Journal of Global Change Data & Discovery. 2023, 7(1): 1-7
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Global Change Research Data Publishing & Repository

Development of Dataset of Climate Change Impacting Grain Yield in Tibet of China (1993–2017)

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Abstract: Tibet is an area with relatively extreme climatic conditions and fragile ecology. Mitigating the negative impact of climate change on agricultural production could help ensure the ecological security and food security of the plateau. Based on the data of meteorological stations and statistical yearbooks, three types of statistical models were integrated to analyze the impact of climate variables (including minimum temperature, precipitation, growing degree days, and solar radiation) on the county-level grain yield in Tibet from 1993 to 2017. The results showed that climate change from 1993 to 2017 has a positive impact with an average impact of 2.39% on the grain yield in Tibet. The dataset covers 7 prefecture-level administrative units and 63 county-level administrative units in Tibet. The dataset includes the following data in Tibet during 1993-2017: (1) annual cereal yields at the prefecture-level cities from 1993 to 2017; (2) annual cereal yields at the county scale from 1993 to 2017; (3) annual climate variables (including minimum air temperature, cumulative precipitation, growing degree days, and cumulative solar radiation) during the cereal growing season at the prefecture-level cities from 1993 to 2017; (4) the impacts of climate change on cereal yields at the county scale from 1993 to 2017. The dataset is archived in .xlsx and .shp data formats and consists of 7 data files with data size of 7.99 MB (Compressed into one data file with 2.62 MB).

Keywords: Tibet; cereal; yield; climate change; county-level

DOI: https://doi.org/10.3974/geodp.2023.01.01

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2023.01.01

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.2021.02.02.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.02.02.V1.

Received: 14-02-2022; **Accepted:** 11-08-2022; **Published:** 25-03-2023

Foundations: Chinese Academy of Sciences (XDA20040301, XDA20010202, XDA23100202, 2018071)

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Data Citation: [1] Ding, R., Shi, W. J. Development of dataset of climate change impacting grain yield in Tibet of China (1993–2017) [J]. *Journal of Global Change Data & Discovery*, 2023, 7(1): 1–7. https://doi.org/10.3974/geodp.2023.01.01. https://cstr.escience.org.cn/CSTR:20146.14.2023.01.01.

[2] Ding, R., Shi, W. J. Dataset of climate change impacting grain yield in Tibet of China (1993–2017) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.02.02.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.02.02.V1.

1 Introduction

Climate change is a global concern and a huge challenge to sustainable development. The Tibetan Plateau (TP) is particularly sensitive to climate change[1] and is known as the "sensor" of climate change in the northern hemisphere[2]. Climate warming, increased precipitation variability, and increased frequency of extreme weather events will seriously affect agricultural production and even endanger food security[3, 4]. Cereal crops are the main crops in Tibet, among which highland barley is the most important crop on the TP[5]. Studying the effect of grain yield on climate change can reflect the response of Tibet's grain yield to climate change. Analyzing the correlation between grain yield and climate variables such as temperature, precipitation, and solar radiation can help analyze the degree of correlation between specific climate variables and crop yields.

Quantitative analysis of the impact of climate change on grain yields in Tibet will help to cope with changes in the plateau agro-ecosystem and formulate reasonable agricultural policies. Tibet has relatively extreme climatic conditions and fragile ecology[6–8]. Actively responding to climate change and reducing its negative impact is of great significance to food and ecological security and sustainable development of the plateau. Based on the data from meteorological stations and statistical yearbooks, we analyzed the impact of climate variables (including minimum temperature, precipitation, growing degree days, and solar radiation) on the county-level grain yield in Tibet from 1993 to 2017. This study aims to provide data support and reference for Tibet to cope with climate change and implement spatially targeted agricultural adaptation measures.

2 Metadata of the Dataset

The metadata of the Dataset of climate change impacting grain yield in Tibet of China (1993–2017)[9] is shown in Table 1.

3 Methods

Statistical data in the study area include cereal production and sown area of 63 counties in Tibet from 1993 to 2017, from the Tibet Statistical Yearbook (1993–2017). In the process of data preparation, outliers in the statistical data were eliminated, and the mean value of adjacent years was used to complete the data of missing values. The meteorological data from 1993 to 2017 came from the Resource and Environment Science Data Center. The specific climate variables include average air temperature, maximum air temperature, minimum air temperature, precipitation, sunshine hours, etc. The calculation period of climate variables was the Tibetan cereal growing season (from April to August). Spatial interpolation was performed using ANUSPLIN interpolation software. Finally, the county-level climate variables were extracted according to the cultivated land.

3.1 Algorithm

Based on the county (district) cereal production and cereal sown area data in Tibet from 1993 to 2017, the ratio of cereal production and cereal sown area was taken as the cereal yield per county (district). Using meteorological station data and ANUSPLIN interpolation,

Table 1 Metadata summary of the Dataset of climate change impacting grain yield in Tibet of China (1993–2017)

Items	Description
Dataset full name	Dataset of climate change impacting grain yield in Tibet of China (1993–2017)
Dataset short name	YieldClimateTibet1993-2017
Authors	Ding, R., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, dingrui_1998@163.com Shi, W. J. S-3255-2018, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, shiwj@lreis.ac.cn
Geographical region	The 63 county-level administrative units in the Tibet autonomous region
Year	1993–2017
Temporal resolution	Annual
Spatial resolution	County scale
Data format	.xlsx, .dbf, .prj, .sbn, .shp, .shx, .xml, .kml
Data size	7.99 MB (2.62 MB after compression)
Data files	The dataset consists of eight files, archived in .shp and .xlsx formats. The table data includes 7 Sheet tables: Sheet-1 is the cereal yields at the prefecture-level cities in Tibet between 1993 and 2017; Sheet-2 is the cereal yields at each county in Tibet between 1993 and 2017; Sheet-3 is the minimum air temperature during the cereal growing season at the prefecture-level cities in Tibet between 1993 and 2017; Sheet-4 is the cumulative precipitation during the grain growing season in Tibet's prefecture-level administrative units from 1993 to 2017; Sheet-5 is the growing degree days during the cereal growing season at the prefecture-level cities in Tibet between 1993 and 2017; Sheet-6 is the cumulative solar radiation during the cereal growing season at the prefecture-level cities in Tibet between 1993 and 2017; Sheet-7 is the joint impacts of climate change on cereal yields at each county in Tibet from 1993 to 2017
Foundations	Chinese Academy of Sciences (XDA20040301, XDA20010202, XDA23100202, 2018071)
Computing environment	Microsoft Excel 2016; ArcGIS
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, 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[10]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

climate variables at each county (district) were calculated. According to Pearson's r between climate variables and cereal yields, four climate variables including minimum temperature, precipitation, growing degree days, and solar radiation were selected for the model analysis. Finally, the effects of climate change on the cereal yield in Tibet from 1993 to 2017 were calculated and analyzed by combining the three types of statistical models, including fixed-effects model, first-difference models, and linear detrending models.

3.2 Data Development Process

We used the county-level statistical data and meteorological data from 1993 to 2017 to develop this dataset, and the following steps were carried out (Figure 1):

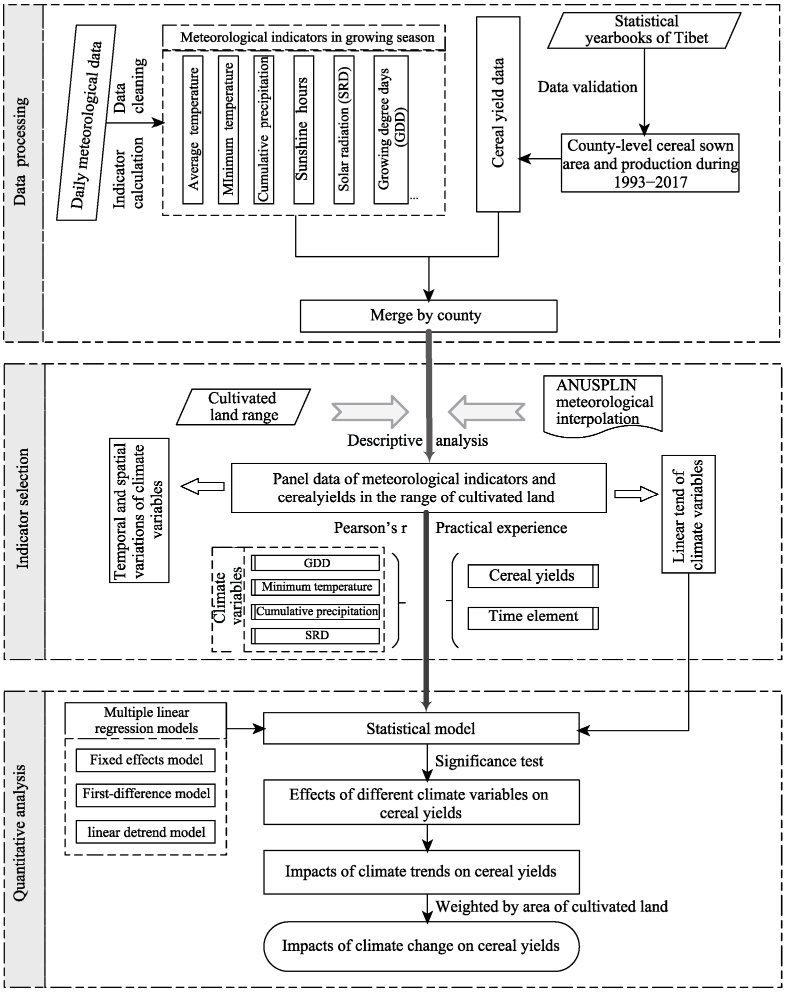

Figure 1 Flowchart of the dataset development

(1) The daily value data from the meteorological stations were cleaned and organized, and climate variables were calculated after removing the abnormal values. Relevant data fields were extracted from the Tibet Statistical Yearbook, and the county-level cereal yield was calculated after data cleaning and processing. The meteorological data and the cereal yield data were merged by the county to form the basic data of this study.

(2) The annual values of the sorted climate variables were calculated according to the range of the cereal growing season on the TP, and then were interpolated by using the ANUSPLIN meteorological interpolation software. The climate variables were extracted by each county's cultivated land after interpolation. The climate variables in the cereal growing season and the cereal yield in the county-level arable land were merged to form panel data, then descriptive analysis was carried out.

(3) The correlations between climate variables and cereal yields were calculated, then final climate variables were selected to build the model according to the correlation and actual experience.

(4) The selected climate variables and cereal yield data were input into statistical models (including fixed-effects model, first-difference models, and linear detrending models). The impacts of different climate variables on grain yield were calculated, then the percentage impacts of all climate trends on grain yield in Tibet were quantitatively analyzed.

4 Data Results and Validation

4.1 Data Composition

The .xlsx file in the dataset includes 7 data tables, including:

Sheet-1 is the cereal yields at the prefecture-level cities in Tibet between 1993 and 2017;

Sheet-2 is the cereal yields at each county in Tibet between 1993 and 2017;

Sheet-3 to Sheet-6 are the minimum air temperature, cumulative precipitation, growing degree days and cumulative solar radiation during the cereal growing season at the prefecture-level cities in Tibet between 1993 and 2017;

Sheet-7 is the joint impacts of climate change on cereal yields at each county in Tibet from 1993 to 2017.

The .shp file in the dataset is the vector boundaries of the county-level administrative units in the study area.

4.2 Data Results

4.2.1 The Cereal Yield in Tibet

The prefecture-level cities with the highest sown area of cereals in Tibet were Lhasa, Shigatse, and Qamdo. Although the sown area of cereals in Shannan was slightly higher than in Nyingchi, its production was less than that of Nyingchi. The prefecture-level cities with the lowest sown were Nagqu and Ali, which are in remote areas and with poor agricultural conditions. Among the cereal production, Lhasa had the highest proportion at 29%, followed by Shigatse, Qamdo, Shannan, Nyingchi, Nagqu, and Ali. There was a huge gap in agricultural conditions between different cities in Tibet. Lhasa and Shigatse, with the highest cereal production, accounted for more than half of the production in Tibet. The overall cereal area in Tibet showed a slight decrease, but the range was roughly stable in the range of 16,000–18,000 ha. From 1994 to the end of the last century, the sown area of cereals in Tibet increased year by year, reaching a historically high level of 18,200 ha in 2000, but it declined from 2000 to 2005, and was basically stable at around 15,500 ha in the following years, then it showed an increase again from 2012 to 2017. The cereal production in Tibet generally increased, rising from 62,900 t in 1993 to 92,700 t in 2017.

For the cereal yields in prefecture-level cities in Tibet, Lhasa and Shannan ,were the highest. However, Lhasa showed a decreasing trend of cereal yields in recent years, while Shannan basically maintained the increasing trend and it was higher than Lhasa after 2011, becoming the highest cereal yield one in Tibet. The cereal yields in Shigatse, Nyingchi and Qamdo were followed, and Nagqu and Ali were the lowest. The cereal yield at the county scale in Tibet showed an increasing trend, and in most counties was around 3–4 $t\cdot ha^{-1}$. Tibet is a region with a complex geographical environment, and the management and development levels of different counties vary greatly, resulting in obvious differences in cereal yields between different counties. In 2017, Gyantse county in Shigatse city was with the highest cereal yield of 9.38 $t\cdot ha^{-1}$, and Baqing county in Nagqu city was with the lowest cereal yield of 2.02 $t\cdot ha^{-1}$. In 2017, there were 31 counties (districts) in Tibet whose cereal yields exceeded 5 $t\cdot ha^{-1}$, accounting for 49%.

4.2.2 The Climate Variables during the Cereal Growing Season in Tibet

The average air temperature of all prefecture-level cities in Tibet showed a fluctuating increasing trend (Figure 2a). Nyingchi, Ngari, and Lhasa were with the highest average air temperatures, followed by Qamdo and Shannan, and Shigatse and Nagqu with the lowest average air temperatures. The minimum air temperature in Nyingchi city was the highest, and Nagqu was the lowest, and other cities were relatively close, roughly in the range of

5–6 °C. The cumulative precipitation during the cereal growing season in Tibet was in the range of 2,000–3,000 mm (Figure 2b). The cumulative precipitation fluctuated greatly between different years, especially in recent years. The cumulative precipitation in Nyingchi city was the highest, and Ali was the lowest, and other cities fluctuated in the range of 250–500 mm. The growing degree days were around 12,000 °C in Tibet (Figure 2c). The growing degree days were like other climate variables of temperature, and the trend was a fluctuating increase, but the increasing range was lower. The growing degree days of prefecture-level cities in Tibet from highest to lowest were: Nyingchi > Lhasa > Shannan > Qamdo > Shigatse > Ngari > Nagqu. The cumulative solar radiation during the cereal growing season in Tibet was greater than 20,000 MJ·m^{-2}. The cumulative solar radiation in all prefecture-level cities showed a fluctuating decreasing trend (Figure 2d). The cumulative solar radiation in Ali was the highest, followed by Lhasa, Shigatse, Shannan, Nagqu, and Qamdo, and Nyingchi is the lowest.

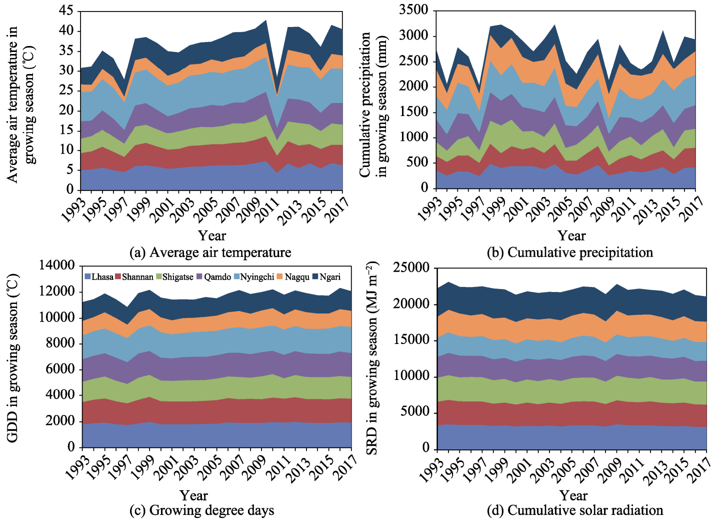

Figure 2 The variation of climate variables in the cultivated land of prefecture-level cities in Tibet (1993–2017)

4.2.3 The Impacts of Climate Change on Cereal Yield in Tibet

Except for the first-difference models that introduced the square term and interaction term of climate variables, all other models indicated that the climate change trend during the study period had a positive impact on cereal yields in Tibet. Climate change had a positive impact on cereal yields in Tibet. The results of seven statistical models showed that the average impact of climate change on cereal yields was 2.39%[11]. All significant climatic variables in the fixed-effects model were summed to calculate the percentage impact of climate change on cereal yields in Tibet during the study period at the county scale. In terms of county-level spatial distribution (Figure 3), climate change from 1993 to 2017 had a positive impact on cereal yields in Tibet, with the greatest impact on some counties in Shannan and Shigatse,

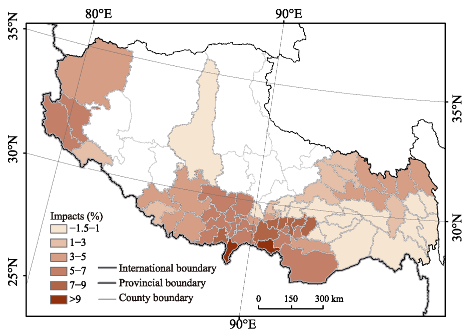

Figure 3 Map of the percentage impact of climate change on cereal yields in Tibet during 1993–2017

ranging from 7% to 12%. In contrast, the impact on some counties in Nyingchi, Lhasa, and Qamdo near the border of Tibet was relatively lower. Among all counties, Luojia county in Shannan city was with the largest positive impact (11.3%). Except for some counties in Lhasa, Qamdo, and Nyingchi, the climate change trend had a positive impact on most areas in Tibet.

5 Discussion and Conclusion

In order to clarify the impact of climate change on the cereal yields in Tibet, we calculated the percentage impact of climate change on the cereal yields in Tibet based on statistical data and meteorological data and analyzed the spatial characteristics of the impacts. The results showed that the climate change trend had an overall positive impact on cereal yields in Tibet, with an average impact of 2.39%. For spatial characteristics at the county scale, the greatest impacts were in some counties in the Yarlung Zangbo River, Nyangqu River, and Lhasa River regions. The impacts on Lhasa city, Nyingchi city, and some counties in Qamdo city were relatively lower. This dataset could provide scientific support for food security and sustainable agricultural development in Tibet. Due to raw statistical data, detailed categories of cereals were not distinguished in this dataset. In addition, the cereal growing season was mainly referred to as the growing season of Tibetan highland barley and spring wheat. The growth period of different crops could be subdivided to study the specific impacts of climate change on crop yields in the plateau in follow-up research.

Author Contributions

Shi, W. J. developed the overall design and model algorithm for the dataset; Ding, R. collected and processed the statistical yearbook data and meteorological data; Ding, R. and Shi, W. J. completed the data verification, wrote and revised the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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