Response to comments of Anonymous Referee #2

General comments:
Wu et al. (2011) have reconstructed soil moisture values across China using the Variable Infiltration Capacity (VIC) model for the period 1951-2009. Using this simulated soil moisture dataset, agricultural drought characteristics over this period for nine study regions are examined. This study contributes to the study of drought in China. It also builds on the existing literature by extending the simulated soil moisture dataset from the previous 35 years to 59 years, which is valuable and could be used in the monitoring and assessment of droughts in China, in particular agricultural droughts. Specific and technical comments are as follows.

We appreciate the valuable and fruitful comments. We address below each point raised by the reviewer, with our response shown in italics.

Response to Specific comments:

1. This paper will benefit from improving the English and its clarity throughout. Some of the changes are specified in the technical comments.

As you will see from the improved manuscript, significant efforts have been made on the improvement of English presentation and its clarity throughout the original manuscript.

2. There appears to be repetition of text for defining drought in Section 3.2 (Page 1872 Lines 13-14 and 24-25) and in Section 3.4 (Page 1976, Lines 17-19], as well as Figure 7 – perhaps omit or refer to Section 2.3?

As suggested, we have removed the repetition of texts for defining drought from the original manuscript. For example, the original sentence – "The drought severity is defined as the product of drought intensity and the drought duration, which is discussed in the last section." (Page 1872 Lines 24-25) *has been cancelled in the revised manuscript.*

3. Some lines appear exactly the same in different sections of the paper – rephrasing some of these will improve the draft.

This suggestion has been well taken in the revised manuscript. For example, the original sentence – "The first center is located in the area partial covered by two drought study regions North and Northwest, which extends to the southeastern portion of Inner Mongolia and the southwest part of Northeast.*"* (P1875 lines 9-13) *has been rephrased to* "As shown in Figure 5, the first centre is located in the area partial covered by two drought study regions (North and Northwest), which extends to the southeastern portion of Inner Mongolia and the southwest part of Northeast." *in the revised manuscript.*

4. The choice of the SMAPI over other agricultural drought indices could be elaborated.

We have redrafted the entire subsection **2.2** *in the revised manuscript. We have added new discussions on the choice of the SMAPI over other agricultural drought indices. We show below the new version of* **2.2.**

"Agricultural drought refers to the phenomenon that the moisture supply falls below the climatically appropriate moisture supply so that the growth of crops is hindered, which may also include crop drought and soil drought. Four drought indices are commonly used the agricultural sector. These indices are the crop moisture index (CMI; Palmer, 1968), the crop drought index (CDI), the soil moisture index (SMI), and the soil moisture anomaly percentage index (SMAPI). CMI is defined as the sum of evapotranspiration deficit and soil demand, being a by-product of PDSI. The model assumes parameters like vegetation, soil properties, land use/ cover are evenly distributed in the whole climatic zone, which varies widely in reality. CDI is built according to crops' physiological and ecological responds to drought, by monitoring changes of crop growth, leaf temperature and leaf moisture to determine the effect of drought. Such index is mainly based on satellite remote sensing measurement with short time series, as well as has certain regional limitation. SMI is defined as the percentage of actual soil moisture accounted for the field capacity, reflecting the relatively dry of soil. CMI can evaluate short-term moisture conditions affecting crops, while its rapid reaction to the

short-term changing information may mislead long-term changing information. Both CDI and SMI are suitable for monitoring small and special areas with particular soil types, crops and vegetative periods."

"Different from the above three indices, SMAPI is developed to characterize agricultural drought over a large area. The SMAPI approach for defining a drought severity is through a measurement on the relative departure of soil moisture from the normal climate at a specific gird point or region. When the current soil moisture is less than the climatology soil moisture, the soil moisture deficit appears to identify the drought phenomenon. The rationale of using the relative soil moisture deficit rather than the absolute magnitude is because anomalies in absolute terms reflect different severities in different parts of a studying domain. Therefore, the dimensionality of SMAPI makes it possible to compare drought severities at disparate grid points and regions in different periods, being available to characterize agricultural drought over a large area. In this study, SMAPI is defined as:

$$SMAPI = \frac{\theta - \overline{\theta}}{\overline{\theta}} \times 100\% \qquad (1)$$

where, θ and $\overline{\theta}$ represent the current value of soil moisture and its climatology respectively. The climatically appropriate moisture should be the value that is based on the multi-year average in the same time series. Thus, the variable $\overline{\theta}$ in Equation (1) can be seen as the mathematical expectation of a soil moisture time series."

"Bergman et al. (1988) reported that SMAPI values change at a rate centred between the rapid CMI and the relatively slow Palmer Drought Severity Index (PDSI; Palmer, 1965), which may both reflect the development of short-term drought and analyse the change of long-term drought. A useful survey on drought indices is found in WMO (1975) and Heim (2000). Keyantash and Dracup (2002) evaluated the most prominent indices that measure each of the three physical types of drought (meteorological, hydrological, and agricultural) using a set of six weighted decision criteria: robustness, tractability, transparency, sophistication, expendability, and dimensionality. The performance of each of the 14 evaluated drought indices is measured with an assigned value from 1 to 5 (5 being the highest). The average value of the six criteria is 3 for the Soil Moisture Anomaly Percentage Index (SMAPI) proposed by Bergman et al. (1988),

which is second highest among the five evaluated indices for agricultural drought. Thus, the SMAPI approach is a simple method with explicit physical meaning and easy to understand and use. SMAPI is capable of identifying the onset of a drought event, its progression, as well as its termination."

5. There seems to be confusion in the orientation and region in Page 1876, Lines 1-4? For example, should Line 2 read "was first developed eastward of the..."?

As suggested, the original sentence – "Over the next two decades, the regional concentration was first developed westward to the drought study region Northwest in the 1990s, and then further extended northeastward to a large portions of the drought study region Inner Mongolia and almost entire Northwest in the 2000s." (Page 1876, Lines 1-4) *has been rephrased to* "Over the next two decades, the regional concentration was first developed westward towards the drought study region Northwest in the 1990s, and then further extended northeastward towards a large portion of the drought study region Inner Mongolia and almost entire Northwest in the 2000s." *in the revised manuscript.*

6. Conclusion could be strengthened by discussing the factors (both physical and human) that could have contributed to the drought trends, and the implications of these trends could be elaborated.

A new paragraph has been added into **Conclusions** – "The upward drought trends are likely the result of interactions of climate change and human activities. Atmospheric circulation anomaly caused by global warming leads to the decrease of areal precipitation and the increase of surface temperature, which can cause frequently occurred drought events. Many human activities like population expansion, urbanization and industrial development can lead to an increase in water demand. The destruction of surface land covers resulted from irrational utilization of land will aggravate the occurrence and development of droughts. The drought trends directly influence the amount of water available for agricultural productivity, slowing down grain production, and reducing crop yields. On the other hand, soil moisture deficits induced by droughts will exacerbate land desertification and the expansion of desertification, as well as enlarge the existing problem of land salinization in northern areas. In addition, the frequently occurred

drought will caused river-lake water levels to decline, lake surface areas to reduce, and even dry up, having serious effect on the ecological environment. Therefore, further analyzing of drought causes and mechanisms and improving the monitoring and prediction ability of droughts would be the key direction in the future drought research." *to strengthening the significance and implications of our results.*

Response to Technical comments:

[Page 1862, Line 2] Change "The recent fifty-nine year (1951-2009) drought..." to "The 1951-2009 drought...". Similar changes are needed elsewhere.

This suggestion has been well taken in the revised manuscript.

[1862, 10-11] Change "As the result" to "As a result". Similar changes are needed elsewhere.

Corrections have been made accordingly in the revised manuscript.

[1862, 20] Change "its progressing" to "its progression".

We have made corrections as suggested.

[1862, 20] Change "has been week in..." to "has been weak in...". Similar changes are needed elsewhere.

We have corrected the typo in the **Abstract** and **Conclusions**.

[1863, 6] Change "agriculture productions" to "agricultural productivity".

Corrections have been made accordingly.

[1863, 17-23] Reference(s) needed.

As suggested, a new reference published by the Chinese Ministry of Water Resources in 1997 has been added in the revised manuscript.

[1864, 8] Change "drought indexes" to "drought indices".

We have replaced “drought indexes” *with* “drought indices” *in the revised manuscript.*

[1865, 28] Change “this could be reduced the...” to “this could reduce the...”.

We have made corrections as suggested.

[1870, 9] Change “minima threshold” to “minimum threshold”. Similar changes are needed elsewhere.

We have corrected the typo in the subsection 2.3.

[1870, 22] Change “known to its diversified” to “known for its diversified”.

Corrections have been made accordingly.

[1871, 1] Change “division scheme is adapted in this study to preserving a consistency...” to “division scheme is adopted in this study to preserve consistency...”.

We have corrected the typo in the revised manuscript.

[1871, 23] Change “soil moisture is usual observed...” to “soil moisture is usually observed...”.

The suggestion has been well taken.

[1873, 17] Should “gain loss” be “grain loss”?

We have corrected the typo.

[1874, 4-5] Change “spatial extension” to “spatial extent”.

Corrections are made in the revised manuscript.

[1875, 7] Change “socio-economical” to “socio-economic”. Similar changes are needed elsewhere.

The suggestion has been well taken.

[1875, 25-26] Change “has been changed dramatically...” to “has changed dramatically...”

Corrections have been made accordingly.

[1876, 24] It may be better to replace “30% in these three upward...” with “30% in the three upward...”.

As suggested, we have replaced “30% in these three upward...” *with* “30% in the three upward...”

[1877, 28] Change “week in the rest five regions...” to “weak in the other five regions...”.

We have corrected the typo in the **Abstract** and **Conclusions**.

References:

Bergman, K. H., Sabol, P., and Miskus, D.: Experimental indices for monitoring global drought conditions, in: Proc. 13th Annual Climate Diagnostics Workshop, Cambridge, MA, US Dept. of Commerce, 190–197, 1988.

Heim, R. R.: Drought indices: a review, in: Drought: A Global Assessment, edited by: Wilhite, D. A., Routledge, 159–167, 2000.

Keyantash, J. and Dracup, A.: The quantification of drought: an evaluation of drought indices, B. Am. Meteorol. Soc., 23, 1167–1180, 2002.

Palmer, W. C.: Meteorological drought, Weather Bureau, Research Paper No. 45, US Dept. of Commerce, Washington, DC, 58 pp., 1965.

WMO: Drought and Agriculture, WMO Tech, Note 138, Geneva, Switzerland, 127 pp., 1975.