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DECADAL PROJECTION OF PRECIPITATION PATTERN USING PRECIS MODEL IN SOUTHERN MOUNTAINOUS REGION OF SINDH

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ABSTRACT

The current study is focused on climate change projections through the precipitation pattern and their influence on water resources in the study area (Southern Mountainous region of Sindh). The PRECIS model data validated with PMD baseline data and statistical analyses using the Pearson correlation coefficient and estimated the strong relationship between PRECIS and PMD baseline data 1961-1990 of 97.57%. The projected results based on the PRECIS baseline data 1961-1990 and assumed as 100% precipitation in the study area, while the projected results-focused in comparison with baseline data. The projection for decadal of 2021-2040 a slight precipitation may receive with a shortfall of -6.13% to -9.48%. However, a severe precipitation deficiency projected during the 2041-2050 decade, expected an adverse impact on the groundwater recharge. However, the decade 2051-2060 projected the noteworthy tendency of increasing precipitation about +10.81%, which is one of the most highest in decades, which receive surplus precipitation. Runoff water can be stored and diverted for rainwater harvesting purposes. The anticipated results, focusing on the future challenging situation to sustainable livelihood and the region would suffer the devastating consequence of climate change.

KEYWORDS: Climate change; precipitation; PRECIS model; groundwater; hill torrents; water scarcity

1. INTRODUCTION

Climate change is an all-around driving issue; the disaster prevents of present and likely future impacts of environmental changes as they influence the improvement of the country. (Chmutina *et al.,* 2018). It is anticipated to build dry spell force and recurrence worldwide due to inconsistent precipitation patterns. Which leads to agricultural and hydrological deficiency, lack of groundwater recharge subsequently leads to enormous financial consequences on the livelihood (Kilimani *et al.,* 2018). The precipitation trend represents the dynamic properties (Soomro *et al.,* 2019) To recognize the flood hazard region of new drought situations are essential to combat flood threat and rainwater harvesting (Farid 2018).

The impact of global warming has been investigated by various researchers worldwide (Dimri *et al.,* 2013). Accurate climate change projection is a difficult task for many decades (Leichenko *et al.,* 1993). However, the predictions of global warming recommended that excess floods would adjust their performance in the future. Livelihood stability is an emerging matter, disposed of the growing level of poverty, financial retardation, and deprived farming system highlights in various areas of the world (Udoh *et al.,* 2017).

The studies for sustainable livelihood are essential to understand the spatial variation of depending on climate factors like variation of precipitation in the region (Donohue and Biggs 2015). The evaluation of the water resources is vital, in most of the remote areas, which are affected by global warming (Soomro, eta al 2020; Jabbar, 2020). In Arid to semi-dry regions of the world, livelihood particularly disadvantaged population of the rural areas depending on the surface and groundwater resources. The existing water resources are threatened by multiple issues, including climate change scenarios (Moses and Hambira 2018).

In the last decades, It was observed that significant incedents of natural desasters were occurred in the country. River floods in 2009 and 2010, heat waves in Karachi in 2015 and heavy monsoon rainfall in 2017 and 2020 indicates thatr climate is diverting towards extreme level day by day. As per German observation of the Global Climate Risk Index, the Pakistan ranking within ten countries which directly affected by global warming, and takes many decades to start a local climate system (Kreft *et al.,* 2014).

The climate change and its impact is being observed and investigated from different parts of the world by many scientist and scholars. This article is also an attempt to investigate the precipitation pattern, using PRECIS model to forecast the changing patern of rainfall in coming decades. Investigation and prediction of climate change and its impact on the livelihood & socioeconomics of the people with their anticipated issues is carried out. It helps policymakers and stakeholders make possible measures (Norton & Gibson 2019).

Zheng *et al.,* (2019) conducted their research on the grain for green project in the remote area of loess mountainous of China, which was executed during 1999. The study aimed to affect the analysis of natural and artificial features. They investigated many factors and concluded that the climate influences on the natural ecosystem, which assume an incredible job and could have significance for the strategy making and ecosystem management.

1.1 Introduction to Study Area

The study area covers about 11,000 km^2, within a longitude of 67^o 12' E and 68^o 27' E and latitudwe 25^o 12' N and 26^o 95' N in the mountainous range of Kohistan region, comprises the hilly tracts of Dadu, Jamshoro, and Thatta districts of Sindh Province, Pakistan (GOS 2006). Geographically, the area bounded by the Arabian Sea in the south through Thatta district Baluchistan province in the western border through Dadu and Jamshoro districts (Figure 1). The majority of the land area of the study area is arid.

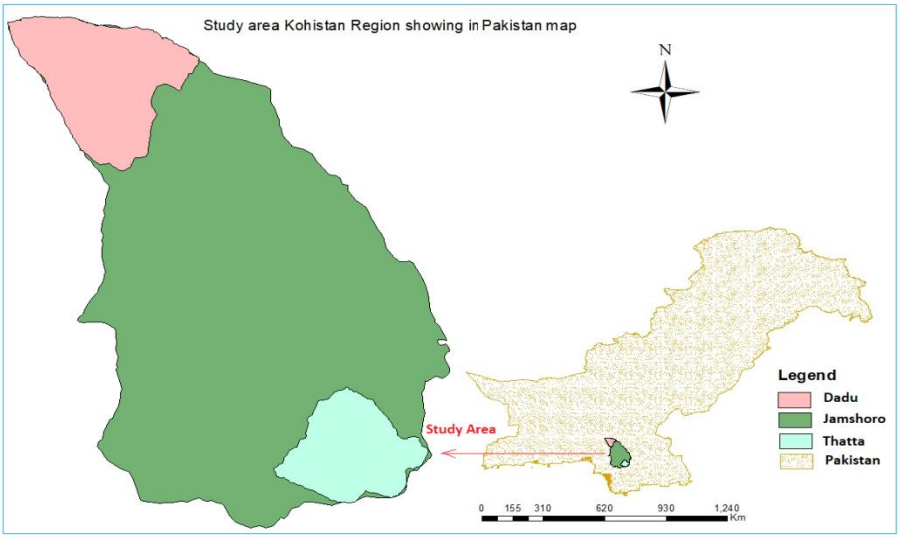

Figure 1: Layout map of the study area

1.2 Physiography and hydrology of the study area

The researched area is a hilly tract "torrents combine" which flows towards the low-lying foothill areas. The study area is depending on the primary source of rainfall. The ephemeral rivers and locally known as the Rod-Kohi/spate/Nai, which originated from the high elevation ranges of the hills. Many ephemeral rivers feed the agriculture lands and flood water collected naturally in the ponds, which are used in the drought seasons. Most of the area is uneven due to bald and high elevated areas about 150 to 1000 feet. High floods are more dangerous especially during the monsoon that could not be controlled easily, and damages the infrastructures. The local farmers divert about 1/3 part of the water to feed their dry lands. The Indus river system does not exist in this area due to high elevation. Precipitations accumulated naturally in the depressions and recharge the groundwater, which is used as the supplement irrigation system for the agricultural lands.

1.3 Climatology of Study Area

The study area is remote and depending on the precipitation pattern as described in the above section. The average precipitation is about 25 cm. The maximum temperature recorded 48 ^{o}C, while the minimum recorded 0 ^{o}C in the study area. An evaporation rate ranges from 180 to 300 cm. The average wind velocity ranges from 8 to 10 km/hr. The agricultural seasons are Kharif (May-September), and Rabi (October-April).

1.4 Vegetation of Study Area

The type of natural vegetation found in the Kohistan area Jamshoro, Dadu, Thatta area, or any place in the study area depends mainly on two factors Climate and Soil. Due to the lack of enough water and hot climate, the natural vegetation in the studied area is not typical; only those species of plants survive which endure these harsh climatic conditions. The soil is clayey and alluvial.

1.5 Research problems

Climate change is becoming the highest hazard in the history of world civilization (Basar, 2009). Pakistan is globally under threat position and has been facing this challenging issue for an extended period of history. Every year it is losing a valuable asset to severe natural disasters, like a flood, drought, and earth quicks. Climate change impacts have been observed as significant variations in rainfall patterns over the past years (Gadiwal 2013). However, the absence of freshwater and deteriorating profitability of vegetation due to drought situations and make a considerable risk to their future sustenance and water security. These are the continuously changing situations of the natural resource attempting the attention of the researcher to examine the natural effect of the climate change impact on livelihood. Accordingly, this study aims at investigating and predicting the inconsistency in rainfall patterns in the study area for the period of 2021-

2060, using the PRECIS regional climate change model to investigate the projected consequences and their possible measures for future planning and management in the Kohistan region of Sindh, Pakistan. The area has experienced devastating conditions through climate change, became especially in the vulnerability of drought situations of water scarcity, which directly impacts environmental sustainability. The poverty alleviation in the region has been experienced, causes the increase in the migrating rate of the local population along with livestock to the irrigated and industrial area of the province

2. MATERIALS AND METHODS

2.1 PRECIS Model Description

Employed model for this research is PRECIS. The "PRECIS" is a regional climate model (RCM) produced by the Hadley Centre of Meteorological Department of United Kingdom, with the collaboration of the Italy Meteorological Department Hadley Centre 2001. PRECIS adopts a similar hypothesis of the climate system as uses for GCM. The RCM delivers high-resolution regional climate change projections, usually depends on the continental scale climate change predictably by the GCM (Memon et al, 2020; Abbass and Khan 2020; Jones 2003).

Most of the researchers had conducted their experiments through the PRECIS regional climate change model to investigate the influence of global warming in the world. The revealed the best accuracy of the projections for the future planning and management in the field of water resources projects. The PRECIS model is used by coupling with the Remote Sensing/Geographical Information System and assembled the accurate projections of the precipitation variation, using minimum time and cost-effective research (Jianqiang 2008).

In this study, PRECIS, version 2, used to provide climate change projections and develop scenarios for impact studies over the study area. A set of projection scenarios have been developed to investigate the impacts of precipitation variability in the Kohistan region. The work comprises the following stages as described in the Figure. 2.

2.2 Validation of PRECIS RCM

The capacity to validate atmosphere factors created by generally coarse worldwide models, at the ideal scales, not just enhances the helpfulness of

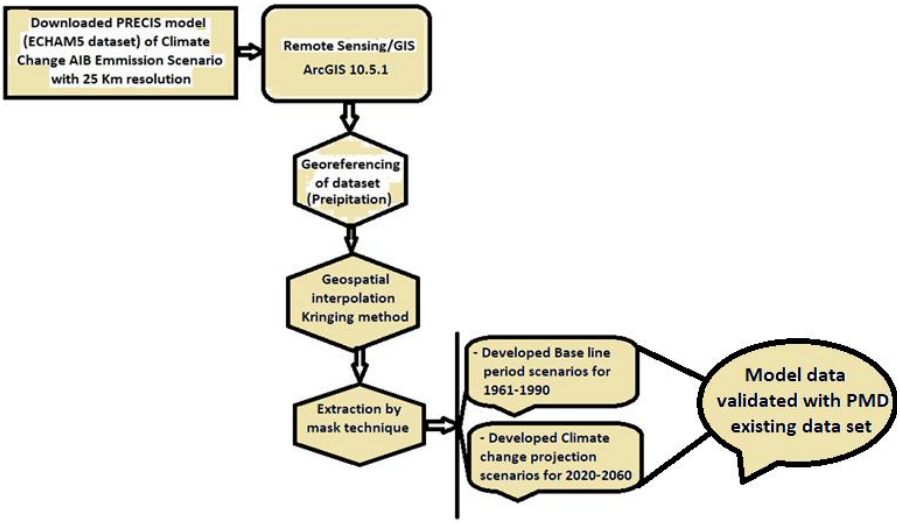

Figure 2: Diagram Stepwise methodology for the development of the Baseline and Projection Scenarios

such models yet additionally induces and explores the effects of environmental change in different areas (Shagega *et al.,* 2019). To validate the model, a set of precipitation measurements from across Pakistan was used. Based on data availability.

2.3 Data preparation

Rainfall data collected from ten different stations in the surrounding study area; one station located within the Kohistan region (TBK), while the rest of the rain gauges located in neighboring rain gauge stations (Khuzdar, Lasbella, Karachi, Hyderabad, Nawabshah, Gaj Guest House, Mohenjo-Daro, Larkana and Jacobabad stations) as mentioned in Table.1, and Fig.3. The observed data from the 10 stations have been interpolated to develop the real scenario between 1961 and 1990. To determine how accurate the model predicts precipitation variation in this study, the observed precipitation data then compared with PRECIS simulated precipitation.

Table 1: Presents the names and the mean annual rainfall for each station as provided by the Meteorological Department of Pakistan

S.	Station Nam	Latitud	Longitu	Elevati	Normal Annual Rainfall
0	Karachi	24.91	67.17	21.34	171.22
0	Hyderabad	25.38	68.37	26.82	166.25
0	Nawabshah	26.24	68.41	33.22	155.43
0	Mohenjo-	27.32	68.14	47.85	99.13
0	Jacobabad	28.29	68.45	58.83	118.37
0	Haj Guest	26.87	67.32	130.76	127.62
0	Khuzdar	27.80	66.62	1233.5	257.56
0	Lasbella	25.84	66.52	24.99	158.55
0	Larkana	27.56	68.22	52.12	140.6
1	TB Khan	25.37	67.84	130.76	120.98

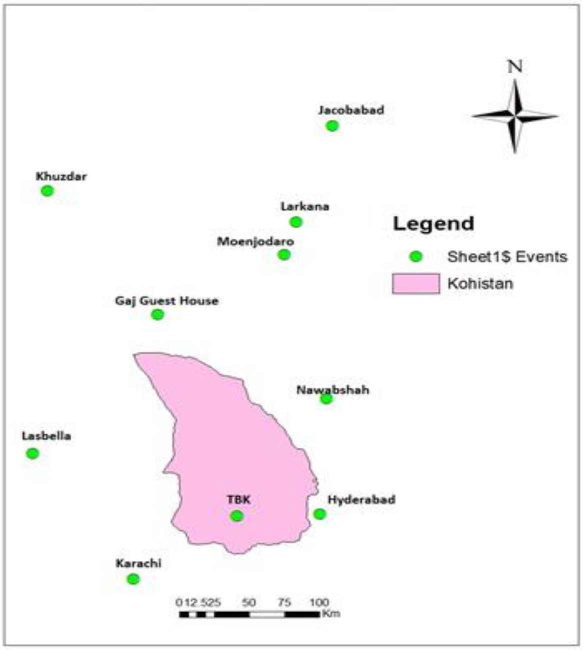

Figure 3: Location of Rain gauge stations within and neighboring the study area

3. RESULTS AND DISCUSSIONS

The PRECIS model in the current research study specifies inconsistency of precipitation over Sindh province related to cumulative temperature and greenhouse gas emissions in the study area due to the burning of coal power plants at the Lakhra area and industrial gases emission in the Nooriabad Area, because of the fast urbanizing in Karachi, Jamshoro, and

Hyderabad shows an alarming situation for climate change. The deforestation and quick cutting of trees and vegetation also imposed a harmful impact on the climate of the study area. Due to these reasons, significant climatological variation occurs in the study area, influence on inconsistency in precipitation pattern, which direct or indirectly affecting the infiltration and percolation beneath the earth's surface. The climatic changes consequences influence the surface and groundwater aquifers, which depleting rapidly with the degrading quality of groundwater, the same results showing in the manuscript reported by Siddiqui *et al.,* 2020, which shows that decreasing the water table annually about three feet in Lahore.

The results of figure 4 reveals that the comparative analysis of PRECIS and PMD baseline 1961-1990 shows the variation at Gauging Station Gaj ± 1.06 mm, Manchar ±0.63, Jhangara/Bajara ±0.46, Ranikot ±0.16, Manjhand ±1.11, Karchat ±1.62, Darwat/Jhanghri ±0.76, Thana Boula Khan ±0.63, T.Ahmad Khan ±0.4, Nooriabad ±0.43, Sari ±1.36, Mole ±1.3, and Hab Catchment ±3.91. The closest data set observed at the gauging station Ranikot within the study area, while the highest margin of the dataset was observed at Hab Catchment. The Hab Catchment, situated in the hilly tract at the southern west neighboring portion region study area in the province of Baluchistan. The correlation and coefficient in PRECIS and PMD baseline data between 1961 and 1990 estimated closely correlated with 0.9757.

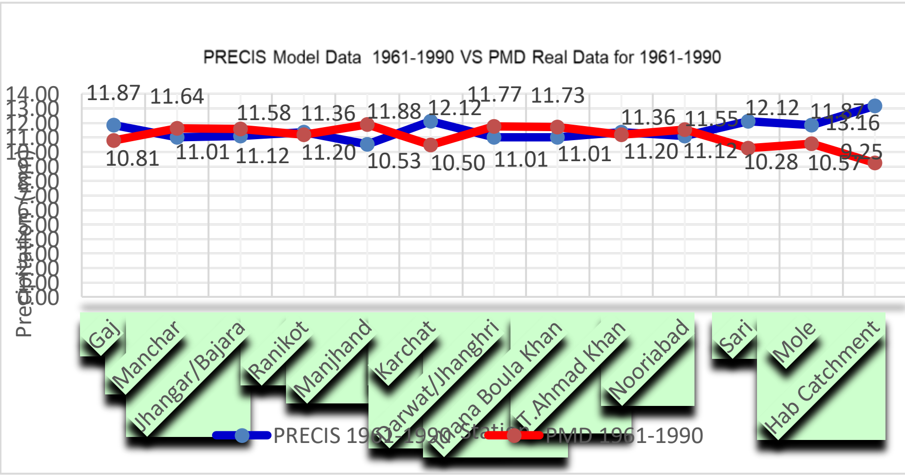

Figure 4: Polylines comparative chart of PMD and PRECIS Model Baseline Data 1961-19960

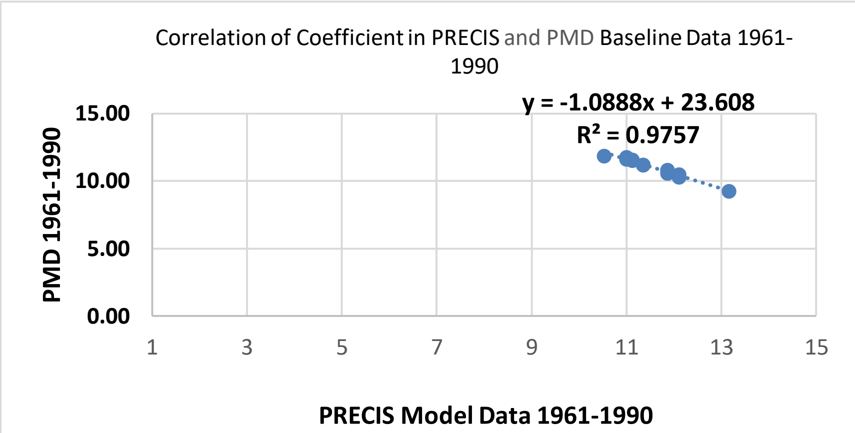

Figure 5: Correlation of PMD Data and PRECIS Model Data Baseline 1961-1990

3.1 Analysis of Decadal Precipitation Projection

Figure 6 and Table 2 Shows actual projected data, which revealed the decadal wise projected results in percentage from 2021 to 2060 for with compare to PRECIS Baseline data 1961-1990. Table. 2. However, the actual projected data; however, the first column PRECIS baseline 1961-1990 data assumed 100%, and the real decadal data has been converted percentage-wise.

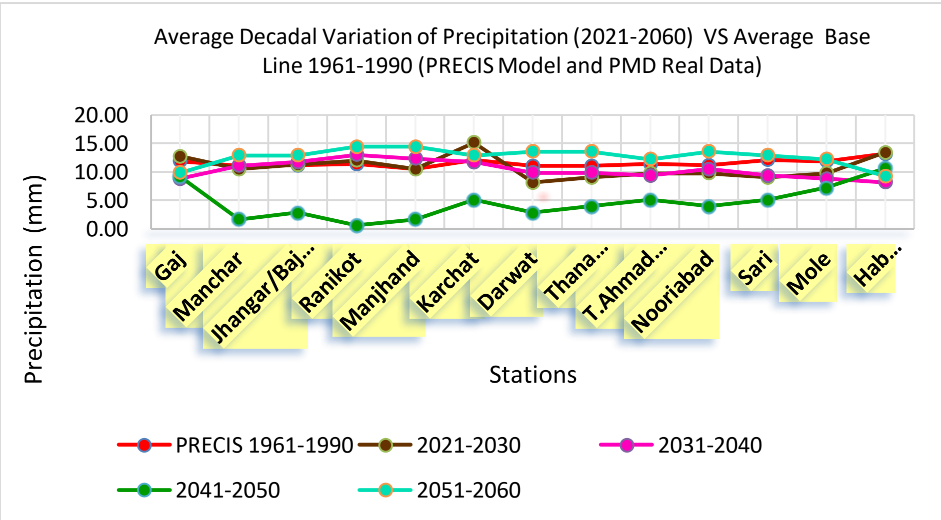

Figure 6: Polylines comparative chart of PMD VS PRECIS Model Baseline Data 1961-1990 and Decadal Projection of precipitation 2021-2060

Table 2: Decadal projection (2021-2060) of precipitation over the baseline period 1961-1990 in mm

Gauging Stations	PRECIS 1961-1990 (mm)	2021-2030	2031-2040	2041-2050	2051-2060
Gaj	11.87	12.69	8.79	9.16	9.86
Manchar	11.01	10.49	11.08	1.64	12.86
Jhangara/Bajara	11.12	11.23	11.73	2.79	12.86
Ranikot	11.36	11.98	13.00	0.54	14.43
Manjhand	10.53	10.49	12.35	1.64	14.43
Karchat	12.12	15.13	11.73	5.06	12.86
Darwat	11.01	8.13	9.86	2.79	13.56
Thana Boula Khan	11.01	9.00	9.86	3.94	13.56
T.Ahmad Khan	11.36	9.76	9.32	5.06	12.22
Nooriabad	11.12	9.76	10.45	3.94	13.56
Sari	12.12	9.00	9.32	5.06	12.86
Mole	11.87	9.76	8.79	7.23	12.22
Hab Catchment	13.16	13.40	8.18	10.65	9.24

Furthermore, table 2 depicted that the data for 2021-2030 revealed that; the station Karchat would receive 15.13 mm (124.85%) precipitation while the Darwat station will receive 8.13 mm (73.80%) as compared to baseline. However, the trend of rainfall will be more as compared to the range of baseline data.

In the decadal 2031-2040, the gauging station Manjhand will receive 12.35 mm (117.24 %) precipitation, and at the lowest range of precipitation, 8.18 mm (62.16%) will receive at the Hab catchment area. Hab gauging station is the primary water resources of Karachi Metropolitan city, which projected adverse effects as a shortfall of 37.84%. During the decade, 2031-2040 needs water resources planning and management to fulfill the water requirements.

The projected precipitation for the decadal 2041-2050, reveals a complicated situation of water resources due to a significant scarcity of rainfall. During this decade, a drought spell may be prolonged for many years and receive maximum precipitation of 10.65 mm (88.89%) at the Hab Catchment. However, 0.54 mm (4.75%) will receive at the Ranikot gauging station as compared to baseline. The Darwat, Gaj, and other small dams would be dry during 2041-2050. As agriculture is the mainstay of the economy, but in this decade, a shortage of food and fiber would be expected due to severe drought projection, which increases poverty alleviation and migration rate from the study area to irrigate and the industrial regions of the Indus river basin.

In the projected decade 2051-2060, the highest range of precipitation would receive at gauging station Darwat and Thana Boula Khan, about 13.56 mm (123.12%). The only 2 gauging stations out of 10, one at the upper location Gaj station and second at the south-west study area namely Hab catchment and have will receive shortfall precipitation of 9.86 mm (83.07) and 9.24 mm (70.17%) respectively as compared to baseline. However, the remaining 8 gauging stations will receive more than 100% precipitation as compared to baseline 1960-1990. More precipitation trends are projected in the study area. This decade would be the wet decade in the study area.

The figure 7 polylines chart depicted PMD and PRECIS Model (1960-1990) vs decadal wise projected precipitation 2021-2060. The baseline data of PMD and PRECIS Model has been assumed as 100%. The projected scenarios 2021-2060 reflects the percentages data compared to both Baseline data set. The Projected data shows 89.90%, 93.31%, 42.98%, and 114.09% in the decadal of 2021-2030, 2031-2040, 2041-2050, and 2051-2060, respectively for the PMD data. However, the PRECIS model data reflects 93.87%, 90.51%, 38.74% and 110.81% followed by 2021-2030, 2031-2040, 2041-2050, and 2051-2060. Thus the overall analysis of the projected period with baseline data set estimated a difference ± 5.03 (2021-2030), ± 2.80 (2031-2040), ± 4.24 (2041-2050), and ± 3.28 (2051-2060) while the average difference was estimated ± 3.84%.

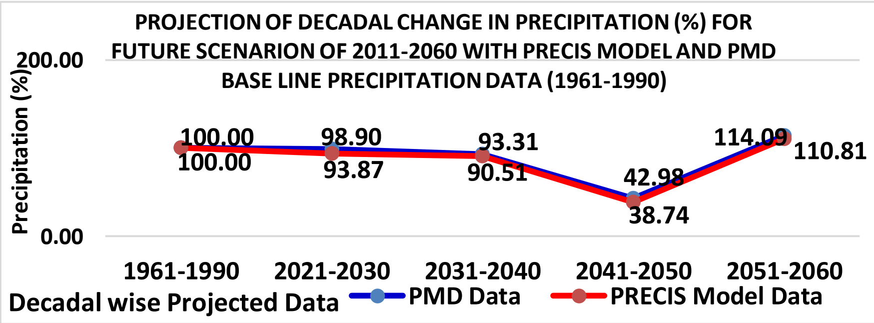

Figure 7: Polylines percentage-wise PMD and PRECIS Model Baseline data 1961-1990 VS Projected decadal precipitation 2021-2060

4. CONCLUSION

The results presented in this study are an attempt to capture the influence of precipitation inconsistency on the available water resources in the region, including hill torrents and groundwater resources. The study revealed overall projected scenarios for 2021-2060 in the study area over the baseline data of PMD and PRECIS modeling 1961-1990. A slight shortfall of about -6.13% in 2021-2030 and -9.48% during 2031-2040. The projected results will marginally affect the water resources, groundwater recharge, and agricultural practice in the study area.

However, a severe shortfall of precipitation projected about -61.26% during the decade 2041-50 over the PRECIS baseline data 1961-1990. Results presented there are increasing threats of the inconsistency of precipitation pattern, dried the reservoir, ponds which impose acute shortage of water and reasons drying agricultural fields, livestock suffered from dehydration. The livelihood does not have an adequate supply of water for their daily household chores. They face additional consumption to fetch water from remote areas or to purchase water, making an additional burden.

However, the decade 2051-2060, is only one decade out of all decadal scenarios, which receive more precipitations about +10.81%, over the baseline period of 1961-1990 in the study area. Runoff water can be stored in reservoirs, ponds, and diverted for rainwater harvesting purposes. Increase the infiltration rate, the recharge rate of groundwater may increase with improving quality. The agricultural activities may be encouraged and boost up in the region. Besides that, the livelihood and socio-economic conditions of the people may recover.

It is further concluded that; during the projected scenarios 2021-2060, the drought spell and extreme floods projected. The water resources planning and management strategies with smart techniques may reduce the adverse effects in the study area.

5. RECOMMENDATIONS

Based on the significant variations in the future precipitation scenarios, the water resources are on threats and adverse impacts on the food requirement in the study area. The investigated period has projected the inconsistency of floods and dry spells in the study area during the projected period. The floods may be accumulated during the wet season (monsoon) through the construction of the hydraulic structures, as well as collected in the natural depressions of the hilly tracts of the study area.

The collected water might be utilized during the dry spells through the efficient use of irrigation systems for the sustainability of food demand in the region. Furthermore, the current study investigated in detail;

a) The procedure by which information has made highlights the benefit of making a reality for basic reflection of spatial-temporal for critical reflection on the climate change projection scenarios using the PRECIS model.

b) The discoveries from the modeling approach presented the challenges and the methodology by which learning was generated on how to combat the scales of disaster prevention and management for sustainable development.

6. ACKNOWLEDGMENT

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8. CONFLICT OF INTEREST

No conflict of interest with the authors.

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