Responses and Changes to Reviewers' Comments

Dear Reviewers,

We really appreciate your helpful suggestions and comments. We have carefully revised the manuscript and addressed all comments. In terms of content, we mainly increased the experimentation of CRU and ERA5 meteorological data to enhance the reliability of the article results. We also conducted a mechanism analysis to investigate how drought regulates the relationship between vegetation and precipitation (temperature). As for the methodology, we detrended all variables before studying the vegetation-climate relationship to prevent statistical analysis independence. Instead of comparing the NDVI and climate relationship between pre- and post-2000, we used multiple sliding windows to emphasize the inter-annual variability of this relationship. In writing, we improved the language use throughout the entire article, made significant changes to the introduction to highlight the innovation of this study, and added descriptions of the interpretation of the results, as well as discussions of the results.

Referee: 1

1. **The description of Introduction is inadequate. For example, no sufficient evidence is provided to support why Northwest China is selected . In addition, I do not fully agree with the author's statement that previous studies pay little attention to the long term changes of vegetation growth to climate change in Northwest China, as this region is usually included in a larger spatial extent, such as northern China, Central Eurasia or even the drylands of the Northern Hemisphere. Meanwhile, the diverse response of vegetation growth to climate variables across land surfaces has always been a hot topic and many interesting findings are found. Above all, the summary of previous studies is insufficient and arbitrary. As a result, the author is unable to give a clear scientific hypothesis.**

Response:

Thank you very much for your important suggestions. We have made significant changes to the introduction.

We added an explanation in the introduction about why Northwest China was selected as the study region: "Northwest China is characterized by vast areas with different land cover types, including grasslands, forests, and barren lands with sparse vegetation. Since the early 1980s, several studies have indicated warmer and more humid conditions in this area (Liu et al., 2013; Shi et al., 2002; Shi et al., 2007; Wang et al., 2020; Wang et al., 2007; Zhang et al., 2021; Zheng et al., 2021). Recent decades have also seen significant changes in the growth of vegetation in this region (Chen et al., 2019; Niu et al., 2019). As a result, Northwest China presents an ideal opportunity for examining the changes in relationship between climate and vegetation across a variety of vegetation types".

We have added a detailed description of previous studies: "The changing correlation between climate and vegetation has recently gained some attention. For example, Wang and Yan (2021) found that the correlation between vegetation and temperature has weakened throughout China over the past 34 years. The precipitation threshold required for vegetation growth in Australia had been found to decrease from 1982 to 2010 (Ukkola et al., 2016). Keenan and Riley (2018) measured how vegetation cover responded to temperature changes and found that the limitations imposed by temperature had decreased over time. Zhao and Yu (2021) found an increased association between climate change and vegetation index variation in Northwest China over the past 34 years. However, most of these studies have solely identified the occurrence of the changes in the relationship between precipitation (or temperature) and vegetation. Uncertainties remain regarding the drivers and how they regulate the changes in the relationship"

The diverse response of vegetation growth to climate variables across land surfaces has indeed always been a hot topic. However, variations may also exist in the patterns of changes in the relationship between climate and vegetation across distinct types of land cover, and the mechanisms behind them are also different, which has been confirmed by our results, but this area of research has not received enough attention yet. Therefore, we provided a detailed description in the introduction: " Vegetation greenness patterns display high spatial heterogeneity across different land surfaces (Gao et al., 2017; Wang et al., 2021), and it's response to climate also varies greatly among different terrestrial ecosystems (Yuan et al., 2019a). The influencing mechanisms of vegetation dynamics in diverse vegetation types have been well documented (Cai et al., 2021; Li et al., 2019; Luo and Chen, 2013; Tao et al., 2015; Upgupta et al., 2015; van Oijen et al., 2018; Wu et al., 2021). Based on previous research, it can be easily inferred that variations may also exist in the patterns of changes in the relationship between climate and vegetation across distinct types of land cover, and the mechanisms behind them are also different, but this area of research has not received enough attention yet"

2. **According to the results, the authors say the year of 2000 is an important turning point in time. However, there is no method description for defining the time turning point. It is unclear whether the turning point is robust and varies in space.**

Response:

Thank you very much for your suggestion. Instead of comparing the NDVI and climate relationship between pre- and post-2000, we now utilize multiple sliding windows to emphasize the inter-annual variability of this relationship

3. **The authors are suggested to add statistical analysis to compare the correlation coefficient of NDVI with temperature and precipitation, such as the results shown in Figure 5.**

Response:

Thank you very much for your suggestion. Based on three sets of meteorological data, we have compared the correlation of NDVI-temperature and the correlation of NDVI-precipitation, shown as below:

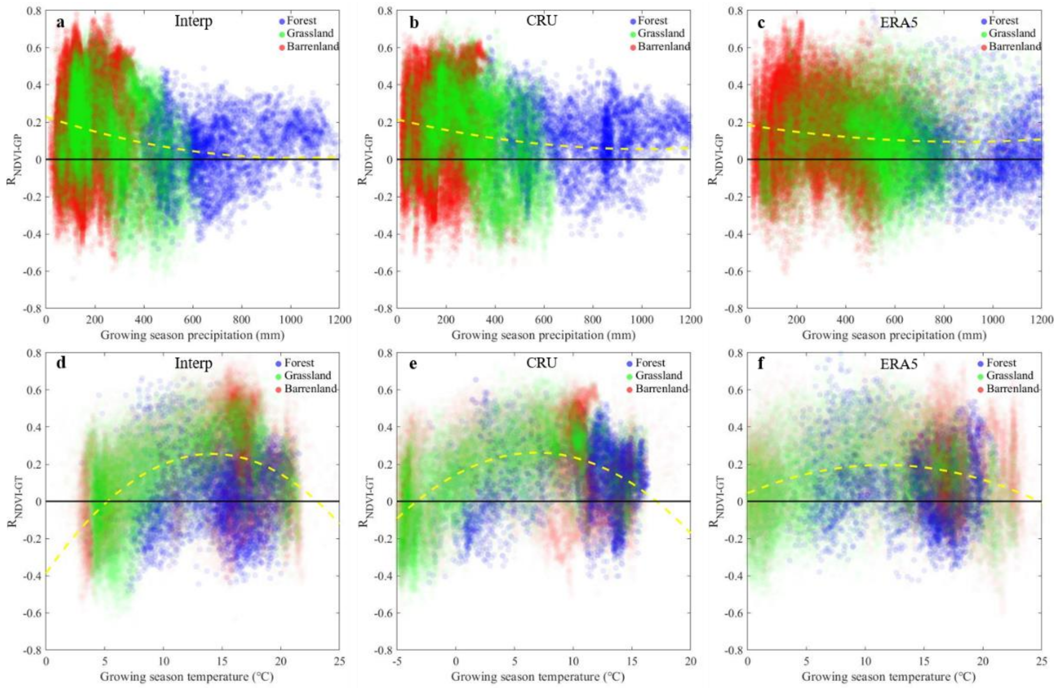


Figure 3. Scatter plots between $R_{NDVI\text{-}GP}$ and precipitation from Interp (a), CRU (b) and ERA5 (c), and scatter plots between $R_{NDVI\text{-}GT}$ and temperature from Interp (d), CRU (e) and ERA5 (f). Here, $R_{NDVI\text{-}GP}$ is the partial correlation coefficient between GS NDVI and GS precipitation, and $R_{NDVI\text{-}GT}$ is the partial correlation coefficient between GS NDVI and GS temperature (All variables are detrended). The yellow dashed line is the quadratic fit for all the scatters.

Then, we compared the trends of the correlation of NDVI-temperature and the correlation of NDVI-precipitation based on multiple sliding windows, The results with a 13-year sliding window are shown below, and the results of additional experiments conducted with sliding windows of 9, 11, 15, and 17 years are displayed in Supplementary Figs. 3~6.

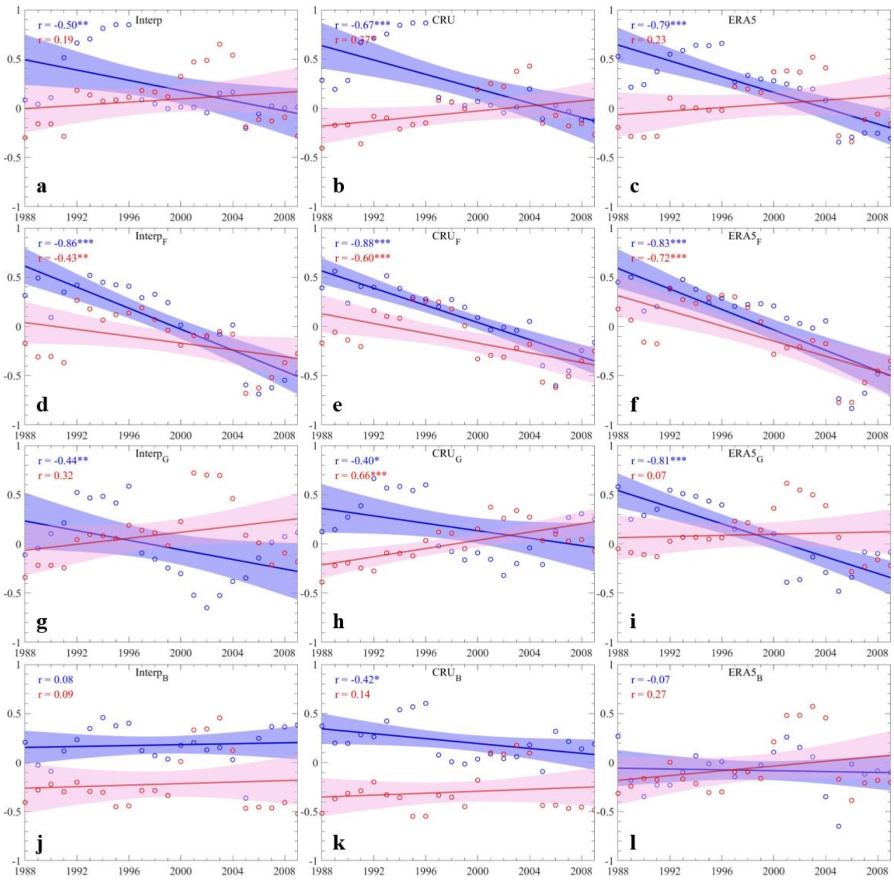


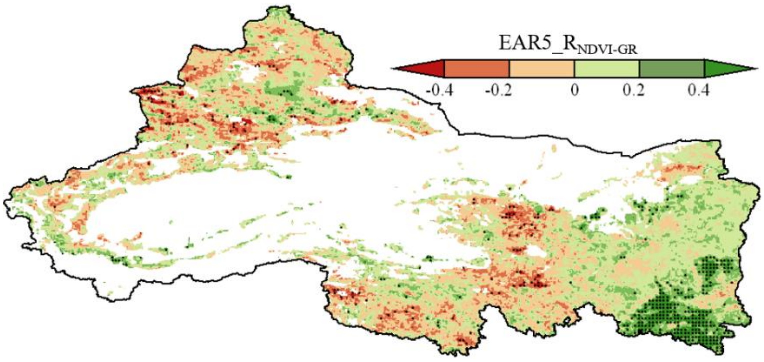
Figure 4. Changes in $R_{NDVI-GP}$ and $R_{NDVI-GT}$ at a 13-year sliding window. Here $R_{NDVI-GP}$ (or $R_{NDVI-GT}$) is the partial correlation coefficient between GS NDVI and GS precipitation (or temperature), and is calculated using a 13-year sliding window during 1982-2015. All variables are detrended. The blue (or red) line represents the changes in $R_{NDVI-GP}$ (or $R_{NDVI-GT}$), and the shaded portion represents the confidence interval. Three types of climate data (Interp, CRU and ERA5) are used, corresponding to three columns. The first to fourth lines correspond to the following areas respectively: all vegetation areas except cropland, forest, grassland, and barren land (As the parts with NDVI<0.1 are removed, the barren areas here represent sparse vegetation). The symbol of *, ** and *** in the upper right of the value of r indicate the significant trend at $P < 0.1$, $P < 0.05$ and $P < 0.01$ respectively.

4. **It is unclear why a nine-year sliding window is used to show the time-varying sensitivity of NDVI to temperature and precipitation. How to consider the impact of solar radiation on vegetation growth? Is it a major driver?**

Response:

Thank you very much for your suggestion. We also realized that using only one sliding window to obtain results lacks scientific validity, so we used multiple sliding windows of 9, 11, 13, 15, and 17 years to enhance the robustness of our findings. The results indicated that the conclusions from different sliding windows were relatively consistent.

Due to the significant impact of radiation on vegetation growth, it was unscientific for us to ignore radiation when studying the correlation between NDVI and precipitation (or temperature). Therefore, when calculating the partial correlation between NDVI and precipitation (or temperature), we also controlled for radiation to eliminate its interference, and we explained this in our methodology: "The relationship between precipitation (temperature) and NDVI is calculated as the partial correlation coefficient between GS precipitation (temperature) and GS NDVI, after statistically controlling for interannual variation in GS temperature (precipitation) and GS radiation". In addition, we also conducted a separate analysis of the relationship between radiation and NDVI, and the results are shown below, which is displayed in Supplementary Fig. 2. Meanwhile, we have added corresponding analyses in the article:" For some forested areas in Shaanxi, NDVI shows a weak negative correlation with precipitation (Figure 2a, c, e), which may be attributed to an increase in solar radiation as precipitation decreases in this region (Supplementary Fig. 1b, e). In order to explore how solar radiation affects vegetation productivity, we analyzed the partial correlations between interannual fluctuations in shortwave radiation and NDVI (Supplementary Fig. 2). The effect of radiation on plants also exhibits significant spatial variability. While enhanced radiation can boost photosynthesis efficiency and stimulate vegetation growth, it can also raise transpiration rates, resulting in soil moisture loss (Piao et al., 2014). NDVI and radiation exhibit the significant positive correlation in forests, while in high-altitude grasslands they mainly exhibit a negative correlation (Supplementary Fig. 2)"



Supplementary Figure 2. Spatial distribution of partial correlation of NDVI and radiation. All variables are detrended. To calculate the partial correlation versus GS radiation, GS temperature and precipitation are controlled for. The dots indicates the regions with significant relationship in $R_{NDVI-GR}$ ($P < 0.05$)

5. **Actually it is difficult to integrate data of different spatial scales. For example, the NDVI data is at the pixel scale; however, the social statistical data is at the county or even provincial scales. It is questionable whether the human activity rather than climate can play a dominant role in shaping regional NDVI. Besides, how to distinguish the effects of afforestation on NDVI, as the analysis of land-use and-cover changes are missing in this study. The relationship between NDVI and social-economic divers such as GDP and population is very complex that should not be the focus of this study. I think the authors should focus on the topic why the response of vegetation NDVI**

changes over time. Ecosystem adaptation (e.g. changes in vegetation structure) or changes in environmental conditions, such as background soil moisture

Response:

Thank you very much for your suggestions. Considering the complexity of human influence, we removed this part of the content in the article. In the discussion section, we analyzed how drought regulates the relationship between NDVI and precipitation (or temperature) based on two indicators, vapor pressure deficit (VPD) and soil water volume (SWV), and the results with a 13-year sliding window are shown below. We found that the fluctuations in $R_{NDVI-GP}$ and $R_{NDVI-GT}$ coincides closely with the variations in drought conditions. In the areas with the trend in VPD less than 0.02 hpa/yr, where grasslands are predominantly distributed, an increase in SWV tends to cause a decrease in $R_{NDVI-GP}$, but an increase in $R_{NDVI-GT.}$ However, when the VPD trend exceeds 0.02 hPa/yr, a more negative trend in SWV tends to result in more negative trends in both $R_{NDVI-GP}$ and $R_{NDVI-GT}$.

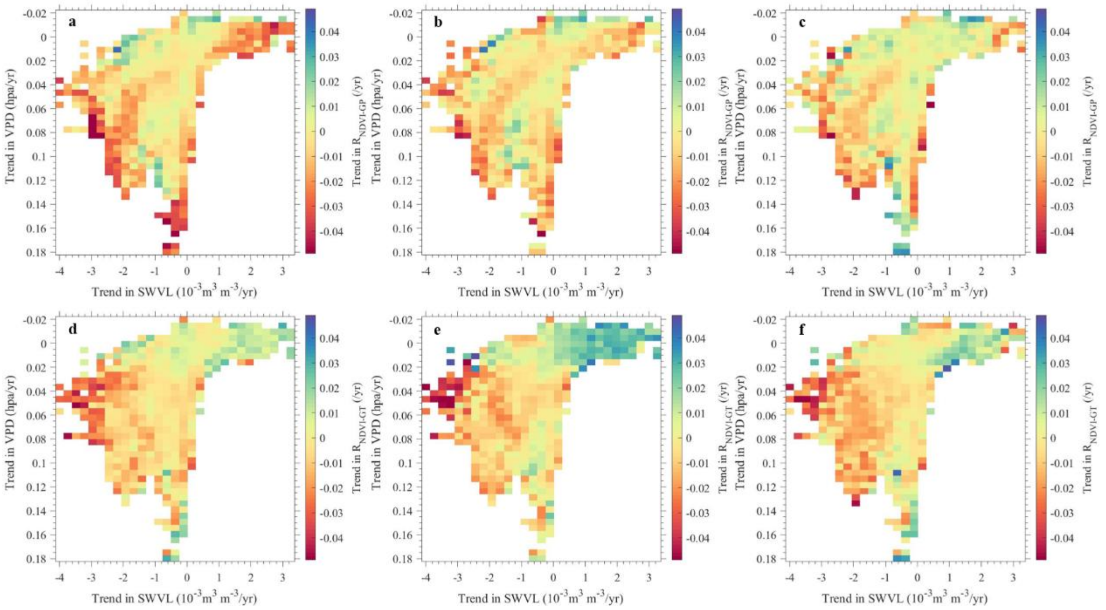


Figure 6. Average trend of $R_{NDVI-GP}$ and $R_{NDVI-GT}$ at a 13-year sliding window in a climate phrase space. Here, $R_{NDVI-GP}$ is the partial correlation coefficient between GS NDVI and GS precipitation from Interp (**a**), CRU (**b**), and ERA5 (**c**); $R_{NDVI-GT}$ is the partial correlation coefficient between GS NDVI and GS temperature from Interp (**d**), CRU (**e**), and ERA5 (**f**). They are calculated using a 13-year sliding window during 1982-2015. All variables are detrended. The climate space is delineated by changes in GS soil water volume (SWV) and changes in vapor pressure deficit (VPD).