Summary of Agricultural Drought Monitoring by Remote Sensing at Home and Abroad

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Abstract. Drought is one of the major natural disasters which causes very severe impacts on economy and society, remote sensing is the efficient method which can dynamic monitor drought at a great range of scale, the research on agricultural drought monitoring has been an important issue. This paper introduces the principle of agricultural drought monitoring based on remote sensing technology, and reviews the current remote sensing approaches in drought monitoring. Combined with the current research hotspots, this paper offers the further research ideas by discussing the dominances and limitations of these methods.

Keywords: Agricultural drought · Remote sensing · Methods
Soil water

1 Introduction

Agriculture is the most fundamental and weakest link in our country's entire national economy. Crop production is directly related to the food security of our country and the increase of agricultural efficiency. Drought is a water shortage caused by the imbalance of water supply. Agricultural drought, the water deficit in crops, is mainly due to the imbalance between soil water supply and crop water demand, depending on the soil's water supply capacity and the physiological needs of crops. In recent years, agricultural disasters in China have occurred many times, agricultural drought because of its high frequency, long duration, large extent, to the agricultural economy caused serious influence, has become a major natural disasters in the world [1, 2].

The traditional drought monitoring method is based on the limited soil moisture monitoring site to determine the status of crops and plants being inhibited by insufficient water supply, and the description is qualitative. This method has limitations, it difficult to obtain accurate and timely agricultural drought and the development of time and space information. Remote sensing technology has the advantages of macro, rapid,

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wide range and economy, which provides a new way for agricultural drought monitoring [3]. Remote sensing technology has become an important means of drought monitoring and has played an important role in agricultural drought monitoring [4].

2 The Background and Status of Drought Remote Sensing Monitoring Technology

Remote sensing technology is based on electromagnetic theory, application of various sensors on long-range target radiation and reflection of electromagnetic wave information, collection, processing, and finally, imaging, and on the ground all sorts of scenery detection and identification of a comprehensive technical [5].

Since the invention of the first airplane, aerial remote sensing was first applied militarily, and has been widely used in geology, engineering construction, map mapping, agricultural resources investigation and so on. Since the launch of the first satellite, remote sensing technology has been widely developed and widely used. With the continuous development of sensor technology, aerospace technology and communication technology, modern remote sensing technology has entered a new stage of multi-platform, multiphase and high resolution. Remote sensing technology and space science, electronic science, earth science, computer science and other edge discipline cross infiltration and mutual confluence, has gradually developed into a new type of earth space information science. According to different energy sources of detection targets, remote sensing is divided into active remote sensing technology and passive remote sensing technology. According to the representation of recorded information, remote sensing can be divided into image and non-image modes. Remote sensing can be divided into space, aviation and ground remote sensing technology according to the platform of remote sensor. Remote sensing technology has been widely used in land resources, land resources, vegetation resources, geology, cities, surveying and mapping, archaeology, environmental investigation monitoring and planning and management.

There are many classifications about drought [6–8], which can be divided into four categories: meteorological drought, hydrological drought, agricultural drought, and economic and social drought. Agricultural drought refers to the phenomenon of crop failure due to insufficient rainfall and inadequate irrigation in the process of crop growth. The key factor to reflect the drought is the soil moisture content [10]. Therefore, the direct target of using remote sensing for drought monitoring is soil moisture content. Remote sensing based on the theory of electromagnetic wave, drought, crops before and after the biochemical components in canopy structure has changed, the sensor receives electromagnetic wave changes, compare before and after the drought disaster information of electromagnetic analysis can obtain the scale of the crop. Research work about the drought remote sensing monitoring at home and abroad have been carried out for a long time, almost all the crops on agricultural drought disaster, the influence of using remote sensing data and other support, obtain accurate soil moisture content, set up the drought monitoring and evaluation methods have a lot of work to do. Scholars at home and abroad often using the thermal inertia method, vegetation index method of water supply, green index method, anomaly vegetation index method, microwave spectroscopy, thermal infrared remote sensing, remote sensing soil moisture for a study of spectral reflection characteristic of soil moisture content, such as the relatively mature method of thermal inertia method, vegetation index method of water supply, the green index method, anomaly vegetation index method and microwave remote sensing.

3 Thermal Inertia Method

The thermal inertia is a measure of the thermal reaction of matter to temperature, reflecting the energy exchange of matter and the surrounding environment. The thermal inertia method is a more mature method for monitoring soil moisture. The thermal inertia reflects a thermal characteristic of soil. Its principle is that the soil with high water content has a large thermal inertia according to the heat capacity and heat conductivity of the water. Soil thermal inertia and there is a correlation between soil moisture content, soil heat capacity, thermal conductivity increases with the increase of soil moisture, soil thermal inertia also increases with the increase of soil water content.

The daily contrast of soil surface temperature is determined by the factors of soil internal and external factors. The internal factors mainly reflect the thermal conductivity of soil heat transfer capacity and heat capacity reflecting the soil heat storage capacity; External factors refer to the surface thermal equilibrium caused by solar radiation, air temperature, relative humidity, wind, cloud, water vapor, etc. Therefore, when using remote sensing information inversion of soil thermal inertia, needs the support of a large number of ground data, not only need to consider the solar radiation, atmospheric absorption and radiation, soil thermal radiation and heat conduction effect, also should take into account the evaporation, condensation and enrage effect on heat exchange, or parameters, calculation is more complicated.

In 1971, Price [11] first applied a model based on thermal inertia. In 1975, Kahle [12], Ju [13], according to the heat balance and heat conduction theory, improved the soil thermal inertia model, which combined the heat flux (H), latent heat flux (E) and surface heat flux (G) to the surface radiation energy. Price [12] proposes the Apparent Thermal Inertia (Apparent Thermal Inertia, ATI) concept, namely, ignore the latitude, the sun Angle, sunshine time, and the influence of the distance, only consider the soil reflectance and surface temperature changes. The apparent thermal inertia of soil can be obtained indirectly through remote sensing inversion of soil reflectivity and surface temperature. In practice, we usually use the apparent thermal inertia to approximate replace real thermal inertia, according to the surface of the heat balance equation and heat conduction equation to establish apparent thermal inertia (ATI) and soil moisture content between remote sensing information inversion model [14]. The surface temperature difference is small, the apparent thermal inertia is large, the soil water content is high; the surface temperature difference is large, the apparent thermal inertia is small, and the soil moisture content is low. In China since the early 1990s in the thermal inertia model theory and experimental research has made great progress, Ji [15], such as using MODIS data, through the establishment of apparent thermal inertia and soil moisture between the linear experience model, in Shaanxi province early February to March, 2005 occurred in late spring drought process monitoring tests have been carried out. The thermal inertia of the surface temperature was calculated by using the modified surface temperature, and the soil moisture was obtained, and the drought conditions in liaoning were monitored for years. By using NOAA/AVHRR satellite data, guo zi [17] and other methods used the apparent thermal inertia method to inversion the shallow soil moisture. The thermal inertia method of soil moisture content requires strict registration of two remote sensing images in the research area, and the temperature difference is obtained by the light temperature. Since remote sensing image is affected by the cloud, it is difficult to get the image of cloud in the same research area day and night, so it is difficult to guarantee the accuracy of the diurnal temperature difference. When the soil vegetation coverage is high, the accuracy of the soil moisture content will be greatly reduced due to the influence of vegetation transpiration and soil moisture exchange.

4 Vegetation Water Supply Index Method

The vegetation water supply index is a comprehensive monitoring drought method based on surface temperature and vegetation index. The principle is that when the plant water supply is insufficient to cause the crop to die due to lack of water, the normalized vegetation index will drop sharply and the surface temperature of the leaf will rise rapidly. Definition [18] of Vegetation Supply Water Index (VSWI):

$$VSWI = NDVI/T_S$$

VSWI is the vegetation water supply index; ts is the canopy temperature of vegetation; NDVI is the normalized vegetation index.

The physical meaning of vegetation water supply index method can be described as: when the vegetation water supply is normal, the vegetation index reflected by remote sensing information is stable during certain growth period. In case of suffering from drought, vegetation growth under water stress, to reduce moisture loss, plant stomata part will close, resulting in increased leaf temperature, vegetation canopy temperature, vegetation water supply is insufficient growth affected at the same time, vegetation remote sensing information is a reflection of the index will be reduced. The use of NOAA/AVHRR data to use the vegetation water supply index method was used to monitor the continuous drought disaster in the winter and spring in Fujian province from 2001 to 2002. Chen [20] and other use vegetation water supply index to monitor Guangdong province in October 2004 drought conditions. Vegetation water supply index when applied to the MODIS data, as a result of the MODIS data to get NDVI easier than NOAA/AVHRR data get NDVI to saturation, so the VSWI is applied to the high density vegetation biomass, its monitoring precision will decline. Ji [15] on the VSWI is improved, the model of NDVI to switch to the enhanced vegetation index (EVI), to improve the sensitivity of biomass area, and early April to may, 2005 in Shaanxi province in late spring drought monitoring.

5 Distance Vegetation Index Method

The distance vegetation index defines [21]:

$$ATNDVI = TNDVI - \overline{TNDVI}$$

$$TNDVI = MAX(NDVI(\mathrm{t}))$$

ATNDVI is the distance vegetation index; TNDVI was the highest value of NDVI in the same period. T is the number of days; the evaluate the annual normalized vegetation index (NDVI).

In general, the light and temperature conditions in certain areas are not very different, and the vegetation growth condition is mainly related to water, and the water supply is the key factor for vegetation growth. The distance vegetation index method is from the perspective of vegetation growth. When the soil water supply is abundant, the vegetation grows well. Conversely, vegetation growth is inhibited. This method needs to be accumulated many years of remote sensing data to calculate the perennial ten-day average vegetation index, then the same period when the observation period of vegetation index compared with perennial average, judge condition of crop growth, and then to evaluate crop drought degree. Using the distance vegetation index method, the NOAA/AVHRR data were used to monitor the extreme drought in Heilongjiang province in the summer of 2000 [22]. According to the distance vegetation index, the drought was divided into severe drought, drought and normal 3 grades. In this paper, the relative distance map of vegetation index is supervised and classified, and the pseudo-color map of drought monitoring is generated, and the affected area of crops is calculated. The drought condition of grassland in Qinghai province was monitored by the vertical vegetation index [23]. Tansey [24], respectively, using 1982–1998 (1999) precipitation and temperature meteorological data, as well as the AVHRR NDVI remote sensing data are calculated by the Yellow River basin climate drought index, and analyzed the NDVI, the Yellow River basin are analyzed from the aspects of climate and vegetation features 18a to drought condition changes.

6 Microwave Remote Sensing

Microwave remote sensing is one of the most important methods for soil moisture monitoring. Microwave remote sensing has the characteristics of all-weather, multi-polarization and a certain transmission capability to the soil layer. The method of microwave remote sensing monitoring of agricultural drought is mainly passive microwave method and active microwave method. Generally passive microwave remote sensing cost is low, the time resolution is high, but the spatial resolution is low; The active microwave remote sensing cost is high, the spatial resolution is high, but the time resolution is low. Regardless of passive microwave remote sensing or active microwave remote sensing, the inversion results are affected by surface roughness and vegetation. How to reduce or eliminate the influence of surface roughness and vegetation is an important research direction of microwave remote sensing. Tansey

Moeremans and [25, 26] research shows that in bare land and sparse vegetation areas, after the near surface soil moisture and to a high degree of correlation between scattering coefficient, and that the surface roughness has a great influence on soil moisture monitoring. Li zhen and other [27] comprehensive active and passive microwave data and optical data monitoring soil moisture change, reduce the influence of vegetation, and improve the accuracy of soil moisture change monitoring. Liu wei, etc. [28] try polarization decomposition technique to overcome the influence of surface roughness and vegetation, the better estimation of vegetation covered surface soil moisture change, but this method requires high temporal resolution, must be full polarization data at the same time, the current spaceborne microwave sensor is difficult to meet the requirements; Rajat Bindlish [29] takes advantage of the improved IEM model to obtain the inverse results of 0.95 correlation with actual soil moisture. Microwave remote sensing is not affected by the interference of cloud, which can be used throughout the day, although greatly influenced by the surface parameters, but its for soil moisture estimation accuracy is high, is the method of monitoring soil moisture potential. However, the current microwave remote sensing usually can only reverse the moisture of soil surface, and the root system of crops is usually under 10 cm–20 cm, so the application of agricultural drought monitoring has certain limitations.

7 Conclusion

In recent years, agricultural drought in China has been frequent and serious, and accurate drought monitoring is of great significance. Agricultural drought involves many subjects such as agriculture, meteorology, hydrology and plant physiology. It is a complex phenomenon, and accurate crop drought monitoring is more difficult. Remote sensing data contains abundant surface comprehensive information and remote sensing technology has great potential in drought monitoring. At present, the domestic and foreign scholars in the field of agricultural drought remote sensing monitoring technology research a series of achievements, and explore some feasible methods and approaches, among the more mature method of thermal inertia method, vegetation water supply index method, anomaly vegetation index method and microwave remote sensing method, etc. Various monitoring technologies have their own advantages and disadvantages, and their applicability and accuracy are subject to further improvement and improvement.

(1) The advantage of thermal inertia is that the method is simple and easy to obtain, suitable for use in the bare ground/low vegetation coverage area, and the disadvantage is that the scope of application is narrow;
(2) The advantages of the vegetation water supply index method are that the parameters are clear and the accuracy is higher, which is suitable for the high and high vegetation coverage area, and the disadvantage is that the vegetation canopy temperature is difficult to obtain.
(3) The advantage of the distance vegetation index method is clear, suitable for the medium and high vegetation coverage area. The disadvantage is that the remote sensing data and the monitoring results are in lag.

(4) The advantages of microwave remote sensing method are all-weather and high precision, suitable for use in bare ground/vegetation coverage area, and the disadvantage is that monitoring soil is effective and shallow and cost is high.

In view of the advantages and disadvantages of the existing agricultural drought remote sensing monitoring technology, further agricultural drought monitoring research should strengthen the combination of crop physiology, morphological indexes and soil moisture content indexes. There are many available remote sensing data sources available, and the application of new remote sensing data sources in agricultural drought monitoring is actively carried out, such as the application of remote sensing data of GF-1. Further considering the use of multiple satellite sensors simultaneously to monitor the agricultural drought situation, the integrated radar data and the advantages of visible data make the monitoring results more comprehensive, accurate and timely. Using the advantages of remote sensing methods and solving the problem of technical practical application, the development and construction of a nationwide system of remote sensing monitoring of drought remote sensing will be a very challenging research work.

References

1. Zhiguo, H., et al.: China's Climate Resources. Science and Technology Press, Beijing (1993)
2. Li, M., Li, S., Li, Y.: Analysis of Drought Disaster in China in nearly 50 years. Chin. Agric. Meteorol. **24**(1), 8–11 (2003)
3. Hong, X., Wu, J., Liu, Y., et al.: Research on drought monitoring in china using remote sensing methods. Remote Sens. Inf. **24**(1), 55–58 (2005)
4. Weiguo, L.: Method and Application of Crop Remote Sensing Monitoring and Application. China Agricultural Science and Technology Press, Beijing (2013)
5. Mei, A., Peng, L., Qiming, Q.: Introduction to Remote Sensing. Higher Education Press, Beijing (2001)
6. American Meteorological Society. Meteorological drought: policy statement. American Meteorological Society (1997)
7. Keli, L.: Research on Drought Disaster in China and Countermeasures. Henan Science and Technology Press, Zhengzhou (1999)
8. Wilhite, D.A.: Preparing for drought: a methodology. In: Wilhite, D.A. (ed.) Drought: A Global Assessment, Hazardsand Disaster Series, vol. II, pp. 89–104. Routledge, New York (2002)
9. Bowers, S.A., Hunks, R.J.: Reflection of radiant energy from soils. Soil Sci. **100**(2), 135–138 (1965)
10. Watson, K., Rownen, L.C., Officeld, T.W.: Application of thermal modeling in the geologic interpretation of IR images. Remote Sens. Environ. **24**(3), 2017–2041 (1971)
11. Price, J.C.: Thermal inertia mapping: a new view of the earth. J. Geophys. Res. **82**(18), 25–31 (1977)
12. Kahle, A.B.: A simple thermal model of the earth's surface for geologic mapping by remote sensing. J. Geophys. Res. **82**(11), 1673 (1977)
13. Ju, W., Sun, H., Tang, Z.: The application of meteorological satellite remote sensing in drought monitoring. Disaster Sci. **12**(4), 25–29 (1996)

14. Zhang, S., Du, J., Jing, Y.: Research on the operational methods of remote sensing drought monitoring based on MODIS data. Agric. Res. Arid Reg. **24**(3), 1–6 (2006)
15. Ji, R., Xiu, B., Rui, F., et al.: Application of NOAA/HAVRR data to monitor soil moisture and drought area. J. Disaster Prev. Mitig. Eng. **25**(2), 157–161 (2005)
16. Guo, Q., Li, G.: Discussion on soil moisture content using thermal inertia method. Chin. Agric. Meteorol. **26**(4), 215–219 (2005)
17. Liping, Y., Xiaohua, Y., Cunhou, Z.: Application of vegetation water supply index method in drought monitoring in inner mongolia. Inner Mongolia Agric. Sci. Technol. **20**(1), 58–62 (2008)
18. Zhang, C., Li, W.: Research on remote sensing mnitoring of dought dsasters in Fjian povince. Meteorology **30**(3), 22–25 (2004)
19. Deng, Y., Xao, Q., Hang, J., et al.: Application of rmote sensing mnitoring of dought in Gangdong province in 2004. J. Trop. Meteorol. **22**(3), 237–240 (2006)
20. Wiying, C., Qanguang, X., Yngwei, S.: The application of the remote vegetation index in the severe drought monitoring in 1992. J. Remote Sens. **24**(2), 106–112 (1994)
21. Xu, Y., Wu, M., Li, X., et al.: NOAA/AVHRR data in drought monitoring in heilongjiang. J. Harbin Inst. Technol. **10**(2), 51–53 (2005)
22. Yongmei, Z.: Application of NOAA/AVHRR data in grassland drought monitoring in pastoral areas of Qinghai province. J. Appl. Meteorol. **9**(4), 496–500 (1998)
23. Shengtian, Y., Changming, L., Rui, S.: Analysis of climate and vegetation characteristics of drought conditions in the yellow river basin. J. Nat. Resour. **18**(2), 136–141 (2003)
24. Tansey, K.J., Millington, A.C., Battikhi, A.M., et al.: Monitoring soil moisture dynamics using satellite imaging radar in northeastern Jordan. Appl. Geograph. **19**(4), 325–344 (1999)
25. Moeremans, B., Dautrebande, S.: Soil moisture evaluation by means of multitemporal ERS SAR PRI images and interferometric coherence. J. Hydrol. **234**(3–4), 162–169 (2000)
26. Li, Z., Guo, D.: Comprehensive active and passive microwave data monitoring soil moisture change. J. Remote Sens. **6**(6), 481–485 (2002)
27. Wei, L., Jianming, W.: Application of polarization decomposition technology in estimating soil moisture change in vegetation cover area. Remote Sens. Inf. **5**(4), 3–6 (2005)
28. Blindish, R., Jackson, T.J., Gasiewski, A.J., et al.: Soil moisture mapping and AMSR-E validation using the PSR in SM EX02. Remote Sens. Environ. **103**(2), 127–139 (2006)