DROUGHT MONITORING BASED ON REMOTELY SENSED DATA IN THE KEY GROWING PERIOD OF WINTER WHEAT: A CASE STUDY IN HEBEI PROVINCE, CHINA

Guo Hu Wang Ying* Cui Weijia

(Key Laboratory of Environment Change and Natural Disaster, MOE, Beijing Normal University, Academy of Disaster Reduction and Emergency Management, Ministry of Civil Affairs&Ministry of Education,Beijing,China,100875)

KEY WORDS: Remote Sensing；Drought；Anomaly Vegetation Index；Winter Wheat；Phenophase

ABSTRACT:

In this research, the historic data of NOAA /AVHRR NDVI (1981-2000) and the anomaly vegetation index were utilized. Monitoring and analyzing the winter wheat drought situation in the pre-green up period, green up period, heading period and filling period from 1997 to 2000 in Hebei province, Discussing the effects of drought situation in the key growing periods on the winter wheat yield, Taking Cangzhou、Xingtai、Hengshui as main research area, we analyzed the drought situation how to affected the winter wheat production. Through the Remote Sensing (RS) dynamic monitoring result, and the winter wheat actual production, the contrast among that three places, we can conclude as follows: 1) the drought situation affects winter wheat finally production differently at the different grow stage. Drought happened in pre-green up period and green up-jointing period is an insignificant affect to winter wheat; and drought in jointing-heading period and heading-filling period will result in the production of winter wheat dropped observably, especially in heading-filling period; 2) the drought situation duration differences in growing stage will result in different affect to winter wheat production. The longer time of drought situation in jointing-heading period and heading-filling period, the effect to winter wheat production is more remarkable.

1. INTRODUCTION

The average of winter wheat planting area is about 2.3×106 hectare every year in Hebei province, where the crop covers over 10% of total winter wheat plating area in China. And the production of winter wheat in Hebei is above 1.0×108t every year, but in this area the spring drought occurs continually. There are about 20 droughts from 1949 to 2000, and the disaster occurs every 2.5 years on an average. The occurring frequency of spring drought is over 0.4, which is over 0.5 in the most area of Hebei province (Huang Zhiying et al, 2003).The spring drought becomes more and more worse in the past few years. The drought happened every spring from 1997 to 2000, The area of spring drought was 3.29×106 hectare, and the drought affect all over 137 counties of Hebei province in 1997. The area of spring drought was 4.47×106 hectare, and the drought situation happened mostly the central and south areas of Hebei Province in 1999. The area of spring drought was 3.73×106 hectare, which affected the most area of the north in Hebei province, and yield of the summer grain crops reduced 0.51 billion kilogram.

The drought situation can be monitored using remote sensing widely, simultaneously and dynamicly. Many Chinese and foreign researchers have done a lot of work in the domain. The satellite of NOAA passes the same region twice every day, the repeat cycle of time is short, the overlay area is large, so which is fit the simultaneous and dynamic drought situation monitoring of large area agriculture. The data of NOAA/AVHRR is serial and long time, so which fit the monitoring and analyzing of long time drought situation. The methods and models of drought situation monitoring based on the data of NOAA/AVHRR has been mature, including thermal inertia, evapotranspiration, and the vegetation index and so on. (John C Price , 1980; Carlson T N et al, 1994; Kogan F N, 1995; Wu Xiaobo et al, 1998; Zhou Yongmei et al,1998; Ji Ruipeng et al, 2005).

The plants will change in the different growth periods, and the period in which the plants take place greatly changes is called as phenophase. Phenophase is a key period in the corps growth. We can explore and research the corps periodic rule in their growth period and investigate deeply the result of climate change effect on the corps. There are many studies on the affects of water deficit on the winter wheat yield in the different growing period. For example, Sun Hongyong et al (2003) concluded that the water in the jointing stage have important effects on the yield and water utilization efficiency of the winter wheat by the drought stress experiment in the winter wheat different growth stage. Experiment of Zhao Shiwei et al (2001) showed that the water deficit from the jointing stage to the heading stage reduced the number of grain, and the water deficit from filling stage to the mature stage reduced the 1000-grain weight. Wu Shaohui et al (2002) discovered that the average time of winter wheat grain filling became short and the average speed of winter wheat grain filling increase on the condition of drought. The effects of grain filling speed on the forming of winter wheat grain weight was obviously, and there were not significant correlation between the duration times of grain filling from the forming of winter wheat grain weight. But above research conclusions were all obtained in the laboratories, and there are few studies on the effects of drought situation on the yield of winter wheat in the key growing periods based on remote sensing data.

* Corresponding author, Email: wy@ires.cn

Supported by the Open Project Program of Key Laboratory of Resources Remote Sensing & Digital Agriculture, Ministry of Agriculture, Beijing, 100081, China

A study of dynamic monitoring of winter wheat drought situation in Hebei province, using the historic data of NOAA /AVHRR Normalized Difference Vegetation Index（NDVI） was taken the daily maximum synthesis processing in 10 days, and taking Cangzhou, Xingtai and Hengshui as example. We also discussed the effects of drought situation on the yield in the winter wheat some key growing periods. Study on the drought situation of winter wheat during several important growth times can be helpful to making scientific measures for the winter wheat protection against drought and drought resistance and avoiding reduction of wheat production.

2. STUDY AREA AND DATA

2.1 Study area

The Hebei province is located at the mid-latitude zone and the costal area conjoin with the inland (36° 05′ N- 42° 37′ N, 113° 11′ E-119° 45′ E). The terrain is high in the northwest and low in the southeast, and the trend of terrain becomes low gradually from the northwest to the southeast showing a half ring. The climate is temperate, and it is continental and monsoonal. The annual average temperature increases from the north to the south, ranging from －0.3～13℃, and the annual precipitation ranges from 340mm～800mm.

Hebei province is an important grain-produced area, where the crop covers over 10% of total winter wheat plating area in China .The mid-south and east of Hebei province covering the Shijiazhuang、 Baoding、 Tangshan、 Xingtai、 Handan、 Cangzhou and Hengshui regions, is a major winter wheat production area, where winter wheat planting area take over 80% of all crop planting area every year.

2.2 Data

The historic data of NOAA /AVHRR Normalized Difference Vegetation Index（NDVI）was derived from Pathfinder Data Sets of Earth Resources Observation System: (EROS). The data from the 4th ten days to the 15th ten days every year since 1981 to 2000 was used in this paper，and 240 basic image files were obtained in total.

The Normalized Difference Vegetation Index(NDVI) can eliminate some effects such as change of solar zenith angle, satellite viewing angle and atmospheric effect. And NDVI was taken the daily maximum synthesis processing in 10 days can reduce some factors which lead NDVI fall down, such as solar zenith angle, water vapor, aerosol, view direction and cloud etc. The other data include the precipitation, the winter wheat yield and the agriculture land use map. The precipitation data include the daily data of meteorological observation station: Shijiazhuang, Botou,Leting ,Chengde and Huailai, and the precipitation interpolation map. The data of winter wheat unit yield includes Xingtai,Cangzhou and Hengshui from 1997 to 2000.

3. THEORY AND METHOD

The winter wheat is overyearing crop, its growth phase is much longer than other crops. The winter wheat growth phase is about 270 days in the north, China. Seeding is at September or October every year, and reaping is at May or June every year. The key periods of winter wheat include green-up, jointing, heading and filling. According to the crop calendar of winter wheat, green-up stage of winter wheat growing in Hebei province is on last ten days in February, jointing stage is generally on first ten days in April, heading stage is on first ten days in May, and filling stage on the last ten days in May. So the growing period of winter wheat can be divided into four stages. The four stages are pre-green up period(from the 4th ten days to the 6th ten days)、green up-jointing period (from the 7th ten days to the 9th ten days)、jointing-heading period (from the 10th ten days to12th ten days) and heading-filling period (from the 13th ten days to the 15th ten days).

The anomaly vegetation index (AVI) is used to monitoring the drought situation of the winter wheat in four growing stages (Wang Pengxin et al, 2003). The anomaly vegetation index using multiyear every ten-day mean normalized difference vegetation index (NDVI) as the background value, and then the background value is subtracted by currently year every ten-day NDVI data to obtain anomaly value of vegetation index, the positive value of AVI can reflect the growth of vegetation is better than normal years, and the negative value of AVI can indicate the growth of vegetation is worse than normal years, then we can fix the drought class according the value of AVI. And the AVI is expressed as:

$$AVI = (NDVI_i - \overline{NDVI}) \big/ \overline{NDVI}$$

In which the value of $NDVI_i$ is value of $NDVI$ per ten days, the value of $\overline{NDVI}$ is average value of 20 years in this ten days. In this research, Setting four thresholds which are A_1 、A_2、A_3、A_4 based on the value of AVI and the precipitation data, and taking $A_1 = -12$ 、$A_2 = -6$ 、$A_3 = 0$ 、$A_4 = 12$ by experimentation, so the monitoring result is divided into five classes, which are:

$AVI \le -12$	Serious drought
$-12 < AVI \le -6$	Middle drought
$-6 < AVI \le 0$	Light drought
$0 < AVI \le 12$	Normalcy
$AVI > 12$	Humidness

At first, we extract the study region from the remote sensing image, and getting the study region data from the 4th ten days to the 15th ten days every year since 1981 to 2000, then do the projection transform and geography correction to the study region images. We calculated the NDVI average value of ten days from the 4th ten days to the 15th ten days, using the twenty years data of NDVI, then calculated the anomaly vegetation index of ten days using the data of NDVI average value from the 4th ten days to the 15th ten days 1997-2000. Then extracting the winter wheat drought areas based on the land use information at which every growing period in Hebei province, then attain the percentage of drought areas in different growing stage, (calculate the drought areas percentage of serious drought、middle drought、light drought in every ten days from the 4th ten days to the 15th ten days, and the percentage of

drought areas in pre-green up period、green up-jointing period、jointing-heading period and heading-filling period respectively)
.

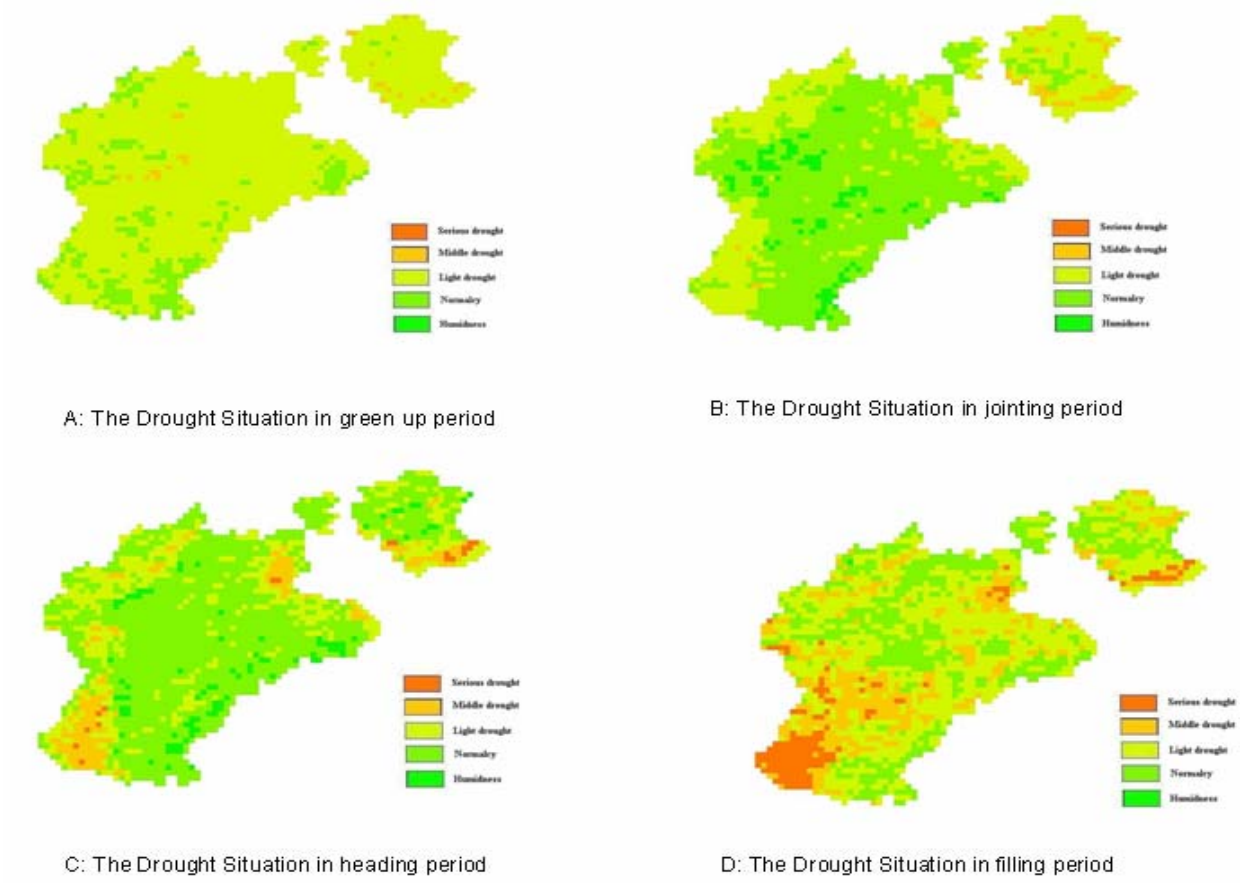

Figure. 1 The Distribution of Drought Situation in the Main Growing Period of Winter Wheat in 2000

4. RESULTS AND DISCUSSION

4.1 Analysis of drought situation in the winter wheat key stages

The distribution of drought situation in the main growing period of winter wheat in 2000 is shown as Fig.1.

There was not a large range rainfall in the winter wheat growth prophase, and the drought situation was severe in the green up period, and the drought area was large. The winter wheat drought situation got relief gradually in the jointing period. There was a rain process in the middle of April, but the precipitation had a great difference in different regions. The precipitation of the last ten-days of April concentrated mainly at the central and the north regions in Hebei province, and the winter wheat drought situation of southwest regions aggravated in the heading period. The

large range drought situation appeared in the filling period, and the drought situation of the northeast and the south was severe.
We make a comparison between the drought monitoring result by the remote sensing and the historic statistical data of drought area and the precipitation data, and it shows that the drought monitoring could well reflect the dynamic changes of the winter wheat drought situation.

4.2 Analysis of drought area in the winter wheat key stages 1997-2000

By the method of the anomaly vegetation index , attaining the percentage of drought areas in different growing stage, and calculating the drought areas percentage of serious drought、middle drought、light drought in every ten days from the 4th ten days to the 15th ten days, the percentage of drought areas in pre-green up period、green up-jointing period、jointing-heading period and heading-filling period respectively. The area ratio suffered from drought in the four growing periods of winter wheat from 1997 to 2000 in Hebei province is shown in Fig.2.

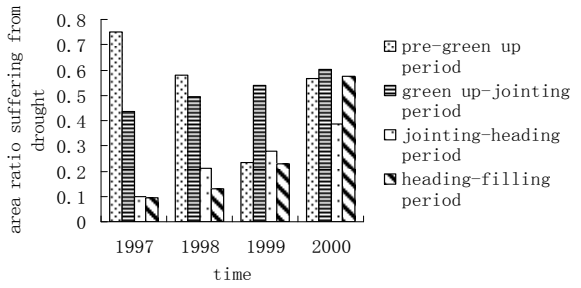

Figure. 2 The area ratio suffering from drought in the four growing periods of winter wheat from 1997 to 2000 in Hebei province

The area ratio of suffering from drought in the early stage of the winter wheat growth is high from 1997 to 2000, and the value is bigger than 0.4. The early stages include pre-green up period and green up-jointing period. The area ratio suffering from drought in pre-green up period in 1997 is the highest in the four years, and the value achieves 0.75. The drought situation in the winter wheat growth early stage in 2000 is the severest; the average value of area ratio suffering from drought is 0.556 in pre-green up period and 0.602 in green up-jointing period.

The middle and last stage of winter wheat growth includes jointing-heading period and heading-filling period, in which the winter wheat area ratio suffering from drought decline significantly. The average value of area ratio suffering from drought is 0.1 in jointing-heading period and 0.096 in heading-filling period in 1997.It indicates that the drought situation disappeared in 1997.The average value of area ratio suffering from drought reach 0.386 in jointing-heading period and 0.575 in heading-filling period in 2000 It indicates that the duration time of drought situation is long and drought situation is severe.

4.3 Analysis the correlation between winter wheat yield and drought situation

In this study, we take Cangzhou、Xingtai、Hengshui as main study areas. The area ratio suffered from drought in the four growing periods of winter wheat from 1997 to 2000 in Cangzhou、Xingtai and Hengshui were shown as Fig.3, Fig.4 and Fig.5

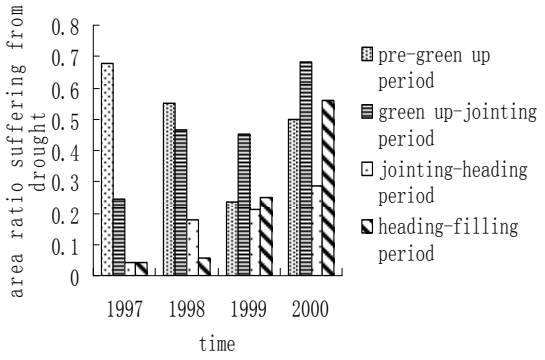

Figure. 3 The area ratio suffering from drought in the four growing periods of winter wheat from 1997 to 2000 in Cangzhou

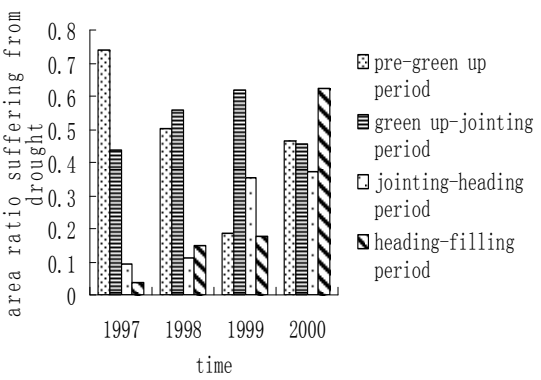

Figure. 4 The area ratio suffering from drought in the four growing periods of winter wheat from 1997 to 2000 in Xingtai

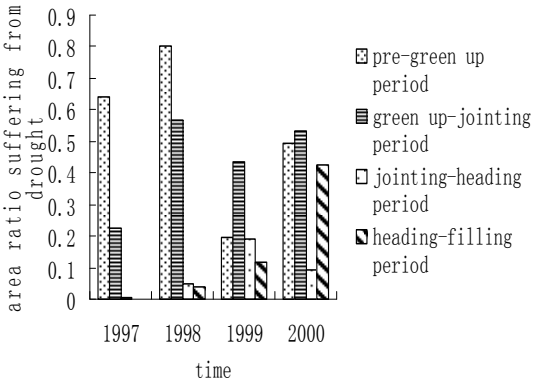

Figure. 5 The area ratio suffering from drought in the four growing periods of winter wheat from 1997 to 2000 in Hengshui

Fig.3, Fig.4 and Fig.5 showed that the area ratio suffering from drought changed greatly in the winter wheat growing period in CangZhou, XingTai and HengShui 1997-2000. The change of area ratio suffering from drought in 1997 was the largest the value of area ratio suffering from drought was about 0.7 in the pre-green up period, and the value was blow 0.01 in the jointing-heading period. The change of area ratio suffering from in HengShui was the largest in 1998, the value of area ratio suffering from drought was about 0.6 in the winter wheat early stage, and the value fall at 0.1. The change of area ratio suffering from drought was not large in 1999, the duration time of winter wheat drought situation in CangZhou was longer than other regions, and the value of area ratio suffering drought was above 0.2. The change of area ratio suffering from drought in 2000 was low, and the value was about 0.5. The area suffering from drought was large and the duration time was long.

The serious drought would effect on the growth and yield of winter wheat. The unit yield of winter wheat in Cangzhou、Xingtai and HengShui from 1997 to 2000 as Fig.6.

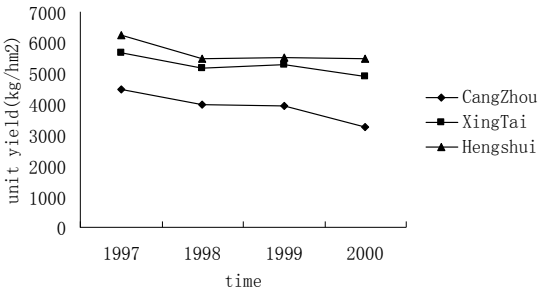

Figure .6 The unit yield of winter wheat in Cangzhou、

Xingtai and HengShui from 1997 to 2000,unit: kg/hm2

The unit yield of winter wheat in 1997 was high in the research areas. Comparing the area ratio suffering from drought, it indicates that the effects of drought situation in the winter wheat early stage on the winter wheat is not significant, and if the drought situation in the winter wheat early stage relief, there were not obvious effects on the growth of winter wheat in the last growing period. Comparing the unit yield of winter wheat in 1997, reduction of winter wheat yield in ZangZhou, XingTai and HengShui was serious from 1998 to 2000. We calculated the percentage of winter wheat yield in Cangzhou、Xingtai and HengShui from 1999 to 2000 based on the winter wheat unit yield in 1997. The data as follow:

	CangZhou	XingTai	HengShui
1998	11.7%	9.9%	14.0%
1999	13.1%	7.4%	13.1%
2000	36.8%	15.6%	14.0%

Table. 7 The percentage of winter wheat yield reduction in Cangzhou、Xingtai and HengShui from 1999 to 2000

The percentage of winter wheat yield in Cangzhou and HengShui was the highest, the value of the percentage of winter wheat yield was above 10%, and the percentage of winter wheat yield in CangZhou reached 36.8% in 2000. The percentage of winter wheat yield in 2000 was the highest in CangZhou, XingTai and HengShui，and the value reach above 14%.

The area ratios suffering from drought in the winter wheat per-green up period were all above 0.6 in CangZhou, XingTai and HengShui from 1997 to 2000. The value was about 0.5 in the winter wheat green up-jointing period. The value of area ratio suffering from drought in jointing-heading period and heading-filling period had great difference. The value of area ratio suffering from drought from 1999 to 2000 was higher than that in 1997, it indicated that the correlation between the winter wheat reduction and the drought situation in heading and filling period was significant, more serious drought situation and more remarkable the winter wheat reduction. The effect of drought situation in green up and jointing period on reduction of the winter wheat was not remarkable. If the drought situation in the early stage relief, which do not have obvious effects on the winter wheat yield.

It was different that the duration time and the change of drought situation in jointing-heading period and heading-filling period in CangZhou,XingTai and HengShui from 1999 to 2000. Comparing monitoring results in 1998 and 1999, we found that the duration time and change of drought situation in 2000 were the smallest. And the percentage of winter wheat yield reduction was the largest. It indicated that there was significant correlation between duration time change of drought situation and reduction of winter wheat, and more duration time change of drought situation and more serious reduction of winter wheat.

5. CONCLUSIONS

In this study, we research the NOAA/AVHRR data from 1981 to 2000 using Anomaly Vegetation Index (AVI). By analyzing the relationship between the degree of winter wheat drought situation in four key periods and the winter wheat unit yield, we can get conclusions as follow.

(1) The effects of drought situation in winter wheat different key periods on the winter wheat ultimate yield is different. The effects of drought situation in pre-green up period and green up-jointing period on the winter wheat yield are not significant. The winter wheat yield reduce significantly because of the drought effect from jointing period to filling period, especially in the filling period.
(2) The effects of different duration time and change of drought situation in winter wheat growing periods on the winter wheat yield are different. The winter wheat yield decrease significantly if the duration time of drought situation becomes long in jointing-heading period and heading-filling period.

There are many factors effect the winter wheat yield, and drought is an important factor. The large area irrigation land, the effects of precipitation delay on the crops growth and the crops will grow better by compensating water when the drought pass and so on. All these factors can result in the effects of drought situation on the winter wheat yield become weak. Thus the further study on the drought monitoring by remote sensing is necessary.

REFERENCES

Carlson T N，Gillies R R，Perry E M.A Method to Make Use of Thermal Infrared Temperatu- re and NDVI Measurements to Infer Surface Soil Water Content and Fractinal Vegetational Cover [J].Remote Sensing Review,1994,52:45-59.

Huang Zhiying,Liang Yanqing,Feng Zhongjiang,Analysis on the Impacts of Drought on the Environment due to the Climate Change in Hbei Prvoince [J].Arid Zone Research, 2003，20(4):326-329.

Ji Ruipeng,Ban Xianxiu,Feng Rui et al. Monitoring Soil Moisture and Arid Area with NOAA/ AVHRR Data[J].Journal of Disaster Prevention and Mitigation Engineering, 2005,25（2）:157-161.

John C Price. The Potential of Remote Sensed Thermal Infrared Data to Infer Surface Soil Moisture and Evaporation [J].Water Resources Research, 1980, 16 (4):787- 795.

Kogan F N. Droughts of the late 1980s in the United State AS Derived From NOAA Polar-o- rbiting Satellite Data [J]. Bulletin of the American Meteorological Society, 1995, 76:655-668.

Sun Hongyong et al.Effects of Water Stress in Different Growth Stage on Water Consumption and Yield in Winter Wheat[J].Journal of Irrigation and Drainage,2003,22(2):13-16.

Wang Pengxin et al.Advance in Drought Monitoring by Remotely Sensed Normalized Difference Vegetation and Land Surface Temperature Product[J].Advance In Earth Sciences, 2003,18(4): 527-533. Wu Shaohui et al.Analysis on the Effect of Drought on the Grain Weight Grow and the Character of the Grain Filling of Winter Wheat[J].Agricultural Research in the Arid Areas, 2002, 20(2): 49-51..

Wu Xiaobo,Yan Shouyong,Tian Guoliang et al. Using NOAA/AVHRR Data to Monitor Drought with GIS Technique [J].Journal of Remote sensing, 1998,2（4）:280-283.

Zhao Shiwei et al. Effects of Water Deficits on Yield and WUE in Winter Wheat [J].Irrigation and Drainage, 2001, 20(4):56-59.

Zhou Yongmei. Monitoring Drought in Qinghai Pastoral Areas Using NOAA/AVHRR Data [J].Quarterly Journal of Applied Meteorology, 1998,9(4):496-500.