-	-	-1.69
Nazdik-i-Herat	-	-1.53	-	-
Pul-i-Hashemi	-	-	-1.90	-

Table 6.11. Severe Hydrological Drought Events in the Helmand RB as per SDI

Stations	Year															
	1955	1958	1963	1966	1970	1971	1974	1977	1979	2010	2011	2012	2013	2015	2017	2018
Adraskan	-	-	-	-	-	-	-	-1.19		-1.04	-1.05	-1.14	-	-	-	-
Farah	-	-1.05	-1.48	-	-	-	-	-	-	-	-	-	-	-	-	-1.35
Gardandiwal	-	-	-	-	-	-1.34	-	-	-	-	-	-	-	-	-	-1.11
Gardiz	-	-	-	-	-	-	-1.23	-	-	-	-	-	-	-	-	-
Khwabgah	-	-	-	-	-	-	-	-	-	-	-	-1.17	-1.45	-1.25	-	-
Lashkargah	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-1.07	-
Nazdik-i-Adraskan	-	-	-	-	-1.05	-	-	-	-	-	-	-	-1.20	-	-	-1.23
Nazdik-i-Gardandiwal	-	-	-	-	-	-1.32	-	-	-1.31	-	-	-	-	-	-	-1.19
Nazdik-i-Kandahar	-1.47	-	-	-1.19	-	-	-	-1.33	-	-	-	-	-	-1.19	-	-
Tarnak	-	-	-	-	-	-	-1.23	-	-	-	-	-	-	-	-	-

Table 6.12. Severe Hydrological Drought Events in the Kabul RB as per SDI

Station	Year						
	1970	1971	1974	1977	2011	2013	2018
Asmar	-	-	-	-	-	-	-
Bagh-i-Lala	-	-	-	-1.53	-	-	-1.52
Bagh-i-Omomi	-	-	-	-	-	-	-
Chaghasarai	-	-1.66	-	-	-	-	-
Doabi	-	-	-	-	-1.77	-	-
Estalif	-	-	-	-	-	-	-
Keraman	-	-	-	-	-	-	-
Naghlo	-	-1.70	-	-1.51	-	-1.58	-1.63
Nawabad	-	-	-	-	-	-	-
Omarz	-	-	-1.75	-	-	-	-
Payin-i-Qargha	-	-	-	-	-	-	-
Pul-i-Behsod	-	-	-	-	-	-	-
Pul-i-Kama	-	-	-	-	-	-	-
Pul-i-Qarghay	-1.53	-	-	-	-	-	-
Sultanpur	-	-	-1.74	-	-	-	-
Tanga-i-Gulbahar	-	-	-	-	-	-	-
Tanga-i-Sayedan	-1.56	-1.95	-	-	-	-	-

Table 6.13. Moderate Hydrological Drought Events in the H-M RB as per SDI

Station	Year			
	1974	2012	2017	2019
Asiabad	-	-	-1.42	-1.18
Dara-i-Zhwandon	-	-1.49	-	-
Dawlatabad	-1.13	-	-	-

6.6. Discussion and Conclusion

Afghanistan is a mountainous country where most of the rivers get flow from the snowmelt of these mountains during the year in all five RBs. The results from two different hydrological time series (1950/1960 – 1978/1979 and 2008/2009 – 2019/2020) do not show likely compromising results with meteorological drought because of three main reasons such as unavailability of meteorological data before 1979 to compare it with the historical streamflow data, snowpacks in the mountainous areas that fed most of the perennial rivers during the spring, summer, and even in some cases, fall seasons in addition to rainfall, and finally, monthly rainfall and streamflow analysis was not performed to detect precise hydrological and meteorological paths, which was out of the scope of this study.

Indeed, there were many extreme, severe, and moderate hydrological drought events in 2017 and 2018 in several stations across all five RBs where considerable meteorological droughts occurred in the same years as well. In addition, all RBs have suffered hydrological drought events in different stations and in different time intervals during the study period. Most importantly, hydrological drought in Afghanistan does not strictly follow meteorological drought patterns due to the huge amount of snow in higher altitudes of the country, which is the main source of water for many rivers during the year. Therefore, readers may take this sign into consideration.

Finally, as the hydrological drought effect across the RBs is lower than meteorological drought, still, most of the water crosses borders and flow to neighboring countries, which has significant implication on availability of surface water throughout the year with lack of infrastructure and storing enough water, especially during drought years with lack of snowfall in addition to reduced rainfall.

CHAPTER 7

CLIMATIC TRENDS

7.1. Introduction

Drought studies usually encompass trends identification in climatic variables as well to understanding their historical behavior and predict future climatic scenarios. Here in this study, it was aimed to understand the trends in four decades of precipitation, temperature, and streamflow time series. Therefore, the well-known non-parametric Mann-Kendall trend test along with Sen's slope estimator were employed. Even though, about 127 stations as operational at present, but some of these stations do not have consistent data or some of these stations are newly installed. Hence, this Chapter presents trend results of 54 stations for precipitation, 44 stations for temperature, and 50 stations for streamflow. Most of the stations showed decreasing trends in precipitation and increasing trends in temperature, especially in the last two decades (1999-2018).

7.2. Data Acquisition and Processing

The rainfall and temperature data for the period 1979-2019 was obtained from the MEW for 55 ground stations as explained in Chapter 3. Streamflow data for two different time periods was also acquired from MEW. In addition, the modeled streamflow data for four stations along four transboundary rivers in this study were also used in hydrological trend analysis, which is explained in Chapter 4.

7.3. Study Area

The study area is Afghanistan as a whole country where climatic and hydrological data of 44 stations across all five RBs as shown in Figure 3.1. in meteorological drought chapter.

7.4. Methodology

We applied the non-parametric Mann-Kendall (MK) and Sen's slope tests in this part of the study to find trends in precipitation, temperature, and streamflow across all five RBs of Afghanistan. The reason for using MK test is its higher power than many other widely used tests as per Hess et al. (2001). In addition, it is highly recommended by the World Meteorological Organization (WMO) for general uses. Choosing Sen's slope test in addition to MK test was to measure the significance of the tendency of meteorological and hydrological parameters.

7.4.1. MK Test

The data in Mann-Kendall test is organized in a rank order first. Then, the statistical variance between two data in the rank order is used to determine whether it is positive or negative. In a simple way, the null hypothesis in this test argues that there is no trend in a time series, whereas the alternative hypothesis says that there is a trend in a time series. Trend can be determined at a 95% level of significance to reject the null hypothesis. The MK trend test fist computes an S statistic as follow:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \tag{12}$$

Where, x_j & x_k = values of k and $j (j > k)$ in time series, $sgn(x_j - x_k)$ is the sign function. n = number of data points.

$$sgn(x_j - x_k) \begin{Bmatrix} +1, \text{if } x_j - x_k > 0 \\ 0, \text{if } x_j - x_k = 0 \\ -1, \text{if } x_j - x_k < 0 \end{Bmatrix} \tag{13}$$

If sample size $n > 10$, the mean and variance are given by:

$$\mu(s) = 0 \tag{14}$$

$$\sigma^2(s) = n(n-1)(2n+5) - \frac{\sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \tag{15}$$

Where, t_i = number of ties of extent i, m = number of ties group.

A set of data containing the same values is called tied group. If tie values are between the observations, then:

$$\sigma^2(s) = \frac{n(n-1)(2n+5)}{18} \tag{16}$$

The standard normal test statistics Z_s is computed as:

$$Z_s = \begin{Bmatrix} \frac{s-1}{\sqrt{\sigma^2(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \frac{s+1}{\sqrt{\sigma^2(S)}}, & \text{if } S < 0 \end{Bmatrix} \tag{17}$$

Positive and negative values of Z_s represent the increasing and decreasing trend, respectively. The trend analysis was carried out at 5% of significance level and at this level the null hypothesis of no trend is rejected.

If $|Z_s| > 1.96$.

7.4.2. Sen's Slope Test

This statistical non-parametric method computes the magnitude of slope in a time series data developed by Sen (1968). The Sen's slope estimator computes the slope (S) of a data x as follows:

$$T_i = x_j - x_k/j - k \tag{18}$$

x_j = data value at time j.

x_k = data value at time k.

$$Q_i = \begin{cases} T_{(N+1)/2} & \text{N is odd} \\ 1/2(T_{\frac{N}{2}} + T_{\frac{N+2}{2}} & \text{N is even} \end{cases} \quad (19)$$

Q_i = positive values show increasing trend.

Q_i = negative values show decreasing trend.

7.5. Trends in Precipitation

Analysis of accumulated monthly rainfall for the period 1979 – 2019 based on Mann-Kendall test showed trends in 21 stations out of all 55 considering the p-value at significance level of alpha = 0.05. Further, employing Sen's slope estimator these 21 stations, 15 stations showed decreasing and 6 showed increasing trends in precipitation during the study period.

Table 7.1. Amu RB Mann-Kendall's Trend and Sen's Slope Results for Precipitation

Station	Year From	Year To	Number of Years	ρ-value	test Z	Sen's Slope (β)
Ahangaran	1979	2019	41	0.92839	-0.08987	-0.06246
Baghlan	1979	2019	41	0.00040	-3.53806	-4.29404
Balay-i-Kelagai	1979	2019	41	0.00186	-3.11125	-3.83387
Bamyan	1979	2019	41	0.00001	-4.48154	-4.29670
Dasht-i-Safid	1979	2019	41	0.00092	-3.31342	-4.52811
Doshi	1979	2019	41	0.07594	-1.77476	-1.58348
Faizabad	1979	2019	41	0.11847	-1.56124	-1.93426
Gerdab	1979	2019	41	0.35121	-0.93225	-0.75515
Keshem	1979	2019	41	0.01390	-2.45979	-2.22414
Khwajaghar	1979	2019	41	0.20437	-1.26921	-1.12861
Nazdik-i-Jurm	1979	2019	41	0.00271	-2.99893	-3.49348
Nazdik-i-Taluqan	1979	2019	41	0.01674	-2.39240	-2.78382

Table 7.2. Harirud-Murghab RB Mann-Kendall’s Trend and Sen’s Slope Results for Precipitation

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Cheldukhtaran	1979	2019	41	0.30673	-1.02211	-1.11243
Dawlatyar	1979	2019	41	0.04681	-1.98805	-1.89751
Nazdik-i-Herat	1979	2019	41	0.92839	-0.08987	-0.06246
Pul-i-Hashemi	1979	2019	41	0.45173	-0.75254	-0.59723
Rabat-i-Akhund	1979	2019	41	0.00018	-3.74024	-5.55855
Shinya	1979	2019	41	0.02692	-2.21269	-2.41940
Torghundi	1979	2019	41	0.00092	-3.31342	-3.97477

Table 7.3. Helmand RB Mann-Kendall’s Trend and Sen’s Slope Results for Precipitation

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Adraskan	1979	2019	41	0.15050	-1.43778	-1.65157
Farah	1979	2019	41	0.20437	-1.26921	-0.94417
Gardandiwal	1979	2019	41	0.07055	-1.80834	-3.18549
Gardiz	1979	2019	41	0.43834	0.77500	1.39264
Lashkargah	1979	2019	41	0.47919	0.70761	0.53681
Nazdik-i-Adraskan	1979	2019	41	0.47919	0.70761	0.53681
Nazdik-i-Gardandiwal	1979	2019	41	0.02260	2.28008	3.84736
Nazdik-i-Kandahar	1979	2019	41	0.00137	-3.20110	-6.57957
Tarnak	1979	2019	41	0.11847	-1.56124	-1.87363
Waras	1979	2019	41	0.00291	2.97646	2.70486

Table 7.4. Kabul RB Mann-Kendall’s Trend and Sen’s Slope Results for Precipitation

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Asmar	1979	2019	41	0.08571	1.71849	3.38603
Bagh-i-Lala	1979	2019	41	0.02260	2.28008	3.85398
Bagh-i-Omomi	1979	2019	41	0.14119	1.47138	2.90591
Chagahsarai	1979	2019	41	0.04934	1.96558	4.03539
Doabi	1979	2019	41	0.55165	-0.59529	-0.68328
Estalif	1979	2019	41	0.00000	-3.89748	-7.3719
Keraman	1979	2019	41	0.24732	1.15689	1.41532
Naghlo	1979	2019	41	0.27593	-1.08950	-1.37848
Nawabad	1979	2019	41	0.10823	1.60616	2.57096
Omarz	1979	2019	41	0.52202	0.64022	0.87659
Payin-i-Qargha	1979	2019	41	0.33972	0.95471	1.28852
Pul-i-Behsod	1979	2019	41	0.20436	-1.26921	-1.60933
Pul-i-Kama	1979	2019	41	0.13522	-1.49385	-1.91679
Pul-i-Qarghai	1979	2019	41	0.76169	-0.30326	-0.48697
Qala-i-Malik	1979	2019	41	0.30673	-1.02211	-1.94935
Sultanpur	1979	2019	41	0.89882	-1.69602	-2.64895
Tanga-i-Gulbahar	1979	2019	41	0.01890	2.34747	4.61453
Tanga-i-Sayedan	1979	2019	41	0.95521	-0.05616	-0.18365

Table 7.5. Northern RB Mann-Kendall's Trend and Sen's Slope Results for Precipitation

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Asiabad	1979	2019	41	0.18502	-1.32545	-1.50901
Dara-i-Zhwandon	1979	2019	41	0.93733	0.07862	0.06883
Dawalatabad	1979	2019	41	0.03376	2.12283	3.14291
Doshqada	1979	2019	41	0.00000	-5.44749	-11.68600
Nazdik-i-Nayak	1979	2019	41	0.25662	1.13443	1.26298
Nazdik-i-Saripul	1979	2019	41	0.61325	-0.50544	-0.55040
Sayad	1979	2019	41	0.12386	-1.53878	-0.89258
Tanga-i-Tashqurghan	1979	2019	41	0.00009	-3.91995	-3.88864

7.6. Trends in Temperature

Analysis of average monthly temperature for the period 1979 – 2019 in majority of the 46 stations across the country in all five RBs showed increasing trends. While significant trends were detected in 34 of the stations, just 3 of these stations had decreasing trends, and the remaining 31 stations had increasing average temperature during the study period.

Table 7.6. Amu RB Mann-Kendall's Trend and Sen's Slope Results for Temperature

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Ahangaran	1979	2019	41	0.00001	4.41415	0.22577
Baghlan	1979	2019	41	0.00000	6.90764	0.11101
Balay-i-Kelagai	1979	2019	41	0.00000	5.58227	0.11124
Bamyan	1979	2019	41	0.08169	-1.74095	-0.01504
Dasht-i-Safid	1979	2019	41	0.00020	3.71777	0.10114
Doshi	1979	2019	41	0.00001	4.34676	0.06787
Faizabad	1979	2019	41	0.00000	5.67213	0.18640
Gerdab	1979	2019	41	0.00000	5.82938	0.07044
Keshem	1979	2019	41	0.00005	4.05473	0.04567
Khwajaghar	1979	2019	41	0.05200	1.94313	0.02739
Nazdik-i-Jurm	1979	2019	41	0.00001	4.36922	0.22106
Nazdik-i-Taluqan	1979	2019	41	0.00252	3.02139	0.03691

Table 7.7. Harirud-Murghab RB Mann-Kendall’s Trend and Sen’s Slope Results for Temperature

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Cheldukhtaran	1979	2019	41	0.24732	1.15689	0.01471
Dawlatyar	1979	2019	41	0.00000	-4.68372	-0.11101
Nazdik-i-Herat	1979	2019	41	0.00001	4.41415	0.22577
Pul-i-Hashemi	1979	2019	41	0.00117	3.24603	0.04103
Rabat-i-Akhund	1979	2019	41	0.00037	3.56052	0.03849
Shinya	1979	2019	41	0.00018	3.74024	0.19272
Torghundi	1979	2019	41	0.00148	3.17864	0.03414

Table 7.8. Helmand RB Mann-Kendall’s Trend and Sen’s Slope Results for Temperature

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Adraskan	1979	2019	41	0.00078	3.35835	0.03628
Farah	1979	2019	41	0.76169	0.30326	0.00296
Gardandiwal	1979	2019	41	0.41226	0.81993	0.00995
Gardiz	1979	2019	41	0.76169	0.30326	0.00321
Lashkargah	1979	2019	41	0.09422	1.67356	0.01686
Nazdik-i-Adraskan	1979	2019	41	0.11847	1.56124	0.01701
Nazdik-i-Gardandiwal	1979	2019	41	0.00006	-4.03227	-0.04547
Nazdik-i-Kandahar	1979	2019	41	0.00001	4.48154	0.06940
Tarnak	1979	2019	41	0.00000	5.08807	0.06252

Table 7.9. Kabul RB Mann-Kendall’s Trend and Sen’s Slope Results for Temperature

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Asmar	1979	2019	41	0.76169	-0.30326	-0.00478
Bagh-i-Lala	1979	2019	41	0.00000	5.87430	0.12502
Bagh-i-Omomi	1979	2019	41	0.00000	5.85184	0.15966
Doabi	1979	2019	41	0.00001	4.54893	0.07164
Keraman	1979	2019	41	0.22943	1.20182	0.01501
Naghlo	1979	2019	41	0.01574	2.41487	0.02385
Payin-i-Qargha	1979	2019	41	0.00029	3.62792	0.03853
Pul-i-Kama	1979	2019	41	0.00000	5.49242	0.05769
Pul-i-Qarghai	1979	2019	41	0.00000	4.72865	0.04419

Table 7.10. Northern RB Mann-Kendall’s Trend and Sen’s Slope Results for Temperature

Station	Year		Number of Years	ρ-value	test Z	Sen's Slope (β)
	From	To				
Asiabad	1979	2019	41	0.00000	4.59386	0.07270
Dara-i-Zhwandon	1979	2019	41	0.00000	5.94170	0.12672
Doshqada	1979	2019	41	0.00002	4.32430	0.12526
Nazdik-i-Nayak	1979	2019	41	0.00012	3.85255	0.15730
Nazdik-i-Saripul	1979	2019	41	0.00482	2.81888	0.04586
Sayad	1979	2019	41	0.00000	5.76198	0.14055
Tanga-i-Tashqurghan	1979	2019	41	0.00000	5.87430	0.14904

7.7. Trends in Streamflow

Analysis of monthly mean streamflow for two different periods (1960/1970 to 1979 and 2008/2009 to 2020) was performed to detect trends across all five RBs in the country. Stations those with significant decreasing trends are Gerdab in Amu RB, Farah, Gardandiwal, Gardiz, Khwabgah, Lashkargah, Nazdik-i-Adraskan, Nazdik-i-Gardandiwal, and Nazdik-i-Kandahar in Helmand RB, and Naghlo in Kabul RB. We can see that the most affected basin is the Helmand RB with most stations with decreasing streamflow during the two time periods. Tables 7.11 to 7.15 represent the Mann-Kendall's trend and Sen's slope results with respect to each RB.

Table 7.11. Amu RB RB Mann-Kendall's Trend and Sen's Slope Results for Streamflow

Station	Year		Number of Years	ρ-value	Kendall's Tau	Sen's Slope (β)
	From	To				
Ahangaran	2009	2020	12	0.3040	0.2424	0.0827
Baghlan	1969	2019	24	0.1366	0.2214	0.2006
Bamyan	1970	2020	18	0.5959	0.0980	0.0160
Dasht-i-Safid	1968	2018	19	0.2342	-0.2047	-0.0189
Doshi	1965	2020	28	0.1856	-0.1799	-0.0929
Faizabad	2009	2020	12	0.0865	0.3939	3.3336
Gerdab	1965	2020	28	-0.0423	-0.0423	-0.0541
Keshem	1970	2020	22	0.8215	-0.0390	-0.0187
Khwajaghar	1965	2020	27	0.4044	-0.1168	-0.3659
Nazdik-i-Jurm	1970	2020	22	0.9326	-0.0174	-0.0073

Note: Number of years are different for each station as hydrological data represents two different periods (historical and new data).

Table 7.12. Harirud-Murghab RB RB Mann-Kendall’s Trend and Sen’s Slope Results for Streamflow

Station	Year From	Year To	Number of Years	ρ-value	Kendall's Tau	Sen's Slope (β)
Dawlatyar	1970	2020	21	0.587	0.091	0.055
Nazdik-i-Herat	1974	2020	16	0.443	0.151	0.012
Pul-i-Hashemi	1974	2020	19	0.345	-0.164	-0.100
Rabat-i-Akhund	1967	2020	26	0.172	-0.194	-0.189
Shinya	2010	2020	11	0.029	0.527	0.519
Torghundi	2015	2020	6	0.133	-0.600	-0.020

Note: Number of years are different for each station as hydrological data represents two different periods (historical and new data).

Table 7.13. Helmand RB RB Mann-Kendall’s Trend and Sen’s Slope Results for Streamflow

Station	Year From	Year To	Number of Years	ρ-value	Kendall's Tau	Sen's Slope (β)
Adraskan	1974	2020	15	0.519	-0.134	-0.506
Farah	1964	2020	27	0.001	-0.445	-12.677
Gardandiwal	1970	2020	18	0.008	-0.467	-0.287
Gardiz	1971	2020	17	0.013	-0.450	-0.274
Khwabgah	1969	2020	21	0.032	-0.343	-9.841
Lashkargah	1973	2020	15	0.003	-0.581	-12.345
Nazdik-i-Adraskan	1964	2020	27	0.004	-0.399	-0.780
Nazdik-i-Gardandiwal	1971	2020	20	0.018	-0.389	-0.115
Nazdik-i-Kandahar	1964	2020	18	0.028	-0.386	-2.766
Tarnak	1970	2020	15	0.215	-0.249	-0.120
Waras	1970	2020	18	0.081	-0.307	-0.674

Note: Number of years are different for each station as hydrological data represents two different periods (historical and new data).

Table 7.14. Kabul RB RB Mann-Kendall's Trend and Sen's Slope Results for Streamflow

Station	Year		Number of Years	ρ-value	Kendall's Tau	Sen's Slope (β)
	From	To				
Asmar	2012	2020	9	0.009	0.722	52.499
Bagh-i-Lala	1966	2020	27	0.901	0.867	-0.008
Bagh-i-Omomi	1968	2020	24	0.901	0.022	0.002
Chaghasarai	1964	2020	28	0.149	-0.196	-0.229
Doabi	2010	2020	11	0.876	-0.055	-0.121
Estalif	2011	2020	10	0.858	-0.067	-0.016
Keraman	2010	2020	11	0.062	-0.455	-0.472
Naghlo	1964	2020	29	0.009	-0.345	-0.852
Nawabad	1964	2020	21	0.000	0.606	3.233
Omarz	1964	2020	27	0.058	-0.262	-0.075
Payin-i-Qargha	1965	2020	28	0.128	0.207	0.001
Pul-i-Behsod	2010	2020	11	0.087	0.418	7.015
Pul-i-Kama	1968	2020	25	0.944	-0.013	-0.031
Pul-i-Qarghai	1964	2020	29	0.639	0.064	0.096
Qala-i-Malik	2009	2019	11	0.276	-0.273	-0.069
Sultanpur	1969	2020	22	0.021	0.359	0.071
Tanga-i-Gulbahar	1964	2020	29	0.639	0.064	0.096
Tanga-i-Sayedan	1964	1979	16	0.053	-0.367	-0.253

Note: Number of years are different for each station as hydrological data represents two different periods (historical and new data).

Table 7.15. Northern RB Mann-Kendall's Trend and Sen's Slope Results for Streamflow

Station	Year		Number of Years	ρ-value	Kendall's Tau	Sen's Slope (β)
	From	To				
Asiabad	1965	2020	28	0.213	-0.169	-0.014
Dara-i-Zhwandon	2009	2018	10	0.474	0.200	0.150
Dawlatabad	1971	2020	20	0.871	0.032	0.001
Nazdik-i-Nayak	1970	2019	19	0.003	0.497	0.041
Nazdik-i-Saripul	1971	2019	21	0.349	0.152	0.007
Tanga-i-Tashqurghan	1970	2020	23	0.00009	0.008	0.031

Note: Number of years are different for each station as hydrological data represents two different periods (historical and new data).

7.8. Discussion and Conclusion

Based on the meteorological and hydrological time series, many stations across all five RBs have shown significant trends. Significant decrease in precipitation in 15 stations out of 55 stations under study indicate a considerable variation in rainfall. Also, increase in temperature in 31 stations out of 46 is another indicator of climate change that exacerbate drought events further. Hydrological trends results show decreasing trend in 10 stations out of 52 for the study periods. Indeed,

These all trends (increase in temperature and decrease in precipitation and streamflow) are indication of rapid climate change in the country, especially South, West, and South-West regions where temperature is higher. Amu, Harirud-Murghab, and Helmand RBs have the highest number of decreasing rainfalls throughout the years. Average temperature is increased in all RBs in most of the stations covered in this study. Further, significant streamflow decrease is detected in many of the stations in Helmand RB.

CHAPTER 8

DROUGHTS AND TRENDS IMPACTS ON TRANSBOUNDARY RIVERS

8.1. Introduction

Therefore, this section of the research is taking an initial step to undertake quantitative assessment that how climate change has affected transboundary river flows in the study area. The long-term ground observed available hydro-meteorological data was used to evaluate its response to changing climate conditions. Further, the of these adverse climatic conditions are studied in the context of transboundary implications river management. Finally, obtained results of the historical data analysis are compared to the available literature in this field.

8.2. Impact of Historical Drought and Trend Conditions on Transboundary Rivers

Water scarcity is currently affecting almost two-thirds of the world's population (Mekonnen and Hoekstra, 2016). Besides, due to recent climate changes, more drought events may occur, and temperature will increase, especially in arid regions such as Afghanistan adding uncertainty to quantity of water resources. Indeed, studying spatial and temporal variations in water resources are important for further water usage and planning.

Hajihosseini et al. (2016) assessed the long-term hydrological condition of the upper Helmand River and evaluated the 1973 HRWT applying remotely sensed data from the Climate Research Unit (CRU) with SWAT modelling for the runoff simulation of Helmand RB from 1940 to 2012. Finally, according to a 30 year monthly simulated streamflow at Dehrawud station (a reference station stipulated in the treaty) in the upper

Helmand RB, there is no considerable trend in the mean annual flow, which indicates 5661.7 MCM/yr. flow is still valid to represent normal year based on the treaty.

Due to the prolonged drought events in Helmand RB, it has exacerbated the problem with downstream neighbor (Iran) about Helmand River Water Treaty. The treaty stipulates those 22 cubic meters per second water plus 4 cubic meters per second due to friendship between the two countries (26 cubic meters per second in total) will be given to Iran during the normal years (Helmand River Treaty, 1973). This is clear that the available supply of water has been reduced, especially since last two decades in the basin according to the historical analysis performed in this study. Therefore, there is a need that the two upstream and downstream countries accept the phenomena of a new normal in the hydrological cycle of this basin.

8.3. Climate Change Adaptation in Transboundary Waters

According to the Intergovernmental Panel on Climate Change (IPCC) (2018), the average temperature is expected to increase by 1.5°C by 2030 globally. Due to temperature increase, more drought events and hydrological inconsistencies will occur in semi-arid and arid regions that can directly affect transboundary river flows. In addition, rapid snowmelt that makes about 80% of Afghanistan's precipitation is happening in recent years has created a new challenge. The climate change will further create various challenges for water resources management, especially when it comes to water sharing with neighboring countries. Hence, cooperation is required to enlarge the set of options under consideration and to prevent the transfer of vulnerabilities across the border (De Stefano et al., 2017).

8.4. Discussion and Conclusion

Afghanistan is a landlocked arid to semi-arid country with four transboundary RBs. Water from Amu RB is shared with Central Asian countries such as Tajikistan, Uzbekistan, and Turkmenistan. Helmand RB's water is flowing to Iran with only one water sharing treaty over Helmand River. Kabul RB's water flows into Pakistan, and

Harirud-Murghab's water is flowing towards Iran and Turkmenistan. While most of water flows to downstream and riparian states with no formal sharing agreement except for the Helmand River Water Treaty (HRWT), this country needs hydropower generation and economic development through agricultural activities in addition to water resources management. Indeed, Afghanistan as a late upstream developer suffers various challenges, but we have focused on droughts and climatic trends implications on transboundary rivers providing a guideline to policymakers and water resources managers in this respect. For this reason, historical droughts and trends in streamflow and meteorological variables is studied to see how they affect transboundary rivers.

Based on the historical meteorological and hydrological drought results, it can be clearly seen that in the four decades of the study period, the last two decades were adversely impacted by frequent episodes of droughts with high magnitudes and the spatial and temporal variability of rainfall is critical to understand at this point with the dynamically changing climate and particularly in the upcoming years. The decadal decrease in the cumulative annual rainfall, increase in decadal average temperature, increased evapotranspiration across the entire country and on RB level are the main reasons of decline in the transboundary river flow volume.

We know that water resources are getting more and more attention almost by all countries around the world. Economic and political stability along with sovereignty are influential factors for a country's hydro-hegemony. Even conflicts over transboundary water are inevitable due to the scarcity of water but can be mitigated or prevented via cooperation, sound hydropolitics, negotiations, and particularly entering into formal and legal sharing agreements and treaties. Usually, upstream countries around the world practice different forms of controls over their water called hydro-hegemony. Afghanistan as a less sovereign and in a weak hydro-hegemon state is facing several water security challenges while most of its water is flowing into neighboring countries without any legal sharing rather than one treaty over Helmand River water sharing with Iran.

On one hand, the country needs agricultural development, food security, generating hydropower, economic development, and water resources management. On the other hand, climate change, lack of necessary resources for these developments, and other exterior influences have made it very challenging to manage transboundary waters.

CHAPTER 9

RESEARCH SUMMARY AND RECOMMENDATIONS

9.1. Research Summary

This study has investigated several topics in the field of water resources engineering i.e., hydrological drought, meteorological drought, trends in hydrological and meteorological variables, and various impacts of these phenomena on transboundary rivers. Particularly, modelling river discharge using a state-of-the-art method in transboundary rivers contributes to the novelty in this research. Further, in-situ, reanalysis, and remotely sensed modeled hydro-meteorological data is used making this research unique among other drought analyses and climatic studies in Afghanistan.

9.2. Key Findings

The key findings of this study were:

1. Obtained and assembled in-situ hydro-meteorological data of Afghanistan for the first time with a considerable scale.
2. For the first time, analyzed a long term (1979-2019) hydrological and meteorological droughts, using data from 55 ground observed gauging stations from that covered whole country.
3. Detected trends and their magnitudes in rainfall, temperature, and streamflow.

9.3. Research Limitations

Each study is associated with at least some kind of limitations whether it is time, data, method, or resource related. Thus, this study has also its limitations that are explained one by one. However, it was aimed to at least use and obtain all ground observed and available data along with employing techniques and methods to eliminate obstacles at a maximum level.

9.3.1. Limitations in Meteorological Drought Analysis

Base on the volume of the stations and the spatial coverage of the study that was a whole country, we opted to employ two well-known meteorological indices viz., SPI and RDI, which are almost similar in performance except RDI requires PET as input in addition to cumulative precipitation. Even the available stations represented each RB, but the spatial coverage of RBs was not satisfactory, especially in the largest Helmand RB due to unavailability of meteorological data. Finally, we used a 12-month time scale for computing SPI and RDI rather than using 1-, 3-, and 6-month time scale due to the large amount of data.

9.3.2. Limitations in River Discharge Modelling

We had the following obstacles while modelling missing river discharge in the last stations along the four transboundary rivers

1. We had to use satellite optical sensors for obtaining SR products with availability period of before 2000 while Landsat SR time series were the only option. Still, the satellite data with low spatial resolution after 2000 was not suitable for this study as well.
2. The widths of the rivers in the study were 200 m at maximum, hence, we had to choose satellite imagery with high spatial resolution such as Landsat. However, the temporal resolution (16 days interval) left us with a limitation of not catching daily streamflow measures, but bi-weekly and monthly.
3. Due to the challenges described above, the correlation between in-situ and predicted discharge ranged from 0.39 to 079 in four gauging stations.

9.3.3. Limitations in Hydrological Drought Analysis

All the in-situ gauging stations across the country have missing streamflow data for the period 1979 – 2008 and some of them even after 2008. Since investigation of hydrological drought needs a reasonable length of streamflow data, this study could use a two-time interval ground observed data from 1956/1960 to 1978/1979 and from 2008 to 2019 except for four stations in four transboundary RBs, which's missing data was modeled using RS method. Still, RS method applied in this study could not provide necessary data before 1988, which means that a gap existed yet in the time series from 1979 to 1987. In fact, to the best of our knowledge, there was not any other satellite data that we could use for this purpose in the considered timeframe and locations.

9.3.4. Limitations in Trend Analysis

Even with analysis of the 55 stations' data across the country, some regions with extreme weather conditions could not be covered because of the in-situ data unavailability in those areas. Hence, the climatic and hydrologic trends results may not provide a precise, detailed and comprehensive knowledge.

9.4. Recommendations for the Further Studies

This study can be used as a good reference for those researchers who want to pursue drought and climate related studies in more details and with different extents, especially for arid and semi-arid regions such as Afghanistan.

1. Most importantly, modelling missing river discharge in rivers with the use of RS techniques using multiple satellite data rather than using a single source satellite data is recommended.
2. Combining radar altimetry and optical sensors to model river discharge in a specifical location along perennial rivers.

3. Employing additional meteorological drought indices that may behave differently than RDI and SPI and with different time scales is highly recommended for monitoring short term temporal droughts.
4. Also, expanding the study with increased number of gauging stations that can cover remote, inaccessible, high altitudes, and spatially strategic areas will provide a detailed insight into the meteorological drought observation topics.
5. Modelling missing river discharge in all hydrological in-situ station may help interested researchers and professionals to detect spatial and temporal preciseness of meteorological and hydrological droughts and the interrelation characteristics for a better planning, future developments, and particularly water security.
6. Quantifying snow via RS methods to find out direct relationship of snow with hydrological drought characteristics, which is critical for transboundary rivers studies.
7. Studying characteristics of snowmelt due to climate changes and their implications on streamflow during drought events with respect to drought severity.

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APPENDIX A

METEOROLOGICAL DROUGHT CLASSIFICATION BASED ON SPI AND RDI INDICES

SPI Classification for Amu RB Stations (1979-2019)

Year	Ahangaran	Baghlan	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Faizabad	Gerdab	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1979	2.14	1.08	0.67	0.51	0.29	0.41	-2.01	0.25	-0.35	0.01	-0.05	-0.43
1980	0.64	0.78	-0.54	0.91	0.66	-0.25	0.95	-0.23	0.61	0.02	0.57	0.50
1981	1.12	1.38	0.50	0.68	0.76	0.57	0.23	0.30	-0.09	0.00	0.06	0.67
1982	1.94	1.31	0.35	0.98	1.41	1.53	2.02	1.12	1.32	0.89	1.28	0.75
1983	1.08	0.34	0.62	0.16	1.02	2.17	0.69	0.57	-0.47	-0.77	0.47	0.99
1984	0.02	-0.31	0.53	0.30	0.12	-0.04	1.60	0.65	1.00	1.24	1.46	0.39
1985	0.38	-1.52	-0.13	0.48	0.47	-0.72	-1.44	-2.61	-2.01	-2.05	0.09	-0.90
1986	0.23	1.52	0.65	0.41	-0.05	0.09	0.80	-0.06	0.95	1.46	0.87	1.55
1987	0.18	0.70	1.52	0.28	0.58	0.95	-0.49	0.48	0.38	0.13	0.47	0.83
1988	0.56	-0.62	1.11	0.18	0.07	0.65	0.12	-0.13	0.18	0.42	0.51	0.67
1989	0.16	0.44	0.29	0.80	-0.10	-0.29	1.38	0.26	0.48	0.05	0.82	0.54
1990	1.90	0.37	1.02	1.44	0.99	0.34	0.53	0.80	0.75	0.79	0.21	0.21
1991	1.05	1.03	0.90	1.33	0.27	1.02	1.70	1.09	1.36	1.07	1.56	0.18
1992	0.81	0.15	1.31	0.34	0.40	0.76	0.42	1.66	0.98	0.57	0.69	-0.12
1993	0.02	0.58	1.68	0.29	0.23	1.11	0.11	0.96	0.18	0.22	0.68	-0.02
1994	0.21	0.65	0.13	0.49	0.16	0.03	-0.84	-0.31	0.64	0.79	0.24	0.92
1995	0.19	1.20	1.45	0.24	0.26	0.90	0.55	1.28	1.61	0.95	1.01	1.72
1996	0.20	1.06	1.16	0.89	0.51	0.60	-0.51	-0.32	-0.09	-0.21	0.27	0.55
1997	1.36	1.45	0.77	1.87	1.20	0.17	2.04	0.60	0.73	1.70	0.41	1.88
1998	-0.41	-0.50	-0.81	-0.23	0.21	-1.41	-0.84	-1.02	-0.10	-0.58	-0.45	-1.07
1999	-1.60	-0.95	-1.57	-0.49	0.90	-2.18	-1.21	-2.05	-2.00	-1.73	-2.21	-2.25
2000	-1.32	-2.43	-2.35	-0.56	0.18	-2.96	-0.77	-2.85	-2.42	-2.60	-1.66	-1.95
2001	-1.01	0.71	-0.23	-0.41	0.13	-0.82	0.57	-0.81	0.71	-0.79	0.95	0.48
2002	-0.89	0.54	-0.13	0.04	-0.09	-0.14	0.60	0.71	-0.26	0.75	0.95	-1.14
2003	-0.28	-0.39	-0.81	-0.56	0.79	-0.71	-0.59	-1.09	-0.45	-0.65	-0.85	-0.54
2004	1.53	1.21	0.42	1.27	0.19	0.21	0.61	0.73	1.49	1.38	0.45	1.13
2005	-0.79	-0.55	-2.02	-0.10	-0.19	-1.32	-0.86	-1.02	0.28	1.06	-0.71	-1.70
2006	1.03	-0.40	1.19	1.26	0.69	0.63	0.71	0.36	0.85	0.02	0.11	0.72
2007	0.10	-1.15	-0.63	-0.22	0.51	-0.91	-1.33	-1.23	-0.61	-0.66	-1.08	-1.33
2008	-0.27	-0.18	-0.50	1.13	0.38	0.46	-0.58	0.79	-0.08	-1.59	0.72	0.72
2009	-0.46	0.05	-0.53	-0.63	0.67	0.49	-0.44	0.75	0.01	0.73	0.64	-0.29
2010	-1.24	-0.19	-0.58	-2.14	0.38	0.46	-2.31	0.61	NA	-0.16	-1.15	0.46
2011	-1.00	0.00	0.31	-1.05	0.78	0.43	0.41	0.53	0.45	0.18	0.89	0.13
2012	-0.75	-0.09	-0.19	-1.43	-1.25	-0.19	-0.82	0.52	-0.38	0.20	-1.25	0.01
2013	-1.23	-0.80	-0.27	-0.78	-1.82	-0.92	-0.30	0.30	-0.38	-0.69	-1.63	-0.49
2014	-0.42	0.21	-0.07	0.21	-1.20	0.61	0.67	0.08	0.15	-0.35	-0.36	-0.68
2015	-0.45	-0.77	-1.20	-0.58	-1.51	0.10	-0.54	-0.52	-0.58	-0.40	-0.23	-0.51
2016	-1.36	-2.08	-1.28	-2.28	-3.21	-1.67	-0.58	-1.01	-1.62	-0.91	-0.98	-1.18
2017	-1.63	-2.20	-2.04	-2.10	-2.03	-1.01	-0.31	-0.99	-2.14	-1.91	-1.83	-2.03
2018	-1.01	-0.64	0.28	-1.68	-1.91	1.24	-0.14	0.72	0.36	1.14	0.47	0.62
2019	-0.84	-0.93	-0.95	-1.20	-1.71	-0.37	0.21	0.21	-1.42	0.32	-2.41	0.00

RDI Classification for Amu RB Stations (1979-2019)

Year	Ahangaran	Baghlan	Bala-i-Kelagai	Bamyan	Dasht-i-Safid	Doshi	Faizabad	Gerdab	Keshem	Khwajaghar	Nazdik-i-Jurm	Nazdik-i-Taluqan
1979	1.97	1.08	0.73	0.34	0.27	0.34	-0.79	0.41	-0.13	0.00	0.40	-0.18
1980	0.61	1.02	-0.12	0.78	0.63	0.14	1.08	0.11	1.05	0.36	0.68	0.88
1981	1.15	1.66	0.72	0.67	0.82	1.10	0.67	0.63	0.32	0.25	0.46	0.85
1982	1.97	1.69	0.45	0.98	1.37	1.99	1.74	1.30	1.34	0.81	1.24	0.80
1983	0.95	0.52	0.57	0.09	0.94	1.76	0.72	0.61	-0.35	-0.26	0.60	0.87
1984	0.00	0.04	0.60	0.26	0.25	0.33	1.35	0.78	1.10	1.12	1.20	0.48
1985	0.48	-0.90	0.10	0.51	0.60	-0.11	-0.41	-2.16	-1.59	-1.60	0.44	-0.70
1986	0.23	1.63	0.77	0.42	0.16	0.44	0.91	0.06	1.03	1.15	0.88	1.45
1987	0.08	0.77	1.29	0.13	0.52	0.91	0.07	0.44	0.30	-0.14	0.59	0.64
1988	0.92	-0.26	1.28	0.27	0.32	0.91	0.56	0.15	0.47	0.45	0.74	1.01
1989	0.13	0.43	0.64	0.77	0.09	-0.33	1.15	0.10	0.17	-0.32	0.88	0.24
1990	1.84	0.43	0.99	1.37	0.97	0.28	0.72	0.95	0.81	0.79	0.49	0.33
1991	1.15	1.24	1.09	1.40	0.50	1.28	1.66	1.48	1.68	1.44	1.58	-0.05
1992	0.82	0.27	1.30	0.36	0.54	0.77	0.67	1.74	1.11	0.63	0.80	0.07
1993	0.02	0.62	1.59	0.30	0.38	0.98	0.54	1.08	0.33	0.22	0.88	0.14
1994	0.27	0.61	0.33	0.56	0.39	0.03	-0.03	-0.23	0.60	0.53	0.56	0.85
1995	0.27	1.22	1.67	0.32	0.46	0.90	0.98	1.51	1.84	1.01	1.24	1.90
1996	0.31	0.95	1.30	1.09	0.80	0.52	0.35	-0.20	0.08	-0.19	0.75	0.63
1997	1.41	1.27	0.85	1.91	1.26	0.13	1.76	0.59	0.72	1.39	0.73	1.81
1998	-0.47	-0.44	-0.48	-0.31	0.26	-1.38	-0.18	-0.90	-0.15	-0.56	0.05	-1.24
1999	-1.64	-0.87	-1.19	-0.45	0.94	-2.08	-0.39	-1.98	-1.93	-1.71	-1.04	-2.19
2000	-1.39	-2.13	-1.81	-0.58	0.28	-2.82	-0.16	-2.71	-2.32	-2.42	-0.73	-2.00
2001	-1.09	0.47	-0.18	-0.49	0.18	-1.03	0.56	-0.84	0.33	-0.93	0.81	0.12
2002	-0.92	0.43	-0.01	0.01	0.07	-0.30	0.72	0.65	-0.31	0.40	0.95	-1.13
2003	-0.42	-0.40	-0.61	-0.64	0.72	-0.85	-0.12	-1.08	-0.62	-0.87	-0.31	-0.72
2004	1.53	1.04	0.52	1.26	0.36	0.11	0.73	0.68	1.29	0.73	0.59	0.99
2005	-0.87	-0.57	-1.54	-0.16	-0.04	-1.43	-0.24	-1.06	-0.35	1.16	-0.21	-1.76
2006	0.94	-0.48	0.93	1.17	0.71	0.14	0.70	0.07	0.34	-0.54	0.35	0.34
2007	-0.04	-1.17	-0.57	-0.32	0.46	-1.24	-0.65	-1.50	-0.75	-1.13	-1.36	-1.61
2008	-0.22	-0.34	-0.78	1.34	-0.09	0.48	-1.17	0.70	-0.02	-1.46	-0.37	0.81
2009	-0.39	-0.30	-0.94	-0.50	0.05	0.43	-1.23	0.55	-0.22	0.81	-0.55	-0.10
2010	-1.23	-0.70	-1.01	-2.13	-0.23	0.18	-2.29	0.13	(*)	-0.38	-1.49	0.19
2011	-0.91	-0.29	-0.15	-0.89	0.19	0.40	-0.68	0.43	0.51	0.46	-0.24	0.30
2012	-0.72	-0.45	-0.72	-1.48	-1.43	-0.38	-1.49	0.18	-0.58	1.96	-1.64	-0.07
2013	-1.16	-0.97	-0.56	-0.65	-1.83	-0.87	-1.13	0.13	-0.37	-1.59	-1.73	-0.40
2014	-0.39	-0.22	-0.51	0.17	-1.38	0.47	-0.63	-0.12	0.06	-0.12	-1.01	-0.53
2015	-0.52	-1.01	-1.47	-0.69	-1.69	-0.21	-1.45	-0.88	-0.89	-0.50	-1.11	-0.66
2016	-1.36	-2.01	-1.52	-2.26	-2.95	-1.61	-1.39	-1.17	-1.62	-0.75	-1.44	-1.15
2017	-1.62	-2.09	-2.10	-2.10	-2.03	-1.02	-1.23	-1.10	-2.10	-1.52	-1.92	-1.83
2018	-0.97	-0.80	-0.28	-1.63	-1.91	1.00	-1.06	0.51	0.19	1.04	-0.51	0.60
2019	-0.78	-0.98	-1.15	-1.14	-1.72	-0.33	-0.93	0.05	-1.34	0.34	-2.20	0.09

SPI Classification for Harirud-Murghab RB Stations (1979-2019)

Year	Cheldukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Rabat-i-Akhund	Shinaya	Torghundi
1979	0.08	0.66	0.15	0.50	0.92	0.67	0.35
1980	-0.26	0.69	0.01	0.15	0.41	0.69	0.03
1981	1.07	0.84	1.06	1.14	1.41	0.83	1.31
1982	0.69	1.67	0.68	0.32	1.25	1.62	0.94
1983	0.67	0.37	0.40	0.00	0.19	0.39	0.92
1984	-0.36	-1.63	-0.68	-0.96	-0.49	-1.51	-0.07
1985	0.10	0.43	0.13	-0.06	0.68	0.44	0.38
1986	-1.10	0.06	-0.87	-0.68	0.09	0.09	-0.78
1987	0.59	-0.23	-0.11	0.27	0.17	-0.18	0.85
1988	-0.98	0.78	0.79	1.00	0.78	0.78	0.33
1989	0.59	1.35	0.37	0.46	1.12	1.32	1.24
1990	2.40	2.08	2.41	2.09	2.13	2.01	2.59
1991	1.31	1.60	1.45	1.43	1.83	1.55	1.54
1992	1.20	0.85	1.07	1.32	1.40	0.84	1.43
1993	-0.44	-0.01	-0.80	-0.83	-0.30	0.03	-0.14
1994	0.84	0.15	-0.12	0.36	0.22	-0.18	0.83
1995	0.87	0.34	0.13	0.44	0.75	-0.08	1.12
1996	0.02	0.27	-0.87	0.01	0.77	0.47	0.30
1997	0.64	0.81	-0.11	0.51	0.78	0.81	0.89
1998	-0.20	-0.60	-0.47	-0.67	-0.22	-0.53	0.09
1999	-1.78	-2.68	-2.53	-2.31	-1.55	-2.51	-1.43
2000	-2.49	-2.19	-2.37	-2.31	-1.17	-1.93	-2.10
2001	-1.43	-1.41	-1.28	-1.06	-0.53	-1.30	-1.09
2002	-0.30	-0.67	-0.26	-0.18	-0.01	-0.59	-0.01
2003	-1.10	-0.61	-1.43	-1.46	-0.99	-0.54	-0.77
2004	-0.24	0.52	0.05	0.43	0.68	0.53	0.04
2005	-1.35	-1.06	-1.53	-1.65	-0.82	-0.97	-1.02
2006	0.33	1.02	0.33	0.18	0.67	1.00	0.60
2007	-0.78	-0.85	-0.16	0.51	-0.75	-1.12	-1.39
2008	0.13	-0.55	1.67	1.60	-3.05	-0.96	-0.04
2009	1.01	-0.02	0.06	0.52	-0.45	0.32	-1.04
2010	-0.16	-1.24	0.47	0.42	-0.58	-1.09	-1.33
2011	-0.15	-0.33	0.41	-0.48	-0.80	(*)	-0.50
2012	-0.63	-0.84	-0.23	0.53	-1.05	-0.39	-0.73
2013	-0.54	-0.05	0.25	-0.12	-0.93	0.42	-0.85
2014	0.46	-0.53	0.75	0.27	-0.26	0.65	-0.49
2015	-0.20	0.33	0.32	0.37	-0.16	-0.11	-0.01
2016	-0.72	-0.73	-0.06	-0.56	-0.74	-1.42	-0.91
2017	-1.13	0.45	-1.29	-2.19	-1.34	-0.51	-1.73
2018	1.91	0.27	1.24	0.88	0.08	1.02	0.60
2019	1.44	0.71	1.06	-0.05	-0.04	-0.54	0.00

RDI Classification for Harirud-Murghab RB Stations (1979-2019)

Year	Cheldukhtaran	Dawlatyar	Nazdik-i-Herat	Pul-i-Hashemi	Rabat-i-Akhund	Shinaya	Torghundi
1979	0.02	0.40	0.33	0.39	0.80	0.72	0.33
1980	-0.24	0.39	0.23	0.17	0.42	0.54	0.08
1981	1.23	0.65	1.48	1.41	1.56	1.07	1.44
1982	0.64	1.55	1.00	0.39	1.25	1.54	0.92
1983	0.67	0.11	0.80	0.12	0.27	0.54	0.95
1984	-0.28	-1.67	-0.33	-0.80	-0.38	-0.94	0.05
1985	0.23	0.23	0.50	0.26	0.76	0.68	0.51
1986	-1.09	-0.06	-0.57	-0.53	0.12	0.39	-0.71
1987	0.49	-0.49	0.08	0.30	0.09	0.02	0.78
1988	-0.93	0.73	0.99	1.01	0.79	1.10	0.35
1989	0.45	1.11	0.54	0.33	0.97	1.29	1.10
1990	2.39	1.96	2.86	2.13	2.13	1.96	2.57
1991	1.52	1.54	2.10	1.72	1.96	1.75	1.75
1992	1.23	0.77	1.38	1.41	1.43	1.00	1.48
1993	-0.30	-0.23	-0.38	-0.69	-0.23	0.41	0.02
1994	0.65	0.10	0.25	0.26	0.26	0.20	0.71
1995	0.86	0.34	0.61	0.48	0.77	0.50	1.13
1996	0.02	0.32	-0.33	0.04	0.78	0.83	0.33
1997	0.53	0.75	0.38	0.48	0.79	1.01	0.82
1998	-0.22	-0.77	-0.11	-0.70	-0.26	-0.10	0.11
1999	-1.80	-2.73	-2.08	-2.31	-1.54	-1.76	-1.38
2000	-2.46	-2.35	-1.96	-2.33	-1.22	-1.41	-2.00
2001	-1.48	-1.53	-0.91	-1.15	-0.60	-0.84	-1.08
2002	-0.29	-0.77	0.14	-0.20	-0.03	-0.17	0.04
2003	-1.09	-0.78	-1.04	-1.45	-0.99	-0.29	-0.71
2004	-0.25	0.41	0.50	0.42	0.66	0.82	0.07
2005	-1.35	-1.28	-1.27	-1.68	-0.85	-0.50	-0.96
2006	0.21	0.81	0.38	0.18	0.57	0.85	0.52
2007	-0.88	-1.08	-0.06	0.24	-0.84	-0.72	-1.35
2008	0.25	-0.42	0.78	1.37	-2.88	-1.32	-0.16
2009	0.98	0.18	-0.66	0.37	-0.33	-0.55	-1.06
2010	-0.22	-0.90	-0.54	0.18	-0.74	-1.56	-1.42
2011	0.00	0.01	-0.38	-0.38	-0.80	(*)	-0.53
2012	-0.59	-0.50	-1.02	0.37	-1.10	-1.08	-0.80
2013	-0.48	0.45	-0.57	-0.17	-0.91	-0.44	-0.89
2014	0.33	-0.14	-0.21	0.18	-0.28	-0.41	-0.55
2015	-0.40	0.63	-0.58	0.26	-0.26	-0.93	-0.25
2016	-0.66	-0.38	-0.87	-0.64	-0.77	-1.77	-0.93
2017	-1.10	0.77	-1.89	-2.16	-1.28	-1.21	-1.75
2018	1.87	0.76	0.22	0.86	0.06	-0.05	0.46
2019	1.53	1.20	0.15	-0.02	-0.09	-1.17	-0.02

SPI Classification for Helmand RB Stations (1979-2019)

Year	Adraskan	Farah	Gardandiwa	Gardiz	Lashkargah	dik-i-Adras	ik-i-Gardan	dik-i-Kanda	Tarnak	Waras
1979	0.50	0.12	0.27	-0.45	0.50	0.33	-0.28	0.65	0.45	0.04
1980	0.13	0.04	0.62	0.17	-0.28	0.01	-0.01	0.75	0.34	-0.42
1981	0.97	0.70	0.98	1.27	0.65	0.76	0.24	1.46	1.47	-0.09
1982	0.61	0.70	1.85	1.92	0.53	0.43	0.95	1.28	1.05	0.82
1983	-0.01	0.16	0.66	0.40	-0.05	-0.33	0.02	0.33	-0.23	-0.46
1984	-1.21	-0.40	-0.59	-0.18	-1.31	-1.22	-1.01	-0.68	-0.70	-1.29
1985	0.80	0.88	0.37	0.01	0.18	-0.05	-0.20	0.88	0.64	-0.49
1986	0.49	0.20	0.46	0.08	-0.85	-0.77	-0.14	-0.06	-0.88	-0.36
1987	0.72	0.28	0.32	-0.34	-0.28	-0.74	-0.07	0.90	0.74	-0.77
1988	-0.09	-0.70	0.02	-0.56	-0.60	0.07	-0.38	0.12	0.02	0.23
1989	0.18	0.65	0.32	-0.27	0.50	0.62	-0.25	1.58	1.51	0.18
1990	1.61	2.23	1.90	0.89	1.95	1.33	0.98	2.26	2.21	1.07
1991	1.58	0.11	1.06	0.63	0.65	2.03	0.33	0.67	0.61	0.98
1992	1.31	1.19	0.40	-0.45	0.03	1.07	-0.18	-0.10	0.49	0.25
1993	-0.75	-0.77	-0.35	-0.21	-0.79	-0.84	-0.77	-0.07	-0.48	-0.49
1994	-0.27	0.06	0.69	0.03	-0.60	-0.38	0.04	0.65	-0.81	-0.12
1995	0.92	1.64	-0.33	-0.12	0.83	0.72	-0.63	0.40	0.91	-0.75
1996	0.51	0.54	0.07	-0.58	0.36	0.34	-0.44	0.78	0.09	-0.61
1997	0.72	0.90	0.95	0.27	1.10	0.53	0.25	1.10	1.49	0.44
1998	-0.45	0.74	-0.80	-1.01	-0.11	-0.54	-1.12	-0.52	-0.65	-1.43
1999	-2.07	-1.79	-2.15	-2.77	-1.76	-2.04	-2.18	-2.29	-2.35	-2.03
2000	-2.22	-1.52	-2.01	-1.84	-1.72	-2.18	-2.07	-1.04	-1.50	-2.65
2001	-0.88	-0.96	-1.41	-1.95	-1.02	-0.95	-1.60	-0.97	-1.43	-1.40
2002	-0.55	-0.46	-1.09	-0.71	-0.42	-0.64	-1.35	0.02	-0.27	-1.15
2003	-0.87	-1.03	-0.90	-1.96	-1.84	-0.94	-1.20	-2.36	-1.32	-1.40
2004	0.44	1.12	1.37	0.05	1.22	0.27	0.57	1.77	1.88	0.01
2005	-1.46	-1.40	-0.97	-0.73	-1.20	-1.48	-1.26	-1.02	-1.31	0.53
2006	-0.09	0.48	1.16	0.85	0.18	-0.21	0.41	0.73	1.11	0.26
2007	-1.43	-0.56	-0.50	-0.63	-0.47	-1.46	-0.89	-0.95	-0.11	-0.77
2008	1.09	-0.68	0.50	0.88	0.46	1.47	0.83	0.18	0.36	0.53
2009	0.32	-1.45	0.18	0.54	1.43	0.88	1.03	-0.64	-0.72	0.71
2010	-0.82	-0.57	-1.70	-0.12	0.36	0.14	-0.20	-0.62	-0.39	0.54
2011	-0.51	-0.58	-1.98	0.47	0.45	0.52	0.91	-0.55	-0.25	0.65
2012	0.32	-0.21	0.31	0.81	-0.04	0.76	1.01	-0.35	-0.14	0.67
2013	-0.17	0.56	0.07	1.73	1.54	0.29	1.01	-0.34	-0.23	1.58
2014	0.97	0.39	-0.23	0.23	0.10	1.28	0.94	-0.79	-0.56	1.24
2015	-1.10	0.00	0.57	1.16	0.96	-0.52	1.53	-0.47	0.01	1.79
2016	0.42	-0.57	-0.49	0.33	0.37	0.08	0.83	-0.75	-0.40	0.59
2017	-1.88	-2.63	-1.08	-0.58	-2.74	-1.44	0.30	-1.40	-1.72	0.70
2018	1.86	1.94	0.28	1.10	1.40	1.95	2.50	-0.49	0.48	1.41
2019	0.41	0.71	1.23	1.76	0.49	0.86	1.56	-0.01	0.56	1.53

RDI Classification for Helmand RB Stations (1979-2019)

Year	Adraskan	Farah	Gardandiwal	Gardiz	Lashkargah	Nazdik-i-Adraskan	Nazdik-i-Gardandiwal	Nazdik-i-Kandahar	Tarnak
1979	0.37	-0.03	0.16	-0.48	0.41	0.18	-0.38	0.59	0.45
1980	0.14	-0.04	0.60	0.14	-0.34	-0.01	-0.08	0.74	0.35
1981	1.18	0.79	0.99	1.32	0.71	0.89	0.26	1.52	1.60
1982	0.62	0.51	1.76	1.92	0.36	0.40	0.93	1.23	0.83
1983	0.05	0.10	0.55	0.34	-0.09	-0.30	-0.11	0.34	-0.21
1984	-1.04	-0.36	-0.55	-0.17	-1.29	-1.06	-1.01	-0.60	-0.63
1985	0.87	0.89	0.40	0.04	0.21	0.02	-0.20	0.93	0.76
1986	0.46	0.08	0.47	0.07	-0.85	-0.74	-0.13	-0.04	-0.80
1987	0.59	0.10	0.18	-0.45	-0.47	-0.77	-0.21	0.84	0.67
1988	-0.01	-0.60	0.27	-0.48	-0.55	0.08	-0.34	0.21	0.19
1989	0.05	0.39	0.25	-0.31	0.34	0.40	-0.30	1.50	1.42
1990	1.62	2.19	1.84	0.86	1.95	1.25	0.91	2.29	2.32
1991	1.76	0.35	1.17	0.70	0.79	2.10	0.41	0.91	0.83
1992	1.35	1.19	0.38	-0.44	0.17	1.07	-0.21	-0.02	0.61
1993	-0.64	-0.66	-0.18	-0.22	-0.73	-0.76	-0.71	0.03	-0.34
1994	-0.29	-0.04	0.70	0.05	-0.63	-0.43	0.02	0.62	-0.75
1995	0.93	1.61	-0.13	-0.08	0.87	0.71	-0.63	0.47	1.03
1996	0.54	0.57	0.29	-0.50	0.45	0.31	-0.35	0.87	0.26
1997	0.73	0.77	0.99	0.29	1.02	0.50	0.28	1.12	1.53
1998	-0.49	0.59	-0.71	-1.04	-0.14	-0.60	-1.12	-0.45	-0.55
1999	-2.03	-1.75	-2.07	-2.71	-1.72	-1.99	-2.16	-2.15	-2.21
2000	-2.22	-1.55	-1.98	-1.85	-1.73	-2.16	-2.08	-0.98	-1.44
2001	-0.93	-0.96	-1.36	-1.94	-1.01	-1.00	-1.61	-0.89	-1.32
2002	-0.55	-0.47	-1.01	-0.71	-0.38	-0.65	-1.33	0.08	-0.18
2003	-0.88	-0.99	-0.96	-1.94	-1.72	-0.95	-1.15	-2.21	-1.18
2004	0.43	1.03	1.45	0.07	1.21	0.24	0.55	1.79	1.98
2005	-1.50	-1.44	-0.96	-0.78	-1.11	-1.51	-1.14	-1.00	-1.29
2006	-0.22	0.23	1.05	0.75	0.08	-0.34	0.51	0.75	0.89
2007	-1.53	-0.75	-0.56	-0.68	-0.61	-1.53	-0.99	-0.92	-0.16
2008	1.12	-0.72	0.36	1.10	0.71	1.49	0.80	-0.01	0.24
2009	0.29	-1.30	0.09	0.60	1.63	0.98	1.12	-0.80	-0.70
2010	-0.82	-0.60	-1.76	-0.04	0.67	0.21	-0.16	-0.79	-0.44
2011	-0.38	-0.40	-1.93	0.53	0.83	0.59	0.97	-0.64	-0.35
2012	0.32	-0.16	0.17	0.82	-0.23	0.80	1.04	-0.54	-0.33
2013	-0.20	0.68	-0.12	1.73	1.45	0.46	1.07	-0.41	-0.29
2014	0.91	0.44	-0.35	0.13	-0.03	1.32	0.96	-0.92	-0.72
2015	-1.13	-0.06	1.30	1.04	0.72	-0.52	1.50	-0.66	-0.26
2016	0.22	-0.51	-0.65	0.25	0.25	0.05	0.72	-0.84	-0.69
2017	-1.81	-2.44	-1.25	-0.64	-2.77	-1.43	0.23	-1.30	-1.86
2018	1.73	2.55	0.11	1.07	1.27	1.89	2.49	-0.60	0.27
2019	0.45	0.75	1.03	1.75	0.42	0.81	1.61	-0.11	0.40

SPI Classification for Kabul RB Stations (1979-2019)

Year	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Chaghasarai	Doabi	Estalif	Keraman	Naghlo	Nawabad	Omarz	Payin-i-Qargha	Pul-i-Behsod	Pul-i-Kama	Pul-i-Qarghay	Qala-i-Malik	Sultanpur	Tanga-i-Gulbahar	Tanga-i-Sayedan
1979	-1.03	-0.04	0.07	-1.07	0.71	0.65	0.39	-0.04	-1.08	0.49	0.12	-0.30	-0.36	-0.35	0.35	-0.21	-0.17	0.21
1980	0.25	-0.54	-0.49	0.00	-0.07	0.67	-0.32	0.84	0.08	-0.24	0.43	1.04	0.98	0.28	0.67	1.04	0.06	0.52
1981	0.27	-0.38	-0.30	0.28	0.37	0.59	0.09	0.16	0.39	0.17	0.18	0.70	0.97	0.51	0.41	0.73	-0.13	0.27
1982	1.30	0.91	1.13	1.36	1.08	1.91	0.73	1.86	1.55	0.83	1.59	1.86	2.20	1.75	1.89	1.80	0.94	1.67
1983	0.46	0.09	0.21	0.49	0.24	0.61	-0.04	0.07	0.60	0.05	-0.41	0.29	0.28	0.23	-0.21	0.35	-0.58	-0.32
1984	-0.29	-0.82	-0.79	-0.30	-0.59	0.05	-0.80	-0.69	-0.24	-0.73	-0.74	-0.86	-0.86	-0.90	-0.56	-0.73	-0.83	-0.65
1985	0.32	-0.51	-0.45	0.34	-0.92	0.55	-1.09	0.39	0.44	-1.04	0.12	0.65	0.76	0.58	0.34	0.68	-0.18	0.20
1986	0.51	-0.44	-0.37	0.53	0.01	0.36	-0.25	0.03	0.66	-0.17	0.12	0.24	0.60	0.18	0.05	0.30	-0.39	-0.07
1987	-0.18	0.10	0.23	-0.19	-0.01	0.59	-0.27	1.25	-0.12	-0.19	0.25	1.37	1.03	1.28	0.49	1.35	-0.07	0.34
1988	-0.64	-0.20	-0.10	-0.67	-0.45	0.64	-0.67	-0.06	-0.65	-0.60	0.25	-0.38	-0.65	-0.43	0.48	-0.28	-0.08	0.33
1989	-0.77	-0.03	0.08	-0.80	0.15	0.72	0.01	-0.53	-0.79	-0.03	0.19	-0.29	-0.19	-0.34	0.41	-0.19	-0.12	0.27
1990	0.61	1.03	1.26	0.64	1.04	2.21	0.69	1.98	0.77	0.79	2.05	1.57	1.51	1.17	2.37	1.54	1.29	2.13
1991	0.24	0.68	0.87	0.26	1.61	1.02	1.21	0.61	0.35	1.33	0.62	0.64	0.69	0.56	0.87	0.67	-0.07	0.34
1992	0.04	0.44	0.60	0.04	0.61	0.86	0.38	0.32	0.12	0.47	-0.05	0.11	0.03	0.05	0.17	0.18	0.14	0.62
1993	0.14	-0.01	0.11	0.14	0.09	0.44	-0.07	-0.38	0.23	0.01	-0.26	-0.36	-0.23	-0.41	-0.05	-0.26	-0.46	-0.17
1994	0.36	0.03	0.15	0.38	0.41	0.84	0.12	-0.35	0.49	0.21	-0.38	0.28	0.54	0.22	-0.18	0.34	-0.56	-0.30
1995	-0.29	0.03	0.14	-0.29	0.17	0.47	-0.10	-0.44	-0.24	-0.02	-0.57	-0.06	0.06	-0.11	-0.38	0.02	-0.70	-0.48
1996	-0.20	-0.98	-0.97	-0.21	-0.42	0.13	-0.41	0.04	-0.15	-0.34	-0.04	0.06	0.17	0.00	0.17	0.13	-0.30	0.04
1997	-0.07	0.12	0.25	-0.07	1.17	1.00	0.81	1.08	0.00	0.92	0.61	0.95	0.97	0.87	0.85	0.96	0.20	0.69
1998	-1.05	-1.17	-1.18	-1.09	-1.07	-0.51	-1.23	-0.29	-1.10	-1.18	-1.01	0.35	0.21	0.28	-0.84	0.40	-1.04	-0.92
1999	-2.56	-2.30	-2.44	-2.67	-2.28	-1.46	-2.35	-0.74	-2.80	-2.32	-2.27	-2.91	-2.96	-2.90	-2.15	-2.63	-2.00	-2.17
2000	-1.87	-2.51	-2.67	-1.94	-1.97	-1.76	-2.06	-1.35	-2.03	-2.02	-2.50	-1.24	-1.47	-2.07	-2.39	-1.08	-2.18	-2.40
2001	-2.08	-1.71	-1.78	-2.17	-1.52	-1.29	-1.64	-2.82	-2.26	-1.60	-2.30	-1.88	-1.76	-1.90	-2.19	-1.68	-2.03	-2.21
2002	-0.38	-0.57	-0.51	-0.26	-0.10	-0.46	-0.35	-0.94	-0.35	-0.27	-1.06	-0.78	-0.73	-0.82	-0.89	-1.32	-1.07	-0.97
2003	-1.78	-1.23	-1.24	-2.06	-1.11	-0.42	-1.27	-1.51	-1.93	-1.22	-1.16	-1.60	-1.60	-1.62	-0.99	-2.09	-1.15	-1.06
2004	-1.45	0.27	0.42	0.12	1.87	0.83	1.44	0.02	0.21	1.57	0.33	0.02	0.20	-0.03	0.56	0.10	-0.02	0.41
2005	0.11	-1.01	-1.00	-0.77	-0.92	-0.42	-1.10	-1.34	-0.75	-1.04	-1.23	-1.17	-1.36	-1.20	-1.06	-1.01	-1.20	-1.13
2006	-0.29	0.87	1.08	0.43	2.49	1.65	2.01	2.43	0.54	2.15	1.43	2.36	2.06	2.25	1.72	2.27	0.82	1.51
2007	-0.86	-0.70	-0.66	-0.87	-0.03	-0.12	-0.28	-0.41	-0.89	-0.20	-0.35	-0.52	0.09	0.78	-0.33	0.25	-0.96	-0.84
2008	0.95	1.17	0.86	1.07	1.08	-0.68	1.75	0.73	0.96	1.03	0.86	0.07	-0.29	1.55	0.14	0.25	1.37	1.62
2009	1.18	0.32	0.75	1.00	0.56	0.01	1.78	0.06	0.79	1.86	0.22	0.22	-0.24	0.23	-0.67	-0.16	0.84	0.52
2010	0.66	0.34	0.01	0.31	-2.02	-1.37	-1.04	-0.95	0.25	-1.40	-0.92	-0.54	-0.72	-0.25	-1.06	-0.74	0.53	-0.81
2011	0.68	1.12	1.04	0.56	-0.36	-0.80	0.60	0.54	0.72	0.31	0.63	-0.74	-0.61	0.04	0.57	-0.51	1.24	0.66
2012	0.99	1.10	0.81	0.98	-0.70	-1.16	-0.84	0.89	0.91	-1.10	0.71	0.47	0.21	0.69	0.34	0.20	1.15	0.22
2013	0.96	0.77	0.92	0.86	0.54	-0.92	0.36	0.45	0.81	1.03	0.92	0.75	-0.40	0.35	0.76	0.13	1.35	1.10
2014	1.31	0.73	0.96	1.03	-0.03	-0.94	1.13	0.67	1.06	0.25	0.30	0.42	0.02	(*)	-0.33	0.35	1.18	-0.29
2015	0.53	1.18	0.80	0.41	0.45	-1.08	0.87	0.00	0.29	1.11	1.16	0.34	-0.42	-0.18	0.39	-0.52	1.20	1.13
2016	-0.03	-0.23	-0.53	-0.21	-0.24	-1.60	0.23	-0.43	-0.39	-0.30	0.72	-1.13	-0.67	-0.75	-0.12	-1.21	0.30	-0.35
2017	0.38	-0.16	-0.68	1.10	-0.71	-1.65	0.12	-1.70	0.63	0.05	-0.56	-0.58	0.40	0.21	-1.31	-1.03	0.24	-0.90
2018	1.72	2.40	2.01	1.65	0.41	-1.00	0.69	-0.17	1.27	0.75	1.11	-0.23	0.48	0.35	0.85	0.49	1.79	0.71
2019	1.97	1.85	1.46	1.81	0.46	0.79	0.80	0.77	1.81	0.65	0.96	0.88	1.14	-0.01	0.91	1.22	1.68	0.56

RDI Classification for Kabul RB Stations (1979-2019)

Year	Asmar	Bagh-i-Lala	Bagh-i-Omomi	Doabi	Keraman	Naghlo	Payin-i-Qarghay	Pul-i-Kama	Pul-i-Qarghay
1979	-0.95	0.10	0.29	0.77	0.38	-0.04	0.13	-0.27	-0.29
1980	0.21	-0.33	-0.15	0.06	-0.29	0.90	0.50	1.09	0.42
1981	0.29	0.00	0.20	0.63	0.26	0.29	0.32	1.12	0.67
1982	1.26	1.56	1.86	1.32	0.90	1.96	1.77	2.36	1.90
1983	0.33	0.24	0.44	0.22	-0.13	-0.06	-0.44	0.31	0.21
1984	-0.36	-0.68	-0.53	-0.44	-0.76	-0.68	-0.71	-0.74	-0.86
1985	0.25	-0.20	-0.01	-0.61	-0.92	0.36	0.20	0.82	0.62
1986	0.37	-0.19	0.00	0.18	-0.18	-0.01	0.17	0.58	0.17
1987	-0.21	0.33	0.54	0.00	-0.34	0.98	0.22	1.00	1.20
1988	-0.64	0.17	0.37	-0.14	-0.49	0.14	0.42	-0.45	-0.27
1989	-0.89	0.11	0.30	0.14	-0.08	-0.67	0.15	-0.23	-0.43
1990	0.44	1.39	1.66	1.08	0.67	1.85	2.11	1.50	1.17
1991	0.34	1.19	1.45	1.84	1.38	0.84	0.83	0.91	0.81
1992	-0.08	0.72	0.95	0.71	0.40	0.27	0.01	0.09	0.07
1993	0.11	0.22	0.41	0.21	-0.05	-0.36	-0.21	-0.09	-0.33
1994	0.40	0.32	0.54	0.62	0.24	-0.27	-0.29	0.73	0.37
1995	-0.09	0.43	0.64	0.48	0.10	-0.24	-0.41	0.31	0.07
1996	-0.24	-0.77	-0.62	-0.08	-0.20	0.13	0.13	0.23	0.10
1997	-0.10	0.48	0.70	1.41	0.98	1.11	0.74	0.98	0.97
1998	-1.06	-1.16	-1.04	-0.99	-1.28	-0.42	-1.01	0.15	0.20
1999	-2.33	-2.40	-2.35	-2.08	-2.31	-0.85	-2.23	-2.75	-2.83
2000	-1.86	-2.64	-2.60	-1.88	-2.11	-1.47	-2.47	-1.45	-2.11
2001	-2.05	-1.82	-1.74	-1.48	-1.74	-2.71	-2.28	-1.70	-1.91
2002	-0.55	-0.53	-0.37	-0.13	-0.46	-0.99	-1.03	-0.68	-0.83
2003	-1.81	-1.33	-1.22	-1.09	-1.38	-1.57	-1.18	-1.57	-1.68
2004	-1.28	0.47	0.67	1.93	1.46	0.06	0.38	0.30	0.05
2005	-0.15	-1.08	-0.96	-0.73	-1.08	-1.41	-1.28	-1.28	-1.06
2006	-0.34	0.95	1.19	2.20	1.74	2.03	1.39	1.92	2.14
2007	-0.94	-0.83	-0.71	-0.18	-0.50	-0.58	-0.46	0.02	0.58
2008	0.99	0.91	0.32	0.71	1.59	0.94	0.78	-0.49	1.45
2009	1.25	-0.08	0.14	0.31	1.80	0.27	0.11	-0.35	0.27
2010	0.74	-0.28	-0.80	-2.24	-1.13	-1.03	-1.11	-0.91	-0.44
2011	0.90	0.87	0.52	-0.48	0.65	0.72	0.55	-0.75	0.01
2012	1.10	0.65	0.13	-0.95	-0.80	0.88	0.56	0.03	0.61
2013	1.05	0.38	0.19	0.28	0.42	0.56	0.86	-0.54	0.26
2014	1.44	0.28	0.27	-0.28	1.13	0.77	0.22	-0.01	(*)
2015	0.51	0.61	-0.03	0.01	0.76	-0.01	0.94	-0.63	-0.40
2016	-0.06	-0.80	-1.36	-0.66	-0.01	-0.54	0.50	-0.91	-0.93
2017	0.32	-0.74	-1.44	-1.01	-0.15	-1.72	-0.74	0.05	-0.01
2018	1.72	2.00	1.33	0.15	0.74	-0.22	1.02	0.35	0.27
2019	2.04	1.53	0.89	0.17	0.80	0.85	0.90	1.00	-0.05

SPI Classification for Northern RB Stations (1979-2019)

Year	Asiabad	Dara-i-Zhwandon	Dawlatabad	Doshqadam	Nazdik-i-Nayak	Nazdik-i-Saripul	Sayad	Tanga-i-Tashqurghan
1979	0.65	0.64	-0.07	0.98	0.01	0.49	0.61	0.87
1980	0.20	0.77	-0.48	0.81	1.40	-0.07	1.26	1.44
1981	0.93	0.30	-1.20	1.26	0.84	0.79	0.55	0.82
1982	1.66	1.26	0.28	1.84	0.45	1.07	2.24	2.30
1983	0.90	0.48	0.18	1.14	0.08	0.80	-0.22	0.13
1984	-0.48	0.33	-0.30	0.42	-0.70	0.00	0.59	0.84
1985	-1.09	-1.43	-0.87	0.90	-0.25	-1.29	-1.51	-1.01
1986	-0.17	0.39	-1.11	0.72	0.22	-0.22	0.79	1.02
1987	0.24	0.55	-0.01	0.31	-0.78	0.09	0.11	0.42
1988	0.27	-0.42	-0.06	0.69	-0.10	0.13	-0.91	-0.48
1989	0.93	-0.22	0.62	1.04	-0.13	0.76	-0.10	0.23
1990	1.93	0.89	0.54	1.57	0.55	1.75	1.77	1.89
1991	2.27	0.93	0.38	1.07	0.62	2.10	1.07	1.27
1992	1.21	0.53	0.35	0.59	-0.22	1.04	0.85	1.08
1993	0.04	-0.17	-0.64	0.54	-0.44	0.05	0.22	0.52
1994	-0.12	0.39	-0.30	0.60	-0.41	-0.18	-0.26	0.09
1995	0.41	-1.43	-0.34	0.31	-0.61	0.36	0.38	0.66
1996	-0.20	0.47	-0.76	0.39	-0.79	-0.30	-0.04	0.29
1997	0.00	0.48	-0.79	1.40	0.27	-0.15	-0.11	0.36
1998	-0.87	-0.95	-1.56	-0.16	-0.28	-0.85	-0.22	0.13
1999	-1.94	-2.46	-1.42	-1.09	-2.55	-2.04	-2.47	-1.86
2000	-1.92	-2.77	-1.40	-1.14	-2.17	-2.25	-1.77	-1.23
2001	-1.04	-1.20	-1.31	-0.98	-1.63	-1.27	-1.57	-1.05
2002	-0.43	-0.40	-0.33	-0.18	-1.12	-0.49	-0.66	-0.25
2003	-1.43	-1.13	-0.99	-0.05	-1.22	-1.48	-1.15	-0.69
2004	-0.10	-0.04	-0.76	0.50	-0.15	-0.07	0.02	0.34
2005	-1.46	-1.40	-1.13	-0.54	-1.39	-1.56	-0.79	-0.37
2006	0.53	0.31	-0.01	0.98	-0.19	0.51	1.04	1.25
2007	-1.41	-1.21	-1.00	-0.03	-0.99	-1.44	-1.04	-0.88
2008	0.59	1.29	1.37	-0.38	1.55	1.02	0.49	0.34
2009	-0.31	1.15	1.98	-1.02	1.68	0.51	1.06	0.05
2010	-1.11	-0.77	0.29	-1.85	0.04	-1.31	-1.89	-2.23
2011	1.36	1.23	1.53	-0.91	0.52	1.25	1.51	0.41
2012	-0.12	0.45	1.45	-1.92	0.18	0.40	-0.24	-0.95
2013	0.03	0.69	1.29	-1.38	1.13	0.74	0.43	-0.81
2014	-0.08	1.02	1.41	-0.99	1.75	0.20	0.20	-0.70
2015	-0.01	-0.50	1.78	-1.05	1.35	0.15	-0.37	-0.74
2016	0.41	-0.50	0.94	-0.87	1.03	0.12	0.10	-0.62
2017	-1.60	1.27	-0.46	-1.35	0.48	-1.17	0.09	-1.79
2018	0.74	0.61	1.69	-0.82	1.16	1.02	0.43	-0.09
2019	0.59	0.63	1.06	-1.35	0.87	0.82	-0.46	-1.01

RDI Classification for Northern RB Stations (1979-2019)

Year	Dara-i-Zhwandon	Dawlatabad	Doshqadam	Nazdik-i-Nayak	Nazdik-i-Sari Pul	Sayad	Tanga-i-Tashqurghan
1979	0.92	-0.12	0.91	0.20	0.51	0.83	0.88
1980	1.07	-0.48	0.78	1.97	0.02	1.41	1.38
1981	0.70	-1.11	1.20	1.39	0.95	0.85	0.92
1982	1.71	0.21	1.62	0.90	1.06	2.28	2.00
1983	0.76	0.13	1.02	0.37	0.77	0.12	0.31
1984	0.78	-0.27	0.50	-0.58	0.12	0.85	0.90
1985	-1.03	-0.80	0.92	0.08	-1.04	-0.84	-0.48
1986	0.64	-1.11	0.76	0.65	-0.18	0.97	1.00
1987	0.72	-0.08	0.33	-0.72	0.07	0.41	0.52
1988	-0.09	-0.06	0.81	0.56	0.24	-0.40	-0.05
1989	-0.06	0.48	0.98	0.22	0.60	0.16	0.36
1990	1.19	0.55	1.39	1.07	1.77	1.88	1.74
1991	1.37	0.54	1.10	1.36	2.35	1.42	1.38
1992	0.81	0.40	0.58	0.06	1.16	1.12	1.11
1993	0.13	-0.54	0.67	0.06	0.43	0.59	0.69
1994	0.71	-0.35	0.64	0.02	-0.16	0.13	0.33
1995	-1.05	-0.25	0.45	-0.42	0.51	0.82	0.91
1996	0.77	-0.76	0.59	-0.31	-0.24	0.38	0.50
1997	0.75	-0.83	1.29	0.76	-0.09	0.26	0.54
1998	-0.80	-1.53	0.03	0.08	-0.80	0.12	0.34
1999	-2.31	-1.45	-0.73	-2.81	-2.00	-1.78	-1.22
2000	-2.62	-1.40	-0.81	-2.46	-2.20	-1.21	-0.76
2001	-1.12	-1.35	-0.68	-1.73	-1.31	-1.04	-0.60
2002	-0.24	-0.31	-0.02	-1.04	-0.44	-0.23	0.05
2003	-1.02	-1.00	0.03	-1.34	-1.43	-0.70	-0.33
2004	0.19	-0.76	0.65	0.37	-0.01	0.31	0.49
2005	-1.30	-1.15	-0.19	-1.36	-1.52	-0.50	-0.13
2006	0.45	-0.10	0.88	-0.16	0.39	1.05	1.04
2007	-1.13	-1.09	0.03	-0.94	-1.50	-0.70	-0.57
2008	0.78	1.45	-0.72	1.08	0.94	0.72	-0.20
2009	0.49	1.99	-1.23	1.09	0.29	0.01	-0.57
2010	-1.32	0.25	-1.82	-0.79	-1.46	-2.35	-2.22
2011	0.62	1.54	-1.11	-0.14	1.09	0.32	-0.26
2012	-0.20	1.44	-1.88	-0.59	0.30	-1.12	-1.27
2013	0.15	1.28	-1.45	0.56	0.58	-0.54	-1.21
2014	0.46	1.43	-1.19	1.18	0.09	-0.74	-1.09
2015	-1.58	1.66	-1.26	0.62	-0.17	-1.35	-1.31
2016	-1.05	0.96	-1.11	0.33	0.04	-0.86	-1.17
2017	0.64	-0.46	-1.46	-0.27	-1.33	-0.86	-1.89
2018	0.06	1.70	-1.05	0.57	0.86	-0.58	-0.75
2019	0.13	1.15	-1.41	0.22	0.79	-1.20	-1.29

APPENDEX B

GEE CODE FOR LANDSAT SATELLITES SURFACE REFLECTANCE PRODUCTS

```
var table = ee.FeatureCollection("users/Ehsanhayt/Afghanistan"),
    P1_W = /* color: #ff00ff */ee.Geometry.Point([71.065743793315,
34.22612634234616]),
    P2_L = /* color: #99ff99 */ee.Geometry.Point([71.06335879102944,
34.233074320248804]),
    P3_W = /* color: #9999ff */ee.Geometry.Point([69.48598441068793,
37.06907292194668]),
    P4_L = /* color: #ffff99 */ee.Geometry.Point([69.48805507604743,
37.071213051568364]),
    P5_W = /* color: #99ffff */ee.Geometry.Point([61.77246837309903,
30.796025168576953]),
    P6_L = /* color: #ff99ff */ee.Geometry.Point([61.78817538909024,
30.796836175004525]),
    P7_W = /* color: #d63000 */ee.Geometry.Point([61.259973995557445,
34.60615501046695]),
    P8_L = /* color: #98ff00 */ee.Geometry.Point([61.259261222832286,
34.61609908892928]),
    brdy =
    /* color: #cbe3e5 */
    /* shown: false */
    /* displayProperties: [
      {
        "type": "rectangle"
      }
    ] */
    ee.Geometry.Polygon(
        [[[60.70945595034679, 36.880536140947655],
          [60.70945595034679, 30.279032812796032],
          [73.0361161065968, 30.279032812796032],
          [73.0361161065968, 36.880536140947655]]], null, false),
    table2 = ee.FeatureCollection("users/Ehsanhayat/Point_Revised1"),
    geometry = /* color: #d63000 */ee.Geometry.MultiPoint(),
    geometry2 =
    /* color: #d63000 */
    /* shown: false */
    /* displayProperties: [
      {
        "type": "rectangle"
      }
    ] */
    ee.Geometry.Polygon(
```

```
        [[[69.483272968288, 37.075754545151796],
          [69.483272968288, 37.06486558965933],
          [69.49520343398625, 37.06486558965933],
          [69.49520343398625, 37.075754545151796]]], null, false);


Map.centerObject(brdy,5);
var region=ee.FeatureCollection([
ee.Feature(ee.Geometry(P1_W),{label:'P1_W'}),
ee.Feature(ee.Geometry(P2_L),{label:'P2_L'}),
ee.Feature(ee.Geometry(P3_W),{label:'P3_W'}),
ee.Feature(ee.Geometry(P4_L),{label:'P4_L'}),
ee.Feature(ee.Geometry(P5_w),{label:'P5_w'}),
ee.Feature(ee.Geometry(P6_L),{label:'P6_L'}),
ee.Feature(ee.Geometry(P7_W),{label:'P7_W'}),
ee.Feature(ee.Geometry(P8_L),{label:'P8_L'})]);

///////////////////////        Start Coding     ///////////////////


var Land= ee.ImageCollection('LANDSAT/LT05/C02/T1_L2')
.filterDate('1986-01-01','1988-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR=Land.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart =ui.Chart.image.seriesByRegion(
  SR,region,ee.Reducer.mean(),'SR_B4',100, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart)


var Land1= ee.ImageCollection('LANDSAT/LT05/C02/T1_L2')
.filterDate('1996-01-01','2002-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR1=Land1.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart1 =ui.Chart.image.seriesByRegion(
  SR1,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
  .setOptions({
```

```
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart1)

var Land2= ee.ImageCollection('LANDSAT/LT05/C02/T1_L2')
.filterDate('2003-01-01','2014-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR2=Land2.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart2 =ui.Chart.image.seriesByRegion(
  SR2,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart2)

var Land3= ee.ImageCollection('LANDSAT/LE07/C02/T1_L2')
.filterDate('2000-01-01','2008-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR3=Land3.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart3 =ui.Chart.image.seriesByRegion(
  SR3,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart3)

var Land4= ee.ImageCollection('LANDSAT/LE07/C02/T1_L2')
.filterDate('2009-01-01','2013-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR4=Land4.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart4 =ui.Chart.image.seriesByRegion(
  SR4,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
```

```
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart4)


var Land5= ee.ImageCollection('LANDSAT/LE07/C02/T1_L2')
.filterDate('2014-01-01','2017-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR5=Land5.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart5 =ui.Chart.image.seriesByRegion(
  SR5,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart5)

var Land6= ee.ImageCollection('LANDSAT/LE07/C02/T1_L2')
.filterDate('2018-01-01','2021-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR6=Land6.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart6 =ui.Chart.image.seriesByRegion(
  SR6,region,ee.Reducer.mean(),'SR_B4',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart6)

var Land7= ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
.filterDate('2013-01-01','2016-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR7=Land7.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});
```

```
var chart7 =ui.Chart.image.seriesByRegion(
  SR7,region,ee.Reducer.mean(),'SR_B5',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart7)


var Land8= ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
.filterDate('2017-01-01','2021-12-30')
.filter(ee.Filter.lessThan('CLOUD_COVER',100));

var SR8=Land8.map(function(img){
  var bands=img.multiply(0.0000275);
  return bands
  .copyProperties(img,['system:time_start','system:time_end']);});

var chart8 =ui.Chart.image.seriesByRegion(
  SR8,region,ee.Reducer.mean(),'SR_B5',30, 'system:time_start','label')
  .setOptions({
    title : 'Surface',
    vAxis : {title :'SR'},
    hAxis : {title :'data'}});
print(chart8)
```

APPENDIX C

LANDSAT WATER AND LAND PIXELS SR VALUES

Khowajaghar Station C and M SR Time Series

Date	Location M	Location C	C/M	C/M*
11-Oct-86	0.308	0.484	1.571428571	#N/A
15-Nov-87	0.275	0.427	1.552727273	1.571428571
17-Dec-87	0.267	0.442	1.655430712	1.558337662
9-May-88	0.374	0.425	1.136363636	1.626302797
26-Jun-88	0.445	0.497	1.116853933	1.283345385
12-Jul-88	0.371	0.468	1.261455526	1.166801368
28-Jul-88	0.357	0.476	1.333333333	1.233059278
13-Aug-88	0.348	0.472	1.356321839	1.303251117
14-Sep-88	0.331	0.476	1.438066465	1.340400622
1-Nov-88	0.333	0.468	1.405405405	1.408766712
17-Nov-88	0.332	0.473	1.424698795	1.406413798
19-Dec-88	0.276	0.396	1.434782609	1.419213296
5-Feb-89	0.302	0.41	1.357615894	1.430111815
25-Mar-89	0.392	0.428	1.091836735	1.37936467
10-Apr-89	0.439	0.45	1.025056948	1.178095115
26-Apr-89	0.392	0.442	1.12755102	1.070968398
28-May-89	0.367	0.438	1.19346049	1.110576234
17-Sep-89	0.364	0.477	1.31043956	1.168595213
3-Oct-89	0.284	0.446	1.570422535	1.267886256
19-Oct-89	0.278	0.442	1.589928058	1.479661652
23-Jan-90	0.297	0.385	1.296296296	1.556848136
31-May-90	0.4	0.462	1.155	1.374461848
16-Jun-90	0.361	0.459	1.271468144	1.220838554
2-Jul-90	0.399	0.478	1.197994987	1.256279267
19-Aug-90	0.32	0.47	1.46875	1.215480271
20-Sep-90	0.349	0.482	1.381088825	1.392769081
22-Oct-90	0.242	0.444	1.834710744	1.384592902
7-Nov-90	0.249	0.438	1.759036145	1.699675391
10-Jan-91	0.488	0.524	1.073770492	1.741227919
16-Apr-91	0.46	0.409	0.889130435	1.27400772
18-May-91	0.461	0.409	0.887201735	1.00459362
3-Jun-91	0.402	0.417	1.037313433	0.922419301
6-Aug-91	0.358	0.414	1.156424581	1.002845193
22-Aug-91	0.387	0.442	1.142118863	1.110350765
7-Sep-91	0.32	0.416	1.3	1.132588434

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
28-Dec-91	0.467	0.462	0.989293362	1.180383118
4-May-92	0.468	0.415	0.886752137	1.046620289
20-May-92	0.452	0.424	0.938053097	0.934712582
7-Jul-92	0.377	0.441	1.169761273	0.937050943
23-Jul-92	0.396	0.448	1.131313131	1.099948174
24-Aug-92	0.347	0.451	1.299711816	1.121903644
9-Sep-92	0.356	0.457	1.283707865	1.246369364
11-Oct-92	0.31	0.466	1.503225806	1.272506315
28-Nov-92	0.315	0.44	1.396825397	1.434009959
14-Dec-92	0.293	0.411	1.402730375	1.407980765
31-Jan-93	0.333	0.415	1.246246246	1.404305492
5-Apr-93	0.462	0.473	1.023809524	1.29366402
21-Apr-93	0.427	0.456	1.067915691	1.104765873
23-May-93	0.435	0.433	0.995402299	1.078970745
8-Jun-93	0.393	0.427	1.086513995	1.020472833
24-Jun-93	0.403	0.45	1.11662531	1.066701646
10-Jul-93	0.354	0.392	1.107344633	1.101648211
26-Jul-93	0.377	0.459	1.217506631	1.105635706
11-Aug-93	0.348	0.434	1.247126437	1.183945354
27-Aug-93	0.327	0.427	1.305810398	1.228172112
28-Sep-93	0.342	0.426	1.245614035	1.282518912
14-Oct-93	0.306	0.427	1.395424837	1.256685498
30-Oct-93	0.386	0.471	1.220207254	1.353803035
3-Feb-94	0.389	0.406	1.043701799	1.260285988
7-Mar-94	0.43	0.435	1.011627907	1.108677056
23-Mar-94	0.434	0.448	1.032258065	1.040742652
8-Apr-94	0.494	0.489	0.989878543	1.034803441
24-Apr-94	0.453	0.473	1.04415011	1.003356012
10-May-94	0.451	0.43	0.953436807	1.031911881
26-May-94	0.422	0.452	1.071090047	0.976979329
11-Jun-94	0.383	0.463	1.208877285	1.042856832
27-Jun-94	0.383	0.468	1.221932115	1.159071149
29-Jul-94	0.373	0.483	1.294906166	1.203073825
14-Aug-94	0.353	0.489	1.385269122	1.267356464
30-Aug-94	0.349	0.494	1.415472779	1.349895324
15-Sep-94	0.338	0.498	1.473372781	1.395799543
1-Oct-94	0.316	0.485	1.534810127	1.45010081
17-Oct-94	0.445	0.501	1.125842697	1.509397331
2-Nov-94	0.472	0.503	1.065677966	1.240909087
20-Dec-94	0.315	0.414	1.314285714	1.118247302

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
5-Jan-95	0.303	0.404	1.333333333	1.255474191
21-Jan-95	0.339	0.39	1.150442478	1.309975591
22-Feb-95	0.352	0.423	1.201704545	1.198302412
10-Mar-95	0.374	0.434	1.160427807	1.200683905
26-Mar-95	0.449	0.406	0.904231626	1.172504637
27-Apr-95	0.446	0.397	0.890134529	0.984713529
13-May-95	0.402	0.439	1.092039801	0.918508229
29-May-95	0.377	0.44	1.167108753	1.039980329
14-Jun-95	0.379	0.463	1.221635884	1.128970226
30-Jun-95	0.368	0.467	1.269021739	1.193836187
1-Aug-95	0.34	0.48	1.411764706	1.246466073
17-Aug-95	0.364	0.489	1.343406593	1.362175116
2-Sep-95	0.332	0.498	1.5	1.34903715
18-Sep-95	0.307	0.474	1.543973941	1.454711145
4-Oct-95	0.289	0.482	1.667820069	1.517195102
20-Oct-95	0.329	0.436	1.325227964	1.622632579
5-Nov-95	0.28	0.459	1.639285714	1.414449348
21-Nov-95	0.269	0.469	1.743494424	1.571834804
9-Feb-96	0.403	0.403	1	1.691996538
25-Feb-96	0.393	0.414	1.053435115	1.207598961
28-Mar-96	0.386	0.313	0.810880829	1.099684269
13-Apr-96	0.475	0.456	0.96	0.897521861
15-May-96	0.411	0.468	1.138686131	0.941256558
31-May-96	0.407	0.482	1.184275184	1.079457259
16-Jun-96	0.384	0.499	1.299479167	1.152829807
2-Jul-96	0.423	0.537	1.269503546	1.255484359
18-Jul-96	0.348	0.496	1.425287356	1.26529779
3-Aug-96	0.43	0.506	1.176744186	1.377290486
19-Aug-96	0.333	0.513	1.540540541	1.236908076
20-Sep-96	0.317	0.524	1.652996845	1.449450801
6-Oct-96	0.326	0.507	1.555214724	1.591933032
7-Nov-96	0.313	0.498	1.591054313	1.566230216
23-Nov-96	0.295	0.386	1.308474576	1.583607084
9-Dec-96	0.31	0.441	1.422580645	1.391014329
10-Jan-97	0.309	0.474	1.533980583	1.41311075
27-Feb-97	0.394	0.422	1.07106599	1.497719633
16-Apr-97	0.42	0.416	0.99047619	1.199062083
18-May-97	0.43	0.469	1.090697674	1.053051958
19-Jun-97	0.378	0.505	1.335978836	1.07940396
21-Jul-97	0.424	0.509	1.200471698	1.259006373

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
6-Aug-97	0.325	0.52	1.6	1.218032101
22-Aug-97	0.373	0.524	1.404825737	1.48540963
7-Sep-97	0.361	0.516	1.429362881	1.429000905
23-Sep-97	0.305	0.519	1.701639344	1.429254288
10-Nov-97	0.31	0.421	1.358064516	1.619923827
13-Jan-98	0.313	0.395	1.261980831	1.43662231
19-Apr-98	0.405	0.507	1.251851852	1.314373274
21-May-98	0.452	0.486	1.075221239	1.270608279
6-Jun-98	0.462	0.481	1.041125541	1.133837351
22-Jun-98	0.397	0.505	1.272040302	1.068939084
24-Jul-98	0.364	0.512	1.406593407	1.211109937
9-Aug-98	0.406	0.496	1.221674877	1.347948366
25-Aug-98	0.327	0.511	1.562691131	1.259556923
10-Sep-98	0.331	0.501	1.513595166	1.471750869
26-Sep-98	0.281	0.504	1.793594306	1.501041877
12-Oct-98	0.288	0.513	1.78125	1.705828577
31-Dec-98	0.329	0.407	1.237082067	1.758623573
16-Jan-99	0.287	0.387	1.348432056	1.393544519
6-Apr-99	0.426	0.457	1.072769953	1.361965795
8-May-99	0.363	0.442	1.217630854	1.159528706
25-Jun-99	0.35	0.514	1.468571429	1.200200209
12-Aug-99	0.336	0.498	1.482142857	1.388060063
28-Aug-99	0.302	0.503	1.665562914	1.453918019
3-Jan-00	0.279	0.46	1.64874552	1.602069445
27-Jan-00	0.31	0.436	1.406451613	1.634742697
20-Feb-00	0.328	0.436	1.329268293	1.474938938
7-Mar-00	0.393	0.443	1.127226463	1.372969486
15-Mar-00	0.487	0.571	1.1724846	1.20094937
31-Mar-00	0.453	0.434	0.958057395	1.181024031
2-May-00	0.375	0.481	1.282666667	1.024947386
26-May-00	0.325	0.507	1.56	1.205350882
3-Jun-00	0.364	0.501	1.376373626	1.453605265
11-Jun-00	0.319	0.511	1.601880878	1.399543118
27-Jun-00	0.381	0.502	1.317585302	1.54117955
13-Jul-00	0.34	0.508	1.494117647	1.384663576
21-Jul-00	0.393	0.506	1.287531807	1.461281426
29-Jul-00	0.321	0.493	1.535825545	1.339656692
14-Aug-00	0.305	0.512	1.678688525	1.476974889
22-Aug-00	0.305	0.506	1.659016393	1.618174434
15-Sep-00	0.306	0.501	1.637254902	1.646763806

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
23-Sep-00	0.31	0.49	1.580645161	1.640107573
1-Oct-00	0.399	0.488	1.223057644	1.598483885
25-Oct-00	0.302	0.457	1.513245033	1.335685516
18-Nov-00	0.318	0.377	1.185534591	1.459977178
26-Nov-00	0.279	0.427	1.53046595	1.267867367
13-Jan-01	0.314	0.458	1.458598726	1.451686375
14-Feb-01	0.337	0.44	1.305637982	1.456525021
10-Mar-01	0.418	0.49	1.172248804	1.350904094
18-Mar-01	0.458	0.467	1.019650655	1.225845391
3-Apr-01	0.394	0.463	1.175126904	1.081509076
11-Apr-01	0.386	0.462	1.196891192	1.147041555
27-Apr-01	0.357	0.456	1.277310924	1.181936301
5-May-01	0.389	0.488	1.254498715	1.248698537
13-May-01	0.391	0.494	1.26342711	1.252758661
21-May-01	0.376	0.506	1.345744681	1.260226575
29-May-01	0.368	0.492	1.336956522	1.320089249
14-Jun-01	0.399	0.505	1.26566416	1.33189634
30-Jun-01	0.361	0.505	1.398891967	1.285533814
8-Jul-01	0.329	0.517	1.571428571	1.364884521
16-Jul-01	0.333	0.527	1.582582583	1.509465356
1-Aug-01	0.341	0.531	1.557184751	1.560647415
17-Aug-01	0.299	0.504	1.685618729	1.55822355
25-Aug-01	0.3	0.516	1.72	1.647400175
18-Sep-01	0.298	0.525	1.761744966	1.698220053
26-Sep-01	0.309	0.515	1.666666667	1.742687492
20-Oct-01	0.333	0.48	1.441441441	1.689472914
15-Dec-01	0.301	0.376	1.249169435	1.515850883
23-Dec-01	0.401	0.387	0.965087282	1.32917387
8-Jan-02	0.331	0.51	1.540785498	1.074313258
16-Jan-02	0.344	0.411	1.194767442	1.400843826
24-Jan-02	0.343	0.505	1.472303207	1.256590357
9-Feb-02	0.298	0.413	1.38590604	1.407589352
25-Feb-02	0.427	0.456	1.067915691	1.392411034
5-Mar-02	0.361	0.478	1.324099723	1.165264294
13-Mar-02	0.38	0.48	1.263157895	1.276449094
21-Mar-02	0.424	0.458	1.080188679	1.267145255
6-Apr-02	0.399	0.395	0.989974937	1.136275652
16-May-02	0.401	0.414	1.032418953	1.033865152
24-May-02	0.412	0.48	1.165048544	1.032852812
17-Jun-02	0.436	0.507	1.162844037	1.125389824

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
25-Jun-02	0.383	0.505	1.318537859	1.151607773
3-Jul-02	0.427	0.49	1.147540984	1.268458833
19-Jul-02	0.338	0.503	1.48816568	1.183816338
27-Jul-02	0.322	0.515	1.599378882	1.396860878
4-Aug-02	0.32	0.509	1.590625	1.538623481
28-Aug-02	0.338	0.516	1.526627219	1.575024544
29-Sep-02	0.493	0.547	1.109533469	1.541146417
31-Oct-02	0.306	0.51	1.666666667	1.239017353
3-Jan-03	0.279	0.421	1.508960573	1.538371873
4-Feb-03	0.308	0.473	1.535714286	1.517783963
8-Mar-03	0.463	0.487	1.051835853	1.530335189
25-Apr-03	0.451	0.487	1.079822616	1.195385654
11-May-03	0.295	0.545	1.847457627	1.114491528
27-May-03	0.484	0.457	0.944214876	1.627567797
30-Jul-03	0.343	0.515	1.501457726	1.149220752
2-Oct-03	0.298	0.518	1.738255034	1.395786634
23-Feb-04	0.449	0.484	1.077951002	1.635514514
26-Mar-04	0.374	0.445	1.189839572	1.245220056
11-Apr-04	0.361	0.437	1.210526316	1.206453717
13-May-04	0.377	0.463	1.228116711	1.209304536
29-May-04	0.373	0.467	1.252010724	1.222473058
30-Jun-04	0.355	0.508	1.430985915	1.243149424
1-Aug-04	0.338	0.5	1.479289941	1.374634968
17-Aug-04	0.32	0.505	1.578125	1.447893449
2-Sep-04	0.306	0.51	1.666666667	1.539055535
18-Sep-04	0.304	0.507	1.667763158	1.628383327
4-Oct-04	0.325	0.51	1.569230769	1.655949209
20-Oct-04	0.427	0.384	0.899297424	1.595246301
9-Feb-05	0.398	0.437	1.09798995	1.108082087
29-Mar-05	0.399	0.411	1.030075188	1.101017591
14-Apr-05	0.413	0.413	1	1.051357909
30-Apr-05	0.453	0.439	0.969094923	1.015407373
16-May-05	0.421	0.437	1.038004751	0.982988658
17-Jun-05	0.461	0.471	1.021691974	1.021499923
3-Jul-05	0.393	0.503	1.279898219	1.021634359
19-Jul-05	0.372	0.508	1.365591398	1.202419061
4-Aug-05	0.343	0.481	1.402332362	1.316639697
20-Aug-05	0.327	0.486	1.486238532	1.376624562
5-Sep-05	0.309	0.489	1.582524272	1.453354341
21-Sep-05	0.306	0.498	1.62745098	1.543773293

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
7-Oct-05	0.306	0.517	1.689542484	1.602347674
10-Dec-05	0.284	0.399	1.404929577	1.663384041
28-Feb-06	0.395	0.424	1.073417722	1.482465916
17-Apr-06	0.406	0.464	1.142857143	1.19613218
19-May-06	0.452	0.5	1.10619469	1.158839654
6-Jul-06	0.353	0.503	1.424929178	1.121988179
22-Jul-06	0.334	0.508	1.520958084	1.334046879
7-Aug-06	0.351	0.52	1.481481481	1.464884722
23-Aug-06	0.338	0.501	1.482248521	1.476502454
8-Sep-06	0.322	0.51	1.583850932	1.480524701
24-Sep-06	0.306	0.506	1.653594771	1.552853062
10-Oct-06	0.336	0.494	1.470238095	1.623372259
14-Jan-07	0.412	0.408	0.990291262	1.516178344
30-Jan-07	0.3	0.456	1.52	1.148057387
15-Feb-07	0.316	0.436	1.379746835	1.408417216
20-Apr-07	0.401	0.488	1.216957606	1.38834795
22-May-07	0.354	0.485	1.370056497	1.268374709
7-Jun-07	0.418	0.494	1.181818182	1.339551961
23-Jun-07	0.363	0.512	1.41046832	1.229138315
9-Jul-07	0.368	0.51	1.385869565	1.356069318
26-Aug-07	0.318	0.53	1.666666667	1.376929491
13-Oct-07	0.326	0.525	1.610429448	1.579745514
16-Dec-07	0.424	0.444	1.047169811	1.601224268
5-Mar-08	0.426	0.474	1.112676056	1.213386148
21-Mar-08	0.389	0.502	1.290488432	1.142889084
6-Apr-08	0.5	0.544	1.088	1.246208627
30-Apr-08	0.391	0.493	1.260869565	1.135462588
24-May-08	0.494	0.566	1.145748988	1.223247472
1-Jun-08	0.399	0.499	1.250626566	1.168998533
9-Jun-08	0.368	0.506	1.375	1.226138156
17-Jun-08	0.384	0.51	1.328125	1.330341447
25-Jun-08	0.402	0.514	1.278606965	1.328789934
3-Jul-08	0.364	0.511	1.403846154	1.293661856
11-Jul-08	0.354	0.516	1.457627119	1.370790864
19-Jul-08	0.373	0.539	1.445040214	1.431576242
27-Jul-08	0.337	0.524	1.554896142	1.441001023
28-Aug-08	0.33	0.536	1.624242424	1.520727607
13-Sep-08	0.338	0.528	1.562130178	1.593187979
21-Sep-08	0.308	0.517	1.678571429	1.571447518
29-Sep-08	0.371	0.523	1.409703504	1.646434255

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
23-Oct-08	0.324	0.477	1.472222222	1.480722729
16-Nov-08	0.464	0.524	1.129310345	1.474772374
2-Dec-08	0.375	0.5	1.333333333	1.232948954
19-Jan-09	0.304	0.392	1.289473684	1.303218019
27-Jan-09	0.333	0.315	0.945945946	1.293596985
28-Feb-09	0.396	0.478	1.207070707	1.050241258
9-Apr-09	0.401	0.465	1.159600998	1.160021872
17-Apr-09	0.403	0.493	1.223325062	1.15972726
25-Apr-09	0.437	0.515	1.178489703	1.204245721
11-May-09	0.472	0.482	1.021186441	1.186216508
19-May-09	0.441	0.505	1.145124717	1.070695461
27-May-09	0.408	0.498	1.220588235	1.12279594
28-Jun-09	0.401	0.517	1.289276808	1.191250547
6-Jul-09	0.483	0.493	1.020703934	1.25986893
14-Jul-09	0.382	0.511	1.337696335	1.092453432
22-Jul-09	0.384	0.524	1.364583333	1.264123464
30-Jul-09	0.373	0.516	1.383378016	1.334445373
7-Aug-09	0.369	0.514	1.39295393	1.368698223
15-Aug-09	0.366	0.514	1.404371585	1.385677218
23-Aug-09	0.347	0.516	1.4870317	1.398763275
8-Sep-09	0.34	0.521	1.532352941	1.460551173
24-Sep-09	0.315	0.484	1.536507937	1.510812411
2-Oct-09	0.333	0.502	1.507507508	1.528799279
10-Oct-09	0.306	0.488	1.594771242	1.513895039
26-Oct-09	0.314	0.513	1.633757962	1.570508381
3-Nov-09	0.301	0.498	1.65448505	1.614783088
11-Nov-09	0.286	0.41	1.433566434	1.642574461
19-Nov-09	0.346	0.492	1.421965318	1.496268842
13-Dec-09	0.296	0.389	1.314189189	1.444256375
14-Jan-10	0.322	0.509	1.580745342	1.353209345
4-Apr-10	0.46	0.405	0.880434783	1.512484543
28-Apr-10	0.424	0.463	1.091981132	1.070049711
30-May-10	0.39	0.474	1.215384615	1.085401706
7-Jun-10	0.384	0.49	1.276041667	1.176389742
15-Jun-10	0.486	0.527	1.08436214	1.246146089
23-Jun-10	0.401	0.503	1.25436409	1.132897325
1-Jul-10	0.37	0.499	1.348648649	1.21792406
9-Jul-10	0.37	0.501	1.354054054	1.309431272
17-Jul-10	0.384	0.495	1.2890625	1.340667219
25-Jul-10	0.359	0.505	1.406685237	1.304543916

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
26-Aug-10	0.371	0.48	1.293800539	1.37604284
14-Nov-10	0.299	0.457	1.528428094	1.31847323
22-Nov-10	0.307	0.46	1.498371336	1.465441634
30-Nov-10	0.298	0.462	1.55033557	1.488492425
8-Dec-10	0.318	0.477	1.5	1.531782627
24-Dec-10	0.295	0.476	1.613559322	1.509534788
1-Jan-11	0.286	0.468	1.636363636	1.582351962
9-Jan-11	0.294	0.393	1.336734694	1.620160134
25-Jan-11	0.317	0.431	1.359621451	1.421762326
22-Mar-11	0.344	0.465	1.351744186	1.378263714
7-Apr-11	0.375	0.478	1.274666667	1.359700044
23-Apr-11	0.349	0.481	1.378223496	1.30017668
1-May-11	0.356	0.493	1.384831461	1.354809451
17-May-11	0.473	0.53	1.1205074	1.375824858
25-May-11	0.383	0.511	1.334203655	1.197102637
2-Jun-11	0.373	0.53	1.420911528	1.29307335
10-Jun-11	0.427	0.53	1.241217799	1.382560075
18-Jun-11	0.356	0.52	1.460674157	1.283620481
26-Jun-11	0.496	0.532	1.072580645	1.407558055
12-Jul-11	0.362	0.532	1.46961326	1.173073868
20-Jul-11	0.34	0.535	1.573529412	1.380651442
5-Aug-11	0.359	0.529	1.473537604	1.515666021
13-Aug-11	0.363	0.529	1.457300275	1.486176129
21-Aug-11	0.319	0.552	1.730407524	1.465963032
6-Sep-11	0.297	0.52	1.750841751	1.651074176
30-Sep-11	0.301	0.516	1.714285714	1.720911478
8-Oct-11	0.485	0.485	1	1.716273444
24-Oct-11	0.383	0.426	1.11227154	1.214882033
11-Dec-11	0.25	0.394	1.576	1.143054688
28-Jan-12	0.269	0.434	1.6133829	1.446116406
17-Apr-12	0.374	0.487	1.302139037	1.563202952
3-May-12	0.423	0.482	1.139479905	1.380458212
19-May-12	0.422	0.46	1.090047393	1.211773397
4-Jun-12	0.476	0.523	1.098739496	1.126565195
20-Jun-12	0.482	0.516	1.070539419	1.107087205
6-Jul-12	0.394	0.529	1.342639594	1.081503755
22-Jul-12	0.405	0.527	1.301234568	1.264298842
7-Aug-12	0.352	0.52	1.477272727	1.29015385
23-Aug-12	0.353	0.529	1.498583569	1.421137064
8-Sep-12	0.363	0.508	1.399449036	1.475349618

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
10-Oct-12	0.293	0.503	1.716723549	1.42221921
26-Oct-12	0.31	0.494	1.593548387	1.628372248
11-Nov-12	0.266	0.468	1.759398496	1.603995545
27-Nov-12	0.271	0.436	1.608856089	1.712777611
14-Jan-13	0.41	0.476	1.16097561	1.640032545
2-Apr-13	0.404	0.448	1.108910891	1.30469269
4-Apr-13	0.368	0.476	1.293478261	1.167645431
6-May-13	0.422	0.481	1.139810427	1.255728412
14-May-13	0.352	0.508	1.443181818	1.174585822
22-May-13	0.411	0.49	1.192214112	1.362603019
30-May-13	0.352	0.527	1.497159091	1.243330784
7-Jun-13	0.379	0.495	1.306068602	1.421010599
15-Jun-13	0.361	0.53	1.468144044	1.340551201
1-Jul-13	0.324	0.526	1.62345679	1.429866191
9-Jul-13	0.353	0.504	1.42776204	1.56537961
17-Jul-13	0.339	0.522	1.539823009	1.469047311
25-Jul-13	0.345	0.504	1.460869565	1.518590299
2-Aug-13	0.378	0.522	1.380952381	1.478185785
10-Aug-13	0.34	0.506	1.488235294	1.410122402
26-Aug-13	0.311	0.493	1.585209003	1.464801427
3-Sep-13	0.291	0.515	1.76975945	1.54908673
11-Sep-13	0.334	0.488	1.461077844	1.703557634
19-Sep-13	0.273	0.526	1.926739927	1.533821781
27-Sep-13	0.374	0.502	1.342245989	1.808864483
5-Oct-13	0.271	0.509	1.878228782	1.482231537
21-Oct-13	0.254	0.502	1.976377953	1.759429609
29-Oct-13	0.281	0.472	1.679715302	1.91129345
30-Nov-13	0.269	0.459	1.706319703	1.749188747
24-Dec-13	0.242	0.419	1.731404959	1.719180416
1-Jan-14	0.298	0.785	2.634228188	1.727737596
17-Jan-14	0.286	0.444	1.552447552	2.36228101
22-Mar-14	0.419	0.439	1.047732697	1.79539759
30-Mar-14	0.354	0.485	1.370056497	1.272032165
7-Apr-14	0.415	0.404	0.973493976	1.340649197
25-May-14	0.4	0.517	1.2925	1.083640542
2-Jun-14	0.398	0.506	1.271356784	1.229842163
10-Jun-14	0.393	0.514	1.307888041	1.258902398
18-Jun-14	0.427	0.536	1.255269321	1.293192348
26-Jun-14	0.383	0.524	1.368146214	1.266646229

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
20-Jul-14	0.319	0.551	1.727272727	1.41282719
5-Aug-14	0.3	0.539	1.796666667	1.632939066
21-Aug-14	0.301	0.531	1.764119601	1.747548387
29-Aug-14	0.361	0.525	1.454293629	1.759148237
6-Sep-14	0.31	0.536	1.729032258	1.545750011
14-Sep-14	0.327	0.512	1.565749235	1.674047584
22-Sep-14	0.299	0.534	1.785953177	1.59823874
30-Sep-14	0.342	0.515	1.505847953	1.729638846
16-Oct-14	0.299	0.481	1.608695652	1.572985221
24-Oct-14	0.408	0.521	1.276960784	1.597982523
1-Nov-14	0.297	0.474	1.595959596	1.373267306
9-Nov-14	0.286	0.419	1.465034965	1.529151909
17-Nov-14	0.288	0.478	1.659722222	1.484270048
11-Dec-14	0.25	0.432	1.728	1.60708657
19-Dec-14	0.243	0.277	1.139917695	1.691725971
27-Dec-14	0.268	0.437	1.630597015	1.305460178
4-Jan-15	0.299	0.469	1.568561873	1.533055964
12-Jan-15	0.298	0.482	1.617449664	1.5579101
5-Feb-15	0.312	0.429	1.375	1.599587795
1-Mar-15	0.412	0.432	1.048543689	1.442376339
9-Mar-15	0.362	0.396	1.093922652	1.166693484
17-Mar-15	0.43	0.501	1.165116279	1.115753902
25-Mar-15	0.409	0.444	1.085574572	1.150307566
20-May-15	0.374	0.533	1.42513369	1.10499447
28-May-15	0.386	0.515	1.334196891	1.329091924
5-Jun-15	0.366	0.538	1.469945355	1.332665401
13-Jun-15	0.397	0.512	1.289672544	1.428761369
21-Jun-15	0.379	0.537	1.416886544	1.331399192
29-Jun-15	0.363	0.522	1.438016529	1.391240338
7-Jul-15	0.409	0.535	1.30806846	1.423983672
23-Jul-15	0.389	0.531	1.36503856	1.342843023
8-Aug-15	0.498	0.541	1.086345382	1.358379899
16-Aug-15	0.343	0.514	1.498542274	1.167955737
9-Sep-15	0.284	0.532	1.873239437	1.399366313
17-Sep-15	0.317	0.506	1.596214511	1.7310775
25-Sep-15	0.271	0.531	1.959409594	1.636673408
3-Oct-15	0.319	0.411	1.288401254	1.862588738
11-Oct-15	0.385	0.536	1.392207792	1.460657499
27-Oct-15	0.245	0.518	2.114285714	1.412742704
4-Nov-15	0.36	0.386	1.072222222	1.903822811

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
28-Nov-15	0.255	0.502	1.968627451	1.321702399
14-Dec-15	0.233	0.413	1.772532189	1.774549935
30-Dec-15	0.24	0.393	1.6375	1.773137513
15-Jan-16	0.249	0.388	1.558232932	1.678191254
23-Jan-16	0.282	0.447	1.585106383	1.594220428
8-Feb-16	0.327	0.498	1.52293578	1.587840597
16-Feb-16	0.263	0.412	1.566539924	1.542407225
24-Feb-16	0.328	0.465	1.417682927	1.559300114
3-Mar-16	0.402	0.494	1.228855721	1.460168083
19-Mar-16	0.461	0.456	0.989154013	1.29824943
27-Mar-16	0.497	0.512	1.030181087	1.081882638
4-Apr-16	0.391	0.435	1.112531969	1.045691552
12-Apr-16	0.45	0.424	0.942222222	1.092479844
22-May-16	0.388	0.504	1.298969072	0.987299509
7-Jun-16	0.363	0.523	1.44077135	1.205468203
23-Jun-16	0.349	0.524	1.501432665	1.370180406
1-Jul-16	0.349	0.51	1.461318052	1.462056987
9-Jul-16	0.336	0.517	1.538690476	1.461539732
17-Jul-16	0.374	0.476	1.272727273	1.515545253
25-Jul-16	0.312	0.515	1.650641026	1.345572667
10-Aug-16	0.3	0.524	1.746666667	1.559120518
26-Aug-16	0.297	0.527	1.774410774	1.690402822
3-Sep-16	0.308	0.513	1.665584416	1.749208389
11-Sep-16	0.297	0.527	1.774410774	1.690671608
19-Sep-16	0.307	0.505	1.64495114	1.749289024
27-Sep-16	0.293	0.519	1.771331058	1.676252505
5-Oct-16	0.324	0.469	1.447530864	1.742807492
13-Oct-16	0.255	0.484	1.898039216	1.536113853
21-Oct-16	0.327	0.478	1.4617737	1.789461607
29-Oct-16	0.483	0.518	1.072463768	1.560080072
14-Nov-16	0.257	0.492	1.914396887	1.218748659
30-Nov-16	0.24	0.368	1.533333333	1.705702419
8-Dec-16	0.369	0.458	1.241192412	1.585044059
16-Dec-16	0.244	0.396	1.62295082	1.344347906
1-Jan-17	0.265	0.413	1.558490566	1.539369946
17-Jan-17	0.28	0.443	1.582142857	1.55275438
10-Feb-17	0.359	0.429	1.194986072	1.573326314
26-Feb-17	0.334	0.411	1.230538922	1.308488145
6-Mar-17	0.363	0.461	1.269972452	1.253923689
7-Apr-17	0.415	0.414	0.997590361	1.265157823

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
15-Apr-17	0.485	0.504	1.039175258	1.0778606
23-Apr-17	0.423	0.505	1.193853428	1.05078086
1-May-17	0.392	0.5	1.275510204	1.150931658
9-May-17	0.427	0.516	1.208430913	1.23813664
17-May-17	0.452	0.503	1.112831858	1.217342631
25-May-17	0.381	0.531	1.393700787	1.14418509
2-Jun-17	0.364	0.516	1.417582418	1.318846078
10-Jun-17	0.375	0.569	1.517333333	1.387961516
18-Jun-17	0.386	0.511	1.323834197	1.478521788
12-Jul-17	0.351	0.529	1.507122507	1.370240474
20-Jul-17	0.334	0.499	1.494011976	1.466057897
28-Jul-17	0.331	0.525	1.586102719	1.485625752
5-Aug-17	0.341	0.505	1.480938416	1.555959629
13-Aug-17	0.314	0.535	1.703821656	1.50344478
21-Aug-17	0.302	0.514	1.701986755	1.643708593
29-Aug-17	0.284	0.527	1.855633803	1.684503306
6-Sep-17	0.311	0.505	1.623794212	1.804294654
14-Sep-17	0.295	0.535	1.813559322	1.677944345
22-Sep-17	0.312	0.497	1.592948718	1.772874829
30-Sep-17	0.373	0.532	1.426273458	1.646926551
8-Oct-17	0.303	0.484	1.597359736	1.492469386
16-Oct-17	0.297	0.505	1.7003367	1.565892631
24-Oct-17	0.34	0.526	1.547058824	1.66000348
1-Nov-17	0.289	0.538	1.861591696	1.58094222
27-Dec-17	0.407	0.407	1	1.777396853
12-Jan-18	0.295	0.465	1.576271186	1.233219056
20-Jan-18	0.271	0.484	1.78597786	1.473355547
17-Mar-18	0.357	0.406	1.137254902	1.692191166
25-Mar-18	0.431	0.519	1.204176334	1.303735781
2-Apr-18	0.481	0.536	1.114345114	1.234044168
26-Apr-18	0.415	0.518	1.248192771	1.150254831
4-May-18	0.437	0.51	1.167048055	1.218811389
5-Jun-18	0.421	0.514	1.220902613	1.182577055
13-Jun-18	0.341	0.542	1.589442815	1.209404946
21-Jun-18	0.365	0.52	1.424657534	1.475431454
29-Jun-18	0.329	0.538	1.635258359	1.43988971
7-Jul-18	0.36	0.517	1.436111111	1.576647764
15-Jul-18	0.362	0.536	1.480662983	1.478272107
23-Jul-18	0.36	0.515	1.430555556	1.479945721
31-Jul-18	0.293	0.551	1.880546075	1.445372605

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
8-Aug-18	0.374	0.52	1.390374332	1.749994034
16-Aug-18	0.352	0.532	1.511363636	1.498260242
24-Aug-18	0.326	0.532	1.63190184	1.507432618
1-Sep-18	0.284	0.542	1.908450704	1.594561074
9-Sep-18	0.303	0.527	1.739273927	1.814283815
17-Sep-18	0.285	0.535	1.877192982	1.761776894
25-Sep-18	0.289	0.511	1.76816609	1.842568156
3-Oct-18	0.266	0.53	1.992481203	1.79048671
11-Oct-18	0.285	0.488	1.712280702	1.931882855
19-Oct-18	0.252	0.478	1.896825397	1.778161348
27-Oct-18	0.356	0.504	1.415730337	1.861226182
4-Nov-18	0.251	0.424	1.689243028	1.549379091
12-Nov-18	0.455	0.523	1.149450549	1.647283847
6-Dec-18	0.245	0.5	2.040816327	1.298800539
14-Dec-18	0.264	0.438	1.659090909	1.81821159
15-Jan-19	0.461	0.483	1.047722343	1.706827113
8-Feb-19	0.286	0.384	1.342657343	1.245453774
16-Feb-19	0.354	0.378	1.06779661	1.313496272
24-Feb-19	0.344	0.393	1.14244186	1.141506509
12-Mar-19	0.354	0.479	1.353107345	1.142161255
28-Mar-19	0.485	0.617	1.272164948	1.289823518
29-Apr-19	0.472	0.499	1.05720339	1.277462519
15-May-19	0.391	0.523	1.337595908	1.123281129
31-May-19	0.361	0.519	1.43767313	1.273301474
16-Jun-19	0.356	0.518	1.45505618	1.388361633
2-Jul-19	0.357	0.529	1.481792717	1.435047816
10-Jul-19	0.38	0.507	1.334210526	1.467769247
18-Jul-19	0.335	0.528	1.576119403	1.374278142
26-Jul-19	0.379	0.515	1.35883905	1.515567025
3-Aug-19	0.338	0.529	1.565088757	1.405857443
11-Aug-19	0.359	0.516	1.437325905	1.517319363
19-Aug-19	0.3	0.538	1.793333333	1.461323943
27-Aug-19	0.324	0.513	1.583333333	1.693730516
4-Sep-19	0.268	0.521	1.944029851	1.616452488
12-Sep-19	0.329	0.512	1.556231003	1.845756642
20-Sep-19	0.266	0.518	1.947368421	1.643088695
14-Oct-19	0.344	0.485	1.409883721	1.856084503
22-Oct-19	0.264	0.498	1.886363636	1.543743956
7-Nov-19	0.28	0.433	1.546428571	1.783577732
1-Dec-19	0.284	0.463	1.63028169	1.61757332

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
25-Dec-19	0.251	0.477	1.900398406	1.626469179
10-Jan-20	0.368	0.541	1.470108696	1.818219638
18-Jan-20	0.307	0.409	1.332247557	1.574541978
11-Feb-20	0.283	0.363	1.282685512	1.404935883
6-Mar-20	0.286	0.793	2.772727273	1.319360624
14-Mar-20	0.286	0.489	1.70979021	2.336717278
22-Mar-20	0.392	0.388	0.989795918	1.89786833
30-Mar-20	0.359	0.5	1.39275766	1.262217642
23-Apr-20	0.368	0.511	1.388586957	1.353595655
9-May-20	0.404	0.512	1.267326733	1.378089566
17-May-20	0.463	0.542	1.17062635	1.300555583
25-May-20	0.401	0.519	1.294264339	1.20960512
2-Jun-20	0.369	0.437	1.184281843	1.268866573
10-Jun-20	0.381	0.534	1.401574803	1.209657262
18-Jun-20	0.48	0.581	1.210416667	1.343999541
26-Jun-20	0.29	0.406	1.4	1.250491529
4-Jul-20	0.33	0.548	1.660606061	1.355147459
12-Jul-20	0.333	0.509	1.528528529	1.56896848
20-Jul-20	0.315	0.543	1.723809524	1.540660514
5-Aug-20	0.299	0.551	1.842809365	1.668864821
13-Aug-20	0.328	0.531	1.618902439	1.790626001
21-Aug-20	0.309	0.547	1.770226537	1.670419508
29-Aug-20	0.33	0.518	1.56969697	1.740284428
6-Sep-20	0.281	0.532	1.893238434	1.620873207
14-Sep-20	0.307	0.517	1.684039088	1.811528866
22-Sep-20	0.291	0.532	1.828178694	1.722286021
8-Oct-20	0.278	0.499	1.794964029	1.796410892
16-Oct-20	0.303	0.46	1.518151815	1.795398088
24-Oct-20	0.318	0.501	1.575471698	1.601325697
12-Jan-21	0.256	0.383	1.49609375	1.583227898
20-Jan-21	0.308	0.392	1.272727273	1.522233994
28-Jan-21	0.265	0.387	1.460377358	1.347579289
5-Feb-21	0.321	0.433	1.348909657	1.426537938
13-Feb-21	0.321	0.443	1.380062305	1.372198141
1-Mar-21	0.331	0.425	1.283987915	1.377703056
2-Apr-21	0.357	0.506	1.417366947	1.312102458
10-Apr-21	0.434	0.606	1.396313364	1.3857876
18-Apr-21	0.388	0.5	1.288659794	1.393155635
26-Apr-21	0.397	0.514	1.294710327	1.320008546
4-May-21	0.401	0.533	1.329177057	1.302299793

Khowajaghar Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
20-May-21	0.375	0.528	1.408	1.321113878
28-May-21	0.361	0.512	1.418282548	1.381934163
5-Jun-21	0.389	0.532	1.367609254	1.407378033
13-Jun-21	0.381	0.51	1.338582677	1.379539888
21-Jun-21	0.379	0.533	1.406332454	1.35086984
7-Jul-21	0.351	0.552	1.572649573	1.38969367
23-Jul-21	0.329	0.536	1.629179331	1.517762802
31-Jul-21	0.438	0.531	1.212328767	1.595754372
8-Aug-21	0.313	0.539	1.722044728	1.327356449
16-Aug-21	0.346	0.523	1.511560694	1.603638245
24-Aug-21	0.295	0.532	1.803389831	1.539183959
1-Sep-21	0.323	0.506	1.566563467	1.724128069
9-Sep-21	0.348	0.529	1.520114943	1.613832848
17-Sep-21	0.302	0.505	1.67218543	1.548230314
25-Sep-21	0.266	0.525	1.973684211	1.634998896
11-Oct-21	0.284	0.529	1.862676056	1.872078616
19-Oct-21	0.316	0.503	1.591772152	1.865496824
27-Oct-21	0.472	0.604	1.279661017	1.673889554
28-Nov-21	0.305	0.447	1.46557377	1.397929578
6-Dec-21	0.329	0.449	1.364741641	1.445280513

Tir Pul Station C and M SR Time Serie

Date	Location M	Location C	C/M	C/M*
4-Jan-88	0.333	0.434	1.303303303	
8-Mar-88	0.284	0.317	1.116197183	1.303303303
31-Mar-88	0.284	0.381	1.341549296	1.172329019
2-May-88	0.34	0.387	1.138235294	1.290783213
18-May-88	0.33	0.4	1.212121212	1.18399967
12-Jun-88	0.297	0.407	1.37037037	1.203684749
19-Jun-88	0.368	0.415	1.127717391	1.320364684
28-Jun-88	0.366	0.419	1.144808743	1.185511579
5-Jul-88	0.366	0.414	1.131147541	1.157019594
21-Jul-88	0.357	0.389	1.089635854	1.138909157
30-Jul-88	0.348	0.419	1.204022989	1.104417845
6-Aug-88	0.335	0.378	1.128358209	1.174141445
15-Aug-88	0.351	0.423	1.205128205	1.14209318
22-Aug-88	0.348	0.4	1.149425287	1.186217698
31-Aug-88	0.307	0.402	1.309446254	1.16046301
7-Sep-88	0.309	0.423	1.368932039	1.264751281
9-Oct-88	0.264	0.406	1.537878788	1.337677811
18-Oct-88	0.257	0.424	1.649805447	1.477818495
25-Oct-88	0.274	0.397	1.448905109	1.598209362
3-Nov-88	0.264	0.414	1.568181818	1.493696385
10-Nov-88	0.275	0.408	1.483636364	1.545836188
19-Nov-88	0.26	0.422	1.623076923	1.502296311
5-Dec-88	0.261	0.409	1.567049808	1.586842739
12-Dec-88	0.256	0.396	1.546875	1.572987688
22-Jan-89	0.24	0.391	1.629166667	1.554708806
29-Jan-89	0.361	0.447	1.238227147	1.606829309
7-Feb-89	0.249	0.403	1.618473896	1.348807795
11-Mar-89	0.268	0.403	1.503731343	1.537574066
3-Apr-89	0.497	0.343	0.690140845	1.51388416
12-Apr-89	0.267	0.415	1.554307116	0.93726384
14-May-89	0.297	0.413	1.390572391	1.369194133
30-May-89	0.305	0.419	1.373770492	1.384158913
3-Sep-89	0.278	0.414	1.489208633	1.376887018
5-Oct-89	0.271	0.414	1.527675277	1.455512149
21-Oct-89	0.286	0.419	1.465034965	1.506026338
25-Jan-90	0.27	0.388	1.437037037	1.477332377
10-Feb-90	0.255	0.373	1.462745098	1.449125639
26-Feb-90	0.4	0.444	1.11	1.45865926
14-Mar-90	0.306	0.418	1.366013072	1.214597778

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
17-May-90	0.329	0.413	1.255319149	1.320588484
24-May-90	0.318	0.422	1.327044025	1.274899949
2-Jun-90	0.29	0.425	1.465517241	1.311400802
18-Jun-90	0.283	0.433	1.530035336	1.41928231
21-Aug-90	0.329	0.422	1.282674772	1.496809428
6-Sep-90	0.345	0.433	1.255072464	1.346915169
8-Oct-90	0.321	0.419	1.30529595	1.282625275
24-Oct-90	0.3	0.387	1.29	1.298494748
2-Dec-90	0.289	0.401	1.387543253	1.292548424
18-Dec-90	0.336	0.39	1.160714286	1.359044804
19-Jan-91	0.283	0.383	1.35335689	1.220213441
4-Feb-91	0.531	0.556	1.047080979	1.313413856
20-Feb-91	0.301	0.377	1.252491694	1.126980842
1-Mar-91	0.299	0.395	1.321070234	1.214838439
24-Mar-91	0.299	0.34	1.137123746	1.289200695
9-Apr-91	0.348	0.341	0.979885057	1.182746831
18-Apr-91	0.286	0.386	1.34965035	1.040743589
4-May-91	0.343	0.42	1.224489796	1.256978322
20-May-91	0.288	0.363	1.260416667	1.234236354
5-Jun-91	0.31	0.403	1.3	1.252562573
12-Jun-91	0.348	0.401	1.152298851	1.285768772
7-Jul-91	0.304	0.421	1.384868421	1.192339827
23-Jul-91	0.315	0.407	1.292063492	1.327109843
8-Aug-91	0.333	0.406	1.219219219	1.302577397
15-Aug-91	0.363	0.419	1.154269972	1.244226673
31-Aug-91	0.336	0.392	1.166666667	1.181256983
9-Sep-91	0.331	0.403	1.217522659	1.171043761
25-Sep-91	0.31	0.4	1.290322581	1.203578989
27-Oct-91	0.282	0.387	1.372340426	1.264299503
12-Nov-91	0.339	0.404	1.191740413	1.339928149
30-Dec-91	0.285	0.363	1.273684211	1.236196734
15-Jan-92	0.326	0.405	1.242331288	1.262437967
7-Feb-92	0.294	0.367	1.24829932	1.248363292
16-Feb-92	0.279	0.367	1.315412186	1.248318511
3-Mar-92	0.33	0.392	1.187878788	1.295284084
6-May-92	0.33	0.407	1.233333333	1.220100377
7-Jun-92	0.309	0.418	1.352750809	1.229363446
23-Jun-92	0.326	0.422	1.294478528	1.3157346
9-Jul-92	0.361	0.44	1.218836565	1.300855349
26-Aug-92	0.327	0.417	1.275229358	1.2434422

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
27-Sep-92	0.272	0.407	1.496323529	1.265693211
29-Oct-92	0.279	0.397	1.422939068	1.427134434
14-Nov-92	0.275	0.39	1.418181818	1.424197678
30-Nov-92	0.272	0.387	1.422794118	1.419986576
16-Dec-92	0.246	0.288	1.170731707	1.421951855
8-Jan-93	0.292	0.442	1.51369863	1.246097752
17-Jan-93	0.254	0.344	1.354330709	1.433418367
24-Jan-93	0.265	0.383	1.445283019	1.378057006
2-Feb-93	0.279	0.403	1.444444444	1.425115215
9-Feb-93	0.38	0.43	1.131578947	1.438645676
29-Mar-93	0.28	0.377	1.346428571	1.223698966
9-May-93	0.299	0.384	1.284280936	1.30960969
25-May-93	0.501	0.526	1.0499002	1.291879562
10-Jun-93	0.287	0.396	1.379790941	1.122494008
17-Jun-93	0.335	0.389	1.16119403	1.302601861
3-Jul-93	0.345	0.4	1.15942029	1.203616379
12-Jul-93	0.317	0.402	1.268138801	1.172679117
19-Jul-93	0.337	0.388	1.151335312	1.239500896
28-Jul-93	0.309	0.399	1.291262136	1.177784987
4-Aug-93	0.344	0.39	1.13372093	1.257218991
20-Aug-93	0.319	0.384	1.203761755	1.170770349
21-Sep-93	0.311	0.391	1.257234727	1.193864333
30-Sep-93	0.306	0.4	1.307189542	1.238223609
16-Oct-93	0.296	0.406	1.371621622	1.286499762
23-Oct-93	0.32	0.399	1.246875	1.346085064
8-Nov-93	0.313	0.338	1.079872204	1.276638019
17-Nov-93	0.313	0.39	1.24600639	1.138901949
24-Nov-93	0.317	0.387	1.220820189	1.213875058
3-Dec-93	0.319	0.439	1.376175549	1.21873665
10-Dec-93	0.302	0.396	1.311258278	1.328943879
19-Dec-93	0.295	0.375	1.271186441	1.316563958
26-Dec-93	0.304	0.411	1.351973684	1.284799696
4-Jan-94	0.519	0.542	1.044315992	1.331821488
11-Jan-94	0.296	0.376	1.27027027	1.130567641
27-Jan-94	0.305	0.351	1.150819672	1.228359481
12-Feb-94	0.306	0.391	1.277777778	1.174081615
9-Mar-94	0.533	0.585	1.097560976	1.246668929
10-Apr-94	0.296	0.394	1.331081081	1.142293362
26-Apr-94	0.296	0.398	1.344594595	1.274444765
28-May-94	0.282	0.387	1.372340426	1.323549646

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
13-Jun-94	0.294	0.399	1.357142857	1.357703192
29-Jun-94	0.334	0.404	1.209580838	1.357310957
15-Jul-94	0.357	0.41	1.148459384	1.253899874
16-Aug-94	0.348	0.441	1.267241379	1.180091531
1-Sep-94	0.341	0.445	1.304985337	1.241096425
3-Oct-94	0.289	0.416	1.439446367	1.285818664
11-Nov-94	0.291	0.397	1.364261168	1.393358056
20-Nov-94	0.311	0.397	1.276527331	1.372990235
27-Nov-94	0.31	0.394	1.270967742	1.305466202
7-Jan-95	0.37	0.426	1.151351351	1.28131728
15-Feb-95	0.312	0.358	1.147435897	1.19034113
24-Feb-95	0.32	0.395	1.234375	1.160307467
12-Mar-95	0.325	0.399	1.227692308	1.21215474
13-Apr-95	0.316	0.395	1.25	1.223031037
15-May-95	0.294	0.398	1.353741497	1.241909311
31-May-95	0.264	0.361	1.367424242	1.320191841
16-Jun-95	0.306	0.404	1.320261438	1.353254522
2-Jul-95	0.296	0.397	1.341216216	1.330159363
18-Jul-95	0.332	0.409	1.231927711	1.33789916
3-Aug-95	0.422	0.429	1.016587678	1.263719146
6-Oct-95	0.267	0.395	1.479400749	1.090727118
22-Oct-95	0.257	0.387	1.505836576	1.36279866
7-Nov-95	0.275	0.394	1.432727273	1.462925201
23-Nov-95	0.279	0.384	1.376344086	1.441786651
9-Dec-95	0.276	0.366	1.326086957	1.395976856
16-Dec-95	0.278	0.37	1.330935252	1.347053926
25-Dec-95	0.281	0.391	1.391459075	1.335770854
1-Jan-96	0.288	0.371	1.288194444	1.374752609
10-Jan-96	0.274	0.39	1.423357664	1.314161894
17-Jan-96	0.264	0.324	1.227272727	1.390598933
2-Feb-96	0.258	0.366	1.418604651	1.276270589
11-Feb-96	0.272	0.334	1.227941176	1.375904433
18-Feb-96	0.273	0.358	1.311355311	1.272330153
27-Feb-96	0.403	0.486	1.205955335	1.299647764
5-Mar-96	0.413	0.462	1.118644068	1.234063064
21-Mar-96	0.273	0.34	1.245421245	1.153269767
30-Mar-96	0.264	0.382	1.446969697	1.217775802
6-Apr-96	0.288	0.342	1.1875	1.378211528
15-Apr-96	0.298	0.398	1.33557047	1.244713459
22-Apr-96	0.305	0.362	1.186885246	1.308313366

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
1-May-96	0.284	0.378	1.330985915	1.223313682
8-May-96	0.536	0.454	0.847014925	1.298684245
17-May-96	0.259	0.382	1.474903475	0.982515721
9-Jun-96	0.355	0.394	1.109859155	1.327187149
18-Jun-96	0.355	0.402	1.132394366	1.175057553
25-Jun-96	0.329	0.381	1.158054711	1.145193322
4-Jul-96	0.32	0.394	1.23125	1.154196295
11-Jul-96	0.339	0.384	1.132743363	1.208133888
20-Jul-96	0.313	0.414	1.322683706	1.15536052
27-Jul-96	0.341	0.41	1.202346041	1.27248675
5-Aug-96	0.34	0.421	1.238235294	1.223388254
12-Aug-96	0.365	0.411	1.126027397	1.233781182
21-Aug-96	0.332	0.419	1.262048193	1.158353533
28-Aug-96	0.325	0.398	1.224615385	1.230939795
6-Sep-96	0.341	0.427	1.252199413	1.226512708
22-Sep-96	0.299	0.406	1.357859532	1.244493402
29-Sep-96	0.297	0.402	1.353535354	1.323849693
8-Oct-96	0.294	0.401	1.363945578	1.344629655
15-Oct-96	0.292	0.391	1.339041096	1.358150801
24-Oct-96	0.292	0.392	1.342465753	1.344774008
31-Oct-96	0.299	0.395	1.321070234	1.34315823
9-Nov-96	0.297	0.394	1.326599327	1.327696633
16-Nov-96	0.314	0.409	1.302547771	1.326928518
2-Dec-96	0.502	0.423	0.842629482	1.309861995
11-Dec-96	0.266	0.369	1.387218045	0.982799236
18-Dec-96	0.279	0.34	1.218637993	1.265892402
27-Dec-96	0.275	0.379	1.378181818	1.232814316
12-Jan-97	0.296	0.386	1.304054054	1.334571567
28-Jan-97	0.368	0.415	1.127717391	1.313209308
4-Feb-97	0.257	0.342	1.3307393	1.183364966
13-Feb-97	0.284	0.399	1.404929577	1.286527
24-Mar-97	0.299	0.391	1.307692308	1.369408804
9-Apr-97	0.301	0.372	1.235880399	1.326207257
25-Apr-97	0.312	0.389	1.246794872	1.262978456
20-May-97	0.256	0.39	1.5234375	1.251649947
27-May-97	0.332	0.387	1.165662651	1.441901234
5-Jun-97	0.283	0.376	1.328621908	1.248534226
12-Jun-97	0.335	0.392	1.170149254	1.304595603
21-Jun-97	0.345	0.414	1.2	1.210483159
28-Jun-97	0.359	0.401	1.116991643	1.203144948

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
7-Jul-97	0.327	0.408	1.247706422	1.142837635
14-Jul-97	0.401	0.445	1.109725686	1.216245786
23-Jul-97	0.355	0.409	1.152112676	1.141681716
8-Aug-97	0.349	0.406	1.163323782	1.148983388
15-Aug-97	0.335	0.442	1.319402985	1.159021664
24-Aug-97	0.33	0.393	1.190909091	1.271288589
31-Aug-97	0.321	0.386	1.202492212	1.21502294
9-Sep-97	0.378	0.473	1.251322751	1.20625143
16-Sep-97	0.356	0.404	1.134831461	1.237801355
25-Sep-97	0.298	0.395	1.325503356	1.165722429
2-Oct-97	0.297	0.389	1.30976431	1.277569078
11-Oct-97	0.29	0.399	1.375862069	1.30010574
27-Oct-97	0.503	0.498	0.990059642	1.35313517
19-Nov-97	0.272	0.388	1.426470588	1.098982301
28-Nov-97	0.248	0.331	1.334677419	1.328224102
5-Dec-97	0.249	0.352	1.413654618	1.332741424
21-Dec-97	0.241	0.359	1.489626556	1.38938066
22-Jan-98	0.354	0.424	1.197740113	1.459552787
7-Feb-98	0.269	0.356	1.323420074	1.276283915
4-Mar-98	0.596	0.439	0.736577181	1.309279227
5-Apr-98	0.371	0.442	1.191374663	0.908387795
12-Apr-98	0.317	0.369	1.164037855	1.106478603
21-Apr-98	0.296	0.386	1.304054054	1.146770079
28-Apr-98	0.343	0.377	1.099125364	1.256868862
7-May-98	0.528	0.454	0.859848485	1.146448414
14-May-98	0.317	0.378	1.192429022	0.945828463
23-May-98	0.297	0.392	1.31986532	1.118448854
30-May-98	0.33	0.385	1.166666667	1.25944038
8-Jun-98	0.342	0.448	1.30994152	1.194498781
15-Jun-98	0.337	0.383	1.136498516	1.275308699
1-Jul-98	0.361	0.387	1.072022161	1.178141571
10-Jul-98	0.355	0.401	1.129577465	1.103857984
17-Jul-98	0.361	0.39	1.08033241	1.12186162
26-Jul-98	0.342	0.405	1.184210526	1.092791173
2-Aug-98	0.357	0.393	1.100840336	1.15678472
11-Aug-98	0.32	0.393	1.228125	1.117623651
18-Aug-98	0.334	0.378	1.131736527	1.194974595
27-Aug-98	0.311	0.388	1.247588424	1.150707947
3-Sep-98	0.376	0.36	0.957446809	1.218524281
12-Sep-98	0.318	0.396	1.245283019	1.03577005

Date	Location M	Location C	C/M	C/M*
19-Sep-98	0.285	0.376	1.319298246	1.182429128
28-Sep-98	0.278	0.38	1.366906475	1.27823751
5-Oct-98	0.333	0.396	1.189189189	1.340305786
14-Oct-98	0.278	0.386	1.388489209	1.234524168
21-Oct-98	0.267	0.376	1.4082397	1.342299696
30-Oct-98	0.266	0.392	1.473684211	1.388457699
6-Nov-98	0.309	0.381	1.233009709	1.448116257
15-Nov-98	0.258	0.386	1.496124031	1.297541673
22-Nov-98	0.253	0.382	1.509881423	1.436549324
1-Dec-98	0.281	0.387	1.377224199	1.487881793
8-Dec-98	0.261	0.393	1.505747126	1.410421477
17-Dec-98	0.277	0.398	1.436823105	1.477149432
24-Dec-98	0.285	0.393	1.378947368	1.448921003
18-Jan-99	0.255	0.373	1.462745098	1.399939459
25-Jan-99	0.258	0.329	1.275193798	1.443903406
3-Feb-99	0.248	0.347	1.399193548	1.325806681
19-Feb-99	0.318	0.362	1.13836478	1.377177488
23-Mar-99	0.269	0.394	1.464684015	1.210008592
30-Mar-99	0.327	0.417	1.275229358	1.388281388
8-Apr-99	0.268	0.395	1.473880597	1.309144967
15-Apr-99	0.317	0.375	1.1829653	1.424459908
24-Apr-99	0.271	0.389	1.435424354	1.255413682
10-May-99	0.276	0.396	1.434782609	1.381421153
26-May-99	0.296	0.398	1.344594595	1.418774172
2-Jun-99	0.331	0.389	1.175226586	1.366848468
18-Jun-99	0.383	0.415	1.083550914	1.232713151
14-Aug-99	0.329	0.449	1.364741641	1.128299585
30-Aug-99	0.328	0.416	1.268292683	1.293809024
6-Sep-99	0.336	0.417	1.241071429	1.275947585
22-Sep-99	0.35	0.439	1.254285714	1.251534276
17-Oct-99	0.297	0.45	1.515151515	1.253460283
25-Nov-99	0.247	0.378	1.530364372	1.436644145
4-Dec-99	0.26	0.39	1.5	1.502248304
11-Dec-99	0.258	0.364	1.410852713	1.500674491
20-Dec-99	0.252	0.404	1.603174603	1.437799247
21-Jan-00	0.335	0.436	1.301492537	1.553561996
5-Feb-00	0.267	0.374	1.400749064	1.377113375
6-Feb-00	0.281	0.38	1.352313167	1.393658357
14-Feb-00	0.261	0.38	1.455938697	1.364716724
22-Feb-00	0.266	0.398	1.496240602	1.428572105

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
1-Mar-00	0.27	0.393	1.455555556	1.475940053
8-Mar-00	0.275	0.38	1.381818182	1.461670905
9-Mar-00	0.263	0.391	1.486692015	1.405773999
16-Mar-00	0.297	0.393	1.323232323	1.46241661
17-Mar-00	0.27	0.392	1.451851852	1.364987609
25-Mar-00	0.584	0.605	1.035958904	1.425792579
9-Apr-00	0.282	0.39	1.382978723	1.152909007
10-Apr-00	0.27	0.399	1.477777778	1.313957808
17-Apr-00	0.319	0.383	1.200626959	1.428631787
18-Apr-00	0.274	0.394	1.437956204	1.269028408
11-May-00	0.351	0.386	1.0997151	1.387277865
12-May-00	0.342	0.399	1.166666667	1.185983929
20-May-00	0.286	0.406	1.41958042	1.172461845
27-May-00	0.351	0.4	1.13960114	1.345444847
28-May-00	0.311	0.412	1.324758842	1.201354252
4-Jun-00	0.323	0.389	1.204334365	1.287737465
13-Jun-00	0.308	0.407	1.321428571	1.229355295
20-Jun-00	0.382	0.416	1.089005236	1.293806589
21-Jun-00	0.319	0.406	1.272727273	1.150445641
29-Jun-00	0.413	0.435	1.053268765	1.236042783
6-Jul-00	0.371	0.405	1.091644205	1.108100971
30-Jul-00	0.393	0.414	1.053435115	1.096581235
7-Aug-00	0.387	0.45	1.162790698	1.066378951
16-Aug-00	0.358	0.413	1.153631285	1.133867174
23-Aug-00	0.336	0.392	1.166666667	1.147702052
24-Aug-00	0.322	0.393	1.220496894	1.160977282
1-Sep-00	0.345	0.414	1.2	1.202641011
17-Sep-00	0.314	0.398	1.267515924	1.200792303
24-Sep-00	0.334	0.428	1.281437126	1.247498837
10-Oct-00	0.302	0.446	1.476821192	1.271255639
11-Oct-00	0.291	0.437	1.501718213	1.415151526
18-Oct-00	0.274	0.425	1.551094891	1.475748207
19-Oct-00	0.28	0.43	1.535714286	1.528490885
26-Oct-00	0.251	0.455	1.812749004	1.533547266
19-Nov-00	0.255	0.424	1.662745098	1.728988482
20-Nov-00	0.267	0.438	1.640449438	1.682618113
27-Nov-00	0.291	0.413	1.419243986	1.653100041
28-Nov-00	0.277	0.423	1.527075812	1.489400803
13-Dec-00	0.251	0.419	1.669322709	1.515773309
22-Dec-00	0.26	0.408	1.569230769	1.623257889

Date	Location M	Location C	C/M	C/M*
30-Dec-00	0.247	0.384	1.55465587	1.585438905
7-Jan-01	0.301	0.408	1.355481728	1.563890781
15-Jan-01	0.254	0.408	1.606299213	1.418004444
23-Jan-01	0.253	0.413	1.632411067	1.549810782
8-Feb-01	0.251	0.414	1.64940239	1.607630982
15-Feb-01	0.263	0.403	1.532319392	1.636870968
24-Feb-01	0.277	0.404	1.458483755	1.563684864
4-Mar-01	0.272	0.42	1.544117647	1.490044088
11-Mar-01	0.323	0.428	1.325077399	1.527895579
12-Apr-01	0.331	0.413	1.247734139	1.385922853
20-Apr-01	0.306	0.35	1.14379085	1.289190753
21-Apr-01	0.284	0.402	1.415492958	1.187410821
6-May-01	0.304	0.434	1.427631579	1.347068317
15-May-01	0.306	0.435	1.421568627	1.4034626
22-May-01	0.336	0.407	1.211309524	1.416136819
23-May-01	0.3	0.421	1.403333333	1.272757712
31-May-01	0.33	0.433	1.312121212	1.364160647
16-Jun-01	0.336	0.42	1.25	1.327733043
2-Jul-01	0.364	0.434	1.192307692	1.273319913
18-Jul-01	0.346	0.423	1.222543353	1.216611358
3-Aug-01	0.375	0.445	1.186666667	1.220763754
11-Aug-01	0.357	0.432	1.210084034	1.196895793
19-Aug-01	0.351	0.471	1.341880342	1.206127561
27-Aug-01	0.344	0.457	1.328488372	1.301154508
4-Sep-01	0.402	0.478	1.189054726	1.320288213
27-Sep-01	0.303	0.446	1.471947195	1.228424772
28-Sep-01	0.273	0.453	1.659340659	1.398890468
6-Oct-01	0.303	0.448	1.478547855	1.581205602
22-Oct-01	0.33	0.444	1.345454545	1.509345179
29-Oct-01	0.338	0.425	1.25739645	1.394621735
6-Nov-01	0.274	0.409	1.49270073	1.298564035
7-Nov-01	0.275	0.427	1.552727273	1.434459722
14-Nov-01	0.248	0.424	1.709677419	1.517247007
23-Nov-01	0.246	0.444	1.804878049	1.651948296
9-Dec-01	0.244	0.438	1.795081967	1.758999123
25-Dec-01	0.303	0.459	1.514851485	1.784257114
2-Jan-02	0.257	0.417	1.622568093	1.595673174
18-Jan-02	0.258	0.411	1.593023256	1.614499618
26-Jan-02	0.253	0.422	1.66798419	1.599466164
10-Feb-02	0.268	0.338	1.26119403	1.647428782

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
11-Feb-02	0.252	0.355	1.408730159	1.377064456
27-Feb-02	0.256	0.344	1.34375	1.399230448
15-Mar-02	0.251	0.415	1.653386454	1.360394134
23-Mar-02	0.408	0.491	1.203431373	1.565488758
8-Apr-02	0.377	0.467	1.23872679	1.312048588
24-Apr-02	0.443	0.627	1.415349887	1.26072333
18-May-02	0.342	0.447	1.307017544	1.36896192
11-Jun-02	0.327	0.425	1.29969419	1.325600857
19-Jun-02	0.354	0.409	1.155367232	1.30746619
21-Jul-02	0.375	0.487	1.298666667	1.200996919
6-Aug-02	0.35	0.47	1.342857143	1.269365742
30-Aug-02	0.367	0.465	1.267029973	1.320809723
15-Sep-02	0.292	0.44	1.506849315	1.283163898
25-Nov-02	0.247	0.4	1.619433198	1.43974369
27-Dec-02	0.252	0.337	1.337301587	1.565526346
5-Jan-03	0.247	0.387	1.566801619	1.405769015
12-Jan-03	0.251	0.381	1.517928287	1.518491838
28-Jan-03	0.254	0.383	1.507874016	1.518097352
22-Feb-03	0.263	0.35	1.330798479	1.510941017
10-Mar-03	0.249	0.339	1.361445783	1.38484124
17-Mar-03	0.317	0.276	0.870662461	1.36846442
27-Apr-03	0.315	0.403	1.279365079	1.020003048
4-May-03	0.311	0.416	1.337620579	1.20155647
13-May-03	0.295	0.371	1.257627119	1.296801346
20-May-03	0.324	0.402	1.240740741	1.269379387
29-May-03	0.34	0.428	1.258823529	1.249332335
1-Aug-03	0.408	0.617	1.512254902	1.255976171
17-Aug-03	0.538	0.553	1.027881041	1.435371283
24-Aug-03	0.336	0.412	1.226190476	1.150128113
2-Sep-03	0.314	0.411	1.308917197	1.203371767
18-Sep-03	0.354	0.459	1.296610169	1.277253568
28-Nov-03	0.243	0.417	1.716049383	1.290803189
24-Jan-04	0.264	0.323	1.223484848	1.588475525
3-Mar-04	0.274	0.398	1.452554745	1.332982051
12-Mar-04	0.288	0.412	1.430555556	1.416682937
13-Apr-04	0.285	0.413	1.449122807	1.42639377
16-Jun-04	0.358	0.424	1.184357542	1.442304096
23-Jun-04	0.354	0.42	1.186440678	1.261741508
2-Jul-04	0.352	0.431	1.224431818	1.209030927
25-Jul-04	0.359	0.418	1.164345404	1.219811551

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
20-Sep-04	0.321	0.396	1.23364486	1.180985248
7-Nov-04	0.26	0.393	1.511538462	1.217846976
9-Dec-04	0.247	0.385	1.558704453	1.423431016
10-Jan-05	0.247	0.36	1.457489879	1.518122422
22-Mar-05	0.313	0.831	2.654952077	1.475679642
2-May-05	0.369	0.41	1.111111111	2.301170346
9-May-05	0.342	0.346	1.011695906	1.468128882
3-Jun-05	0.281	0.397	1.412811388	1.148625799
5-Jul-05	0.31	0.413	1.332258065	1.333555711
12-Jul-05	0.38	0.436	1.147368421	1.332647359
6-Aug-05	0.315	0.427	1.355555556	1.202952102
13-Aug-05	0.347	0.347	1	1.30977452
22-Aug-05	0.332	0.409	1.231927711	1.092932356
29-Aug-05	0.361	0.408	1.130193906	1.190229104
23-Sep-05	0.296	0.405	1.368243243	1.148204465
9-Oct-05	0.29	0.401	1.382758621	1.30223161
12-Dec-05	0.247	0.378	1.530364372	1.358600517
28-Dec-05	0.269	0.38	1.412639405	1.478835216
5-May-06	0.292	0.406	1.390410959	1.432498148
21-May-06	0.315	0.444	1.40952381	1.403037116
6-Jun-06	0.297	0.435	1.464646465	1.407577801
29-Jun-06	0.371	0.416	1.121293801	1.447525866
8-Jul-06	0.334	0.41	1.22754491	1.21916342
15-Jul-06	0.356	0.402	1.129213483	1.225030463
31-Jul-06	0.343	0.398	1.160349854	1.157958577
10-Sep-06	0.318	0.384	1.20754717	1.159632471
19-Oct-06	0.276	0.372	1.347826087	1.19317276
22-Dec-06	0.249	0.325	1.305220884	1.301430089
1-Feb-07	0.263	0.375	1.425855513	1.304083645
8-Feb-07	0.266	0.374	1.406015038	1.389323953
5-Mar-07	0.255	0.343	1.345098039	1.401007712
22-Apr-07	0.325	0.408	1.255384615	1.361870941
9-Jun-07	0.28	0.406	1.45	1.287330513
18-Jul-07	0.359	0.39	1.086350975	1.401199154
19-Aug-07	0.368	0.402	1.092391304	1.180805429
28-Aug-07	0.323	0.401	1.241486068	1.118915542
4-Sep-07	0.33	0.402	1.218181818	1.20471491
13-Sep-07	0.324	0.404	1.24691358	1.214141746
23-Nov-07	0.272	0.398	1.463235294	1.23708203
19-Jan-08	0.261	0.347	1.329501916	1.395389315

Date	Location M	Location C	C/M	C/M*
11-Feb-08	0.251	0.361	1.438247012	1.349268135
16-Apr-08	0.34	0.347	1.020588235	1.411553349
23-Apr-08	0.313	0.386	1.233226837	1.137877769
17-May-08	0.336	0.396	1.178571429	1.204622117
18-May-08	0.316	0.418	1.32278481	1.186386635
25-May-08	0.397	0.397	1	1.281865358
26-May-08	0.344	0.4	1.162790698	1.084559607
3-Jun-08	0.33	0.404	1.224242424	1.139321371
10-Jun-08	0.365	0.391	1.071232877	1.198766108
19-Jun-08	0.346	0.411	1.187861272	1.109492846
26-Jun-08	0.377	0.403	1.068965517	1.164350744
27-Jun-08	0.355	0.413	1.163380282	1.097581085
5-Jul-08	0.375	0.42	1.12	1.143640523
13-Jul-08	0.341	0.396	1.161290323	1.127092157
29-Jul-08	0.345	0.412	1.194202899	1.151030873
13-Aug-08	0.377	0.425	1.127320955	1.181251291
30-Aug-08	0.331	0.427	1.290030211	1.143500056
15-Sep-08	0.306	0.42	1.37254902	1.246071165
9-Oct-08	0.348	0.386	1.109195402	1.334605663
17-Oct-08	0.264	0.387	1.465909091	1.176818481
25-Oct-08	0.283	0.396	1.399293286	1.379181908
2-Nov-08	0.274	0.383	1.397810219	1.393259873
17-Nov-08	0.415	0.395	0.951807229	1.396445115
18-Nov-08	0.279	0.377	1.35125448	1.085198595
26-Nov-08	0.257	0.366	1.424124514	1.271437715
4-Dec-08	0.261	0.369	1.413793103	1.378318474
12-Dec-08	0.243	0.375	1.543209877	1.403150715
19-Dec-08	0.317	0.389	1.227129338	1.501192128
20-Jan-09	0.259	0.325	1.254826255	1.309348175
21-Jan-09	0.273	0.354	1.296703297	1.271182831
6-Feb-09	0.245	0.329	1.342857143	1.289047157
14-Feb-09	0.523	0.418	0.799235182	1.326714147
21-Feb-09	0.275	0.368	1.338181818	0.957478871
2-Mar-09	0.307	0.365	1.188925081	1.223970934
9-Mar-09	0.323	0.331	1.024767802	1.199438837
25-Mar-09	0.304	0.334	1.098684211	1.077169112
3-Apr-09	0.301	0.378	1.255813953	1.092229681
10-Apr-09	0.46	0.464	1.008695652	1.206738672
18-Apr-09	0.338	0.41	1.213017751	1.068108558
19-Apr-09	0.328	0.442	1.347560976	1.169544993

Date	Location M	Location C	C/M	C/M*
26-Apr-09	0.388	0.444	1.144329897	1.294156181
12-May-09	0.332	0.4	1.204819277	1.189277782
13-May-09	0.281	0.404	1.43772242	1.200156829
21-May-09	0.325	0.409	1.258461538	1.366452743
28-May-09	0.328	0.409	1.24695122	1.2908589
6-Jun-09	0.311	0.38	1.221864952	1.260123524
13-Jun-09	0.33	0.42	1.272727273	1.233342523
22-Jun-09	0.275	0.428	1.556363636	1.260911848
29-Jun-09	0.364	0.423	1.162087912	1.4677281
8-Jul-09	0.35	0.457	1.305714286	1.253779968
15-Jul-09	0.353	0.433	1.226628895	1.290133991
24-Jul-09	0.316	0.441	1.39556962	1.245680424
31-Jul-09	0.343	0.409	1.192419825	1.350602861
1-Aug-09	0.323	0.426	1.318885449	1.239874736
9-Aug-09	0.356	0.437	1.22752809	1.295182235
16-Aug-09	0.351	0.427	1.216524217	1.247824333
17-Aug-09	0.345	0.442	1.28115942	1.225914252
25-Aug-09	0.327	0.43	1.314984709	1.26458587
1-Sep-09	0.348	0.395	1.135057471	1.299865058
10-Sep-09	0.288	0.426	1.479166667	1.184499747
17-Sep-09	0.287	0.409	1.425087108	1.390766591
26-Sep-09	0.323	0.422	1.306501548	1.414790953
3-Oct-09	0.313	0.453	1.447284345	1.338988369
4-Oct-09	0.376	0.355	0.944148936	1.414795552
11-Oct-09	0.28	0.438	1.564285714	1.085342921
12-Oct-09	0.278	0.445	1.600719424	1.420602876
19-Oct-09	0.281	0.442	1.572953737	1.54668446
4-Nov-09	0.466	0.548	1.175965665	1.565072954
13-Nov-09	0.24	0.402	1.675	1.292697852
20-Nov-09	0.248	0.396	1.596774194	1.560309356
29-Nov-09	0.244	0.394	1.614754098	1.585834742
6-Dec-09	0.251	0.393	1.565737052	1.606078291
7-Dec-09	0.271	0.398	1.468634686	1.577839424
15-Dec-09	0.246	0.397	1.613821138	1.501396108
8-Jan-10	0.268	0.401	1.496268657	1.580093629
16-Jan-10	0.454	0.531	1.169603524	1.521416148
23-Jan-10	0.265	0.395	1.490566038	1.275147311
9-Feb-10	0.247	0.336	1.360323887	1.42594042
24-Feb-10	0.351	0.46	1.310541311	1.380008847
5-Mar-10	0.269	0.383	1.423791822	1.331381571

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
12-Mar-10	0.304	0.404	1.328947368	1.396068747
13-Mar-10	0.287	0.397	1.383275261	1.349083782
20-Mar-10	0.336	0.419	1.24702381	1.373017817
6-Apr-10	0.262	0.385	1.469465649	1.284822012
14-Apr-10	0.301	0.391	1.299003322	1.414072558
21-Apr-10	0.362	0.348	0.961325967	1.333524093
29-Apr-10	0.307	0.384	1.250814332	1.072985405
16-May-10	0.312	0.427	1.368589744	1.197465654
24-May-10	0.303	0.429	1.415841584	1.317252517
8-Jun-10	0.331	0.401	1.211480363	1.386264864
9-Jun-10	0.307	0.418	1.361563518	1.263915713
16-Jun-10	0.367	0.415	1.130790191	1.332269176
25-Jun-10	0.58	0.402	0.693103448	1.191233886
2-Jul-10	0.359	0.412	1.147632312	0.84254258
3-Jul-10	0.32	0.421	1.315625	1.056105392
10-Jul-10	0.342	0.414	1.210526316	1.237769118
11-Jul-10	0.315	0.419	1.33015873	1.218699156
18-Jul-10	0.367	0.407	1.108991826	1.296720858
19-Jul-10	0.342	0.425	1.242690058	1.165310535
12-Aug-10	0.347	0.422	1.216138329	1.219476202
19-Aug-10	0.361	0.415	1.149584488	1.21713969
20-Aug-10	0.345	0.426	1.234782609	1.169851048
27-Aug-10	0.357	0.401	1.1232493	1.215303141
28-Aug-10	0.348	0.416	1.195402299	1.150865452
4-Sep-10	0.349	0.407	1.166189112	1.182041245
12-Sep-10	0.326	0.382	1.171779141	1.170944752
13-Sep-10	0.328	0.402	1.225609756	1.171528824
29-Sep-10	0.329	0.454	1.37993921	1.209385477
6-Oct-10	0.275	0.428	1.556363636	1.32877309
14-Oct-10	0.286	0.431	1.506993007	1.488086472
15-Oct-10	0.293	0.437	1.491467577	1.501321047
22-Oct-10	0.315	0.448	1.422222222	1.494423618
31-Oct-10	0.259	0.441	1.702702703	1.443882641
7-Nov-10	0.33	0.421	1.275757576	1.625056684
16-Nov-10	0.245	0.42	1.714285714	1.380547308
23-Nov-10	0.264	0.405	1.534090909	1.614164192
24-Nov-10	0.246	0.421	1.711382114	1.558112894
2-Dec-10	0.246	0.415	1.68699187	1.665401348
9-Dec-10	0.248	0.411	1.657258065	1.680514713
18-Dec-10	0.26	0.42	1.615384615	1.664235059

Date	Location M	Location C	C/M	C/M*
25-Dec-10	0.261	0.416	1.593869732	1.630039749
3-Jan-11	0.253	0.396	1.565217391	1.604720737
10-Jan-11	0.247	0.385	1.558704453	1.577068395
19-Jan-11	0.248	0.373	1.504032258	1.564213636
26-Jan-11	0.259	0.375	1.447876448	1.522086671
27-Feb-11	0.245	0.384	1.567346939	1.470139515
8-Mar-11	0.24	0.386	1.608333333	1.538184712
23-Mar-11	0.273	0.392	1.435897436	1.587288747
24-Mar-11	0.262	0.409	1.561068702	1.481314829
31-Mar-11	0.282	0.391	1.386524823	1.53714254
1-Apr-11	0.268	0.43	1.604477612	1.431710138
16-Apr-11	0.39	0.434	1.112820513	1.55264737
24-Apr-11	0.281	0.394	1.402135231	1.24476857
25-Apr-11	0.288	0.408	1.416666667	1.354925233
2-May-11	0.317	0.397	1.252365931	1.398144237
3-May-11	0.298	0.401	1.345637584	1.296099422
11-May-11	0.292	0.41	1.404109589	1.330776135
18-May-11	0.355	0.413	1.163380282	1.382109553
19-May-11	0.339	0.423	1.247787611	1.228999063
26-May-11	0.422	0.45	1.066350711	1.242151046
27-May-11	0.318	0.414	1.301886792	1.119090812
3-Jun-11	0.34	0.401	1.179411765	1.247047998
11-Jun-11	0.377	0.405	1.074270557	1.199702635
12-Jun-11	0.339	0.417	1.230088496	1.11190018
28-Jun-11	0.395	0.455	1.151898734	1.194632001
5-Jul-11	0.36	0.424	1.177777778	1.164718714
6-Jul-11	0.356	0.436	1.224719101	1.173860059
14-Jul-11	0.409	0.473	1.156479218	1.209461388
21-Jul-11	0.37	0.407	1.1	1.172373869
22-Jul-11	0.335	0.414	1.235820896	1.121712161
30-Jul-11	0.387	0.398	1.028423773	1.201588275
15-Aug-11	0.349	0.403	1.154727794	1.080373123
22-Aug-11	0.35	0.404	1.154285714	1.132421393
7-Sep-11	0.331	0.392	1.18429003	1.147726418
15-Sep-11	0.546	0.761	1.393772894	1.173320946
16-Sep-11	0.389	0.464	1.192802057	1.32763731
2-Oct-11	0.261	0.425	1.62835249	1.233252632
17-Oct-11	0.256	0.437	1.70703125	1.509822533
2-Nov-11	0.349	0.335	0.959885387	1.647868635
11-Nov-11	0.236	0.362	1.533898305	1.166280361

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
18-Nov-11	0.242	0.378	1.561983471	1.423612922
13-Dec-11	0.233	0.407	1.746781116	1.520472306
20-Dec-11	0.584	0.592	1.01369863	1.678888473
15-Feb-12	0.297	0.372	1.252525253	1.213255583
9-Mar-12	0.298	0.403	1.352348993	1.240744352
5-May-12	0.287	0.43	1.49825784	1.318867601
13-Jun-12	0.34	0.393	1.155882353	1.444440768
22-Jun-12	0.326	0.419	1.285276074	1.242449877
29-Jun-12	0.348	0.402	1.155172414	1.272428215
15-Jul-12	0.366	0.407	1.112021858	1.190349154
24-Jul-12	0.345	0.429	1.243478261	1.135520047
26-Sep-12	0.339	0.47	1.386430678	1.211090797
12-Oct-12	0.258	0.411	1.593023256	1.333828714
28-Oct-12	0.257	0.403	1.568093385	1.515264893
13-Nov-12	0.287	0.391	1.362369338	1.552244838
29-Nov-12	0.243	0.358	1.473251029	1.419331988
22-Dec-12	0.231	0.364	1.575757576	1.457075317
31-Dec-12	0.238	0.334	1.403361345	1.540152898
16-Jan-13	0.289	0.384	1.328719723	1.444398811
8-Feb-13	0.264	0.346	1.310606061	1.363423449
17-Feb-13	0.242	0.373	1.541322314	1.326451277
5-Mar-13	0.286	0.376	1.314685315	1.476861003
21-Mar-13	0.269	0.315	1.171003717	1.363338021
7-Apr-13	0.334	0.464	1.389221557	1.228704009
14-Apr-13	0.291	0.412	1.41580756	1.341066292
21-Apr-13	0.323	0.392	1.213622291	1.39338518
30-Apr-13	0.336	0.373	1.110119048	1.267551158
8-May-13	0.291	0.437	1.501718213	1.157348681
16-May-13	0.285	0.43	1.50877193	1.398407353
23-May-13	0.356	0.407	1.143258427	1.475662557
24-May-13	0.324	0.411	1.268518519	1.242979666
31-May-13	0.337	0.399	1.183976261	1.260856863
1-Jun-13	0.287	0.414	1.442508711	1.207040442
8-Jun-13	0.365	0.402	1.101369863	1.37186823
16-Jun-13	0.366	0.4	1.092896175	1.182519373
17-Jun-13	0.324	0.414	1.277777778	1.119783134
24-Jun-13	0.371	0.405	1.091644205	1.230379385
3-Jul-13	0.309	0.439	1.420711974	1.133264759
10-Jul-13	0.369	0.442	1.197831978	1.33447781
19-Jul-13	0.34	0.445	1.308823529	1.238825728

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
26-Jul-13	0.37	0.431	1.164864865	1.287824189
27-Jul-13	0.364	0.435	1.195054945	1.201752662
4-Aug-13	0.416	0.399	0.959134615	1.19706426
11-Aug-13	0.37	0.41	1.108108108	1.030513509
19-Aug-13	0.359	0.393	1.094707521	1.084829728
20-Aug-13	0.332	0.358	1.078313253	1.091744183
27-Aug-13	0.348	0.405	1.163793103	1.082342532
4-Sep-13	0.347	0.394	1.135446686	1.139357932
5-Sep-13	0.316	0.405	1.28164557	1.13662006
12-Sep-13	0.352	0.409	1.161931818	1.238137917
28-Sep-13	0.348	0.407	1.16954023	1.184793648
29-Sep-13	0.351	0.409	1.165242165	1.174116255
7-Oct-13	0.303	0.401	1.323432343	1.167904392
14-Oct-13	0.341	0.332	0.973607038	1.276773958
23-Oct-13	0.285	0.399	1.4	1.064557114
8-Nov-13	0.261	0.329	1.260536398	1.299367134
15-Nov-13	0.22	0.356	1.618181818	1.272185619
24-Nov-13	0.215	0.37	1.720930233	1.514382958
1-Dec-13	0.218	0.371	1.701834862	1.65896605
10-Dec-13	0.23	0.377	1.639130435	1.688974219
17-Dec-13	0.243	0.364	1.497942387	1.65408357
26-Dec-13	0.215	0.379	1.762790698	1.544784742
2-Jan-14	0.225	0.376	1.671111111	1.697388911
10-Jan-14	0.254	0.365	1.437007874	1.678994451
11-Jan-14	0.21	0.368	1.752380952	1.509603847
18-Jan-14	0.221	0.368	1.665158371	1.679547821
27-Jan-14	0.23	0.388	1.686956522	1.669475206
11-Feb-14	0.244	0.373	1.528688525	1.681712127
12-Feb-14	0.229	0.378	1.650655022	1.574595605
20-Feb-14	0.292	0.417	1.428082192	1.627837197
27-Feb-14	0.267	0.369	1.382022472	1.488008693
28-Feb-14	0.24	0.373	1.554166667	1.413818338
7-Mar-14	0.264	0.368	1.393939394	1.512062168
8-Mar-14	0.312	0.405	1.298076923	1.429376226
16-Mar-14	0.272	0.356	1.308823529	1.337466714
1-Apr-14	0.258	0.376	1.457364341	1.317416485
8-Apr-14	0.34	0.344	1.011764706	1.415379984
9-Apr-14	0.327	0.394	1.204892966	1.132849289
17-Apr-14	0.3	0.433	1.443333333	1.183279863
24-Apr-14	0.318	0.414	1.301886792	1.365317292

Date	Location M	Location C	C/M	C/M*
2-May-14	0.346	0.411	1.187861272	1.320915942
3-May-14	0.355	0.369	1.03943662	1.227777673
10-May-14	0.351	0.391	1.113960114	1.095938936
19-May-14	0.313	0.411	1.313099042	1.10855376
26-May-14	0.339	0.401	1.182890855	1.251735457
27-May-14	0.291	0.412	1.41580756	1.203544236
4-Jun-14	0.279	0.407	1.458781362	1.352128563
11-Jun-14	0.362	0.395	1.091160221	1.426785522
19-Jun-14	0.598	0.499	0.834448161	1.191847811
20-Jun-14	0.325	0.419	1.289230769	0.941668056
27-Jun-14	0.369	0.406	1.100271003	1.184961955
28-Jun-14	0.314	0.421	1.340764331	1.125678288
6-Jul-14	0.358	0.412	1.150837989	1.276238518
13-Jul-14	0.368	0.408	1.108695652	1.188458148
22-Jul-14	0.326	0.421	1.291411043	1.132624401
29-Jul-14	0.38	0.406	1.068421053	1.24377505
30-Jul-14	0.376	0.426	1.132978723	1.121027252
6-Aug-14	0.374	0.41	1.096256684	1.129393282
7-Aug-14	0.577	0.485	0.840554593	1.106197664
14-Aug-14	0.358	0.417	1.164804469	0.920247514
22-Aug-14	0.344	0.366	1.063953488	1.091437383
23-Aug-14	0.319	0.409	1.282131661	1.072198657
30-Aug-14	0.306	0.402	1.31372549	1.21915176
8-Sep-14	0.324	0.415	1.280864198	1.285353371
15-Sep-14	0.276	0.403	1.460144928	1.28221095
24-Sep-14	0.311	0.418	1.344051447	1.406764734
1-Oct-14	0.296	0.406	1.371621622	1.362865433
2-Oct-14	0.333	0.407	1.222222222	1.368994765
10-Oct-14	0.291	0.413	1.419243986	1.266253985
17-Oct-14	0.254	0.346	1.362204724	1.373346986
18-Oct-14	0.237	0.289	1.219409283	1.365547403
26-Oct-14	0.27	0.379	1.403703704	1.263250719
11-Nov-14	0.239	0.397	1.661087866	1.361567808
18-Nov-14	0.231	0.397	1.718614719	1.571231849
27-Nov-14	0.314	0.598	1.904458599	1.674399858
4-Dec-14	0.241	0.396	1.643153527	1.835440976
13-Dec-14	0.261	0.434	1.662835249	1.700839762
20-Dec-14	0.238	0.353	1.483193277	1.674236603
28-Dec-14	0.242	0.398	1.644628099	1.540506275
29-Dec-14	0.242	0.407	1.681818182	1.613391552

Date	Location M	Location C	C/M	C/M*
5-Jan-15	0.399	0.484	1.213032581	1.661290193
6-Jan-15	0.258	0.407	1.57751938	1.347509865
14-Jan-15	0.254	0.395	1.55511811	1.508516525
30-Jan-15	0.237	0.342	1.443037975	1.541137635
6-Feb-15	0.528	0.562	1.064393939	1.472467873
15-Feb-15	0.525	0.619	1.179047619	1.186816119
22-Feb-15	0.332	0.389	1.171686747	1.181378169
10-Mar-15	0.28	0.346	1.235714286	1.174594174
11-Mar-15	0.309	0.365	1.181229773	1.217378252
19-Mar-15	0.291	0.404	1.388316151	1.192074317
26-Mar-15	0.358	0.418	1.167597765	1.329443601
4-Apr-15	0.293	0.363	1.23890785	1.216151516
11-Apr-15	0.391	0.434	1.109974425	1.23208095
12-Apr-15	0.269	0.401	1.49070632	1.146606382
20-Apr-15	0.341	0.34	0.997067449	1.387476338
28-Apr-15	0.298	0.427	1.432885906	1.114190116
6-May-15	0.285	0.458	1.607017544	1.337277169
13-May-15	0.373	0.376	1.008042895	1.526095431
21-May-15	0.338	0.441	1.304733728	1.163458656
22-May-15	0.265	0.464	1.750943396	1.262351206
30-May-15	0.277	0.416	1.501805054	1.604365739
6-Jun-15	0.348	0.401	1.152298851	1.53257326
7-Jun-15	0.266	0.423	1.590225564	1.266381173
14-Jun-15	0.381	0.414	1.086614173	1.493072247
23-Jun-15	0.326	0.417	1.279141104	1.208551595
30-Jun-15	0.346	0.415	1.199421965	1.257964252
8-Jul-15	0.327	0.343	1.048929664	1.216984651
9-Jul-15	0.355	0.434	1.222535211	1.09934616
16-Jul-15	0.374	0.413	1.104278075	1.185578496
25-Jul-15	0.532	0.496	0.932330827	1.128668201
10-Aug-15	0.372	0.42	1.129032258	0.991232039
17-Aug-15	0.371	0.392	1.056603774	1.087692192
18-Aug-15	0.337	0.405	1.201780415	1.065930299
25-Aug-15	0.351	0.373	1.062678063	1.161025381
26-Aug-15	0.325	0.383	1.178461538	1.092182258
2-Sep-15	0.323	0.391	1.210526316	1.152577754
11-Sep-15	0.29	0.386	1.331034483	1.193141747
18-Sep-15	0.317	0.39	1.230283912	1.289666662
19-Sep-15	0.329	0.392	1.191489362	1.248098737
27-Sep-15	0.281	0.384	1.366548043	1.208472174

Date	Location M	Location C	C/M	C/M*
4-Oct-15	0.245	0.406	1.657142857	1.319125282
5-Oct-15	0.286	0.396	1.384615385	1.555737585
13-Oct-15	0.306	0.44	1.437908497	1.435952045
20-Oct-15	0.316	0.426	1.348101266	1.437321561
21-Oct-15	0.326	0.418	1.282208589	1.374867354
28-Oct-15	0.282	0.396	1.404255319	1.310006219
29-Oct-15	0.266	0.411	1.545112782	1.375980589
5-Nov-15	0.354	0.395	1.115819209	1.494373124
14-Nov-15	0.293	0.33	1.126279863	1.229385384
21-Nov-15	0.236	0.398	1.686440678	1.15721152
22-Nov-15	0.257	0.399	1.552529183	1.52767193
29-Nov-15	0.395	0.45	1.139240506	1.545072007
30-Nov-15	0.238	0.404	1.697478992	1.260989957
7-Dec-15	0.268	0.398	1.485074627	1.566532281
16-Dec-15	0.227	0.41	1.806167401	1.509511923
23-Dec-15	0.246	0.401	1.630081301	1.717170758
24-Dec-15	0.238	0.394	1.655462185	1.656208138
1-Jan-16	0.227	0.4	1.762114537	1.655685971
8-Jan-16	0.206	0.381	1.849514563	1.730185967
9-Jan-16	0.49	0.54	1.102040816	1.813715984
16-Jan-16	0.239	0.342	1.430962343	1.315543367
17-Jan-16	0.222	0.359	1.617117117	1.39633665
24-Jan-16	0.23	0.383	1.665217391	1.550882977
25-Jan-16	0.293	0.367	1.252559727	1.630917067
2-Feb-16	0.222	0.385	1.734234234	1.366066929
9-Feb-16	0.279	0.385	1.379928315	1.623784043
18-Feb-16	0.203	0.396	1.950738916	1.453085034
25-Feb-16	0.244	0.392	1.606557377	1.801442751
26-Feb-16	0.26	0.405	1.557692308	1.665022989
21-Mar-16	0.253	0.362	1.43083004	1.589891512
5-Apr-16	0.33	0.356	1.078787879	1.478548481
6-Apr-16	0.306	0.383	1.251633987	1.19871606
13-Apr-16	0.291	0.389	1.336769759	1.235758609
21-Apr-16	0.494	0.494	1	1.306466414
22-Apr-16	0.274	0.4	1.459854015	1.091939924
29-Apr-16	0.296	0.391	1.320945946	1.349479787
30-Apr-16	0.28	0.397	1.417857143	1.329506098
8-May-16	0.303	0.399	1.316831683	1.39135183
15-May-16	0.35	0.39	1.114285714	1.339187727
24-May-16	0.312	0.4	1.282051282	1.181756318

Date	Location M	Location C	C/M	C/M*
31-May-16	0.356	0.403	1.132022472	1.251962793
9-Jun-16	0.318	0.405	1.273584906	1.168004568
16-Jun-16	0.385	0.407	1.057142857	1.241910804
17-Jun-16	0.345	0.41	1.188405797	1.112573241
25-Jun-16	0.335	0.419	1.250746269	1.16565603
2-Jul-16	0.374	0.407	1.088235294	1.225219197
11-Jul-16	0.342	0.416	1.216374269	1.129330465
18-Jul-16	0.398	0.411	1.032663317	1.190261128
19-Jul-16	0.351	0.406	1.156695157	1.07994266
26-Jul-16	0.385	0.411	1.067532468	1.133669408
3-Aug-16	0.366	0.403	1.101092896	1.08737355
12-Aug-16	0.335	0.414	1.235820896	1.096977092
19-Aug-16	0.335	0.395	1.179104478	1.194167755
20-Aug-16	0.322	0.399	1.239130435	1.183623461
27-Aug-16	0.357	0.391	1.095238095	1.222478343
28-Aug-16	0.306	0.391	1.277777778	1.133410169
4-Sep-16	0.334	0.424	1.269461078	1.234467495
5-Sep-16	0.299	0.416	1.391304348	1.258963003
13-Sep-16	0.338	0.436	1.289940828	1.351601944
20-Sep-16	0.29	0.409	1.410344828	1.308439163
29-Sep-16	0.322	0.416	1.291925466	1.379773128
6-Oct-16	0.341	0.416	1.219941349	1.318279765
7-Oct-16	0.323	0.397	1.229102167	1.249442874
14-Oct-16	0.284	0.424	1.492957746	1.235204379
15-Oct-16	0.26	0.426	1.638461538	1.415631736
22-Oct-16	0.264	0.438	1.659090909	1.571612598
23-Oct-16	0.493	0.512	1.038539554	1.632847416
31-Oct-16	0.288	0.413	1.434027778	1.216831912
7-Nov-16	0.221	0.415	1.877828054	1.368869018
8-Nov-16	0.24	0.41	1.708333333	1.725140343
16-Nov-16	0.257	0.404	1.571984436	1.713375436
23-Nov-16	0.286	0.424	1.482517483	1.614401736
24-Nov-16	0.582	0.586	1.006872852	1.522082759
2-Dec-16	0.226	0.416	1.840707965	1.161435824
9-Dec-16	0.282	0.395	1.40070922	1.636926322
10-Dec-16	0.484	0.433	0.894628099	1.471574351
18-Dec-16	0.236	0.387	1.639830508	1.067711975
25-Dec-16	0.22	0.407	1.85	1.468194948
10-Jan-17	0.222	0.38	1.711711712	1.735458484
19-Jan-17	0.241	0.316	1.31120332	1.718835744

Date	Location M	Location C	C/M	C/M*
27-Jan-17	0.451	0.436	0.966740576	1.433493047
11-Feb-17	0.237	0.372	1.569620253	1.106766318
20-Feb-17	0.288	0.393	1.364583333	1.430764072
27-Feb-17	0.221	0.407	1.841628959	1.384437555
7-Mar-17	0.267	0.403	1.509363296	1.704471538
24-Mar-17	0.311	0.413	1.327974277	1.567895769
8-Apr-17	0.266	0.397	1.492481203	1.399950724
9-Apr-17	0.228	0.403	1.76754386	1.464722059
16-Apr-17	0.264	0.407	1.541666667	1.67669732
17-Apr-17	0.279	0.411	1.47311828	1.582175863
25-Apr-17	0.262	0.398	1.519083969	1.505835554
2-May-17	0.529	0.689	1.302457467	1.515109445
3-May-17	0.489	0.501	1.024539877	1.36625306
11-May-17	0.279	0.421	1.508960573	1.127053832
18-May-17	0.333	0.409	1.228228228	1.394388551
27-May-17	0.293	0.436	1.488054608	1.278076325
3-Jun-17	0.358	0.422	1.17877095	1.425061123
4-Jun-17	0.32	0.429	1.340625	1.252658002
12-Jun-17	0.318	0.424	1.333333333	1.3142349
19-Jun-17	0.368	0.43	1.168478261	1.327603803
28-Jun-17	0.371	0.438	1.180592992	1.216215924
5-Jul-17	0.393	0.418	1.063613232	1.191279871
14-Jul-17	0.348	0.433	1.244252874	1.101913224
21-Jul-17	0.376	0.403	1.071808511	1.201550979
22-Jul-17	0.365	0.412	1.128767123	1.110731251
29-Jul-17	0.391	0.391	1	1.123356362
30-Jul-17	0.339	0.393	1.159292035	1.037006908
6-Aug-17	0.376	0.422	1.122340426	1.122606497
15-Aug-17	0.315	0.396	1.257142857	1.122420247
22-Aug-17	0.345	0.398	1.153623188	1.216726074
31-Aug-17	0.303	0.397	1.310231023	1.172554054
7-Sep-17	0.314	0.403	1.28343949	1.268927932
8-Sep-17	0.327	0.407	1.244648318	1.279086023
16-Sep-17	0.297	0.402	1.353535354	1.25497963
23-Sep-17	0.267	0.391	1.464419476	1.323968636
24-Sep-17	0.323	0.405	1.253869969	1.422284224
2-Oct-17	0.253	0.402	1.588932806	1.304394245
9-Oct-17	0.256	0.405	1.58203125	1.503571238
10-Oct-17	0.27	0.406	1.503703704	1.558493246
17-Oct-17	0.272	0.402	1.477941176	1.520140567

Date	Location M	Location C	C/M	C/M*
18-Oct-17	0.267	0.407	1.524344569	1.490600993
25-Oct-17	0.224	0.4	1.785714286	1.514221497
3-Nov-17	0.291	0.398	1.367697595	1.704266449
10-Nov-17	0.343	0.415	1.209912536	1.468668251
11-Nov-17	0.319	0.393	1.231974922	1.287539251
18-Nov-17	0.365	0.365	1	1.24864422
19-Nov-17	0.228	0.323	1.416666667	1.074593266
26-Nov-17	0.241	0.365	1.514522822	1.314044646
27-Nov-17	0.241	0.359	1.489626556	1.454379369
5-Dec-17	0.217	0.37	1.705069124	1.4790524
12-Dec-17	0.211	0.272	1.289099526	1.637264107
21-Dec-17	0.227	0.363	1.599118943	1.3935489
28-Dec-17	0.211	0.379	1.796208531	1.53744793
6-Jan-18	0.251	0.38	1.513944223	1.718580351
13-Jan-18	0.221	0.378	1.71040724	1.575335061
22-Jan-18	0.244	0.385	1.577868852	1.669885586
30-Jan-18	0.301	0.394	1.3089701	1.605473873
6-Feb-18	0.255	0.395	1.549019608	1.397921232
7-Feb-18	0.225	0.397	1.764444444	1.503690095
14-Feb-18	0.351	0.422	1.202279202	1.68621814
15-Feb-18	0.302	0.382	1.264900662	1.347460883
22-Feb-18	0.258	0.38	1.472868217	1.289668729
2-Mar-18	0.598	0.794	1.327759197	1.417908371
3-Mar-18	0.29	0.396	1.365517241	1.354803949
11-Mar-18	0.269	0.361	1.342007435	1.362303254
18-Mar-18	0.378	0.464	1.227513228	1.348096181
19-Mar-18	0.292	0.428	1.465753425	1.263688113
27-Mar-18	0.57	0.547	0.959649123	1.405133831
3-Apr-18	0.333	0.399	1.198198198	1.093294535
12-Apr-18	0.284	0.388	1.366197183	1.166727099
19-Apr-18	0.545	0.543	0.996330275	1.306356158
27-Apr-18	0.25	0.406	1.624	1.08933804
28-Apr-18	0.262	0.419	1.599236641	1.463601412
5-May-18	0.273	0.427	1.564102564	1.558546072
14-May-18	0.566	0.562	0.992932862	1.562435617
21-May-18	0.357	0.414	1.159663866	1.163783689
22-May-18	0.286	0.425	1.486013986	1.160899812
30-May-18	0.268	0.434	1.619402985	1.388479734
6-Jun-18	0.387	0.416	1.074935401	1.55012601
22-Jun-18	0.462	0.542	1.173160173	1.217492583

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
23-Jun-18	0.318	0.476	1.496855346	1.186459896
1-Jul-18	0.295	0.421	1.427118644	1.403736711
8-Jul-18	0.364	0.422	1.159340659	1.420104064
17-Jul-18	0.348	0.462	1.327586207	1.237569681
2-Aug-18	0.341	0.431	1.263929619	1.300581249
9-Aug-18	0.349	0.411	1.17765043	1.274925108
10-Aug-18	0.341	0.413	1.211143695	1.206832833
18-Aug-18	0.349	0.407	1.166189112	1.209850436
25-Aug-18	0.347	0.411	1.18443804	1.179287509
3-Sep-18	0.359	0.424	1.181058496	1.182892881
10-Sep-18	0.316	0.409	1.294303797	1.181608811
19-Sep-18	0.275	0.393	1.429090909	1.260495302
26-Sep-18	0.507	0.559	1.102564103	1.378512227
27-Sep-18	0.281	0.397	1.412811388	1.18534854
4-Oct-18	0.311	0.402	1.292604502	1.344572533
5-Oct-18	0.259	0.394	1.521235521	1.308194911
12-Oct-18	0.305	0.394	1.291803279	1.457323338
13-Oct-18	0.304	0.395	1.299342105	1.341459297
21-Oct-18	0.239	0.386	1.615062762	1.311977263
28-Oct-18	0.24	0.381	1.5875	1.524137112
6-Nov-18	0.239	0.377	1.577405858	1.568491134
13-Nov-18	0.253	0.374	1.47826087	1.57473144
29-Nov-18	0.232	0.418	1.801724138	1.507202041
30-Nov-18	0.232	0.39	1.681034483	1.713367509
8-Dec-18	0.24	0.397	1.654166667	1.690734391
15-Dec-18	0.218	0.366	1.678899083	1.665136984
16-Dec-18	0.237	0.37	1.561181435	1.674770453
24-Dec-18	0.224	0.383	1.709821429	1.59525814
31-Dec-18	0.236	0.379	1.605932203	1.675452442
9-Jan-19	0.226	0.388	1.716814159	1.626788275
17-Jan-19	0.234	0.392	1.675213675	1.689806394
24-Jan-19	0.262	0.372	1.419847328	1.679591491
25-Jan-19	0.224	0.374	1.669642857	1.497770577
1-Feb-19	0.419	0.327	0.780429594	1.618081173
2-Feb-19	0.247	0.337	1.36437247	1.031725068
9-Feb-19	0.258	0.365	1.414728682	1.264578249
10-Feb-19	0.228	0.371	1.627192982	1.369683552
5-Mar-19	0.222	0.33	1.486486486	1.549940153
6-Mar-19	0.244	0.345	1.413934426	1.505522587
13-Mar-19	0.392	0.439	1.119897959	1.441410874

Date	Location M	Location C	C/M	C/M*
21-Mar-19	0.294	0.337	1.146258503	1.216351834
22-Mar-19	0.298	0.371	1.244966443	1.167286502
6-Apr-19	0.308	0.366	1.188311688	1.221662461
22-Apr-19	0.335	0.375	1.119402985	1.19831692
1-May-19	0.264	0.385	1.458333333	1.143077166
8-May-19	0.295	0.386	1.308474576	1.363756483
9-May-19	0.292	0.403	1.380136986	1.325059148
17-May-19	0.503	0.583	1.159045726	1.363613635
24-May-19	0.569	0.541	0.950790861	1.220416098
25-May-19	0.37	0.38	1.027027027	1.031678432
2-Jun-19	0.281	0.45	1.601423488	1.028422449
9-Jun-19	0.339	0.41	1.209439528	1.429523176
10-Jun-19	0.292	0.419	1.434931507	1.275464622
18-Jun-19	0.281	0.422	1.501779359	1.387091442
25-Jun-19	0.384	0.404	1.052083333	1.467372984
26-Jun-19	0.312	0.412	1.320512821	1.176670229
4-Jul-19	0.335	0.419	1.250746269	1.277360043
11-Jul-19	0.372	0.41	1.102150538	1.258730401
20-Jul-19	0.339	0.419	1.235988201	1.149124497
27-Jul-19	0.402	0.374	0.930348259	1.209929089
28-Jul-19	0.359	0.453	1.26183844	1.014222508
5-Aug-19	0.327	0.416	1.272171254	1.18755366
12-Aug-19	0.352	0.391	1.110795455	1.246785976
21-Aug-19	0.302	0.45	1.490066225	1.151592611
28-Aug-19	0.319	0.473	1.482758621	1.388524141
29-Aug-19	0.326	0.462	1.417177914	1.454488277
6-Sep-19	0.317	0.486	1.533123028	1.428371023
13-Sep-19	0.315	0.474	1.504761905	1.501697427
22-Sep-19	0.285	0.486	1.705263158	1.503842561
29-Sep-19	0.332	0.467	1.406626506	1.644836979
30-Sep-19	0.347	0.478	1.377521614	1.478089648
8-Oct-19	0.259	0.43	1.66023166	1.407692024
15-Oct-19	0.252	0.421	1.670634921	1.584469769
23-Oct-19	0.25	0.414	1.656	1.644785375
24-Oct-19	0.248	0.422	1.701612903	1.652635613
31-Oct-19	0.235	0.436	1.855319149	1.686919716
9-Nov-19	0.228	0.375	1.644736842	1.804799319
17-Nov-19	0.247	0.328	1.327935223	1.692755585
24-Nov-19	0.233	0.291	1.248927039	1.437381331
25-Nov-19	0.237	0.378	1.594936709	1.305463326

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
2-Dec-19	0.228	0.399	1.75	1.508094694
11-Dec-19	0.222	0.328	1.477477477	1.677428408
18-Dec-19	0.551	0.561	1.01814882	1.537462757
19-Dec-19	0.248	0.394	1.588709677	1.173943001
27-Dec-19	0.22	0.407	1.85	1.464279675
4-Jan-20	0.255	0.409	1.603921569	1.734283902
19-Jan-20	0.404	0.907	2.245049505	1.643030269
20-Jan-20	0.254	0.313	1.232283465	2.064443734
27-Jan-20	0.349	0.364	1.042979943	1.481931545
28-Jan-20	0.288	0.473	1.642361111	1.174665424
5-Feb-20	0.372	0.458	1.231182796	1.502052405
21-Feb-20	0.242	0.337	1.392561983	1.312443678
7-Mar-20	0.289	0.328	1.134948097	1.368526492
16-Mar-20	0.254	0.396	1.559055118	1.205021615
8-Apr-20	0.326	0.394	1.208588957	1.452845067
9-Apr-20	0.303	0.417	1.376237624	1.28186579
24-Apr-20	0.366	0.418	1.142076503	1.347926074
3-May-20	0.372	0.423	1.137096774	1.203831374
10-May-20	0.316	0.4	1.265822785	1.157117154
19-May-20	0.28	0.399	1.425	1.233211096
26-May-20	0.346	0.401	1.158959538	1.367463329
27-May-20	0.297	0.409	1.377104377	1.221510675
4-Jun-20	0.285	0.413	1.449122807	1.330426266
11-Jun-20	0.367	0.417	1.136239782	1.413513845
12-Jun-20	0.324	0.409	1.262345679	1.219422001
20-Jun-20	0.304	0.41	1.348684211	1.249468576
27-Jun-20	0.367	0.41	1.117166213	1.31891952
6-Jul-20	0.309	0.411	1.330097087	1.177692205
13-Jul-20	0.353	0.407	1.152974504	1.284375623
14-Jul-20	0.358	0.41	1.145251397	1.19239484
22-Jul-20	0.291	0.42	1.443298969	1.15939443
29-Jul-20	0.343	0.415	1.209912536	1.358127607
30-Jul-20	0.345	0.412	1.194202899	1.254377058
7-Aug-20	0.316	0.418	1.32278481	1.212255146
14-Aug-20	0.346	0.41	1.184971098	1.289625911
15-Aug-20	0.331	0.407	1.229607251	1.216367542
22-Aug-20	0.337	0.411	1.21958457	1.225635338
23-Aug-20	0.331	0.425	1.283987915	1.2213998
30-Aug-20	0.355	0.413	1.163380282	1.265211481
8-Sep-20	0.297	0.405	1.363636364	1.193929641

Date	Location M	Location C	C/M	C/M*
15-Sep-20	0.295	0.403	1.366101695	1.312724347
16-Sep-20	0.308	0.398	1.292207792	1.350088491
24-Sep-20	0.273	0.411	1.505494505	1.309572002
1-Oct-20	0.276	0.377	1.365942029	1.446717754
10-Oct-20	0.259	0.394	1.521235521	1.390174747
17-Oct-20	0.231	0.391	1.692640693	1.481917289
18-Oct-20	0.251	0.395	1.573705179	1.629423672
26-Oct-20	0.224	0.403	1.799107143	1.590420727
11-Nov-20	0.496	0.616	1.241935484	1.736501218
18-Nov-20	0.235	0.313	1.331914894	1.390305204
19-Nov-20	0.549	0.533	0.970856102	1.349431987
27-Nov-20	0.224	0.329	1.46875	1.084428867
13-Dec-20	0.469	0.449	0.957356077	1.35345366
20-Dec-20	0.287	0.459	1.599303136	1.076185352
21-Dec-20	0.331	0.481	1.453172205	1.442367801
29-Dec-20	0.22	0.336	1.527272727	1.449930884
14-Jan-21	0.298	0.402	1.348993289	1.504070174
21-Jan-21	0.261	0.42	1.609195402	1.395516354
30-Jan-21	0.221	0.401	1.814479638	1.545091688
6-Feb-21	0.243	0.393	1.617283951	1.733663253
7-Feb-21	0.247	0.408	1.651821862	1.652197741
15-Feb-21	0.241	0.402	1.668049793	1.651934626
22-Feb-21	0.234	0.285	1.217948718	1.663215243
23-Feb-21	0.273	0.365	1.336996337	1.351528675
3-Mar-21	0.229	0.392	1.711790393	1.341356038
10-Mar-21	0.266	0.384	1.443609023	1.600660087
19-Mar-21	0.258	0.396	1.534883721	1.490724342
26-Mar-21	0.409	0.535	1.30806846	1.521635907
11-Apr-21	0.264	0.387	1.465909091	1.372138694
27-Apr-21	0.275	0.386	1.403636364	1.437777972
6-May-21	0.306	0.341	1.114379085	1.413878846
13-May-21	0.323	0.39	1.207430341	1.204229013
14-May-21	0.285	0.394	1.38245614	1.206469942
22-May-21	0.259	0.41	1.583011583	1.329660281
29-May-21	0.342	0.404	1.18128655	1.507006192
30-May-21	0.299	0.409	1.367892977	1.279002443
7-Jun-21	0.319	0.416	1.304075235	1.341225816
14-Jun-21	0.412	0.439	1.065533981	1.315220409
15-Jun-21	0.356	0.42	1.179775281	1.140439909
23-Jun-21	0.298	0.423	1.419463087	1.167974669

Tir Pul Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
30-Jun-21	0.364	0.406	1.115384615	1.344016562
1-Jul-21	0.34	0.422	1.241176471	1.183974199
9-Jul-21	0.333	0.415	1.246246246	1.224015789
16-Jul-21	0.387	0.413	1.067183463	1.239577109
25-Jul-21	0.311	0.491	1.578778135	1.118901557
1-Aug-21	0.362	0.489	1.350828729	1.440815161
2-Aug-21	0.347	0.462	1.331412104	1.377824659
10-Aug-21	0.321	0.469	1.46105919	1.34533587
17-Aug-21	0.328	0.462	1.408536585	1.426342194
26-Aug-21	0.305	0.441	1.445901639	1.413878268
2-Sep-21	0.322	0.441	1.369565217	1.436294628
3-Sep-21	0.326	0.422	1.294478528	1.389584041
11-Sep-21	0.348	0.415	1.192528736	1.323010181
18-Sep-21	0.312	0.428	1.371794872	1.231673169
27-Sep-21	0.296	0.432	1.459459459	1.329758361
4-Oct-21	0.314	0.429	1.366242038	1.42054913
13-Oct-21	0.254	0.424	1.669291339	1.382534166
20-Oct-21	0.254	0.423	1.665354331	1.583264187
29-Oct-21	0.243	0.395	1.625514403	1.640727288
5-Nov-21	0.247	0.384	1.55465587	1.630078269
14-Nov-21	0.252	0.393	1.55952381	1.57728259
21-Nov-21	0.231	0.4	1.731601732	1.564851444
30-Nov-21	0.228	0.414	1.815789474	1.681576645
7-Dec-21	0.232	0.408	1.75862069	1.775525625
16-Dec-21	0.223	0.418	1.874439462	1.76369217
24-Dec-21	0.263	0.403	1.532319392	1.841215274

Khwabgah Station C and M SR Time Series

Date	Location M	Location C	C/M	C/M*
9-Feb-86	0.463	0.371	0.801	#N/A
30-Apr-86	0.494	0.43	0.870	0.801
16-May-86	0.498	0.421	0.845	0.850
17-Jun-86	0.491	0.432	0.880	0.847
23-Oct-86	0.492	0.408	0.829	0.870
27-Jan-87	0.492	0.39	0.793	0.841
28-Feb-87	0.484	0.404	0.835	0.807
16-Mar-87	0.529	0.514	0.972	0.826
1-Apr-87	0.52	0.504	0.969	0.928
17-Apr-87	0.508	0.464	0.913	0.957
3-May-87	0.477	0.427	0.895	0.926
19-May-87	0.483	0.469	0.971	0.905
4-Jun-87	0.491	0.449	0.914	0.951
20-Jun-87	0.503	0.49	0.974	0.925
6-Jul-87	0.503	0.517	1.028	0.960
7-Aug-87	0.57	0.579	1.016	1.007
23-Aug-87	0.513	0.532	1.037	1.013
8-Sep-87	0.568	0.583	1.026	1.030
24-Sep-87	0.523	0.531	1.015	1.027
11-Nov-87	0.503	0.473	0.940	1.019
13-Dec-87	0.458	0.443	0.967	0.964
14-Jan-88	0.488	0.445	0.912	0.966
30-Jan-88	0.478	0.449	0.939	0.928
2-Mar-88	0.57	0.572	1.004	0.936
3-Apr-88	0.513	0.458	0.893	0.983
19-Apr-88	0.5	0.442	0.884	0.920
5-May-88	0.496	0.449	0.905	0.895
21-May-88	0.487	0.486	0.998	0.902
6-Jun-88	0.481	0.527	1.096	0.969
22-Jun-88	0.502	0.525	1.046	1.058
24-Jul-88	0.536	0.565	1.054	1.049
9-Aug-88	0.557	0.582	1.045	1.053
25-Aug-88	0.508	0.536	1.055	1.047
10-Sep-88	0.482	0.533	1.106	1.053
26-Sep-88	0.52	0.547	1.052	1.090
12-Oct-88	0.487	0.514	1.055	1.063
13-Nov-88	0.485	0.517	1.066	1.058
15-Dec-88	0.46	0.518	1.126	1.064
16-Jan-89	0.505	0.496	0.982	1.107

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
5-Mar-89	0.536	0.495	0.924	1.020
6-Apr-89	0.523	0.505	0.966	0.952
8-May-89	0.561	0.536	0.955	0.962
24-May-89	0.484	0.408	0.843	0.957
25-Jun-89	0.443	0.47	1.061	0.877
12-Aug-89	0.454	0.519	1.143	1.006
28-Aug-89	0.462	0.531	1.149	1.102
13-Sep-89	0.453	0.52	1.148	1.135
15-Oct-89	0.446	0.516	1.157	1.144
3-Jan-90	0.436	0.453	1.039	1.153
20-Feb-90	0.492	0.471	0.957	1.073
8-Mar-90	0.473	0.466	0.985	0.992
25-Apr-90	0.495	0.449	0.907	0.987
27-May-90	0.476	0.477	1.002	0.931
12-Jun-90	0.465	0.466	1.002	0.981
28-Jun-90	0.447	0.521	1.166	0.996
14-Jul-90	0.412	0.519	1.260	1.115
30-Jul-90	0.425	0.52	1.224	1.216
15-Aug-90	0.427	0.52	1.218	1.221
16-Sep-90	0.449	0.508	1.131	1.219
2-Oct-90	0.449	0.527	1.174	1.158
3-Nov-90	0.417	0.522	1.252	1.169
5-Dec-90	0.421	0.515	1.223	1.227
11-Mar-91	0.57	0.574	1.007	1.224
27-Mar-91	0.418	0.451	1.079	1.072
28-Apr-91	0.471	0.445	0.945	1.077
14-May-91	0.504	0.471	0.935	0.984
30-May-91	0.493	0.47	0.953	0.949
15-Jun-91	0.459	0.419	0.913	0.952
1-Jul-91	0.439	0.405	0.923	0.925
17-Jul-91	0.456	0.443	0.971	0.923
18-Aug-91	0.412	0.507	1.231	0.957
3-Sep-91	0.442	0.511	1.156	1.149
19-Sep-91	0.412	0.496	1.204	1.154
5-Oct-91	0.449	0.477	1.062	1.189
21-Oct-91	0.464	0.494	1.065	1.100
6-Nov-91	0.401	0.476	1.187	1.075
8-Dec-91	0.428	0.457	1.068	1.154
24-Dec-91	0.417	0.445	1.067	1.093
9-Jan-92	0.41	0.436	1.063	1.075

Date	Location M	Location C	C/M	C/M*
10-Feb-92	0.487	0.457	0.938	1.067
26-Feb-92	0.433	0.442	1.021	0.977
13-Mar-92	0.432	0.458	1.060	1.008
29-Mar-92	0.536	0.502	0.937	1.044
14-Apr-92	0.494	0.482	0.976	0.969
30-Apr-92	0.489	0.463	0.947	0.974
16-May-92	0.485	0.46	0.948	0.955
1-Jun-92	0.47	0.446	0.949	0.950
17-Jun-92	0.462	0.415	0.898	0.949
3-Jul-92	0.457	0.39	0.853	0.914
19-Jul-92	0.432	0.393	0.910	0.871
4-Aug-92	0.463	0.418	0.903	0.898
20-Aug-92	0.468	0.426	0.910	0.901
5-Sep-92	0.422	0.415	0.983	0.908
21-Sep-92	0.408	0.393	0.963	0.961
7-Oct-92	0.408	0.365	0.895	0.962
23-Oct-92	0.425	0.367	0.864	0.915
8-Nov-92	0.416	0.36	0.865	0.879
24-Nov-92	0.389	0.343	0.882	0.869
10-Dec-92	0.491	0.477	0.971	0.878
26-Dec-92	0.408	0.422	1.034	0.943
11-Jan-93	0.543	0.529	0.974	1.007
27-Jan-93	0.427	0.427	1.000	0.984
28-Feb-93	0.443	0.424	0.957	0.995
1-Apr-93	0.481	0.457	0.950	0.969
3-May-93	0.466	0.43	0.923	0.956
19-May-93	0.474	0.441	0.930	0.933
4-Jun-93	0.457	0.395	0.864	0.931
20-Jun-93	0.462	0.475	1.028	0.884
6-Jul-93	0.43	0.459	1.067	0.985
22-Jul-93	0.437	0.542	1.240	1.043
7-Aug-93	0.448	0.548	1.223	1.181
23-Aug-93	0.447	0.529	1.183	1.211
24-Sep-93	0.475	0.505	1.063	1.192
26-Oct-93	0.422	0.503	1.192	1.102
11-Nov-93	0.45	0.504	1.120	1.165
27-Nov-93	0.48	0.451	0.940	1.133
13-Dec-93	0.462	0.496	1.074	0.998
29-Dec-93	0.39	0.482	1.236	1.051
15-Feb-94	0.436	0.491	1.126	1.180

Date	Location M	Location C	C/M	C/M*
3-Mar-94	0.39	0.405	1.038	1.142
19-Mar-94	0.417	0.472	1.132	1.070
4-Apr-94	0.47	0.467	0.994	1.113
20-Apr-94	0.454	0.44	0.969	1.029
6-May-94	0.451	0.386	0.856	0.987
22-May-94	0.426	0.392	0.920	0.895
7-Jun-94	0.454	0.477	1.051	0.913
23-Jun-94	0.454	0.506	1.115	1.009
9-Jul-94	0.467	0.558	1.195	1.083
25-Jul-94	0.507	0.529	1.043	1.161
10-Aug-94	0.483	0.516	1.068	1.079
26-Aug-94	0.442	0.499	1.129	1.071
11-Sep-94	0.476	0.495	1.040	1.112
27-Sep-94	0.42	0.487	1.160	1.061
14-Nov-94	0.438	0.428	0.977	1.130
16-Dec-94	0.519	0.454	0.875	1.023
1-Jan-95	0.45	0.447	0.993	0.919
17-Jan-95	0.475	0.504	1.061	0.971
2-Feb-95	0.417	0.474	1.137	1.034
18-Feb-95	0.454	0.388	0.855	1.106
6-Mar-95	0.397	0.449	1.131	0.930
7-Apr-95	0.56	0.526	0.939	1.071
9-May-95	0.452	0.416	0.920	0.979
10-Jun-95	0.439	0.407	0.927	0.938
26-Jun-95	0.442	0.455	1.029	0.930
12-Jul-95	0.426	0.502	1.178	1.000
28-Jul-95	0.417	0.478	1.146	1.125
13-Aug-95	0.476	0.492	1.034	1.140
29-Aug-95	0.45	0.514	1.142	1.065
30-Sep-95	0.422	0.494	1.171	1.119
16-Oct-95	0.408	0.48	1.176	1.155
24-Mar-96	0.485	0.485	1.000	1.170
9-Apr-96	0.418	0.463	1.108	1.051
25-Apr-96	0.406	0.417	1.027	1.091
11-May-96	0.385	0.507	1.317	1.046
27-May-96	0.378	0.598	1.582	1.236
12-Jun-96	0.416	0.561	1.349	1.478
14-Jul-96	0.339	0.524	1.546	1.387
30-Jul-96	0.365	0.513	1.405	1.498
15-Aug-96	0.375	0.51	1.360	1.433

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
31-Aug-96	0.371	0.521	1.404	1.382
16-Sep-96	0.285	0.53	1.860	1.398
2-Oct-96	0.496	0.558	1.125	1.721
3-Nov-96	0.292	0.52	1.781	1.304
19-Nov-96	0.422	0.528	1.251	1.638
5-Dec-96	0.252	0.54	2.143	1.367
21-Dec-96	0.28	0.507	1.811	1.910
6-Jan-97	0.269	0.531	1.974	1.841
7-Feb-97	0.292	0.528	1.808	1.934
23-Feb-97	0.344	0.528	1.535	1.846
11-Mar-97	0.332	0.527	1.587	1.628
27-Mar-97	0.477	0.413	0.866	1.600
12-Apr-97	0.428	0.445	1.040	1.086
28-Apr-97	0.477	0.428	0.897	1.054
14-May-97	0.432	0.449	1.039	0.944
30-May-97	0.374	0.537	1.436	1.011
15-Jun-97	0.345	0.514	1.490	1.308
1-Jul-97	0.318	0.513	1.613	1.435
17-Jul-97	0.32	0.52	1.625	1.560
2-Aug-97	0.36	0.513	1.425	1.605
3-Sep-97	0.263	0.536	2.038	1.479
5-Oct-97	0.297	0.538	1.811	1.870
21-Oct-97	0.293	0.539	1.840	1.829
6-Nov-97	0.268	0.505	1.884	1.836
22-Nov-97	0.269	0.528	1.963	1.870
8-Dec-97	0.252	0.506	2.008	1.935
9-Jan-98	0.396	0.483	1.220	1.986
25-Jan-98	0.415	0.474	1.142	1.450
10-Feb-98	0.461	0.527	1.143	1.234
26-Feb-98	0.43	0.417	0.970	1.171
14-Mar-98	0.423	0.423	1.000	1.030
30-Mar-98	0.44	0.419	0.952	1.009
15-Apr-98	0.422	0.426	1.009	0.969
17-May-98	0.433	0.447	1.032	0.997
2-Jun-98	0.386	0.446	1.155	1.022
18-Jun-98	0.379	0.523	1.380	1.115
4-Jul-98	0.321	0.5	1.558	1.301
20-Jul-98	0.312	0.495	1.587	1.481
5-Aug-98	0.317	0.521	1.644	1.555
21-Aug-98	0.291	0.52	1.787	1.617

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
22-Sep-98	0.269	0.514	1.911	1.736
8-Oct-98	0.284	0.515	1.813	1.858
24-Oct-98	0.3	0.509	1.697	1.827
9-Nov-98	0.276	0.522	1.891	1.736
25-Nov-98	0.245	0.524	2.139	1.845
11-Dec-98	0.252	0.527	2.091	2.051
27-Dec-98	0.26	0.515	1.981	2.079
12-Jan-99	0.253	0.513	2.028	2.010
28-Jan-99	0.414	0.521	1.258	2.022
1-Mar-99	0.457	0.471	1.031	1.488
18-Apr-99	0.35	0.528	1.509	1.168
4-May-99	0.31	0.517	1.668	1.406
20-May-99	0.328	0.527	1.607	1.589
5-Jun-99	0.347	0.522	1.504	1.601
21-Jun-99	0.302	0.533	1.765	1.533
7-Jul-99	0.412	0.533	1.294	1.695
23-Jul-99	0.273	0.53	1.941	1.414
24-Aug-99	0.314	0.535	1.704	1.783
9-Sep-99	0.305	0.533	1.748	1.728
25-Sep-99	0.294	0.535	1.820	1.742
11-Oct-99	0.261	0.538	2.061	1.796
27-Oct-99	0.271	0.537	1.982	1.982
12-Nov-99	0.497	0.521	1.048	1.982
28-Nov-99	0.561	0.577	1.029	1.328
14-Dec-99	0.228	0.528	2.316	1.118
30-Dec-99	0.229	0.55	2.402	1.957
15-Jan-00	0.252	0.543	2.155	2.268
23-Jan-00	0.258	0.499	1.934	2.189
31-Jan-00	0.247	0.534	2.162	2.011
16-Feb-00	0.253	0.526	2.079	2.117
19-Mar-00	0.353	0.445	1.261	2.090
4-Apr-00	0.308	0.539	1.750	1.510
12-Apr-00	0.346	0.528	1.526	1.678
20-Apr-00	0.564	0.596	1.057	1.572
6-May-00	0.407	0.566	1.391	1.211
22-May-00	0.413	0.544	1.317	1.337
7-Jun-00	0.397	0.533	1.343	1.323
23-Jun-00	0.396	0.536	1.354	1.337
9-Jul-00	0.466	0.546	1.172	1.348
17-Jul-00	0.474	0.535	1.129	1.225

Date	Location M	Location C	C/M	C/M*
25-Jul-00	0.467	0.567	1.214	1.158
10-Aug-00	0.489	0.554	1.133	1.197
18-Aug-00	0.461	0.538	1.167	1.152
26-Aug-00	0.394	0.528	1.340	1.163
11-Sep-00	0.373	0.526	1.410	1.287
19-Sep-00	0.413	0.521	1.262	1.373
27-Sep-00	0.386	0.531	1.376	1.295
5-Oct-00	0.397	0.511	1.287	1.351
13-Oct-00	0.376	0.537	1.428	1.306
29-Oct-00	0.332	0.532	1.602	1.392
14-Nov-00	0.307	0.529	1.723	1.539
22-Nov-00	0.351	0.536	1.527	1.668
30-Nov-00	0.344	0.539	1.567	1.569
16-Dec-00	0.315	0.526	1.670	1.568
1-Jan-01	0.337	0.533	1.582	1.639
17-Jan-01	0.256	0.521	2.035	1.599
18-Feb-01	0.356	0.486	1.365	1.904
26-Feb-01	0.284	0.53	1.866	1.527
6-Mar-01	0.325	0.535	1.646	1.764
22-Mar-01	0.344	0.546	1.587	1.682
30-Mar-01	0.426	0.526	1.235	1.616
7-Apr-01	0.428	0.539	1.259	1.349
23-Apr-01	0.473	0.533	1.127	1.286
9-May-01	0.479	0.549	1.146	1.175
25-May-01	0.465	0.532	1.144	1.155
10-Jun-01	0.528	0.57	1.080	1.147
26-Jun-01	0.5	0.541	1.082	1.100
12-Jul-01	0.514	0.557	1.084	1.087
28-Jul-01	0.525	0.545	1.038	1.085
13-Aug-01	0.588	0.585	0.995	1.052
29-Aug-01	0.52	0.56	1.077	1.012
6-Sep-01	0.482	0.541	1.122	1.057
14-Sep-01	0.558	0.583	1.045	1.103
30-Sep-01	0.485	0.557	1.148	1.062
16-Oct-01	0.456	0.533	1.169	1.123
24-Oct-01	0.474	0.529	1.116	1.155
1-Nov-01	0.479	0.536	1.119	1.128
17-Nov-01	0.482	0.545	1.131	1.122
25-Nov-01	0.485	0.536	1.105	1.128
3-Dec-01	0.492	0.536	1.089	1.112

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
19-Dec-01	0.405	0.523	1.291	1.096
20-Jan-02	0.468	0.531	1.135	1.233
28-Jan-02	0.481	0.54	1.123	1.164
5-Feb-02	0.271	0.532	1.963	1.135
21-Feb-02	0.513	0.586	1.142	1.715
18-Apr-02	0.391	0.523	1.338	1.314
13-Jun-02	0.49	0.536	1.094	1.331
29-Jun-02	0.485	0.535	1.103	1.165
15-Jul-02	0.502	0.555	1.106	1.122
31-Jul-02	0.532	0.552	1.038	1.110
8-Aug-02	0.49	0.543	1.108	1.059
24-Aug-02	0.527	0.556	1.055	1.094
11-Oct-02	0.496	0.525	1.058	1.067
12-Nov-02	0.25	0.519	2.076	1.061
30-Dec-02	0.376	0.513	1.364	1.771
31-Jan-03	0.277	0.467	1.686	1.486
4-Mar-03	0.41	0.525	1.280	1.626
21-Apr-03	0.454	0.506	1.115	1.384
7-May-03	0.381	0.491	1.289	1.195
23-May-03	0.349	0.53	1.519	1.261
14-Oct-03	0.304	0.554	1.822	1.441
15-Nov-03	0.428	0.531	1.241	1.708
2-Jan-04	0.258	0.538	2.085	1.381
19-Feb-04	0.367	0.537	1.463	1.874
6-Mar-04	0.509	0.584	1.147	1.586
7-Apr-04	0.382	0.536	1.403	1.279
9-May-04	0.283	0.542	1.915	1.366
25-May-04	0.407	0.548	1.346	1.750
26-Jun-04	0.555	0.598	1.077	1.468
13-Aug-04	0.319	0.561	1.759	1.195
29-Aug-04	0.446	0.548	1.229	1.589
14-Sep-04	0.504	0.568	1.127	1.337
17-Nov-04	0.428	0.533	1.245	1.190
19-Dec-04	0.355	0.574	1.617	1.229
5-Feb-05	0.431	0.522	1.211	1.500
9-Mar-05	0.489	0.468	0.957	1.298
25-Mar-05	0.51	0.517	1.014	1.059
26-Apr-05	0.392	0.516	1.316	1.027
12-May-05	0.454	0.486	1.070	1.230
13-Jun-05	0.328	0.52	1.585	1.118

Date	Location M	Location C	C/M	C/M*
29-Jun-05	0.4	0.495	1.238	1.445
15-Jul-05	0.345	0.518	1.501	1.300
16-Aug-05	0.344	0.516	1.500	1.441
17-Sep-05	0.332	0.524	1.578	1.482
3-Oct-05	0.303	0.525	1.733	1.550
19-Oct-05	0.285	0.525	1.842	1.678
4-Nov-05	0.263	0.537	2.042	1.793
22-Dec-05	0.254	0.53	2.087	1.967
7-Jan-06	0.241	0.547	2.270	2.051
8-Feb-06	0.307	0.522	1.700	2.204
29-Apr-06	0.375	0.526	1.403	1.851
15-May-06	0.349	0.376	1.077	1.537
31-May-06	0.51	0.577	1.131	1.215
16-Jun-06	0.398	0.537	1.349	1.157
19-Aug-06	0.379	0.54	1.425	1.291
4-Sep-06	0.351	0.548	1.561	1.385
6-Oct-06	0.401	0.557	1.389	1.508
22-Oct-06	0.319	0.56	1.755	1.425
7-Nov-06	0.305	0.553	1.813	1.656
10-Jan-07	0.4	0.55	1.375	1.766
26-Jan-07	0.285	0.518	1.818	1.492
11-Feb-07	0.298	0.545	1.829	1.720
16-Apr-07	0.44	0.451	1.025	1.796
2-May-07	0.442	0.442	1.000	1.256
23-Sep-07	0.457	0.54	1.182	1.077
25-Oct-07	0.285	0.354	1.242	1.150
12-Dec-07	0.251	0.509	2.028	1.215
28-Dec-07	0.263	0.54	2.053	1.784
29-Jan-08	0.416	0.512	1.231	1.972
17-Mar-08	0.422	0.527	1.249	1.453
10-Apr-08	0.369	0.528	1.431	1.310
18-Apr-08	0.39	0.5	1.282	1.395
26-Apr-08	0.373	0.531	1.424	1.316
4-May-08	0.374	0.521	1.393	1.391
28-May-08	0.307	0.523	1.704	1.393
13-Jun-08	0.342	0.528	1.544	1.610
29-Jun-08	0.578	0.606	1.048	1.564
7-Jul-08	0.387	0.527	1.362	1.203
15-Jul-08	0.439	0.546	1.244	1.314
23-Jul-08	0.485	0.543	1.120	1.265

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
8-Aug-08	0.426	0.534	1.254	1.163
24-Aug-08	0.403	0.542	1.345	1.226
25-Sep-08	0.414	0.53	1.280	1.309
3-Oct-08	0.456	0.547	1.200	1.289
11-Oct-08	0.47	0.548	1.166	1.226
19-Oct-08	0.425	0.54	1.271	1.184
20-Nov-08	0.367	0.547	1.490	1.245
6-Dec-08	0.43	0.559	1.300	1.417
22-Dec-08	0.348	0.532	1.529	1.335
15-Jan-09	0.425	0.531	1.249	1.471
23-Jan-09	0.348	0.41	1.178	1.316
31-Jan-09	0.469	0.574	1.224	1.219
8-Feb-09	0.34	0.545	1.603	1.223
24-Feb-09	0.434	0.546	1.258	1.489
12-Mar-09	0.375	0.54	1.440	1.327
20-Mar-09	0.402	0.529	1.316	1.406
28-Mar-09	0.45	0.529	1.176	1.343
29-Apr-09	0.435	0.449	1.032	1.226
15-May-09	0.433	0.449	1.037	1.090
31-May-09	0.453	0.488	1.077	1.053
16-Jun-09	0.391	0.569	1.455	1.070
2-Jul-09	0.393	0.534	1.359	1.340
26-Jul-09	0.318	0.531	1.670	1.353
3-Aug-09	0.43	0.542	1.260	1.575
11-Aug-09	0.416	0.538	1.293	1.355
19-Aug-09	0.362	0.536	1.481	1.312
27-Aug-09	0.337	0.534	1.585	1.430
4-Sep-09	0.424	0.544	1.283	1.538
12-Sep-09	0.293	0.54	1.843	1.360
28-Sep-09	0.31	0.53	1.710	1.698
6-Oct-09	0.262	0.549	2.095	1.706
22-Oct-09	0.302	0.542	1.795	1.979
30-Oct-09	0.396	0.572	1.444	1.850
23-Nov-09	0.281	0.55	1.957	1.566
1-Dec-09	0.28	0.539	1.925	1.840
17-Dec-09	0.268	0.483	1.802	1.899
18-Jan-10	0.408	0.605	1.483	1.831
26-Jan-10	0.596	0.56	0.940	1.587
11-Feb-10	0.442	0.572	1.294	1.134
19-Feb-10	0.456	0.468	1.026	1.246

Date	Location M	Location C	C/M	C/M*
23-Mar-10	0.387	0.546	1.411	1.092
31-Mar-10	0.365	0.529	1.449	1.315
16-Apr-10	0.379	0.534	1.409	1.409
18-May-10	0.376	0.459	1.221	1.409
19-Jun-10	0.327	0.562	1.719	1.277
13-Jul-10	0.368	0.533	1.448	1.586
21-Jul-10	0.44	0.555	1.261	1.490
29-Jul-10	0.366	0.538	1.470	1.330
6-Aug-10	0.347	0.545	1.571	1.428
14-Aug-10	0.404	0.542	1.342	1.528
30-Aug-10	0.445	0.543	1.220	1.397
23-Sep-10	0.418	0.557	1.333	1.273
1-Oct-10	0.459	0.58	1.264	1.315
10-Nov-10	0.266	0.547	2.056	1.279
26-Nov-10	0.281	0.542	1.929	1.823
12-Dec-10	0.304	0.551	1.813	1.897
28-Dec-10	0.252	0.547	2.171	1.838
5-Jan-11	0.271	0.554	2.044	2.071
13-Jan-11	0.351	0.562	1.601	2.052
21-Jan-11	0.412	0.444	1.078	1.736
29-Jan-11	0.308	0.509	1.653	1.275
14-Feb-11	0.309	0.528	1.709	1.539
22-Feb-11	0.478	0.478	1.000	1.658
10-Mar-11	0.497	0.492	0.990	1.197
26-Mar-11	0.433	0.52	1.201	1.052
3-Apr-11	0.425	0.532	1.252	1.156
19-Apr-11	0.486	0.536	1.103	1.223
5-May-11	0.392	0.543	1.385	1.139
17-Aug-11	0.466	0.576	1.236	1.311
4-Oct-11	0.466	0.556	1.193	1.259
7-Dec-11	0.397	0.57	1.436	1.213
23-Dec-11	0.384	0.588	1.531	1.369
8-Jan-12	0.305	0.547	1.793	1.483
25-Feb-12	0.52	0.555	1.067	1.700
8-May-12	0.425	0.487	1.146	1.257
16-Jun-12	0.334	0.59	1.766	1.179
2-Jul-12	0.318	0.576	1.811	1.590
18-Jul-12	0.35	0.559	1.597	1.745
19-Aug-12	0.347	0.553	1.594	1.642
20-Sep-12	0.285	0.567	1.989	1.608

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
23-Nov-12	0.297	0.541	1.822	1.875
9-Dec-12	0.255	0.512	2.008	1.838
25-Dec-12	0.288	0.532	1.847	1.957
26-Jan-13	0.354	0.527	1.489	1.880
11-Feb-13	0.534	0.534	1.000	1.606
27-Feb-13	0.415	0.545	1.313	1.182
15-Mar-13	0.342	0.52	1.520	1.274
24-Apr-13	0.442	0.554	1.253	1.446
2-May-13	0.5	0.583	1.166	1.311
26-May-13	0.357	0.561	1.571	1.210
11-Jun-13	0.412	0.556	1.350	1.463
27-Jun-13	0.399	0.568	1.424	1.384
13-Jul-13	0.245	0.573	2.339	1.412
21-Jul-13	0.412	0.548	1.330	2.061
29-Jul-13	0.348	0.569	1.635	1.549
14-Aug-13	0.417	0.572	1.372	1.609
22-Aug-13	0.397	0.556	1.401	1.443
30-Aug-13	0.385	0.564	1.465	1.413
7-Sep-13	0.333	0.551	1.655	1.449
15-Sep-13	0.309	0.562	1.819	1.593
1-Oct-13	0.329	0.561	1.705	1.751
9-Oct-13	0.418	0.563	1.347	1.719
17-Oct-13	0.258	0.496	1.922	1.459
25-Oct-13	0.311	0.56	1.801	1.783
2-Nov-13	0.348	0.52	1.494	1.795
10-Nov-13	0.286	0.55	1.923	1.585
26-Nov-13	0.281	0.516	1.836	1.822
4-Dec-13	0.466	0.557	1.195	1.832
12-Dec-13	0.34	0.535	1.574	1.386
28-Dec-13	0.268	0.545	2.034	1.517
5-Jan-14	0.242	0.557	2.302	1.879
13-Jan-14	0.369	0.501	1.358	2.175
29-Jan-14	0.328	0.514	1.567	1.603
22-Feb-14	0.373	0.547	1.466	1.578
2-Mar-14	0.301	0.545	1.811	1.500
10-Mar-14	0.248	0.566	2.282	1.717
26-Mar-14	0.576	0.552	0.958	2.113
11-Apr-14	0.458	0.433	0.945	1.305
27-Apr-14	0.349	0.442	1.266	1.053
5-May-14	0.396	0.441	1.114	1.202

Date	Location M	Location C	C/M	C/M*
13-May-14	0.382	0.437	1.144	1.140
29-May-14	0.481	0.5	1.040	1.143
14-Jun-14	0.485	0.556	1.146	1.071
30-Jun-14	0.387	0.535	1.382	1.124
8-Jul-14	0.337	0.558	1.656	1.305
16-Jul-14	0.493	0.58	1.176	1.550
1-Aug-14	0.437	0.558	1.277	1.289
17-Aug-14	0.403	0.562	1.395	1.280
25-Aug-14	0.436	0.548	1.257	1.360
2-Sep-14	0.455	0.542	1.191	1.288
18-Sep-14	0.399	0.545	1.366	1.220
4-Oct-14	0.388	0.552	1.423	1.322
12-Oct-14	0.357	0.538	1.507	1.393
20-Oct-14	0.473	0.559	1.182	1.473
28-Oct-14	0.404	0.536	1.327	1.269
5-Nov-14	0.408	0.488	1.196	1.309
13-Nov-14	0.383	0.536	1.399	1.230
21-Nov-14	0.285	0.54	1.895	1.349
7-Dec-14	0.34	0.55	1.618	1.731
15-Dec-14	0.278	0.539	1.939	1.652
23-Dec-14	0.265	0.545	2.057	1.853
8-Jan-15	0.375	0.55	1.467	1.995
16-Jan-15	0.433	0.586	1.353	1.625
24-Jan-15	0.251	0.532	2.120	1.435
9-Feb-15	0.361	0.594	1.645	1.914
25-Feb-15	0.363	0.534	1.471	1.726
5-Mar-15	0.307	0.515	1.678	1.548
21-Mar-15	0.324	0.499	1.540	1.639
29-Mar-15	0.475	0.558	1.175	1.570
14-Apr-15	0.368	0.53	1.440	1.293
22-Apr-15	0.344	0.525	1.526	1.396
30-Apr-15	0.304	0.536	1.763	1.487
8-May-15	0.361	0.552	1.529	1.680
16-May-15	0.341	0.539	1.581	1.574
24-May-15	0.491	0.542	1.104	1.579
1-Jun-15	0.339	0.552	1.628	1.246
17-Jun-15	0.267	0.555	2.079	1.514
25-Jun-15	0.343	0.57	1.662	1.909
3-Jul-15	0.334	0.558	1.671	1.736
19-Jul-15	0.367	0.557	1.518	1.690

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
4-Aug-15	0.357	0.55	1.541	1.569
12-Aug-15	0.531	0.548	1.032	1.549
20-Aug-15	0.386	0.553	1.433	1.187
28-Aug-15	0.441	0.547	1.240	1.359
5-Sep-15	0.374	0.55	1.471	1.276
13-Sep-15	0.445	0.544	1.222	1.412
21-Sep-15	0.463	0.561	1.212	1.279
29-Sep-15	0.442	0.551	1.247	1.232
7-Oct-15	0.388	0.542	1.397	1.242
31-Oct-15	0.461	0.539	1.169	1.351
16-Nov-15	0.413	0.524	1.269	1.224
24-Nov-15	0.521	0.521	1.000	1.255
2-Dec-15	0.349	0.515	1.476	1.077
10-Dec-15	0.366	0.544	1.486	1.356
18-Dec-15	0.337	0.536	1.591	1.447
11-Jan-16	0.412	0.529	1.284	1.548
19-Jan-16	0.308	0.531	1.724	1.363
27-Jan-16	0.271	0.575	2.122	1.616
4-Feb-16	0.448	0.563	1.257	1.970
12-Feb-16	0.338	0.544	1.609	1.471
28-Feb-16	0.274	0.532	1.942	1.568
15-Mar-16	0.496	0.523	1.054	1.829
8-Apr-16	0.512	0.512	1.000	1.287
16-Apr-16	0.438	0.445	1.016	1.086
24-Apr-16	0.436	0.463	1.062	1.037
2-May-16	0.387	0.48	1.240	1.054
18-May-16	0.366	0.529	1.445	1.185
26-May-16	0.411	0.519	1.263	1.367
3-Jun-16	0.329	0.541	1.644	1.294
19-Jun-16	0.305	0.546	1.790	1.539
5-Jul-16	0.362	0.548	1.514	1.715
21-Jul-16	0.294	0.553	1.881	1.574
29-Jul-16	0.377	0.537	1.424	1.789
6-Aug-16	0.327	0.556	1.700	1.534
14-Aug-16	0.344	0.55	1.599	1.650
22-Aug-16	0.322	0.549	1.705	1.614
30-Aug-16	0.379	0.543	1.433	1.678
7-Sep-16	0.276	0.542	1.964	1.506
15-Sep-16	0.333	0.532	1.598	1.827
23-Sep-16	0.271	0.547	2.018	1.666

Date	Location M	Location C	C/M	C/M*
1-Oct-16	0.374	0.531	1.420	1.913
9-Oct-16	0.221	0.548	2.480	1.568
25-Oct-16	0.29	0.533	1.838	2.206
2-Nov-16	0.291	0.525	1.804	1.948
10-Nov-16	0.222	0.539	2.428	1.847
18-Nov-16	0.268	0.532	1.985	2.254
26-Nov-16	0.503	0.553	1.099	2.066
4-Dec-16	0.276	0.517	1.873	1.389
12-Dec-16	0.319	0.508	1.592	1.728
20-Dec-16	0.3	0.528	1.760	1.633
5-Jan-17	0.297	0.51	1.717	1.722
29-Jan-17	0.474	0.538	1.135	1.719
22-Feb-17	0.352	0.532	1.511	1.310
2-Mar-17	0.433	0.534	1.233	1.451
10-Mar-17	0.423	0.526	1.243	1.299
18-Mar-17	0.323	0.533	1.650	1.260
26-Mar-17	0.472	0.561	1.189	1.533
3-Apr-17	0.418	0.542	1.297	1.292
19-Apr-17	0.348	0.531	1.526	1.295
27-Apr-17	0.448	0.526	1.174	1.457
5-May-17	0.467	0.548	1.173	1.259
13-May-17	0.367	0.541	1.474	1.199
21-May-17	0.319	0.554	1.737	1.392
29-May-17	0.351	0.543	1.547	1.633
6-Jun-17	0.367	0.549	1.496	1.573
14-Jun-17	0.355	0.545	1.535	1.519
22-Jun-17	0.325	0.552	1.698	1.530
30-Jun-17	0.421	0.557	1.323	1.648
8-Jul-17	0.393	0.552	1.405	1.421
16-Jul-17	0.447	0.552	1.235	1.409
24-Jul-17	0.417	0.547	1.312	1.287
1-Aug-17	0.42	0.548	1.305	1.304
9-Aug-17	0.406	0.547	1.347	1.305
17-Aug-17	0.506	0.575	1.136	1.334
25-Aug-17	0.442	0.553	1.251	1.196
2-Sep-17	0.415	0.538	1.296	1.235
10-Sep-17	0.477	0.557	1.168	1.278
18-Sep-17	0.436	0.531	1.218	1.201
26-Sep-17	0.409	0.543	1.328	1.213
12-Oct-17	0.397	0.541	1.363	1.293

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
20-Oct-17	0.399	0.531	1.331	1.342
28-Oct-17	0.425	0.532	1.252	1.334
13-Nov-17	0.409	0.541	1.323	1.276
29-Nov-17	0.424	0.545	1.285	1.309
15-Dec-17	0.377	0.535	1.419	1.292
23-Dec-17	0.407	0.525	1.290	1.381
31-Dec-17	0.424	0.534	1.259	1.317
8-Jan-18	0.49	0.555	1.133	1.277
16-Jan-18	0.49	0.545	1.112	1.176
1-Feb-18	0.237	0.538	2.270	1.131
9-Feb-18	0.266	0.528	1.985	1.928
17-Feb-18	0.323	0.547	1.693	1.968
5-Mar-18	0.325	0.528	1.625	1.776
21-Mar-18	0.338	0.534	1.580	1.670
29-Mar-18	0.31	0.412	1.329	1.607
6-Apr-18	0.454	0.542	1.194	1.412
14-Apr-18	0.476	0.532	1.118	1.259
22-Apr-18	0.422	0.495	1.173	1.160
30-Apr-18	0.462	0.548	1.186	1.169
8-May-18	0.435	0.547	1.257	1.181
16-May-18	0.463	0.507	1.095	1.235
24-May-18	0.451	0.544	1.206	1.137
1-Jun-18	0.456	0.536	1.175	1.185
9-Jun-18	0.474	0.505	1.065	1.178
17-Jun-18	0.448	0.531	1.185	1.099
25-Jun-18	0.467	0.527	1.128	1.159
3-Jul-18	0.573	0.597	1.042	1.138
11-Jul-18	0.478	0.542	1.134	1.071
19-Jul-18	0.444	0.54	1.216	1.115
27-Jul-18	0.5	0.551	1.102	1.186
28-Aug-18	0.4	0.536	1.340	1.127
13-Sep-18	0.495	0.555	1.121	1.276
29-Sep-18	0.433	0.536	1.238	1.168
7-Oct-18	0.572	0.592	1.035	1.217
15-Oct-18	0.429	0.535	1.247	1.090
23-Oct-18	0.417	0.514	1.233	1.200
31-Oct-18	0.291	0.347	1.192	1.223
8-Nov-18	0.412	0.532	1.291	1.202
16-Nov-18	0.541	0.634	1.172	1.264
2-Dec-18	0.399	0.539	1.351	1.200

Date	Location M	Location C	C/M	C/M*
18-Dec-18	0.36	0.546	1.517	1.306
26-Dec-18	0.4	0.535	1.338	1.453
3-Jan-19	0.408	0.489	1.199	1.372
11-Jan-19	0.415	0.535	1.289	1.251
19-Jan-19	0.407	0.544	1.337	1.278
27-Jan-19	0.415	0.532	1.282	1.319
20-Feb-19	0.489	0.45	0.920	1.293
28-Feb-19	0.417	0.529	1.269	1.032
8-Mar-19	0.523	0.435	0.832	1.198
16-Mar-19	0.451	0.549	1.217	0.942
1-Apr-19	0.531	0.598	1.126	1.135
9-Apr-19	0.372	0.566	1.522	1.129
17-Apr-19	0.419	0.571	1.363	1.404
25-Apr-19	0.463	0.446	0.963	1.375
3-May-19	0.414	0.502	1.213	1.087
11-May-19	0.363	0.534	1.471	1.175
27-May-19	0.33	0.566	1.715	1.382
12-Jun-19	0.358	0.561	1.567	1.615
20-Jun-19	0.33	0.552	1.673	1.582
28-Jun-19	0.292	0.558	1.911	1.645
6-Jul-19	0.387	0.55	1.421	1.831
14-Jul-19	0.284	0.552	1.944	1.544
22-Jul-19	0.368	0.538	1.462	1.824
30-Jul-19	0.326	0.55	1.687	1.571
7-Aug-19	0.44	0.545	1.239	1.652
15-Aug-19	0.319	0.544	1.705	1.363
31-Aug-19	0.366	0.552	1.508	1.603
16-Sep-19	0.257	0.547	2.128	1.536
24-Sep-19	0.308	0.537	1.744	1.951
2-Oct-19	0.286	0.534	1.867	1.806
18-Oct-19	0.253	0.539	2.130	1.849
26-Oct-19	0.324	0.525	1.620	2.046
3-Nov-19	0.274	0.524	1.912	1.748
11-Nov-19	0.299	0.533	1.783	1.863
19-Nov-19	0.341	0.428	1.255	1.807
5-Dec-19	0.227	0.533	2.348	1.421
29-Dec-19	0.265	0.528	1.992	2.070
6-Jan-20	0.226	0.508	2.248	2.016
14-Jan-20	0.415	0.408	0.983	2.178
22-Jan-20	0.58	0.405	0.698	1.342

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
30-Jan-20	0.332	0.521	1.569	0.891
7-Feb-20	0.374	0.538	1.439	1.366
15-Feb-20	0.323	0.54	1.672	1.417
23-Feb-20	0.497	0.537	1.080	1.595
2-Mar-20	0.468	0.542	1.158	1.235
10-Mar-20	0.445	0.544	1.222	1.181
18-Mar-20	0.41	0.534	1.302	1.210
3-Apr-20	0.441	0.522	1.184	1.275
11-Apr-20	0.494	0.561	1.136	1.211
27-Apr-20	0.443	0.508	1.147	1.158
5-May-20	0.381	0.506	1.328	1.150
13-May-20	0.395	0.528	1.337	1.275
21-May-20	0.438	0.538	1.228	1.318
29-May-20	0.361	0.539	1.493	1.255
6-Jun-20	0.352	0.53	1.506	1.422
14-Jun-20	0.285	0.541	1.898	1.480
30-Jun-20	0.297	0.558	1.879	1.773
16-Jul-20	0.257	0.541	2.105	1.847
24-Jul-20	0.296	0.537	1.814	2.028
1-Aug-20	0.261	0.548	2.100	1.878
9-Aug-20	0.315	0.515	1.635	2.033
17-Aug-20	0.281	0.542	1.929	1.754
25-Aug-20	0.377	0.536	1.422	1.876
2-Sep-20	0.236	0.542	2.297	1.558
10-Sep-20	0.324	0.533	1.645	2.075
18-Sep-20	0.296	0.547	1.848	1.774
26-Sep-20	0.293	0.54	1.843	1.826
4-Oct-20	0.232	0.541	2.332	1.838
12-Oct-20	0.317	0.539	1.700	2.184
20-Oct-20	0.23	0.536	2.330	1.845
28-Oct-20	0.325	0.538	1.655	2.185
21-Nov-20	0.244	0.528	2.164	1.814
29-Nov-20	0.253	0.52	2.055	2.059
23-Dec-20	0.211	0.53	2.512	2.056
8-Jan-21	0.268	0.533	1.989	2.375
24-Jan-21	0.218	0.536	2.459	2.105
1-Feb-21	0.294	0.529	1.799	2.353
9-Feb-21	0.248	0.534	2.153	1.965
5-Mar-21	0.289	0.541	1.872	2.097
21-Mar-21	0.312	0.539	1.728	1.939

Khwabgah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
29-Mar-21	0.418	0.554	1.325	1.791
30-Apr-21	0.498	0.568	1.141	1.465
8-May-21	0.38	0.527	1.387	1.238
16-May-21	0.401	0.536	1.337	1.342
1-Jun-21	0.332	0.538	1.620	1.338
9-Jun-21	0.397	0.532	1.340	1.536
17-Jun-21	0.32	0.541	1.691	1.399
25-Jun-21	0.344	0.533	1.549	1.603
3-Jul-21	0.302	0.533	1.765	1.566
11-Jul-21	0.374	0.54	1.444	1.705
19-Jul-21	0.303	0.536	1.769	1.522
27-Jul-21	0.581	0.593	1.021	1.695
4-Aug-21	0.279	0.539	1.932	1.223
20-Aug-21	0.264	0.526	1.992	1.719
28-Aug-21	0.33	0.534	1.618	1.910
5-Sep-21	0.39	0.548	1.405	1.706
21-Sep-21	0.278	0.546	1.964	1.495
7-Oct-21	0.295	0.536	1.817	1.823
15-Oct-21	0.4	0.56	1.400	1.819
23-Oct-21	0.235	0.534	2.272	1.526
31-Oct-21	0.298	0.524	1.758	2.048
8-Nov-21	0.251	0.532	2.120	1.845
16-Nov-21	0.237	0.527	2.224	2.037
24-Nov-21	0.281	0.522	1.858	2.168
10-Dec-21	0.255	0.53	2.078	1.951
18-Dec-21	0.291	0.527	1.811	2.040
26-Dec-21	0.218	0.533	2.445	1.880

Dakah Station C and M SR Time Series

Date	Location M	Location C	C/M	C/M*
4-Jan-88	0.333	0.434	1.303303303	
8-Mar-88	0.284	0.317	1.116197183	1.303303303
31-Mar-88	0.284	0.381	1.341549296	1.172329019
2-May-88	0.34	0.387	1.138235294	1.290783213
18-May-88	0.33	0.4	1.212121212	1.18399967
12-Jun-88	0.297	0.407	1.37037037	1.203684749
19-Jun-88	0.368	0.415	1.127717391	1.320364684
28-Jun-88	0.366	0.419	1.144808743	1.185511579
5-Jul-88	0.366	0.414	1.131147541	1.157019594
21-Jul-88	0.357	0.389	1.089635854	1.138909157
30-Jul-88	0.348	0.419	1.204022989	1.104417845
6-Aug-88	0.335	0.378	1.128358209	1.174141445
15-Aug-88	0.351	0.423	1.205128205	1.14209318
22-Aug-88	0.348	0.4	1.149425287	1.186217698
31-Aug-88	0.307	0.402	1.309446254	1.16046301
7-Sep-88	0.309	0.423	1.368932039	1.264751281
9-Oct-88	0.264	0.406	1.537878788	1.337677811
18-Oct-88	0.257	0.424	1.649805447	1.477818495
25-Oct-88	0.274	0.397	1.448905109	1.598209362
3-Nov-88	0.264	0.414	1.568181818	1.493696385
10-Nov-88	0.275	0.408	1.483636364	1.545836188
19-Nov-88	0.26	0.422	1.623076923	1.502296311
5-Dec-88	0.261	0.409	1.567049808	1.586842739
12-Dec-88	0.256	0.396	1.546875	1.572987688
22-Jan-89	0.24	0.391	1.629166667	1.554708806
29-Jan-89	0.361	0.447	1.238227147	1.606829309
7-Feb-89	0.249	0.403	1.618473896	1.348807795
11-Mar-89	0.268	0.403	1.503731343	1.537574066
3-Apr-89	0.497	0.343	0.690140845	1.51388416
12-Apr-89	0.267	0.415	1.554307116	0.93726384
14-May-89	0.297	0.413	1.390572391	1.369194133
30-May-89	0.305	0.419	1.373770492	1.384158913
3-Sep-89	0.278	0.414	1.489208633	1.376887018
5-Oct-89	0.271	0.414	1.527675277	1.455512149
21-Oct-89	0.286	0.419	1.465034965	1.506026338
25-Jan-90	0.27	0.388	1.437037037	1.477332377
10-Feb-90	0.255	0.373	1.462745098	1.449125639
26-Feb-90	0.4	0.444	1.11	1.45865926
14-Mar-90	0.306	0.418	1.366013072	1.214597778

Date	Location M	Location C	C/M	C/M*
17-May-90	0.329	0.413	1.255319149	1.320588484
24-May-90	0.318	0.422	1.327044025	1.274899949
2-Jun-90	0.29	0.425	1.465517241	1.311400802
18-Jun-90	0.283	0.433	1.530035336	1.41928231
21-Aug-90	0.329	0.422	1.282674772	1.496809428
6-Sep-90	0.345	0.433	1.255072464	1.346915169
8-Oct-90	0.321	0.419	1.30529595	1.282625275
24-Oct-90	0.3	0.387	1.29	1.298494748
2-Dec-90	0.289	0.401	1.387543253	1.292548424
18-Dec-90	0.336	0.39	1.160714286	1.359044804
19-Jan-91	0.283	0.383	1.35335689	1.220213441
4-Feb-91	0.531	0.556	1.047080979	1.313413856
20-Feb-91	0.301	0.377	1.252491694	1.126980842
1-Mar-91	0.299	0.395	1.321070234	1.214838439
24-Mar-91	0.299	0.34	1.137123746	1.289200695
9-Apr-91	0.348	0.341	0.979885057	1.182746831
18-Apr-91	0.286	0.386	1.34965035	1.040743589
4-May-91	0.343	0.42	1.224489796	1.256978322
20-May-91	0.288	0.363	1.260416667	1.234236354
5-Jun-91	0.31	0.403	1.3	1.252562573
12-Jun-91	0.348	0.401	1.152298851	1.285768772
7-Jul-91	0.304	0.421	1.384868421	1.192339827
23-Jul-91	0.315	0.407	1.292063492	1.327109843
8-Aug-91	0.333	0.406	1.219219219	1.302577397
15-Aug-91	0.363	0.419	1.154269972	1.244226673
31-Aug-91	0.336	0.392	1.166666667	1.181256983
9-Sep-91	0.331	0.403	1.217522659	1.171043761
25-Sep-91	0.31	0.4	1.290322581	1.203578989
27-Oct-91	0.282	0.387	1.372340426	1.264299503
12-Nov-91	0.339	0.404	1.191740413	1.339928149
30-Dec-91	0.285	0.363	1.273684211	1.236196734
15-Jan-92	0.326	0.405	1.242331288	1.262437967
7-Feb-92	0.294	0.367	1.24829932	1.248363292
16-Feb-92	0.279	0.367	1.315412186	1.248318511
3-Mar-92	0.33	0.392	1.187878788	1.295284084
6-May-92	0.33	0.407	1.233333333	1.220100377
7-Jun-92	0.309	0.418	1.352750809	1.229363446
23-Jun-92	0.326	0.422	1.294478528	1.3157346
9-Jul-92	0.361	0.44	1.218836565	1.300855349
26-Aug-92	0.327	0.417	1.275229358	1.2434422

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
27-Sep-92	0.272	0.407	1.496323529	1.265693211
29-Oct-92	0.279	0.397	1.422939068	1.427134434
14-Nov-92	0.275	0.39	1.418181818	1.424197678
30-Nov-92	0.272	0.387	1.422794118	1.419986576
16-Dec-92	0.246	0.288	1.170731707	1.421951855
8-Jan-93	0.292	0.442	1.51369863	1.246097752
17-Jan-93	0.254	0.344	1.354330709	1.433418367
24-Jan-93	0.265	0.383	1.445283019	1.378057006
2-Feb-93	0.279	0.403	1.444444444	1.425115215
9-Feb-93	0.38	0.43	1.131578947	1.438645676
29-Mar-93	0.28	0.377	1.346428571	1.223698966
9-May-93	0.299	0.384	1.284280936	1.30960969
25-May-93	0.501	0.526	1.0499002	1.291879562
10-Jun-93	0.287	0.396	1.379790941	1.122494008
17-Jun-93	0.335	0.389	1.16119403	1.302601861
3-Jul-93	0.345	0.4	1.15942029	1.203616379
12-Jul-93	0.317	0.402	1.268138801	1.172679117
19-Jul-93	0.337	0.388	1.151335312	1.239500896
28-Jul-93	0.309	0.399	1.291262136	1.177784987
4-Aug-93	0.344	0.39	1.13372093	1.257218991
20-Aug-93	0.319	0.384	1.203761755	1.170770349
21-Sep-93	0.311	0.391	1.257234727	1.193864333
30-Sep-93	0.306	0.4	1.307189542	1.238223609
16-Oct-93	0.296	0.406	1.371621622	1.286499762
23-Oct-93	0.32	0.399	1.246875	1.346085064
8-Nov-93	0.313	0.338	1.079872204	1.276638019
17-Nov-93	0.313	0.39	1.24600639	1.138901949
24-Nov-93	0.317	0.387	1.220820189	1.213875058
3-Dec-93	0.319	0.439	1.376175549	1.21873665
10-Dec-93	0.302	0.396	1.311258278	1.328943879
19-Dec-93	0.295	0.375	1.271186441	1.316563958
26-Dec-93	0.304	0.411	1.351973684	1.284799696
4-Jan-94	0.519	0.542	1.044315992	1.331821488
11-Jan-94	0.296	0.376	1.27027027	1.130567641
27-Jan-94	0.305	0.351	1.150819672	1.228359481
12-Feb-94	0.306	0.391	1.277777778	1.174081615
9-Mar-94	0.533	0.585	1.097560976	1.246668929
10-Apr-94	0.296	0.394	1.331081081	1.142293362
26-Apr-94	0.296	0.398	1.344594595	1.274444765
28-May-94	0.282	0.387	1.372340426	1.323549646

Date	Location M	Location C	C/M	C/M*
13-Jun-94	0.294	0.399	1.357142857	1.357703192
29-Jun-94	0.334	0.404	1.209580838	1.357310957
15-Jul-94	0.357	0.41	1.148459384	1.253899874
16-Aug-94	0.348	0.441	1.267241379	1.180091531
1-Sep-94	0.341	0.445	1.304985337	1.241096425
3-Oct-94	0.289	0.416	1.439446367	1.285818664
11-Nov-94	0.291	0.397	1.364261168	1.393358056
20-Nov-94	0.311	0.397	1.276527331	1.372990235
27-Nov-94	0.31	0.394	1.270967742	1.305466202
7-Jan-95	0.37	0.426	1.151351351	1.28131728
15-Feb-95	0.312	0.358	1.147435897	1.19034113
24-Feb-95	0.32	0.395	1.234375	1.160307467
12-Mar-95	0.325	0.399	1.227692308	1.21215474
13-Apr-95	0.316	0.395	1.25	1.223031037
15-May-95	0.294	0.398	1.353741497	1.241909311
31-May-95	0.264	0.361	1.367424242	1.320191841
16-Jun-95	0.306	0.404	1.320261438	1.353254522
2-Jul-95	0.296	0.397	1.341216216	1.330159363
18-Jul-95	0.332	0.409	1.231927711	1.33789916
3-Aug-95	0.422	0.429	1.016587678	1.263719146
6-Oct-95	0.267	0.395	1.479400749	1.090727118
22-Oct-95	0.257	0.387	1.505836576	1.36279866
7-Nov-95	0.275	0.394	1.432727273	1.462925201
23-Nov-95	0.279	0.384	1.376344086	1.441786651
9-Dec-95	0.276	0.366	1.326086957	1.395976856
16-Dec-95	0.278	0.37	1.330935252	1.347053926
25-Dec-95	0.281	0.391	1.391459075	1.335770854
1-Jan-96	0.288	0.371	1.288194444	1.374752609
10-Jan-96	0.274	0.39	1.423357664	1.314161894
17-Jan-96	0.264	0.324	1.227272727	1.390598933
2-Feb-96	0.258	0.366	1.418604651	1.276270589
11-Feb-96	0.272	0.334	1.227941176	1.375904433
18-Feb-96	0.273	0.358	1.311355311	1.272330153
27-Feb-96	0.403	0.486	1.205955335	1.299647764
5-Mar-96	0.413	0.462	1.118644068	1.234063064
21-Mar-96	0.273	0.34	1.245421245	1.153269767
30-Mar-96	0.264	0.382	1.446969697	1.217775802
6-Apr-96	0.288	0.342	1.1875	1.378211528
15-Apr-96	0.298	0.398	1.33557047	1.244713459
22-Apr-96	0.305	0.362	1.186885246	1.308313366

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
1-May-96	0.284	0.378	1.330985915	1.223313682
8-May-96	0.536	0.454	0.847014925	1.298684245
17-May-96	0.259	0.382	1.474903475	0.982515721
9-Jun-96	0.355	0.394	1.109859155	1.327187149
18-Jun-96	0.355	0.402	1.132394366	1.175057553
25-Jun-96	0.329	0.381	1.158054711	1.145193322
4-Jul-96	0.32	0.394	1.23125	1.154196295
11-Jul-96	0.339	0.384	1.132743363	1.208133888
20-Jul-96	0.313	0.414	1.322683706	1.15536052
27-Jul-96	0.341	0.41	1.202346041	1.27248675
5-Aug-96	0.34	0.421	1.238235294	1.223388254
12-Aug-96	0.365	0.411	1.126027397	1.233781182
21-Aug-96	0.332	0.419	1.262048193	1.158353533
28-Aug-96	0.325	0.398	1.224615385	1.230939795
6-Sep-96	0.341	0.427	1.252199413	1.226512708
22-Sep-96	0.299	0.406	1.357859532	1.244493402
29-Sep-96	0.297	0.402	1.353535354	1.323849693
8-Oct-96	0.294	0.401	1.363945578	1.344629655
15-Oct-96	0.292	0.391	1.339041096	1.358150801
24-Oct-96	0.292	0.392	1.342465753	1.344774008
31-Oct-96	0.299	0.395	1.321070234	1.34315823
9-Nov-96	0.297	0.394	1.326599327	1.327696633
16-Nov-96	0.314	0.409	1.302547771	1.326928518
2-Dec-96	0.502	0.423	0.842629482	1.309861995
11-Dec-96	0.266	0.369	1.387218045	0.982799236
18-Dec-96	0.279	0.34	1.218637993	1.265892402
27-Dec-96	0.275	0.379	1.378181818	1.232814316
12-Jan-97	0.296	0.386	1.304054054	1.334571567
28-Jan-97	0.368	0.415	1.127717391	1.313209308
4-Feb-97	0.257	0.342	1.3307393	1.183364966
13-Feb-97	0.284	0.399	1.404929577	1.286527
24-Mar-97	0.299	0.391	1.307692308	1.369408804
9-Apr-97	0.301	0.372	1.235880399	1.326207257
25-Apr-97	0.312	0.389	1.246794872	1.262978456
20-May-97	0.256	0.39	1.5234375	1.251649947
27-May-97	0.332	0.387	1.165662651	1.441901234
5-Jun-97	0.283	0.376	1.328621908	1.248534226
12-Jun-97	0.335	0.392	1.170149254	1.304595603
21-Jun-97	0.345	0.414	1.2	1.210483159
28-Jun-97	0.359	0.401	1.116991643	1.203144948

Date	Location M	Location C	C/M	C/M*
7-Jul-97	0.327	0.408	1.247706422	1.142837635
14-Jul-97	0.401	0.445	1.109725686	1.216245786
23-Jul-97	0.355	0.409	1.152112676	1.141681716
8-Aug-97	0.349	0.406	1.163323782	1.148983388
15-Aug-97	0.335	0.442	1.319402985	1.159021664
24-Aug-97	0.33	0.393	1.190909091	1.271288589
31-Aug-97	0.321	0.386	1.202492212	1.21502294
9-Sep-97	0.378	0.473	1.251322751	1.20625143
16-Sep-97	0.356	0.404	1.134831461	1.237801355
25-Sep-97	0.298	0.395	1.325503356	1.165722429
2-Oct-97	0.297	0.389	1.30976431	1.277569078
11-Oct-97	0.29	0.399	1.375862069	1.30010574
27-Oct-97	0.503	0.498	0.990059642	1.35313517
19-Nov-97	0.272	0.388	1.426470588	1.098982301
28-Nov-97	0.248	0.331	1.334677419	1.328224102
5-Dec-97	0.249	0.352	1.413654618	1.332741424
21-Dec-97	0.241	0.359	1.489626556	1.38938066
22-Jan-98	0.354	0.424	1.197740113	1.459552787
7-Feb-98	0.269	0.356	1.323420074	1.276283915
4-Mar-98	0.596	0.439	0.736577181	1.309279227
5-Apr-98	0.371	0.442	1.191374663	0.908387795
12-Apr-98	0.317	0.369	1.164037855	1.106478603
21-Apr-98	0.296	0.386	1.304054054	1.146770079
28-Apr-98	0.343	0.377	1.099125364	1.256868862
7-May-98	0.528	0.454	0.859848485	1.146448414
14-May-98	0.317	0.378	1.192429022	0.945828463
23-May-98	0.297	0.392	1.31986532	1.118448854
30-May-98	0.33	0.385	1.166666667	1.25944038
8-Jun-98	0.342	0.448	1.30994152	1.194498781
15-Jun-98	0.337	0.383	1.136498516	1.275308699
1-Jul-98	0.361	0.387	1.072022161	1.178141571
10-Jul-98	0.355	0.401	1.129577465	1.103857984
17-Jul-98	0.361	0.39	1.08033241	1.12186162
26-Jul-98	0.342	0.405	1.184210526	1.092791173
2-Aug-98	0.357	0.393	1.100840336	1.15678472
11-Aug-98	0.32	0.393	1.228125	1.117623651
18-Aug-98	0.334	0.378	1.131736527	1.194974595
27-Aug-98	0.311	0.388	1.247588424	1.150707947
3-Sep-98	0.376	0.36	0.957446809	1.218524281
12-Sep-98	0.318	0.396	1.245283019	1.03577005

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
19-Sep-98	0.285	0.376	1.319298246	1.182429128
28-Sep-98	0.278	0.38	1.366906475	1.27823751
5-Oct-98	0.333	0.396	1.189189189	1.340305786
14-Oct-98	0.278	0.386	1.388489209	1.234524168
21-Oct-98	0.267	0.376	1.4082397	1.342299696
30-Oct-98	0.266	0.392	1.473684211	1.388457699
6-Nov-98	0.309	0.381	1.233009709	1.448116257
15-Nov-98	0.258	0.386	1.496124031	1.297541673
22-Nov-98	0.253	0.382	1.509881423	1.436549324
1-Dec-98	0.281	0.387	1.377224199	1.487881793
8-Dec-98	0.261	0.393	1.505747126	1.410421477
17-Dec-98	0.277	0.398	1.436823105	1.477149432
24-Dec-98	0.285	0.393	1.378947368	1.448921003
18-Jan-99	0.255	0.373	1.462745098	1.399939459
25-Jan-99	0.258	0.329	1.275193798	1.443903406
3-Feb-99	0.248	0.347	1.399193548	1.325806681
19-Feb-99	0.318	0.362	1.13836478	1.377177488
23-Mar-99	0.269	0.394	1.464684015	1.210008592
30-Mar-99	0.327	0.417	1.275229358	1.388281388
8-Apr-99	0.268	0.395	1.473880597	1.309144967
15-Apr-99	0.317	0.375	1.1829653	1.424459908
24-Apr-99	0.271	0.389	1.435424354	1.255413682
10-May-99	0.276	0.396	1.434782609	1.381421153
26-May-99	0.296	0.398	1.344594595	1.418774172
2-Jun-99	0.331	0.389	1.175226586	1.366848468
18-Jun-99	0.383	0.415	1.083550914	1.232713151
14-Aug-99	0.329	0.449	1.364741641	1.128299585
30-Aug-99	0.328	0.416	1.268292683	1.293809024
6-Sep-99	0.336	0.417	1.241071429	1.275947585
22-Sep-99	0.35	0.439	1.254285714	1.251534276
17-Oct-99	0.297	0.45	1.515151515	1.253460283
25-Nov-99	0.247	0.378	1.530364372	1.436644145
4-Dec-99	0.26	0.39	1.5	1.502248304
11-Dec-99	0.258	0.364	1.410852713	1.500674491
20-Dec-99	0.252	0.404	1.603174603	1.437799247
21-Jan-00	0.335	0.436	1.301492537	1.553561996
5-Feb-00	0.267	0.374	1.400749064	1.377113375
6-Feb-00	0.281	0.38	1.352313167	1.393658357
14-Feb-00	0.261	0.38	1.455938697	1.364716724
22-Feb-00	0.266	0.398	1.496240602	1.428572105

Date	Location M	Location C	C/M	C/M*
1-Mar-00	0.27	0.393	1.455555556	1.475940053
8-Mar-00	0.275	0.38	1.381818182	1.461670905
9-Mar-00	0.263	0.391	1.486692015	1.405773999
16-Mar-00	0.297	0.393	1.323232323	1.46241661
17-Mar-00	0.27	0.392	1.451851852	1.364987609
25-Mar-00	0.584	0.605	1.035958904	1.425792579
9-Apr-00	0.282	0.39	1.382978723	1.152909007
10-Apr-00	0.27	0.399	1.477777778	1.313957808
17-Apr-00	0.319	0.383	1.200626959	1.428631787
18-Apr-00	0.274	0.394	1.437956204	1.269028408
11-May-00	0.351	0.386	1.0997151	1.387277865
12-May-00	0.342	0.399	1.166666667	1.185983929
20-May-00	0.286	0.406	1.41958042	1.172461845
27-May-00	0.351	0.4	1.13960114	1.345444847
28-May-00	0.311	0.412	1.324758842	1.201354252
4-Jun-00	0.323	0.389	1.204334365	1.287737465
13-Jun-00	0.308	0.407	1.321428571	1.229355295
20-Jun-00	0.382	0.416	1.089005236	1.293806589
21-Jun-00	0.319	0.406	1.272727273	1.150445641
29-Jun-00	0.413	0.435	1.053268765	1.236042783
6-Jul-00	0.371	0.405	1.091644205	1.108100971
30-Jul-00	0.393	0.414	1.053435115	1.096581235
7-Aug-00	0.387	0.45	1.162790698	1.066378951
16-Aug-00	0.358	0.413	1.153631285	1.133867174
23-Aug-00	0.336	0.392	1.166666667	1.147702052
24-Aug-00	0.322	0.393	1.220496894	1.160977282
1-Sep-00	0.345	0.414	1.2	1.202641011
17-Sep-00	0.314	0.398	1.267515924	1.200792303
24-Sep-00	0.334	0.428	1.281437126	1.247498837
10-Oct-00	0.302	0.446	1.476821192	1.271255639
11-Oct-00	0.291	0.437	1.501718213	1.415151526
18-Oct-00	0.274	0.425	1.551094891	1.475748207
19-Oct-00	0.28	0.43	1.535714286	1.528490885
26-Oct-00	0.251	0.455	1.812749004	1.533547266
19-Nov-00	0.255	0.424	1.662745098	1.728988482
20-Nov-00	0.267	0.438	1.640449438	1.682618113
27-Nov-00	0.291	0.413	1.419243986	1.653100041
28-Nov-00	0.277	0.423	1.527075812	1.489400803
13-Dec-00	0.251	0.419	1.669322709	1.515773309
22-Dec-00	0.26	0.408	1.569230769	1.623257889

Date	Location M	Location C	C/M	C/M*
30-Dec-00	0.247	0.384	1.55465587	1.585438905
7-Jan-01	0.301	0.408	1.355481728	1.563890781
15-Jan-01	0.254	0.408	1.606299213	1.418004444
23-Jan-01	0.253	0.413	1.632411067	1.549810782
8-Feb-01	0.251	0.414	1.64940239	1.607630982
15-Feb-01	0.263	0.403	1.532319392	1.636870968
24-Feb-01	0.277	0.404	1.458483755	1.563684864
4-Mar-01	0.272	0.42	1.544117647	1.490044088
11-Mar-01	0.323	0.428	1.325077399	1.527895579
12-Apr-01	0.331	0.413	1.247734139	1.385922853
20-Apr-01	0.306	0.35	1.14379085	1.289190753
21-Apr-01	0.284	0.402	1.415492958	1.187410821
6-May-01	0.304	0.434	1.427631579	1.347068317
15-May-01	0.306	0.435	1.421568627	1.4034626
22-May-01	0.336	0.407	1.211309524	1.416136819
23-May-01	0.3	0.421	1.403333333	1.272757712
31-May-01	0.33	0.433	1.312121212	1.364160647
16-Jun-01	0.336	0.42	1.25	1.327733043
2-Jul-01	0.364	0.434	1.192307692	1.273319913
18-Jul-01	0.346	0.423	1.222543353	1.216611358
3-Aug-01	0.375	0.445	1.186666667	1.220763754
11-Aug-01	0.357	0.432	1.210084034	1.196895793
19-Aug-01	0.351	0.471	1.341880342	1.206127561
27-Aug-01	0.344	0.457	1.328488372	1.301154508
4-Sep-01	0.402	0.478	1.189054726	1.320288213
27-Sep-01	0.303	0.446	1.471947195	1.228424772
28-Sep-01	0.273	0.453	1.659340659	1.398890468
6-Oct-01	0.303	0.448	1.478547855	1.581205602
22-Oct-01	0.33	0.444	1.345454545	1.509345179
29-Oct-01	0.338	0.425	1.25739645	1.394621735
6-Nov-01	0.274	0.409	1.49270073	1.298564035
7-Nov-01	0.275	0.427	1.552727273	1.434459722
14-Nov-01	0.248	0.424	1.709677419	1.517247007
23-Nov-01	0.246	0.444	1.804878049	1.651948296
9-Dec-01	0.244	0.438	1.795081967	1.758999123
25-Dec-01	0.303	0.459	1.514851485	1.784257114
2-Jan-02	0.257	0.417	1.622568093	1.595673174
18-Jan-02	0.258	0.411	1.593023256	1.614499618
26-Jan-02	0.253	0.422	1.66798419	1.599466164
10-Feb-02	0.268	0.338	1.26119403	1.647428782

Date	Location M	Location C	C/M	C/M*
11-Feb-02	0.252	0.355	1.408730159	1.377064456
27-Feb-02	0.256	0.344	1.34375	1.399230448
15-Mar-02	0.251	0.415	1.653386454	1.360394134
23-Mar-02	0.408	0.491	1.203431373	1.565488758
8-Apr-02	0.377	0.467	1.23872679	1.312048588
24-Apr-02	0.443	0.627	1.415349887	1.26072333
18-May-02	0.342	0.447	1.307017544	1.36896192
11-Jun-02	0.327	0.425	1.29969419	1.325600857
19-Jun-02	0.354	0.409	1.155367232	1.30746619
21-Jul-02	0.375	0.487	1.298666667	1.200996919
6-Aug-02	0.35	0.47	1.342857143	1.269365742
30-Aug-02	0.367	0.465	1.267029973	1.320809723
15-Sep-02	0.292	0.44	1.506849315	1.283163898
25-Nov-02	0.247	0.4	1.619433198	1.43974369
27-Dec-02	0.252	0.337	1.337301587	1.565526346
5-Jan-03	0.247	0.387	1.566801619	1.405769015
12-Jan-03	0.251	0.381	1.517928287	1.518491838
28-Jan-03	0.254	0.383	1.507874016	1.518097352
22-Feb-03	0.263	0.35	1.330798479	1.510941017
10-Mar-03	0.249	0.339	1.361445783	1.38484124
17-Mar-03	0.317	0.276	0.870662461	1.36846442
27-Apr-03	0.315	0.403	1.279365079	1.020003048
4-May-03	0.311	0.416	1.337620579	1.20155647
13-May-03	0.295	0.371	1.257627119	1.296801346
20-May-03	0.324	0.402	1.240740741	1.269379387
29-May-03	0.34	0.428	1.258823529	1.249332335
1-Aug-03	0.408	0.617	1.512254902	1.255976171
17-Aug-03	0.538	0.553	1.027881041	1.435371283
24-Aug-03	0.336	0.412	1.226190476	1.150128113
2-Sep-03	0.314	0.411	1.308917197	1.203371767
18-Sep-03	0.354	0.459	1.296610169	1.277253568
28-Nov-03	0.243	0.417	1.716049383	1.290803189
24-Jan-04	0.264	0.323	1.223484848	1.588475525
3-Mar-04	0.274	0.398	1.452554745	1.332982051
12-Mar-04	0.288	0.412	1.430555556	1.416682937
13-Apr-04	0.285	0.413	1.449122807	1.42639377
16-Jun-04	0.358	0.424	1.184357542	1.442304096
23-Jun-04	0.354	0.42	1.186440678	1.261741508
2-Jul-04	0.352	0.431	1.224431818	1.209030927
25-Jul-04	0.359	0.418	1.164345404	1.219811551

Date	Location M	Location C	C/M	C/M*
20-Sep-04	0.321	0.396	1.23364486	1.180985248
7-Nov-04	0.26	0.393	1.511538462	1.217846976
9-Dec-04	0.247	0.385	1.558704453	1.423431016
10-Jan-05	0.247	0.36	1.457489879	1.518122422
22-Mar-05	0.313	0.831	2.654952077	1.475679642
2-May-05	0.369	0.41	1.111111111	2.301170346
9-May-05	0.342	0.346	1.011695906	1.468128882
3-Jun-05	0.281	0.397	1.412811388	1.148625799
5-Jul-05	0.31	0.413	1.332258065	1.333555711
12-Jul-05	0.38	0.436	1.147368421	1.332647359
6-Aug-05	0.315	0.427	1.355555556	1.202952102
13-Aug-05	0.347	0.347	1	1.30977452
22-Aug-05	0.332	0.409	1.231927711	1.092932356
29-Aug-05	0.361	0.408	1.130193906	1.190229104
23-Sep-05	0.296	0.405	1.368243243	1.148204465
9-Oct-05	0.29	0.401	1.382758621	1.30223161
12-Dec-05	0.247	0.378	1.530364372	1.358600517
28-Dec-05	0.269	0.38	1.412639405	1.478835216
5-May-06	0.292	0.406	1.390410959	1.432498148
21-May-06	0.315	0.444	1.40952381	1.403037116
6-Jun-06	0.297	0.435	1.464646465	1.407577801
29-Jun-06	0.371	0.416	1.121293801	1.447525866
8-Jul-06	0.334	0.41	1.22754491	1.21916342
15-Jul-06	0.356	0.402	1.129213483	1.225030463
31-Jul-06	0.343	0.398	1.160349854	1.157958577
10-Sep-06	0.318	0.384	1.20754717	1.159632471
19-Oct-06	0.276	0.372	1.347826087	1.19317276
22-Dec-06	0.249	0.325	1.305220884	1.301430089
1-Feb-07	0.263	0.375	1.425855513	1.304083645
8-Feb-07	0.266	0.374	1.406015038	1.389323953
5-Mar-07	0.255	0.343	1.345098039	1.401007712
22-Apr-07	0.325	0.408	1.255384615	1.361870941
9-Jun-07	0.28	0.406	1.45	1.287330513
18-Jul-07	0.359	0.39	1.086350975	1.401199154
19-Aug-07	0.368	0.402	1.092391304	1.180805429
28-Aug-07	0.323	0.401	1.241486068	1.118915542
4-Sep-07	0.33	0.402	1.218181818	1.20471491
13-Sep-07	0.324	0.404	1.24691358	1.214141746
23-Nov-07	0.272	0.398	1.463235294	1.23708203
19-Jan-08	0.261	0.347	1.329501916	1.395389315

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
11-Feb-08	0.251	0.361	1.438247012	1.349268135
16-Apr-08	0.34	0.347	1.020588235	1.411553349
23-Apr-08	0.313	0.386	1.233226837	1.137877769
17-May-08	0.336	0.396	1.178571429	1.204622117
18-May-08	0.316	0.418	1.32278481	1.186386635
25-May-08	0.397	0.397	1	1.281865358
26-May-08	0.344	0.4	1.162790698	1.084559607
3-Jun-08	0.33	0.404	1.224242424	1.139321371
10-Jun-08	0.365	0.391	1.071232877	1.198766108
19-Jun-08	0.346	0.411	1.187861272	1.109492846
26-Jun-08	0.377	0.403	1.068965517	1.164350744
27-Jun-08	0.355	0.413	1.163380282	1.097581085
5-Jul-08	0.375	0.42	1.12	1.143640523
13-Jul-08	0.341	0.396	1.161290323	1.127092157
29-Jul-08	0.345	0.412	1.194202899	1.151030873
13-Aug-08	0.377	0.425	1.127320955	1.181251291
30-Aug-08	0.331	0.427	1.290030211	1.143500056
15-Sep-08	0.306	0.42	1.37254902	1.246071165
9-Oct-08	0.348	0.386	1.109195402	1.334605663
17-Oct-08	0.264	0.387	1.465909091	1.176818481
25-Oct-08	0.283	0.396	1.399293286	1.379181908
2-Nov-08	0.274	0.383	1.397810219	1.393259873
17-Nov-08	0.415	0.395	0.951807229	1.396445115
18-Nov-08	0.279	0.377	1.35125448	1.085198595
26-Nov-08	0.257	0.366	1.424124514	1.271437715
4-Dec-08	0.261	0.369	1.413793103	1.378318474
12-Dec-08	0.243	0.375	1.543209877	1.403150715
19-Dec-08	0.317	0.389	1.227129338	1.501192128
20-Jan-09	0.259	0.325	1.254826255	1.309348175
21-Jan-09	0.273	0.354	1.296703297	1.271182831
6-Feb-09	0.245	0.329	1.342857143	1.289047157
14-Feb-09	0.523	0.418	0.799235182	1.326714147
21-Feb-09	0.275	0.368	1.338181818	0.957478871
2-Mar-09	0.307	0.365	1.188925081	1.223970934
9-Mar-09	0.323	0.331	1.024767802	1.199438837
25-Mar-09	0.304	0.334	1.098684211	1.077169112
3-Apr-09	0.301	0.378	1.255813953	1.092229681
10-Apr-09	0.46	0.464	1.008695652	1.206738672
18-Apr-09	0.338	0.41	1.213017751	1.068108558
19-Apr-09	0.328	0.442	1.347560976	1.169544993

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
26-Apr-09	0.388	0.444	1.144329897	1.294156181
12-May-09	0.332	0.4	1.204819277	1.189277782
13-May-09	0.281	0.404	1.43772242	1.200156829
21-May-09	0.325	0.409	1.258461538	1.366452743
28-May-09	0.328	0.409	1.24695122	1.2908589
6-Jun-09	0.311	0.38	1.221864952	1.260123524
13-Jun-09	0.33	0.42	1.272727273	1.233342523
22-Jun-09	0.275	0.428	1.556363636	1.260911848
29-Jun-09	0.364	0.423	1.162087912	1.4677281
8-Jul-09	0.35	0.457	1.305714286	1.253779968
15-Jul-09	0.353	0.433	1.226628895	1.290133991
24-Jul-09	0.316	0.441	1.39556962	1.245680424
31-Jul-09	0.343	0.409	1.192419825	1.350602861
1-Aug-09	0.323	0.426	1.318885449	1.239874736
9-Aug-09	0.356	0.437	1.22752809	1.295182235
16-Aug-09	0.351	0.427	1.216524217	1.247824333
17-Aug-09	0.345	0.442	1.28115942	1.225914252
25-Aug-09	0.327	0.43	1.314984709	1.26458587
1-Sep-09	0.348	0.395	1.135057471	1.299865058
10-Sep-09	0.288	0.426	1.479166667	1.184499747
17-Sep-09	0.287	0.409	1.425087108	1.390766591
26-Sep-09	0.323	0.422	1.306501548	1.414790953
3-Oct-09	0.313	0.453	1.447284345	1.338988369
4-Oct-09	0.376	0.355	0.944148936	1.414795552
11-Oct-09	0.28	0.438	1.564285714	1.085342921
12-Oct-09	0.278	0.445	1.600719424	1.420602876
19-Oct-09	0.281	0.442	1.572953737	1.54668446
4-Nov-09	0.466	0.548	1.175965665	1.565072954
13-Nov-09	0.24	0.402	1.675	1.292697852
20-Nov-09	0.248	0.396	1.596774194	1.560309356
29-Nov-09	0.244	0.394	1.614754098	1.585834742
6-Dec-09	0.251	0.393	1.565737052	1.606078291
7-Dec-09	0.271	0.398	1.468634686	1.577839424
15-Dec-09	0.246	0.397	1.613821138	1.501396108
8-Jan-10	0.268	0.401	1.496268657	1.580093629
16-Jan-10	0.454	0.531	1.169603524	1.521416148
23-Jan-10	0.265	0.395	1.490566038	1.275147311
9-Feb-10	0.247	0.336	1.360323887	1.42594042
24-Feb-10	0.351	0.46	1.310541311	1.380008847
5-Mar-10	0.269	0.383	1.423791822	1.331381571

Date	Location M	Location C	C/M	C/M*
12-Mar-10	0.304	0.404	1.328947368	1.396068747
13-Mar-10	0.287	0.397	1.383275261	1.349083782
20-Mar-10	0.336	0.419	1.24702381	1.373017817
6-Apr-10	0.262	0.385	1.469465649	1.284822012
14-Apr-10	0.301	0.391	1.299003322	1.414072558
21-Apr-10	0.362	0.348	0.961325967	1.333524093
29-Apr-10	0.307	0.384	1.250814332	1.072985405
16-May-10	0.312	0.427	1.368589744	1.197465654
24-May-10	0.303	0.429	1.415841584	1.317252517
8-Jun-10	0.331	0.401	1.211480363	1.386264864
9-Jun-10	0.307	0.418	1.361563518	1.263915713
16-Jun-10	0.367	0.415	1.130790191	1.332269176
25-Jun-10	0.58	0.402	0.693103448	1.191233886
2-Jul-10	0.359	0.412	1.147632312	0.84254258
3-Jul-10	0.32	0.421	1.315625	1.056105392
10-Jul-10	0.342	0.414	1.210526316	1.237769118
11-Jul-10	0.315	0.419	1.33015873	1.218699156
18-Jul-10	0.367	0.407	1.108991826	1.296720858
19-Jul-10	0.342	0.425	1.242690058	1.165310535
12-Aug-10	0.347	0.422	1.216138329	1.219476202
19-Aug-10	0.361	0.415	1.149584488	1.21713969
20-Aug-10	0.345	0.426	1.234782609	1.169851048
27-Aug-10	0.357	0.401	1.1232493	1.215303141
28-Aug-10	0.348	0.416	1.195402299	1.150865452
4-Sep-10	0.349	0.407	1.166189112	1.182041245
12-Sep-10	0.326	0.382	1.171779141	1.170944752
13-Sep-10	0.328	0.402	1.225609756	1.171528824
29-Sep-10	0.329	0.454	1.37993921	1.209385477
6-Oct-10	0.275	0.428	1.556363636	1.32877309
14-Oct-10	0.286	0.431	1.506993007	1.488086472
15-Oct-10	0.293	0.437	1.491467577	1.501321047
22-Oct-10	0.315	0.448	1.422222222	1.494423618
31-Oct-10	0.259	0.441	1.702702703	1.443882641
7-Nov-10	0.33	0.421	1.275757576	1.625056684
16-Nov-10	0.245	0.42	1.714285714	1.380547308
23-Nov-10	0.264	0.405	1.534090909	1.614164192
24-Nov-10	0.246	0.421	1.711382114	1.558112894
2-Dec-10	0.246	0.415	1.68699187	1.665401348
9-Dec-10	0.248	0.411	1.657258065	1.680514713
18-Dec-10	0.26	0.42	1.615384615	1.664235059

Date	Location M	Location C	C/M	C/M*
25-Dec-10	0.261	0.416	1.593869732	1.630039749
3-Jan-11	0.253	0.396	1.565217391	1.604720737
10-Jan-11	0.247	0.385	1.558704453	1.577068395
19-Jan-11	0.248	0.373	1.504032258	1.564213636
26-Jan-11	0.259	0.375	1.447876448	1.522086671
27-Feb-11	0.245	0.384	1.567346939	1.470139515
8-Mar-11	0.24	0.386	1.608333333	1.538184712
23-Mar-11	0.273	0.392	1.435897436	1.587288747
24-Mar-11	0.262	0.409	1.561068702	1.481314829
31-Mar-11	0.282	0.391	1.386524823	1.53714254
1-Apr-11	0.268	0.43	1.604477612	1.431710138
16-Apr-11	0.39	0.434	1.112820513	1.55264737
24-Apr-11	0.281	0.394	1.402135231	1.24476857
25-Apr-11	0.288	0.408	1.416666667	1.354925233
2-May-11	0.317	0.397	1.252365931	1.398144237
3-May-11	0.298	0.401	1.345637584	1.296099422
11-May-11	0.292	0.41	1.404109589	1.330776135
18-May-11	0.355	0.413	1.163380282	1.382109553
19-May-11	0.339	0.423	1.247787611	1.228999063
26-May-11	0.422	0.45	1.066350711	1.242151046
27-May-11	0.318	0.414	1.301886792	1.119090812
3-Jun-11	0.34	0.401	1.179411765	1.247047998
11-Jun-11	0.377	0.405	1.074270557	1.199702635
12-Jun-11	0.339	0.417	1.230088496	1.11190018
28-Jun-11	0.395	0.455	1.151898734	1.194632001
5-Jul-11	0.36	0.424	1.177777778	1.164718714
6-Jul-11	0.356	0.436	1.224719101	1.173860059
14-Jul-11	0.409	0.473	1.156479218	1.209461388
21-Jul-11	0.37	0.407	1.1	1.172373869
22-Jul-11	0.335	0.414	1.235820896	1.121712161
30-Jul-11	0.387	0.398	1.028423773	1.201588275
15-Aug-11	0.349	0.403	1.154727794	1.080373123
22-Aug-11	0.35	0.404	1.154285714	1.132421393
7-Sep-11	0.331	0.392	1.18429003	1.147726418
15-Sep-11	0.546	0.761	1.393772894	1.173320946
16-Sep-11	0.389	0.464	1.192802057	1.32763731
2-Oct-11	0.261	0.425	1.62835249	1.233252632
17-Oct-11	0.256	0.437	1.70703125	1.509822533
2-Nov-11	0.349	0.335	0.959885387	1.647868635
11-Nov-11	0.236	0.362	1.533898305	1.166280361

Date	Location M	Location C	C/M	C/M*
18-Nov-11	0.242	0.378	1.561983471	1.423612922
13-Dec-11	0.233	0.407	1.746781116	1.520472306
20-Dec-11	0.584	0.592	1.01369863	1.678888473
15-Feb-12	0.297	0.372	1.252525253	1.213255583
9-Mar-12	0.298	0.403	1.352348993	1.240744352
5-May-12	0.287	0.43	1.49825784	1.318867601
13-Jun-12	0.34	0.393	1.155882353	1.444440768
22-Jun-12	0.326	0.419	1.285276074	1.242449877
29-Jun-12	0.348	0.402	1.155172414	1.272428215
15-Jul-12	0.366	0.407	1.112021858	1.190349154
24-Jul-12	0.345	0.429	1.243478261	1.135520047
26-Sep-12	0.339	0.47	1.386430678	1.211090797
12-Oct-12	0.258	0.411	1.593023256	1.333828714
28-Oct-12	0.257	0.403	1.568093385	1.515264893
13-Nov-12	0.287	0.391	1.362369338	1.552244838
29-Nov-12	0.243	0.358	1.473251029	1.419331988
22-Dec-12	0.231	0.364	1.575757576	1.457075317
31-Dec-12	0.238	0.334	1.403361345	1.540152898
16-Jan-13	0.289	0.384	1.328719723	1.444398811
8-Feb-13	0.264	0.346	1.310606061	1.363423449
17-Feb-13	0.242	0.373	1.541322314	1.326451277
5-Mar-13	0.286	0.376	1.314685315	1.476861003
21-Mar-13	0.269	0.315	1.171003717	1.363338021
7-Apr-13	0.334	0.464	1.389221557	1.228704009
14-Apr-13	0.291	0.412	1.41580756	1.341066292
21-Apr-13	0.323	0.392	1.213622291	1.39338518
30-Apr-13	0.336	0.373	1.110119048	1.267551158
8-May-13	0.291	0.437	1.501718213	1.157348681
16-May-13	0.285	0.43	1.50877193	1.398407353
23-May-13	0.356	0.407	1.143258427	1.475662557
24-May-13	0.324	0.411	1.268518519	1.242979666
31-May-13	0.337	0.399	1.183976261	1.260856863
1-Jun-13	0.287	0.414	1.442508711	1.207040442
8-Jun-13	0.365	0.402	1.101369863	1.37186823
16-Jun-13	0.366	0.4	1.092896175	1.182519373
17-Jun-13	0.324	0.414	1.277777778	1.119783134
24-Jun-13	0.371	0.405	1.091644205	1.230379385
3-Jul-13	0.309	0.439	1.420711974	1.133264759
10-Jul-13	0.369	0.442	1.197831978	1.33447781
19-Jul-13	0.34	0.445	1.308823529	1.238825728

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
26-Jul-13	0.37	0.431	1.164864865	1.287824189
27-Jul-13	0.364	0.435	1.195054945	1.201752662
4-Aug-13	0.416	0.399	0.959134615	1.19706426
11-Aug-13	0.37	0.41	1.108108108	1.030513509
19-Aug-13	0.359	0.393	1.094707521	1.084829728
20-Aug-13	0.332	0.358	1.078313253	1.091744183
27-Aug-13	0.348	0.405	1.163793103	1.082342532
4-Sep-13	0.347	0.394	1.135446686	1.139357932
5-Sep-13	0.316	0.405	1.28164557	1.13662006
12-Sep-13	0.352	0.409	1.161931818	1.238137917
28-Sep-13	0.348	0.407	1.16954023	1.184793648
29-Sep-13	0.351	0.409	1.165242165	1.174116255
7-Oct-13	0.303	0.401	1.323432343	1.167904392
14-Oct-13	0.341	0.332	0.973607038	1.276773958
23-Oct-13	0.285	0.399	1.4	1.064557114
8-Nov-13	0.261	0.329	1.260536398	1.299367134
15-Nov-13	0.22	0.356	1.618181818	1.272185619
24-Nov-13	0.215	0.37	1.720930233	1.514382958
1-Dec-13	0.218	0.371	1.701834862	1.65896605
10-Dec-13	0.23	0.377	1.639130435	1.688974219
17-Dec-13	0.243	0.364	1.497942387	1.65408357
26-Dec-13	0.215	0.379	1.762790698	1.544784742
2-Jan-14	0.225	0.376	1.671111111	1.697388911
10-Jan-14	0.254	0.365	1.437007874	1.678994451
11-Jan-14	0.21	0.368	1.752380952	1.509603847
18-Jan-14	0.221	0.368	1.665158371	1.679547821
27-Jan-14	0.23	0.388	1.686956522	1.669475206
11-Feb-14	0.244	0.373	1.528688525	1.681712127
12-Feb-14	0.229	0.378	1.650655022	1.574595605
20-Feb-14	0.292	0.417	1.428082192	1.627837197
27-Feb-14	0.267	0.369	1.382022472	1.488008693
28-Feb-14	0.24	0.373	1.554166667	1.413818338
7-Mar-14	0.264	0.368	1.393939394	1.512062168
8-Mar-14	0.312	0.405	1.298076923	1.429376226
16-Mar-14	0.272	0.356	1.308823529	1.337466714
1-Apr-14	0.258	0.376	1.457364341	1.317416485
8-Apr-14	0.34	0.344	1.011764706	1.415379984
9-Apr-14	0.327	0.394	1.204892966	1.132849289
17-Apr-14	0.3	0.433	1.443333333	1.183279863
24-Apr-14	0.318	0.414	1.301886792	1.365317292

Date	Location M	Location C	C/M	C/M*
2-May-14	0.346	0.411	1.187861272	1.320915942
3-May-14	0.355	0.369	1.03943662	1.227777673
10-May-14	0.351	0.391	1.113960114	1.095938936
19-May-14	0.313	0.411	1.313099042	1.10855376
26-May-14	0.339	0.401	1.182890855	1.251735457
27-May-14	0.291	0.412	1.41580756	1.203544236
4-Jun-14	0.279	0.407	1.458781362	1.352128563
11-Jun-14	0.362	0.395	1.091160221	1.426785522
19-Jun-14	0.598	0.499	0.834448161	1.191847811
20-Jun-14	0.325	0.419	1.289230769	0.941668056
27-Jun-14	0.369	0.406	1.100271003	1.184961955
28-Jun-14	0.314	0.421	1.340764331	1.125678288
6-Jul-14	0.358	0.412	1.150837989	1.276238518
13-Jul-14	0.368	0.408	1.108695652	1.188458148
22-Jul-14	0.326	0.421	1.291411043	1.132624401
29-Jul-14	0.38	0.406	1.068421053	1.24377505
30-Jul-14	0.376	0.426	1.132978723	1.121027252
6-Aug-14	0.374	0.41	1.096256684	1.129393282
7-Aug-14	0.577	0.485	0.840554593	1.106197664
14-Aug-14	0.358	0.417	1.164804469	0.920247514
22-Aug-14	0.344	0.366	1.063953488	1.091437383
23-Aug-14	0.319	0.409	1.282131661	1.072198657
30-Aug-14	0.306	0.402	1.31372549	1.21915176
8-Sep-14	0.324	0.415	1.280864198	1.285353371
15-Sep-14	0.276	0.403	1.460144928	1.28221095
24-Sep-14	0.311	0.418	1.344051447	1.406764734
1-Oct-14	0.296	0.406	1.371621622	1.362865433
2-Oct-14	0.333	0.407	1.222222222	1.368994765
10-Oct-14	0.291	0.413	1.419243986	1.266253985
17-Oct-14	0.254	0.346	1.362204724	1.373346986
18-Oct-14	0.237	0.289	1.219409283	1.365547403
26-Oct-14	0.27	0.379	1.403703704	1.263250719
11-Nov-14	0.239	0.397	1.661087866	1.361567808
18-Nov-14	0.231	0.397	1.718614719	1.571231849
27-Nov-14	0.314	0.598	1.904458599	1.674399858
4-Dec-14	0.241	0.396	1.643153527	1.835440976
13-Dec-14	0.261	0.434	1.662835249	1.700839762
20-Dec-14	0.238	0.353	1.483193277	1.674236603
28-Dec-14	0.242	0.398	1.644628099	1.540506275
29-Dec-14	0.242	0.407	1.681818182	1.613391552

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
5-Jan-15	0.399	0.484	1.213032581	1.661290193
6-Jan-15	0.258	0.407	1.57751938	1.347509865
14-Jan-15	0.254	0.395	1.55511811	1.508516525
30-Jan-15	0.237	0.342	1.443037975	1.541137635
6-Feb-15	0.528	0.562	1.064393939	1.472467873
15-Feb-15	0.525	0.619	1.179047619	1.186816119
22-Feb-15	0.332	0.389	1.171686747	1.181378169
10-Mar-15	0.28	0.346	1.235714286	1.174594174
11-Mar-15	0.309	0.365	1.181229773	1.217378252
19-Mar-15	0.291	0.404	1.388316151	1.192074317
26-Mar-15	0.358	0.418	1.167597765	1.329443601
4-Apr-15	0.293	0.363	1.23890785	1.216151516
11-Apr-15	0.391	0.434	1.109974425	1.23208095
12-Apr-15	0.269	0.401	1.49070632	1.146606382
20-Apr-15	0.341	0.34	0.997067449	1.387476338
28-Apr-15	0.298	0.427	1.432885906	1.114190116
6-May-15	0.285	0.458	1.607017544	1.337277169
13-May-15	0.373	0.376	1.008042895	1.526095431
21-May-15	0.338	0.441	1.304733728	1.163458656
22-May-15	0.265	0.464	1.750943396	1.262351206
30-May-15	0.277	0.416	1.501805054	1.604365739
6-Jun-15	0.348	0.401	1.152298851	1.53257326
7-Jun-15	0.266	0.423	1.590225564	1.266381173
14-Jun-15	0.381	0.414	1.086614173	1.493072247
23-Jun-15	0.326	0.417	1.279141104	1.208551595
30-Jun-15	0.346	0.415	1.199421965	1.257964252
8-Jul-15	0.327	0.343	1.048929664	1.216984651
9-Jul-15	0.355	0.434	1.222535211	1.09934616
16-Jul-15	0.374	0.413	1.104278075	1.185578496
25-Jul-15	0.532	0.496	0.932330827	1.128668201
10-Aug-15	0.372	0.42	1.129032258	0.991232039
17-Aug-15	0.371	0.392	1.056603774	1.087692192
18-Aug-15	0.337	0.405	1.201780415	1.065930299
25-Aug-15	0.351	0.373	1.062678063	1.161025381
26-Aug-15	0.325	0.383	1.178461538	1.092182258
2-Sep-15	0.323	0.391	1.210526316	1.152577754
11-Sep-15	0.29	0.386	1.331034483	1.193141747
18-Sep-15	0.317	0.39	1.230283912	1.289666662
19-Sep-15	0.329	0.392	1.191489362	1.248098737
27-Sep-15	0.281	0.384	1.366548043	1.208472174

Date	Location M	Location C	C/M	C/M*
4-Oct-15	0.245	0.406	1.657142857	1.319125282
5-Oct-15	0.286	0.396	1.384615385	1.555737585
13-Oct-15	0.306	0.44	1.437908497	1.435952045
20-Oct-15	0.316	0.426	1.348101266	1.437321561
21-Oct-15	0.326	0.418	1.282208589	1.374867354
28-Oct-15	0.282	0.396	1.404255319	1.310006219
29-Oct-15	0.266	0.411	1.545112782	1.375980589
5-Nov-15	0.354	0.395	1.115819209	1.494373124
14-Nov-15	0.293	0.33	1.126279863	1.229385384
21-Nov-15	0.236	0.398	1.686440678	1.15721152
22-Nov-15	0.257	0.399	1.552529183	1.52767193
29-Nov-15	0.395	0.45	1.139240506	1.545072007
30-Nov-15	0.238	0.404	1.697478992	1.260989957
7-Dec-15	0.268	0.398	1.485074627	1.566532281
16-Dec-15	0.227	0.41	1.806167401	1.509511923
23-Dec-15	0.246	0.401	1.630081301	1.717170758
24-Dec-15	0.238	0.394	1.655462185	1.656208138
1-Jan-16	0.227	0.4	1.762114537	1.655685971
8-Jan-16	0.206	0.381	1.849514563	1.730185967
9-Jan-16	0.49	0.54	1.102040816	1.813715984
16-Jan-16	0.239	0.342	1.430962343	1.315543367
17-Jan-16	0.222	0.359	1.617117117	1.39633665
24-Jan-16	0.23	0.383	1.665217391	1.550882977
25-Jan-16	0.293	0.367	1.252559727	1.630917067
2-Feb-16	0.222	0.385	1.734234234	1.366066929
9-Feb-16	0.279	0.385	1.379928315	1.623784043
18-Feb-16	0.203	0.396	1.950738916	1.453085034
25-Feb-16	0.244	0.392	1.606557377	1.801442751
26-Feb-16	0.26	0.405	1.557692308	1.665022989
21-Mar-16	0.253	0.362	1.43083004	1.589891512
5-Apr-16	0.33	0.356	1.078787879	1.478548481
6-Apr-16	0.306	0.383	1.251633987	1.19871606
13-Apr-16	0.291	0.389	1.336769759	1.235758609
21-Apr-16	0.494	0.494	1	1.306466414
22-Apr-16	0.274	0.4	1.459854015	1.091939924
29-Apr-16	0.296	0.391	1.320945946	1.349479787
30-Apr-16	0.28	0.397	1.417857143	1.329506098
8-May-16	0.303	0.399	1.316831683	1.39135183
15-May-16	0.35	0.39	1.114285714	1.339187727
24-May-16	0.312	0.4	1.282051282	1.181756318

Date	Location M	Location C	C/M	C/M*
31-May-16	0.356	0.403	1.132022472	1.251962793
9-Jun-16	0.318	0.405	1.273584906	1.168004568
16-Jun-16	0.385	0.407	1.057142857	1.241910804
17-Jun-16	0.345	0.41	1.188405797	1.112573241
25-Jun-16	0.335	0.419	1.250746269	1.16565603
2-Jul-16	0.374	0.407	1.088235294	1.225219197
11-Jul-16	0.342	0.416	1.216374269	1.129330465
18-Jul-16	0.398	0.411	1.032663317	1.190261128
19-Jul-16	0.351	0.406	1.156695157	1.07994266
26-Jul-16	0.385	0.411	1.067532468	1.133669408
3-Aug-16	0.366	0.403	1.101092896	1.08737355
12-Aug-16	0.335	0.414	1.235820896	1.096977092
19-Aug-16	0.335	0.395	1.179104478	1.194167755
20-Aug-16	0.322	0.399	1.239130435	1.183623461
27-Aug-16	0.357	0.391	1.095238095	1.222478343
28-Aug-16	0.306	0.391	1.277777778	1.133410169
4-Sep-16	0.334	0.424	1.269461078	1.234467495
5-Sep-16	0.299	0.416	1.391304348	1.258963003
13-Sep-16	0.338	0.436	1.289940828	1.351601944
20-Sep-16	0.29	0.409	1.410344828	1.308439163
29-Sep-16	0.322	0.416	1.291925466	1.379773128
6-Oct-16	0.341	0.416	1.219941349	1.318279765
7-Oct-16	0.323	0.397	1.229102167	1.249442874
14-Oct-16	0.284	0.424	1.492957746	1.235204379
15-Oct-16	0.26	0.426	1.638461538	1.415631736
22-Oct-16	0.264	0.438	1.659090909	1.571612598
23-Oct-16	0.493	0.512	1.038539554	1.632847416
31-Oct-16	0.288	0.413	1.434027778	1.216831912
7-Nov-16	0.221	0.415	1.877828054	1.368869018
8-Nov-16	0.24	0.41	1.708333333	1.725140343
16-Nov-16	0.257	0.404	1.571984436	1.713375436
23-Nov-16	0.286	0.424	1.482517483	1.614401736
24-Nov-16	0.582	0.586	1.006872852	1.522082759
2-Dec-16	0.226	0.416	1.840707965	1.161435824
9-Dec-16	0.282	0.395	1.40070922	1.636926322
10-Dec-16	0.484	0.433	0.894628099	1.471574351
18-Dec-16	0.236	0.387	1.639830508	1.067711975
25-Dec-16	0.22	0.407	1.85	1.468194948
10-Jan-17	0.222	0.38	1.711711712	1.735458484
19-Jan-17	0.241	0.316	1.31120332	1.718835744

Date	Location M	Location C	C/M	C/M*
27-Jan-17	0.451	0.436	0.966740576	1.433493047
11-Feb-17	0.237	0.372	1.569620253	1.106766318
20-Feb-17	0.288	0.393	1.364583333	1.430764072
27-Feb-17	0.221	0.407	1.841628959	1.384437555
7-Mar-17	0.267	0.403	1.509363296	1.704471538
24-Mar-17	0.311	0.413	1.327974277	1.567895769
8-Apr-17	0.266	0.397	1.492481203	1.399950724
9-Apr-17	0.228	0.403	1.76754386	1.464722059
16-Apr-17	0.264	0.407	1.541666667	1.67669732
17-Apr-17	0.279	0.411	1.47311828	1.582175863
25-Apr-17	0.262	0.398	1.519083969	1.505835554
2-May-17	0.529	0.689	1.302457467	1.515109445
3-May-17	0.489	0.501	1.024539877	1.36625306
11-May-17	0.279	0.421	1.508960573	1.127053832
18-May-17	0.333	0.409	1.228228228	1.394388551
27-May-17	0.293	0.436	1.488054608	1.278076325
3-Jun-17	0.358	0.422	1.17877095	1.425061123
4-Jun-17	0.32	0.429	1.340625	1.252658002
12-Jun-17	0.318	0.424	1.333333333	1.3142349
19-Jun-17	0.368	0.43	1.168478261	1.327603803
28-Jun-17	0.371	0.438	1.180592992	1.216215924
5-Jul-17	0.393	0.418	1.063613232	1.191279871
14-Jul-17	0.348	0.433	1.244252874	1.101913224
21-Jul-17	0.376	0.403	1.071808511	1.201550979
22-Jul-17	0.365	0.412	1.128767123	1.110731251
29-Jul-17	0.391	0.391	1	1.123356362
30-Jul-17	0.339	0.393	1.159292035	1.037006908
6-Aug-17	0.376	0.422	1.122340426	1.122606497
15-Aug-17	0.315	0.396	1.257142857	1.122420247
22-Aug-17	0.345	0.398	1.153623188	1.216726074
31-Aug-17	0.303	0.397	1.310231023	1.172554054
7-Sep-17	0.314	0.403	1.28343949	1.268927932
8-Sep-17	0.327	0.407	1.244648318	1.279086023
16-Sep-17	0.297	0.402	1.353535354	1.25497963
23-Sep-17	0.267	0.391	1.464419476	1.323968636
24-Sep-17	0.323	0.405	1.253869969	1.422284224
2-Oct-17	0.253	0.402	1.588932806	1.304394245
9-Oct-17	0.256	0.405	1.58203125	1.503571238
10-Oct-17	0.27	0.406	1.503703704	1.558493246
17-Oct-17	0.272	0.402	1.477941176	1.520140567

Date	Location M	Location C	C/M	C/M*
18-Oct-17	0.267	0.407	1.524344569	1.490600993
25-Oct-17	0.224	0.4	1.785714286	1.514221497
3-Nov-17	0.291	0.398	1.367697595	1.704266449
10-Nov-17	0.343	0.415	1.209912536	1.468668251
11-Nov-17	0.319	0.393	1.231974922	1.287539251
18-Nov-17	0.365	0.365	1	1.24864422
19-Nov-17	0.228	0.323	1.416666667	1.074593266
26-Nov-17	0.241	0.365	1.514522822	1.314044646
27-Nov-17	0.241	0.359	1.489626556	1.454379369
5-Dec-17	0.217	0.37	1.705069124	1.4790524
12-Dec-17	0.211	0.272	1.289099526	1.637264107
21-Dec-17	0.227	0.363	1.599118943	1.3935489
28-Dec-17	0.211	0.379	1.796208531	1.53744793
6-Jan-18	0.251	0.38	1.513944223	1.718580351
13-Jan-18	0.221	0.378	1.71040724	1.575335061
22-Jan-18	0.244	0.385	1.577868852	1.669885586
30-Jan-18	0.301	0.394	1.3089701	1.605473873
6-Feb-18	0.255	0.395	1.549019608	1.397921232
7-Feb-18	0.225	0.397	1.764444444	1.503690095
14-Feb-18	0.351	0.422	1.202279202	1.68621814
15-Feb-18	0.302	0.382	1.264900662	1.347460883
22-Feb-18	0.258	0.38	1.472868217	1.289668729
2-Mar-18	0.598	0.794	1.327759197	1.417908371
3-Mar-18	0.29	0.396	1.365517241	1.354803949
11-Mar-18	0.269	0.361	1.342007435	1.362303254
18-Mar-18	0.378	0.464	1.227513228	1.348096181
19-Mar-18	0.292	0.428	1.465753425	1.263688113
27-Mar-18	0.57	0.547	0.959649123	1.405133831
3-Apr-18	0.333	0.399	1.198198198	1.093294535
12-Apr-18	0.284	0.388	1.366197183	1.166727099
19-Apr-18	0.545	0.543	0.996330275	1.306356158
27-Apr-18	0.25	0.406	1.624	1.08933804
28-Apr-18	0.262	0.419	1.599236641	1.463601412
5-May-18	0.273	0.427	1.564102564	1.558546072
14-May-18	0.566	0.562	0.992932862	1.562435617
21-May-18	0.357	0.414	1.159663866	1.163783689
22-May-18	0.286	0.425	1.486013986	1.160899812
30-May-18	0.268	0.434	1.619402985	1.388479734
6-Jun-18	0.387	0.416	1.074935401	1.55012601
22-Jun-18	0.462	0.542	1.173160173	1.217492583

Date	Location M	Location C	C/M	C/M*
23-Jun-18	0.318	0.476	1.496855346	1.186459896
1-Jul-18	0.295	0.421	1.427118644	1.403736711
8-Jul-18	0.364	0.422	1.159340659	1.420104064
17-Jul-18	0.348	0.462	1.327586207	1.237569681
2-Aug-18	0.341	0.431	1.263929619	1.300581249
9-Aug-18	0.349	0.411	1.17765043	1.274925108
10-Aug-18	0.341	0.413	1.211143695	1.206832833
18-Aug-18	0.349	0.407	1.166189112	1.209850436
25-Aug-18	0.347	0.411	1.18443804	1.179287509
3-Sep-18	0.359	0.424	1.181058496	1.182892881
10-Sep-18	0.316	0.409	1.294303797	1.181608811
19-Sep-18	0.275	0.393	1.429090909	1.260495302
26-Sep-18	0.507	0.559	1.102564103	1.378512227
27-Sep-18	0.281	0.397	1.412811388	1.18534854
4-Oct-18	0.311	0.402	1.292604502	1.344572533
5-Oct-18	0.259	0.394	1.521235521	1.308194911
12-Oct-18	0.305	0.394	1.291803279	1.457323338
13-Oct-18	0.304	0.395	1.299342105	1.341459297
21-Oct-18	0.239	0.386	1.615062762	1.311977263
28-Oct-18	0.24	0.381	1.5875	1.524137112
6-Nov-18	0.239	0.377	1.577405858	1.568491134
13-Nov-18	0.253	0.374	1.47826087	1.57473144
29-Nov-18	0.232	0.418	1.801724138	1.507202041
30-Nov-18	0.232	0.39	1.681034483	1.713367509
8-Dec-18	0.24	0.397	1.654166667	1.690734391
15-Dec-18	0.218	0.366	1.678899083	1.665136984
16-Dec-18	0.237	0.37	1.561181435	1.674770453
24-Dec-18	0.224	0.383	1.709821429	1.59525814
31-Dec-18	0.236	0.379	1.605932203	1.675452442
9-Jan-19	0.226	0.388	1.716814159	1.626788275
17-Jan-19	0.234	0.392	1.675213675	1.689806394
24-Jan-19	0.262	0.372	1.419847328	1.679591491
25-Jan-19	0.224	0.374	1.669642857	1.497770577
1-Feb-19	0.419	0.327	0.780429594	1.618081173
2-Feb-19	0.247	0.337	1.36437247	1.031725068
9-Feb-19	0.258	0.365	1.414728682	1.264578249
10-Feb-19	0.228	0.371	1.627192982	1.369683552
5-Mar-19	0.222	0.33	1.486486486	1.549940153
6-Mar-19	0.244	0.345	1.413934426	1.505522587
13-Mar-19	0.392	0.439	1.119897959	1.441410874

Date	Location M	Location C	C/M	C/M*
21-Mar-19	0.294	0.337	1.146258503	1.216351834
22-Mar-19	0.298	0.371	1.244966443	1.167286502
6-Apr-19	0.308	0.366	1.188311688	1.221662461
22-Apr-19	0.335	0.375	1.119402985	1.19831692
1-May-19	0.264	0.385	1.458333333	1.143077166
8-May-19	0.295	0.386	1.308474576	1.363756483
9-May-19	0.292	0.403	1.380136986	1.325059148
17-May-19	0.503	0.583	1.159045726	1.363613635
24-May-19	0.569	0.541	0.950790861	1.220416098
25-May-19	0.37	0.38	1.027027027	1.031678432
2-Jun-19	0.281	0.45	1.601423488	1.028422449
9-Jun-19	0.339	0.41	1.209439528	1.429523176
10-Jun-19	0.292	0.419	1.434931507	1.275464622
18-Jun-19	0.281	0.422	1.501779359	1.387091442
25-Jun-19	0.384	0.404	1.052083333	1.467372984
26-Jun-19	0.312	0.412	1.320512821	1.176670229
4-Jul-19	0.335	0.419	1.250746269	1.277360043
11-Jul-19	0.372	0.41	1.102150538	1.258730401
20-Jul-19	0.339	0.419	1.235988201	1.149124497
27-Jul-19	0.402	0.374	0.930348259	1.209929089
28-Jul-19	0.359	0.453	1.26183844	1.014222508
5-Aug-19	0.327	0.416	1.272171254	1.18755366
12-Aug-19	0.352	0.391	1.110795455	1.246785976
21-Aug-19	0.302	0.45	1.490066225	1.151592611
28-Aug-19	0.319	0.473	1.482758621	1.388524141
29-Aug-19	0.326	0.462	1.417177914	1.454488277
6-Sep-19	0.317	0.486	1.533123028	1.428371023
13-Sep-19	0.315	0.474	1.504761905	1.501697427
22-Sep-19	0.285	0.486	1.705263158	1.503842561
29-Sep-19	0.332	0.467	1.406626506	1.644836979
30-Sep-19	0.347	0.478	1.377521614	1.478089648
8-Oct-19	0.259	0.43	1.66023166	1.407692024
15-Oct-19	0.252	0.421	1.670634921	1.584469769
23-Oct-19	0.25	0.414	1.656	1.644785375
24-Oct-19	0.248	0.422	1.701612903	1.652635613
31-Oct-19	0.235	0.436	1.855319149	1.686919716
9-Nov-19	0.228	0.375	1.644736842	1.804799319
17-Nov-19	0.247	0.328	1.327935223	1.692755585
24-Nov-19	0.233	0.291	1.248927039	1.437381331
25-Nov-19	0.237	0.378	1.594936709	1.305463326

Date	Location M	Location C	C/M	C/M*
2-Dec-19	0.228	0.399	1.75	1.508094694
11-Dec-19	0.222	0.328	1.477477477	1.677428408
18-Dec-19	0.551	0.561	1.01814882	1.537462757
19-Dec-19	0.248	0.394	1.588709677	1.173943001
27-Dec-19	0.22	0.407	1.85	1.464279675
4-Jan-20	0.255	0.409	1.603921569	1.734283902
19-Jan-20	0.404	0.907	2.245049505	1.643030269
20-Jan-20	0.254	0.313	1.232283465	2.064443734
27-Jan-20	0.349	0.364	1.042979943	1.481931545
28-Jan-20	0.288	0.473	1.642361111	1.174665424
5-Feb-20	0.372	0.458	1.231182796	1.502052405
21-Feb-20	0.242	0.337	1.392561983	1.312443678
7-Mar-20	0.289	0.328	1.134948097	1.368526492
16-Mar-20	0.254	0.396	1.559055118	1.205021615
8-Apr-20	0.326	0.394	1.208588957	1.452845067
9-Apr-20	0.303	0.417	1.376237624	1.28186579
24-Apr-20	0.366	0.418	1.142076503	1.347926074
3-May-20	0.372	0.423	1.137096774	1.203831374
10-May-20	0.316	0.4	1.265822785	1.157117154
19-May-20	0.28	0.399	1.425	1.233211096
26-May-20	0.346	0.401	1.158959538	1.367463329
27-May-20	0.297	0.409	1.377104377	1.221510675
4-Jun-20	0.285	0.413	1.449122807	1.330426266
11-Jun-20	0.367	0.417	1.136239782	1.413513845
12-Jun-20	0.324	0.409	1.262345679	1.219422001
20-Jun-20	0.304	0.41	1.348684211	1.249468576
27-Jun-20	0.367	0.41	1.117166213	1.31891952
6-Jul-20	0.309	0.411	1.330097087	1.177692205
13-Jul-20	0.353	0.407	1.152974504	1.284375623
14-Jul-20	0.358	0.41	1.145251397	1.19239484
22-Jul-20	0.291	0.42	1.443298969	1.15939443
29-Jul-20	0.343	0.415	1.209912536	1.358127607
30-Jul-20	0.345	0.412	1.194202899	1.254377058
7-Aug-20	0.316	0.418	1.32278481	1.212255146
14-Aug-20	0.346	0.41	1.184971098	1.289625911
15-Aug-20	0.331	0.407	1.229607251	1.216367542
22-Aug-20	0.337	0.411	1.21958457	1.225635338
23-Aug-20	0.331	0.425	1.283987915	1.2213998
30-Aug-20	0.355	0.413	1.163380282	1.265211481
8-Sep-20	0.297	0.405	1.363636364	1.193929641

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
15-Sep-20	0.295	0.403	1.366101695	1.312724347
16-Sep-20	0.308	0.398	1.292207792	1.350088491
24-Sep-20	0.273	0.411	1.505494505	1.309572002
1-Oct-20	0.276	0.377	1.365942029	1.446717754
10-Oct-20	0.259	0.394	1.521235521	1.390174747
17-Oct-20	0.231	0.391	1.692640693	1.481917289
18-Oct-20	0.251	0.395	1.573705179	1.629423672
26-Oct-20	0.224	0.403	1.799107143	1.590420727
11-Nov-20	0.496	0.616	1.241935484	1.736501218
18-Nov-20	0.235	0.313	1.331914894	1.390305204
19-Nov-20	0.549	0.533	0.970856102	1.349431987
27-Nov-20	0.224	0.329	1.46875	1.084428867
13-Dec-20	0.469	0.449	0.957356077	1.35345366
20-Dec-20	0.287	0.459	1.599303136	1.076185352
21-Dec-20	0.331	0.481	1.453172205	1.442367801
29-Dec-20	0.22	0.336	1.527272727	1.449930884
14-Jan-21	0.298	0.402	1.348993289	1.504070174
21-Jan-21	0.261	0.42	1.609195402	1.395516354
30-Jan-21	0.221	0.401	1.814479638	1.545091688
6-Feb-21	0.243	0.393	1.617283951	1.733663253
7-Feb-21	0.247	0.408	1.651821862	1.652197741
15-Feb-21	0.241	0.402	1.668049793	1.651934626
22-Feb-21	0.234	0.285	1.217948718	1.663215243
23-Feb-21	0.273	0.365	1.336996337	1.351528675
3-Mar-21	0.229	0.392	1.711790393	1.341356038
10-Mar-21	0.266	0.384	1.443609023	1.600660087
19-Mar-21	0.258	0.396	1.534883721	1.490724342
26-Mar-21	0.409	0.535	1.30806846	1.521635907
11-Apr-21	0.264	0.387	1.465909091	1.372138694
27-Apr-21	0.275	0.386	1.403636364	1.437777972
6-May-21	0.306	0.341	1.114379085	1.413878846
13-May-21	0.323	0.39	1.207430341	1.204229013
14-May-21	0.285	0.394	1.38245614	1.206469942
22-May-21	0.259	0.41	1.583011583	1.329660281
29-May-21	0.342	0.404	1.18128655	1.507006192
30-May-21	0.299	0.409	1.367892977	1.279002443
7-Jun-21	0.319	0.416	1.304075235	1.341225816
14-Jun-21	0.412	0.439	1.065533981	1.315220409
15-Jun-21	0.356	0.42	1.179775281	1.140439909
23-Jun-21	0.298	0.423	1.419463087	1.167974669

Dakah Station C and M SR Time Series…

Date	Location M	Location C	C/M	C/M*
30-Jun-21	0.364	0.406	1.115384615	1.344016562
1-Jul-21	0.34	0.422	1.241176471	1.183974199
9-Jul-21	0.333	0.415	1.246246246	1.224015789
16-Jul-21	0.387	0.413	1.067183463	1.239577109
25-Jul-21	0.311	0.491	1.578778135	1.118901557
1-Aug-21	0.362	0.489	1.350828729	1.440815161
2-Aug-21	0.347	0.462	1.331412104	1.377824659
10-Aug-21	0.321	0.469	1.46105919	1.34533587
17-Aug-21	0.328	0.462	1.408536585	1.426342194
26-Aug-21	0.305	0.441	1.445901639	1.413878268
2-Sep-21	0.322	0.441	1.369565217	1.436294628
3-Sep-21	0.326	0.422	1.294478528	1.389584041
11-Sep-21	0.348	0.415	1.192528736	1.323010181
18-Sep-21	0.312	0.428	1.371794872	1.231673169
27-Sep-21	0.296	0.432	1.459459459	1.329758361
4-Oct-21	0.314	0.429	1.366242038	1.42054913
13-Oct-21	0.254	0.424	1.669291339	1.382534166
20-Oct-21	0.254	0.423	1.665354331	1.583264187
29-Oct-21	0.243	0.395	1.625514403	1.640727288
5-Nov-21	0.247	0.384	1.55465587	1.630078269
14-Nov-21	0.252	0.393	1.55952381	1.57728259
21-Nov-21	0.231	0.4	1.731601732	1.564851444
30-Nov-21	0.228	0.414	1.815789474	1.681576645
7-Dec-21	0.232	0.408	1.75862069	1.775525625
16-Dec-21	0.223	0.418	1.874439462	1.76369217
24-Dec-21	0.263	0.403	1.532319392	1.841215274

APPENDIX D

PREDICTED DISCHARGE DATA

Predicted Discharge (m^3/s) for Khwajaghar Station (Amu RB)												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1988	149	168	189	245	106	191	225	183	171	168	152	149
1989	130	146	160	264	272	203	225	198	240	161	130	131
1990	119	154	174	225	161	215	201	218	156	158	96	97
1991	90	117	150	194	348	429	352	307	229	207	235	234
1992	161	153	198	255	360	352	336	265	205	195	145	152
1993	153	198	174	225	292	317	276	222	191	183	132	134
1994	185	199	295	336	348	278	223	182	155	134	207	267
1995	191	225	231	365	370	243	211	183	153	116	131	133
1996	143	141	278	459	343	248	199	182	141	112	115	156
1997	150	130	174	225	310	291	200	168	146	155	108	109
1998	144	187	139	180	195	277	220	183	133	95	84	88
1999	156	202	127	165	244	225	185	148	130	125	111	112
2000	108	135	203	225	269	138	155	120	104	137	164	166
2001	141	140	189	257	195	182	144	113	93	97	86	148
2002	206	154	209	257	324	256	191	119	122	208	184	186
2003	122	126	124	227	162	185	250	157	138	155	138	139
2004	83	105	205	222	218	206	185	151	114	107	95	96
2005	216	273	278	324	367	334	271	169	130	110	98	101
2006	106	134	175	226	245	225	212	136	126	107	95	108
2007	174	152	122	157	196	190	166	160	120	114	101	111
2008	117	146	235	229	214	198	158	126	110	134	135	210
2009	185	312	183	237	262	229	208	158	133	122	114	143
2010	167	217	145	188	287	232	187	161	120	130	148	126
2011	121	157	160	175	181	171	193	132	97	138	130	253
2012	142	184	89	117	186	268	238	167	135	125	102	130
2013	104	135	159	209	200	159	131	141	103	93	89	93
2014	61	79	123	171	289	198	161	94	105	113	138	123
2015	121	111	216	225	217	162	158	198	113	115	109	86
2016	105	117	192	298	363	189	142	107	93	102	138	138
2017	121	143	202	260	230	155	143	111	92	116	114	86
2018	167	154	130	228	216	176	131	113	89	79	111	118
2019	95	210	217	193	225	157	142	126	95	96	85	107
2020	96	153	95	167	186	196	132	93	93	91	111	130
2021	133	154	160	167	173	160	130	132	106	83	154	142

Predicted Discharge (m^3/s) for Tir Pul Station (Harirud-Murghab RB)												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1988	5.9	21.1	16.1	21.3	23.2	6.6	6.8	12.6	14.2	16.2	10.5	12.5
1989	8.0	10.2	2.1	3.2	21.7	28.6	18.7	3.0	10.2	13.1	5.1	14.6
1990	13.2	16.0	20.7	28.2	30.8	30.8	17.9	2.9	3.8	3.3	3.1	3.7
1991	3.2	2.4	3.8	18.7	24.8	30.5	5.7	6.1	2.2	2.9	2.1	2.1
1992	6.7	14.4	22.6	34.5	35.1	36.0	18.8	3.9	8.2	8.5	7.4	6.6
1993	19.3	36.2	26.0	32.0	34.4	31.8	2.3	2.5	4.4	2.5	2.1	2.2
1994	8.3	7.4	32.7	22.9	13.2	2.1	3.9	10.6	15.2	14.2	14.4	13.4
1995	14.5	12.9	19.8	26.3	35.8	18.5	2.1	6.1	10.1	5.1	7.7	4.8
1996	3.7	2.6	9.5	2.6	10.0	18.7	2.1	2.1	2.1	2.9	2.1	2.9
1997	2.1	2.4	2.1	23.9	29.3	25.0	7.9	2.2	6.2	4.8	2.5	7.8
1998	11.3	12.3	59.7	33.6	33.3	27.7	7.2	2.1	2.4	2.3	3.8	22.0
1999	13.2	2.1	3.4	22.1	7.2	4.7	10.4	8.4	12.8	8.7	9.9	4.7
2000	2.4	7.2	2.3	6.0	14.8	12.6	7.8	7.8	7.6	5.7	5.2	8.0
2001	10.4	4.3	7.9	19.3	18.0	17.4	20.2	27.2	20.5	16.0	12.9	11.7
2002	10.7	7.0	14.3	19.8	24.2	23.6	23.6	18.6	19.9	17.5	14.3	13.4
2003	14.9	4.6	7.1	4.7	19.9	18.7	10.5	5.4	18.7	9.5	7.4	17.9
2004	8.8	11.2	4.8	11.2	7.8	10.1	15.5	10.0	12.0	10.1	10.5	11.3
2005	8.8	4.0	2.1	2.8	11.0	16.2	7.2	4.0	9.5	7.8	10.4	11.2
2006	2.1	2.4	5.3	8.4	7.3	5.0	13.7	10.7	7.4	6.0	2.3	2.4
2007	9.6	4.2	25.2	22.8	33.1	12.6	10.2	4.3	5.1	4.0	11.3	12.1
2008	5.7	3.9	2.1	4.3	4.8	2.5	10.0	5.4	2.8	5.3	3.6	3.2
2009	3.8	3.8	19.2	19.4	35.7	15.9	2.2	2.4	2.2	2.7	20.9	3.8
2010	4.8	2.1	38.2	31.0	29.4	19.8	3.4	7.2	6.2	7.5	2.8	2.5
2011	2.9	2.1	2.7	3.0	4.1	3.0	6.6	8.6	11.2	4.7	6.3	3.1
2012	5.6	3.1	6.9	8.2	27.9	2.5	2.7	3.5	10.4	12.4	4.6	6.1
2013	2.4	6.3	5.1	15.6	7.1	2.4	6.8	13.6	17.8	13.6	3.6	7.7
2014	4.9	11.1	4.9	2.1	8.9	6.8	10.6	20.6	15.6	6.2	2.7	2.6
2015	2.2	2.2	24.5	19.7	12.4	3.9	4.9	14.8	16.9	7.7	9.7	9.3
2016	5.3	6.1	2.6	13.7	8.2	3.6	12.0	12.5	8.6	12.5	9.0	21.4
2017	11.5	8.9	8.4	5.5	2.8	2.3	7.4	22.1	22.9	26.0	8.0	2.4
2018	2.4	2.7	5.5	3.1	3.6	6.5	11.2	18.5	12.0	13.5	3.4	3.8
2019	7.6	12.1	2.3	21.2	12.6	5.9	5.6	5.6	15.1	9.4	5.5	7.2
2020	2.2	8.5	14.0	2.8	21.0	2.5	3.7	2.2	2.2	2.9	4.7	4.3
2021	15.6	13.0	6.1	3.5	5.4	4.4	16.5	22.8	23.0	15.7	12.0	2.3

Predicted Discharge (m^3/s) for Khwabgah Stations (Helmand RB)												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1988	442	362	453	437	493	377	344	343	324	331	336	331
1989	294	282	371	437	429	516	212	340	271	264	300	260
1990	257	323	397	402	458	401	248	207	209	254	245	203
1991	326	180	261	319	422	437	466	432	259	264	321	280
1992	321	369	365	418	434	439	500	492	455	451	520	480
1993	394	394	343	420	445	483	376	225	228	298	260	367
1994	390	237	295	324	448	428	282	321	311	283	275	368
1995	444	325	460	325	410	455	332	298	284	255	106	160
1996	55	165	244	325	267	71	85	100	105	16	74	26
1997	15	20	31	326	411	152	64	33	70	16	16	27
1998	16	221	371	420	392	327	108	38	15	15	13	61
1999	46	27	67	246	64	42	46	13	15	20	24	51
2000	97	80	70	37	173	140	192	244	146	129	36	42
2001	30	16	19	147	248	280	312	359	322	268	279	296
2002	223	92	109	149	219	190	287	320	325	328	333	13
2003	68	13	29	111	203	183	115	124	104	85	17	222
2004	113	18	37	170	45	75	99	108	136	80	229	202
2005	157	63	238	364	202	168	157	86	69	31	13	34
2006	56	120	41	16	115	254	152	162	111	75	23	73
2007	28	16	13	13	184	157	123	133	319	259	62	63
2008	35	41	80	134	108	37	181	226	151	199	192	116
2009	137	126	124	204	324	325	131	96	52	15	43	18
2010	17	229	220	100	100	171	74	81	173	148	47	17
2011	13	34	279	230	268	1959	141	150	113	182	42	162
2012	69	18	70	109	183	237	22	26	32	77	18	21
2013	19	107	173	83	181	93	21	67	56	20	15	39
2014	19	39	13	238	250	302	91	151	185	121	159	14
2015	19	14	38	108	32	45	16	96	157	159	195	161
2016	60	21	14	270	221	96	18	30	22	21	50	38
2017	16	151	111	130	118	42	117	166	200	144	161	140
2018	204	21	19	188	234	255	277	278	207	235	199	146
2019	154	250	326	181	212	31	19	50	14	21	14	14
2020	33	78	216	212	188	45	27	19	14	45	27	58
2021	140	99	28	76	163	74	30	30	34	13	46	31

Predicted Discharge (m^3/s) fro Dakah Station (Kabul RB)												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1988	384	449	568	586	569	571	867	758	513	248	217	176
1989	176	377	201	596	341	449	542	660	341	241	315	449
1990	243	263	622	660	453	355	315	229	379	465	449	409
1991	609	609	538	951	552	504	523	558	694	514	389	572
1992	517	546	457	660	609	498	448	556	511	287	292	292
1993	372	283	601	542	448	627	664	624	619	423	634	471
1994	585	732	549	638	412	365	534	715	561	474	366	418
1995	482	729	628	602	482	371	397	515	660	593	264	363
1996	362	440	655	433	750	619	666	630	512	378	407	665
1997	412	575	350	458	379	560	754	663	651	433	625	361
1998	258	491	434	981	928	575	902	792	719	408	322	261
1999	292	373	451	403	315	450	1001	631	515	535	278	241
2000	191	325	282	464	525	565	991	890	617	271	148	179
2001	219	165	220	471	361	406	553	583	424	230	245	102
2002	165	246	255	473	351	423	657	458	478	375	275	184
2003	241	219	341	1437	534	449	660	483	563	542	465	226
2004	172	266	344	288	477	372	623	660	712	660	614	291
2005	214	226	245	585	76	813	398	662	815	446	375	296
2006	214	226	315	304	297	287	658	745	777	678	609	447
2007	216	379	314	360	480	471	314	809	635	609	570	375
2008	320	376	449	494	688	837	841	768	551	455	472	287
2009	466	684	754	756	519	440	475	533	414	360	226	187
2010	259	312	359	491	527	460	857	674	705	265	197	139
2011	184	249	202	319	475	691	733	973	618	348	302	166
2012	226	626	562	449	419	418	767	1001	631	290	237	227
2013	271	382	294	437	438	604	565	1013	731	745	359	149
2014	145	189	288	479	656	650	680	1047	411	398	202	134
2015	216	484	590	611	339	373	784	1095	613	314	351	160
2016	174	175	171	476	465	738	803	799	439	341	172	361
2017	152	437	149	209	394	438	889	781	433	240	356	218
2018	147	271	364	600	353	421	370	576	569	336	171	139
2019	155	416	342	634	561	459	709	474	218	168	187	248
2020	157	307	472	361	571	439	569	567	464	221	326	402
2021	240	161	235	310	413	519	682	314	386	222	160	96

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