Chapter: VI

6. Results and Discussions

The objective of the present study is to provide decision support system for drought management. The Drought characterization is attempted using optical remote sensing data from various sources. A satellite-based protocol inference has been made to exploit the use of the generated indicators for drought characterization. The evaluation of the drought indicators also envisages comparison of the indicators with available in situ conventional data and various data products from different satellite sensors. The data processing and analysis was done for the study area of Lakhpat and Nakhatrana Taluka of Kachchh. The drought analysis was carried on by deriving the vegetative and meteorological indices. Figure 6.1 is given for the reference to identify geographical areas during indices analysis.

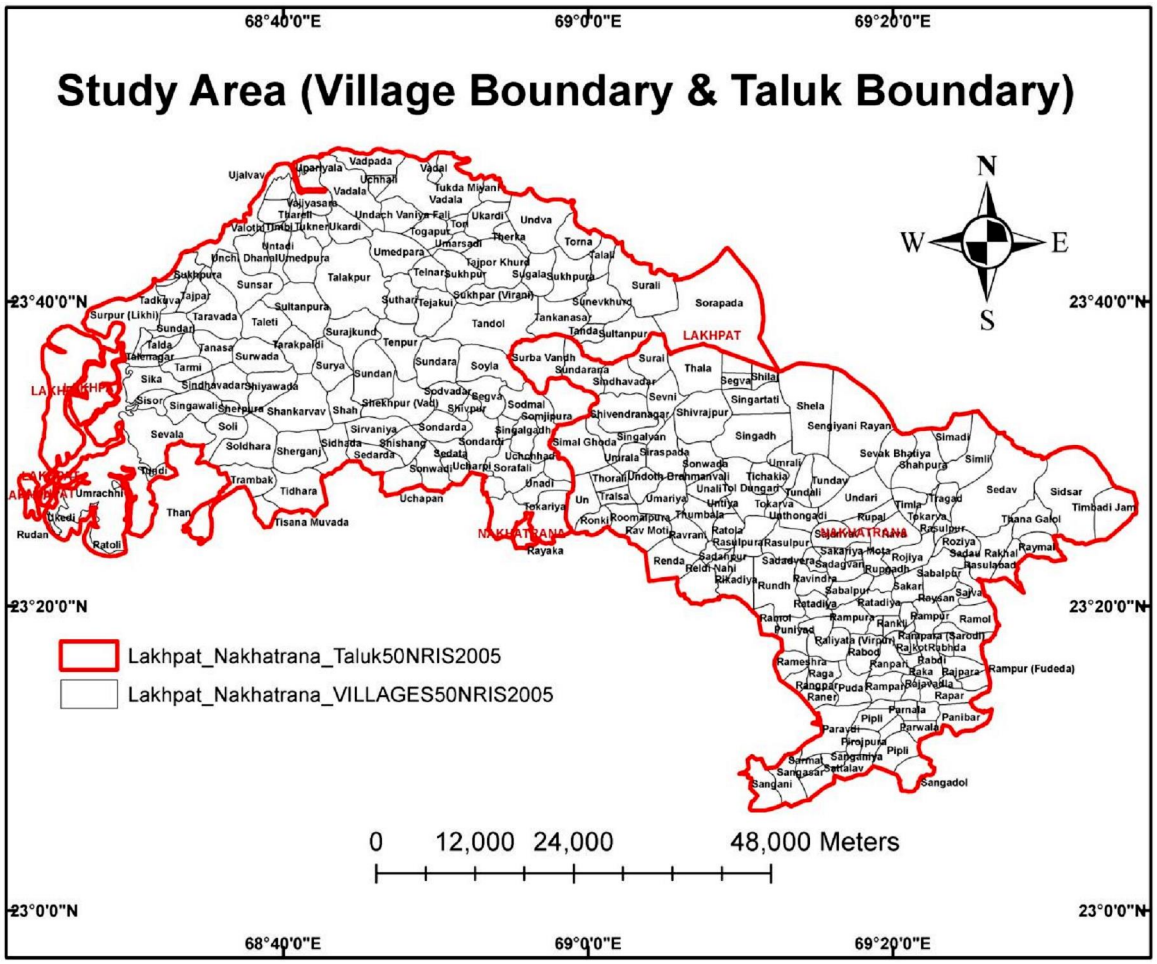

Figure 6.1 Study area with Village and Taluk Boundary

6.1 Drought Analysis Using Vegetation Indices:

This Study aims to analyse spatial and temporal drought analysis over study area using various vegetative and meteorological indices derived from remote sensing datasets. As discussed in chapter-4 various vegetation indices derived and the results are described to provide accurate assessment of the drought over study area.

6.1.1 Spatio-Temporal Drought Analysis using VCI

The spatial and temporal patterns of 16-day VCI is analysed for years (2007-2016) are shown in Figures below. This index standardizes NDVI and isolates the ecological signals from the local environmental sign from the transient in this sense it ends up being a superior marker for checking water stress condition when contrasted with NDVI (Kogan and Sullivan, 1993). The resulted images of Vegetation Condition Index (VCI) were classified. The seasonal drought conditions were analysed and maps from 2011-2016 taking into 16 days temporal interval. This is a good indicator for monitoring the agriculture and vegetation growth. a surrogate measure of the drought condition

6.1.1.1 VCI Analysis for the Year of 2011-2012:

The NDVI derived VCI index is used to quantify drought from a long term observation from space. Figure 6.2 and figure 6.3 illustrate the vegetation condition for different fortnights of kharif season and Rabi season respectively for the crop year 2011 and 2012. It was found that year 2011-2012 is not stressed except image of 04 august 2011 (Kharif Season) VCI in North- western part of the study Area.

The spatial distribution of VCI from derived from MODIS NDVI dataset for the year 2011-2012 Kharif and Rabi season at 16 day interval are shown below, during the kharif season partial stress in vegetation condition especially in Lakhpat Taluka and southern part of Nakhatrana. Figure 6.2 and figure 6.3 shows, overall normal vegetation condition over the study area there are no severe drought condition revealed from the VCI index for the crop year 2011-2012.

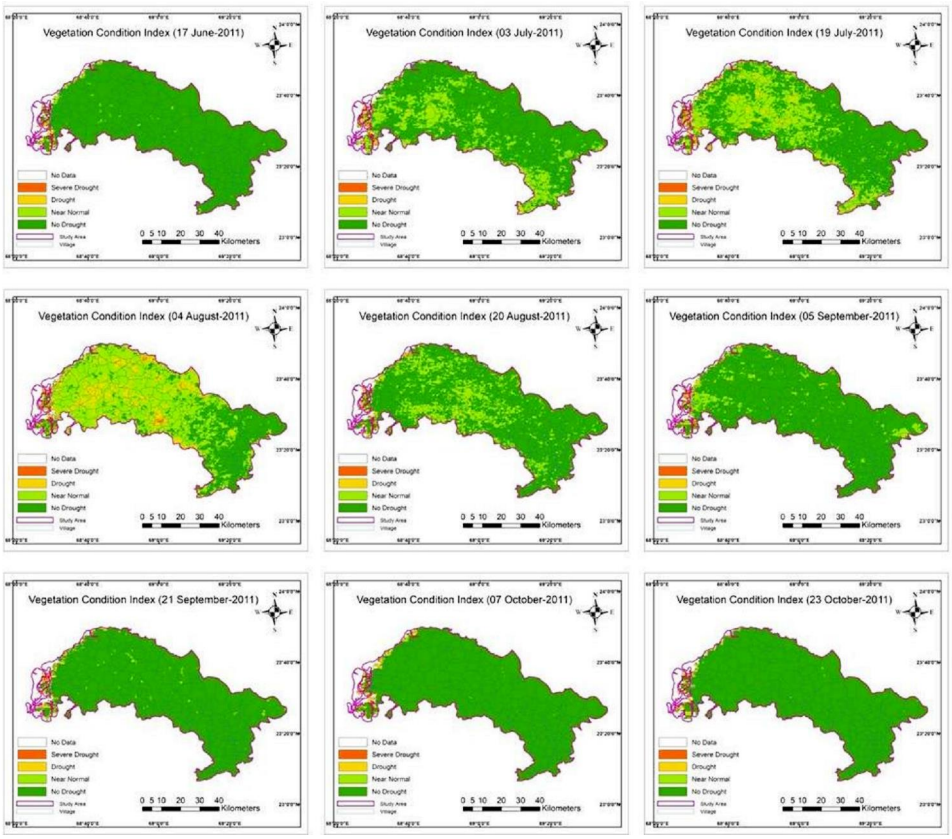

Figure 6.2 VCI 2011-2012 (Kharif Season)

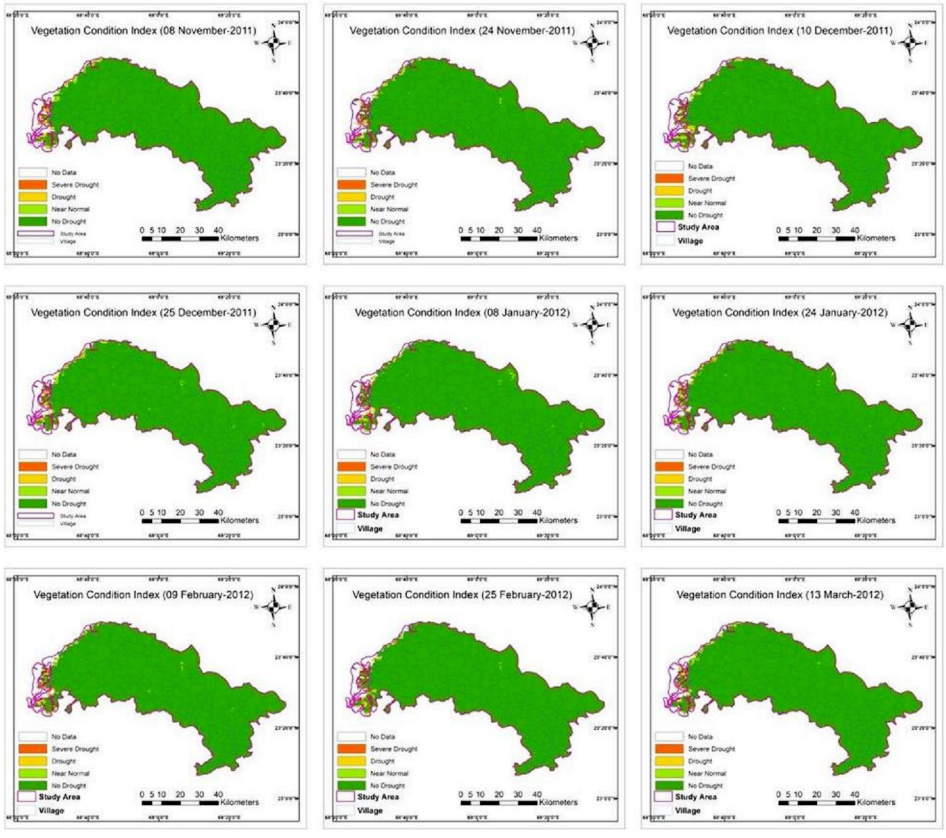

Figure 6.3 VCI 2011-2012 (Rabi Season)

6.1.1.2 VCI Analysis for the Year of 2012-2013:

VCI analysis of the crop year 2012-2013 is described in Fig.6.4 and 6.5 for Kharif and Rabi season respectively. Figure 6.4 and Figure 6.5 illustrate the vegetation condition for every 16 days of kharif and Rabi crops for the year 2012 and 2013. It was found that severe drought condition experienced during kharif season of the year 2012-2013 in the maximum part of study area. The water scarcity can be clearly identified in Kharif season 2012-2013 Whereas, VCI for Rabi season indicates normal condition over study area. It has been observed that Kharif season of 2012-2013 is experiencing drought condition in consecutive four dates (19 July, 04 August, 20 August and 05 September) in sixteen days interval. Suggesting that the water stress has prevailed and crop productivity would have been reduced as compared to the net sown area.

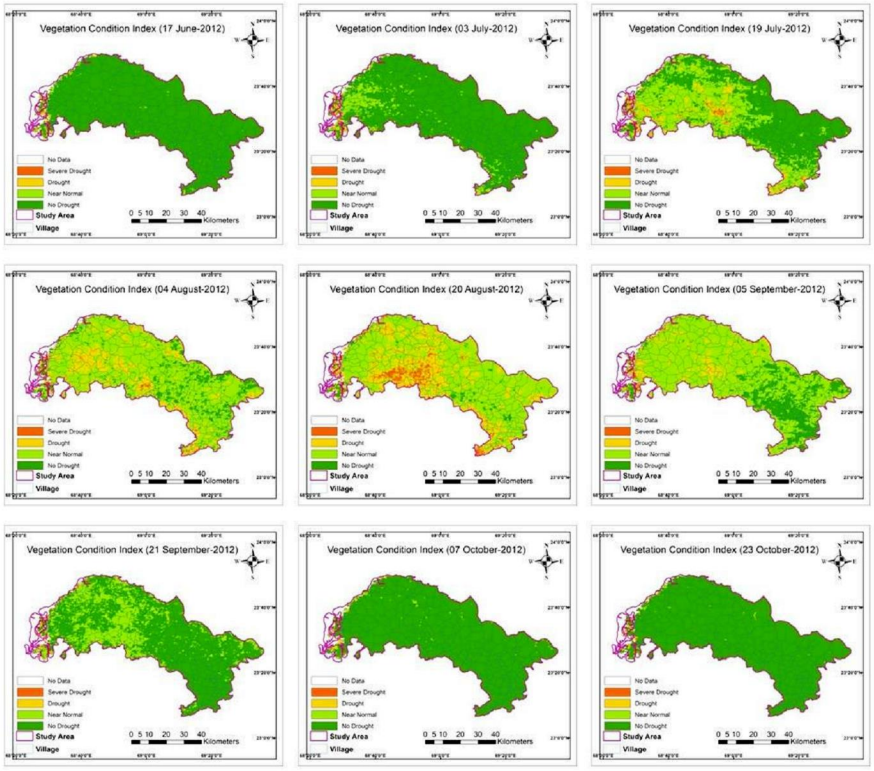

Figure 6.4 VCI 2012-2013 (Kharif Season)

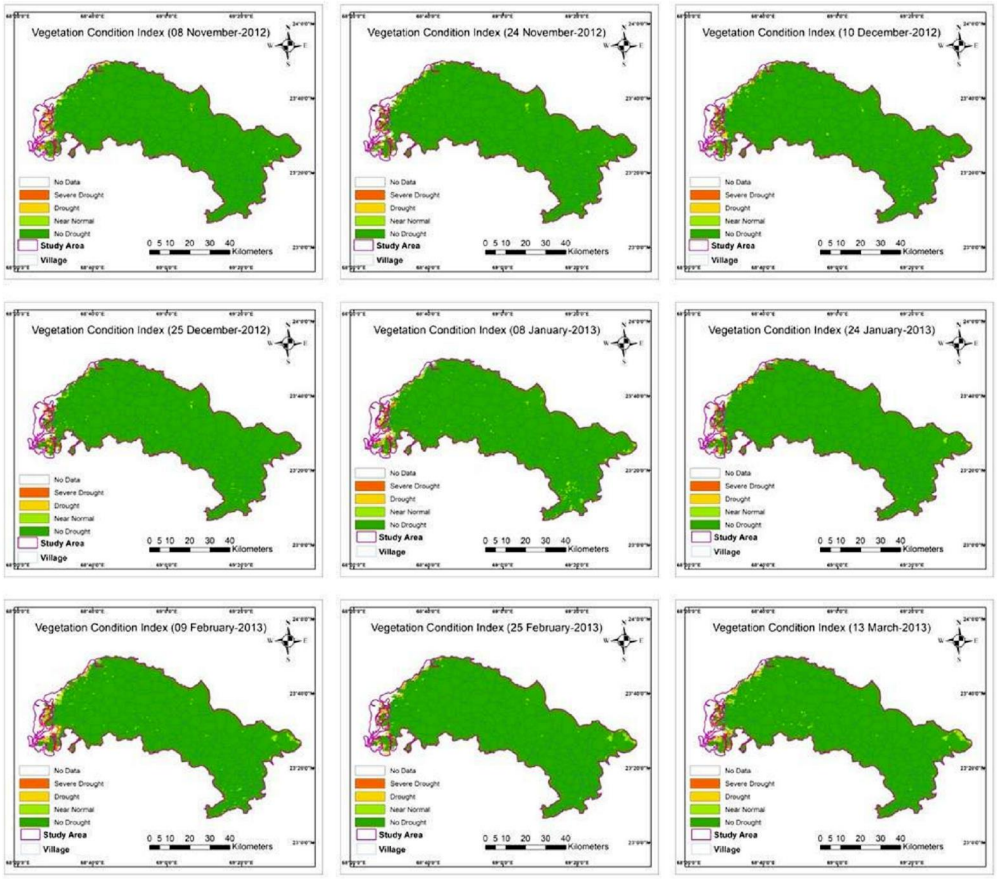

Figure 6.5 VCI 2012-2013 (Kharif Season)

6.1.1.3 VCI Analysis for the Year of 2013-2014:

Figure 6.6 shows maps describing the spatial variability of the NDVI-derived VCI for different fortnights of kharif crops for the year 2013-2014. It was found that moderate drought condition prevailed during kharif season of the year 2013-2014 over a small area of study region specially in Lakhpat taluk. The onset and extent of drought can be clearly observed from the VCI maps of consecutive fortnights of 2013-14. Rabi season of year 3013-2014 has been observed as normal condition as shown in figure 6.7.

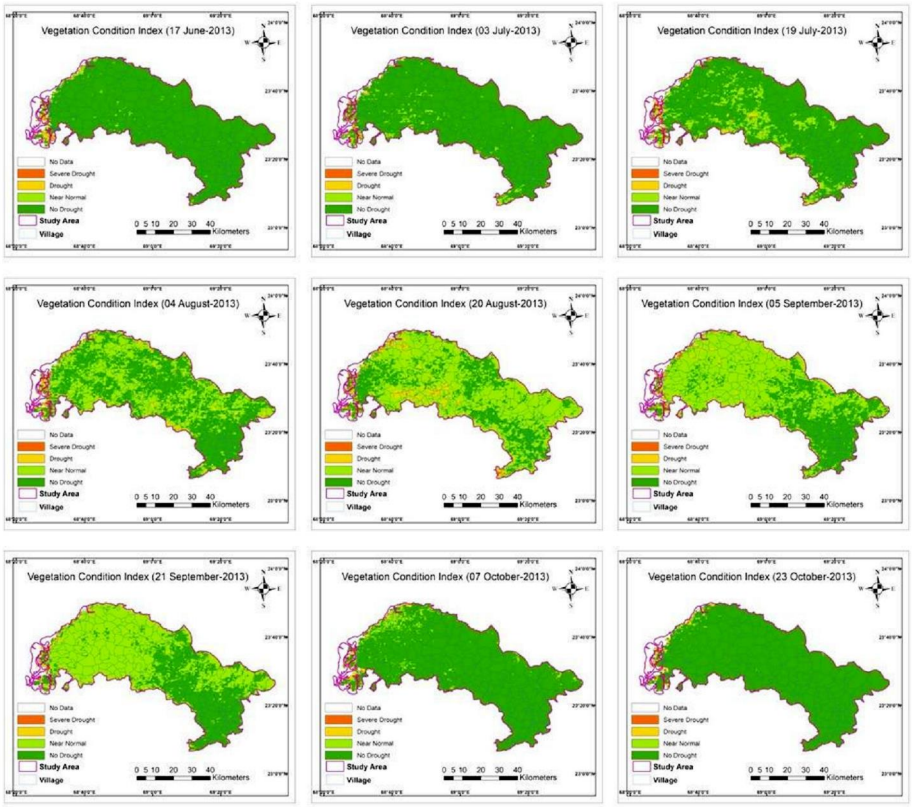

Figure 6.6 VCI 2012-2013 (Kharif Season)

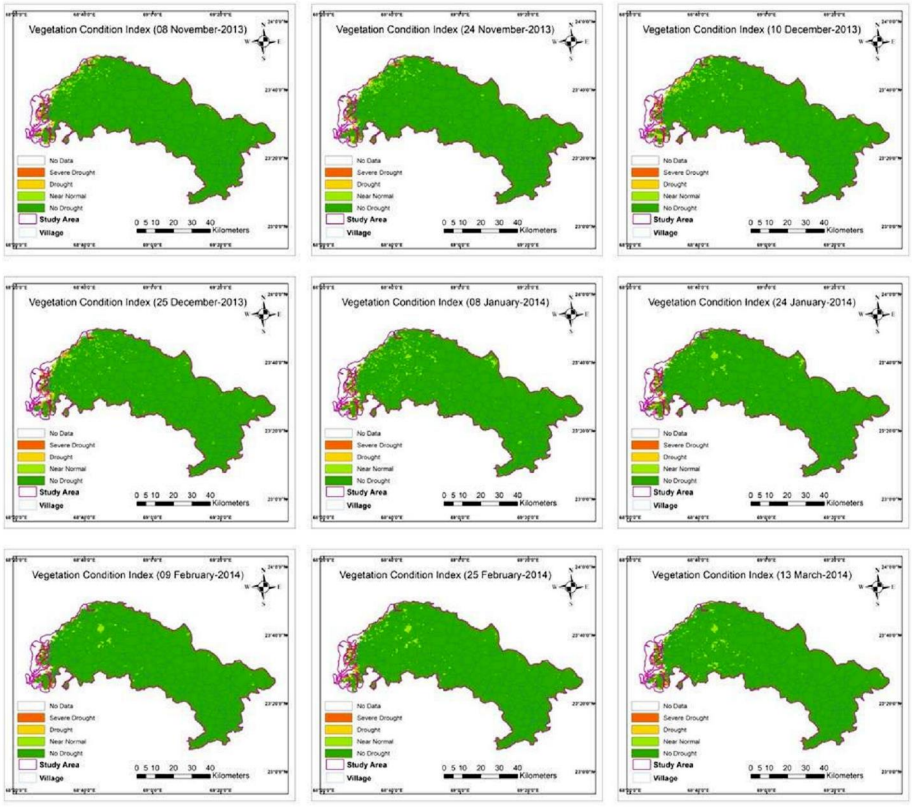

Figure 6.7 VCI 2013-2014 (Rabi Season)

6.1.1.4 VCI Analysis for the Year of 2014-2015:

Figure 6.8 describes the spatio-temporal variation of VCI for different fortnights of kharif crops for the year 2014-2015. It was found that Severe to moderate drought condition prevailed during kharif season of the year 2014-2015 over a large area of study region. Acute water stress is evident all over the study area during the 19 July, 20014 to 20 August 2014. Whereas, condition was quite improved over the Nakhatrana taluk as compared to Lakhpat Taluk from the 05 September 2014 onwards in kharif Season.

Figure 6.9 describes the VCI variation in Rabi Season of year 2014-2015. As figure 6.9 shows Lakhpat taluka still experiencing stress in vegetation conditions as compared to the Nakhatrana Taluka. From 08 January 2015 to Second fortnight of March shows the missing data set in VCI, due to the limitations of the Optical remote sensing acquisition (cloud cover/ No data).

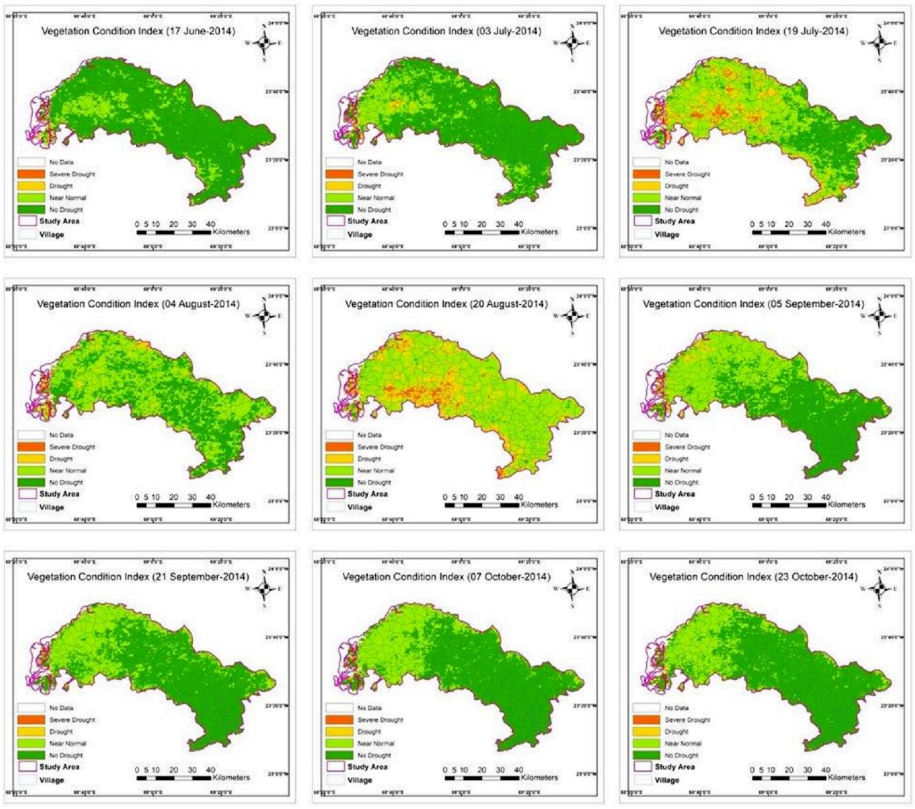

Figure 6.8 VCI 2014-2015 (Kharif Season)

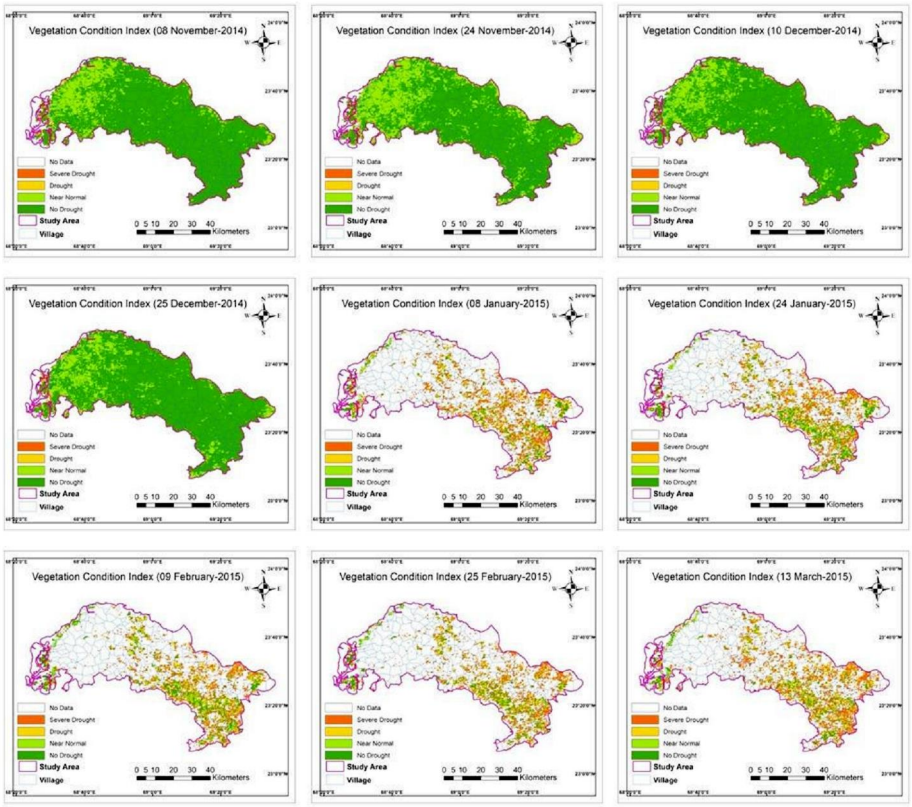

Figure 6.9 VCI 2014-2015 (Rabi Season)

6.1.1.5 VCI Analysis for the Year of 2015-2016:

A keen observation of the NDVI derived VCI maps for the year 2015-2016 over the study area are shown in Figure 6.10 and Figure 6.11 for Kharif and Rabi Crop season respectively. In the Kharif Season year 2015, drought intensity maps reveal that maximum part of the study area experienced severe drought condition. Sever to moderate drought condition starts from the second fortnight of the June 2015 to second fort night of the October 2015.

Figure 6.11 describes the VCI variation in Rabi Season of year 2015-2016. Spatio-Temporal variation analysis shows that Rabi season of the year also experienced severe to moderate drought condition throughout the Rabi crop season 2015-2016.

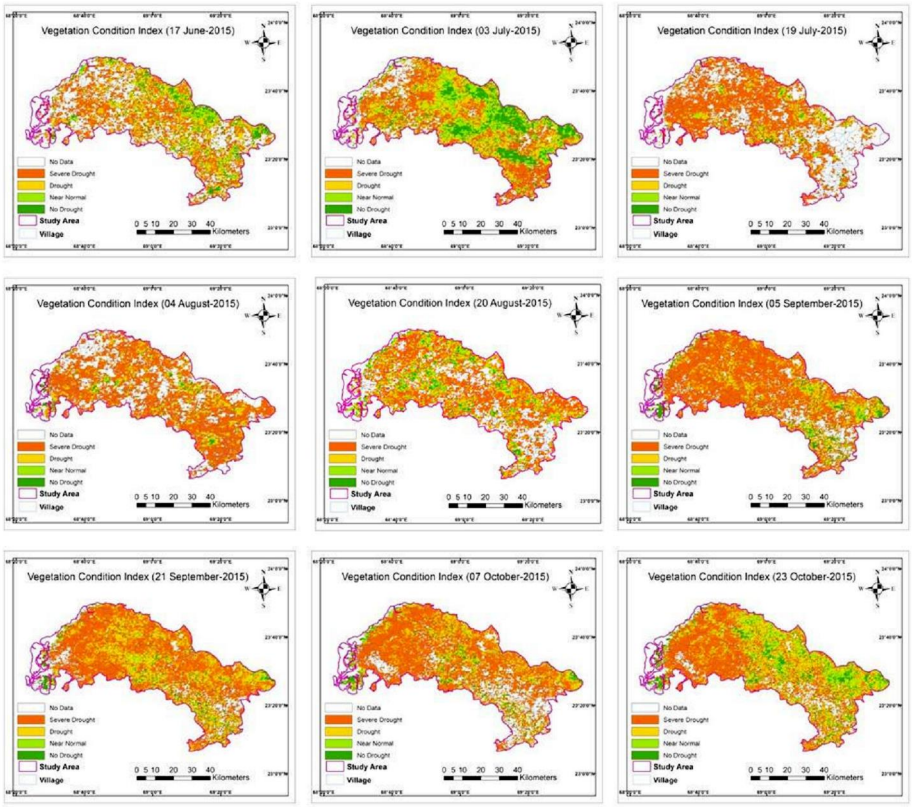

Figure 6.10 VCI 2015-2016 (Kharif Season)

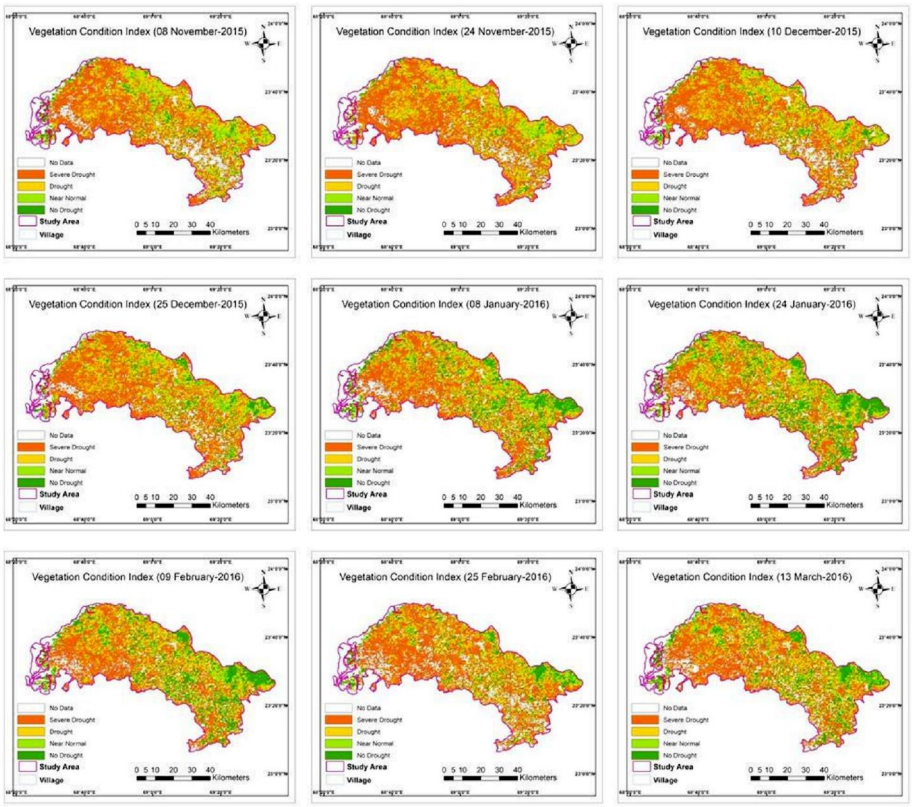

Figure 6.11 VCI 2015-2016 (Rabi Season)

6.1.2 Spatio-Temporal Drought Analysis using NDWI Anomaly

As mentioned in section 4.3.4, Normalized Difference Water Index (NDWI) uses the NIR and Short Wave Infra-Red (SWIR) bands in the wavelengths 0.86 μm and 1.24 μm respectively. The liquid water absorption ability is high in the SWIR region than the NIR region; therefore, the crop with high liquid water content has the higher NDWI values while stressed vegetation has minus or very low NDWI values. Equation 4.1 shows the formula used for the calculation of NDWI and equation 4.2 illustrates NDWI anomaly calculation for drought analysis. NDWI have been considered as an independent vegetation index. It is complementary to NDVI but not a substitute for NDVI. NDWI describes the plant water stress and NDWI is not an agricultural drought index. The NDWI also informs the presence of the water content and even shallow water or wet soil conditions are also differentiated by this.

6.1.2.1 NDWI Anomaly Analysis for the Year of 2011-2012:

A seasonal plant water stress maps was generated at the 16 days of interval to evaluate the actual stress in the plant water of the kharif and rabi season. NDWI anomaly maps describe the actual deviation in Plant water from the reference values.

The spatial distribution of drought classes based on NDWI Anomaly is shown in Figure 6.12 and figure 6.13 for kharif and rabi season of the year 2011-2012 respectively. It has been observed that during kharif season 2011-2012, NDWI anomaly values lies in normal conditions except 19 July 2011, 04 August 2011 and 20 August 2011.

Figure 6.12 describes the NDWI anomaly for the Rabi season of year 2011-12. NDWI anomaly maps reveal that maximum part of the study area experienced normal condition over the study area. Plant Water stress using NDWI anomaly maps shows positive values throughout the season.

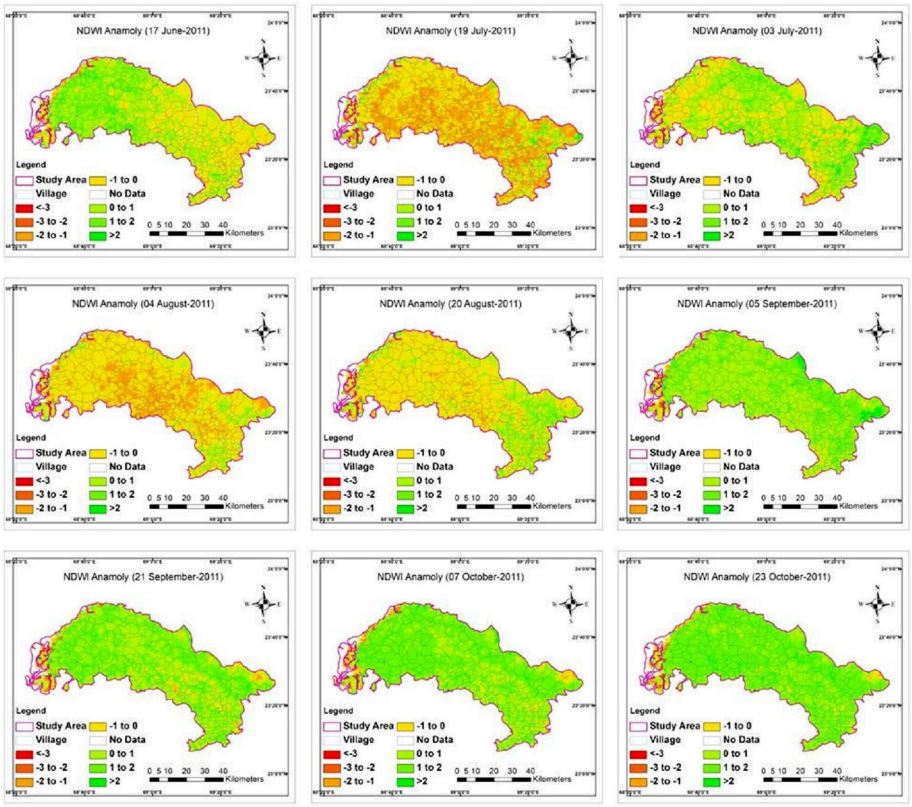

Figure 6.12 NDWI Anomaly 2011-2012 Kharif Season

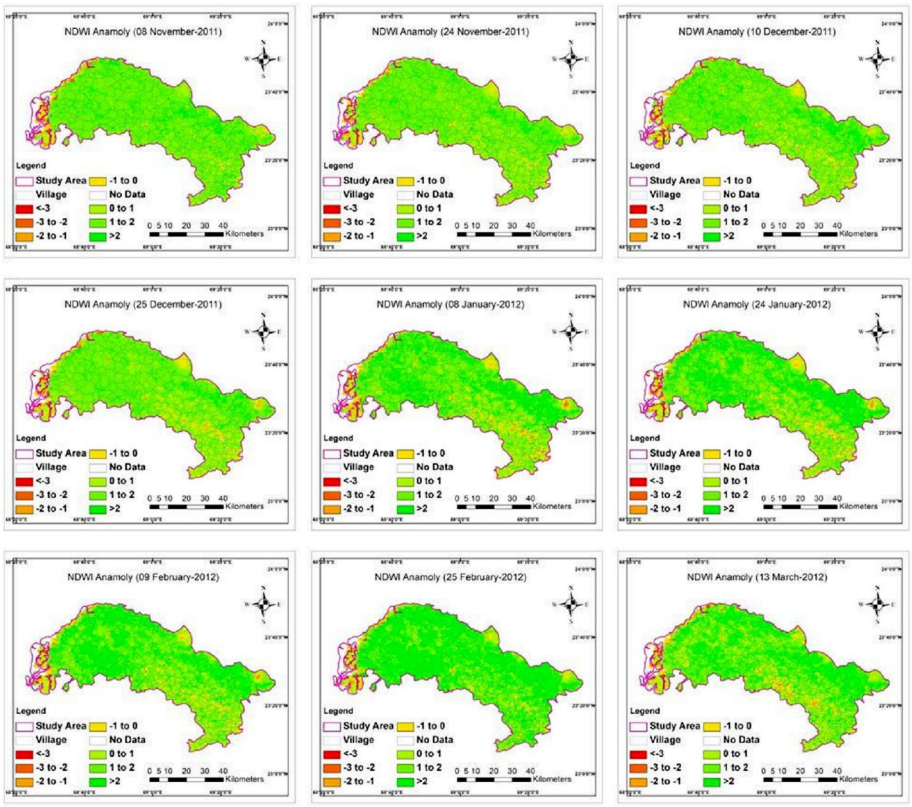

Figure 6.13 NDWI Anomaly 2011-2012 Rabi Season

6.1.2.2 NDWI Anomaly Analysis for the Year of 2012-2013:

Figure 6.14 describes the spatio-temporal variation of NDWI anomaly for different fortnights of kharif crops for the year 2012-2013. It was found that Severe to moderate crop water stress prevailed during kharif season of the year 2012-2013 over a large area of study region. Figure 6.14 shows that the crop water stress starts from 03 July2012 to throughout the season.

Figure 6.15 shows the NDWI anomaly variation in Rabi Season of year 2012-2013. As figure 6.15 shows the NDWI anomaly variation in Rabi season 2012-2013 is in normal conditions except some pockets of villages in Nakhatrana Taluk.

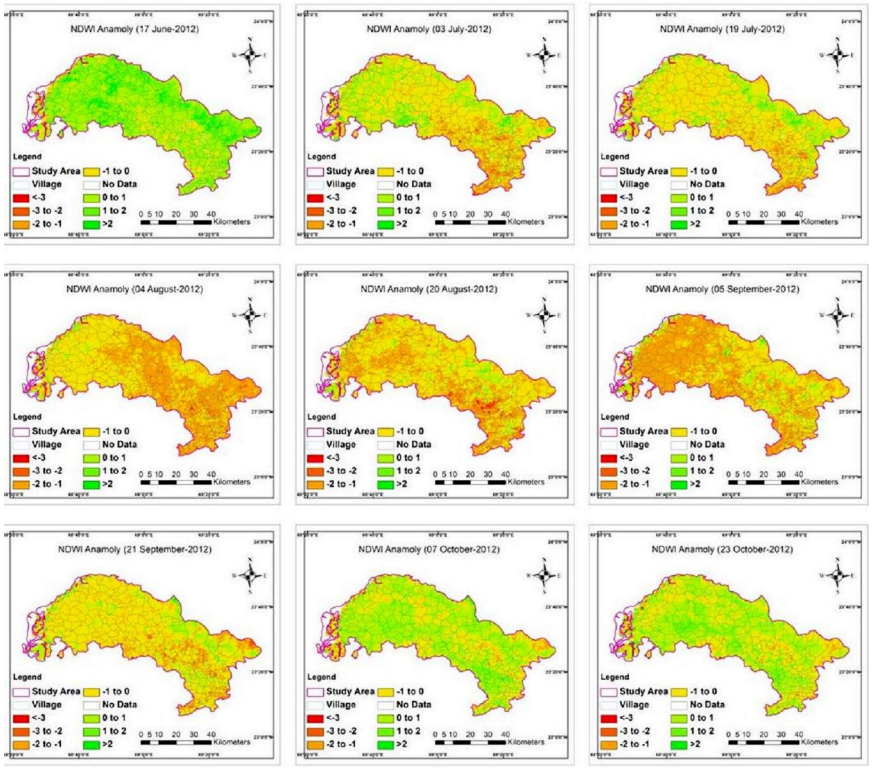

Figure 6.14 NDWI Anomaly 2012-2013 Kharif Season

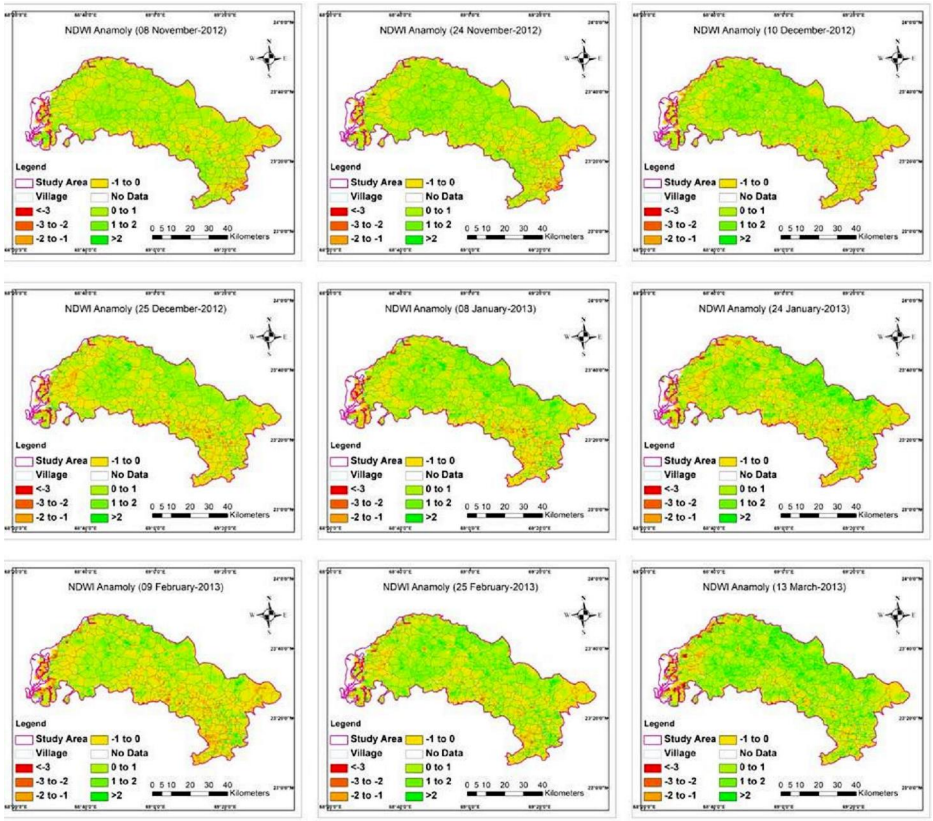

Figure 6.15 NDWI Anomaly 2012-2013 Rabi Season

6.1.2.3 NDWI Anomaly Analysis for the Year of 2013-2014:

NDWI anomaly analysis of the crop year 2013-2014 is described in figure 6.16 and 6.17 for Kharif and Rabi season respectively. Figure 6.16 and figure 6.17 illustrate the Plant water stress condition for every 16 days of kharif and Rabi crops for the year 2013 and 2014. It was found that severe plant water stress condition experienced during late season of kharif for the year 2013-2014 in the maximum part of study area. Spatio-temporal variation shows plant water conditions were normal in 17 June, 03 July and 19 July whereas, late season from 04 August to 07 October 2013 Plant water stress analysed as in severe condition over the study area. Figure 6.17 illustrates the spatial distributions of NDWI anomaly for the Rabi season of crop year 2013-2014. An NDWI anomaly map shows the normal crop water conditions over study area except northern part of Lakhpat taluka.

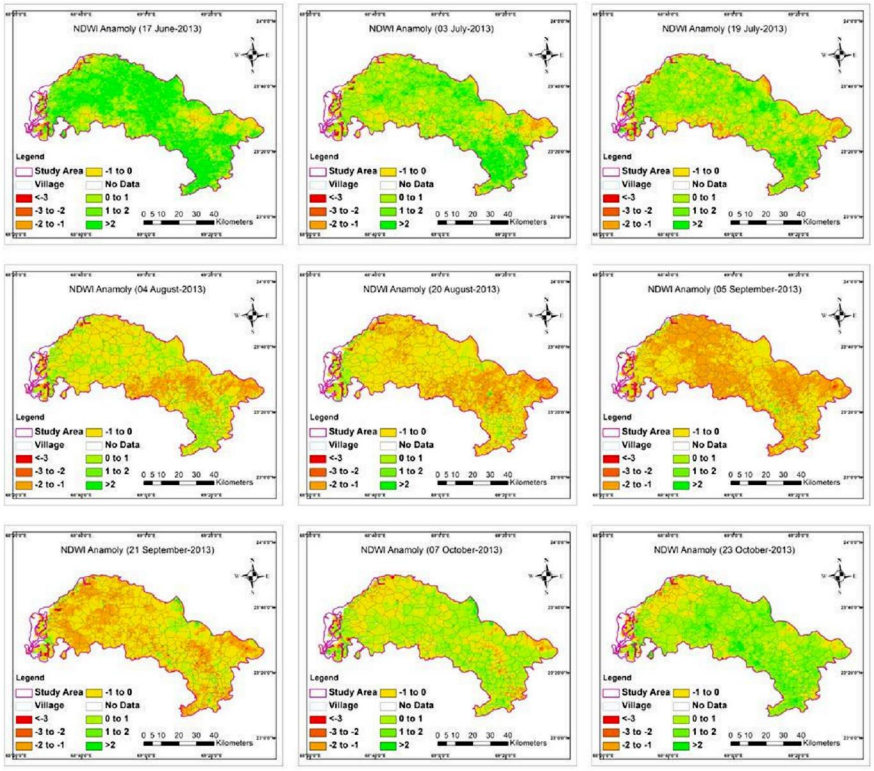

Figure 6.16 NDWI Anomaly 2013-2014 Kharif Season

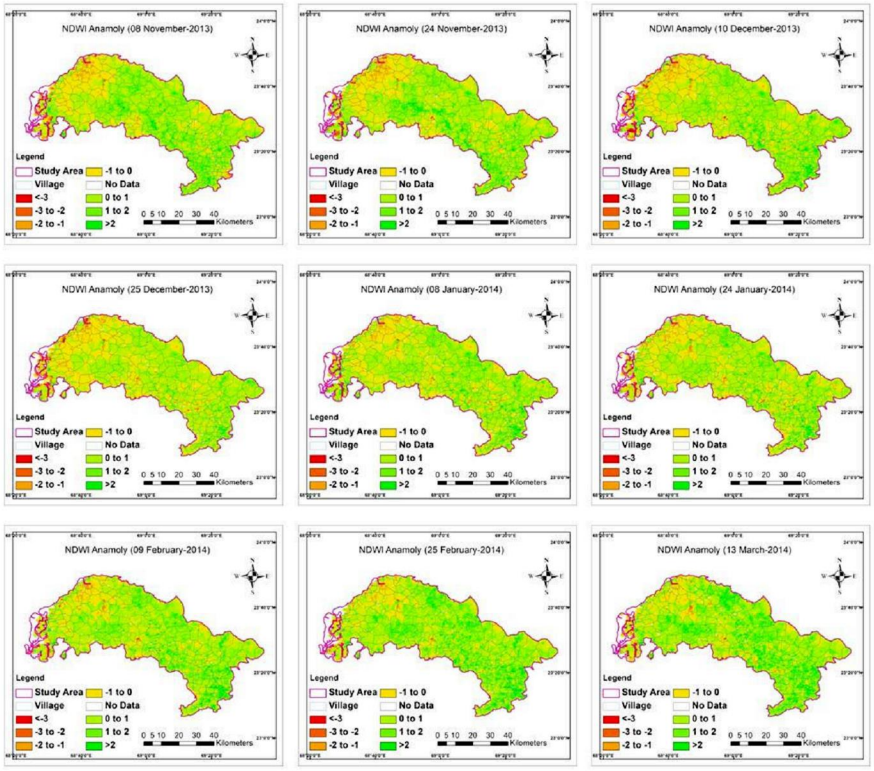

Figure 6.17 NDWI Anomaly 2013-2014 Rabi Season

6.1.2.4 NDWI Anomaly Analysis for the Year of 2014-2015:

Figure 6.18 describes the spatio-temporal variation of NDWI anomaly for different fortnights of kharif crops for the year 2014-2015. It was found that Severe to moderate crop water stress prevailed during kharif season of the year 2014-2015 over a large area of study region. Figure 6.18 shows that the crop water stress starts from the beginning of the season to throughout the season.

Figure 6.19 shows the NDWI anomaly variation in Rabi Season of year 2014-2015. As figure 6.19 shows the NDWI anomaly variation in Rabi season of year 2014-2015 is also experienced moderate to severe water stress.

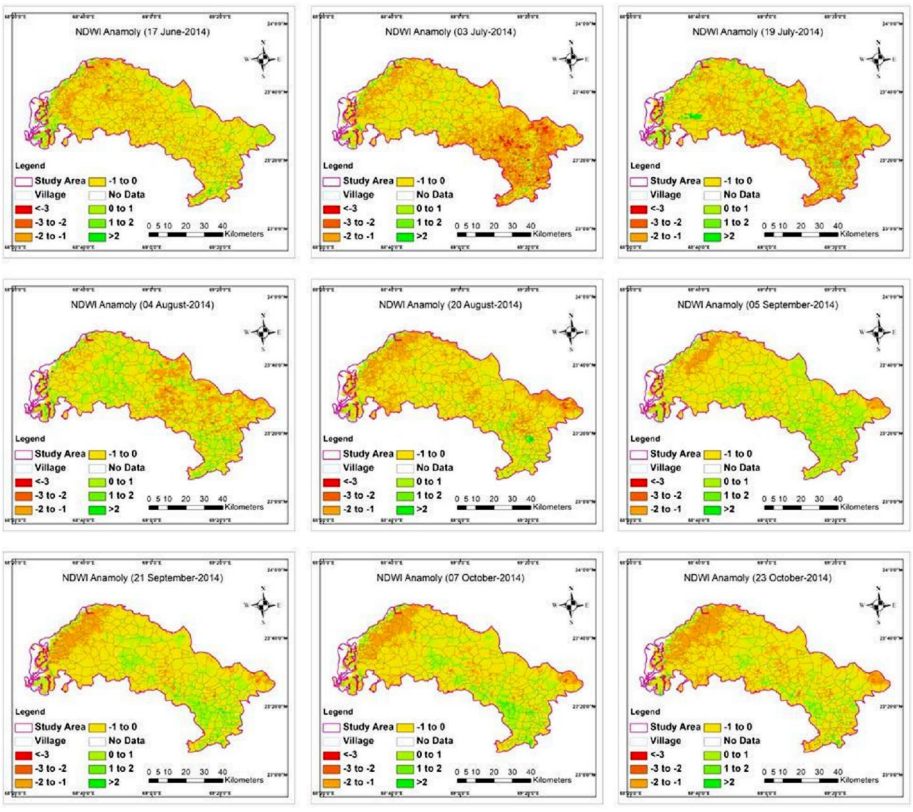

Figure 6.18 NDWI Anomaly 2014-2015 Kharif Season

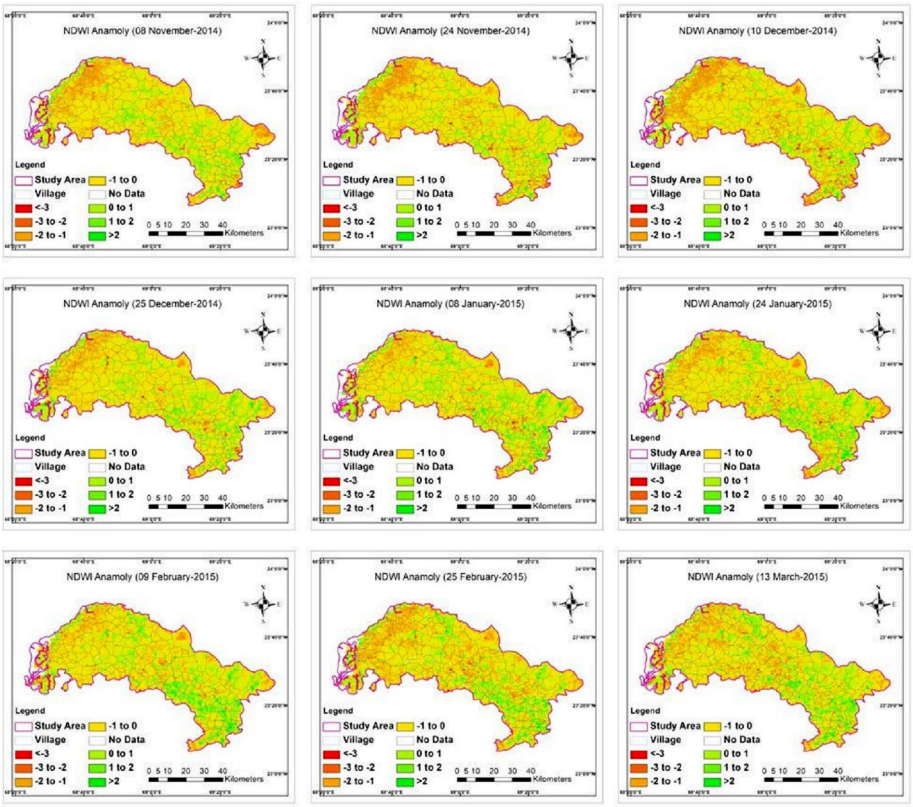

Figure 6.19 NDWI Anomaly 2014-2015 Rabi Season

6.1.2.5 NDWI Anomaly Analysis for the Year of 2015-2016:

NDWI anomaly analysis of the crop year 2015-2016 is described in Fig.6.20 and 6.21 for Kharif and Rabi season respectively. Figure 6.20 and figure 6.21 illustrate the Plant water stress condition for every 16 days of kharif and Rabi crops for the year 2015-2016. Analysis shows that severe plant water stress condition experienced during kharif season in crop year 2015-2016 in the maximum part of study area. Spatio-temporal variation of NDWI anomaly of Rabi season in crop year 2015-2016 shown in figure 6.21, plant water conditions were normal over the study area. Figure 6.21 illustrates the spatial distributions of NDWI anomaly for the rabi season of crop year 2015-2016.

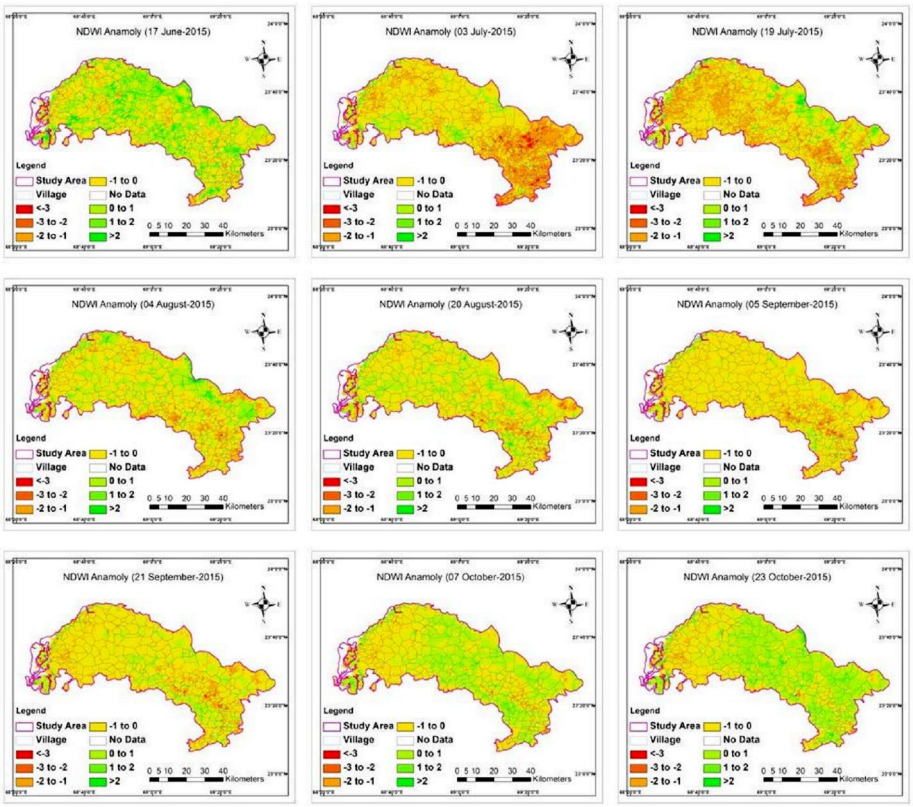

Figure 6.20 NDWI Anomaly 2015-2016 Kharif Season

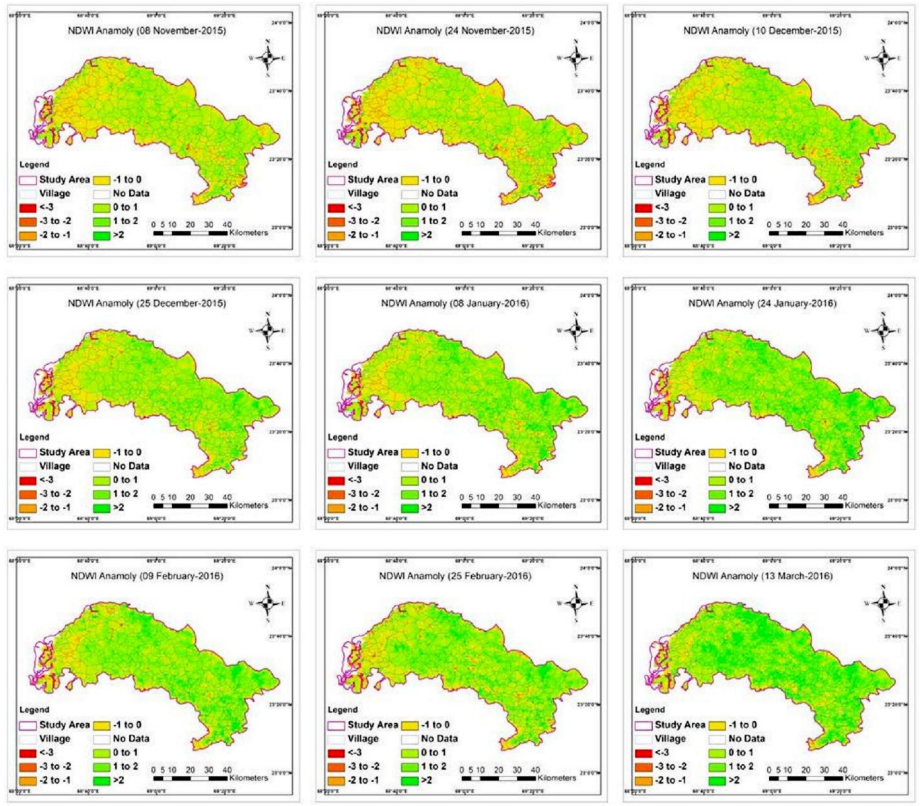

Figure 6.21 NDWI Anomaly 2015-2016 Rabi Season

6.1.3 Spatio-Temporal Analysis NDVI Deviation from Previous Five Years

To qualitatively assess the crop health based on NDVI deviation, from previous five years (also known as Short Term Average (STA)). NDVI deviation is calculated using very simple and linear formula to identify the vegetative growth deficient areas with reference to the past five years. Figures below represent the spatial distribution of vegetative conditions in both the season in given cropping years. Symbologies of the maps are classified from dark red colour to dark green colour with yellow shades in intermediate ranges. Dark red colour represents severe drought like situation and dark green colour represents very healthy and positive vegetative conditions where as yellow shade represents intermediate or normal conditions of the vegetation.

NDVI deviation from STA for the year 2011-12 Kharif and Rabi season illustrated in figure 6.22 and figure 6.23 respectively. Normal condition has been analysed from the visual interpretation of the map in both (kharif and rabi) season. Figure 6.24 and figure 6.25 represents NDVI deviation from STA for the year 2012-2013, kharif and rabi crop season respectively. Deviation of NDVI represents mild stress in crop condition during the mid of kharif season and late rabi season. Year 2013-2014 NDVI deviation described in figure 6.26 and 6.27 for the kharif and rabi season, where vegetation condition experienced mild stress throughout the seasons. Kharif season for the year 2014-2015 NDVI deviation is illustrated in figure 6.28 which represents normal to mild drought condition over the study area. Figure 6.29 represents Rabi season deviation for the year 2014-2015, which also indicates normal to mild drought condition over the study area. Figure 6.30 and figure 6.31 illustrates the NDVI deviation for the year 2015-2016 from STA, where maps indicate that kharif season crop stressed by normal to mild conditions and rabi season crop experienced mild drought condition over study area.

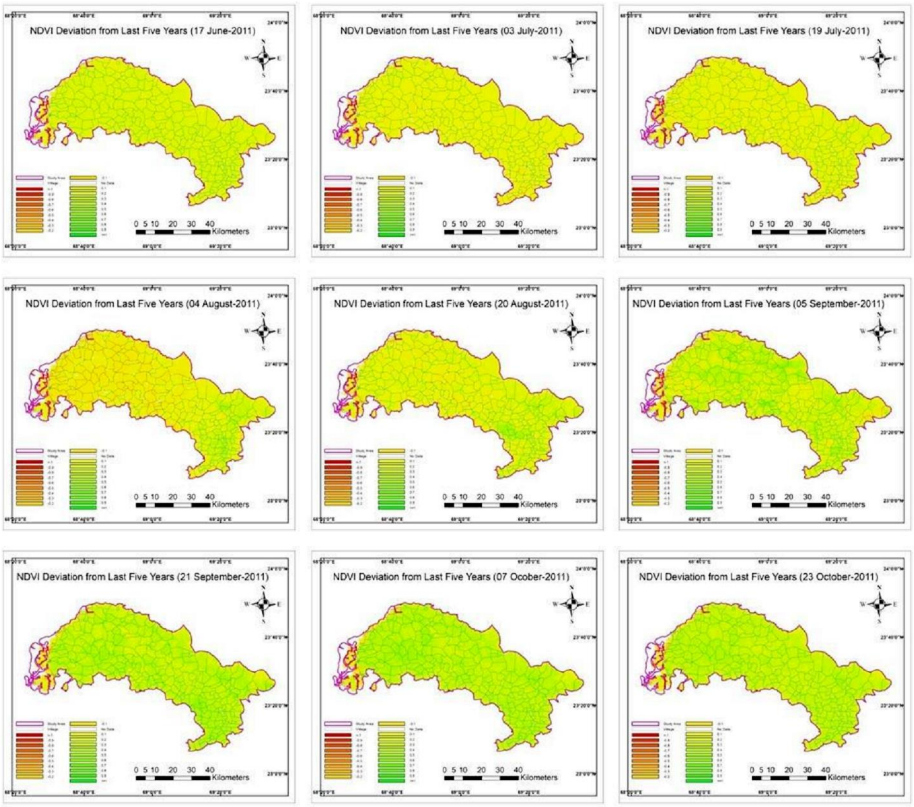

Figure 6.22 NDVI Deviation (Kharif Season, 2011-2012)

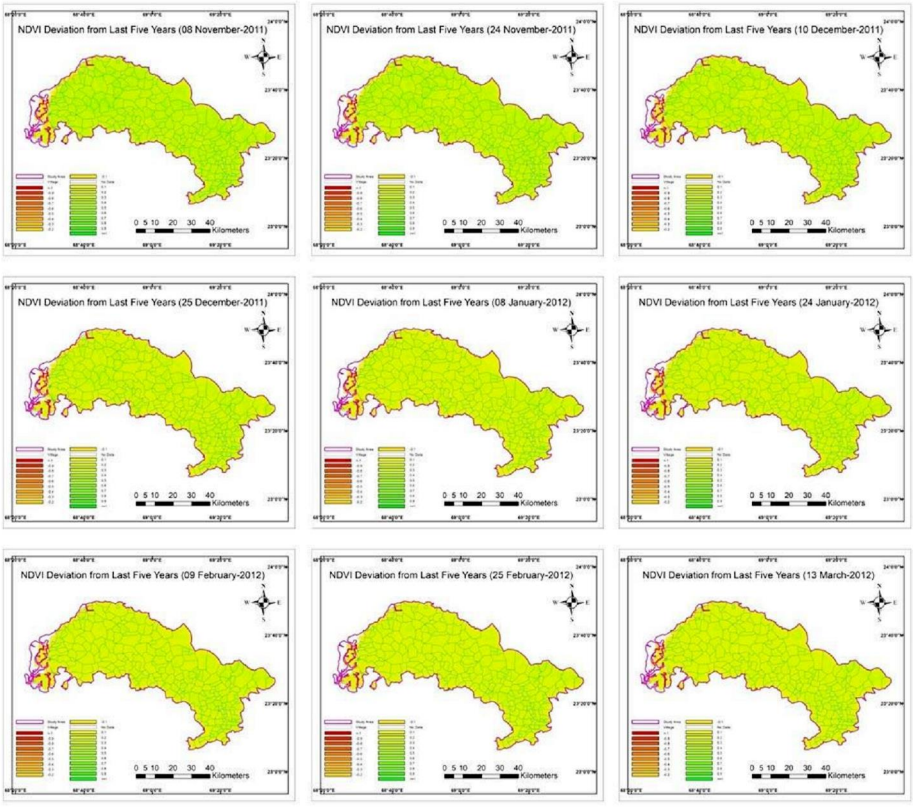

Figure 6.23 NDVI Deviation (Rabi Season, 2011-2012)

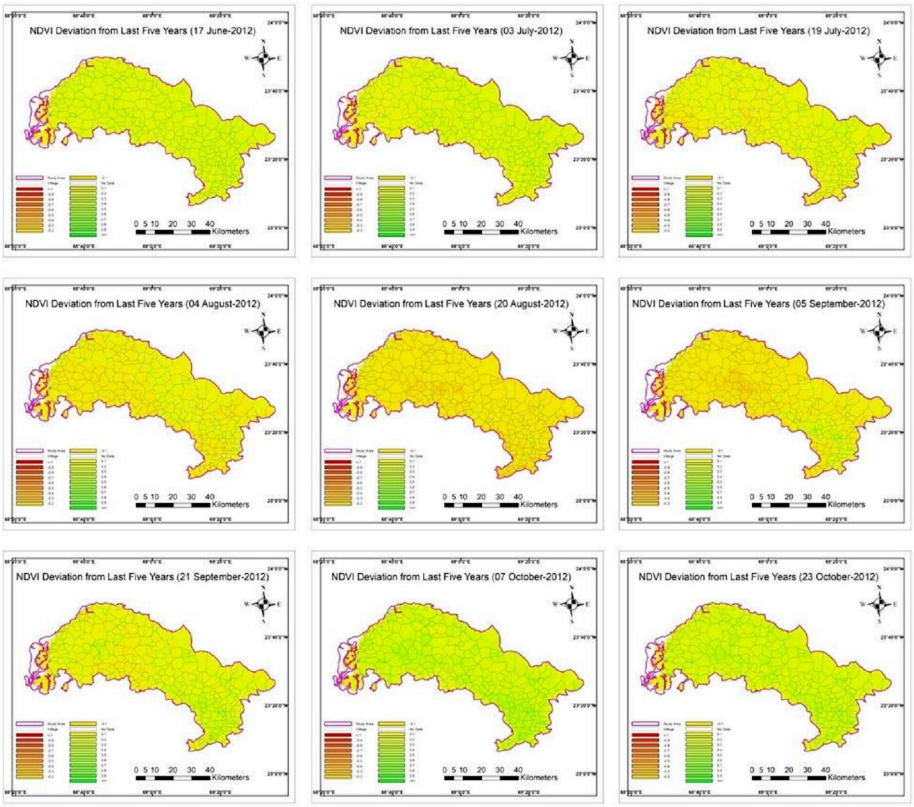

Figure 6.24 NDVI Deviation (Kharif Season, 2012-2013)

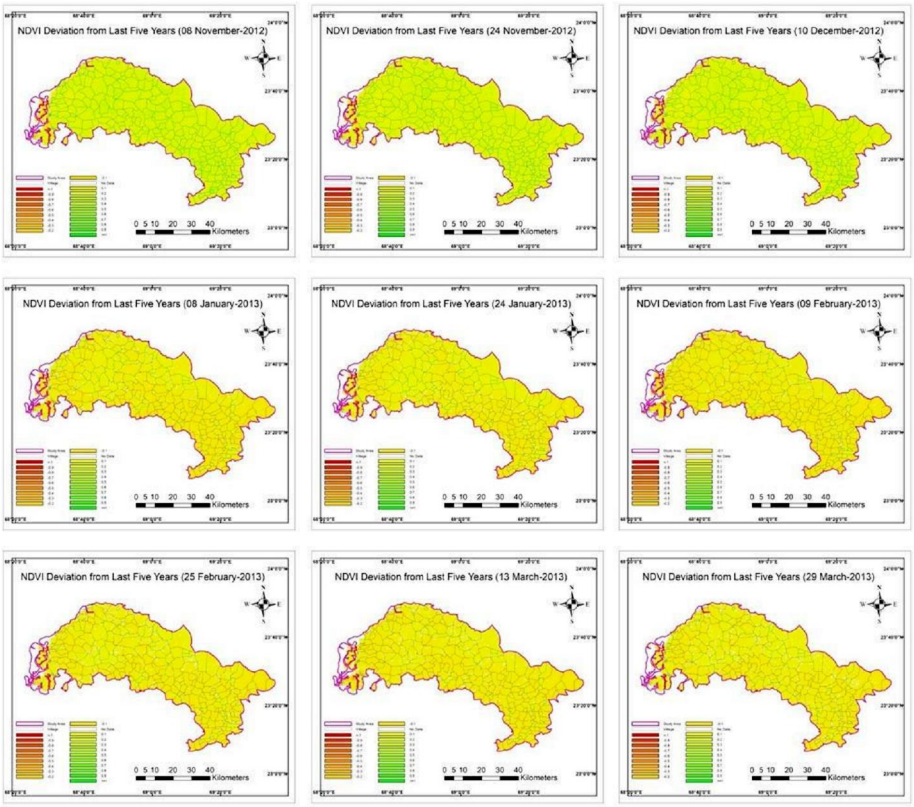

Figure 6.25 NDVI Deviation (Rabi Season, 2012-2013)

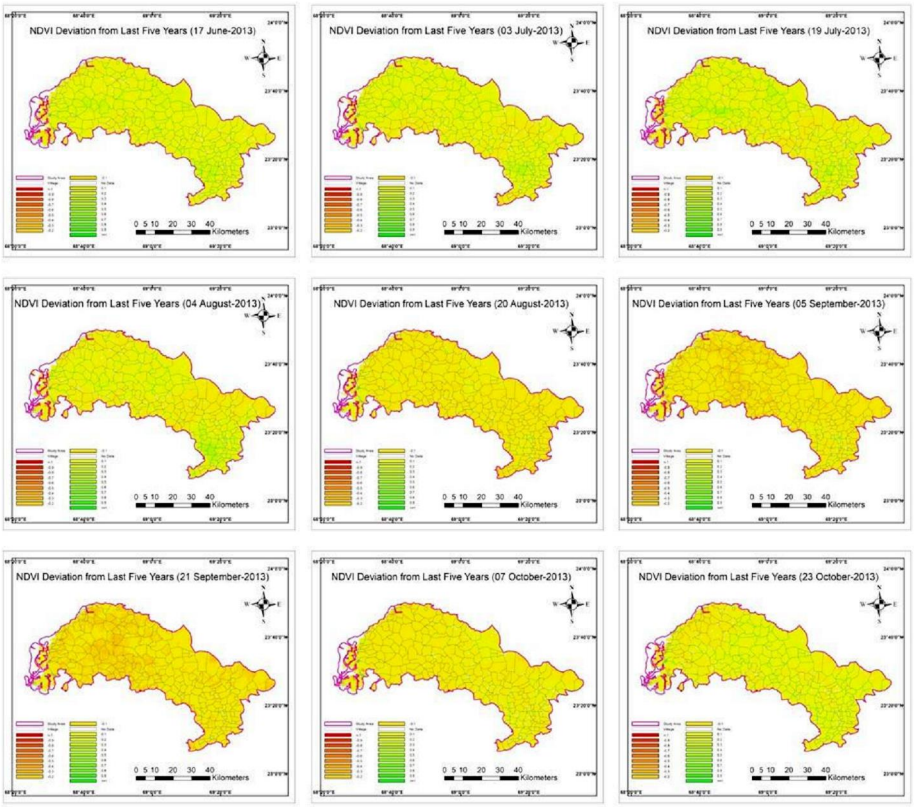

Figure 6.26 NDVI Deviation (Kharif Season, 2013-2014)

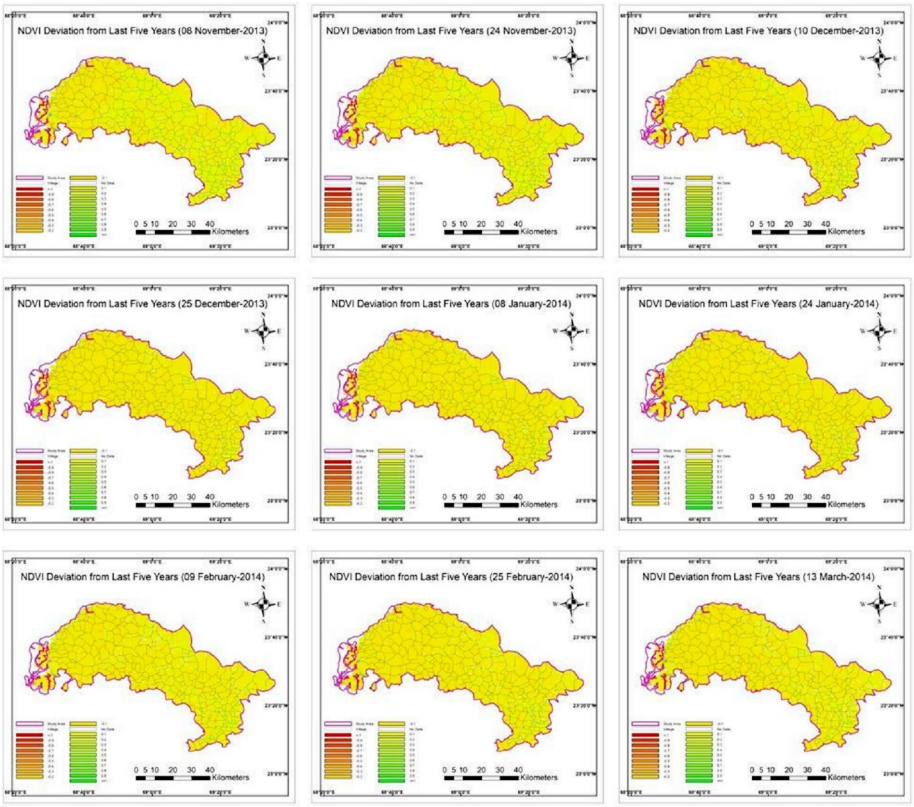

Figure 6.27 NDVI Deviation (Rabi Season, 2013-2014)

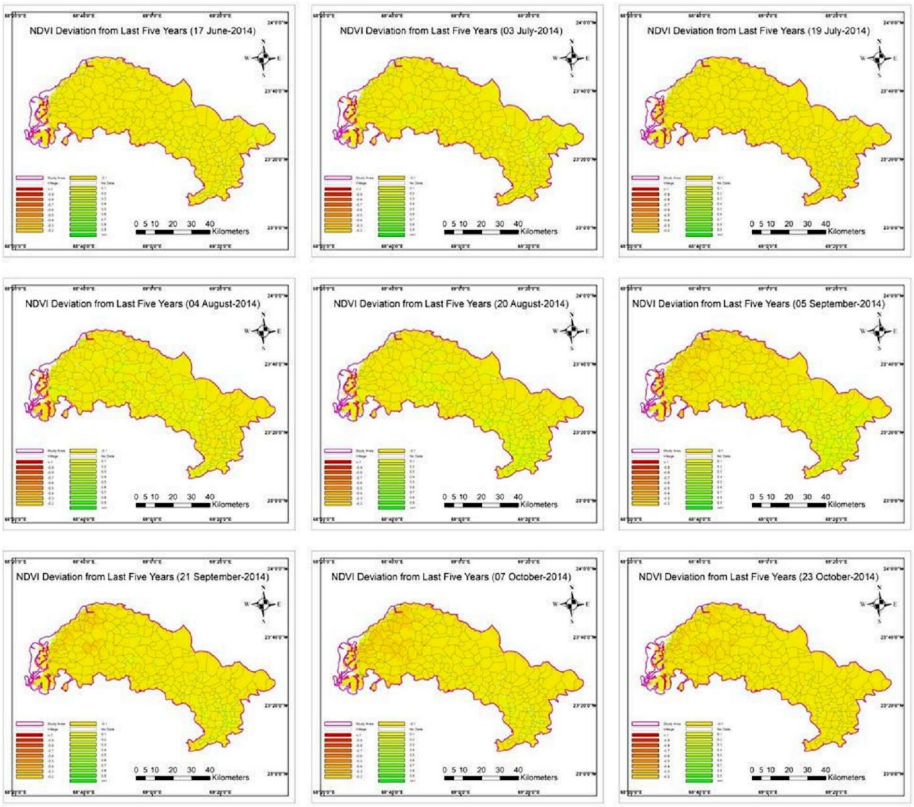

Figure 6.28 NDVI Deviation (Kharif Season, 2014-2015)

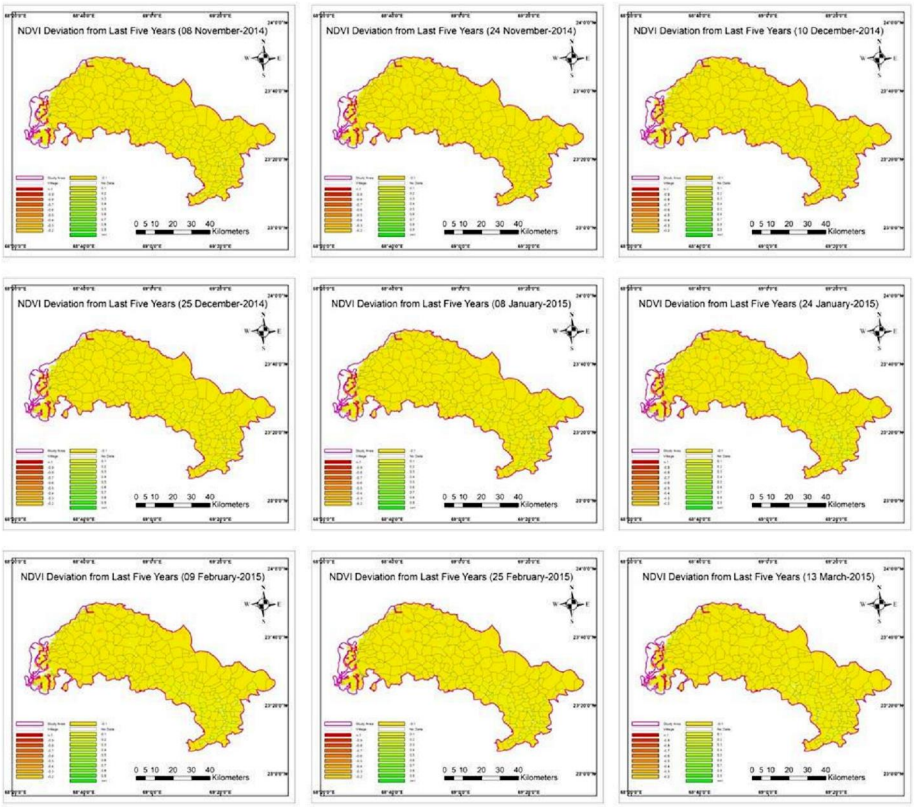

Figure 6.29 NDVI Deviation (Rabi Season, 2014-2015)

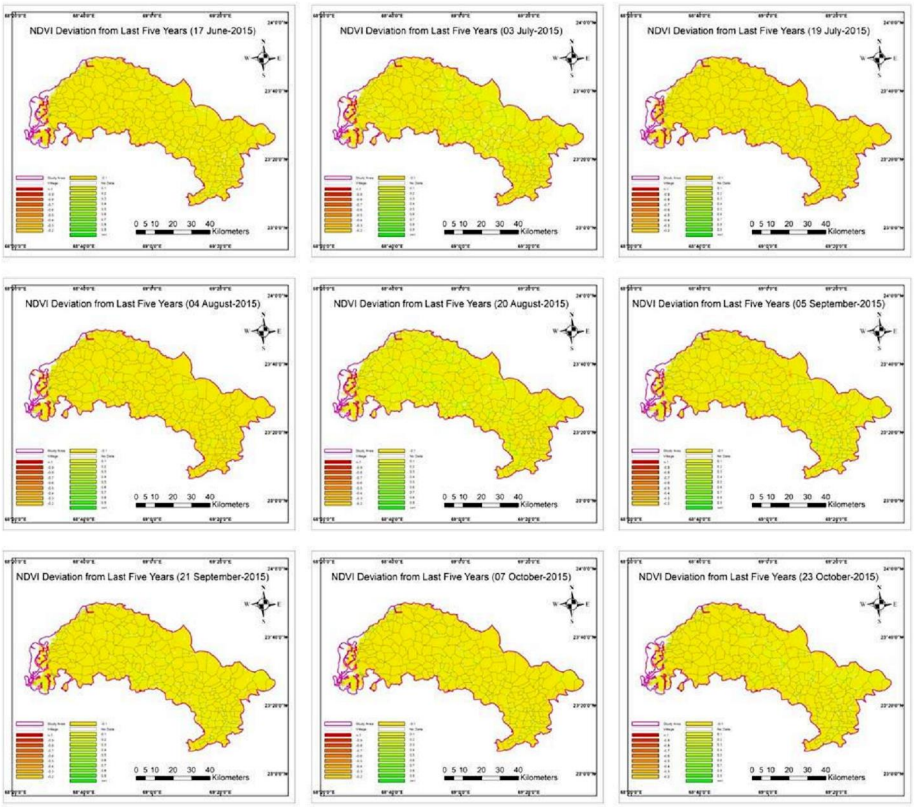

Figure 6.30 NDVI Deviation (Kharif Season, 2015-2016)

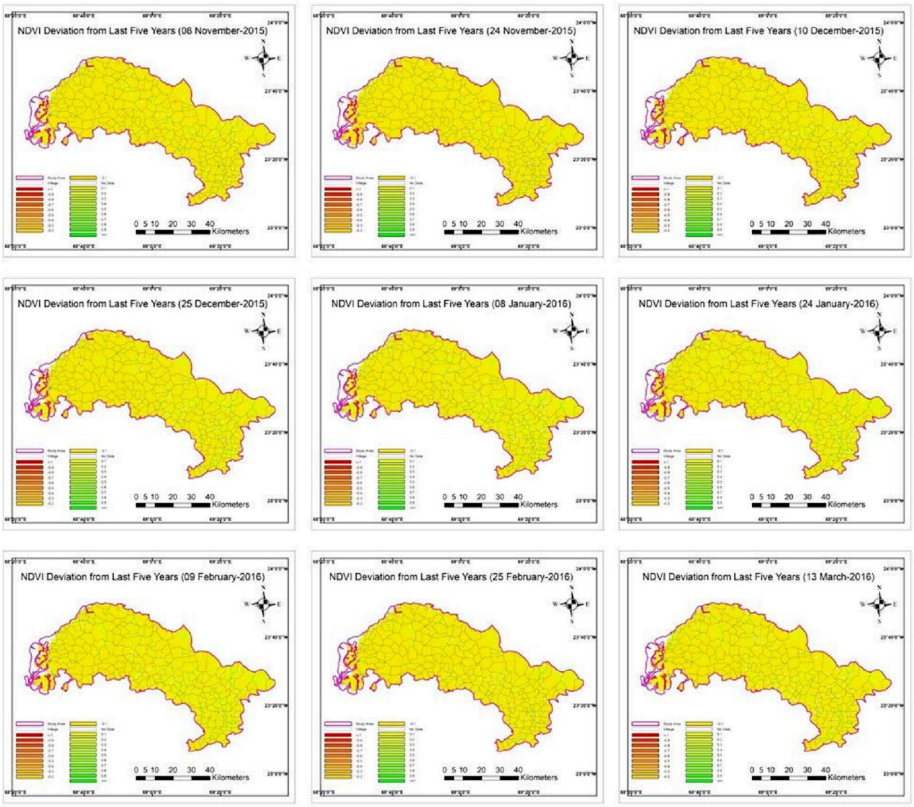

Figure 6.31 NDVI Deviation (Rabi Season, 2015-2016)

6.2 Spatio-Temporal Analysis of Standardized Precipitation Index:

Meteorological drought is the earliest indicator and most precise event in the process of occurrence and progression of drought conditions. To indicate severity of drought various methods and indices have developed for drought analysis based on different parameters (Patel et.al. 2015). The advantage of the SPI is that it is applicable to any time scale and it is not specific to any location.

6.2.1 Spatial distributions of mean monsoon rainfall characteristics

In this section, the mean features of the rainfall are presented from CHIRPS v-2 precipitation data for 30 year period. The mean monsoon rainfall distribution at 0.05 degree spatial resolution is shown in Figure 6.32. Large spatial variability is clearly seen across Gujarat state. Mean monsoon rainfall varies from 100 mm in North-west Gujarat to 2000 mm in Southern Gujarat. The most rainfall occurs along the south of Gujarat. The least occurs in north-west Gujarat. Looking to the distribution the Study area receives comparatively very less amount of rainfall (<=400 mm) during the monsoon season as analysed from climatology with duration from 1981-2010.

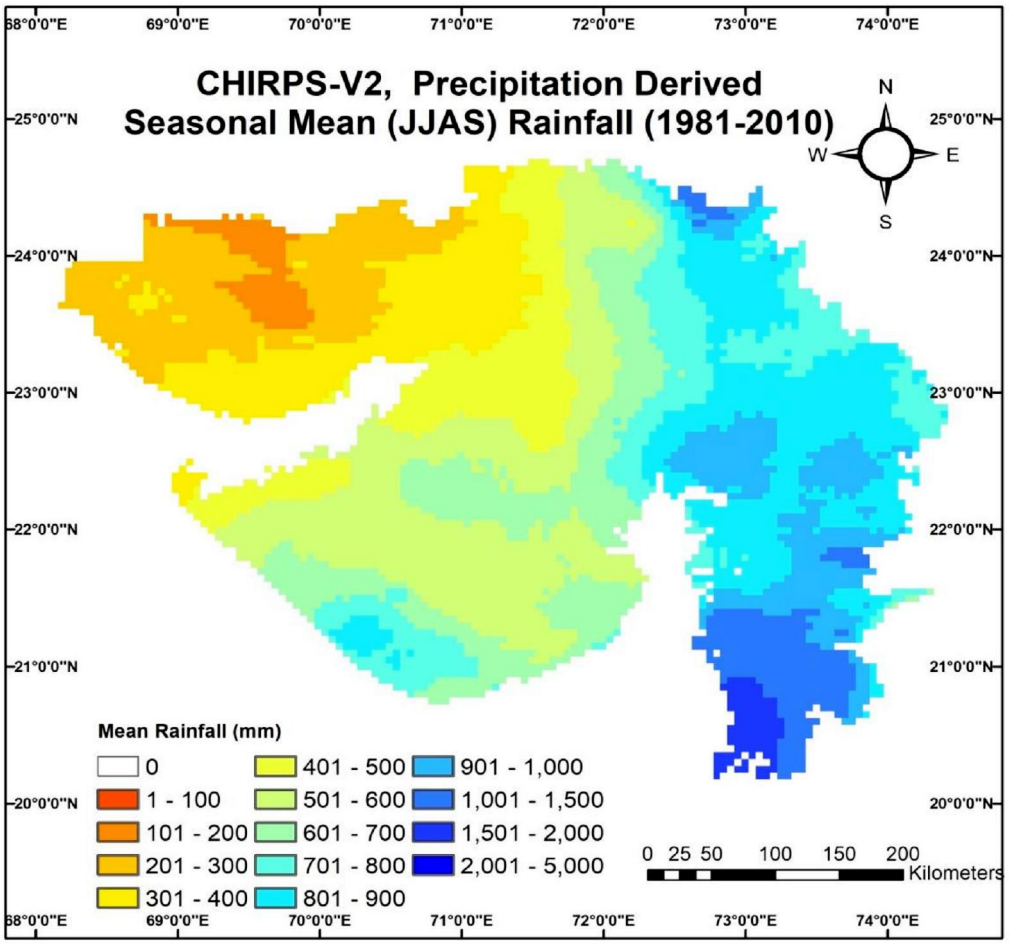

Figure 6.32 Seasonal Mean Rainfall (Climatology)

6.2.2 Assessment of Monthly and Seasonal Standardized Precipitation Index (SPI)

In this section, Assessment of meteorological drought using Monthly SPI has been discussed, where monthly SPI are calculated for the rainfall deficiency measurement from the long term climatology. The negative values indicate the occurrence of drought event and the positive values indicates that better conditions from hydrological drought prospective. SPI is a standardized index; therefore, it is possible to expect the percentage of specific drought event from normal distribution of SPI.

6.2.2.1 Assessment of Monthly and Seasonal SPI during 2011

Figure 6.33 illustrates the Monthly SPI analysis for the monsoon season of year 2011. The SPI value shows the increasing trend with range of -1 to 3 from June to September. 0 to -1 in most of the study area for the June and in the July Month the area had mostly-1 and -0.5 ranges respectively. In the year 2011 month of August and September shows highest SPI values ranges from 1 to 2.5 in August and >=2.5 in September. The results of monthly SPI analysis indicated the drought severity in the month of June and July in year 2011, whereas month of August and September show normal conditions on the basis of monthly SPI.

Overall Seasonal SPI is illustrated in Figure 6.34, which indicates overall normal condition over the study area as computed from the long term climatology. Spatial variation of the seasonal SPI values over the study area ranges from 2 to 3, which indicates wet condition over the Lakhpat and Nakhatrana Taluka in Kutchh district during year 2011 monsoon season.

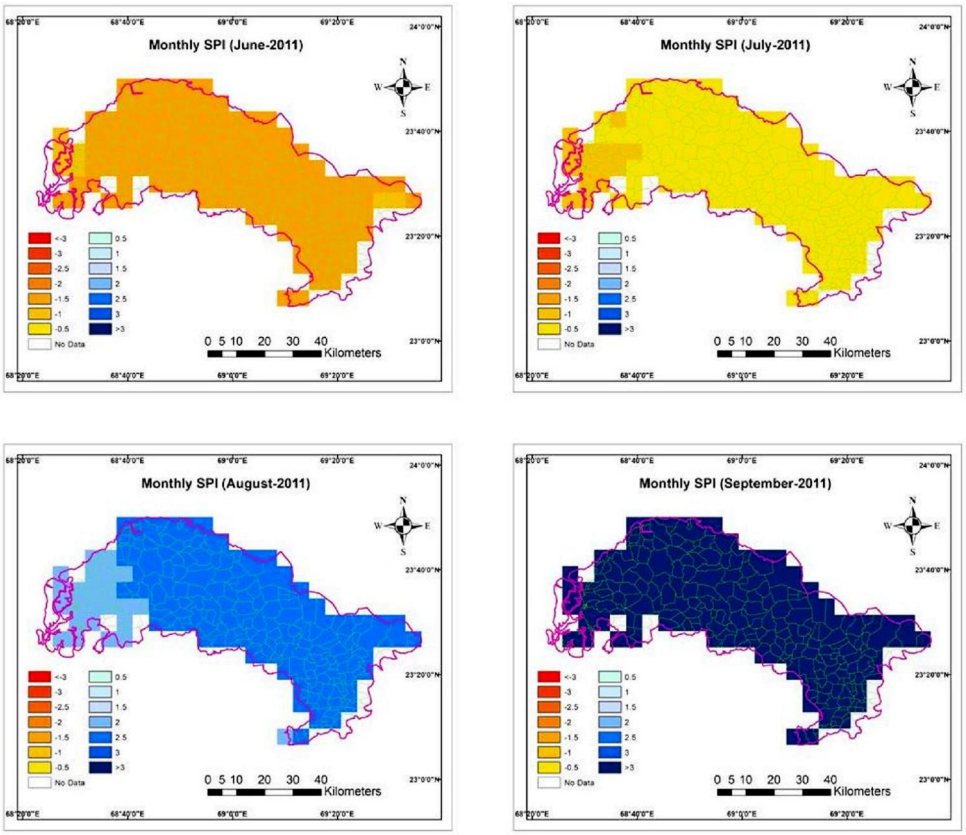

Figure 6.33 Monthly SPI (monsoon Season-2011)

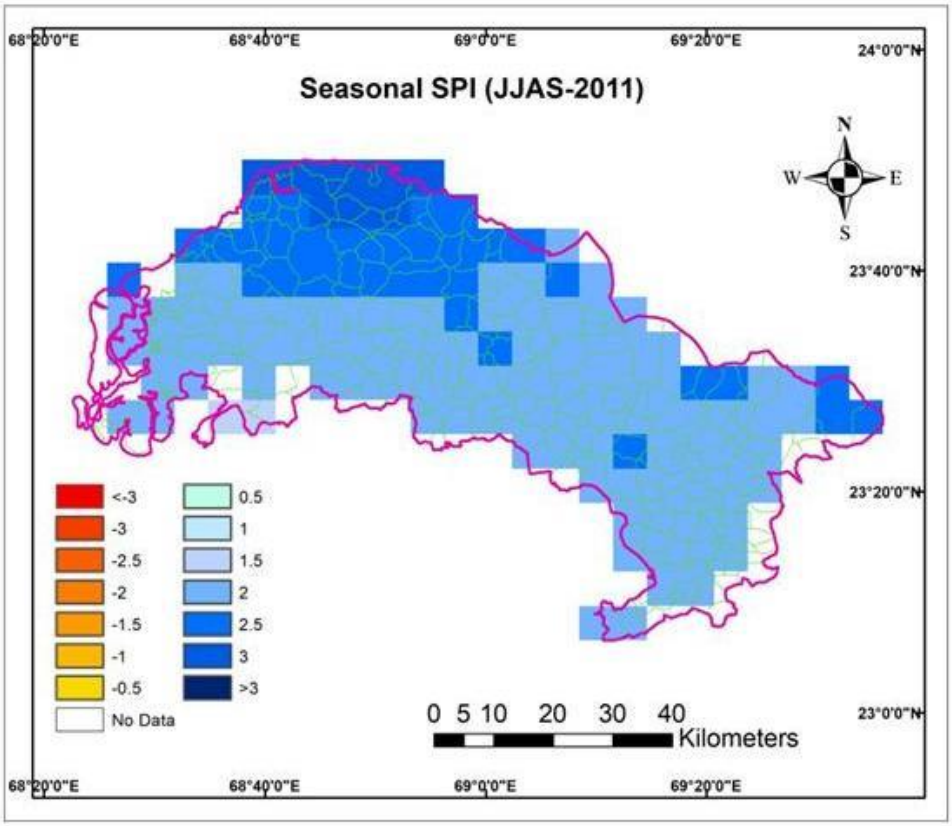

Figure 6.34 Seasonal SPI (monsoon Season-2011)

6.2.2.2 Assessment of Monthly and Seasonal SPI during 2012

During 2012, most parts of study area affected by below-average rainfall. The monthly SPI of monsoon season 2012 are described in figure 6.35. SPI values for the Month of June-2012, shows very severe drought condition over study area, where SPI values ranges from -0.5 to -1.5. Figure 6.35 shows SPI values for the month of july-2012, which indicates severe drought conditions over study area and SPI values ranges from -0.5 to -1.5. Month of August-2012 also received severely dry conditions over study area where values range from 0 to -0.5. Monthly SPI for the year-2012 indicates the month of September received good amount of rainfall which resulted positive SPI values. The results of monthly SPI analysis indicates that three consecutive months experienced severe drought condition during the monsoon season, that affects the agriculture thus, drought prevailed due to rainfall delay in study area.

The spatial distribution of seasonal SPI for the monsoon season-2012 (June to September) is illustrated in Figure 6.36. During the monsoon period most parts of the area were drought affected except some part of Lakhpat Taluk. Seasonal SPI vales range from -1 to 1, where 70 percent part of study area has been covered by negative values which illustrate Moderate drought conditions over the study area.

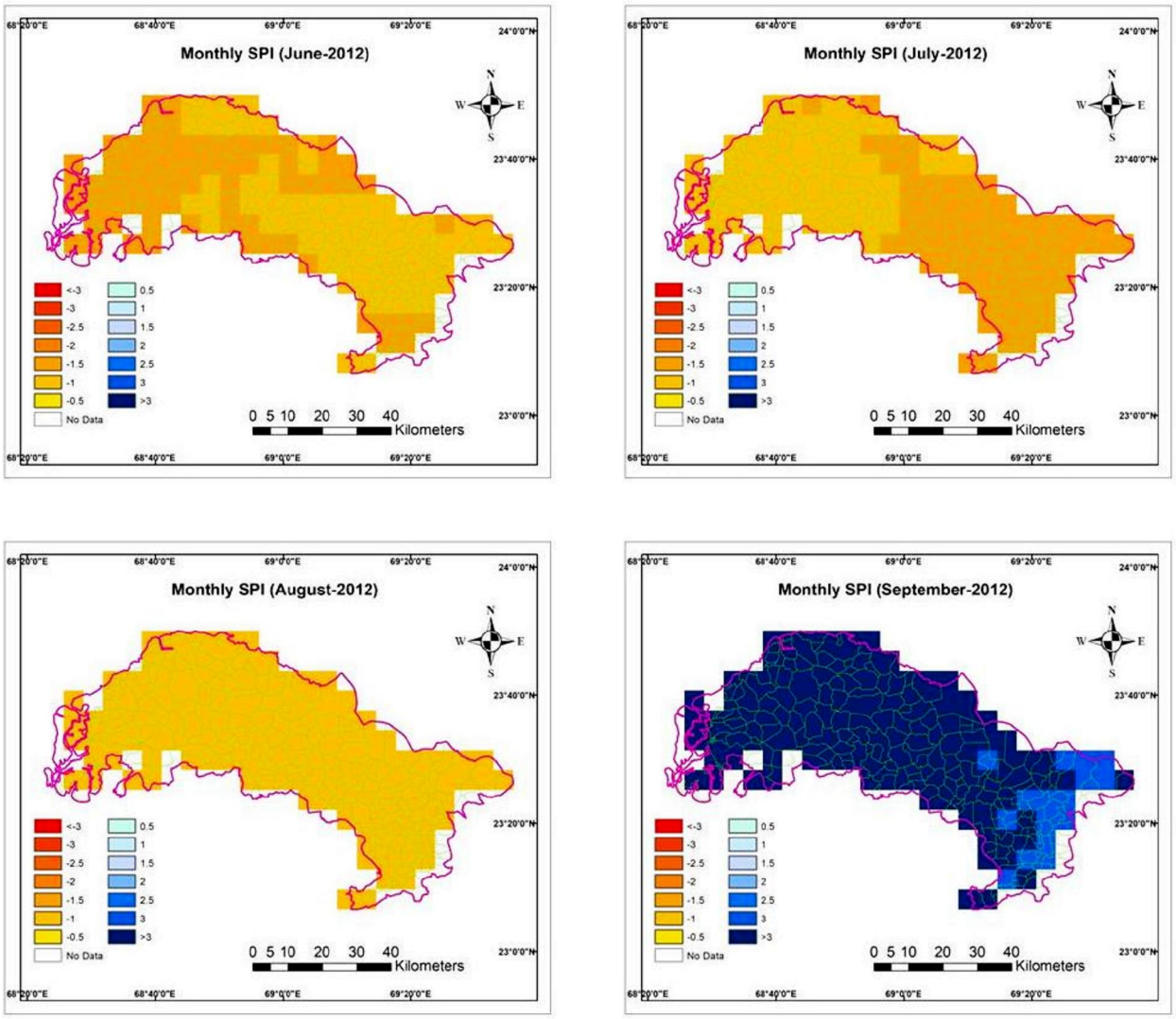

Figure 6.35 Monthly SPI (monsoon Season-2012)

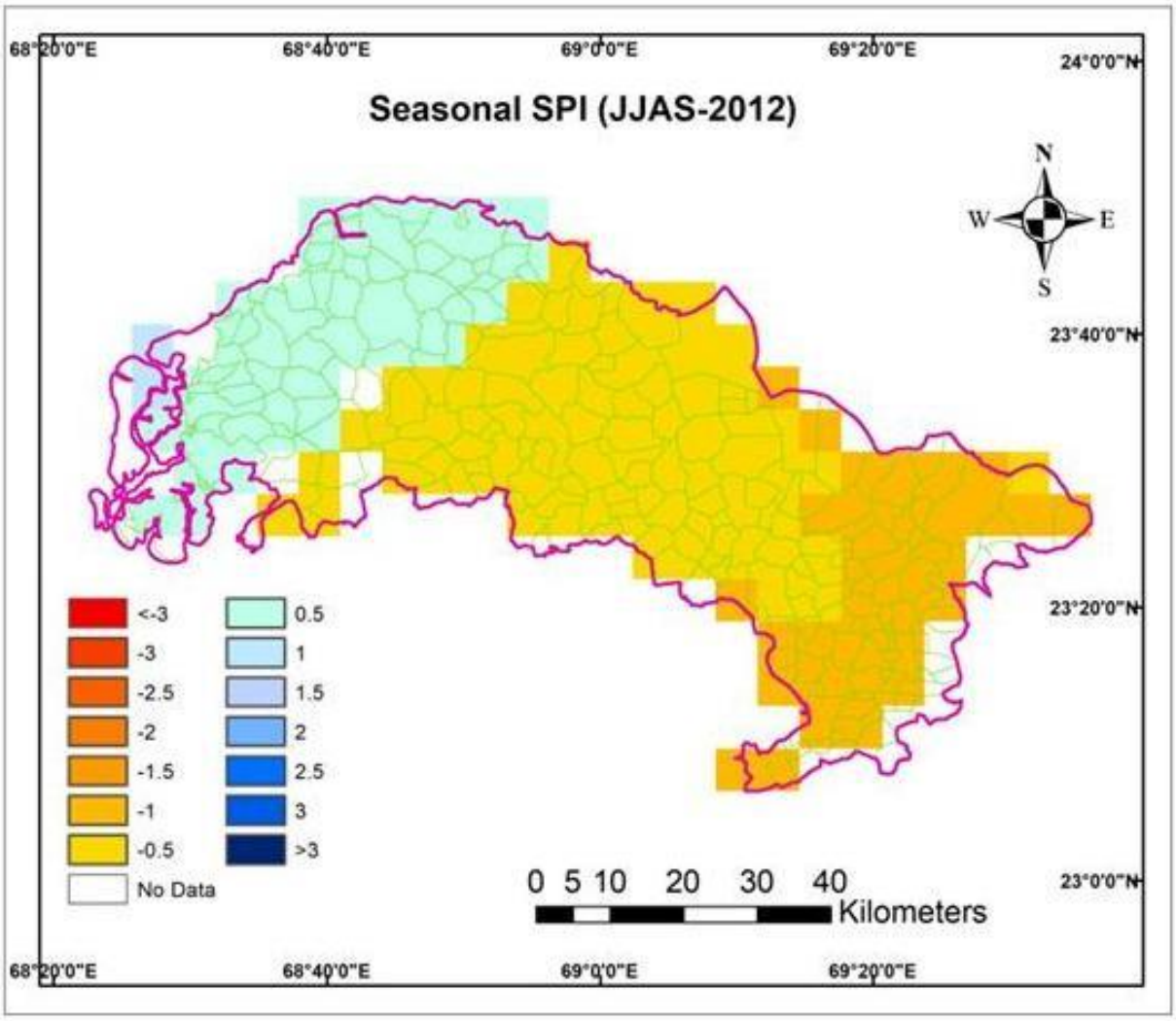

Figure 6.36 Seasonal SPI (monsoon Season-2012)

6.2.2.3 Assessment of Monthly and Seasonal SPI during 2013

Spatial distribution of monthly SPI for the year 2013 is illustrated in Figure 6.37; where SPI values in the month of June, ranged between -0.5 to 0.5 in most of the study area. Study area covered by Positive values in the Month of June that indicates normal drought condition. Month of July and August SPI also ranged from -0.5 to -1. SPI values in July and August month mostly covered by -0.5 to -1 range that indicates severe drought condition over the study area. Distribution of the SPI values in September month indicates the normal condition in Lakhpat and Nakhtrana Taluk where SPI values ranges from 1 to 1.5.

Overall Seasonal SPI for the year 2013 is illustrated in Figure 6.38, which indicates overall normal condition over the study area as computed from the long term climatology. Spatial variation of the seasonal SPI values over the study area ranges from 0 to -0.5.

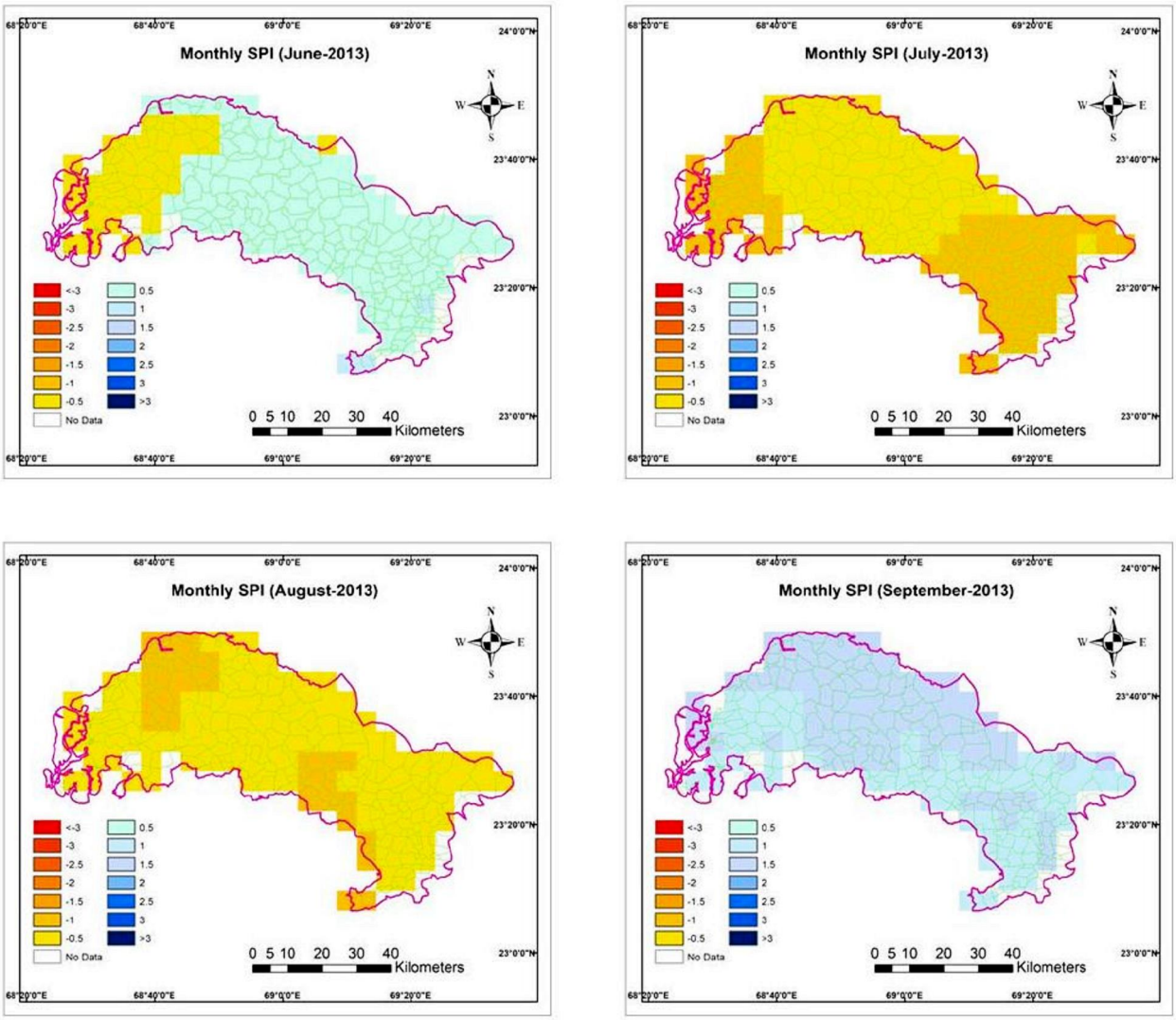

Figure 6.37 Monthly SPI (monsoon Season-2013)

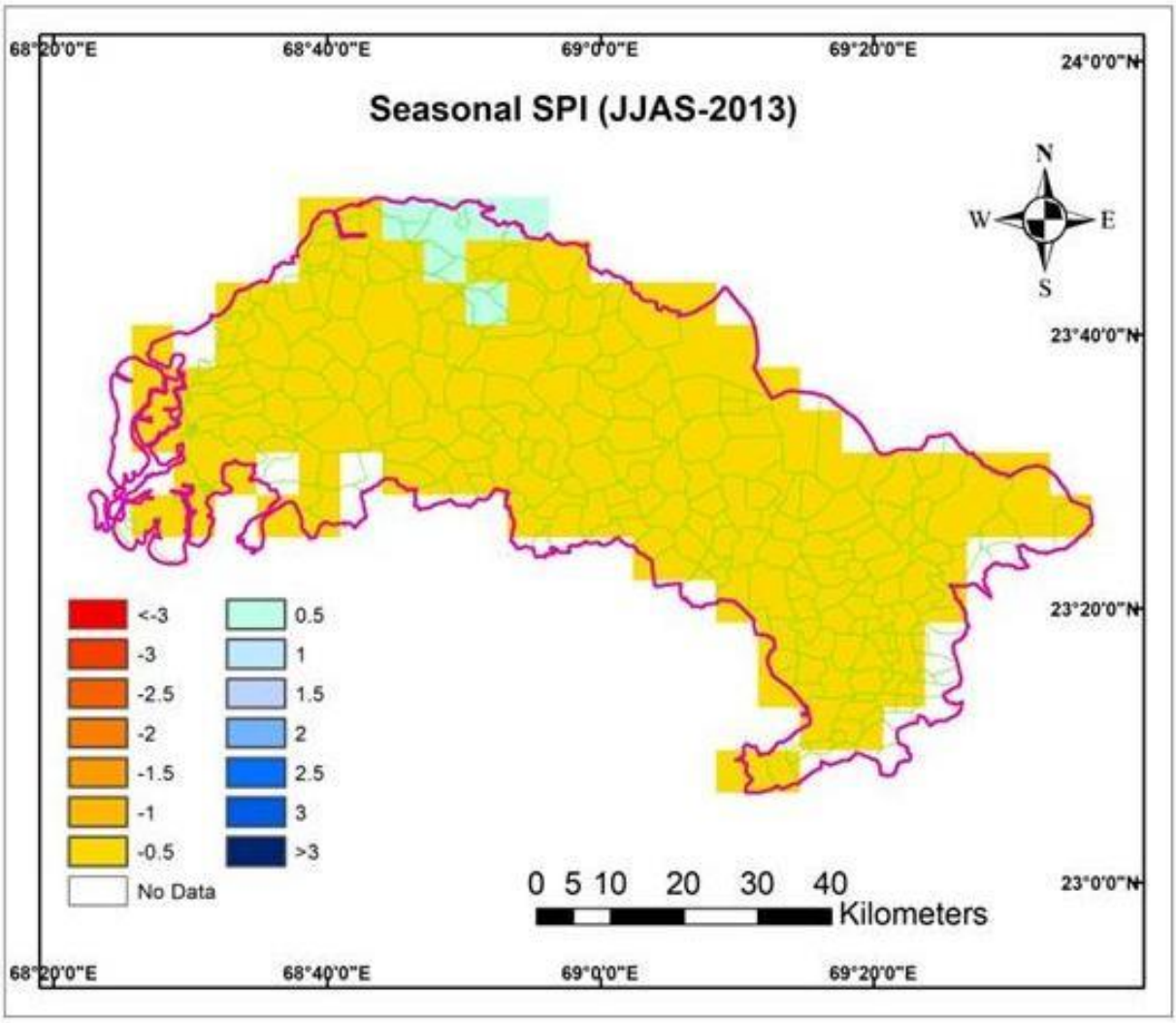

Figure 6.38 Seasonal SPI (monsoon Season-2013)

6.2.2.4 Assessment of Monthly and Seasonal SPI during 2014

Spatial variation of monthly SPI values of monsoon season 2014 illustrated in figure 6.39 for entire study region. During 2014, most parts of study area affected by below-average rainfall. The monthly SPI of monsoon season 2014 are described in figure 6.39. SPI values for the Month of June-2014, shows very severe drought condition over study area, where SPI values ranges from -1 to -1.5. SPI values for the month of july-2014, also indicates severe drought conditions over study area and SPI values ranges from -0.5 to -1. Month of August-2014 also received dry conditions over study area where values range from 0 to -0.5. Monthly SPI for the year-2014 indicates the month of September received good amount of rainfall which resulted positive SPI values. The results of monthly SPI analysis indicates that three consecutive months experienced severe drought condition during the monsoon season.

The spatial distribution of seasonal SPI for the monsoon season-2014 (June to September) is illustrated in Figure 6.40. During the monsoon period most parts of the study area were drought affected where SPI vales range from -0.5 to -1.

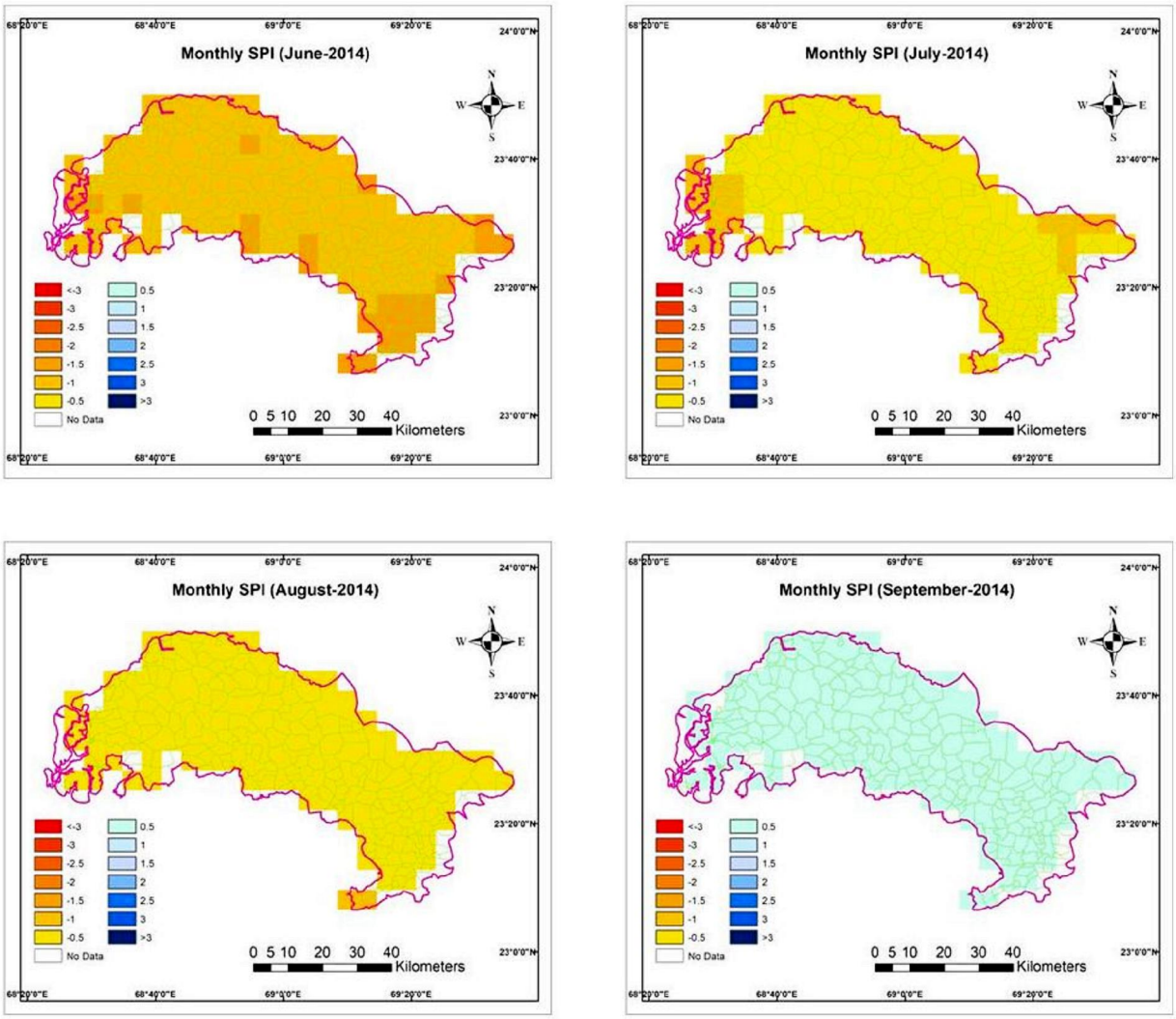

Figure 6.39 Monthly SPI (monsoon Season-2014)

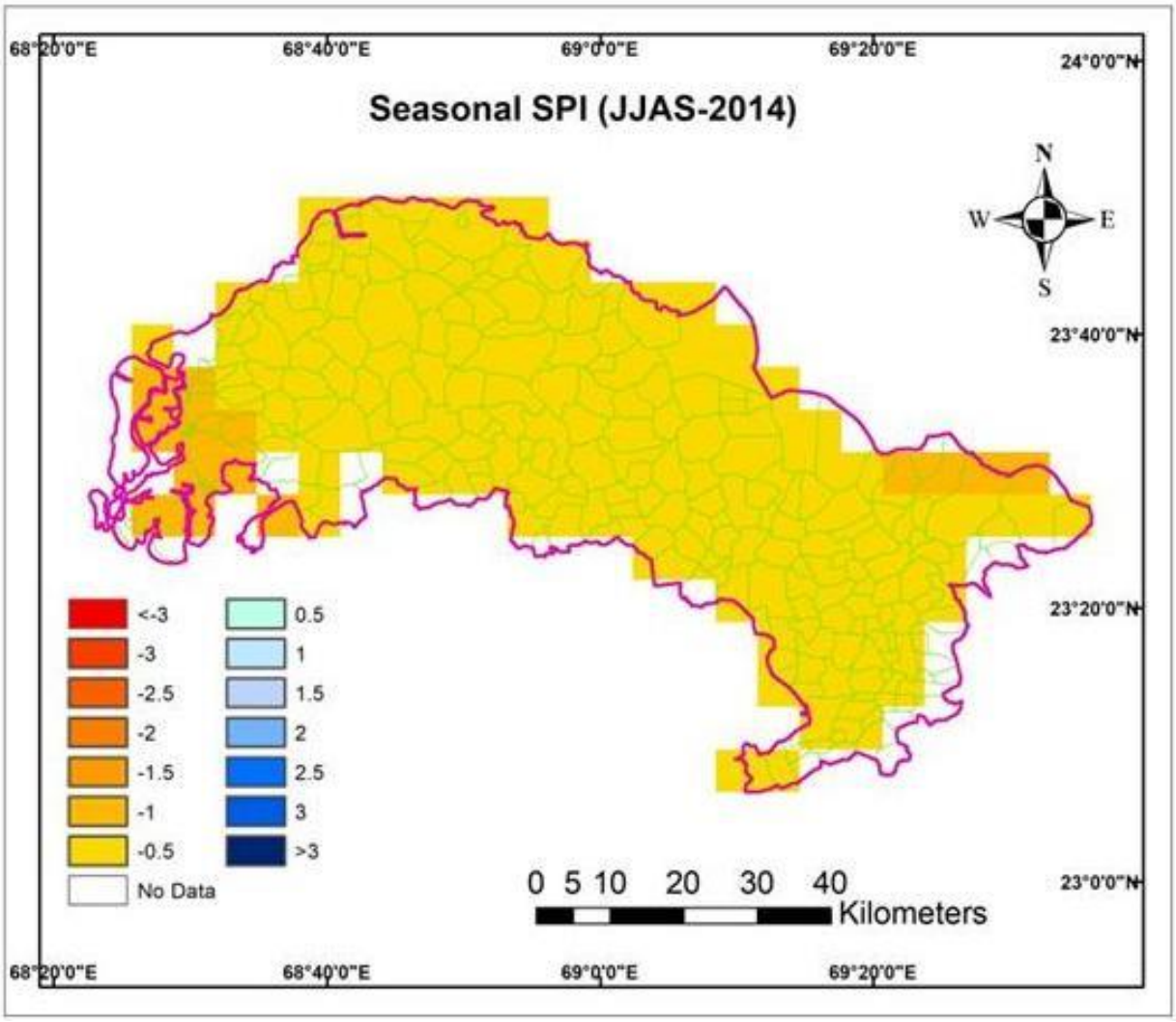

Figure 6.40 Seasonal SPI (monsoon Season-2014)

6.2.2.5 Assessment of Monthly and Seasonal SPI during 2015

Spatial distribution of monthly SPI for the year 2015 is illustrated in Figure 6.41; where SPI values in the month of June, ranged from 0 to 1.5 over the study area. Study area covered by Positive values in the Month of June that indicates normal condition. SPI values in month of July ranged from 0 to 2.5. Figure 6.25 illustrates that the month of August received severe drought condition based on the SPI values which ranges from -0.5 to -1,5. Distribution of the SPI values in September month indicates the normal condition in Lakhpat and Nakhtrana Taluk where SPI values ranges from 0 to -0.5.

Figure 6.42 illustrates the Seasonal SPI for the year 2015, which describes overall normal condition over the study area as computed from the long term climatology. Spatial variation of the seasonal SPI values over the study area ranges from 0 to 1.5.

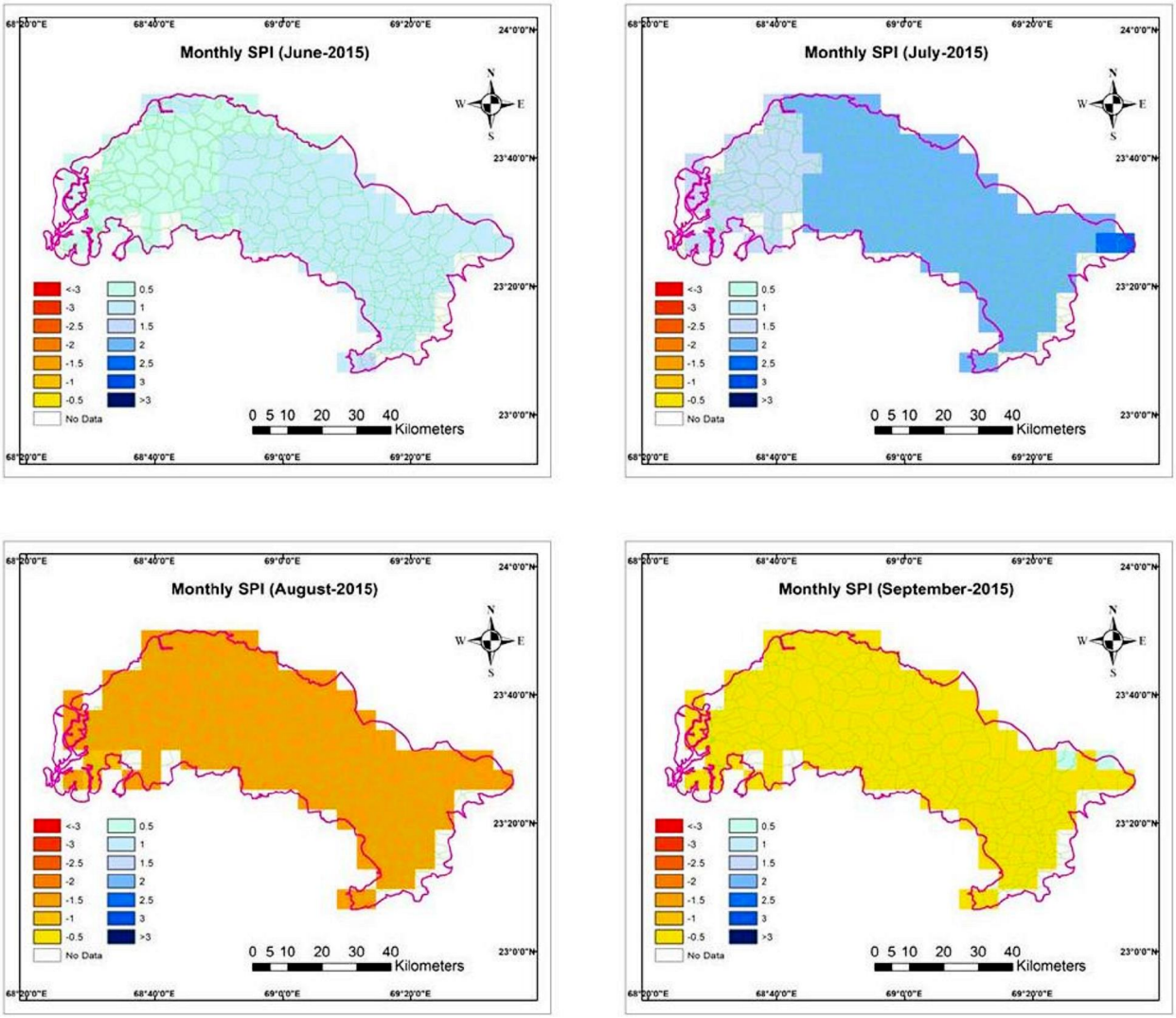

Figure 6.41 Monthly SPI (monsoon Season-2015)

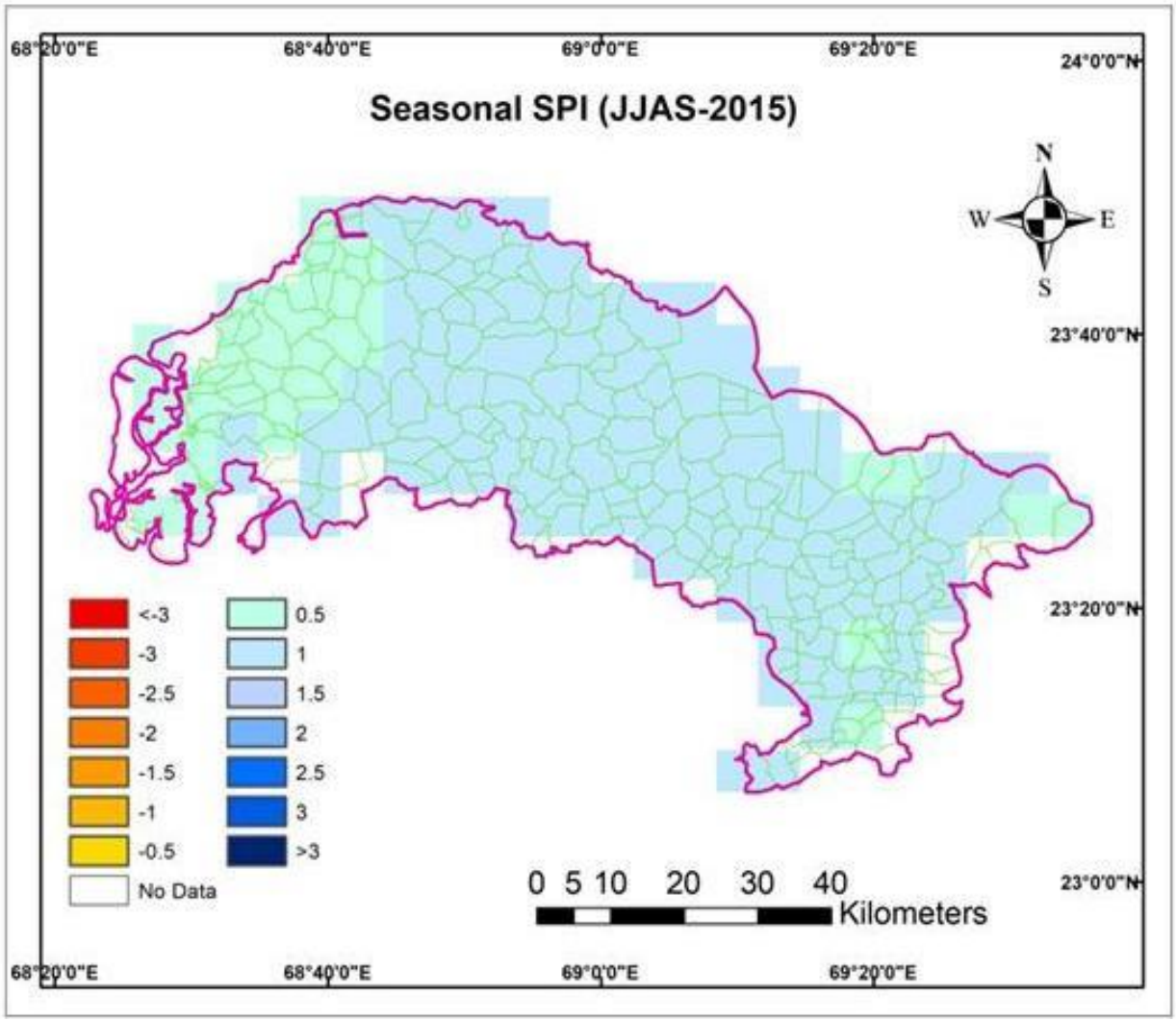

Figure 6.42 Seasonal SPI (monsoon Season-2015)

6.2.2.6 Assessment of Monthly and Seasonal SPI during 2016

Figure 6.43 shows maps describing the spatial variability and of the monthly SPI for the year 2016. According to the figure 6.43 month of June-2016 SPI indicates wet condition over the study area where values range from 0.5 to 2. SPI ranging values for the month of July and September experienced normal to moderate drought condition. SPI values of August month 2016 normal to wet condition over the study area.

Figure 6.44 illustrates the Seasonal SPI for the year 2016, which describes overall normal to moderate drought condition over the study area as computed from the long term climatology. Spatial variation of the seasonal SPI values over the study area ranges from 0 to -1.

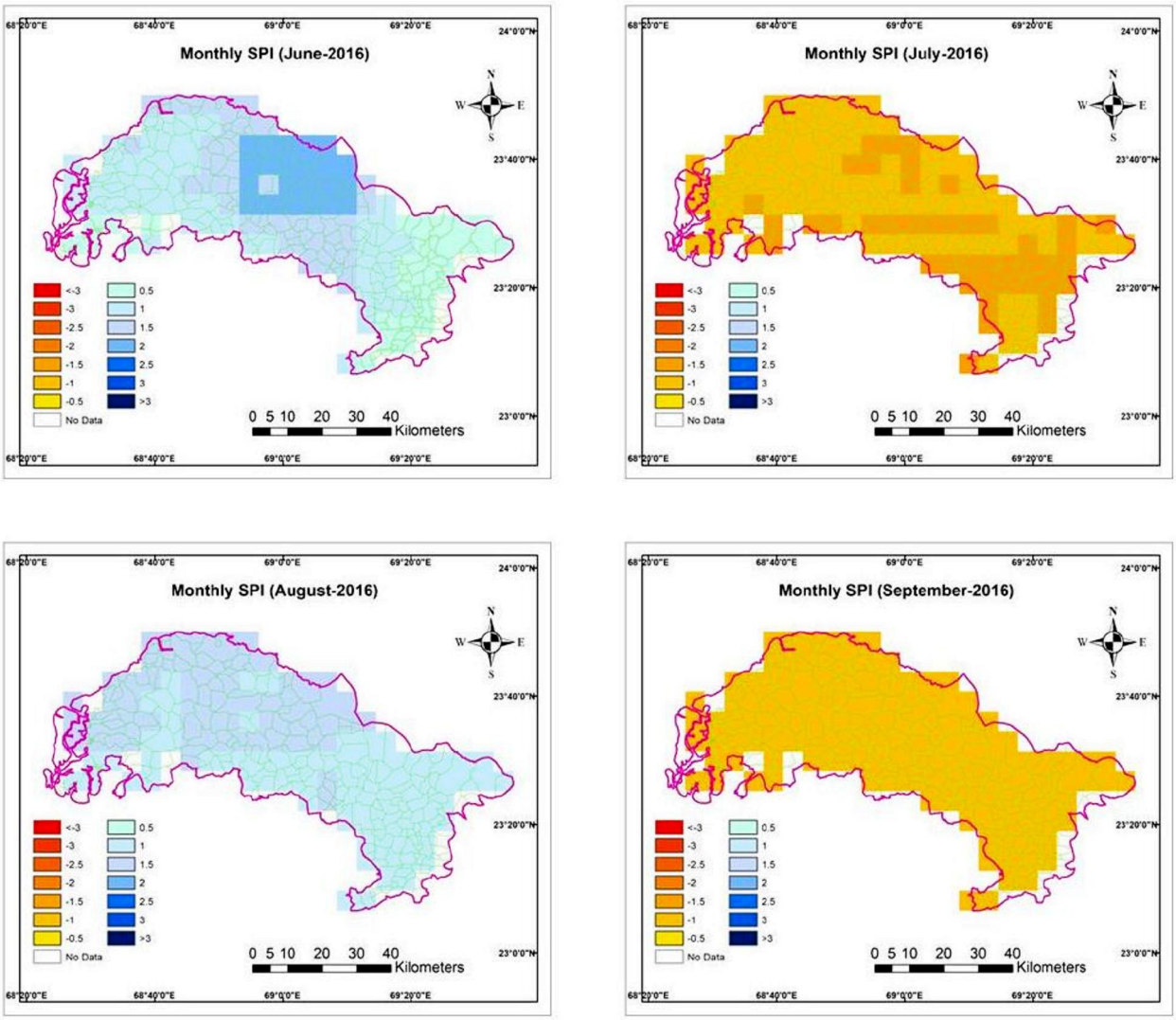

Figure 6.43 Monthly SPI (monsoon Season-2016)

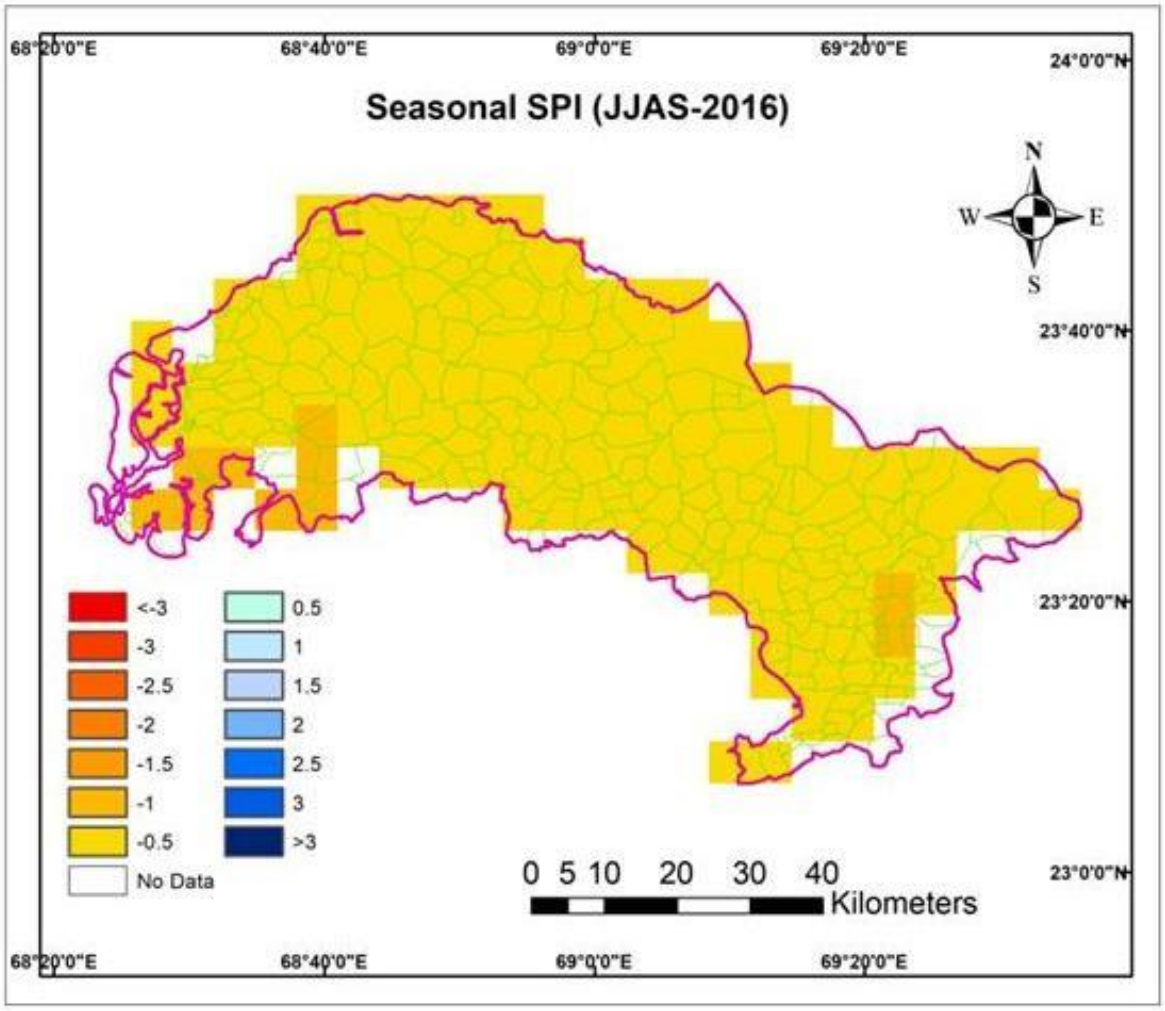

Figure 6.44 Monthly SPI (monsoon Season-2016)

6.3 Spatio-Temporal Analysis of Precipitation Condition Index (PCI):

PCI index accounts for the rainfall condition over the study area. PCI uses precipitation data as input and calculates the amount of precipitation with 0 to 100 as a range. The spatial distribution of precipitation condition index in Monthly and seasonal scale are discussed in this section.

6.3.1 Assessment of Monthly PCI for the monsoon season (2011-2016)

Spatial distribution of monthly PCI for the year 2011 is illustrated in Figure 6.45; where PCI values in the month of June values ranges are 0 in maximum part of study area, whereas in the month of July values ranges below 20 in Lakhpat Taluk and 20-30 in Nakhatrana taluka which depicts that this month is stressed due to less amount of rainfall as compared to 30 years climatology. As shown in figure 6.45, PCI values in year 2011for the month of August

and September are greater than 70 which indicates very good amount of precipitation received in entire study area.

Figure 6.46 describes spatial distribution of monthly PCI in year 2012. According to the figure 6.46 month of June-2012 PCI indicates wet condition over the study area where values range is higher than 70 and PCI values for the month of July are less than 20 which indicates precipitation stress in study area for the specified month. PCI values for the month of July and August experienced moderate to severe drought condition. PCI values of September month 2012 shows normal to wet condition over the study area.

Spatial distribution of monthly PCI for the year 2013 is illustrated in Figure 6.47, where month of June experienced below normal PCI values and Month of July shows PCI values ranged from 11 to 30 that indicates severe drought conditions over the study area for the given month. PCI values for the month of August also indicates the stressed condition over the study area, whereas month of September shows the normal to good condition with reference to the PCI values.

During 2014, most parts of study area affected by below-average rainfall. The monthly PCI of monsoon season 2014 are described in figure 6.48. PCI values for the Month of June-2014, shows very severe drought/dry condition over study area, where PCI values ranges below 10. Spatial distribution of PCI values for the month of July-2014 are also illustrated in figure 6.48, which also indicates severe drought conditions over study area with values range from 11 to 30. Month of August-2014 also received moderate to severely dry conditions over study area. Monthly PCI for the year-2014 indicates the month of September also experienced moderate drought condition over study area. The results of monthly PCI analysis indicates those four consecutive months (monsoon Season) experienced moderate to severe drought condition, which will lead to the meteorological and agricultural drought over the study area.

Spatial distribution of monthly PCI for the year 2015 is illustrated in Figure 6.49, where month of June and July shows moderate to Normal PCI values over the study area for the year of 2015 and Month of August and September represents stressed PCI values over the study area.

Figure 6.50 describes the PCI maps of year 2016 monsoon season. PCI values for the Month of June-2016, shows Normal to good condition over study area, where PCI values ranges 30

to 70. Spatial distribution of PCI values for the month of July-2016 are also illustrated in figure 6.50, which indicates severe drought conditions over study area with values range from 1 to 20. Month of August-2016 shows normal PCI values over study area. Monthly PCI for the year-2016 indicates the month of September also experienced Severe to moderate drought condition over study area.

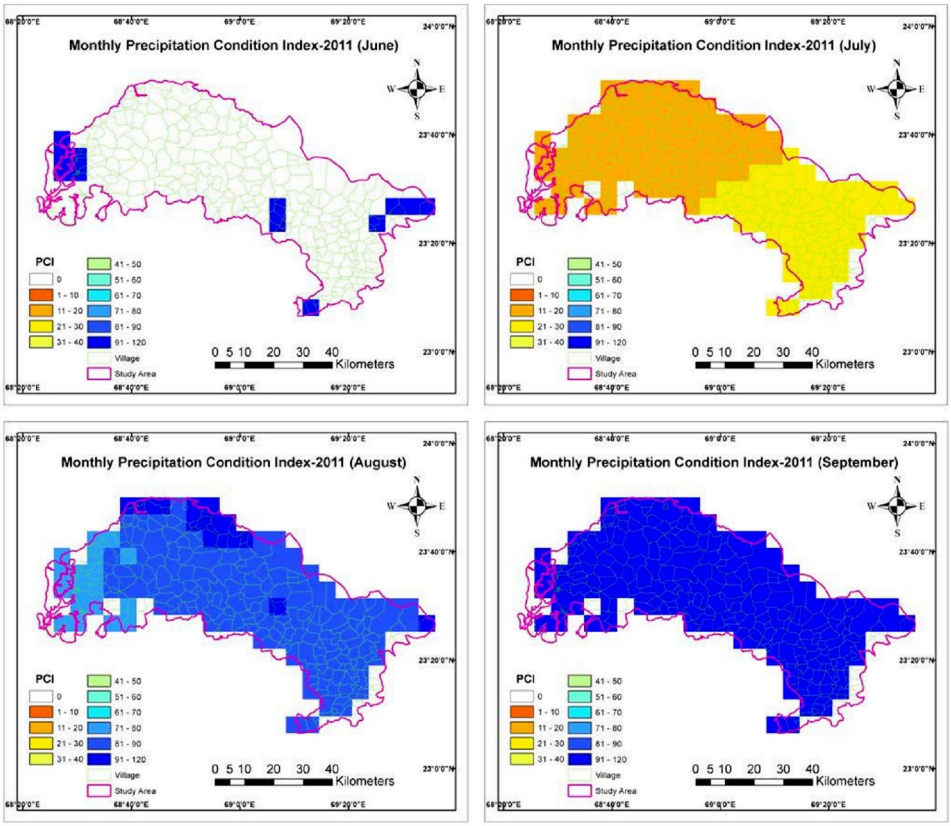

Figure 6.45 Monthly PCI (monsoon Season-2011)

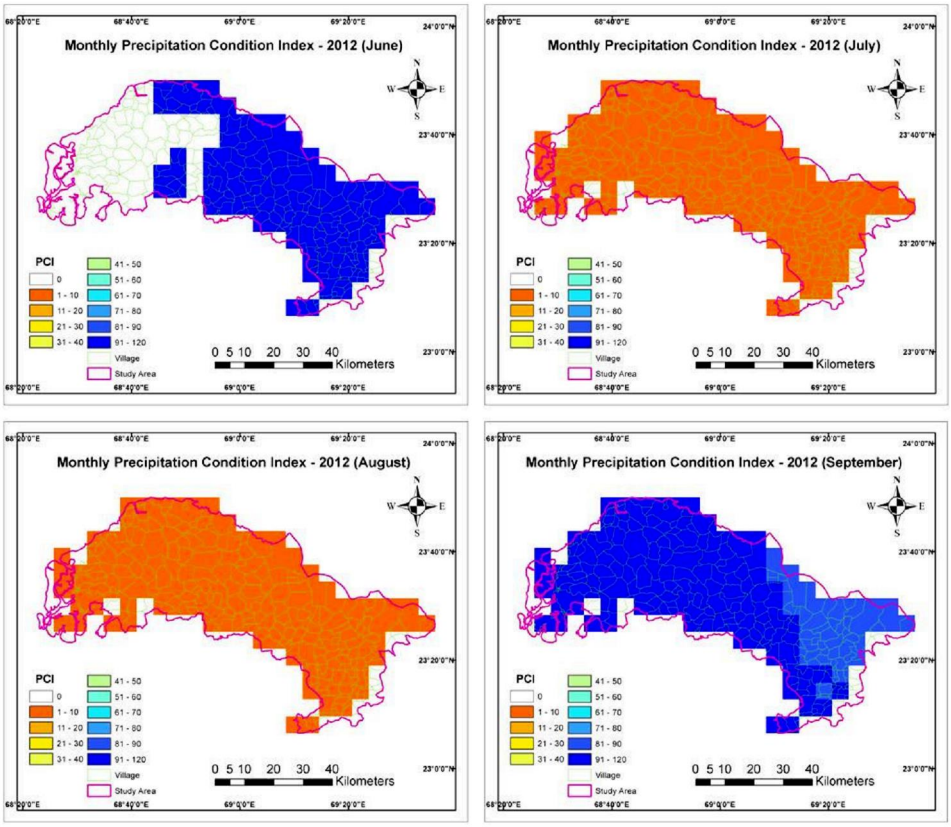

Figure 6.46 Monthly PCI (monsoon Season-2012)

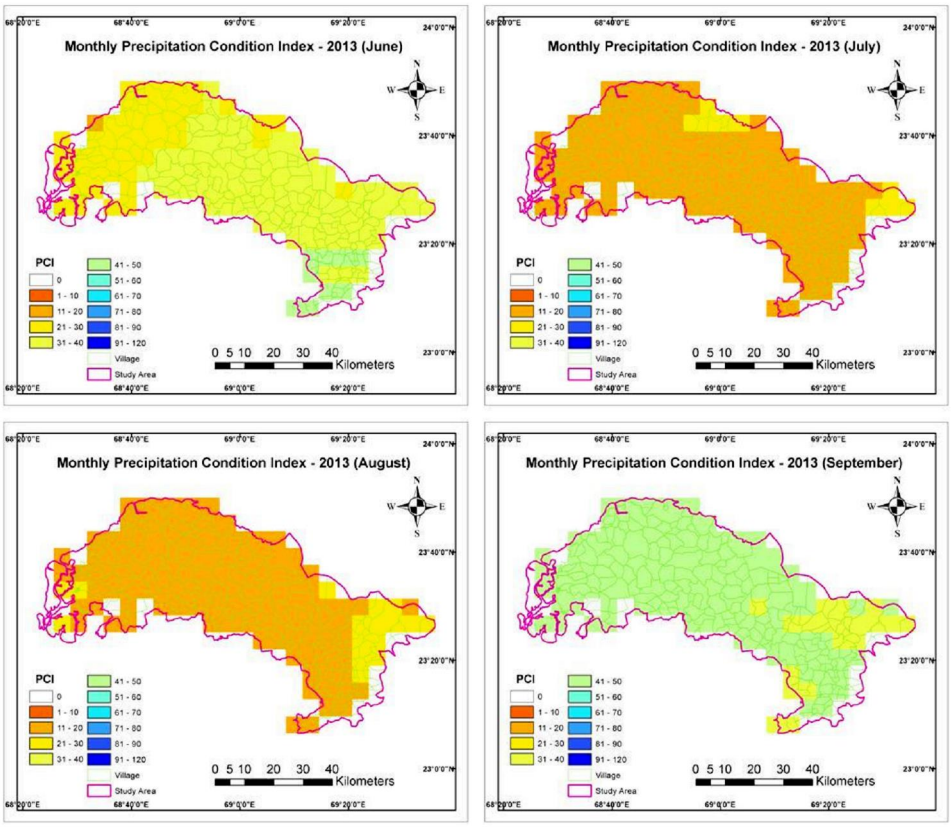

Figure 6.47 Monthly PCI (monsoon Season-2013)

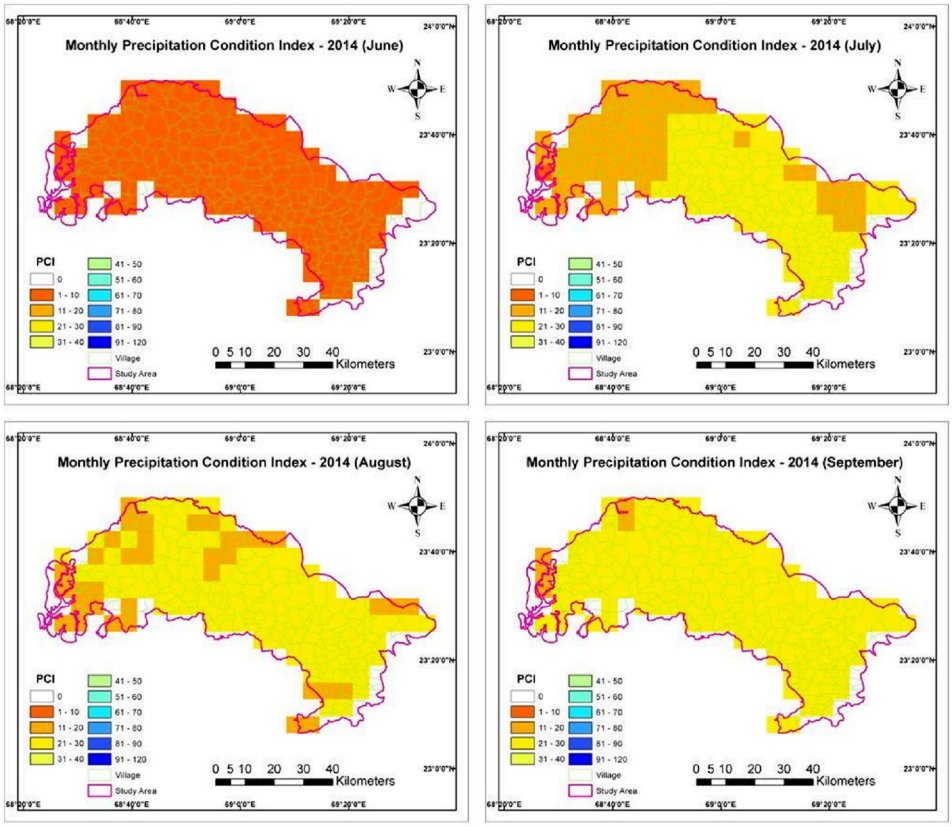

Figure 6.48 Monthly PCI (monsoon Season-2014)

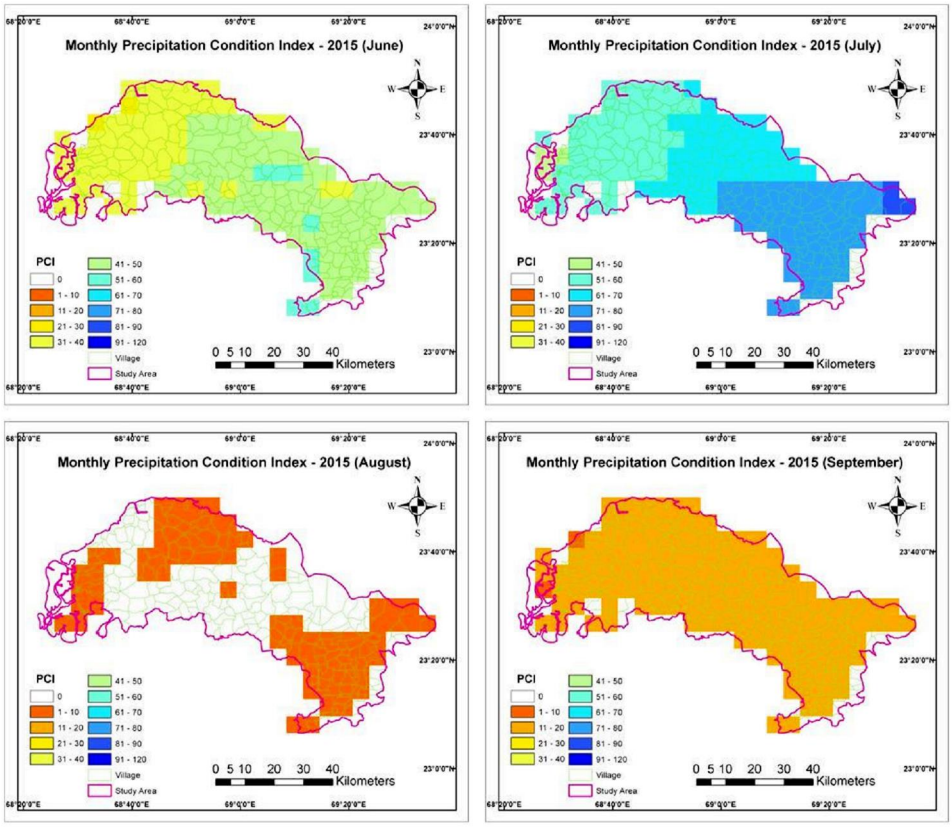

Figure 6.49 Monthly PCI (monsoon Season-2015)

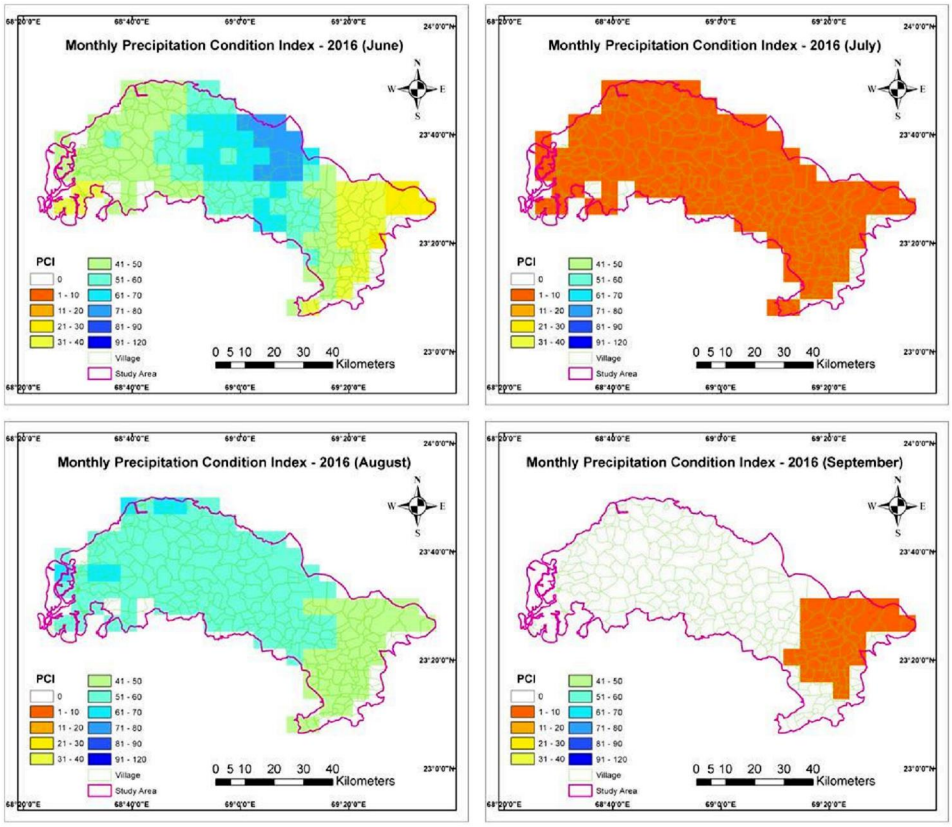

Figure 6.50 Monthly PCI (monsoon Season-2016)

6.3.2 Assessment of Seasonal Precipitation Condition Index from year 2011 to 2016

A seasonal PCI based drought assessment maps was generated at the end of the monsoon season to evaluate the drought situation at the end of the season. The Seasonal PCI Maps were generated by incorporating precipitation data for the entire season and its ratio from long term climatology for the year 2011 to 2016.

The spatial distribution of Seasonal PCI for the year 2011, 2012, 2013, 2014, 2015 and 2016 are described in Fig.6.51. PCI values from figure 6.51 are suggesting monsoon season for the year 2011 is the one with highly wet conditions over study area, whereas year 2012 shows variations of PCI values in study area, where Nakhtrana taluk experienced moderate to severe drought condition during the monsoon period and Lakhpat taluk shows normal condition based on the PCI vales. Seasonal PCI analysis for the Year 2013and 2014 revels that the monsoon season for the year 2013 and 2014 experienced Severe to moderate drought conditions over the study area. Seasonal PCI values for the year 2015 shows the normal to good condition of rainfall over the study area. PCI values for the Year 2016 are displaying less amount of rainfall as compared from long term climatology. Based on PCI analysis study

reveals that the except year 2011 and 2015, remaining all study years experienced drought like condition where year 2012 and 2016 were in severe condition.

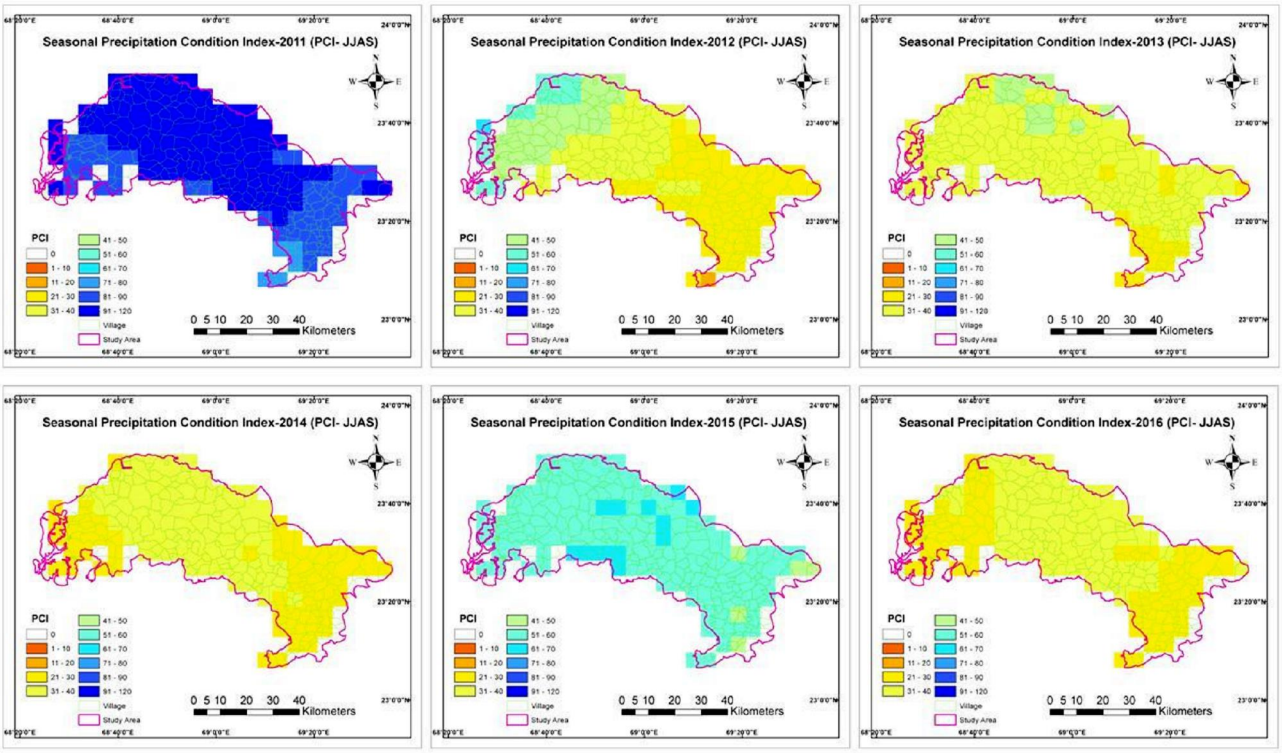

Figure 6.51 Seasonal PCI for the years 2011, 2012, 2013, 2014, 2015 and 2016.

6.4 Drought Characterization using Integrated Spatial Drought Index (ISDI)

The ISDI map and drought severity classes produced using current methodology illustrated in figure 6.52. The spatial distribution of Seasonal ISDI based drought maps for the year 2011, 2012, 2013, 2014, 2015 and 2016 are analysed in this section. Figure 6.52 illustrates the year 2011 experienced normal condition with respect to the drought classes. ISDI analysis reviled that year 2012 shows mild drought category in maximum part of the study area. Figure 6.52 illustrates the mild drought classes identified in around 60 percent of the study area and 40 percent of total area shows normal condition in year 2013.Year 2014 experienced mild drought over study area, whereas year 2015 and 2016 shows moderate to severe drought conditions as analysed by Integrated Spatial Drought Index.

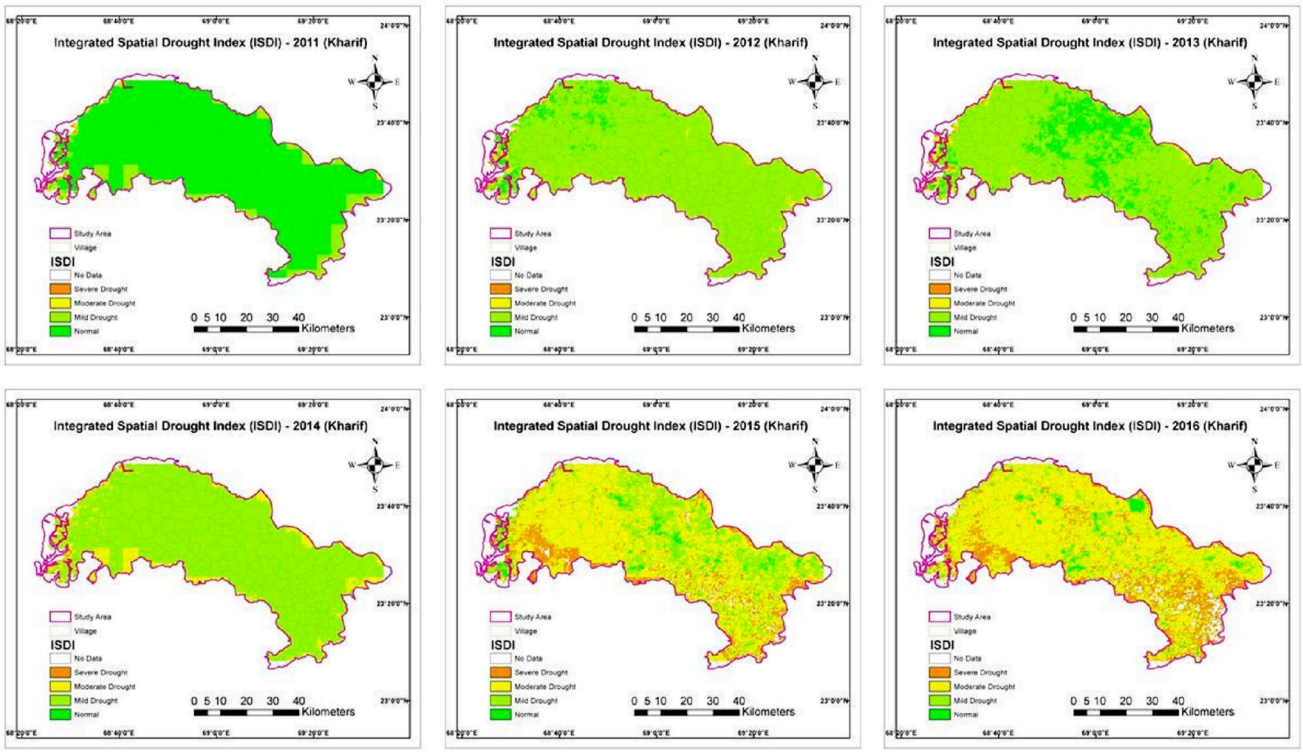

Figure 6.52 ISDI for the years 2011, 2012, 2013, 2014, 2015 and 2016 (Kharif Season).

The overall results of our analysis show a close resemblance to the various reports from government departments and research article for the study area. ISDI based droughts observed in the Nakhatrana and Lakhpat Taluk of Kutchh district. Department of Agriculture, Cooperation & Farmers Welfare released a manual for drought management and mentioned that kutchh rainfall variability is exceeding more than 50 % of normal and it is under drought prone area (Manual for Drought Management, 2016).

6.5 Additional Indices and Supporting Data Analysis:

A seasonal agricultural drought assessment maps was generated at the end of the season to evaluate the agricultural drought situation at the end of the kharif growing season. The ISDI was generated by incorporating information from satellite derived parameters for Kharif season. Indices was used in ISDI are PCI and VCI, whereas in Indian scenario, Rainfall occurs only in monsoon season over the study area which nurtures only kharif crop cultivation. Whereas, analysis cannot be performed for rabi season using ISDI, because of the very less rainfall. In account of this we can use some other indices to quantify drought conditions over the study area viz. Soil Moisture Content (SMC), SMC deviation,

Temperature condition Index etc. Weekly SMC maps for the kharif season have been discussed in below section.

6.5.1 Spatial Distribution of Weekly Soil Moisture Content and Analysis:

Spatial and temporal distribution of AMSR2-Soil Moisture Content (SMC) has been analysed in this section from the year 2012 to 2016. AMSR2-SMC product has been pre-processed from daily to weekly dataset and analysed for entire year, results in this section presented from 09 July to 30 September only and rest of the data set is available in SDSS-DM, which is explained in chapter-5. Figure 6.53 describes weekly soil moisture distribution in year 2012 for the study area, where Nakhatrana taluk experienced stress in moisture as compare to the Lakhpat Taluk throughout the season. Figure 6.54, 6.55, 6.56 and 6.57 illustrates spatio-temporal variability of the SMC for the year 2013, 2014, 2015 and 2016 respectively.

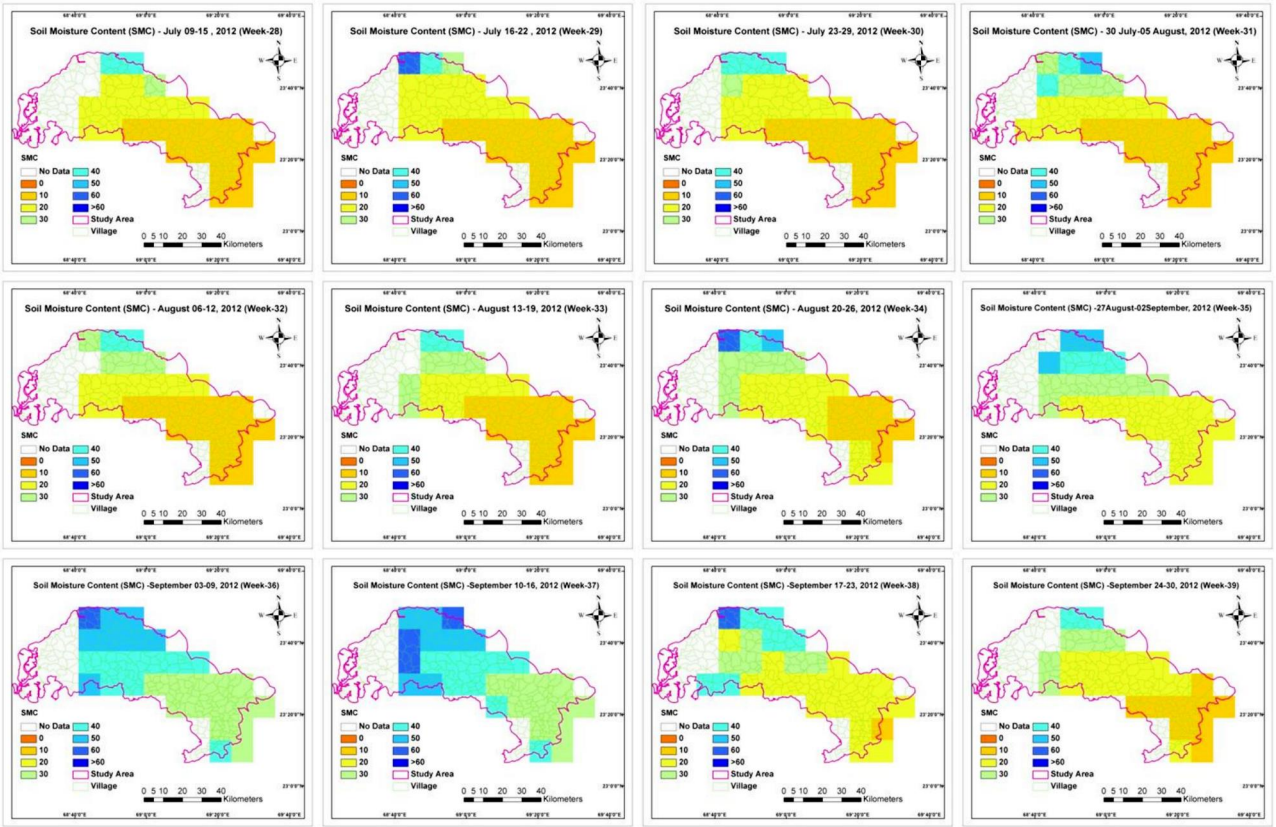

Figure 6.53 Weekly Soil Moisture Content Year 2012(09 July to 30 September)

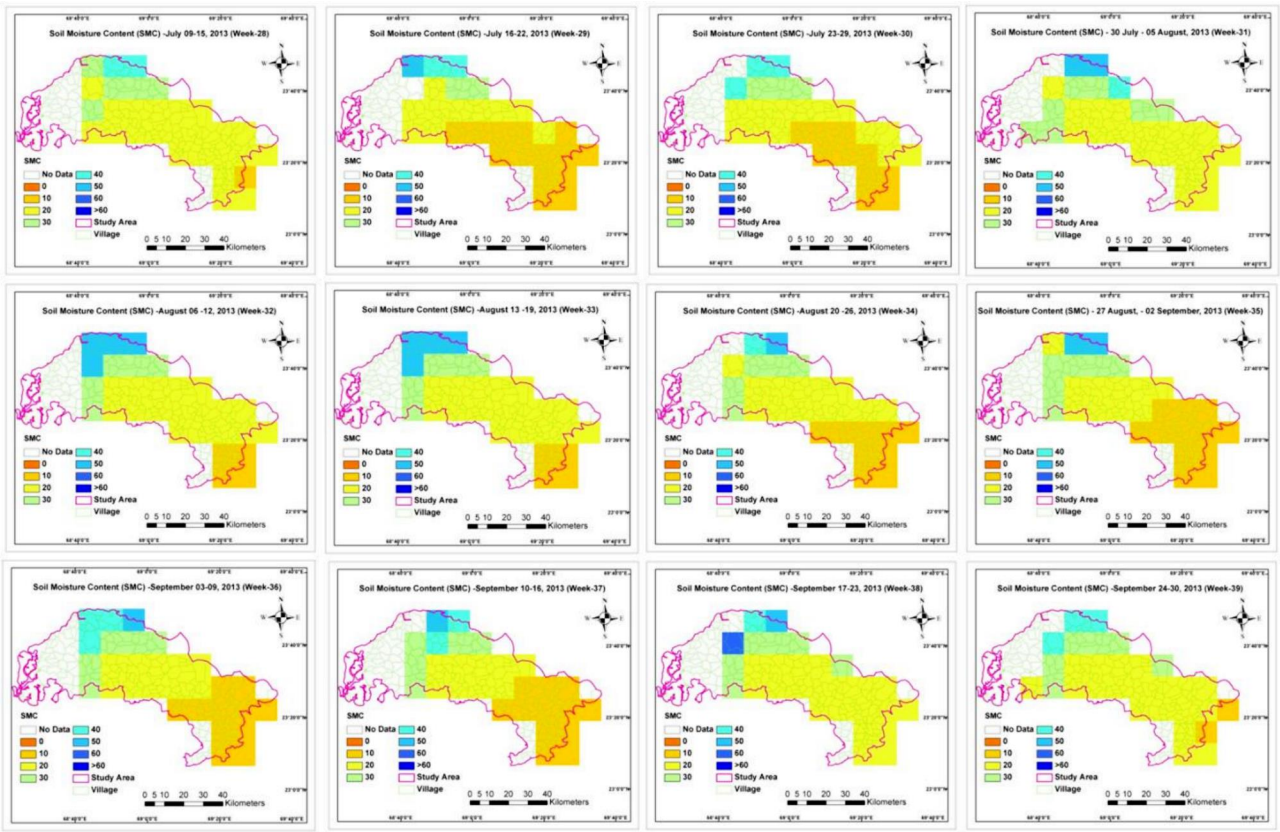

Figure 6.54 Weekly Soil Moisture Content Year 2013 (09 July to 30 September)

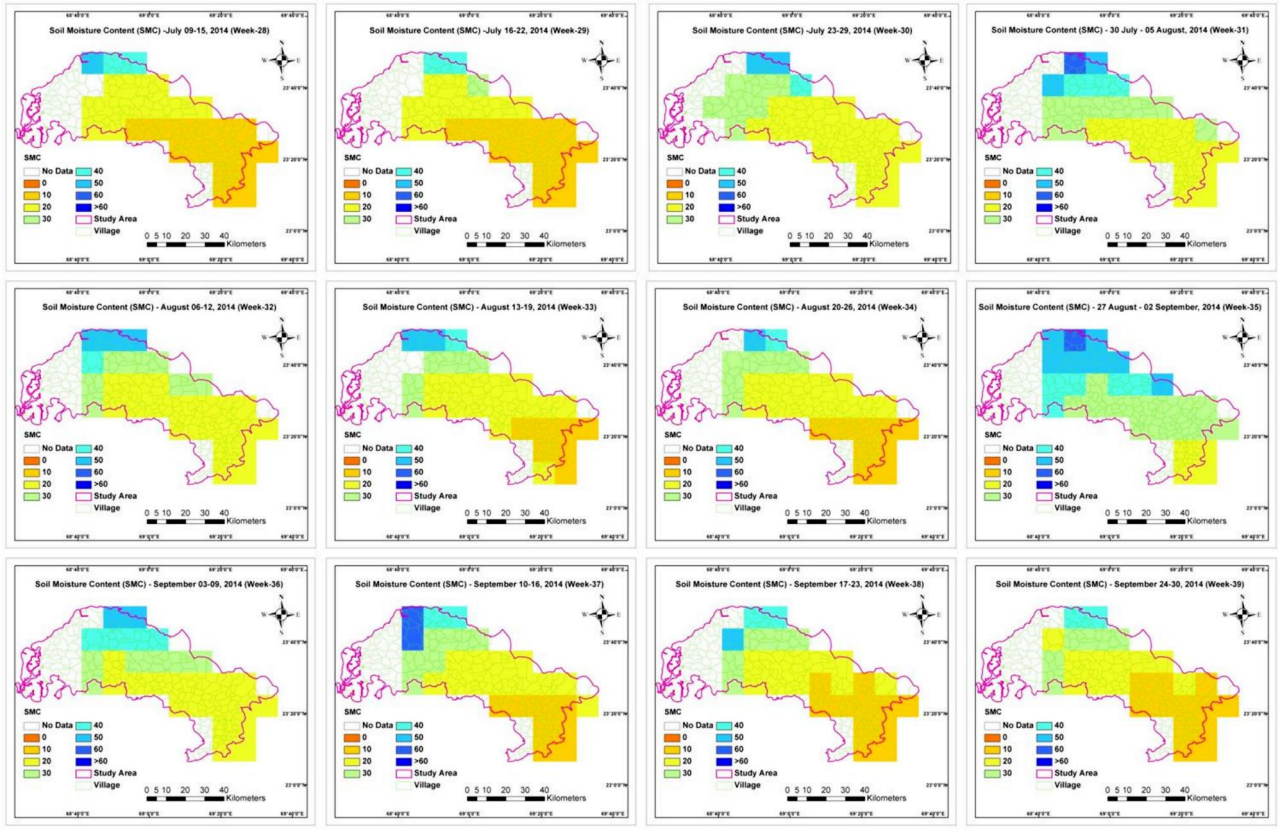

Figure 6.55 Weekly Soil Moisture Content Year 2014 (09 July to 30 September)

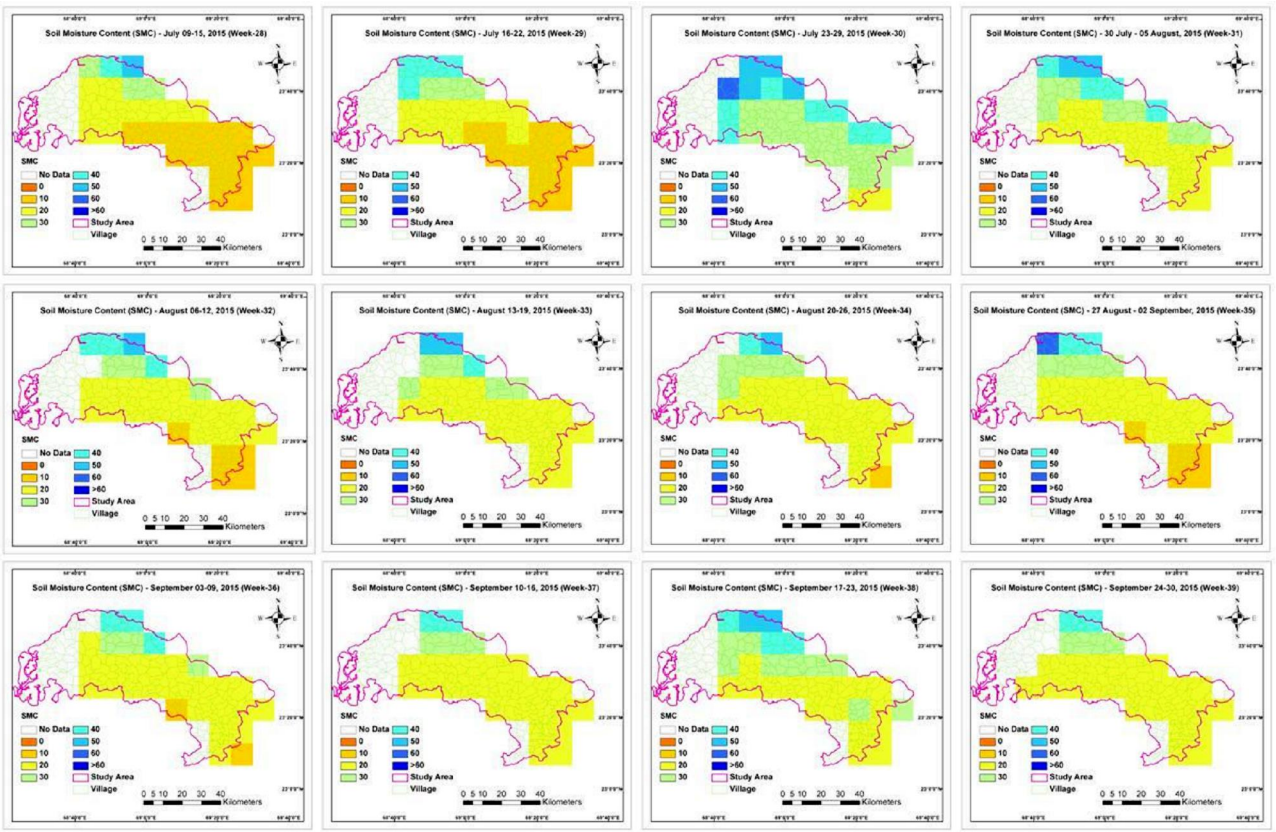

Figure 6.56 Weekly Soil Moisture Content Year 2015 (09 July to 30 September)

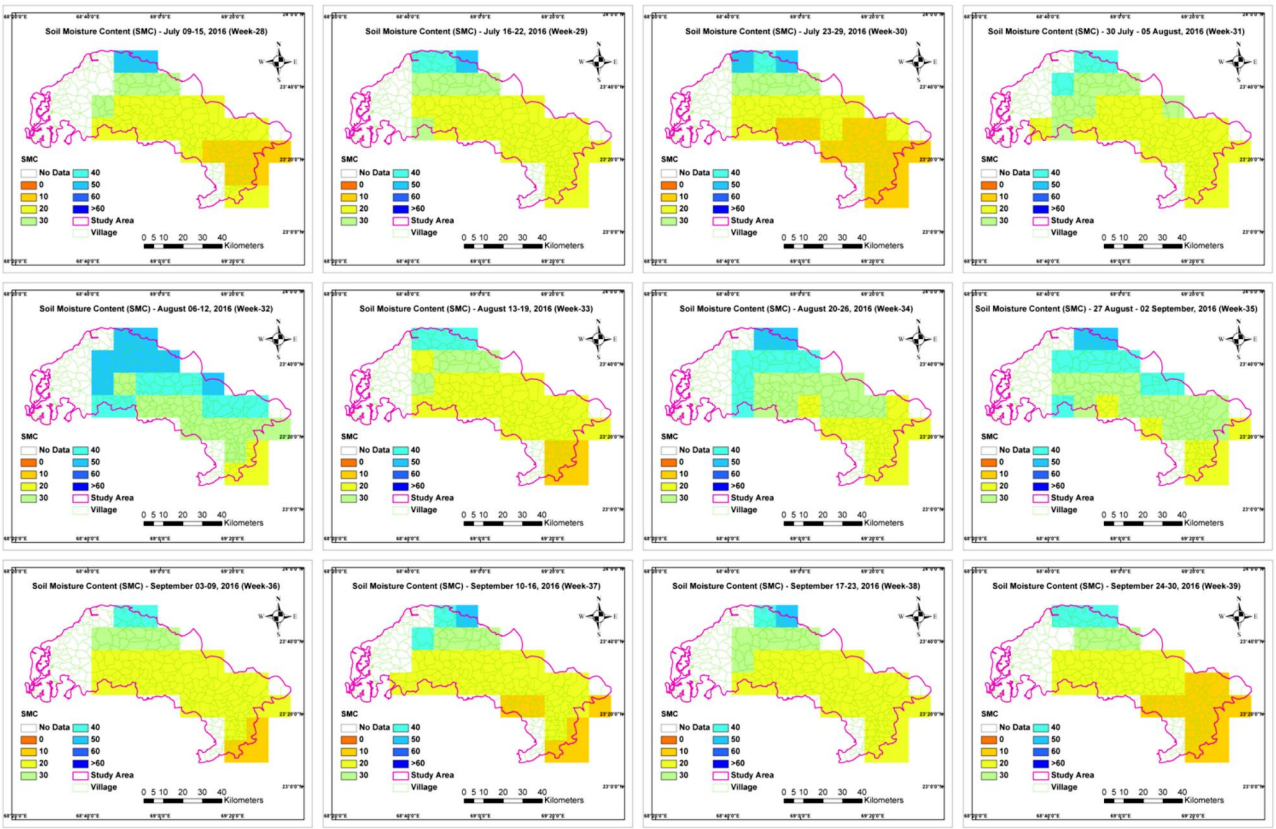

Figure 6.57 Weekly Soil Moisture Content Year 2016 (09 July to 30 September)

6.5.2 Spatio-temporal Distribution of Monthly Land Surface Temperature:

To determine the temporal variation of the surface temperature, LST was plotted at monthly intervals during January to December for the years 2002–2014. The spatial distribution of short term average (STA) of monthly LST is shown in Figure 6.58 for entire study area. Surface temperature patterns derived from this study shows that the Monthly STA varies spatially as well as temporal.

Figure 6.58 represents the study area experienced 300-306 degree Kelvin in the month of December and January which is lowest LST throughout the year. Month of March, April, and May experienced very high LST values (312-330 degree Kelvin), which shows very hot climate in the study area. The spatial distribution of surface temperature in the month of June, July, August, and September using STA analysis represents the temperature ranging from 302K to 312 K in the entire study area, whereas month of June experienced 308 to 316 degree Kelvin LST in the study area.

Figure 6.59, 6.60 and 6.61 describes spatial and temporal variation of LST for the year 2012, 2013 and 2014 respectively and all the data set is available in SDSS-DM with interactive visualization tool. Spatial and Temporal variation of LST also shows that the Nakhtrana Taluk recived less LST as compared to the Lakhpat Taluk in the study area.

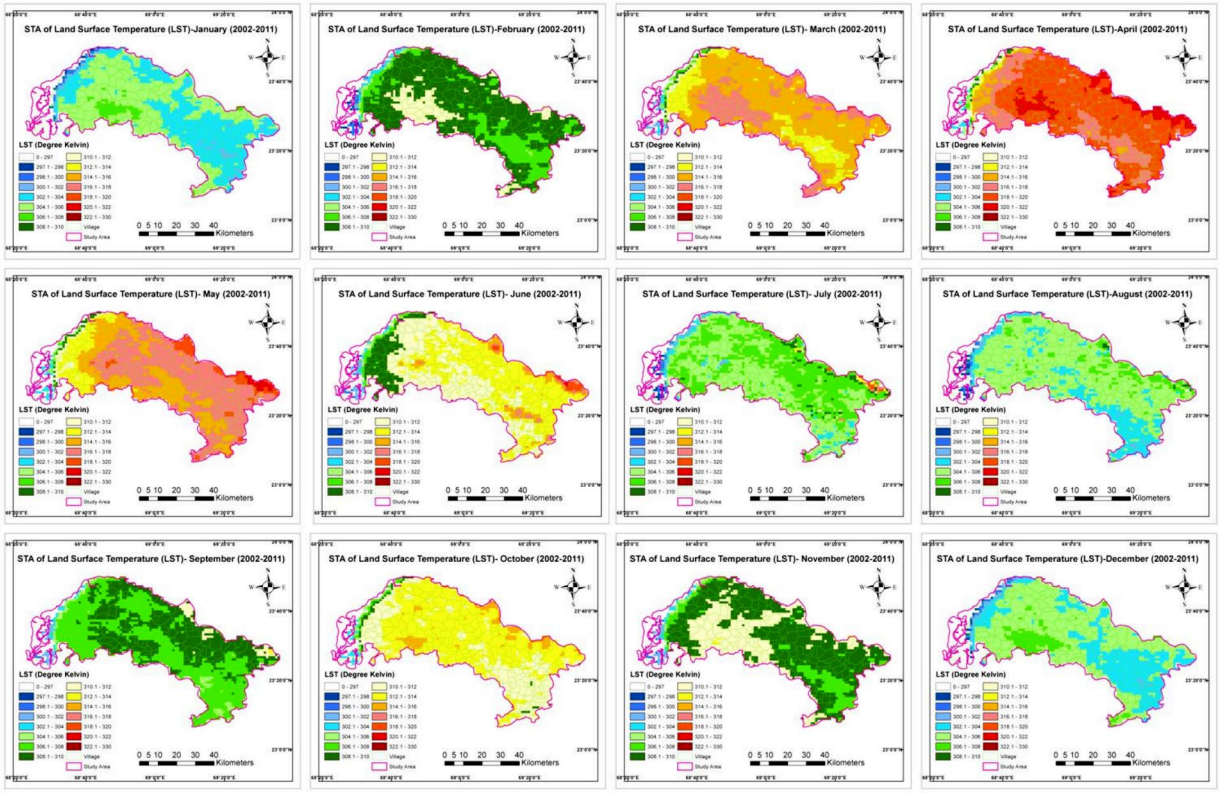

Figure 6.58 Monthly Short Term Average (10-Years) of Land Surface Temperature (2002-2011)

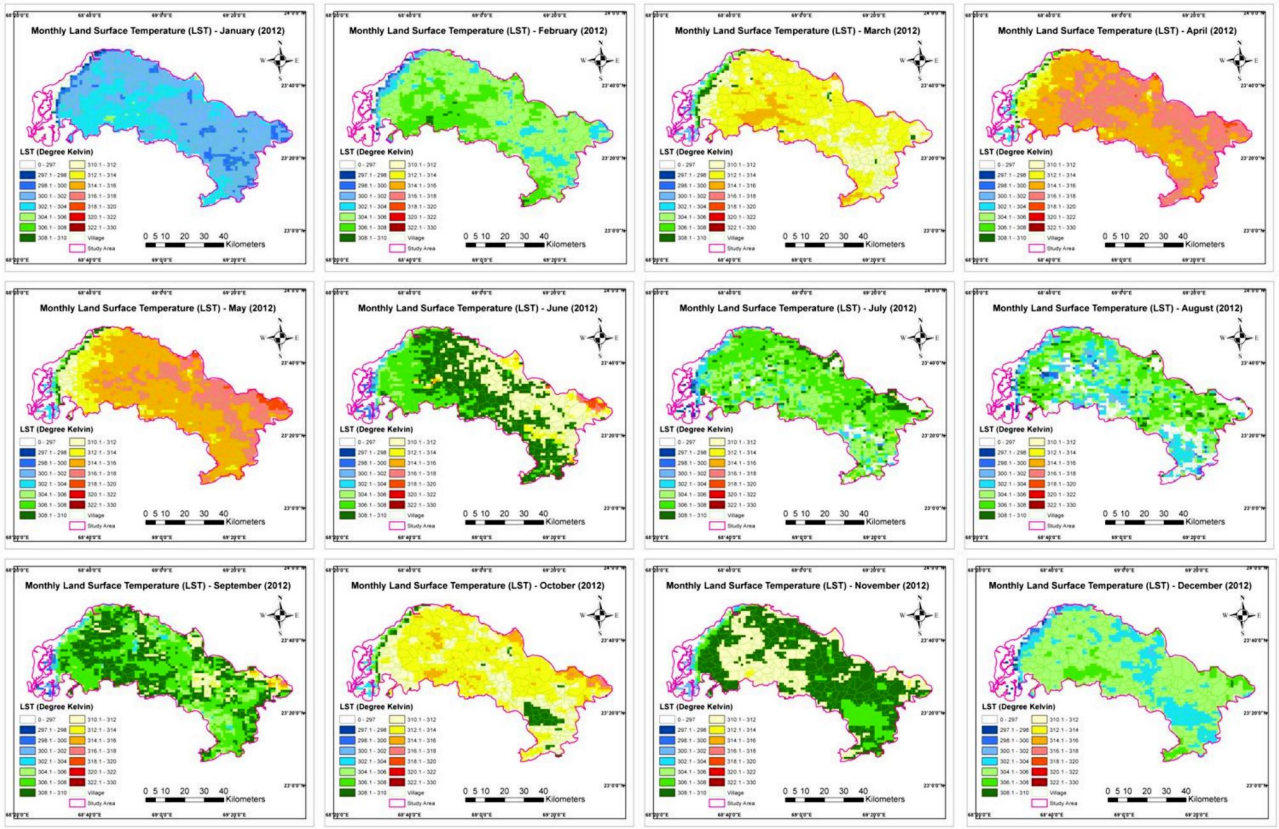

Figure 6.59 Monthly Average of Land Surface Temperature (Year-2012)

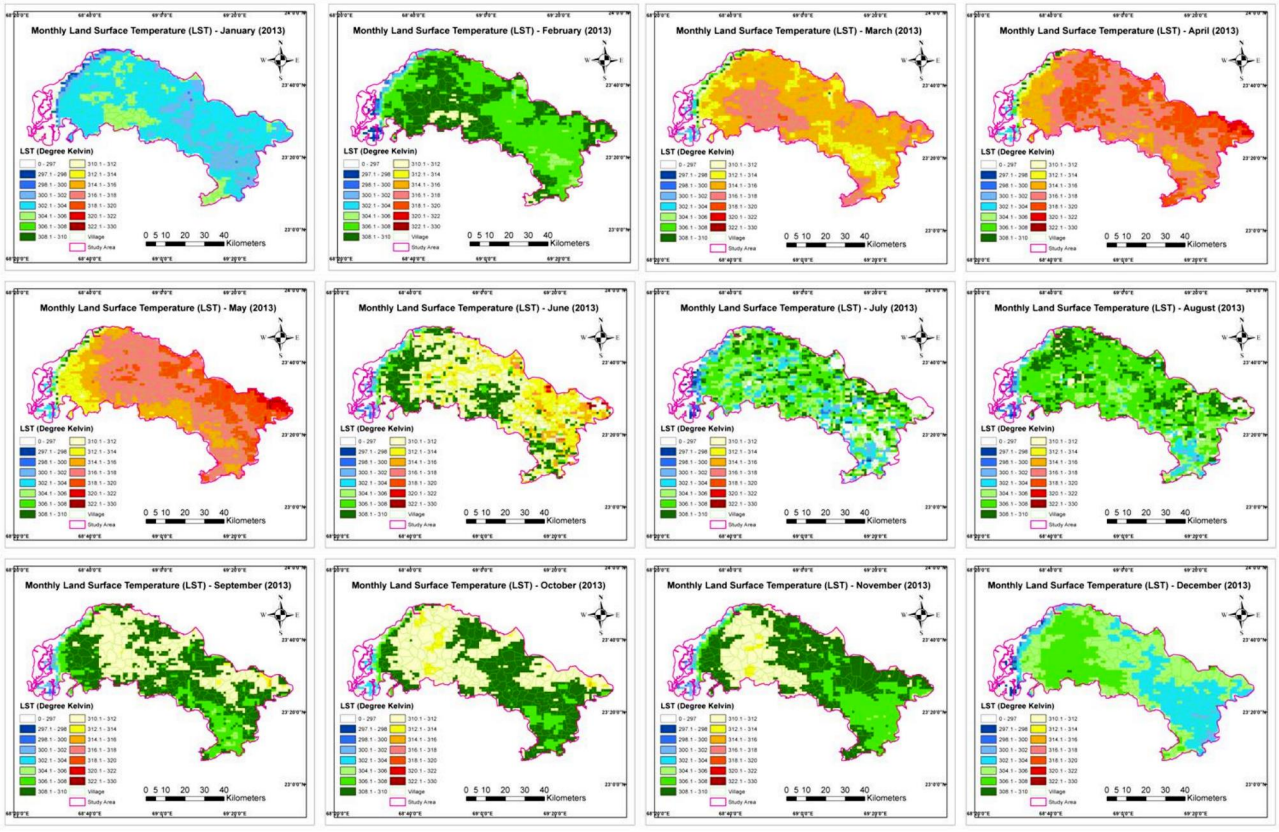

Figure 6.60 Monthly Average of Land Surface Temperature (Year-2013)

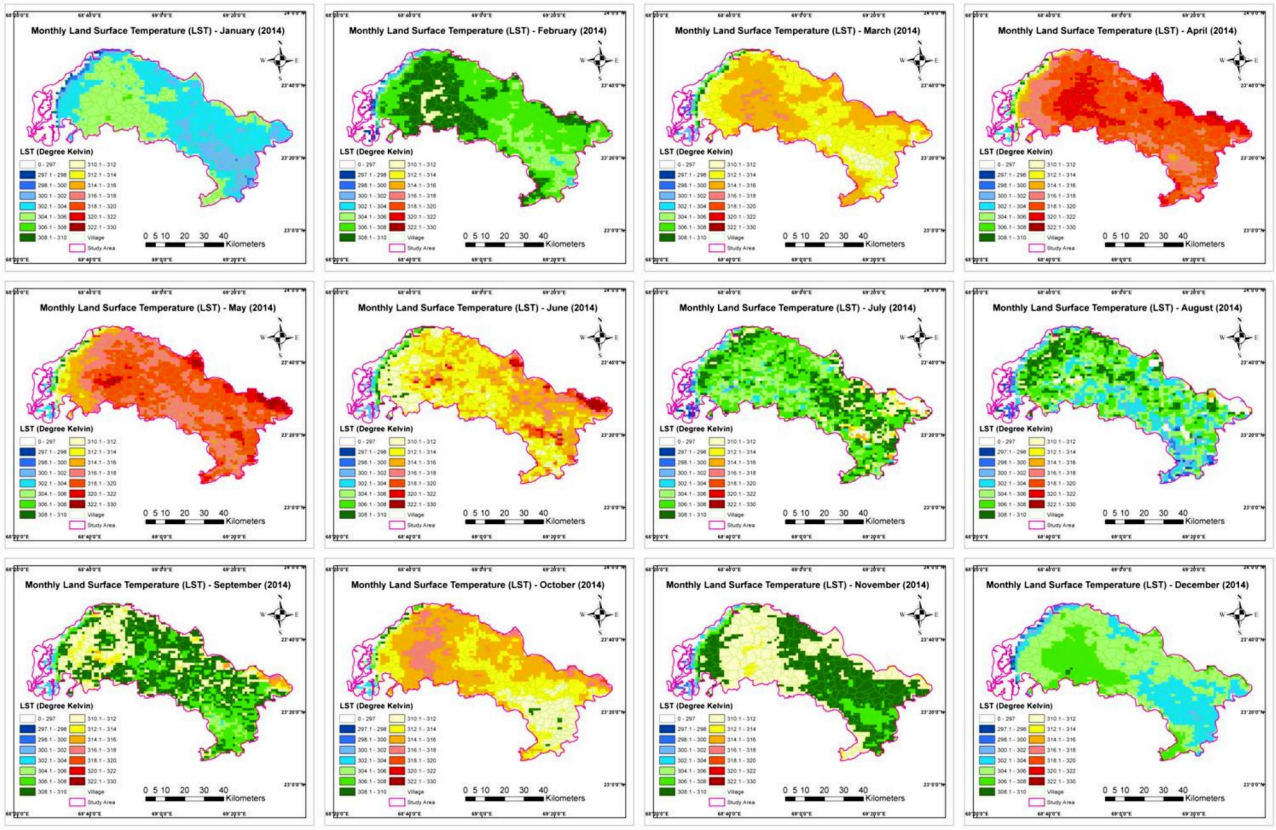

Figure 6.61 Monthly Average of Land Surface Temperature (Year-2014)

From the methodology adapted and the wide indices used to understand the feasibility and its applications for deriving the spatial decision support system. The study suggest that Vegetation Condition Index, NDVI, NDWI, SPI and PCI index stands promising to be used for the SDSS. The major cropping season (Kharif) in the rain fed agriculture can be monitored and the correct approach can be devised for safeguarding the productivity.