# Historical Drought Monitoring and Analysis in Southeastern Tibet Based on Multi-source Data (Postprint)

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## Abstract

Drought, as one of the frequently occurring global natural disasters, has caused severe social, economic, and ecological environmental problems. Taking the major cropping regions of Tibet as the study area and using MODIS, TRMM, and SRTM-DEM data from 2001-2015 as data sources, this study utilizes model parameters such as the Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Precipitation Condition Index (PCI) to construct a regional drought comprehensive monitoring model via spatial principal component analysis; the model' s accuracy and reliability are verified and validated, and the established model is employed to identify monthly drought in the study area from 2001-2015, while geographic spatiotemporal analysis methods are used to investigate drought variation characteristics and trends in the study area. The results indicate that the Drought Comprehensive Monitoring Index (DCMI) can effectively reflect changes in regional soil relative humidity and the Standardized Precipitation Evapotranspiration Index (SPEI), and that the drought comprehensive monitoring model exhibits good applicability; the annual drought frequency in the study area shows a spatial distribution pattern of higher in the west and lower in the east, with drought frequency being less than 20% in most areas and approximately 12.41% of the region experiencing drought frequency exceeding 20%; in terms of occurrence frequency of different drought severity levels, Shigatse City is a prone area for light and moderate drought, while severe drought prone areas are concentrated in the central and eastern parts of Shigatse City and Qamdo City; the spatial pattern of regional inter-monthly drought frequency varies considerably, with drought being prone to occur in months such as January, August, and November throughout the year, though local differences in drought-prone months exist; the intra-annual drought variation trend shows significant regional differences, and from October to September of the following year, areas with intensifying drought exhibit a

gradual shift from the eastern to western parts of the cropping region as months progress.

## Full Text

## Preamble

### Monitoring and Analysis of Historical Drought in Southeast Tibet Based on Multi-Source Data

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**Abstract:** As one of the global natural disasters that occur frequently, drought has caused significant problems for society, economy, and ecological environment. Based on MODIS, TRMM, and SRTM-DEM data from 2001 to 2015 as data sources, this paper takes the main farming area of Tibet Province, China as the research area and constructs a regional drought comprehensive monitoring model using the spatial principal component analysis method and adopting the vegetation condition index (VCI), temperature condition index (TCI), and precipitation condition index (PCI). The accuracy and reliability of the model is verified. The model was then used to identify monthly drought in the study area from 2001 to 2015, and the geospatial-temporal analysis method was used to study the characteristics and trends of drought changes in the study area. The results show that the drought comprehensive monitoring index (DCMI) can better reflect changes of regional soil relative humidity and standardized precipitation evapotranspiration index (SPEI), and the comprehensive drought monitoring model has good applicability. The spatial distribution of annual drought frequency in the west of the study area was higher than that in the east, and the drought frequency in most areas was less than 20%, with about 12.41% of the region having drought frequency more than 20%. From the perspective of frequency of droughts in different grades, Shigatse City was a light drought and moderate drought area, while severe drought areas were concentrated in the central and eastern parts of Shigatse City and Changdu City. The spatial pattern of monthly drought frequency in the study area was quite different. Drought throughout the year was prone to occur in January, August, and November, with differences in drought-prone months in some areas. The change trend of drought in the study area was quite different during a year. From October to September, the drought-intensified area showed a trend of gradually shifting from the east to the west of the cultivated area along the month.

**Keywords:** multi-source data; drought; monitoring; Tibet

## 1. Study Area and Data

### 1.1 Study Area

The study area is located in the main agricultural region of Tibet, covering the valley areas of the Yarlung Zangbo River, Nianchu River, and Lhasa River, with a total area of approximately 51.69×10 $km^2$. The terrain is high in the north and low in the south, with elevations mostly between 3,000-5,000 m, accounting for 97.43% of the total area. The region has a typical plateau temperate semi-arid monsoon climate, with an average annual temperature of 3.6°C, annual precipitation of 420 mm, annual sunshine hours of 2,000 h, and a frost-free period of 100-180 days. According to meteorological station data from 1983-2013, the region experienced 350 drought events, with 308 events occurring in summer and autumn, accounting for 85% of the total.

### 1.2 Data Sources

The primary data sources for this study include MODIS vegetation index products (MOD13A3), surface temperature products (MOD11A2), land cover products (MCD12Q1), TRMM precipitation data (TRMM 3B43), and SRTM-DEM elevation data from 2001-2015. Detailed information is provided in Table 1.

The MODIS data were preprocessed using mosaicking, projection transformation, and resampling to a uniform spatial resolution of 1 km. The TRMM precipitation data were interpolated to 1 km resolution using kriging method. Land cover data were reclassified into six types: cropland, forest, grassland, water bodies, built-up land, and barren land.

## 2. Methods

### 2.1 Drought Monitoring Model Construction

The drought comprehensive monitoring index (DCMI) was constructed using spatial principal component analysis (SPCA) based on three individual indices: VCI, TCI, and PCI. The model building process is shown in Figure 2.

[Figure 2: see original paper]

**Vegetation Condition Index (VCI):** Calculated using NDVI data from MOD13A3 products. The formula is:

$$VCI_i = \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100$$

where $NDVI_i$ is the monthly NDVI value for pixel $i$, and $NDVI_{max}$ and $NDVI_{min}$ are the maximum and minimum NDVI values for the same month across all years.

**Temperature Condition Index (TCI):** Calculated using land surface temperature (LST) data from MOD11A2 products:

$$TCI_i = \frac{LST_{max} - LST_i}{LST_{max} - LST_{min}} \times 100$$

where $LST_i$ is the monthly LST value for pixel $i$, and $LST_{max}$ and $LST_{min}$ are the maximum and minimum LST values for the same month across all years.

**Precipitation Condition Index (PCI):** Calculated using TRMM precipitation data:

$$PCI_i = \frac{TRMM_i - TRMM_{min}}{TRMM_{max} - TRMM_{min}} \times 100$$

where $TRMM_i$ is the monthly precipitation for pixel $i$, and $TRMM_{max}$ and $TRMM_{min}$ are the maximum and minimum precipitation values for the same month across all years.

**Land Cover (LC):** The MODIS land cover product MCD12Q1 was used to mask non-cropland areas, ensuring that drought monitoring focused only on agricultural areas.

### 2.2 Drought Comprehensive Monitoring Index (DCMI)

The DCMI was calculated using spatial principal component analysis to integrate VCI, TCI, and PCI. The first principal component, which explained 68.3% of the variance, was selected as the DCMI after normalization:

$$DCMI = \frac{PC1 - PC1_{min}}{PC1_{max} - PC1_{min}}$$

The DCMI ranges from 0 to 1, with higher values indicating better moisture conditions and lower values indicating more severe drought.

### 2.3 Model Validation

The DCMI was validated using two independent datasets: soil relative humidity data from agricultural meteorological stations and SPEI calculated from meteorological station data.

**Validation with Soil Moisture:** Correlation analysis was performed between DCMI and 10 cm soil relative humidity data from 12 meteorological stations during the growing season (May-September) from 2001-2013. The results showed significant positive correlations ($p < 0.01$) at all stations, with correlation coefficients ranging from 0.423 to 0.537 (Table 4).

**Validation with SPEI:** DCMI was also validated against 1-month, 3-month, and 6-month SPEI values. The correlation analysis showed that DCMI had the highest correlation with 3-month SPEI, with correlation coefficients of 0.515-0.599 ($p < 0.01$) for different months (Table 5).

### 2.4 Drought Classification Standard

Based on the DCMI values and following national drought classification standards, the drought severity was classified into five grades (Table 6).

## 3. Spatiotemporal Analysis of Drought Characteristics

### 3.1 Spatial Distribution of Drought Frequency

The annual drought frequency was calculated for each pixel based on the monthly DCMI values from 2001-2015. The results show that the western part of the study area had higher drought frequency than the eastern part. Approximately 87.59% of the region had drought frequency less than 20%, while 12.41% had drought frequency exceeding 20%. Areas with drought frequency of 20-30% accounted for 11.97% of the region, mainly distributed in the central and eastern parts of Shigatse City and Changdu City. Only 0.44% of the area had drought frequency greater than 30%.

[Figure 4: see original paper]

### 3.2 Seasonal Variation of Drought Frequency

The monthly distribution of drought frequency shows distinct seasonal patterns (Figure 5). Drought was most frequent in January (25.3%), August (22.1%), and November (24.8%). The spatial distribution of drought frequency varied significantly by month.

[Figure 5: see original paper]

### 3.3 Interannual Variation Trends

The Sen' s slope method was used to analyze the trend of DCMI changes from 2001-2015. The results show that 99.46% of the region had a positive slope, indicating an overall improvement in moisture conditions. However, the trend magnitude varied spatially, with stronger positive trends in the western part of the study area (Figure 6).

[Figure 6: see original paper]

Areas with significant positive trends ($p < 0.05$) accounted for 65% of the cultivated land, primarily distributed in the river valleys of the Yarlung Zangbo River and its tributaries. Only 0.54% of the region showed negative trends, mainly in high-altitude areas above 4,500 m.

## 5. Conclusions

This study constructed a drought comprehensive monitoring model (DCMI) based on multi-source remote sensing data (MODIS, TRMM, SRTM-DEM) and validated its accuracy using soil moisture and SPEI data. The main conclusions are:

1. The DCMI, developed using spatial principal component analysis of VCI, TCI, and PCI, effectively integrates vegetation, temperature, and precipitation information. It shows strong correlations with soil relative humidity ($r = 0.423$-$0.537$, $p < 0.01$) and SPEI ($r = 0.515$-$0.599$, $p < 0.01$), demonstrating good applicability for drought monitoring in the study area.
2. The spatial distribution of annual drought frequency shows a clear pattern of higher frequency in the west and lower frequency in the east. Most areas (87.59%) have drought frequency below 20%, while 12.41% of the region experiences drought frequency exceeding 20%. Severe drought areas are concentrated in the central and eastern parts of Shigatse City and Changdu City.
3. The seasonal distribution of drought varies significantly across months, with January, August, and November being the most drought-prone months. The spatial pattern of monthly drought frequency differs throughout the year, reflecting the complex interactions between the monsoon climate and local topography.
4. The interannual trend analysis reveals that 99.46% of the study area shows improving moisture conditions from 2001-2015, with significant positive trends in major agricultural areas. This suggests an overall alleviation of drought severity in the region during the study period.

The DCMI model provides an effective tool for operational drought monitoring in Tibet's agricultural areas, offering valuable support for drought early warning and agricultural water resource management.

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*Note: Figure translations are in progress. See original paper for figures.*