Journal of Global Change Data & Discovery. 2021, 5(4): 1-13
www.geodoi.ac.cn

Global Change Research Data Publishing & Repository

Temperature Vegetation Dryness Index 1-km Grid Dataset in Heilongjiang River Basin (2007–2018)

Zhou, Y. Z.[1,2] Wang. J. L.[1,3*] Li, K.[1,2]

1. State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;
2. College of Geoscience and Surveying Engineering, China University of Mining & Technology (Beijing), Beijing 100083, China;
3. Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing 210023, China

Abstract: Temperature Vegetation Dryness Index（TVDI）is the metric parameter which can estimate the status of land surface soil moisture so as to reflect the drought level of the region. The area covered by this dataset is Heilongjiang River Basin, the time series is from April to October (Vegetation growing season) during 2007-2018. The dataset is obtained by the combination formed by TVDI calculation model and the data of monthly normalized differential vegetation index (NDVI) MODIS13A3, 8-day synthesized land surface temperature (LST) MOD11A2 and ASTER-DEM data. The dataset is in GeoTiff format, with a spatial resolution of 1 km and consists of 84 files, the data size is 362MB.

Keywords: Heilongjiang River Basin; Growing season; Temperature Vegetation Dryness Index; General NDVI-LST feature space

DOI: https://doi.org/10.3974/geodp.2021.04.01
CSTR: CSTR:20146.14.2021.04.01

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2021.05.02.V1 or CSTR:20146.11.2021.05.12.V1.

1 Introduction

The Heilongjiang River Basin located in the northeastern Asia (Figure 1). The basin is converged by two sources of Argun river (south) and Shilka river (north) in the west of Mohe county, Heilongjiang Province. After Containing several Russian tributaries named Zeya, Bureya and Amgun with Chinese tributaries named Songhua and Ussuri, the basin finally afflux into Tartar Strait. The area of basin is 2,083,345.35 km^2[1,2], It ranks 10th in the world in terms of river basin area[1]. As one of the most important boundary rivers in the

Received: 24-04-2021; **Accepted:** 23-06-2021; **Published:** 20-10-2021
Foundations: Chinese Academy of Sciences (Y9X90050Y2); Chinese Academy of Engineering (CKCEST-2020-2-4)
***Corresponding Author:** Wang, J. L., Institute of Geographic Sciences and Natural Resources Research, wangjl@igsnrr.ac.cn.
Data Citation: [1] Zhou, Y. Z., Wang, J. L., Li, K. Temperature vegetation dryness index 1-km grid dataset in Heilongjiang River Basin (2007–2018) [J]. *Journal of Global Change Data & Discovery*, 2021, 5(4): 1-13. https://doi.org/10.3974/geodp.2021.04.01. CSTR:20146.14.2021.04.01.
[2] Zhou, Y. Z., Wang, J. L. Temperature vegetation dryness index 1-km grid dataset in Heilongjiang River Basin (2007–2018) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2021. https://doi.org/10.3974/ geodb.2021.05.02.V1. CSTR:20146.11.2021.05.12.V1.

world, its cross-border section is nearly 4,000 km and connects 15 first-level administrative regions of China, Mongolia, Russia and North Korea. Therefore, the changes in its internal resources and environment have a significant impact on the ecological development of the regions along the economic corridor of China, Mongolia and Russia. In recent years, drought events occurred frequently in various regions of the basin, which increased the risk to various fields, especially food security in the areas along the river [3–5]. Through multi-source data and scientific research methods, long-term drought monitoring was carried out along the Heilongjiang River basin, this will help to provide scientific reference and basic support for the implementation of drought prevention and future risk assessment in this basin, and contributing to cooperative control and international cooperation of managing the dryness disaster events in the areas which covered by the catchment.

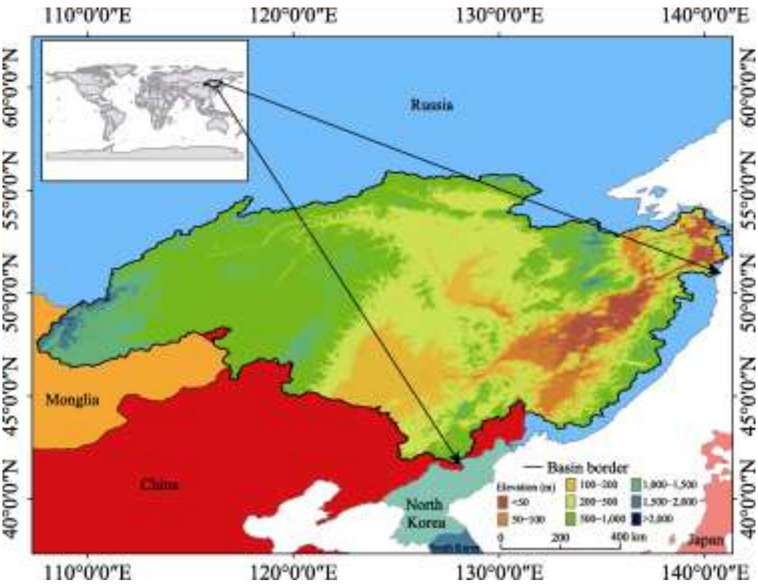

Figure 1 Geographical location and elevation classification of Heilongjiang River basin

Drought monitoring and early warning have gradually become a hot topic of concern and research in academic circles in recent years. The early research method in this field is to collect meteorological, hydrological, and soil moisture data such as precipitation, temperature, evapotranspiration, and shallow soil moisture monitored by the site, and perform statistical analysis based on various drought evaluation indicators to quantify the degree of drought in the study area[6]. Because the site is affected by factors such as natural environment and economic costs, the monitoring data volume is limited and the spatial distribution is uneven. Therefore, the quality of the results obtained by the site data in the process of monitoring drought is affected in terms of time, space, and efficiency. The mature development of related technologies in the field of remote sensing makes it possible to integrate research with traditional methods. The new method can efficiently, objectively, and economically complete the extraction of aridification information in a multi-scale range[7]. In the drought monitoring and evaluation based on remote sensing technology, the correlation index with vegetation index and surface temperature as evaluation factors is more common[8]. Among them, the Temperature Vegetation Dryness Index (TVDI) was originally proposed by Sandholt *et al*.[9]. The principle of the index model is to estimate the soil surface moisture status based on the correlation between the vegetation index and the surface temperature and then reflect the area in which it is located the degree of drought [10]. Relevant scholars have used the index to conduct a large number of drought monitoring applications at the geographic unit level, national level, regional level, provincial and municipal level, and other spatial scales. For example, Cao Xiaoming and others have used the TVDI method to monitor the Mongolian Plateau for nearly 40 years of long-term drought monitoring.

The research results show that the use of this index can effectively reflect the drought and its evolution characteristics in large-scale areas[11]. Cong *et al.*[12] conducted a combined analysis based on the calculation results of the TVDI and the 10 cm soil moisture data monitored by the site and verified that it is feasible to use this index to monitor the dynamic drought of the whole year in Northeast China. Qin *et al.* [13] used TVDI to monitor and evaluate the drought characteristics of the growing season in Inner Mongolia since 2000 and combined the temperature and precipitation in the corresponding period to discuss the trend and magnitude of the impact of changes in climatic conditions during the period. However, when the TVDI is used to monitor drought in large-scale areas, due to the influence of surface elevation fluctuations and excessive longitude and latitude spans, there is a large deviation between the surface temperature data and the actual situation, which affects the evaluation effect of the corresponding feature space and reduces the accuracy of inversion of surface soil moisture data by TVDI[14].

In response to this problem, Liu *et al.*[15] used the digital elevation data of the study area and carried out a topographic correction on Ts in the process of constructing a variety of common vegetation index (VI)—surface temperature (Ts) feature spaces, which reduced the influence of terrain factors on the surface energy balance, and significantly improves the effect of inversion of soil surface moisture in large-scale areas based on the TVDI.

2 Metadata of the Dataset

The metadata summary of the dataset[16] is summarized in Table 1, which includes the dataset full name, short name, authors, year, temporal resolution, spatial resolution, data format, data size, data files, publisher, and sharing policies, etc.

3 Methods

Remote sensing data prepared for the dataset include the products of monthly normalized differential vegetation index (NDVI) MODIS13A3[18] and 8-day synthesized land surface temperature (LST) MOD11A2[19], the temporal extent is from April to October (Vegetation growing season) during 2007–2018. (NDVI class include the data from day 97 of the year 2000 to day 305 of the year, LST class include the data from day 89 of the year 2000 to day 305 of the year), The row and column number of Images include h24v03, h25v03-04, h26v03-04 and h27v04; The elevation data include elevation Cluster Dataset Covering the Heilongjiang River Basin[20]; Meteorological data include the dataset of remote-sensing-based surface soil moisture[21] and monthly precipitation data, 10-day soil-moisture data counted by the sites[22,23].

3.1 Algorithm Principle

Temperature Vegetation Dryness Index (TVDI) is a kind of method for monitoring soil moisture based on NDVI-LST feature space[9], Its calculation formula is as follows:

Table 1 Metadata summary of the Temperature vegetation dryness index 1-km grid dataset in Heilongjiang River Basin (2007—2018)

Item	description
Dataset full name	Temperature Vegetation Dryness Index 1-km Grid Dataset in Heilongjiang River Basin (2007–2018)
Dataset short name	TVDI_AmurRiverBasin_2007-2018
Authors	Zhou, Y. Z., Institute of Geographic Sciences and Natural Resources Research, zhouyz@lreis.ac.cn Wang, J. L., Institute of Geographic Sciences and Natural Resources Research, wangjl@igsnrr.ac.cn
Geographical region	Heilongjiang River Basin: 41°42′N –55°56′N, 107°31′E –141°14′E, Including15 first-level administrative regions of China, Mongolia, Russia and North Korea
Year	2007–2018
Temporal resolution	monthly
Spatial resolution	1 km
Data format	.tif
Data size	319 MB (after compression) The dataset includes 84 monthly temperature vegetation dryness index data files, the format of filename is TVDI.YYYYMM.1_km_monthly.tif
Foundation item	Special Exchange Program of Chinese Academy of Sciences (Y9X90050Y2); China Knowledge Center for Engineering Sciences and Technology (CKCEST-2021-2-18)
Computing environment	ENVI, ArcGIS
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11 A Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset [17]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

$$TVDI = \frac{T - T_{\min}}{T_{\max} - T_{\min}} \tag{1}$$

$$T_{\min} = a \times NDVI + b \tag{2}$$

$$T_{\max} = c \times NDVI + d \tag{3}$$

where T is the surface temperature of any pixel, and $Tmax$ and $Tmin$ are respectively the lowest and the highest surface temperatures corresponding to a certain NDVI, a, b, c, d are respectively the undetermined coefficients and the value range of TVDI is [0, 1].

In the NDVI-LST theorical feature space, when the land cover conditions in the study area meet the conditions from bare land to full vegetation, and the soil water content meet the conditions from complete drought to full water storage, the scatter plot of this index approximately turn to triangular or trapezoidal.[24]. But in the actual cases, for the land cover types of monitoring area and various aspects of other factors, physical condition often cannot completely satisfy the terms needed for theoretical feature space, and therefore in the process of feature space construction based on single-period remote sensing image, scatter data of the dry and wet edges cannot completely cover the theoretical feature space boundary.

In view of this problem, the land cover and soil water content in the monitoring area will change greatly in a long time series. Therefore, the general feature space was built by extreme value composite method based on long-time contemporaneous data, the building scheme can include areas within different period of land cover changes and soil moisture, so as to approximately get the setting conditions of land surface coverage and water content in the theoretical feature space. This measure can effectively improve the low feedback to drought conditions.

According to the above theories, relevant scholars have verified the feasibility and superiority of the scheme on drought monitoring in different regions[24,25]. In this study, correlation analysis was conducted between the mean 10-cm soil moisture values and the calculation based on the single and general feature space in representative months of the growing season (April, July and October) in domestic provinces (Heilongjiang, Jilin and Inner Mongolia) during 2007–2012 (Figure 2).

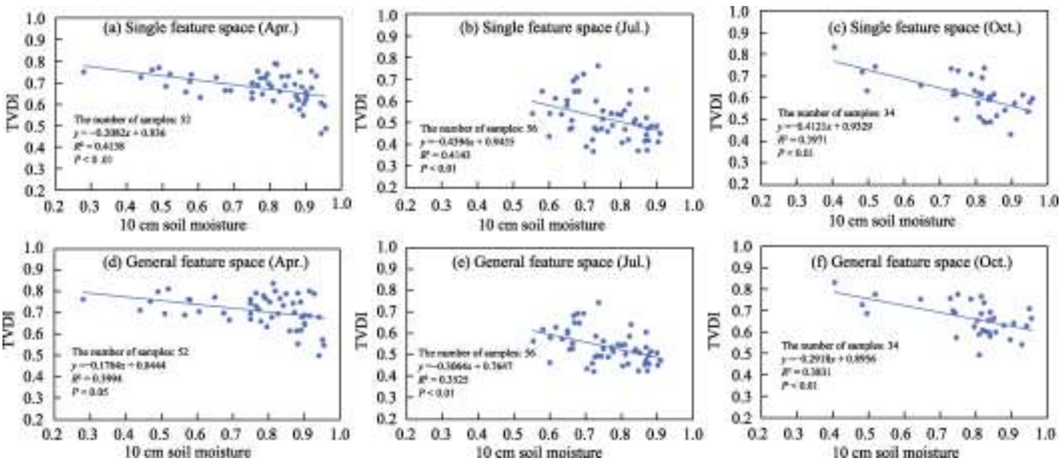

Figure 2 Comparison of correlation results based on single/general feature space

The results showed that: The correlation coefficient of single feature space is 0.352,5 at the minimum and 0.399,4 at the maximum. In comparison, the results of general feature space increased in the same period, with the minimum value being 0.397,1 and the maximum value being 0.413,8. The TVDI results were more strongly correlated with the measured values than using single feature space. In this study, the changes of LST extreme values based on general feature space method and the dry-wet edge fitting equations are shown in Table 2 and Figure 3.

Table 2 Monthly dry-wet edge fitting equations in Heilongjiang River Basin

Month	Dry edge fitting equations	Wet edge fitting equations
April	$y = –20.234x + 52.094$	$y = 12.216x – 6.9245$
May	$y = 11.838x – 6.7406$	$y = 11.441x – 2.8382$
June	$y = –6.7647x + 54.671$	$y = 0.7518x + 12.232$
July	$y = –11.188x + 62.355$	$y = –3.6056x +21.516$
August	$y = –20.381x + 68.587$	$y = –3.8234x + 22.905$
September	$y = –6.9896x + 40.358$	$y = 8.3332x – 8.3254$
October	$y = –12.249x + 26.295$	$y = 4.1039x – 18.233$

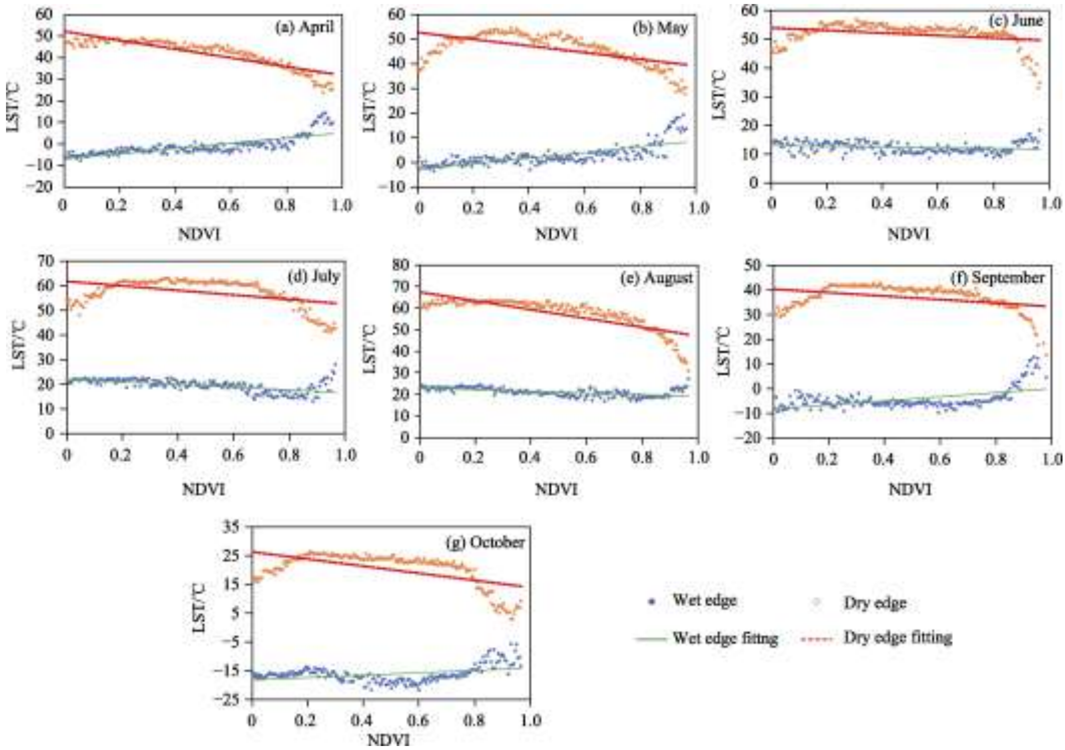

Figure 3 The general feature space of growing season in Heilongjiang River Basin

3.2 Technical route

Data processing progress includes original NDVI and LST data preprocessing, spatio-temporal sequence reconstruction, NDVI-LST general feature space building and evaluation of TVDI calculation results (Figure 4).

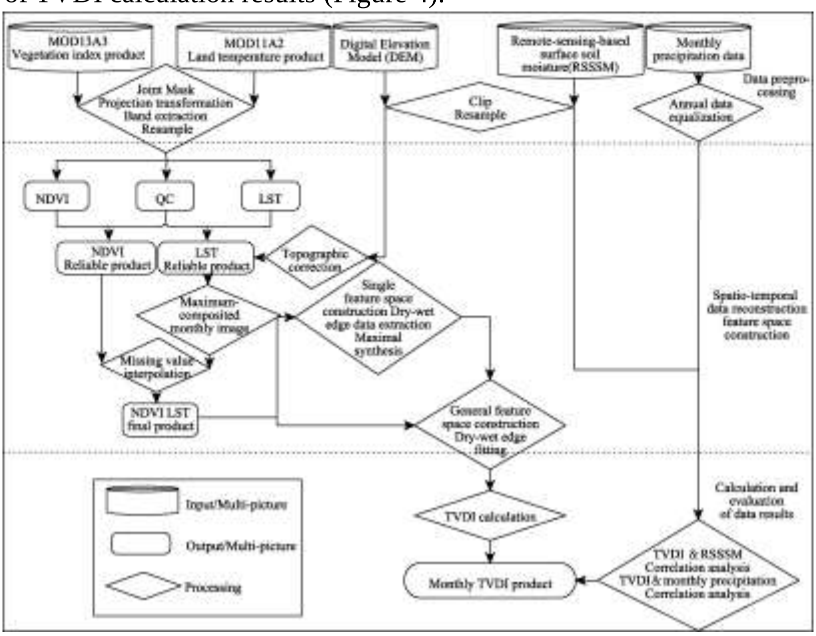

Figure 4 Flowchart of the TVDI research algorithms

Data preprocessing is mainly composed of fractional data splicing, projection conversion, band extraction and pixel resampling. The reconstruction of spatio-temporal data series includes spatial interpolation, terrain correction, time-series completion and unification. The part of general feature space construction mainly includes the extraction of dry and wet points in single space and the extreme value composite of the general dry and wet edges. TVDI calculation and evaluation is to analyze the correlation between the calculation results with meteorological data in the study area to verify its monitoring applicability.

(1) Data preprocessing

For the remote sensing data products obtained in this dataset, the data format of vegetation index and land surface temperature products is. hdf, and the projection method is sinusoidal projection. In order to directly reflect the information contained in the two types of data, we set relevant parameters in the MODIS Rejection Tool (MRT), convert the projection to the geographical type based on WGS 84, The nearest neighbor sampling method which is suitable for continuous data resampling was selected to set the pixel size as0.008,333,333,3 degrees (the spatial resolution after unit conversion was 1 km), and the normalized vegetation index (NDVI), land surface temperature (LST) and the quality control data band QC were selected. Finally, the above bands were set as Geotiff format for output.

Based on the function of ArcPy in ArcGIS software, combined with the boundary file of Heilongjiang River Basin and the QA value of MODIS product and the band data QC, the batch clipping and mask of above data were carried out, and the unreliable pixels were removed to generate the high-quality datasets in the study area.

(2) Spatio-temporal sequence reconstruction

Data sequence reconstruction is mainly manifested in two aspects of time and space, in time segments, the time scales of different data are unified by the extreme value synthesis and make up the observed value losses under the influence of the bad weather conditions. In the spatial part, we interpolate missing or unreliable pixels and combine digital elevation model to simulate the terrain correction so as to weaken the influence of topographic factors on the deviation of observed values.

A. Data time-series unification

Since the temporal resolution of the final generated product is month and the availability of LST data is greatly affected by cloud covering, the MOD11A2 data product is converted from the original 8-day to the monthly scale. The processing method is to assign the pixel value to the maximum through the maximum composite method of the four images.

B.Reliable pixel value extraction and unreliable pixel value interpolation

According to the QA value in MODIS NDVI data quality specification and the bit flag information in LST quality control band data (QC), the target pixels were extracted in batch by using Python language based on the trusted pixel types specified in the above data.

For the pixel in depletion and unreliable-quality, using condition function ‘con’, judgement function ‘isNull’ and statistical function ‘Focal Statistics’ to do the interpolation task. The code is wrote as ‘Con (IsNull (“raster”), FocalStatistics (“raster”, NbrRectangle (5,5, “CELL”), “MEAN”), “raster”)’. In the sentence, the value of NbrRectangle (5,5, “CELL”) is the length of a square centered on the target pixel, setting according to the actual situation.

C.Terrain correction processing

In this part, the terrain of the study area is corrected based on the classical C-correction model [13]. Firstly, slope and aspect data are extracted from ENVI software using DEM data. Then, based on the Bandmath function in the software combined with IDL language, slope matching and correction were carried out twice for all kinds of slope areas to eliminate the relationship deviation between the DN value of the land surface temperature data and the solar incidence Angle caused by atmospheric scattering and surface reflected light refraction, so as to improve the data accuracy and output the final result.

(3) NDVI-LST general feature space construction

In this part, the specific processing method is to use NDVI and LST images in the same month of each year in the research period to construct a monthly single feature space and extract the maximum LST values of each point along the horizontal axis (NDVI value) with step size of 0.005 along the dry and wet edges. Finally, these values were used as extreme values to calculate the maximum LST values in the corresponding period of each year to construct general feature space and generate dry and wet edge fitting equations.

(4) The calculation and evaluation of TVDI

According to the coefficients of the dry-wet boundary and equations (1)–(3), the monthly TVDI in the growing season from 2007 to 2018 was calculated. Then, the correlation analysis was conducted between the results and the measured data related to surface soil moisture content to evaluate the quality and effect of this data product.

4 Data Results and Validation

4.1 Data Composition

The 1-km Grid TVDI dataset in Heilongjiang River Basin is a single wave band package of files. The data format is set as TVDI.YYYYMM.1_km_monthly.tif, the specific respective meanings are:

(1) TVDI: represents the temperature vegetation drought index product;

(2) YYYYMM: represents that the production time is MM month of YYYY year;

(3) 1_km: represents that the product spatial resolution is 1 km;

(4) month: represents that the product is monthly data. Among them, TVDI ranges from 0 to 1, and is magnified 10,000 times during storage.

The pixel value ranges from 0 to 10,000 and the multiplication factor is multiplied by a scale factor of 0.000,1.

Table 3 Attribute information of the product

Number	Attribute	Value
1	Data type	unsigned int16
2	row	4,045
3	column	1,708
4	Pixel value	0–10,000
5	Pixel size	0.008,333,333,3、0.008,333,333,3
6	Padding value	65,535
7	Applied proportionality coefficient	0.000,1
8	coordinated system	WGS84

4.2 Data Results

The monthly drought situation in Heilongjiang River Basin during 2007–2018 is divided into 5 levels based on the calculation result[25]: Wet(TVDI∈[0,0.2], Normal

(TVDI∈(0.2,0.4]), Slightly drought (TVDI∈(0.4,0.6]), Medium drought(TVDI∈(0.6,0.8]), and Severe drought (TVDI∈(0.8,1.0]). The measured results are listed as below: In order to reflect the interannual variation of the drought condition, this paper selected three periods of growing season (April-May for beginning, June-August for middle, and September-October for end) to make trend analysis of mean TVDI in each period.

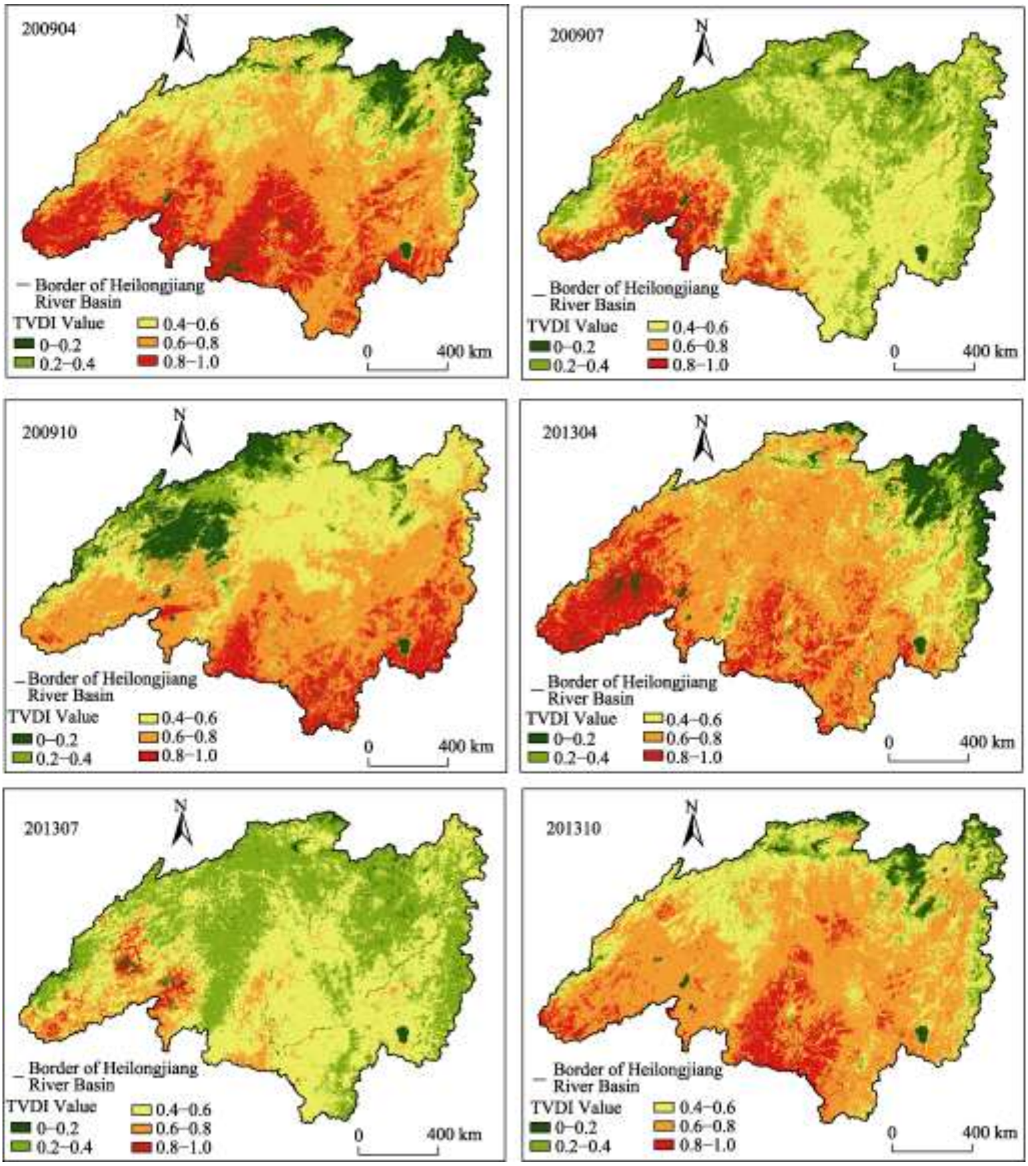

Figure 5 Drought grade distribution map of representative month during growing season in Heilongjiang River Basin based on TVDI

4.3 Data validation

Remote-sensing-based surface soil moisture (RSSSM) dataset is the reversion result obtained by the fusion of various active and passive microwave remote sensing data. The data accuracy is at the same level as the current optimal remote sensing Soil water data product, Soil Moisture Active Passive (SMAP)[26]. Therefore, RSSSM and the precipitation data monitored by 50 meteorological stations evenly distributed in the research area were selected in the quality assessment part to conduct correlation analysis with the TVDI results (Figure 7–8).

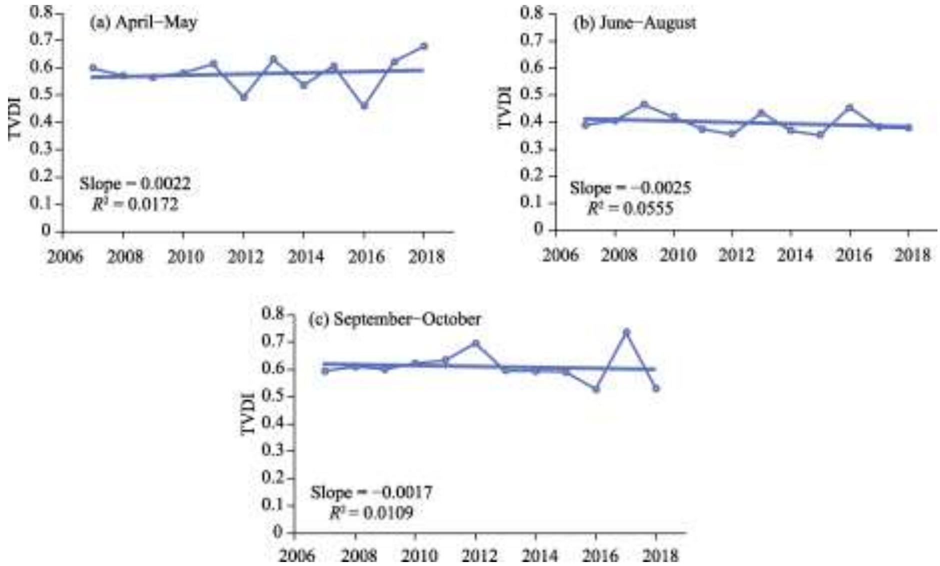

Figure 6 Interannual variation trend of mean TVDI during different periods of growing season in Heilongjiang River Basin

In the correlation analysis between the index results and the former dataset at pixel level, the analysis results show that the two results are negatively correlated, the absolute value of the correlation coefficient is greater than 0.45, and all the correlations between the image points have all passed the significance test of P<0.05. In the correlation analysis with precipitation data, the results showed that the TVDI of the station location was negatively correlated with precipitation, and the maximum and minimum absolute values of the correlation coefficients were 0.558,1 and 0.129,1, respectively. The correlation analysis results of all the data passed the significance test of P<0.01.

5 Discussion and Conclusion

Drought monitoring for the Heilongjiang River Basin, a climate-sensitive area, has very important practical significance for the green and safe development of the China-Mongolia-Russia Economic Corridor. For this reason, this article combines multi-source data to construct a common feature space to calculate the TVDI results of the 2007–2018 growing season in the region, Obtain the month-by-month drought characteristics in this period. From the dry edge results in the general feature space of each month, it can be seen that the surface temperature of most months in the NDVI range of 0–0.2 "climbs". The reason may be that the vegetation in these areas is too sparse, and the near-surface is covered by wind. Natural factors, such as taking away more heat, cause the temperature to be slightly lower than that in areas covered by vegetation. When the NDVI value is greater than 0.8, the dry edge LST value in the feature space from June to October has a significant downward trend, indicating that this transpiration in areas with high vegetation coverage during the period can effectively reduce the energy near the surface. In contrast to the wet edge equation, the general trend of surface temperature in April–May and September–October increases with the increase of the vegetation index, while the NDVI–LST relationship is generally negatively correlated in the middle of the growing season (June–August). The reason for the difference between the two is related to the seasonal transpiration capacity of vegetation and the temperature conditions of the season. It can be seen from the inter-annual change trend of the average TVDI in each period of the Heilongjiang River Basin that the soil water content in each period in the basin has remained stable. The index values of the initial and final periods fluctuate around 0.6, while the mid-term index statistics approach0.4. The results, combined with the distribution map of the drought grades of the basin, show that the relatively severe drought areas are mainly concentrated in the central and southern parts of the Heilongjiang basin.

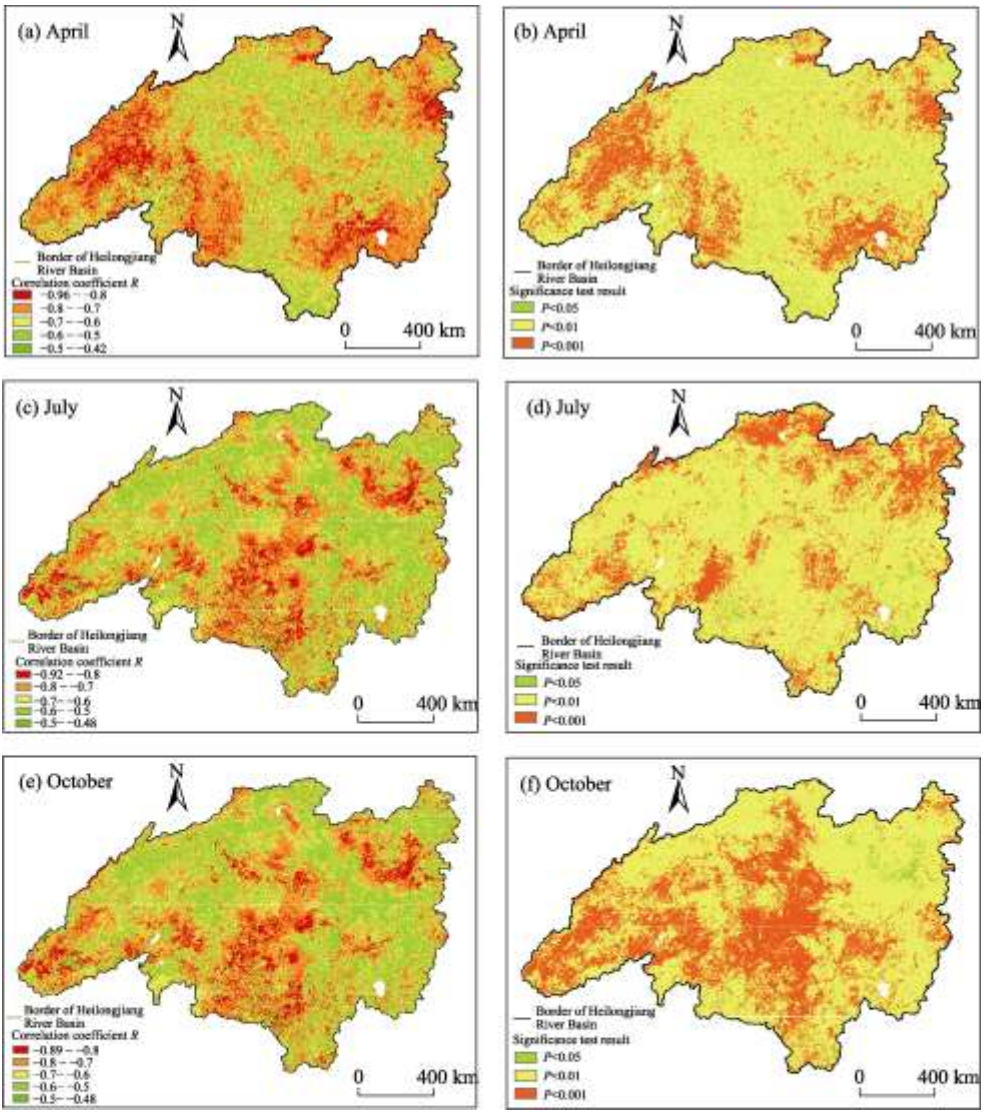

Figure 7 Correlation coefficient and significance test results of TVDI and RSSSM

(a–b. April; c–d. July; e–f. October)

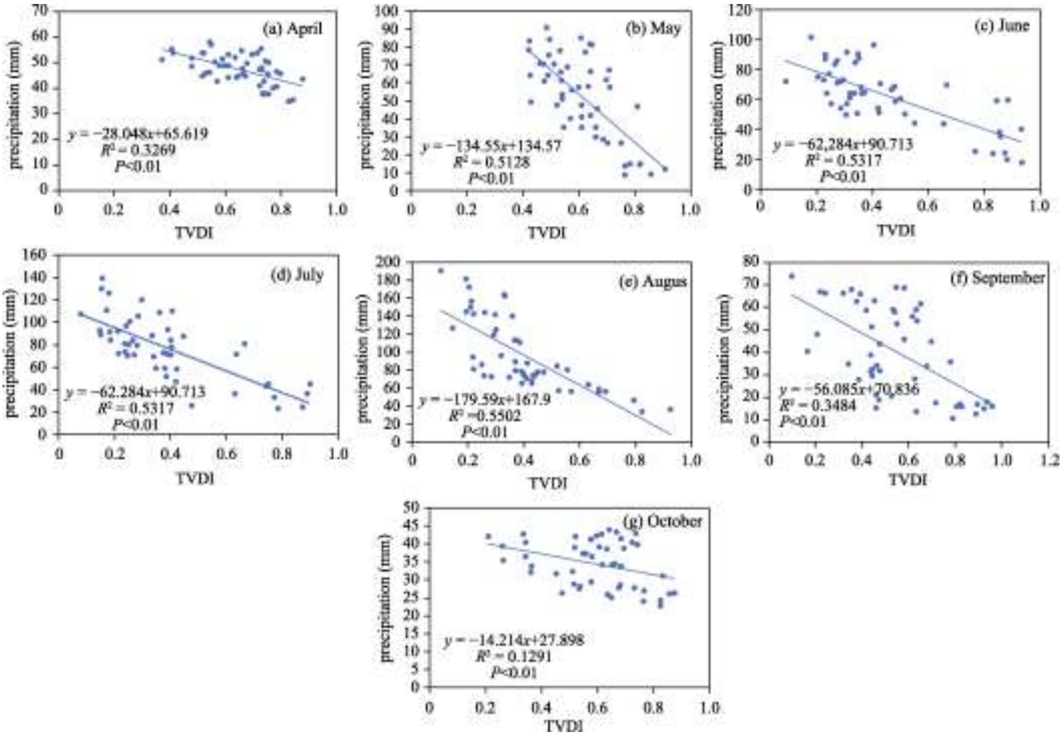

Figure 8 Correlation coefficient and significance test results of TVDI and precipitation data

Among them, Mongolia and the border between China and Mongolia have the highest drought grades each month. Based on the above findings, this study provides basic reference materials for exploring the drought characteristics of the growing season in the Heilongjiang River Basin and for the joint prevention and control mechanism of drought disasters in the corresponding cross-border areas of China, Mongolia, Russia and North Korea.

Author Contributions

Wang, J. L. developed the total design of the experiment and final dataset; Zhou, Y. Z. and Li, K. are responsible for data collection, processing and verification; Wang, J. L., Zhou, Y. Z. and Li, K. jointly wrote the paper.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Huang, Y. F., Li, T. J., Lv, E. Z., *et al*. Boundary data of the Amur River Basin [DB/OL]. *Global Change Data Repository*, 2016. https://doi.org/10.3974/geodb.2016.03.11.V1.

[2] Huang, Y. F., Li, T. J., Lv, E. Z., *et al*. Boundary data of the Amur River Basin [J]. *Journal of Global Change Data & Discovery*, 2017, 1(1): 114. https://doi.org/10.3974/geodp.2017.01.18.

[3] Dai, C. L., Wang, S. C., Li, Z. J., *et al*. Review on hydrological geography in Heilongjiang River Basin [J]. *Acta Geographica Sinica*, 2015, 70(11): 1823–1834.

[4] Haruyama, S., Takayuki, S. Environmental Change and the Social Response in the Amur River Basin [M]. Japan: Springer Press, 2015: 37–38.

[5] Yang, R., Li, X. Y., Mao, D. H., *et al*. Examining fractional vegetation cover dynamics in response to

climate from 1982 to 2015 in the Amur River Basin for SDG 13 [J]. *Sustainability*, 2020, 12(14): 5866.

[6] Liu, X. F., Zhu, X. F., Pan, Y. Z., *et al*. Agricultural drought monitoring: Progress, challenges, and prospects. [J]. *Acta Geographica Sinica*, 2015, 70(11): 1835–1848.

[7] Liu, Q. H., Xin, J. F., Xin, X. Z., *et al*. Agricultural drought remote sensing monitoring method based on surface temperature and vegetation index [J]. *Science* & *Technology Review*, 2007(6): 12–18.

[8] Zhang, S. Q., Qing, Q. T., Hou, M. T., *et al*. Remote sensing monitoring and impact assessment of drought in sichuan based on temperature vegetation dryness index [J]. *Transactions of the CSAE*, 2007(9): 141–146, 294.

[9] Sandholt, I., Rasmussen, K., Andersen, J. A simple interpretation of the surface temperature/vegetation index space for assessment of surface moisture status [J]. *Remote Sensing of Environment*, 2002, 79(2): 213–224.

[10] Sha, S., Guo, N., Li, Y. H., *et al*. Introduction of application of temperature vegetation dryness index in China [J]. *Journal of Arid Meteorology*, 2014, 32(1): 128–134.

[11] Cao, X. M., Feng, Y. M., Shi, Z. J. Spatio-temporal Variations in Drought with Remote Sensing from the Mongolian Plateau During 1982–2018. *Chinese Geographical Science*, 30(6): 1081–1094.

[12] Cong, D. M., Zhao, S. H., Xian, L., et al. Temporal and spatial distribution of drought in Northeast China based on temperature vegetation drought index (TVDI) from 2001–2013[C]. *IGARSS 2016 - 2016 IEEE International Geoscience and Remote Sensing Symposium*. IEEE, 2016.

[13] Zhang, Y., Zhang, Y. B., Yi, G. H., et al. Remote sensing monitoring and analysis of influencing factors of drought in Inner Mongolia growing season since 2000 [J]. *Journal of Natural Resources* 2021, 36(2): 459–475.

[14] Zhao, J. P., Zhang, X. F., Liao, C. H., *et al*. Remote sensing inversion model of soil moisture in large arid area based on TVDI [J]. *Remote Sensing Technology and Application*, 2011, 26: 742–750.

[15] Liu, L. W., Zhang, W. P., Duan, Y. H. Terrain corrected TVDI for agricultural drought monitoring using MODIS data [J]. *Acta Ecologica Sinica*, 2014, 34(13): 3704–3711.

[16] Zhou, Y. Z., Wang, J. L., Li, K. Temperature Vegetation Dryness Index 1-km Grid Dataset in Heilongjiang River Basin (2007-2018) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2021(期): **. DOI: 10.3974/ geodb.2021.05.02. V1.

[17] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. https://doi.org/10.3974/dp.policy.2014.05 (Updated 2017).

[18] MODIS13A3 data [DB/OL]. https://ladsweb.modaps.eosdis.nasa.gov/.

[19] MODIS11A2 data [DB/OL]. https://ladsweb.modaps.eosdis.nasa.gov/.

[20] Zha, F. L., Liu, C., Shi, R. X. Elevation cluster dataset covering the Amur River Basin [DB/OL]. *Global Change Data Repository*, 2016. https://doi.org/10.3974/geodb.2016.04.17.V1.

[21] Chen, Y. Z., Feng, X. M., Fu, B. J. Global 10-day Surface Soil Moisture Dataset (RSSSM, 2003–2018) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2021. https://doi.org/10.3974/geodb.2021.02.01.V1.

[22] Dataset of crop growth and farmland soil moisture values in China [DB/OL]. http://data.cma.cn/data/cdcdetail/dataCode/AGME_AB2_CHN_TEN.html.

[23] Dataset of world monthly surface climatological data [DB/OL]. https://gis.ncdc.noaa.gov/maps/ncei/summaries/monthly.

[24] Yu, M., Cheng, M. H., Liu, H. An improvement of the land surface temperature-NDVI space drought monitoring method and its applications [J]. *Acta Meteorologica Sinica*, 2011, 69(5): 922–931.

[25] Cao, X. M., Feng, Y. M., Wang, J. L. An improvement of the Ts-NDVI space drought monitoring method and its applications in the Mongolian plateau with MODIS, 2000–2012 [J]. *Arabian Journal of Geosciences*, 2016, 9(6): 433.

[26] Chen, Y. Z., Feng, X. M., Fu, B. J. An improved global remote-sensing-based surface soil moisture (RSSSM) dataset covering 2003–2018 [J]. *Earth System Scientific Data*, 2021, 13: 1–31.