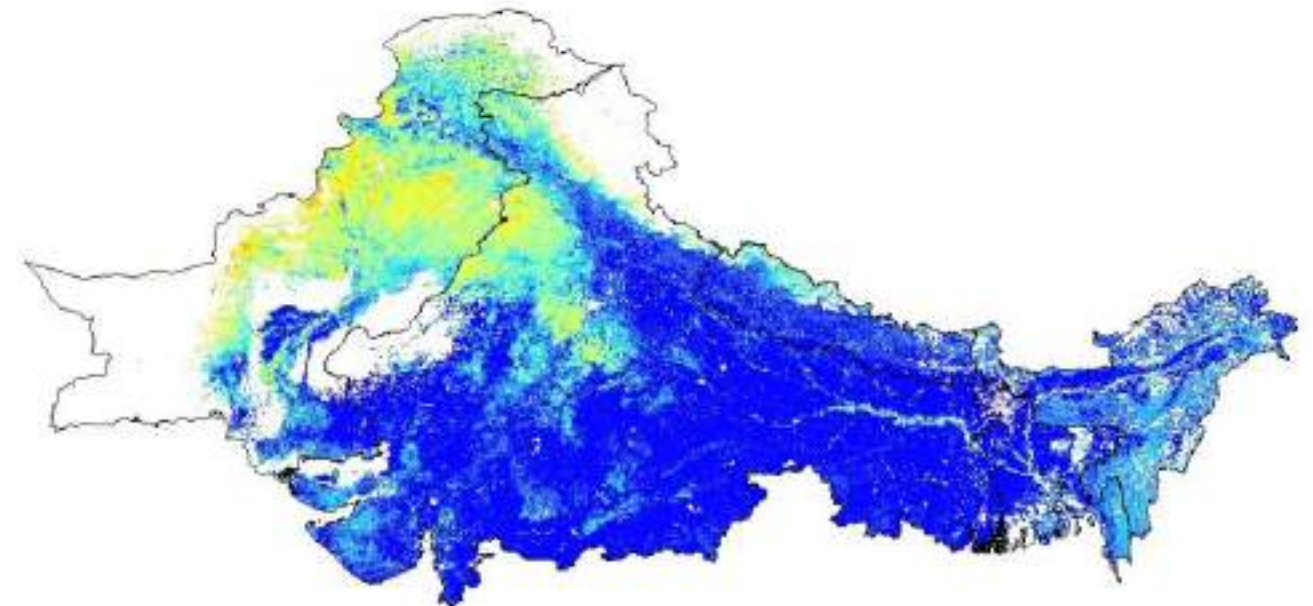
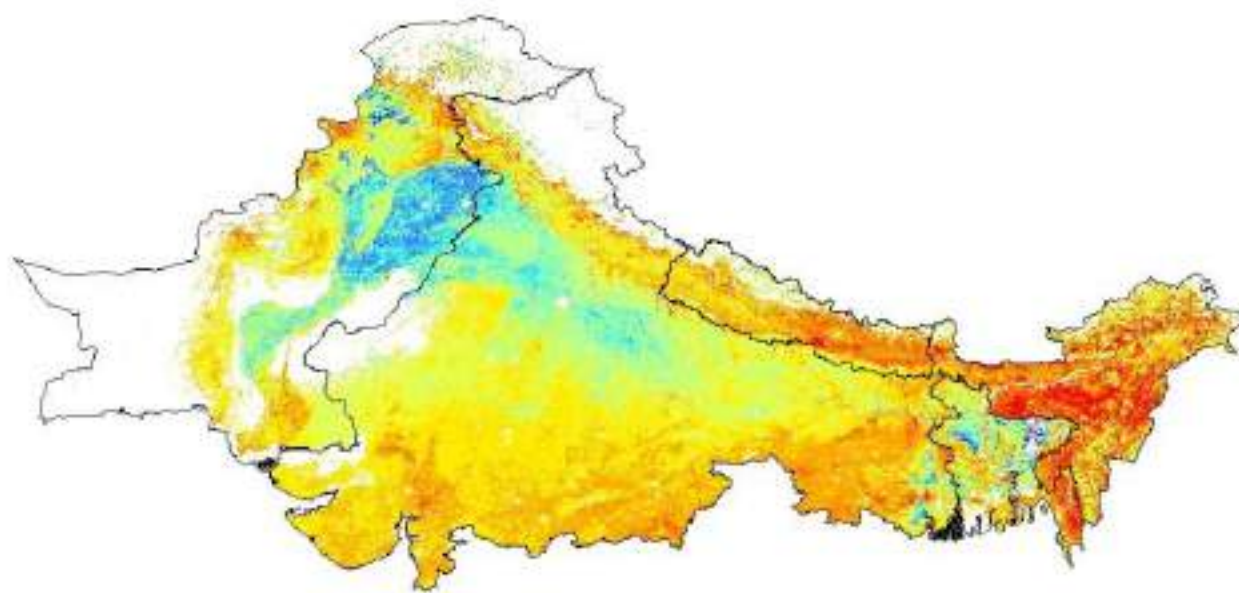
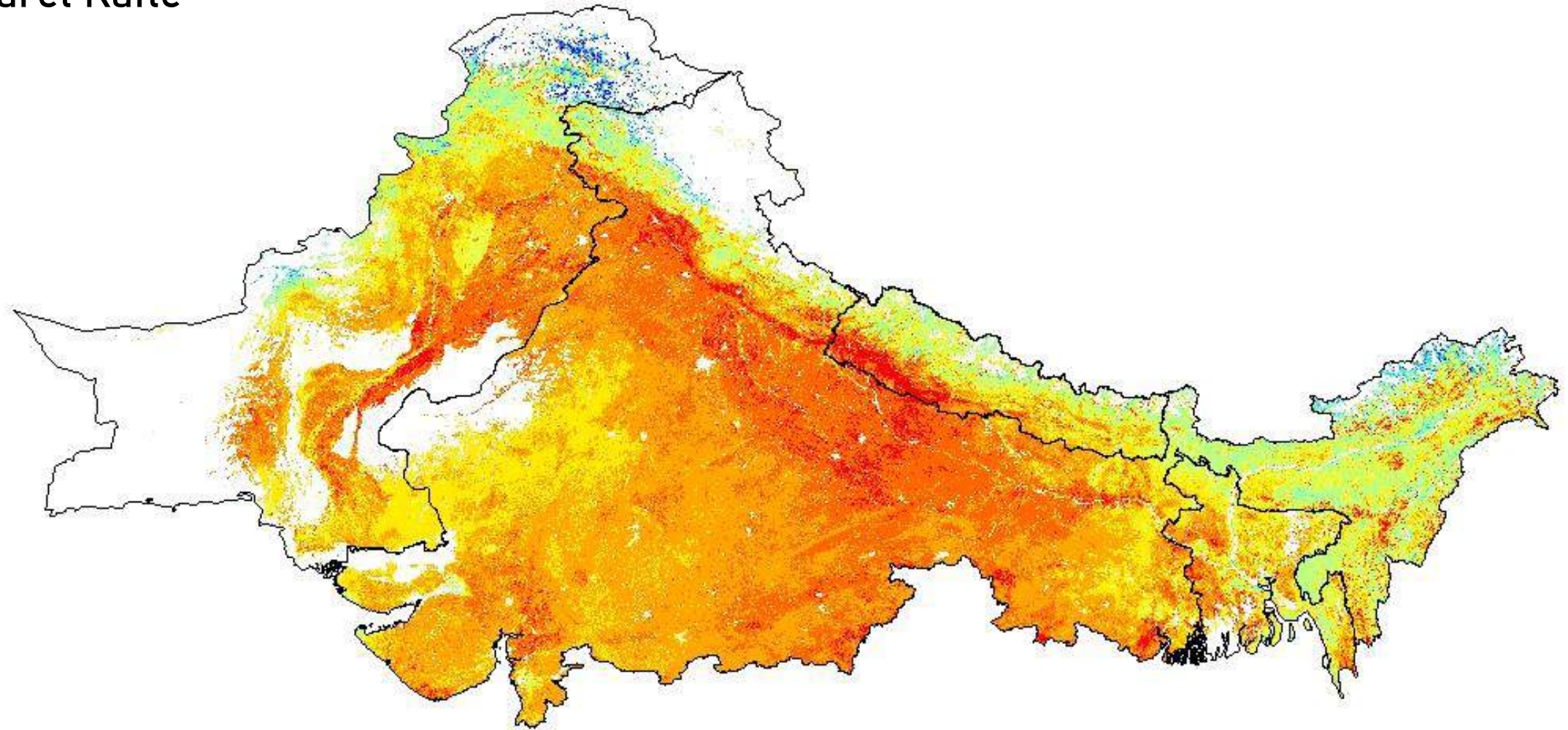


# THE DROUGHT ATLAS OF SOUTH ASIA

Dr. Hemu Kharel Kafle





# The Drought Atlas of South Asia

Dr. Hemu Kharel Kafle

Center for Water and Atmospheric Research



The Drought Atlas of South Asia

(Historical monthly drought of South Asia from 2000-2020)

Dr. Hemu Kharel Kafle

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The Center for Water and Atmospheric Research (CENWAR) at Kathmandu Institute of Applied Sciences has produced the first edition of the South Asia Drought Atlas. This Atlas uses a Drought Severity Index (DSI) to highlight the intensity of drought. Descriptive graphs and visuals are used to highlight the drivers and effects of drought in South Asia.

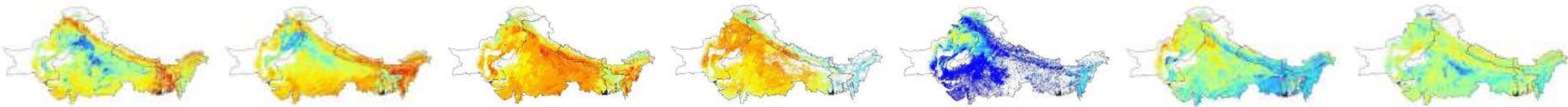
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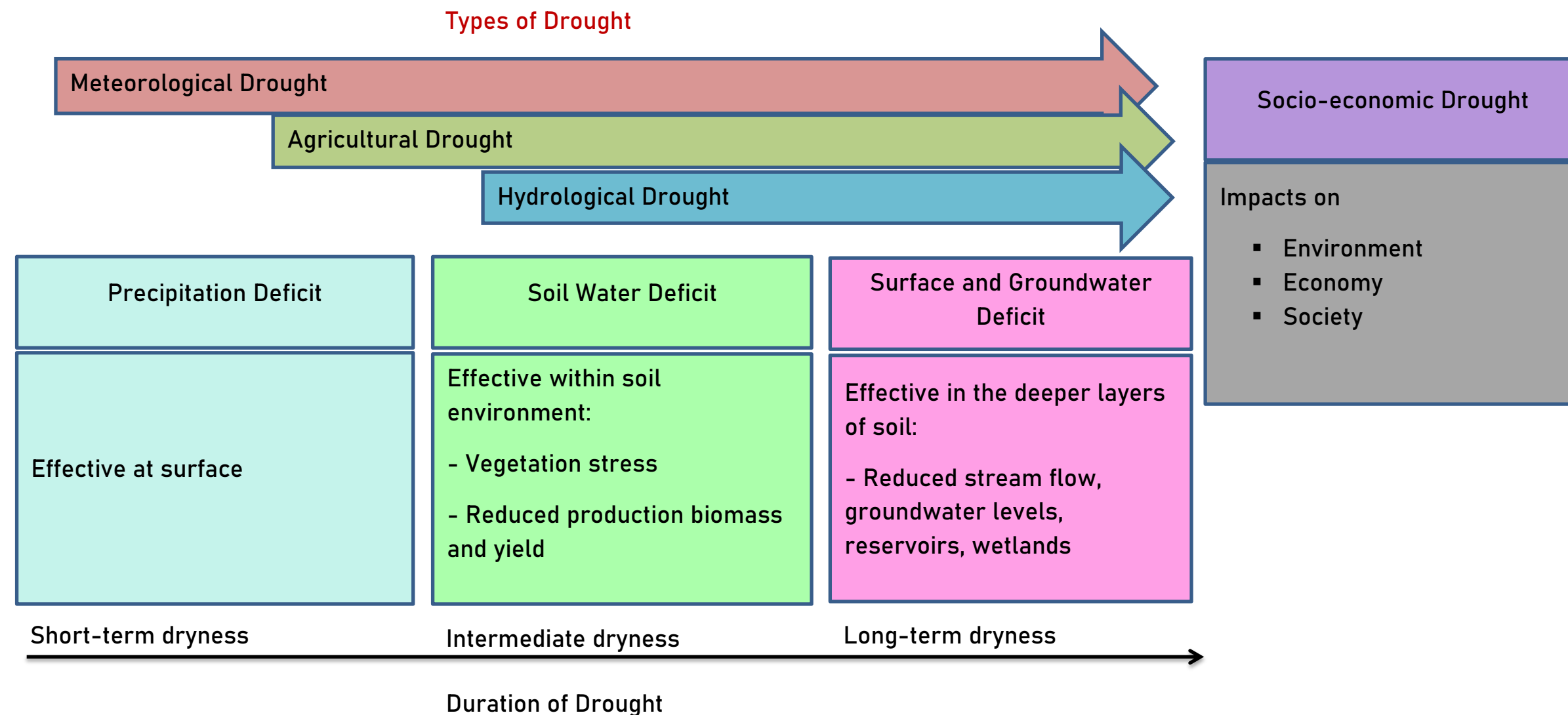


## What is Drought?

Drought is a period of time when there is a lack of water on land. Drought mainly results from abnormally low rainfall leading to water scarcity (Wilhite, 2000b). It is defined as “severe water shortage”.

Drought is a complicated phenomenon, yet one of the least understood of all natural hazards impacting more people than any other disaster (Obasi, 1994). Since the demand for water is increasing along with the population in many parts of the world, water supply interruptions caused by drought can be expected to produce greater impacts (Hewitt, 1997).

Drought is a global phenomenon; however, their effects are more vulnerable in developing countries because of the lesser potential to mitigate the impacts of such extreme events (Wilhite, 2000).

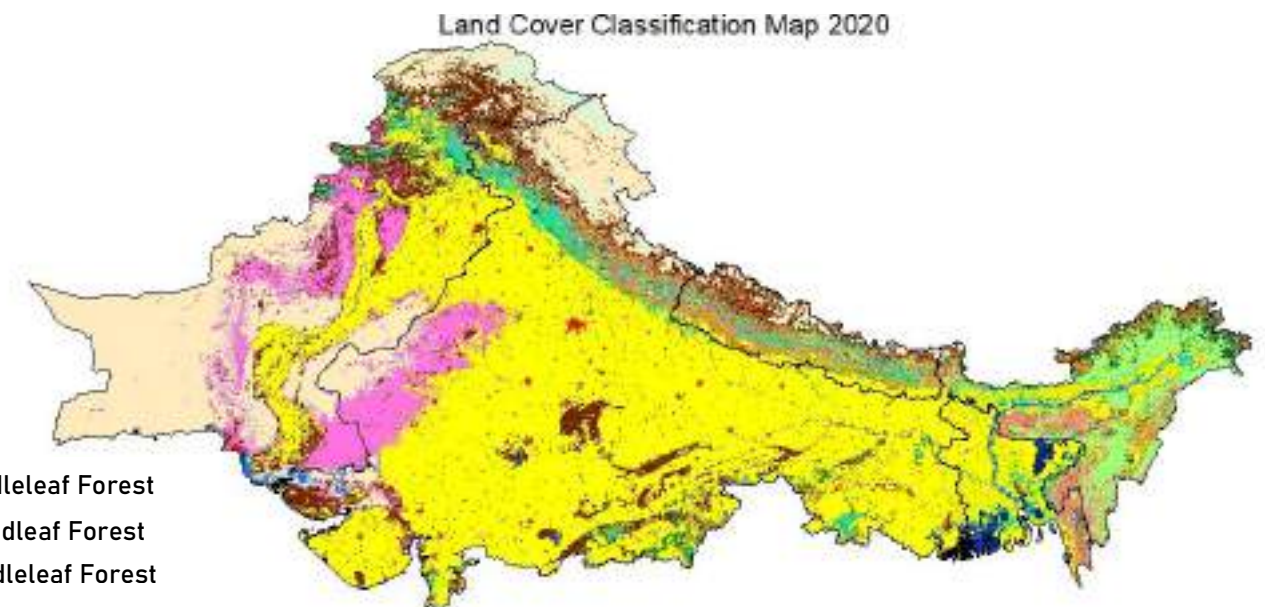
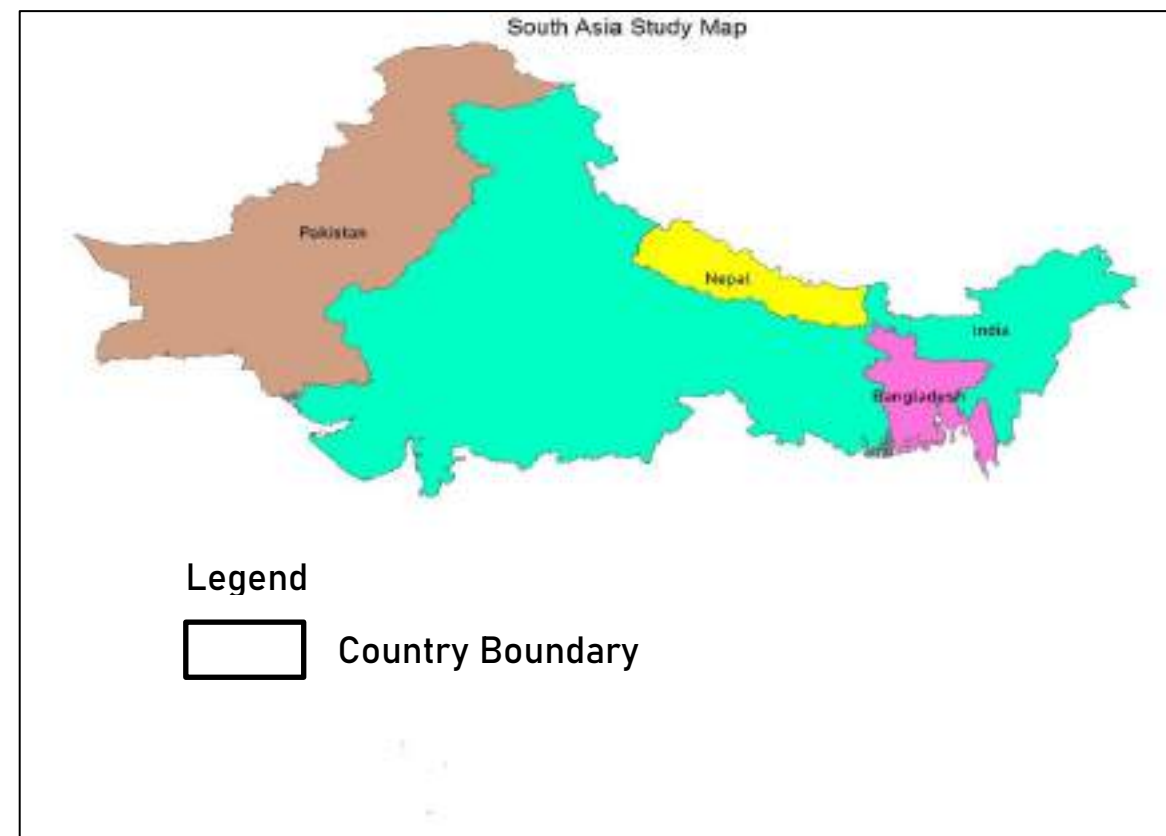


## South Asia Overview

South Asia is the southernmost part of Asia, characterized both geographically and ethnographically. According to the World Fact Book, the region encompasses Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, South Asia, and Sri Lanka, and covers 5.2 million square kilometers (2.0 million square miles). South Asia accounts for only 3% of the world's surface area yet accounts for 24% of the global population (Bloom & Rosenberg, 2011). The Indian Plate dominates the topography, which is mostly defined by the Indian Ocean on the south and the Himalayas, Karakoram, and Pamir Mountains on the north. South Asia is bordered on the land (clockwise) by Western Asia, Central Asia, East Asia, and Southeast Asia. South Asia has a population of about 1.891 billion people, or roughly one-fourth of the world's

population, making it the world's most populous and densely populated geographical region. It is home to a diverse population, accounting for 39.49 % of Asia's population and over 24 % of the world's population.

Nepal, sections of India, South Asia, and Bangladesh are among the countries studied in this atlas. The land cover type data were taken from Terra and Aqua combined MODIS MCD12Q1 data (collection v005, 500m) retrieved from Earth Data (<https://earthdata.nasa.gov>) for the years 2000-2020. The landcover was divided into 17 categories by the International Geosphere-Biosphere Programme (IGBP) (International Geosphere Biosphere Programme, 2017).





## Remotely Sensed Data

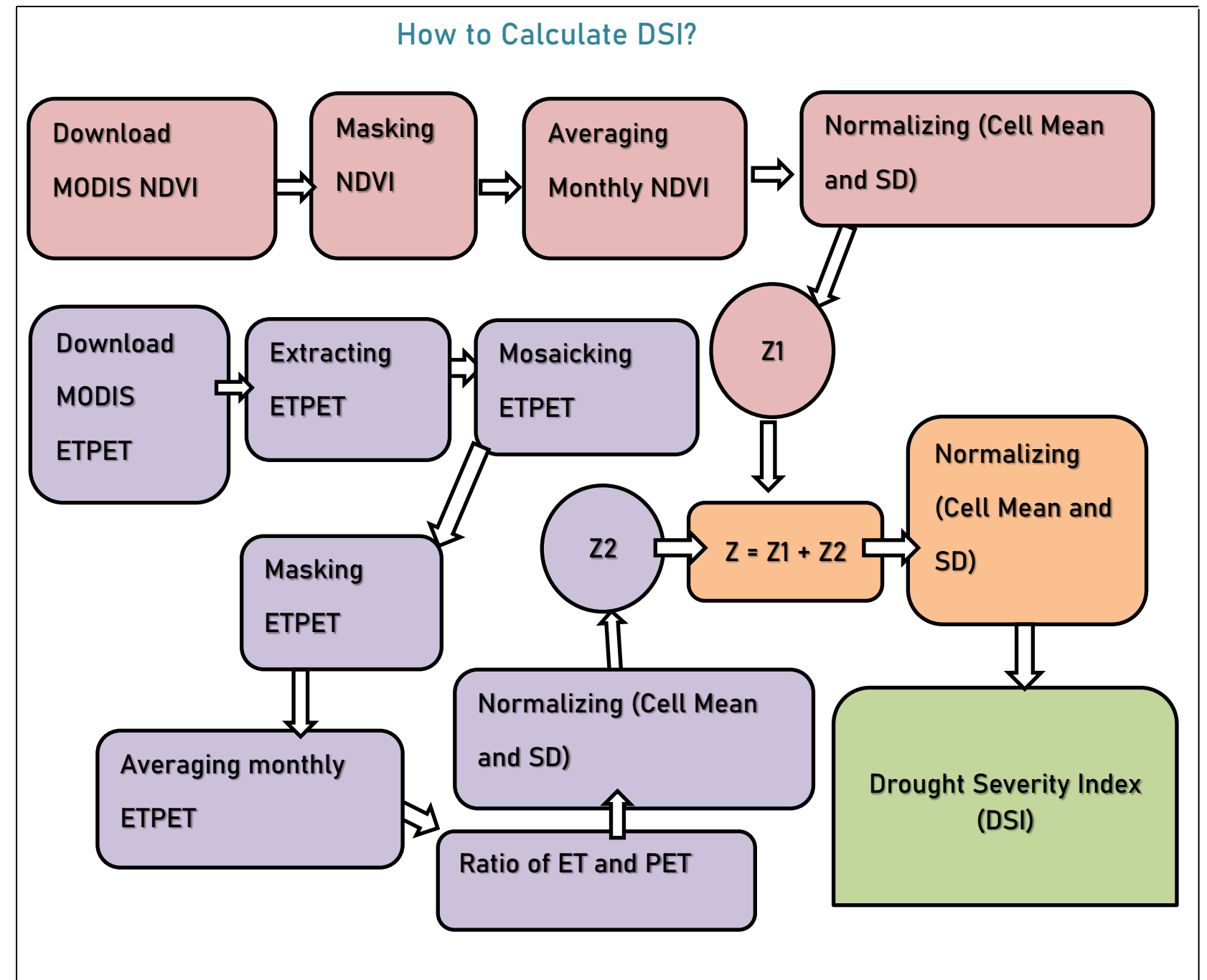
The Moderate-Resolution Imaging Spectrometer (MODIS) is an advanced narrowband-width sensor from which NASA and the USGS allow free composited reflectance data available every eight days via the Earth Resources Observation Systems (EROS) data center (Justice and Townshend, 2002a). MODIS products of Land cover, NDVI and ET/PET have been used for this study.

### MODIS NDVI Data

This data includes MOD13A1 (MODIS/Terra Vegetation Indices 16-Day L3 Global 500m SIN Grid) NDVI products at 500m spatial resolution for twenty one years (2000-2020). Global MOD13A1 data are provided every 16 days at 500-meter spatial resolution as a gridded level-3 product in the Sinusoidal projection i.e obtained from NASA Land Processes Distributed Active Archive Center (LP DAAC, <https://lpdaac.usgs.gov/>).

### MODIS ET, PET

This data set includes 8-day MOD16A2 Gap-Filled ET/PET (MODIS/Terra Net Evapotranspiration Gap-Filled 8-Day L4 Global 500m SIN Grid V006). The MOD16A2GF Version 6 product is a year-end gap-filled 8-day composite dataset produced at 500 meter (m) pixel resolution. The ET/PET datasets are obtained from Earth Data (<https://earthdata.nasa.gov/>).



## Drought Severity Index (DSI)

DSI was chosen to investigate the spatiotemporal variability of droughts across the country using observed satellite products from 2000 to 2020. This newly proposed remote sensing index by Mu et al., 2013 has performed well in many parts of the world. According to Mu et al. (2013), the DSI Index, which combines the NDVI and ET/PET, is calculated as shown in equations (1) to (4). The incorporation of both transpiration and vegetation indicator data in DSI has been regarded as an improvement over other drought index. To study drought in South Asia, monthly DSI values were calculated over a twenty one year period (2000–2020). Following are the equation systems that were used:

$$Z_{Ratio} = \frac{ET/PET - \overline{ET/PET}}{\sigma_{ET/PET}} \quad (1)$$

$$Z_{NDVI} = \frac{NDVI - \overline{NDVI}}{\sigma_{NDVI}} \quad (2)$$

$$Z = Z_{Ratio} + Z_{NDVI} \quad (3)$$

$$DSI = \frac{Z - \bar{Z}}{\sigma_Z} \quad (4)$$

Where  $Z_{Ratio}$  and  $Z_{NDVI}$  is the standardized value of ET/PET ratio and NDVI respectively.  $\overline{ET/PET}$  and  $\overline{NDVI}$  is mean.  $\sigma_{Ratio}$  and  $\sigma_{NDVI}$  is the standard deviation of ET/PET ratio and NDVI respectively.  $\bar{Z}$  and  $\sigma_Z$  represents the mean and standard deviation of the sum of  $Z_{Ratio}$  and  $Z_{NDVI}$  respectively. Drought Severity Index is represented by the DSI calculated in equation (4). Positive DSI value indicates wet condition, while negative values indicate dry conditions, Mu et al. (2013) classified DSI, as shown in table.

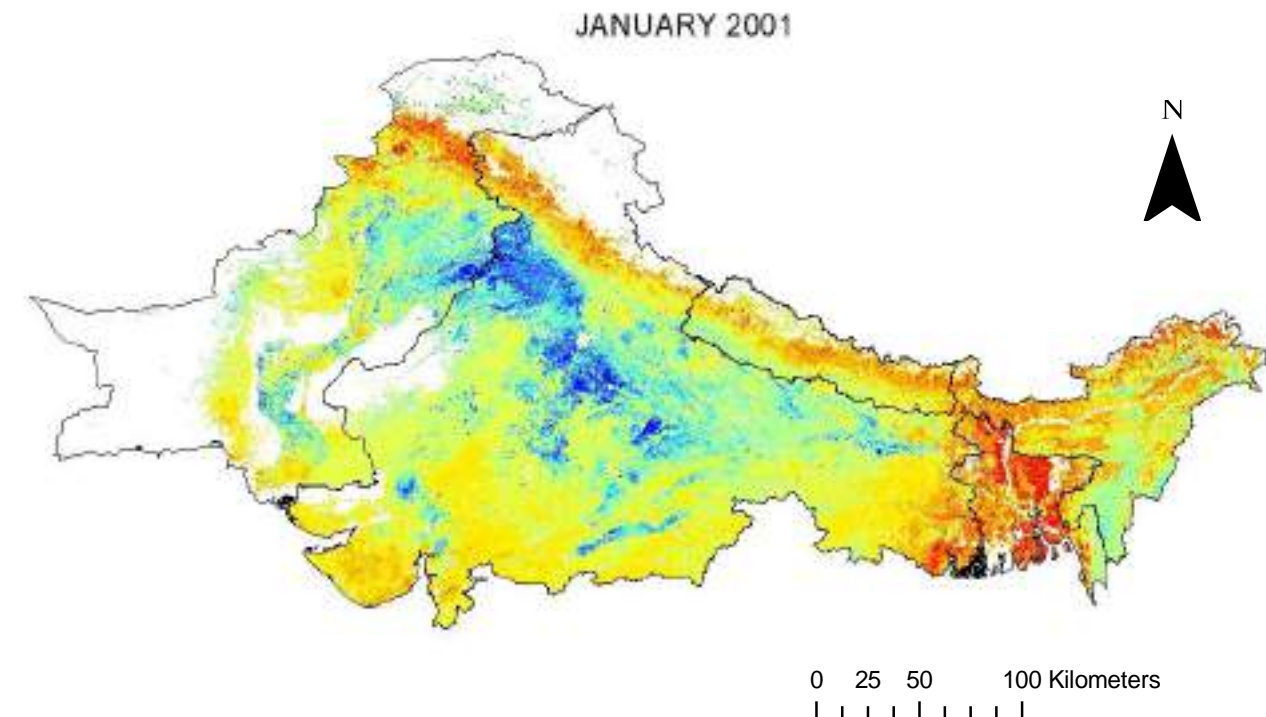
The generate DSI is then imported to ArcGis to export monthly DSI maps i.e displayed in this atlas. In mean monthly DSI maps of South Asia, extreme dry condition is denoted by Red colour whereas dark blue colour denotes extreme wet condition.

Category	DSI Values	Colour
Extreme Drought	-1.5 or less	Red
Severe Drought	-1.2 to -1.49	Orange
Moderate Drought	-0.9 to -1.19	Yellow-Orange
Mild Drought	-0.6 to -0.89	Yellow
Incipient Drought	-0.3 to -0.59	Light Yellow
Near Normal	0.29 to -0.29	Light Green
Incipient Wet Spell	0.3 to 0.59	Light Cyan
Slightly Wet	0.6 to 0.89	Cyan
Moderately Wet	0.9 to 1.19	Blue-Cyan
Very Wet	1.2 to 1.49	Blue
Extremely Wet	1.5 or greater	Dark Blue

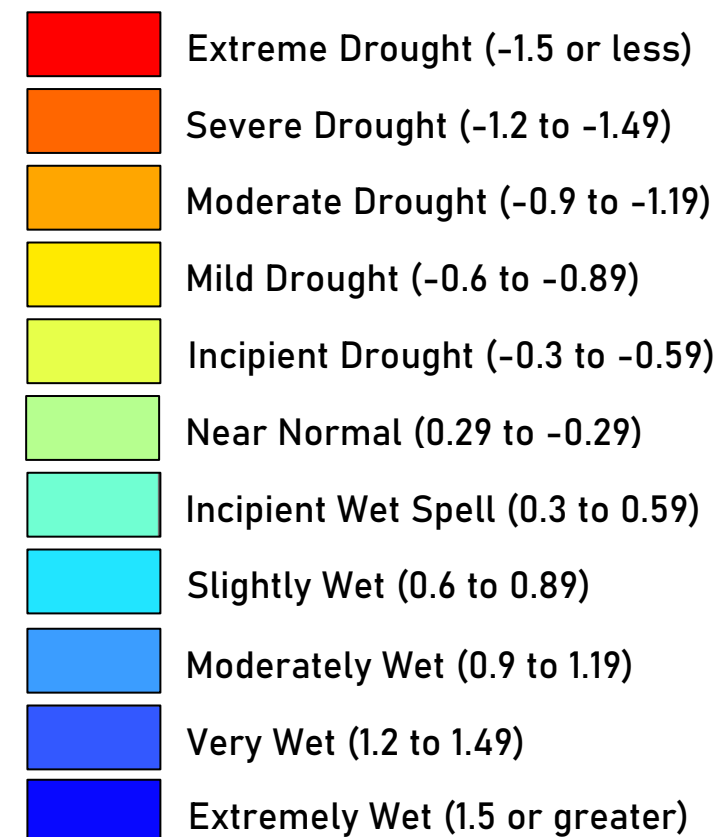
## January DSI Maps

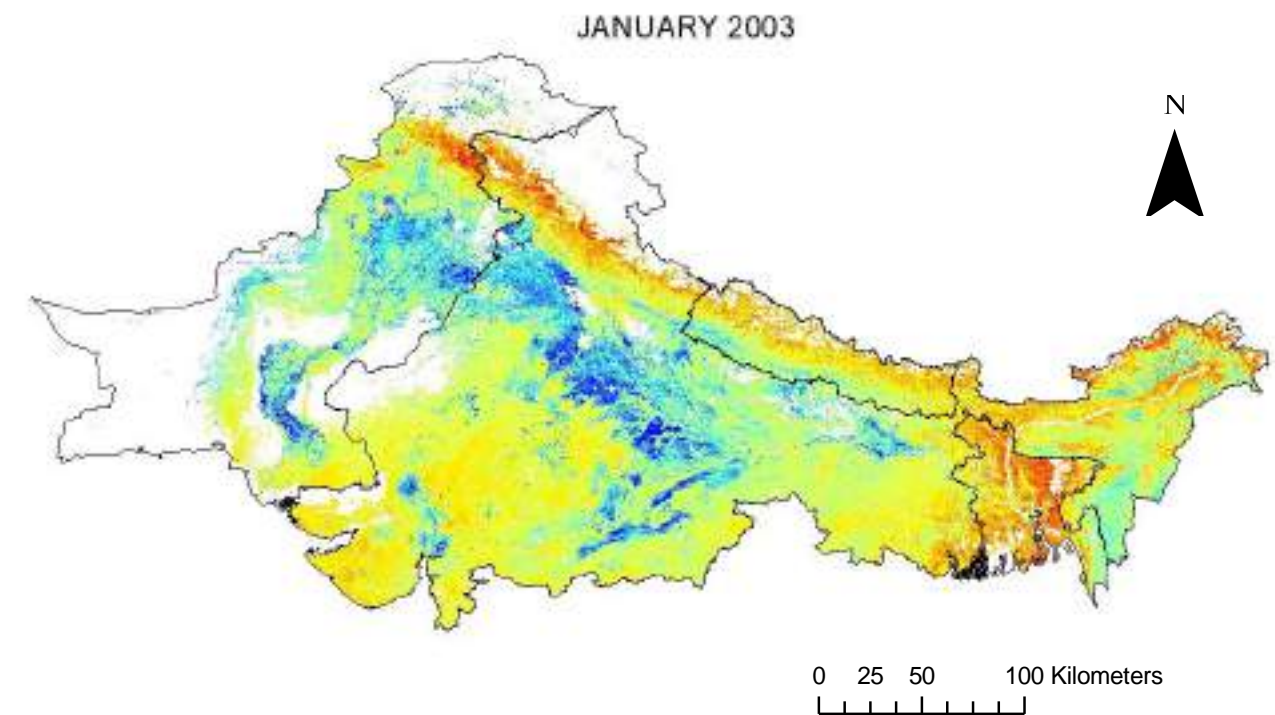
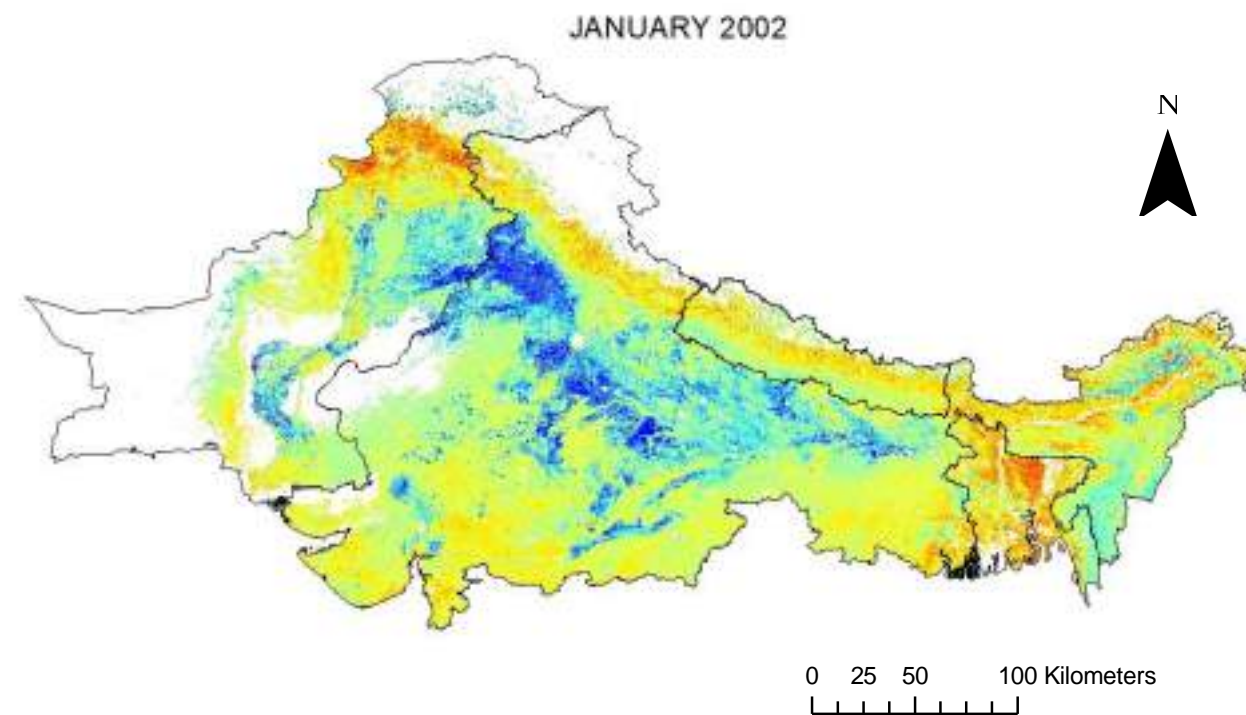
Drought in January ranges from mild drought to incipient wet spell. The lowest DSI value was seen in 2001 (-0.63). This cold and dry month is characterized by near normal and incipient drought conditions.

Mean January DSI Values		
Year	DSI Values	Drought Condition
2001	-0.63	Mild Drought
2002	-0.31	Incipient Drought
2003	-0.43	Incipient Drought
2004	-0.05	Near Normal
2005	0.00	Near Normal
2006	-0.27	Near Normal
2007	-0.27	Near Normal
2008	-0.12	Near Normal
2009	0.00	Near Normal
2010	-0.31	Incipient Drought
2011	-0.39	Incipient Drought
2012	-0.33	Incipient Drought
2013	-0.49	Incipient Drought
2014	-0.14	Near Normal
2015	-0.38	Incipient Drought
2016	-0.47	Incipient Drought
2017	-0.22	Near Normal
2018	-0.47	Incipient Drought
2019	-0.25	Near Normal
2020	0.40	Incipient Wet Spell

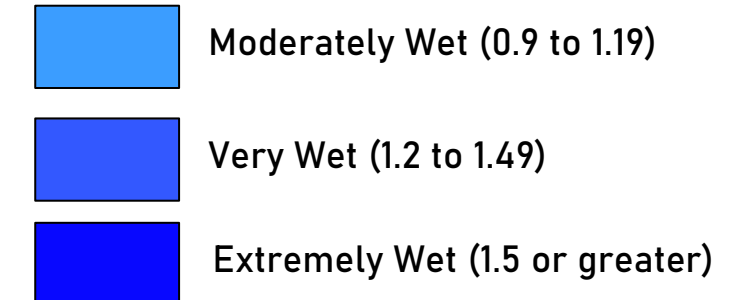
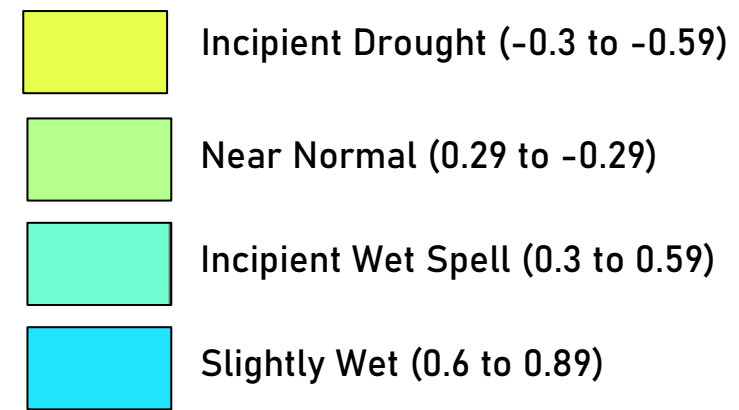
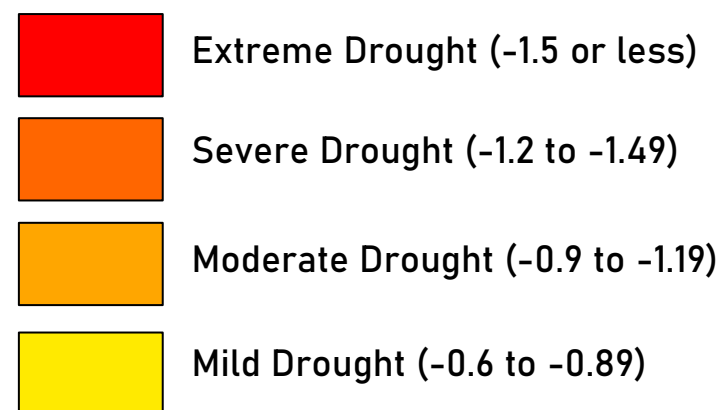


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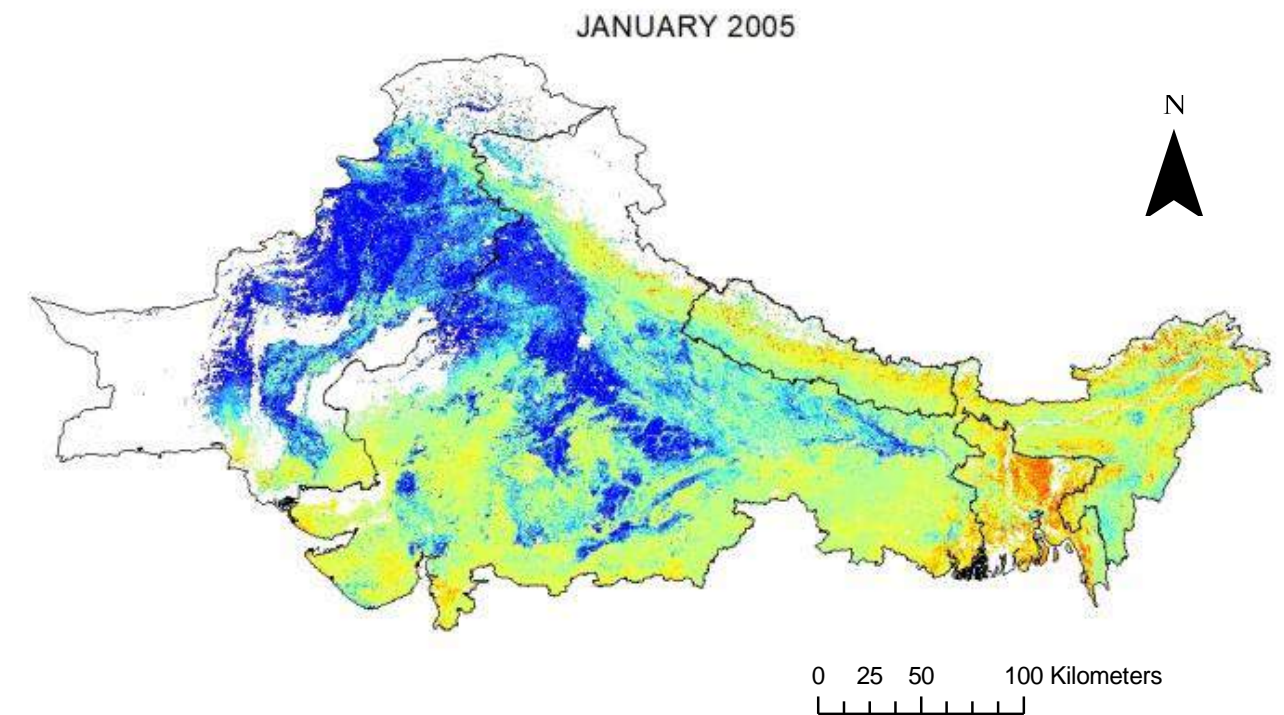
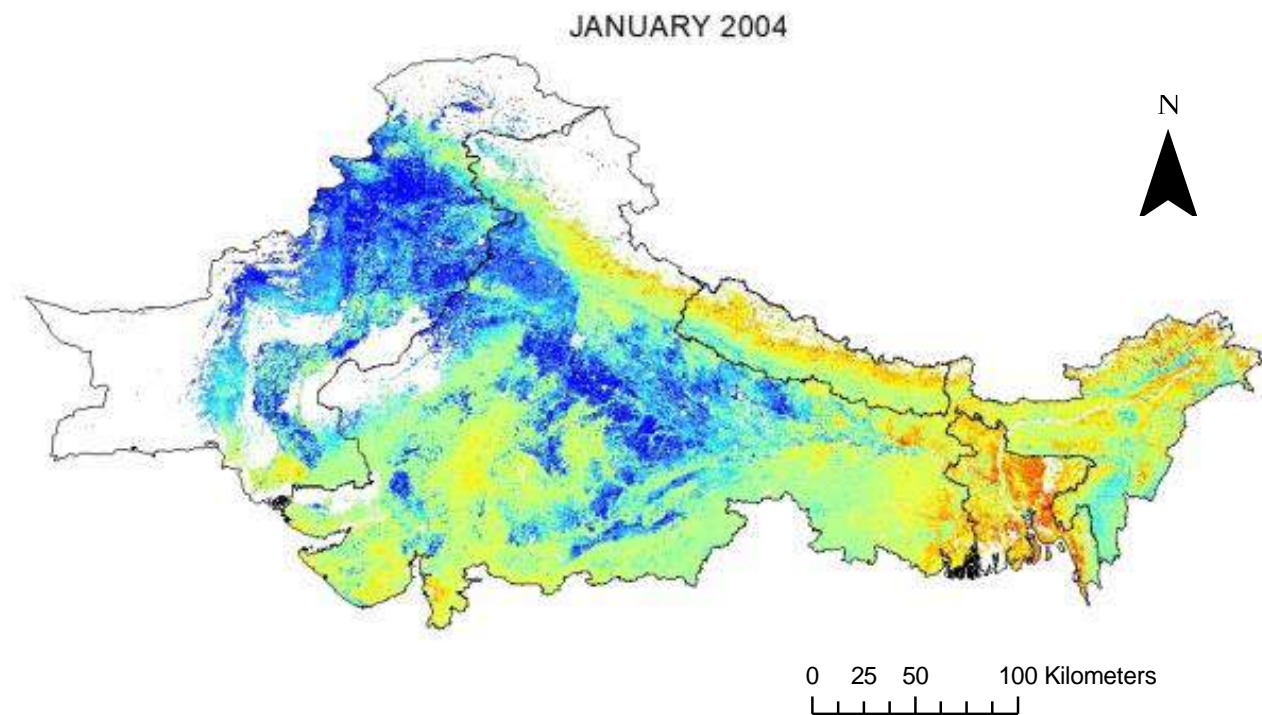




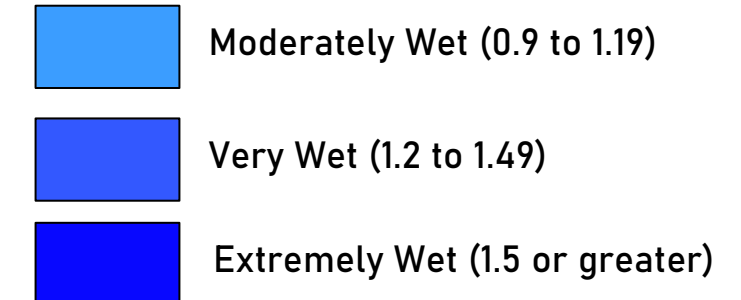
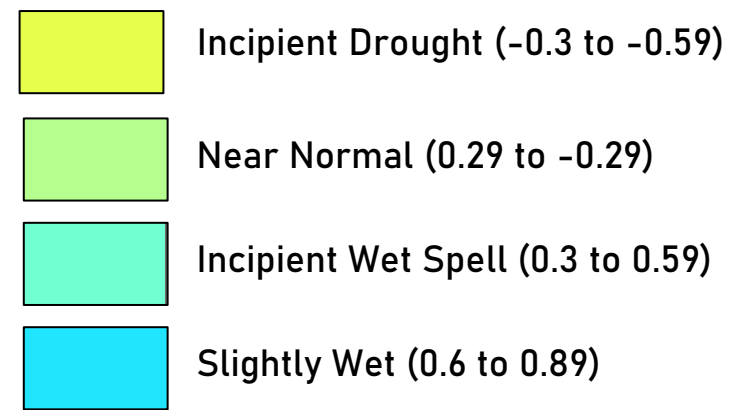
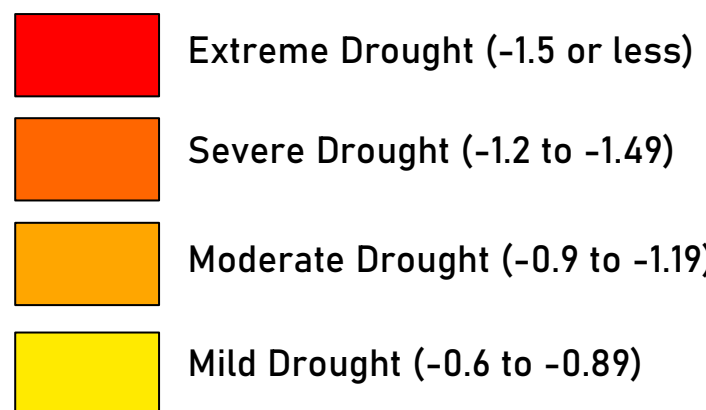
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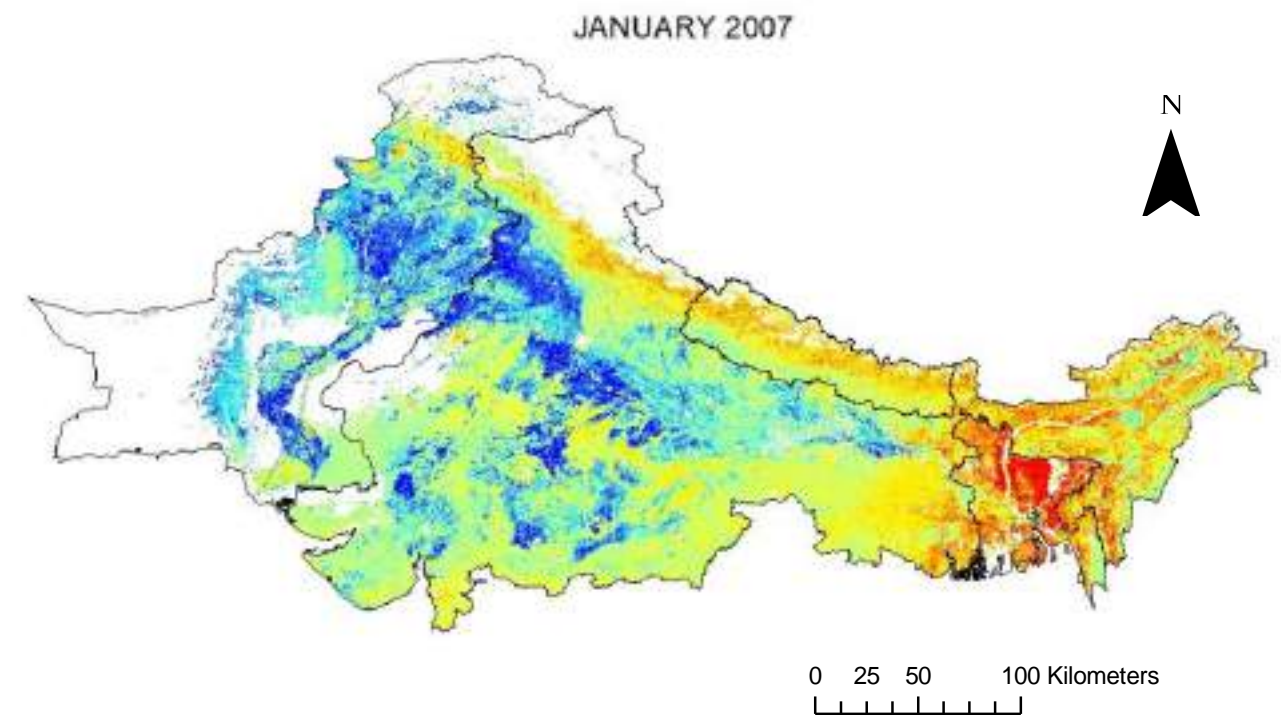
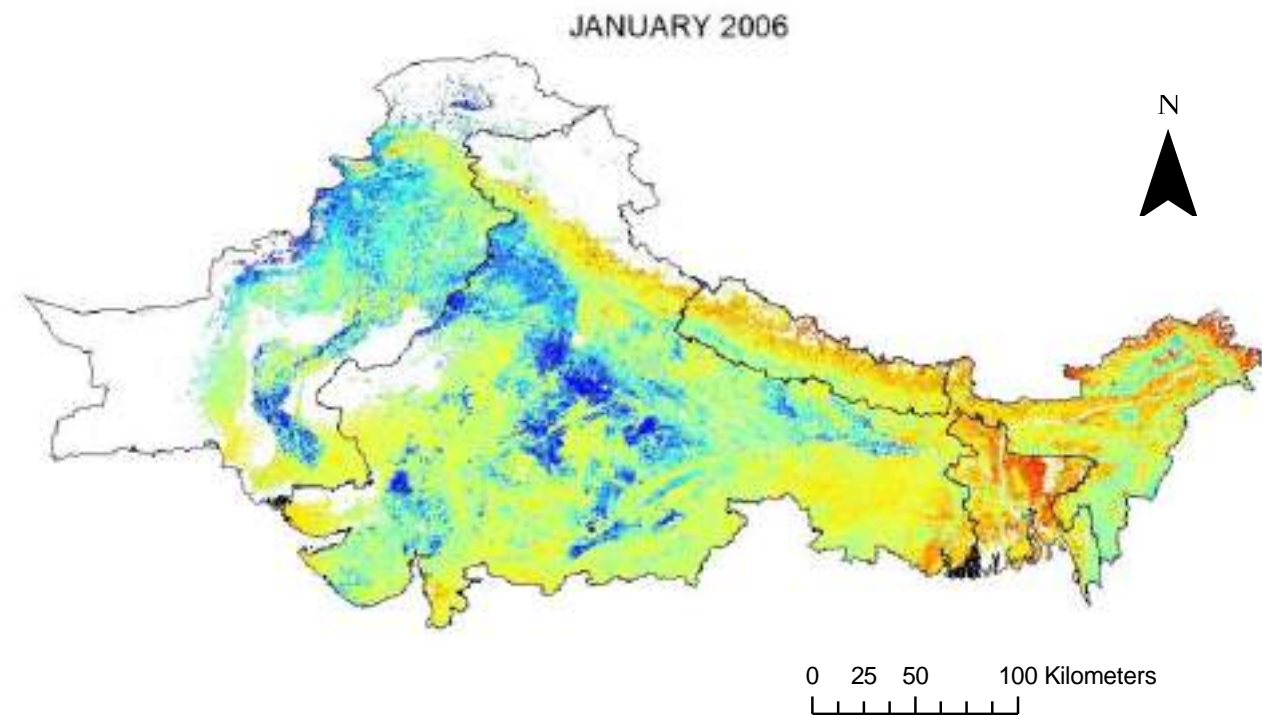




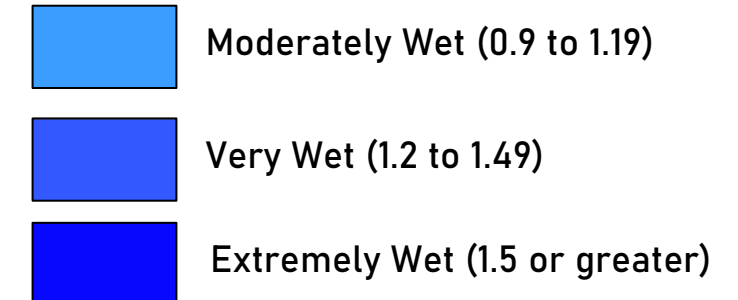
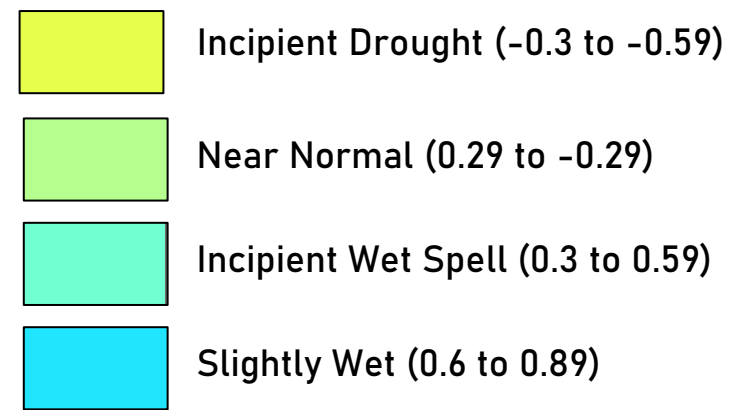
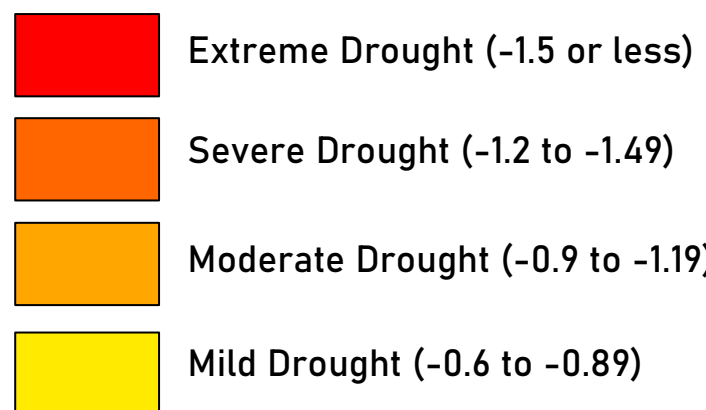
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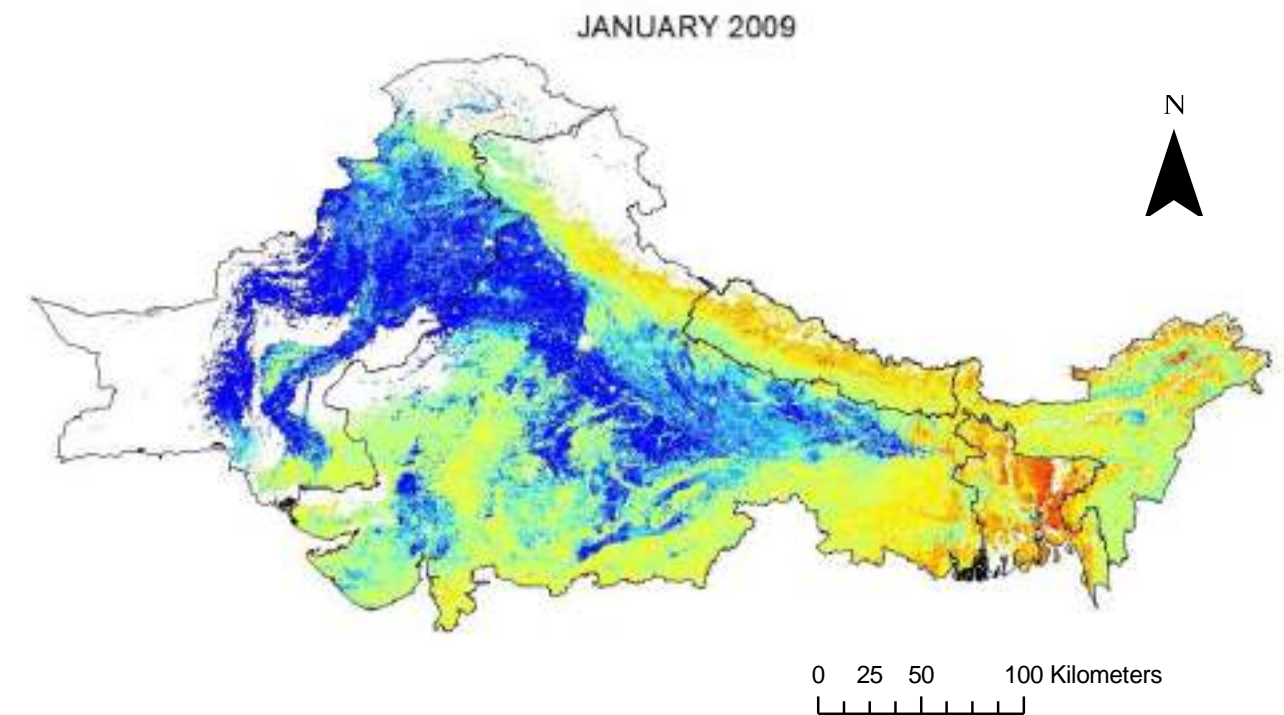
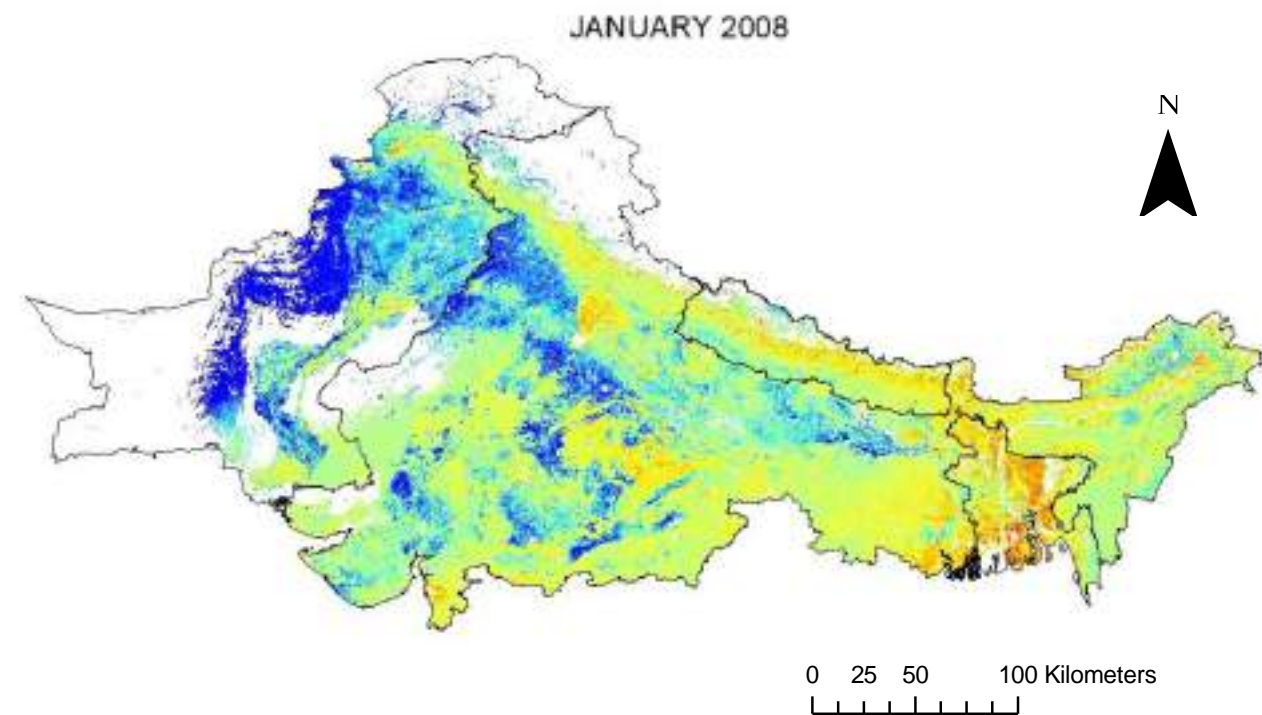




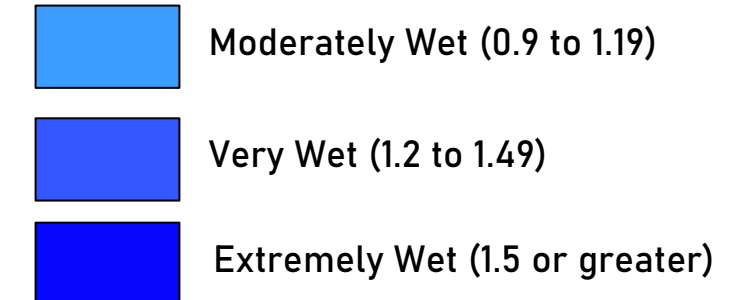
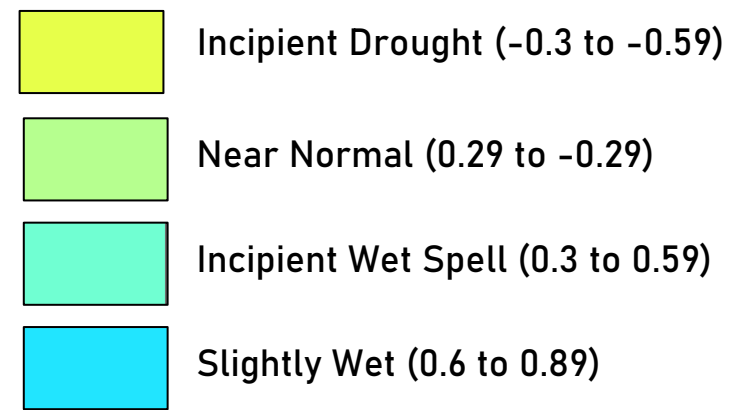
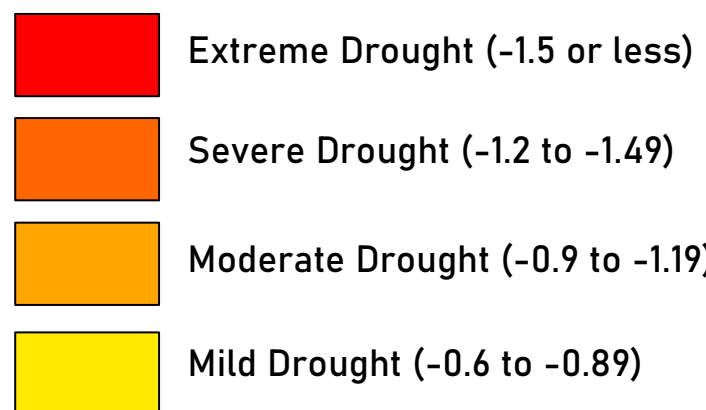


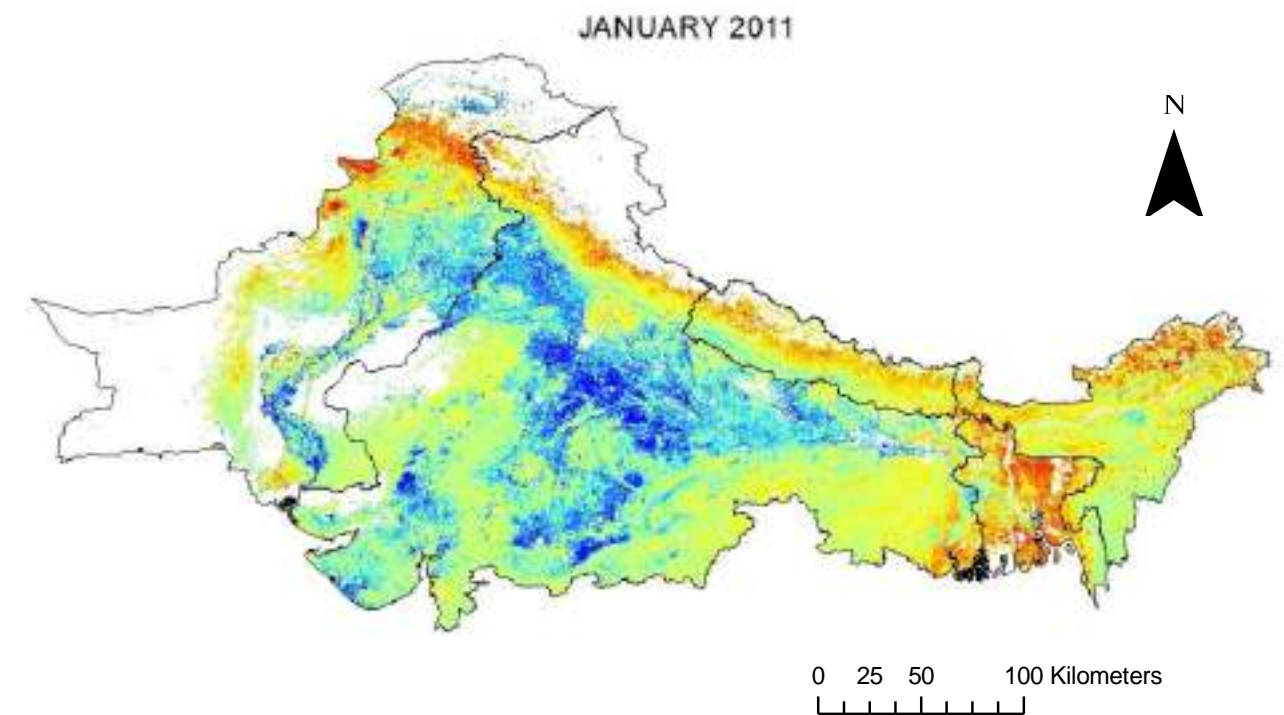
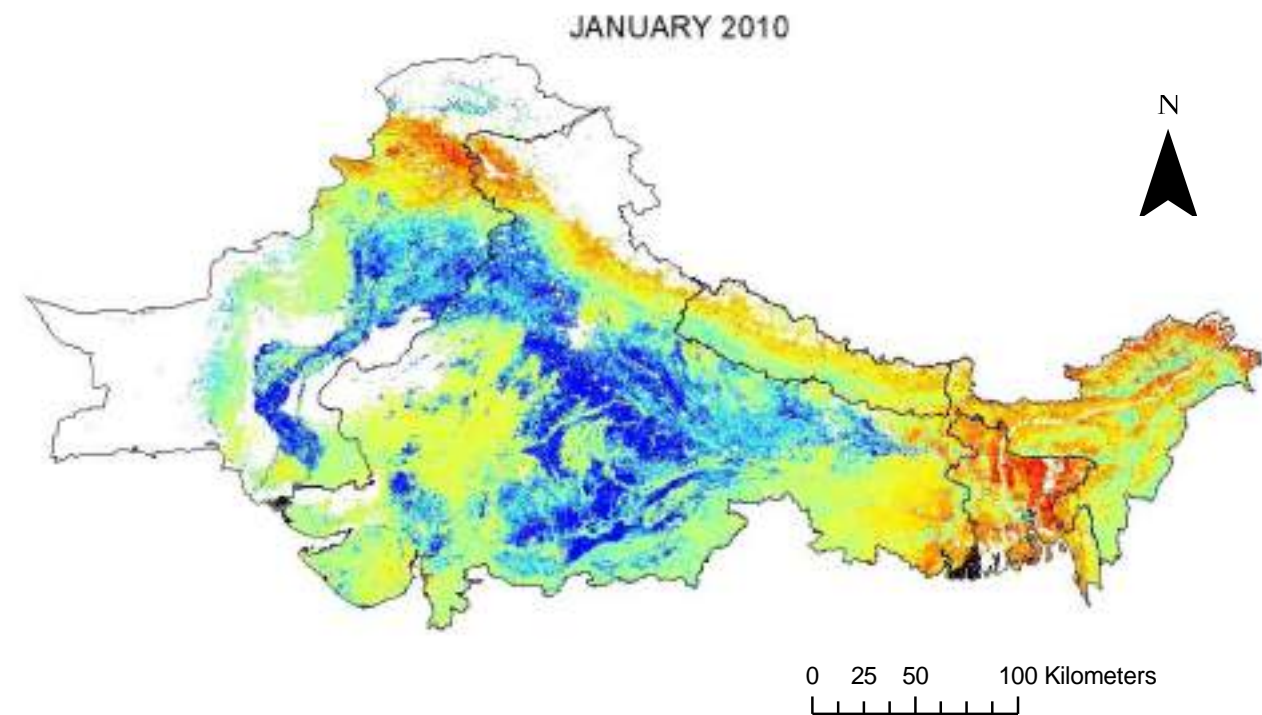
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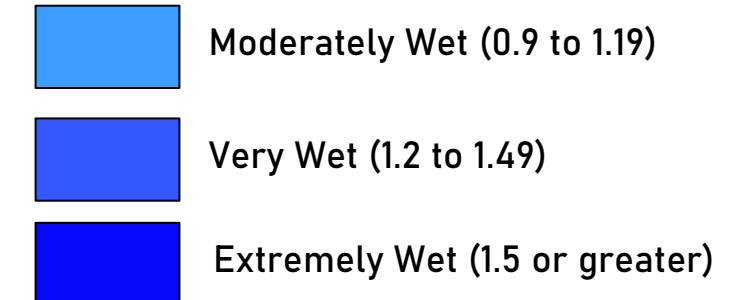
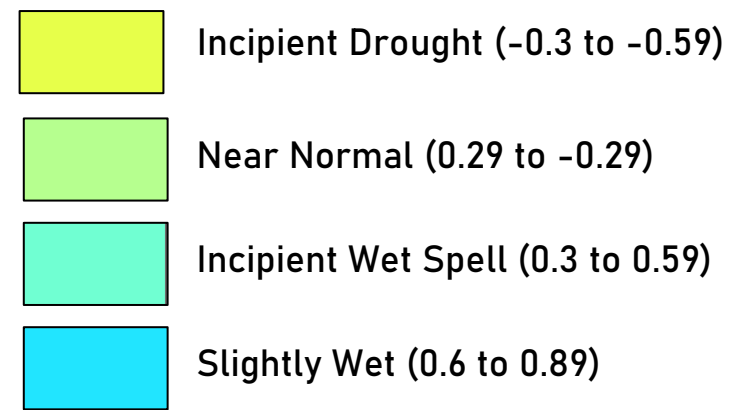
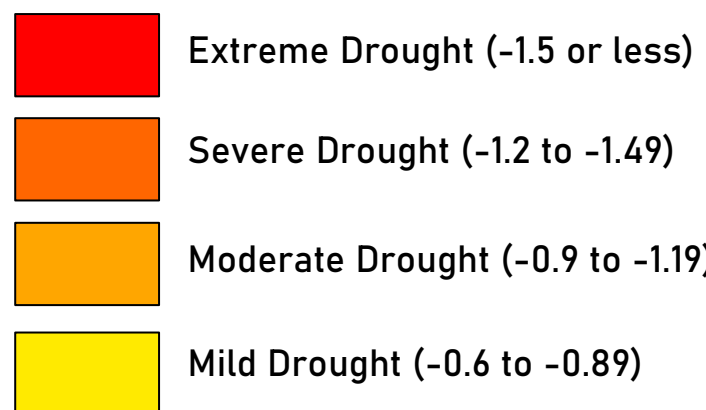


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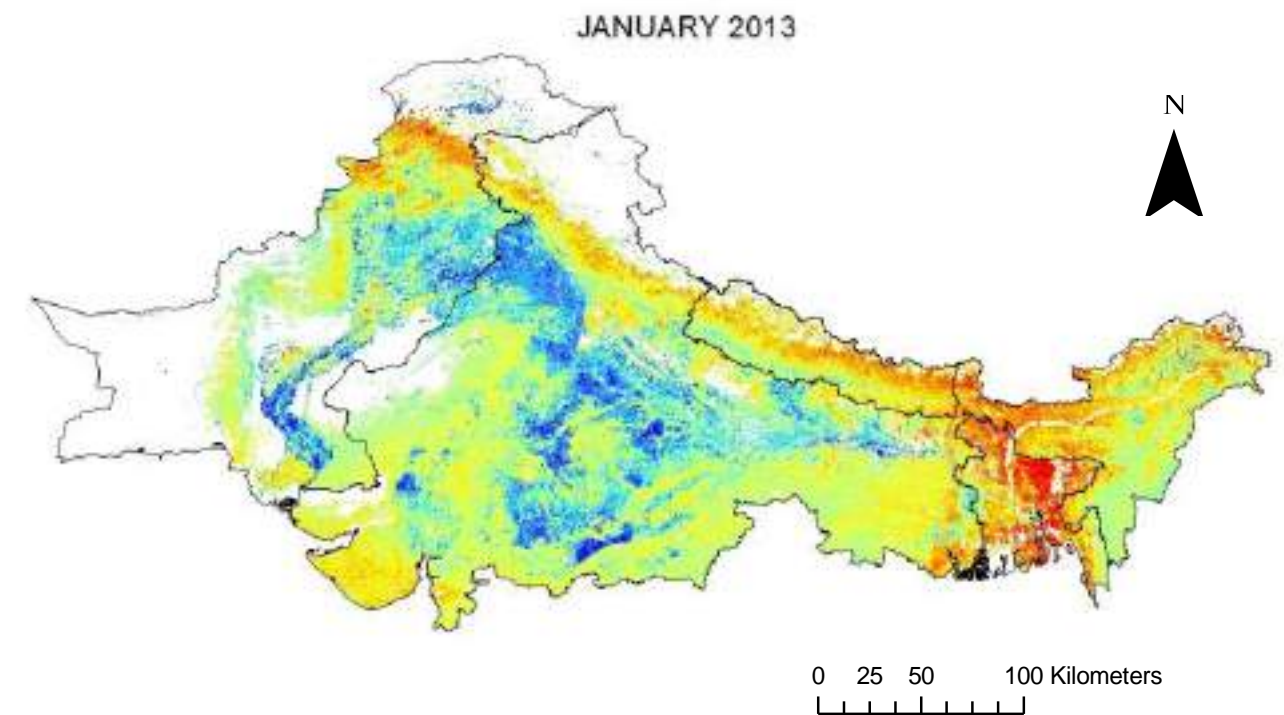
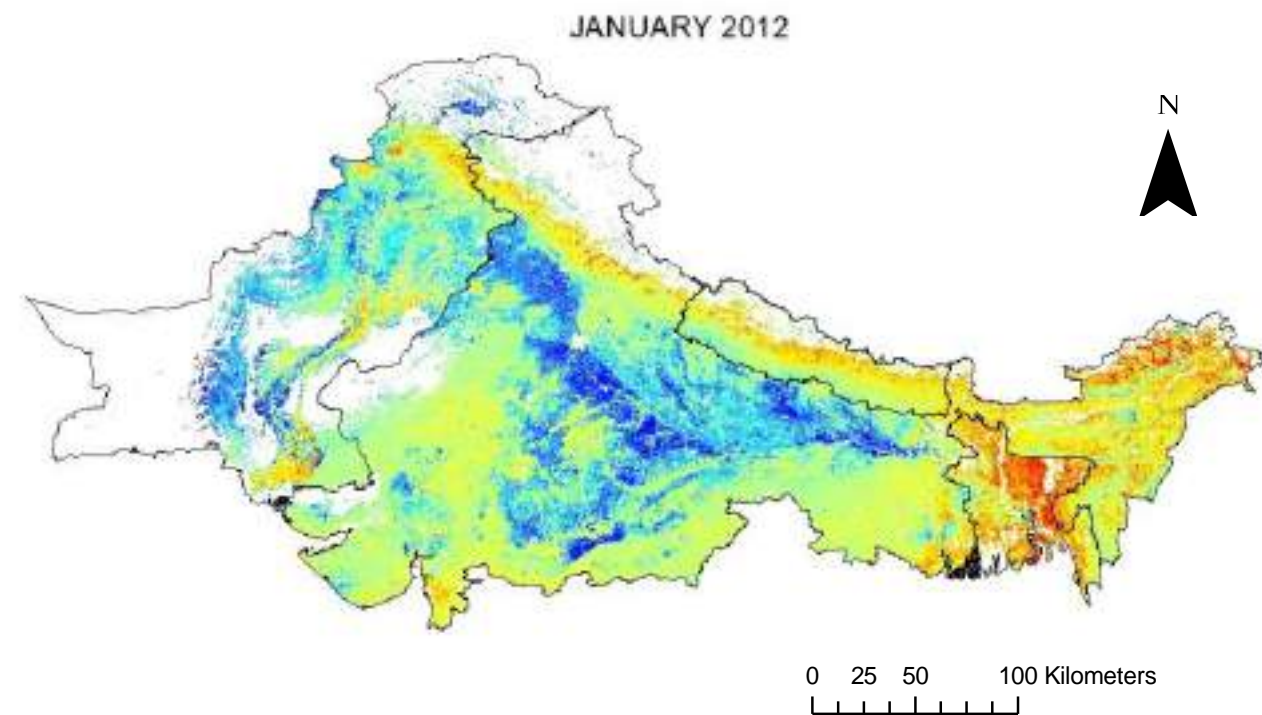




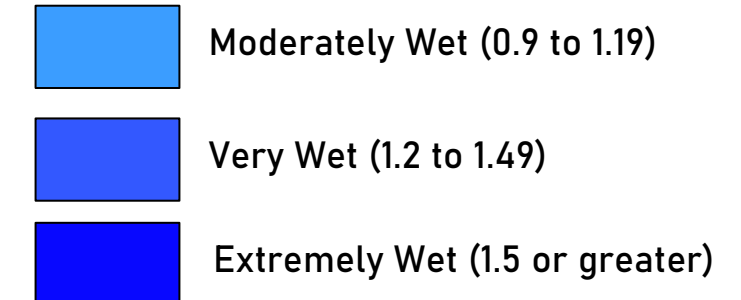
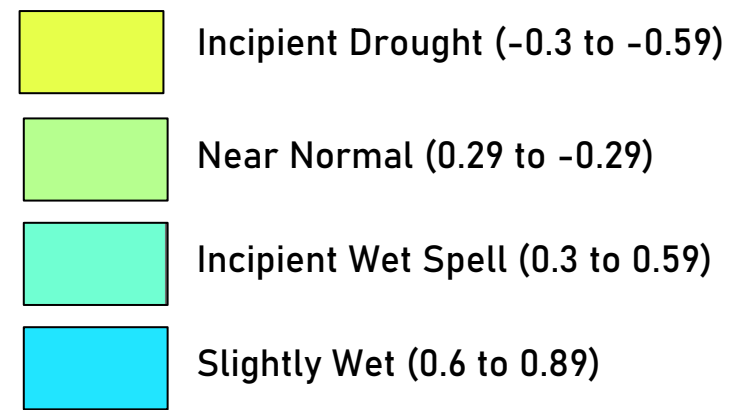
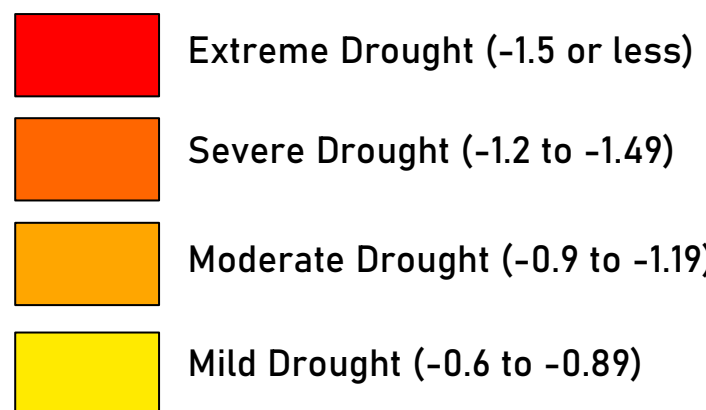
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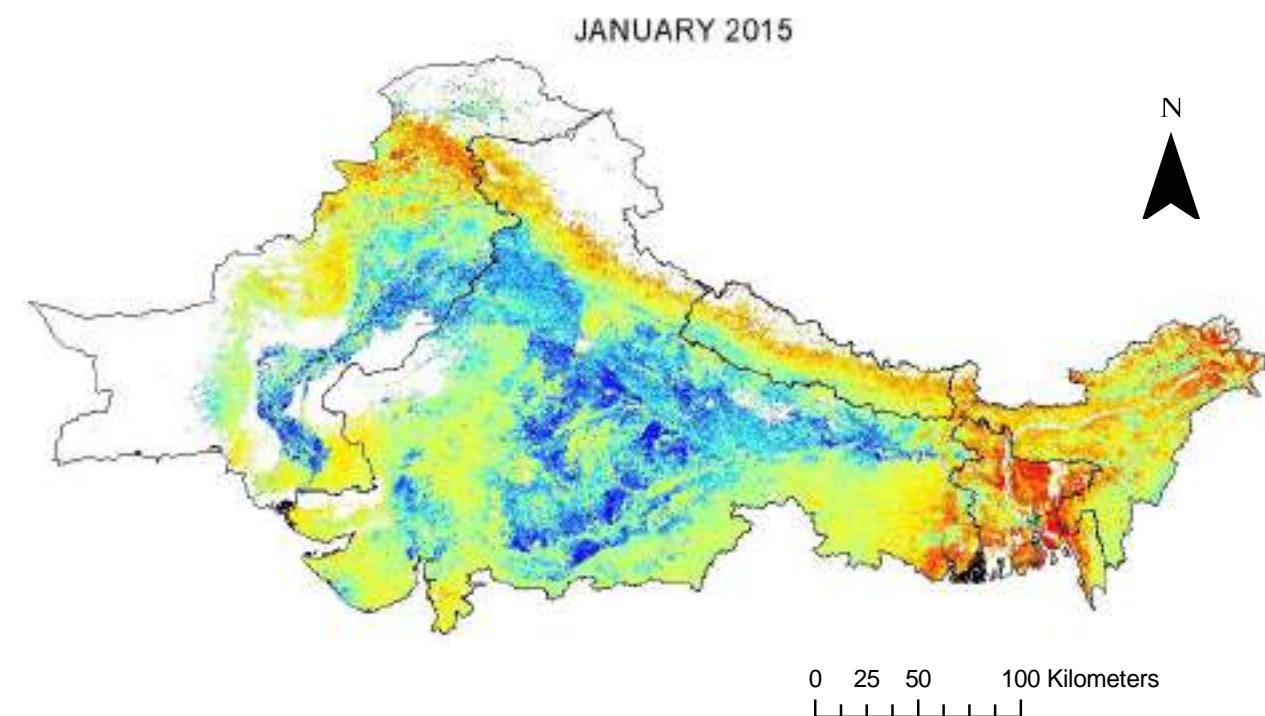
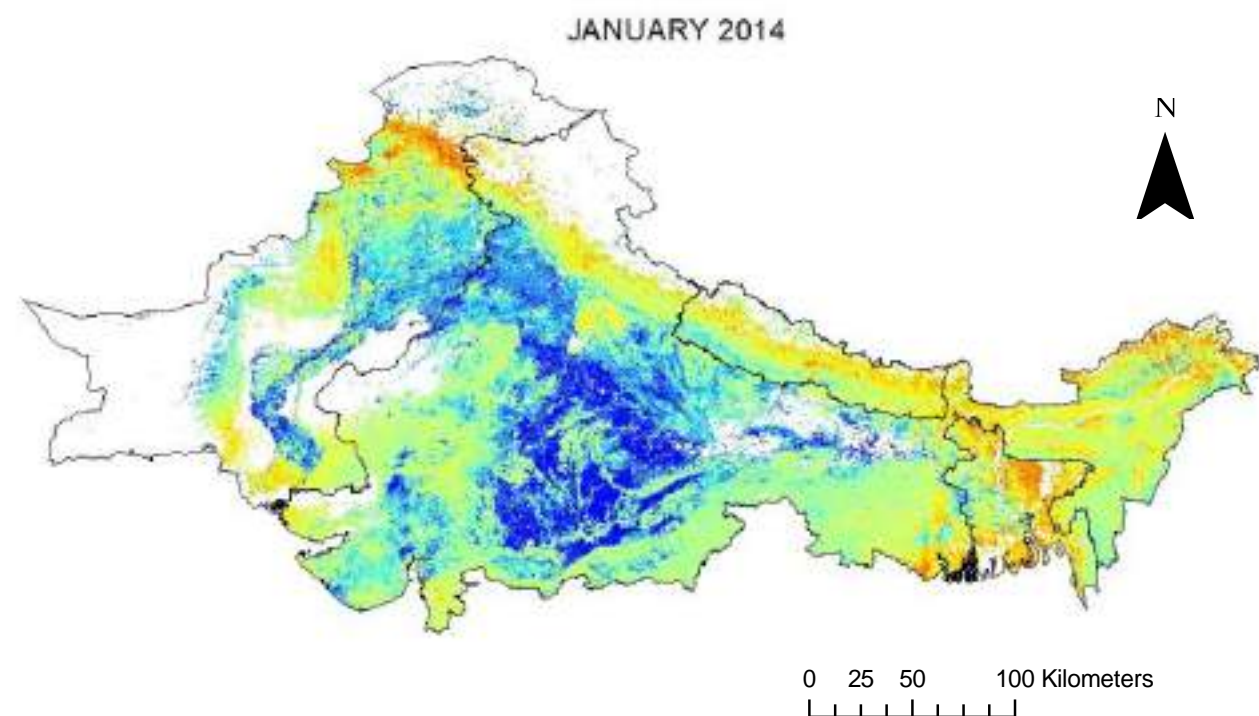




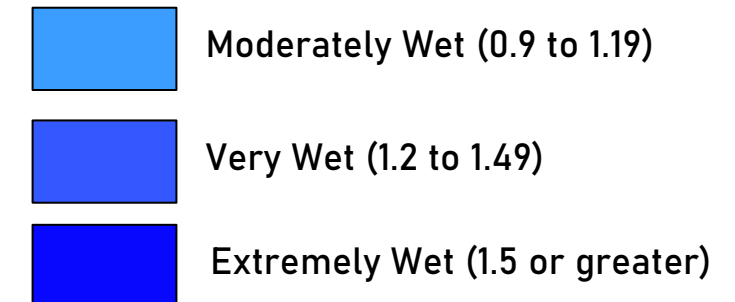
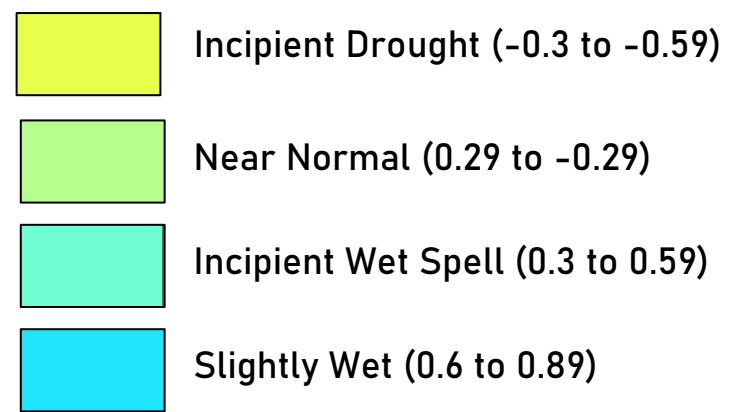
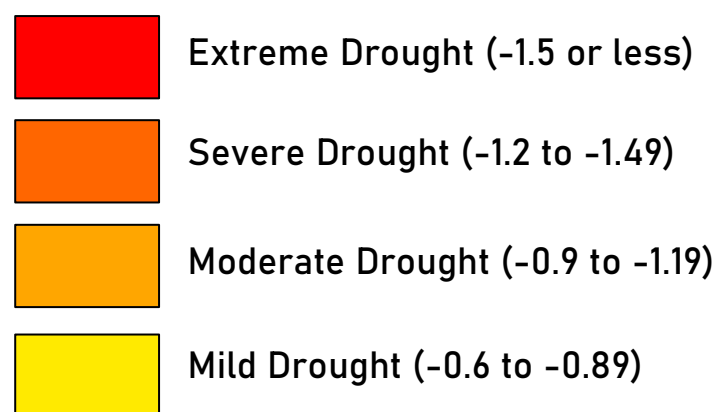


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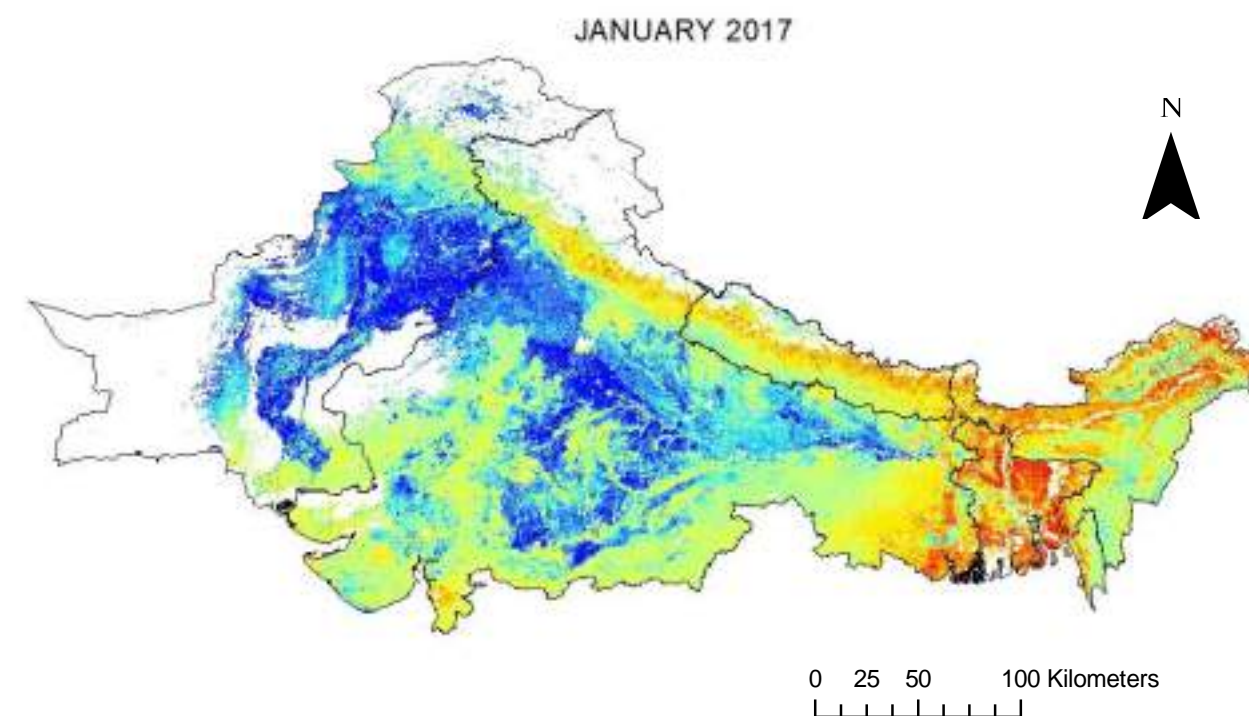
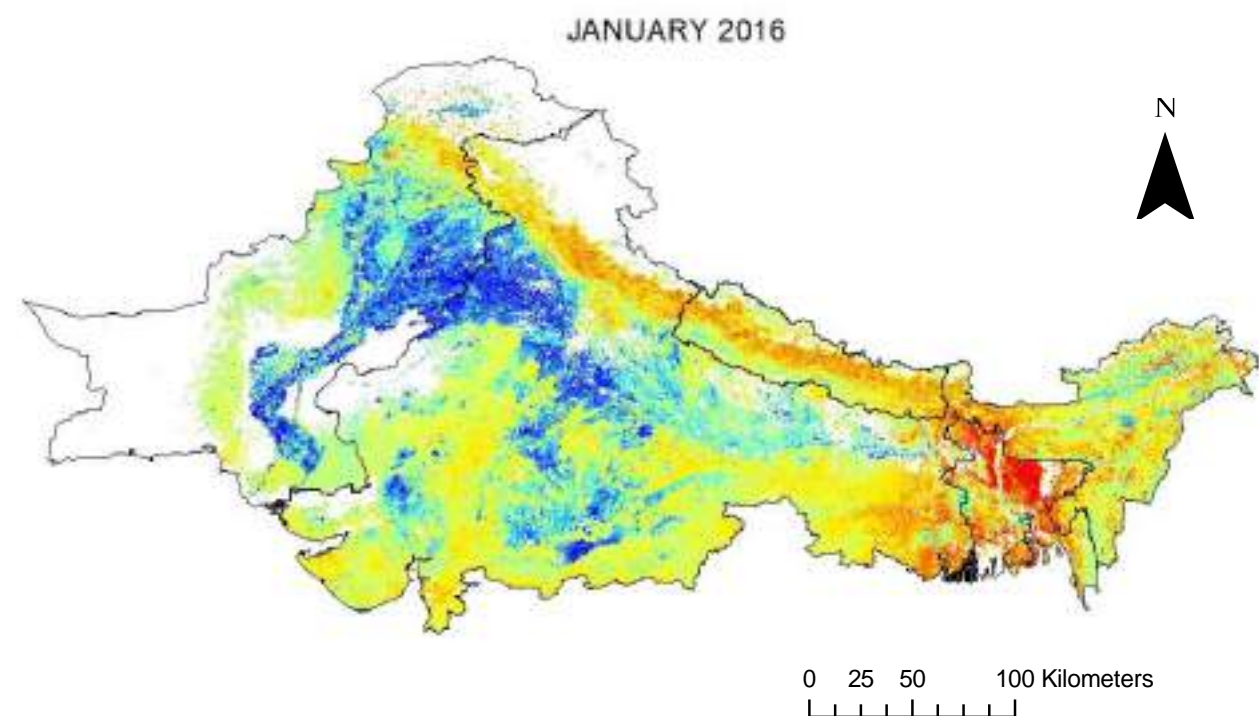




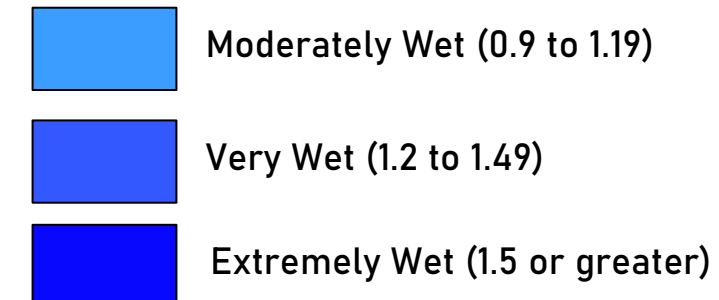
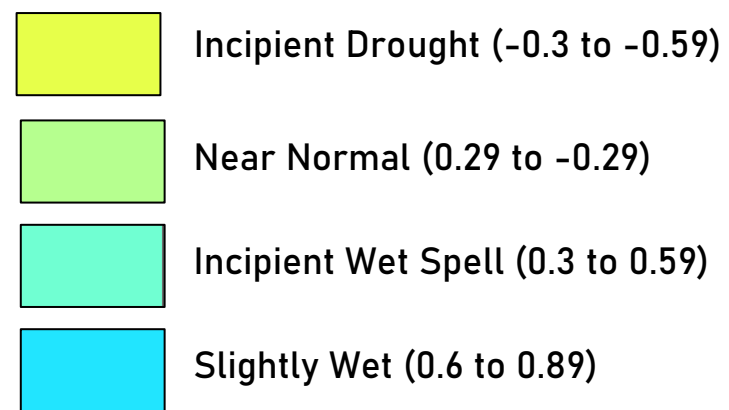
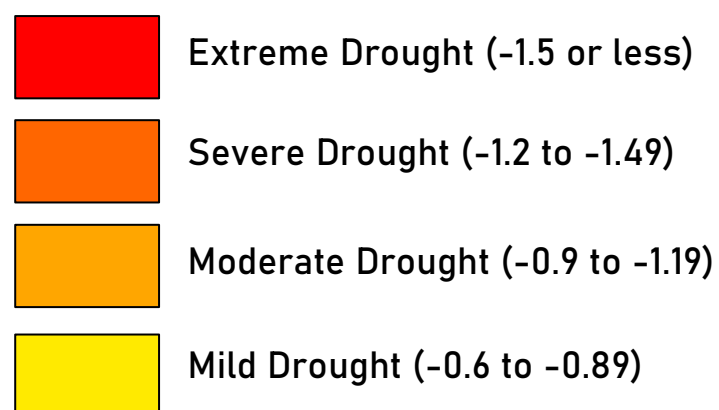
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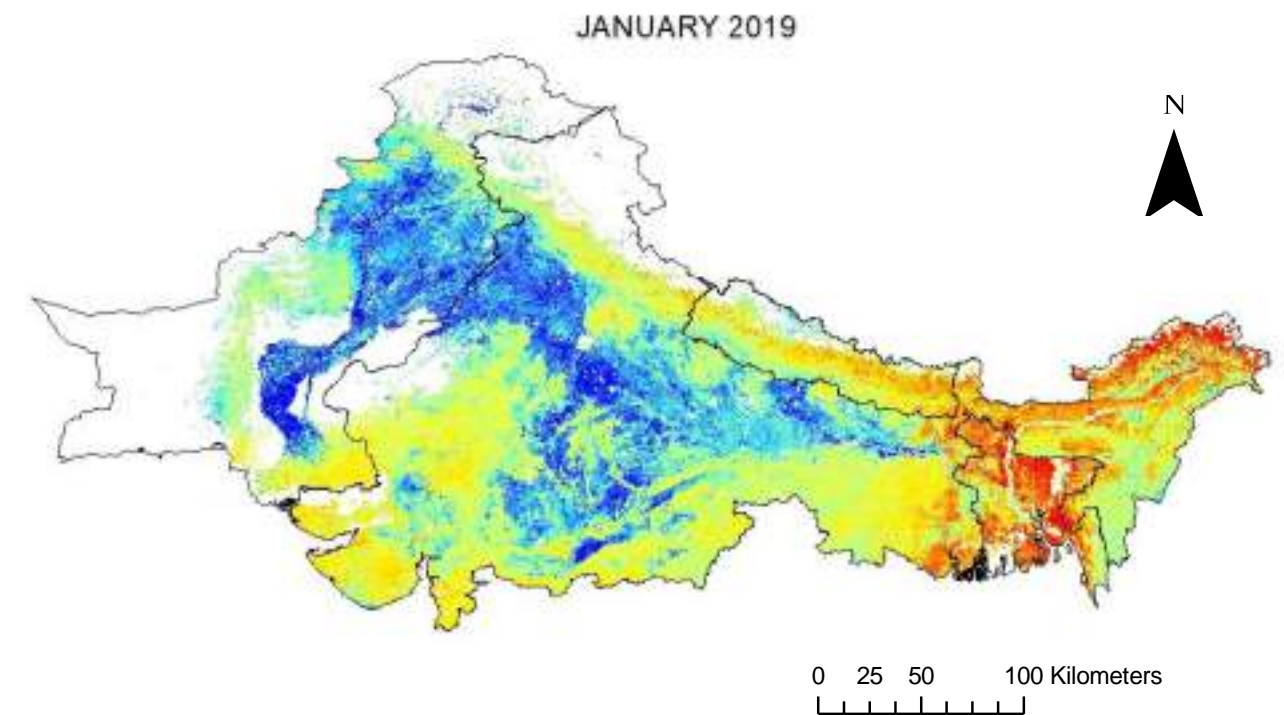
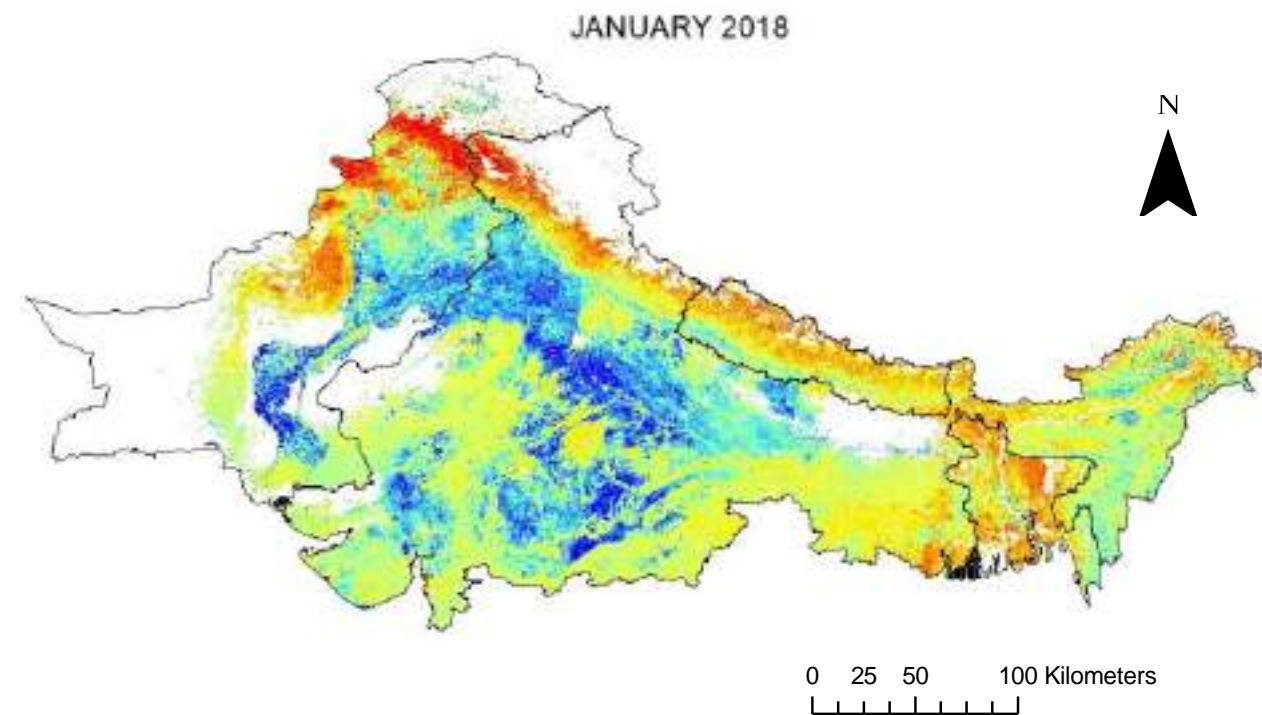




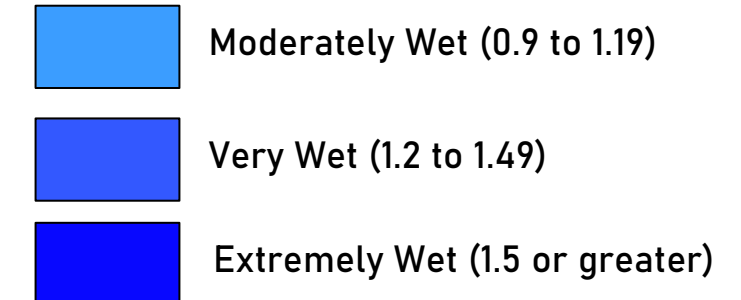
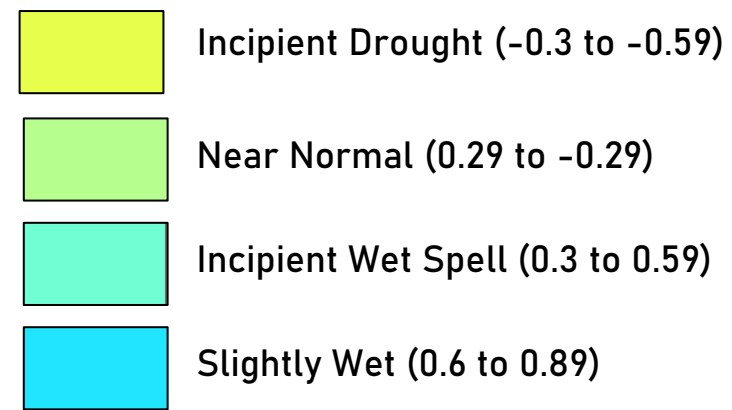
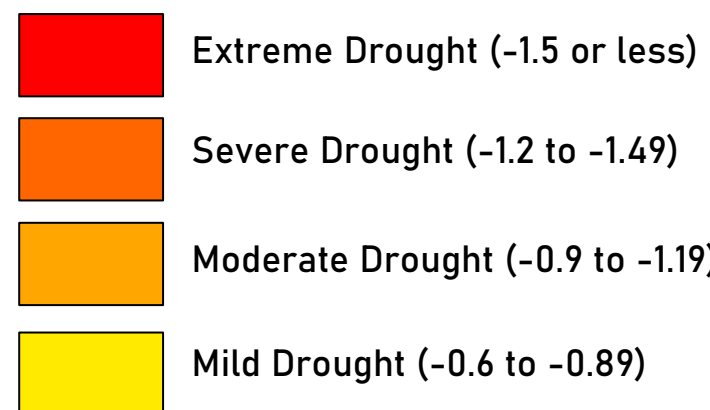


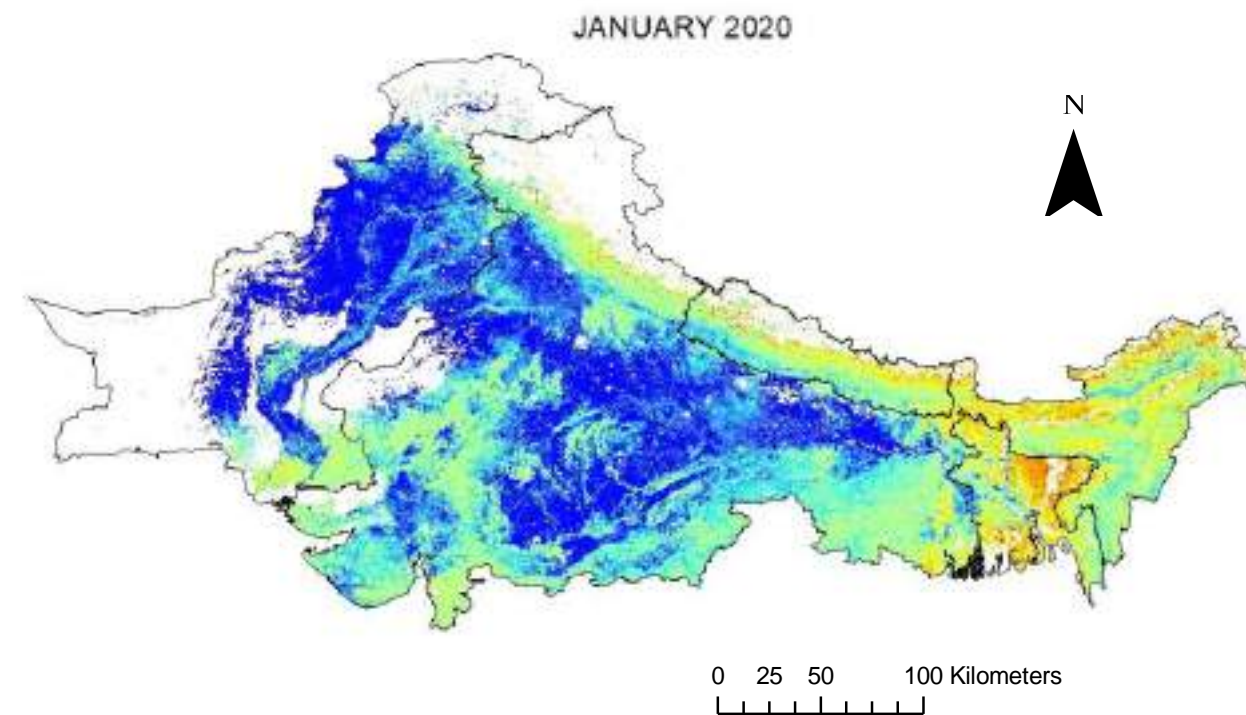
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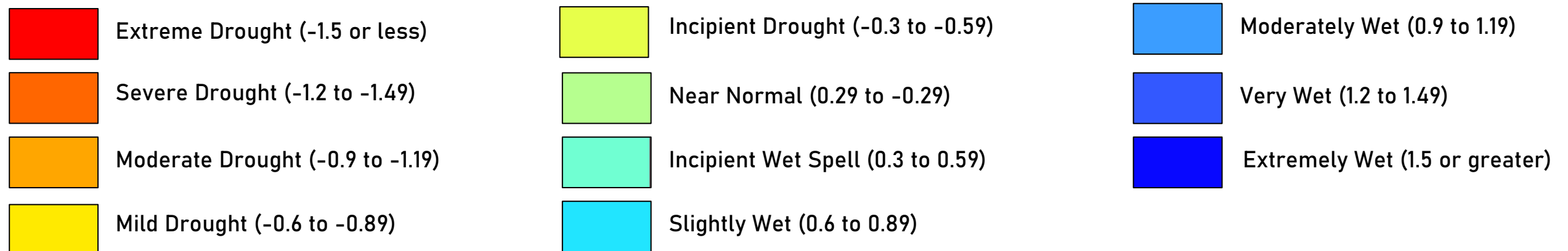


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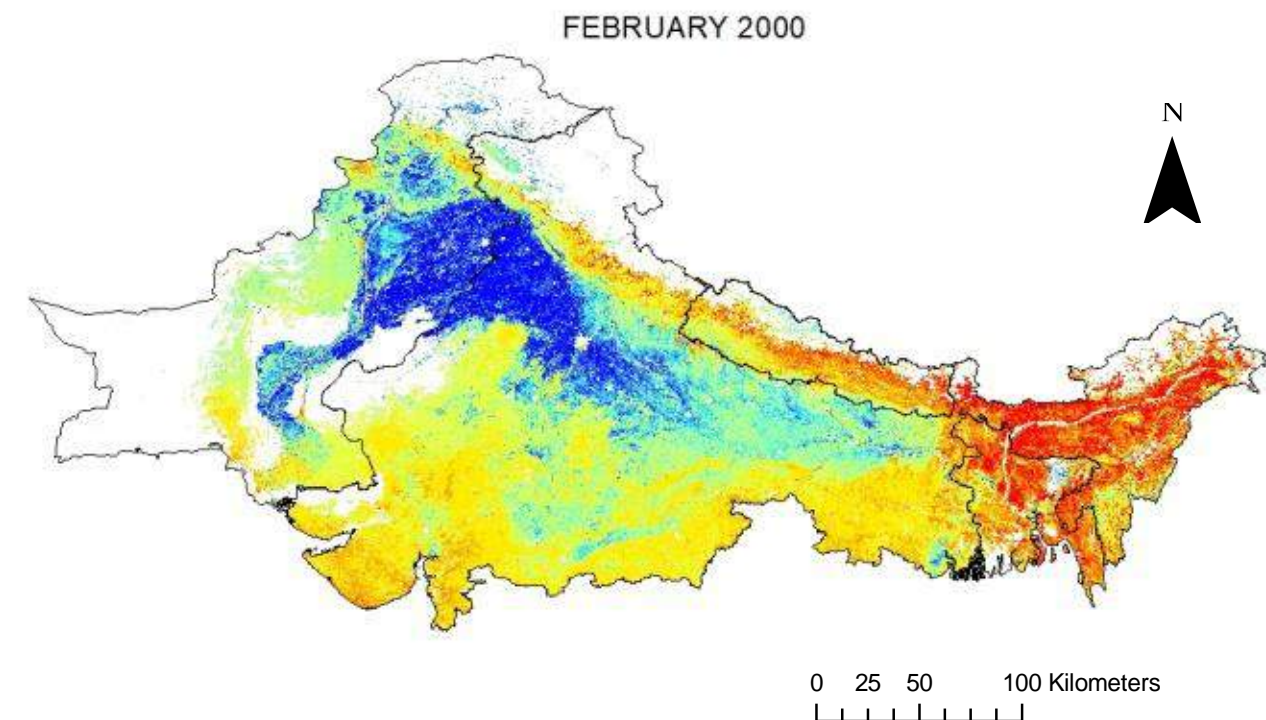




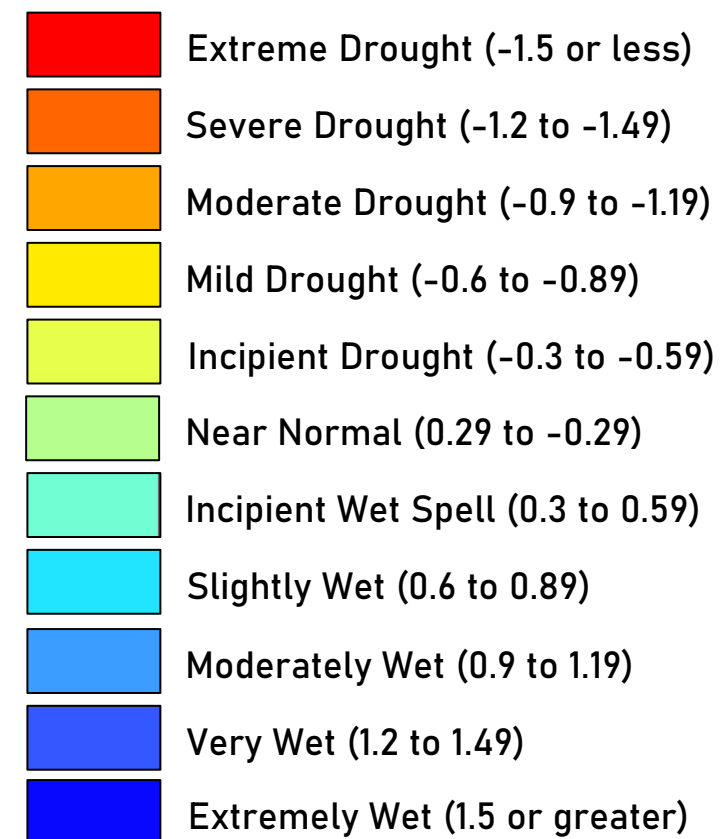
## February DSI Maps

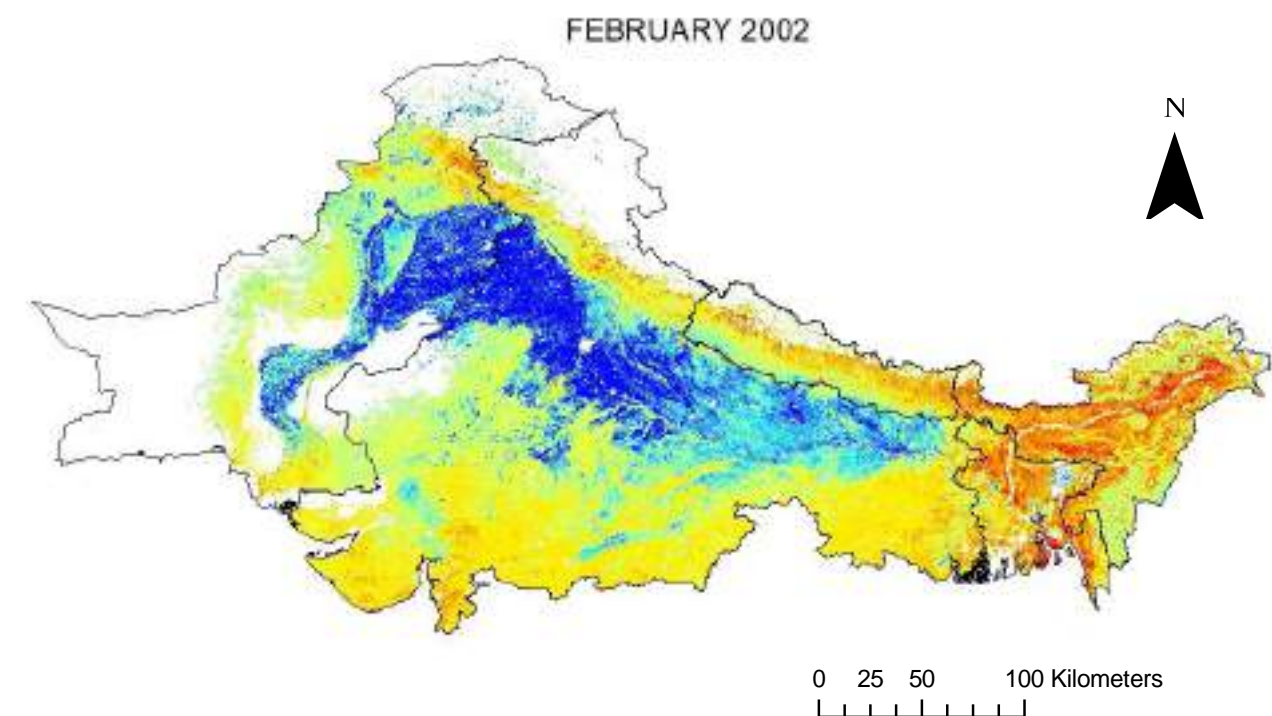
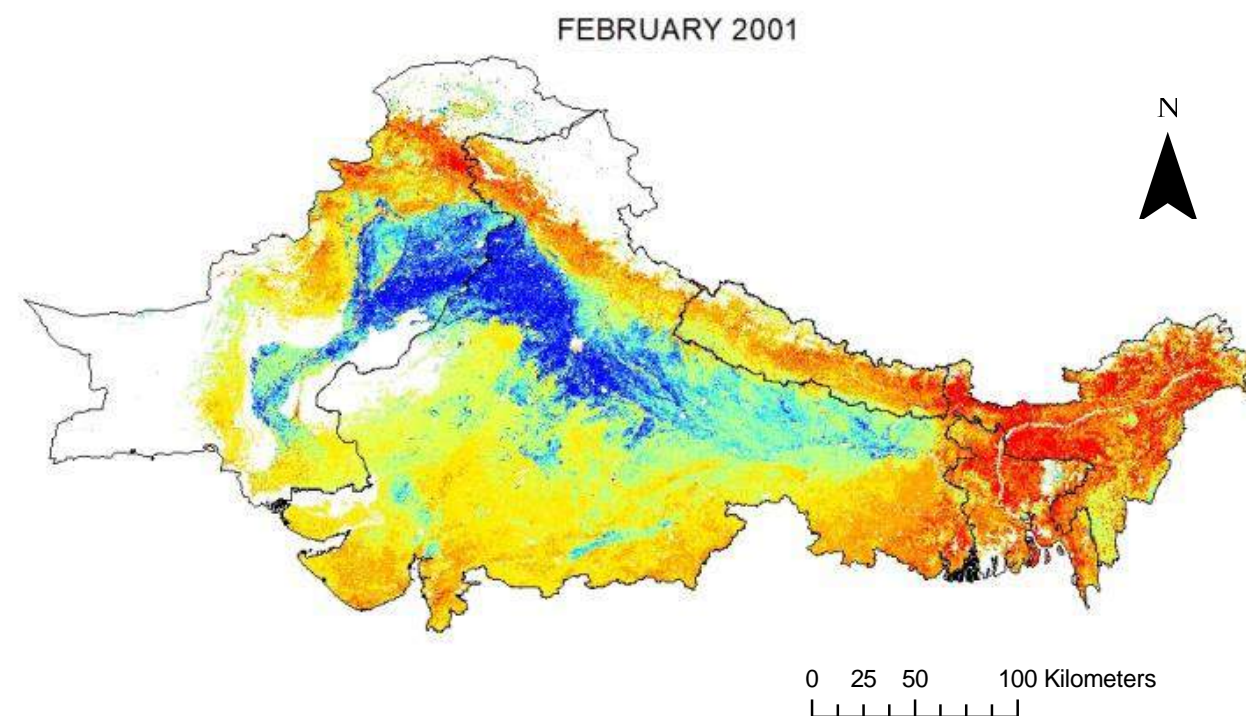
Drought in February ranges from mild drought to near normal. DSI value with -0.74 was identified as most dry condition in 2001. This cold month is marked by near normal drought.

Mean February DSI Values		
Year	DSI Values	Drought Condition
2000	-0.52	Incipient Drought
2001	-0.74	Mild Drought
2002	-0.32	Incipient Drought
2003	-0.28	Near Normal
2004	-0.29	Near Normal
2005	0.10	Near Normal
2006	-0.43	Incipient Drought
2007	0.28	Near Normal
2008	-0.35	Incipient Drought
2009	-0.26	Near Normal
2010	-0.27	Near Normal
2011	-0.18	Near Normal
2012	-0.54	Incipient Drought
2013	-0.21	Near Normal
2014	-0.07	Near Normal
2015	-0.34	Incipient Drought
2016	-0.56	Incipient Drought
2017	-0.49	Incipient Drought
2018	-0.51	Incipient Drought
2019	-0.12	Near Normal
2020	0.07	Near Normal

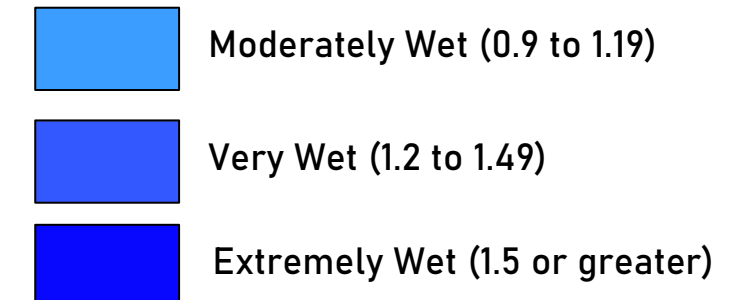
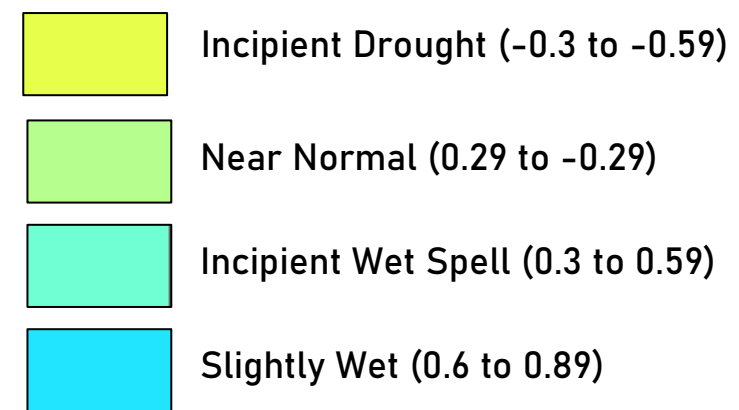
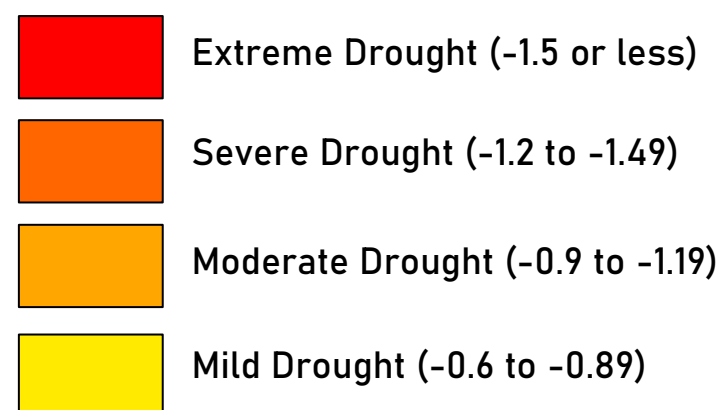


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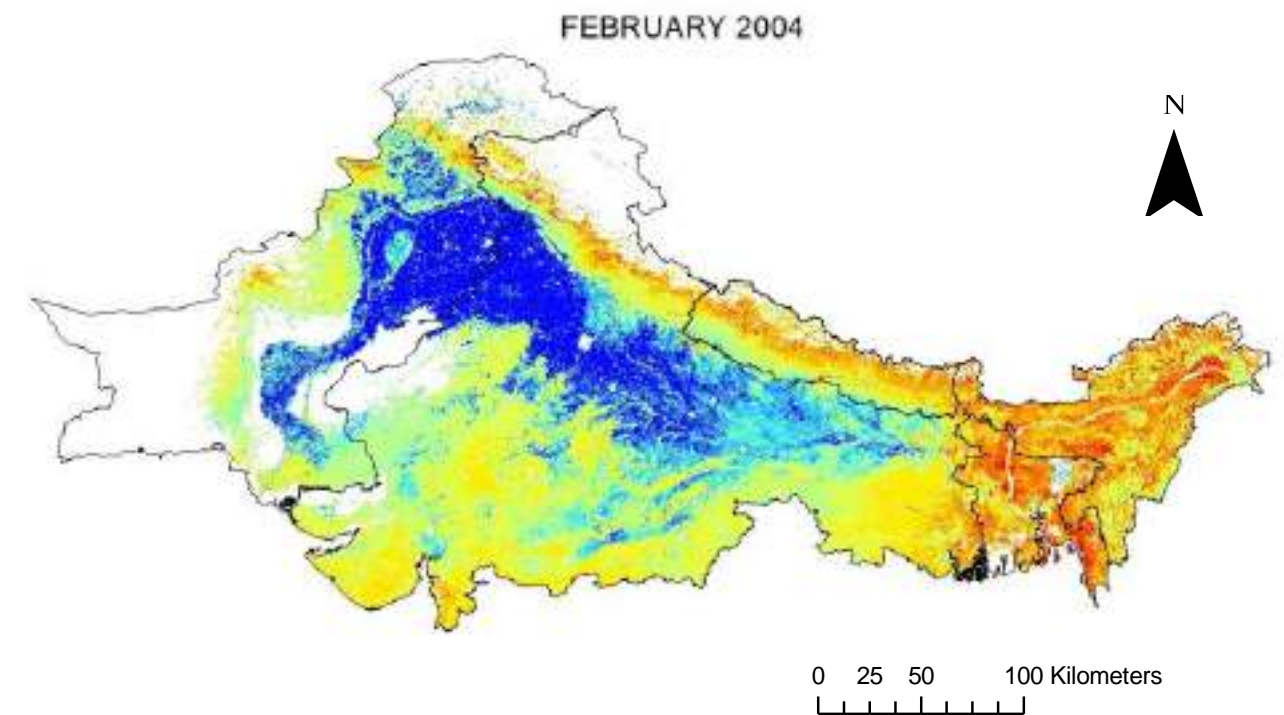
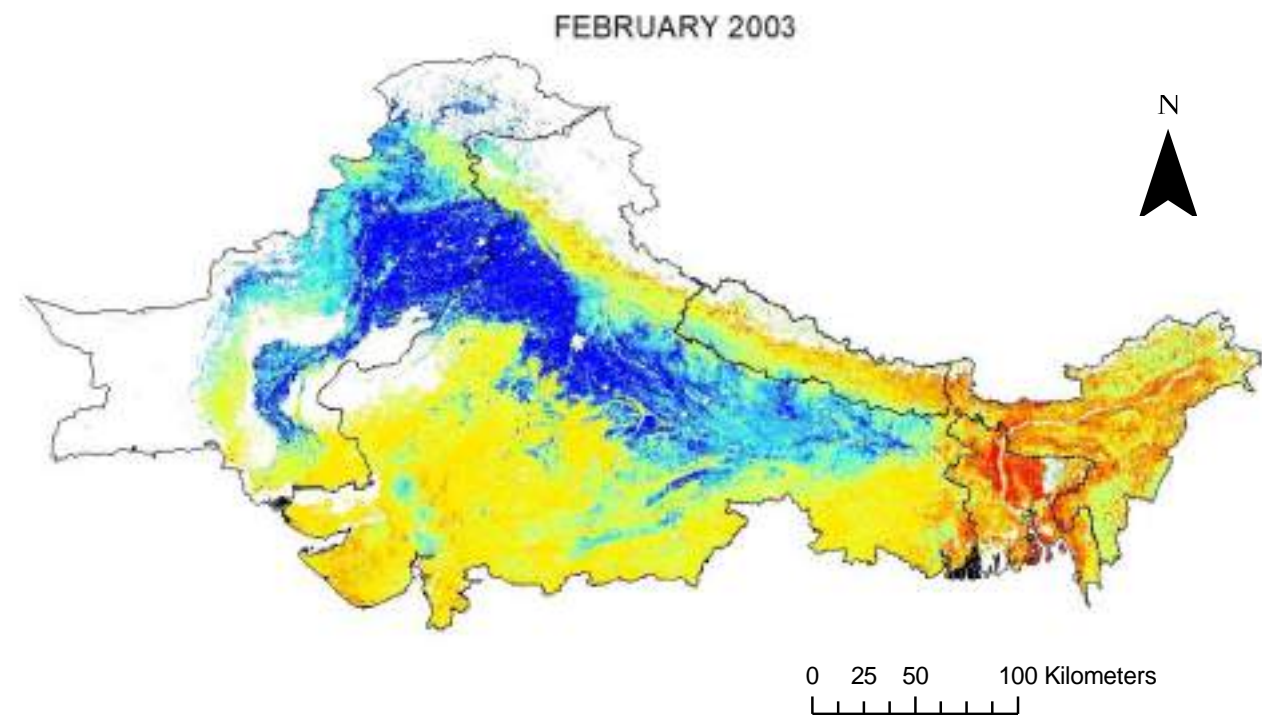




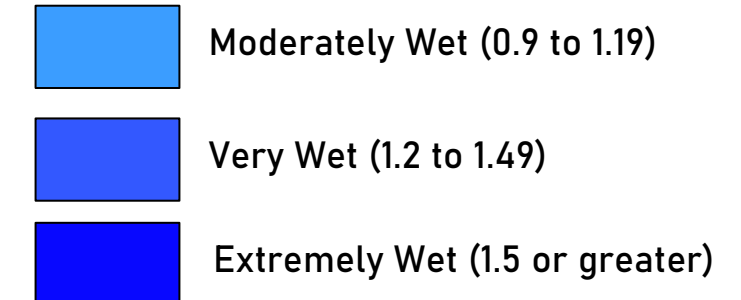
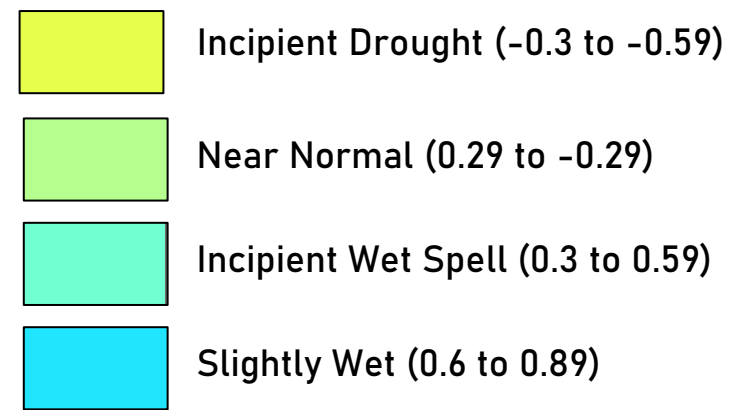
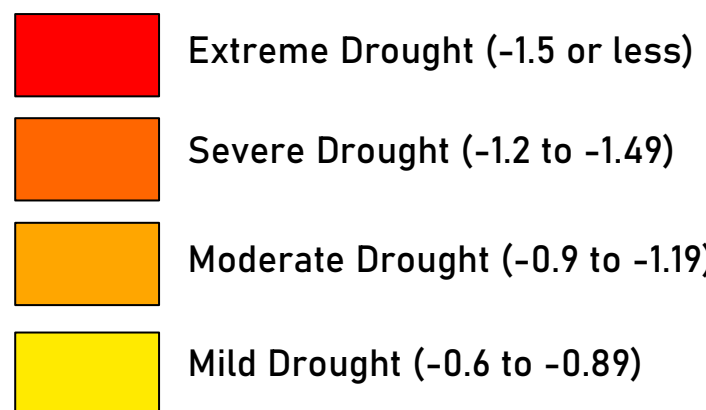
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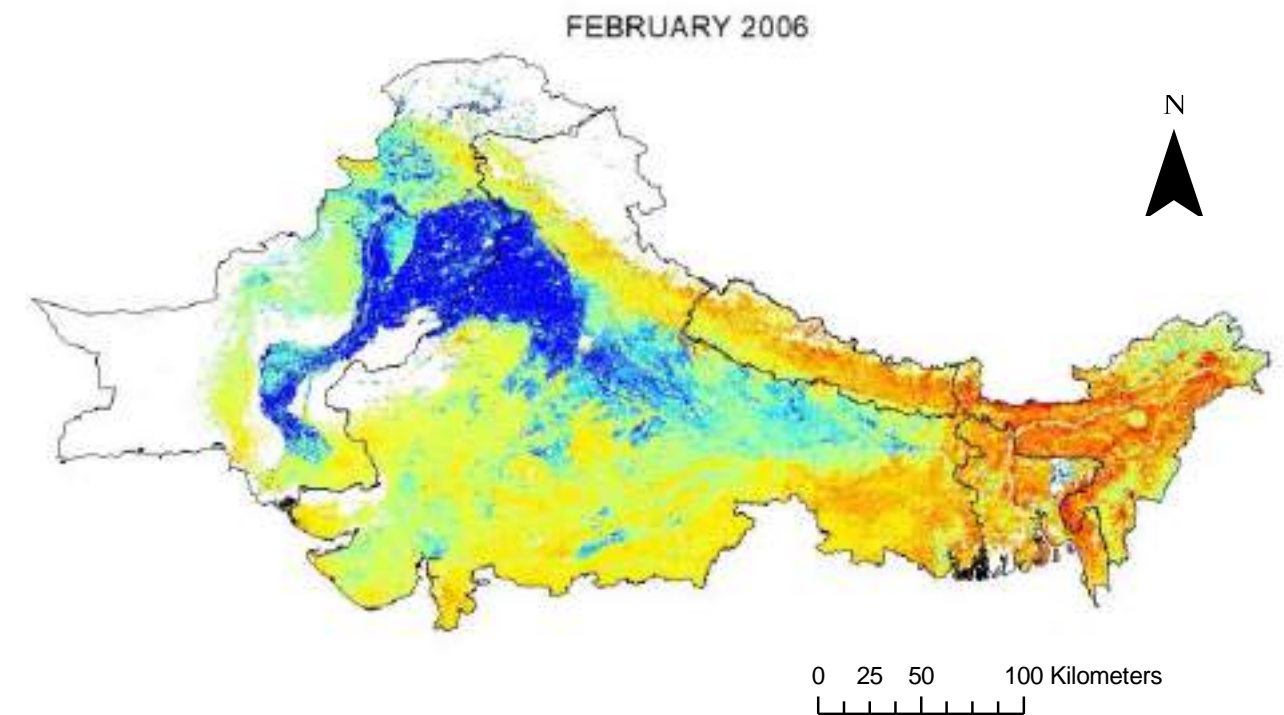
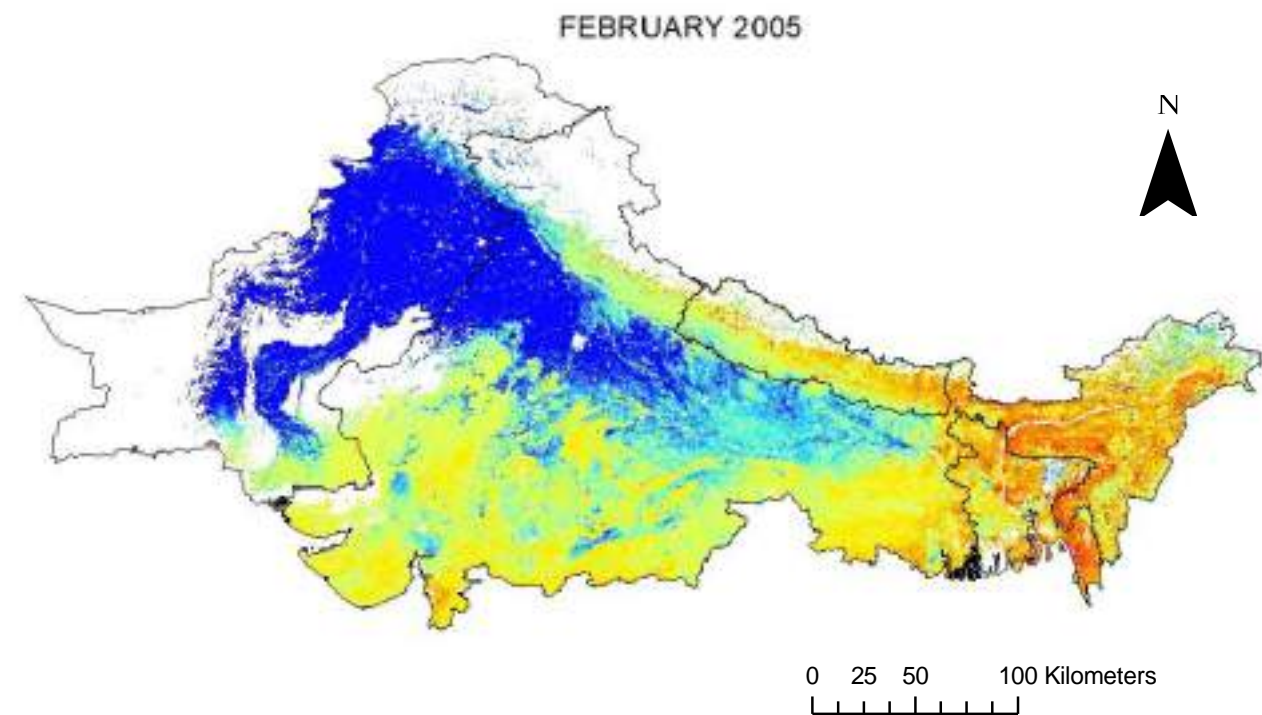




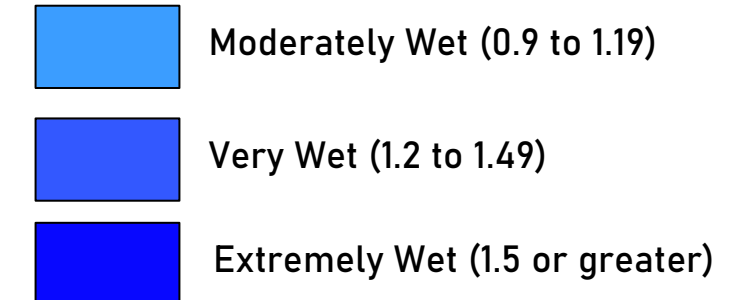
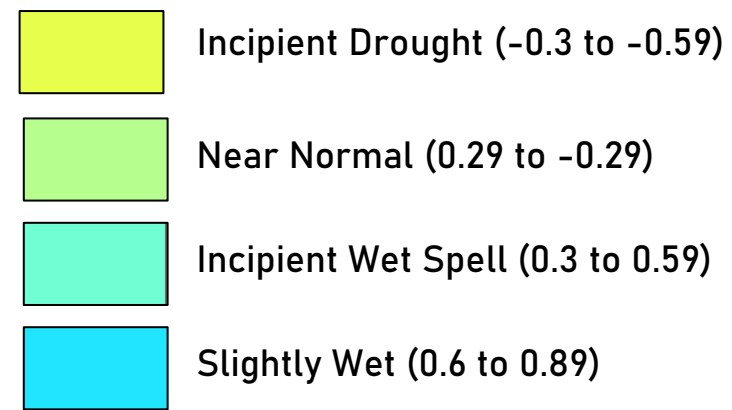
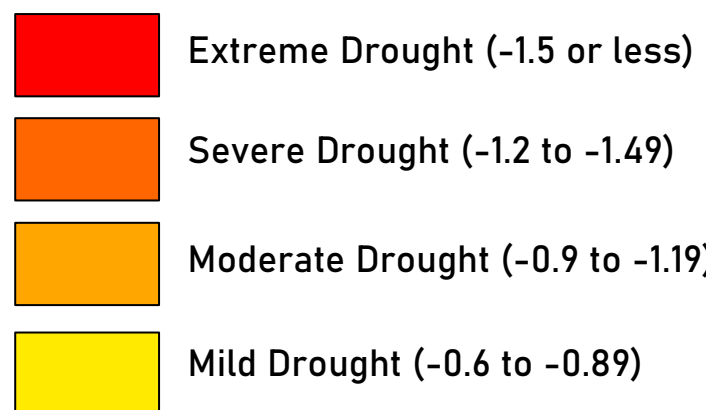


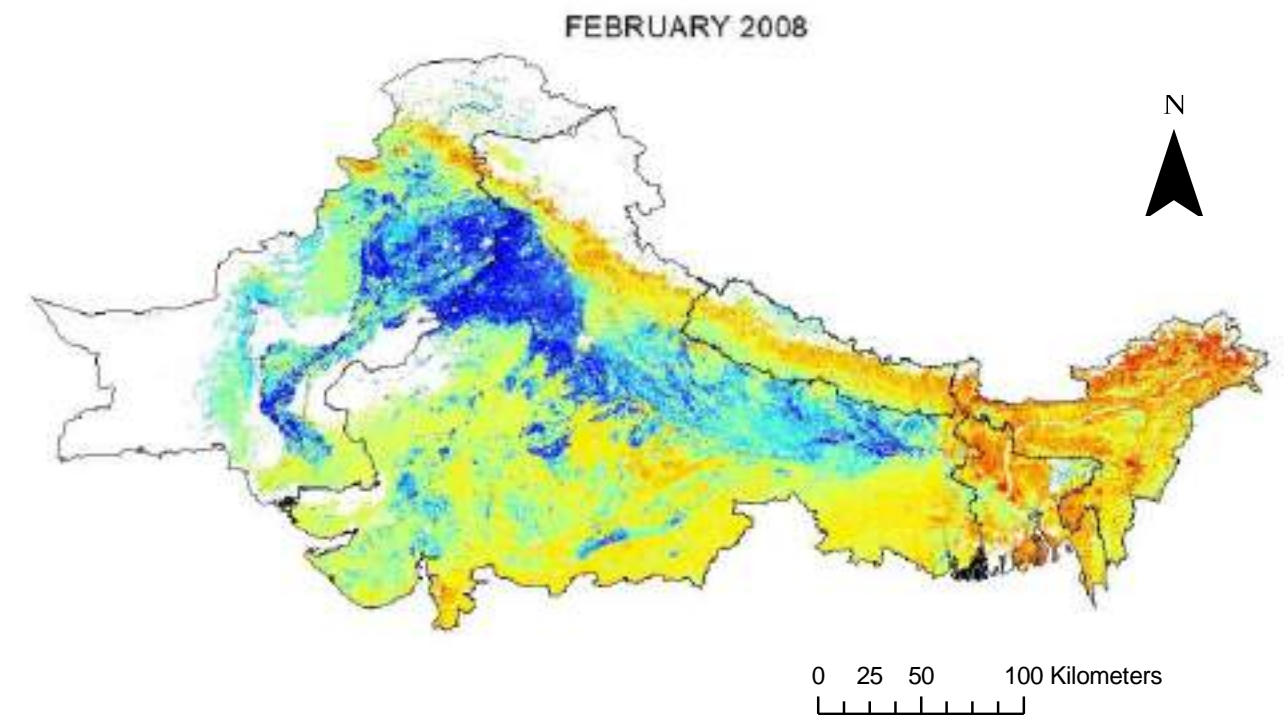
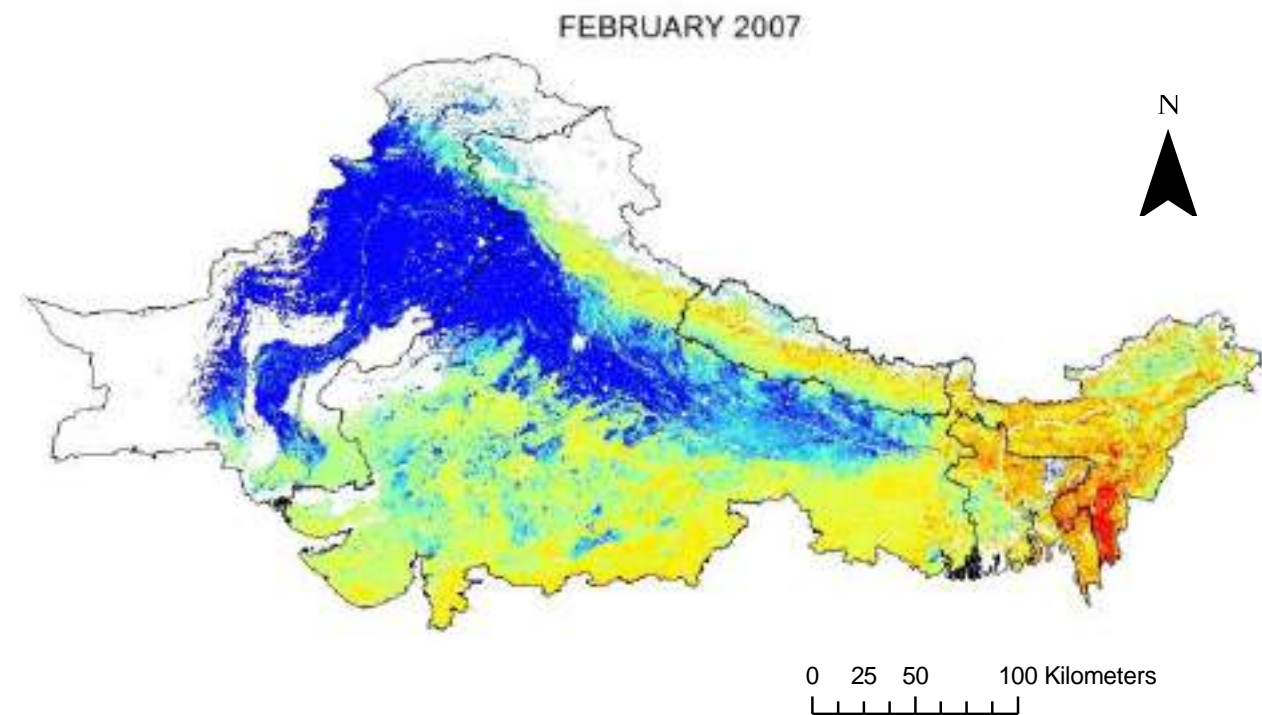
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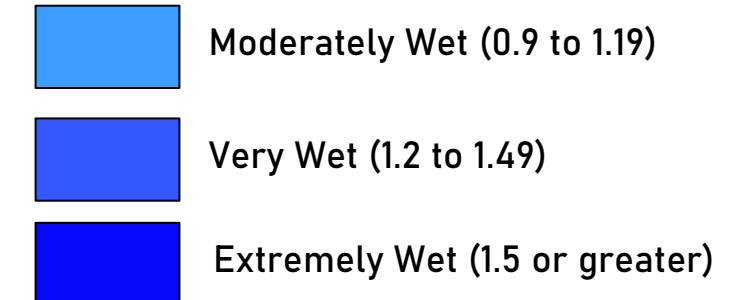
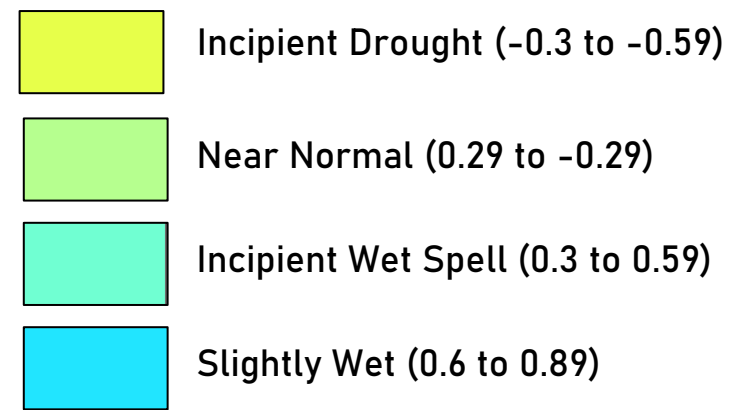
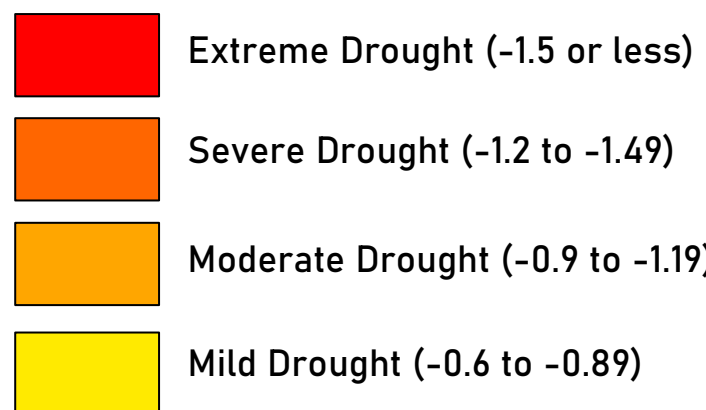


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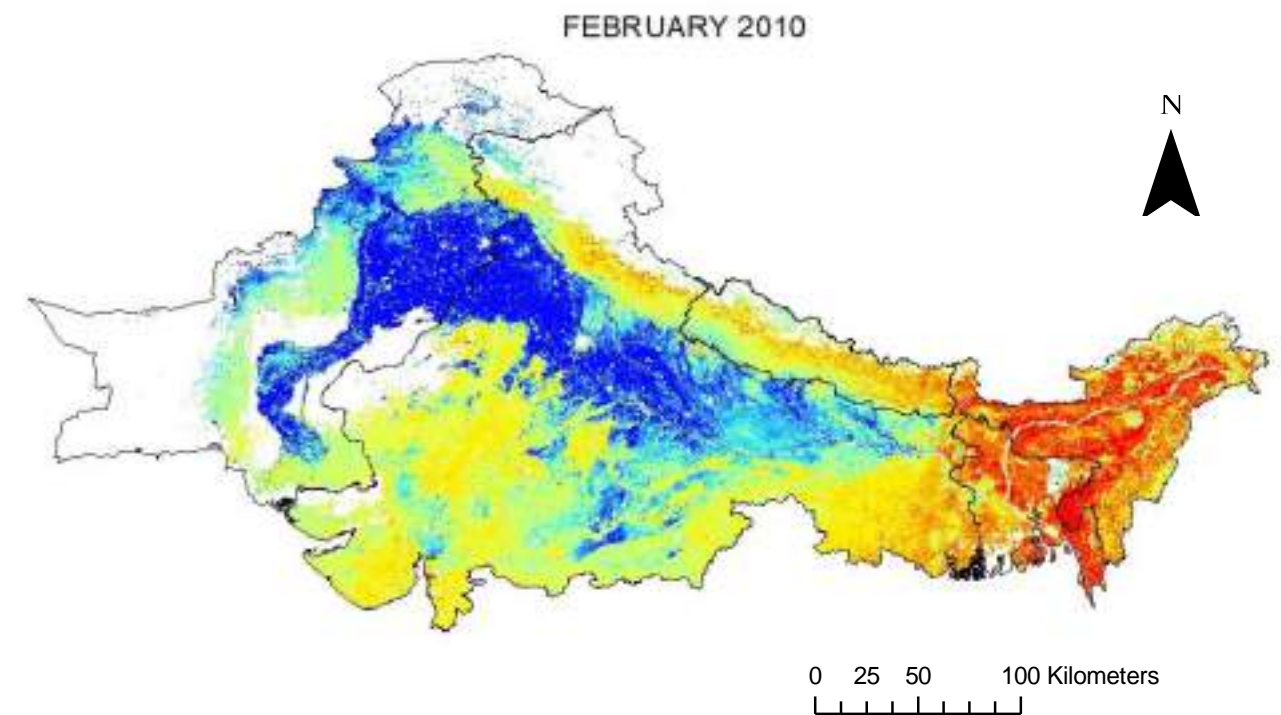
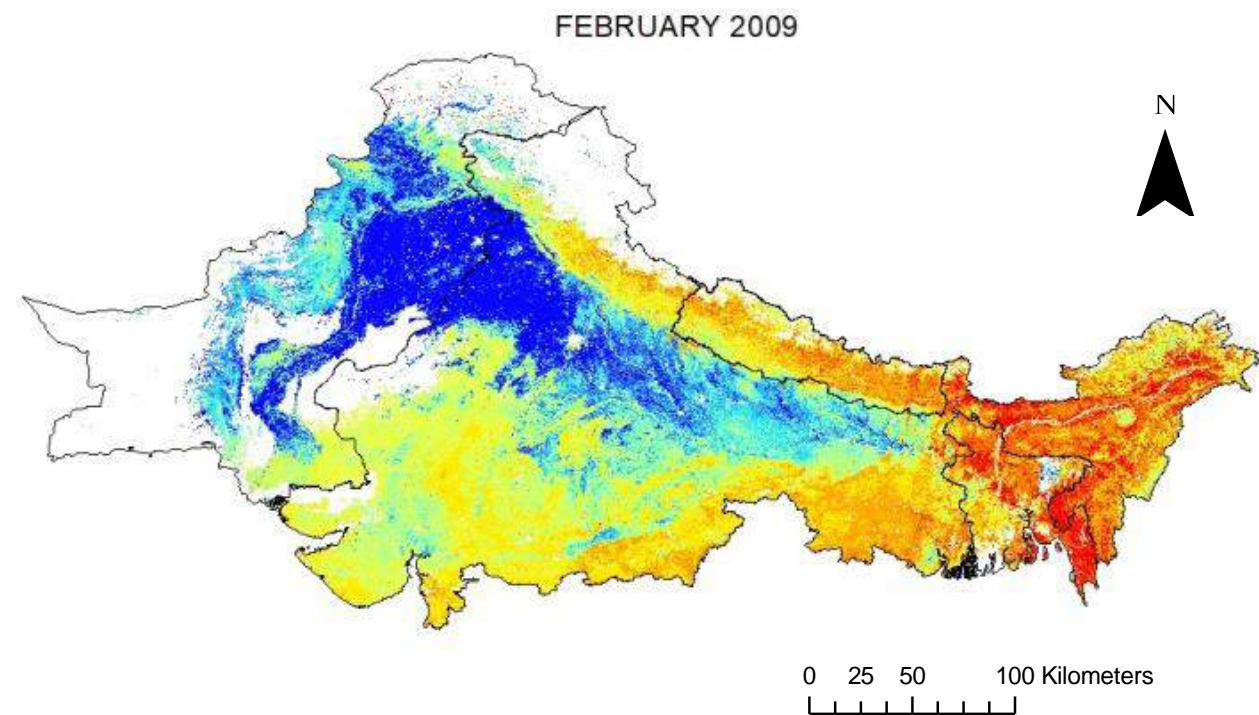




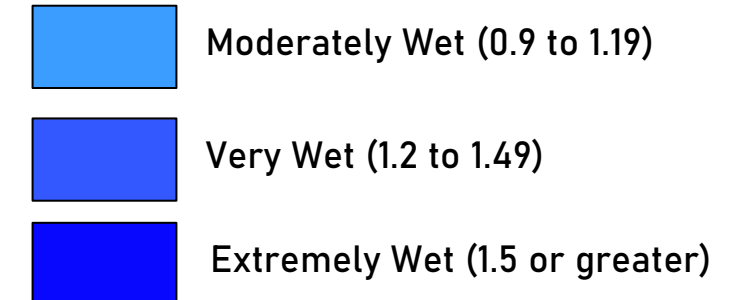
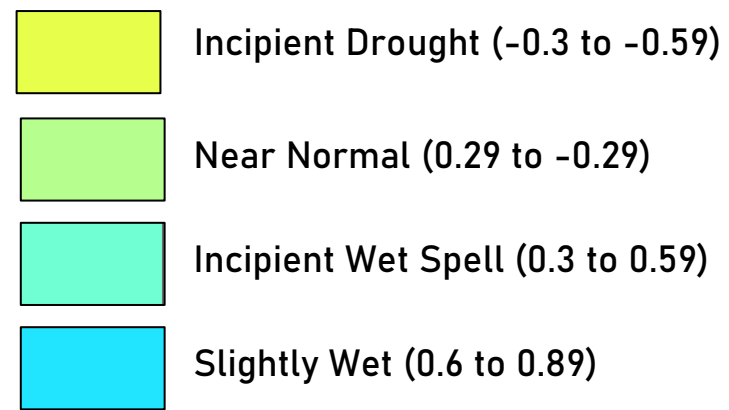
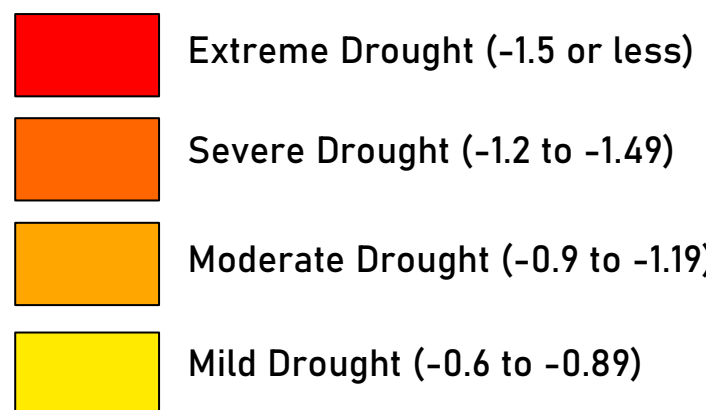
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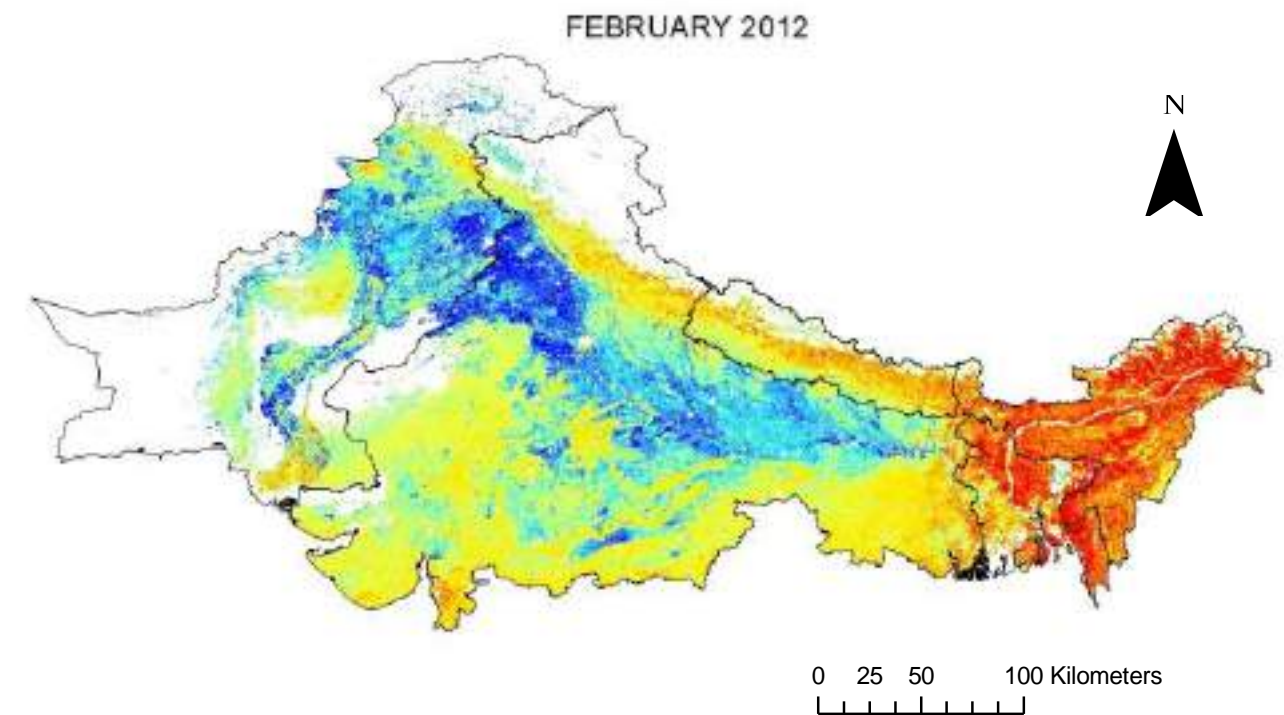
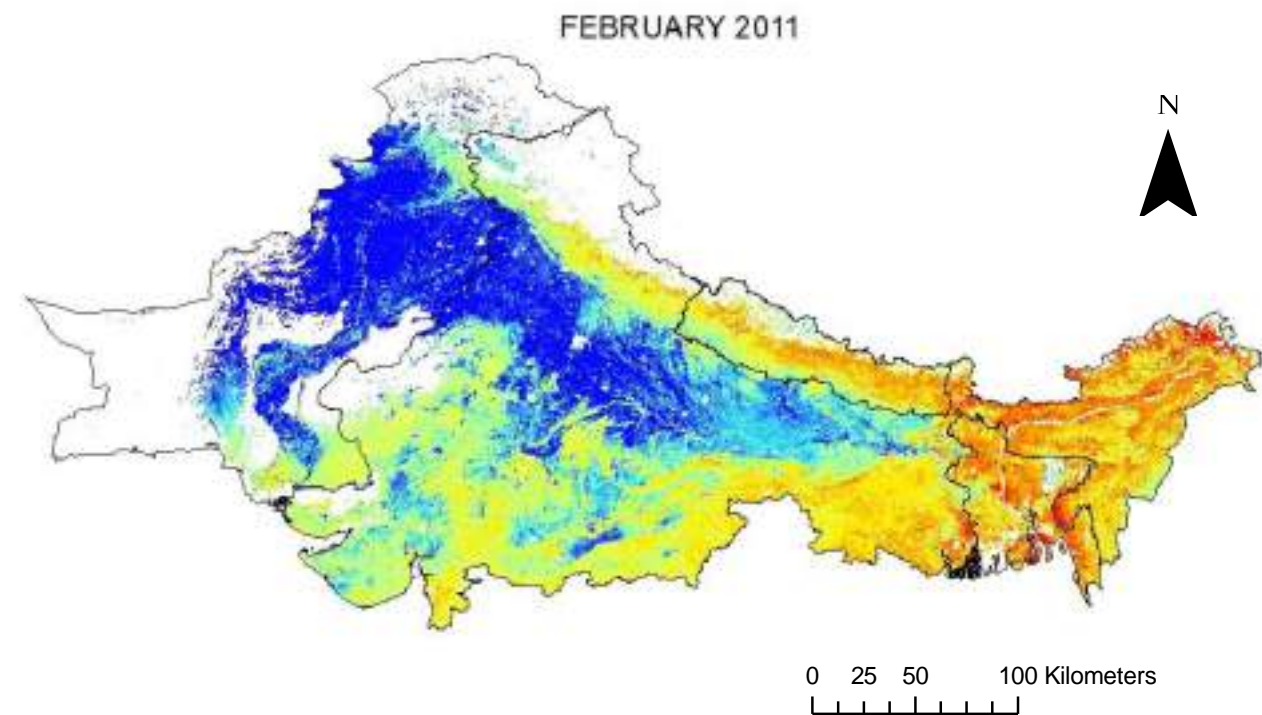




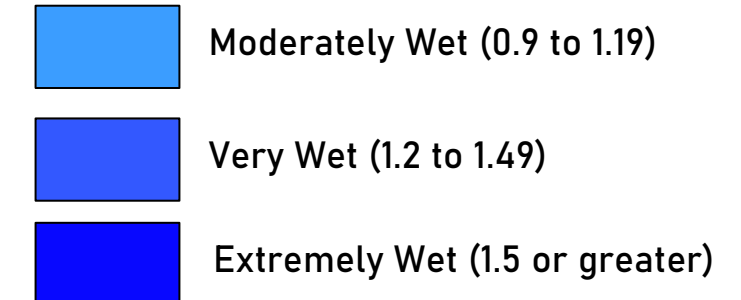
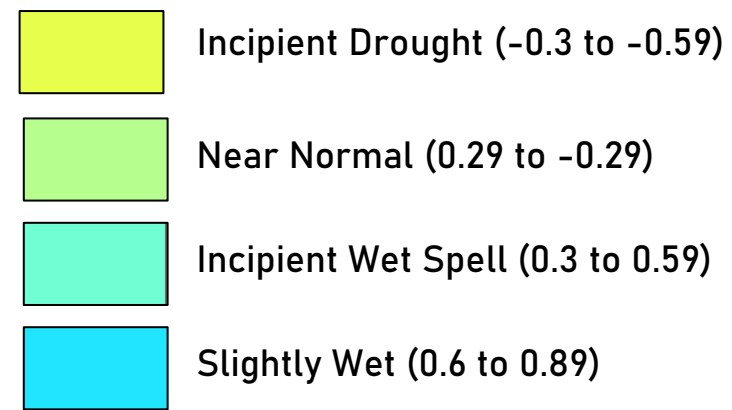
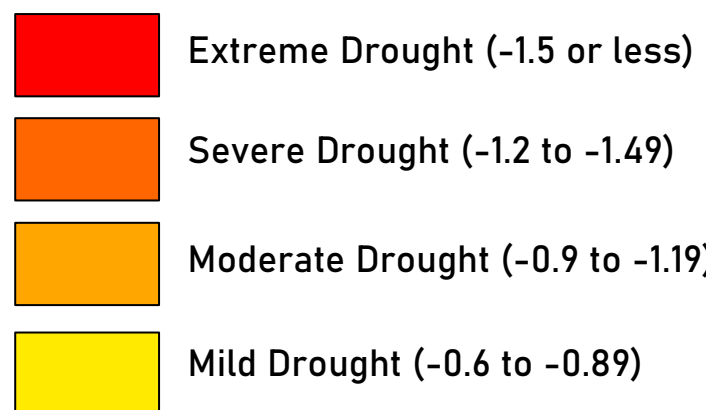


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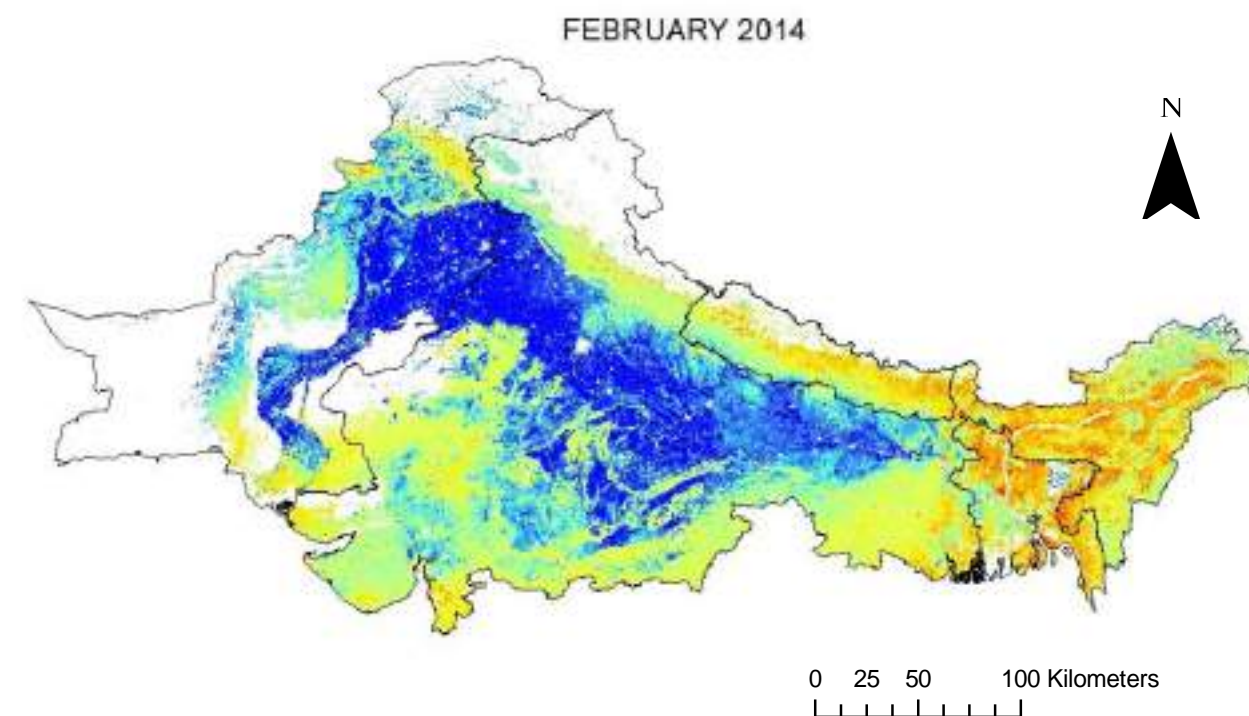
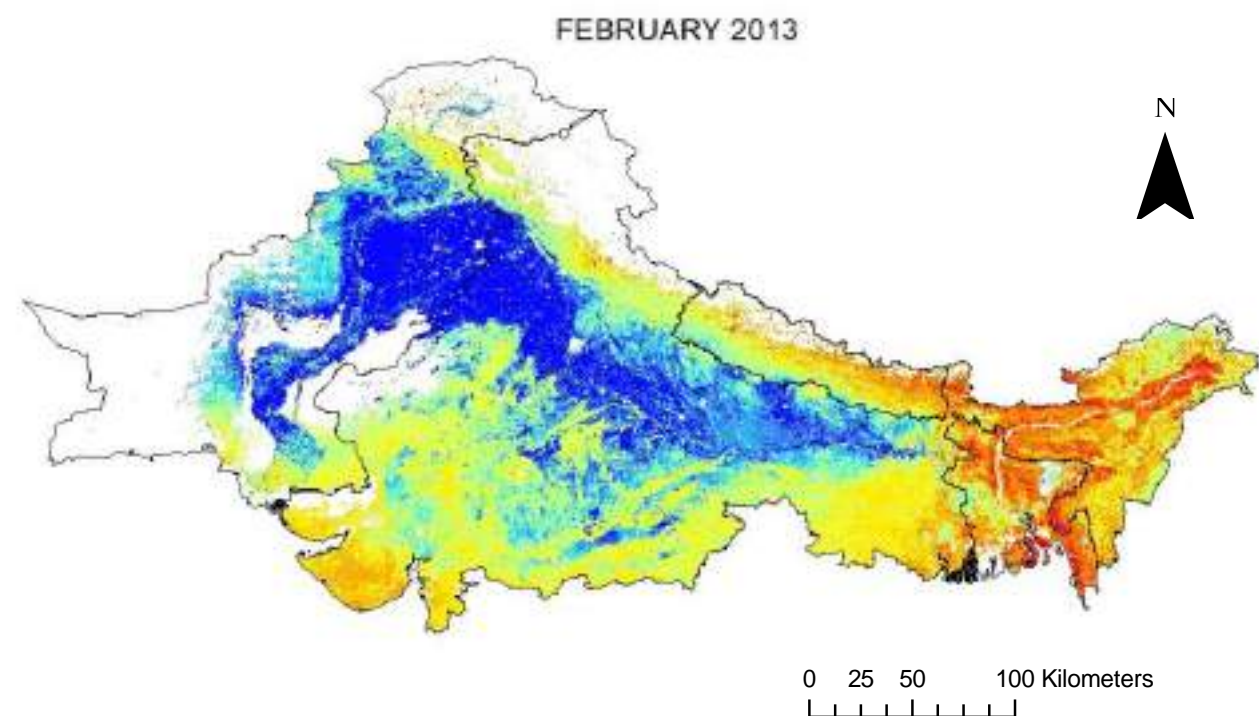




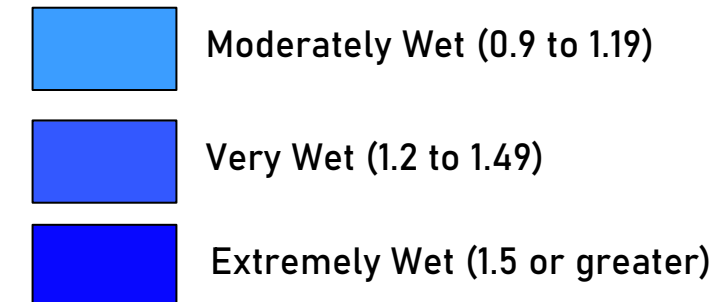
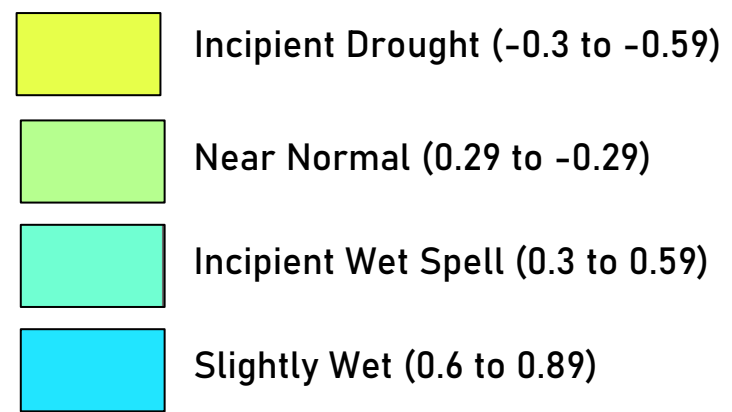
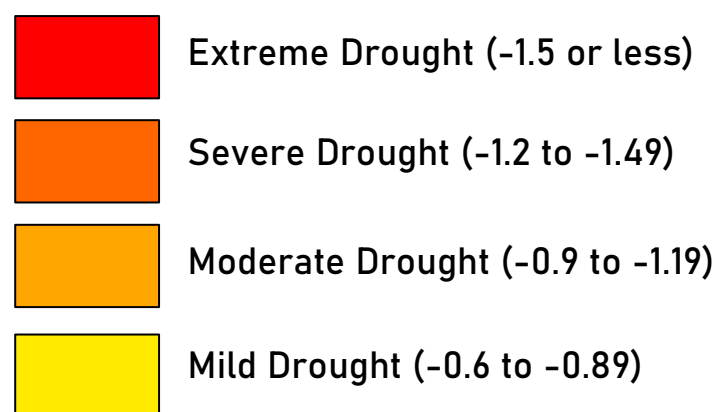
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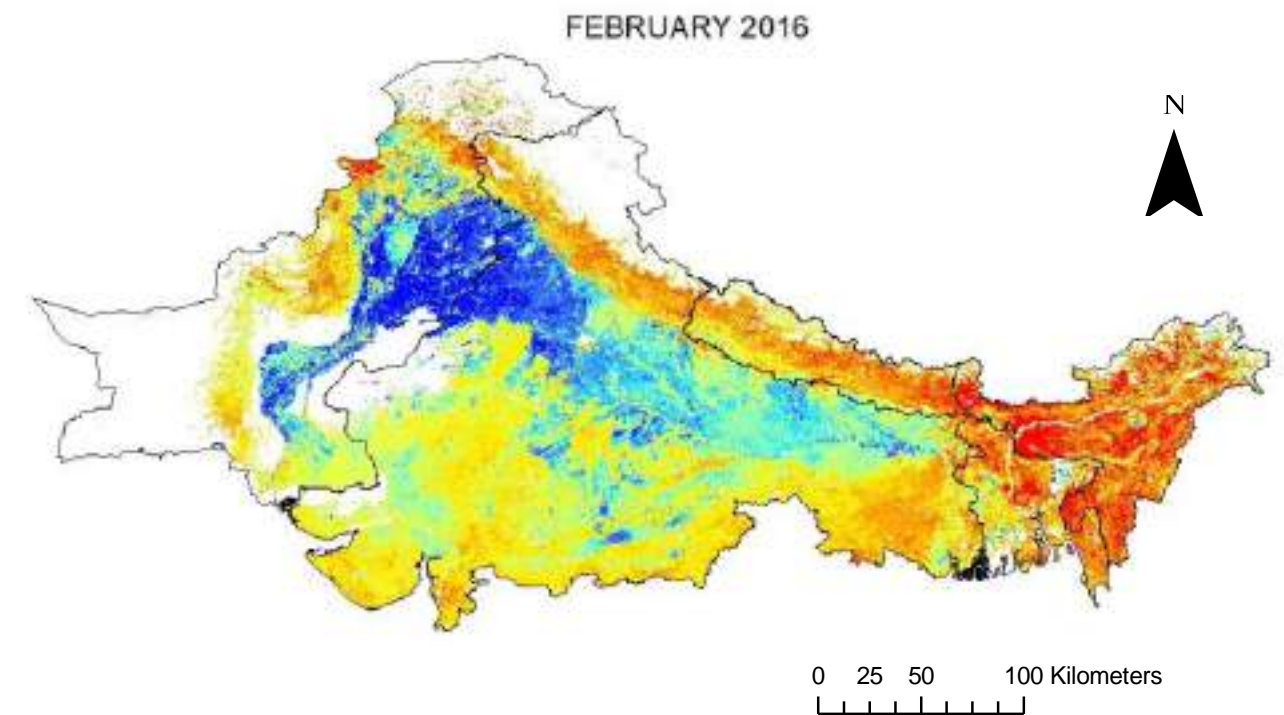
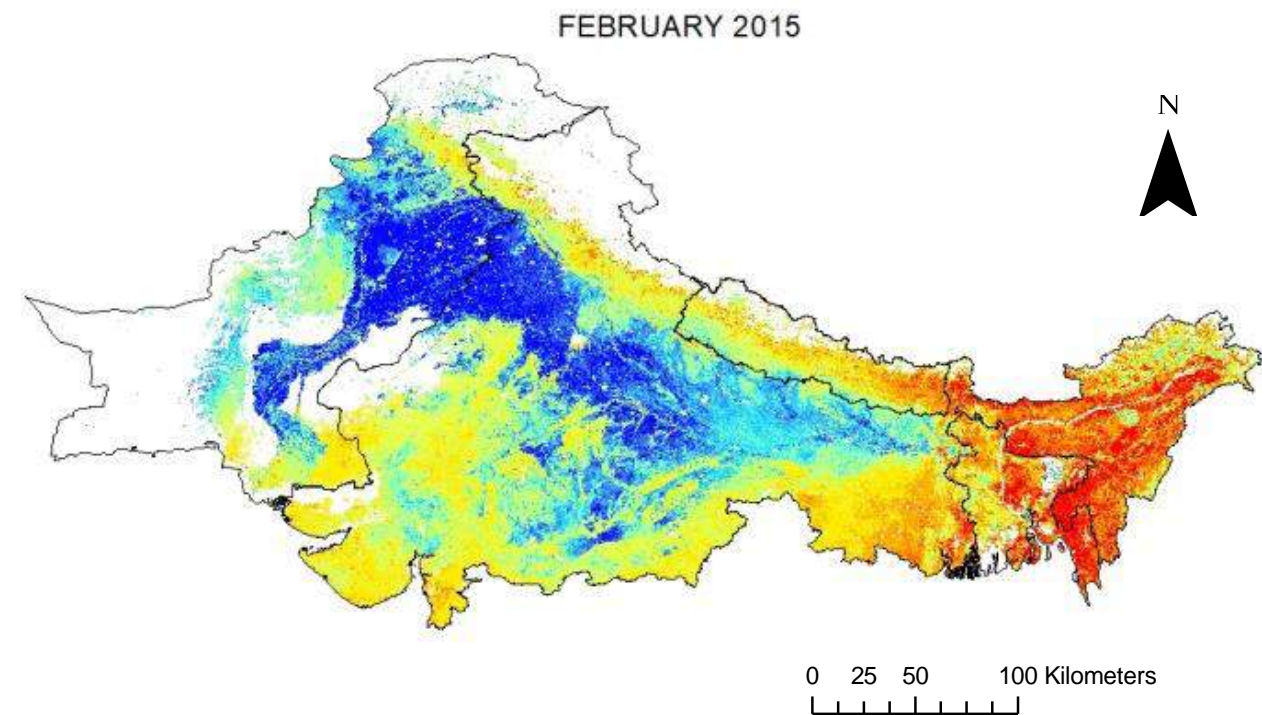




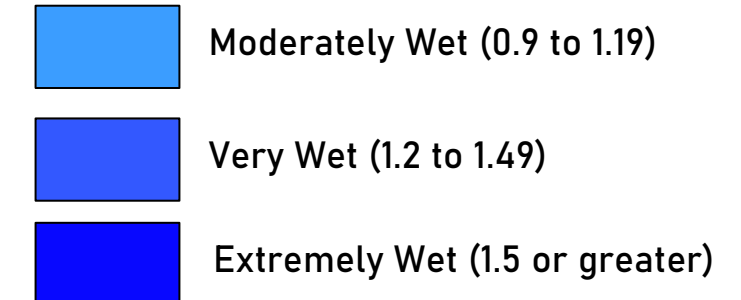
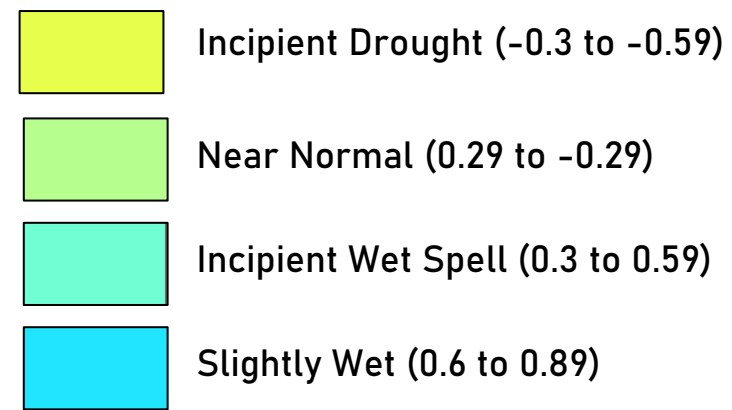
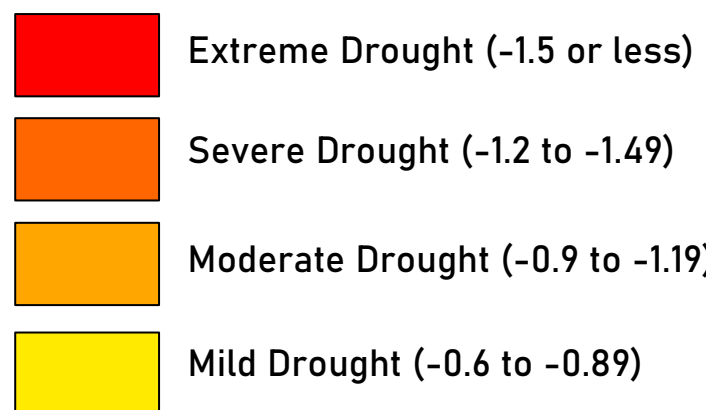


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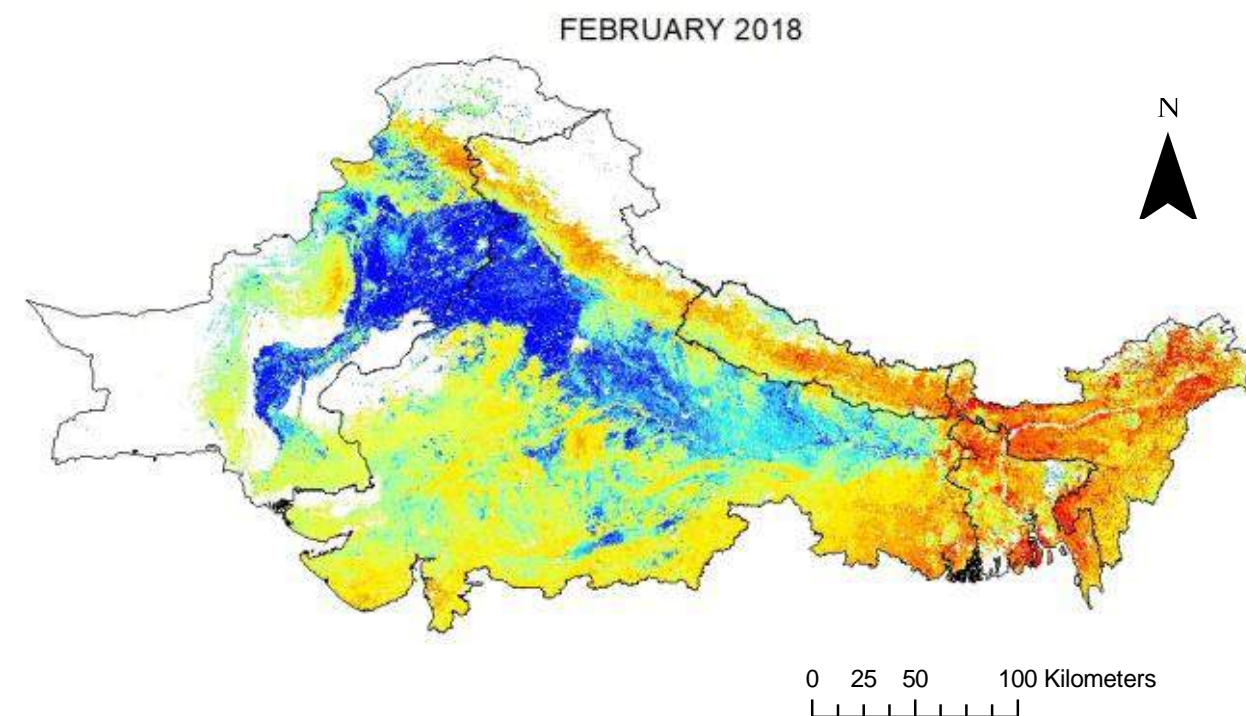
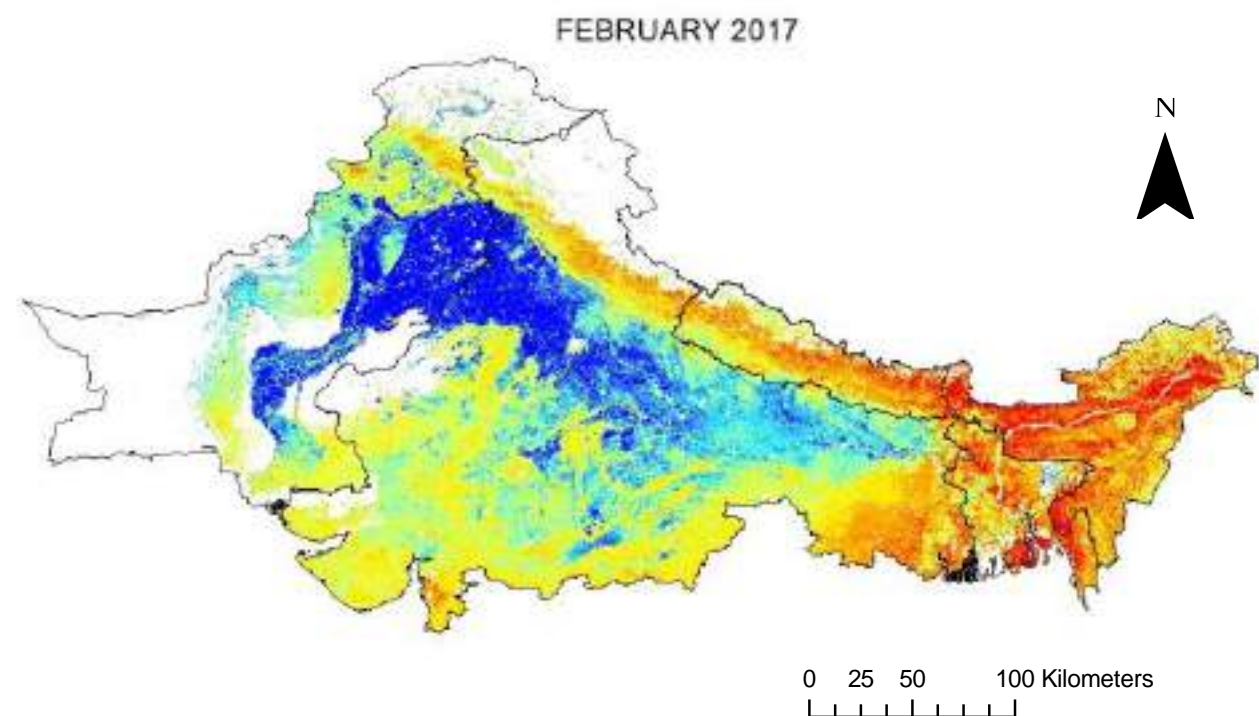




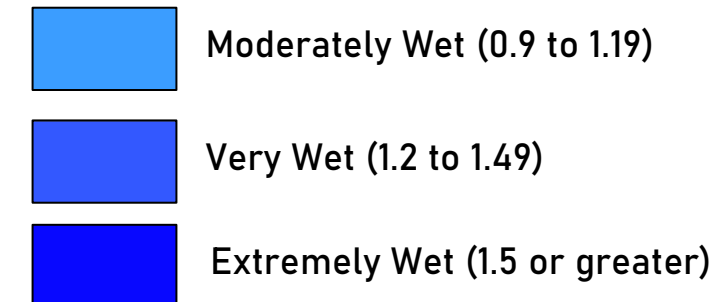
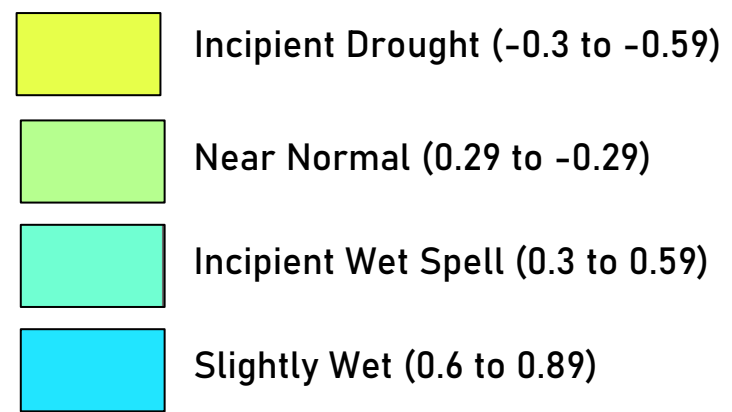
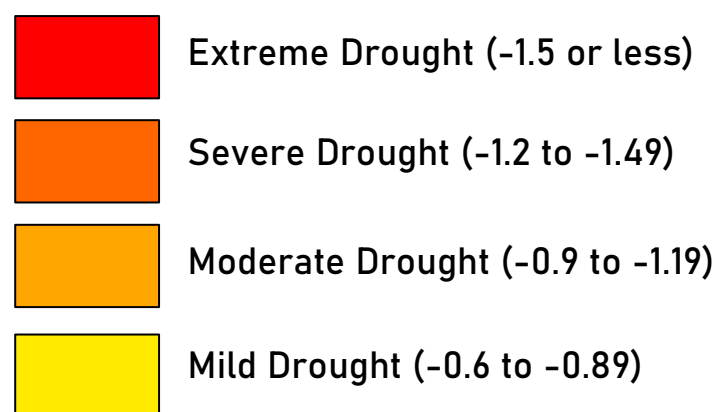
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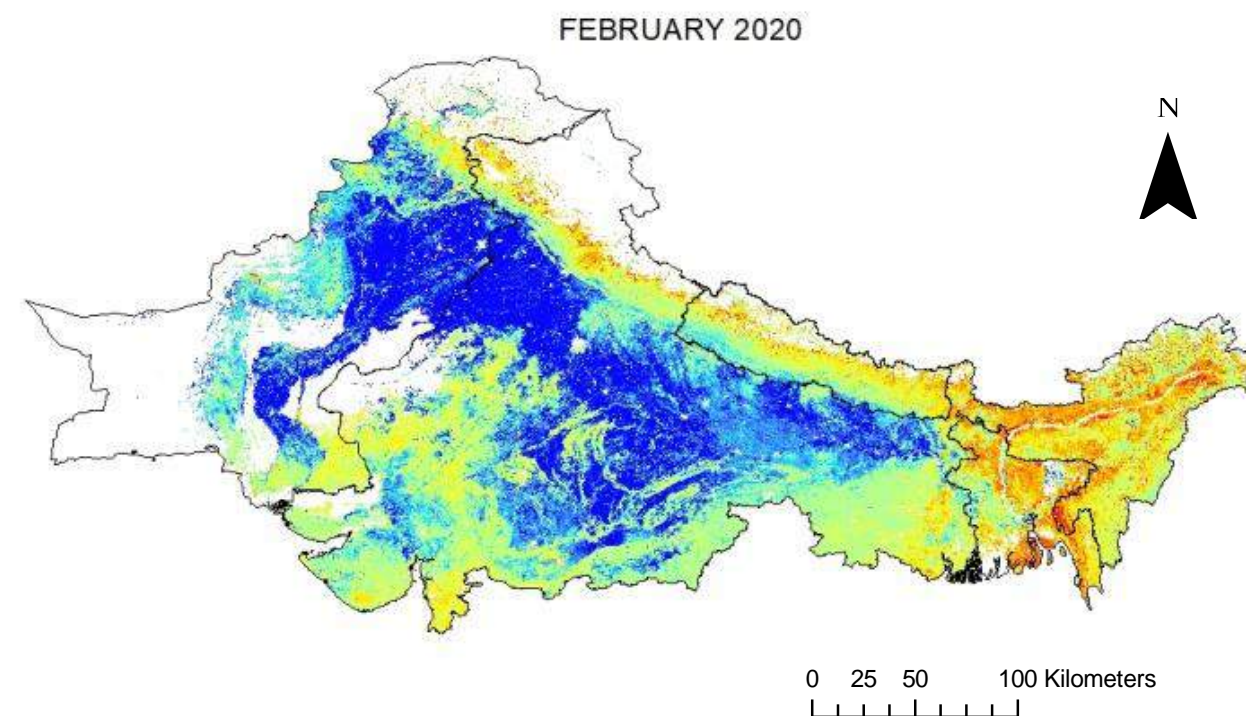
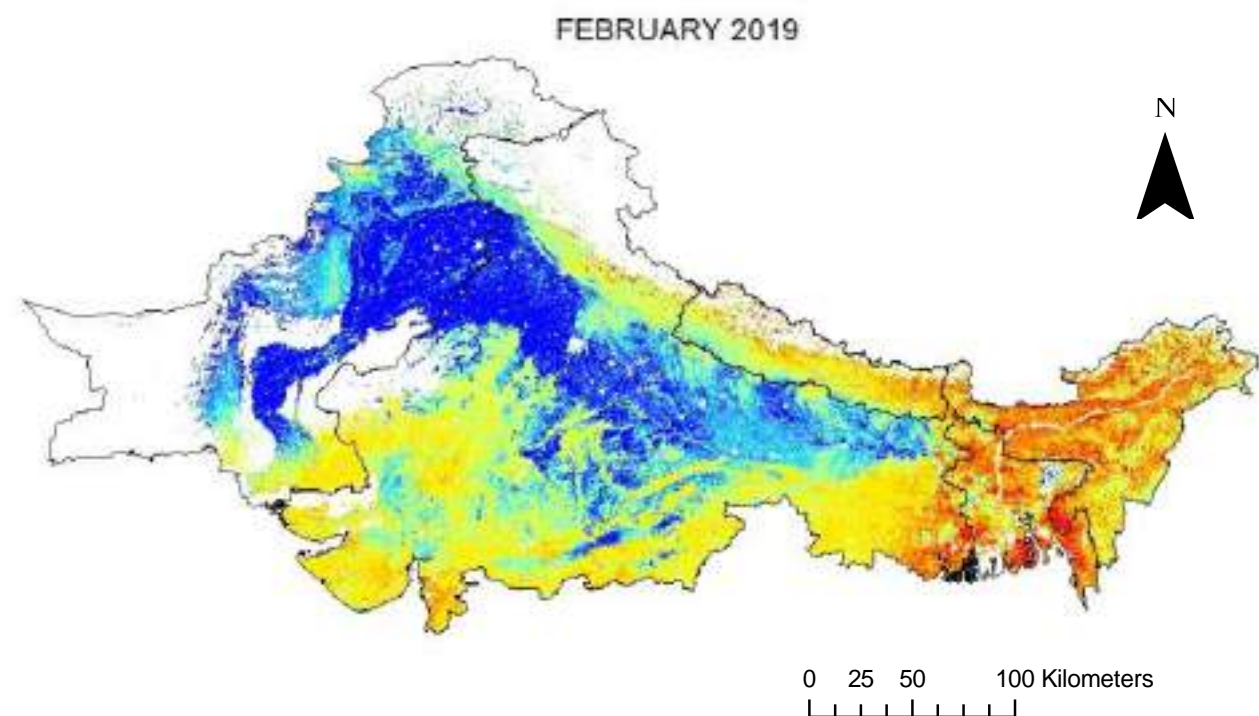




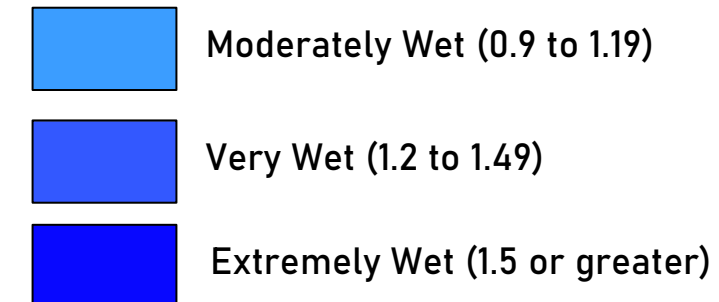
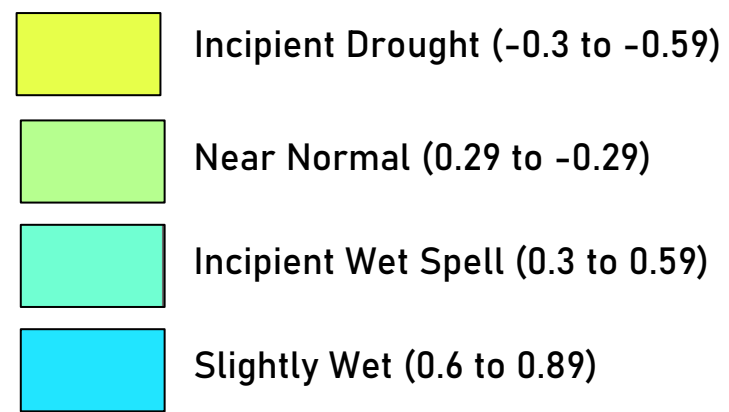
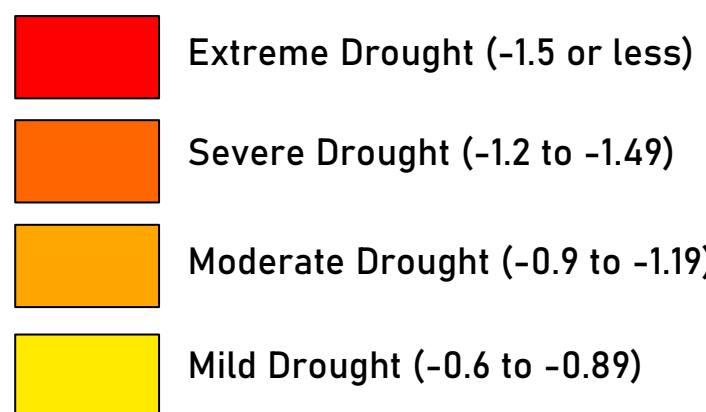


### Legend





### Legend

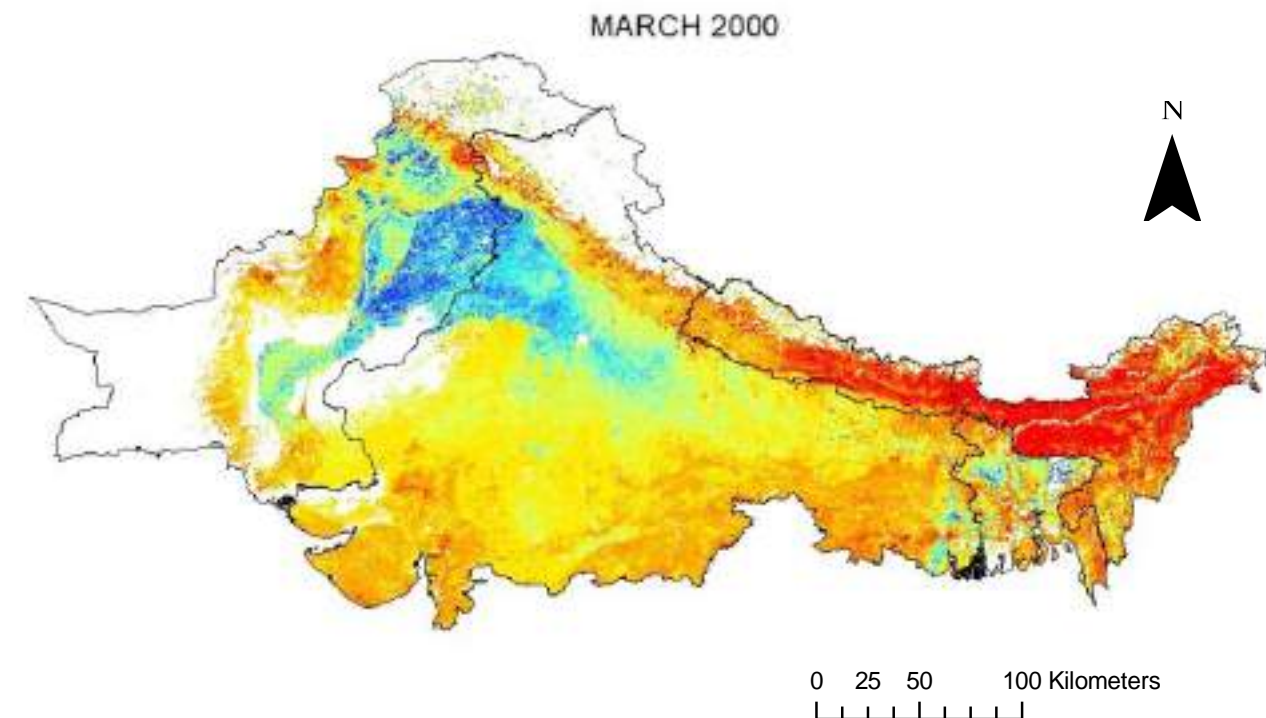




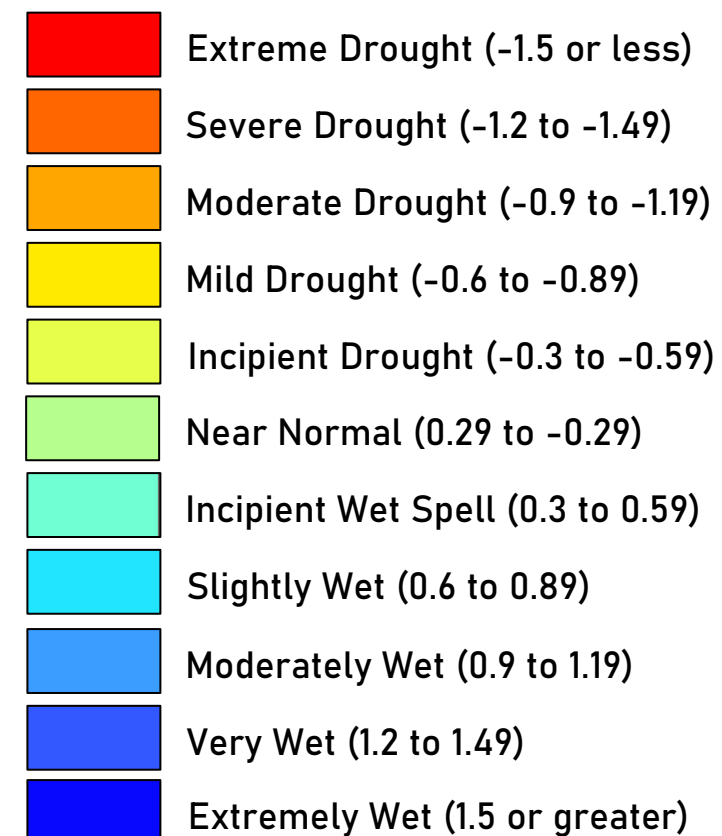
## March DSI Maps

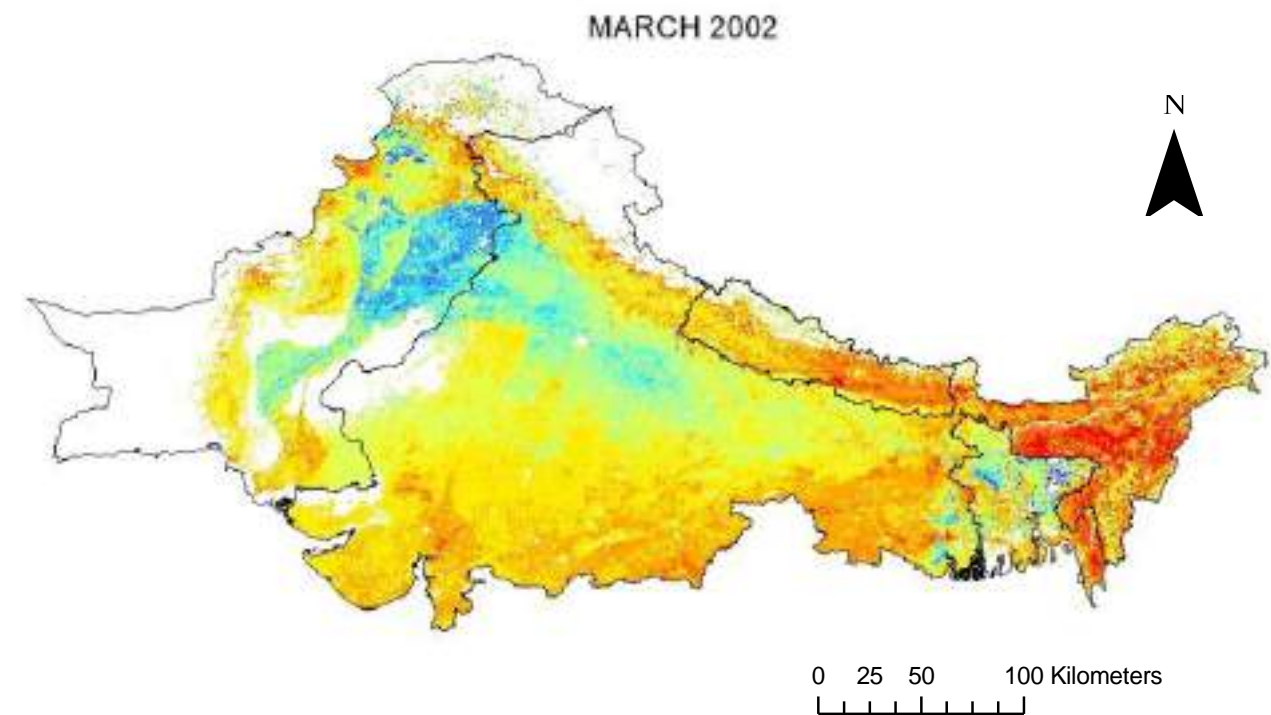
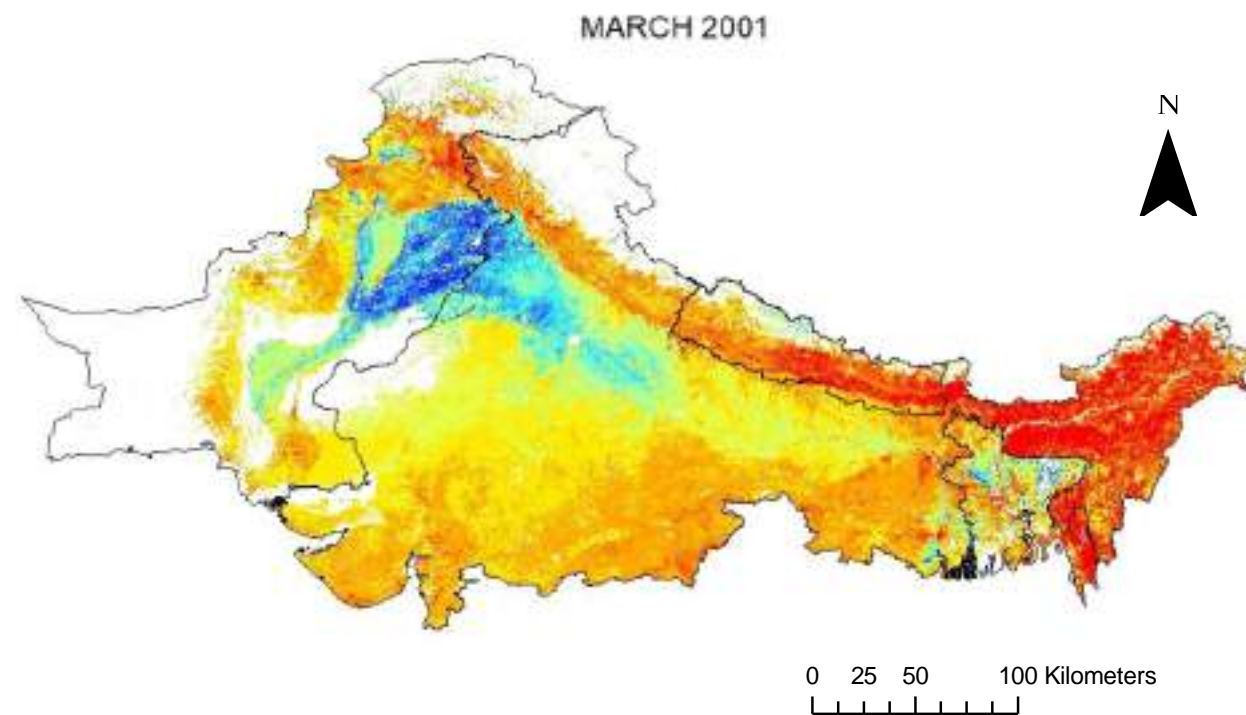
Drought in March can range from mild drought to near normal. In 2001, the DSI value of -0.85 was noted as most dry conditions. This month is characterized by mild drought conditions.

Mean March DSI Values		
Year	DSI Values	Drought Condition
2000	-0.80	Mild Drought
2001	-0.85	Mild Drought
2002	-0.63	Mild Drought
2003	-0.46	Incipient Drought
2004	-0.70	Mild Drought
2005	-0.24	Near Normal
2006	-0.46	Incipient Drought
2007	-0.22	Near Normal
2008	-0.55	Incipient Drought
2009	-0.63	Mild Drought
2010	-0.70	Mild Drought
2011	-0.65	Mild Drought
2012	-0.80	Mild Drought
2013	-0.47	Incipient Drought
2014	-0.31	Incipient Drought
2015	-0.53	Incipient Drought
2016	-0.64	Mild Drought
2017	-0.58	Incipient Drought
2018	-0.71	Mild Drought
2019	-0.45	Incipient Drought
2020	-0.08	Near Normal

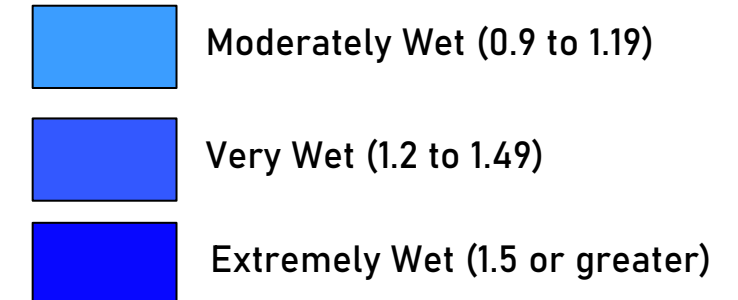
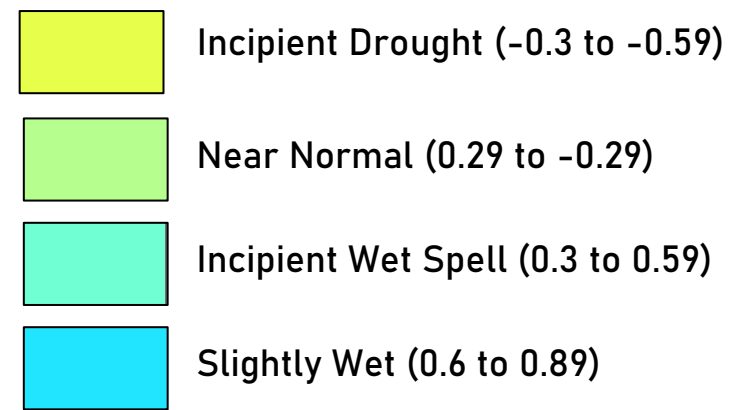
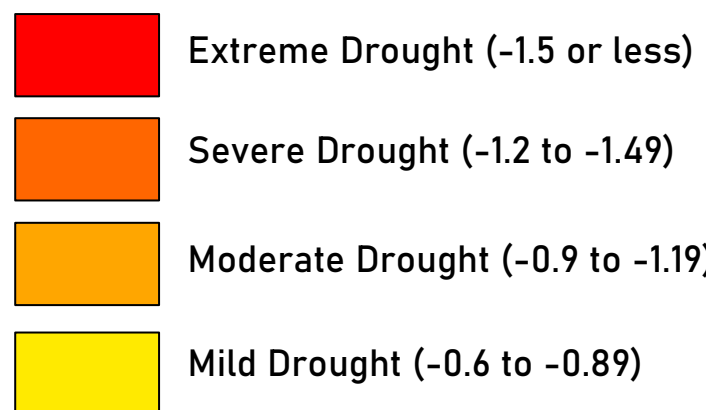


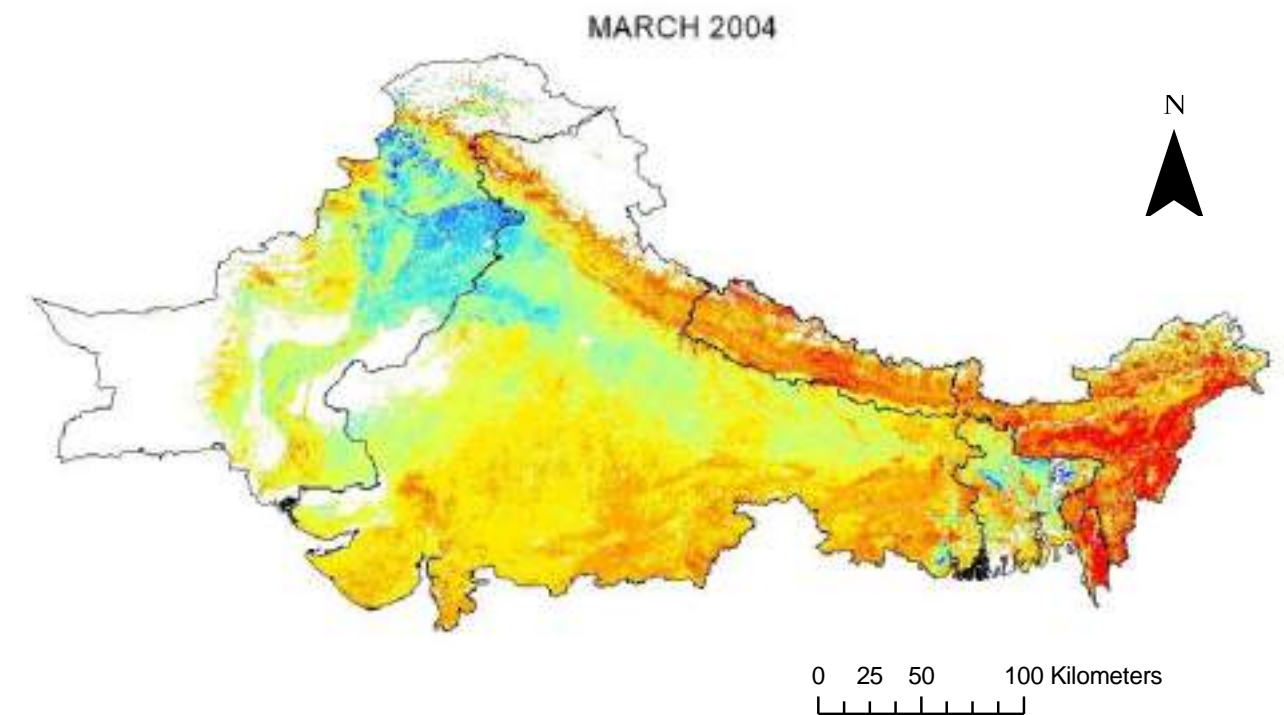
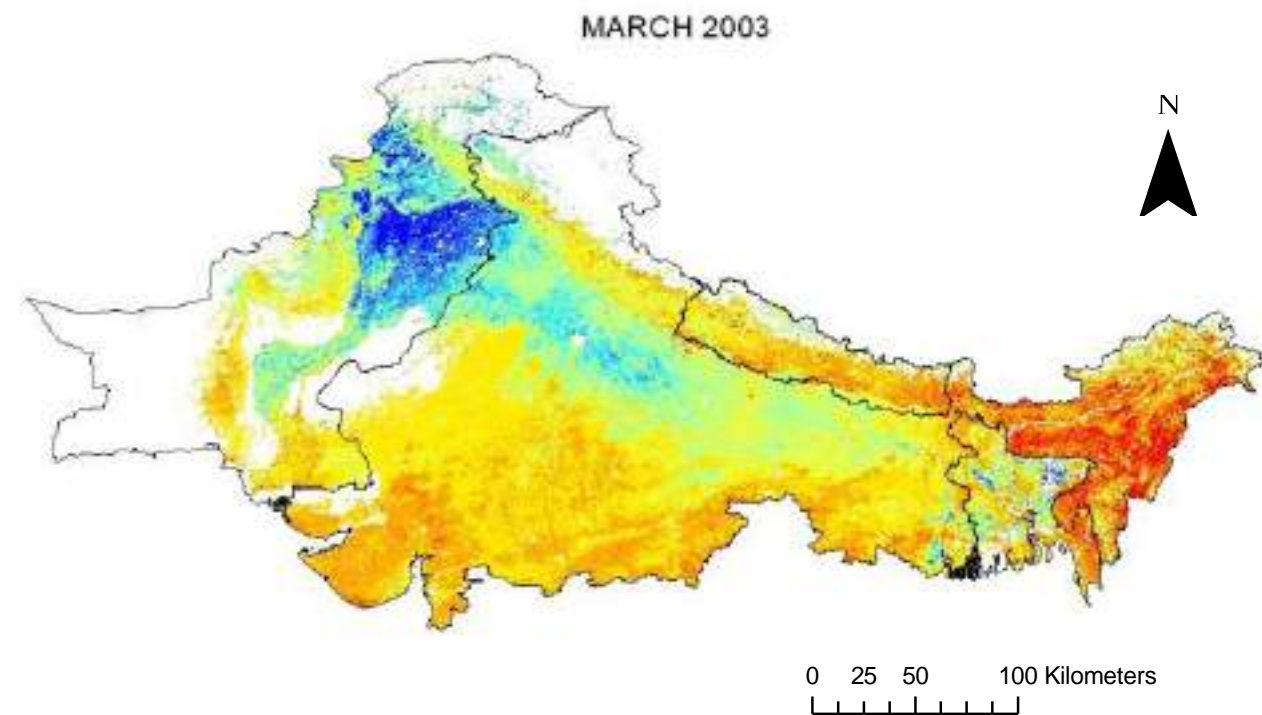
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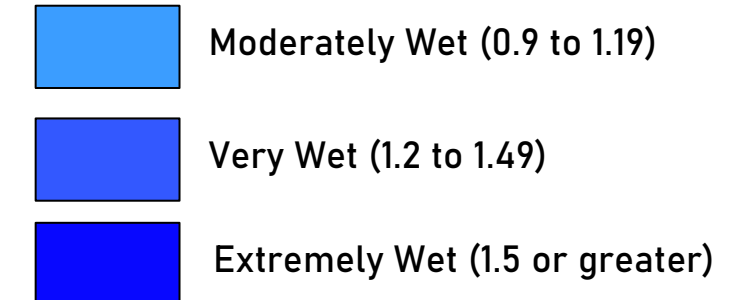
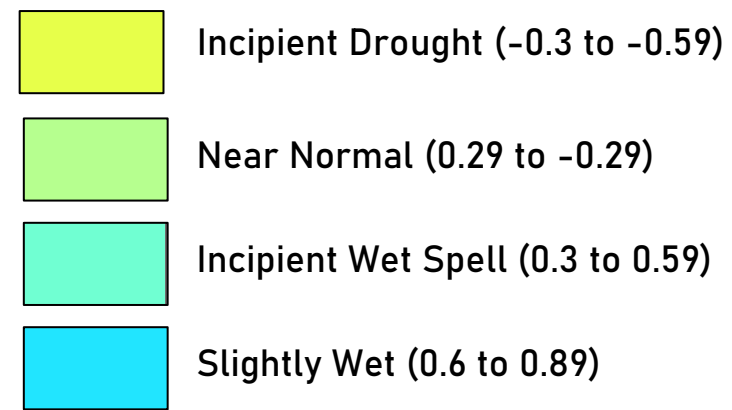
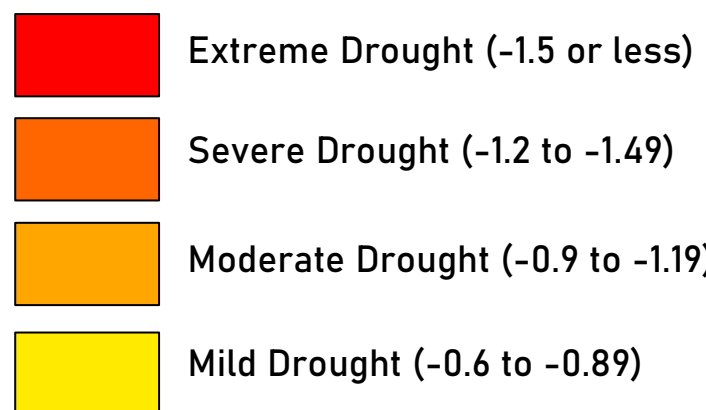


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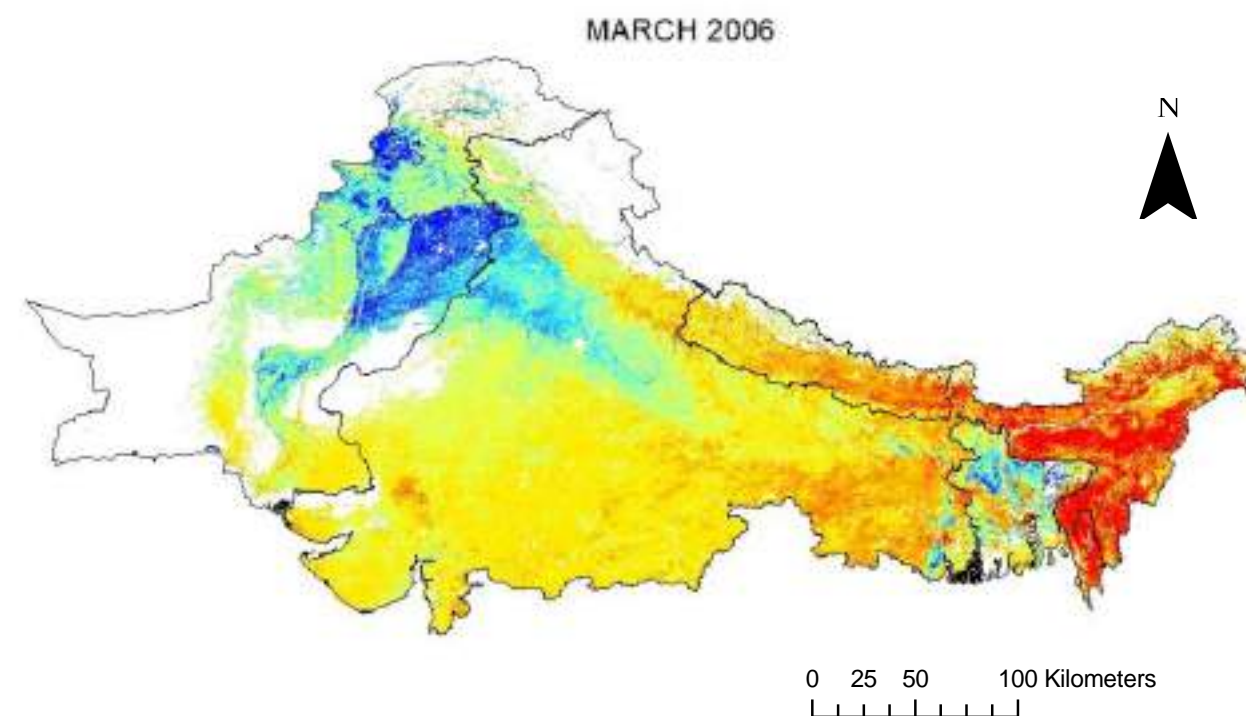
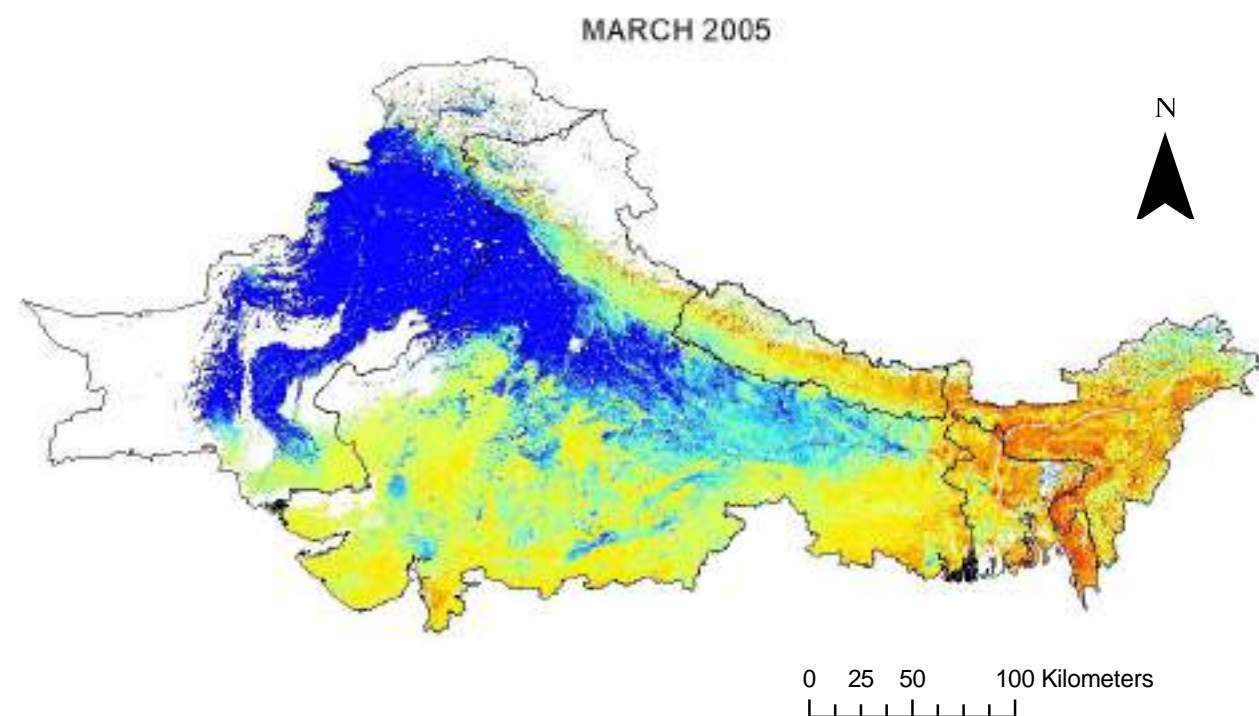




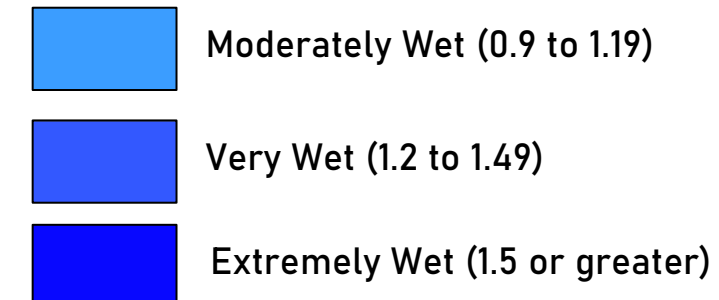
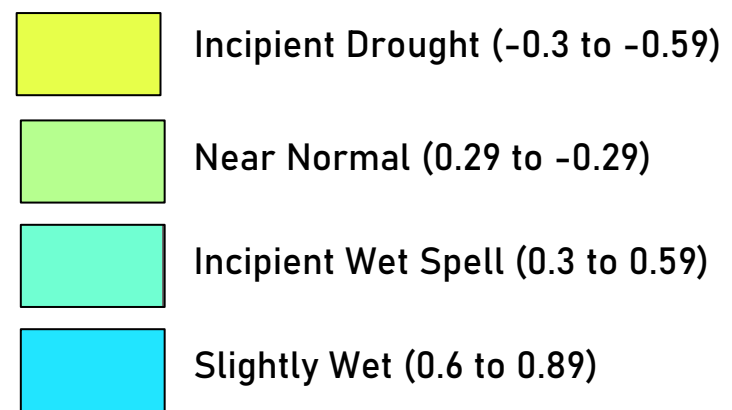
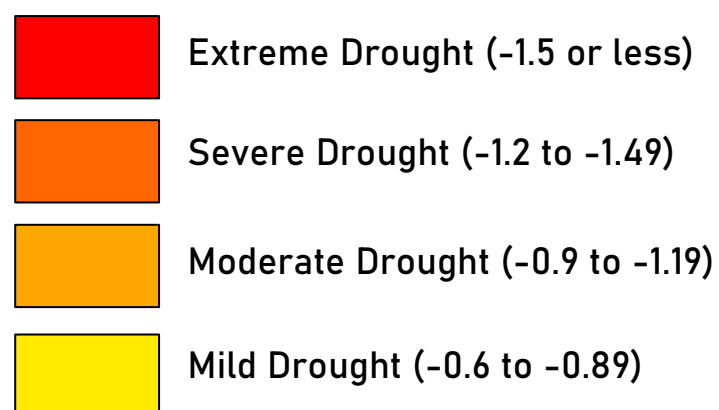
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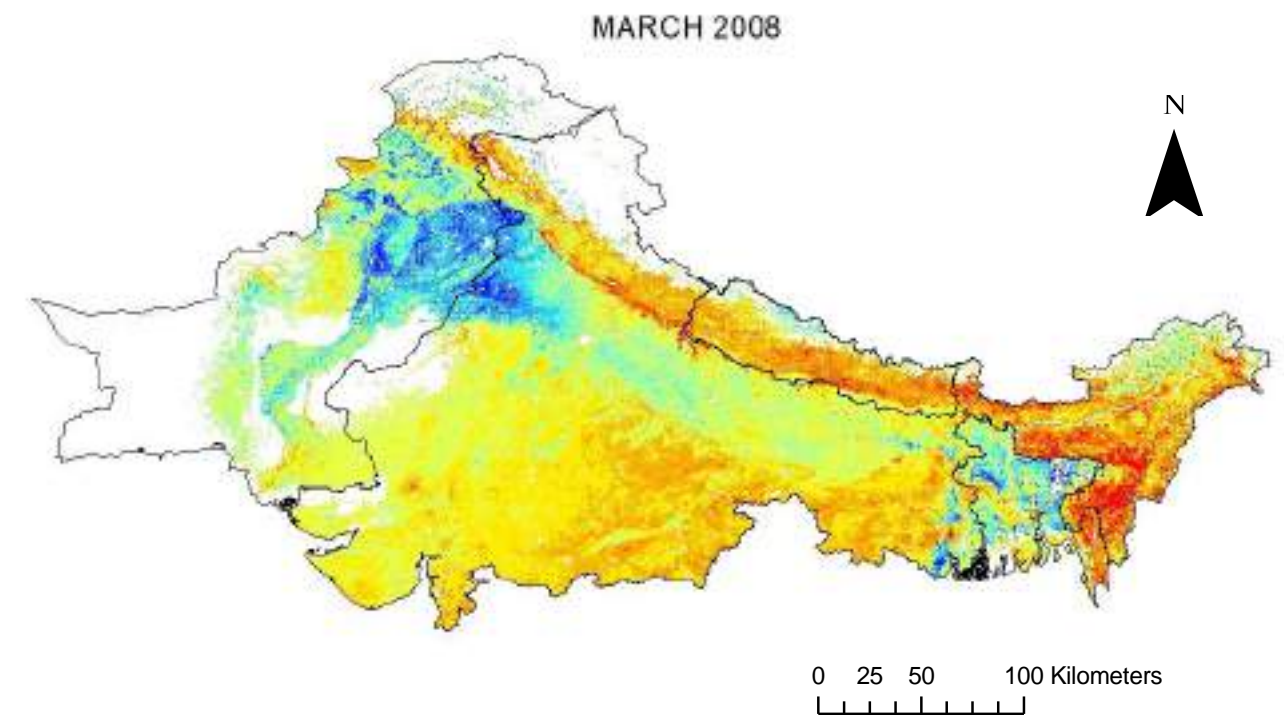
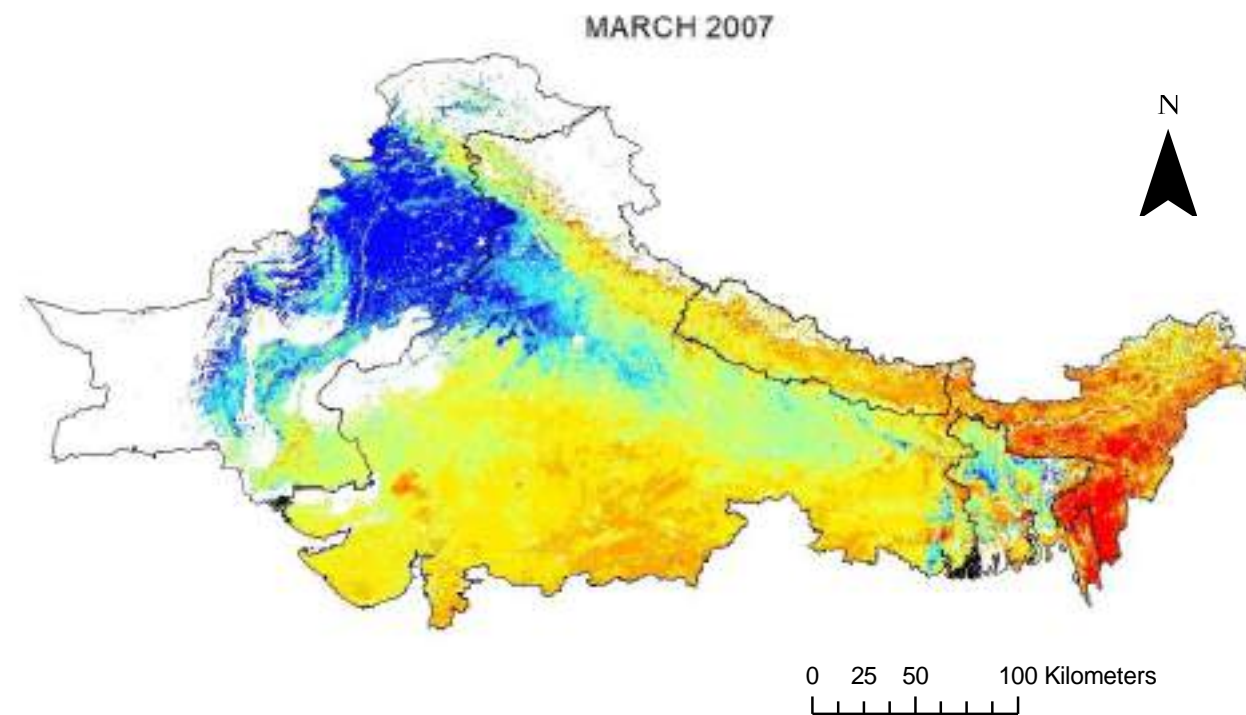




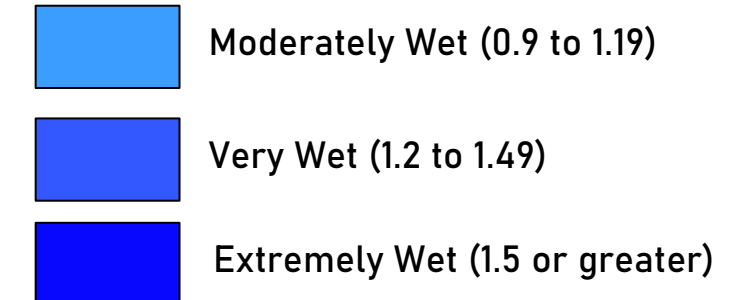
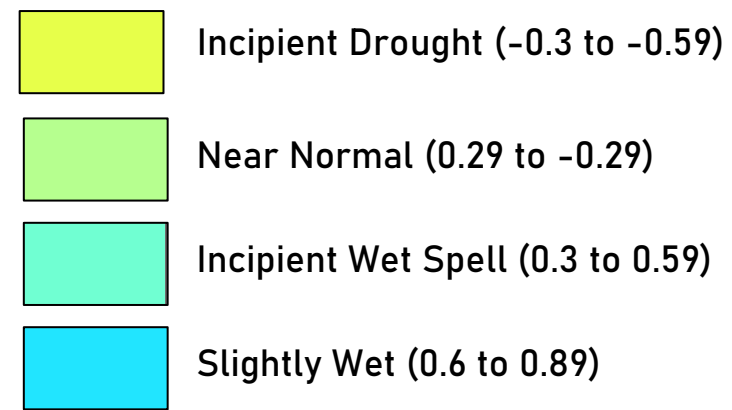
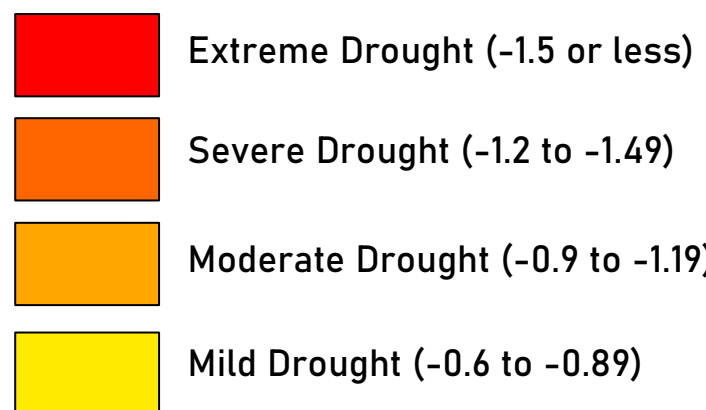
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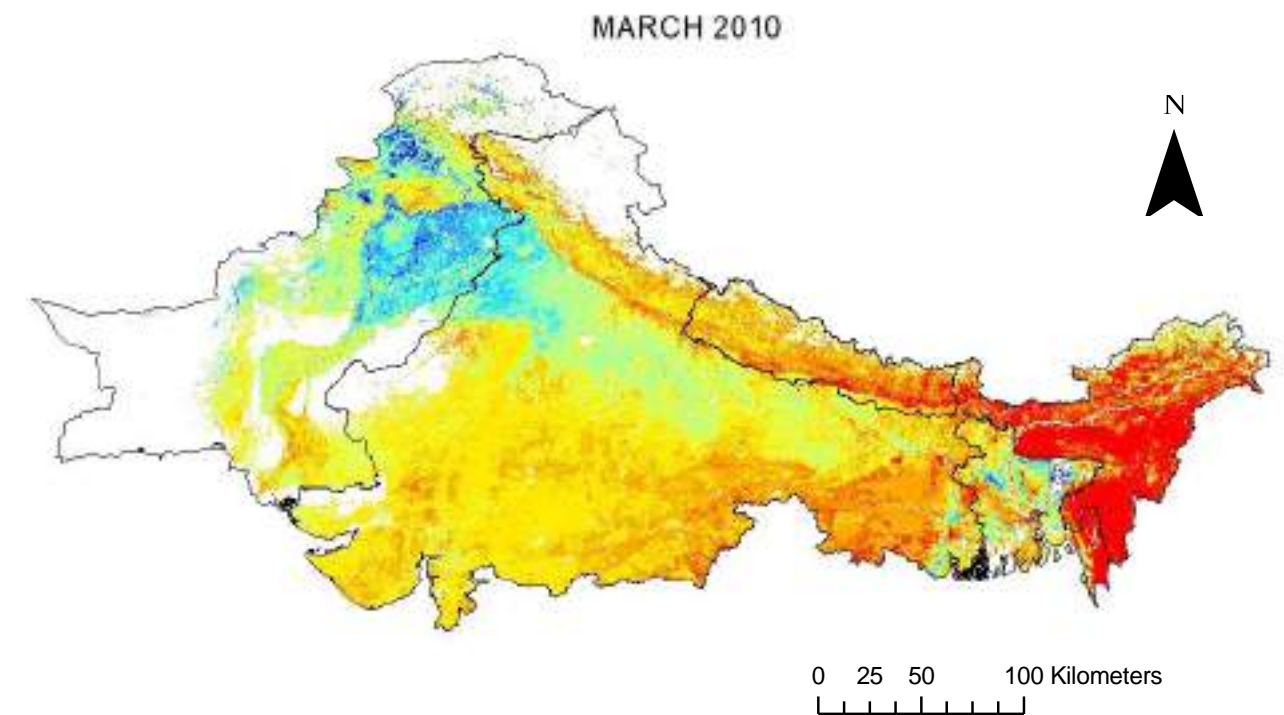
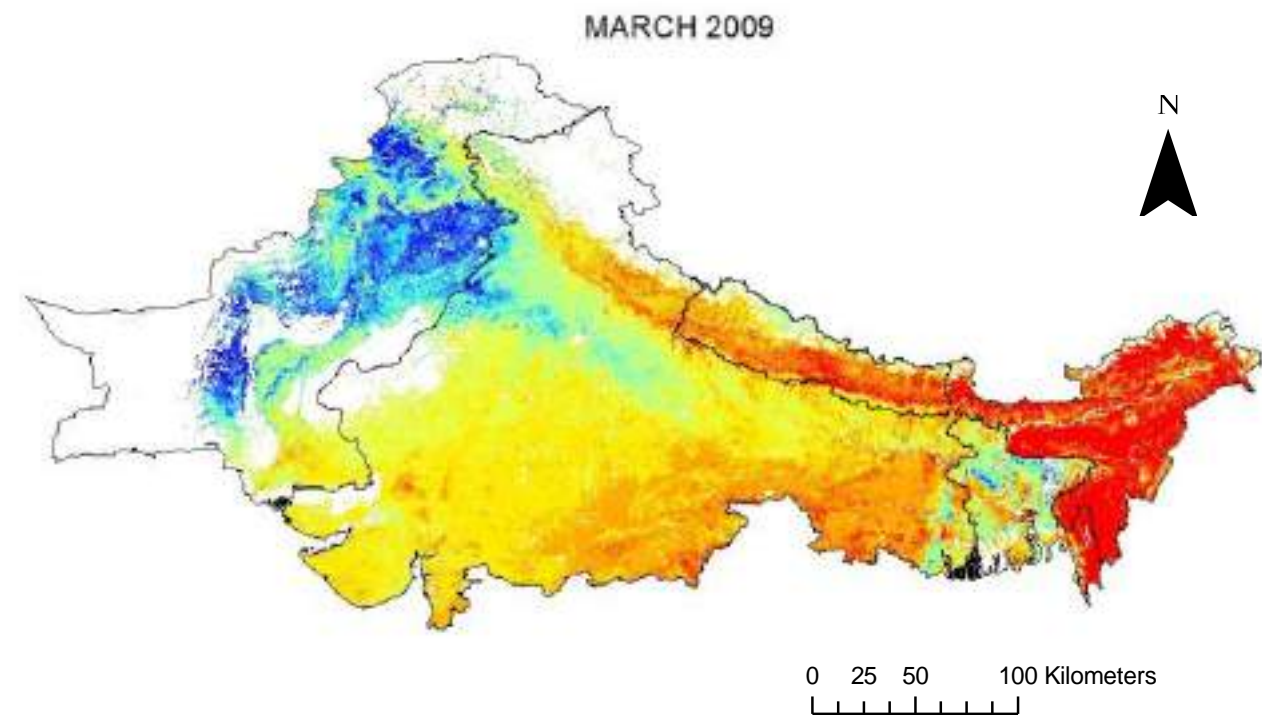




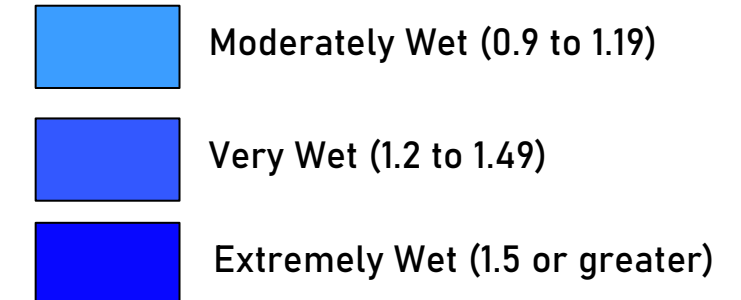
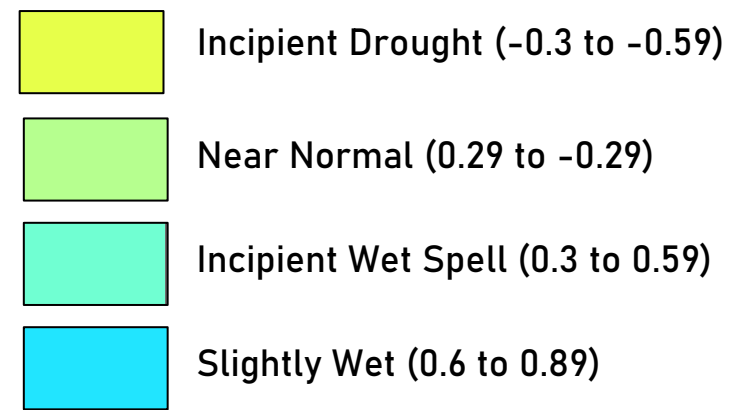
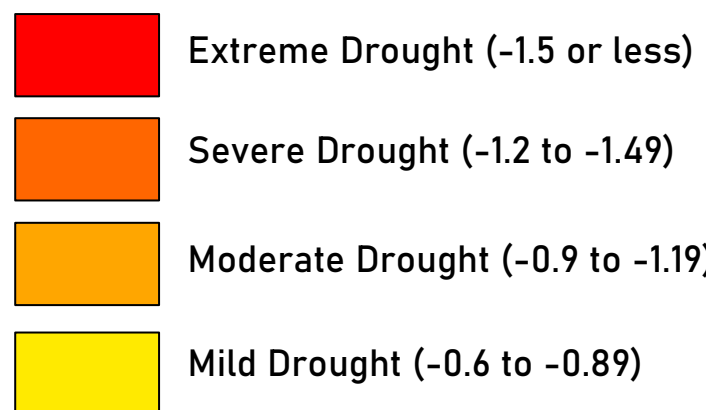


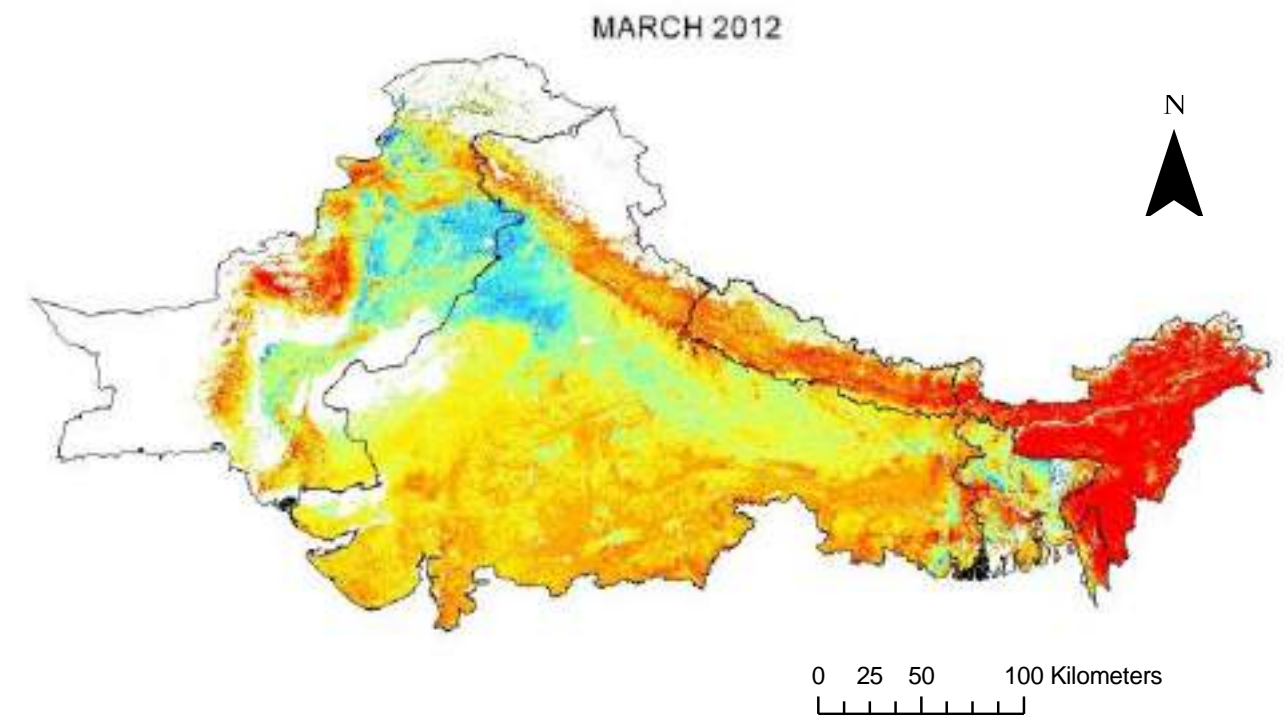
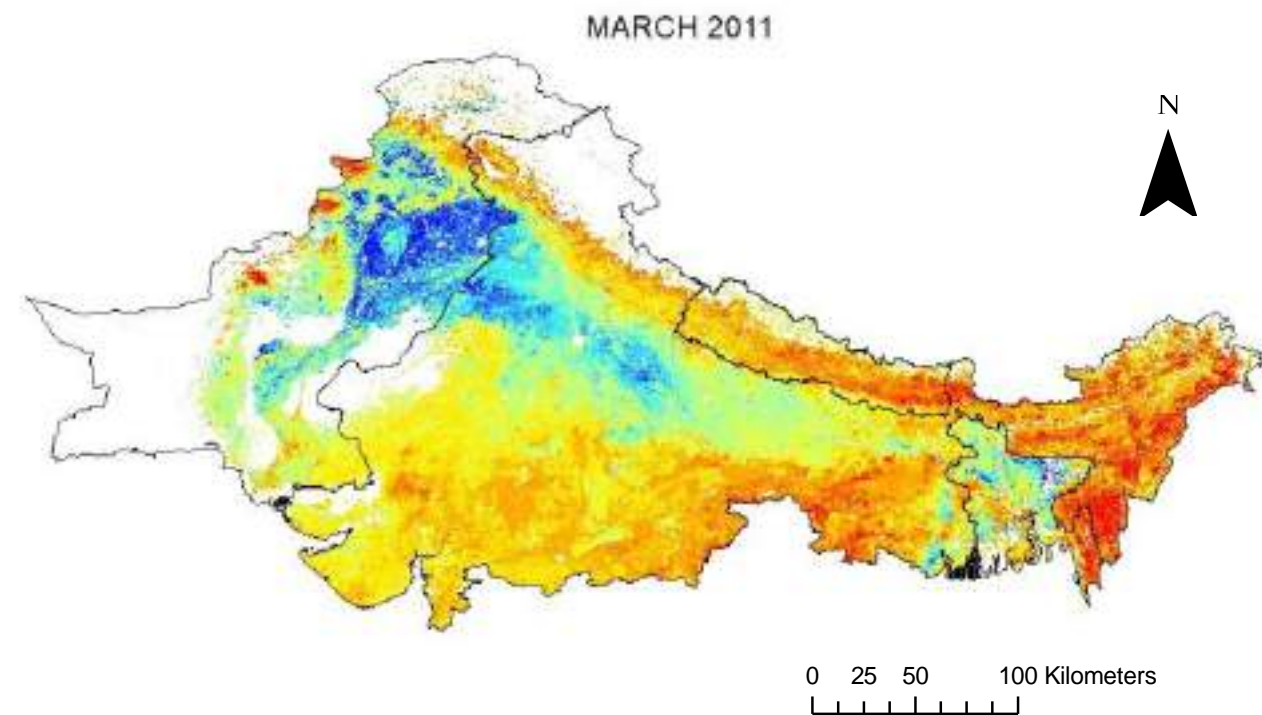
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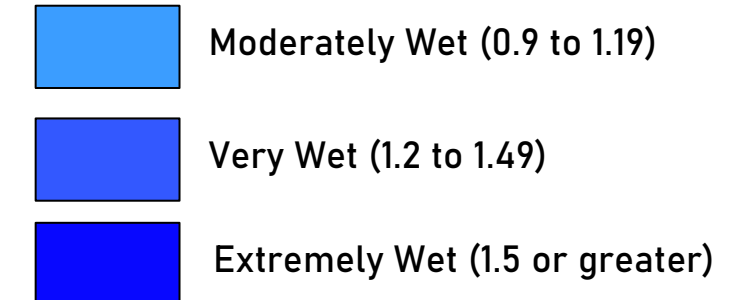
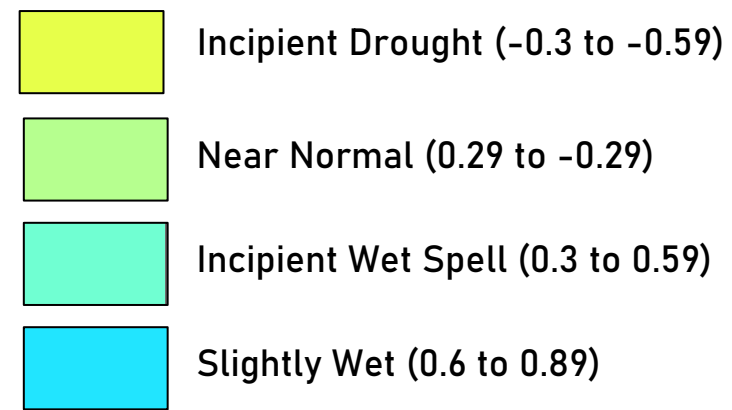
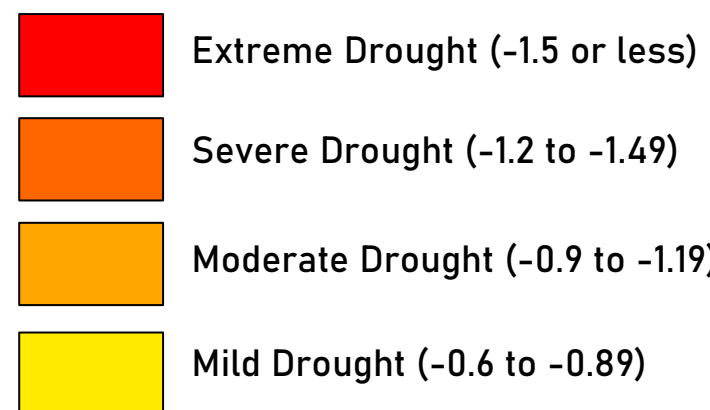


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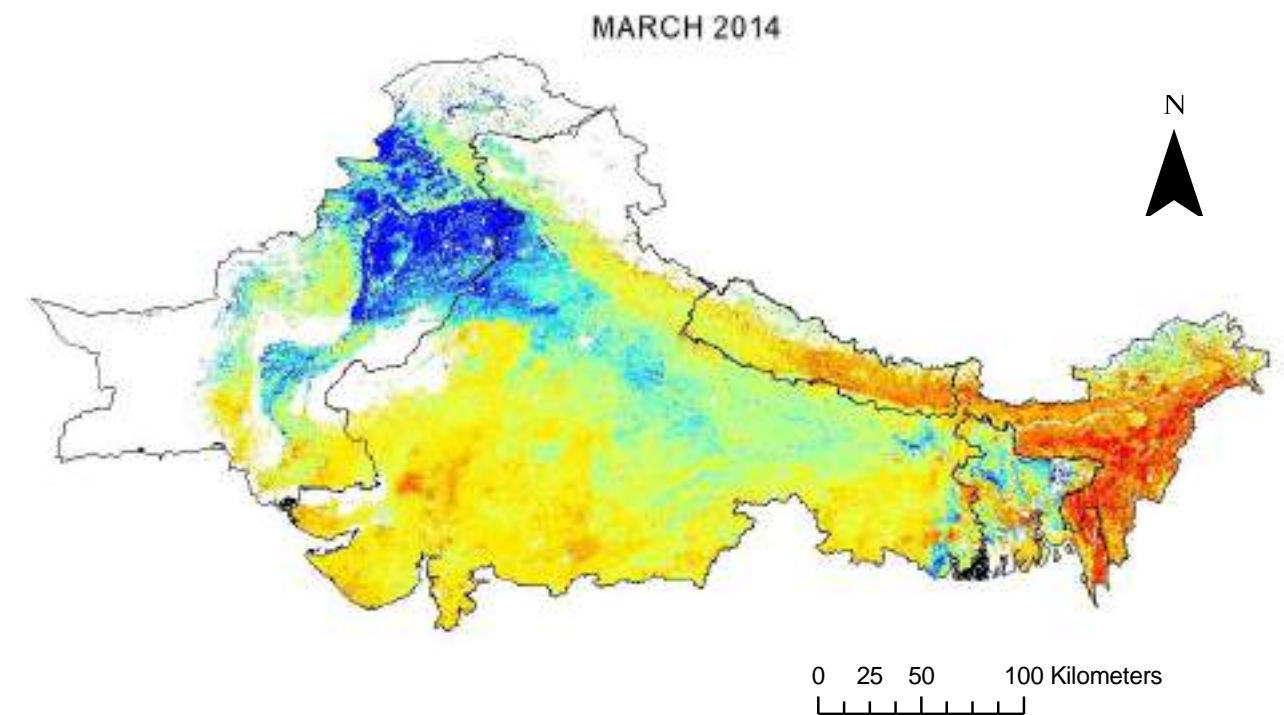
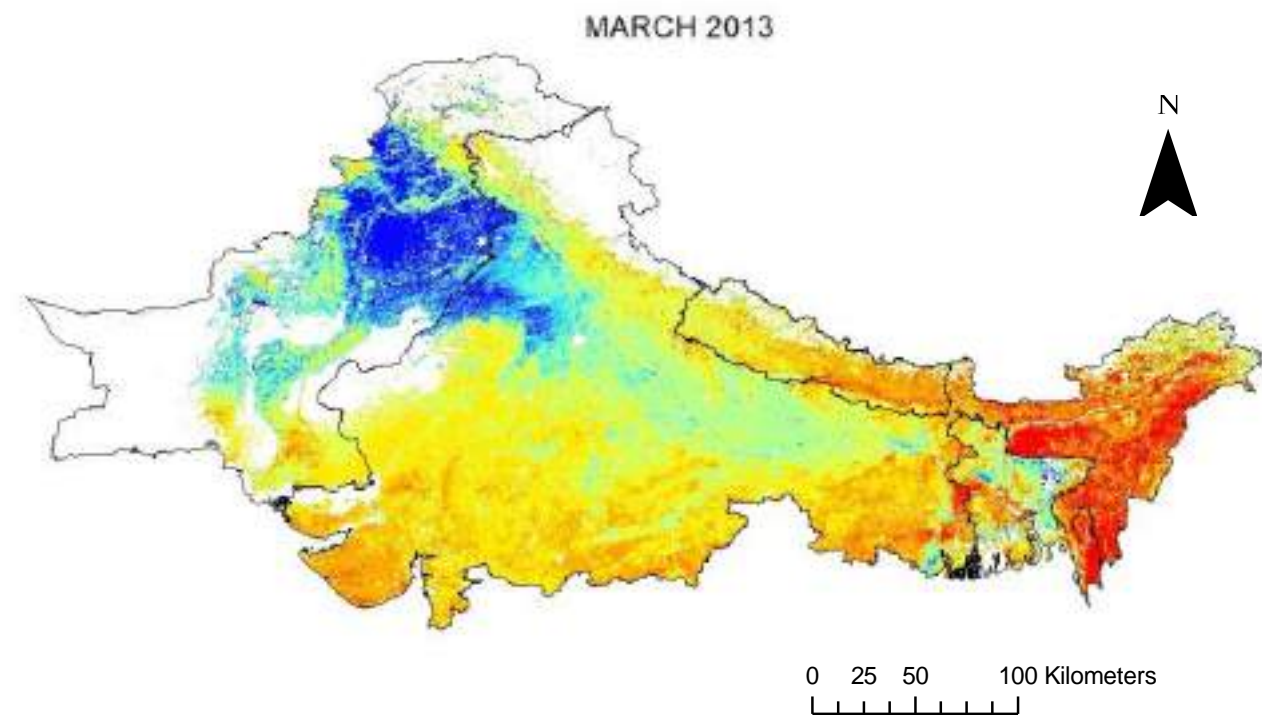




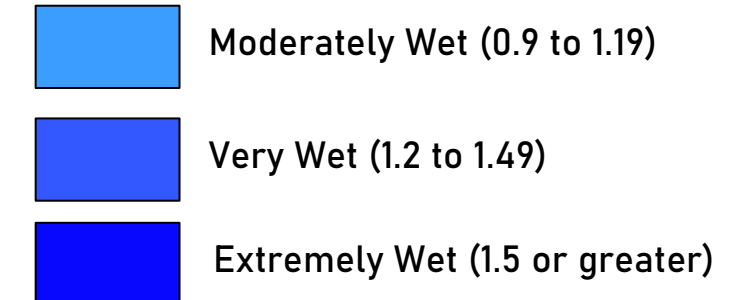
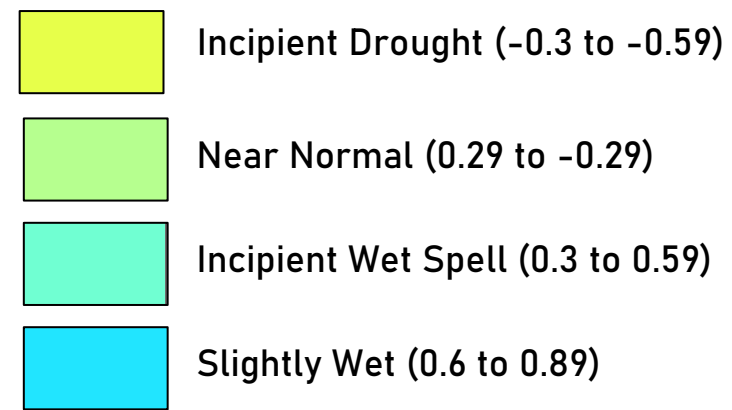
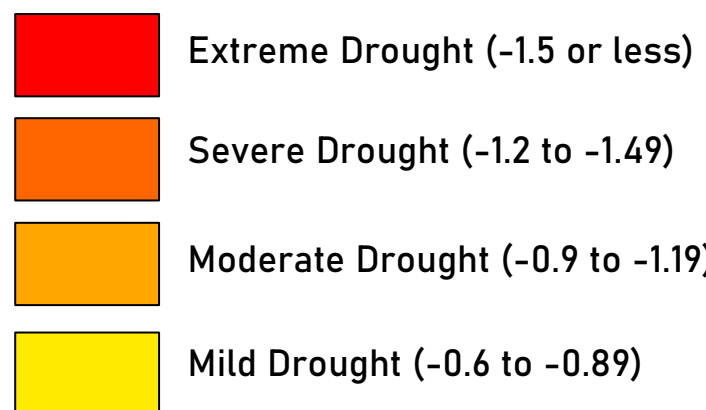
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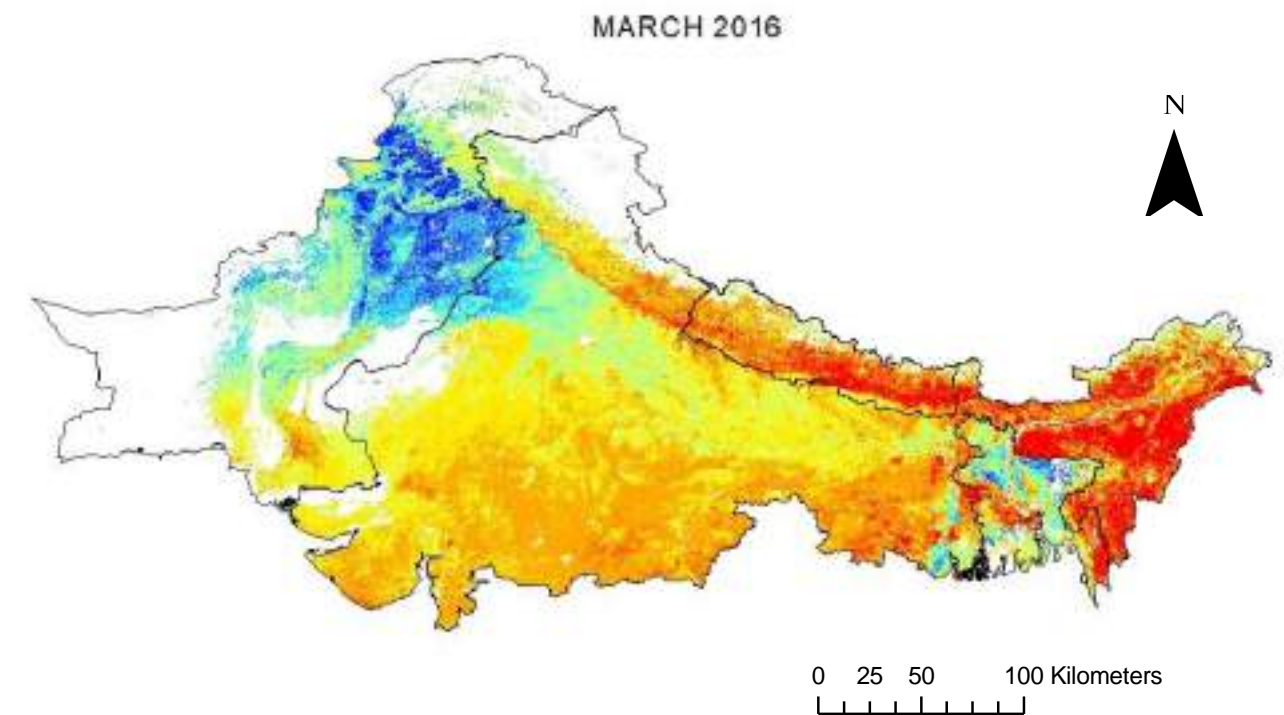
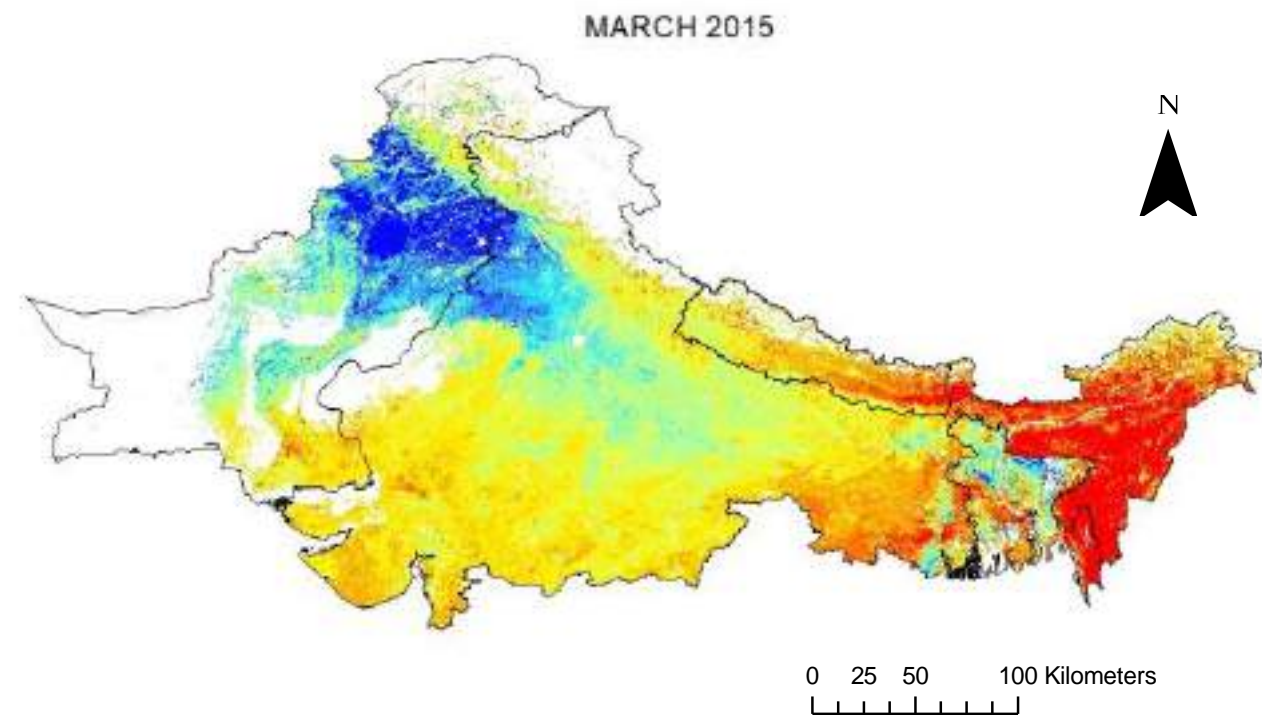




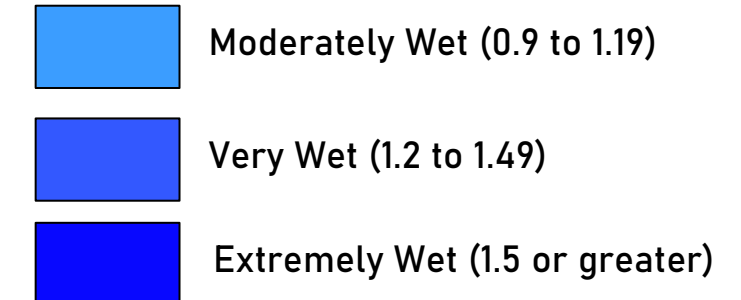
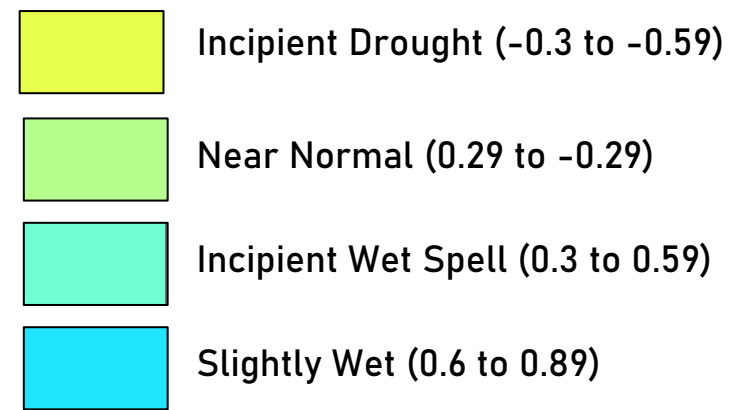
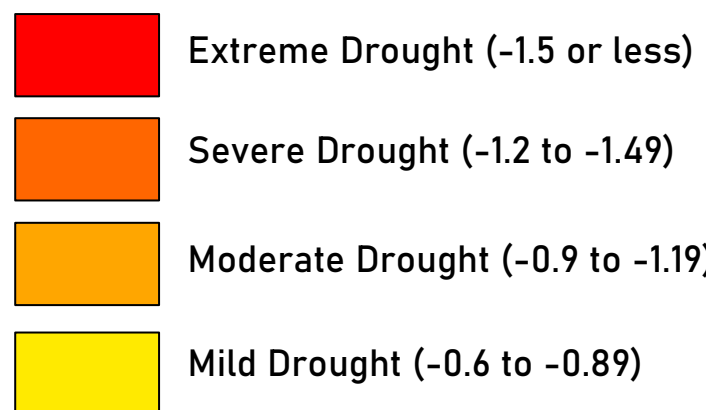


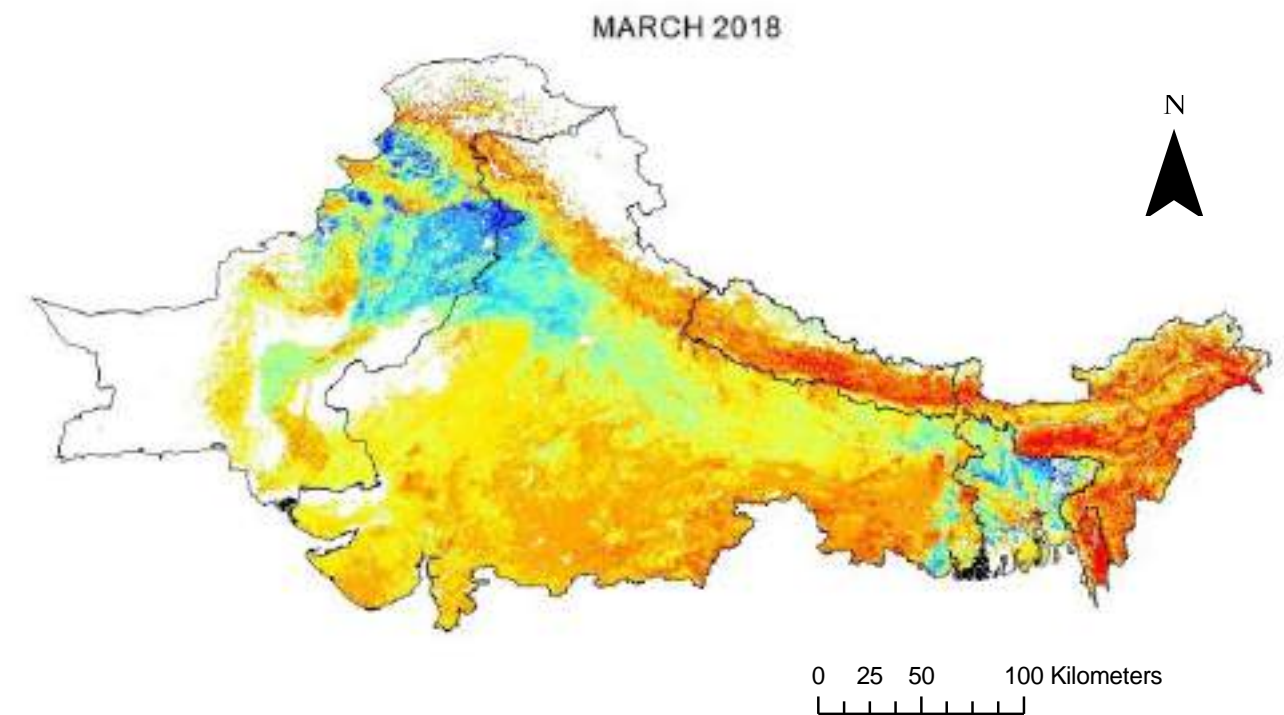
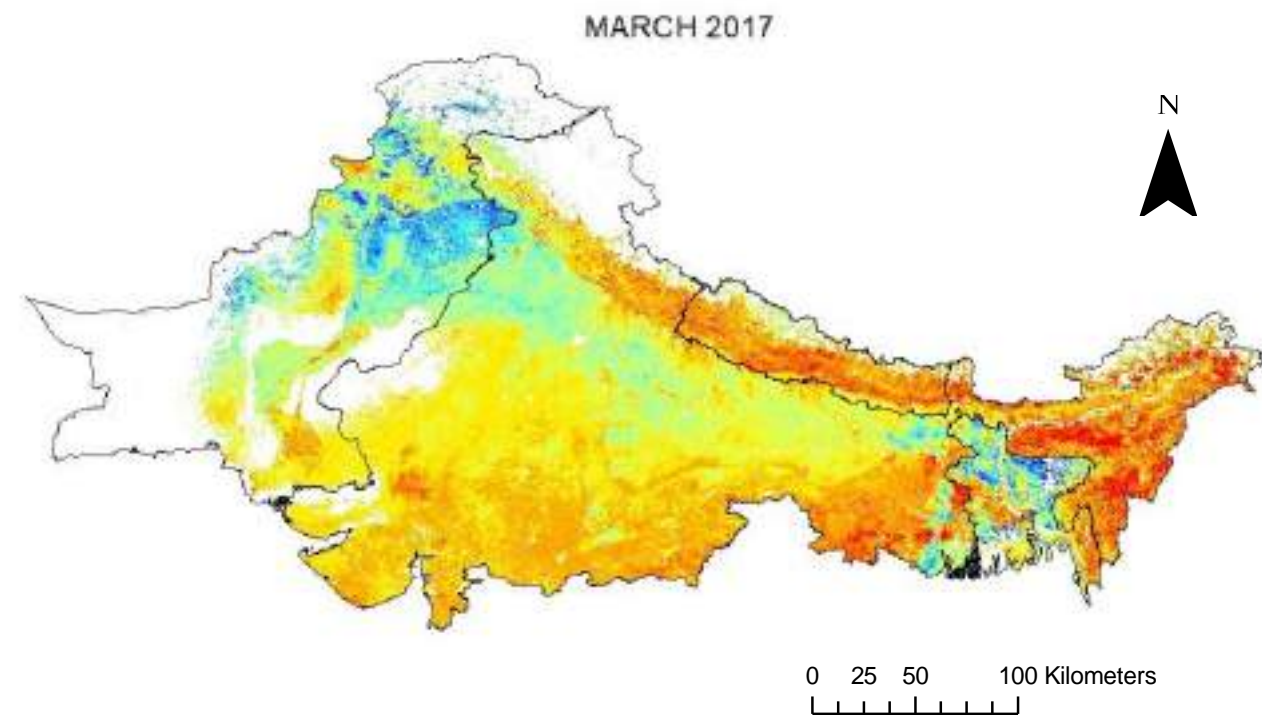
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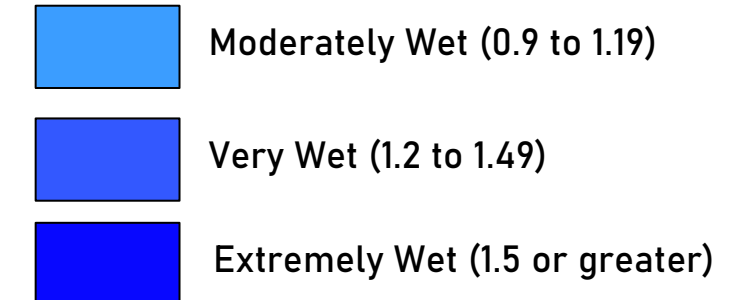
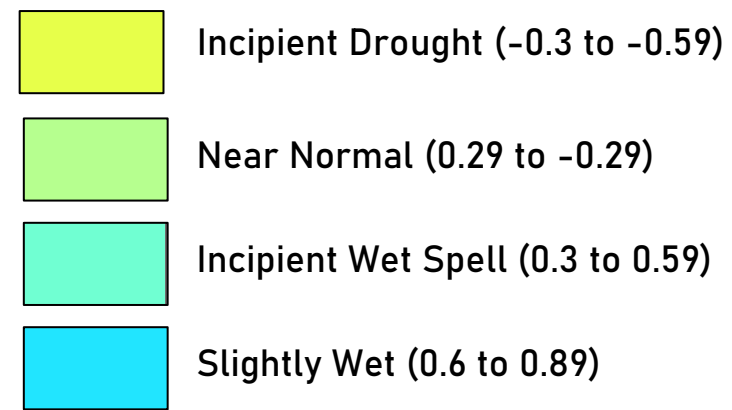
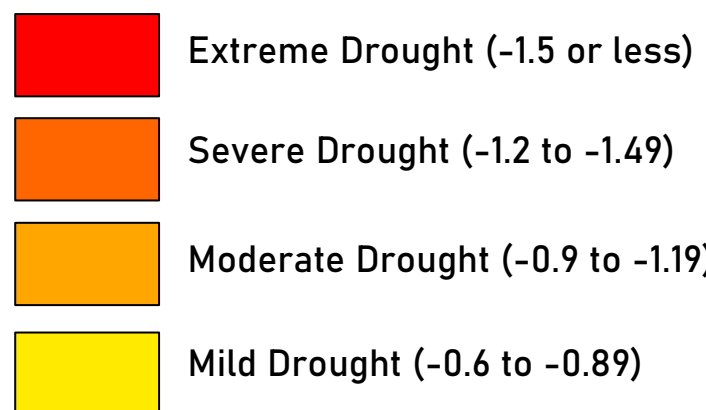


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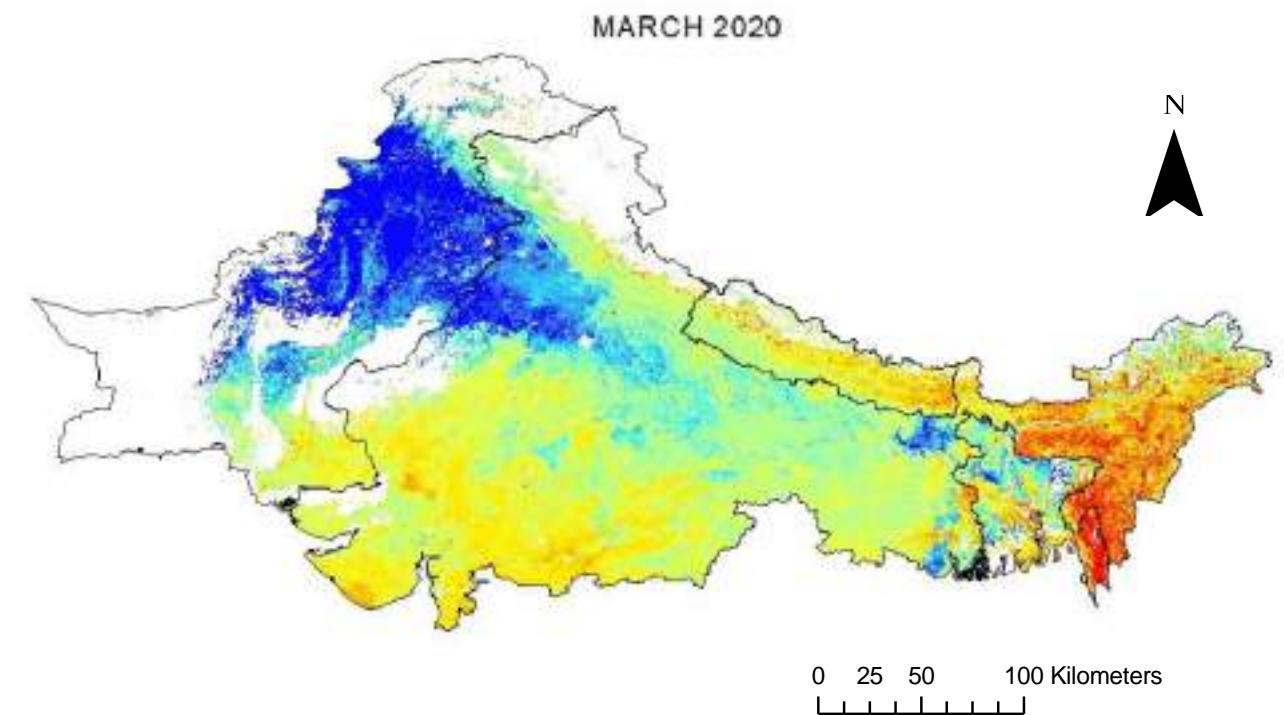
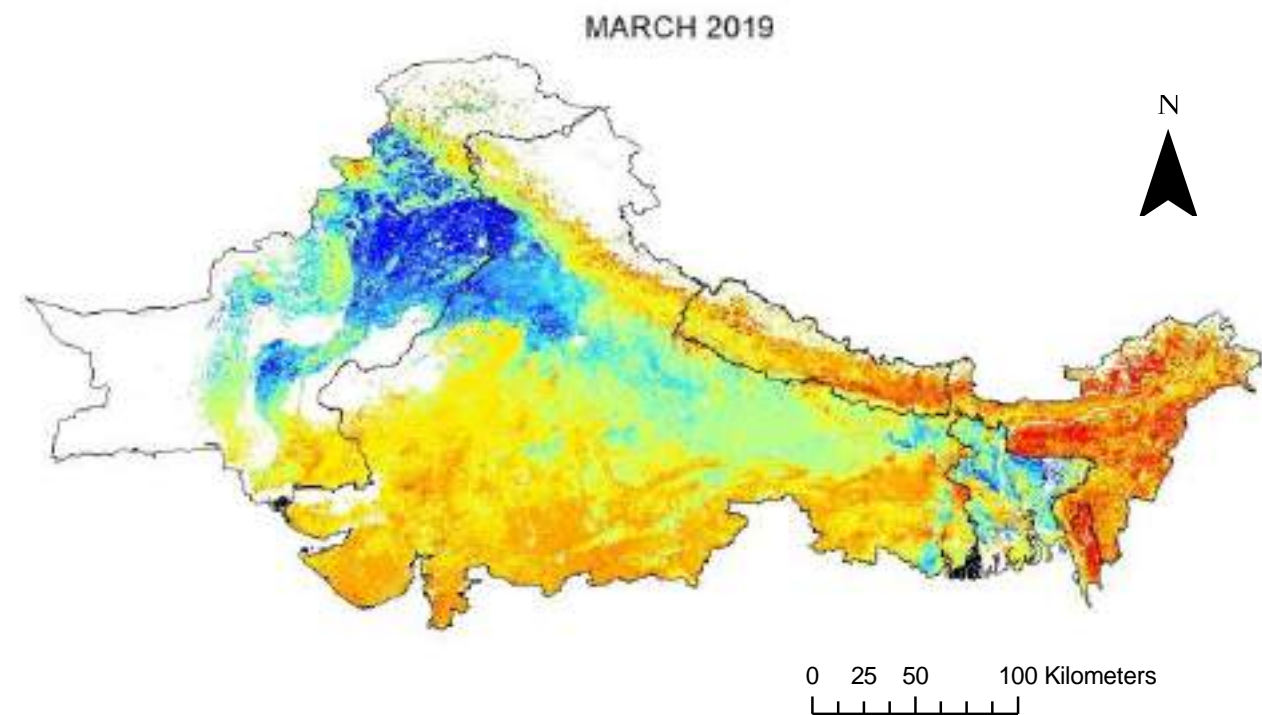




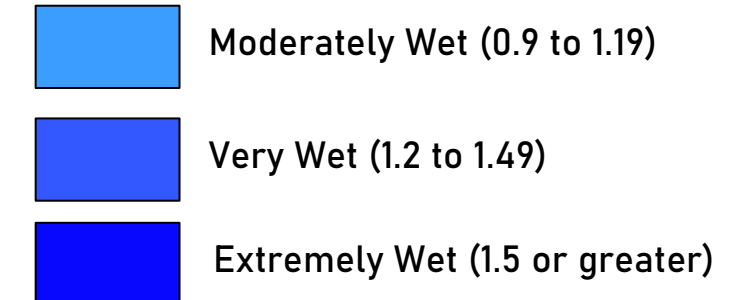
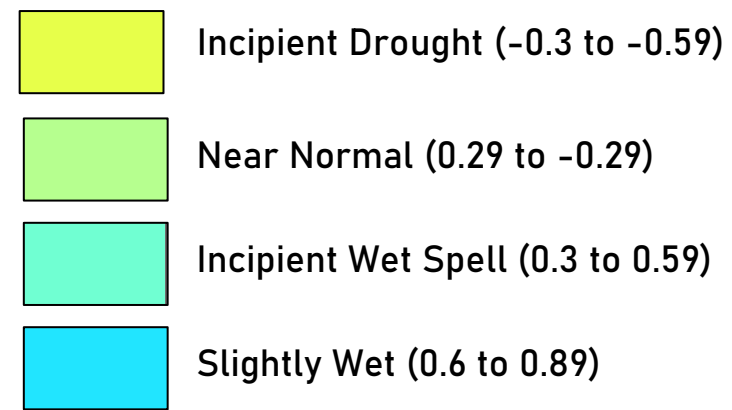
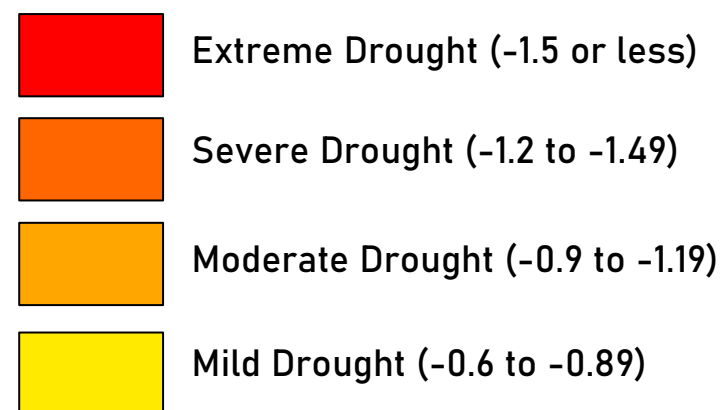
### Legend







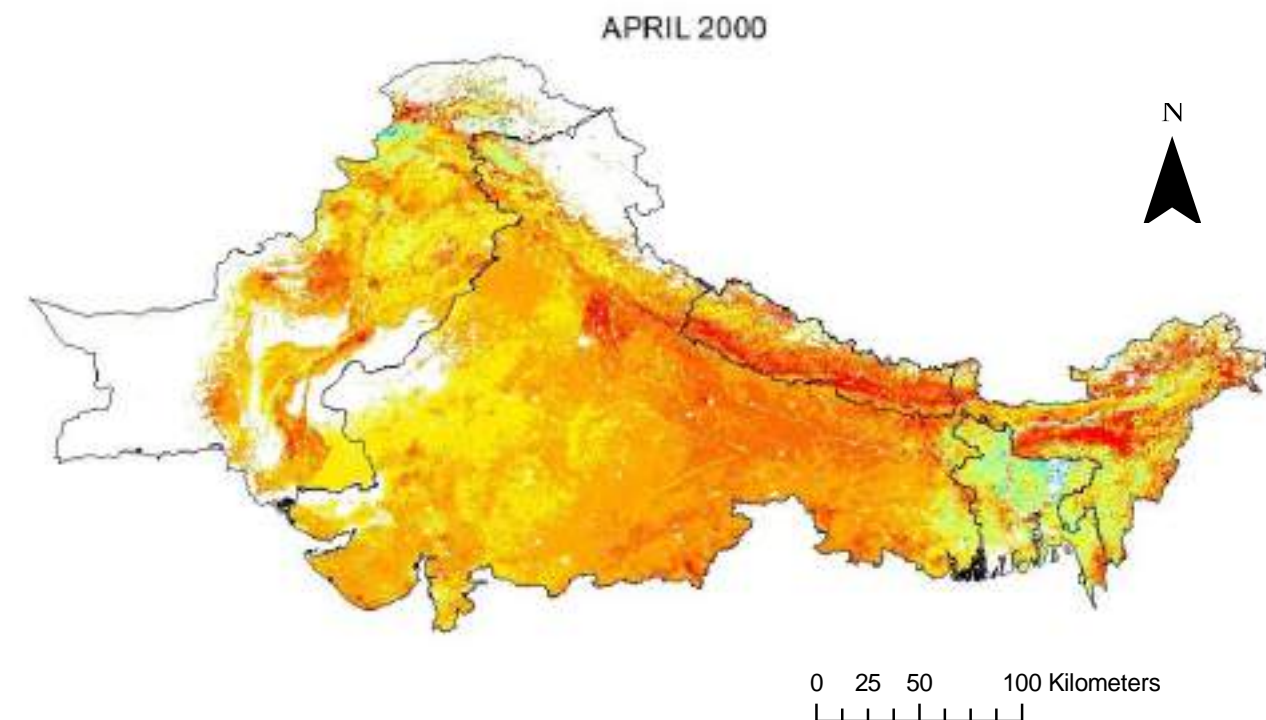
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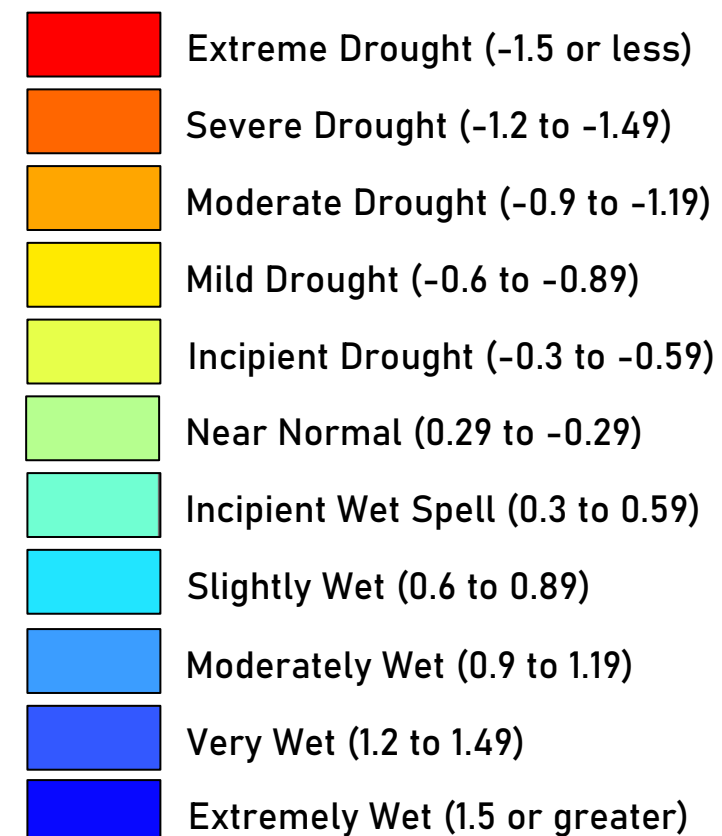
## April DSI Maps

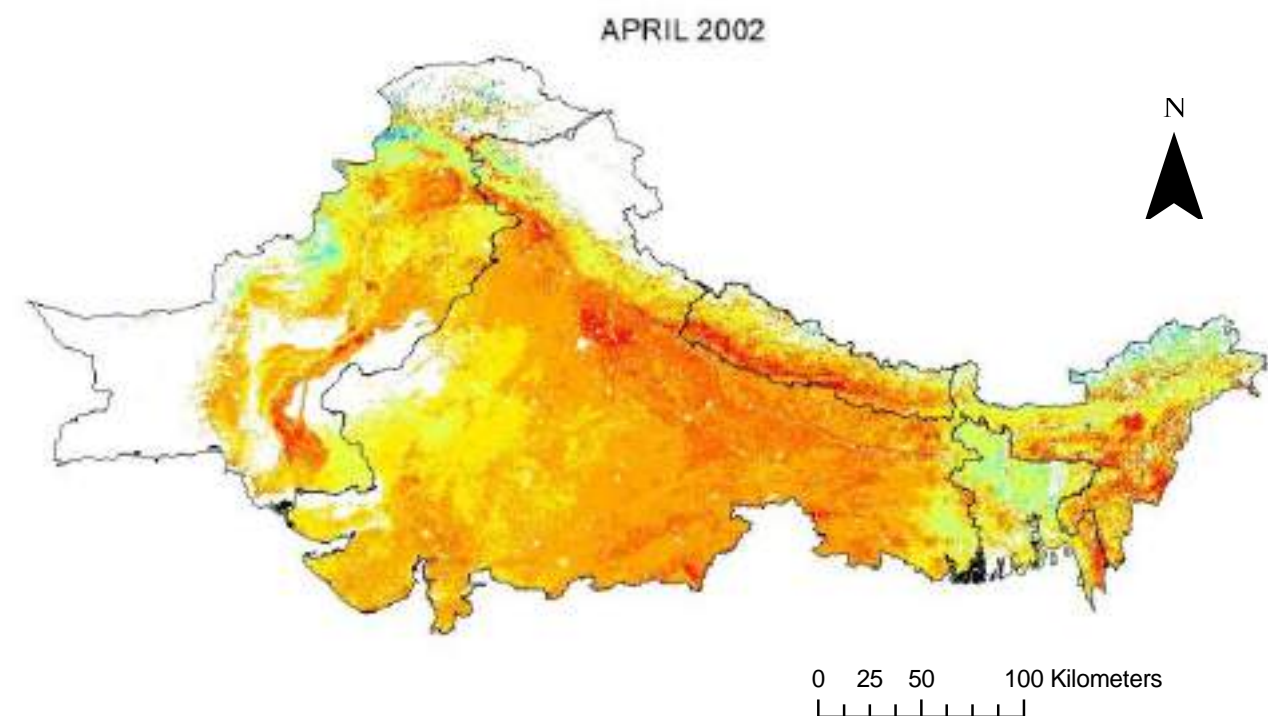
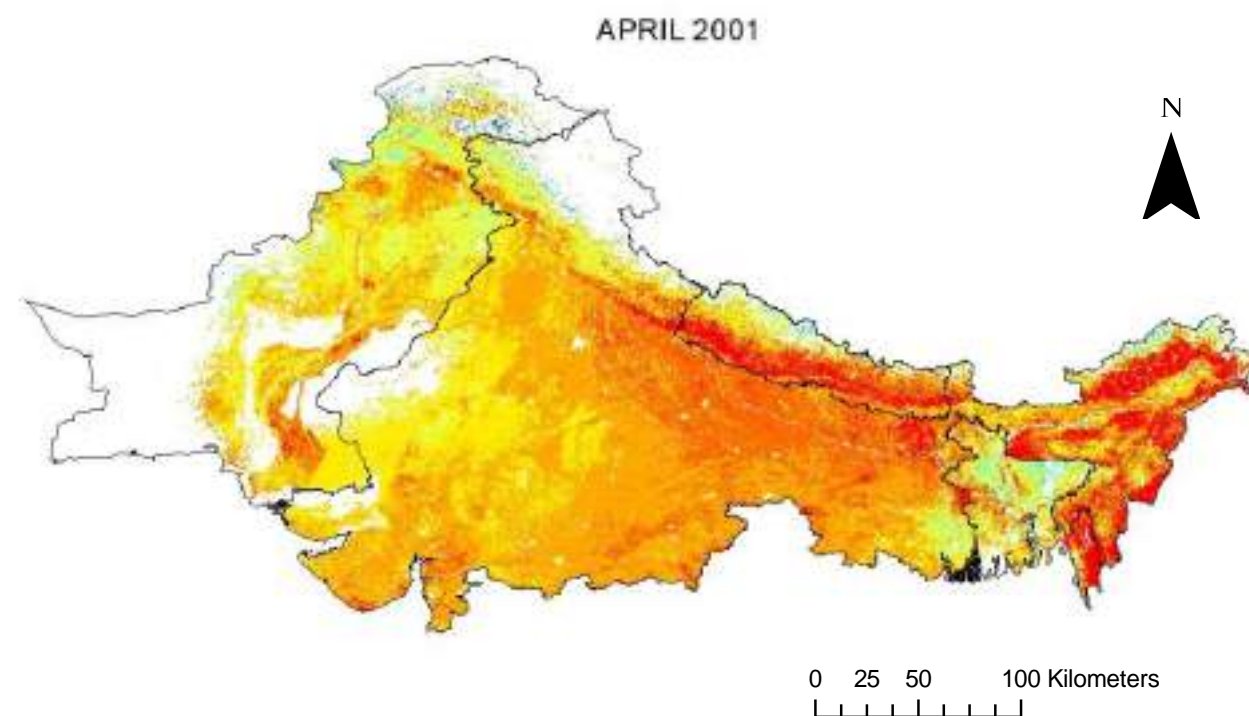
Moderate drought to incipient drought can be prevailed in April. Most dry condition was identified in 2000 with DSI value -0.93. This hot and dry month is characterized by mild drought condition.

Mean April DSI Values		
Year	DSI Values	Drought Condition
2000	-0.93	Moderate Drought
2001	-1.01	Moderate Drought
2002	-0.81	Mild Drought
2003	-0.71	Mild Drought
2004	-0.79	Mild Drought
2005	-0.70	Mild Drought
2006	-0.78	Mild Drought
2007	-0.54	Incipient Drought
2008	-0.76	Mild Drought
2009	-0.74	Mild Drought
2010	-0.88	Mild Drought
2011	-0.70	Mild Drought
2012	-0.69	Mild Drought
2013	-0.63	Mild Drought
2014	-0.77	Mild Drought
2015	-0.62	Mild Drought
2016	-0.96	Moderate Drought
2017	-0.81	Mild Drought
2018	-0.71	Mild Drought
2019	-0.47	Incipient Drought
2020	-0.39	Incipient Drought

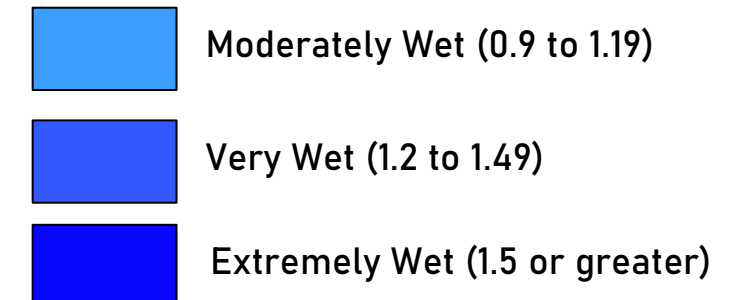
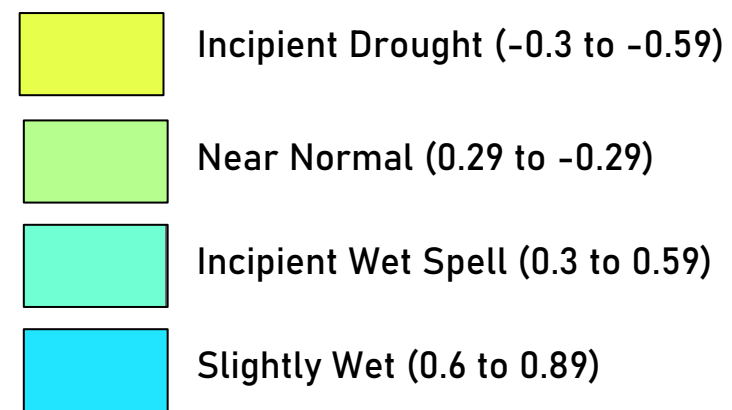
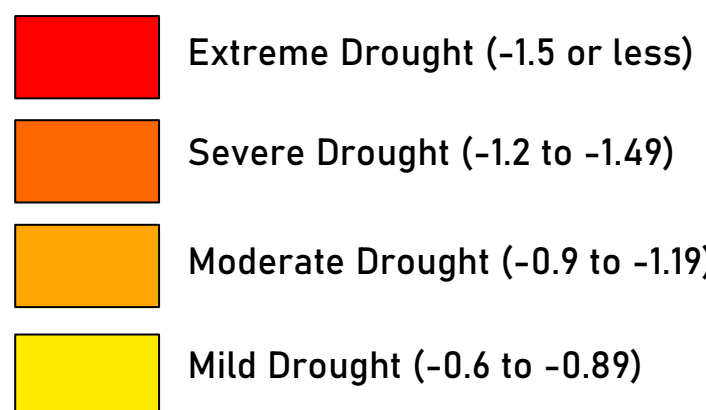


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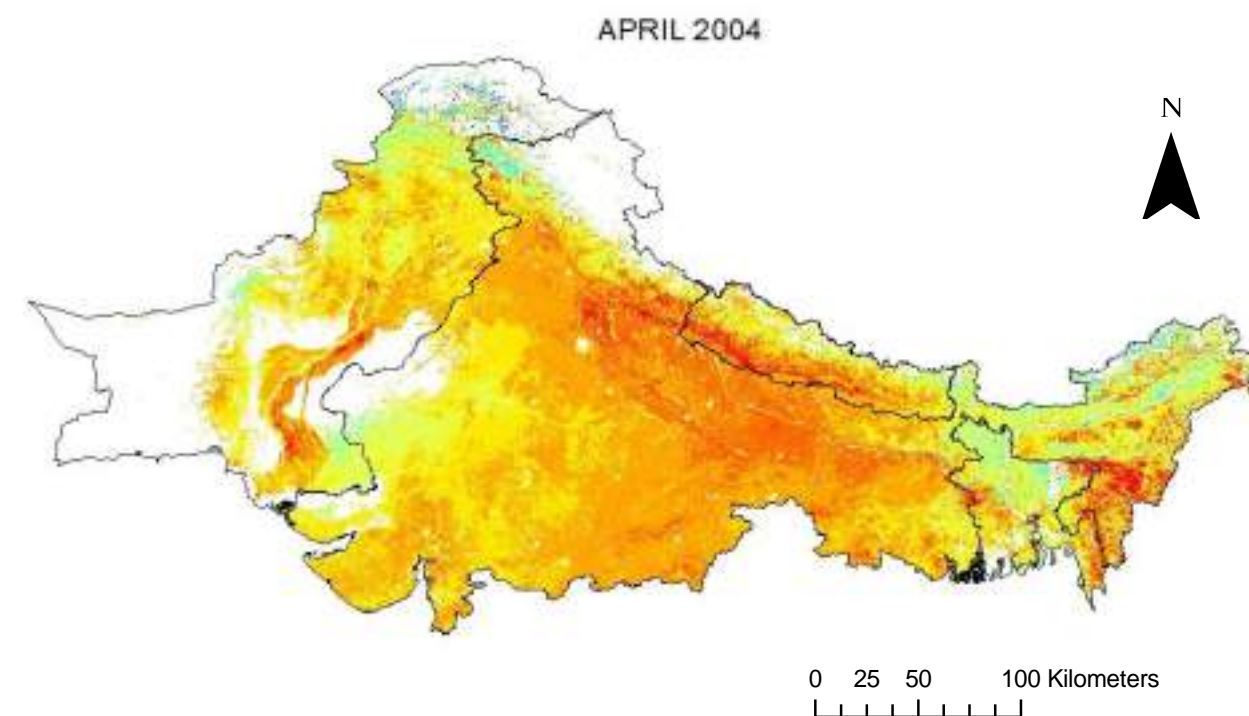
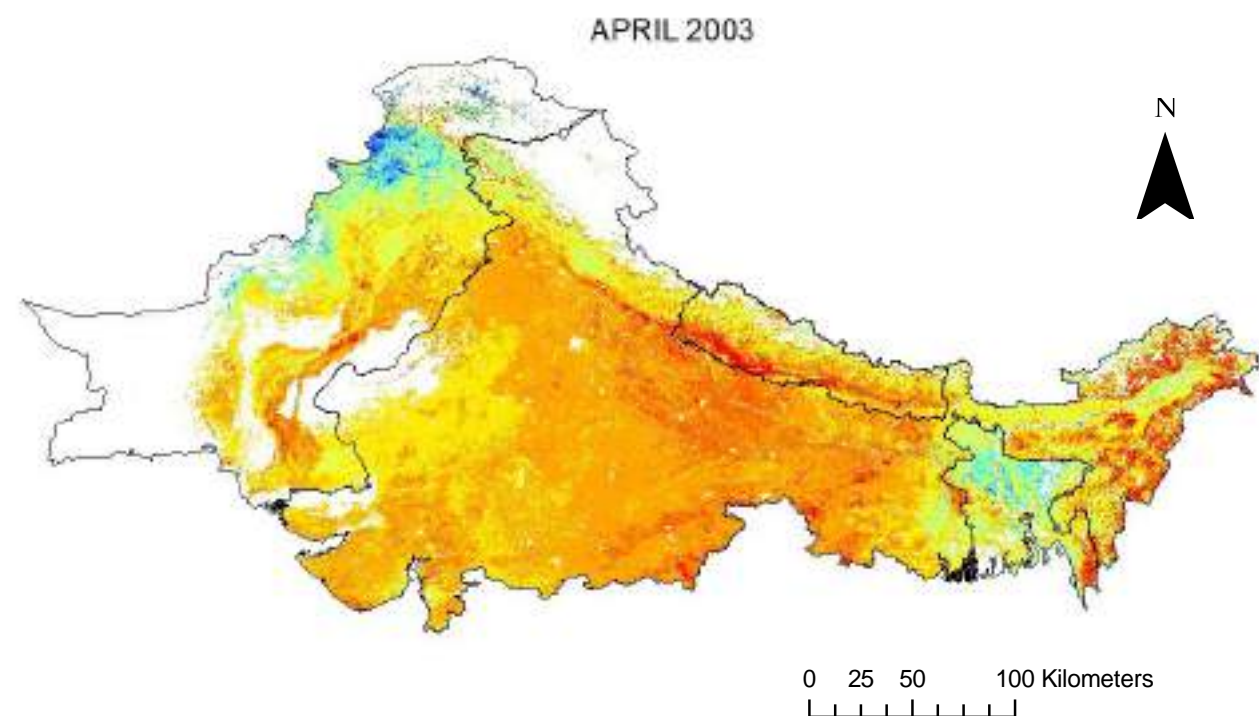




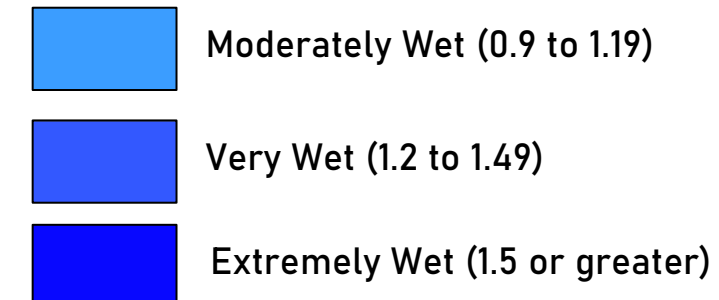
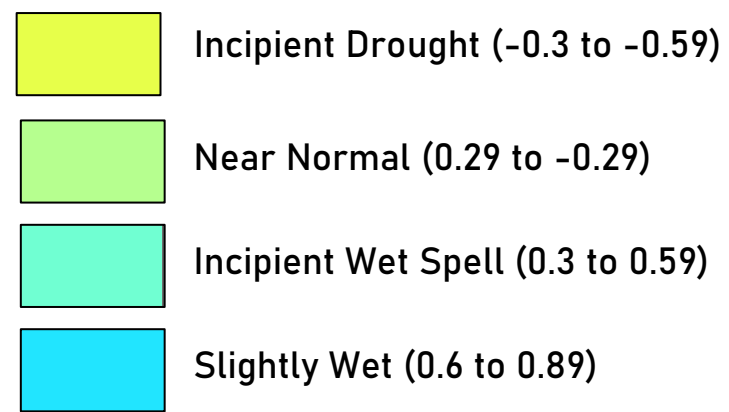
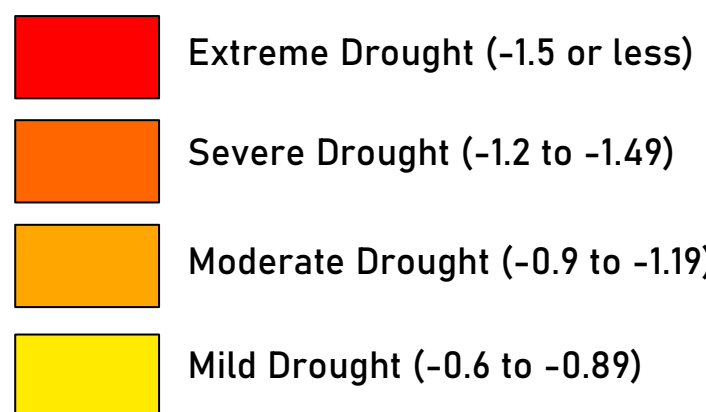
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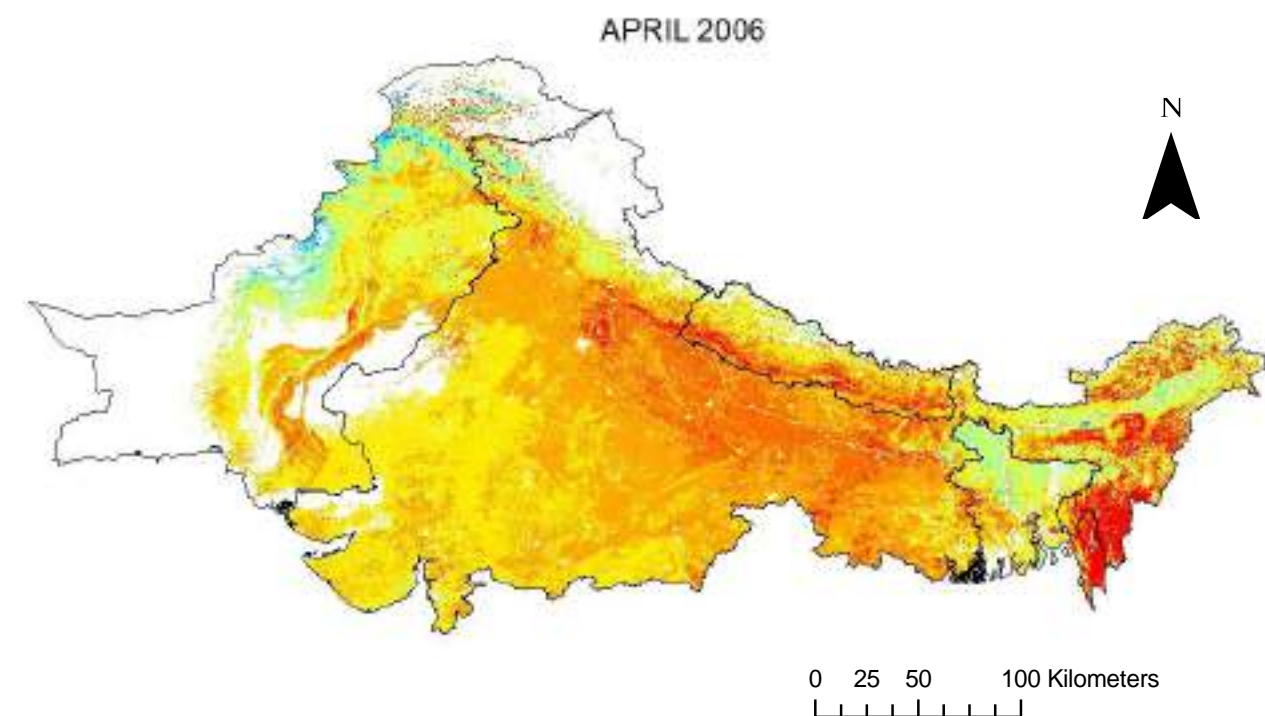
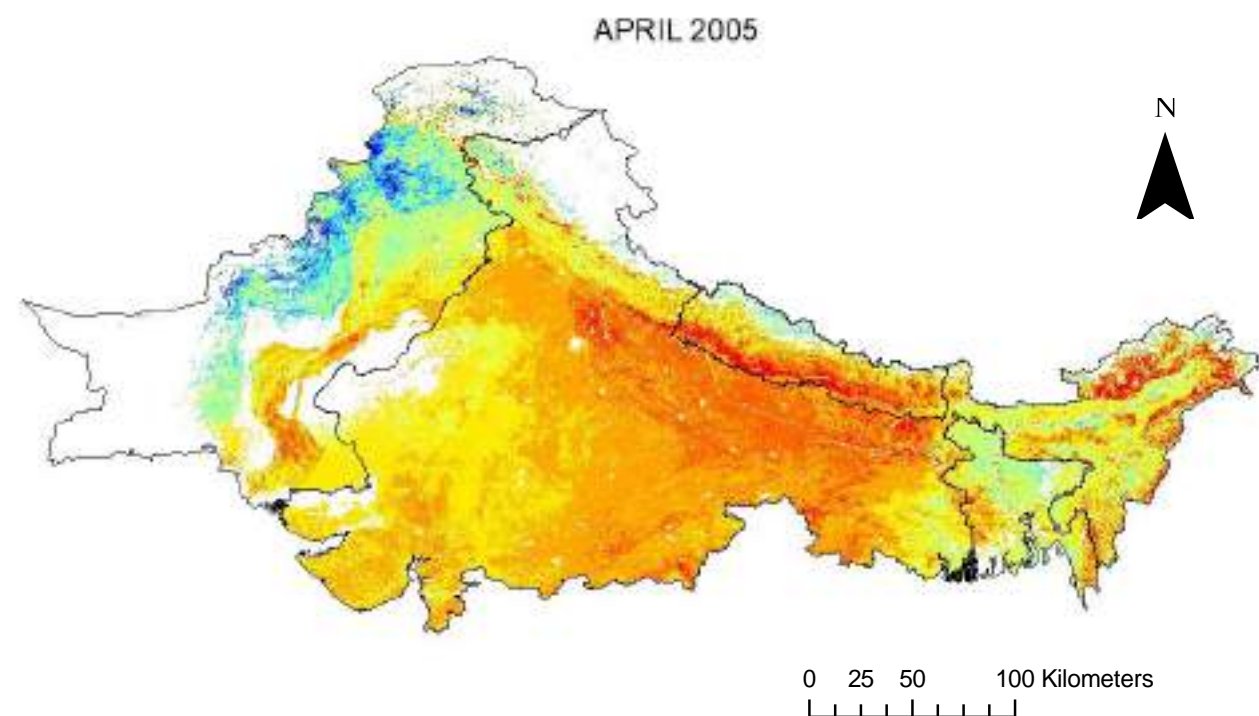




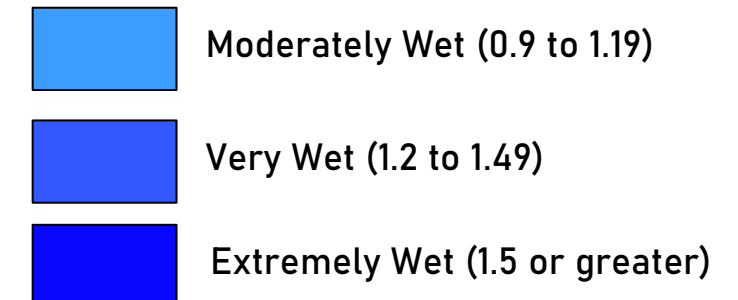
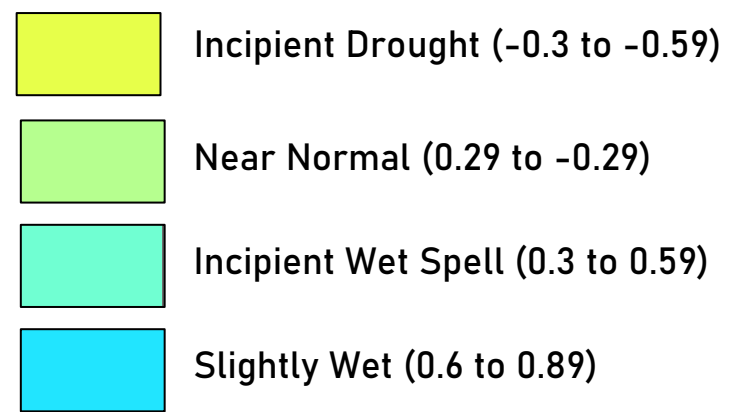
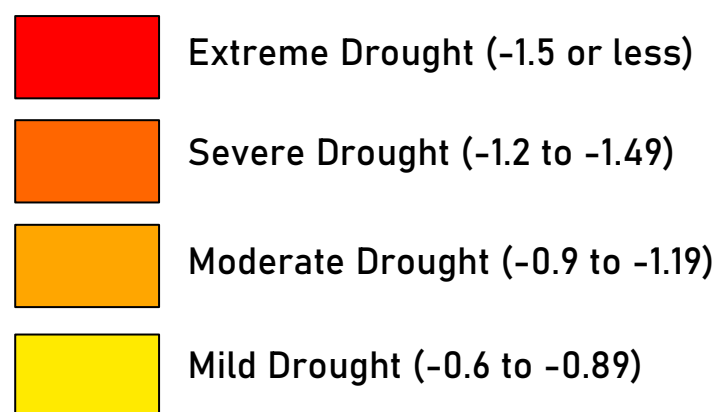


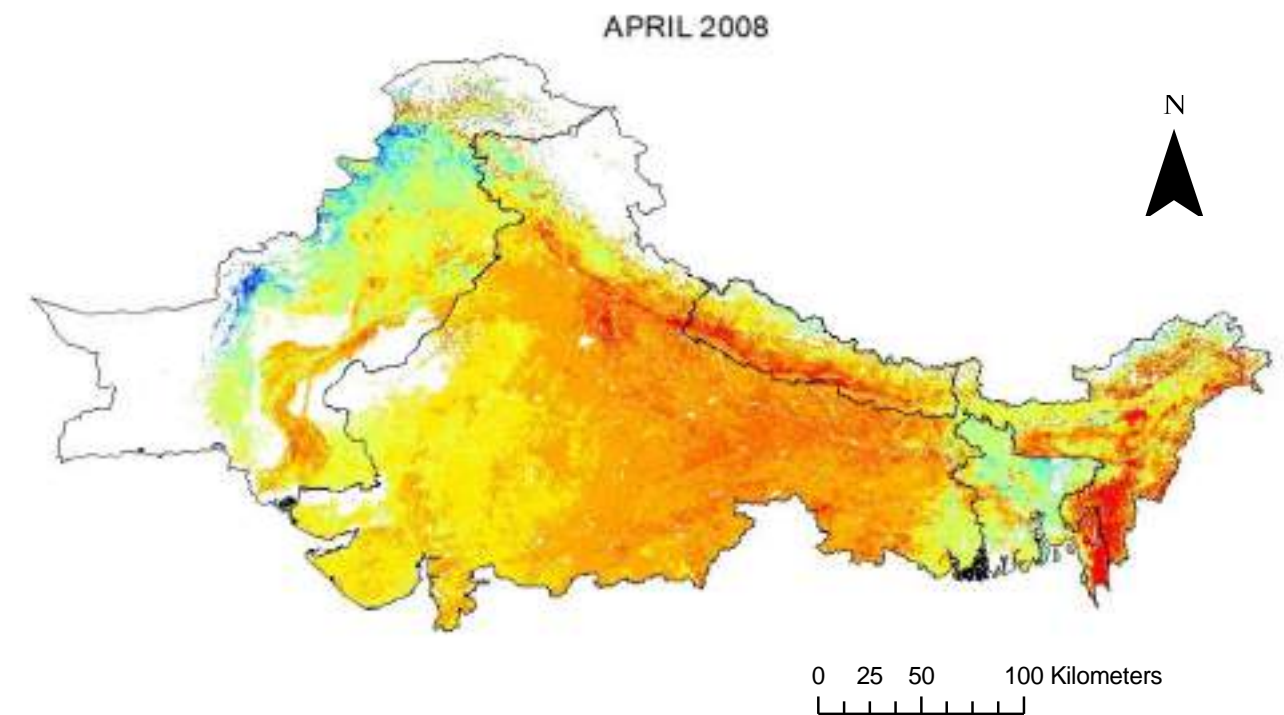
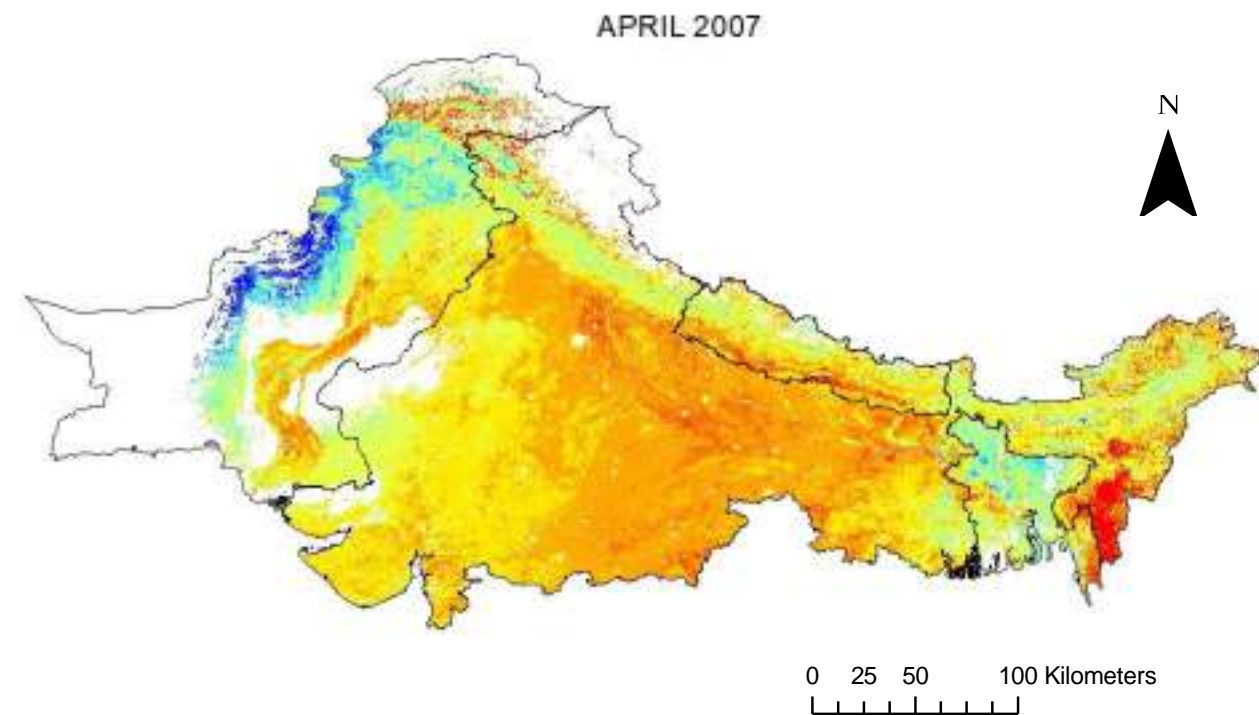
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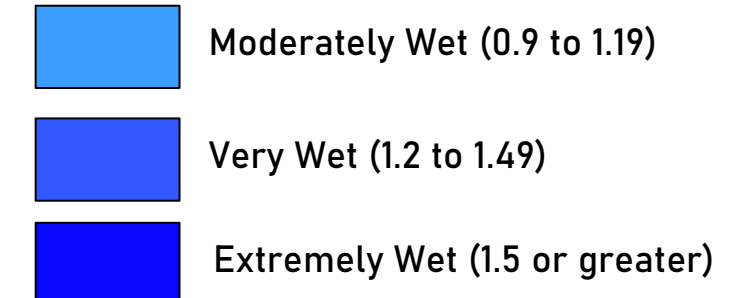
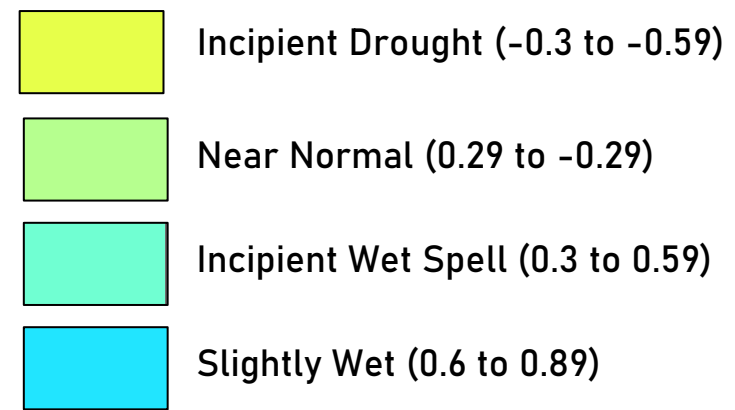
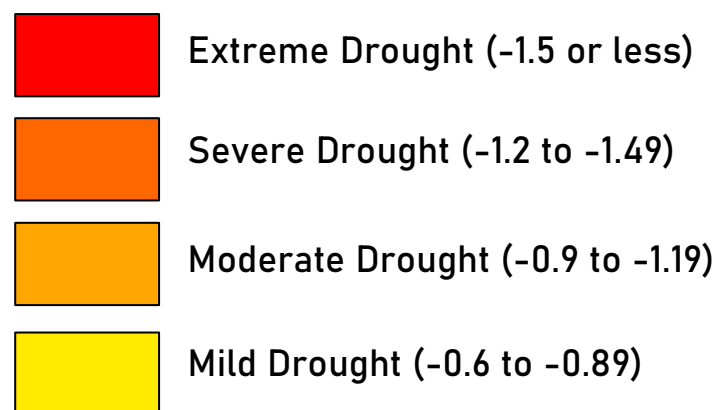


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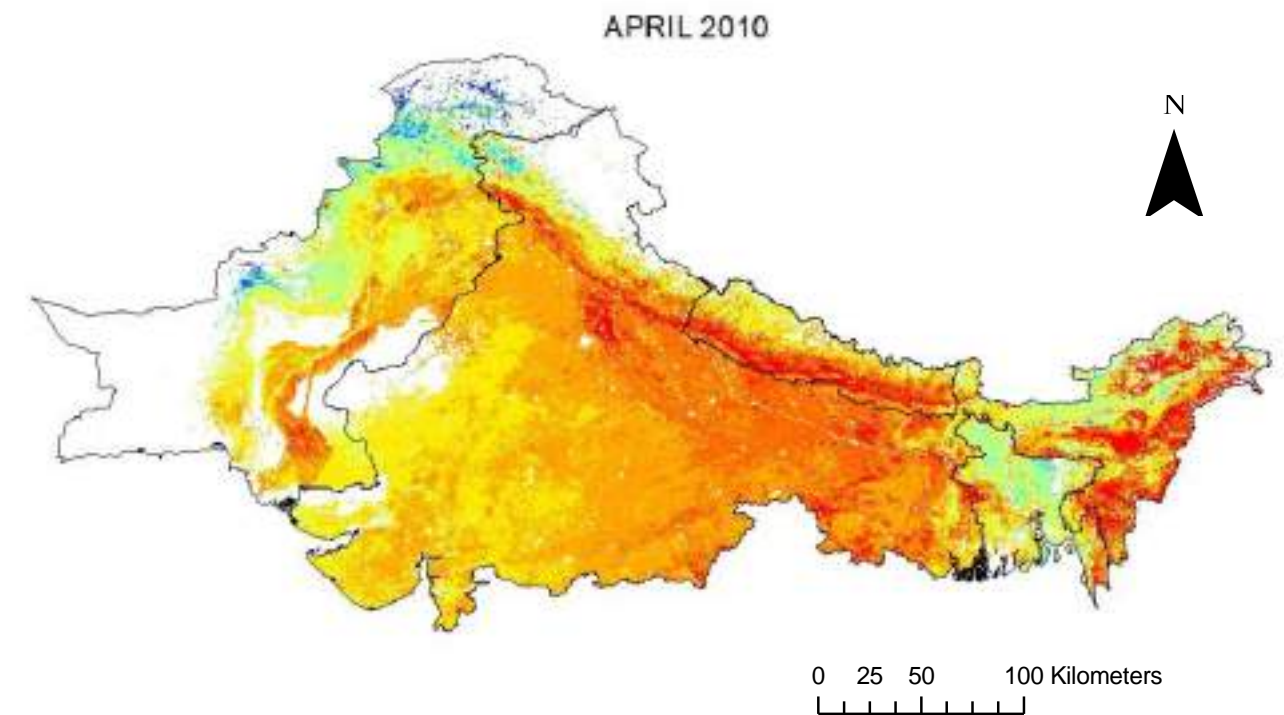
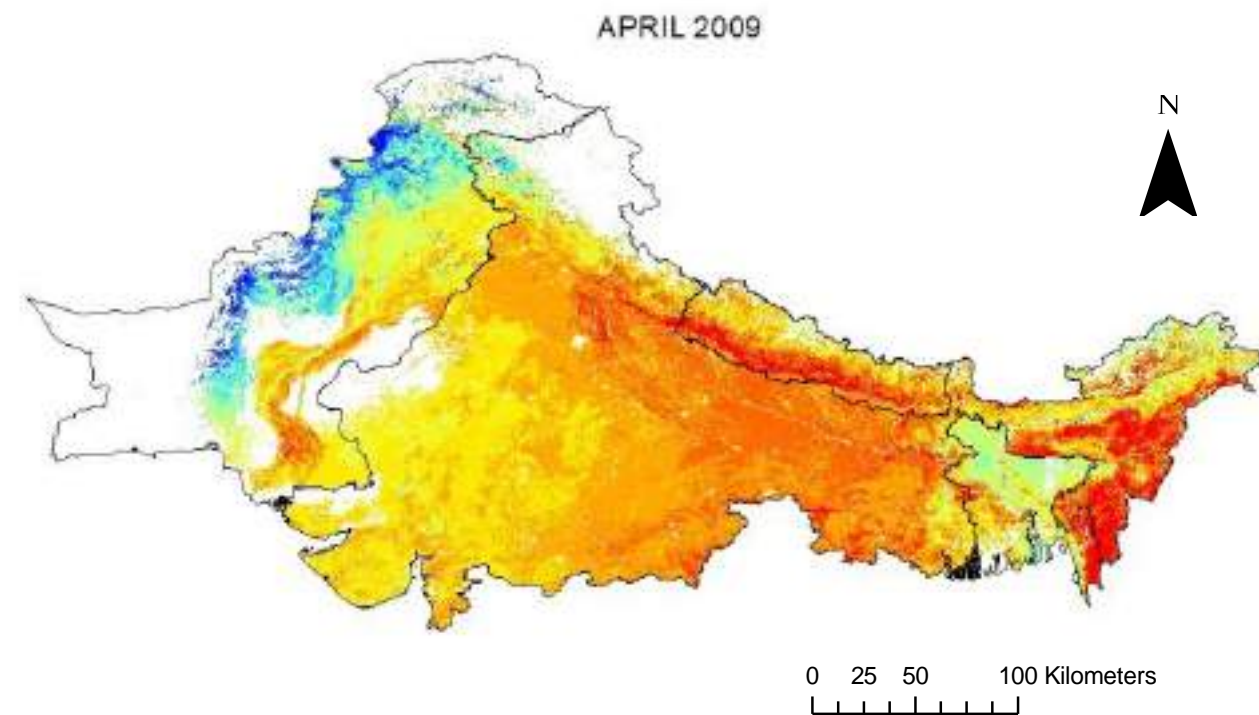




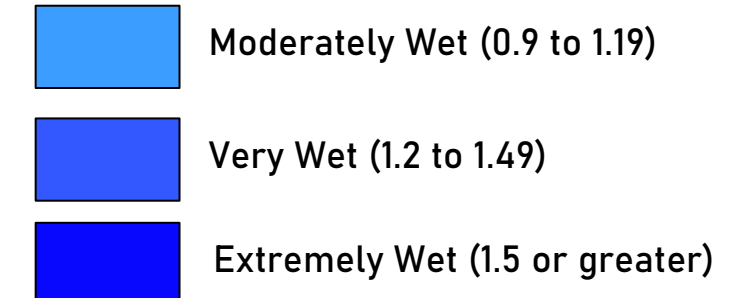
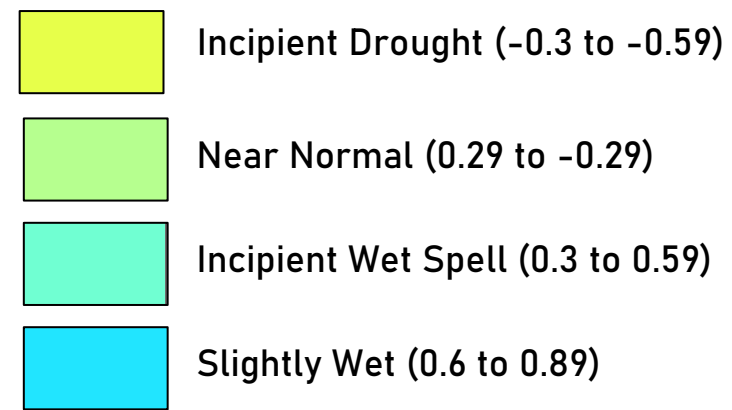
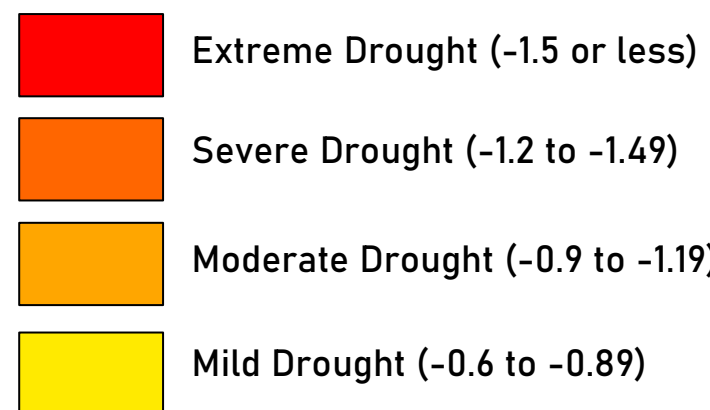
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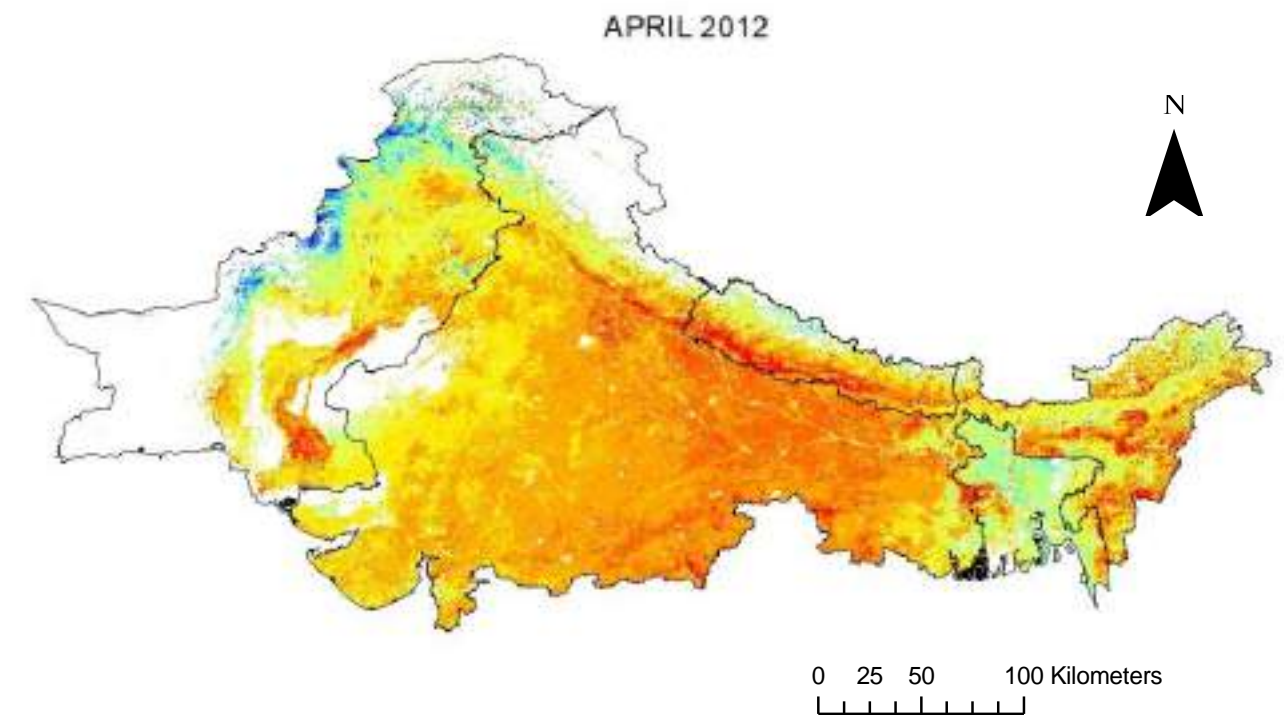
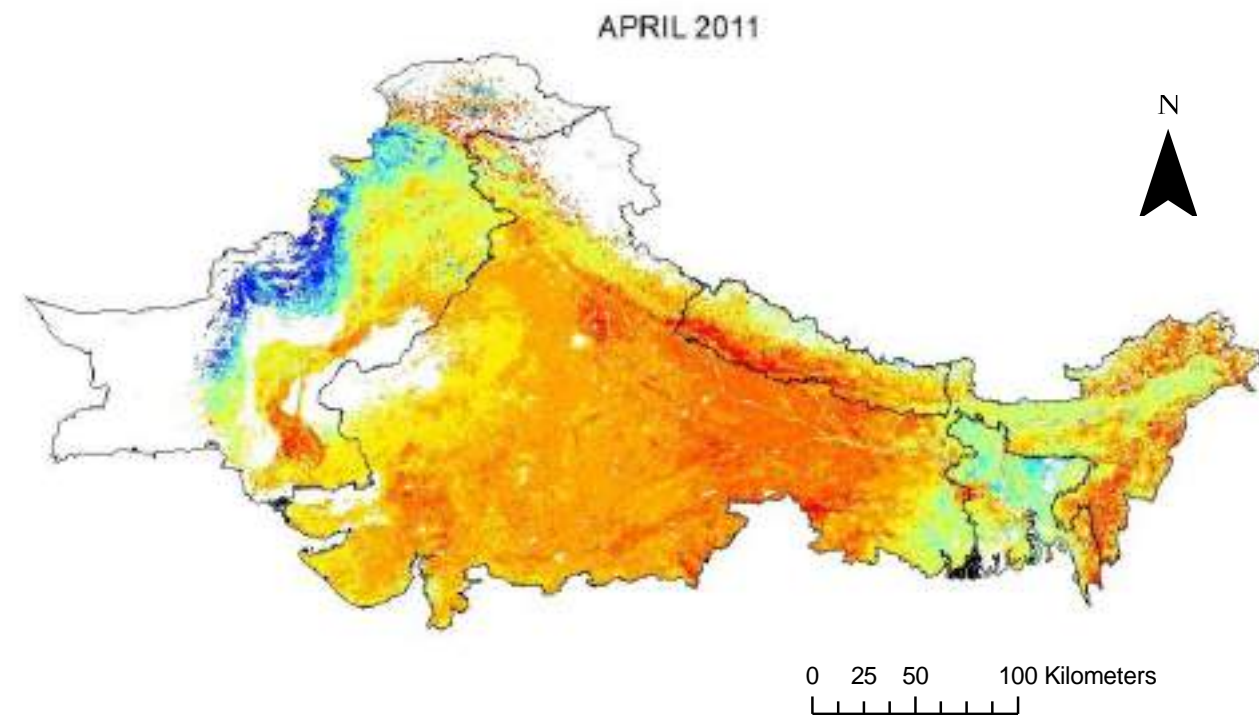




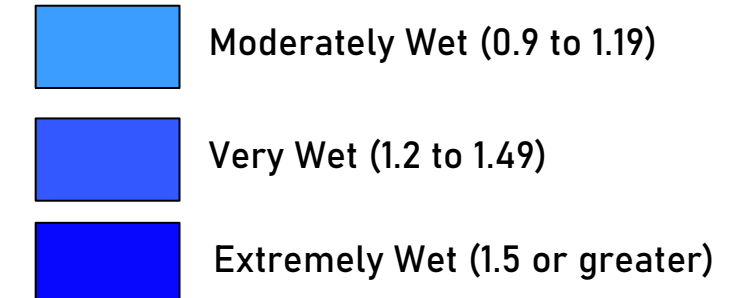
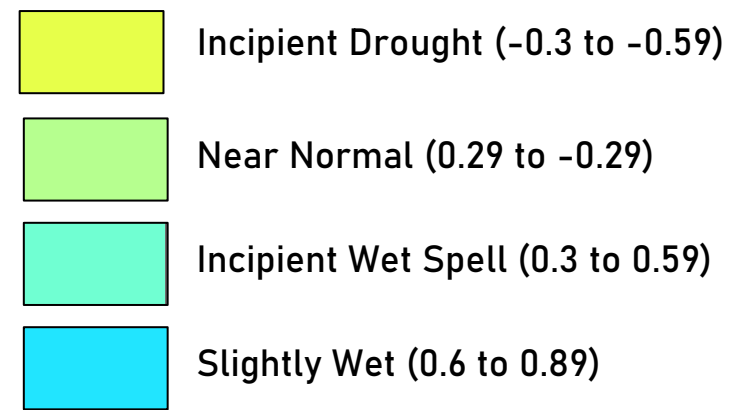
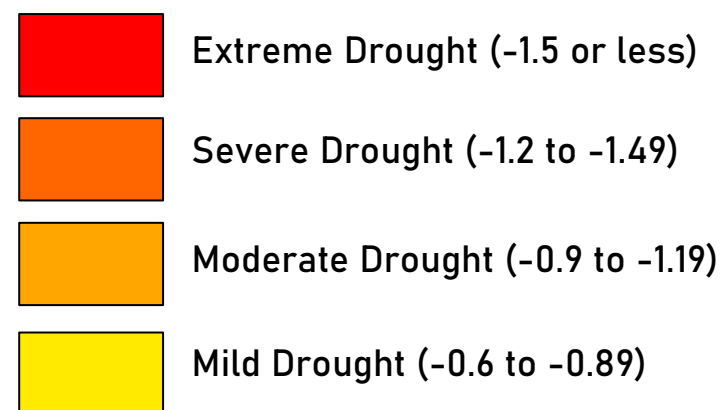


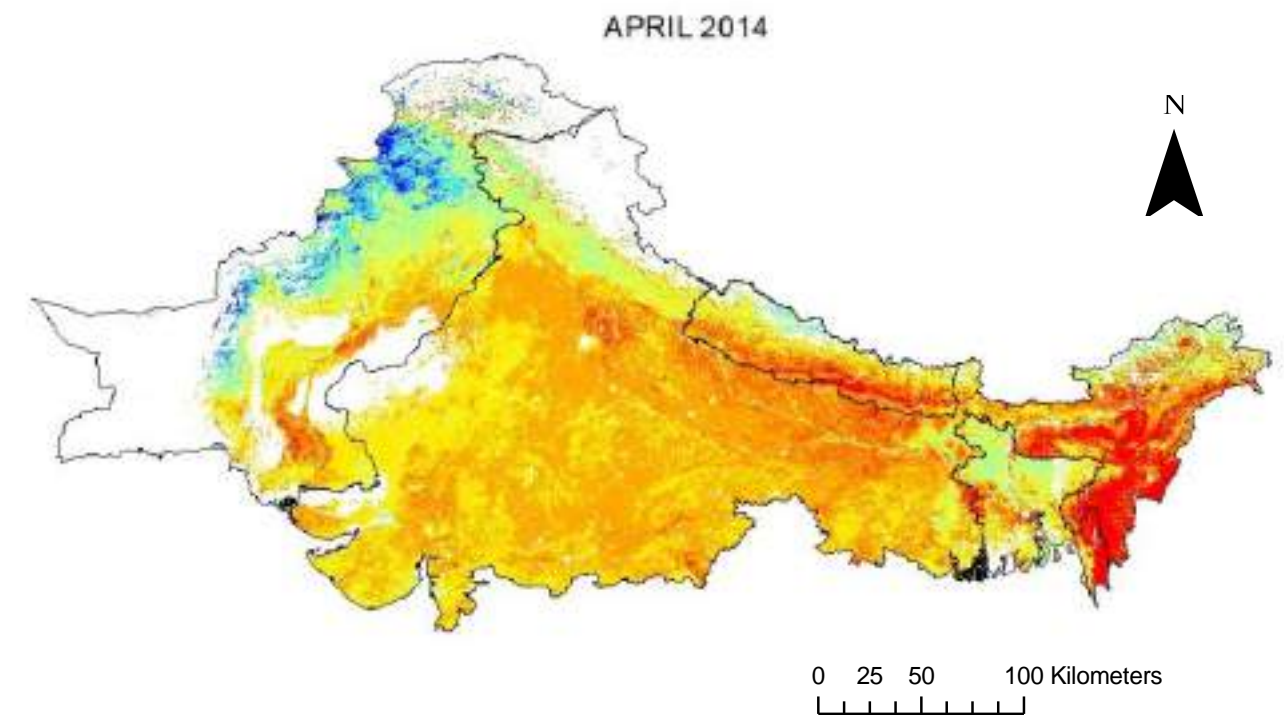
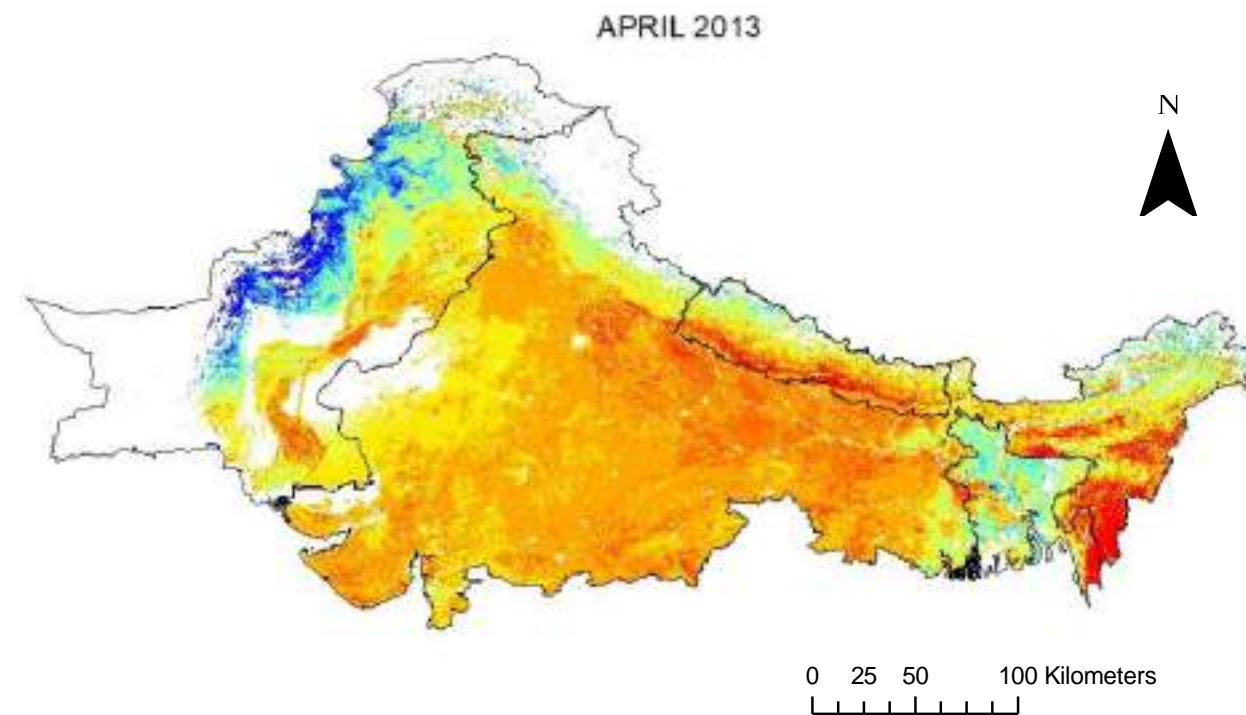
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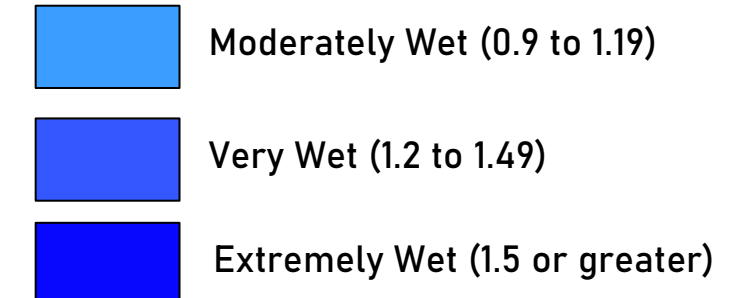
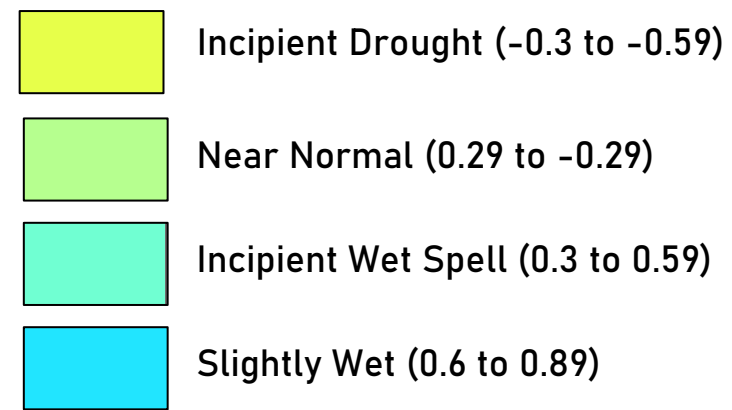
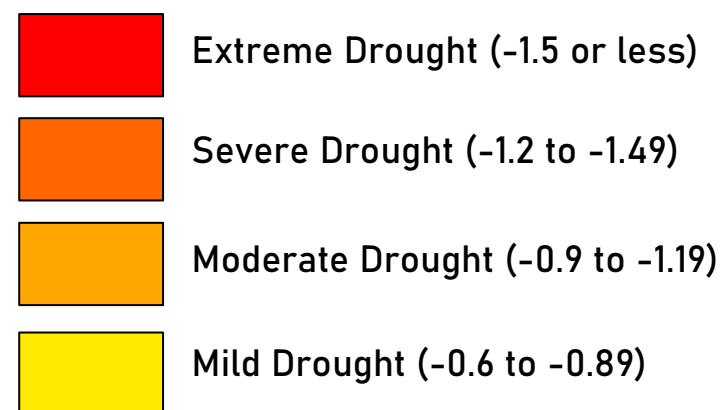


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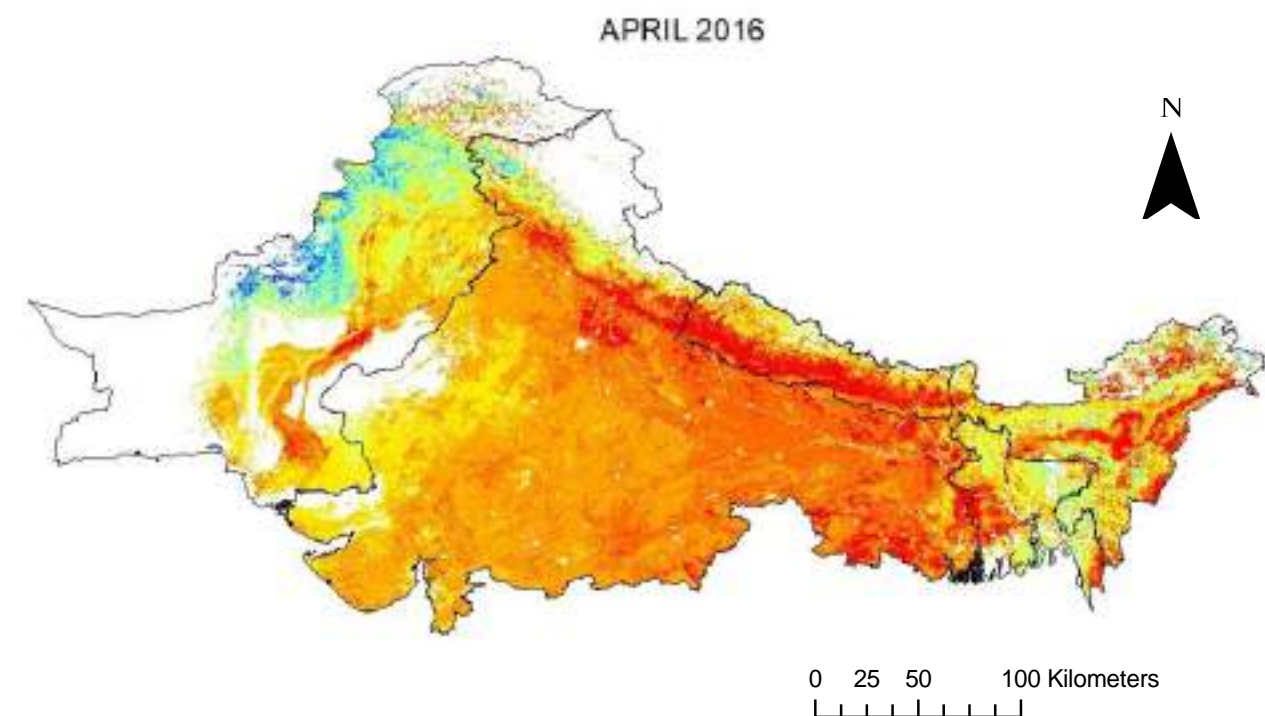
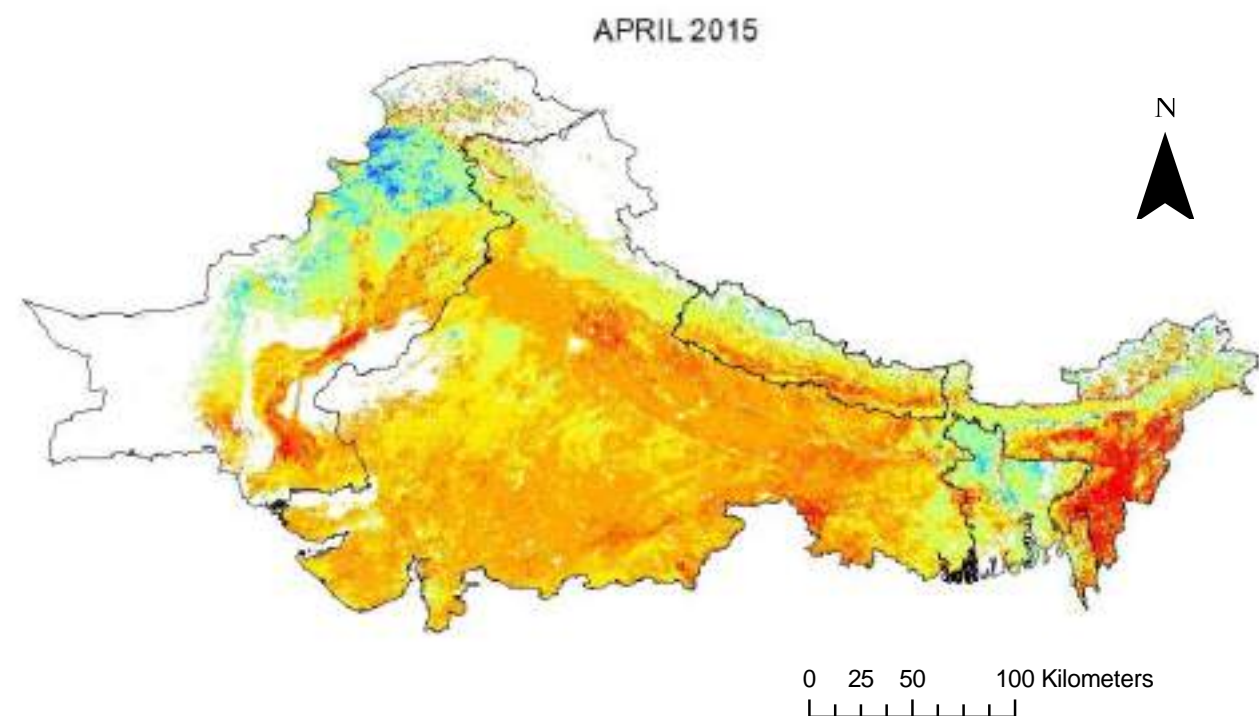




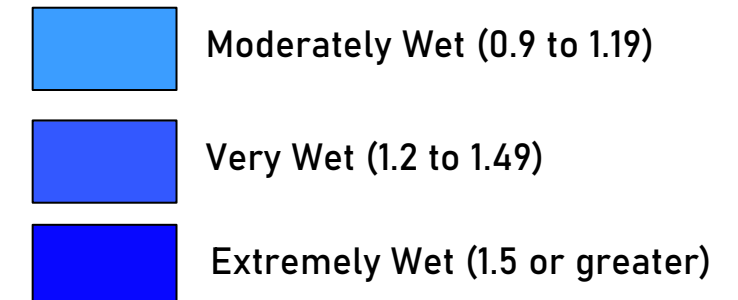
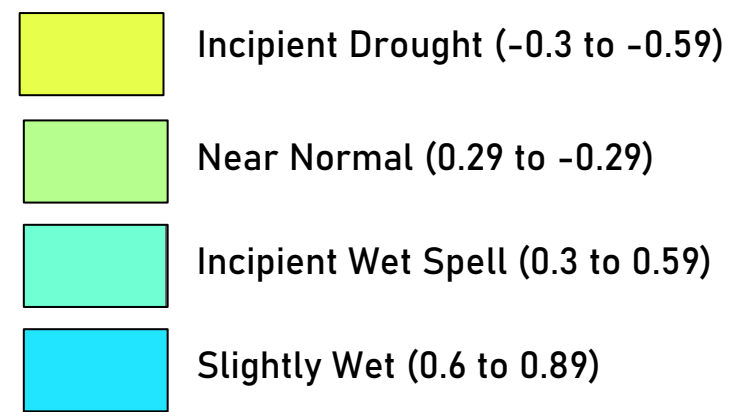
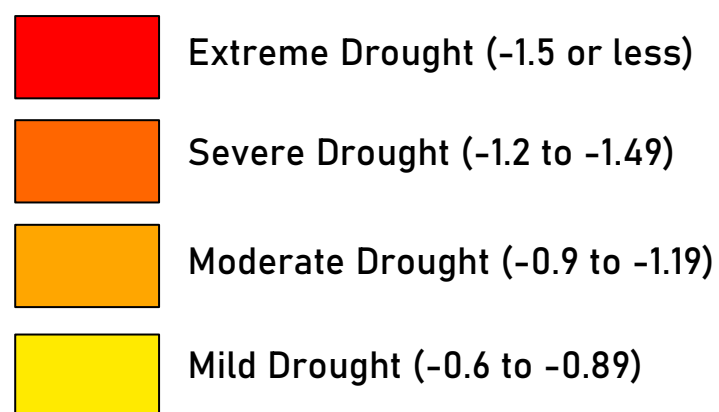
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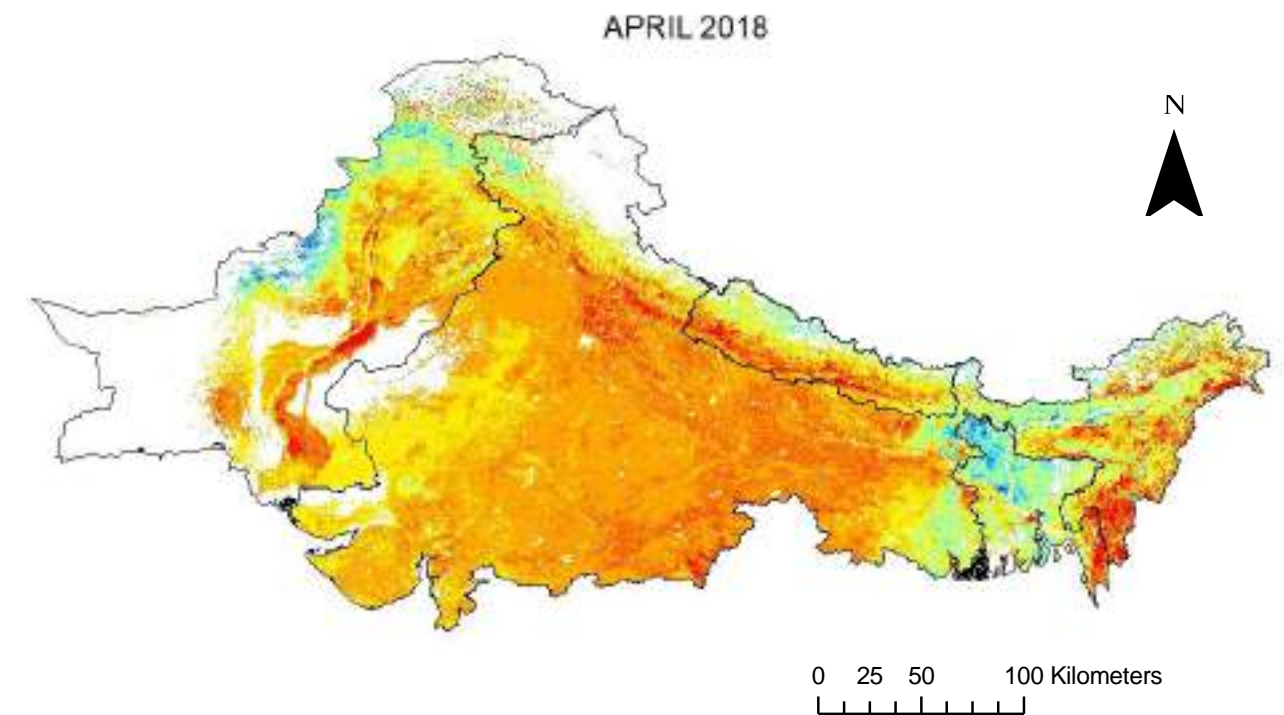
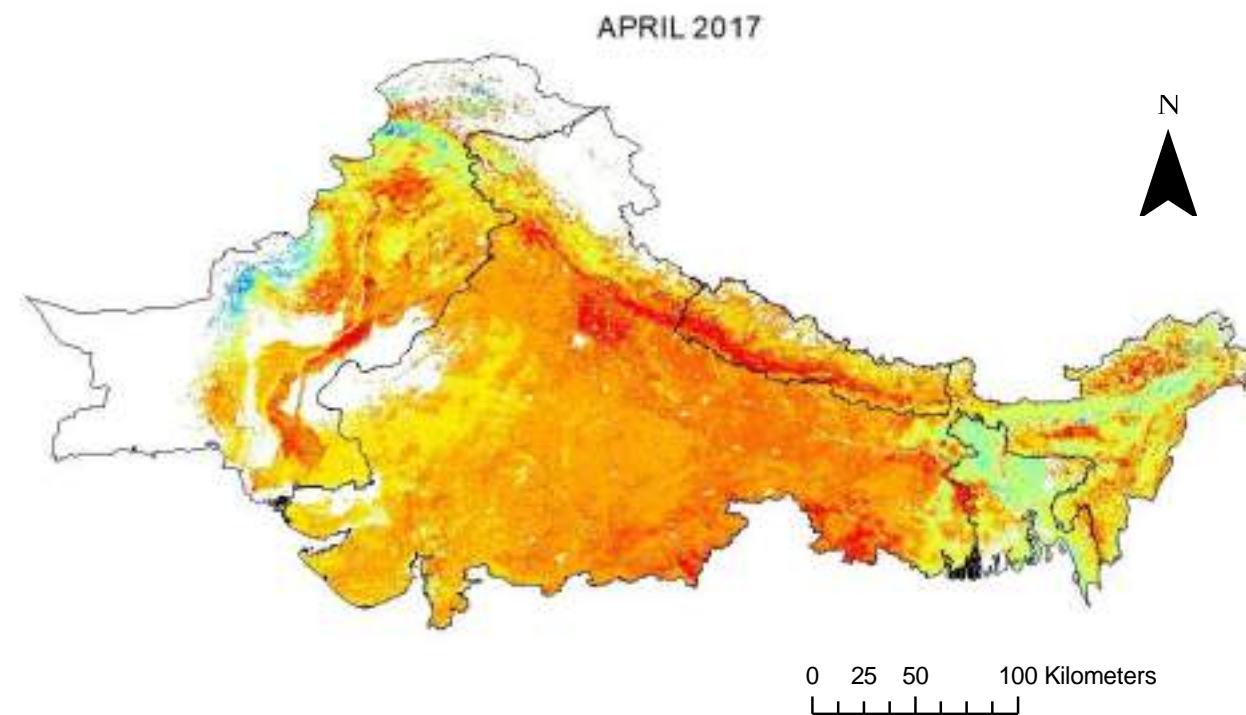




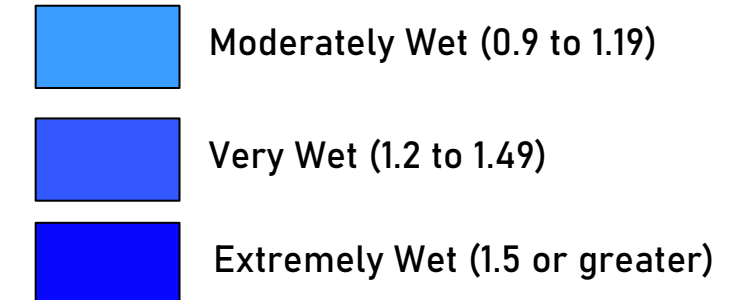
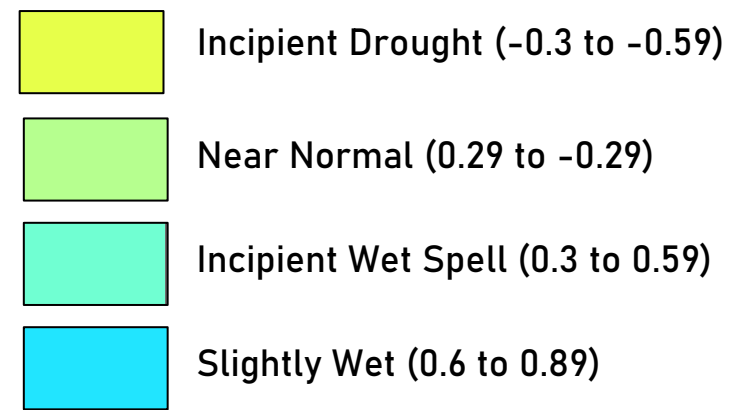
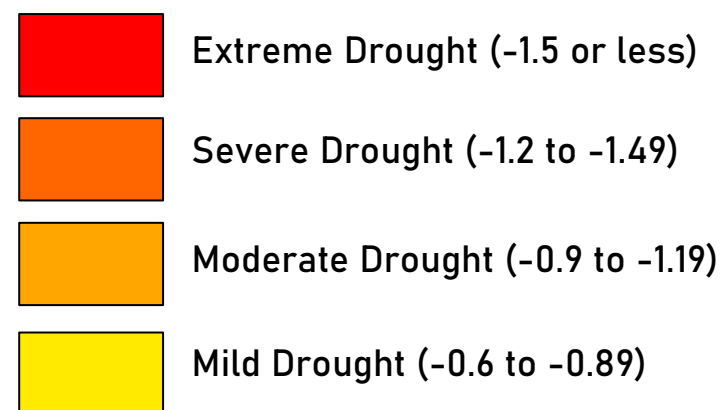


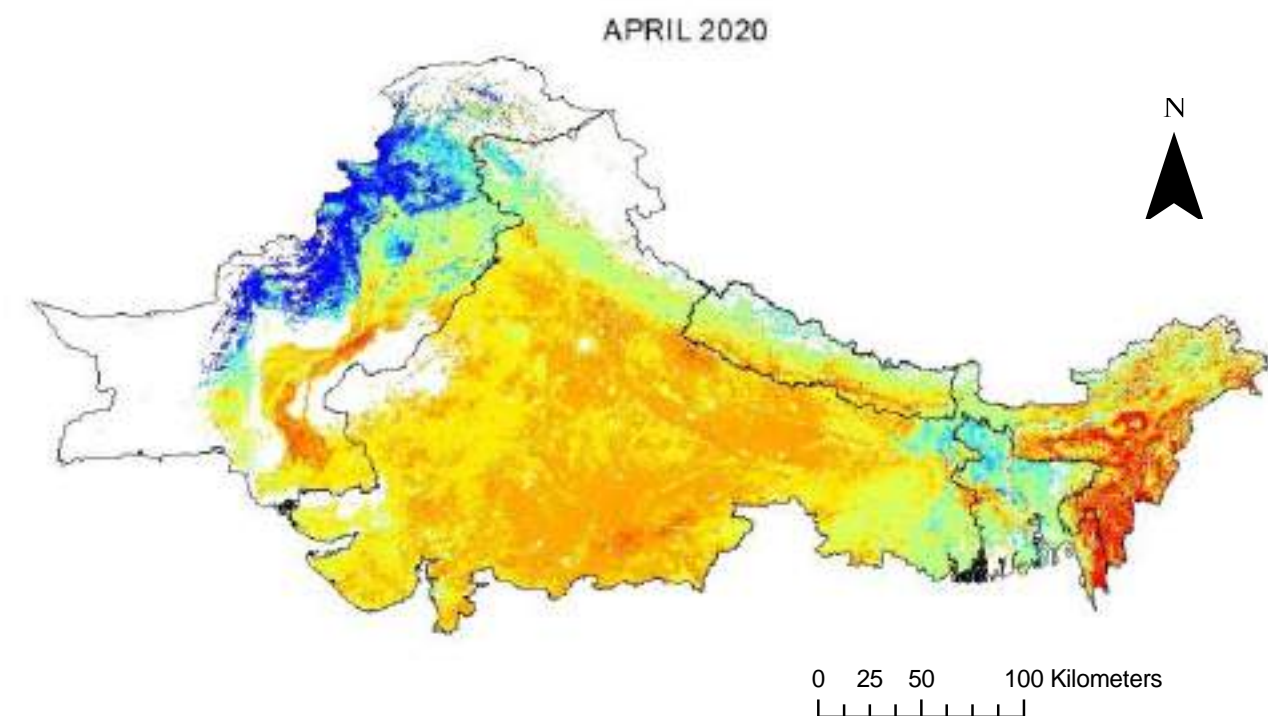
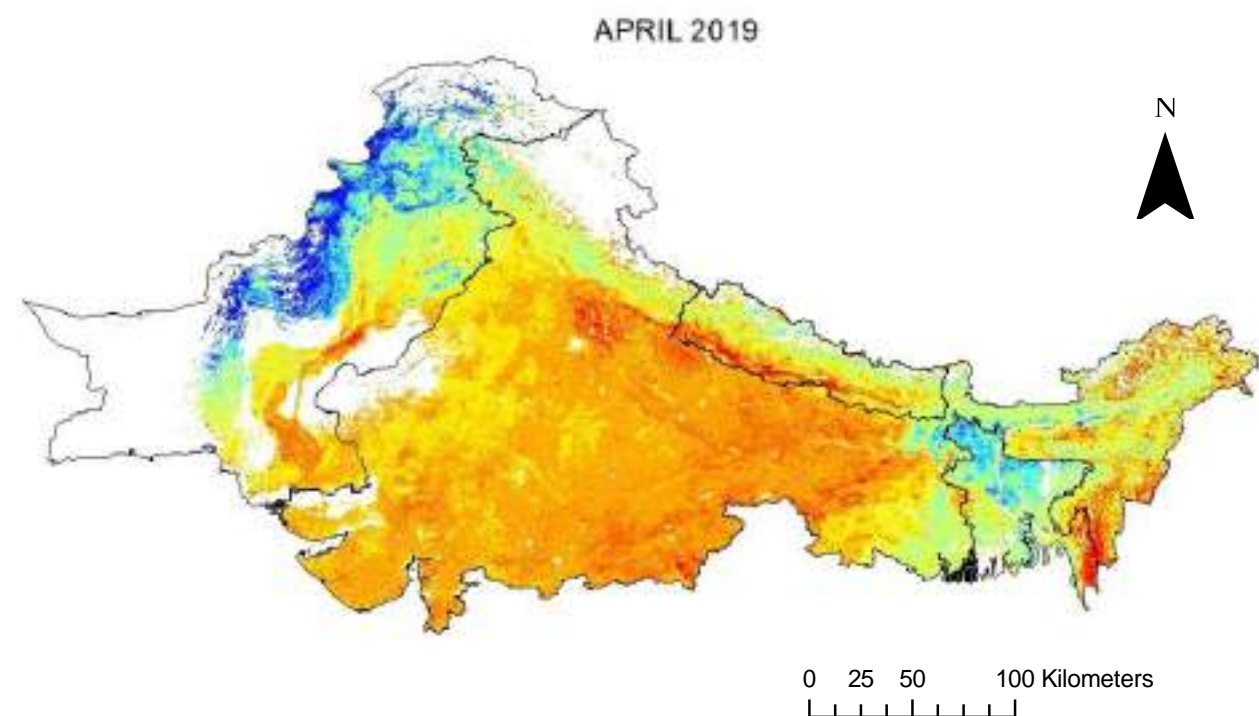
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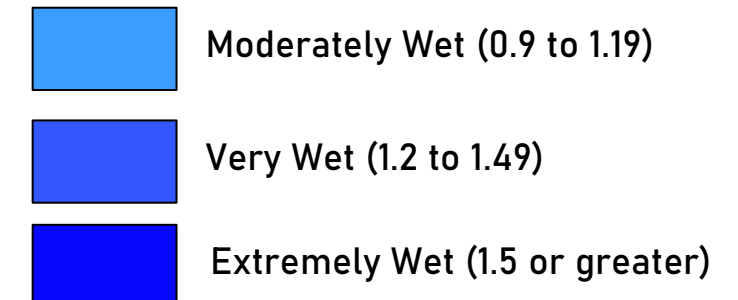
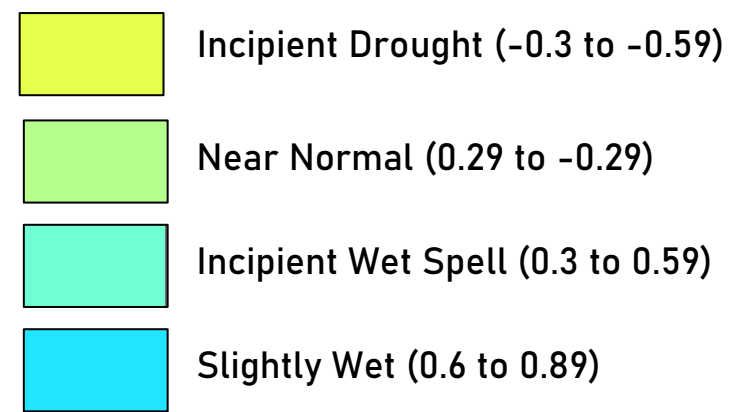
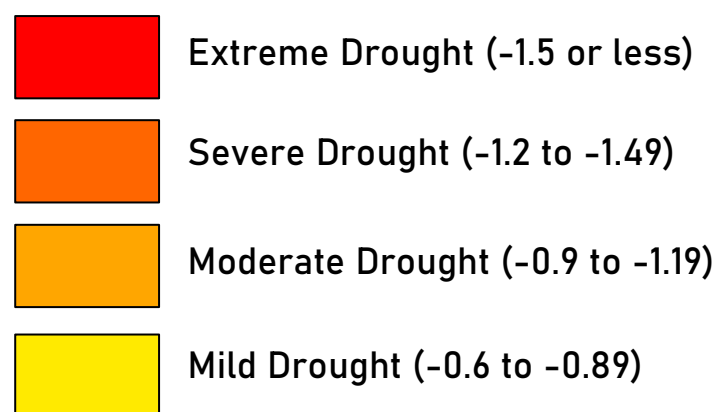


### Legend





### Legend

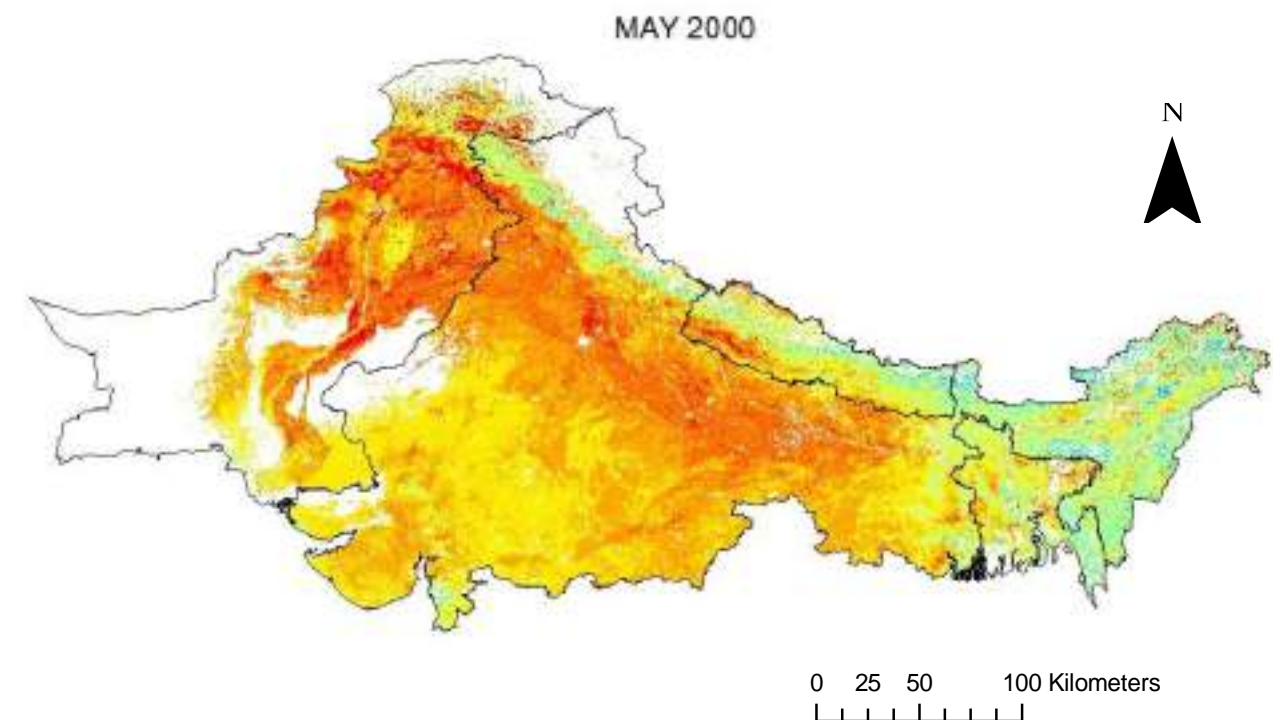




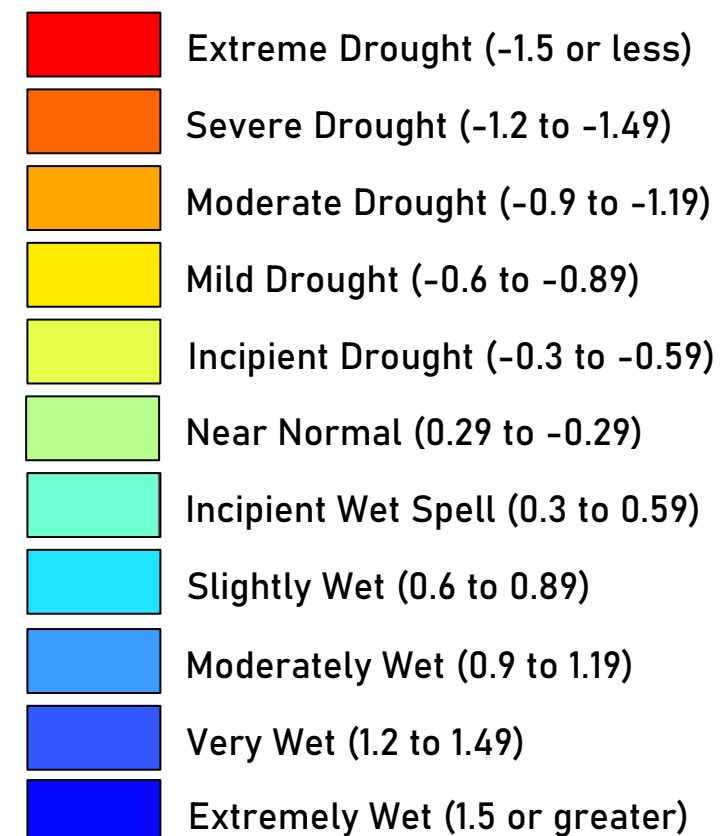
## May DSI Maps

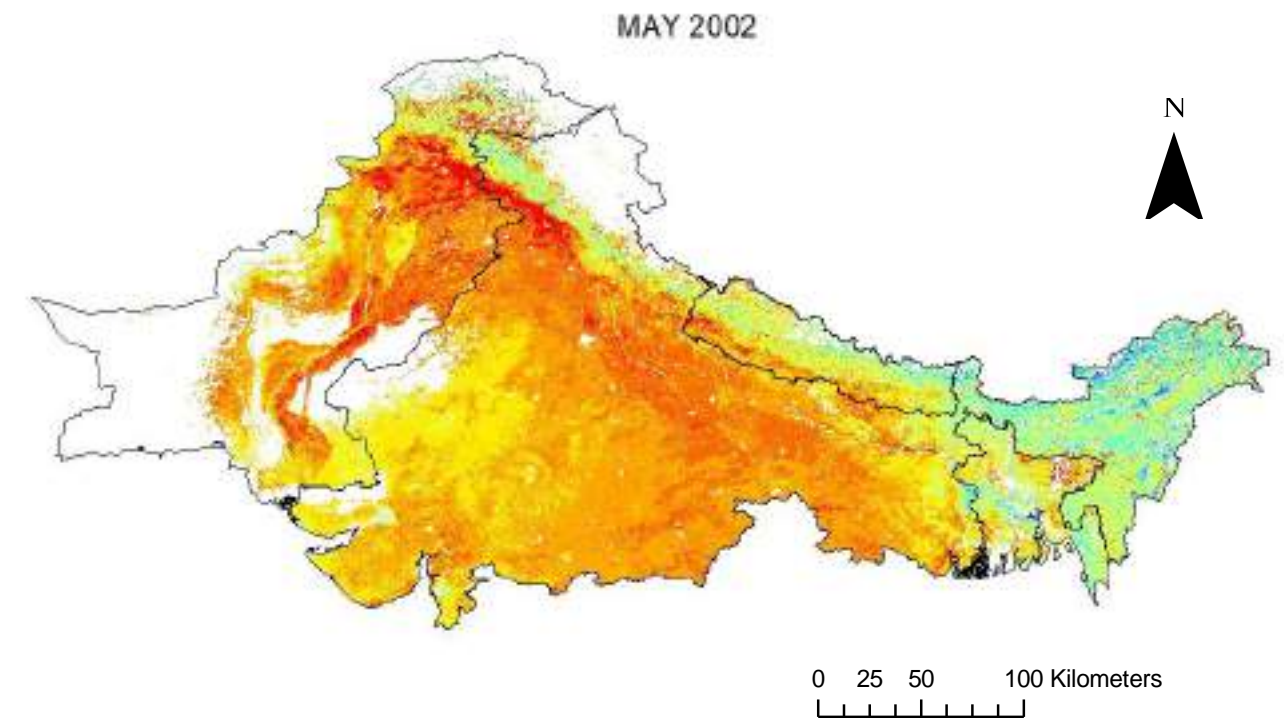
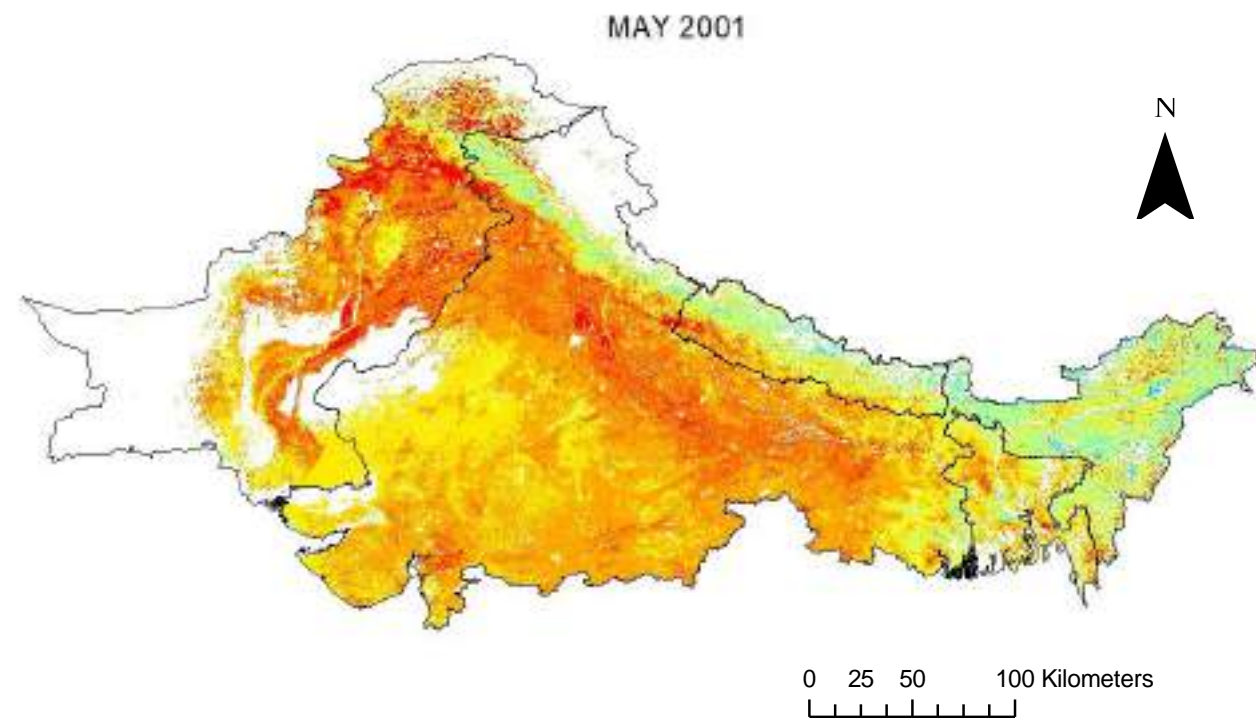
Drought in May typically ranges from mild drought to incipient drought. Mildest drought was seen in 2003 with DSI value -0.86. This hot month is marked by mild drought.

Mean May DSI Values		
Year	DSI Values	Drought Condition
2000	-0.71	Mild Drought
2001	-0.79	Mild Drought
2002	-0.73	Mild Drought
2003	-0.86	Mild Drought
2004	-0.81	Mild Drought
2005	-0.71	Mild Drought
2006	-0.64	Mild Drought
2007	-0.51	Incipient Drought
2008	-0.70	Mild Drought
2009	-0.60	Mild Drought
2010	-0.76	Mild Drought
2011	-0.75	Mild Drought
2012	-0.82	Mild Drought
2013	-0.71	Mild Drought
2014	-0.65	Mild Drought
2015	-0.70	Mild Drought
2016	-0.83	Mild Drought
2017	-0.69	Mild Drought
2018	-0.60	Mild Drought
2019	-0.53	Incipient Drought
2020	-0.41	Incipient Drought

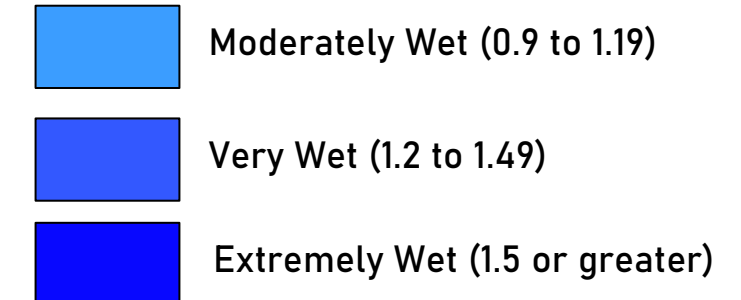
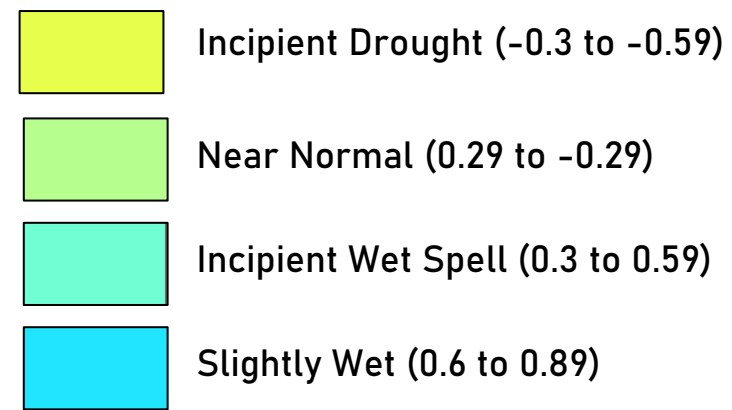
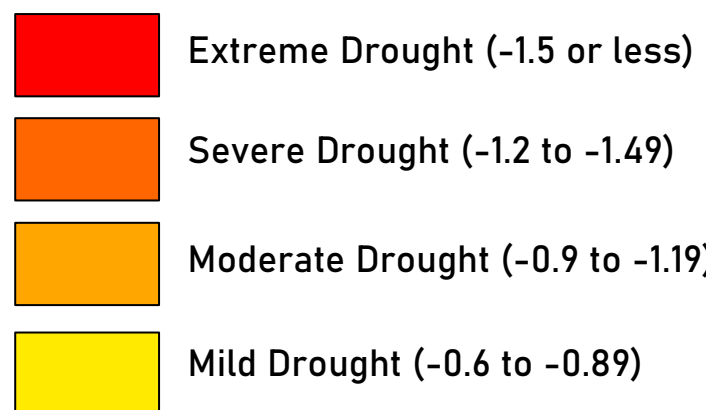


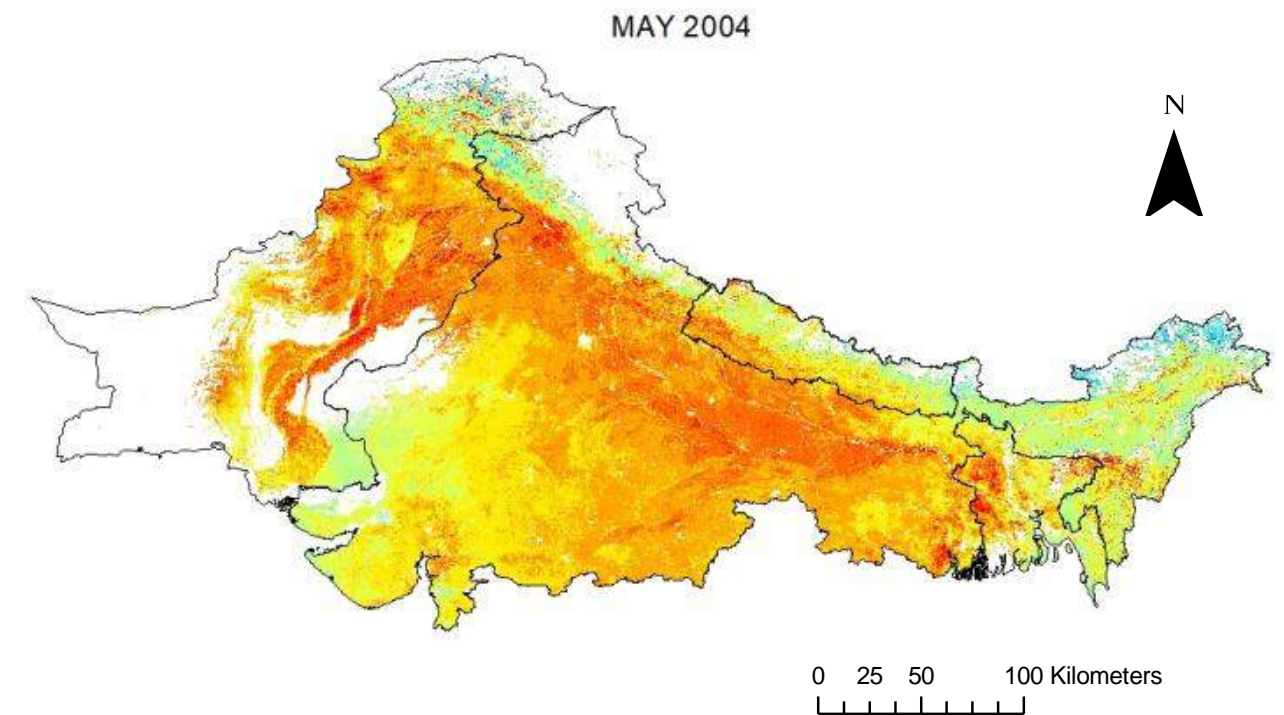
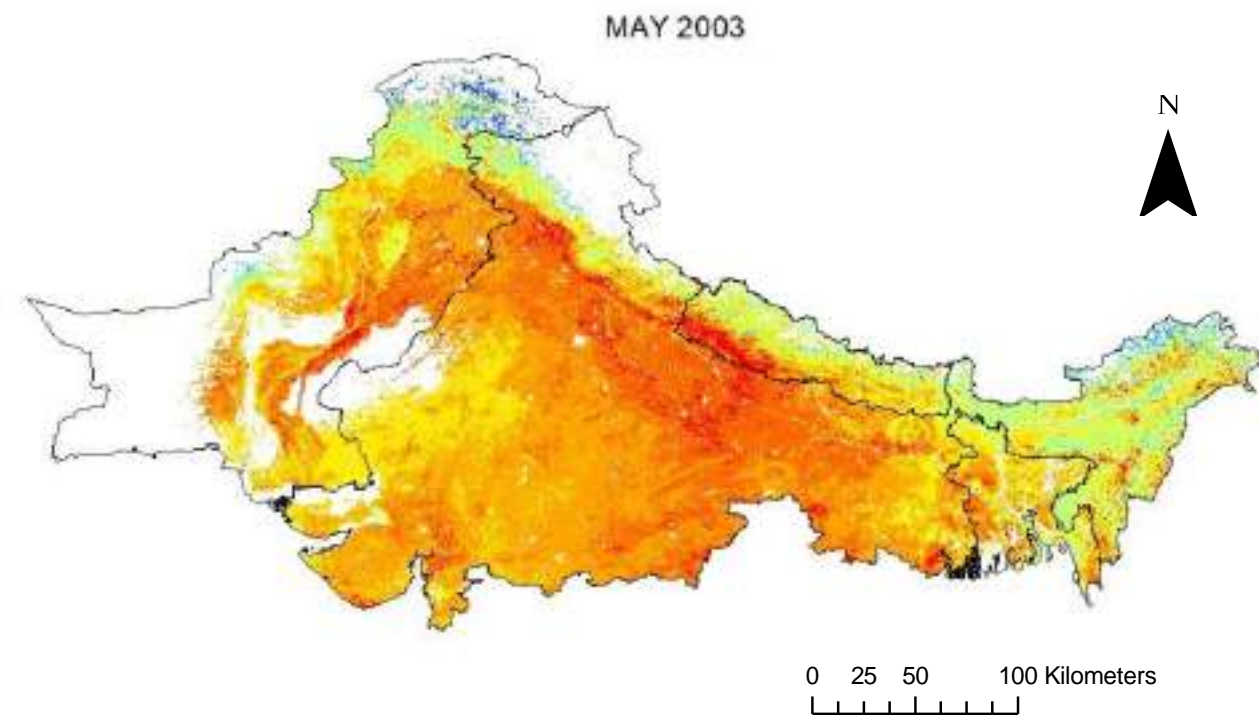
### Legend



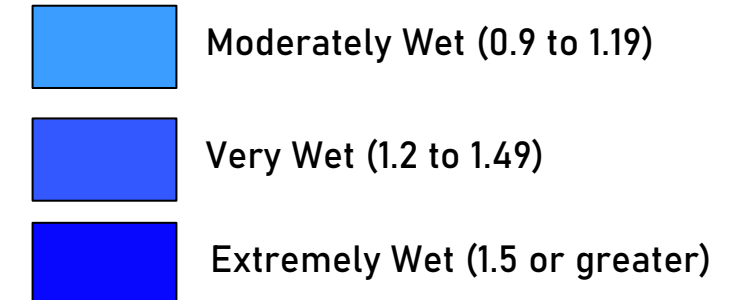
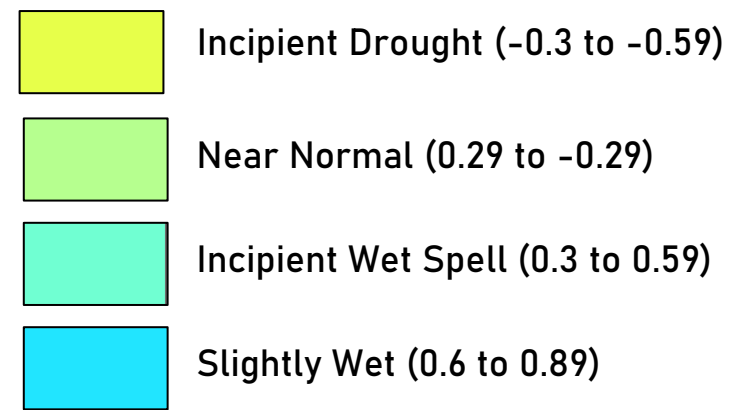
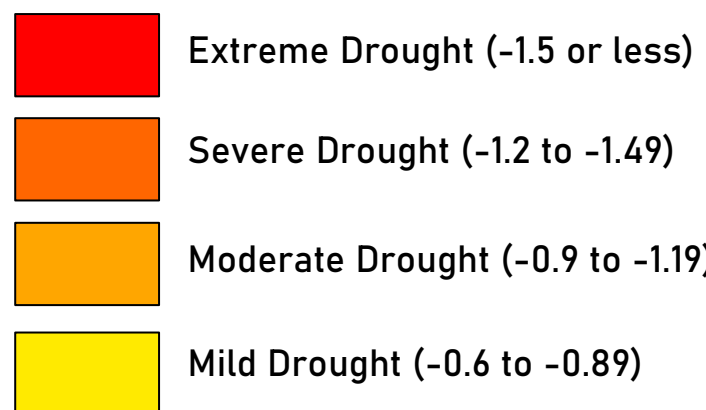


### Legend

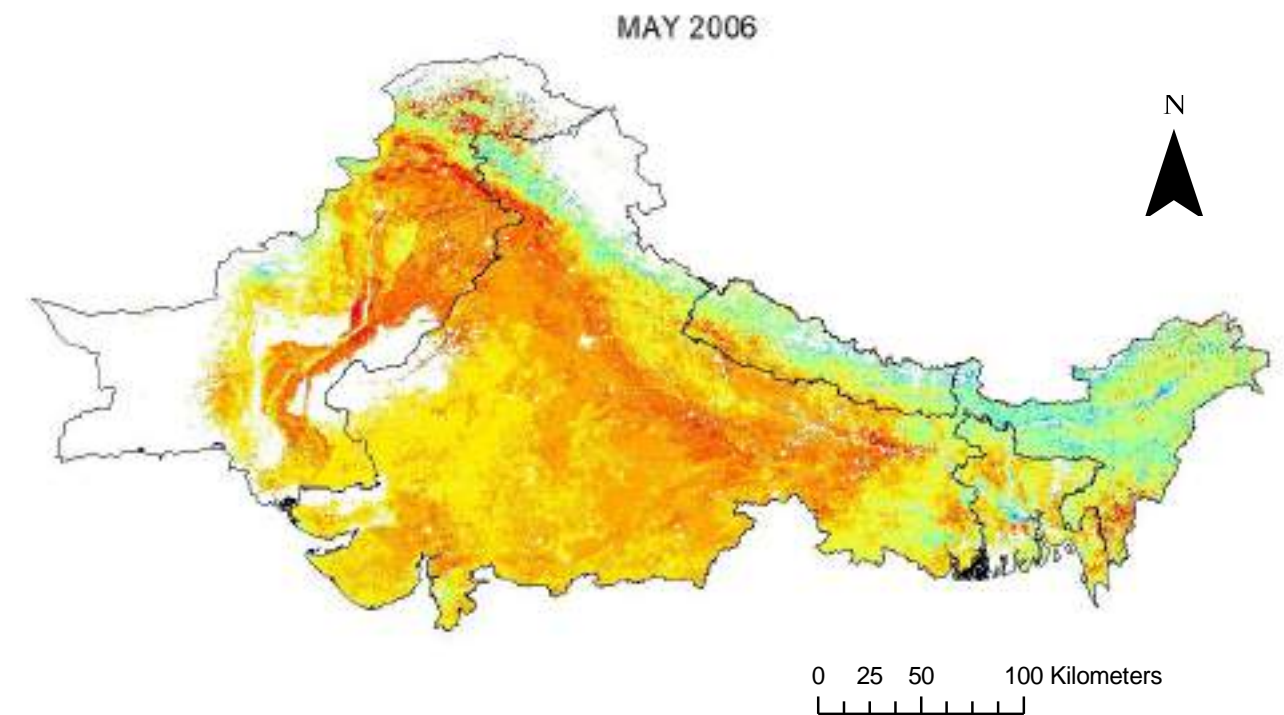
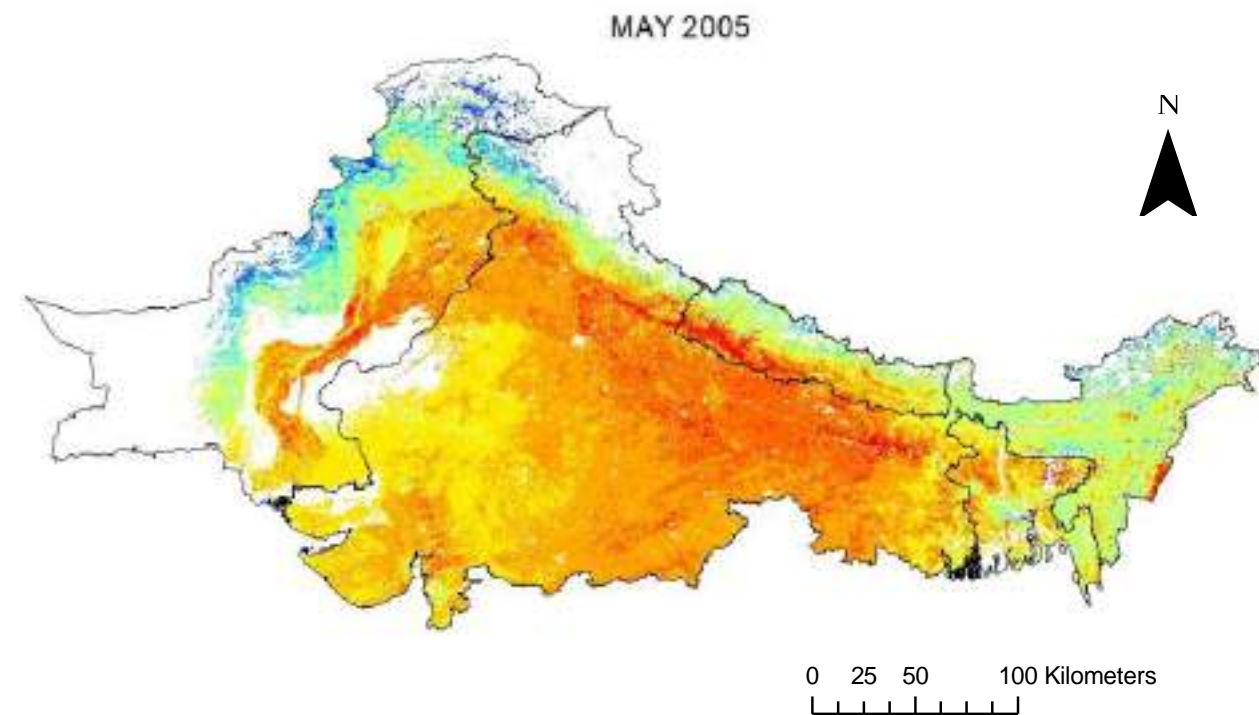




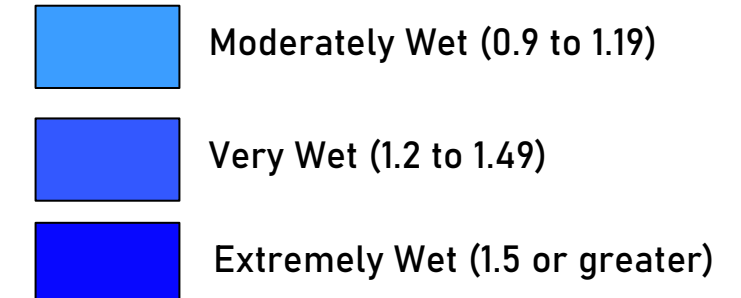
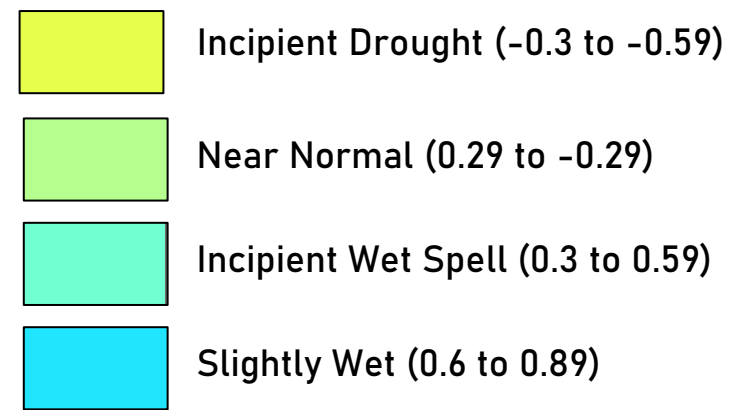
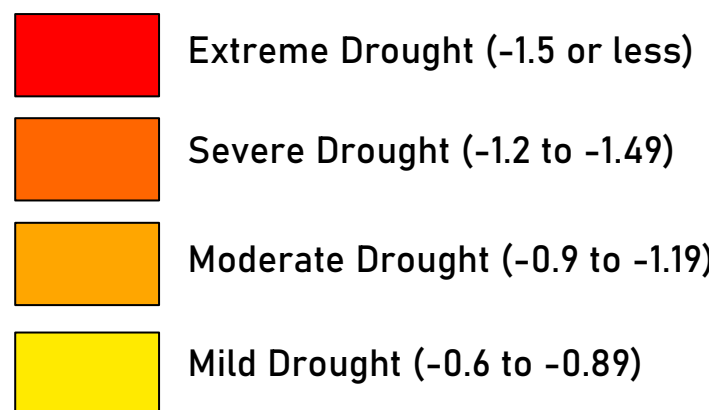
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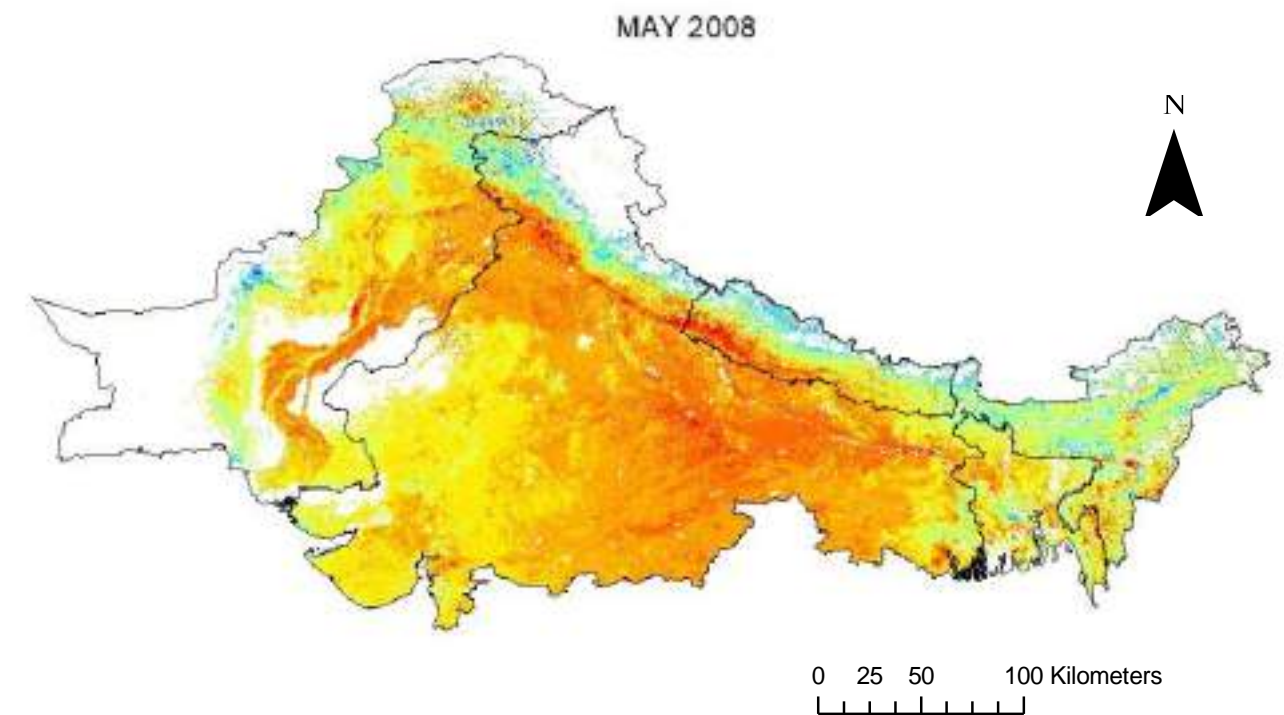
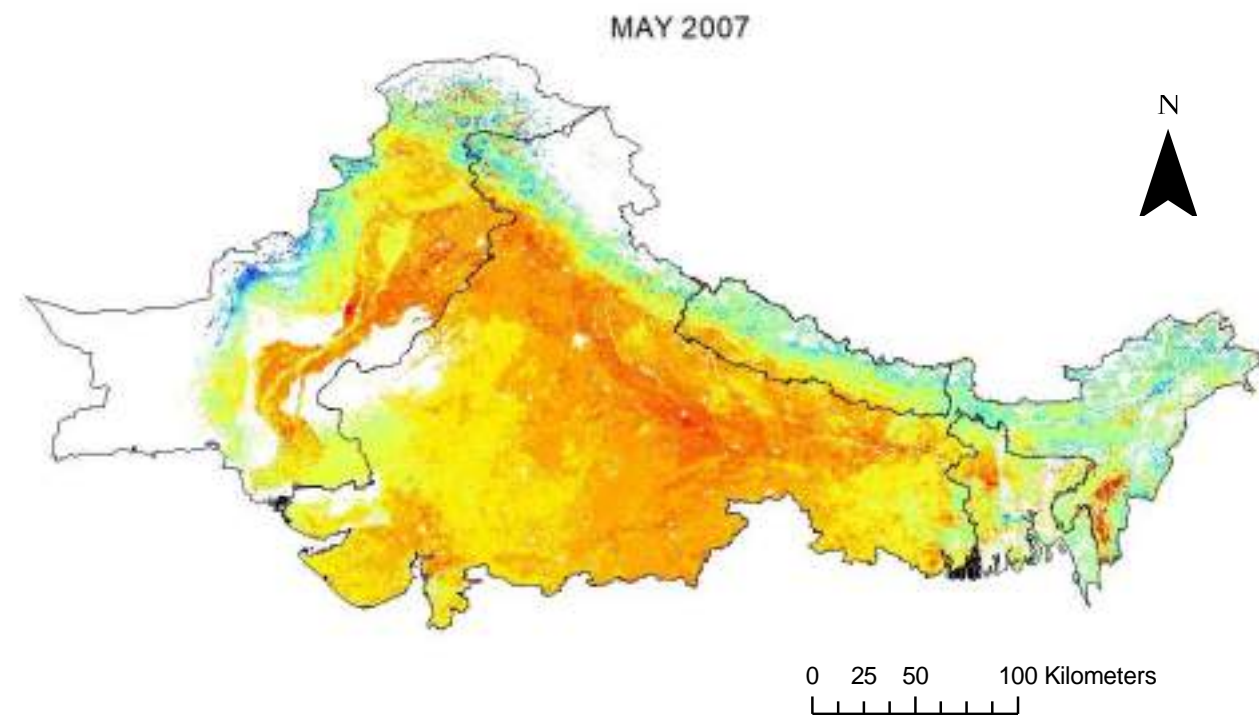




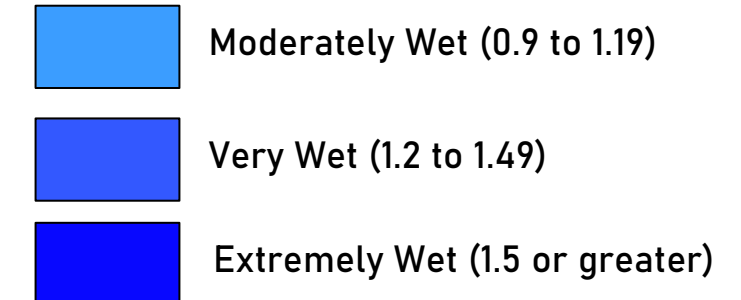
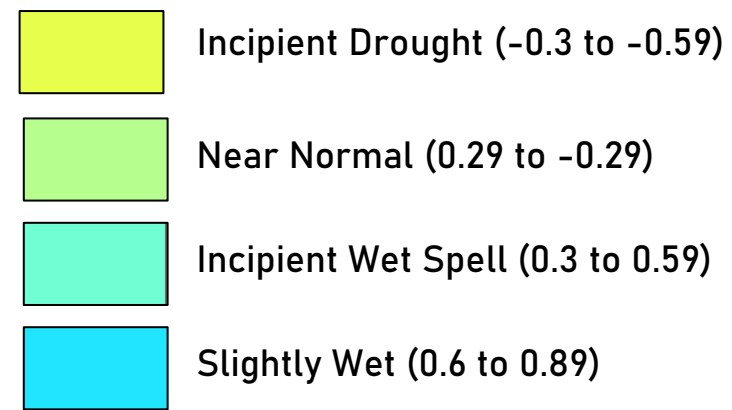
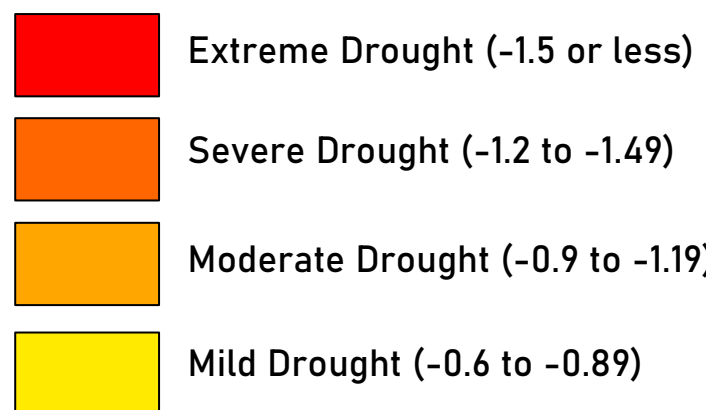


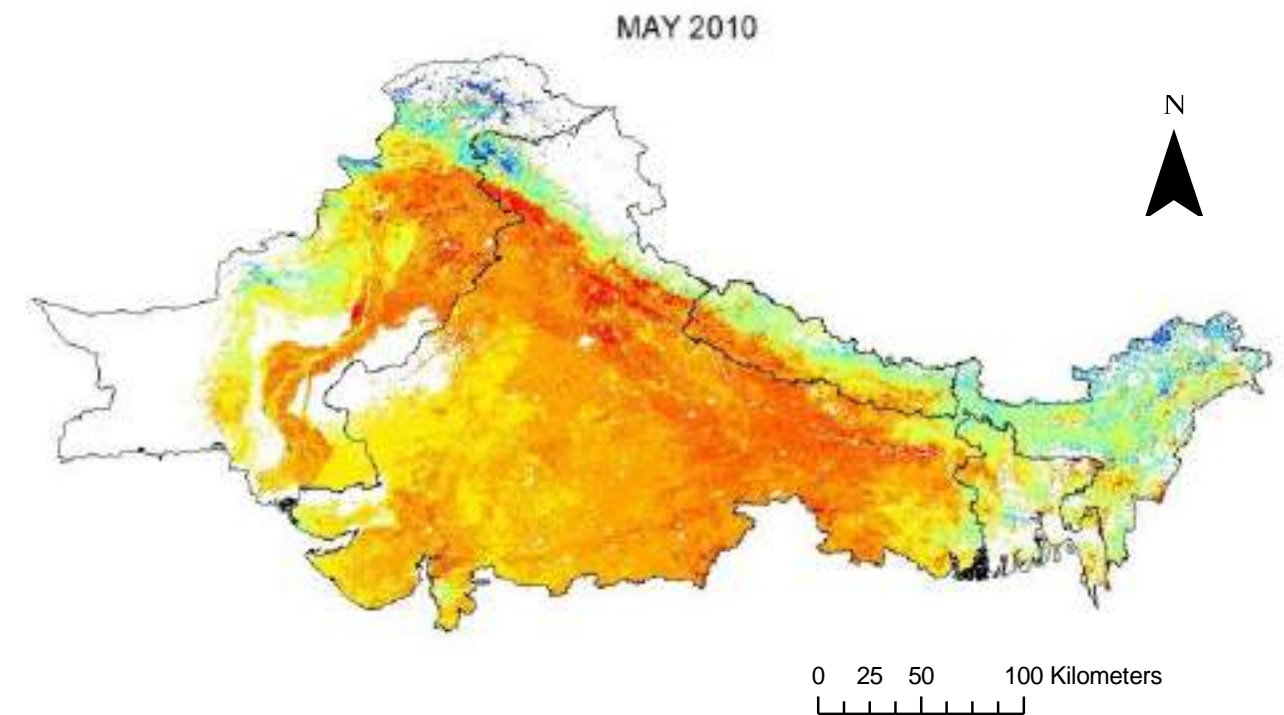
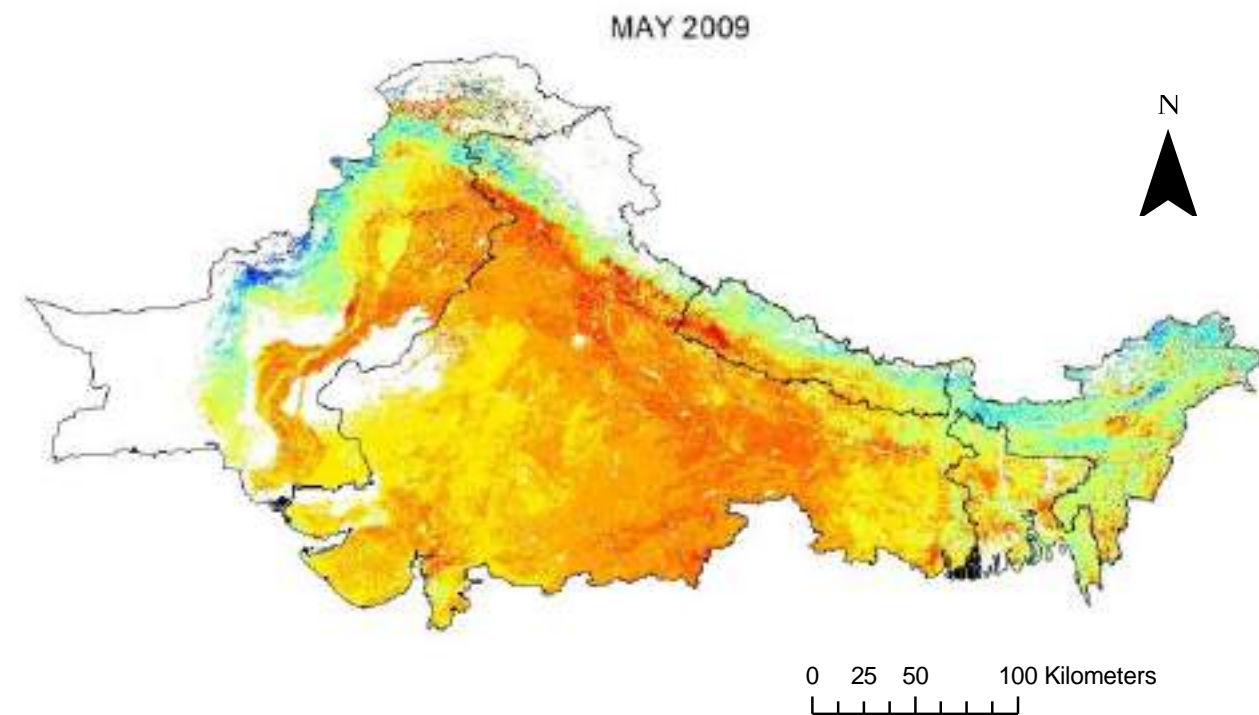
### Legend



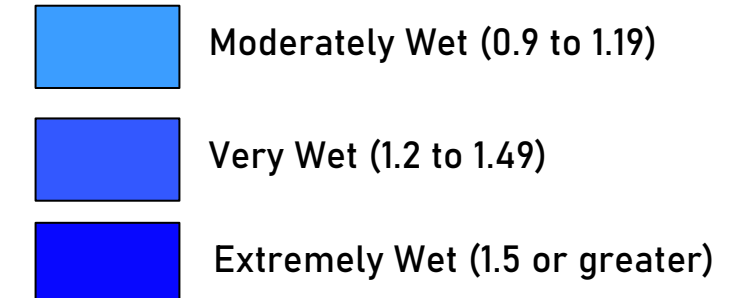
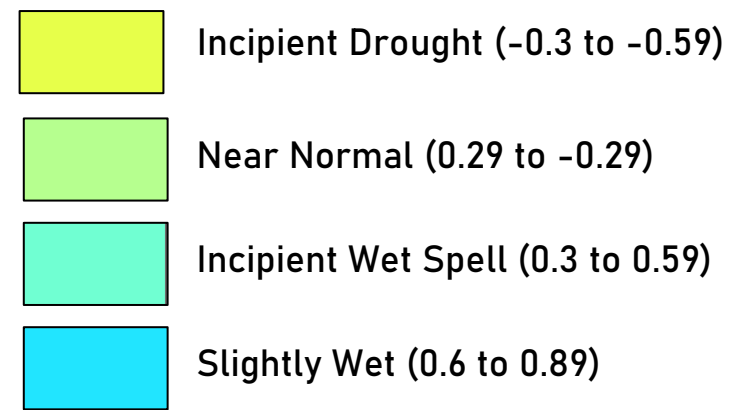
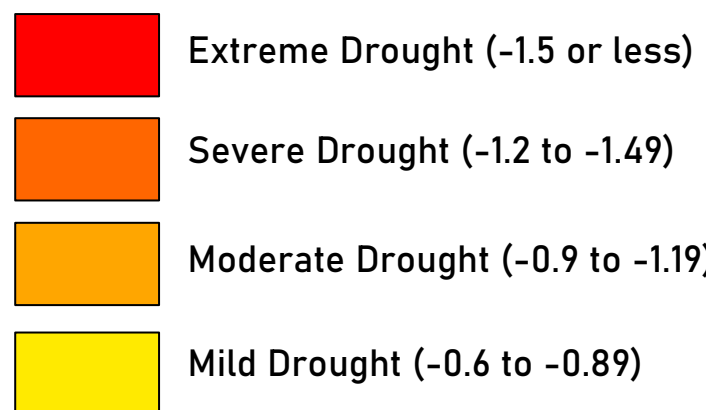


### Legend

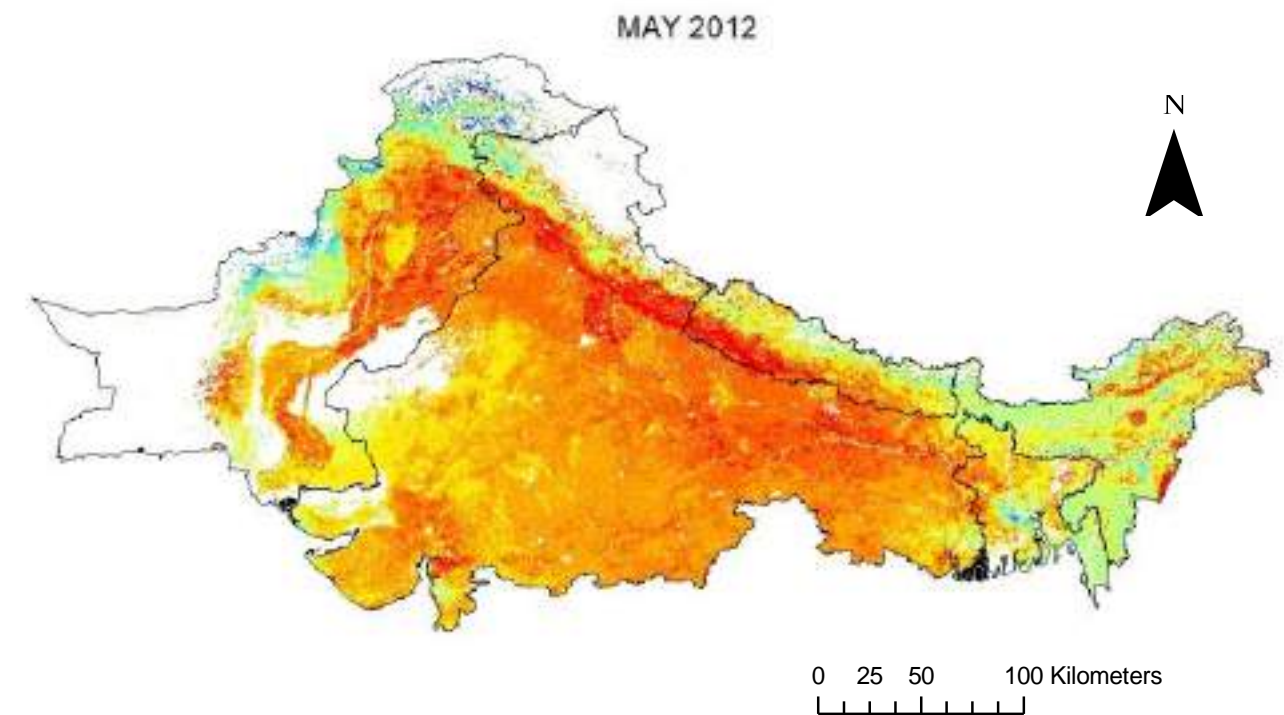
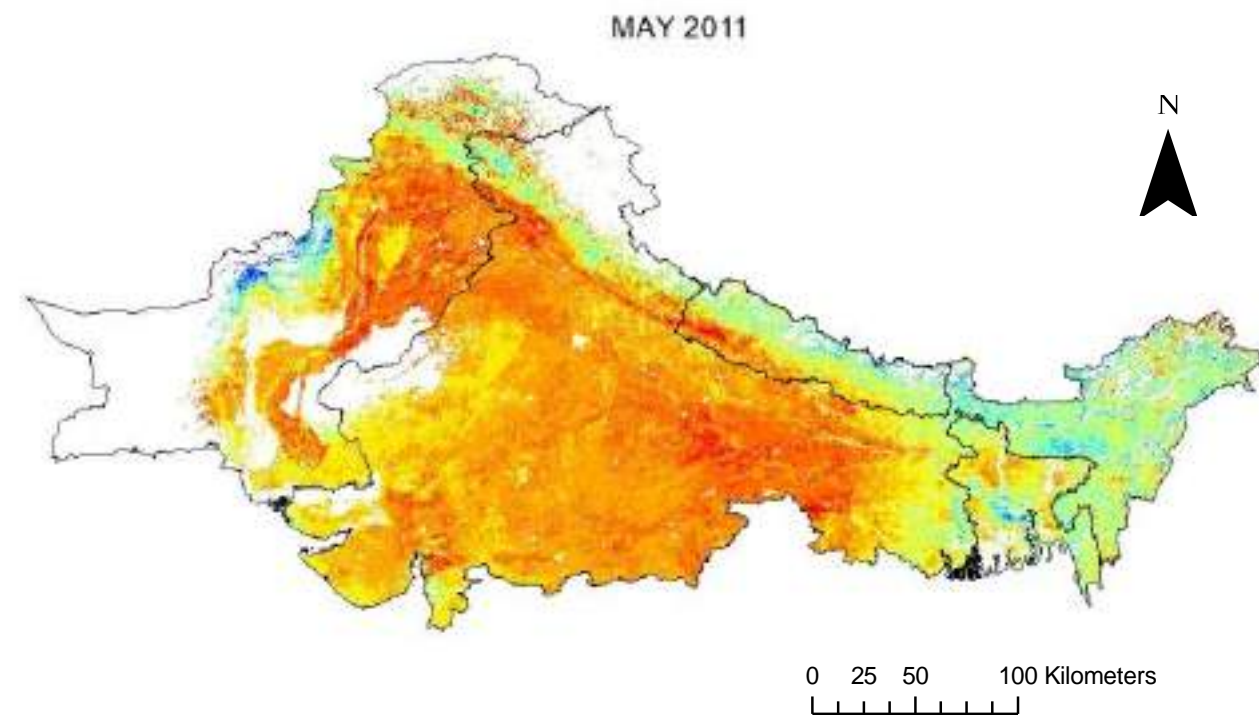




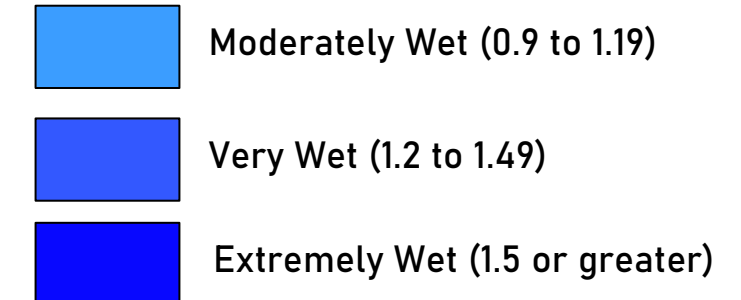
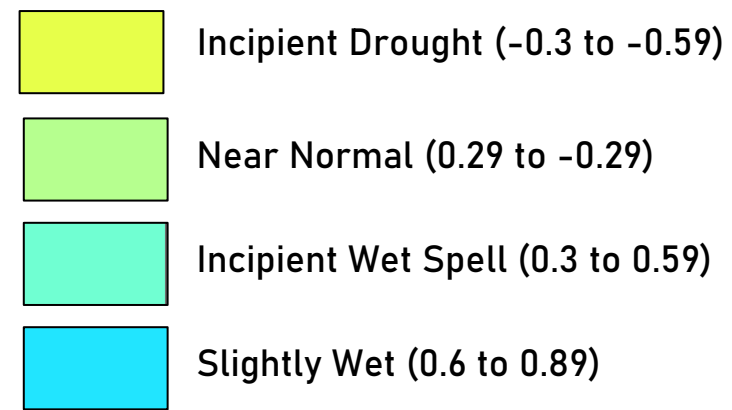
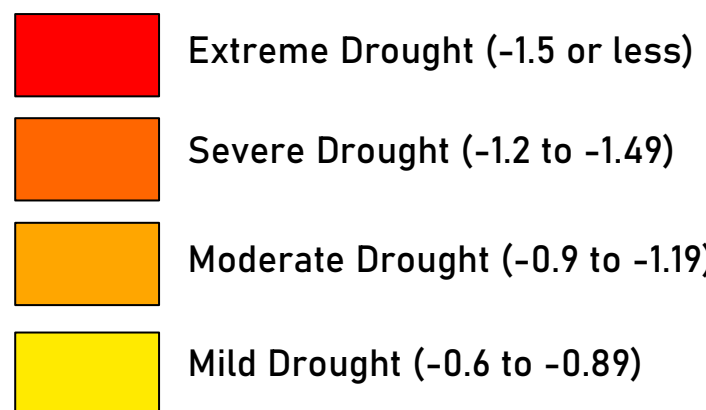
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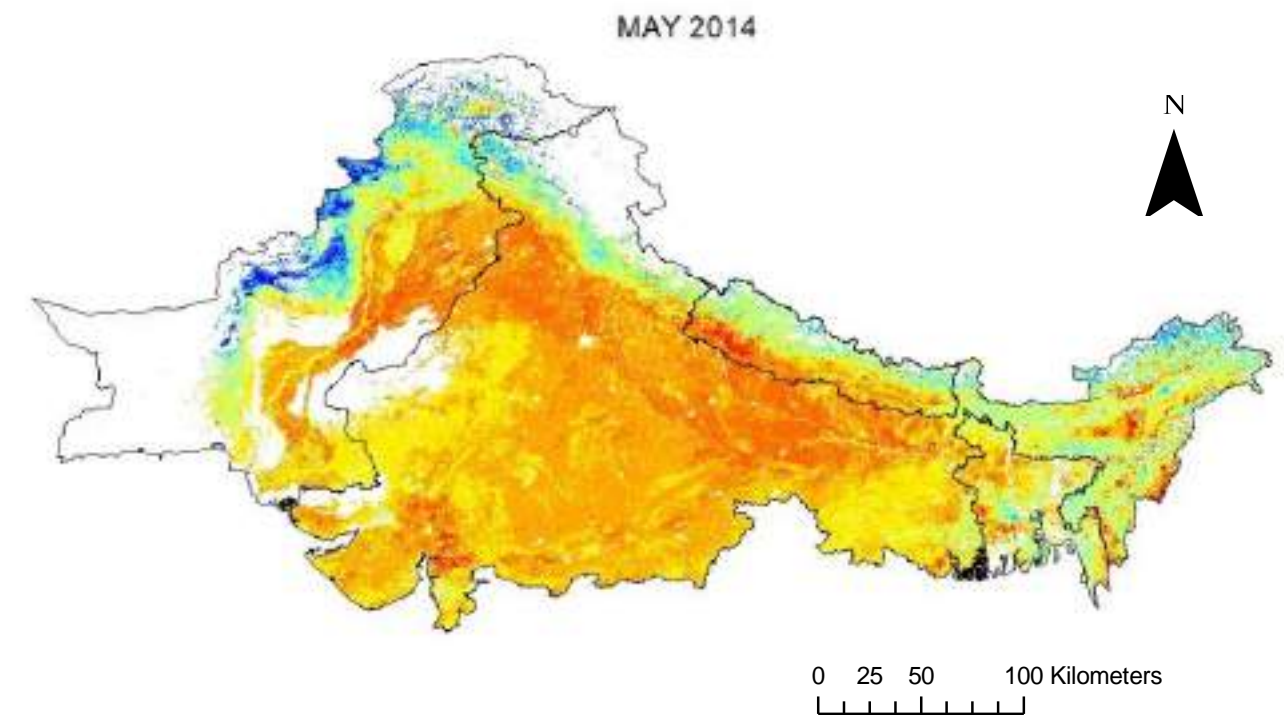
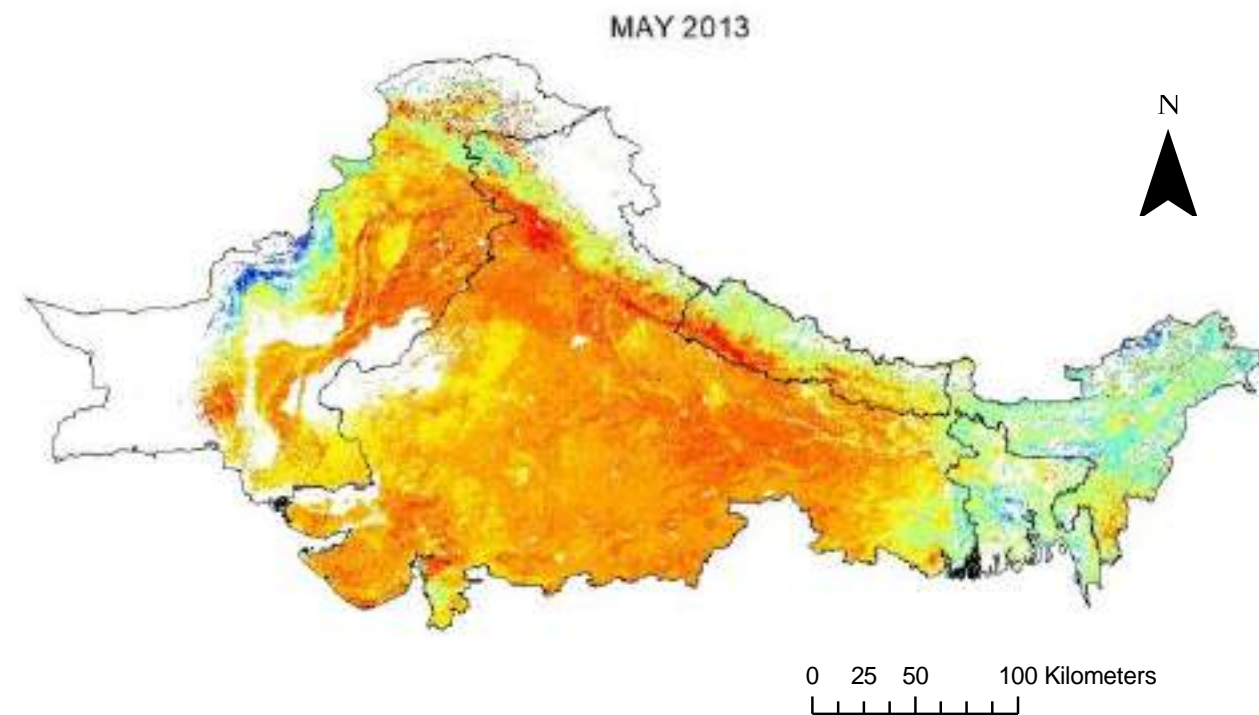




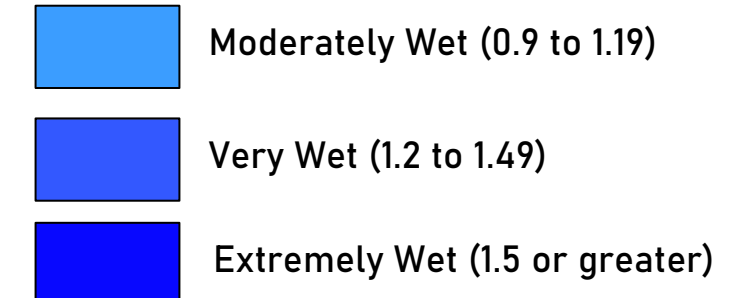
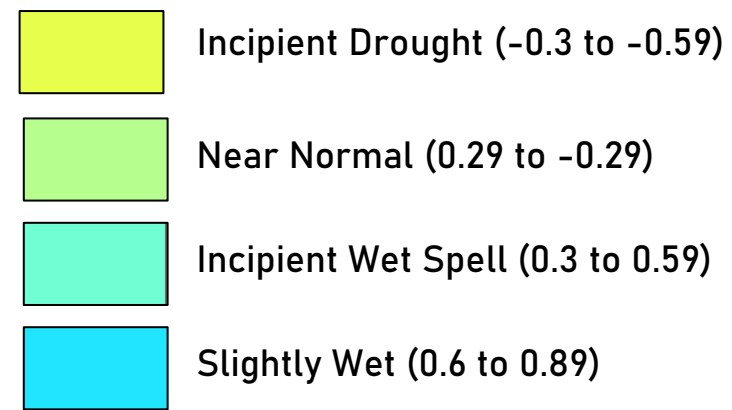
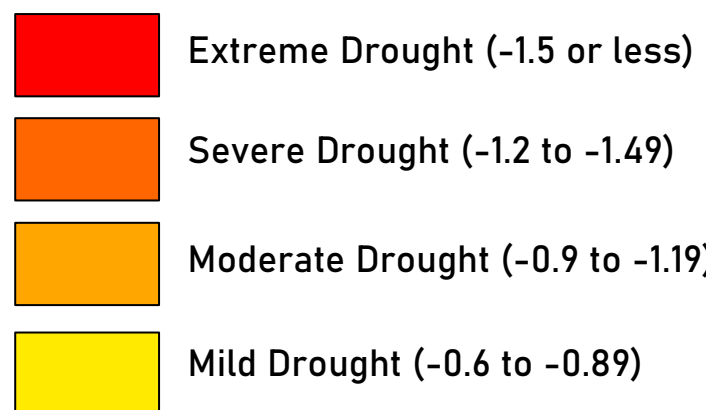


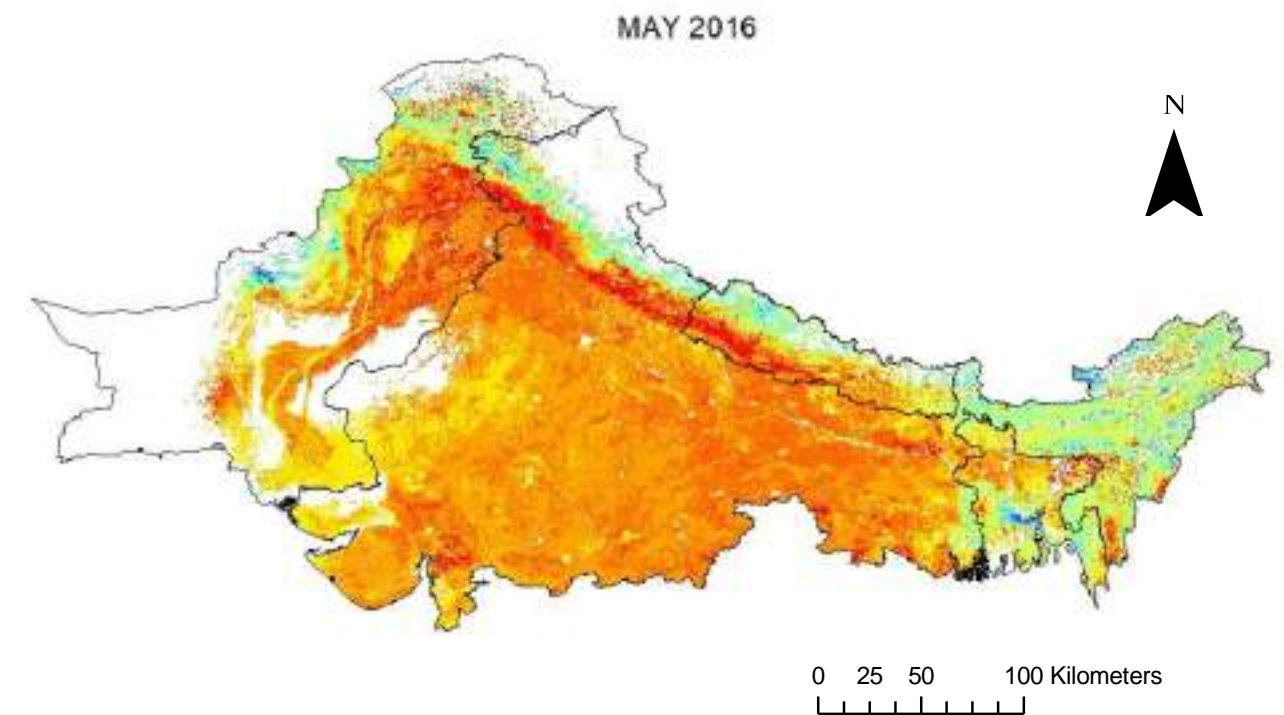
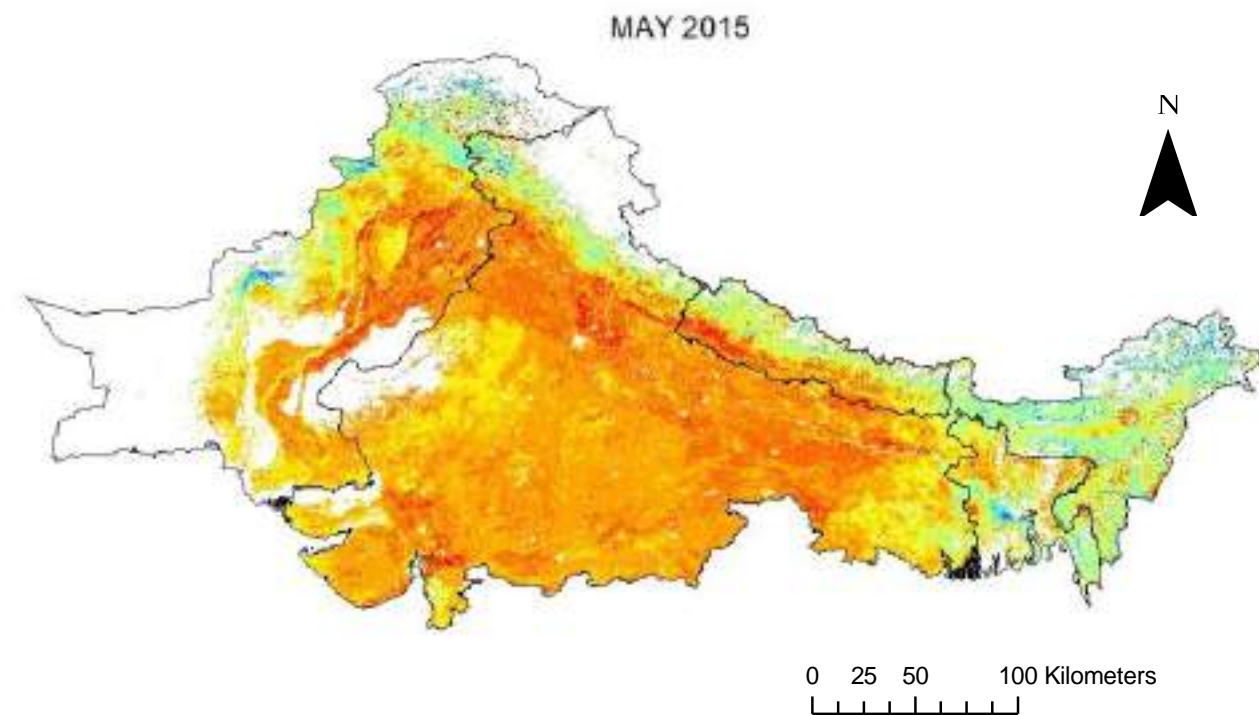
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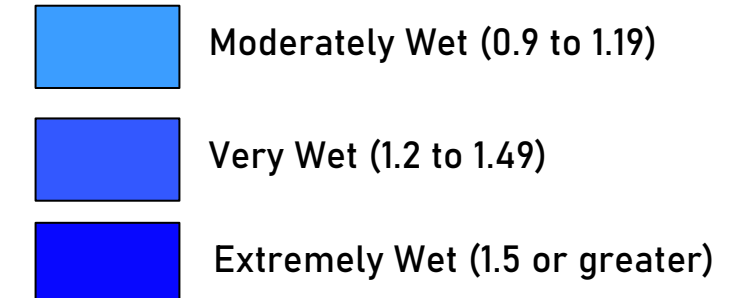
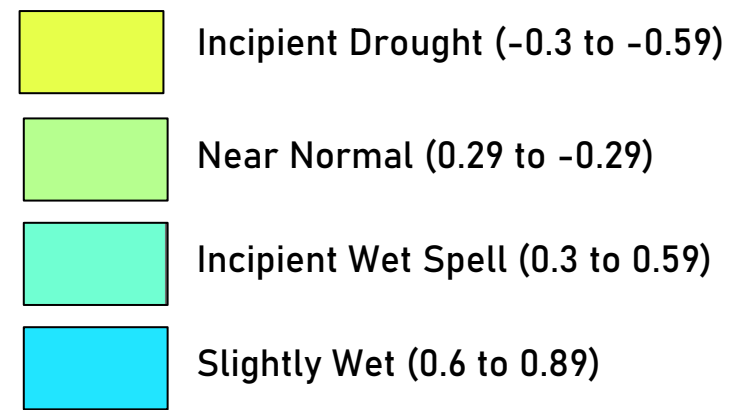
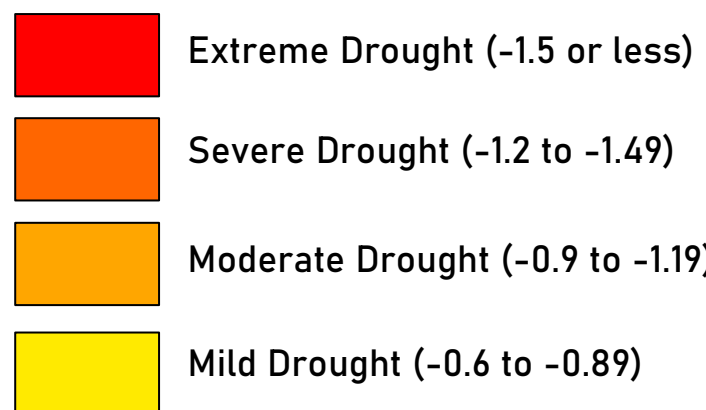


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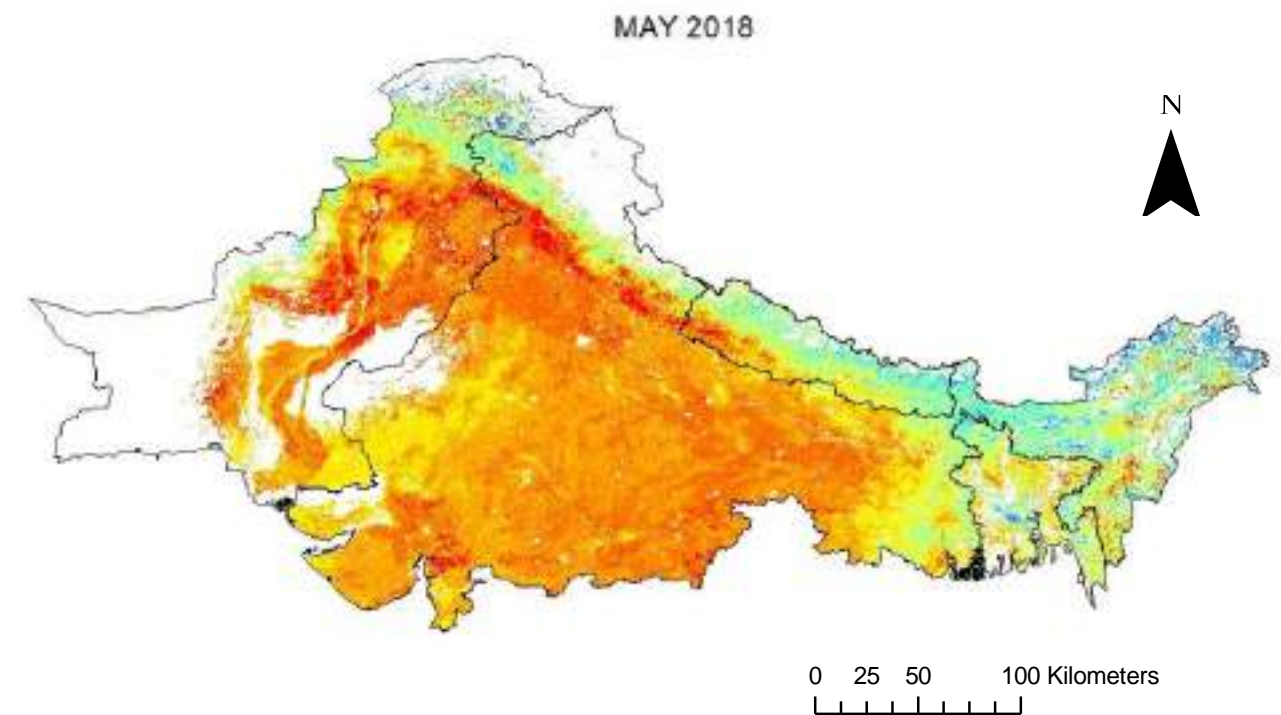
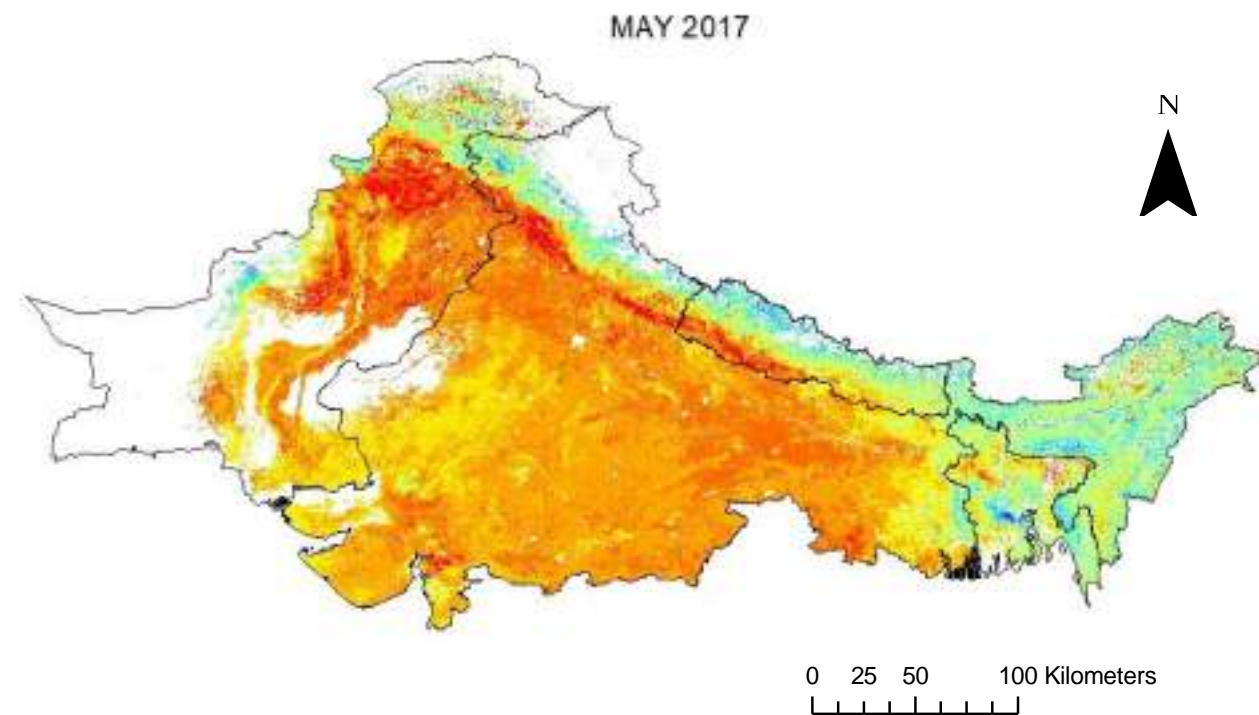




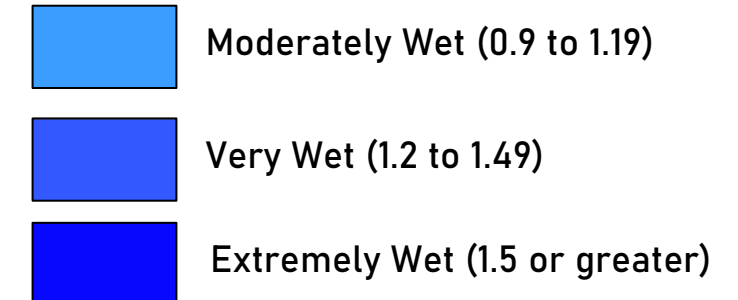
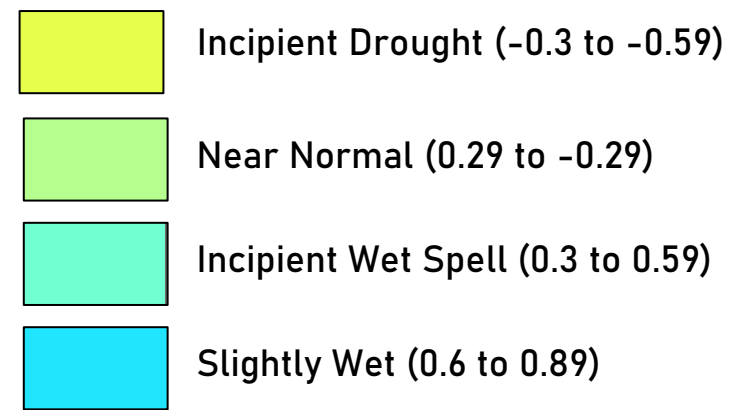
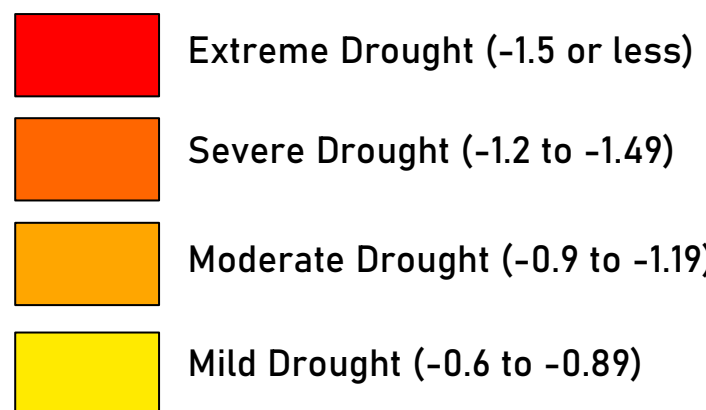
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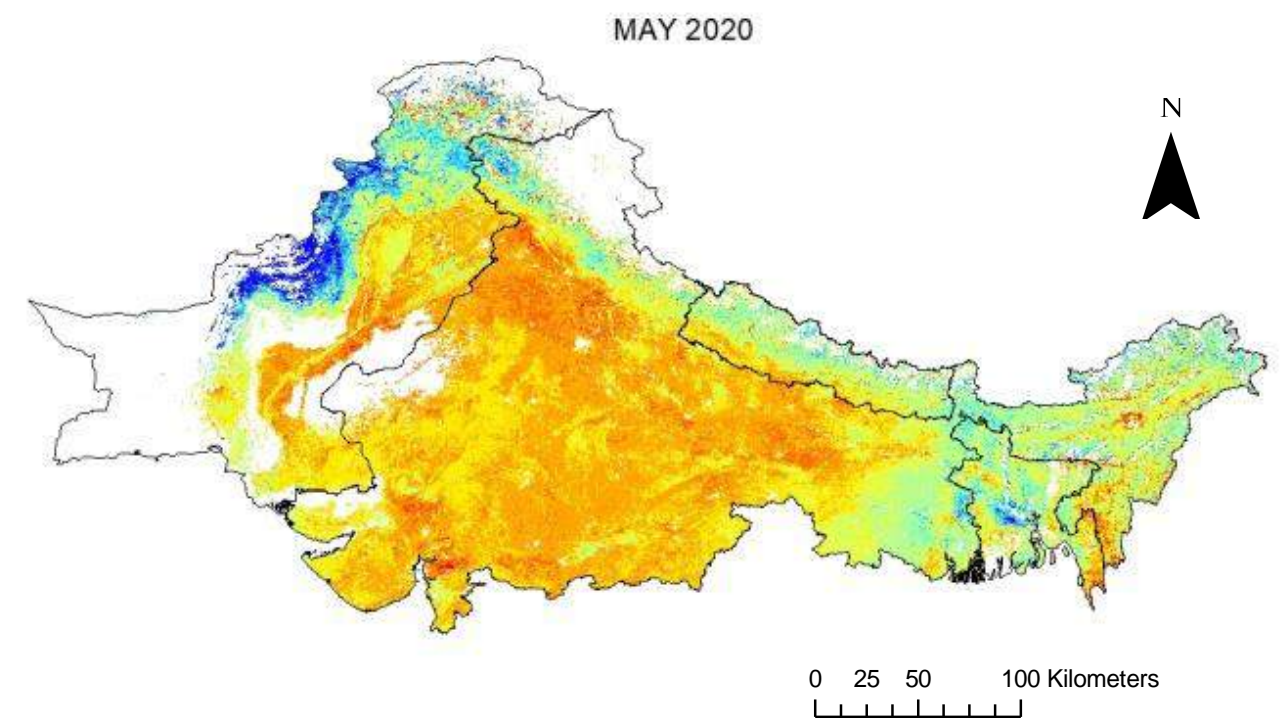
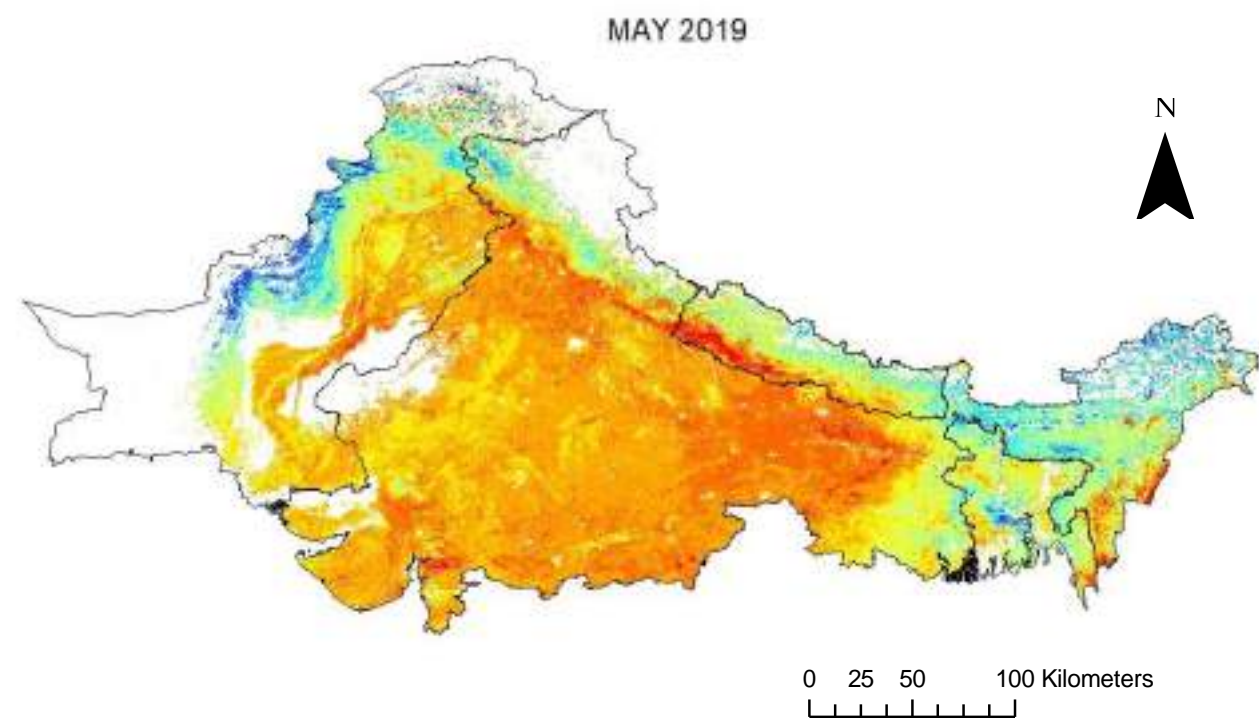




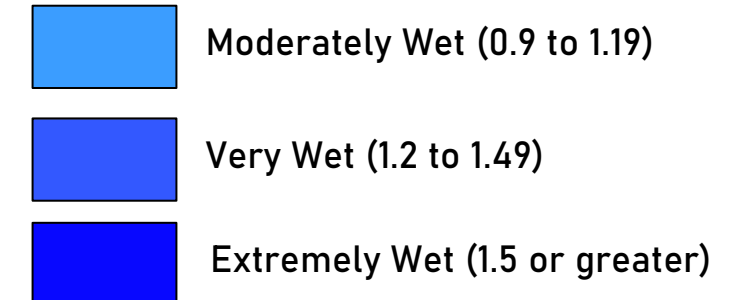
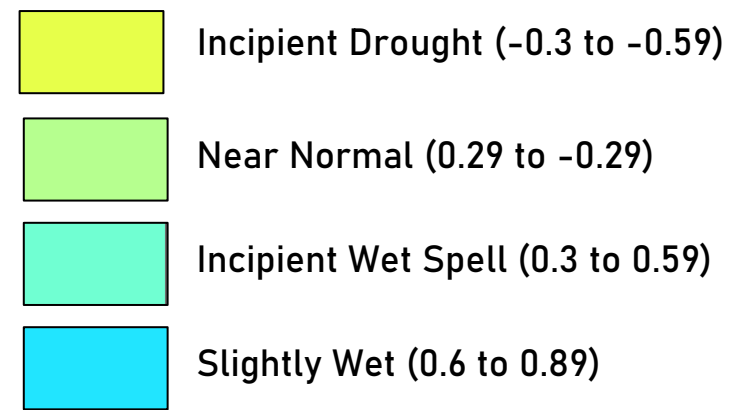
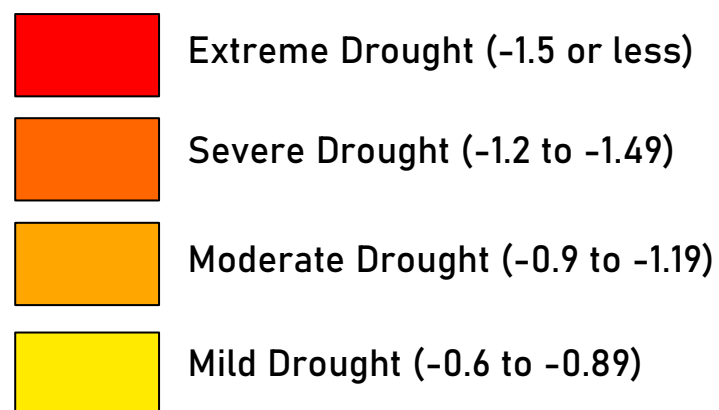


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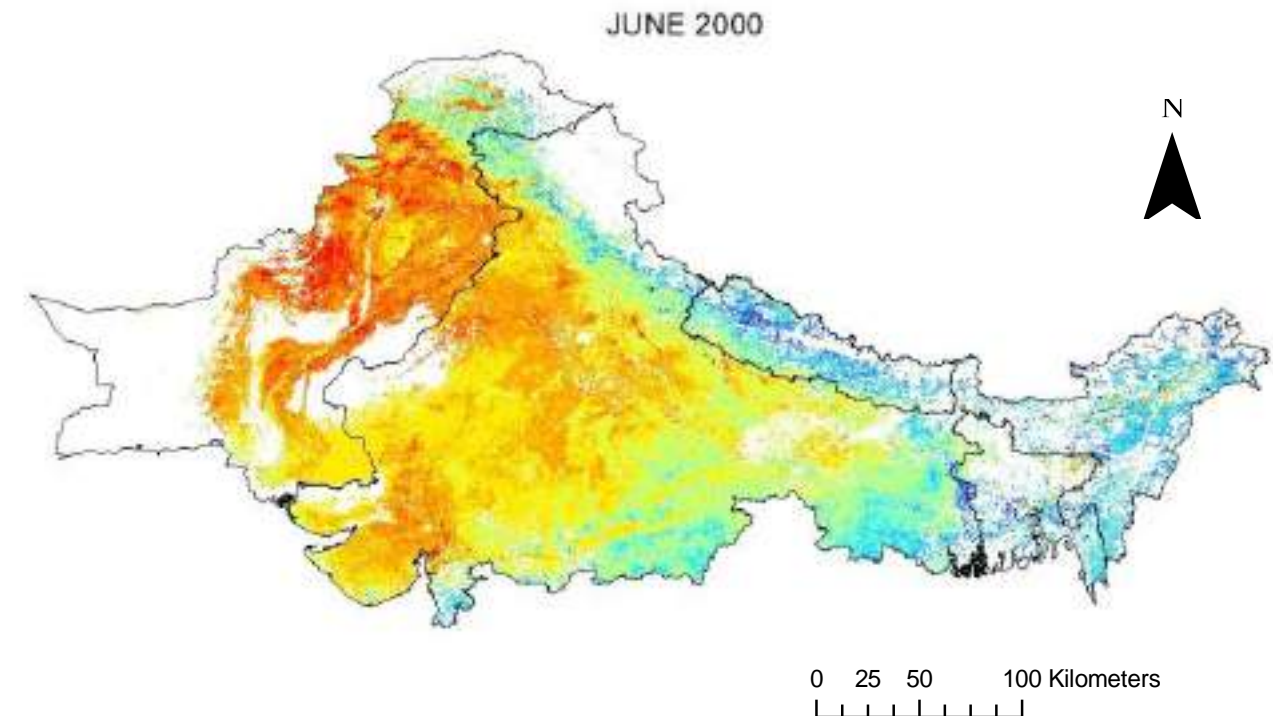
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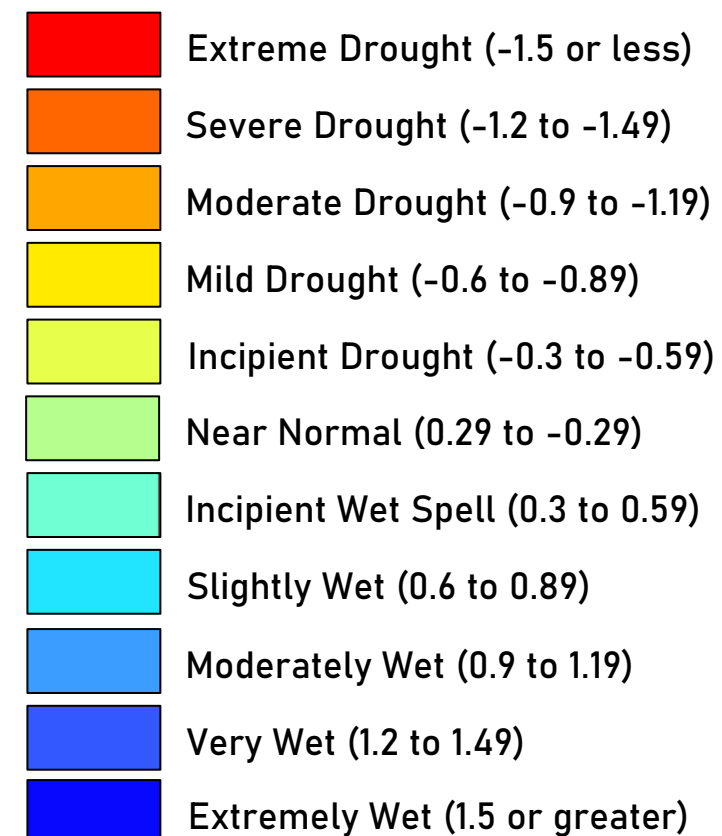
## June DSI Maps

Drought in June normally ranges from moderate drought to near normal. This month is characterized by incipient drought. The lowest DSI value of -0.9 was noted as driest condition of June in 2012.

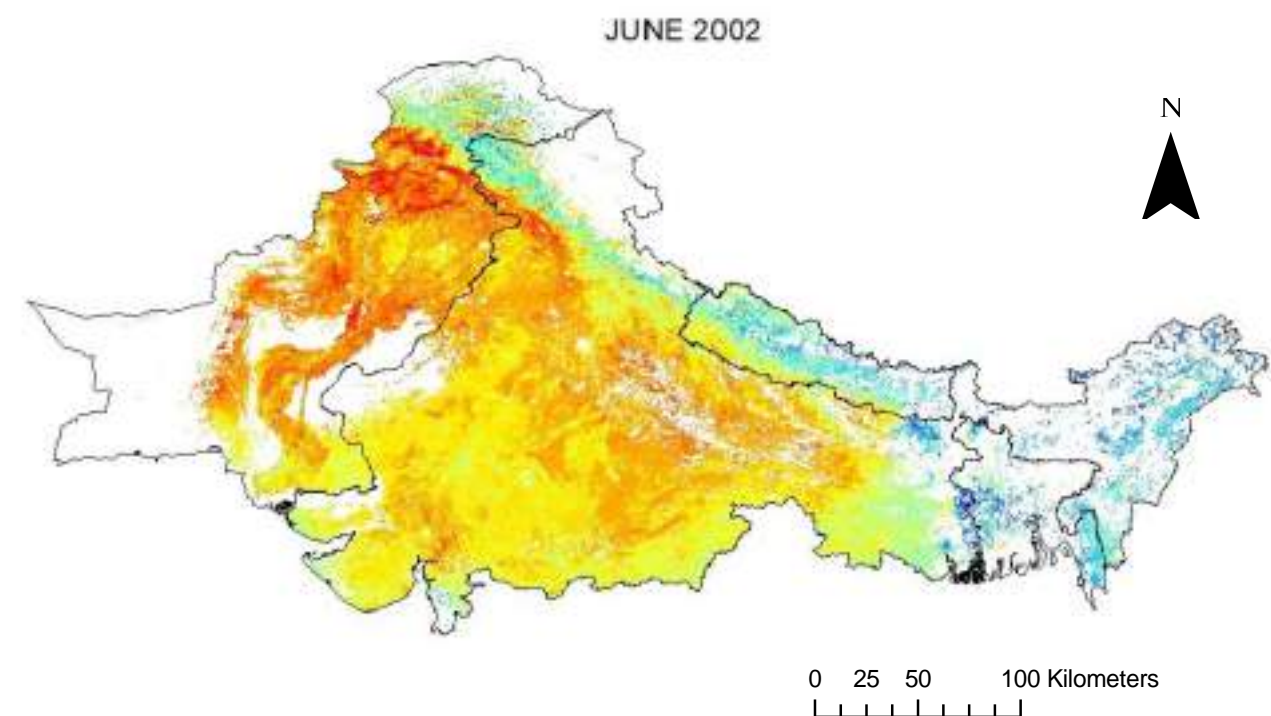
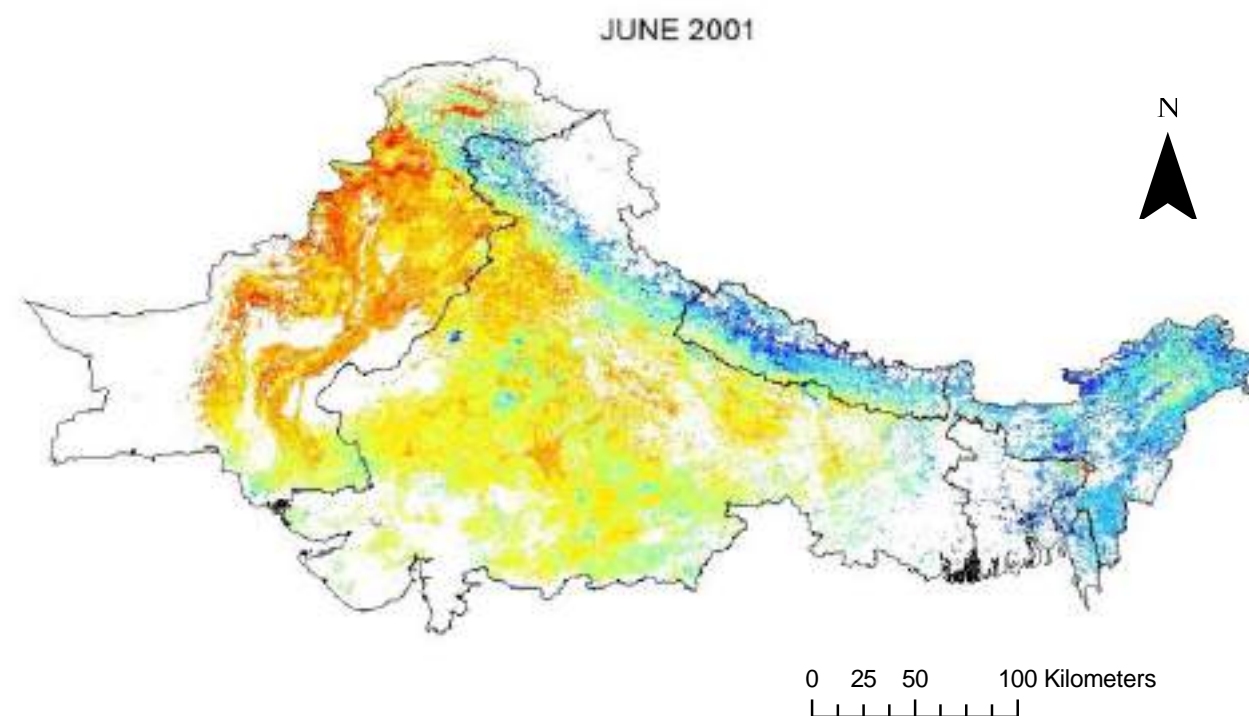
Mean June DSI Values		
Year	DSI Values	Drought Condition
2000	-0.32	Incipient Drought
2001	0.00	Near Normal
2002	-0.50	Incipient Drought
2003	-0.49	Incipient Drought
2004	-0.30	Incipient Drought
2005	-0.62	Mild Drought
2006	-0.13	Near Normal
2007	0.10	Near Normal
2008	0.05	Near Normal
2009	-0.36	Incipient Drought
2010	-0.44	Incipient Drought
2011	-0.34	Incipient Drought
2012	-0.90	Moderate Drought
2013	-0.05	Near Normal
2014	-0.54	Incipient Drought
2015	-0.61	Mild Drought
2016	-0.47	Incipient Drought
2017	-0.40	Incipient Drought
2018	-0.49	Incipient Drought
2019	-0.50	Incipient Drought
2020	-0.12	Near Normal



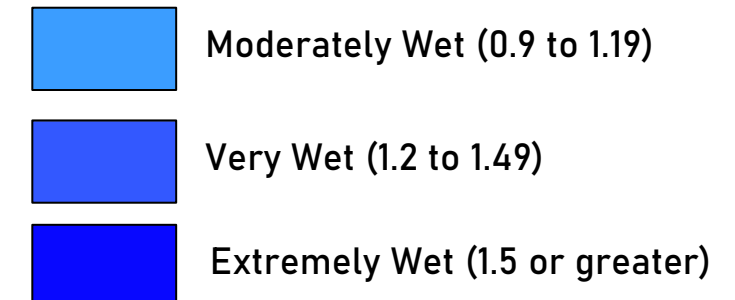
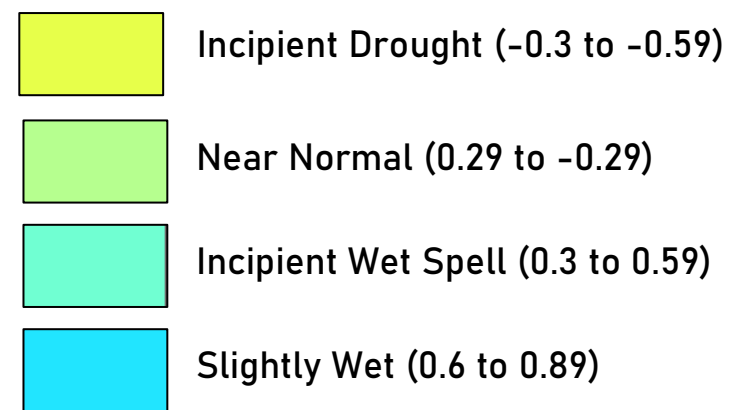
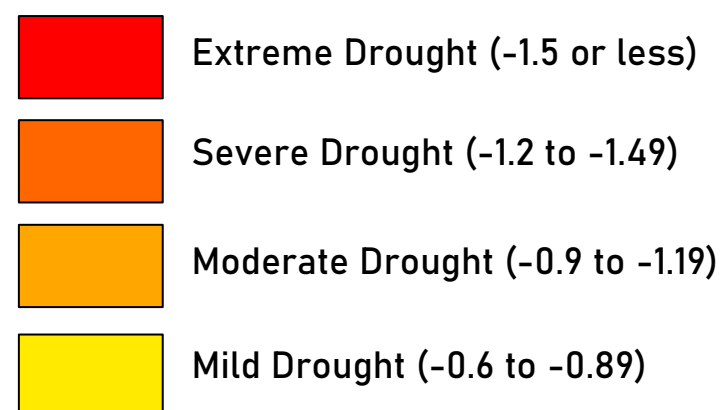
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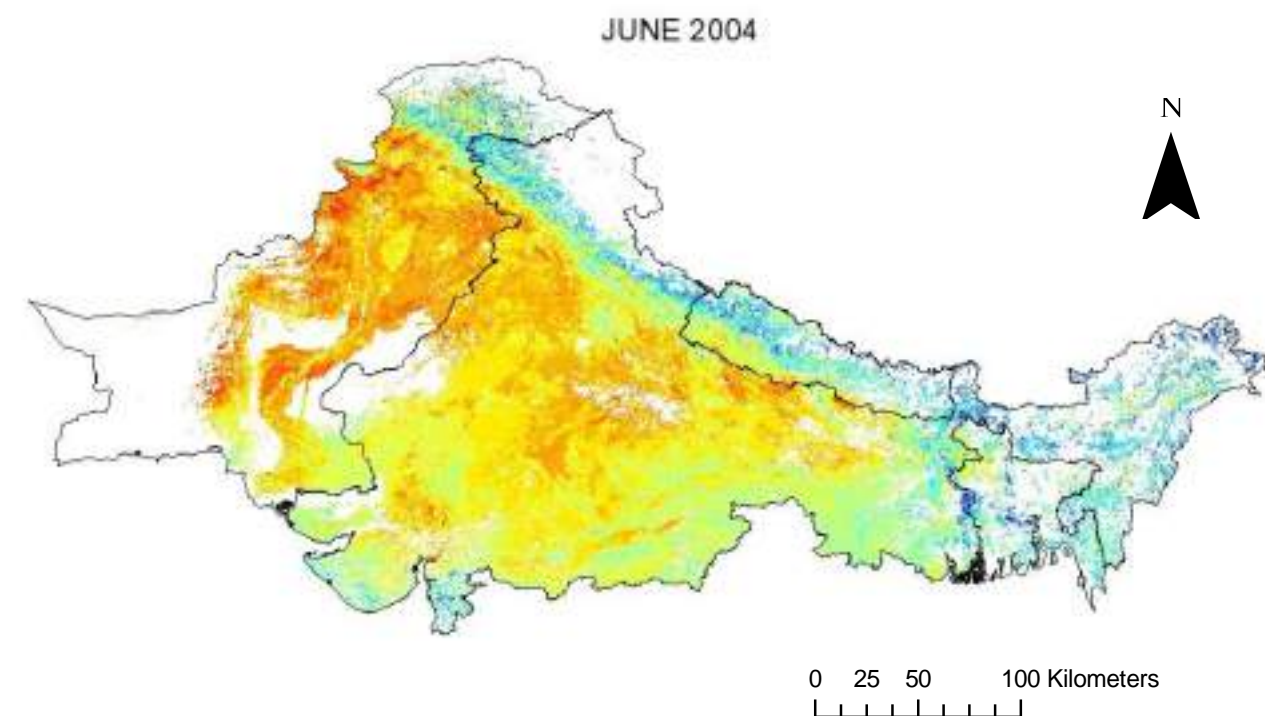
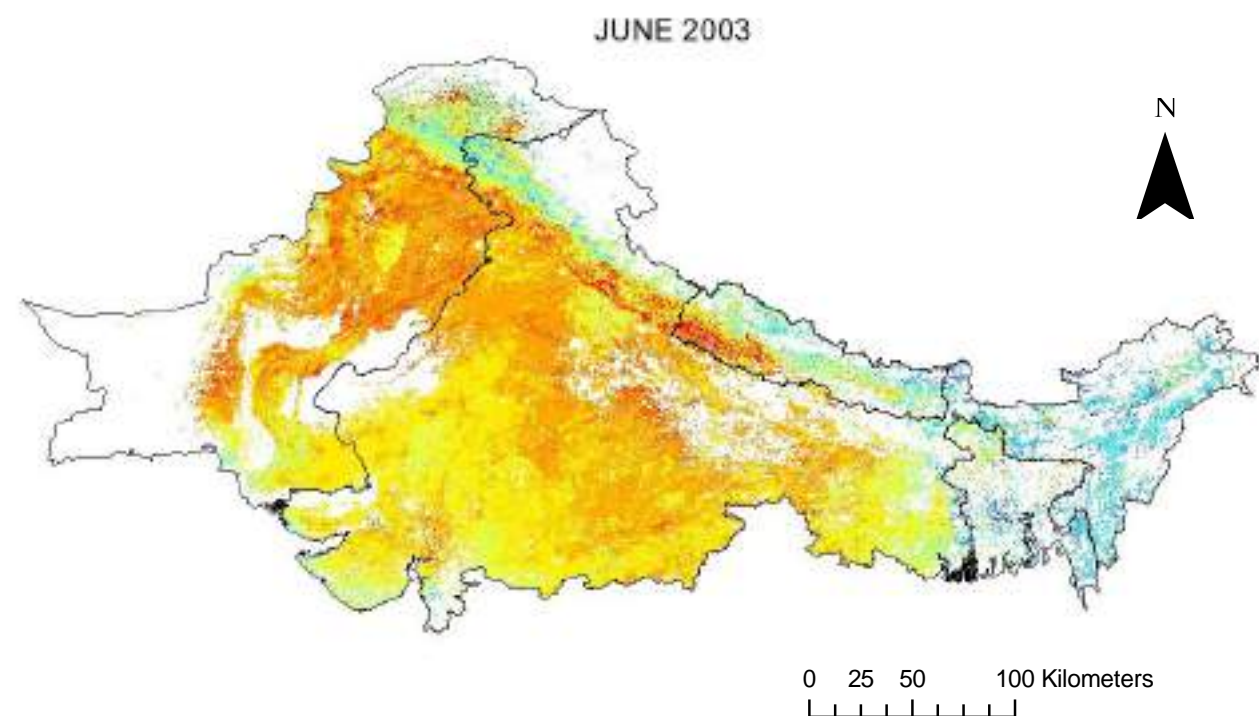




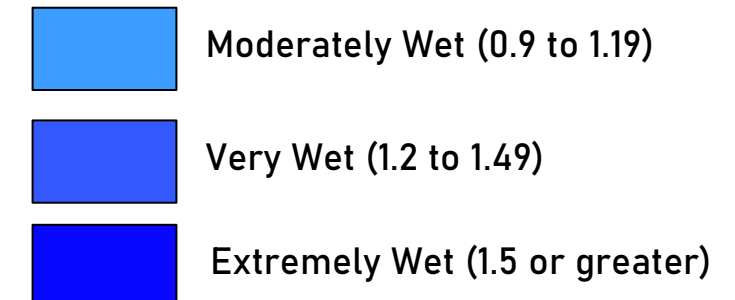
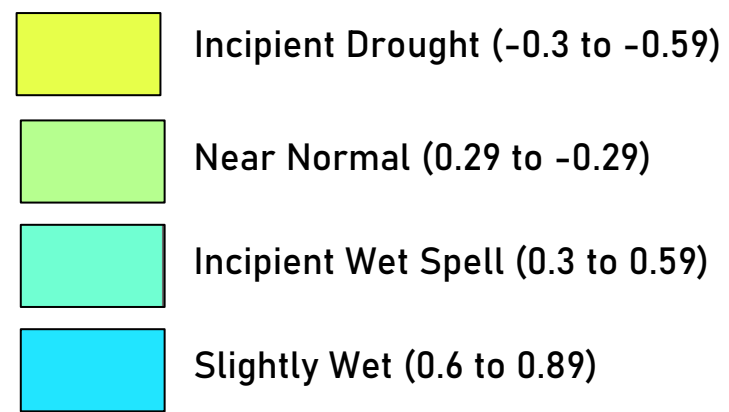
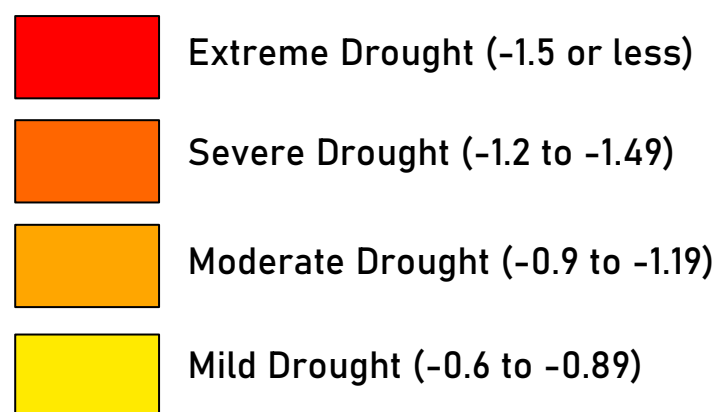


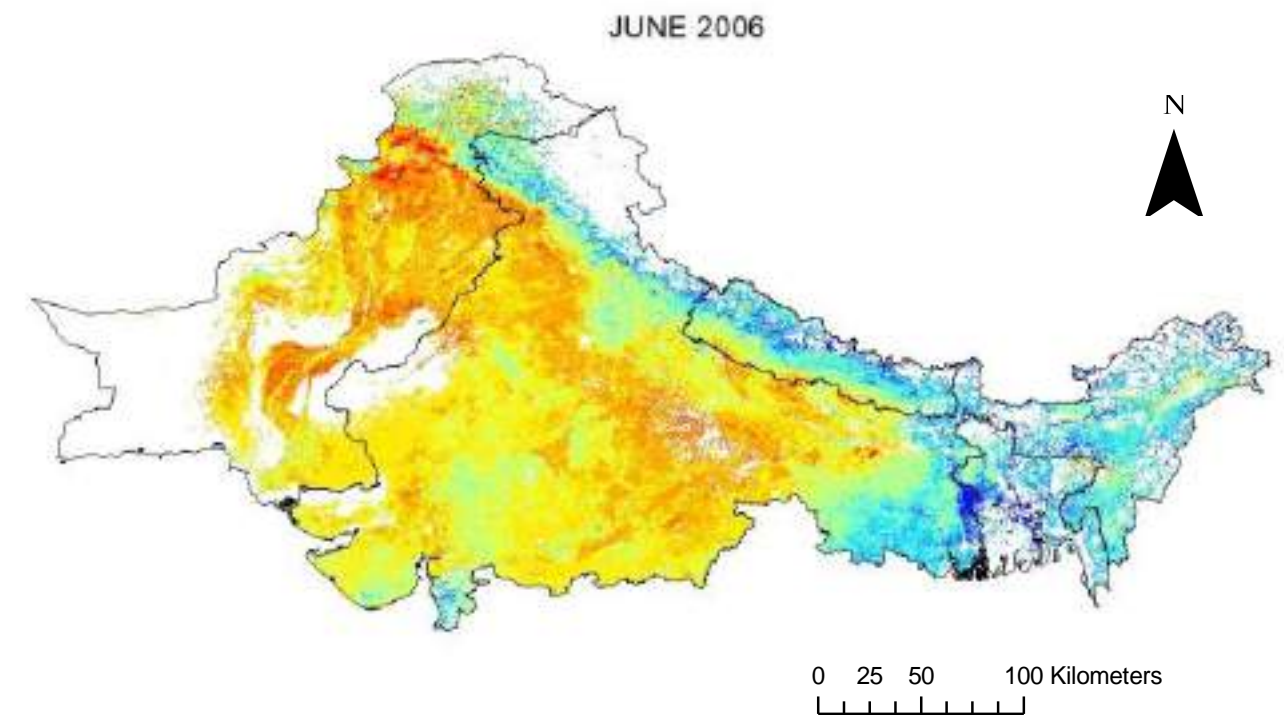
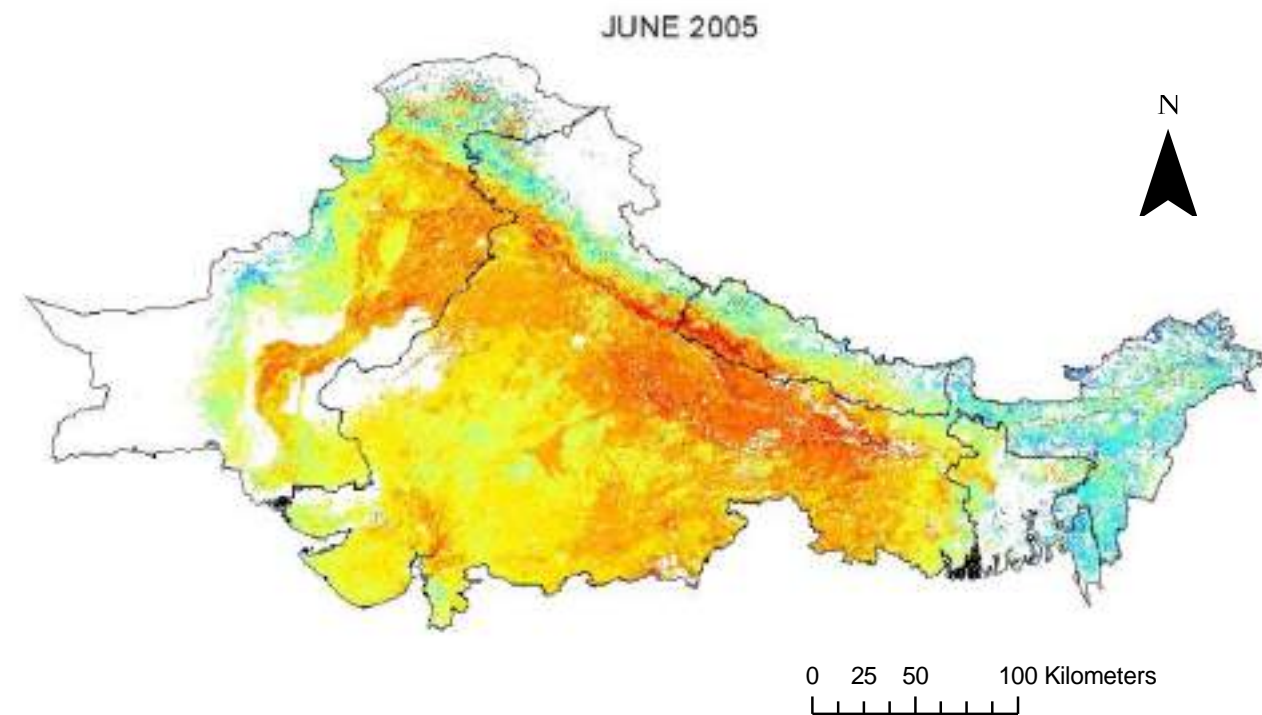
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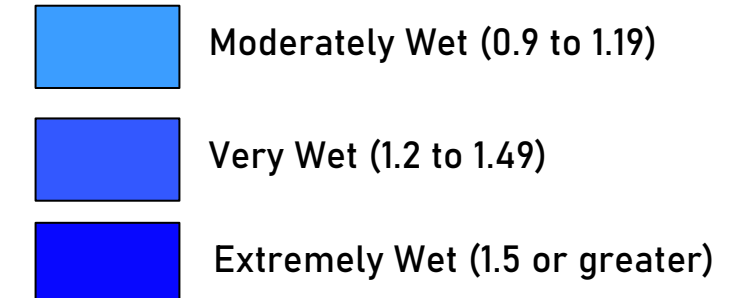
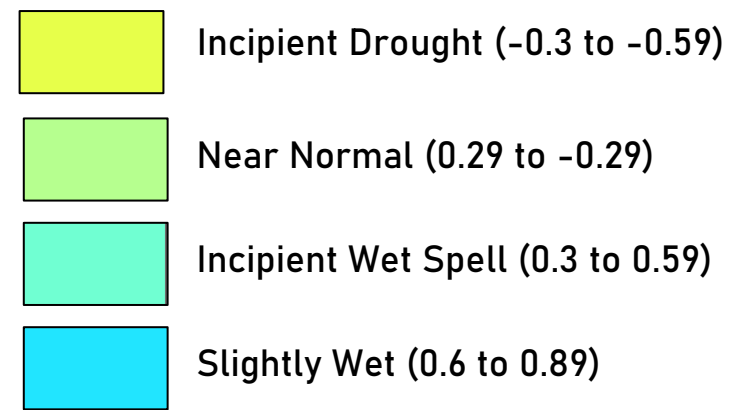
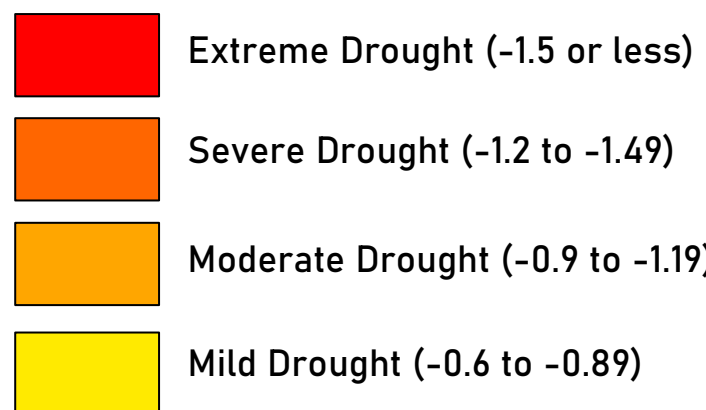


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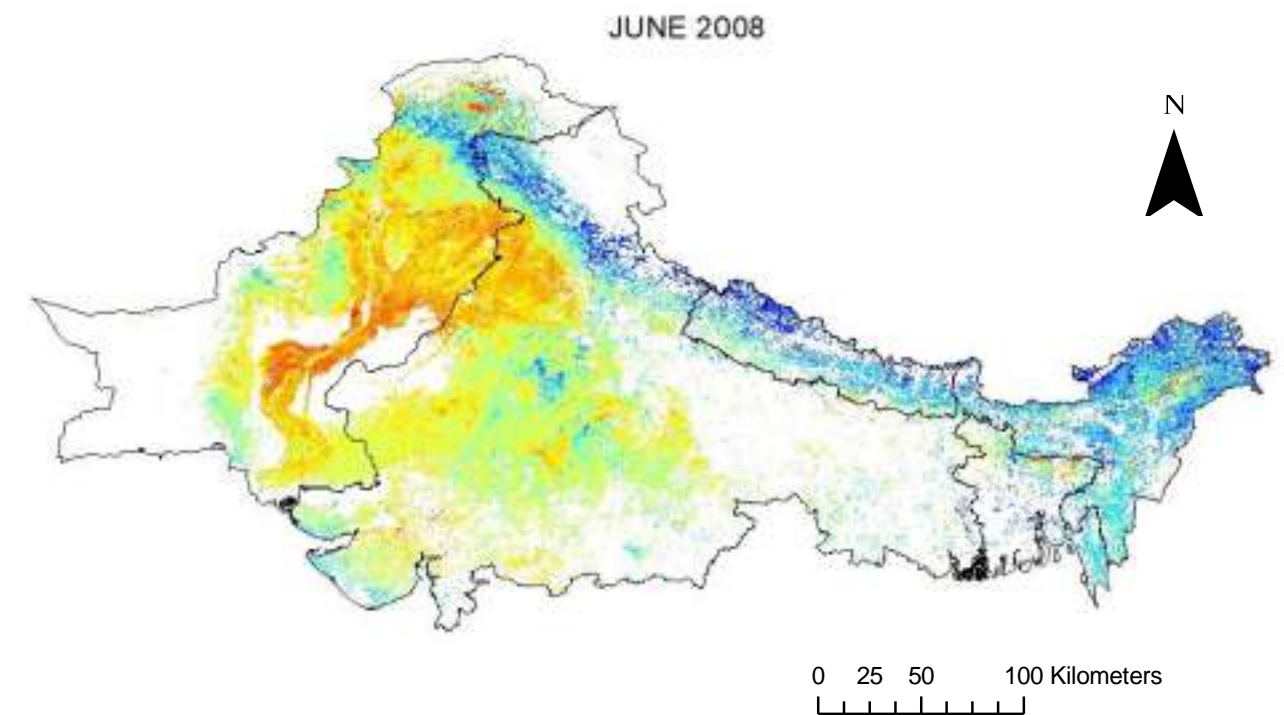
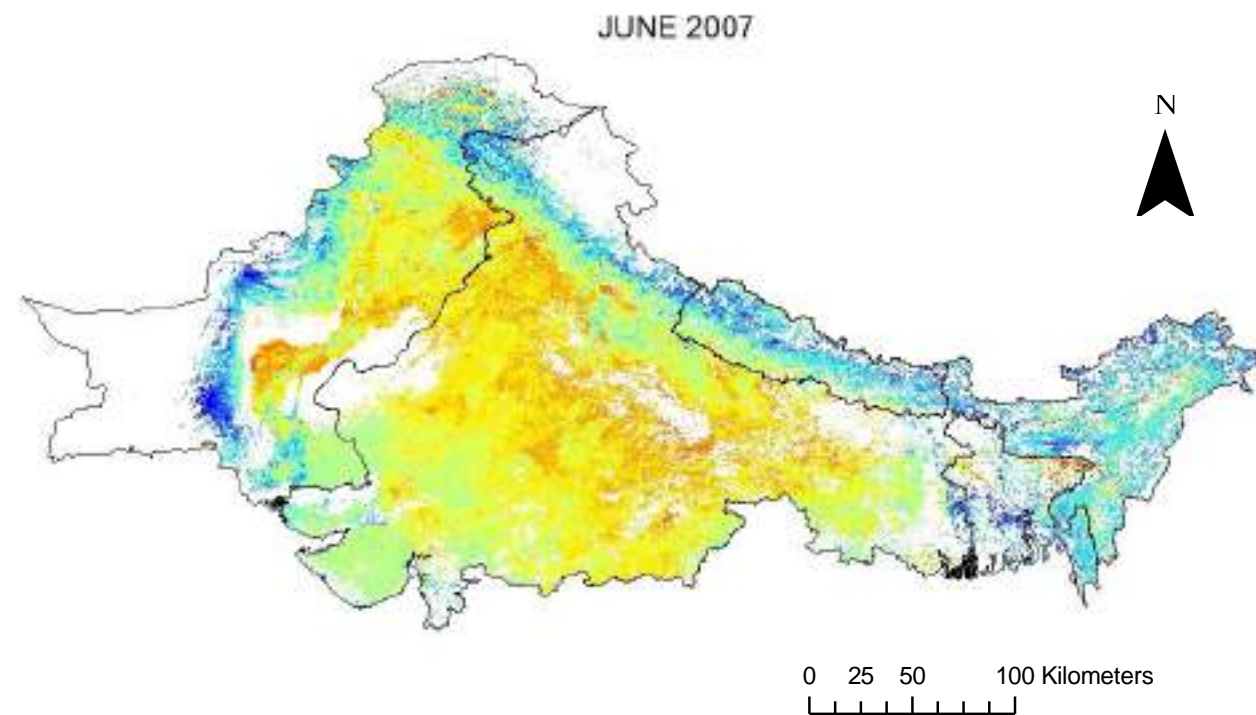




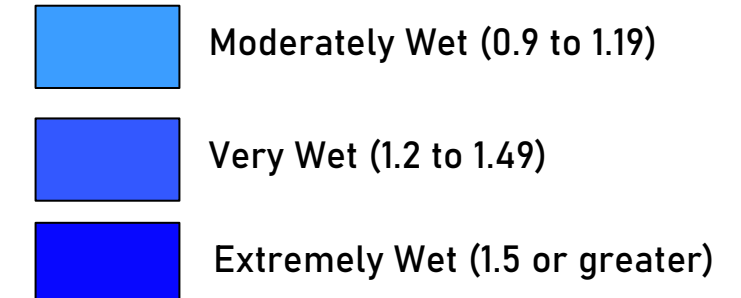
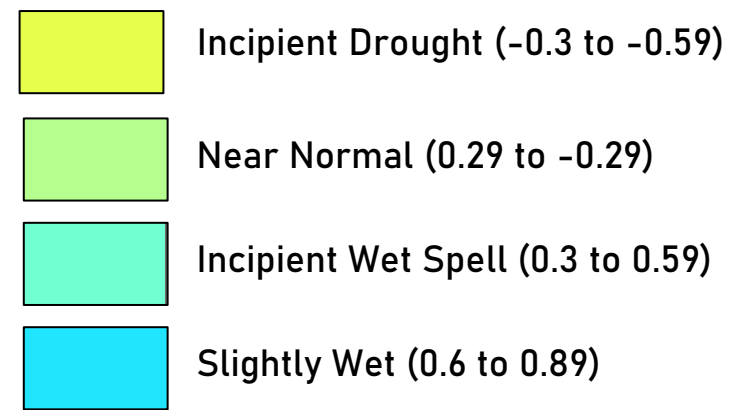
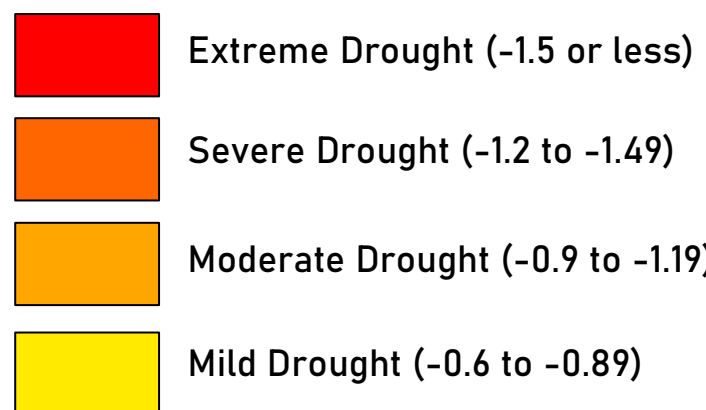
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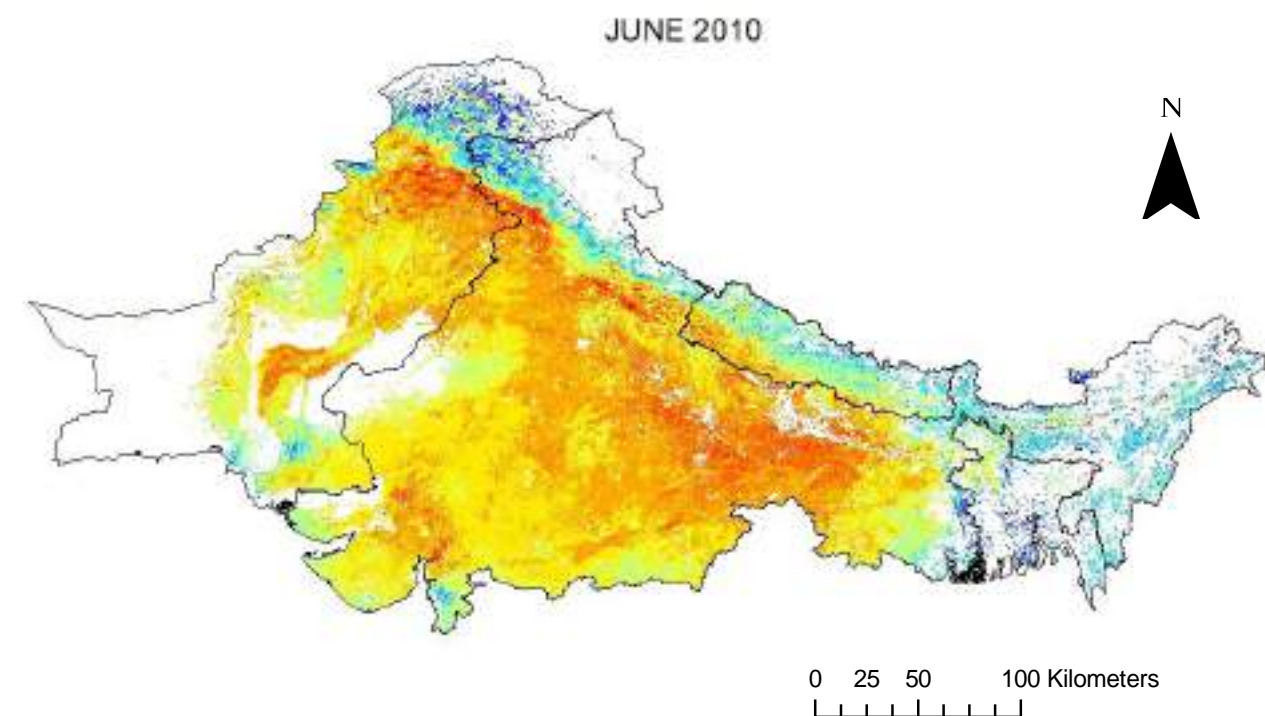
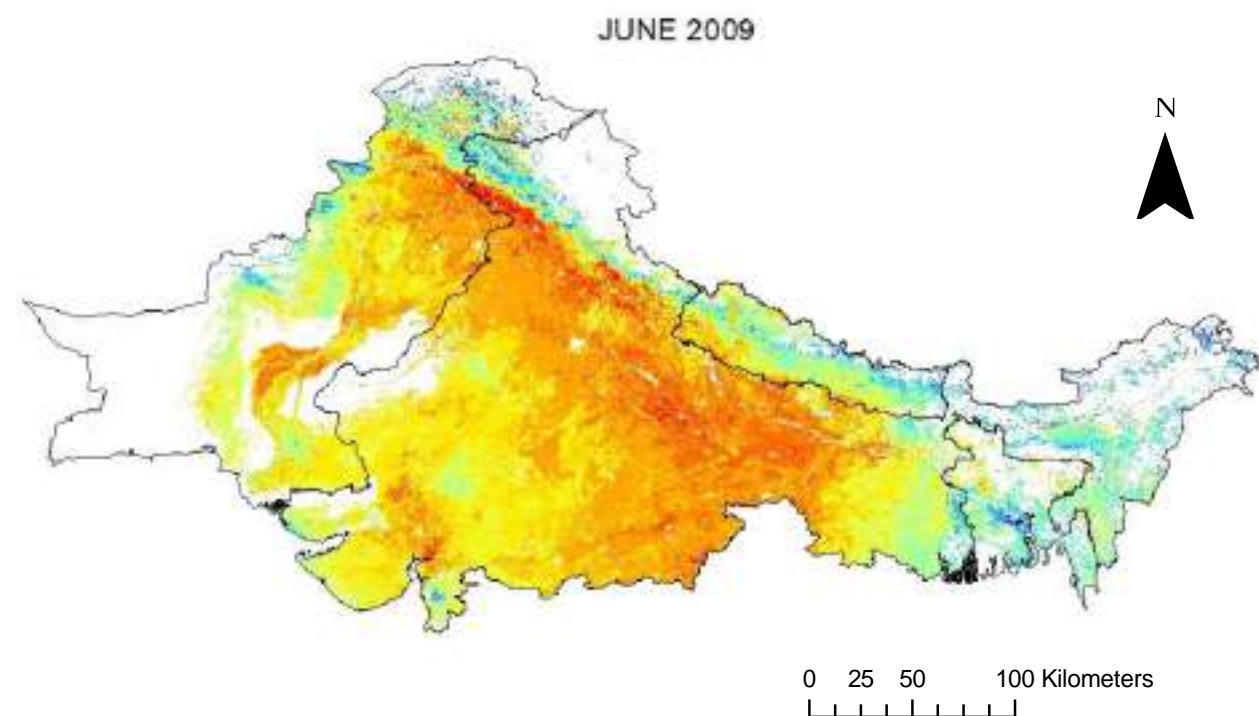




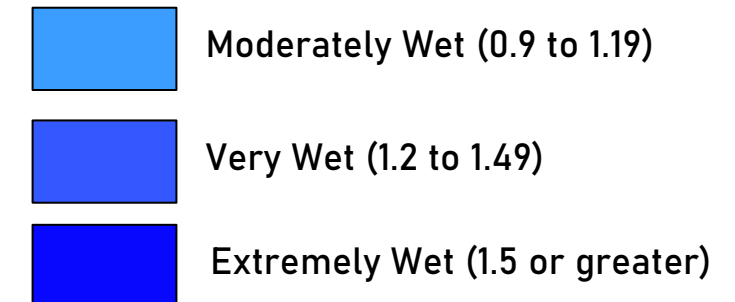
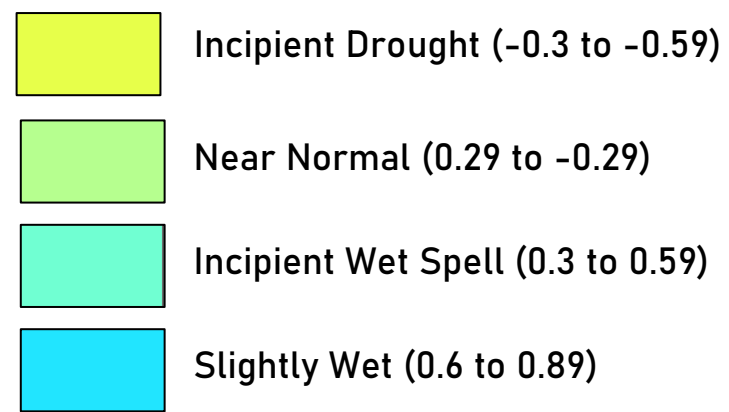
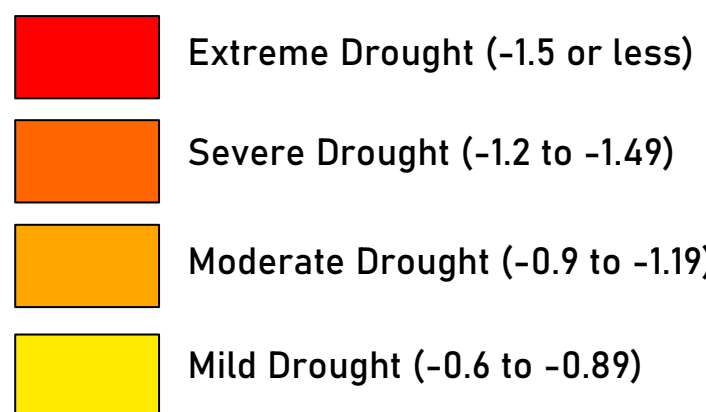


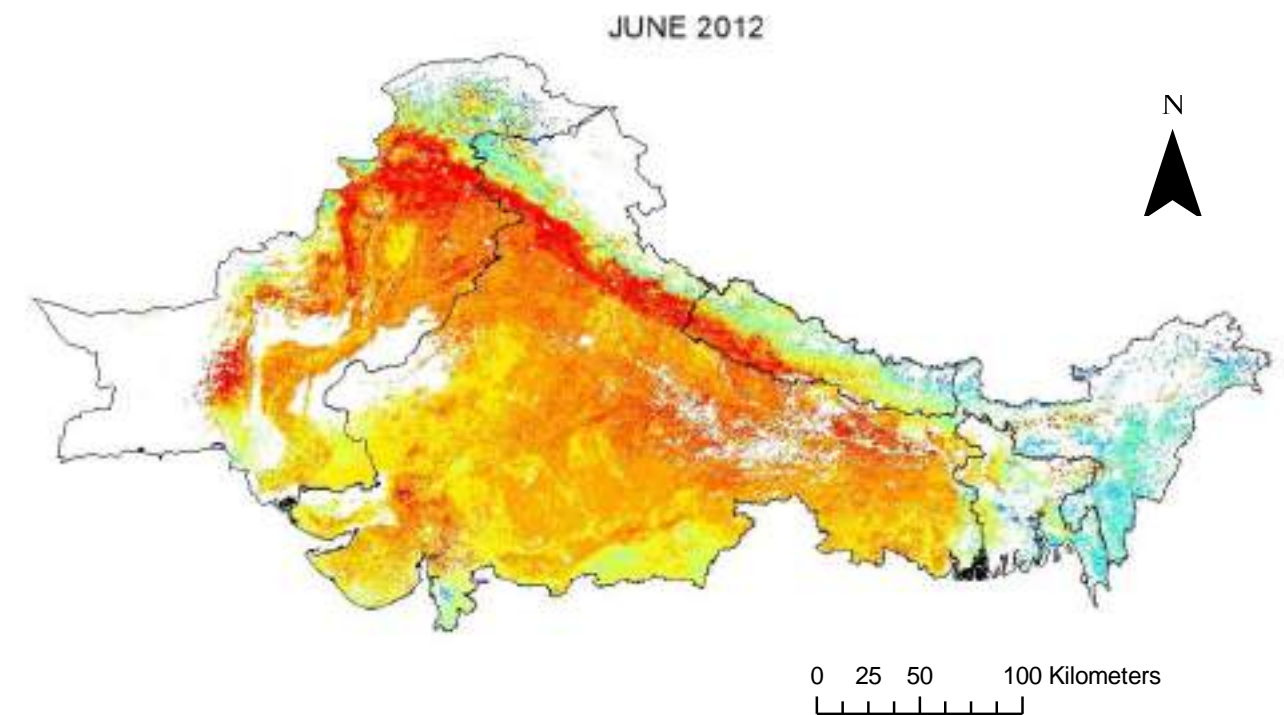
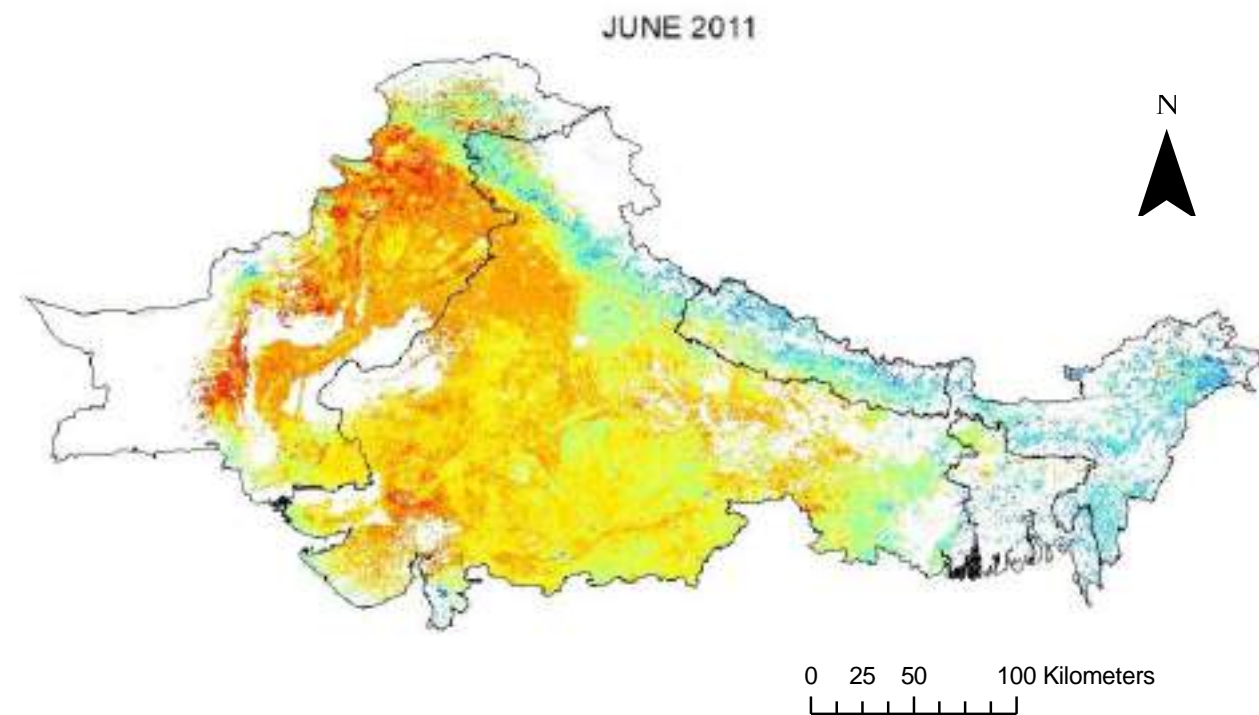
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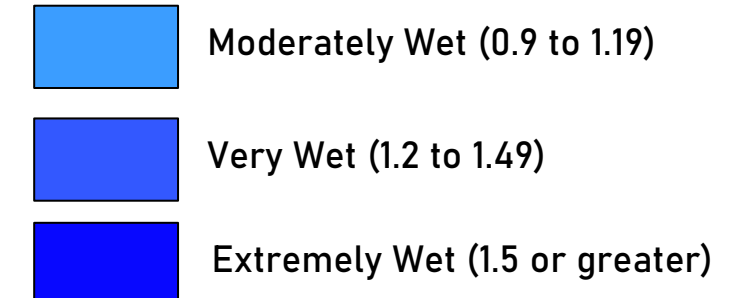
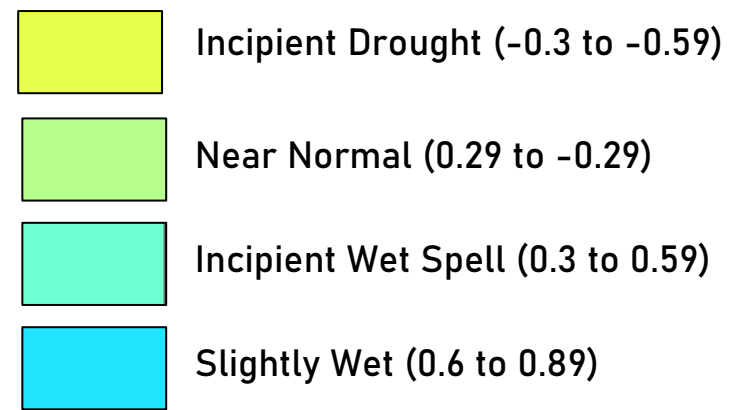
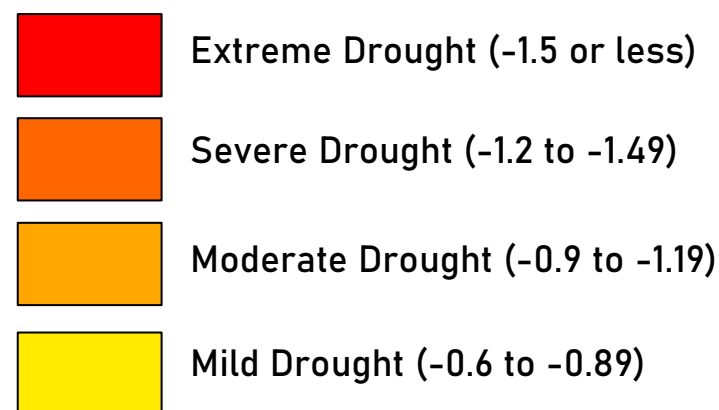


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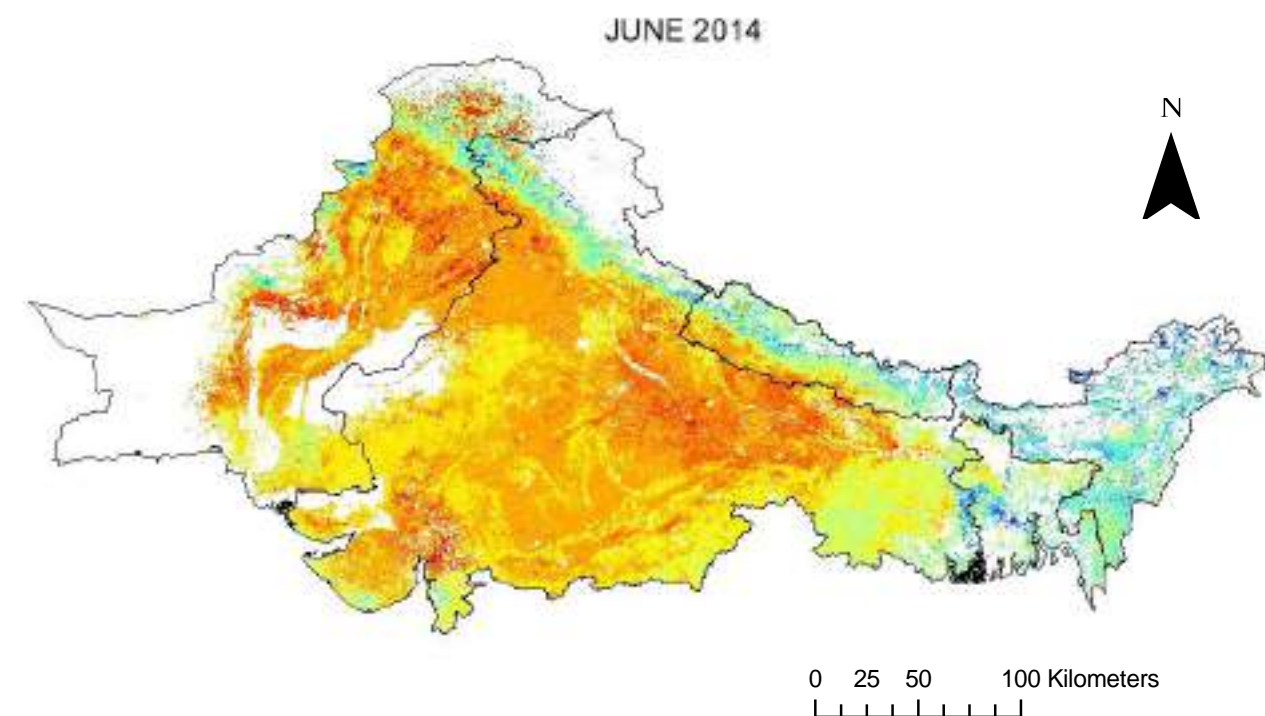
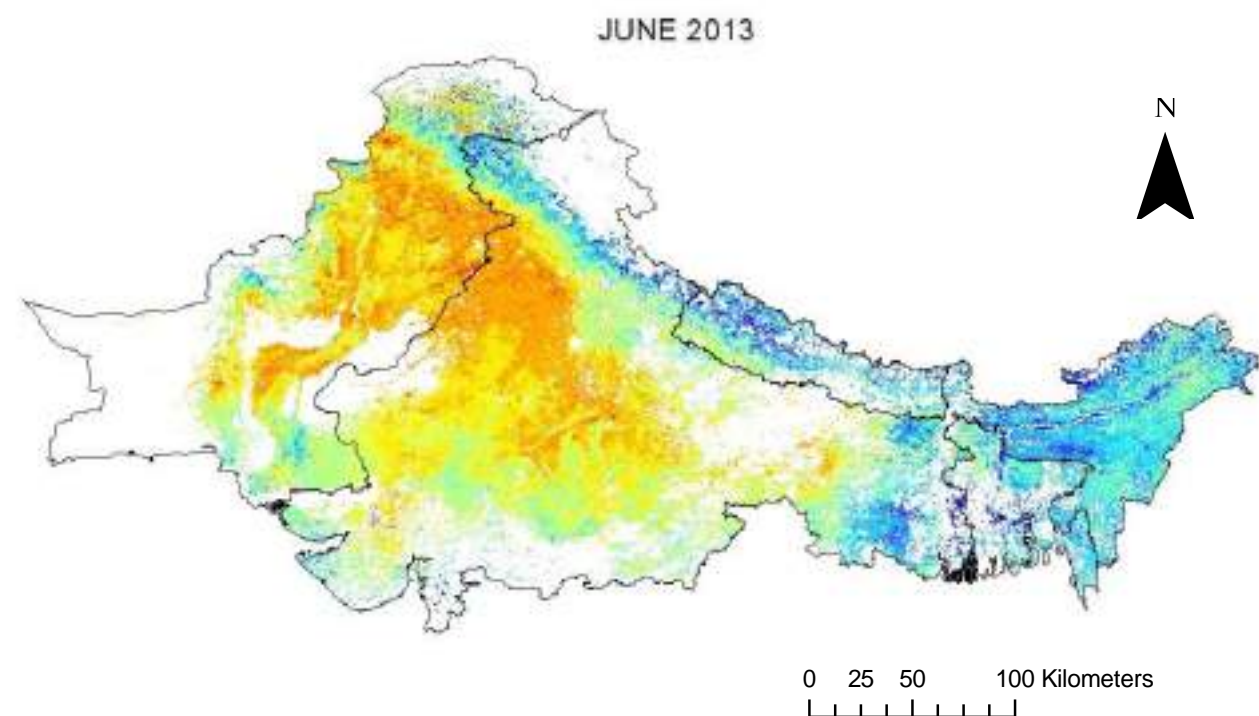




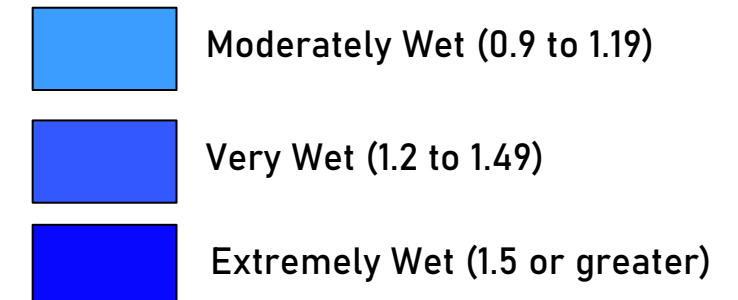
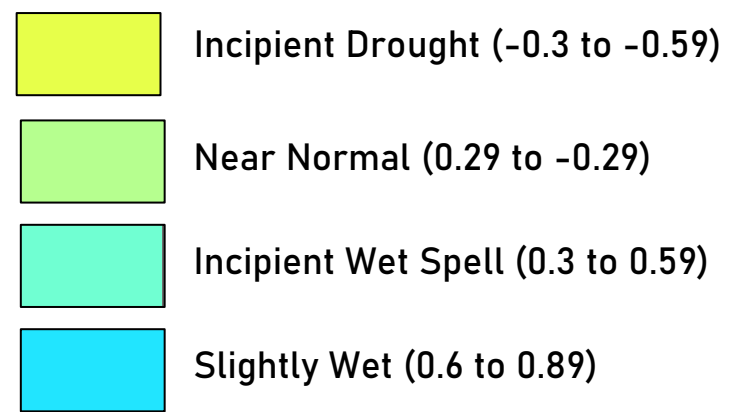
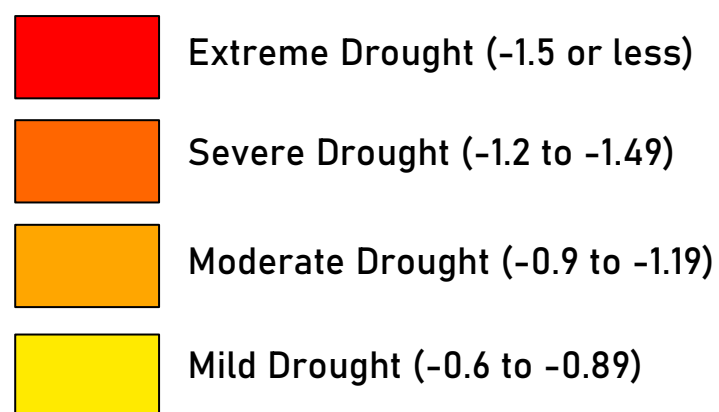
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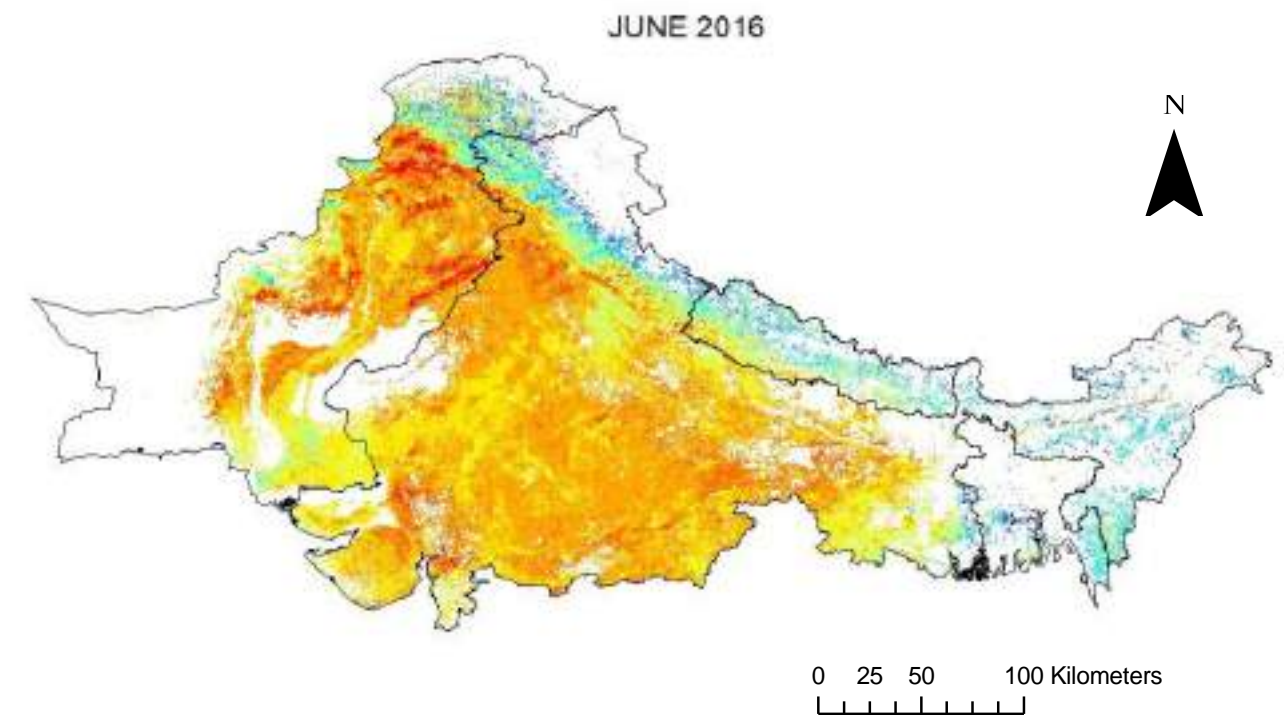
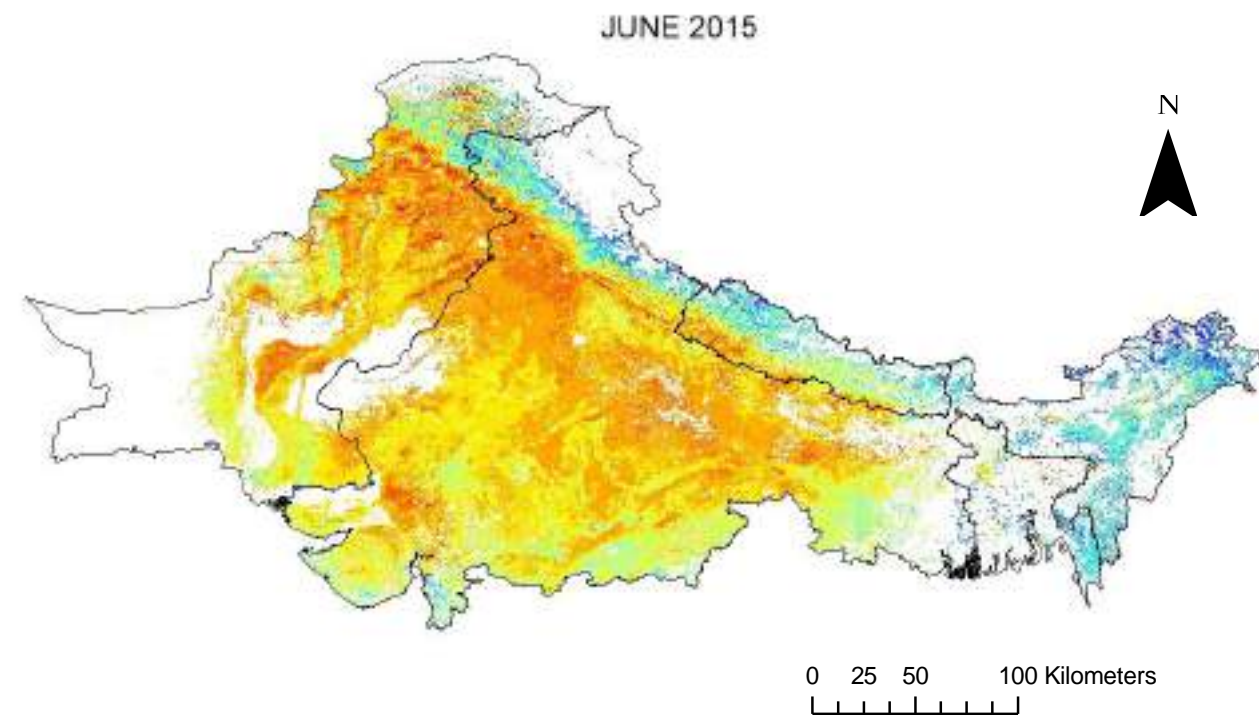




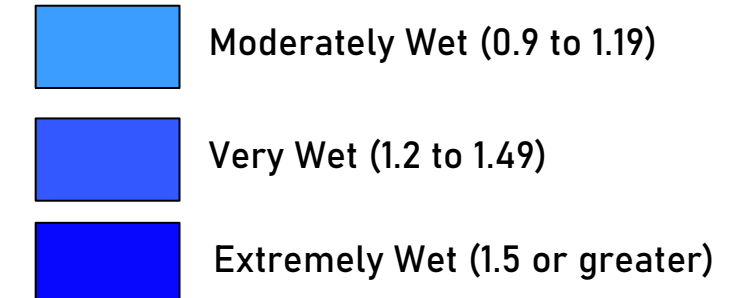
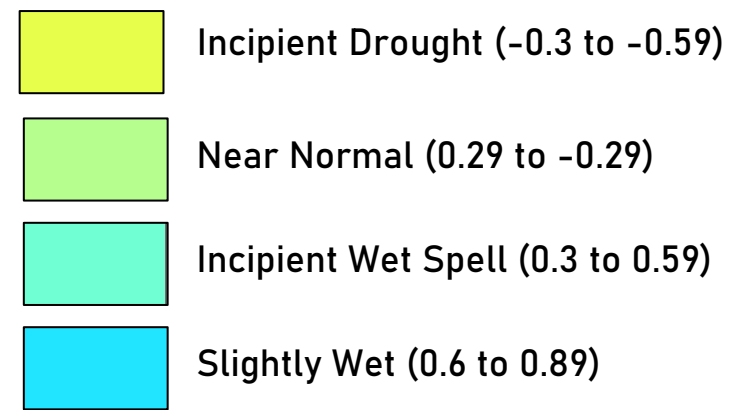
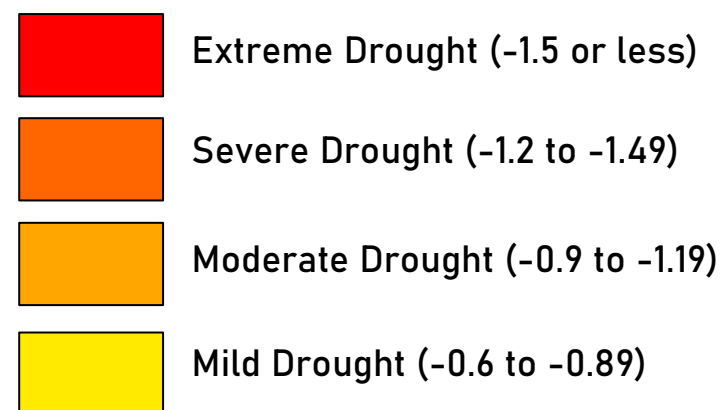


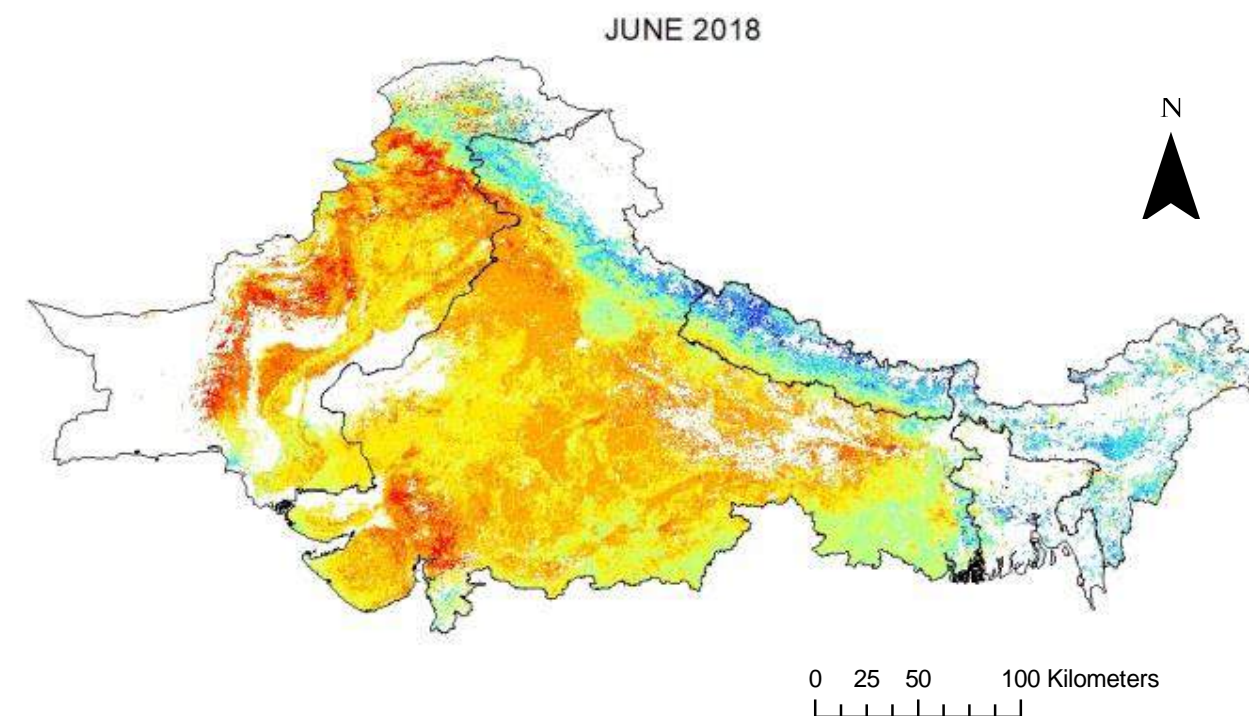
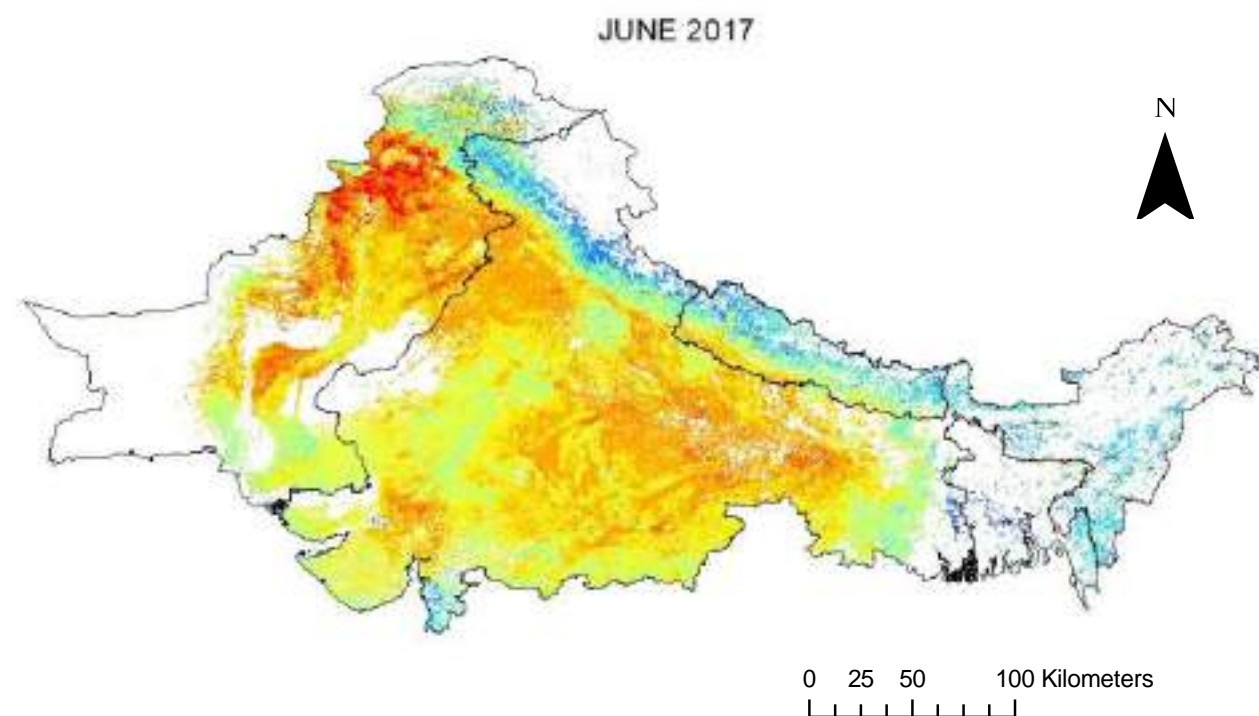
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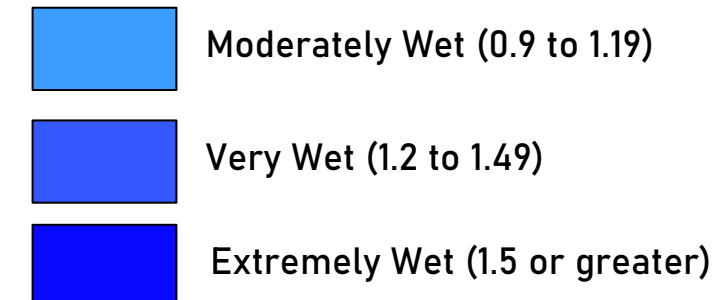
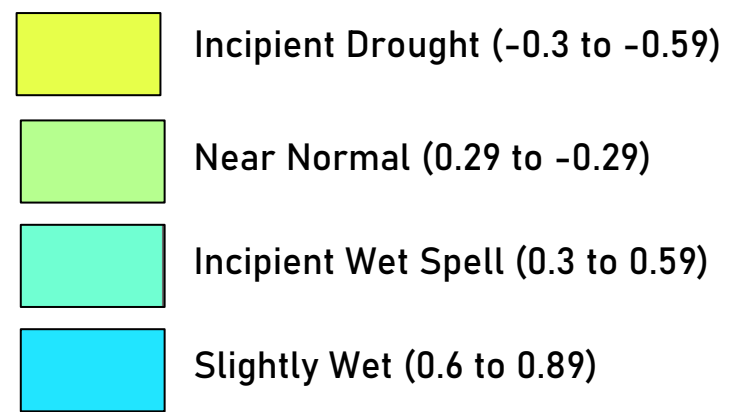
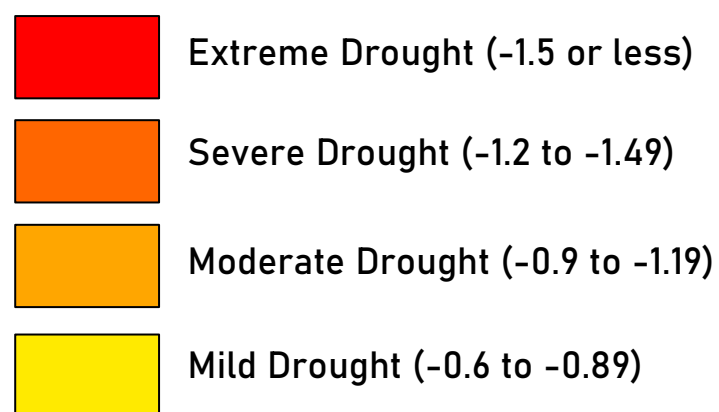


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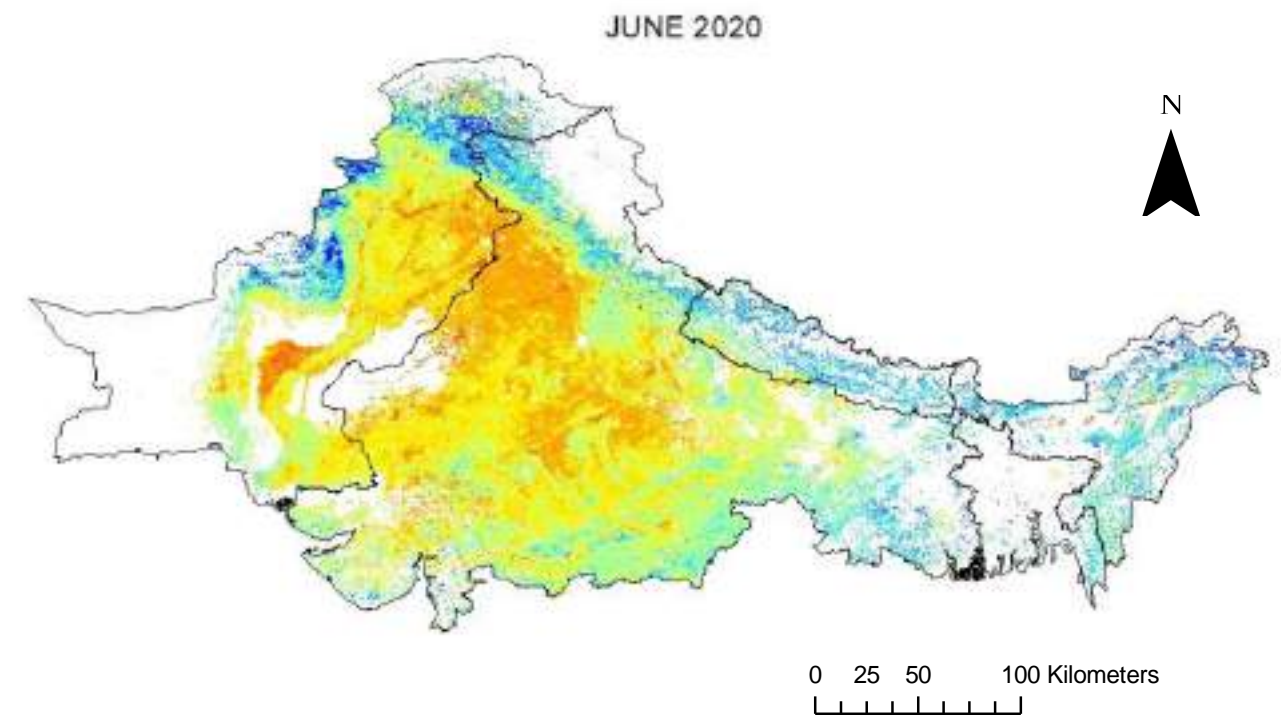
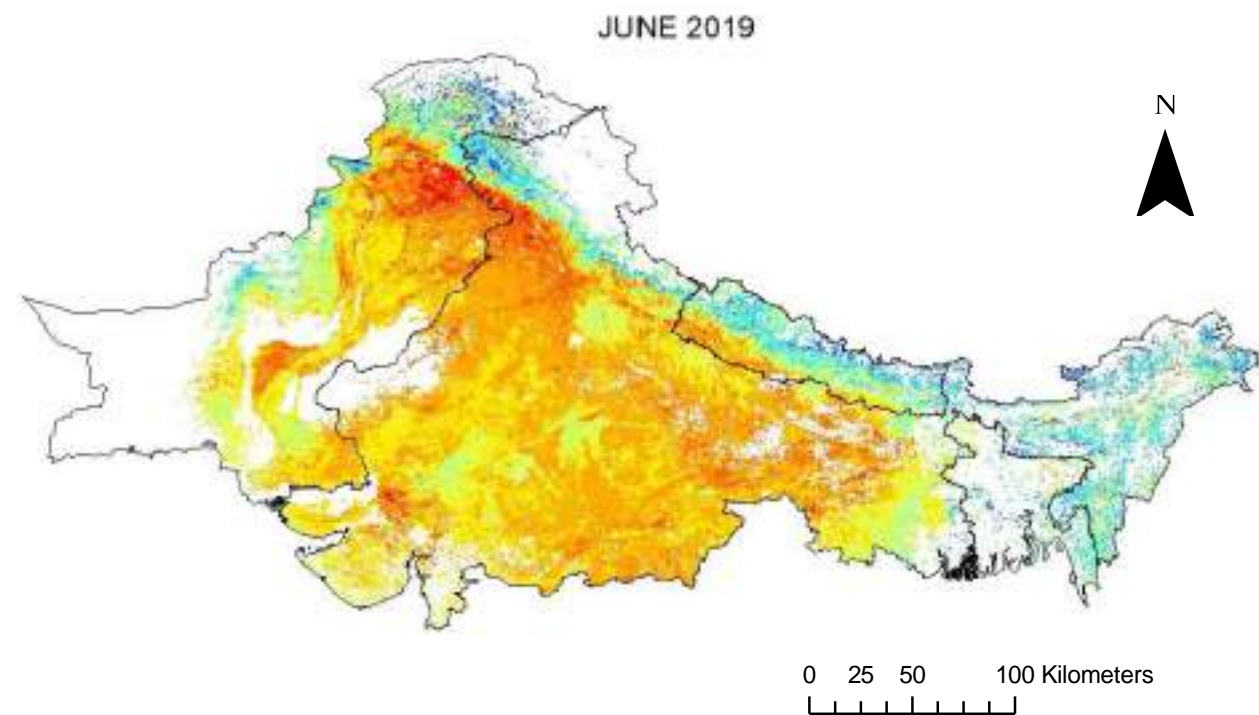




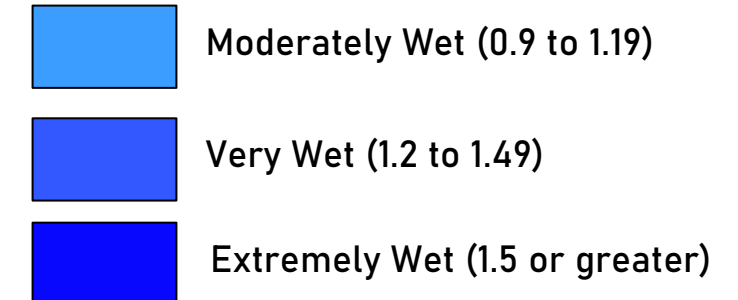
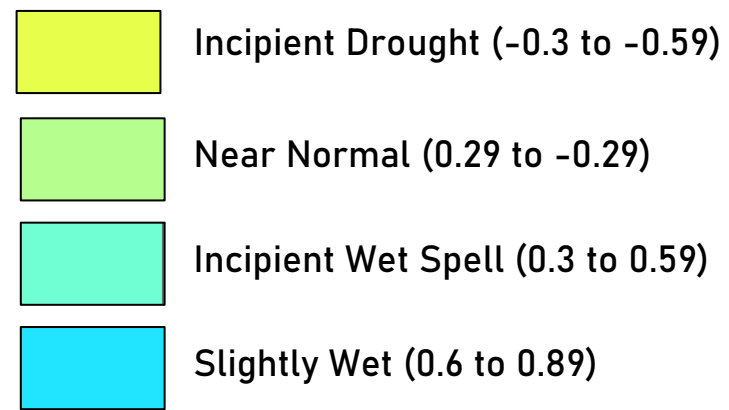
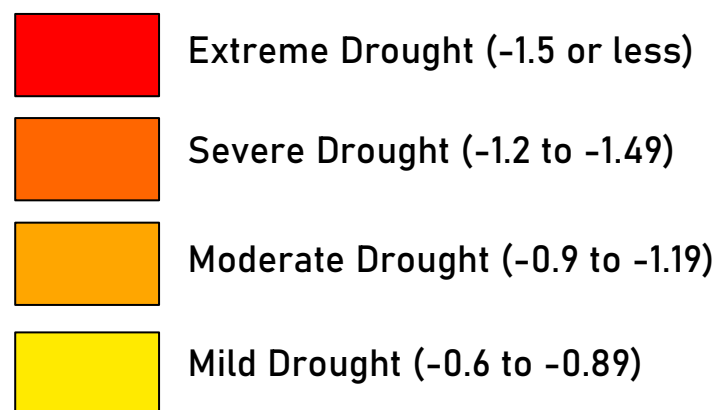
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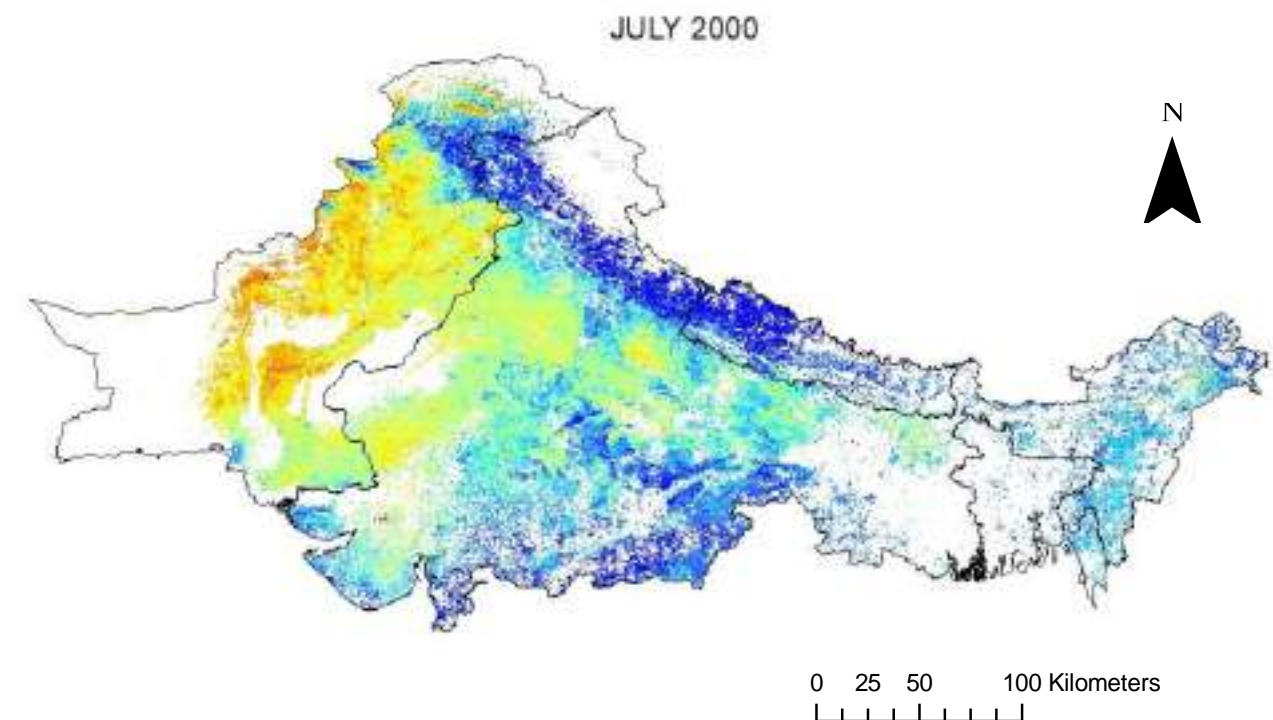
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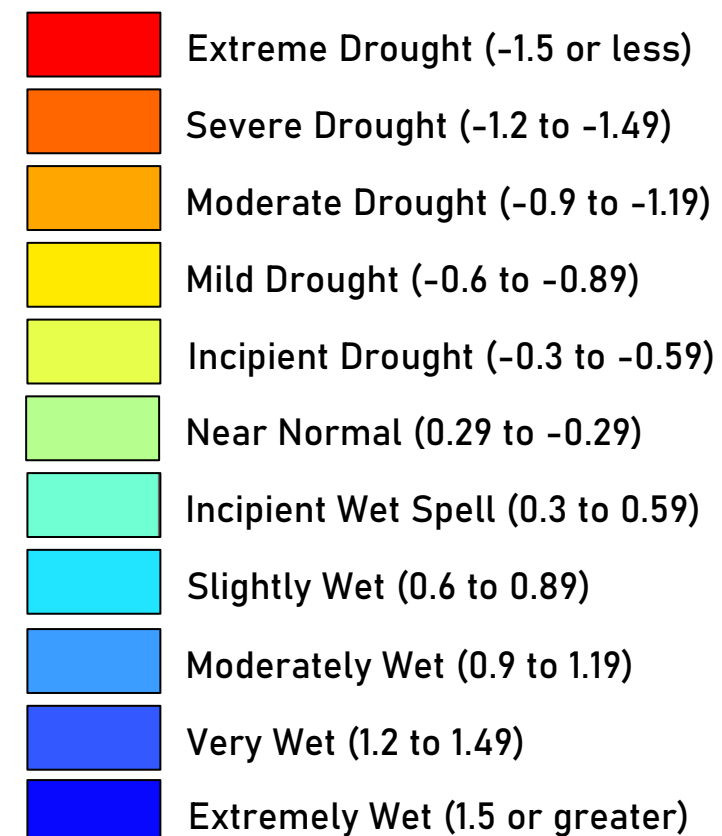
## July DSI Maps

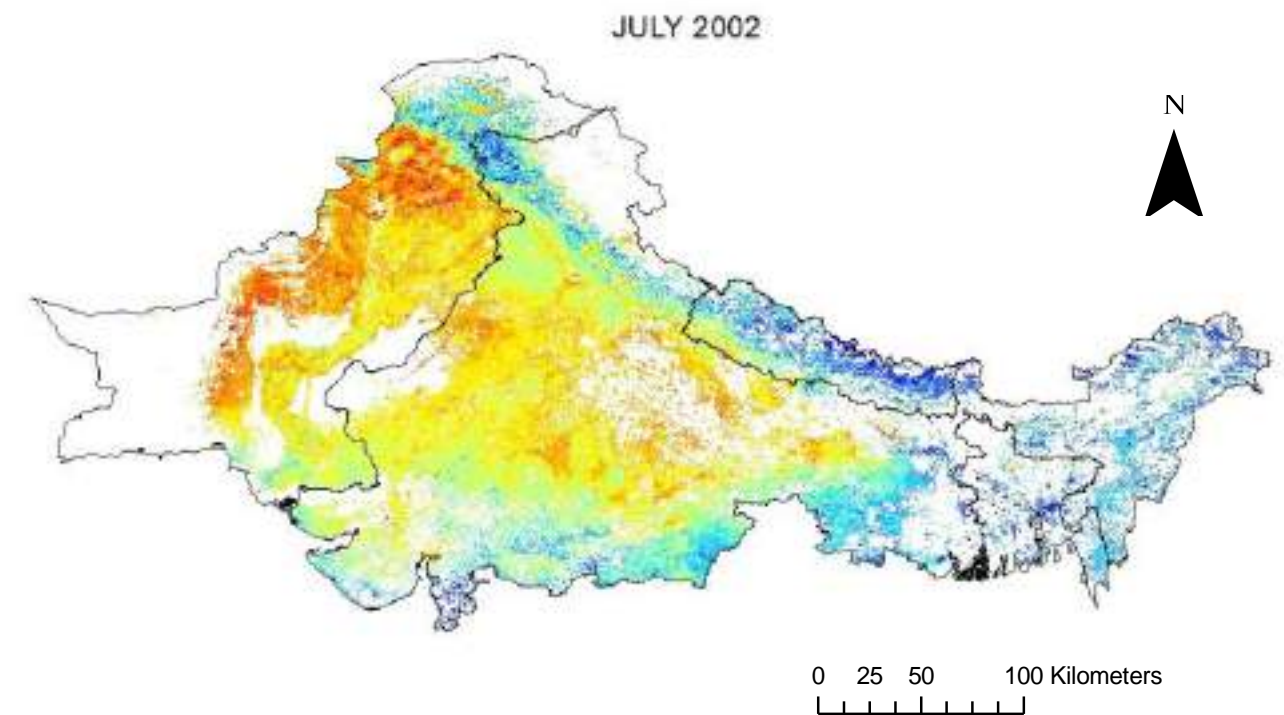
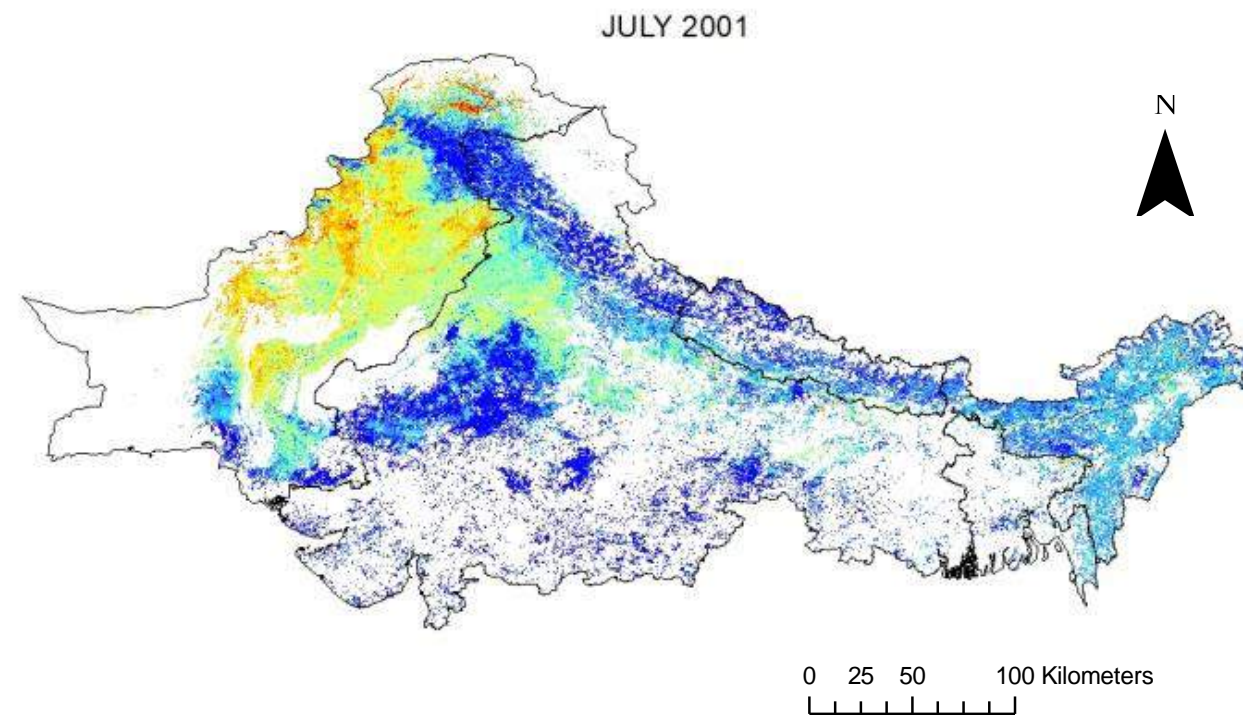
Drought in July ranges from near normal to very wet. This rainy month is usually exhibit slightly wet condition. Month of July is normally wet but near normal condition was noted in 2002.

Mean July DSI Values		
Year	DSI Values	Drought Condition
2000	0.61	Slightly Wet
2001	0.85	Slightly Wet
2002	-0.07	Near Normal
2003	1.38	Very Wet
2004	0.34	Incipient Wet Spell
2005	0.76	Slightly Wet
2006	0.86	Slightly Wet
2007	0.92	Moderately Wet
2008	0.91	Moderately Wet
2009	0.42	Incipient Wet Spell
2010	0.92	Moderately Wet
2011	0.69	Slightly Wet
2012	0.27	Near Normal
2013	0.74	Slightly Wet
2014	0.54	Incipient Wet Spell
2015	0.60	Slightly Wet
2016	0.66	Slightly Wet
2017	0.80	Slightly Wet
2018	0.78	Slightly Wet
2019	0.77	Slightly Wet
2020	0.92	Moderately Wet

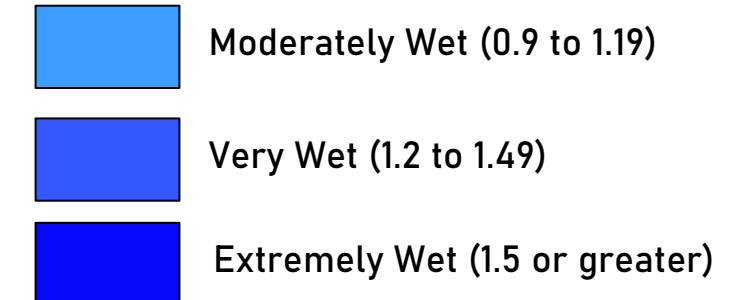
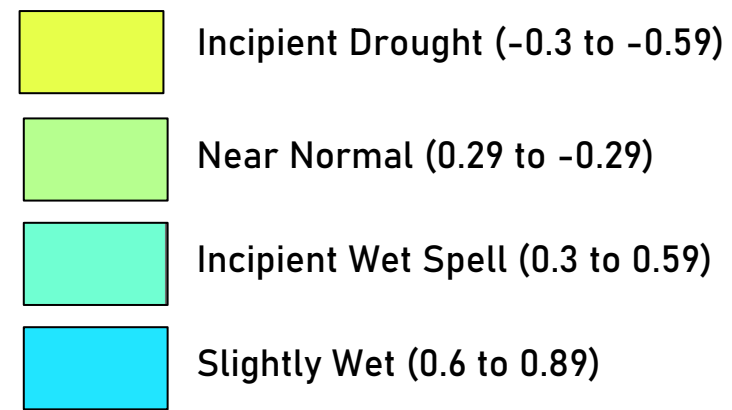
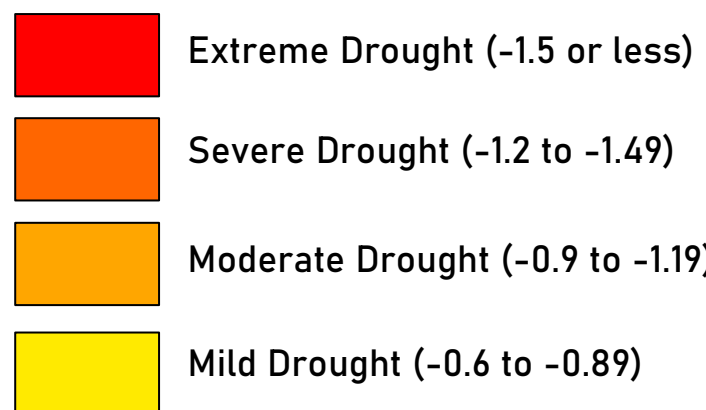


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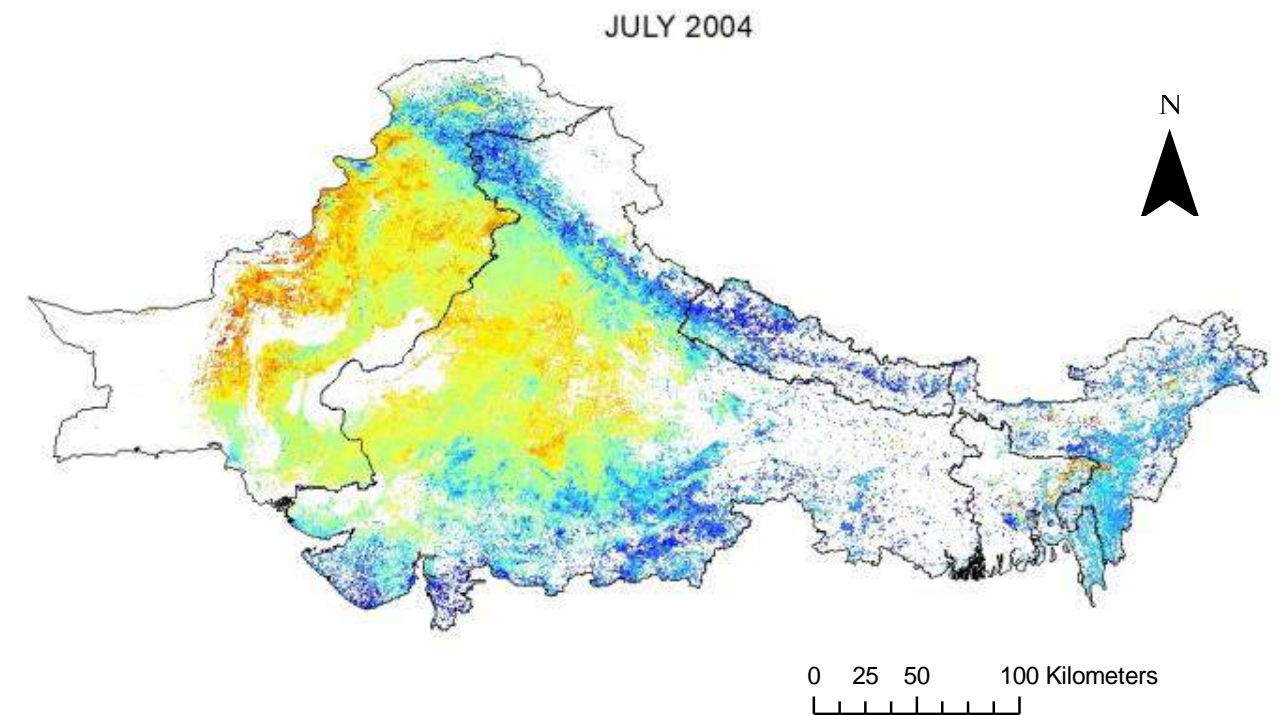
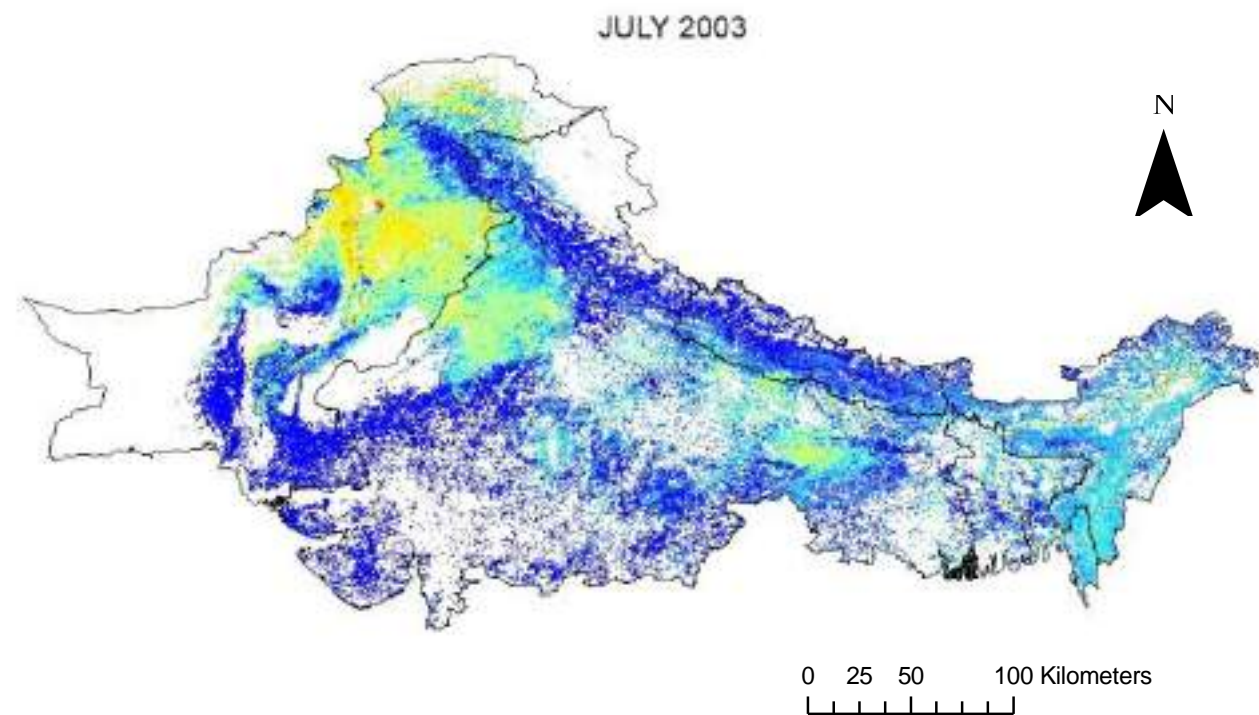




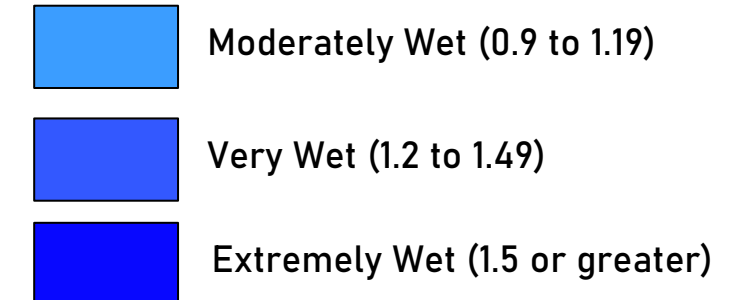
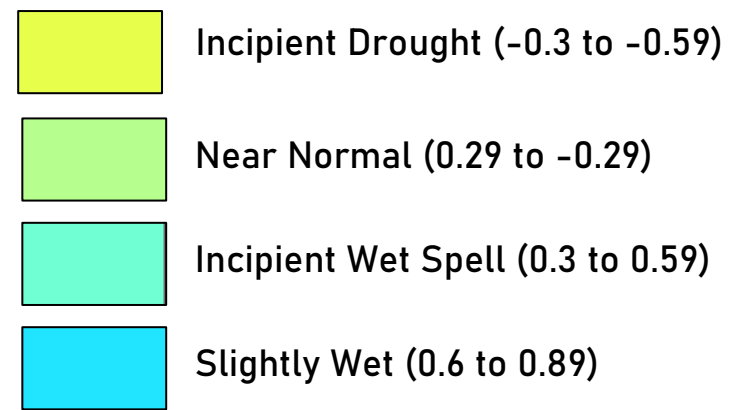
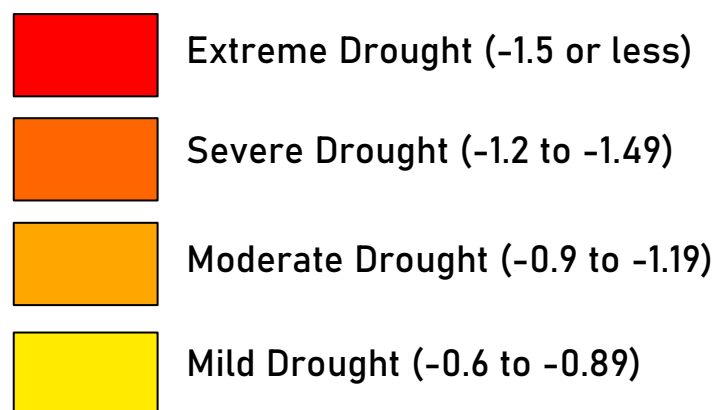
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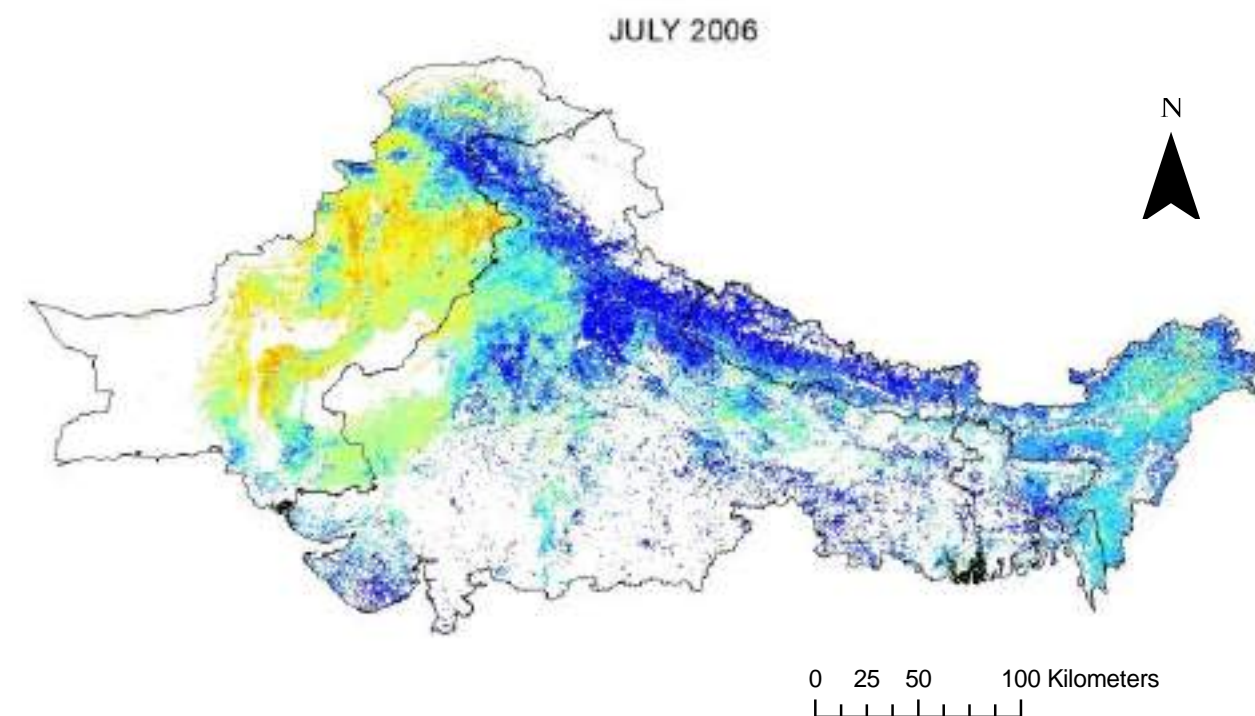
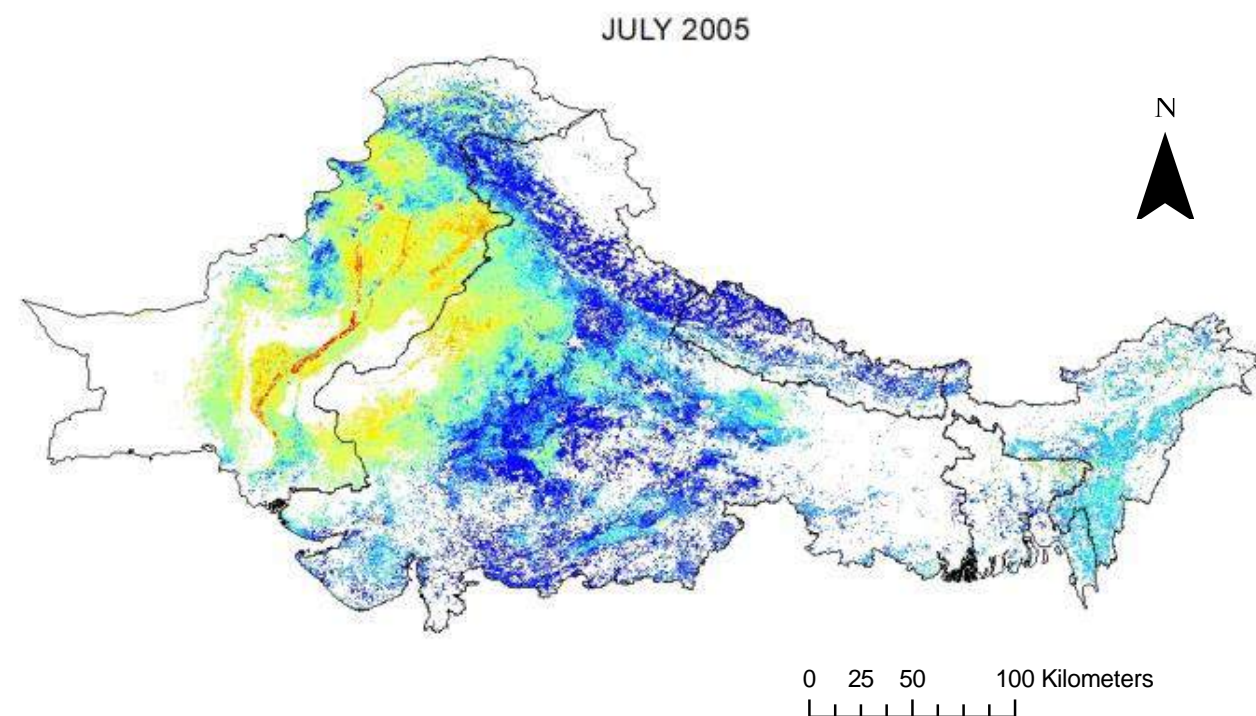




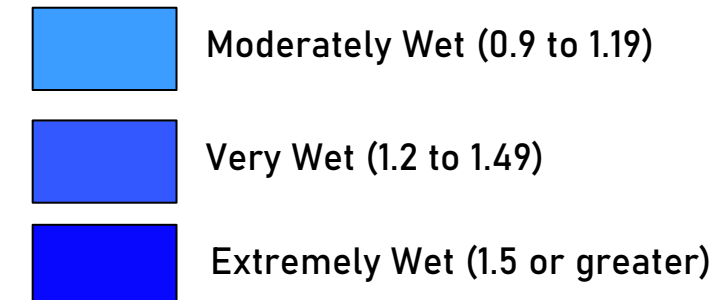
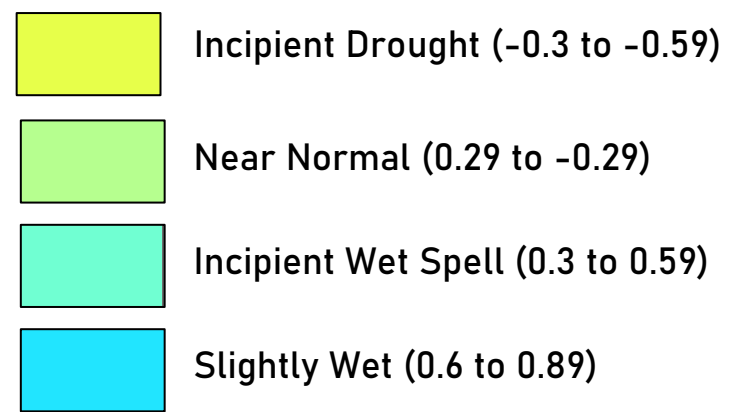
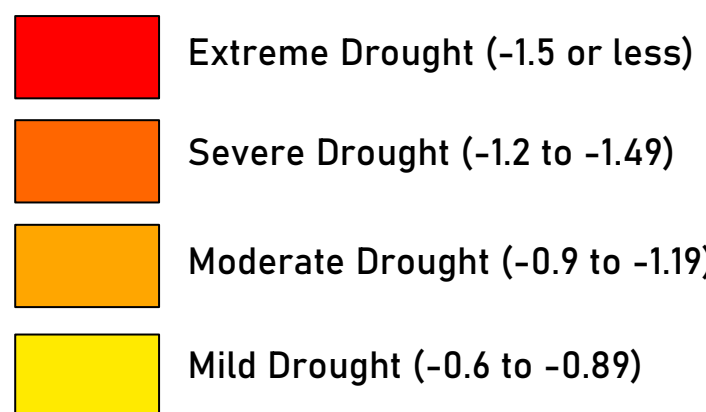


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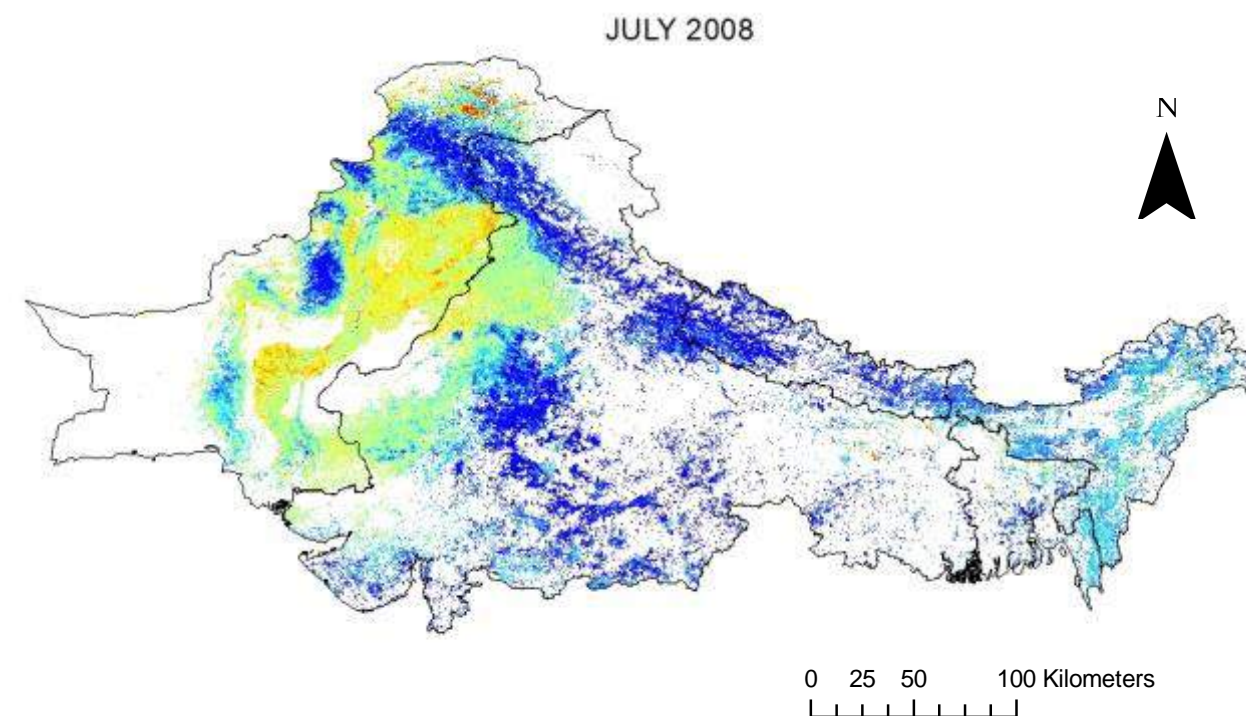
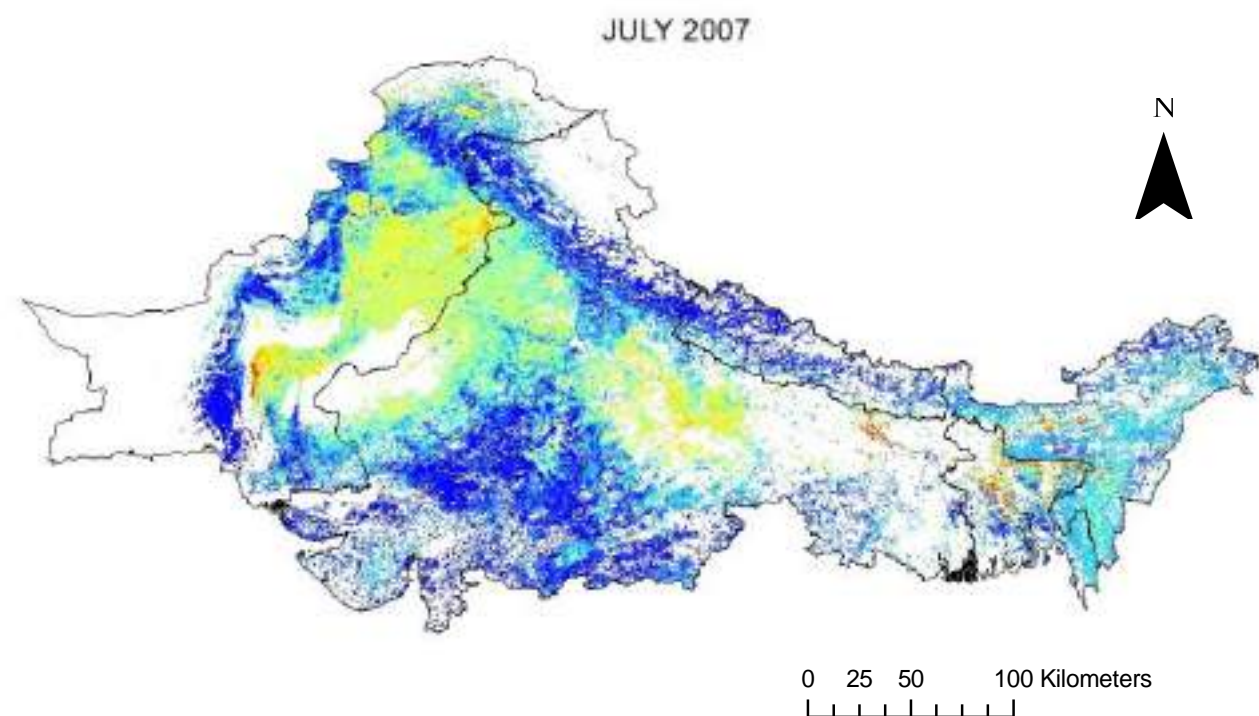




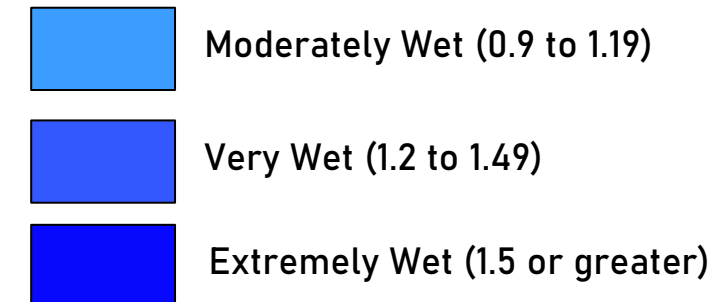
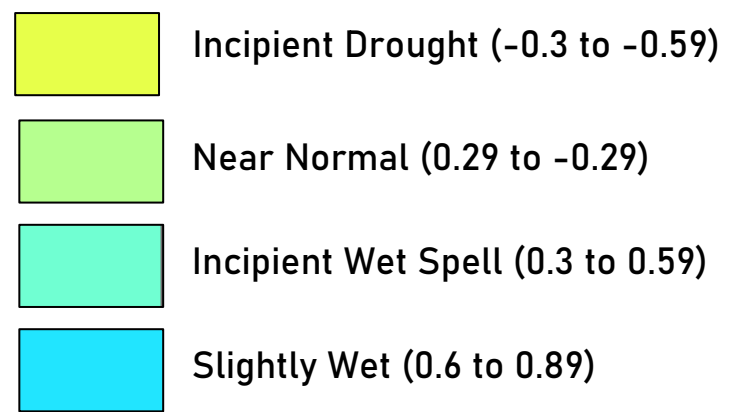
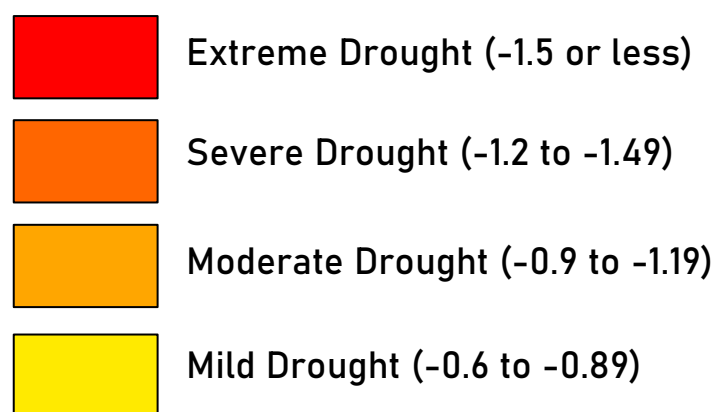
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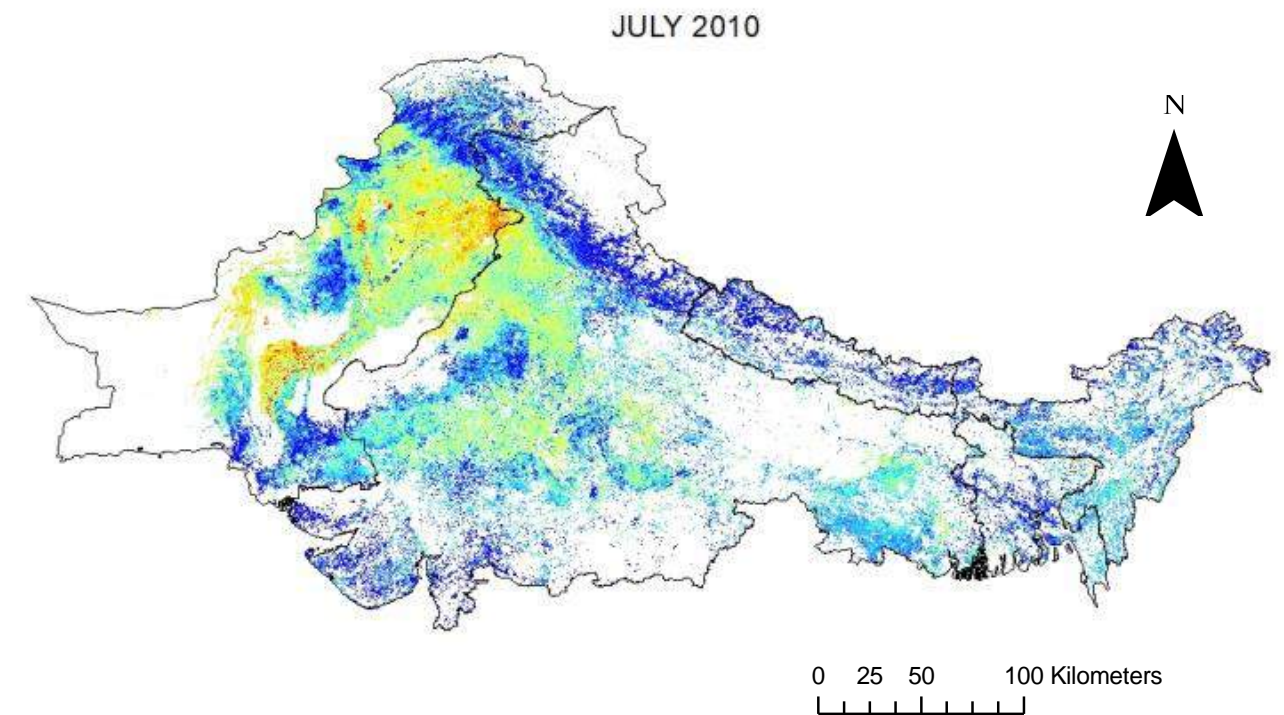
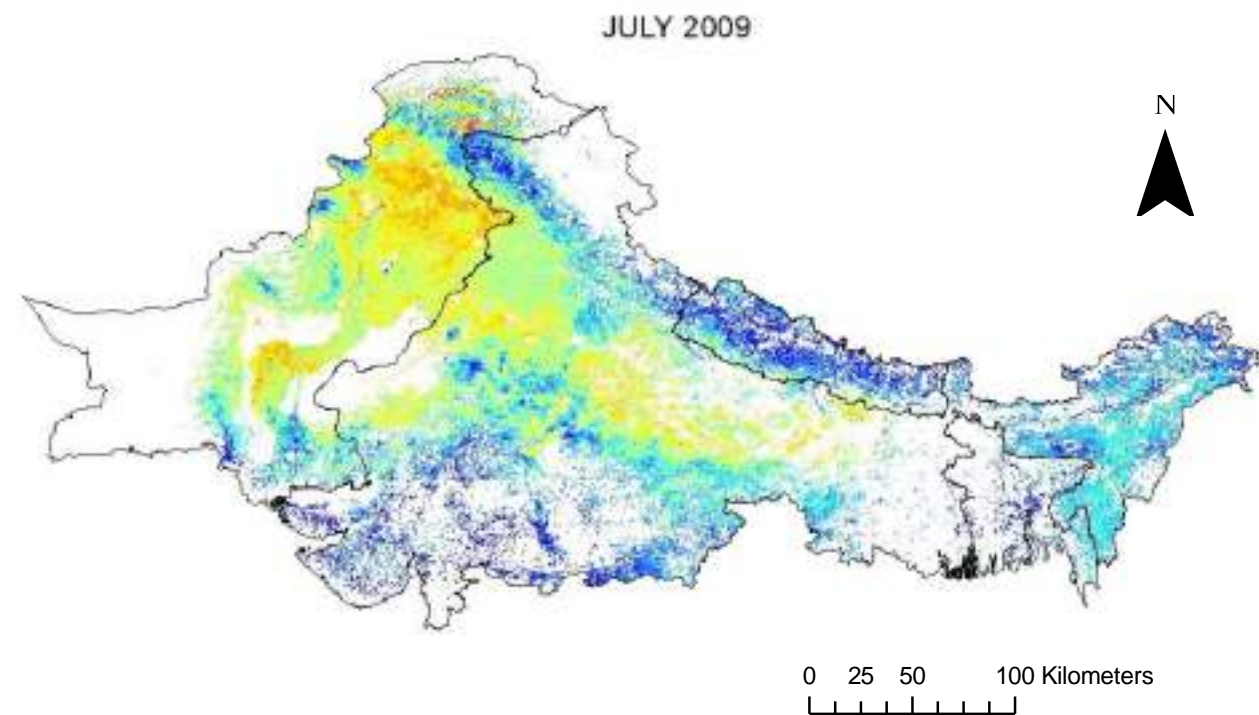




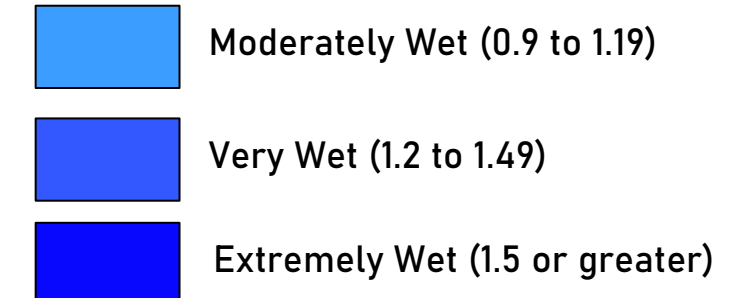
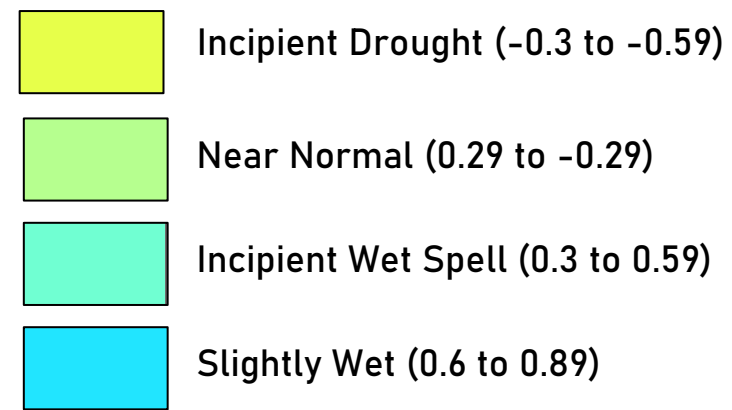
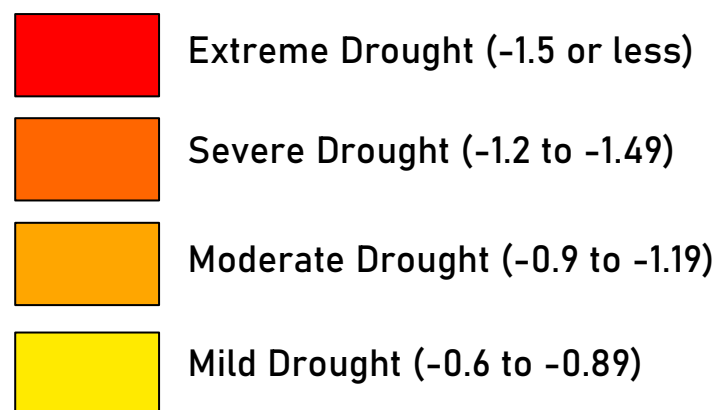
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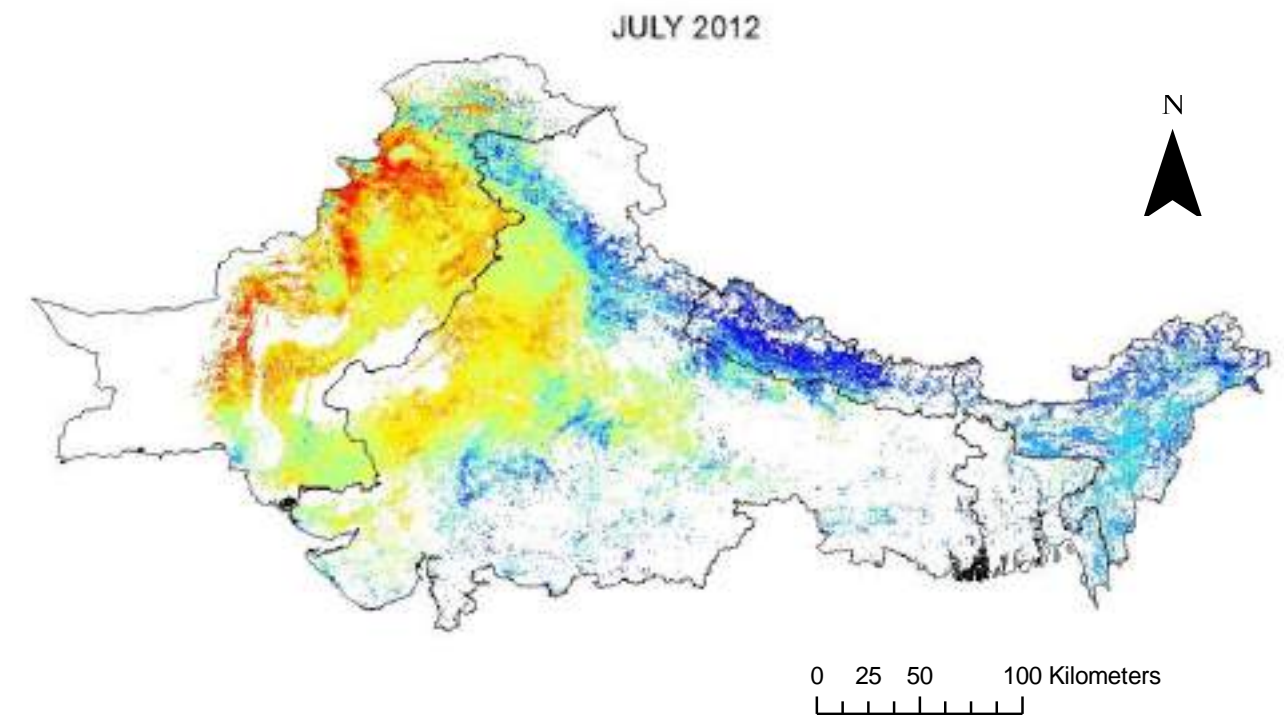
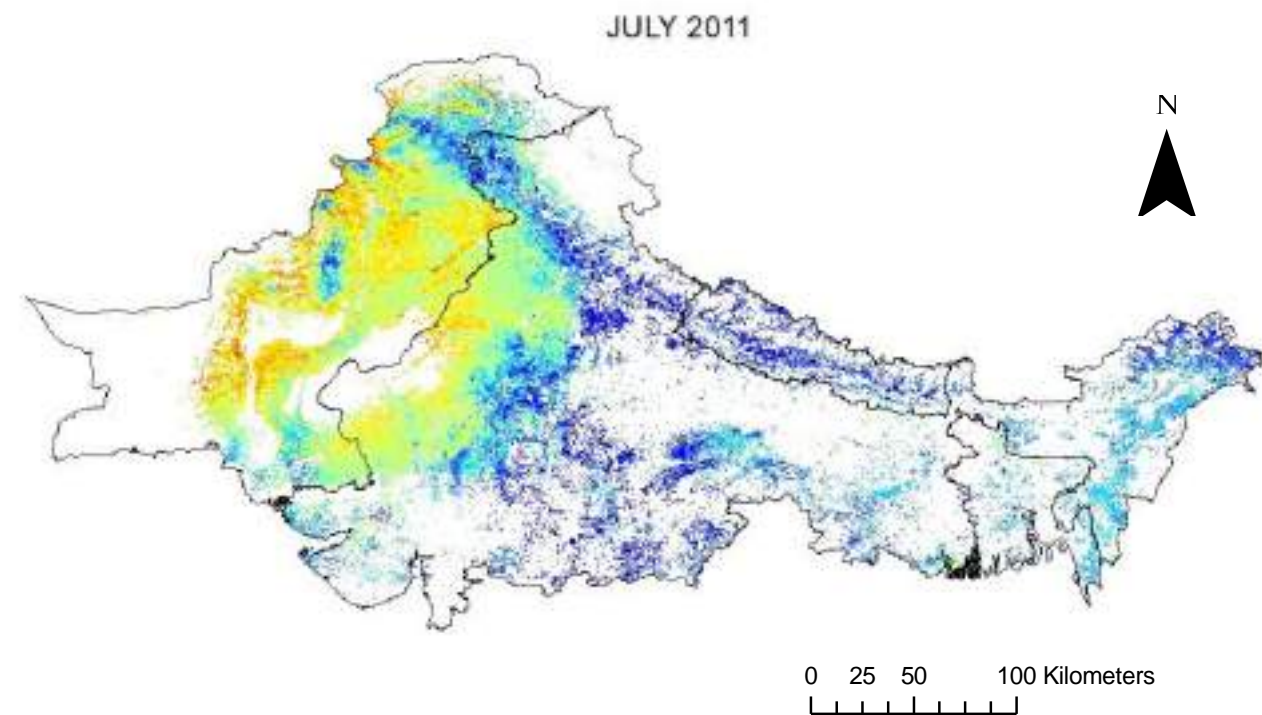




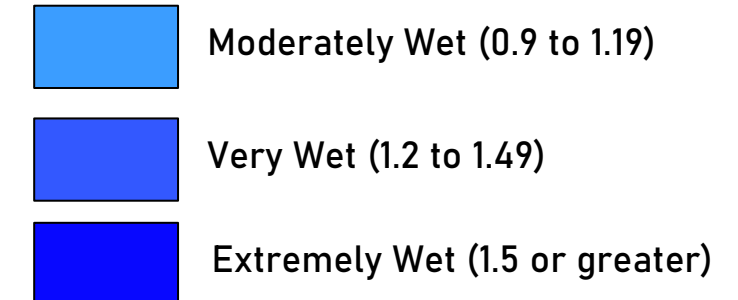
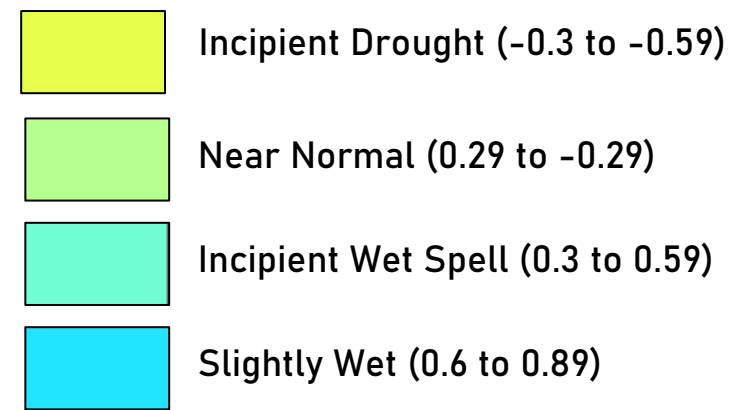
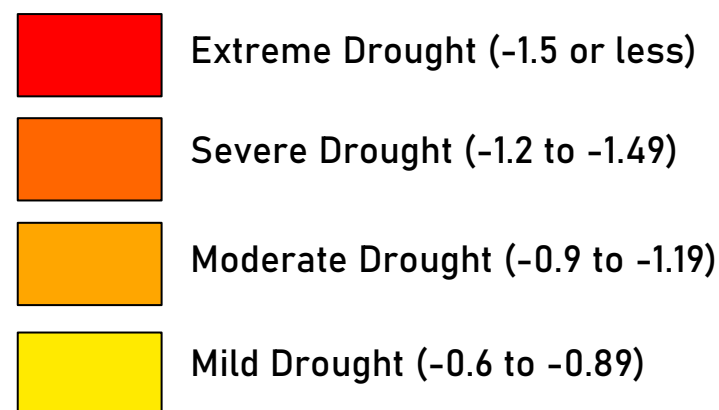


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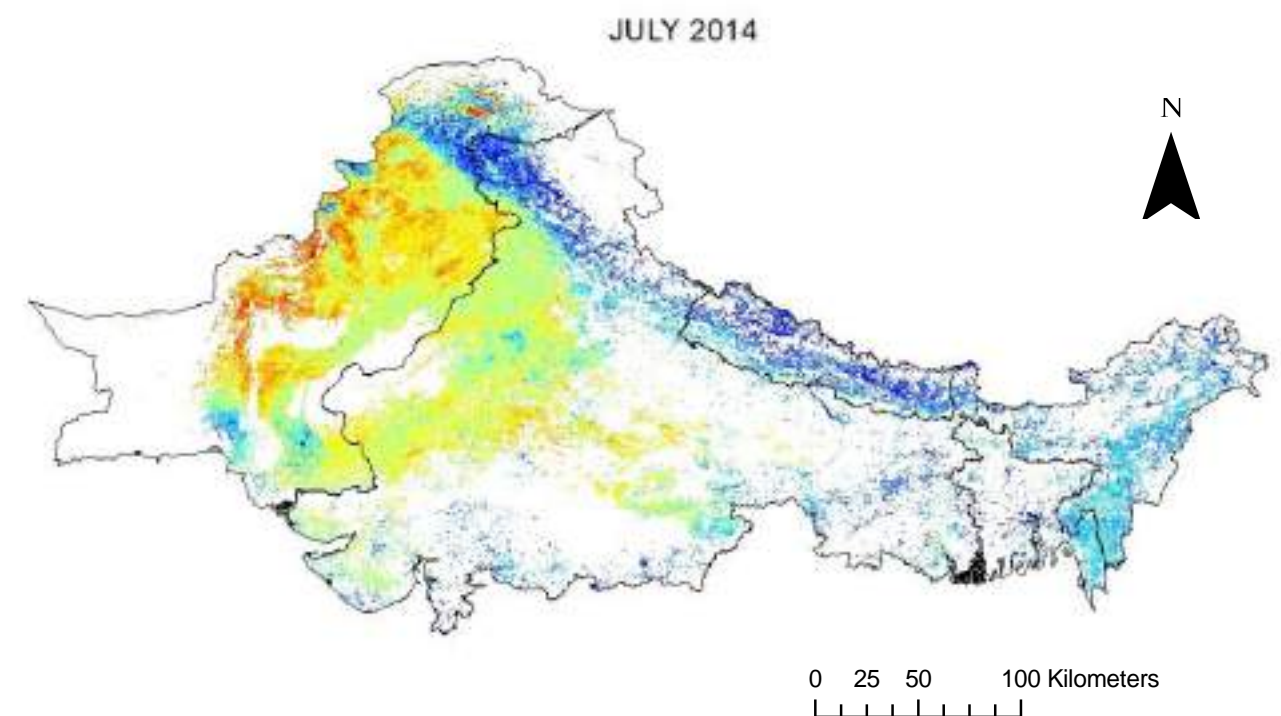
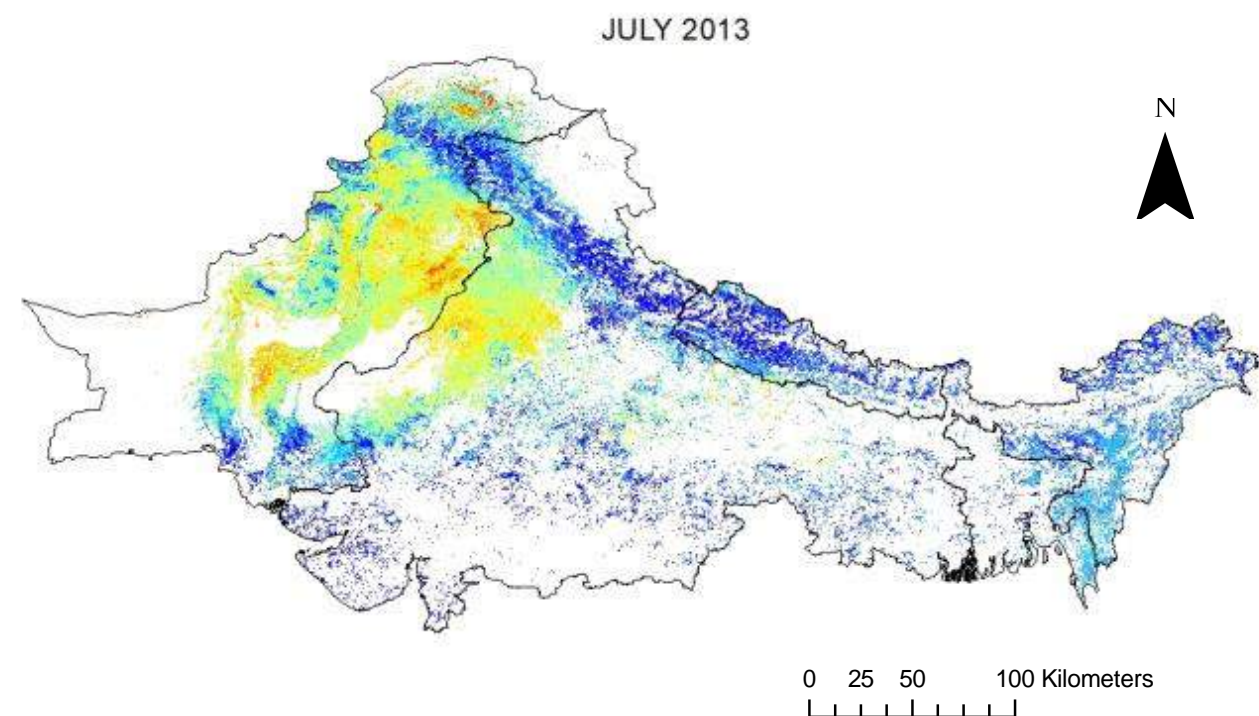




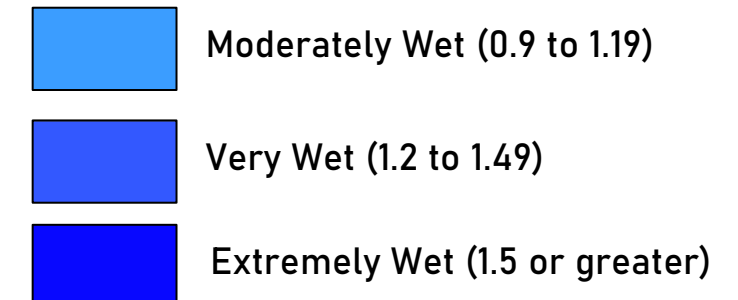
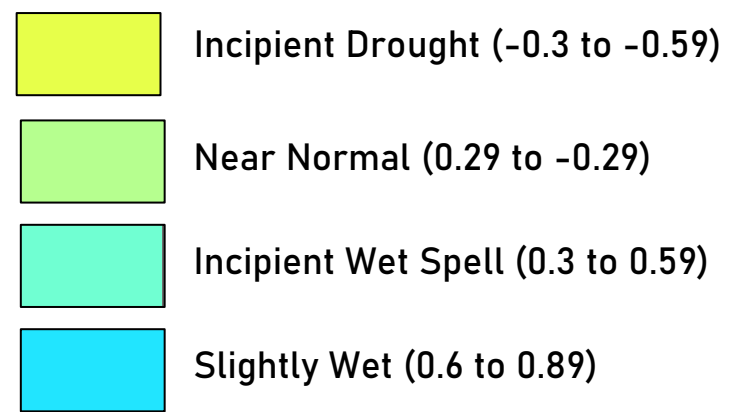
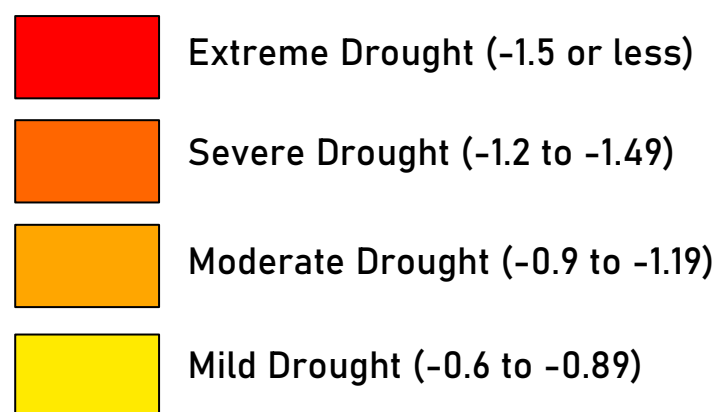
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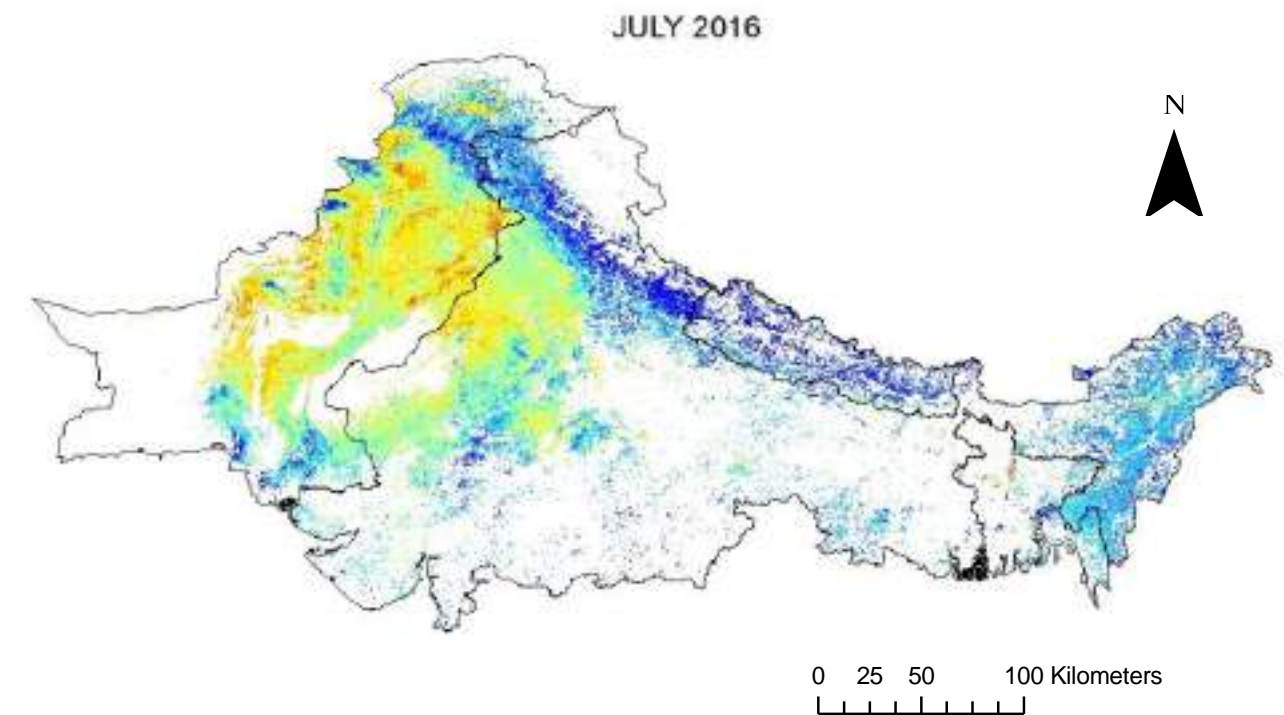
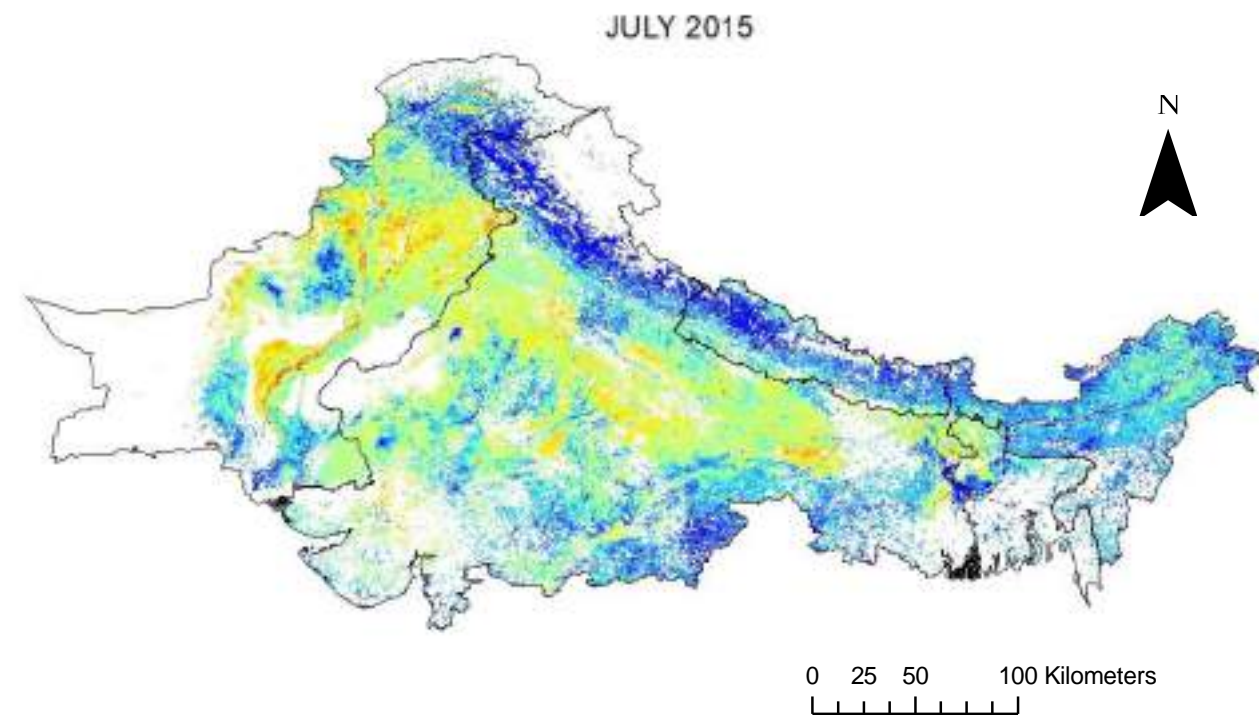




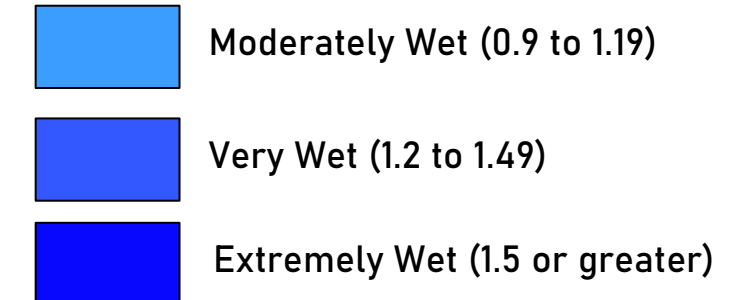
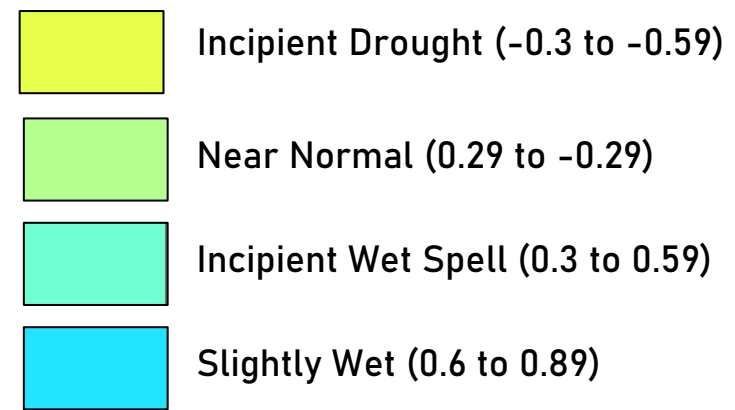
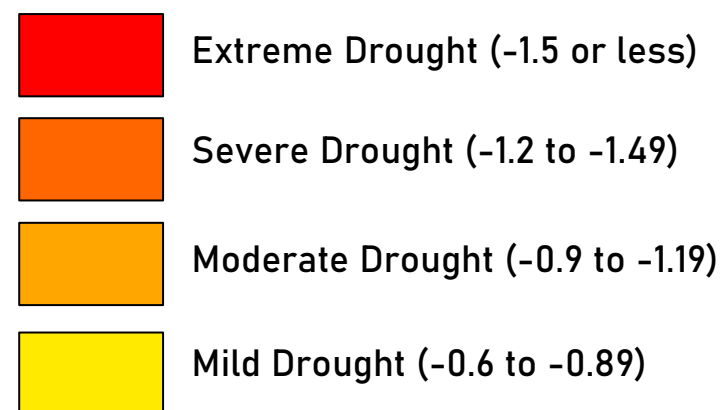
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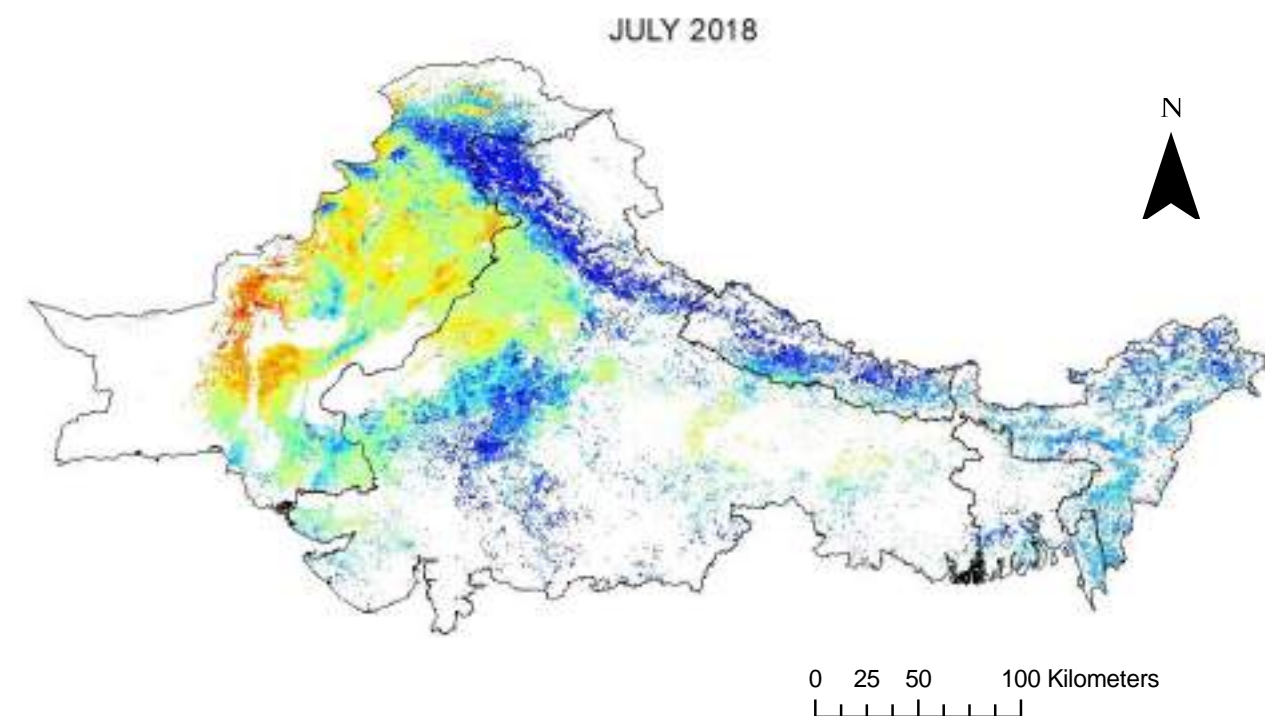
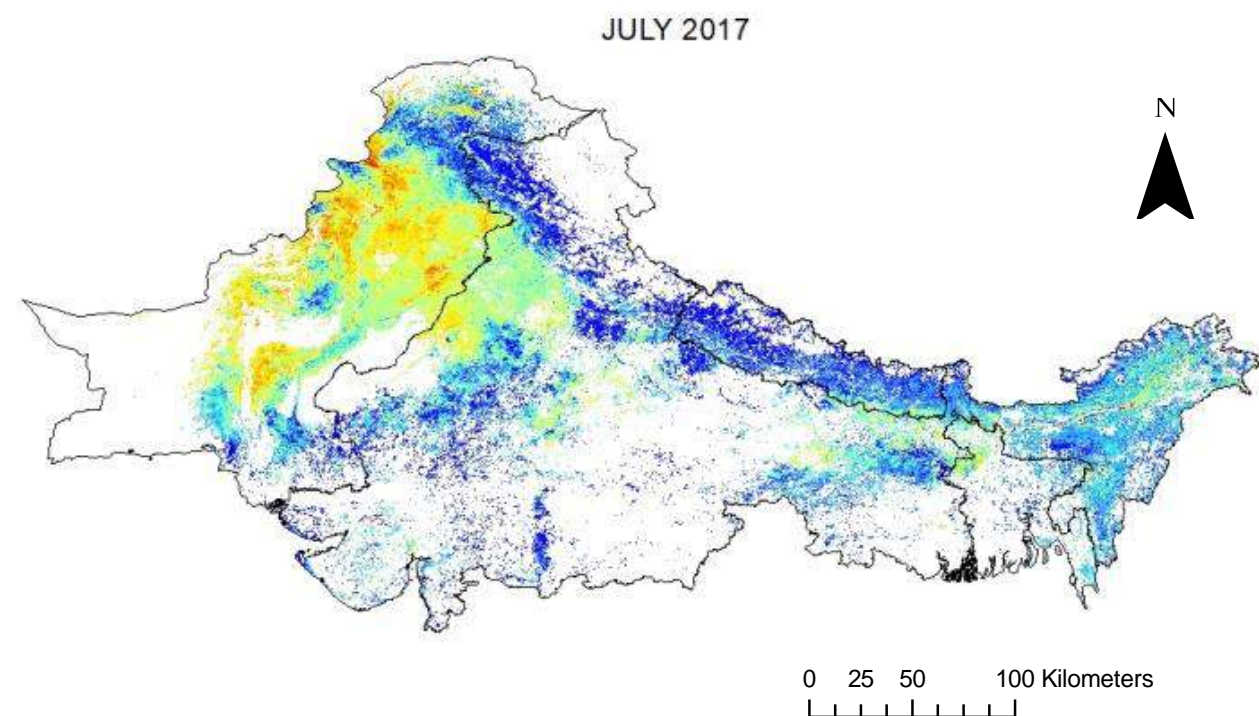




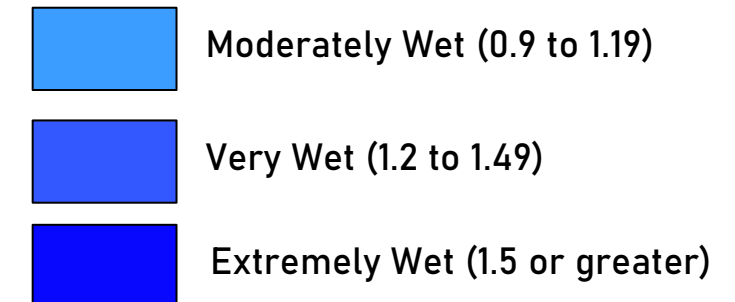
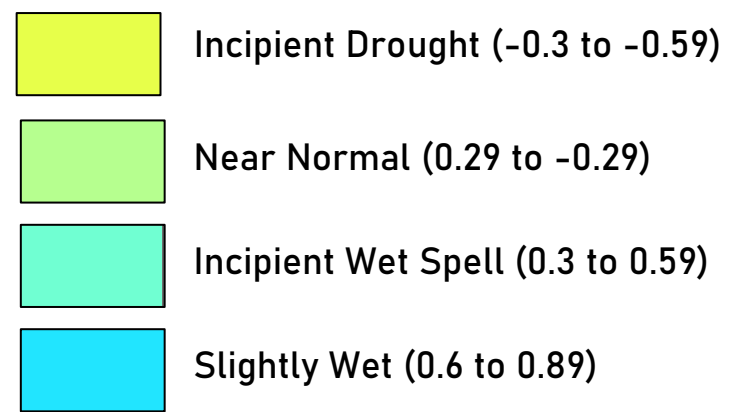
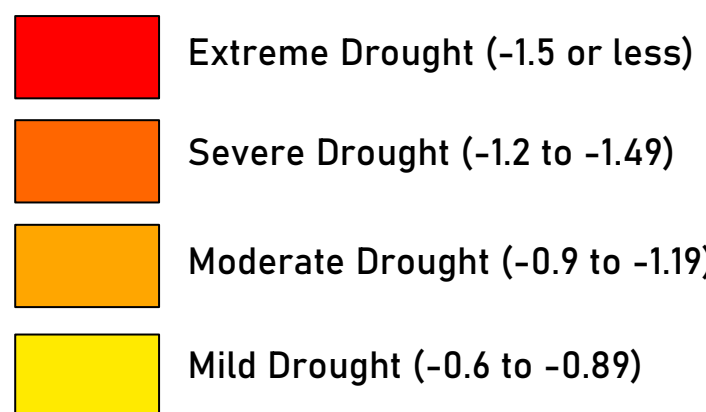


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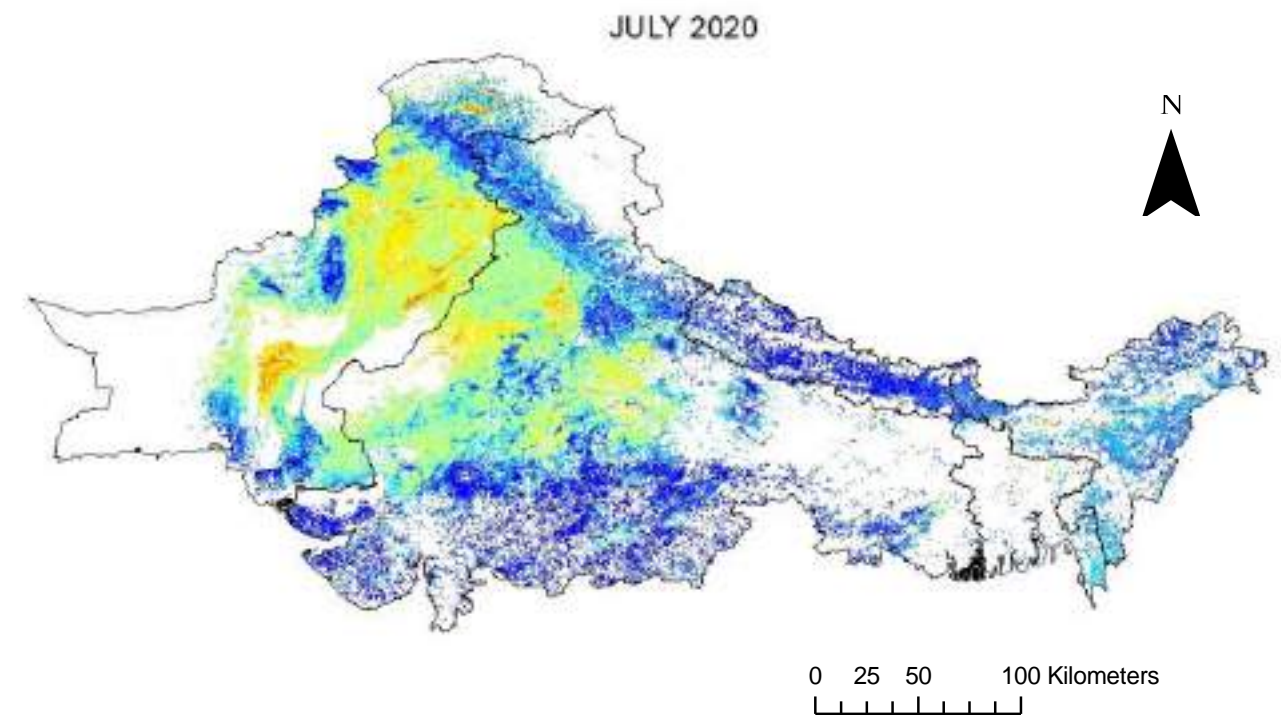
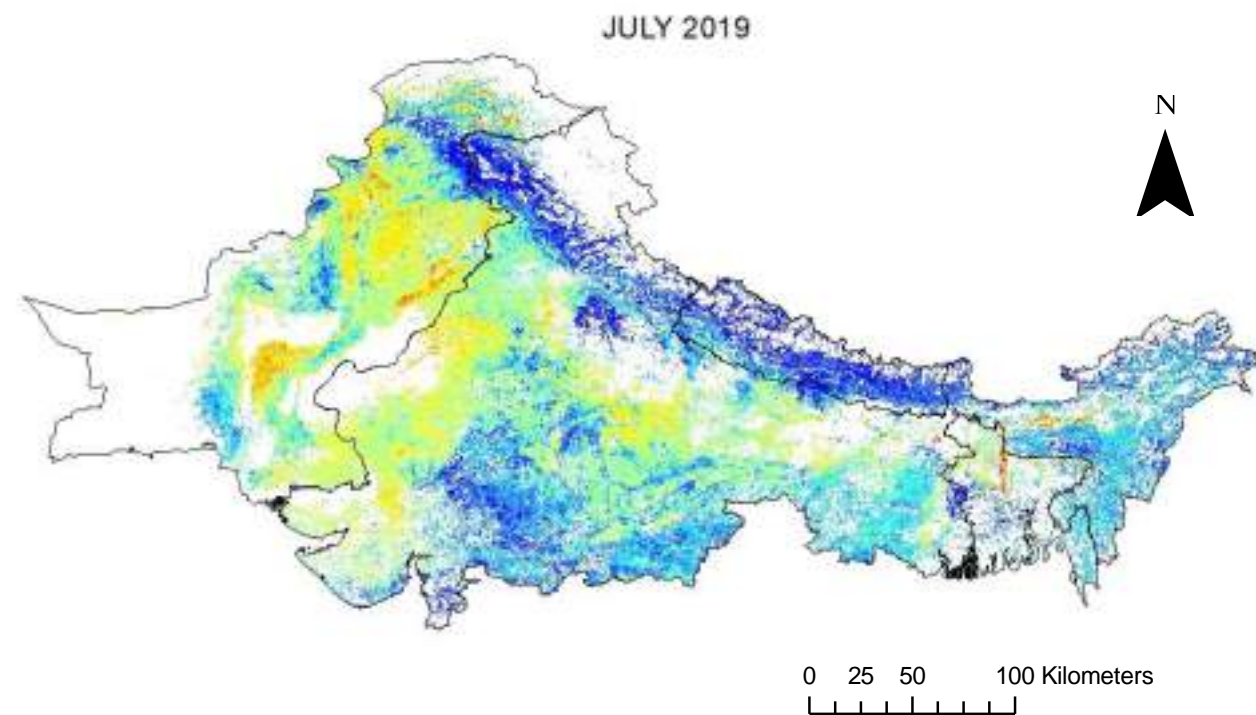




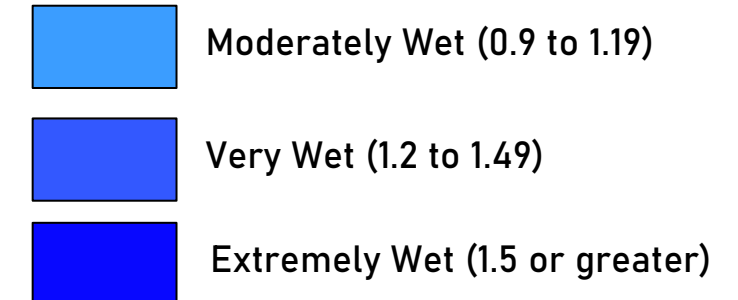
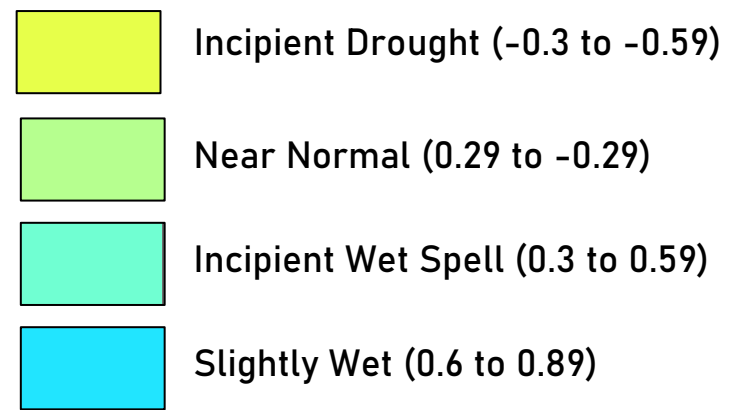
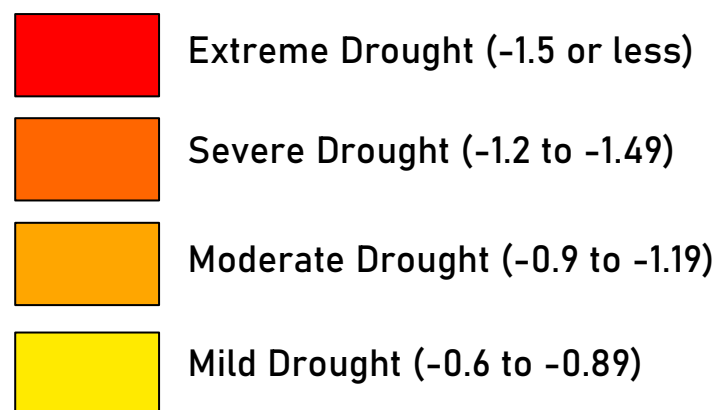
### Legend







### Legend

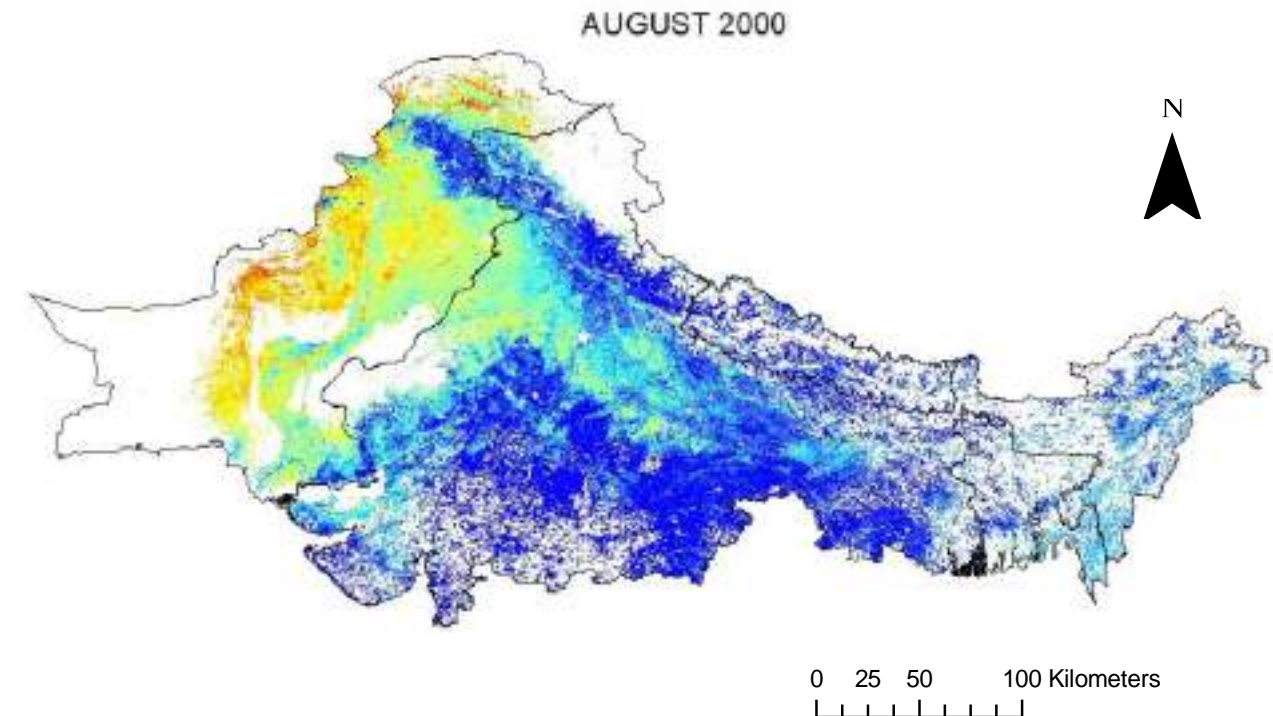




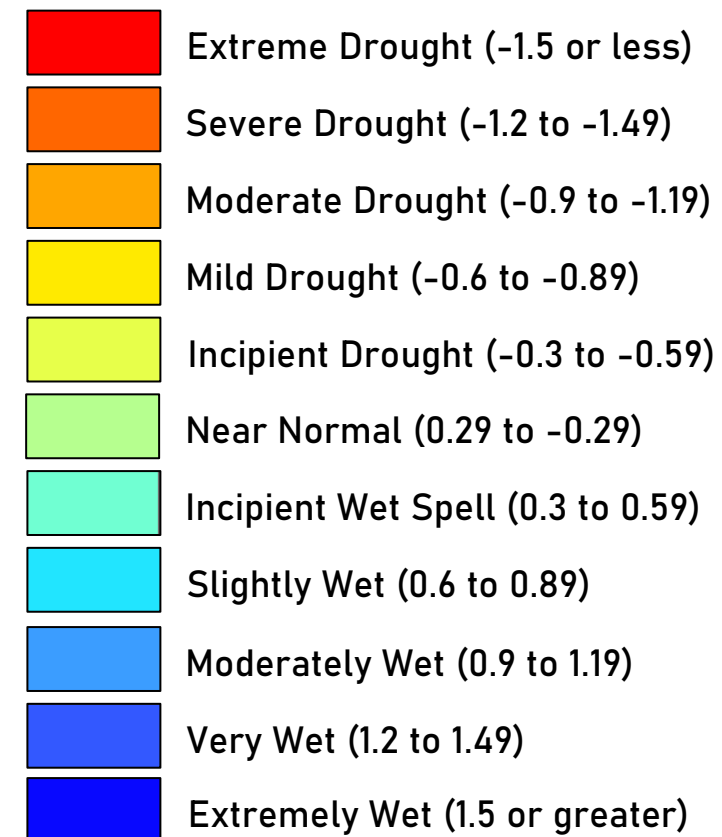
## August DSI Maps

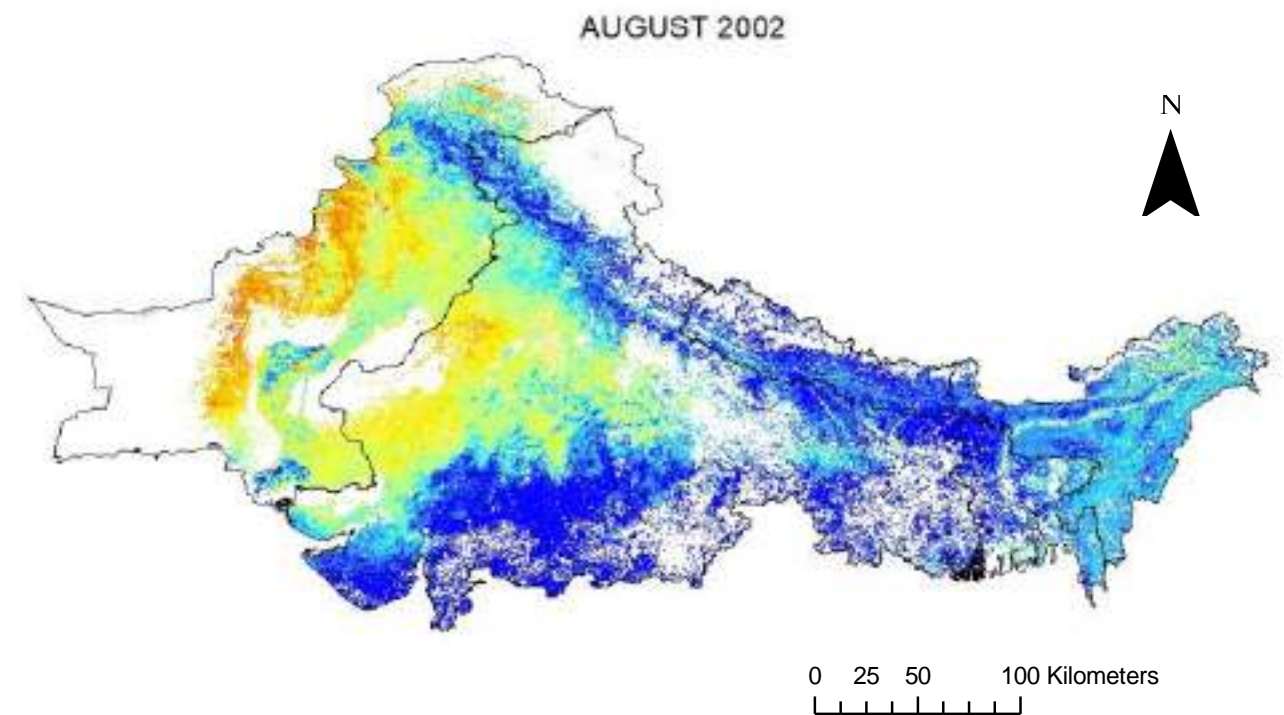
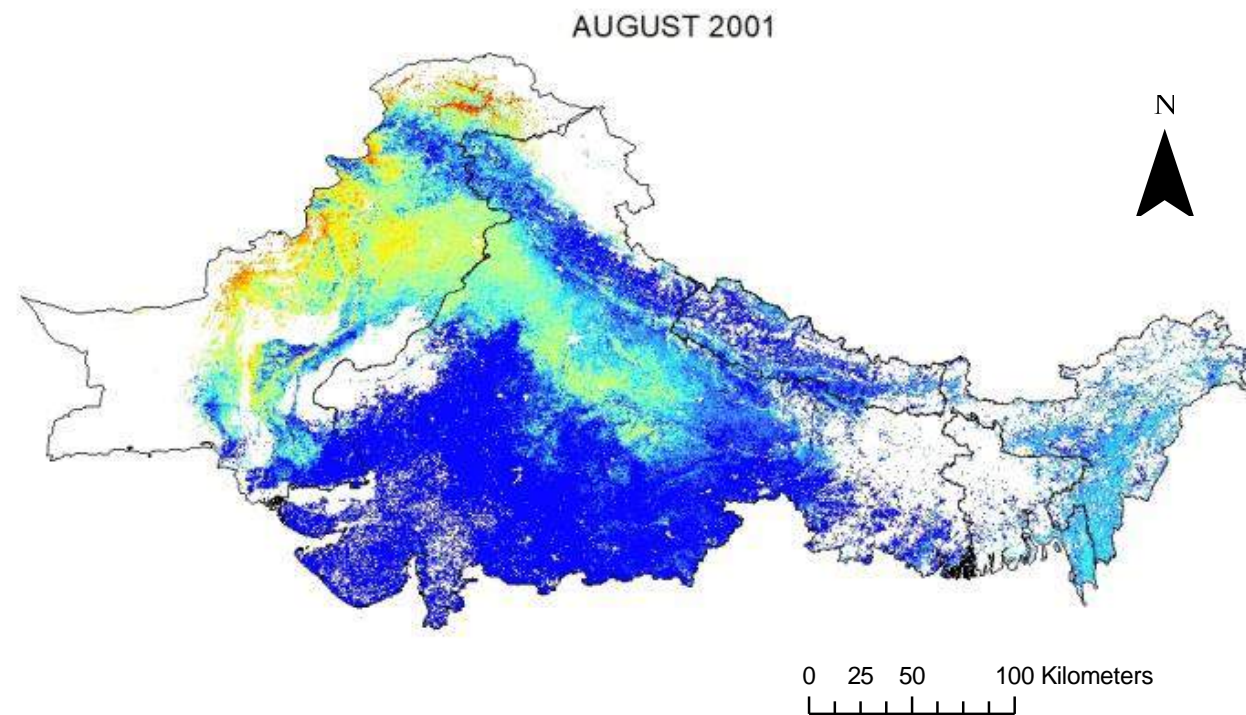
Drought in August normally ranges from moderately wet to extremely wet. This wet and rainy month is mostly exhibited by extremely wet condition. Wettest condition was identified in 2010.

Mean August DSI Values		
Year	DSI Values	Drought Condition
2000	0.93	Moderately Wet
2001	1.16	Moderately Wet
2002	0.94	Moderately Wet
2003	1.66	Extremely Wet
2004	1.20	Very Wet
2005	1.22	Very Wet
2006	1.60	Extremely Wet
2007	1.36	Very Wet
2008	1.69	Extremely Wet
2009	1.23	Very Wet
2010	2.17	Extremely Wet
2011	1.78	Extremely Wet
2012	1.28	Very Wet
2013	1.66	Extremely Wet
2014	1.05	Moderately Wet
2015	1.08	Moderately Wet
2016	1.28	Very Wet
2017	1.04	Moderately Wet
2018	1.28	Very Wet
2019	1.64	Extremely Wet
2020	1.95	Extremely Wet

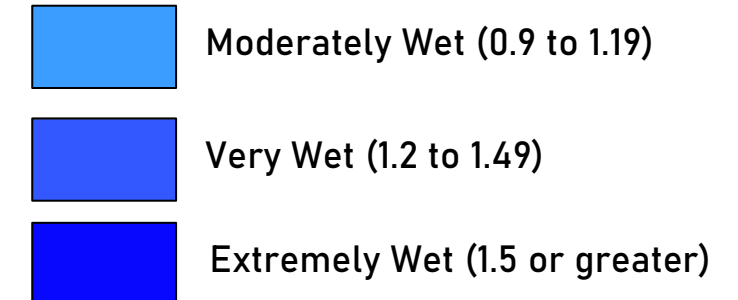
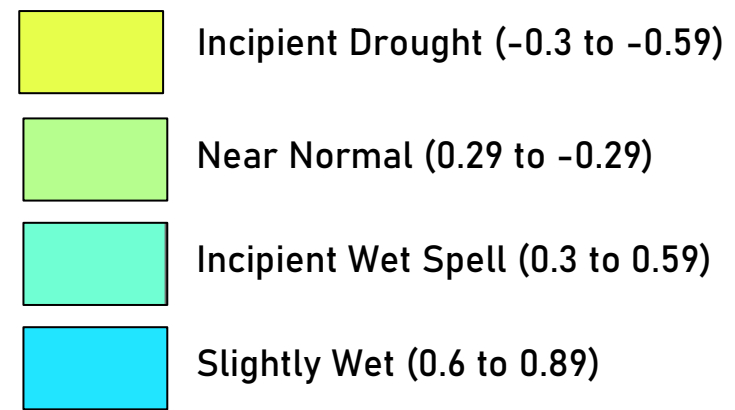
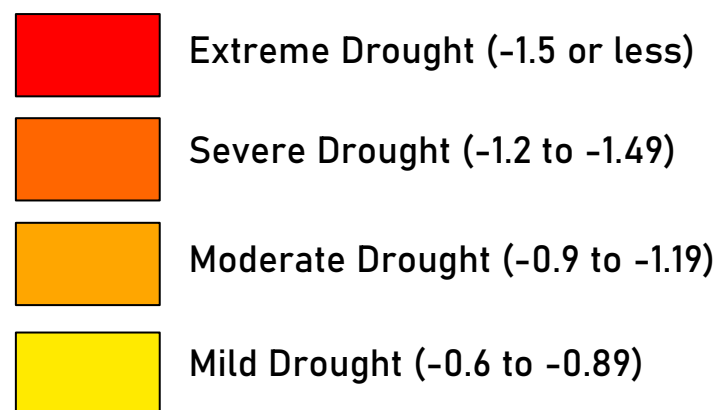


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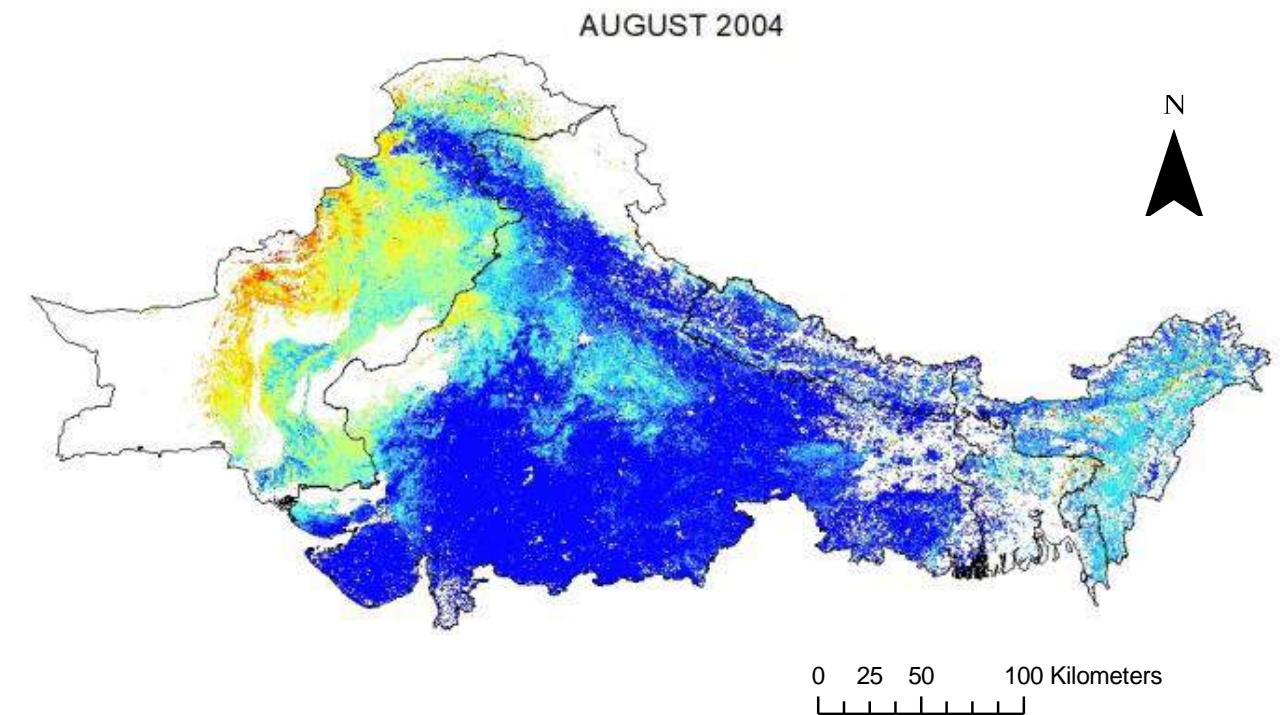
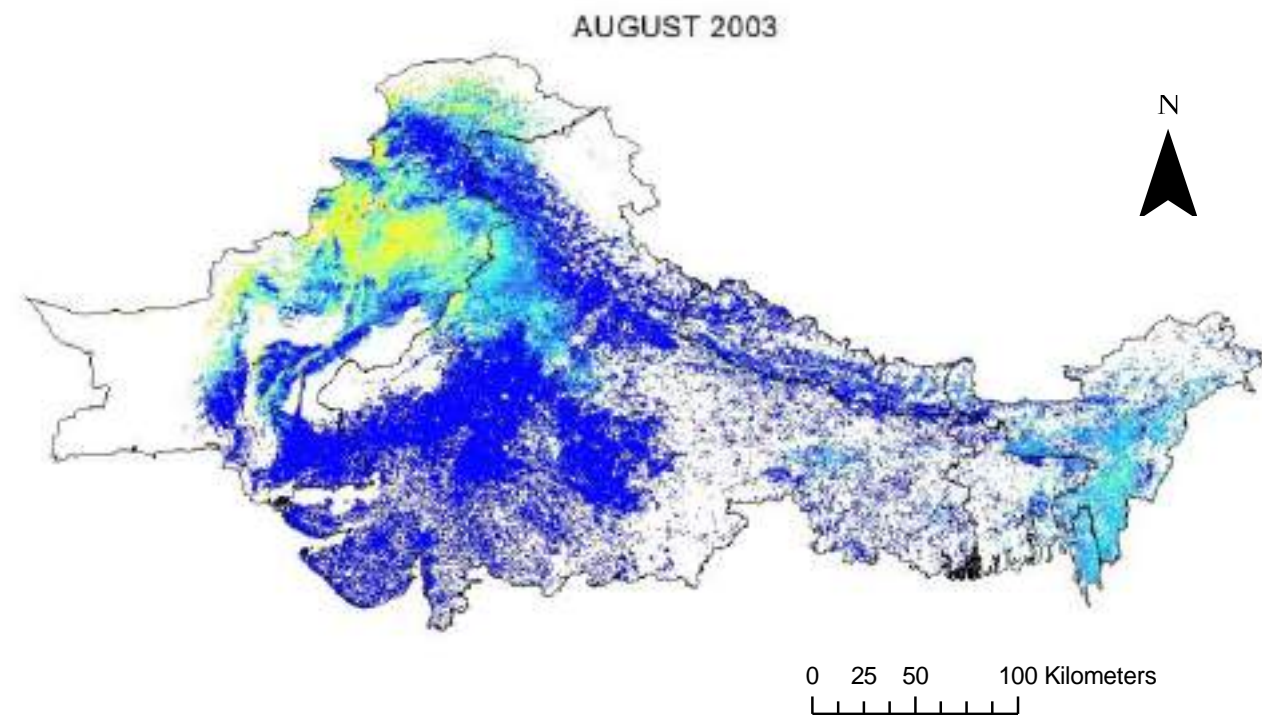




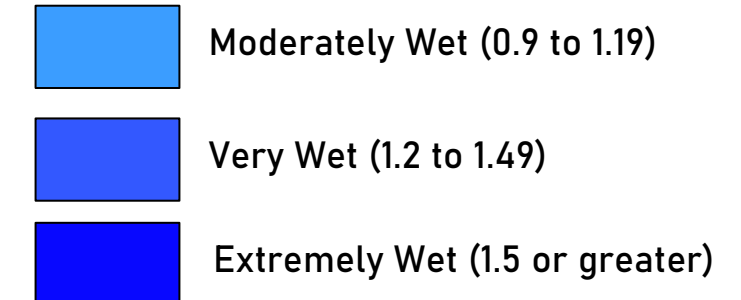
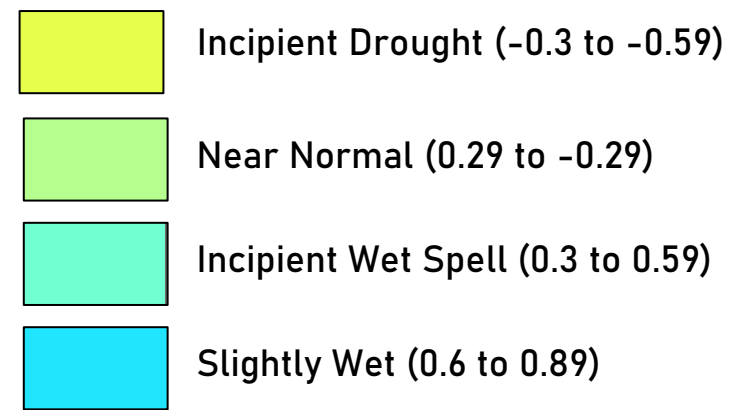
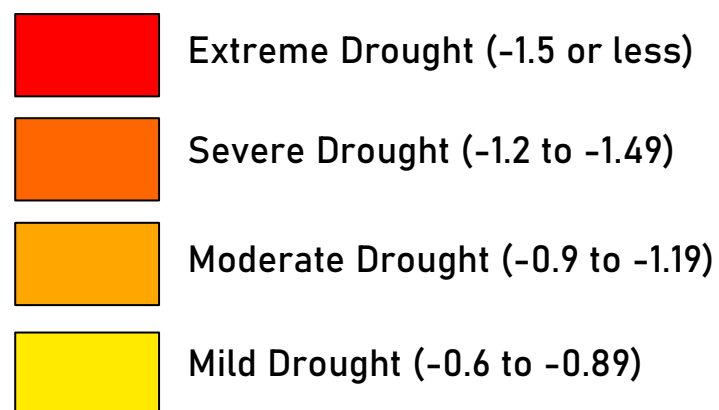
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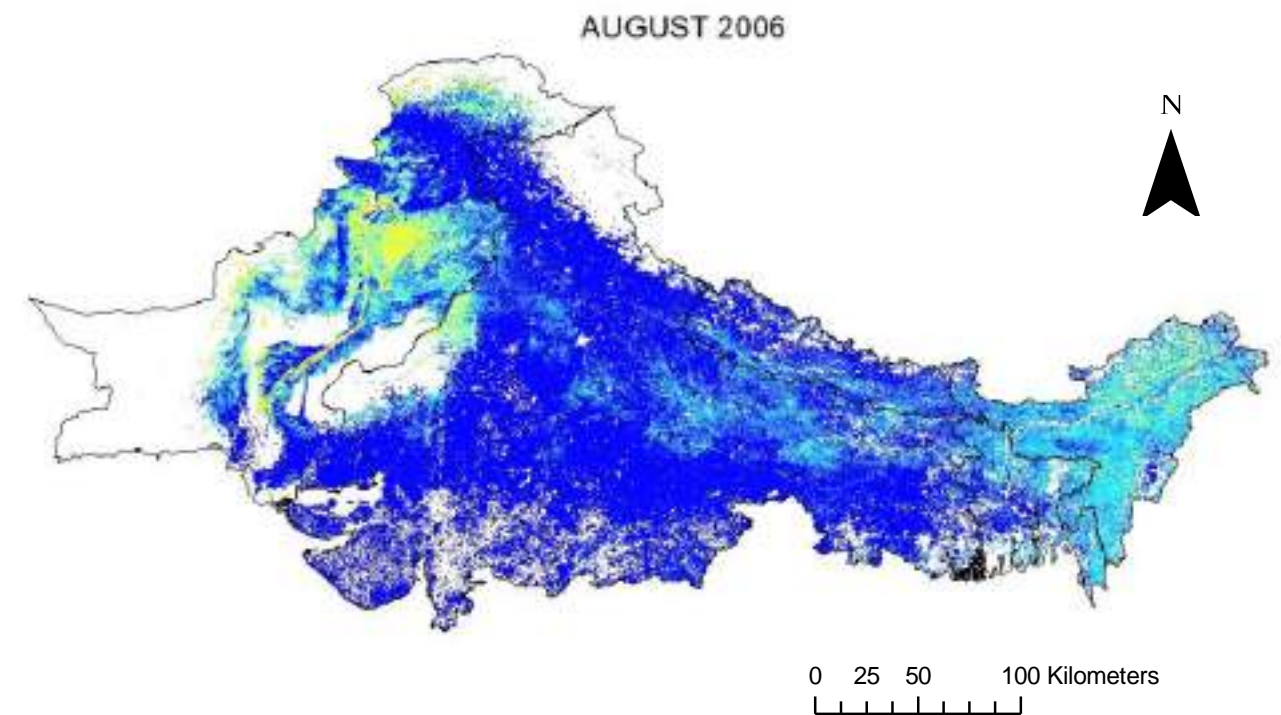
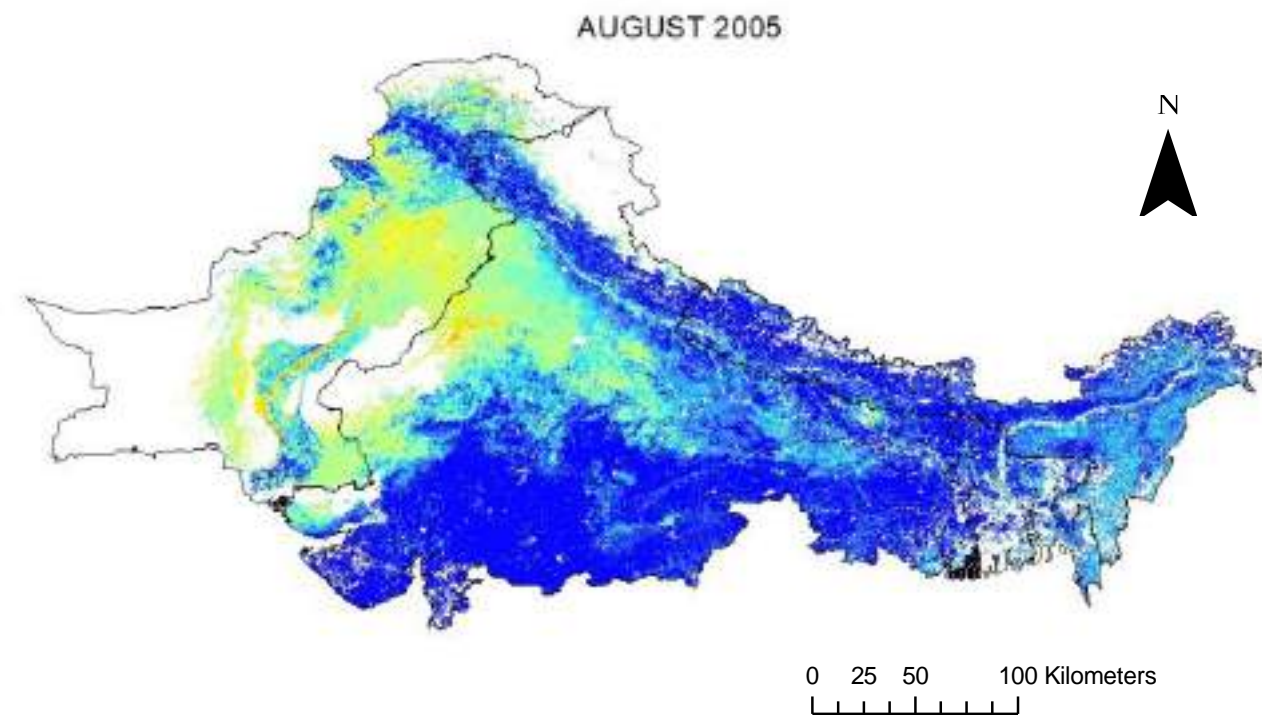




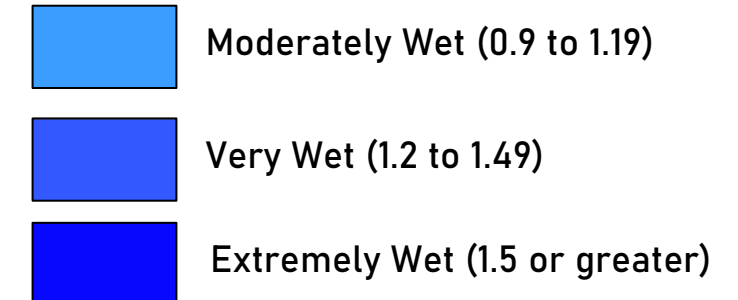
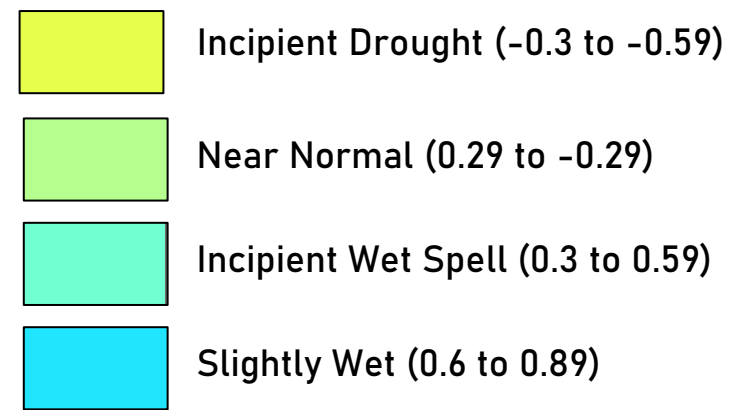
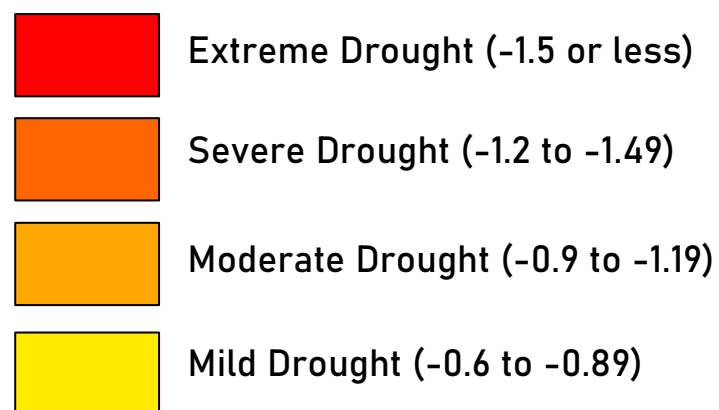
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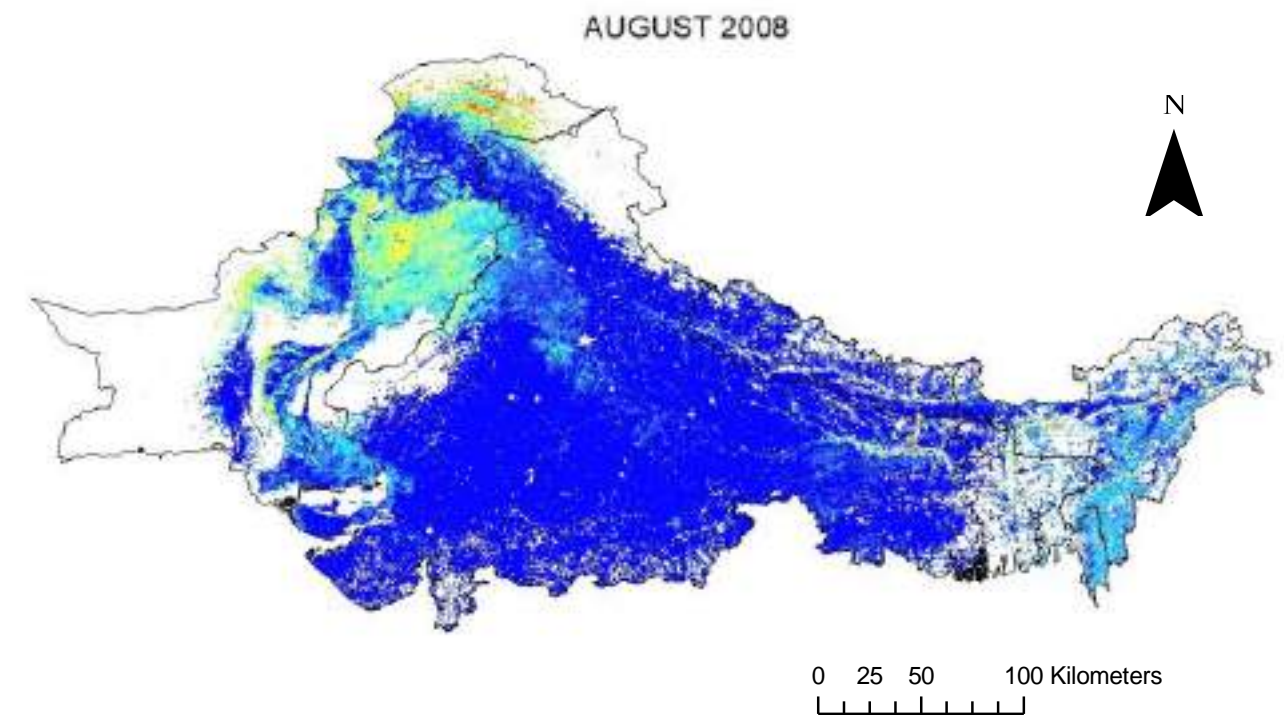
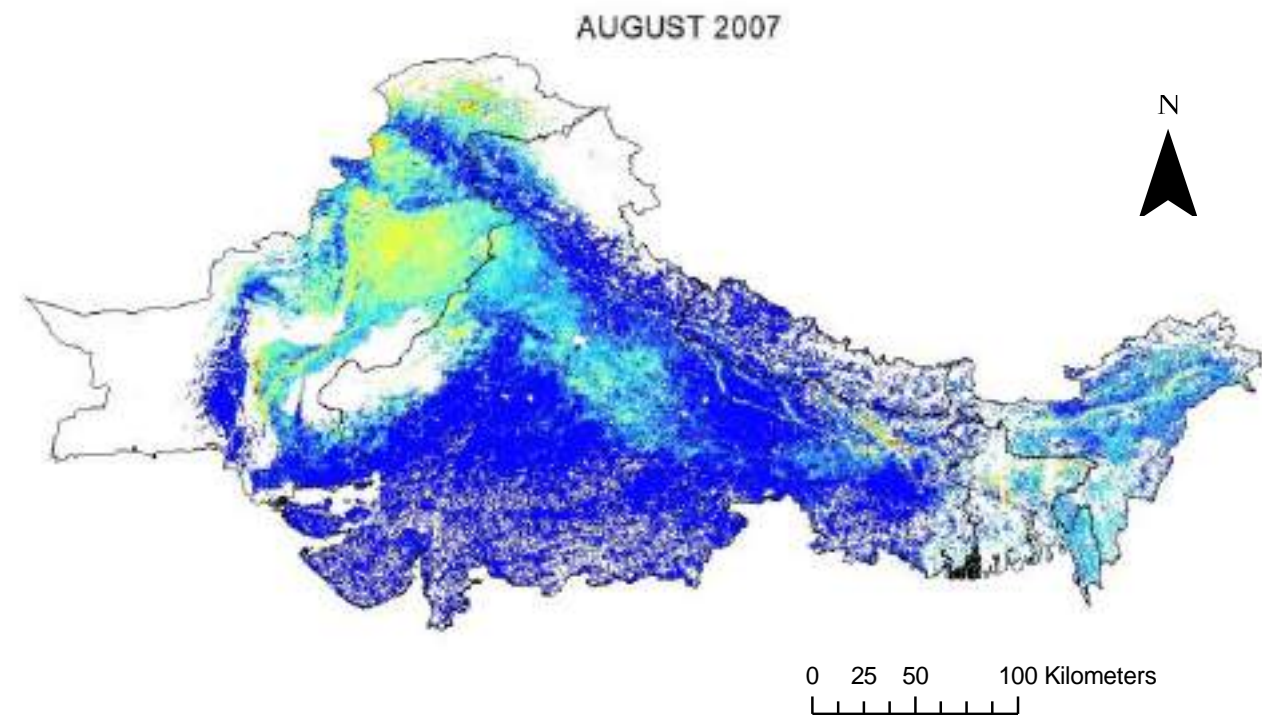




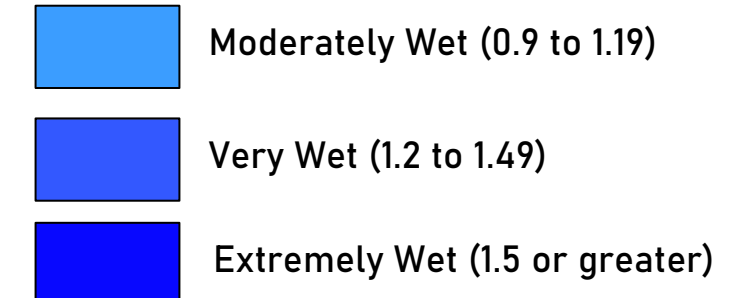
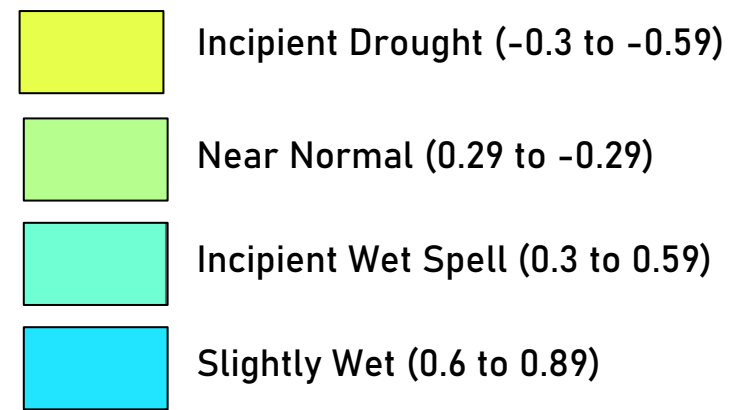
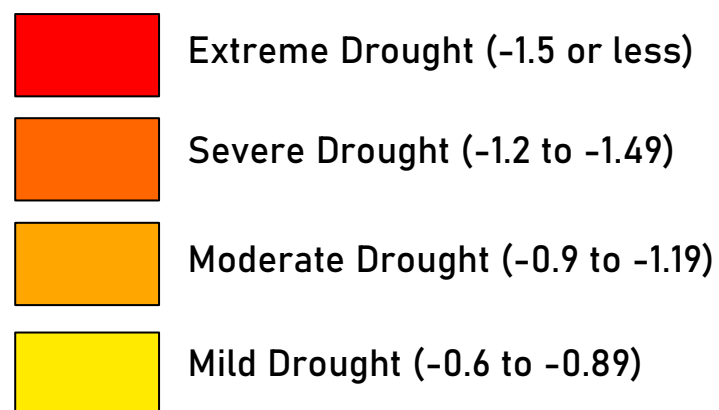


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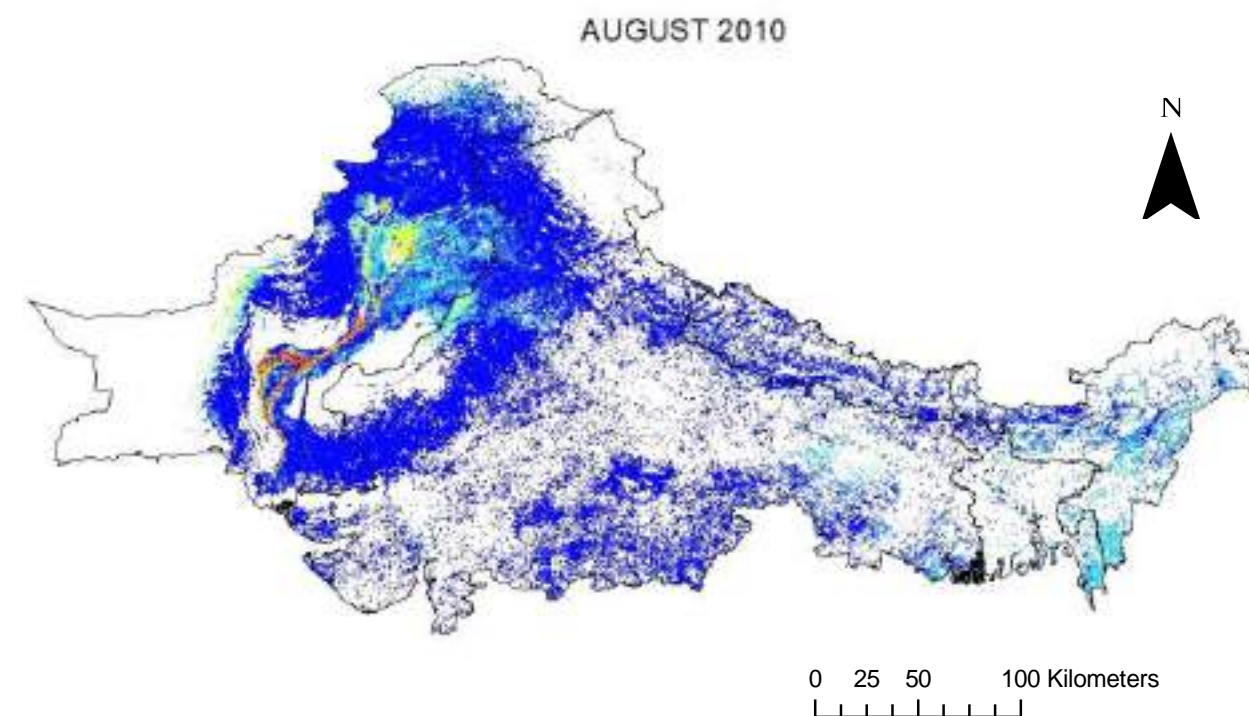
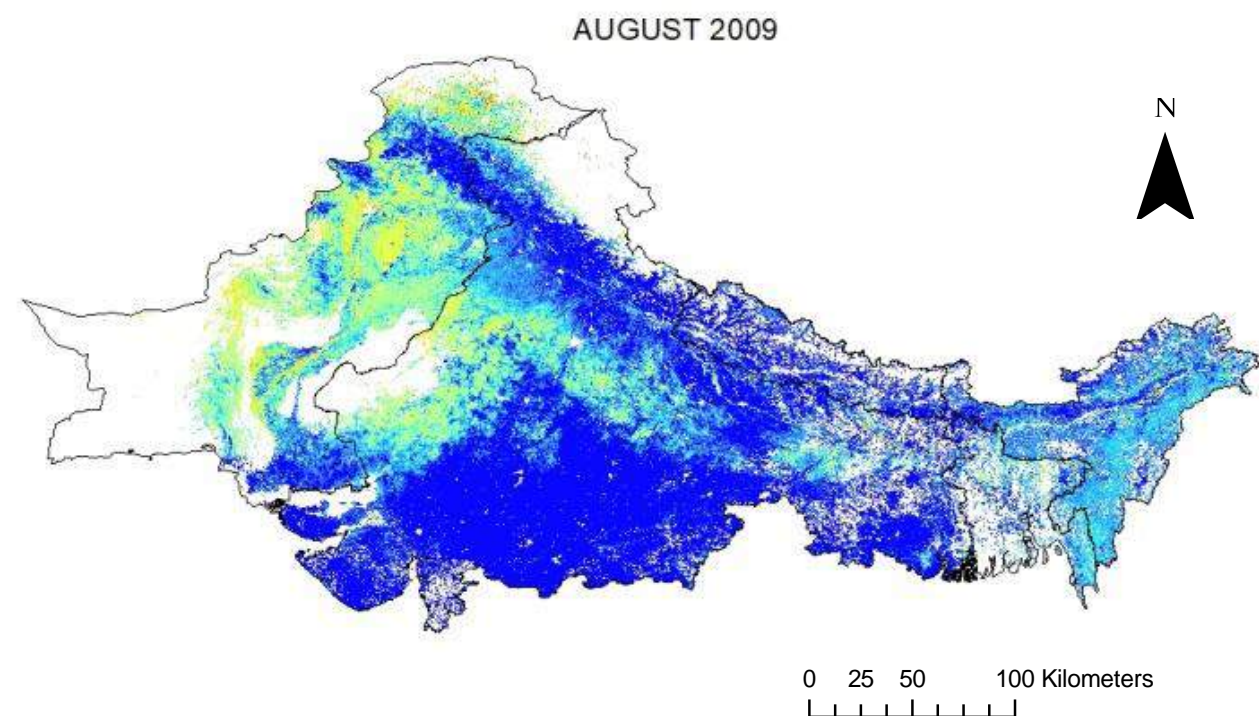




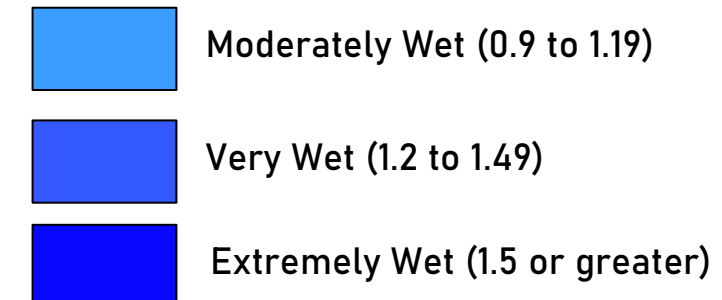
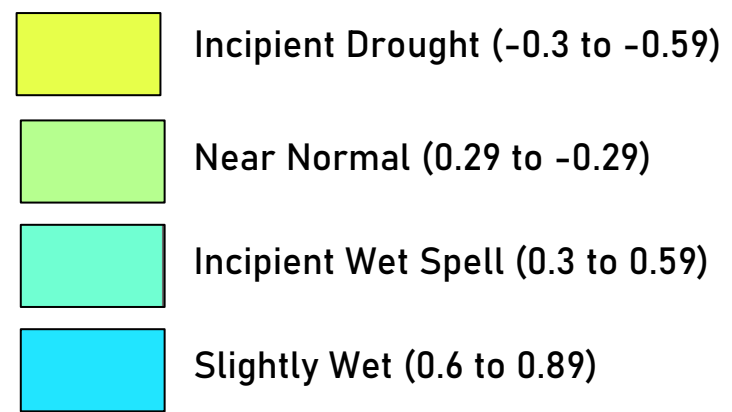
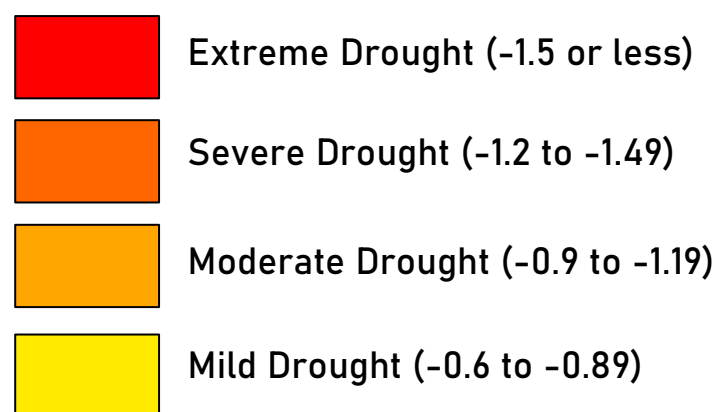
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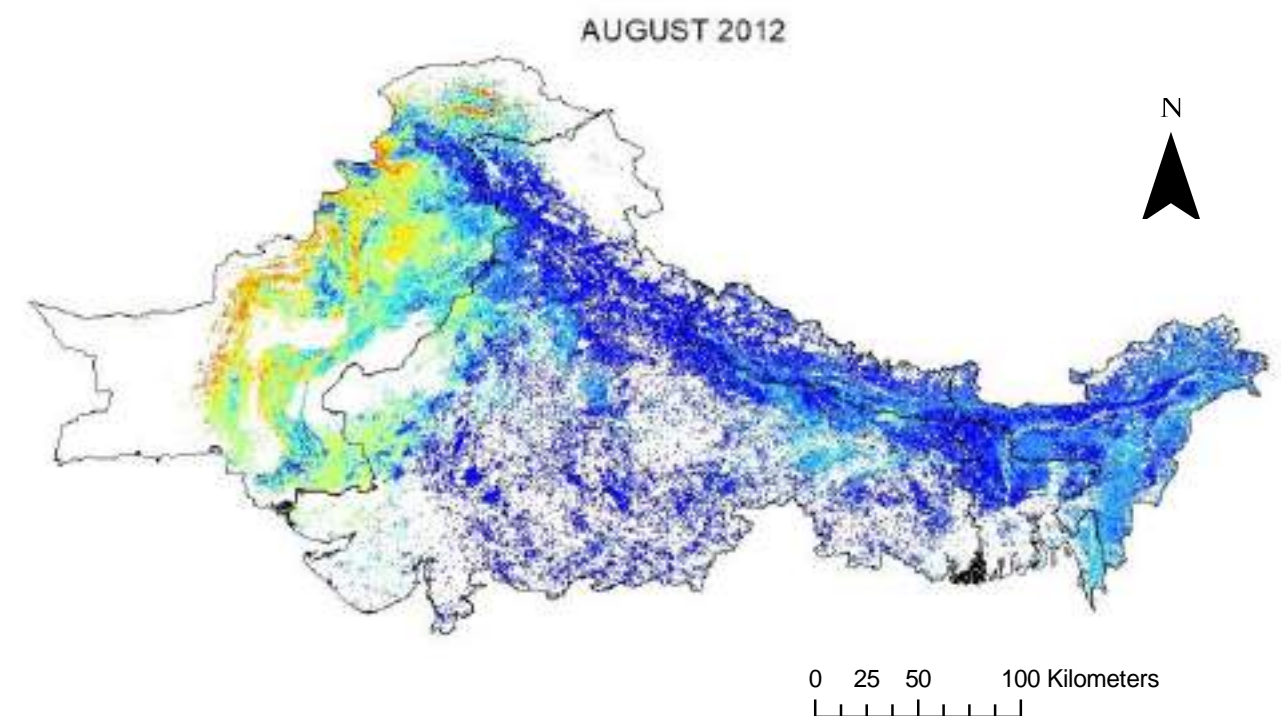
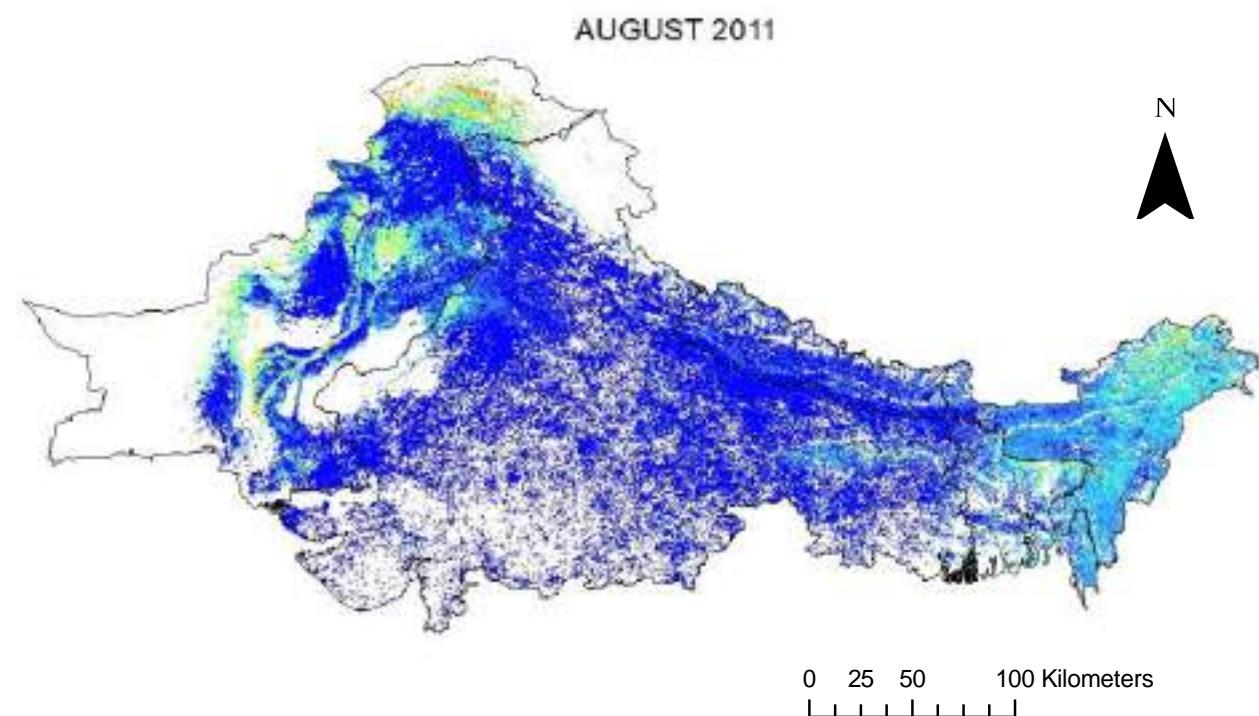




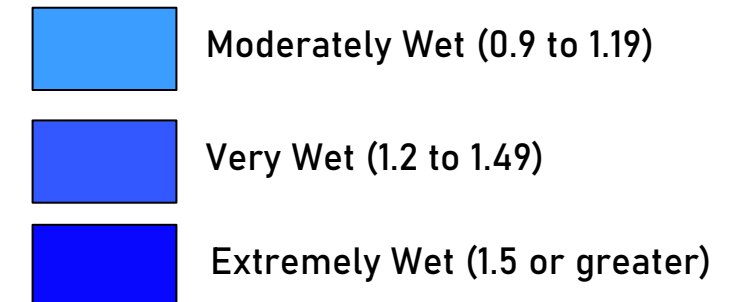
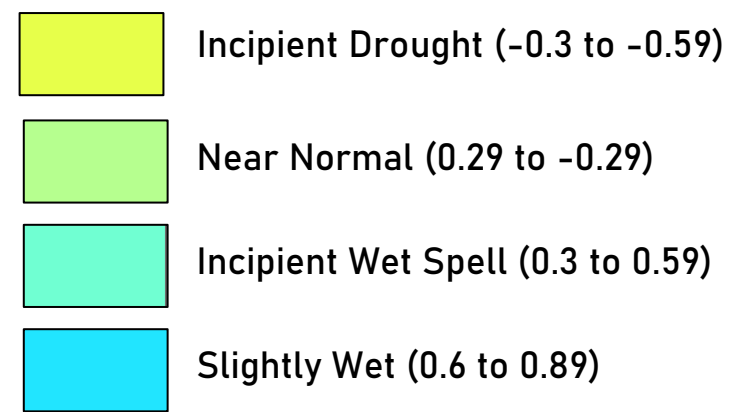
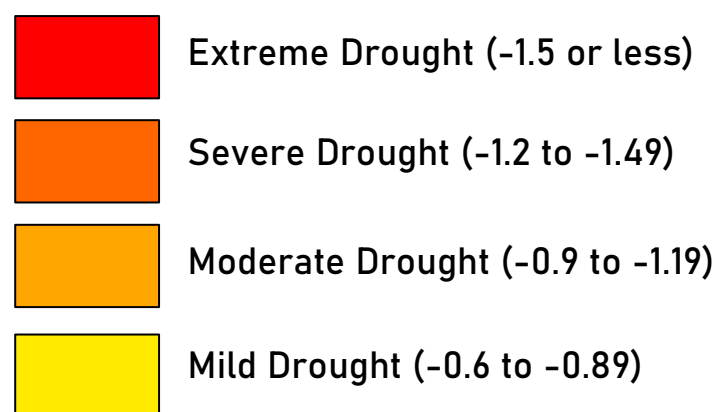
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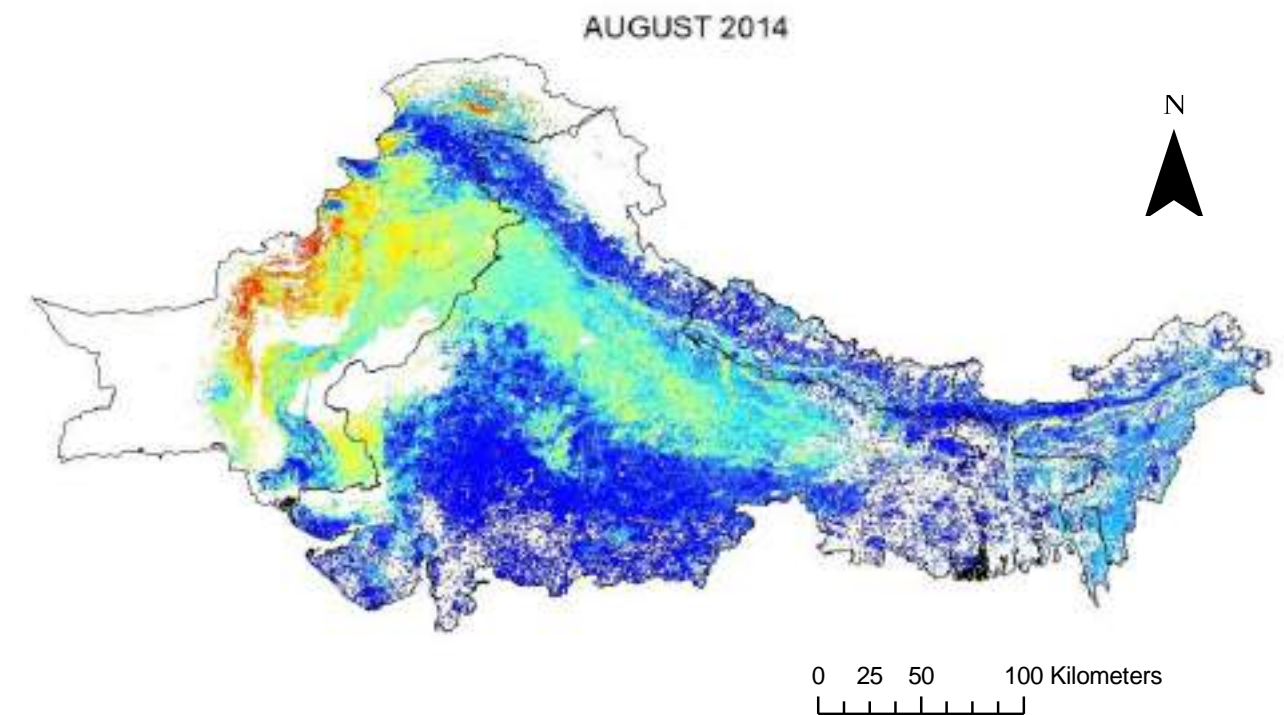
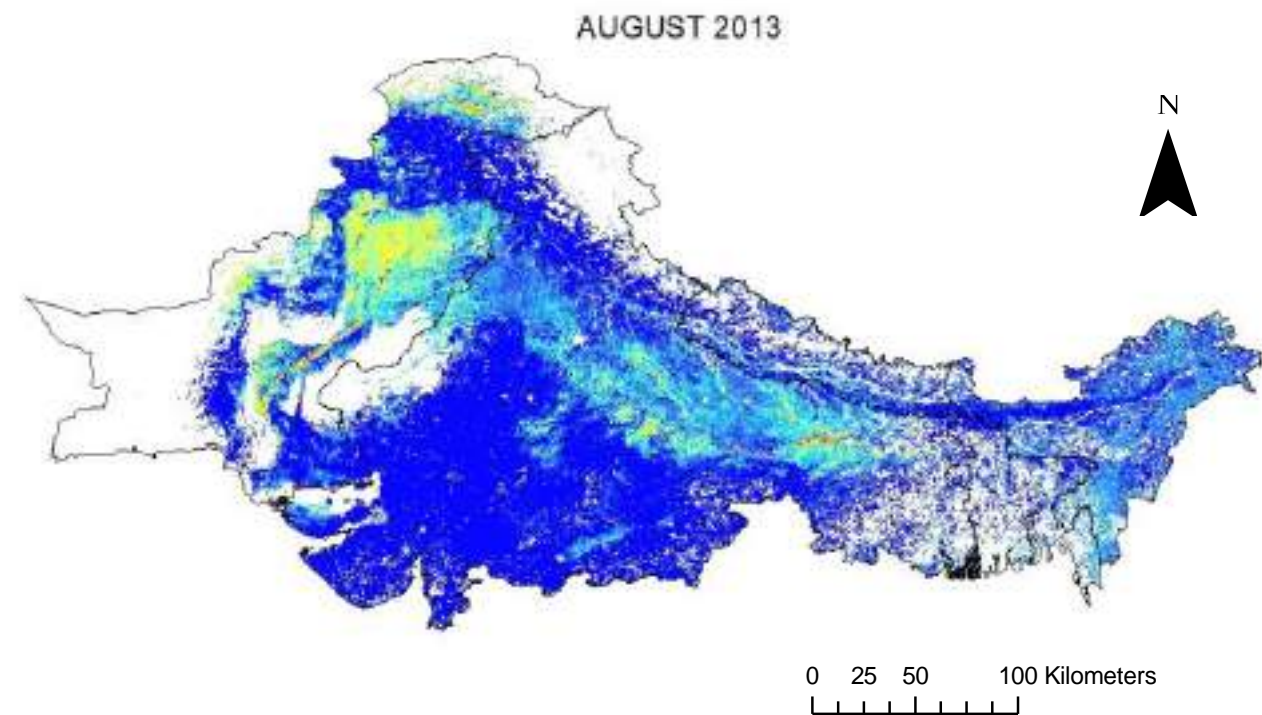




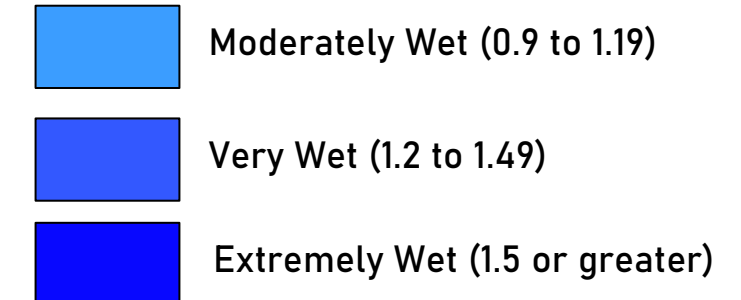
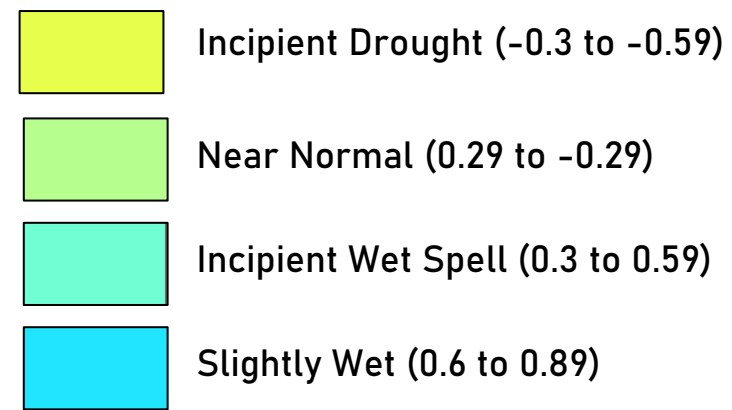
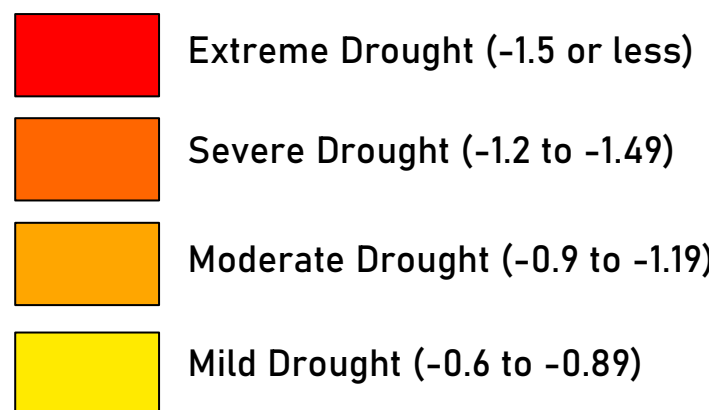


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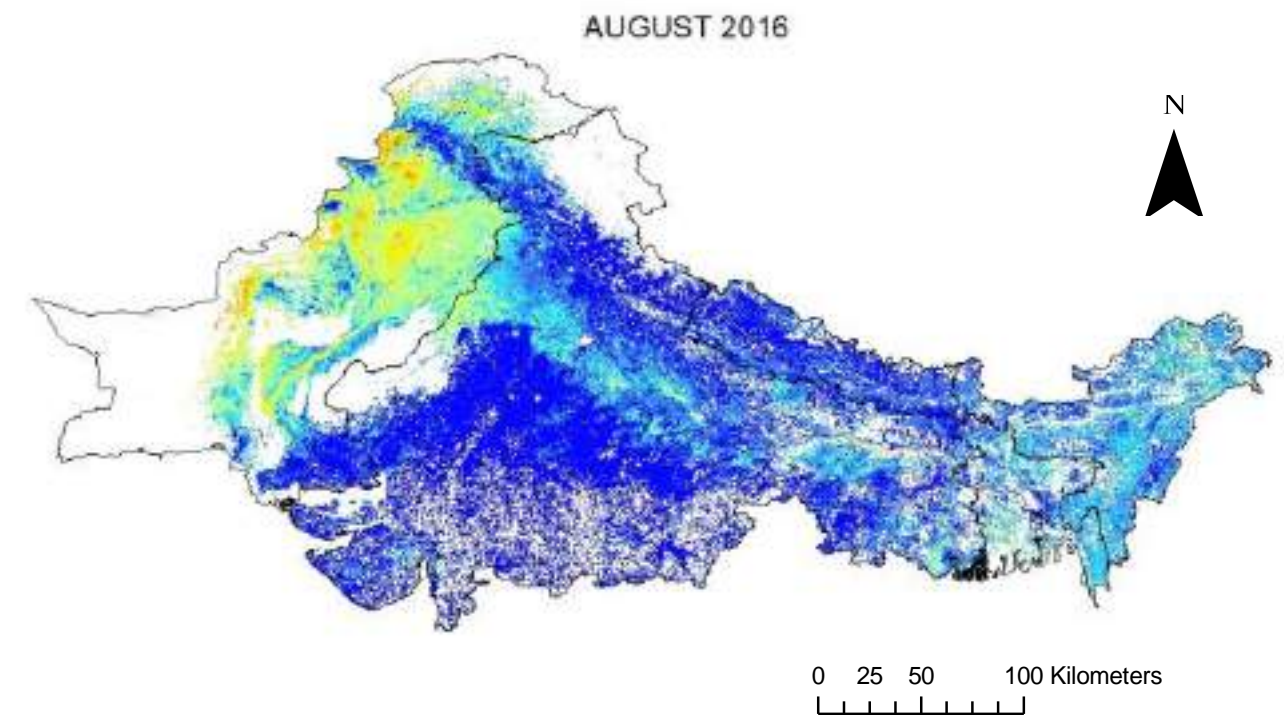
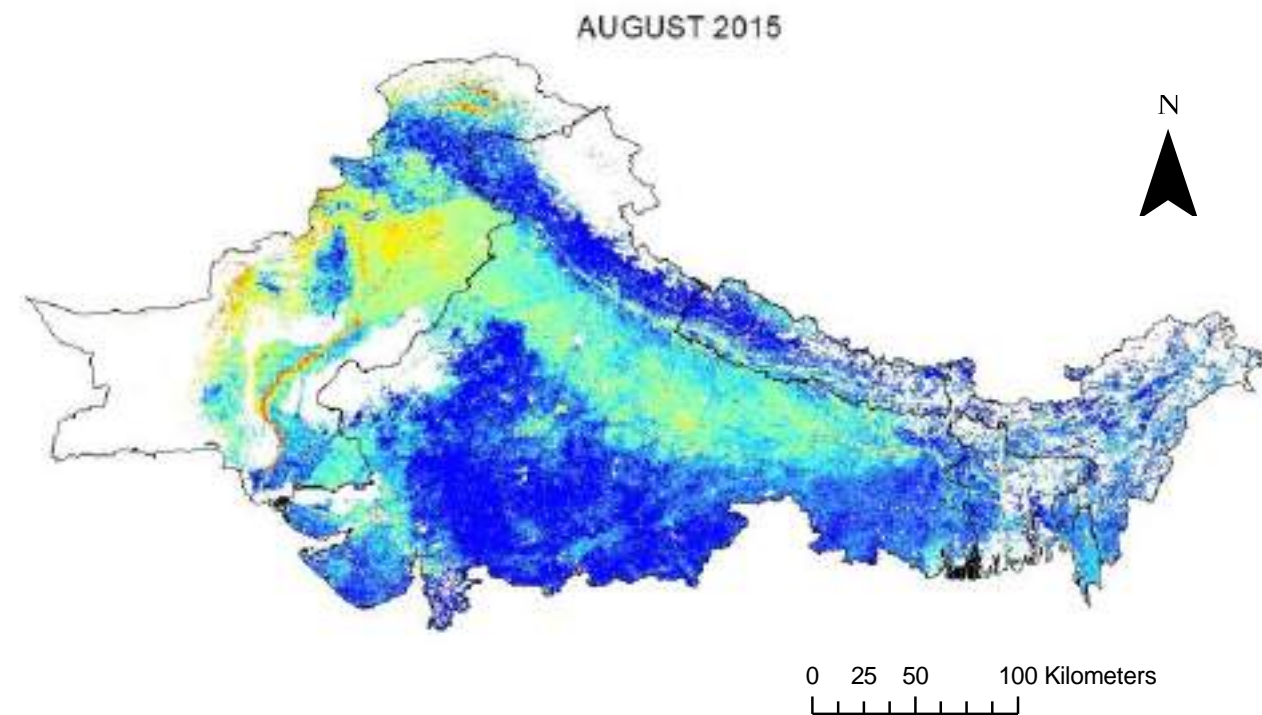




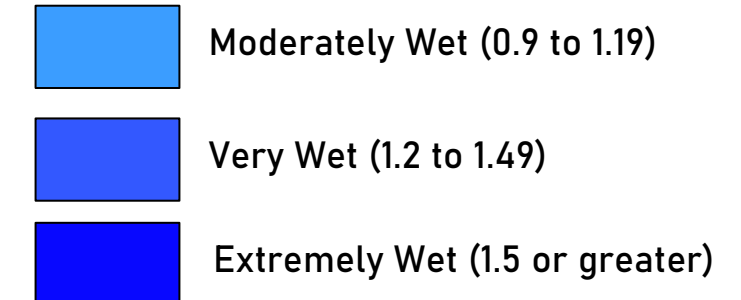
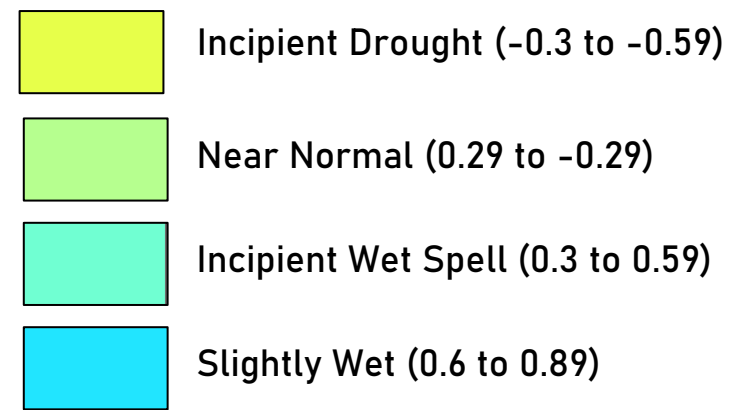
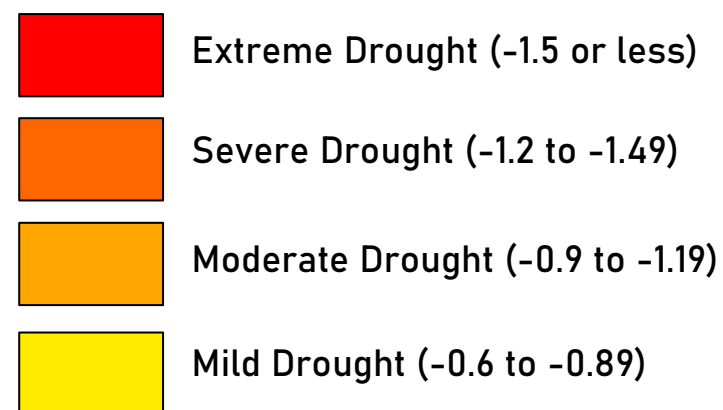
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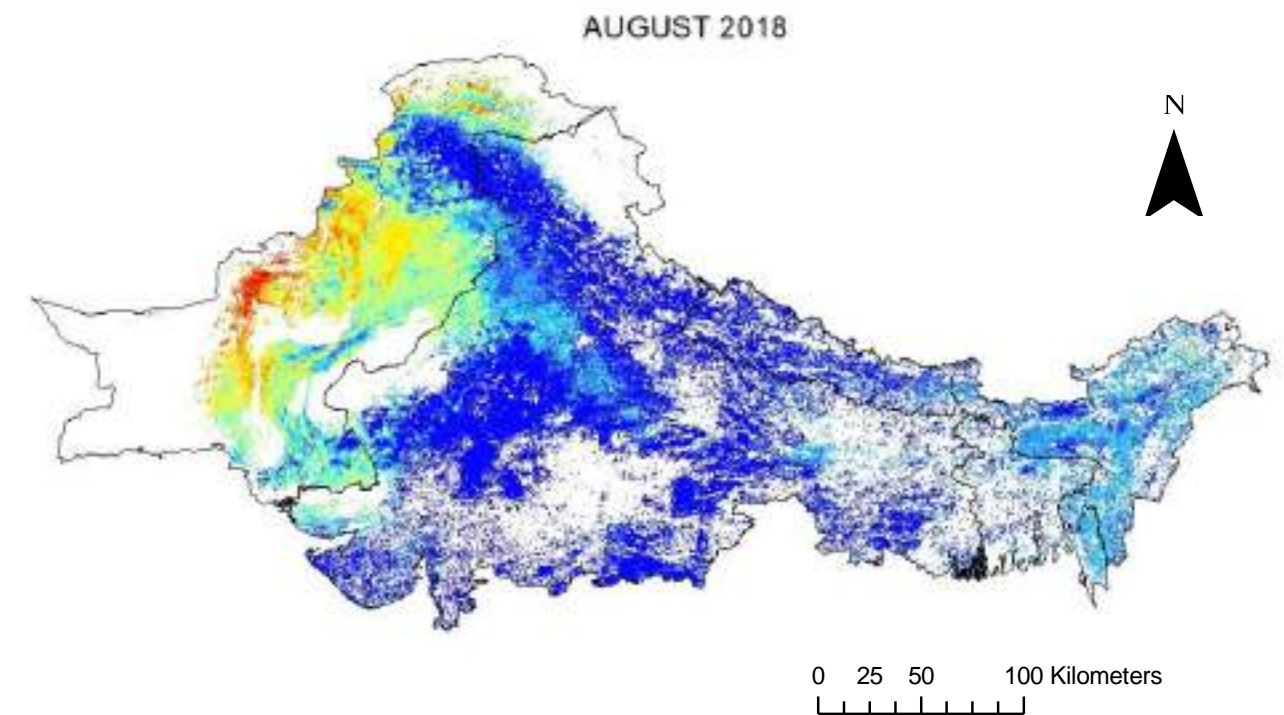
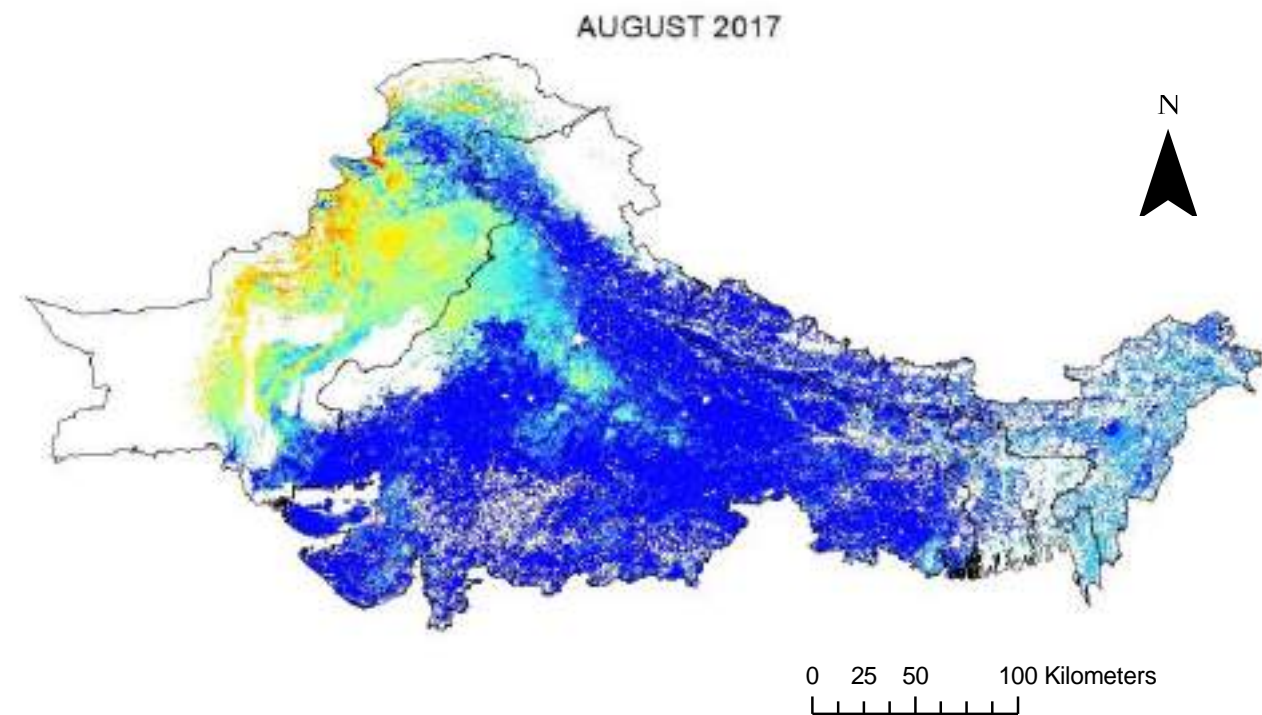




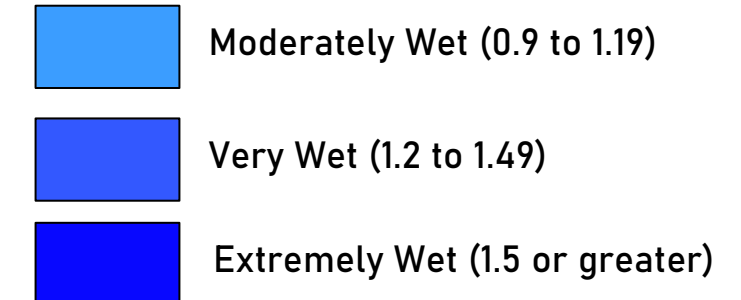
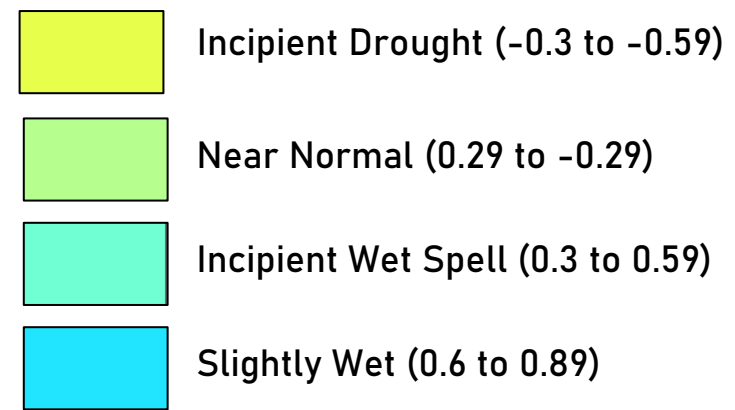
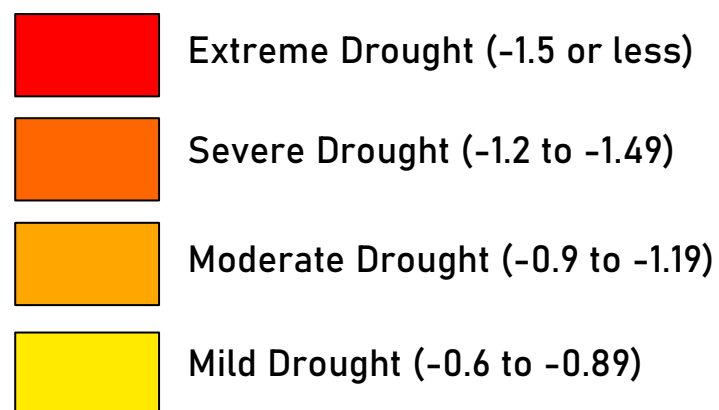
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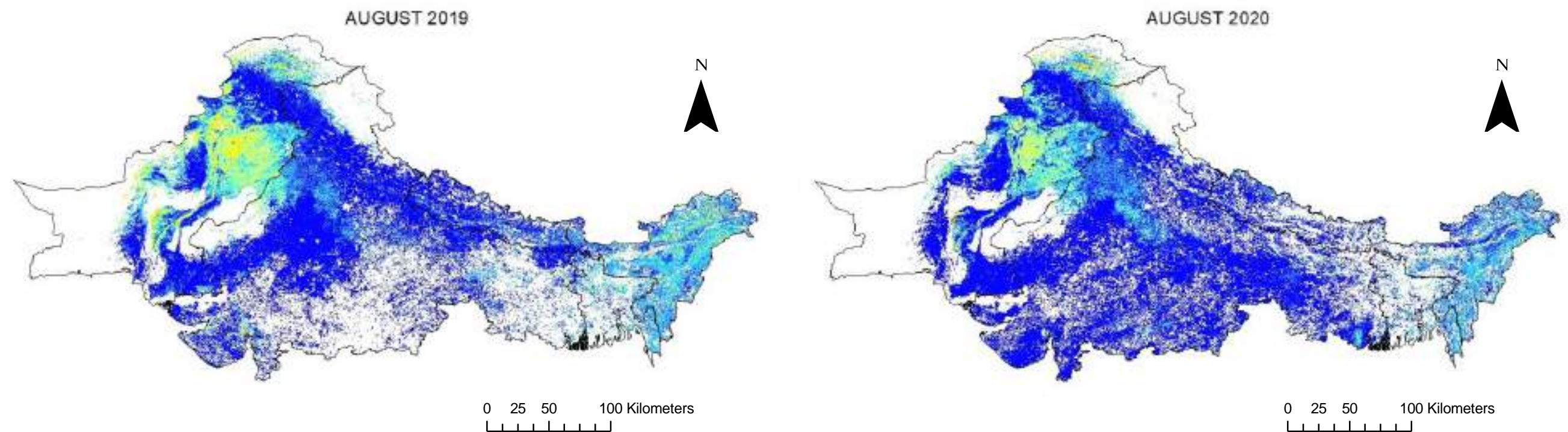




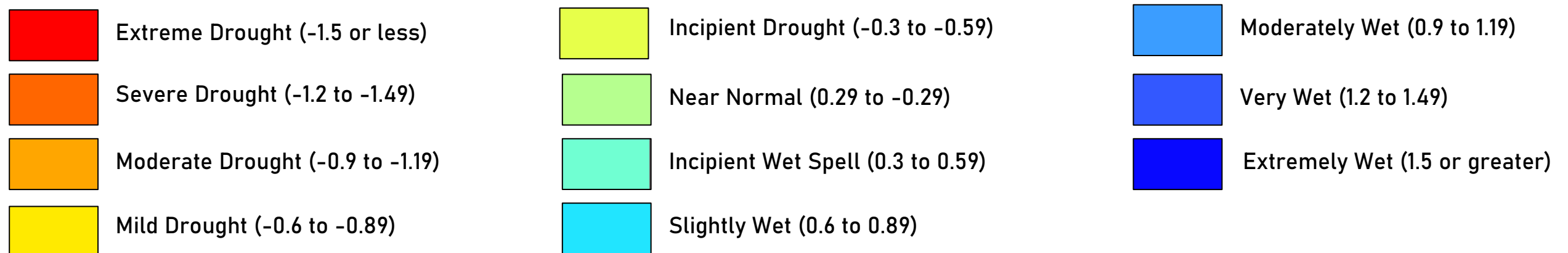


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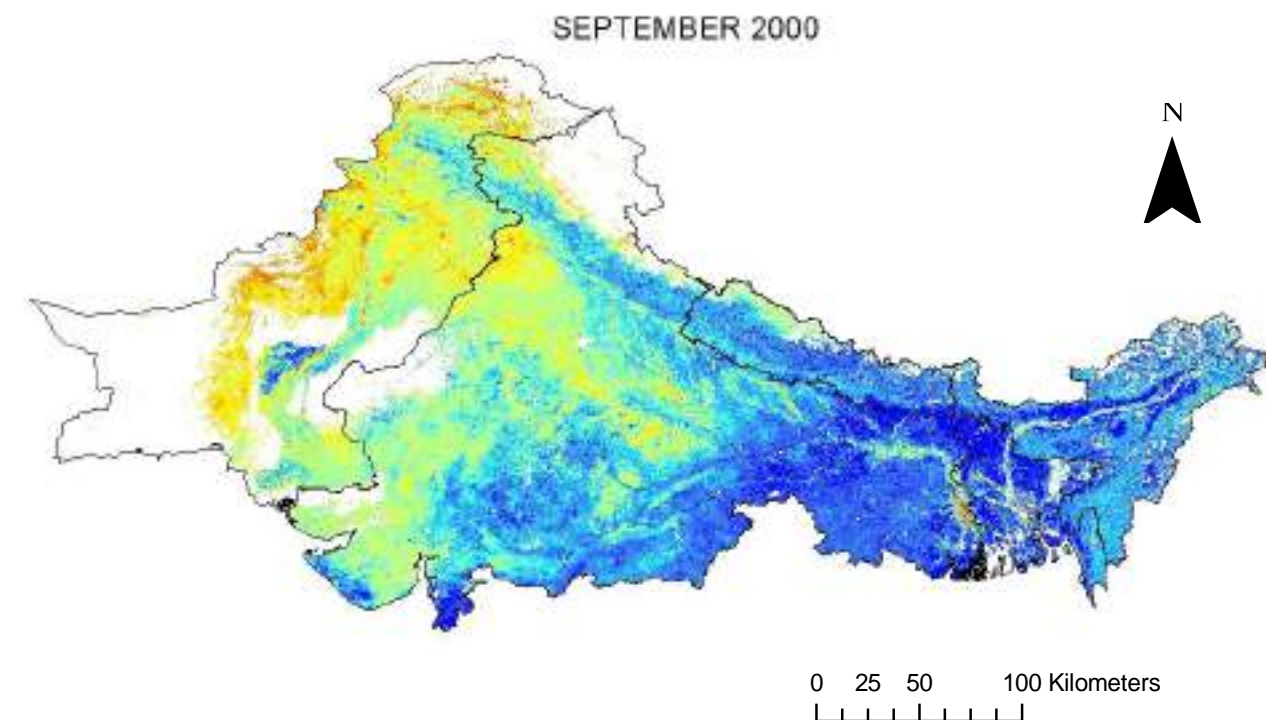
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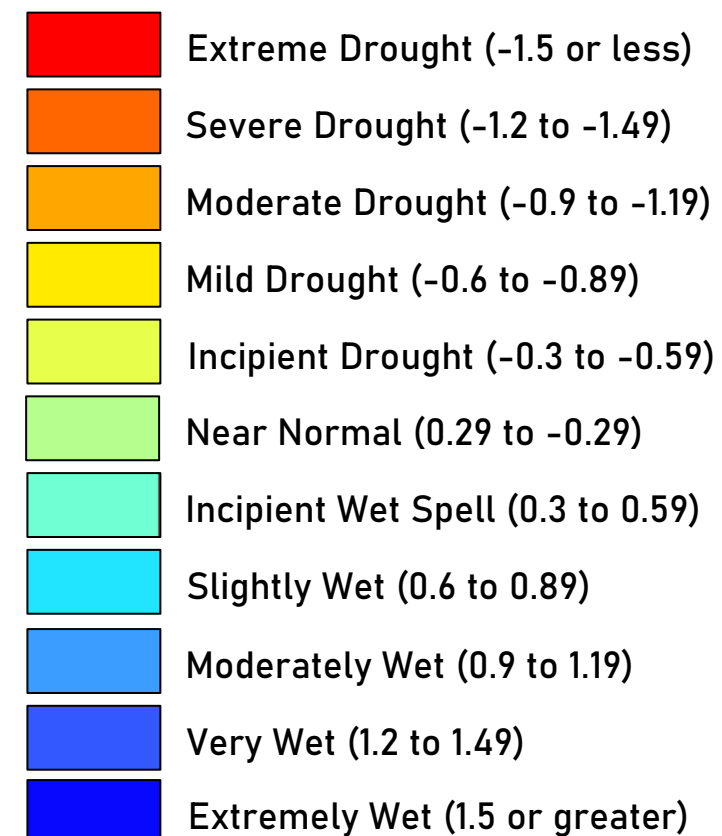
## September DSI Maps

Drought in September ranges from slightly wet to extremely wet. This wet month is characterized by slightly wet and extremely wet condition. DSI value of 1.58 was exhibited in 2010 making it the wettest year.

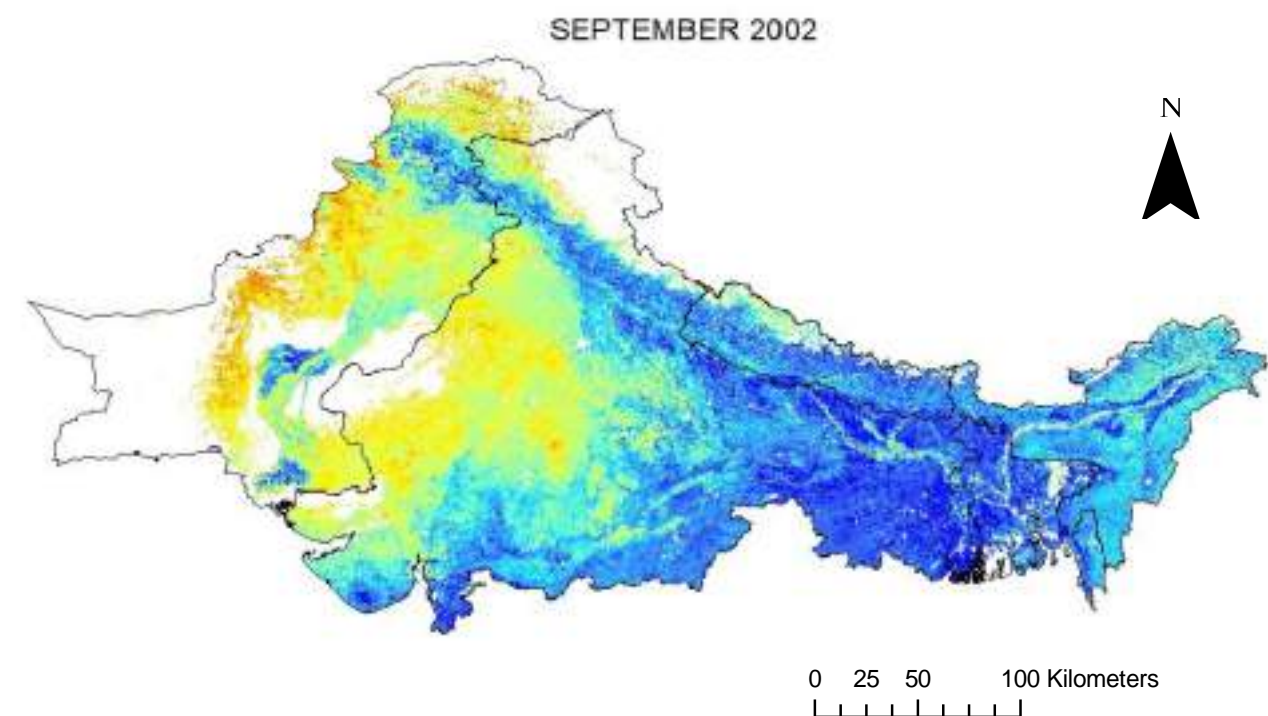
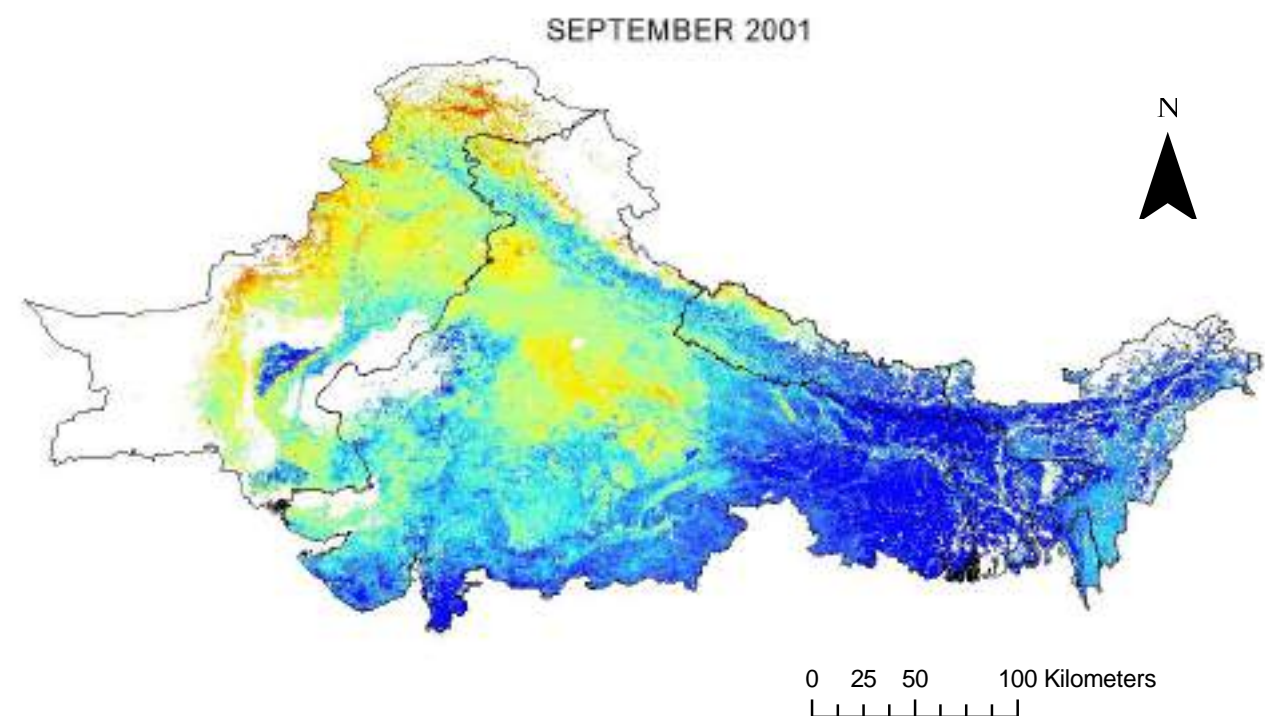
Mean September DSI Values		
Year	DSI Values	Drought Condition
2000	0.80	Slightly Wet
2001	0.86	Slightly Wet
2002	0.80	Slightly Wet
2003	1.34	Very Wet
2004	1.09	Moderately Wet
2005	1.38	Very Wet
2006	1.15	Moderately Wet
2007	1.22	Very Wet
2008	1.26	Very Wet
2009	1.13	Moderately Wet
2010	1.58	Extremely Wet
2011	1.50	Extremely Wet
2012	1.28	Very Wet
2013	1.24	Very Wet
2014	1.11	Moderately Wet
2015	0.72	Slightly Wet
2016	1.09	Moderately Wet
2017	1.08	Moderately Wet
2018	1.03	Moderately Wet
2019	1.57	Extremely Wet
2020	1.43	Very Wet



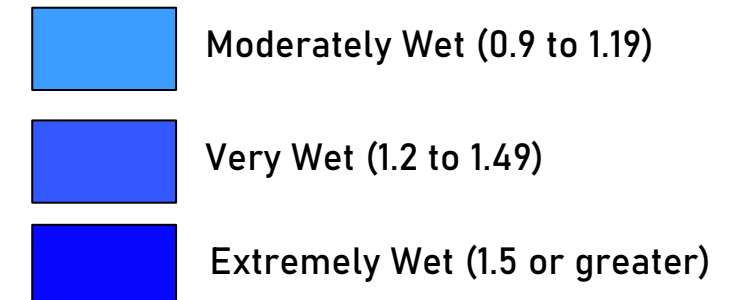
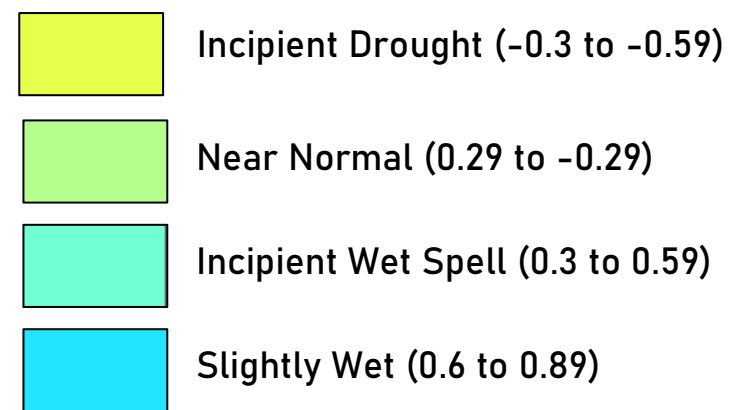
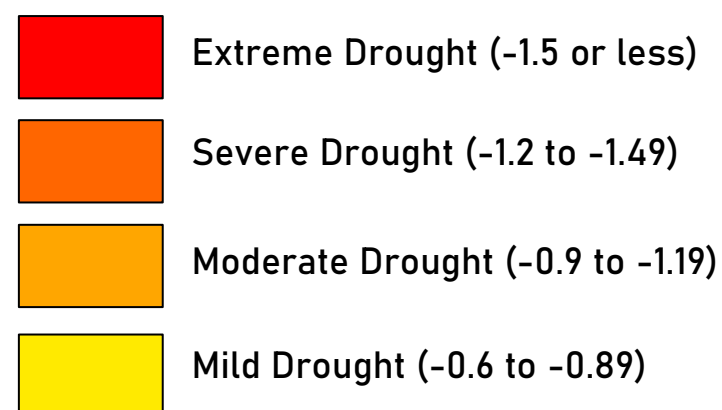
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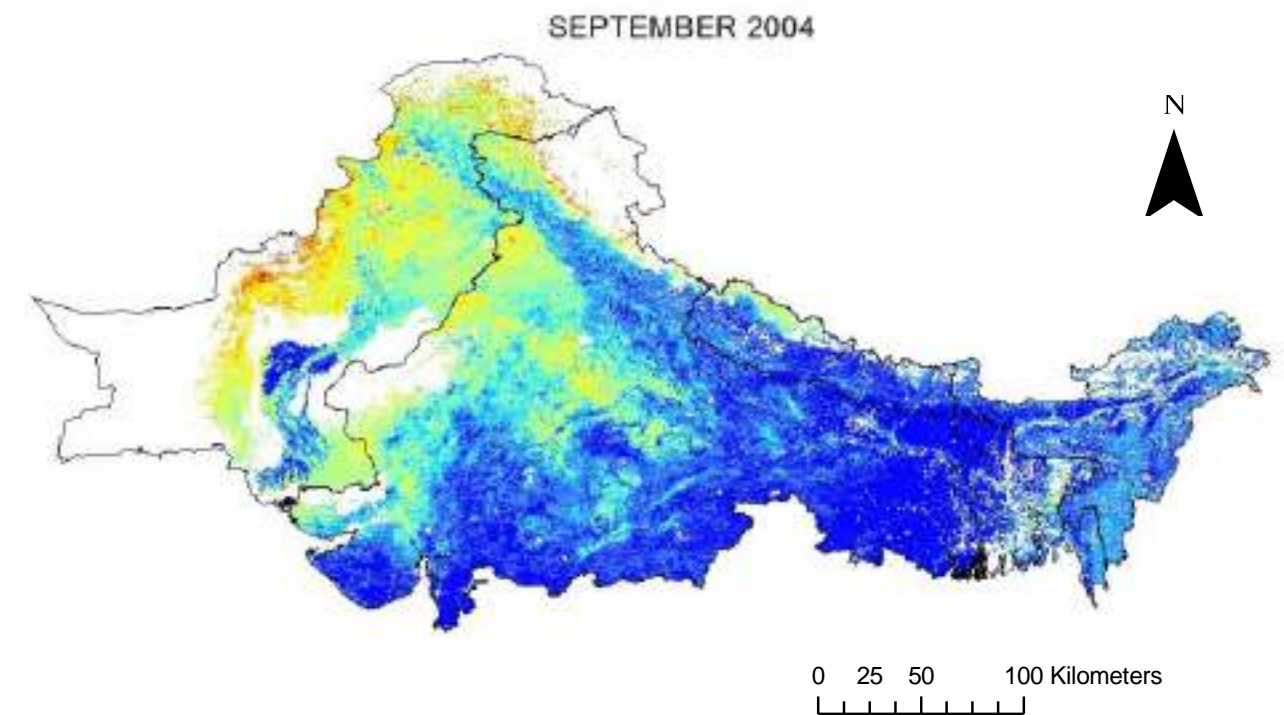
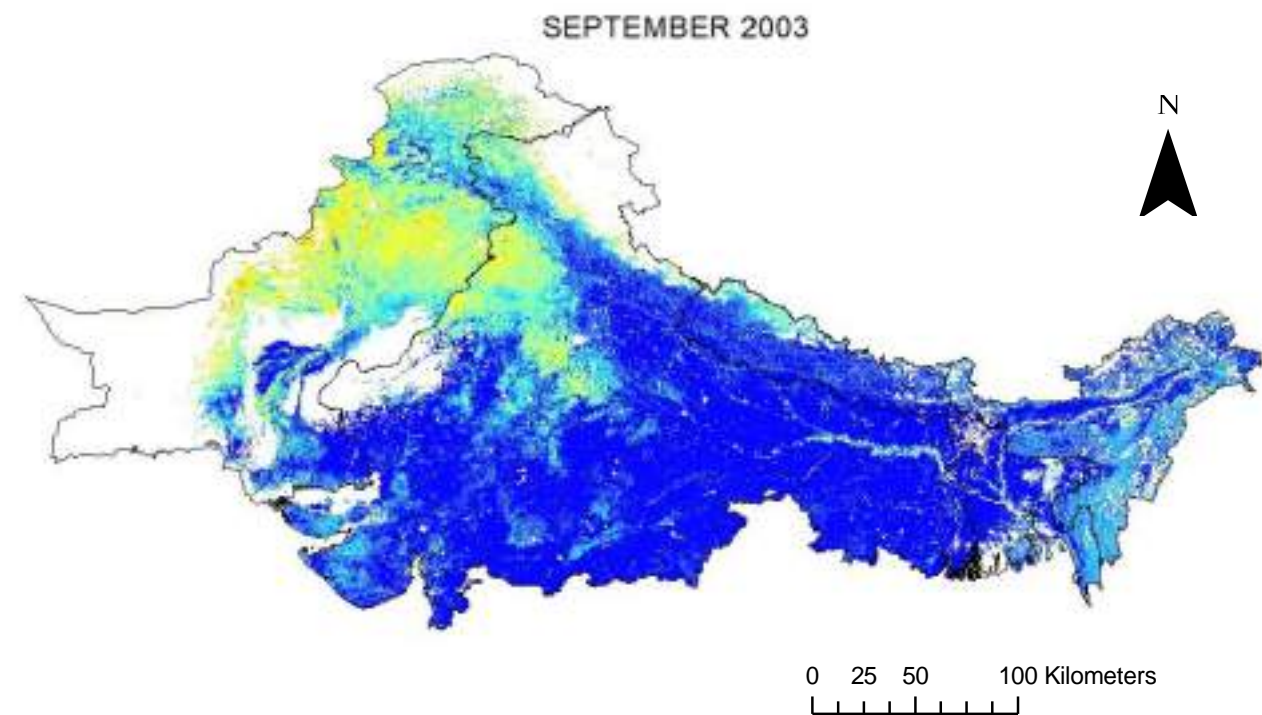




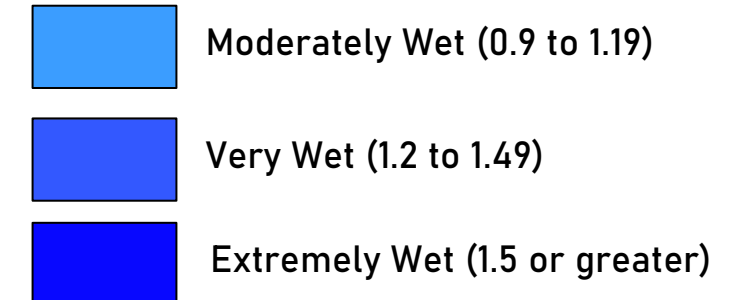
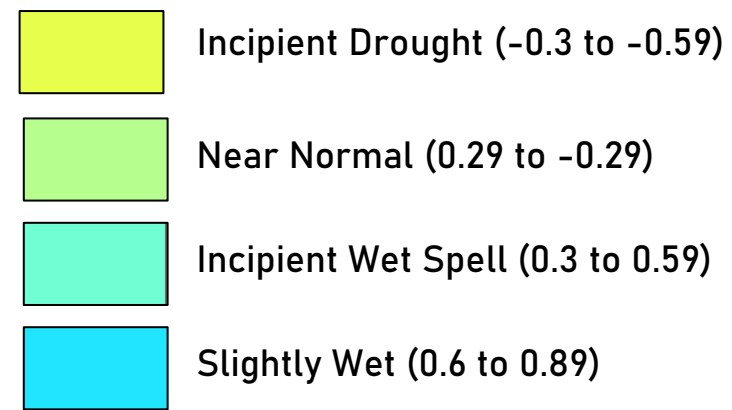
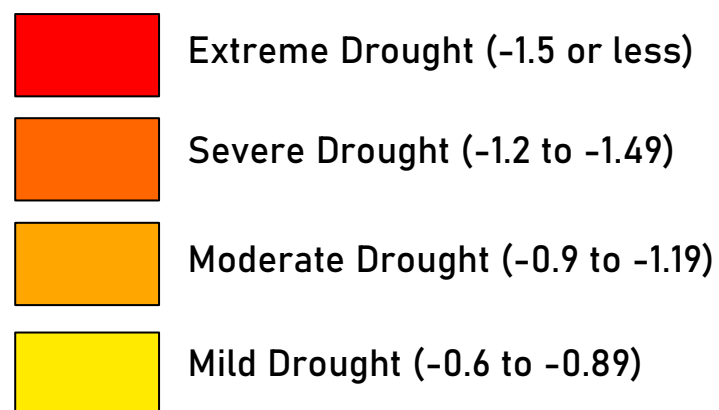


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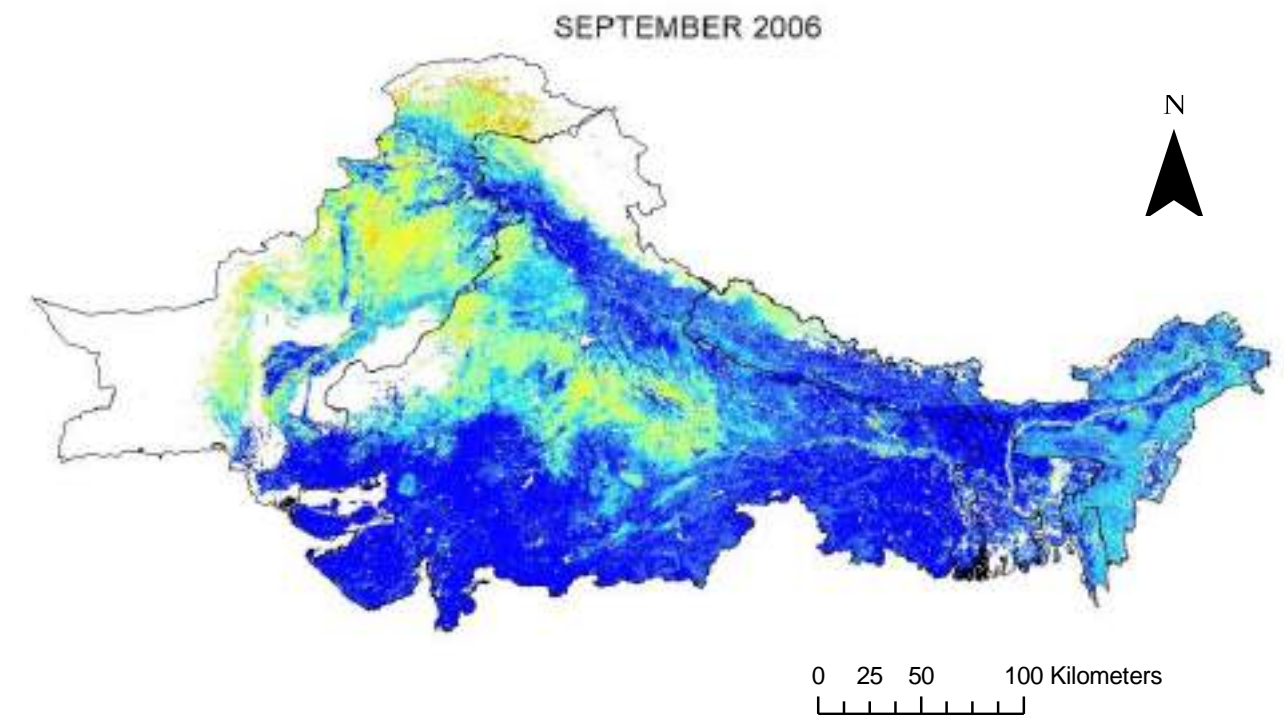
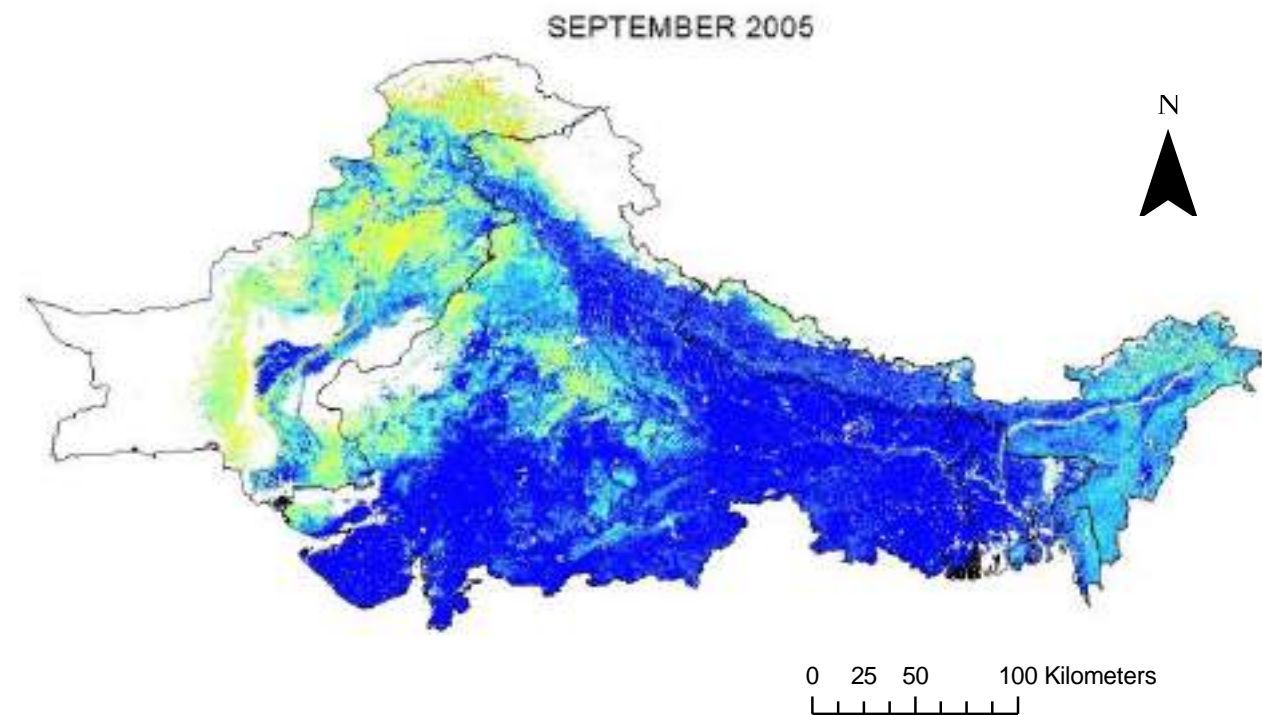




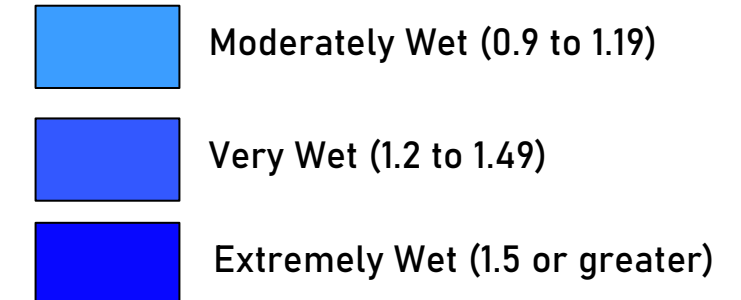
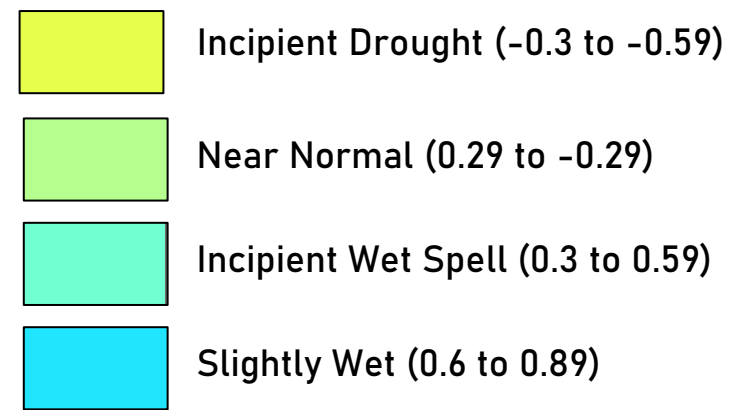
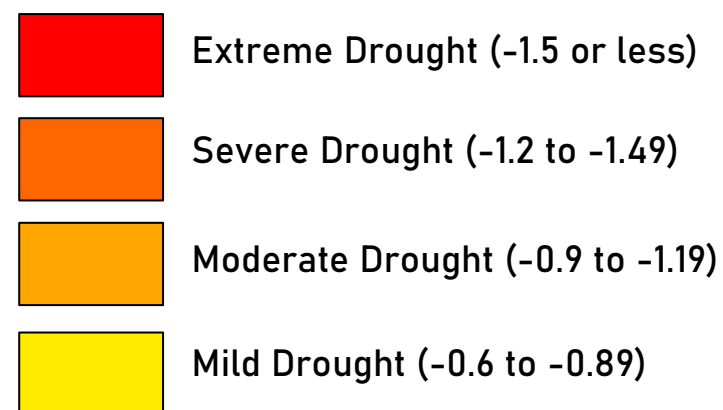
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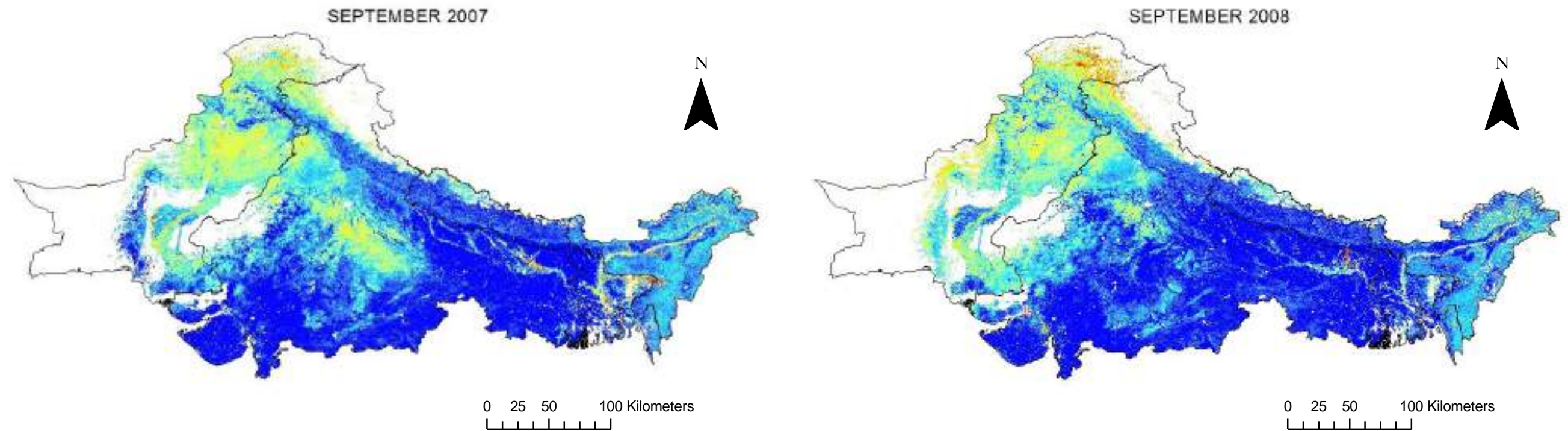




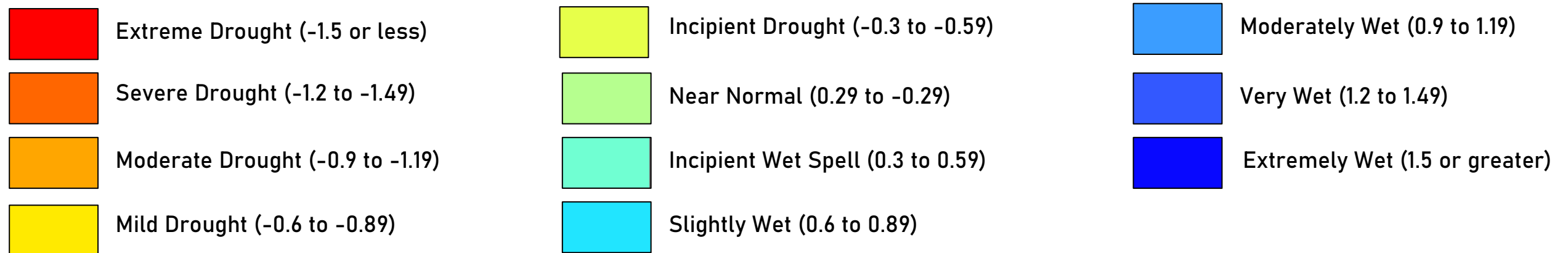
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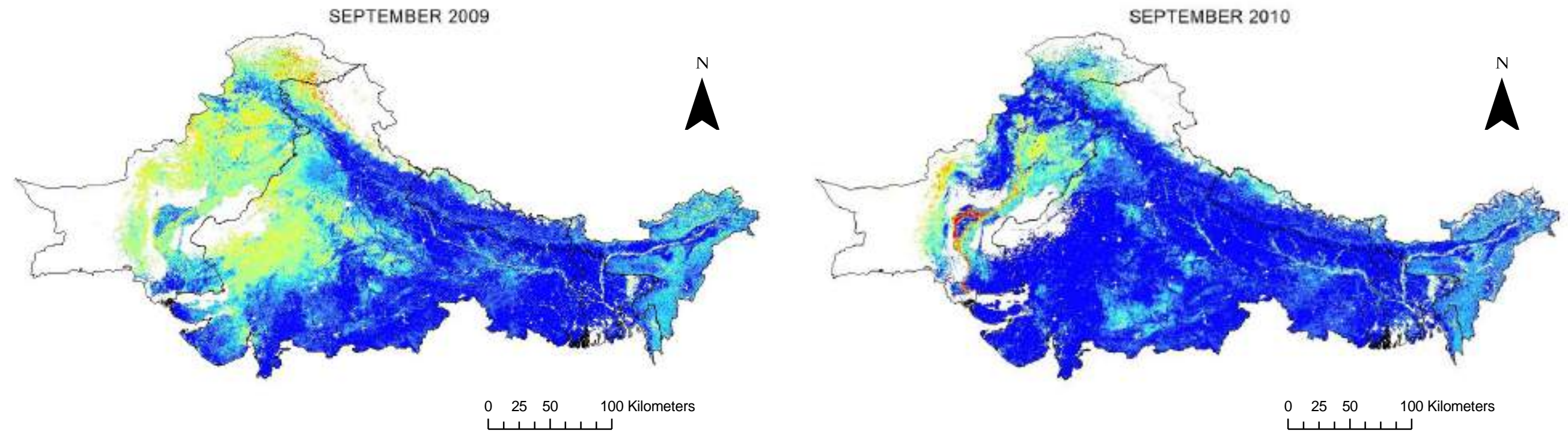




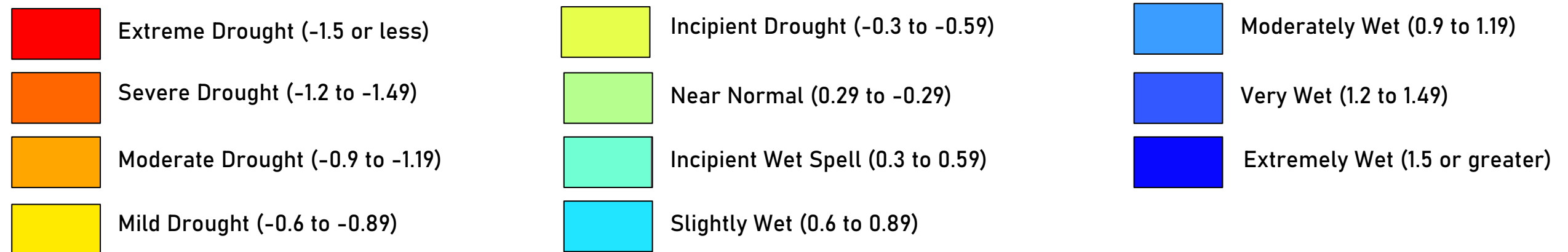


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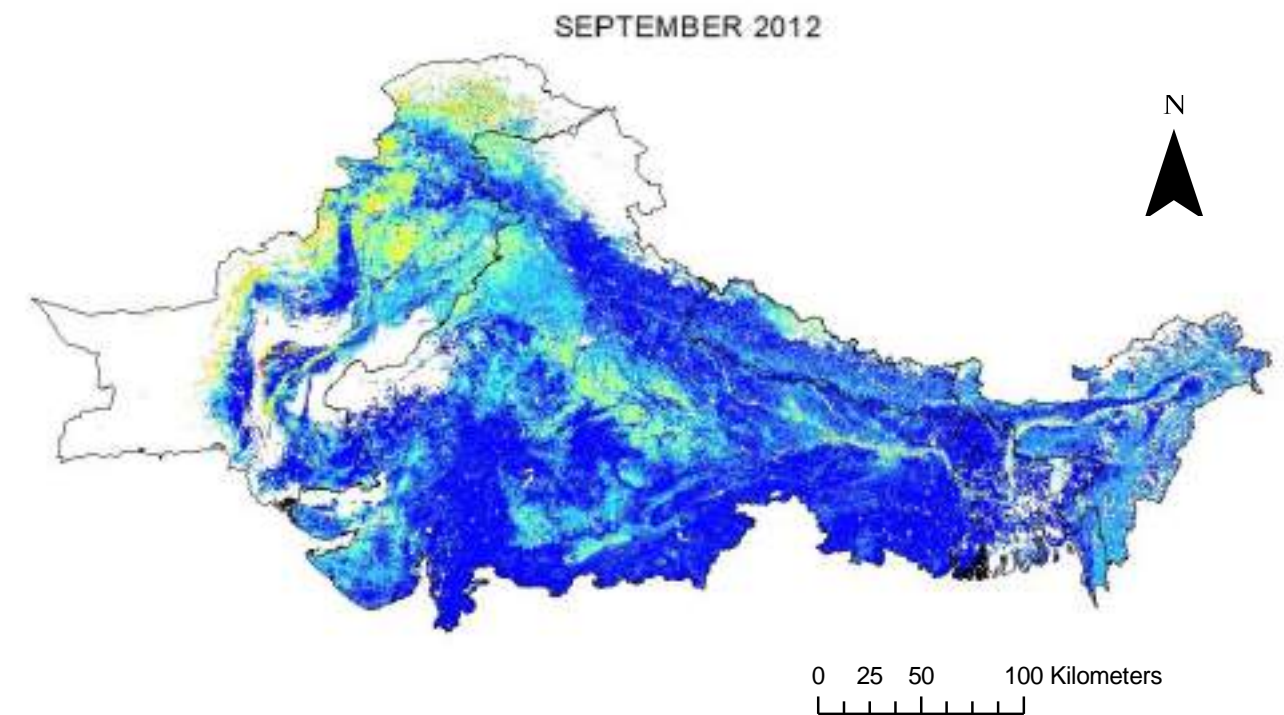
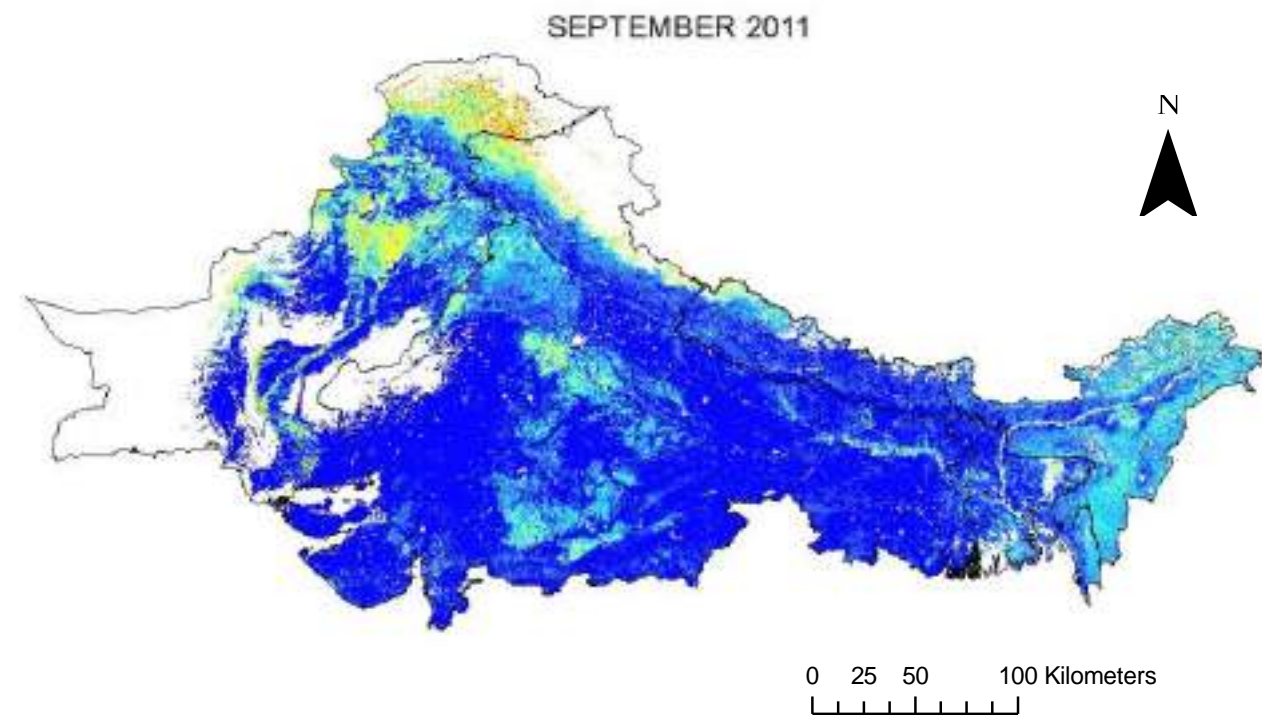




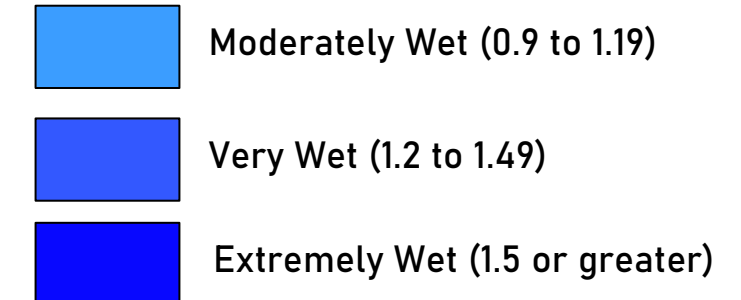
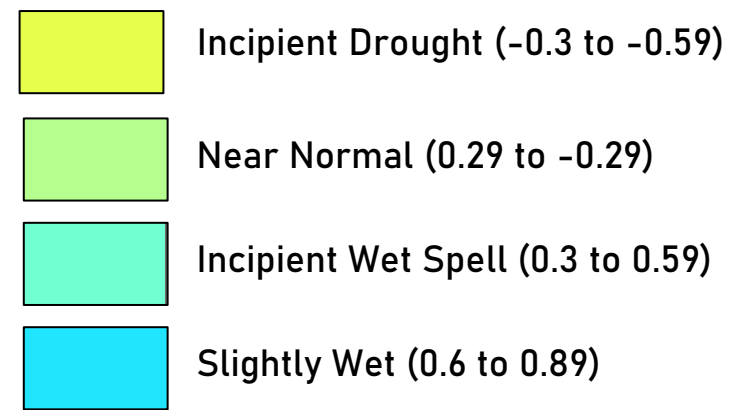
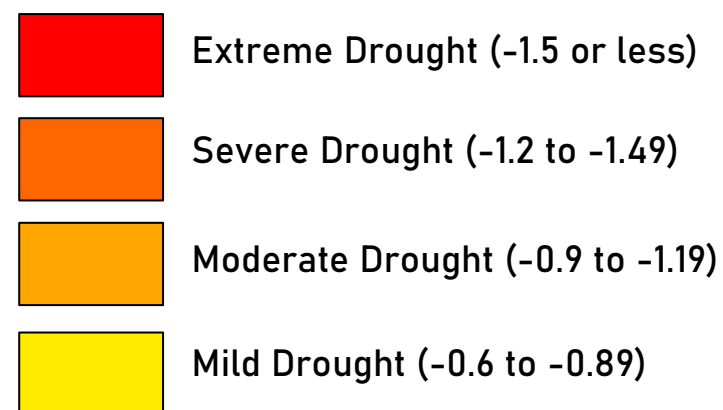
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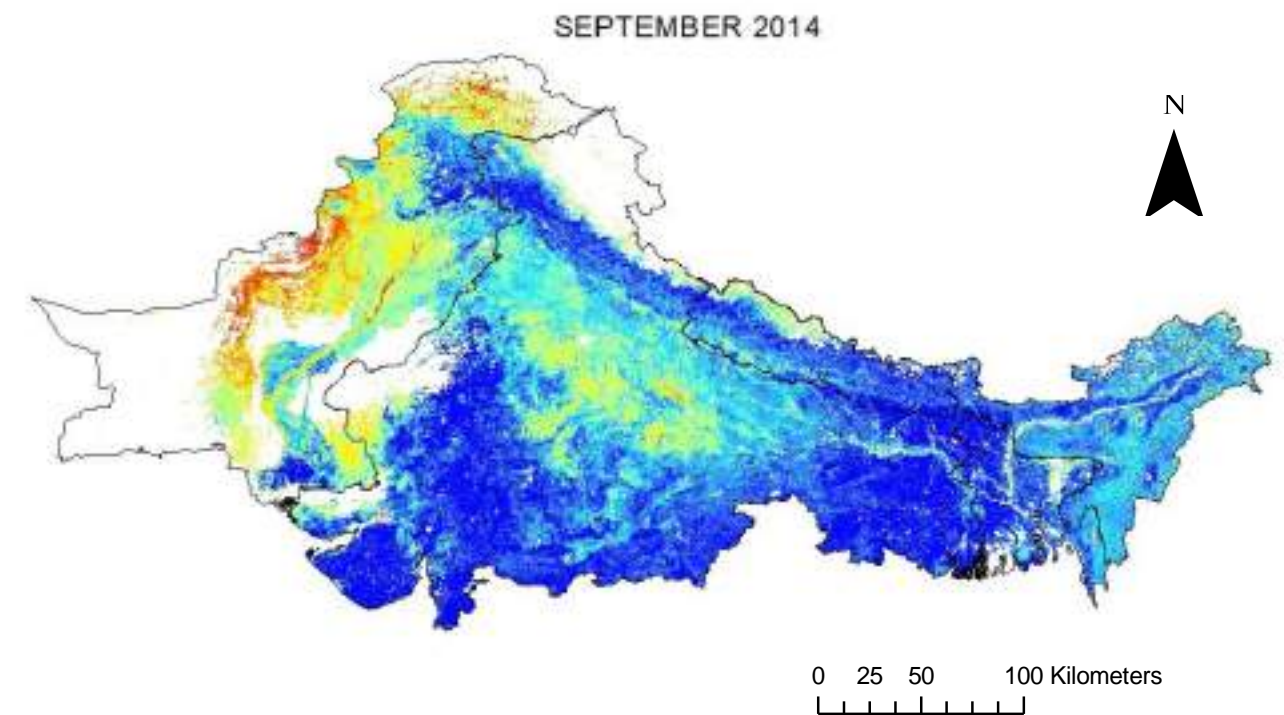
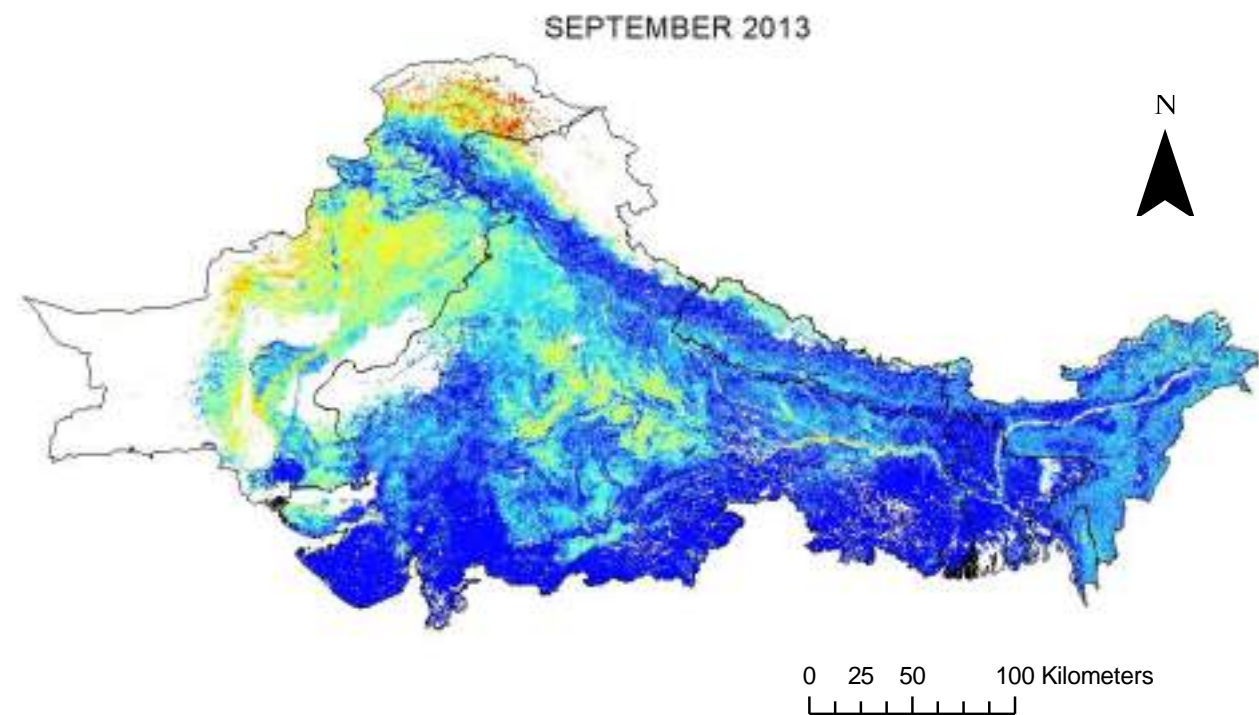




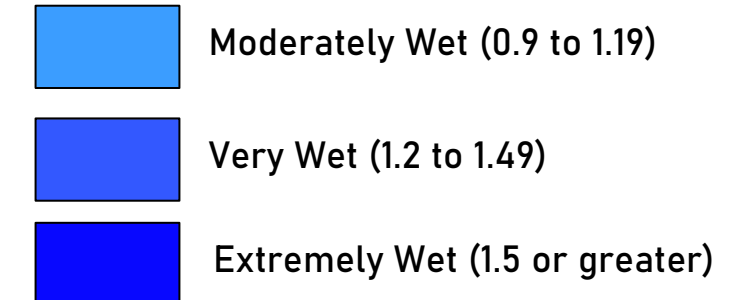
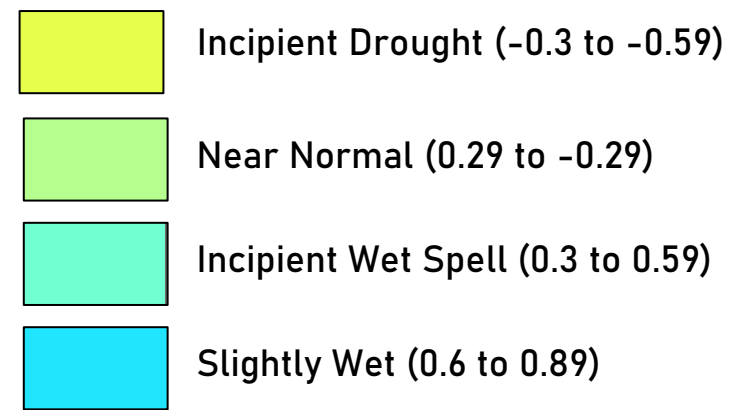
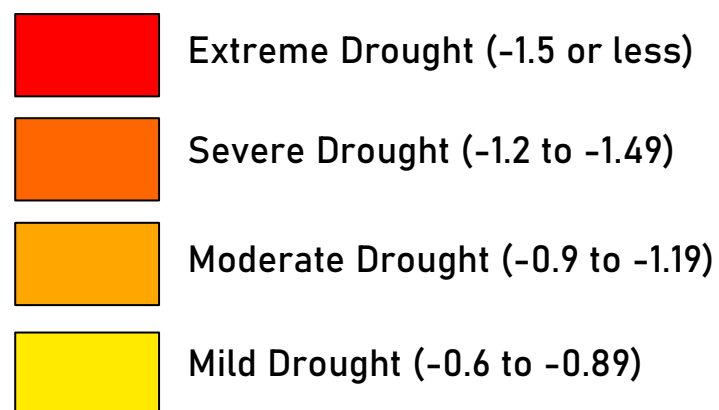
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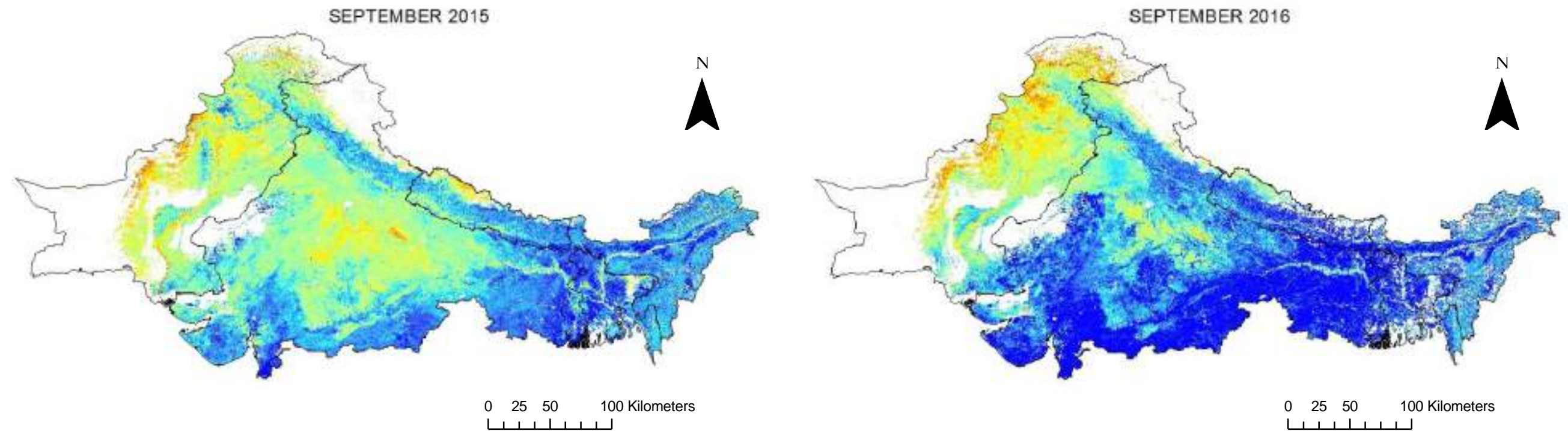




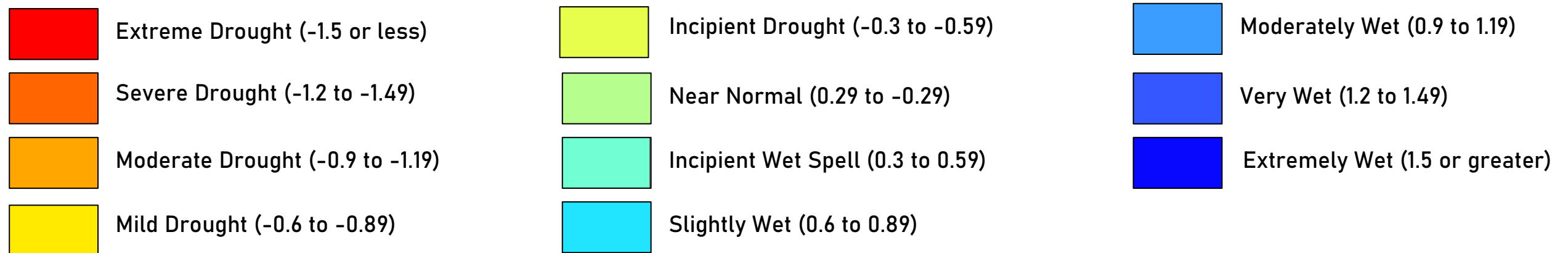


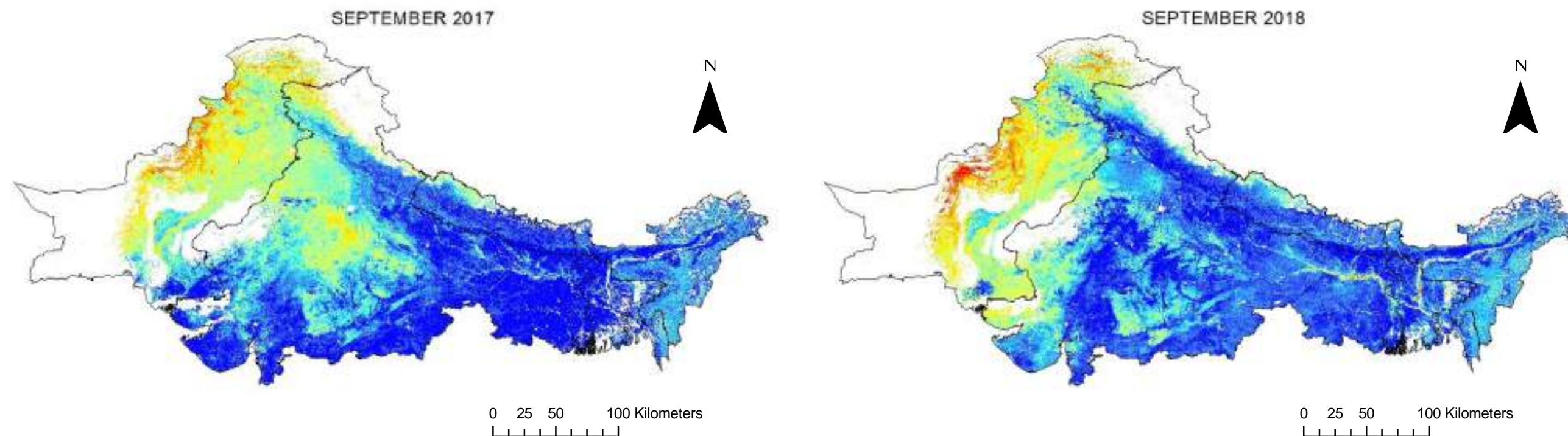
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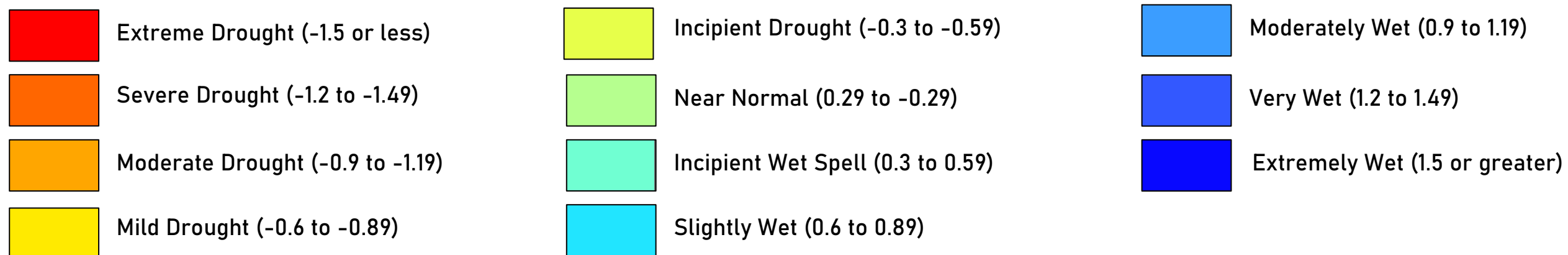


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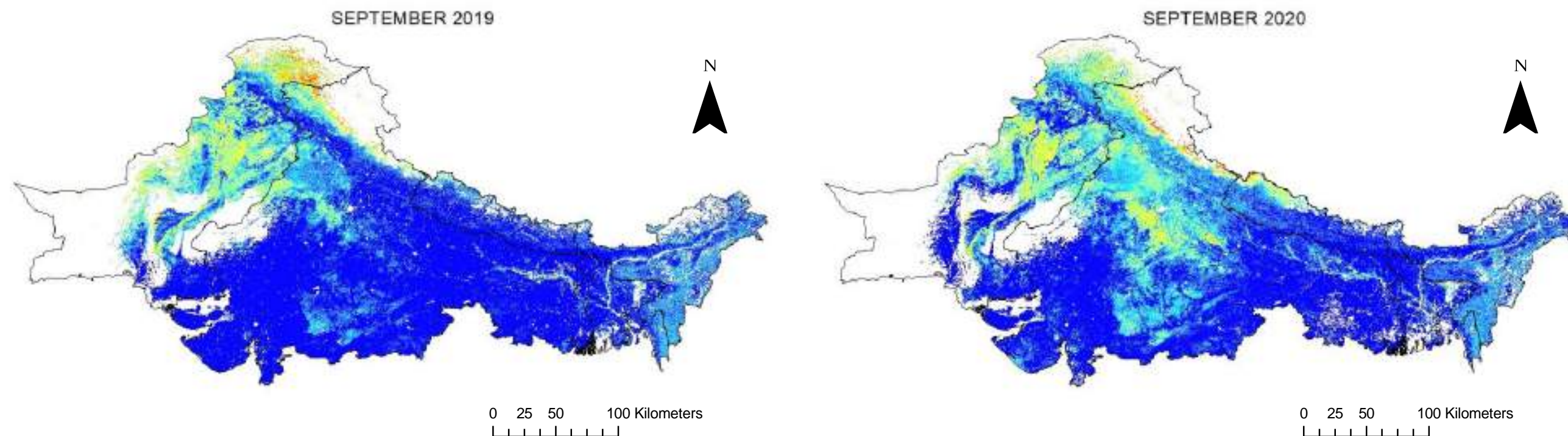




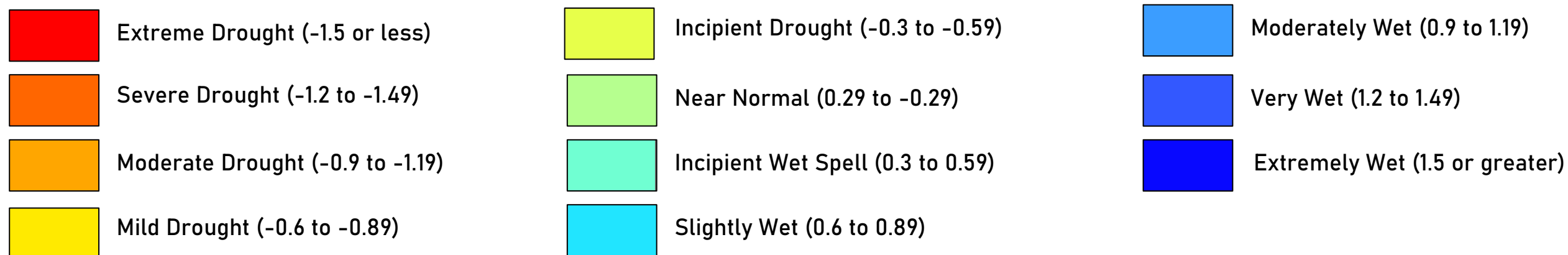
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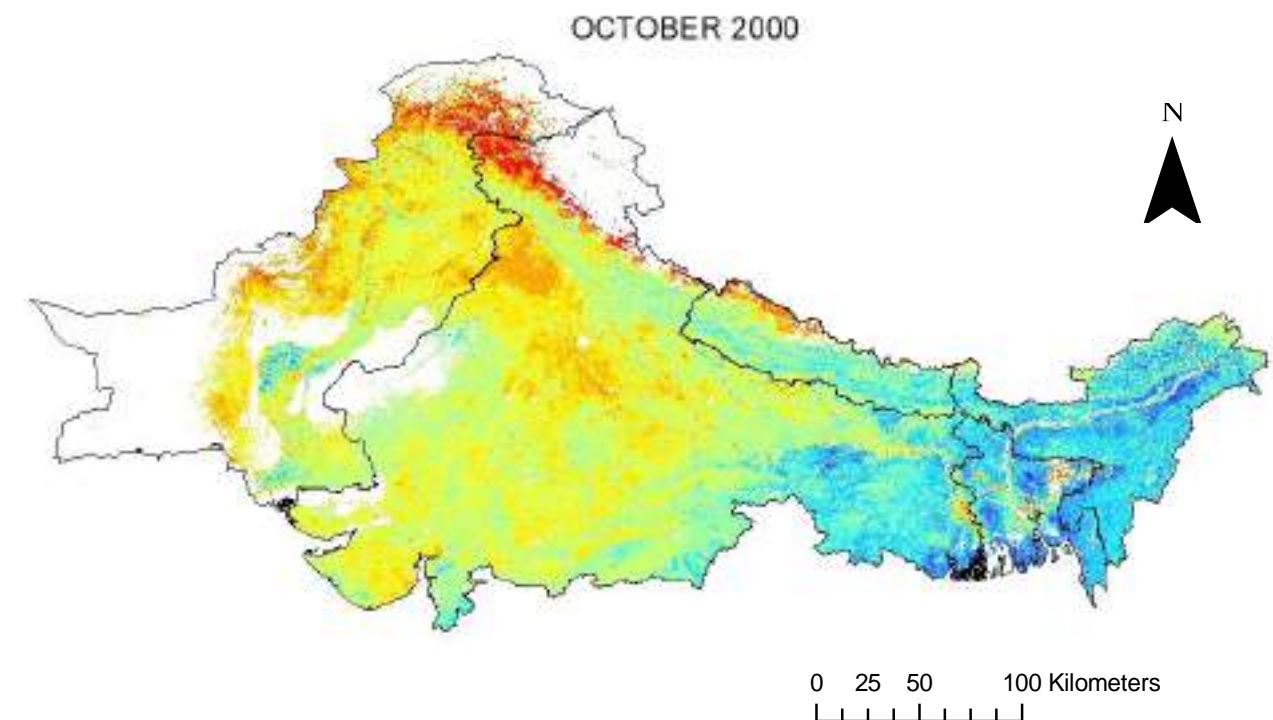
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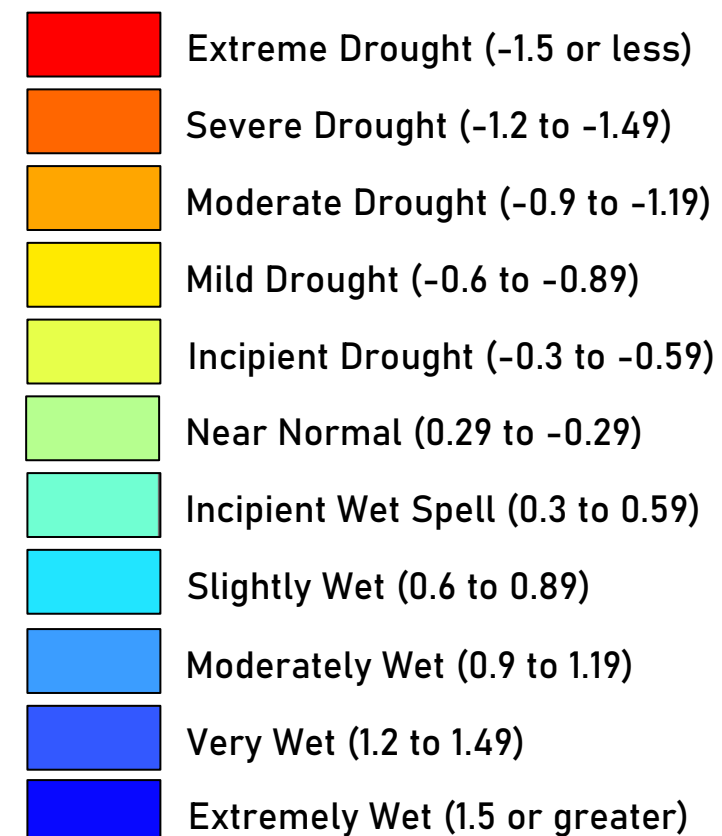
## October DSI Maps

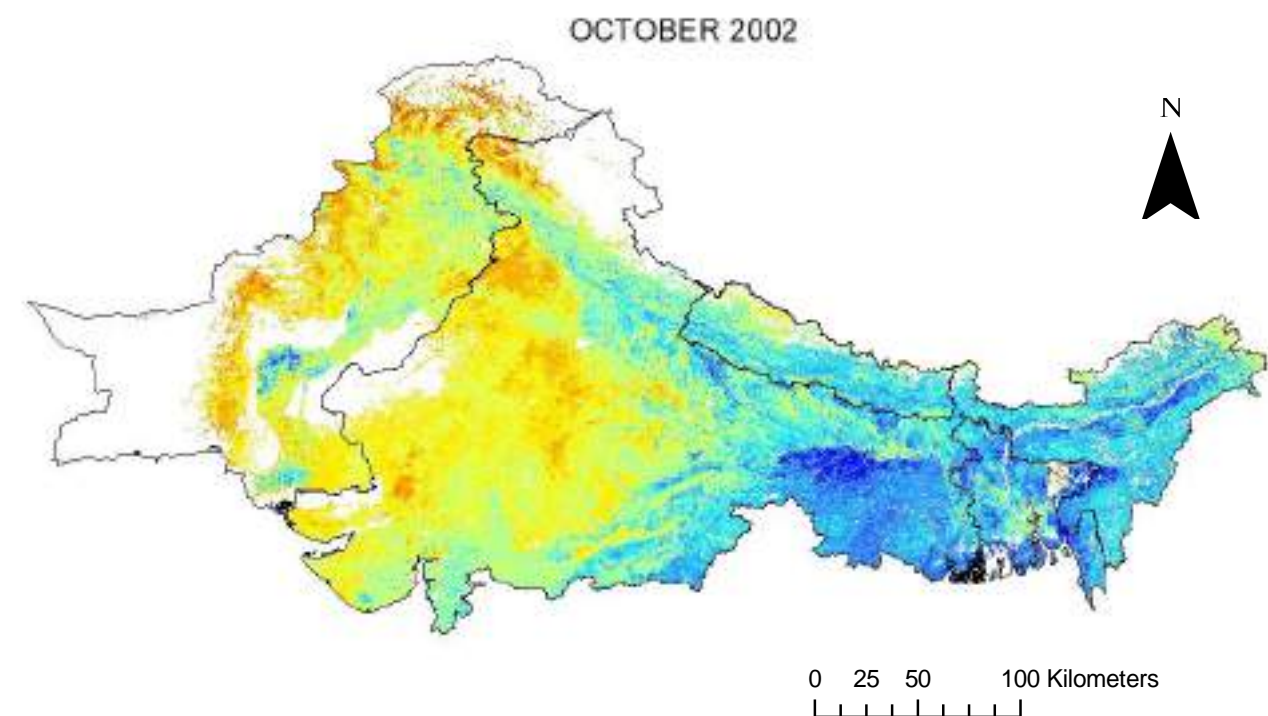
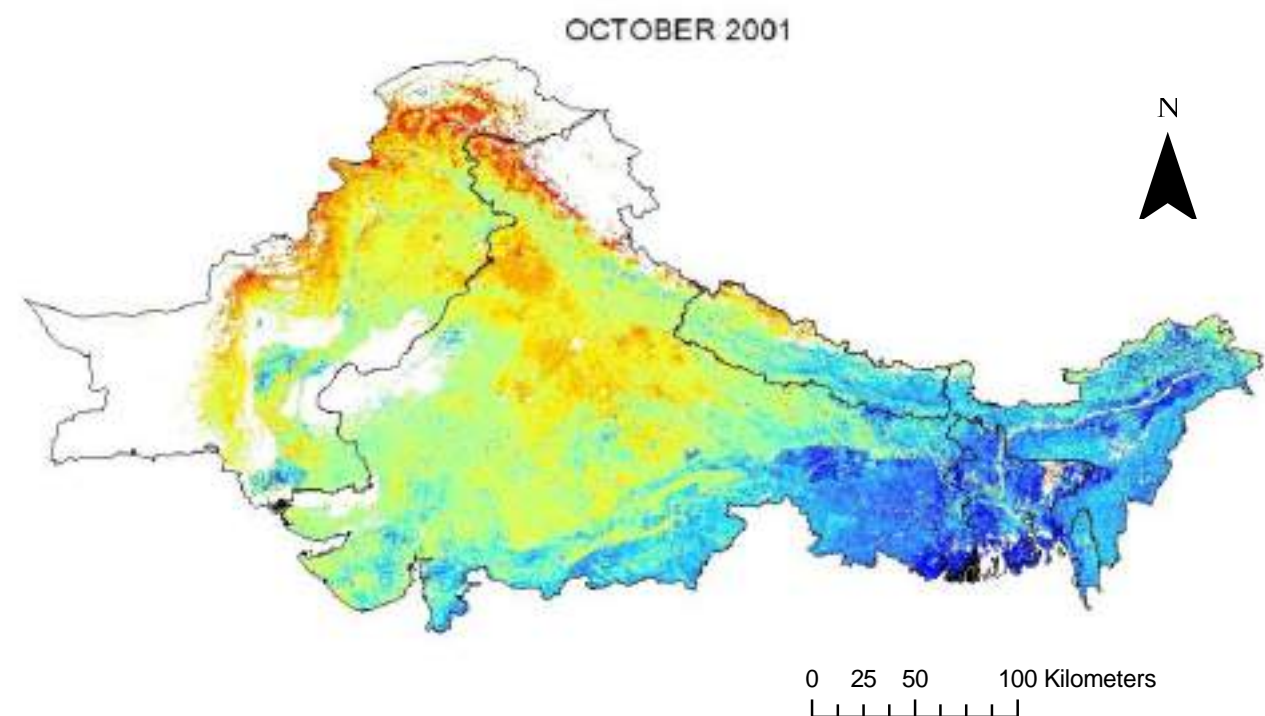
Near normal to moderately wet conditions can be seen in month of October.  
This month is characterized by incipient wet spell condition.

Mean October DSI Values		
Year	DSI Values	Drought Condition
2000	0.11	Near Normal
2001	0.37	Incipient Wet Spell
2002	0.33	Incipient Wet Spell
2003	0.62	Slightly Wet
2004	0.38	Incipient Wet Spell
2005	0.75	Slightly Wet
2006	0.60	Slightly Wet
2007	0.56	Incipient Wet Spell
2008	0.42	Incipient Wet Spell
2009	0.46	Incipient Wet Spell
2010	0.88	Slightly Wet
2011	0.60	Slightly Wet
2012	0.39	Incipient Wet Spell
2013	0.90	Moderately Wet
2014	0.60	Slightly Wet
2015	0.30	Incipient Wet Spell
2016	0.25	Near Normal
2017	0.45	Incipient Wet Spell
2018	0.31	Incipient Wet Spell
2019	0.91	Moderately Wet
2020	0.40	Incipient Wet Spell

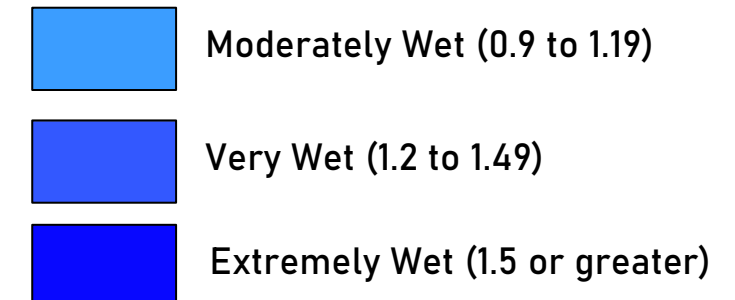
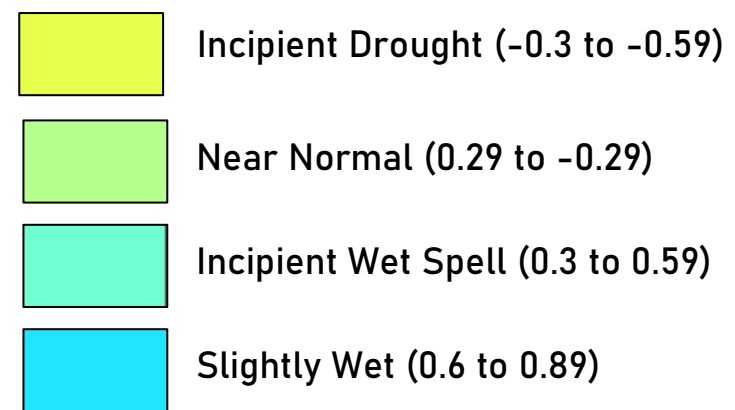
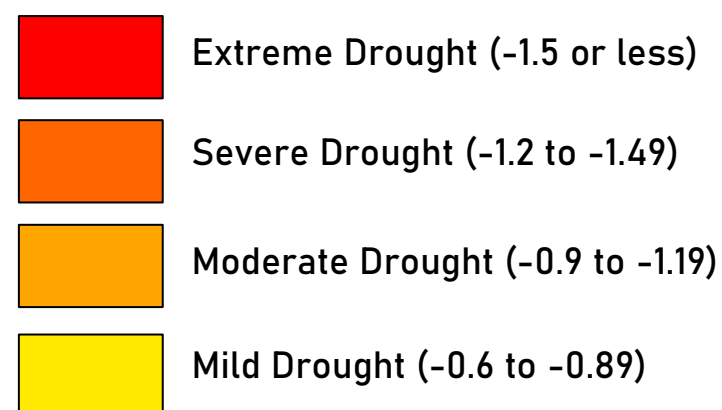


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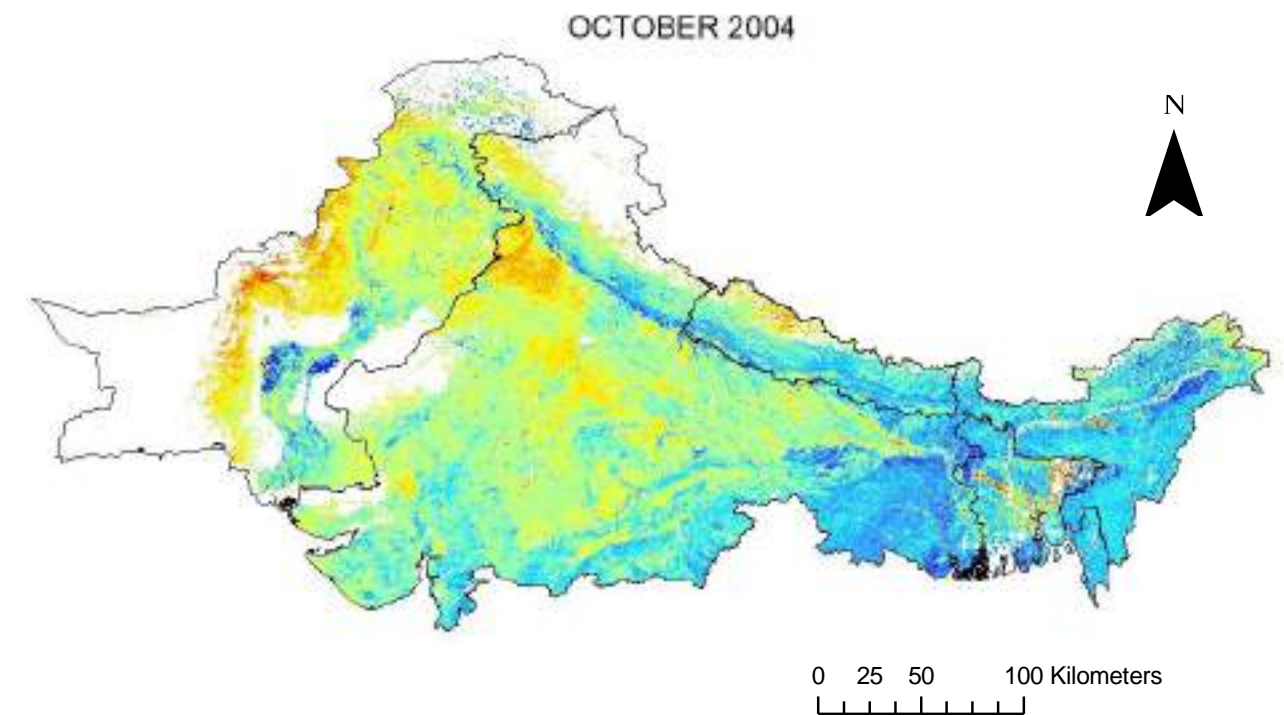
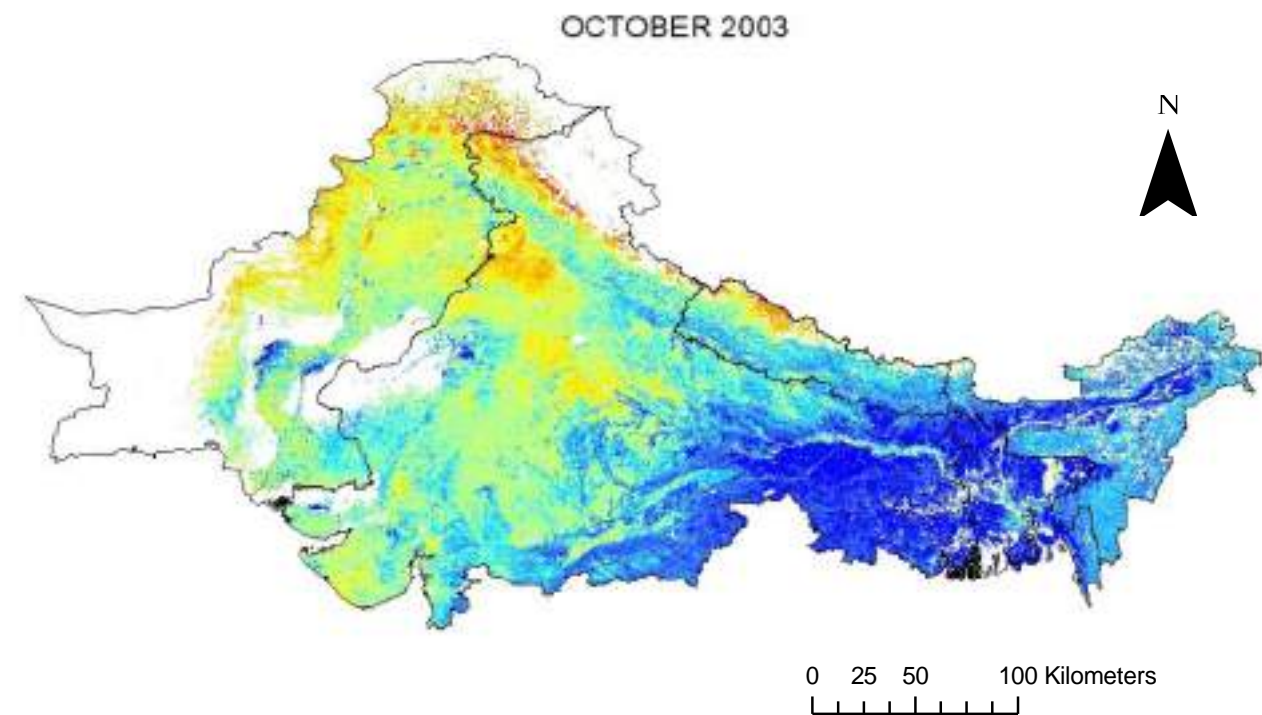




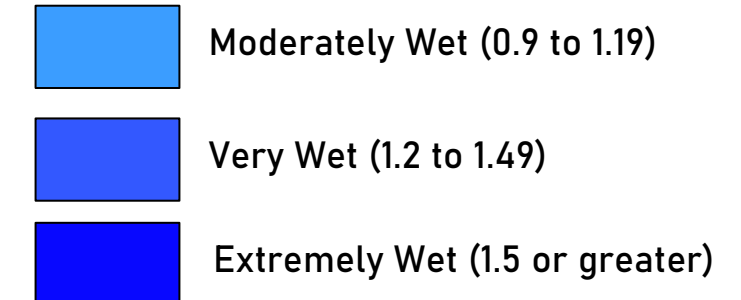
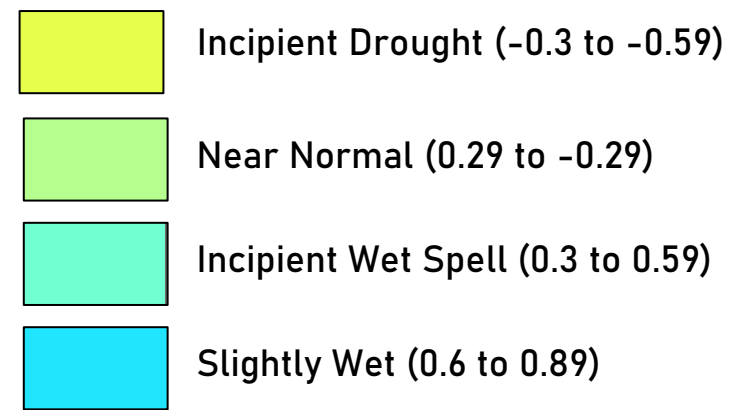
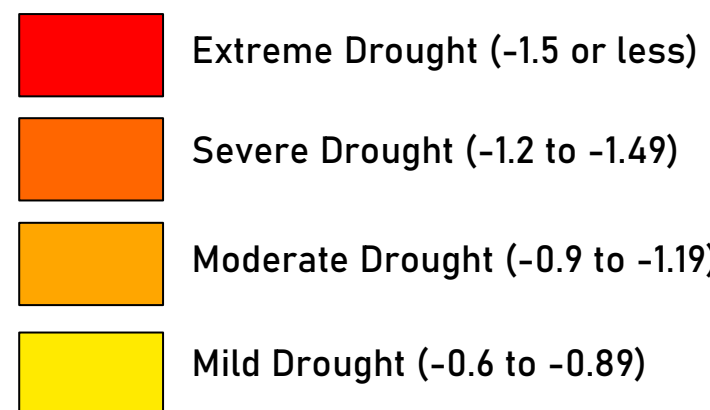
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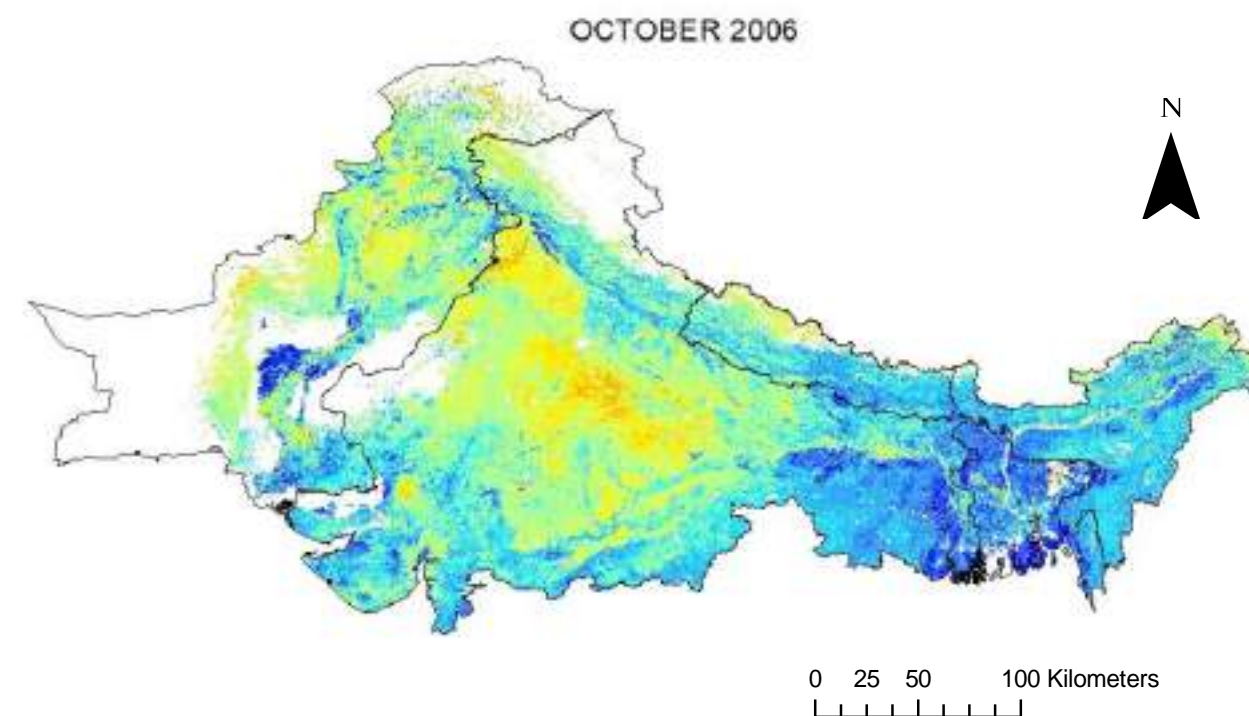
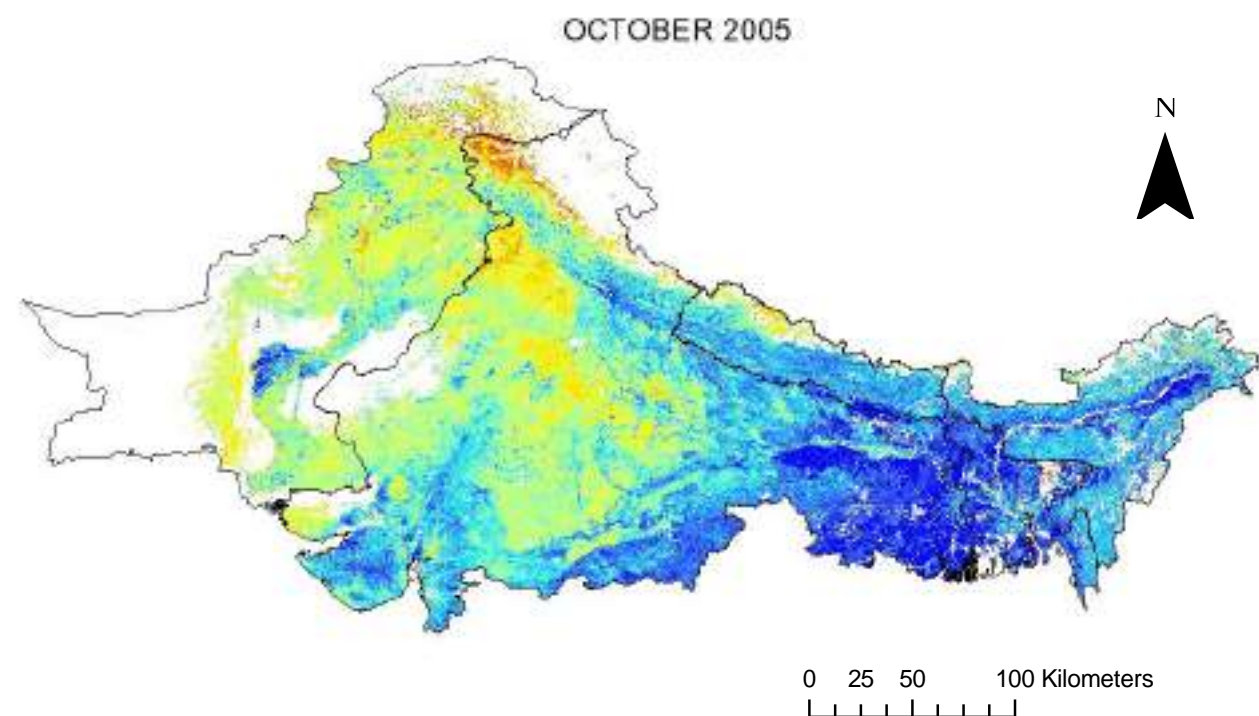




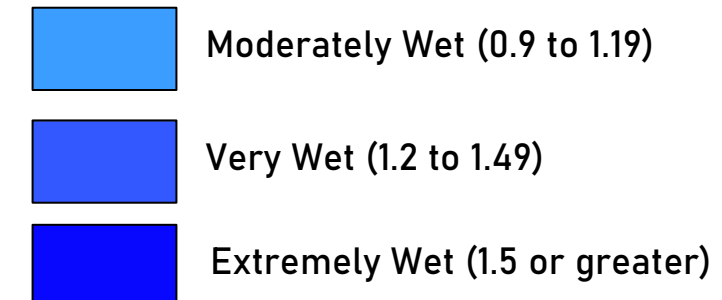
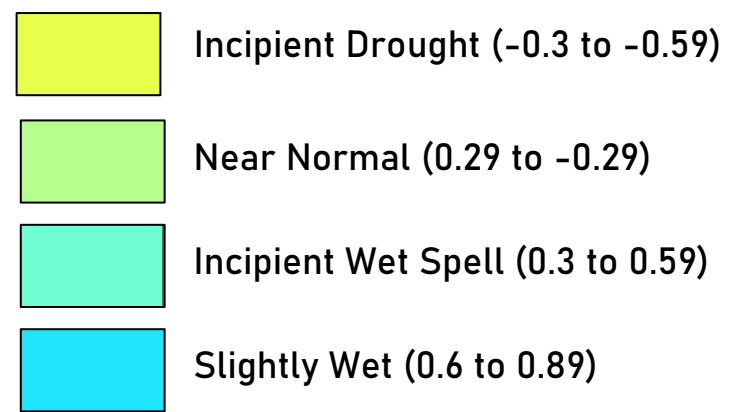
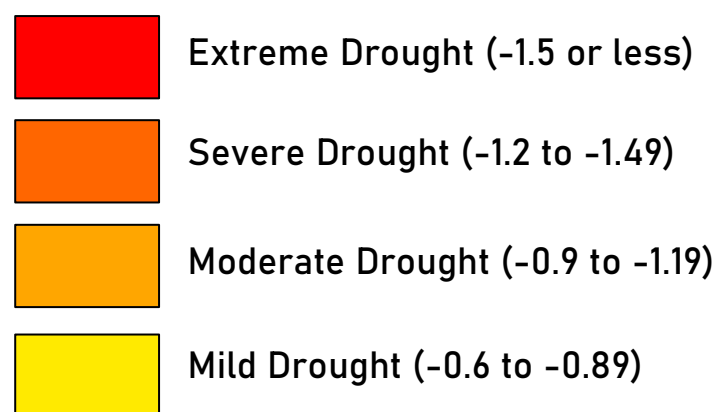


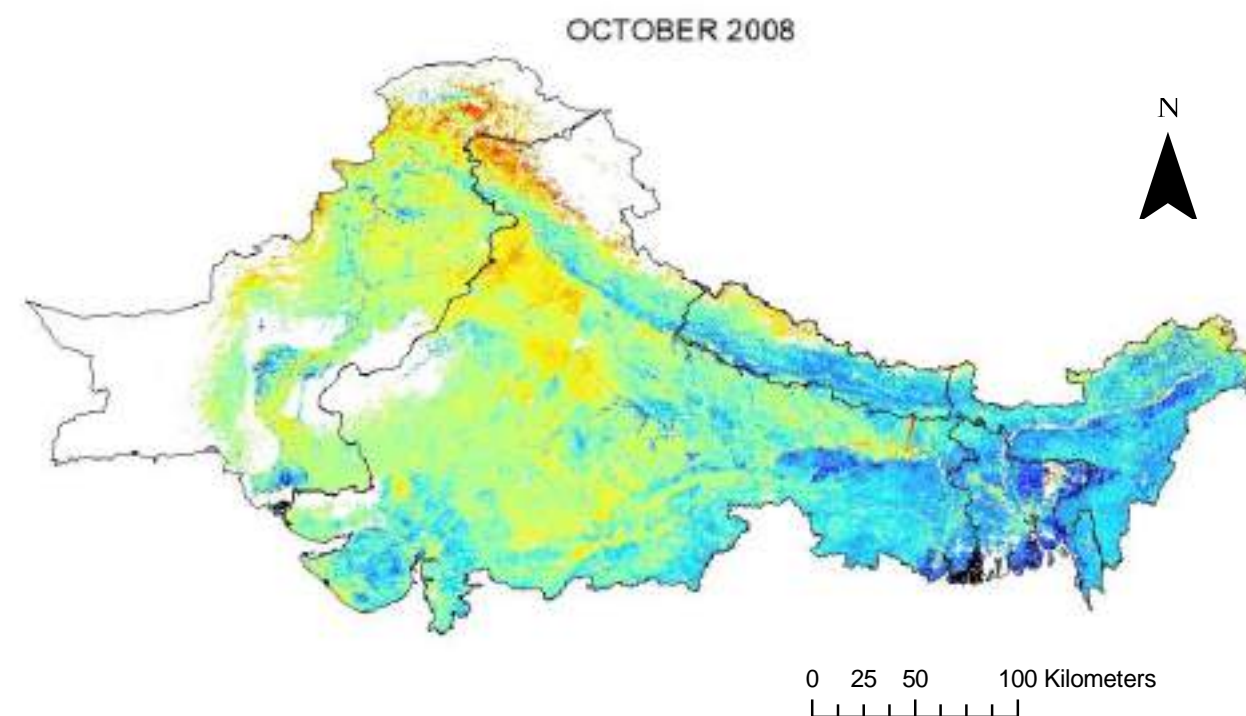
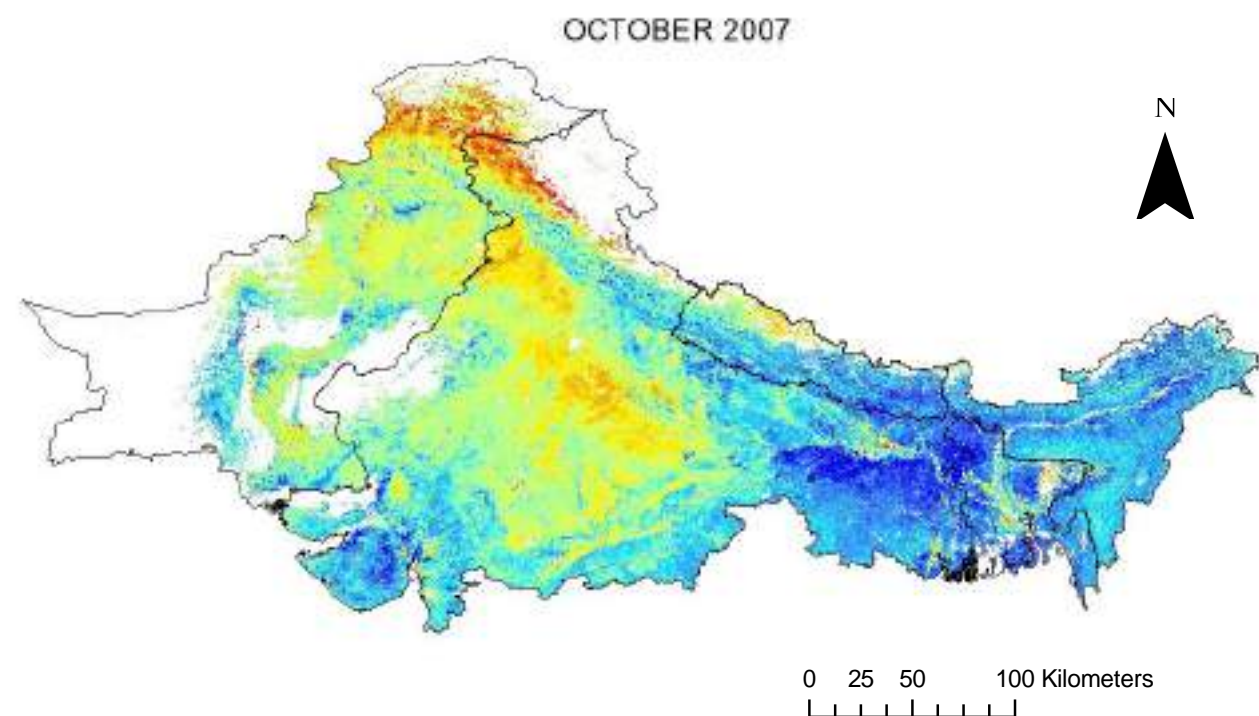
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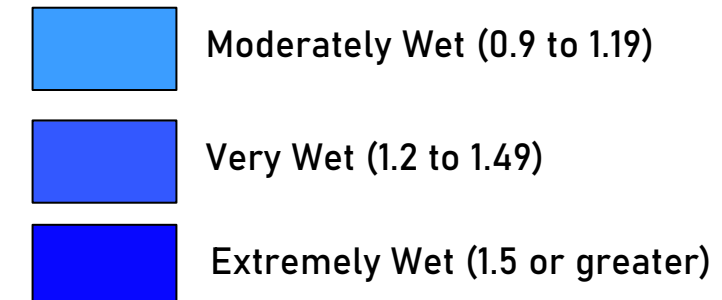
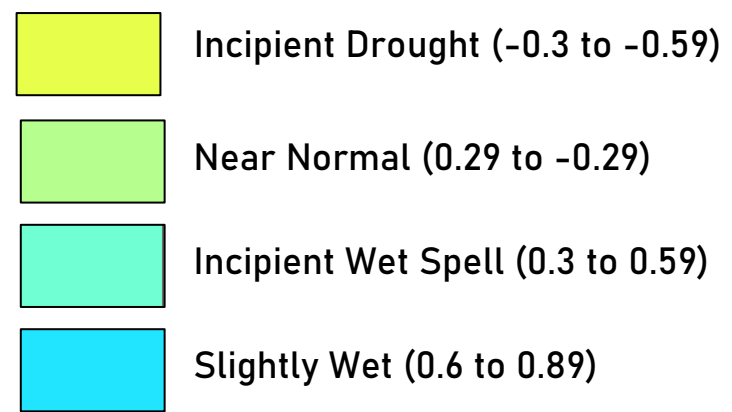
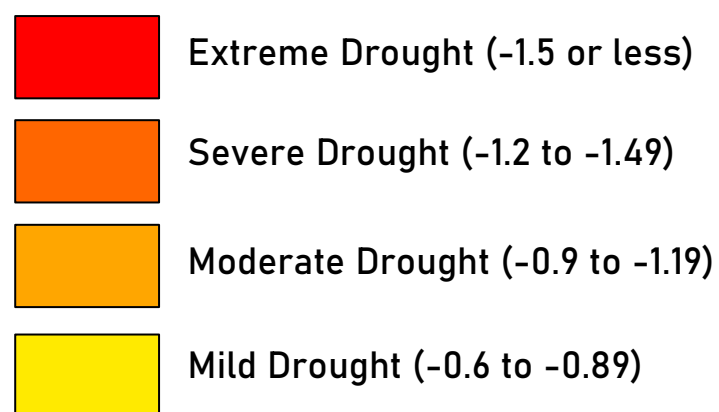


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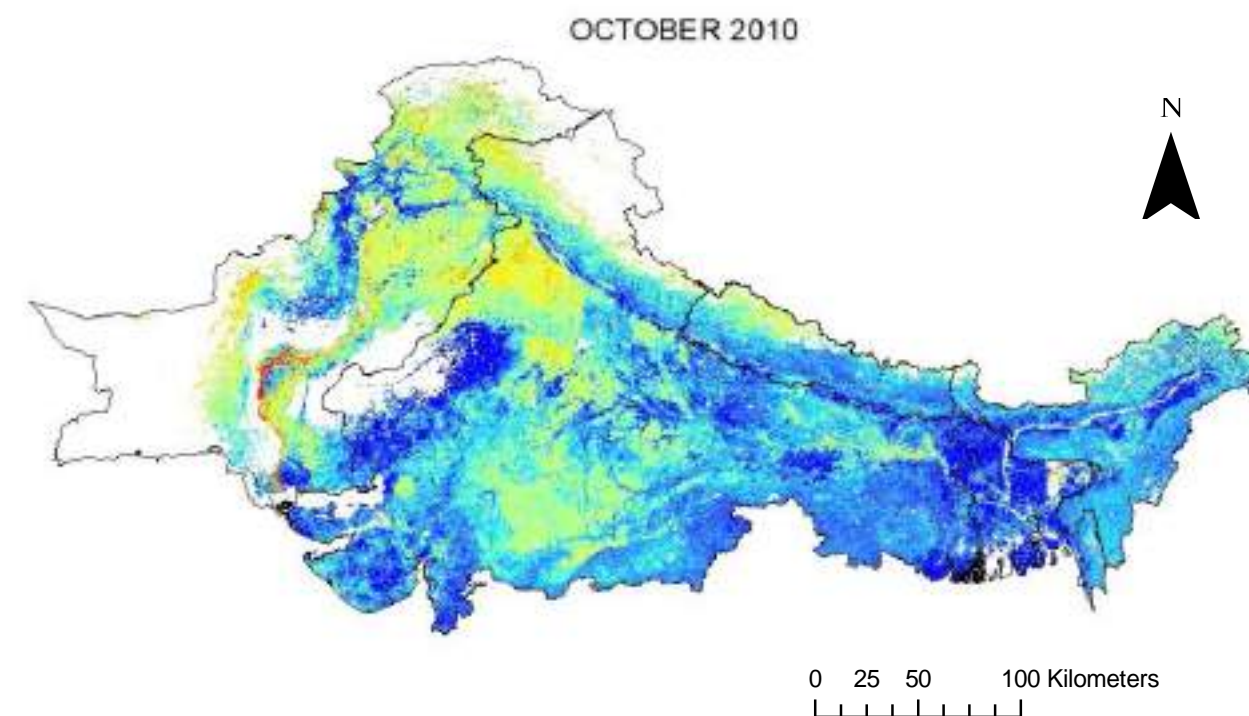
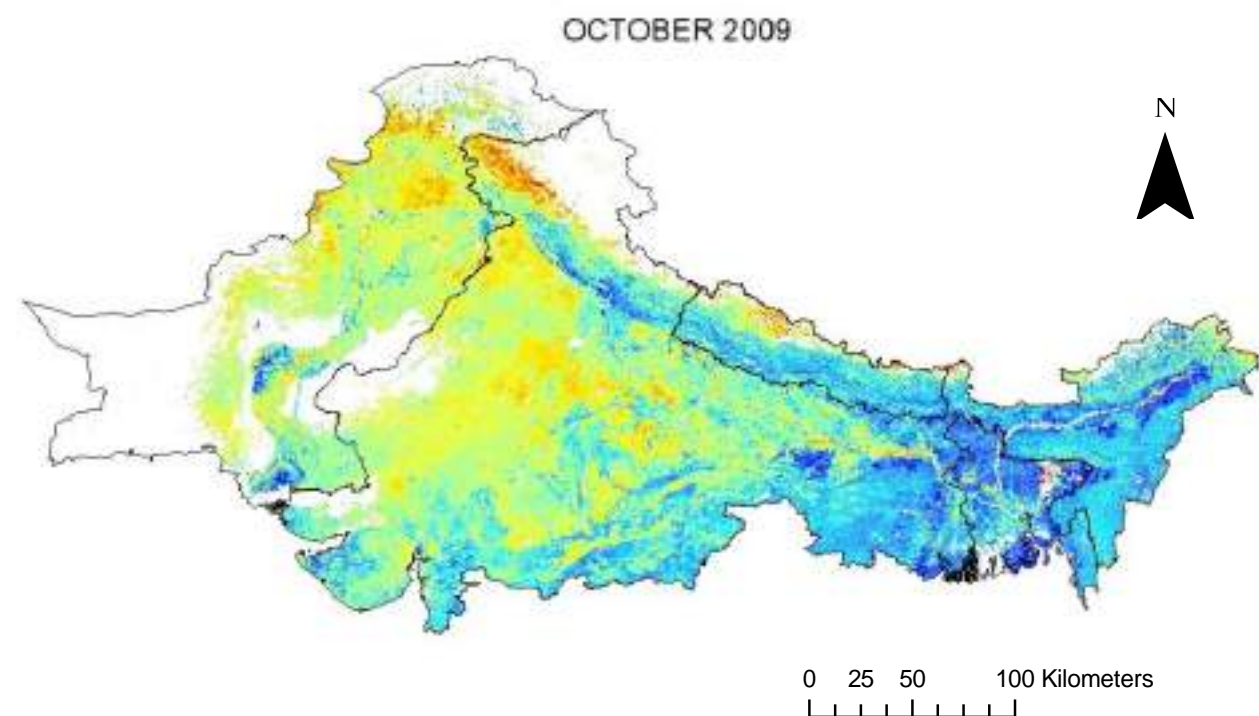




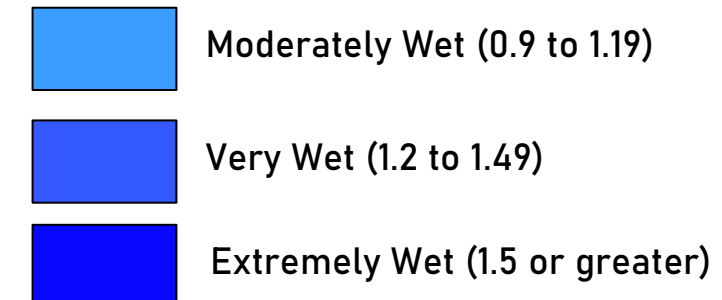
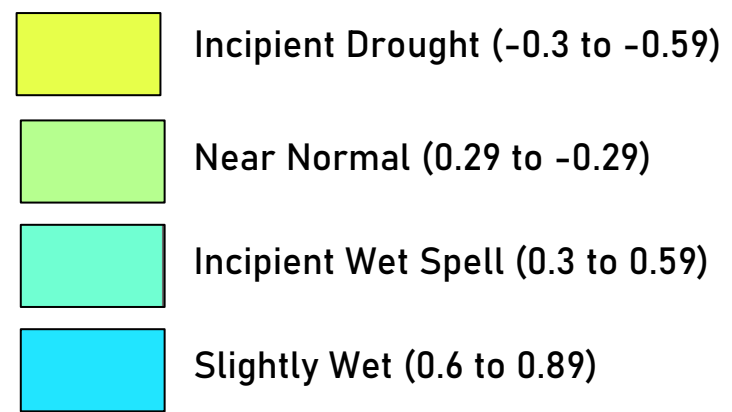
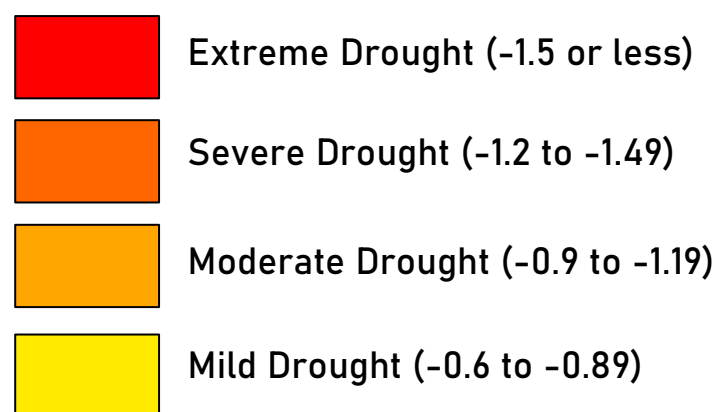
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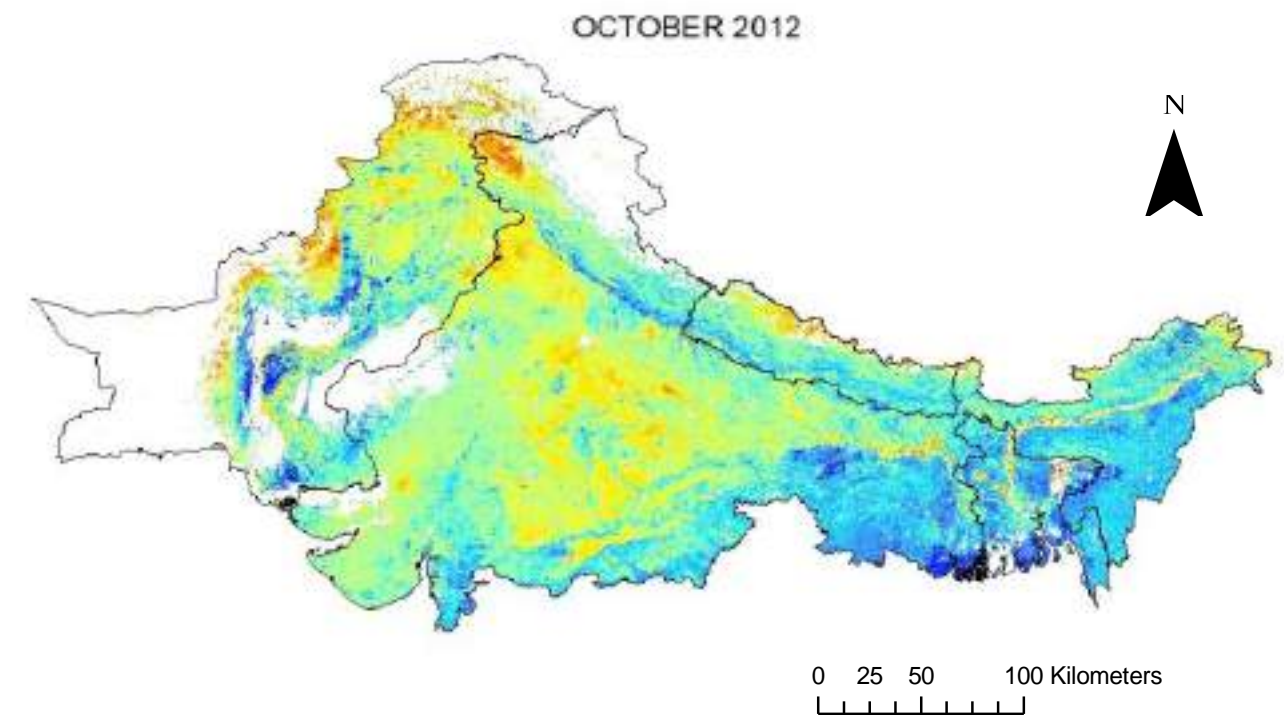
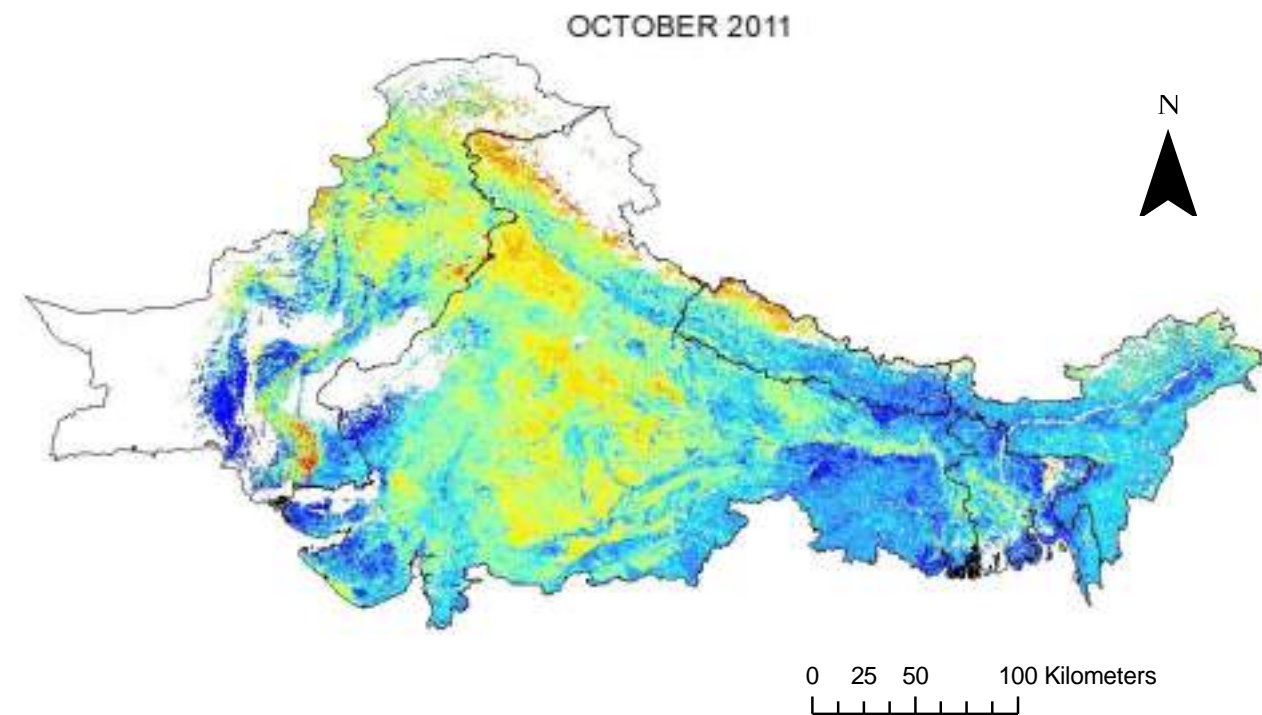




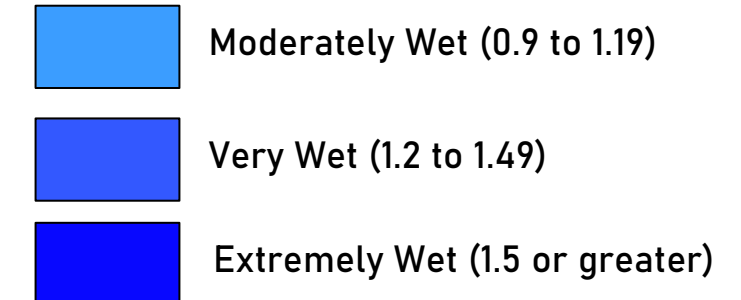
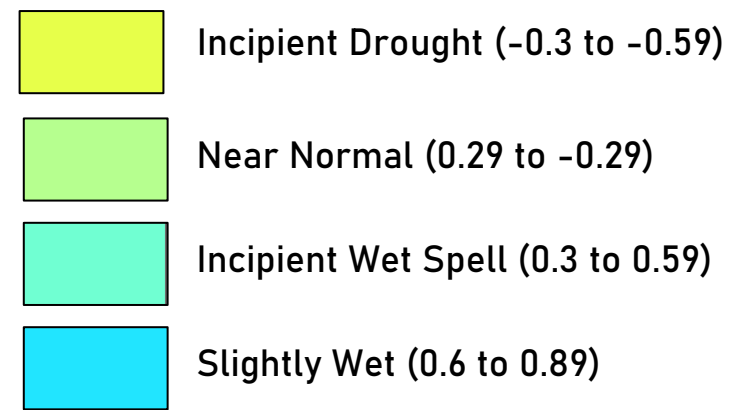
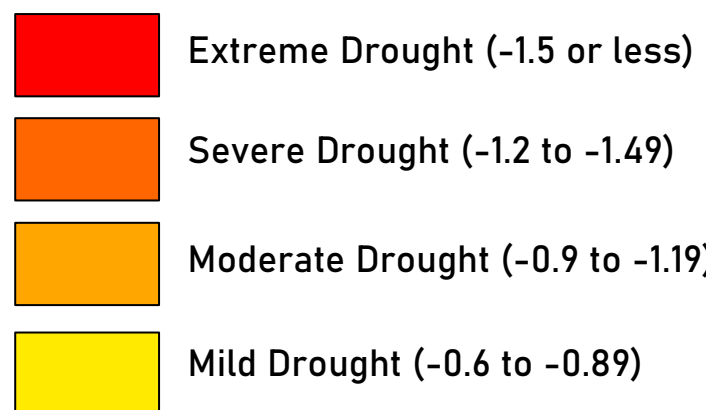


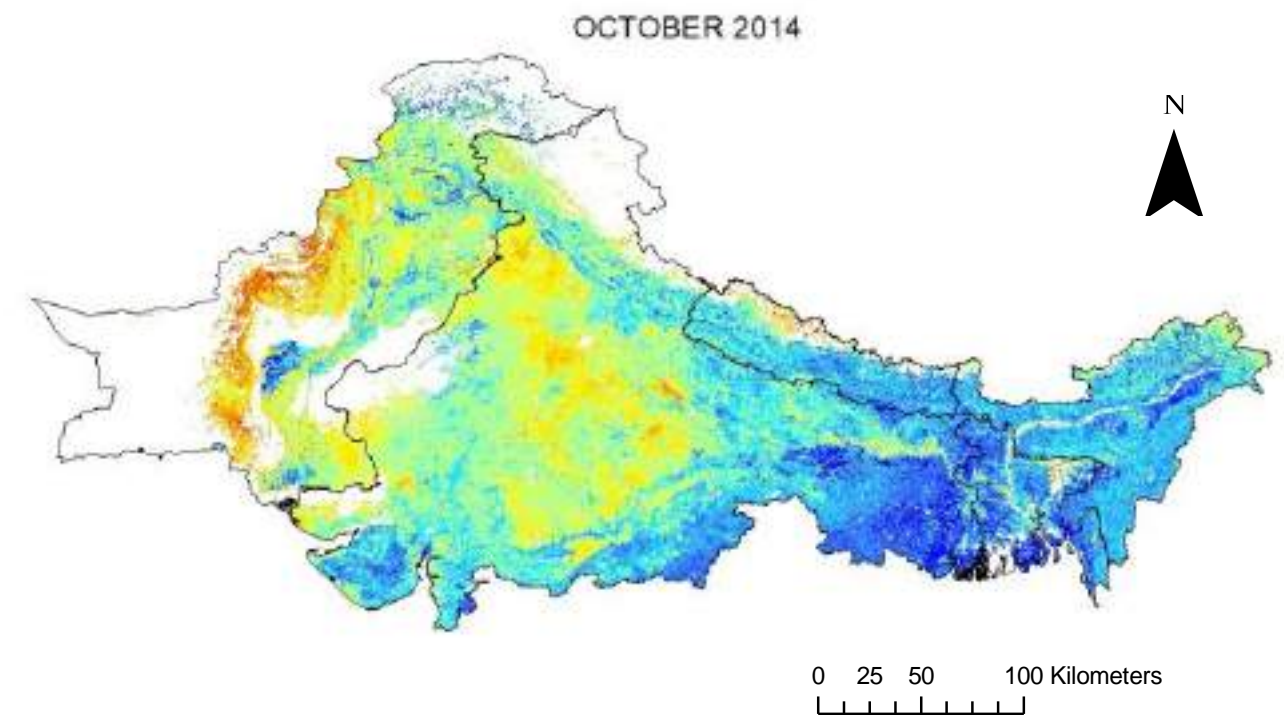
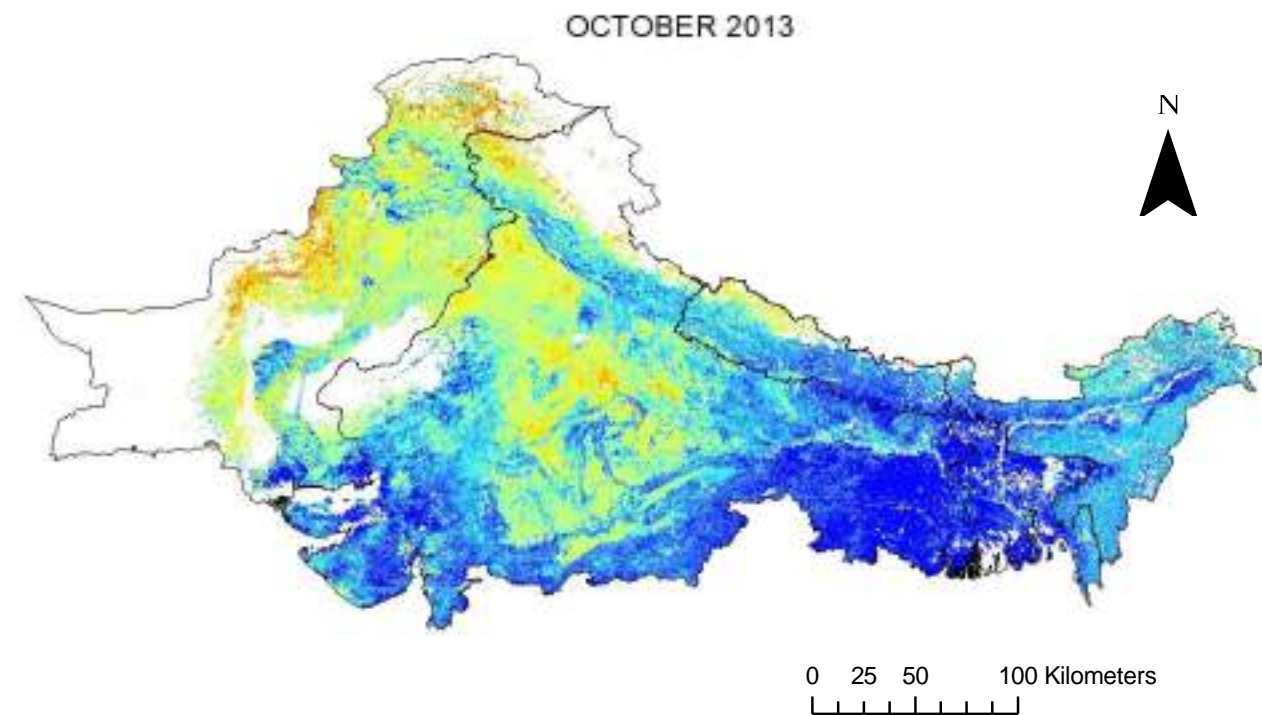
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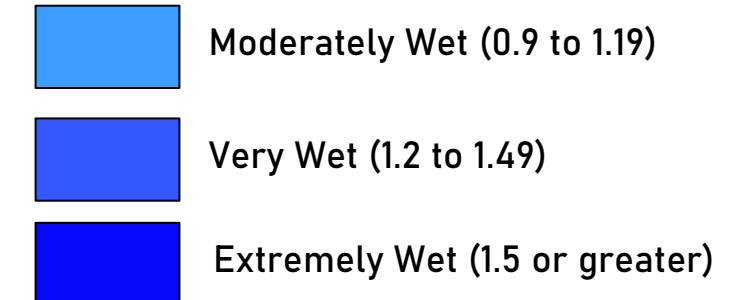
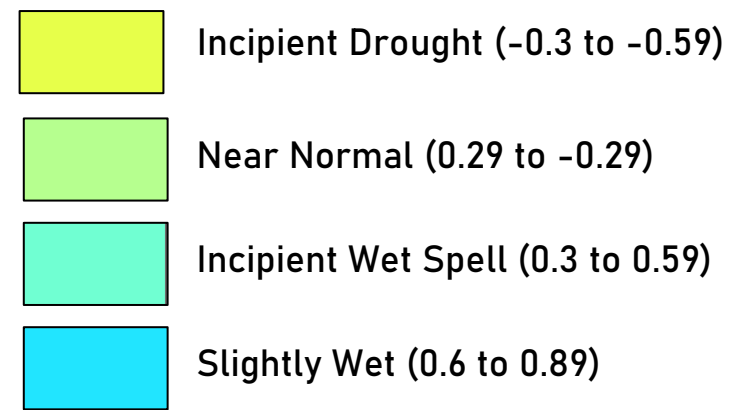
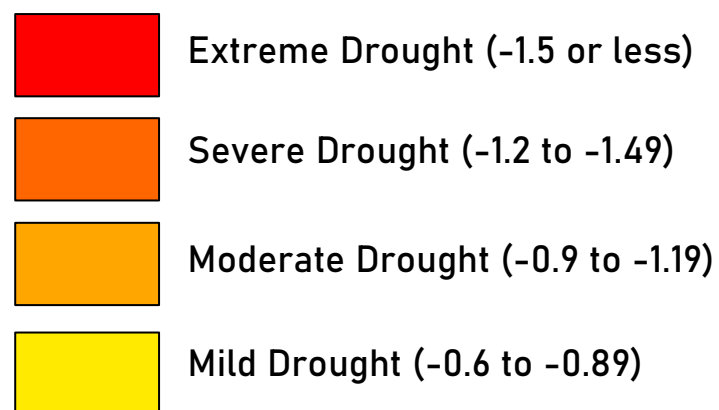


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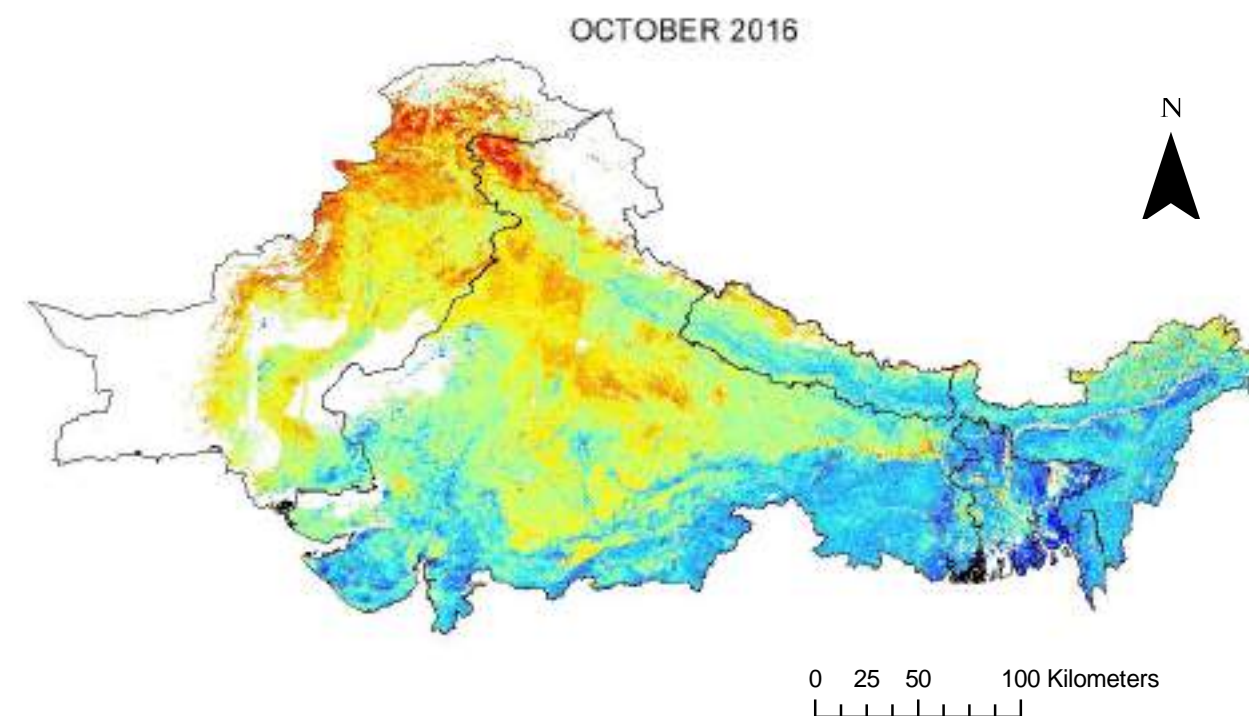
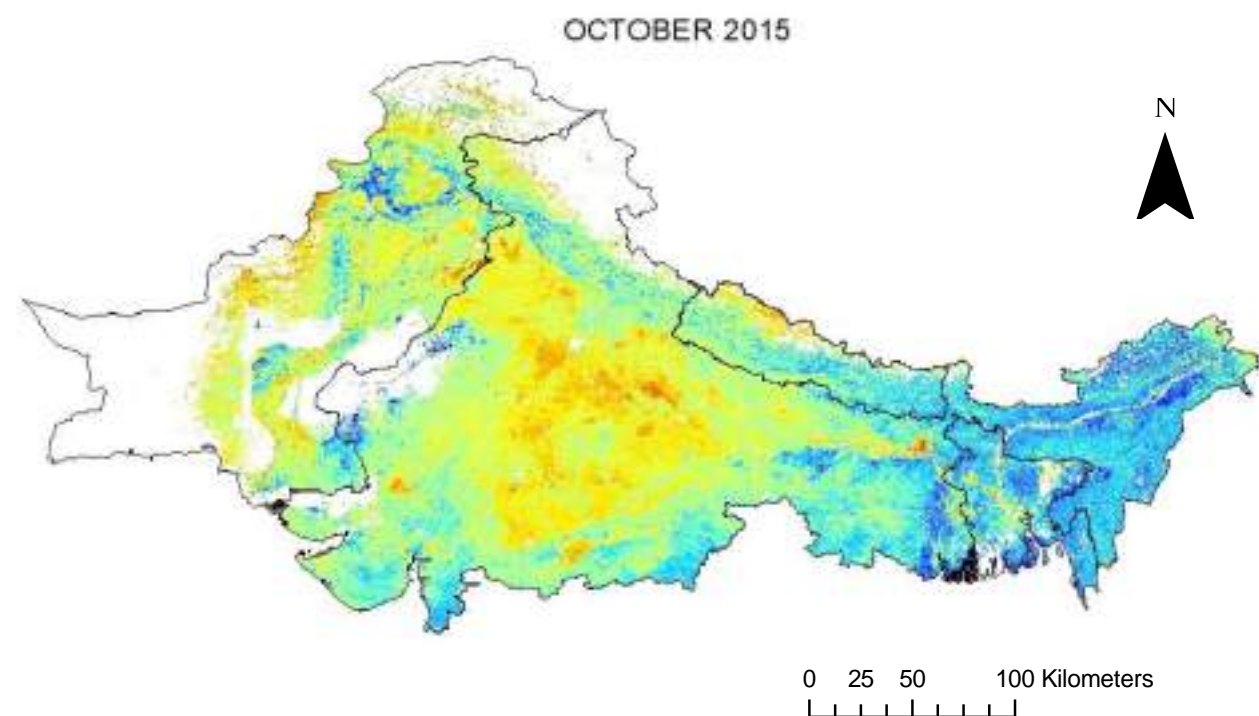




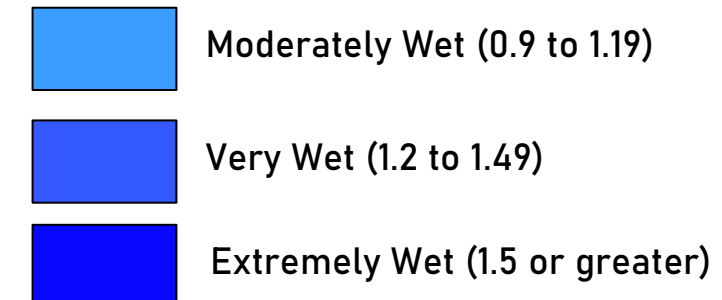
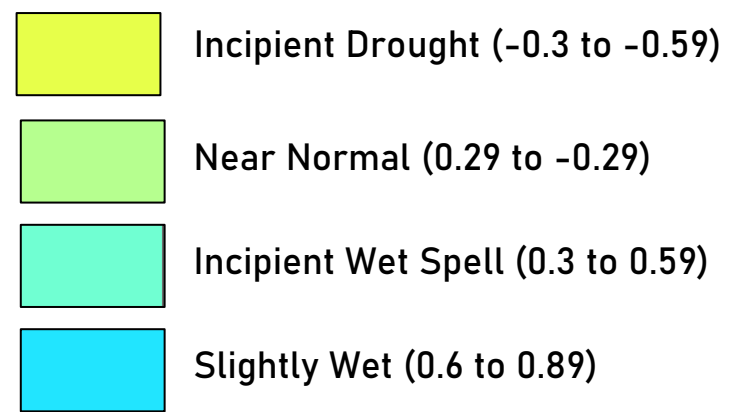
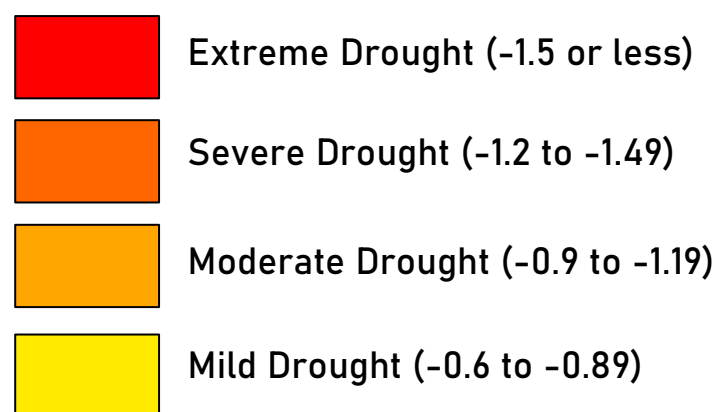
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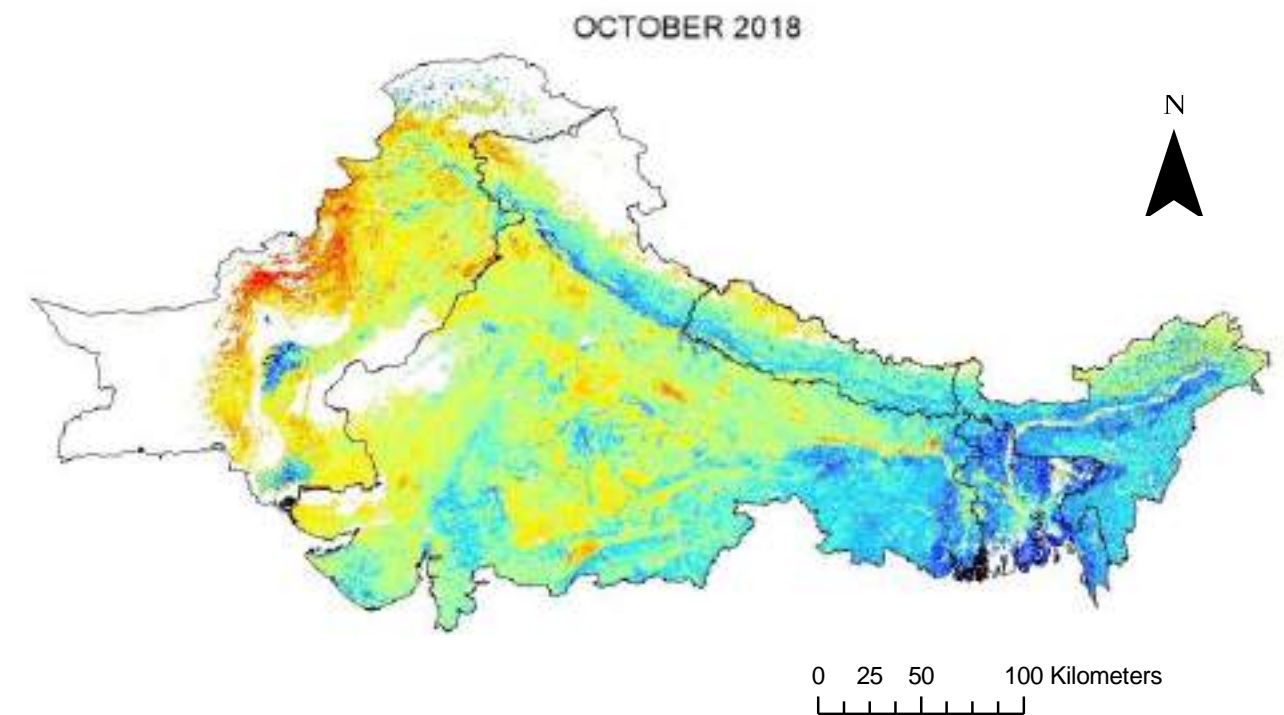
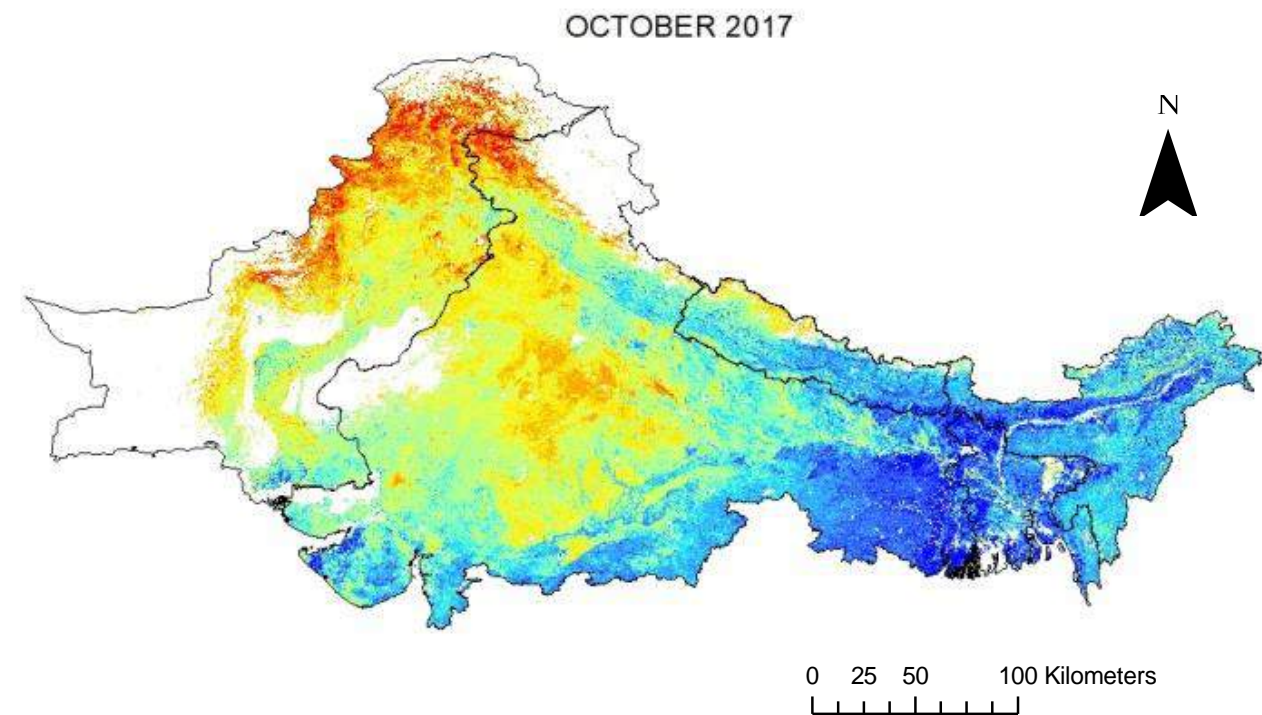




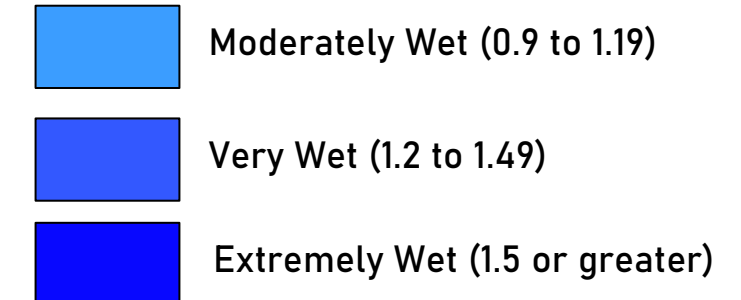
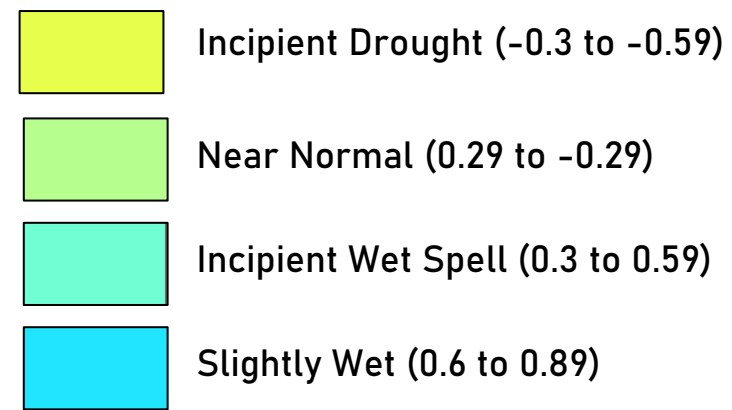
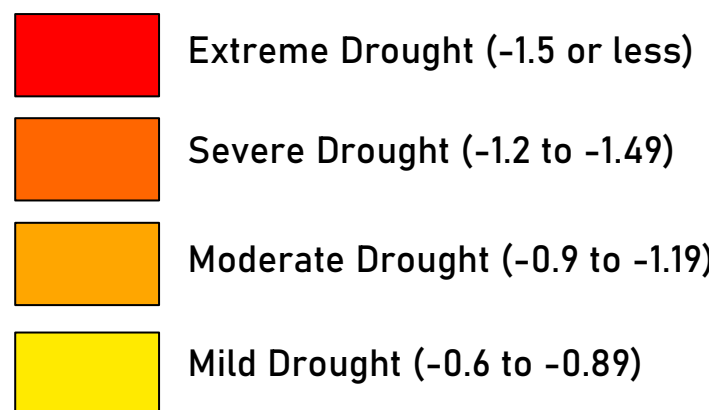


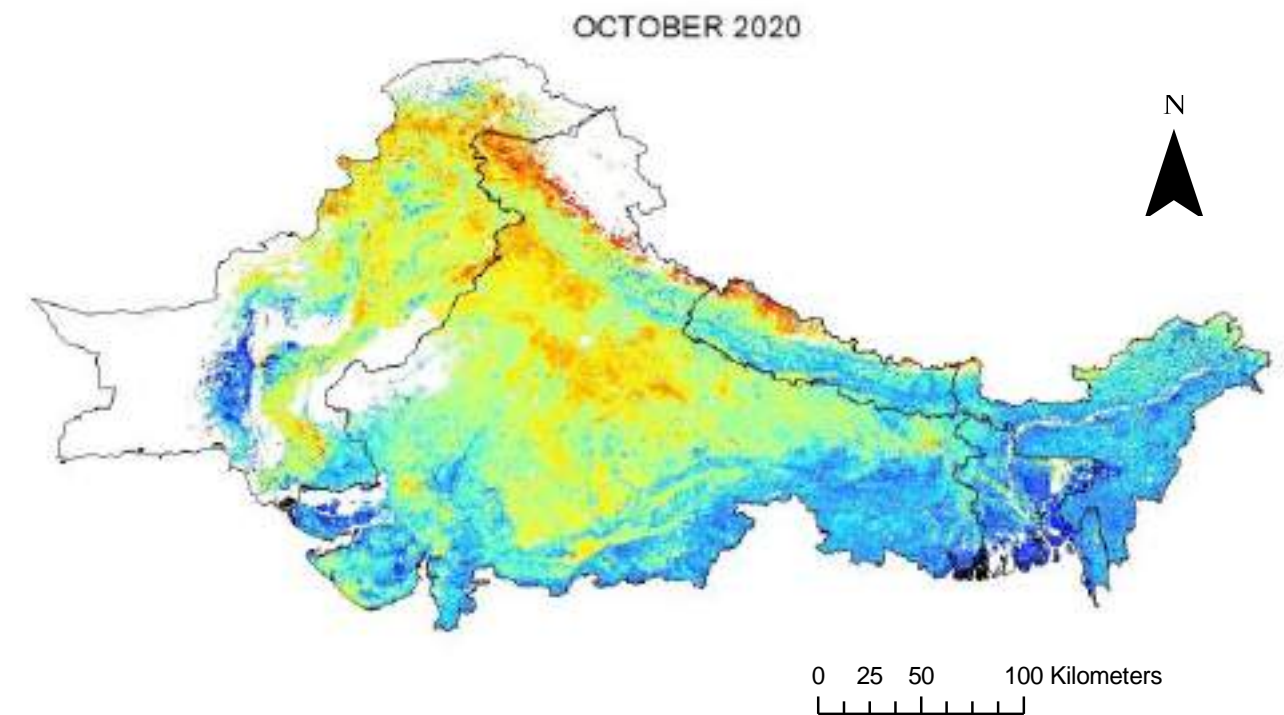
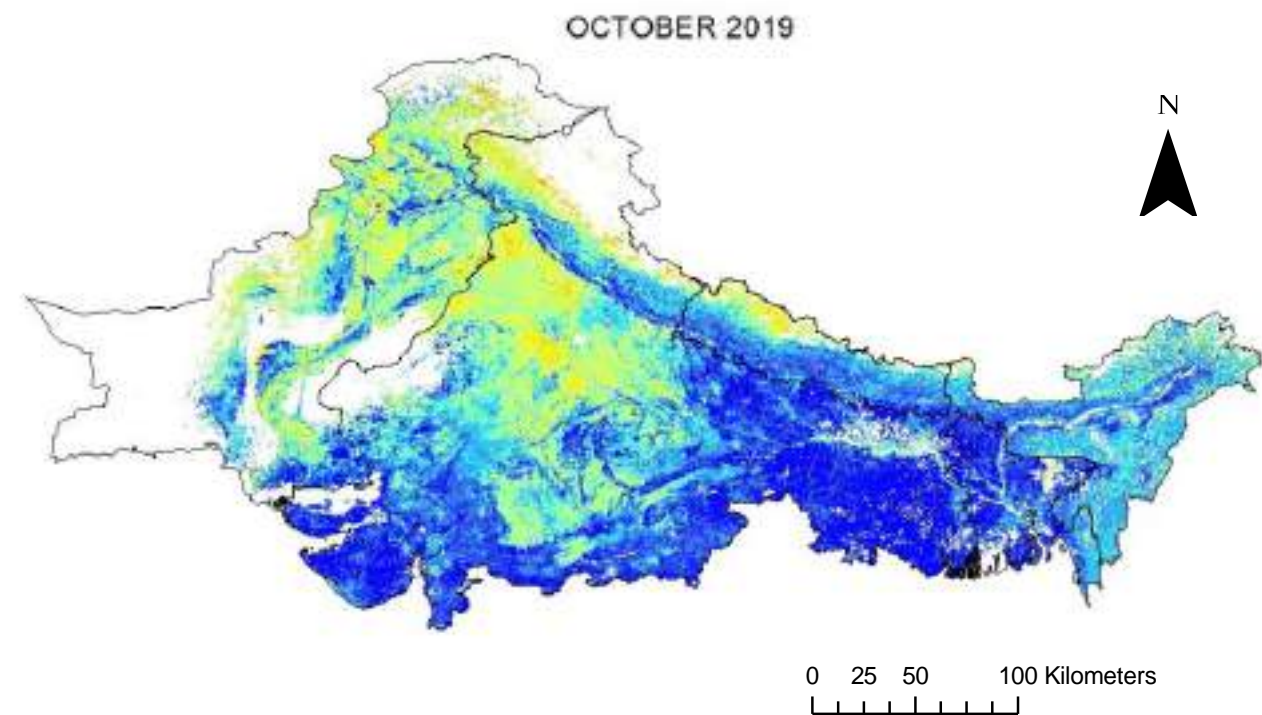
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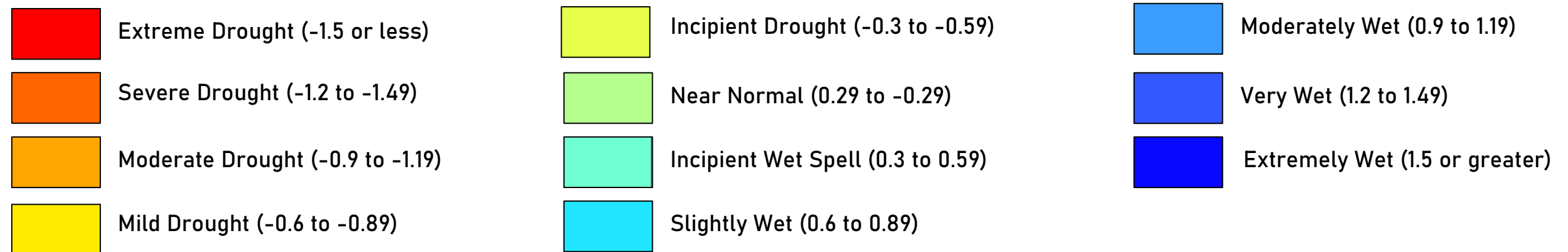


### Legend





### Legend

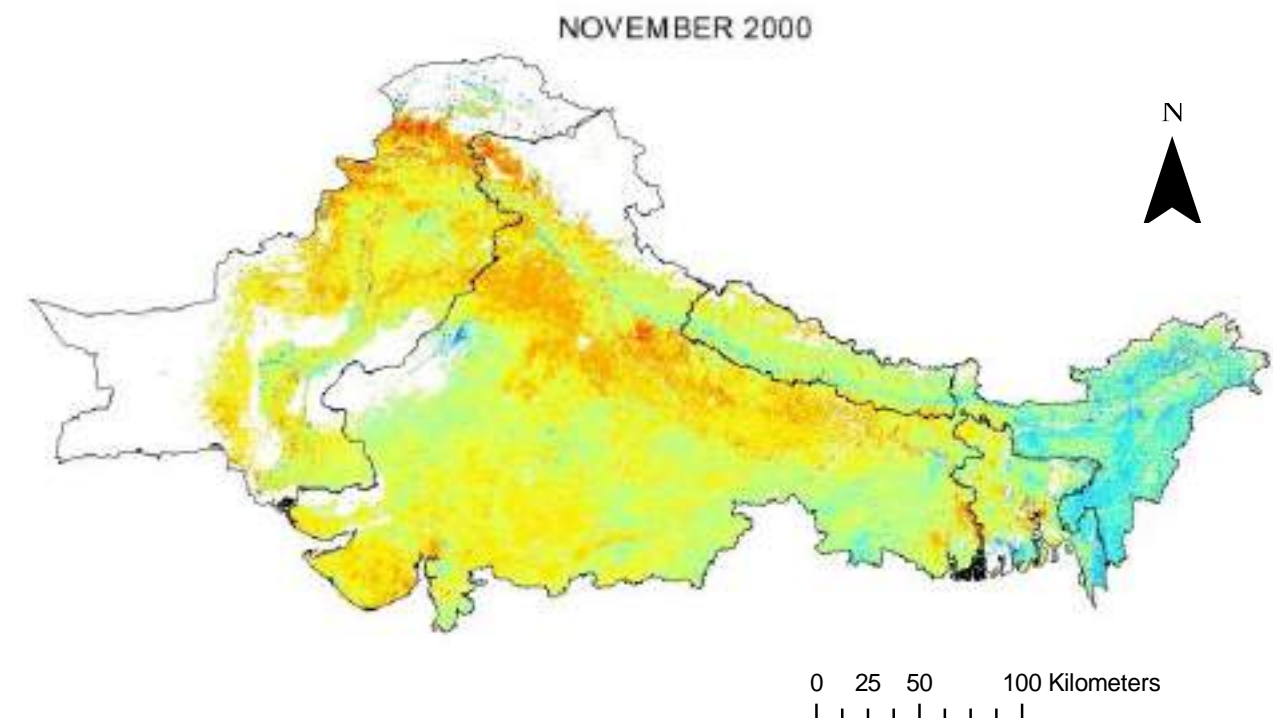




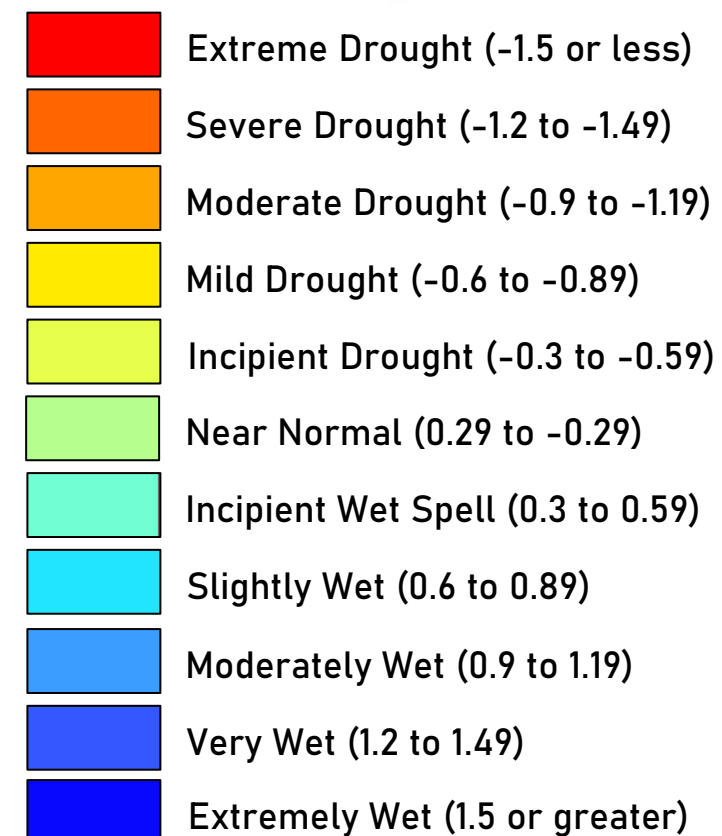
## November DSI Maps

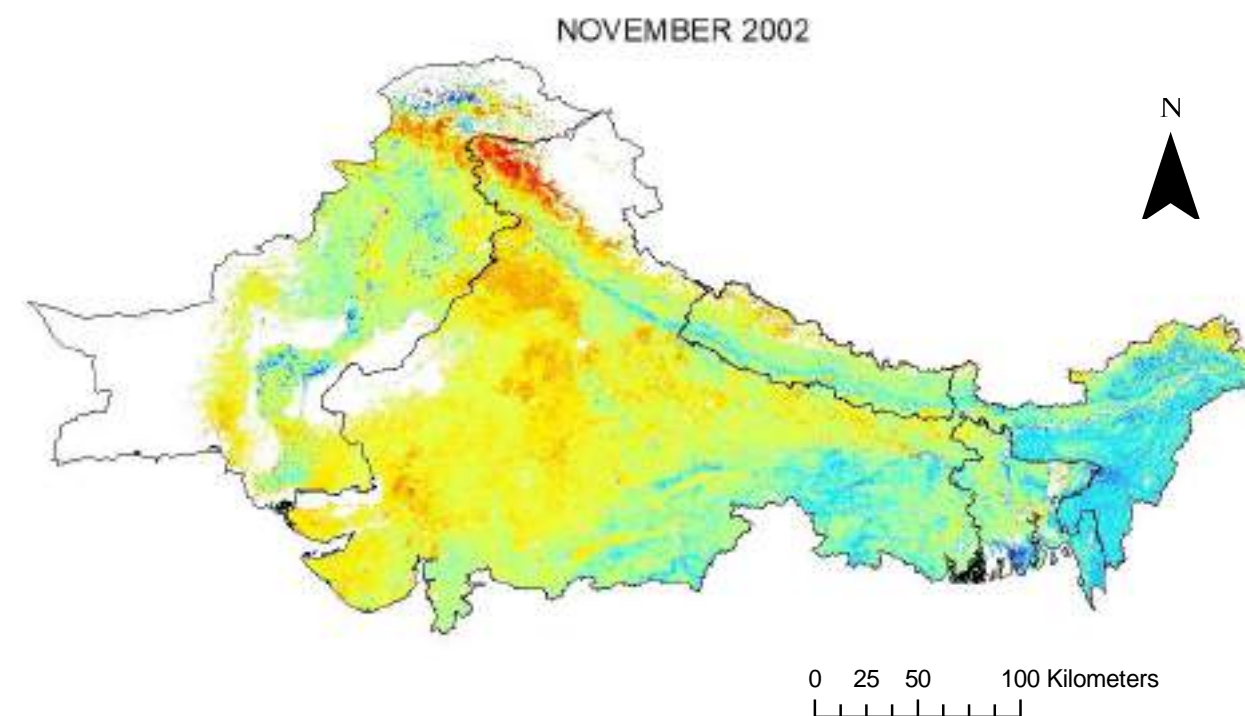
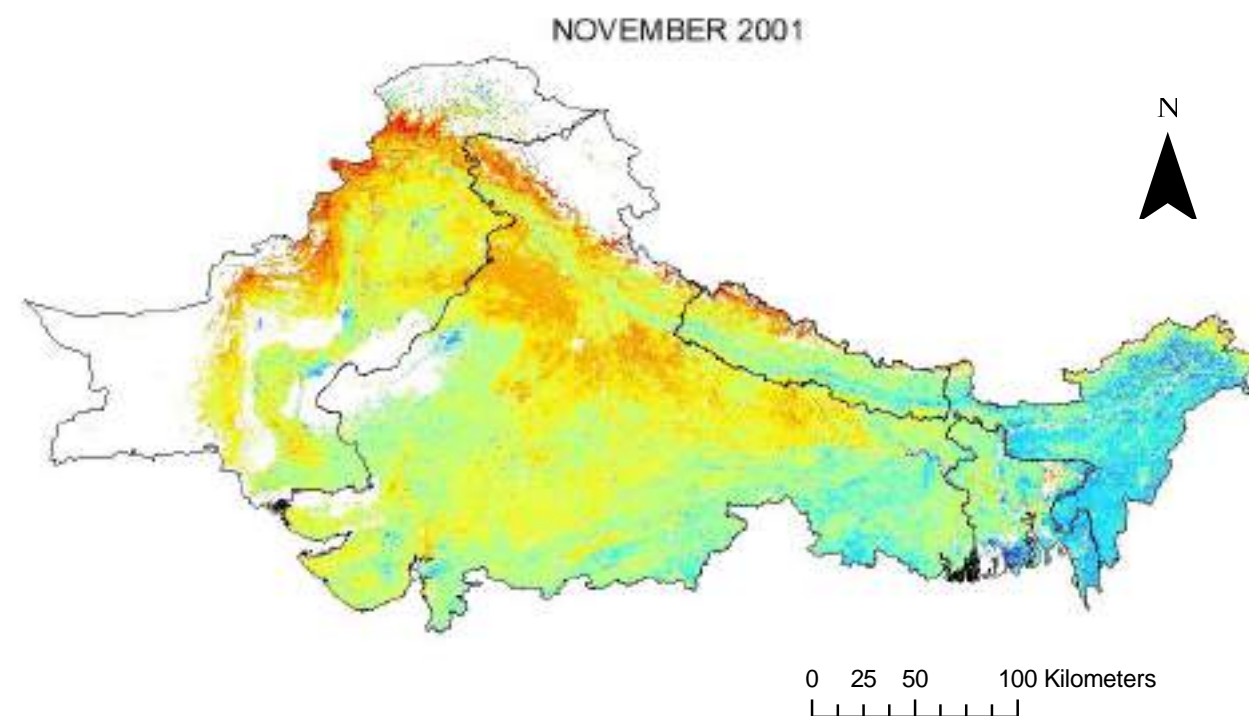
Drought in November ranges from incipient drought to near normal. This month is characterized by near normal. The driest year was noted in 2000 with DSI value -0.34.

Mean November DSI Values		
Year	DSI Values	Drought Condition
2000	-0.34	Incipient Drought
2001	-0.10	Near Normal
2002	-0.06	Near Normal
2003	0.10	Near Normal
2004	-0.06	Near Normal
2005	0.03	Near Normal
2006	0.17	Near Normal
2007	0.07	Near Normal
2008	-0.07	Near Normal
2009	0.03	Near Normal
2010	0.31	incipient Wet Spell
2011	0.14	Near Normal
2012	-0.17	Near Normal
2013	0.21	Near Normal
2014	-0.06	Near Normal
2015	-0.16	Near Normal
2016	-0.32	Incipient Drought
2017	-0.05	Near Normal
2018	-0.11	Near Normal
2019	0.49	incipient Wet Spell
2020	0.00	Near Normal

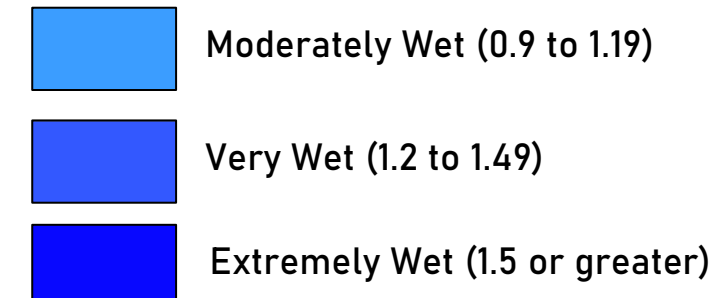
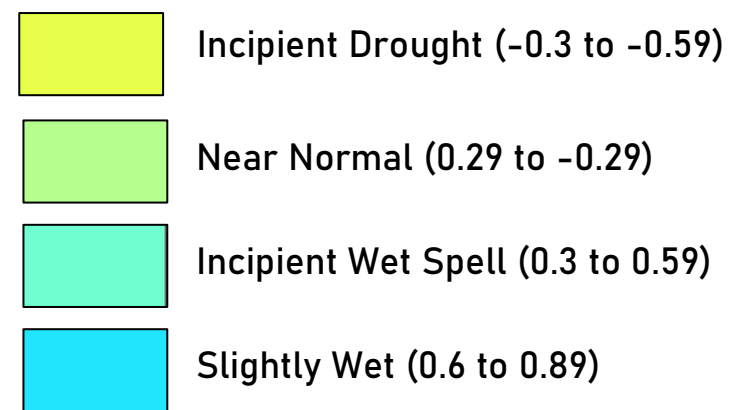
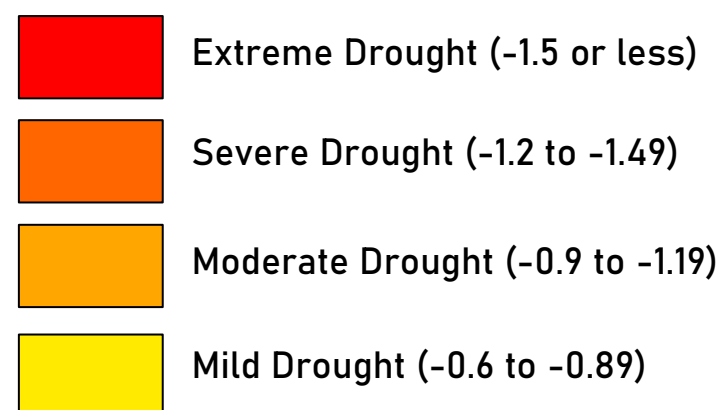


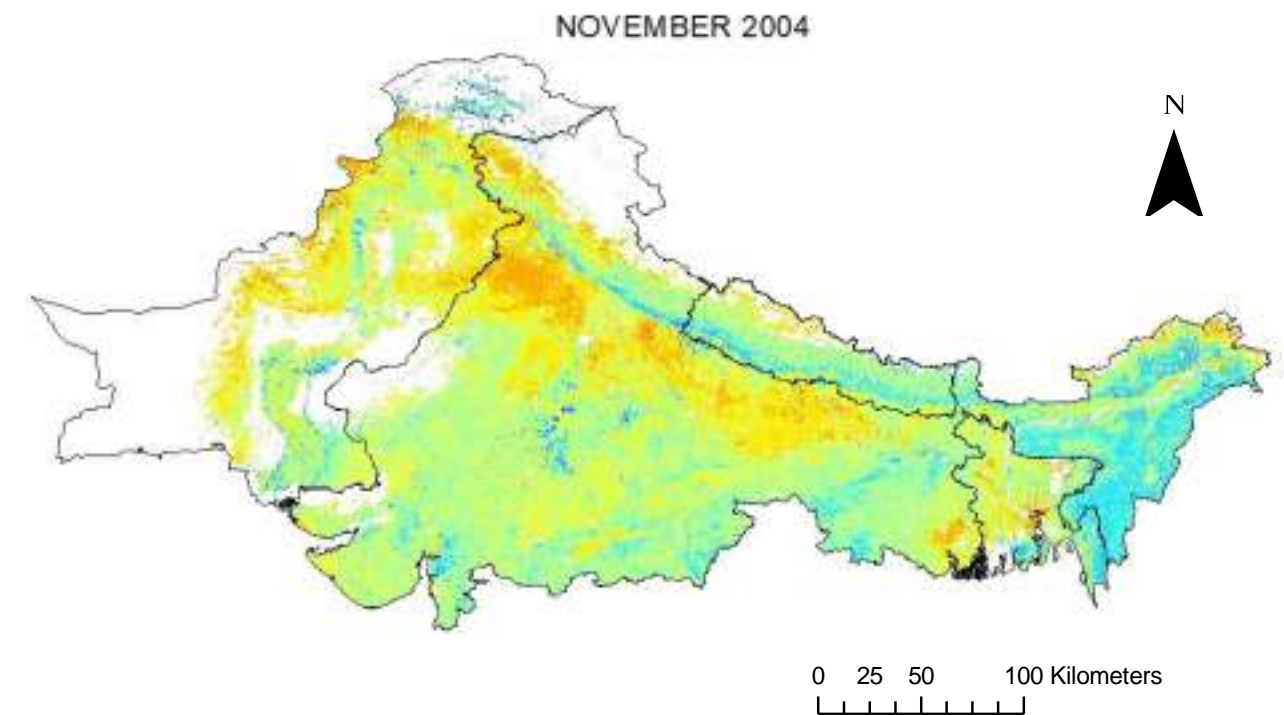
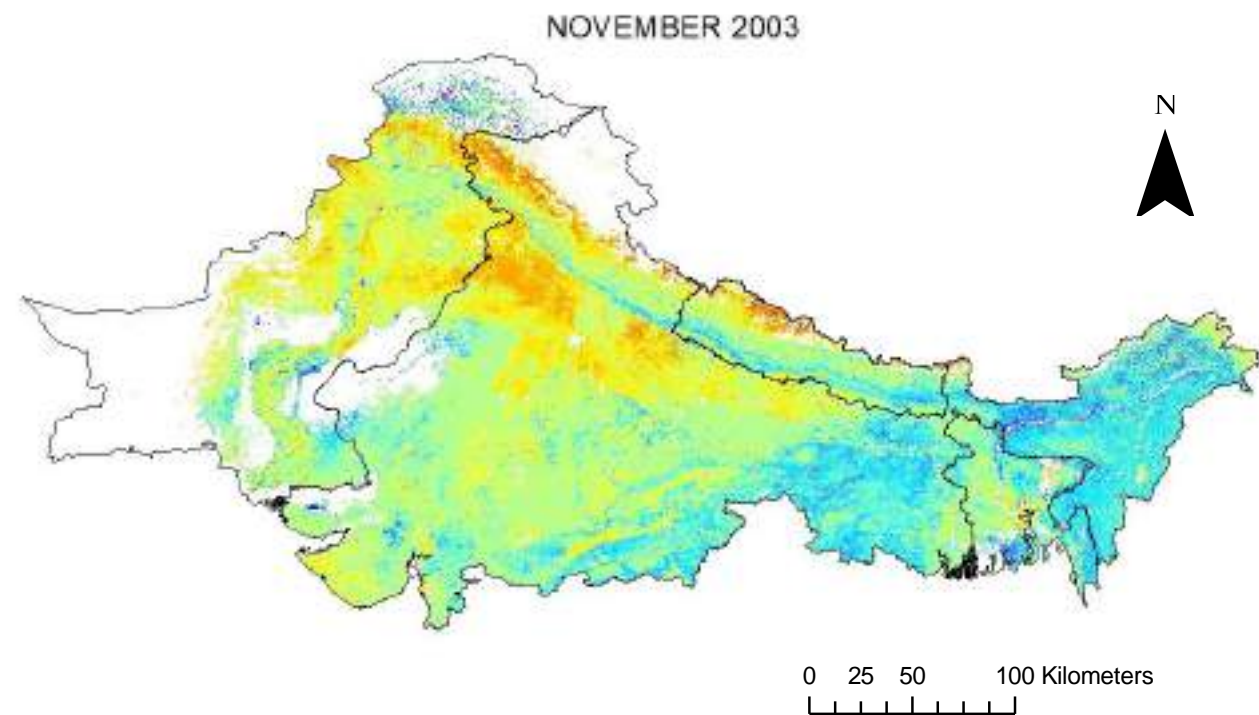
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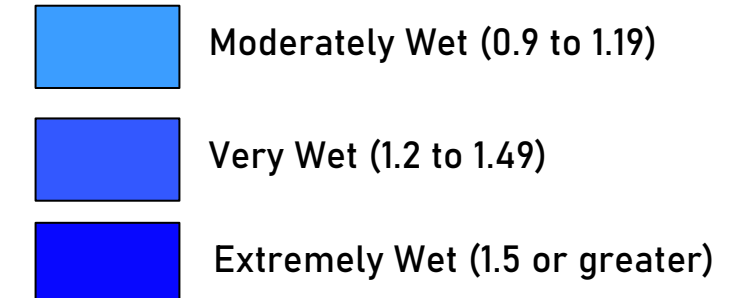
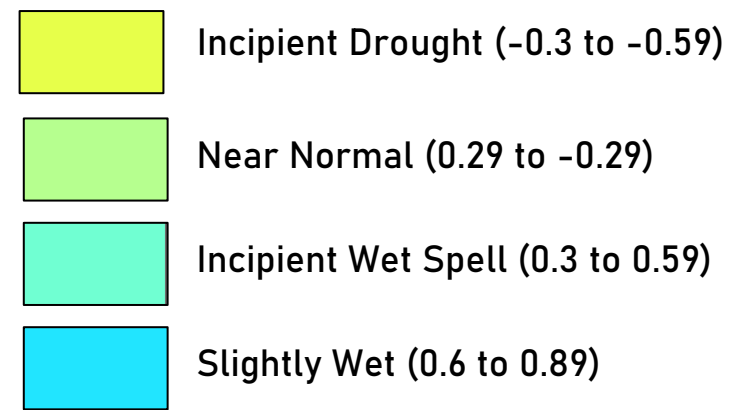
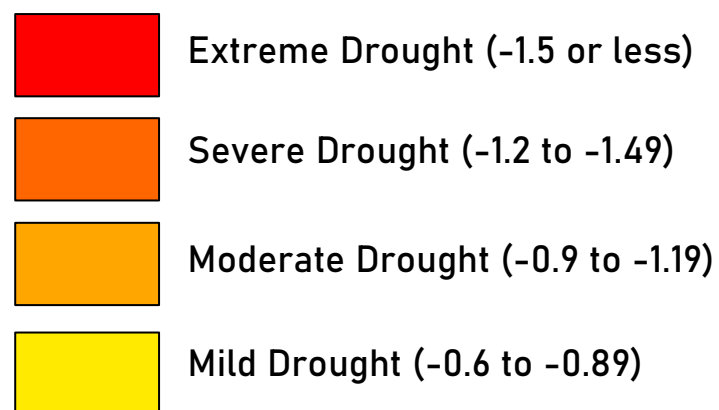


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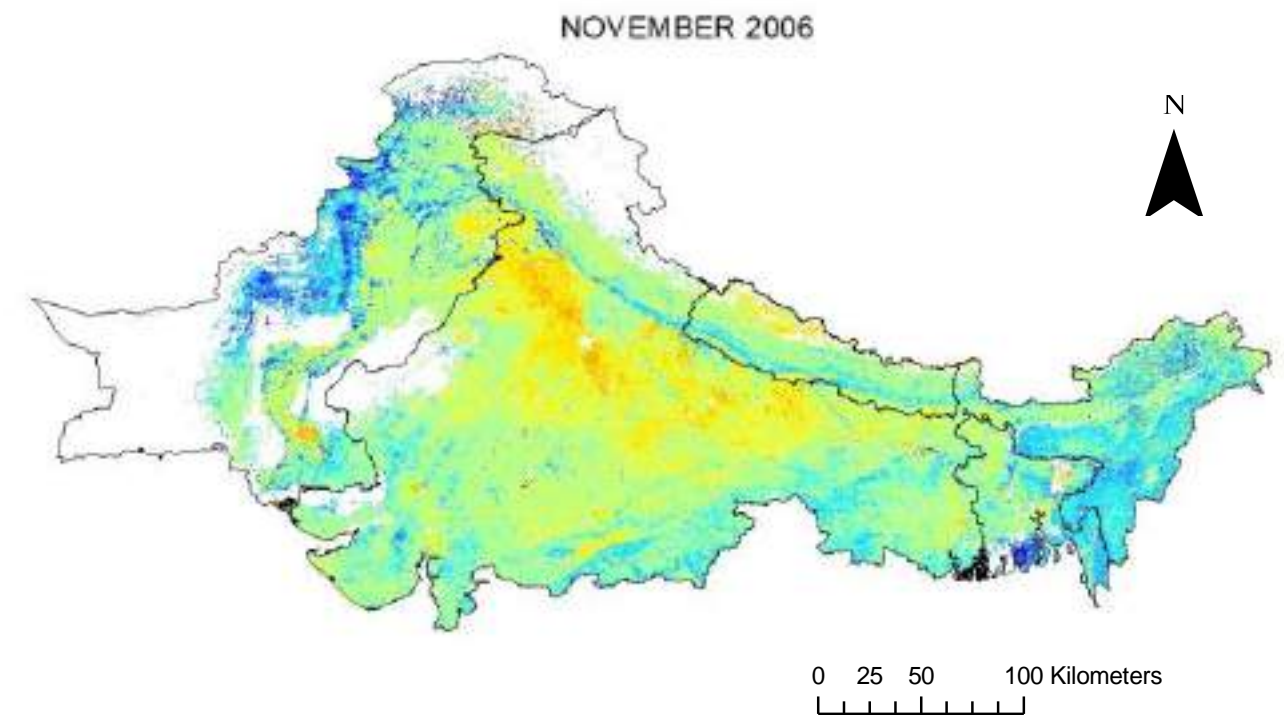
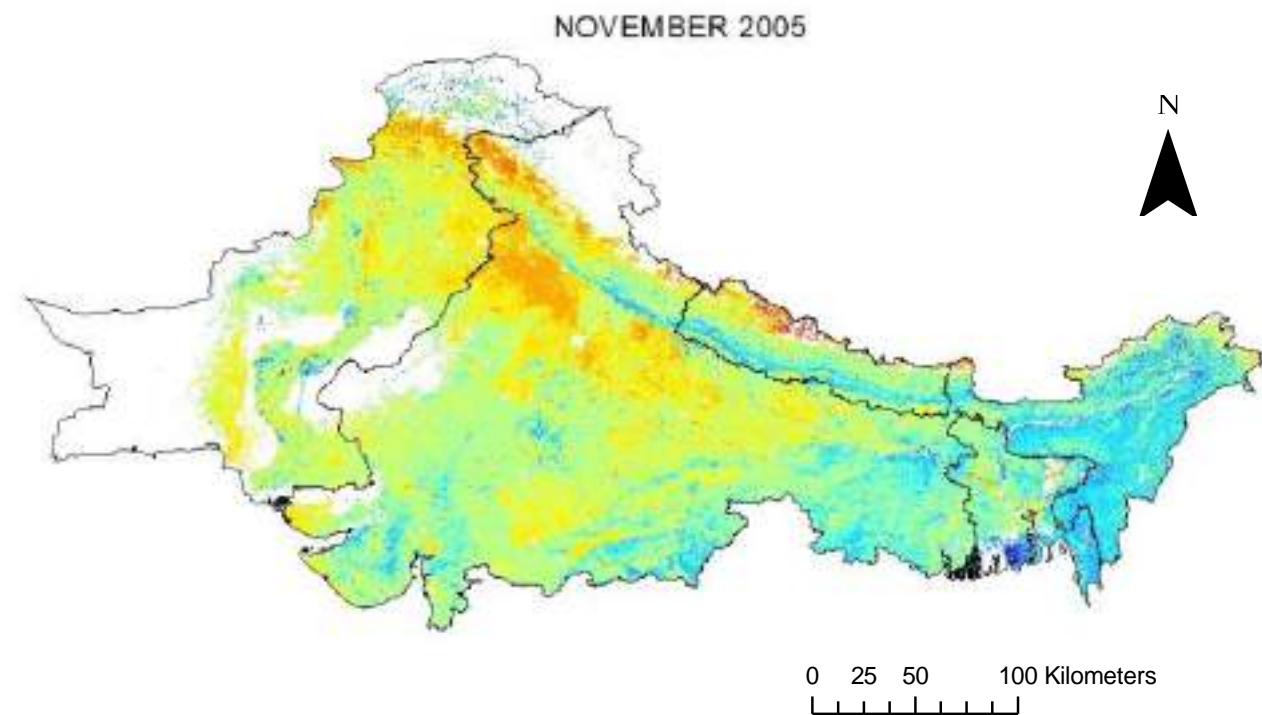




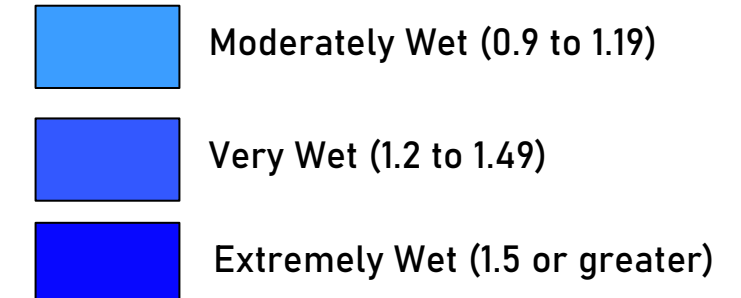
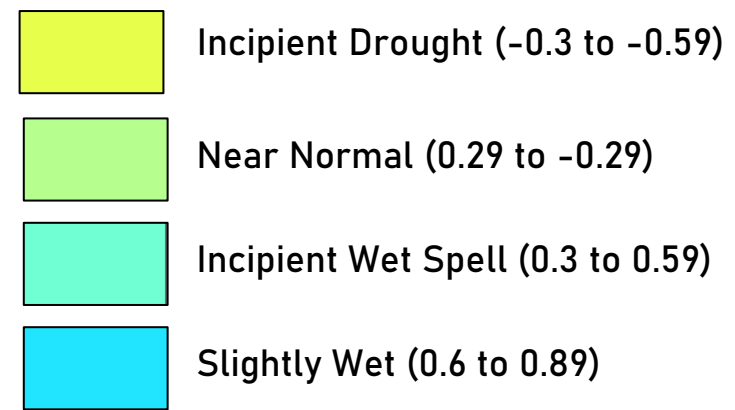
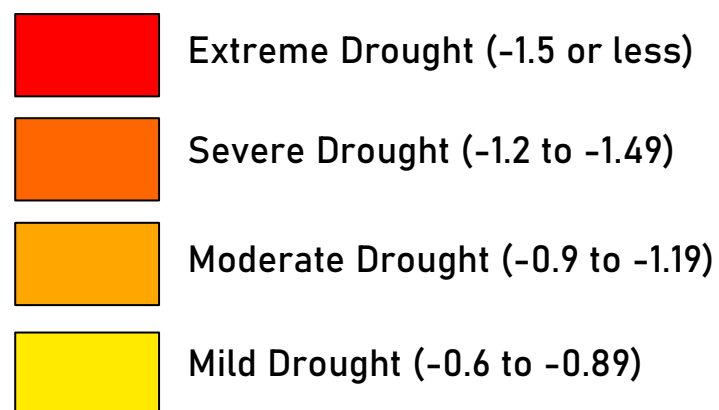
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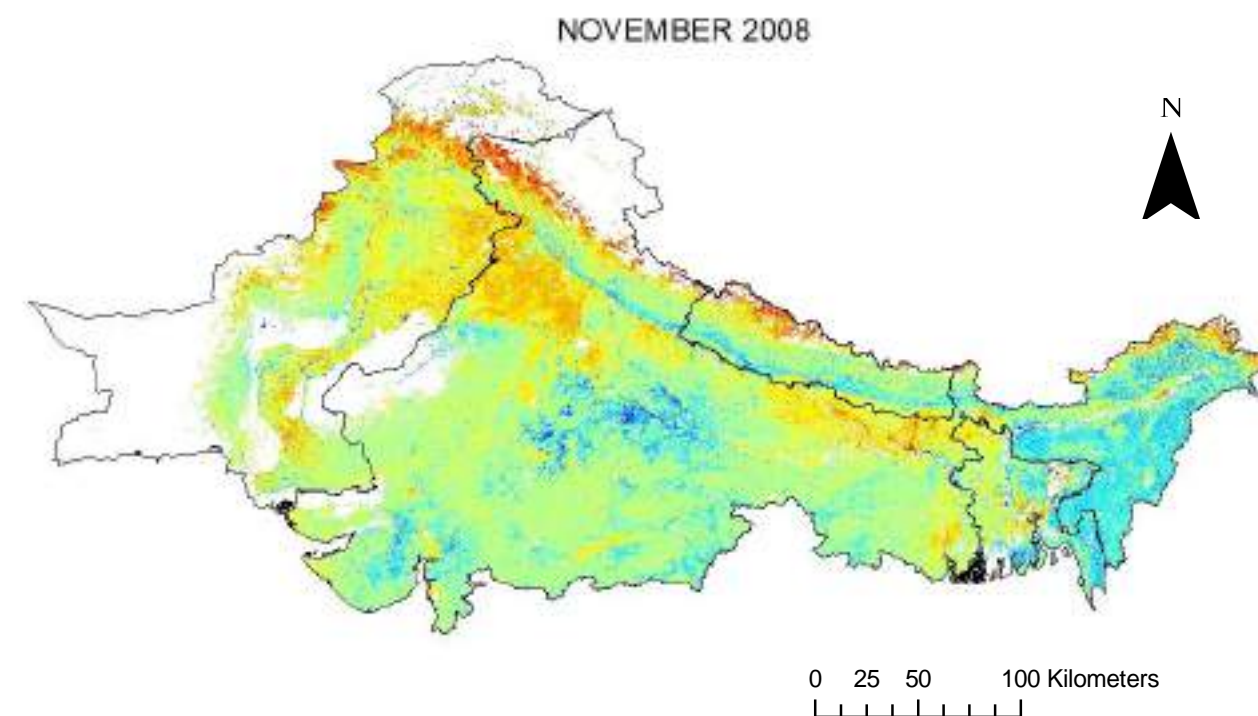
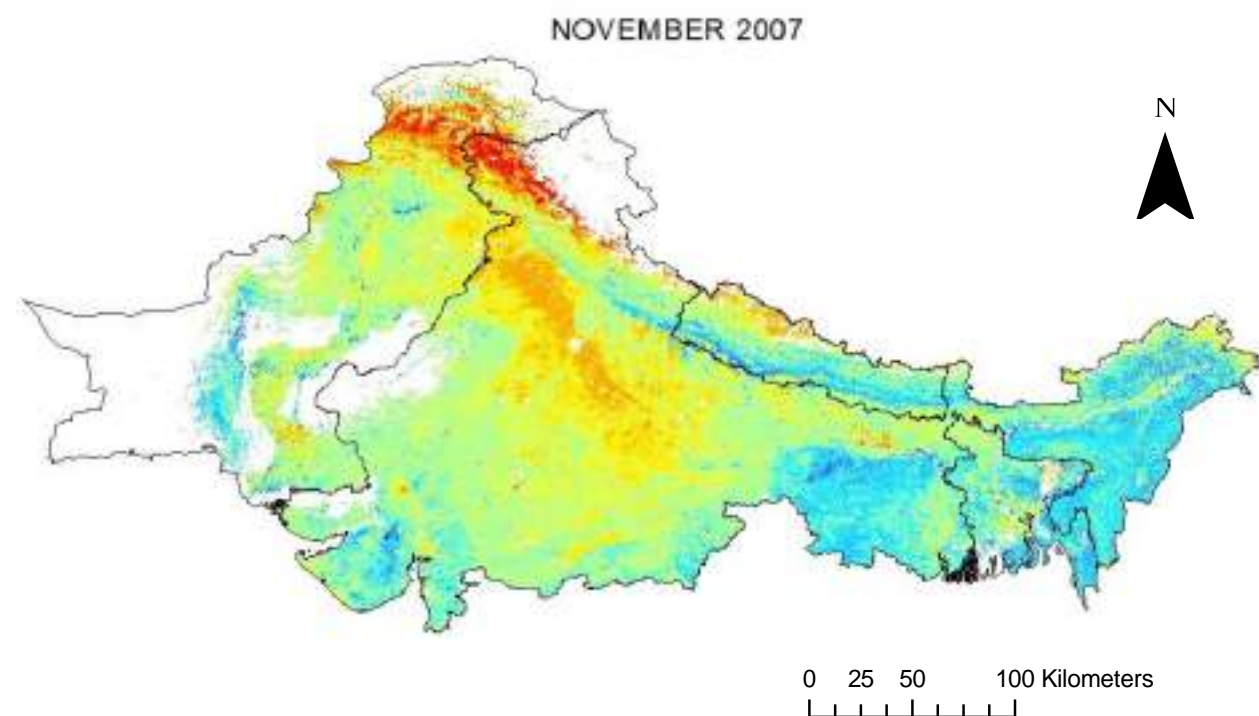




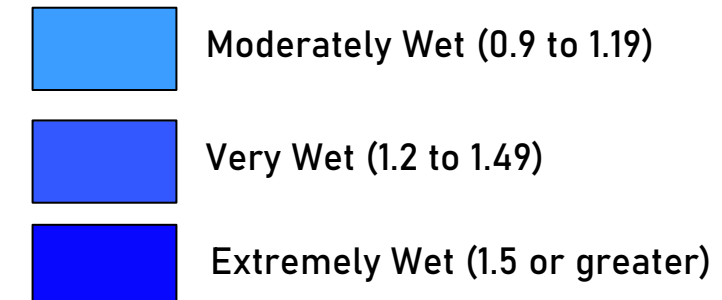
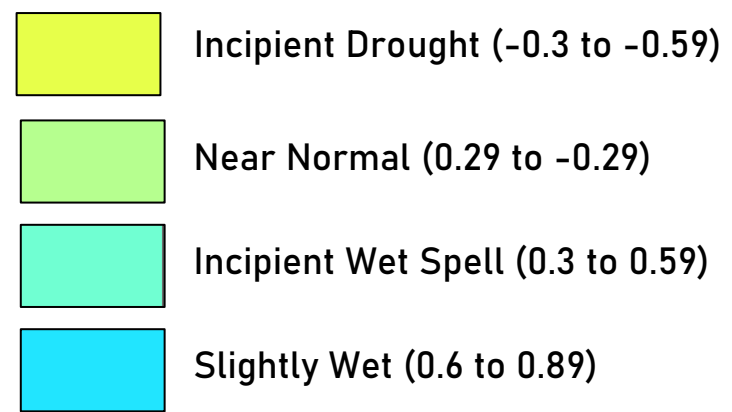
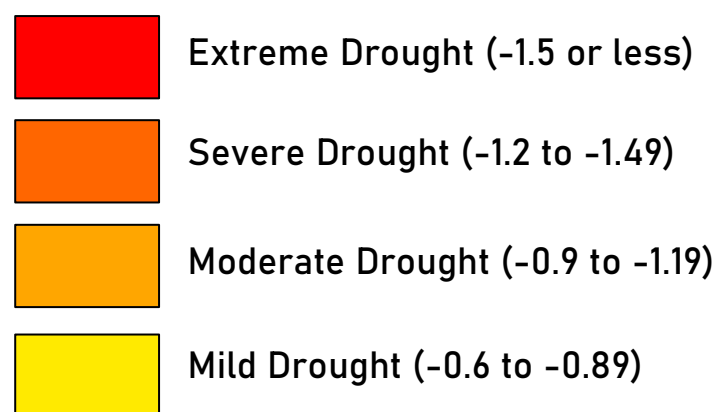


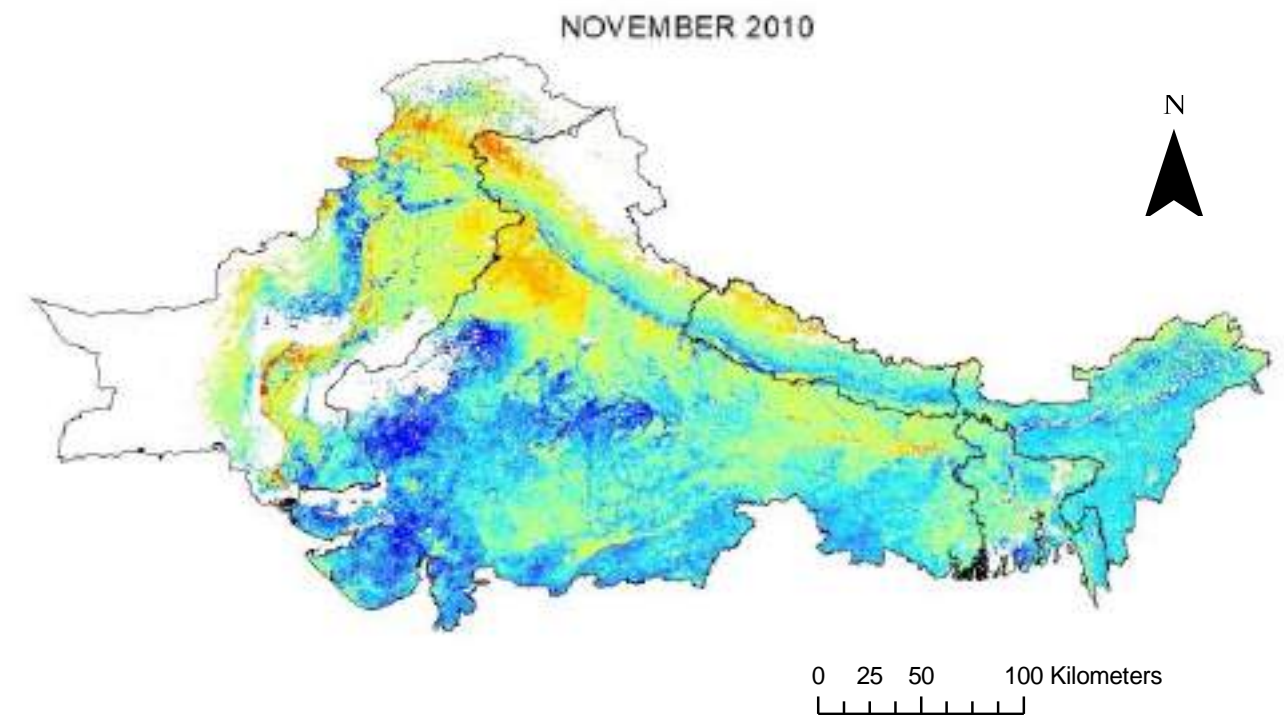
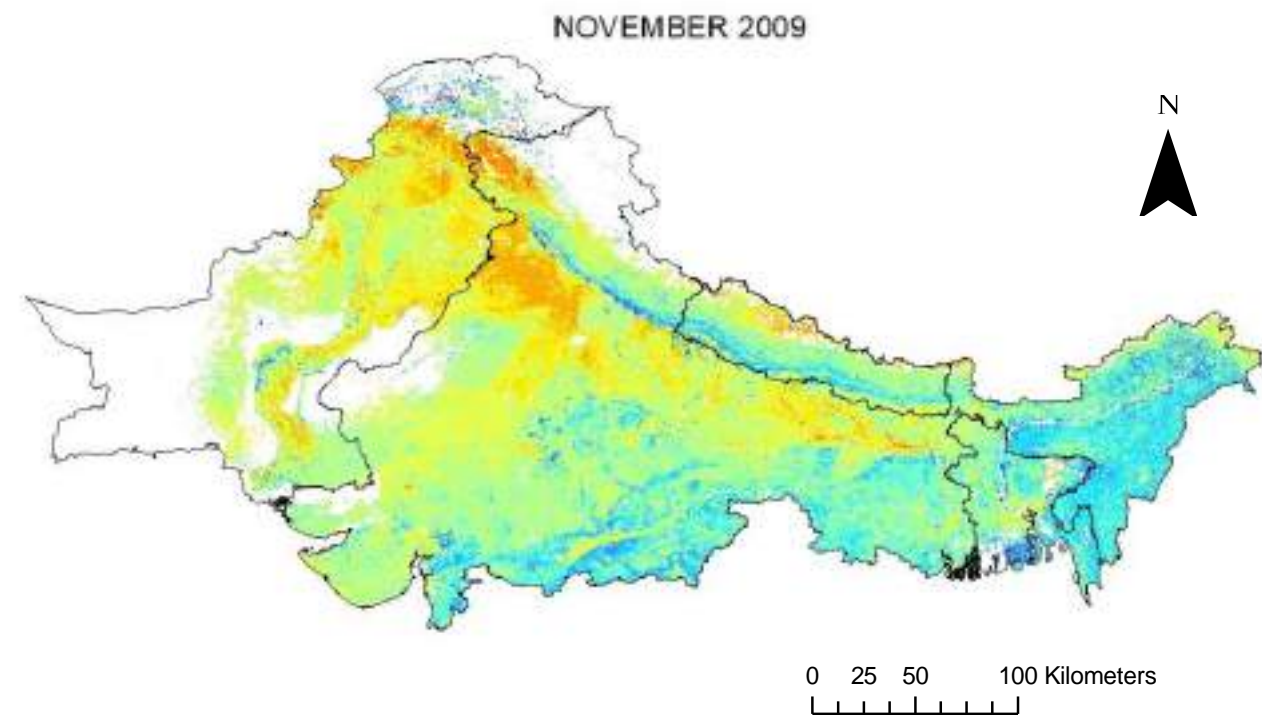
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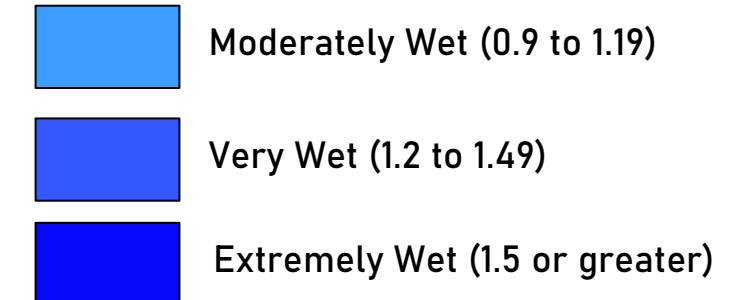
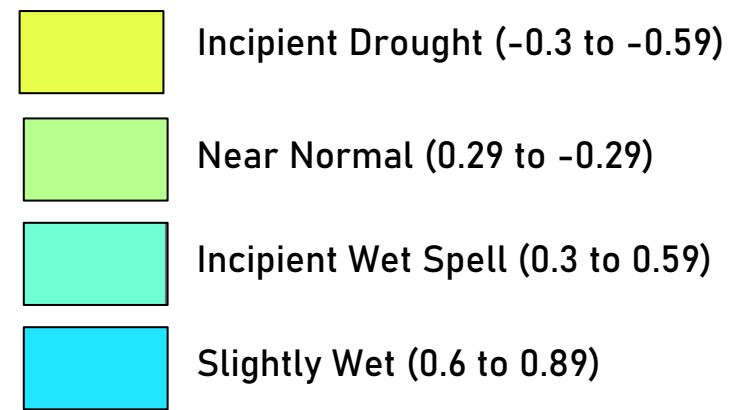
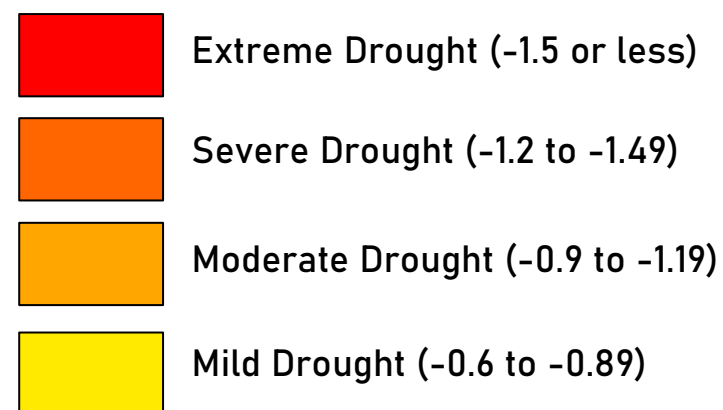


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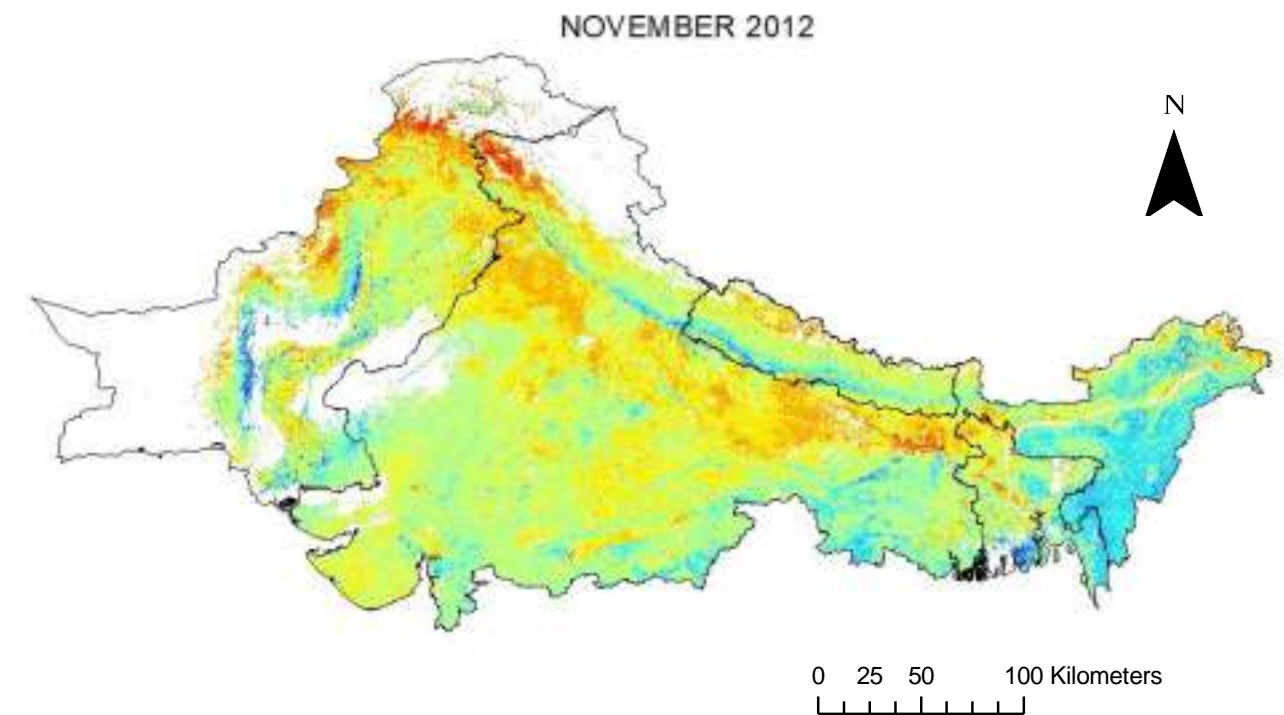
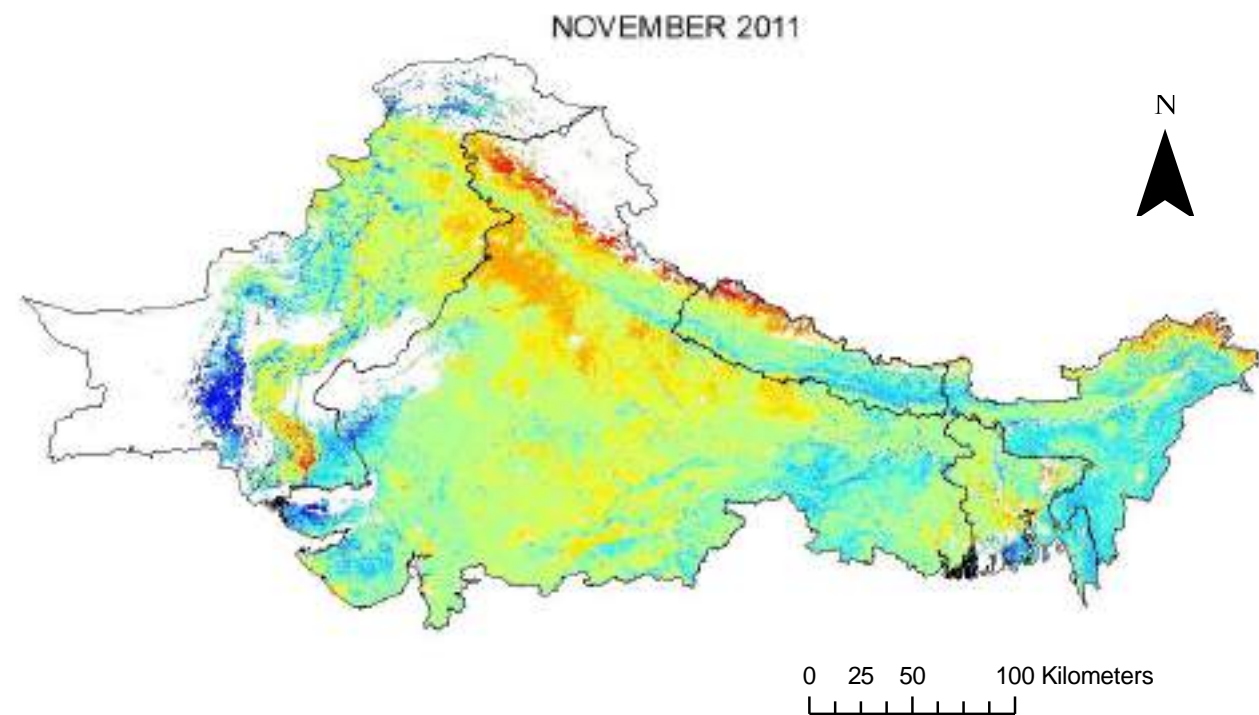




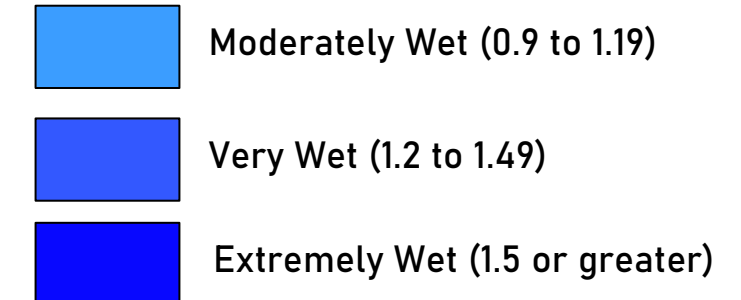
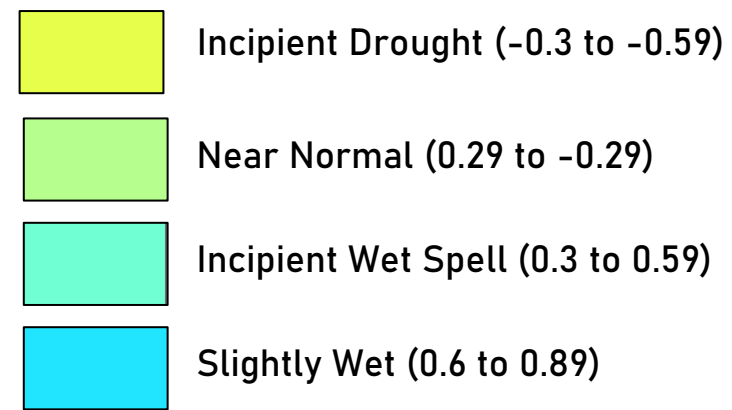
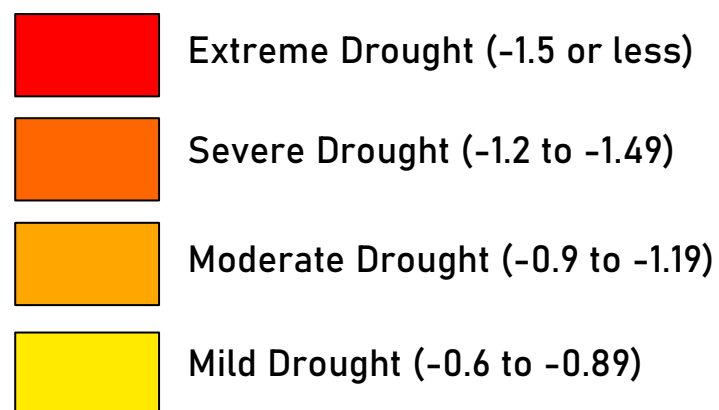
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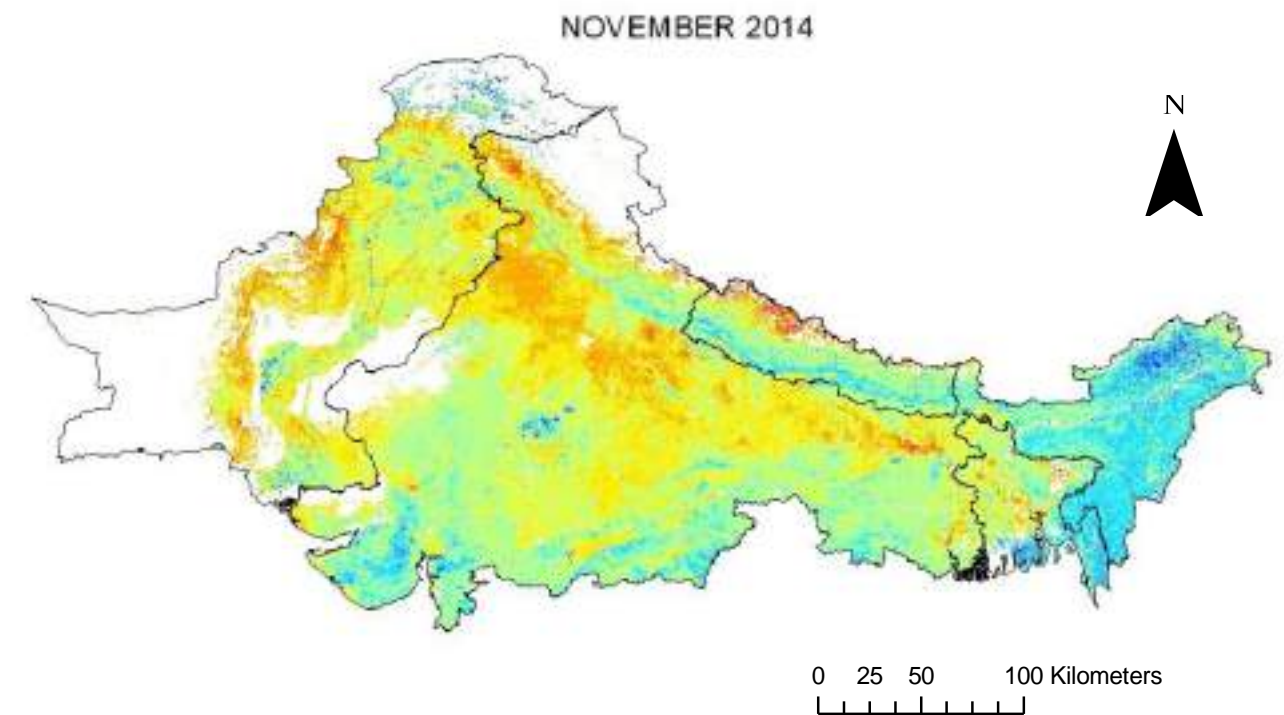
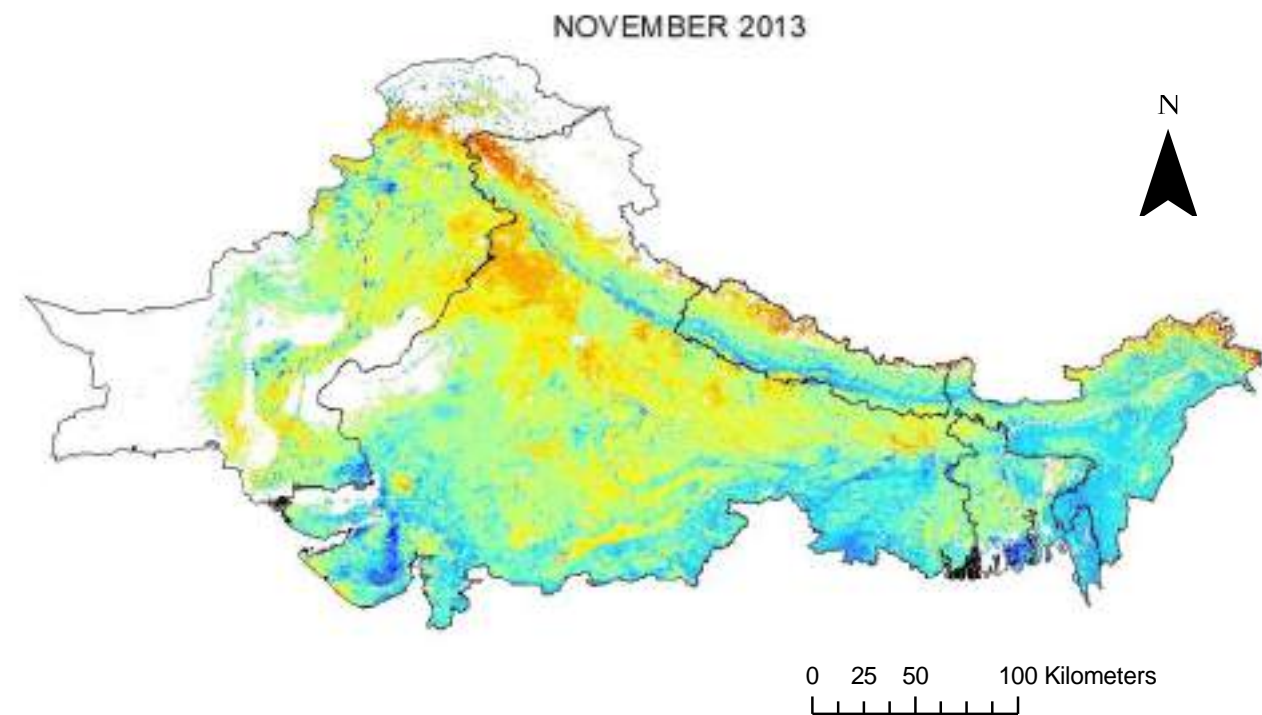




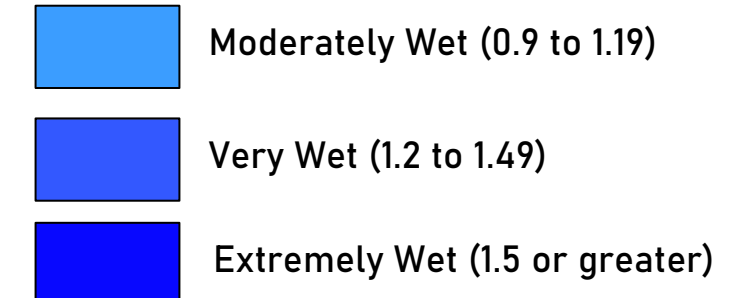
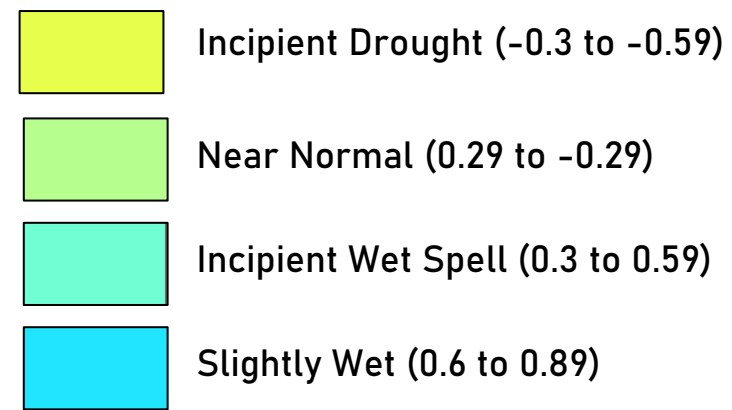
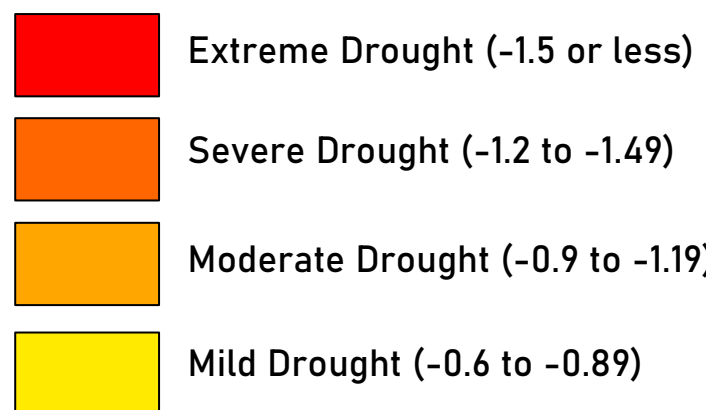


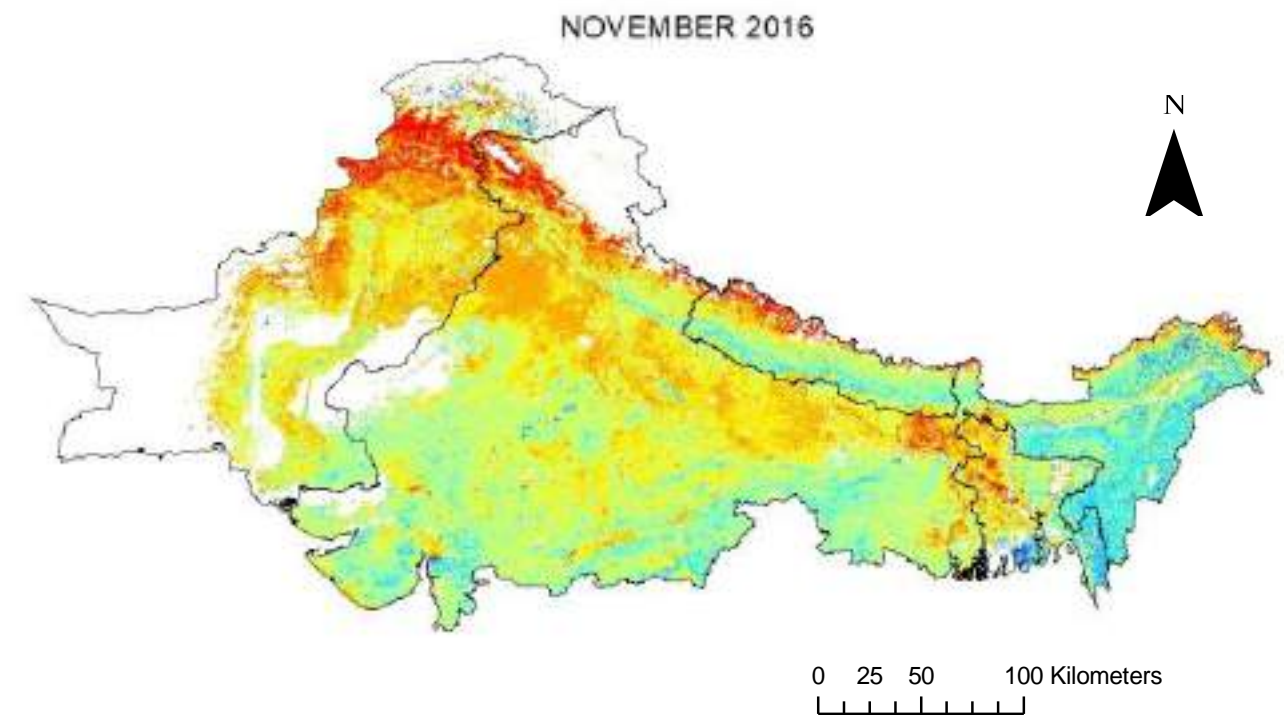
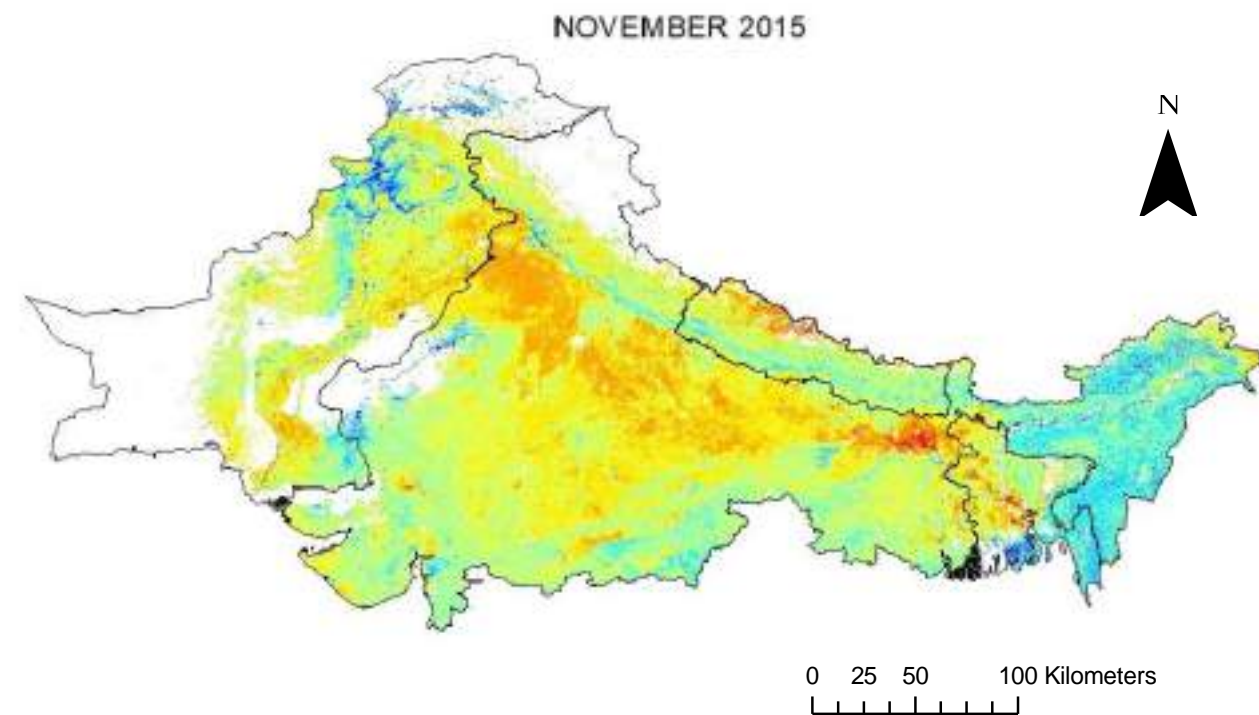
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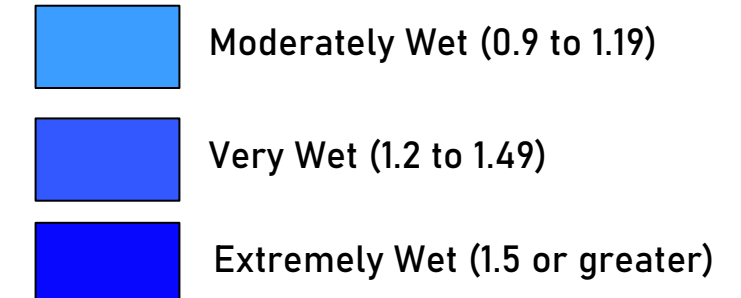
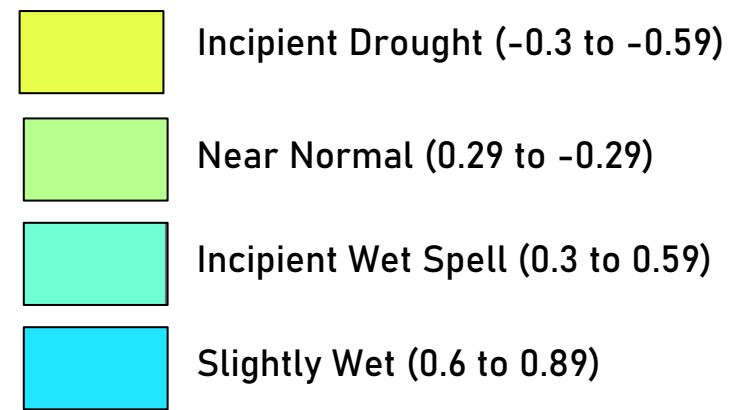
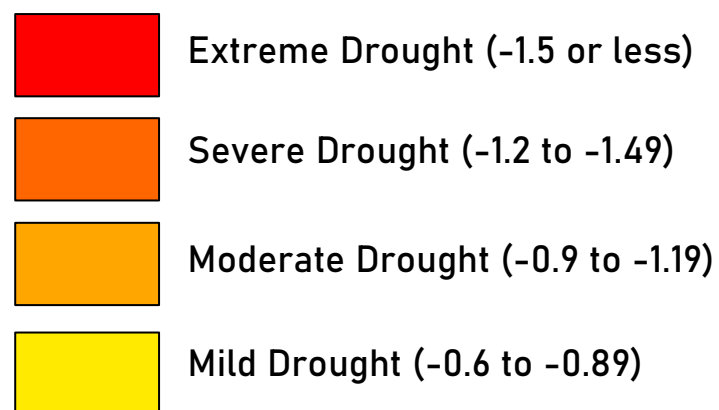


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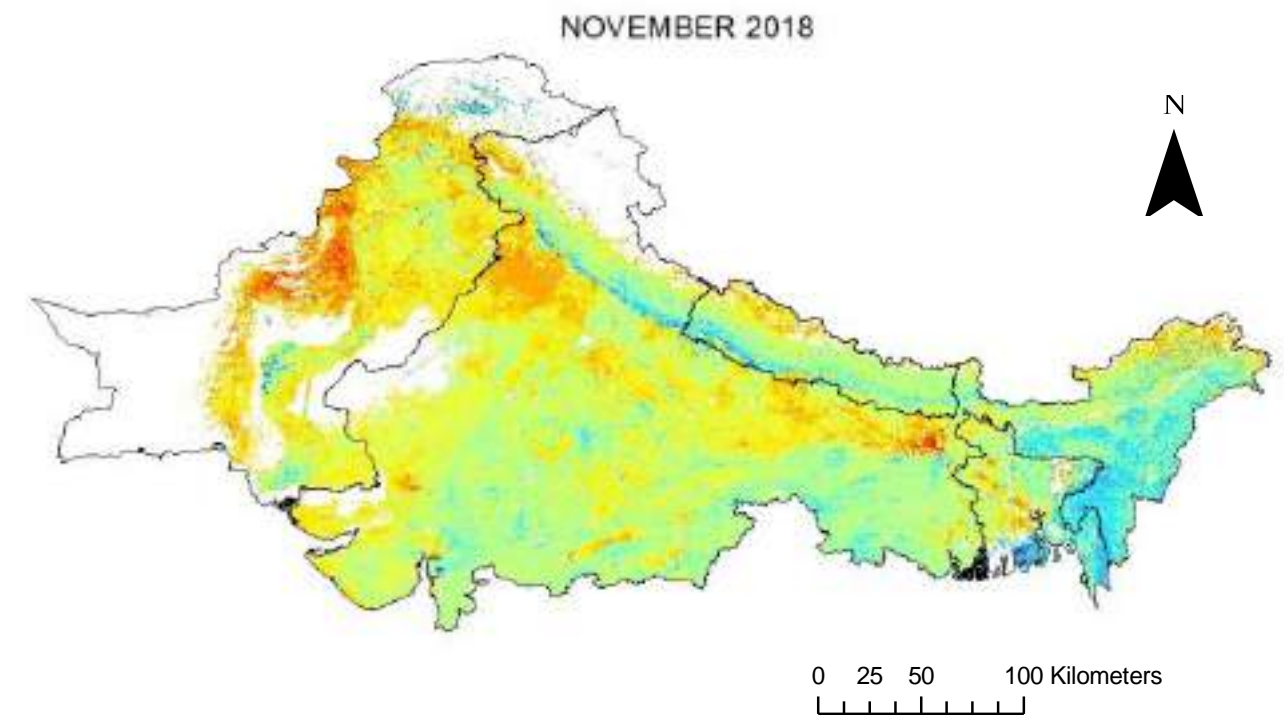
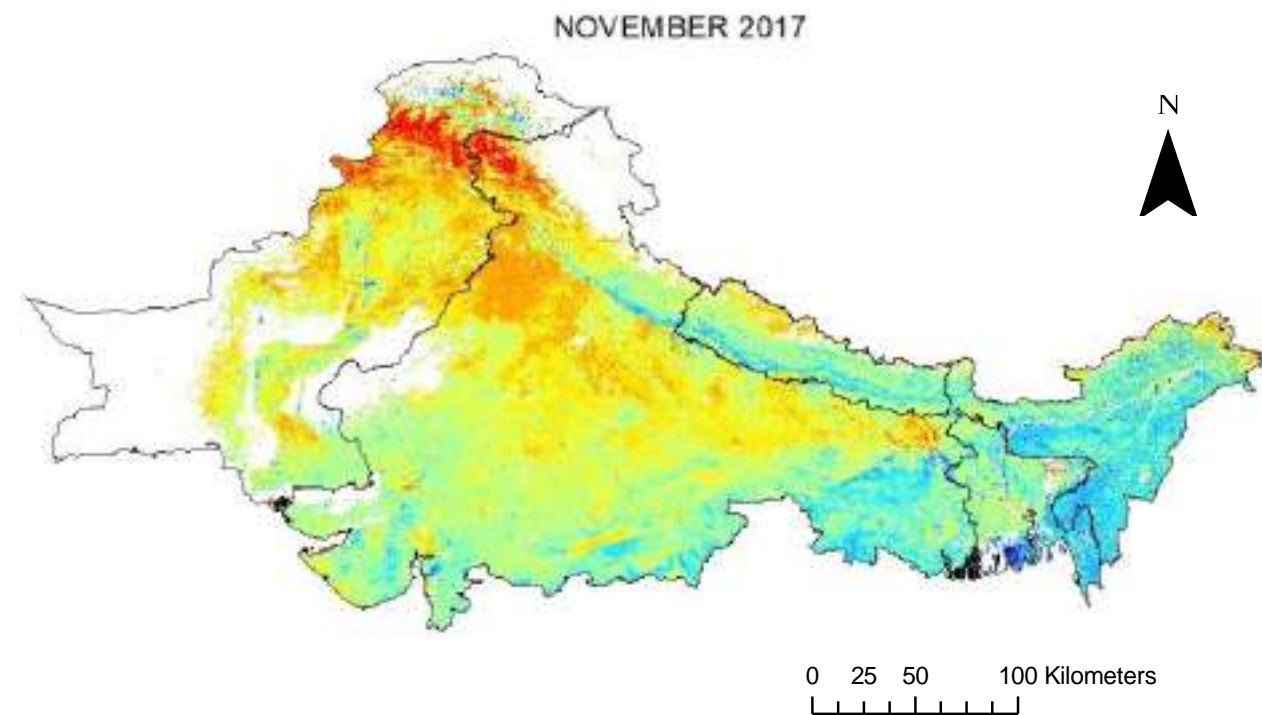




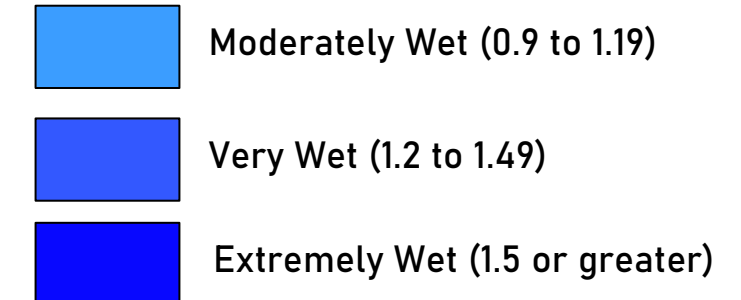
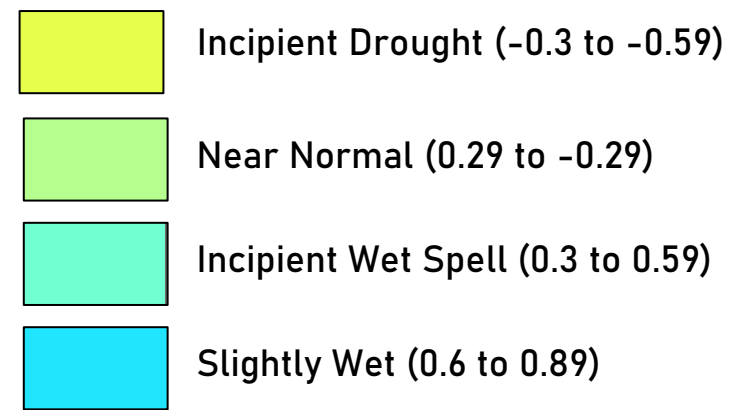
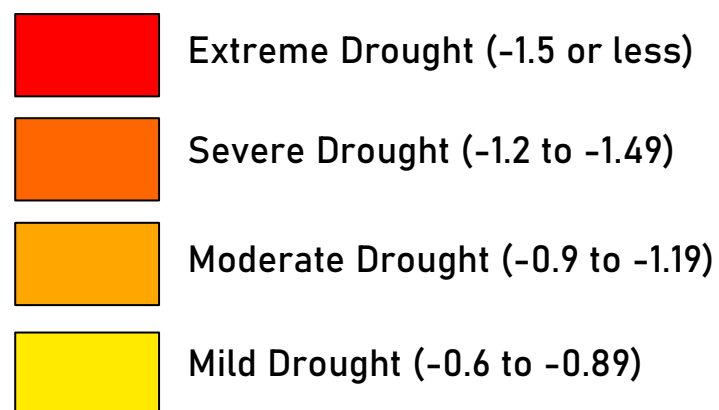
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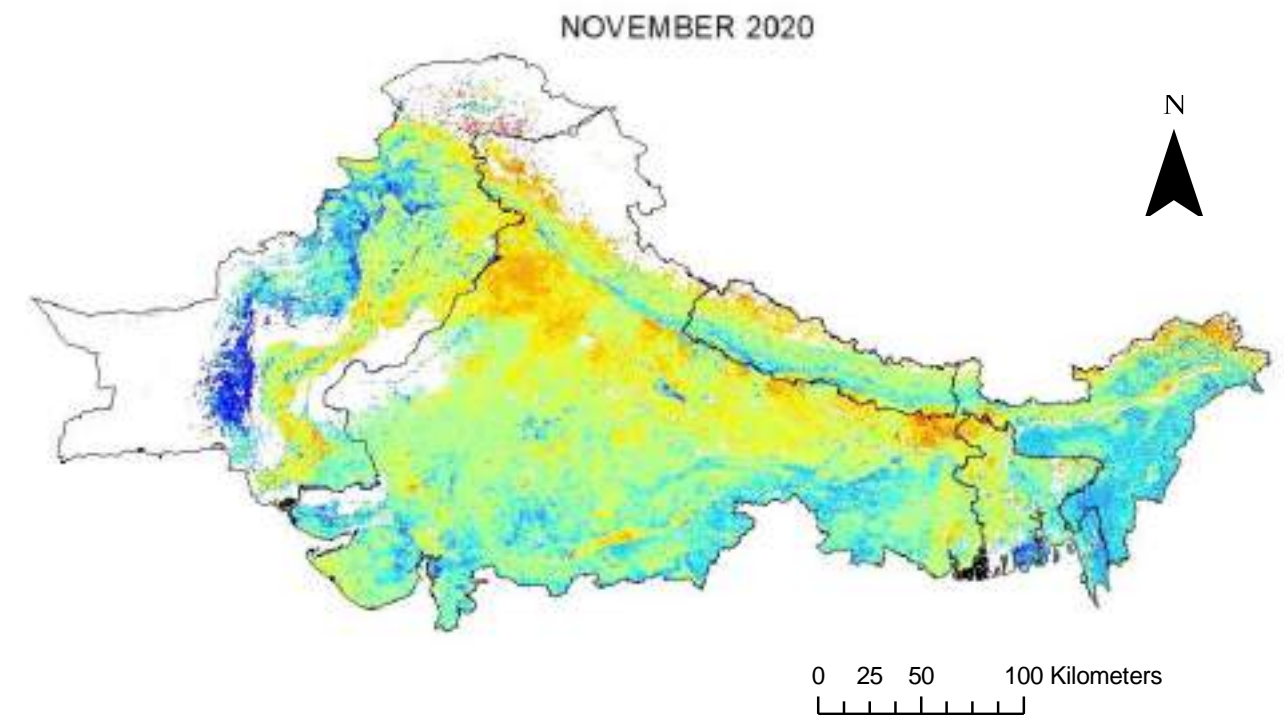
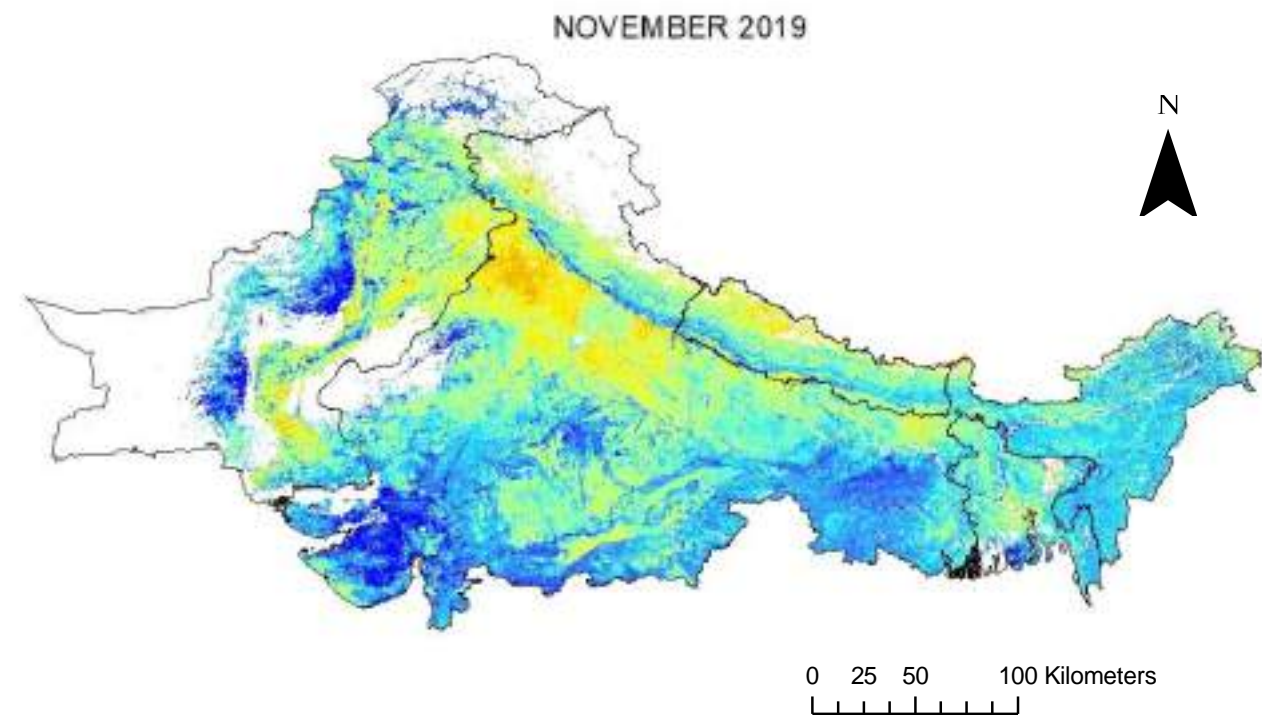




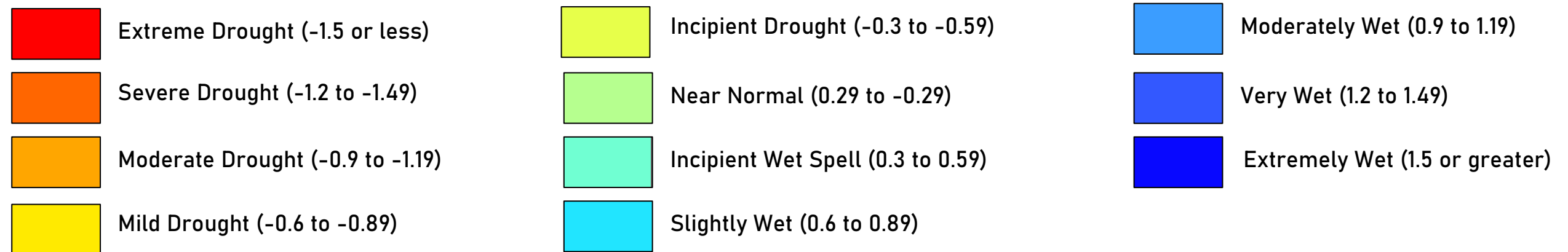


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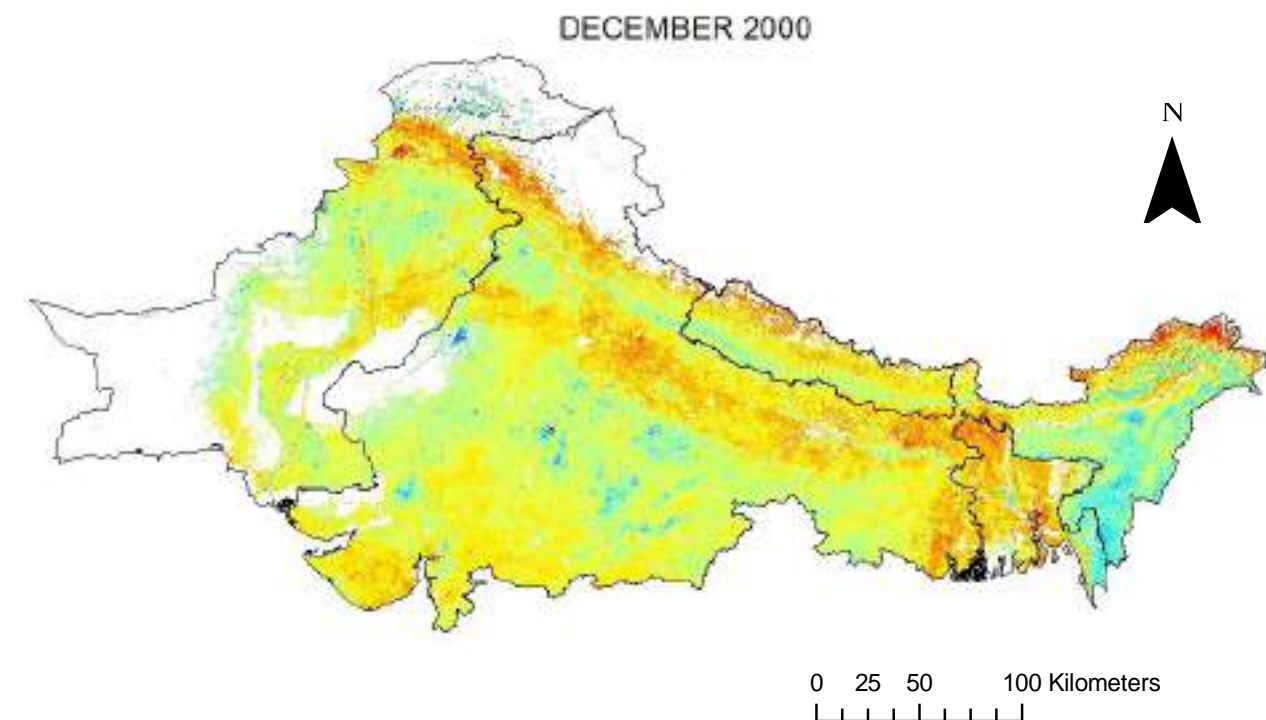
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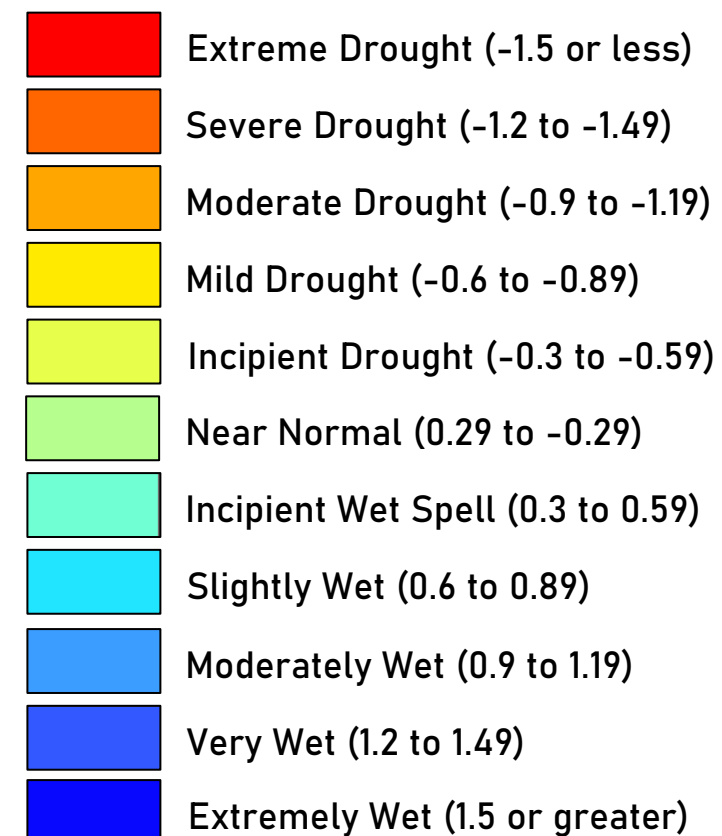
## December DSI Maps

Drought in December ranges from incipient drought to incipient wet spell. This month is characterized by near normal conditions. DSI value of -0.56 was noted as driest condition in 2000.

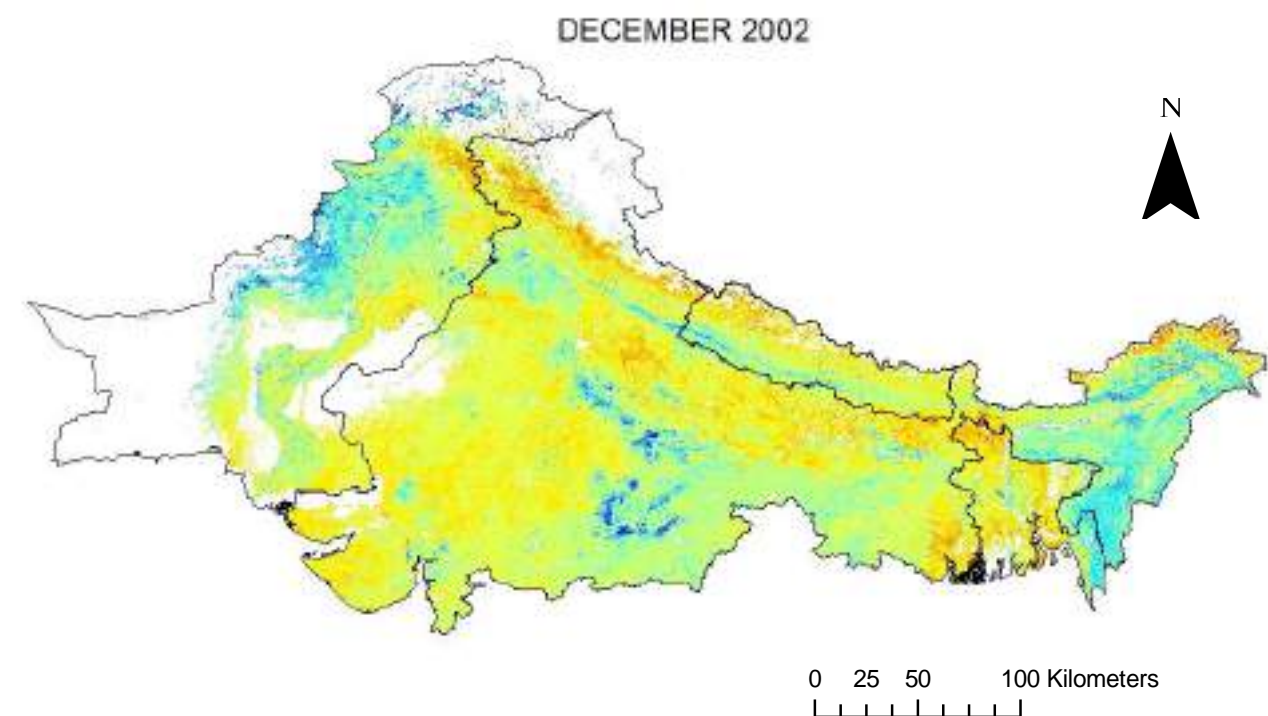
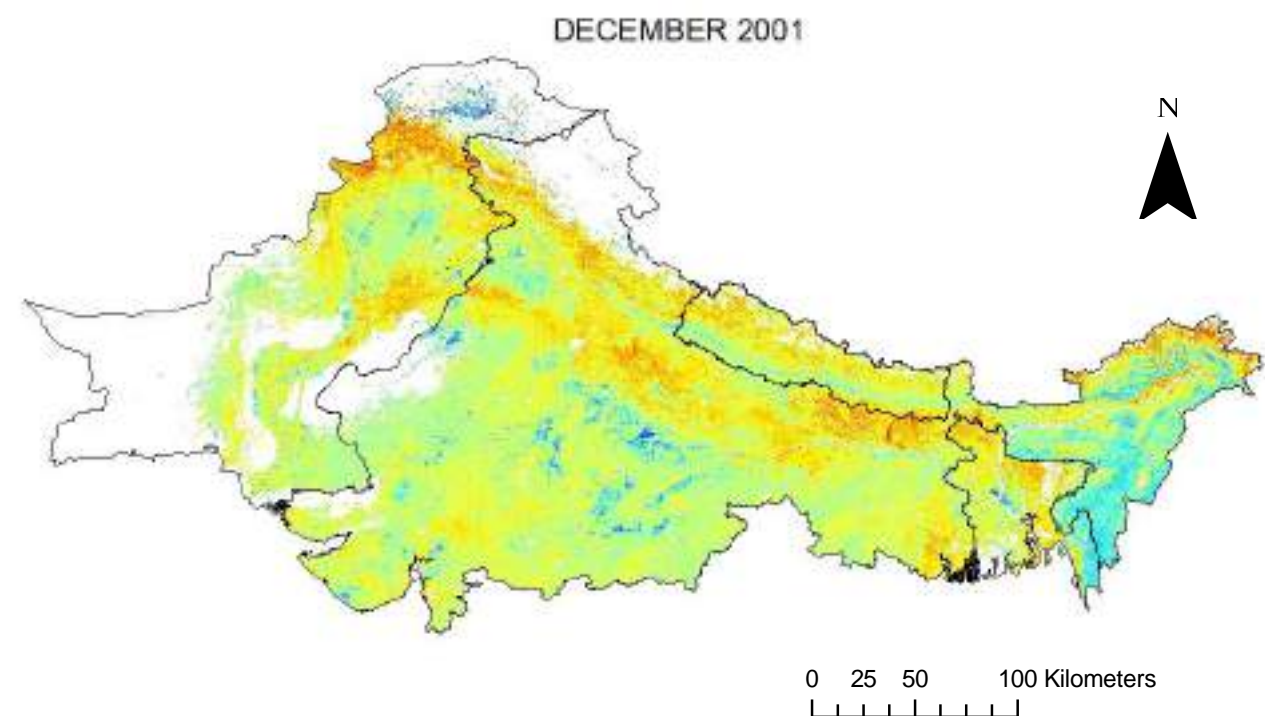
Mean December DSI Values		
Year	DSI Values	Drought Condition
2000	-0.56	Incipient Drought
2001	-0.40	Incipient Drought
2002	-0.34	Incipient Drought
2003	-0.05	Near Normal
2004	-0.15	Near Normal
2005	-0.27	Near Normal
2006	0.00	Near Normal
2007	-0.18	Near Normal
2008	-0.02	Near Normal
2009	-0.20	Near Normal
2010	-0.11	Near Normal
2011	-0.37	Incipient Drought
2012	-0.34	Incipient Drought
2013	-0.11	Near Normal
2014	-0.32	Incipient Drought
2015	-0.49	Incipient Drought
2016	-0.52	Incipient Drought
2017	-0.29	Near Normal
2018	-0.40	Incipient Drought
2019	0.02	Near Normal
2020	-0.04	Near Normal



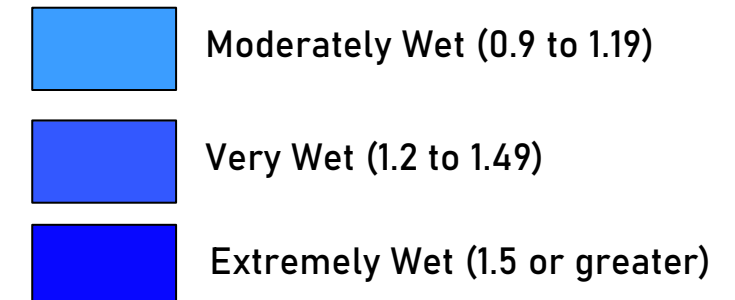
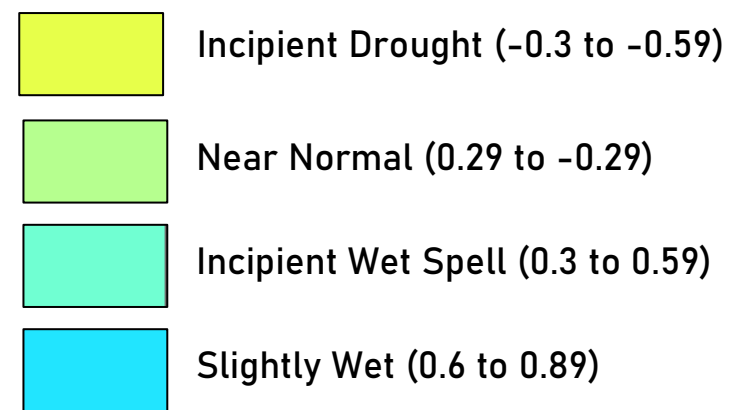
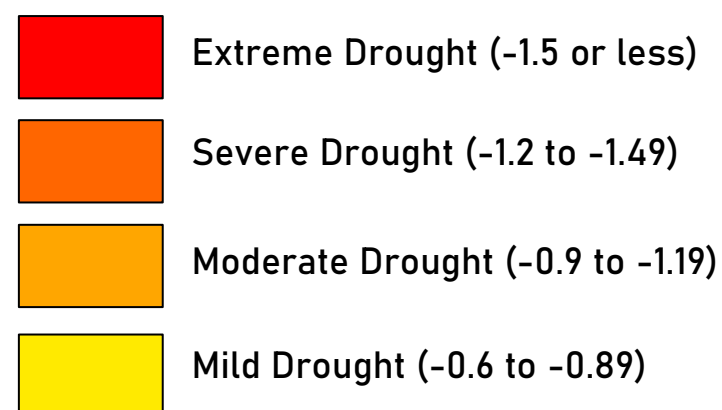
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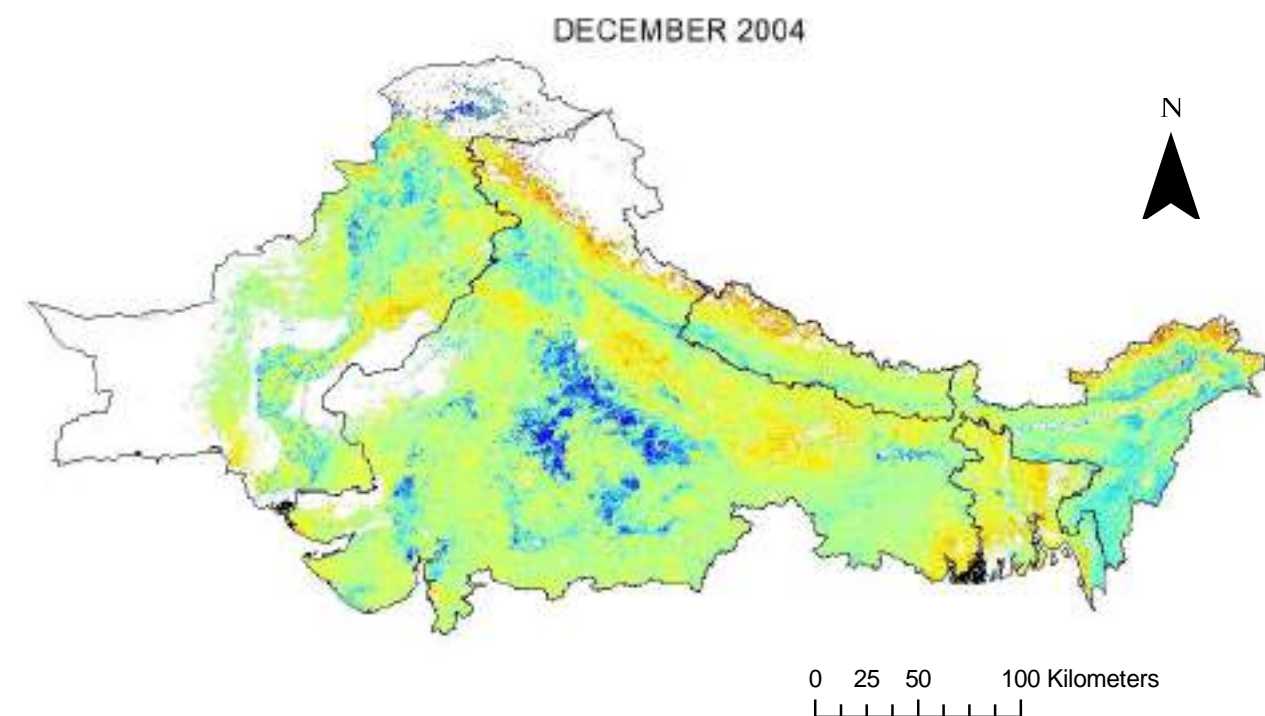
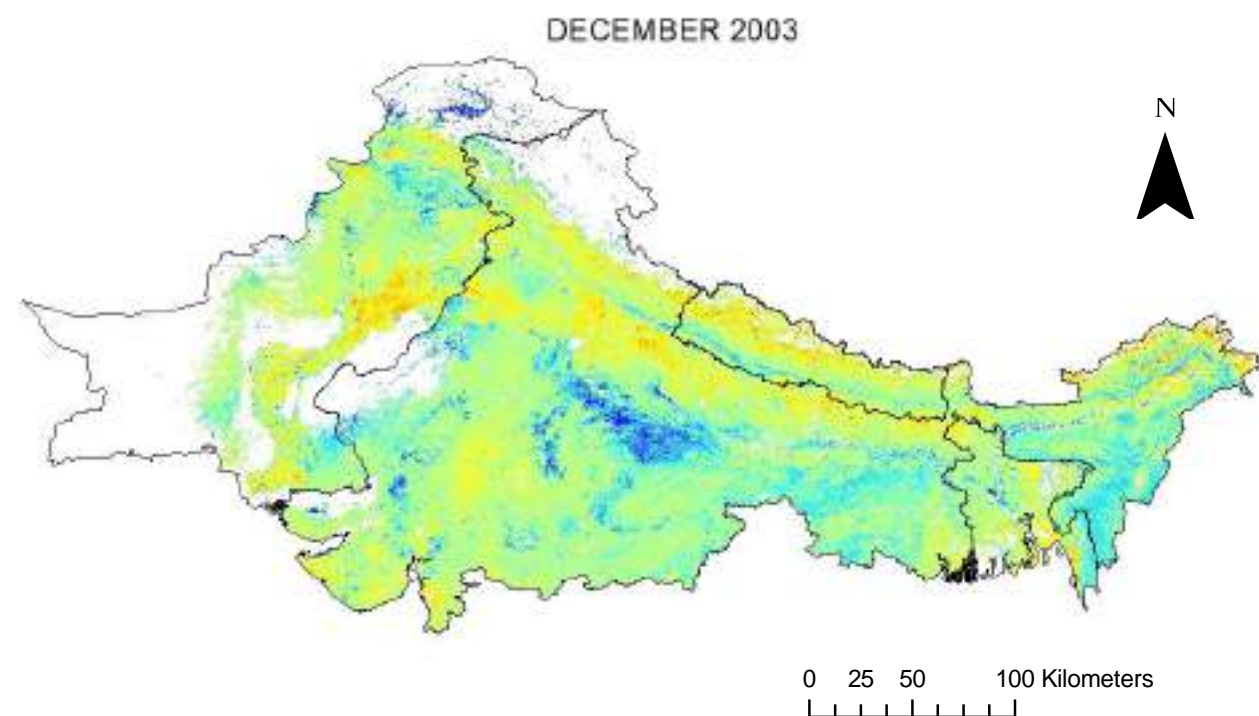




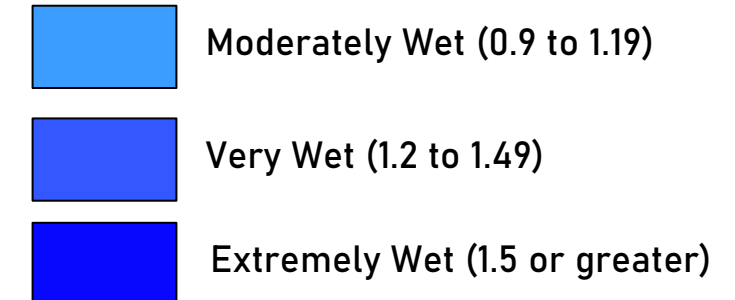
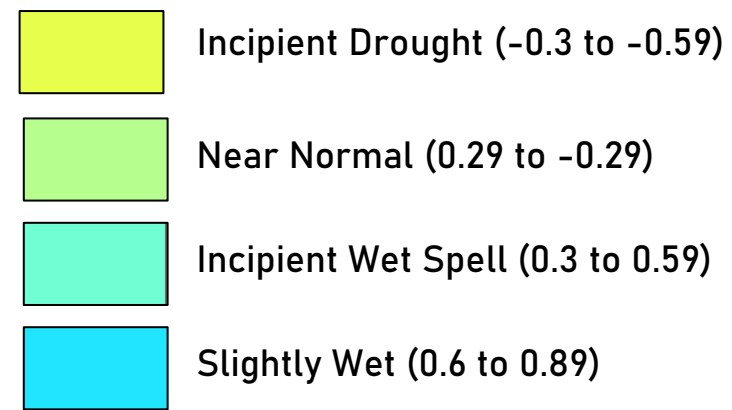
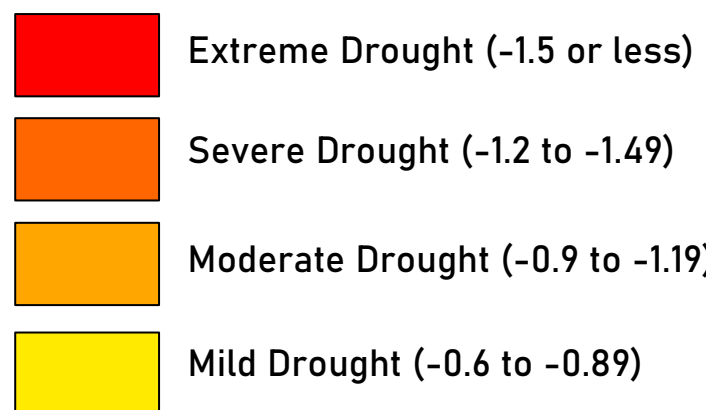


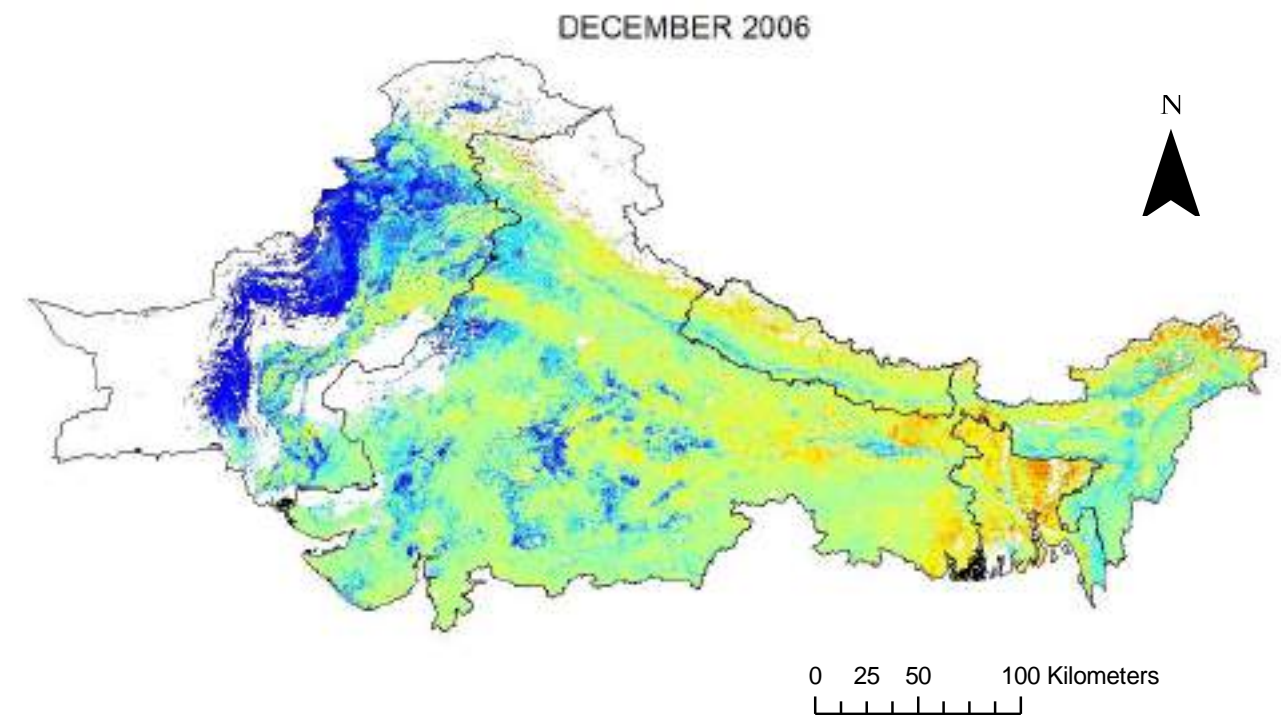
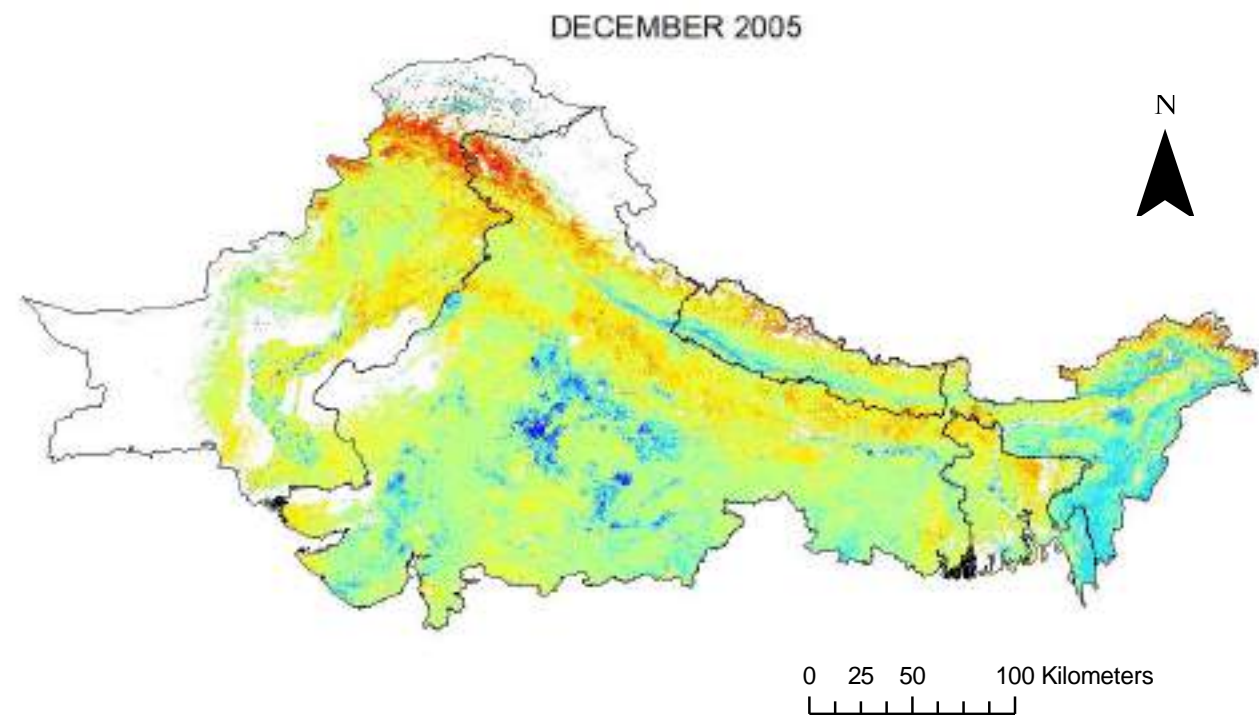
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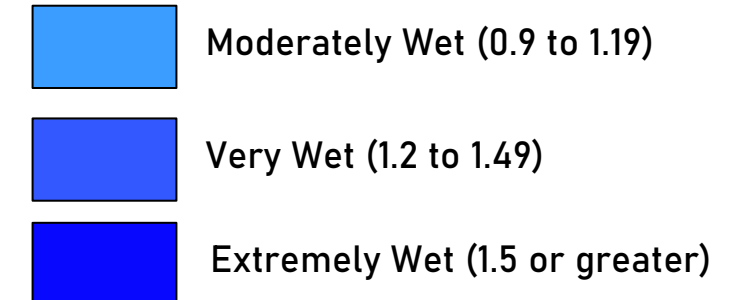
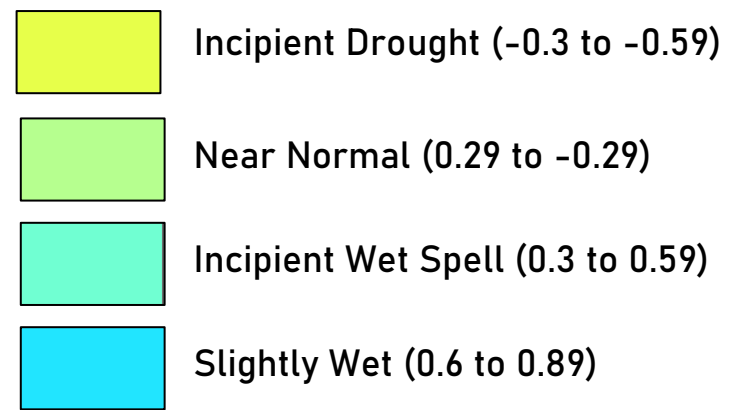
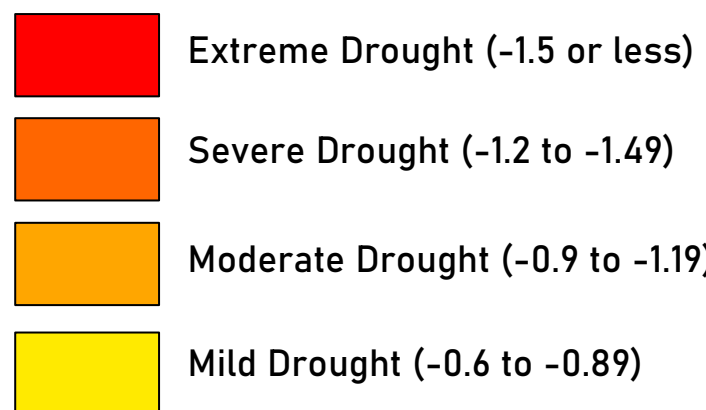


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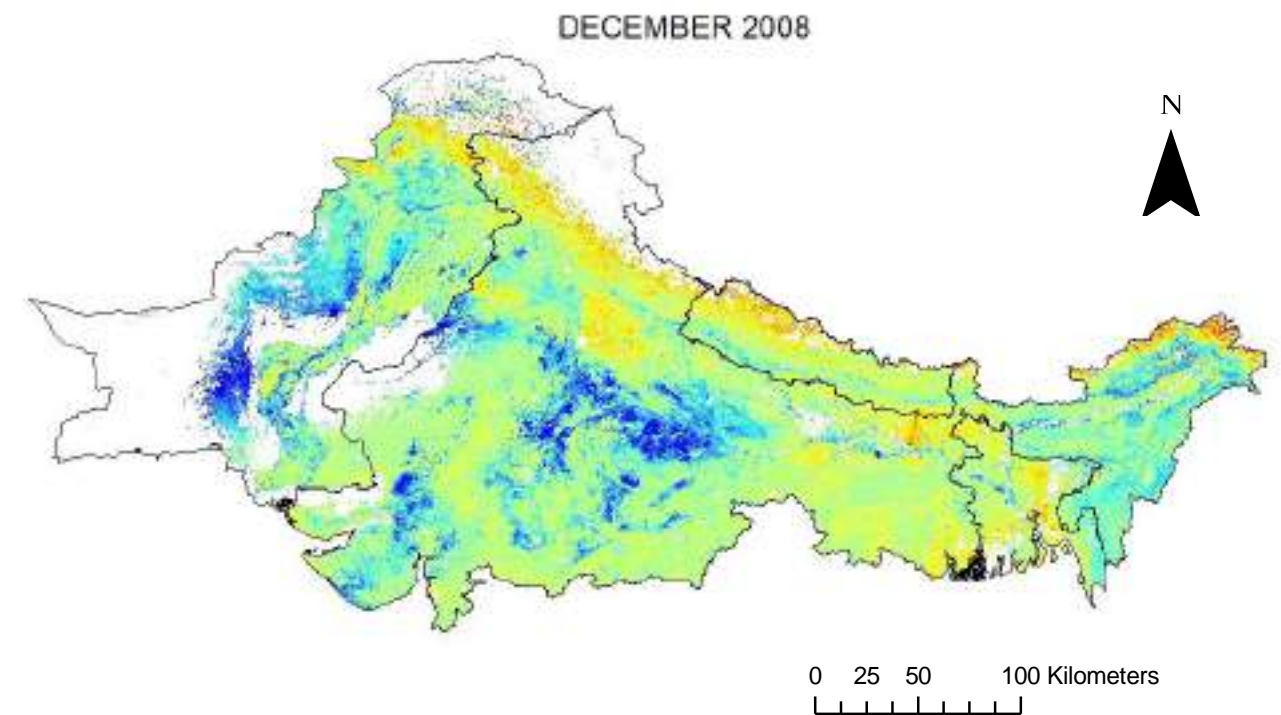
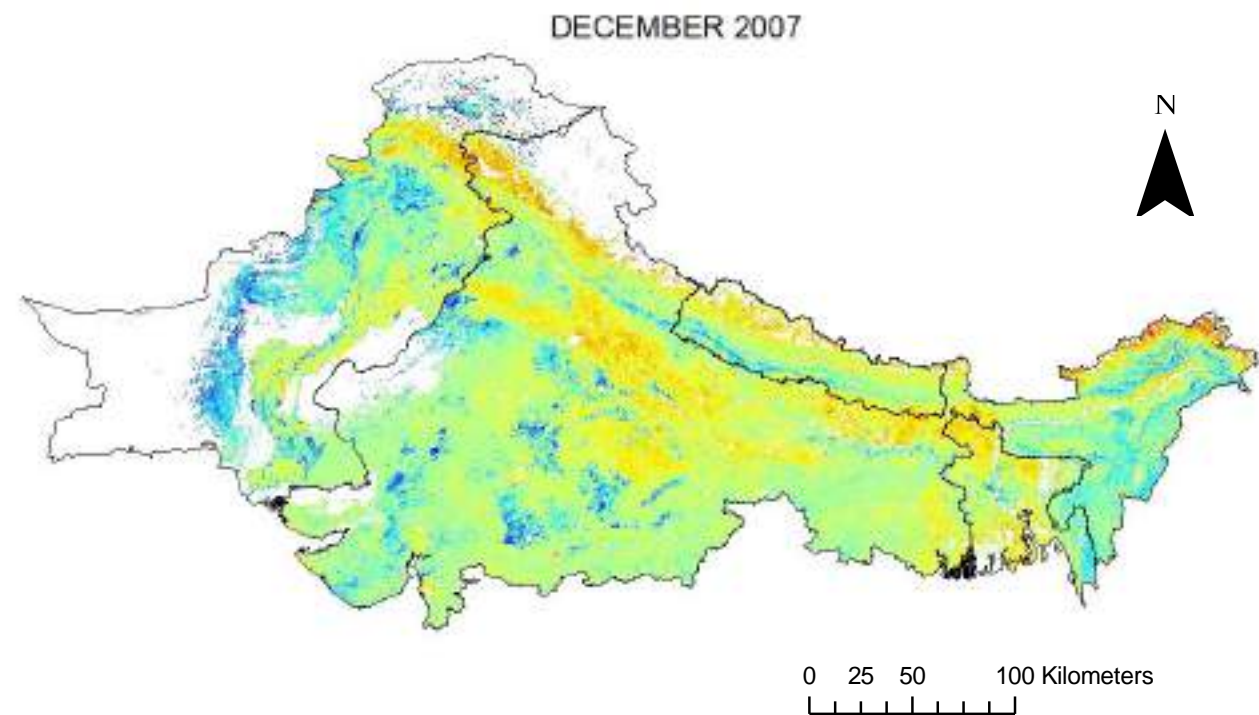




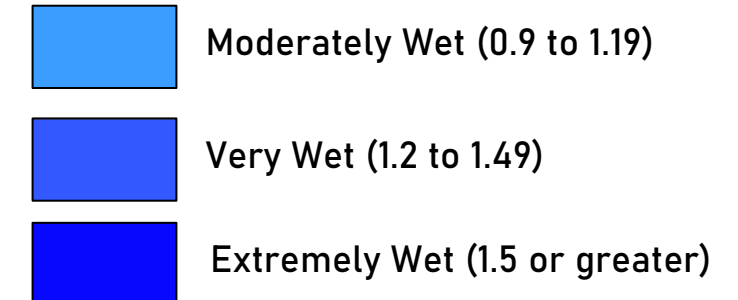
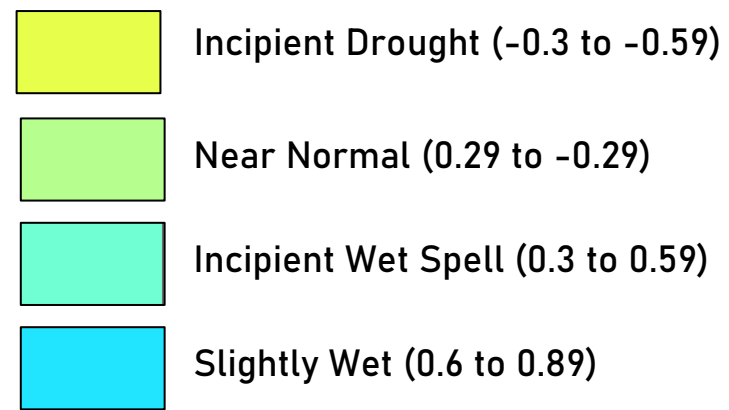
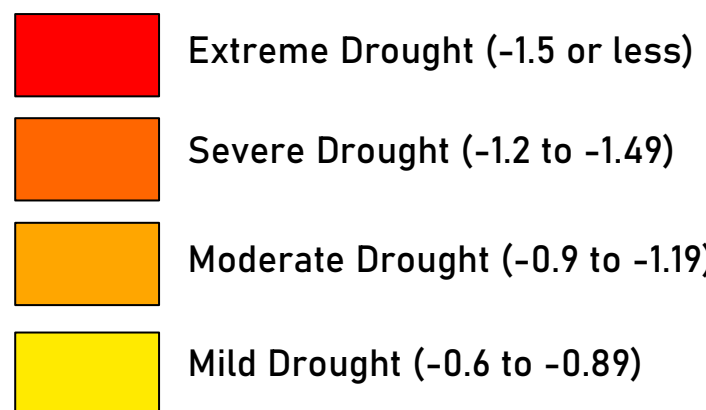
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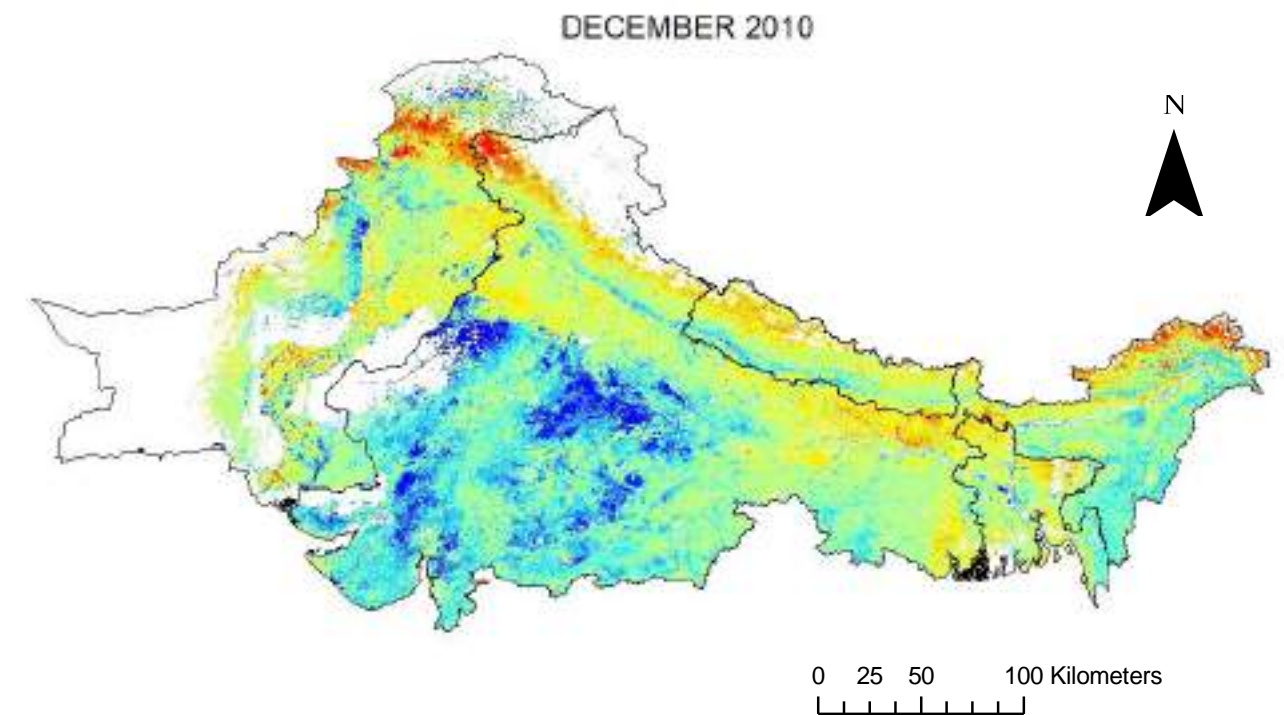
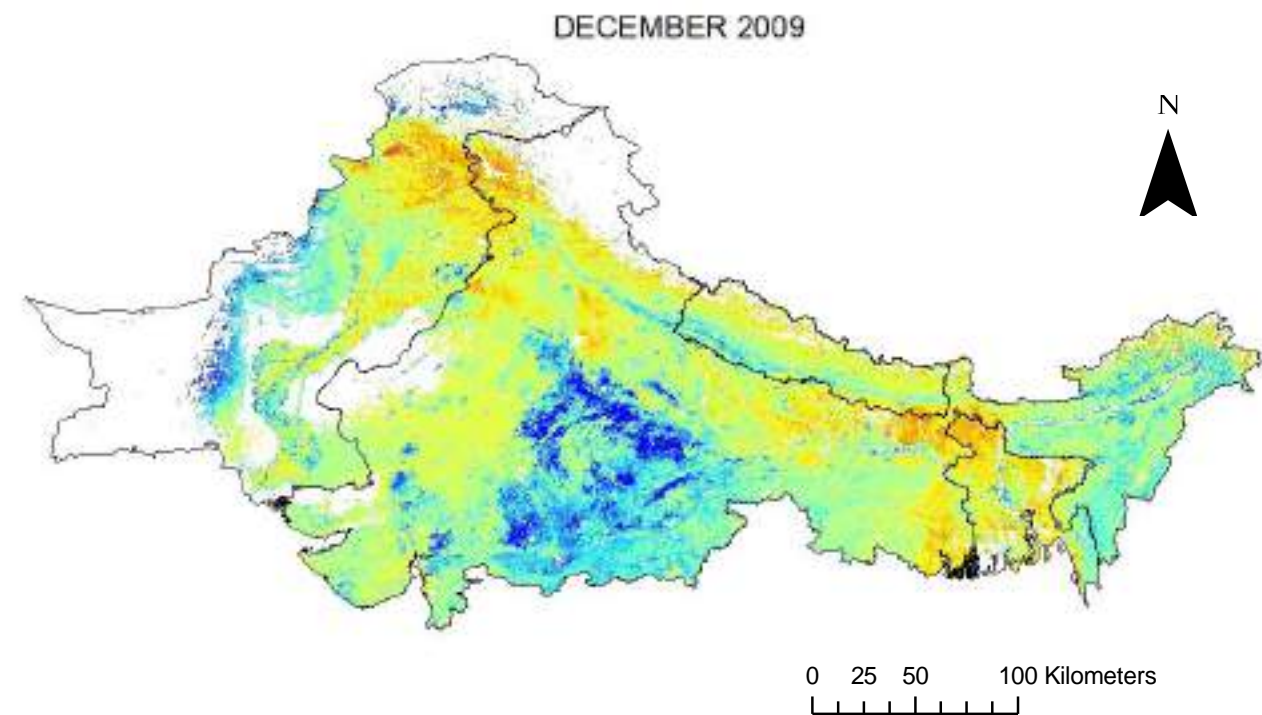




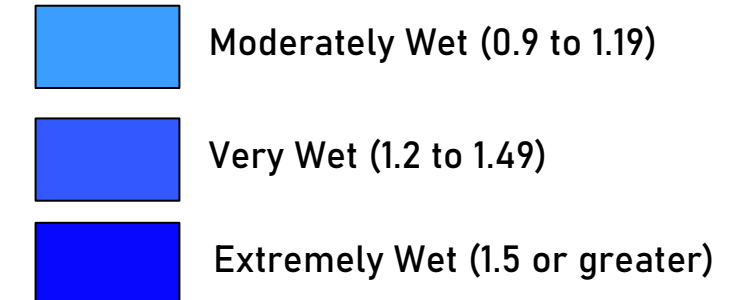
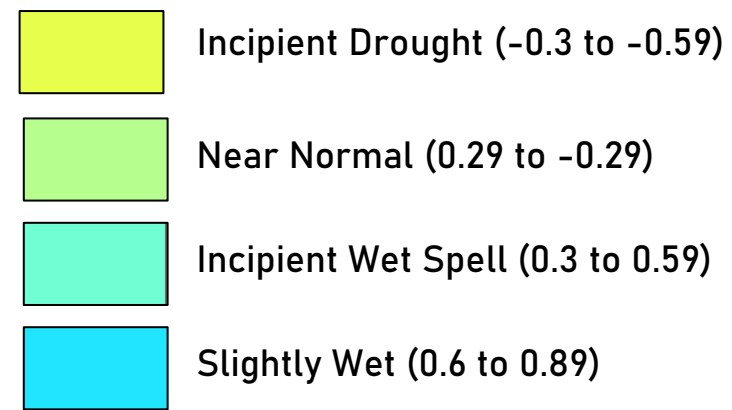
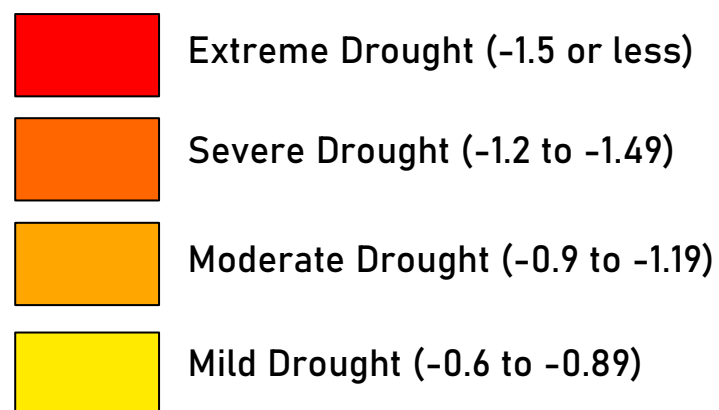


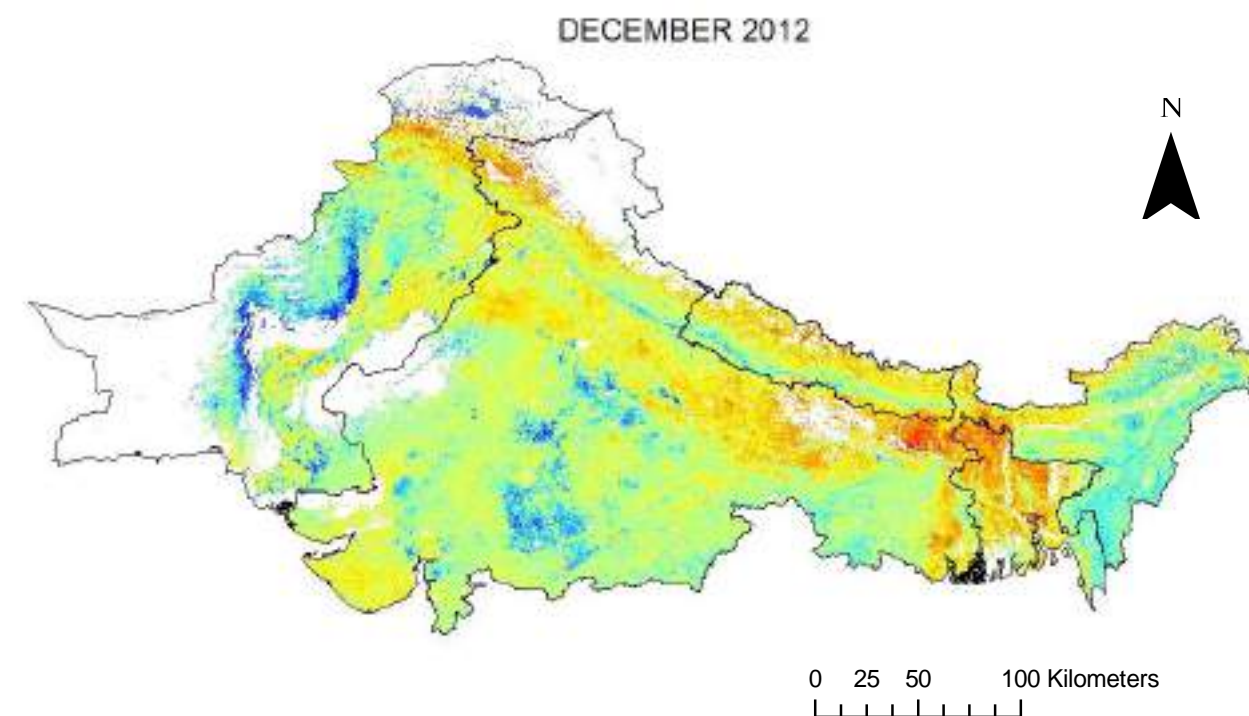
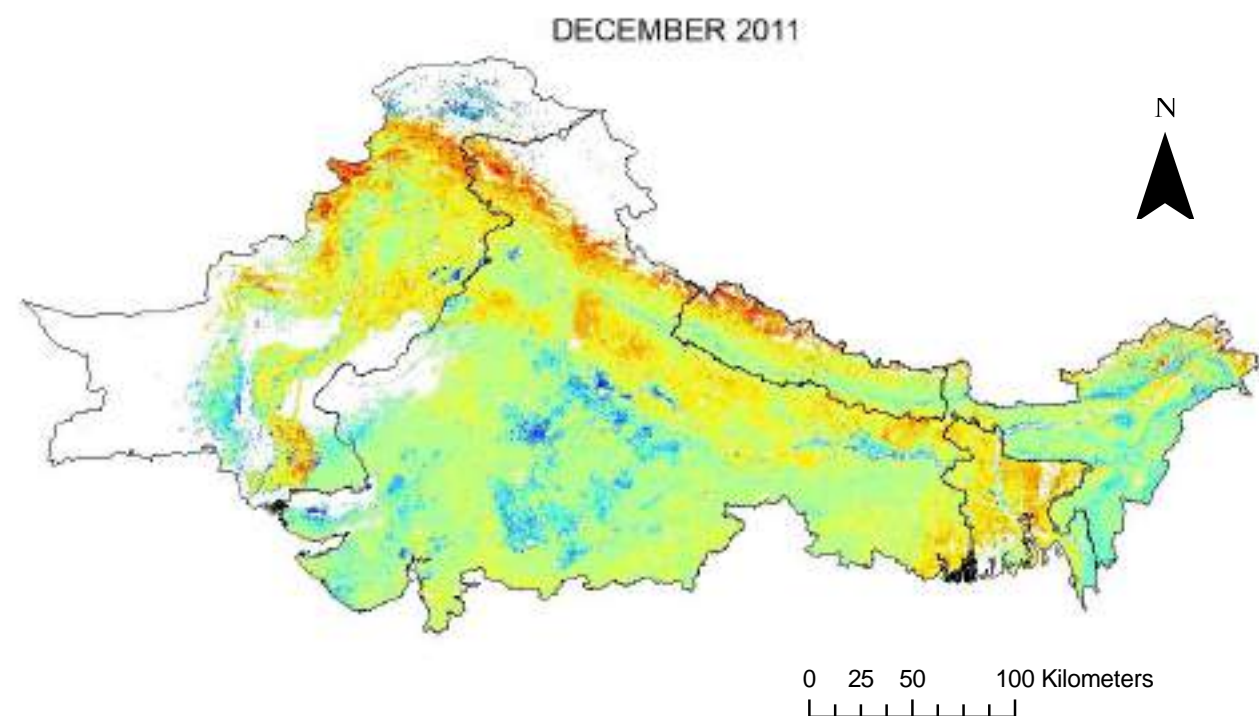
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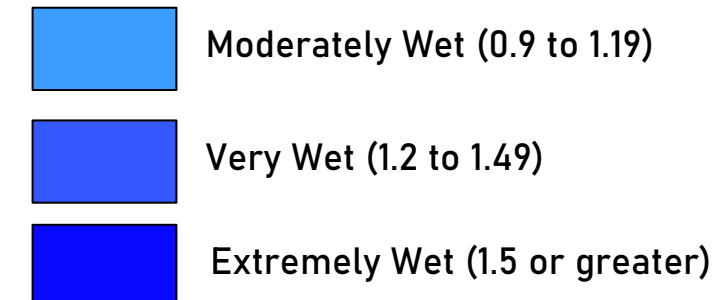
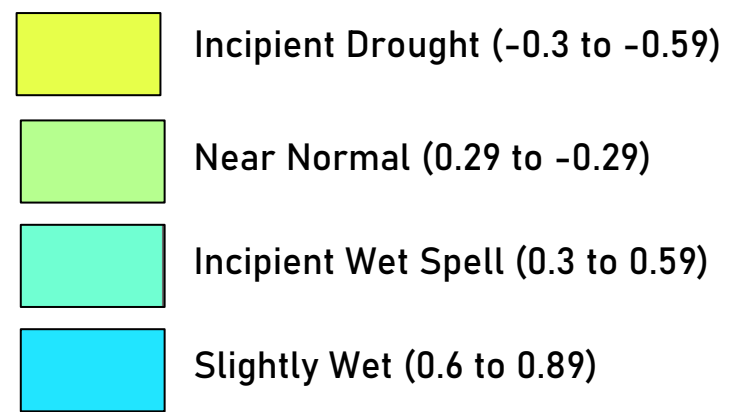
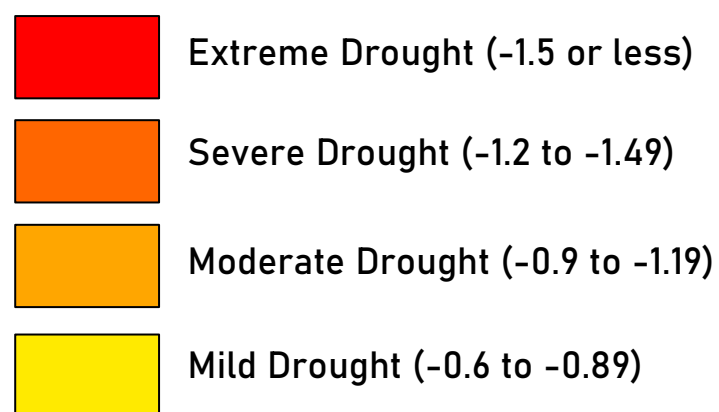


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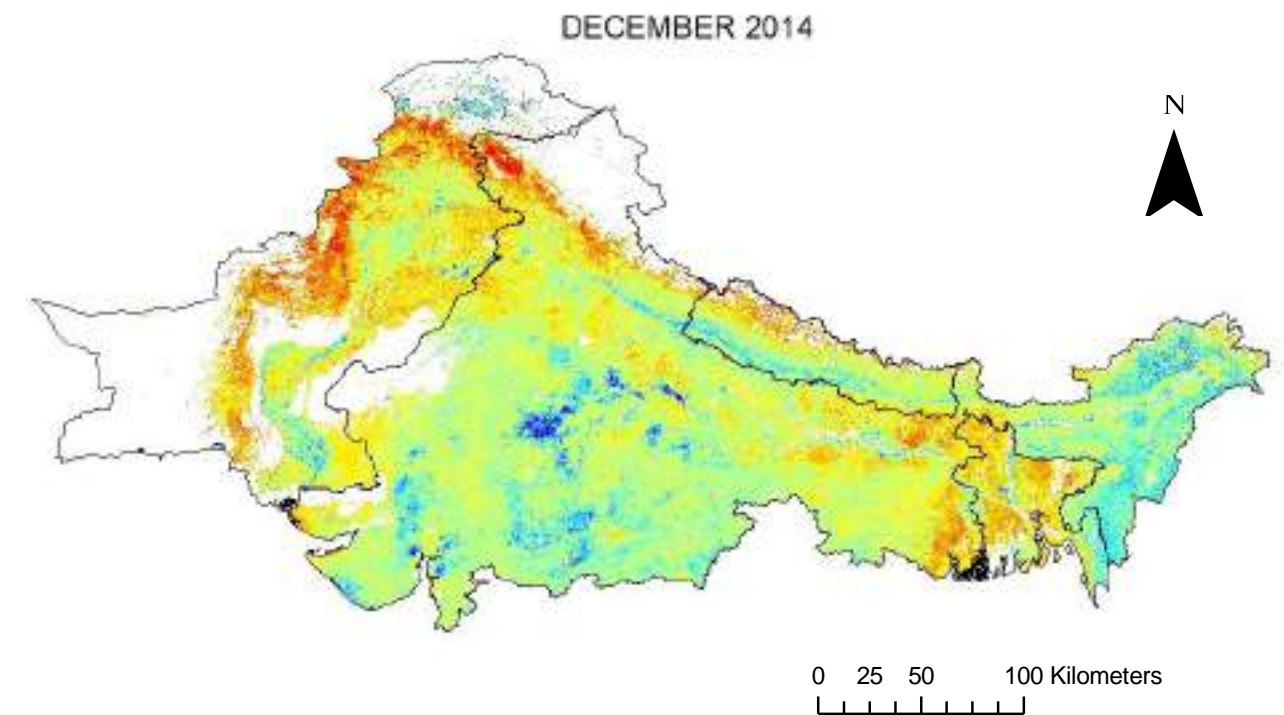
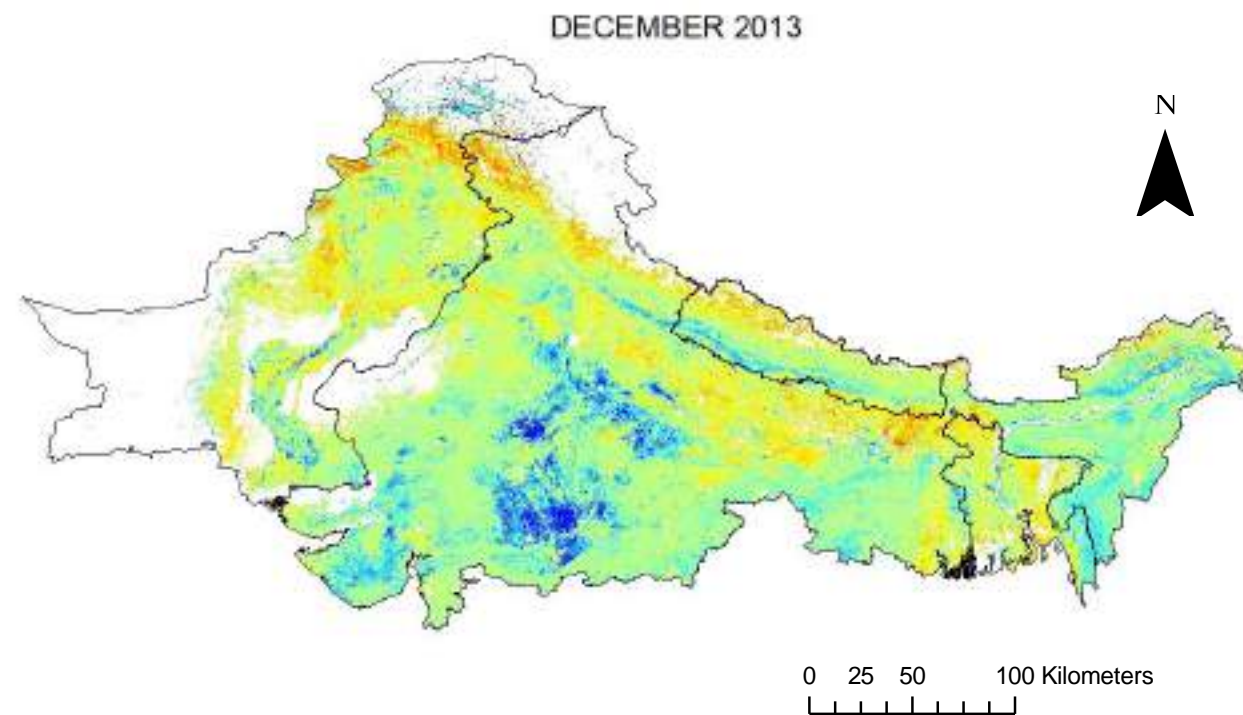




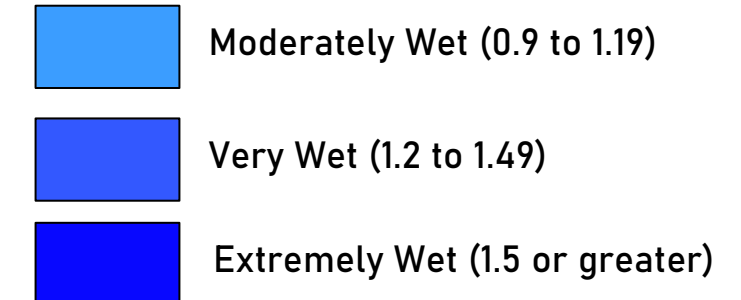
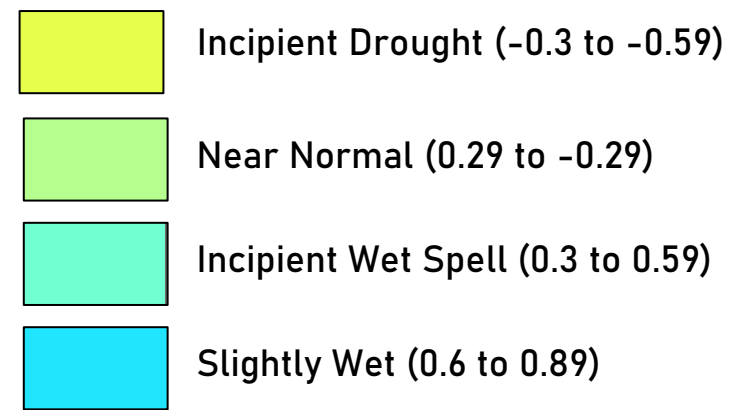
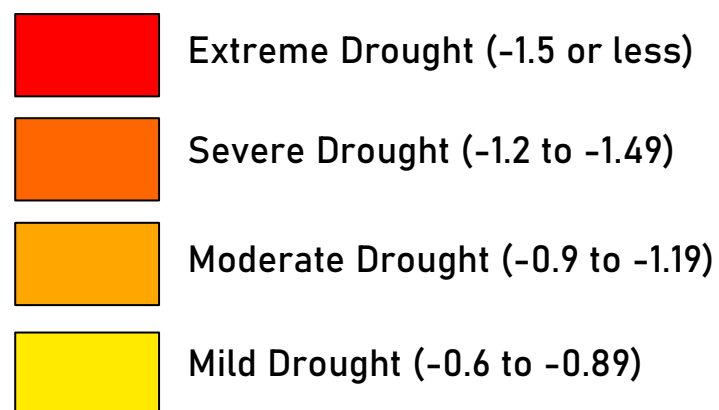
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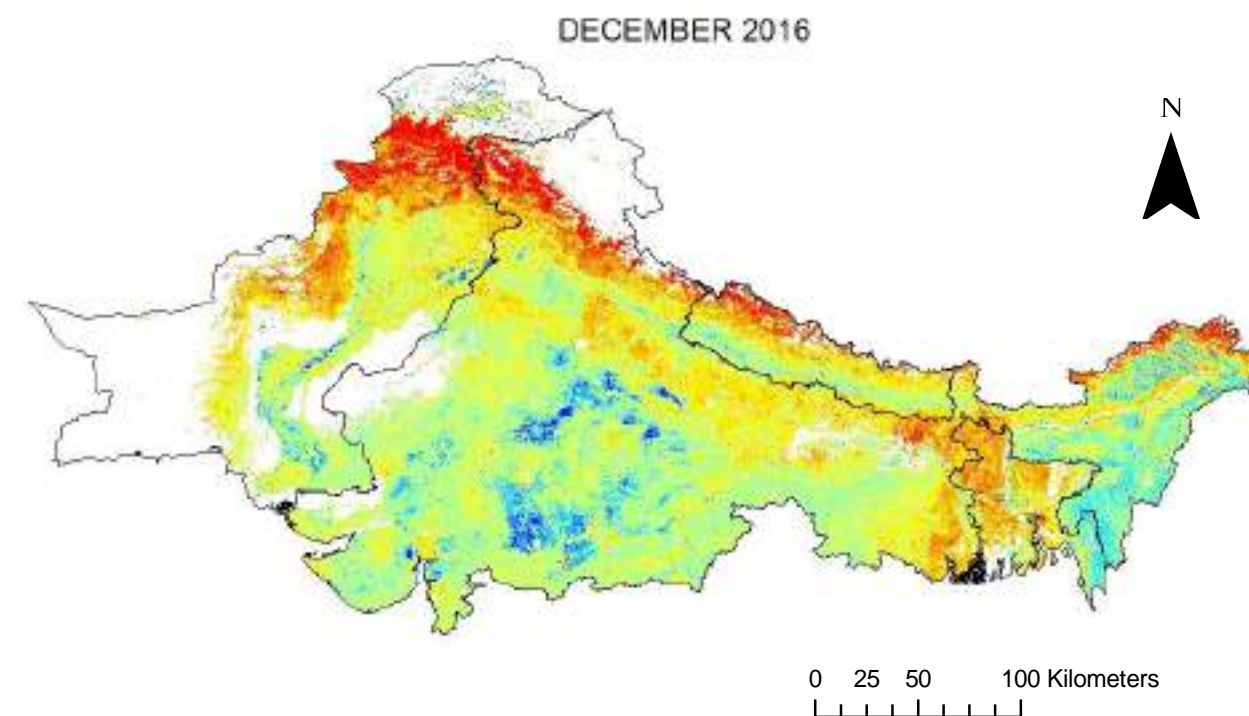
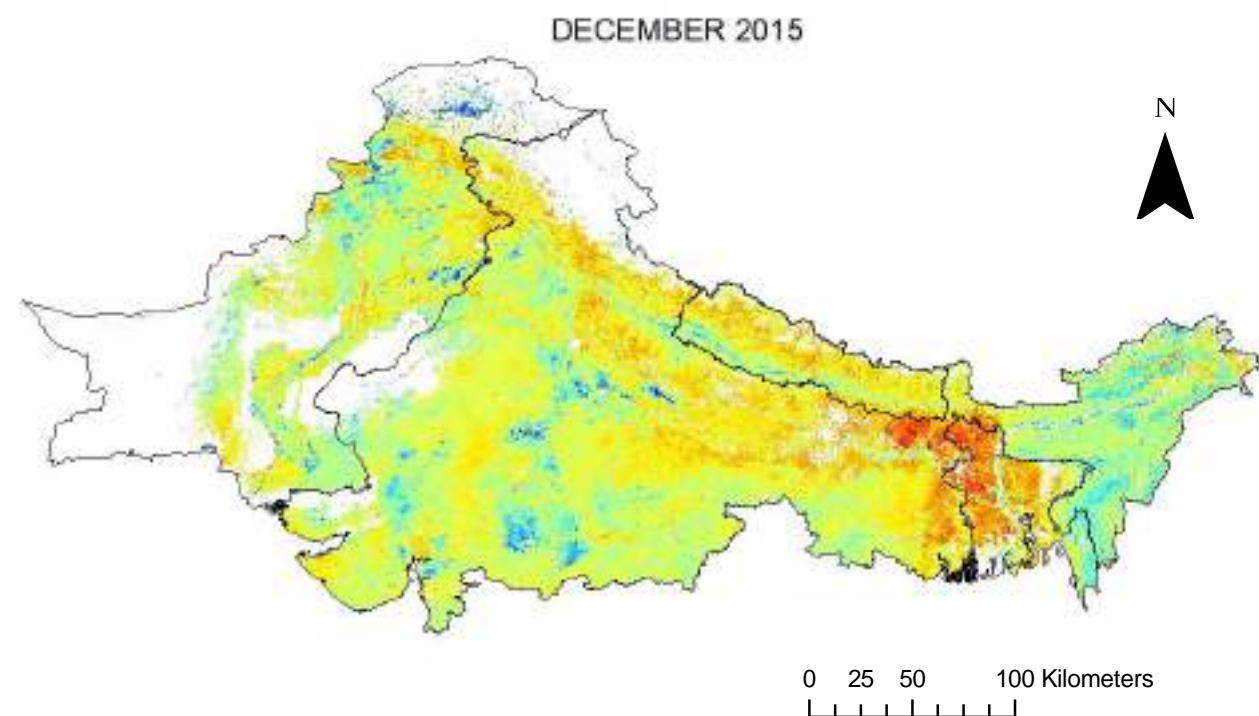




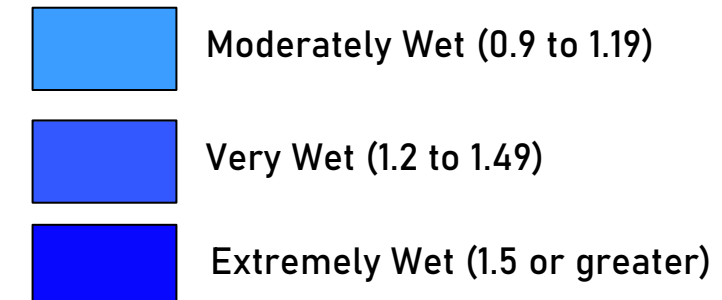
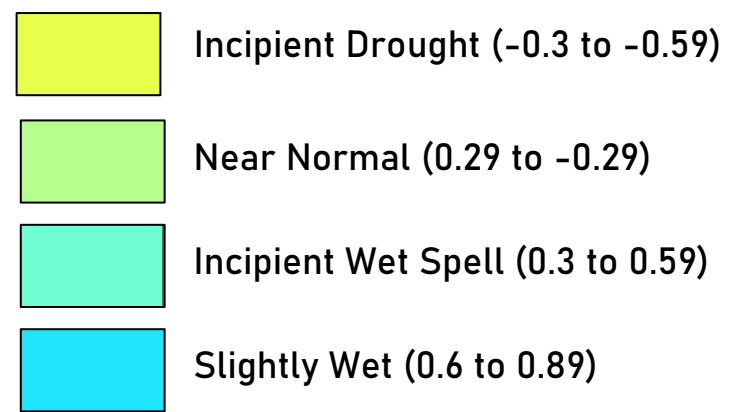
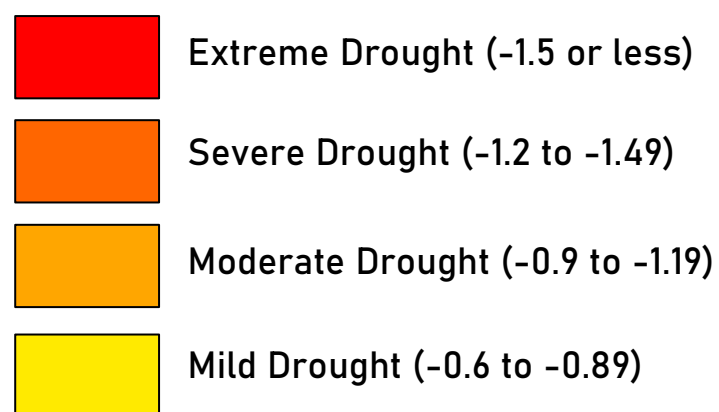


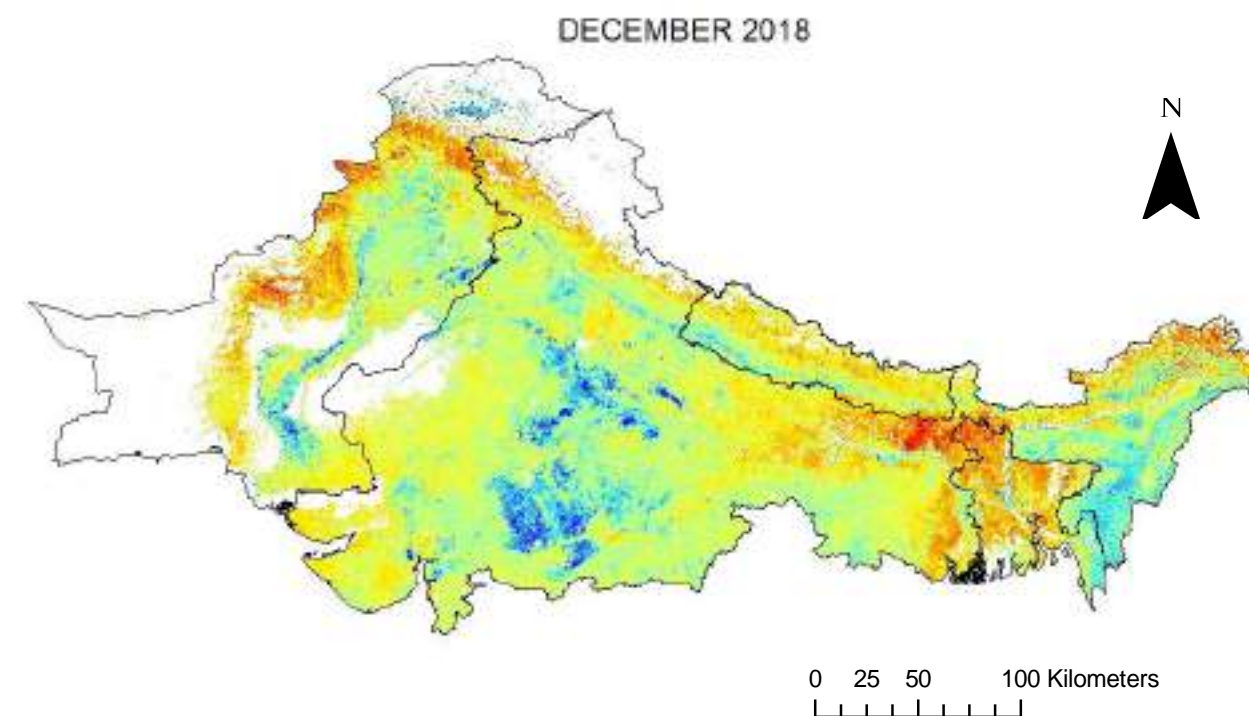
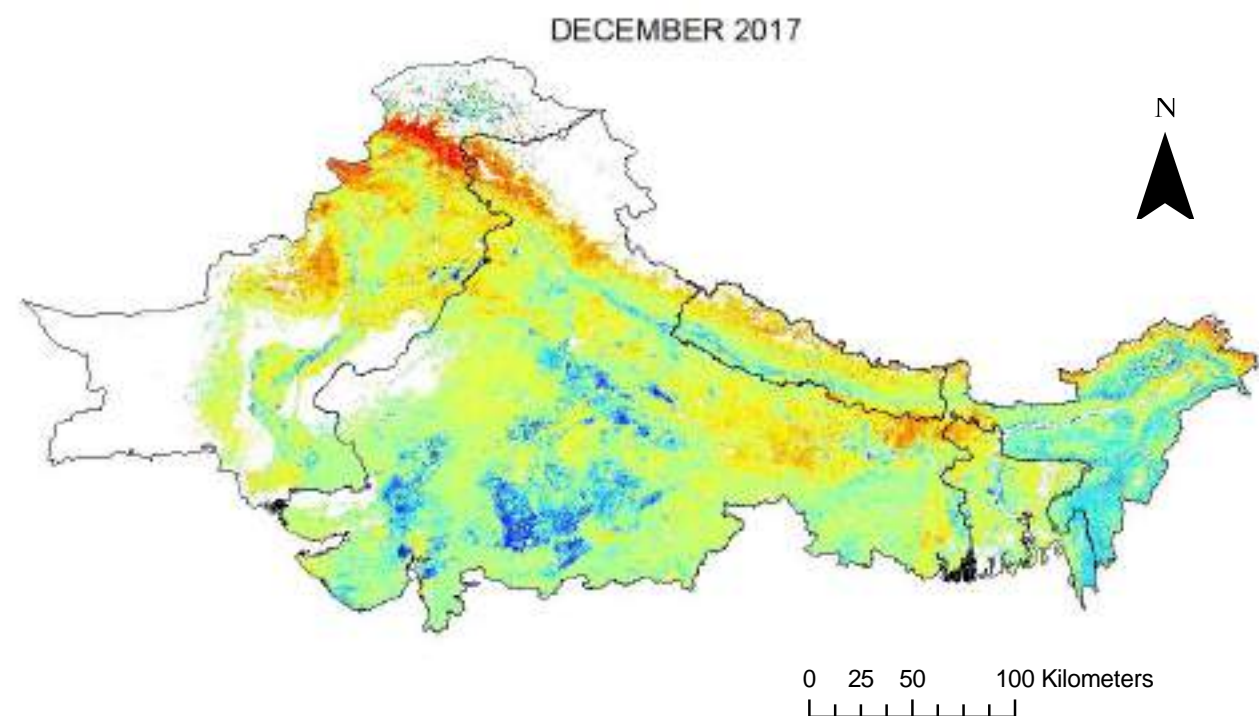
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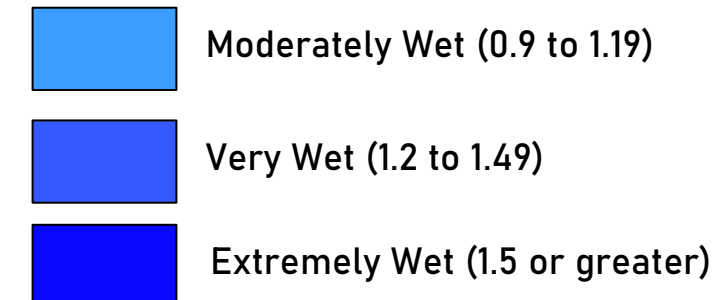
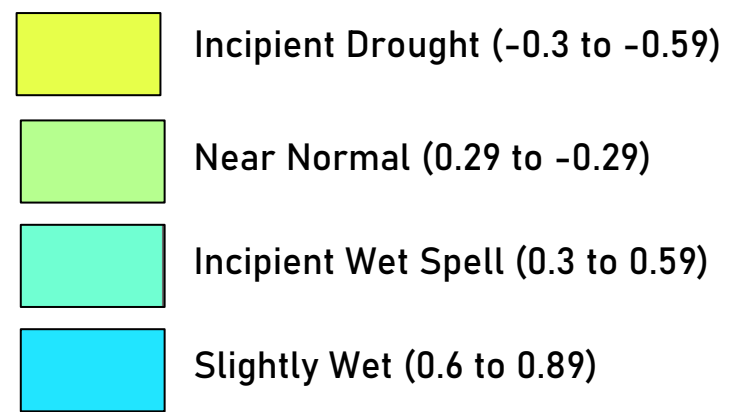
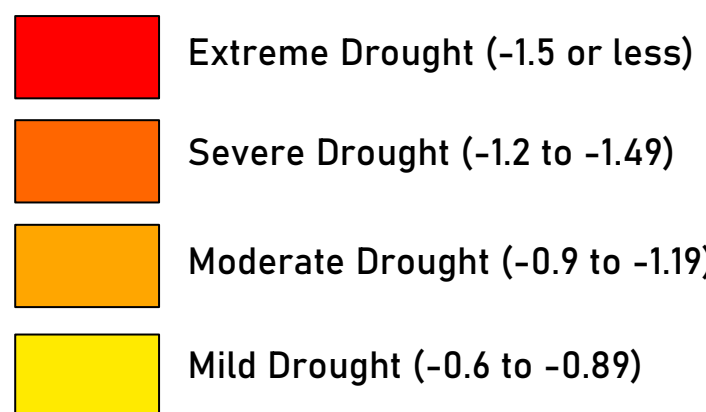


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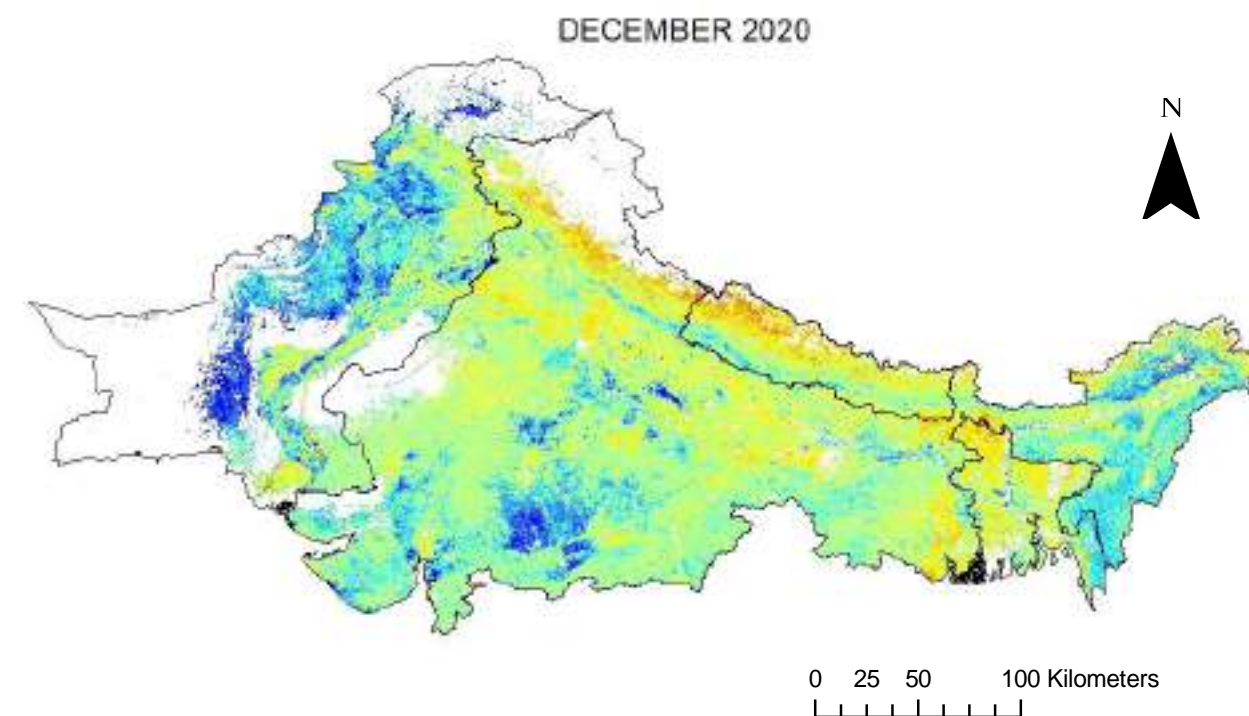
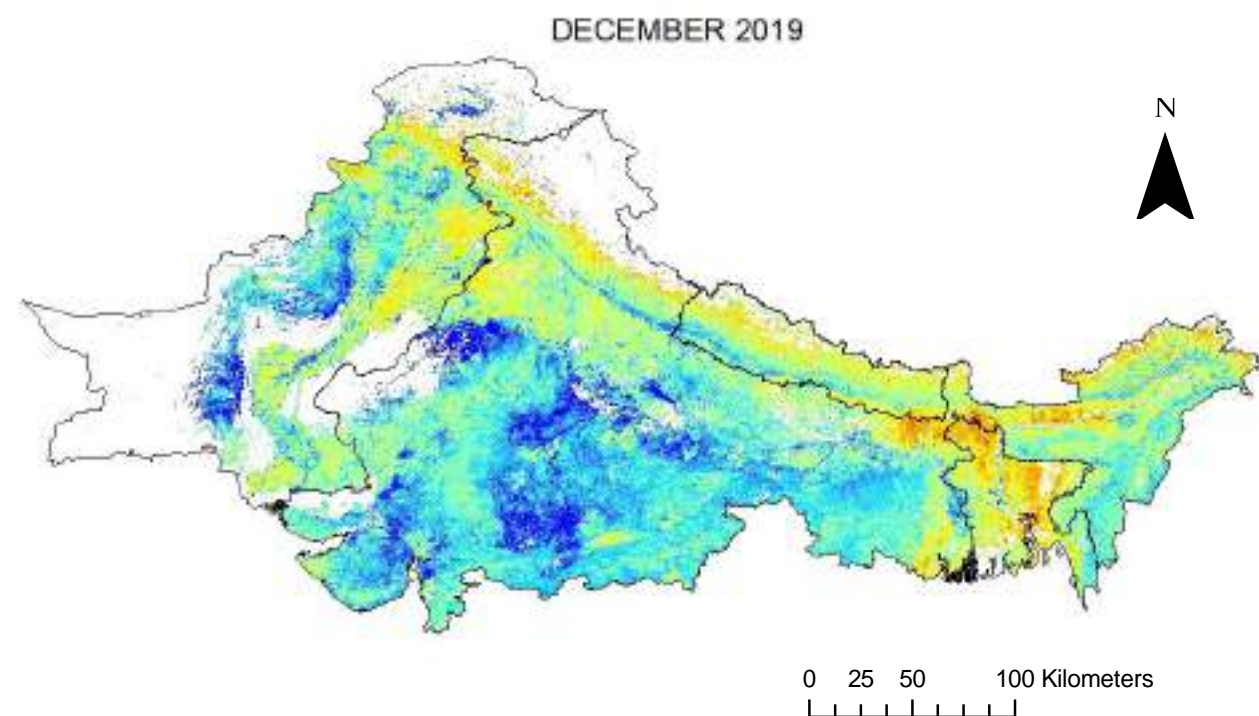




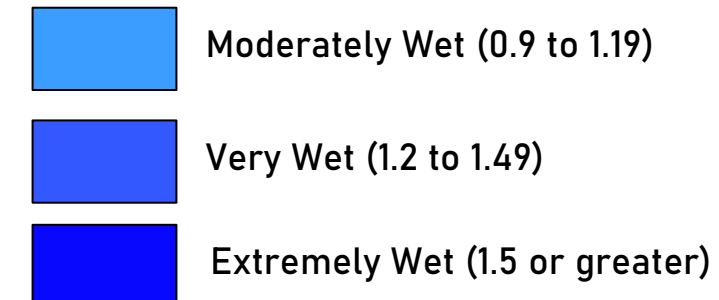
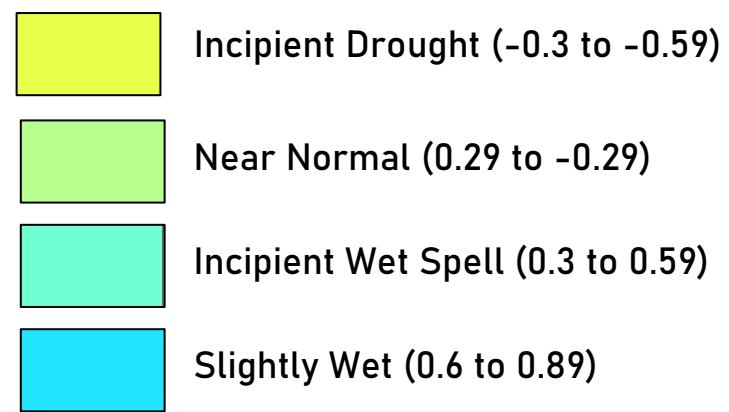
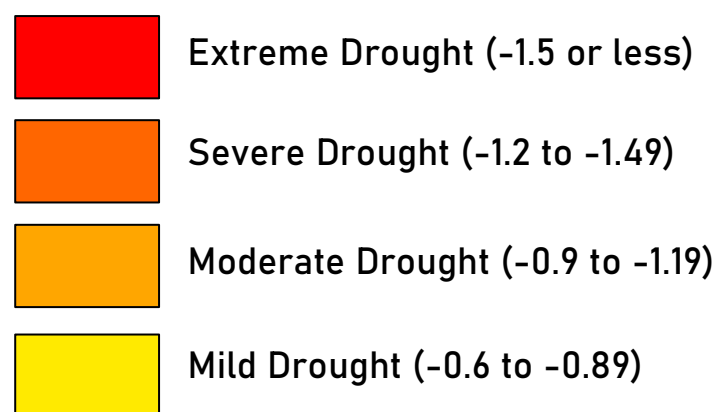
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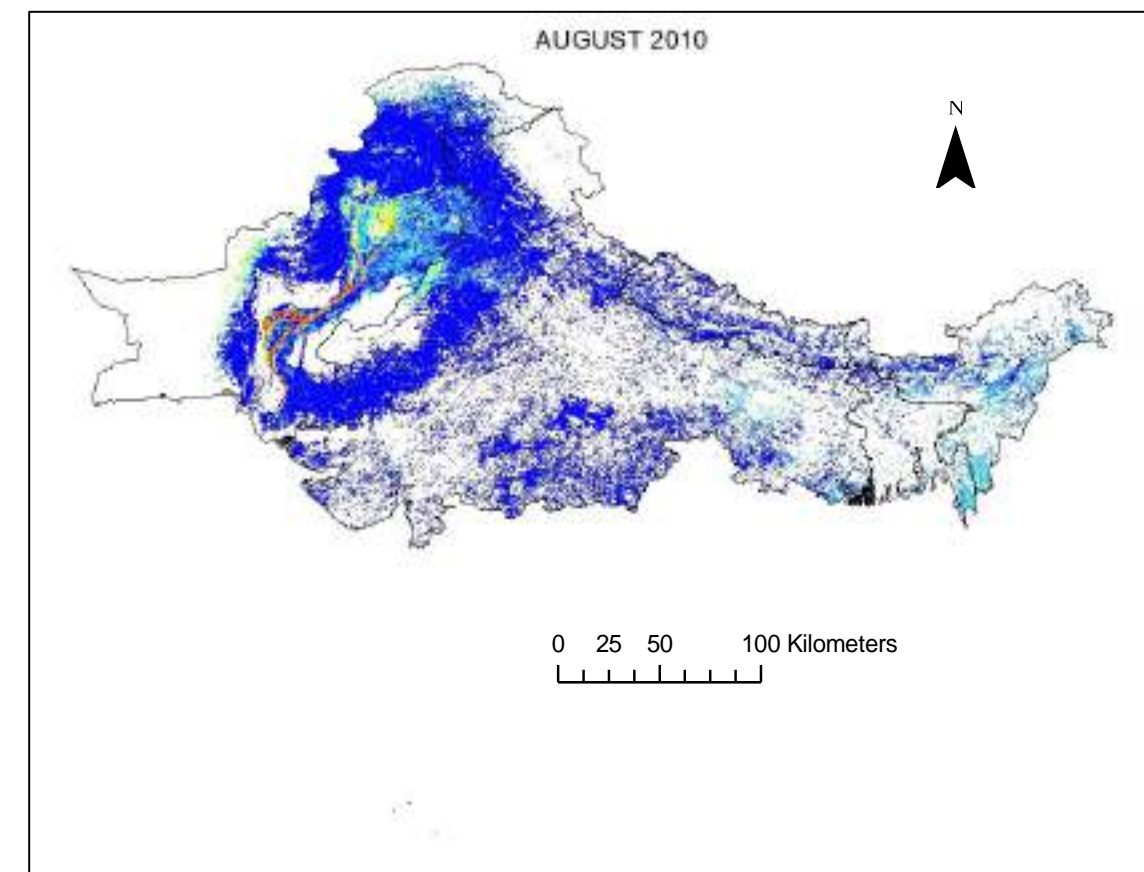
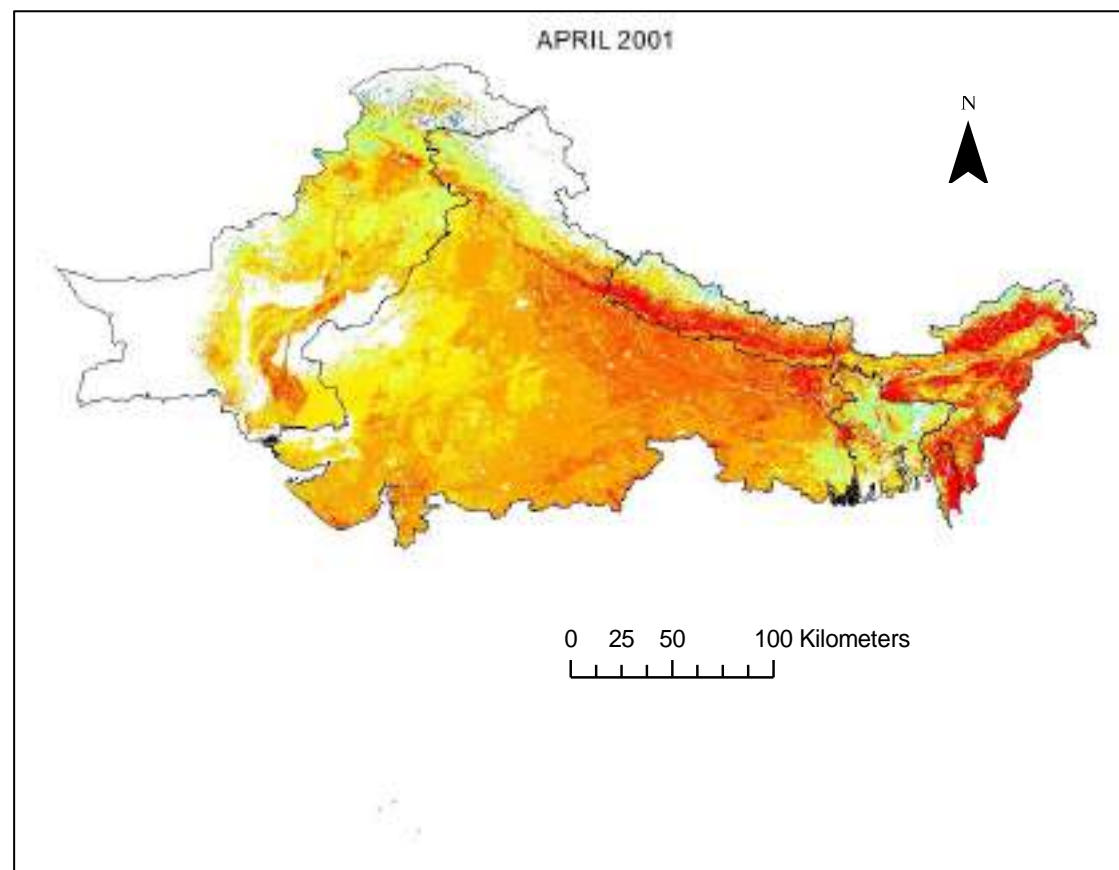
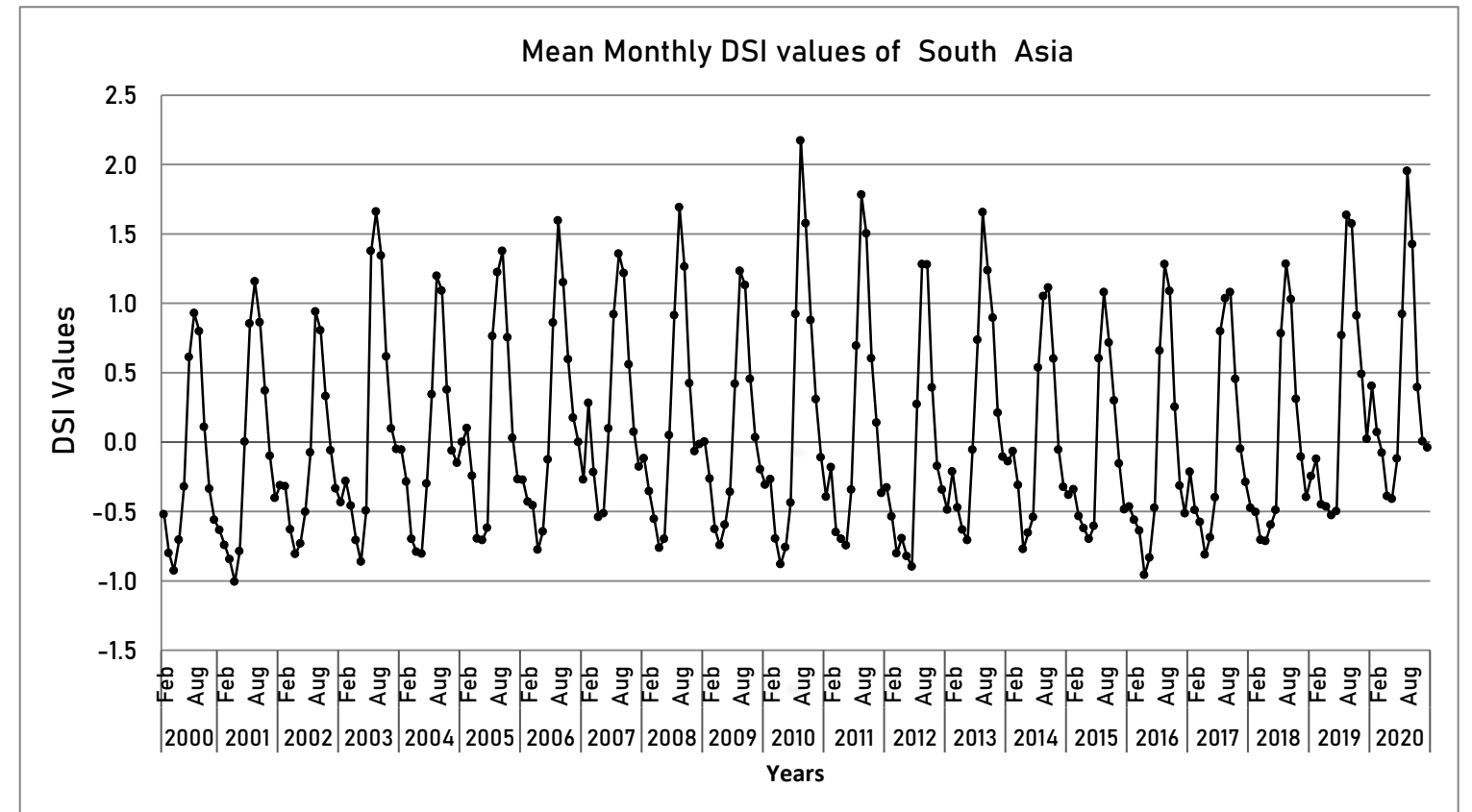
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## Drought Severity Index of South Asia

Given that South Asia's economy is heavily based on agriculture, droughts are one of the biggest threats to the region's agricultural crop production. This atlas illustrates the spatial and temporal aspects of drought using satellite-based MODIS data.

Plotting the mean monthly DSI for South Asia from 2000 to 2020 allowed researchers to examine the temporal features of the DSI. The research period was marked by significant drought, as indicated by the lowest DSI value (-1.01), which was observed in April 2001. The wettest month in 2010 was August (2.17). The worst drought conditions occurred from 2000 to 2002. The hot and dry months of March, April, and May were most affected by moderate to mild drought intensity during the majority of the studied year. August and September was the wettest month as per the DSI values of those months.



## References

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As a result of changing climatic conditions, alter in precipitation events such as drought have emerged as a source of vulnerability in several South Asian nations, including Nepal, India, Pakistan, and Bangladesh. Recent declines in agricultural productivity have weakened rural economies, encouraging widespread famine and urban migration.

Drought monitoring and assessment techniques are used to forecast drought and identify drought-prone areas, allowing drought mitigation measures to be put in place to lessen the impact of drought on food production and water supplies. To estimate the severity of the drought in Pakistan, we applied the Drought Severity Index (DSI), which combines the Normalized Difference Vegetation Index (NDVI) and the ratio of Evapotranspiration to Potential Evapotranspiration (ET/PET).

This Atlas provides an overview of Pakistan's drought frequency during the last two decades. It portrays the spatiotemporal occurrences of drought in Pakistan's several provinces. I hope this atlas will assist in the creation of policies and plans for timely drought mitigation and forecasting in the agricultural sector.

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