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Study on the Method of Retrieving Surface Soil Moisture in Western Semi-arid Area by Remote Sensing

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Abstract: *Soil moisture is a very important index parameter in the field of hydrology and meteorology, which plays a very important role in the development of agriculture. Large scale monitoring and retrieval of soil moisture is the main component of agricultural research and ecological environment assessment. The region of the soil water environment is one of the essential parameters in examining the land surface process model. Therefore, remote sensing inversion of soil moisture is a very convincing research topic, and it is also the boundary field of remote sensing technology application research, which is one of the global recognized research problems. With the development of remote sensing technology and GIS, GPS and 3S integration and other related disciplines, not only can the large-scale real-time monitoring of soil moisture dynamics be carried out, but also the accuracy of soil moisture inversion has been greatly improved. Looking back on the development of several decades, several remote sensing methods of soil moisture retrieval have appeared, and these methods have been well verified and applied in corresponding areas.*

Keywords: *Remote Sensing Retrieval, Soil Moisture, Drought, Visible Light*

1. Introduction

1.1. Research Background

Drought is the most common agricultural natural disaster in China. Persistent low rainfall levels can lead to a sharp drop in water levels in rivers and lakes, crop failure and even forest fires. Satellite Meteorological remote sensing monitoring shows that the control flow of the Yangtze River in dry years is 25% to 70% less than that in normal years. Remote sensing and GIS technology can effectively monitor the drought situation in large area in real time. It is a common method in drought monitoring and has a good application prospect.

Soil moisture is an important part of the surface system, which cannot be ignored in the fields of ecology, environment and agriculture. Remote sensing is a technology that uses non-contact sensors to detect the radiation and reflection characteristics of electromagnetic waves of objects, and analyzes the properties, characteristics and states of objects according to their characteristics. It can make up for the lack of sampling of conventional drought monitoring methods, and has the advantages of wide coverage, high spatial resolution, short revisit period, convenient data acquisition and objective data [1]. At present, the relationship between remote sensing technology and soil moisture research lacks the cascade characteristics of data, methods and applications, which easily leads to data misuse and unsafe use of remote sensing soil moisture products. On this basis, soil moisture retrieval method is studied.

1.2. Research Status at Home and Abroad

1.2.1. Foreign Research Status

With the rapid development of remote sensing technology since the 1970s, the countries that use relatively advanced remote sensing technology in the world have conducted extensive research on soil moisture to varying degrees. American Geographers Bowers and Hanks have studied the spectral information of ground emission and reflection, and combined these spectral reflectance characteristics with thermal infrared data information, which is feasible for soil information research. In the early 1970s, in the field of passive microwave remote sensing, NASA used a microwave radiometer to conduct flight tests on farmland in Alexandria, and observed soil moisture distribution ranging from 0 to 15 cm. The results show that the brightness temperature has a positive linear correlation with soil moisture content. According to the radiation transfer equation, the light temperature and soil moisture were set, and the nonlinear equation parameters were solved by iteration and least square method to determine the soil moisture. In the field of active microwave remote sensing, synthetic aperture radar is the most advanced technology of international ground observation. Remote sensing technology for soil moisture extraction has also attracted the attention of meteorology, which makes the method and research more complex. In 1986, Carlson conducted a study based on meteorological satellite data. The calculation of thermal inertia was studied by estimating the distribution of available moisture in a large area of soil [2]. A new method for remote sensing soil moisture was developed in the 1990s.

1.2.2. Domestic Research Status

Since the "Seventh Five Year Plan" in the mid-1980s, the research on remote sensing of soil moisture in China began. The early research direction in China was based on the spectral reflectance of soil surface. Most soil parameters are calculated by thermal inertia method or plant water deficit index method. Zhang Renhua put forward an improved thermal inertia model, summarized the influence factors of surface sensitive heat flow and latent heat energy, and used the improved model to obtain soil moisture. In 1984, Zhang Qiang created the first household thermal inertia map based on aerial photo data. In the 1990's, the theoretical knowledge of soil moisture remote sensing was studied while various experimental tasks were carried out using NOAA / AVHRR remote sensing satellite data. Compared with other countries, it significantly reduces soil moisture or dryness. Reduce macro probe research and other gaps [3]. In the 21st century, many local scientists extend the application of remote sensing inversion to soil moisture monitoring theory. In 2001, Wang Pengxin et al. Studied the application conditions and characteristics of conditional vegetation index in remote sensing drought monitoring. In 2011, Zhang Xianfeng and Zhao jiepeng estimated a wide range of surface soil moisture using remote sensing inversion and assimilation simulation technology, and established a soil moisture calculation model suitable for arid areas.

2. Soil Moisture Retrieval Methods and Models

Thermal Infrared Method.

Thermal infrared remote sensing technology is used to monitor and maintain soil moisture based on emissivity and temperature of soil surface. Because of the negative correlation between soil moisture and soil surface temperature, the relationship between vegetation index, canopy, soil surface temperature and soil moisture can be used to establish various related indicators to monitor soil moisture remotely.

2.1. Thermal Inertia Method

Due to the high heat capacity and thermal conductivity of water, the thermal inertia of soil with high air humidity increases, and the thermodynamic properties of soil with different air humidity change significantly, which affects the change of soil surface temperature. At the same time, it also provides a physical basis for extracting soil moisture information about soil surface temperature. Thermal inertia is the physical quantity to measure the thermal inertia of matter. Under natural conditions, due to the influence of various factors, the thermal inertia of different substances is very different. This difference plays an important role in the temperature change of materials. Through the establishment of remote sensing data soil thermal inertia relationship model and soil thermal inertia soil moisture relationship model, the purpose of using remote sensing to monitor and determine soil moisture is achieved [4]. Here, the thermal inertia can be obtained by remote monitoring the changes of soil surface reflectance and temperature.

According to the surface heat balance equation and heat conduction equation, different amounts of heat are considered, such as solar radiation, atmospheric absorption and radiation, geothermal radiation and heat conduction, evaporation and condensation, heat exchange between soil and air. The inertial model is currently under study. Generally, the thermal inertia of the surface is approximately expressed as a linear function of the surface temperature. Therefore, thermal inertia method has been widely studied in Japan and abroad. The difference between the visible light provided by the satellite, the

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reflectivity of the near-infrared channel and the temperature of the infrared thermal radiation can be used to calculate the thermal inertia and estimate the soil moisture. Sui Hongzhi and others simplified the energy balance equation, calculated the apparent thermal inertia directly from satellite data, and correlated it with soil moisture to monitor drought. When improving the thermal inertia model, Zhang Renhua proposed a realistic thermal inertia model suitable for bare soil, which overcomes the interference between sensitive heat and latent heat transfer, and improves the estimation accuracy of apparent thermal inertia [5]. Tao Yu et al. Improved the method to solve the surface thermal inertia, which considered the surface sensitive heat and latent heat coefficient, directly obtained the actual thermal inertia from the remote sensing image, and determined the relationship between the relevant parameters through experiments. In order to achieve the purpose of soil and water distribution inversion monitoring.

The apparent thermal inertia (Pati) is a simplified form of basic thermal inertia, which does not take into account factors such as the latitude and altitude of the sun:

$$P_{ATI} = \frac{(1-ABE)}{(T_{max}-T_{min})} \tag{1}$$

Where: ABE is the full band albedo, Tmax. Tmin is the daily maximum and minimum surface temperature [6].

The results show that the relationship between the apparent thermal inertia Pati and soil moisture can be expressed as a linear or nonlinear relationship (exponential or power function)

$$W = P_{ATI} \times a + b \text{ or } W = (a^P \times b) \tag{2}$$

Where a and B are the undetermined regression coefficients.

2.2. Temperature Vegetation Index Method

Vegetation index is a spectral size value extracted from multi spectral remote sensing data related to the state of vegetation on the earth's surface [7]. Because it can quantitatively reflect the growth of plants and improve the interpretation of remote sensing images, it is often used as a remote sensing method. It has been used to monitor land use cover, assess vegetation cover density, identify and predict crops, and improve the classification options for objects. At present, the normalized vegetation index (NDVI) is most commonly used. The index is very sensitive to the change of soil background, which largely eliminates the influence of shadow in terrain and community structure, and reduces atmospheric interference. Therefore, the monitoring sensitivity of vegetation coverage is greatly improved. It is usually used to reflect vegetation status, vegetation coverage and biomass information, and is an important indicator of vegetation ecological environment [8].

The principle of NDVI is that vegetation is strongly absorbed in the visible red zone and has high reflectivity in the near-infrared range, so the contrast between them can be used to indicate the physiological state of vegetation. NDVI is most commonly used in remote sensing of vegetation. The reasons are as follows:

1) NDVI is the best index of vegetation growth and vegetation coverage. NDVI is an effective index to detect regional or global changes of vegetation and ecological environment.

2) Partial processing of NDVI can eliminate the influence of radiation conditions (atmospheric radiation) related to solar elevation, satellite observation angle, terrain, cloud / shadow and atmospheric conditions. At the same time, NDVI normalization reduces the angle effect caused by atmospheric influence. Therefore, NDVI increases the corresponding vegetation capacity.

3) For large-scale land cover, the NDVI of cloud, water and snow disaster is higher than that of near-infrared band, so the NDVI value is negative. Two rocks and bare land have similar reflection effect in this band. Therefore, the NDVI value is close to 0, and for vegetation coverage, NDVI is positive and increases with the increase of vegetation coverage. Larger NDVI images clearly distinguish some typical ground cover types and effectively highlight vegetation. Therefore, it is particularly suitable for dynamic monitoring of large vegetation at the global or continental level.

In addition to the above advantages, NDVI also has some disadvantages. NDVI can improve the contrast of reflectivity in the near infrared and red channels. This is the nonlinear range of the ratio of NIR to red, thus highlighting the low value region, suppressing the high value region, and reducing the sensitivity to the high vegetation area. NDVI is more sensitive to the coronal background of plants, and its sensitivity is related to vegetation coverage. In the early stage of plant growth, NDVI overestimates

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the vegetation coverage, but in the later stage of plant growth, NDVI is lower. Therefore, NDVI is more suitable for detecting medium vegetation or medium coverage vegetation.

2.3. Microwave Method

The difference of soil dielectric properties indicates the change of soil water content. This parameter can be obtained by remote sensing, so soil moisture can be monitored by remote sensing. Microwave remote sensing technology for monitoring soil moisture can be divided into passive microwave method and active microwave method. Based on the TRMM / TMI microwave data, Koike proposed a more practical surface moisture index to monitor the hydrological conditions of the surface and determine the season, year and spring. Good results are obtained when the spatial variation is checked by this method. Bertuzzi tested the relationship between soil moisture and radar parameters by linear relationship under different vegetation conditions. If the soil moisture is less than 50% of the water intake, the estimation accuracy is acceptable. If the water intake is between 50% and 150%, the impact of vegetation cannot be ignored. In 1994, Li Xingchao of Japan measured the soil backscattering coefficient by using X, HH polarimetric zone scatterometer, and obtained the X-band and HH polarization simultaneously by using remote sensing technology. The results show that the gray value of the X-band SAR image is the moisture content of the surface soil (0-10 cm), the backscatter coefficient of polarized soil at 35 °HH and SAR. There is also a good correlation between soil water content and soil water content, and the relative error of monitoring is only 12%. Tian Guoliang et al. Used X-band radar images with synthetic aperture (CHH polarization) taken in Fenggang City, Henan Province on November 15, 1987. Soil moisture was monitored and divided into 8 different humidity levels. All weather, all-weather, multi polarization, high resolution, permeability and sensitivity to water content make remote sensing a very effective method for monitoring soil moisture.

However, the current microwave remote sensing data sources are not smooth, and they are often hindered by environmental factors such as surface roughness, surface slope and vegetation while monitoring soil moisture. In this context, Ge Jianjun et al. Carried out microwave experiments to monitor soil moisture in vegetation areas, and created an appropriate model to eliminate the impact of vegetation on soil water extraction, and proposed a method to establish it. AMSR (advanced microwave scanning radiometer) and AMSR-E were used in 2001 and 2002 respectively [9]. As an improved multi frequency and multi polarization passive microwave radiometer, it not only inherits the main frequency bands of three radiometers (SMMR, SSM / I and TMI), but also significantly improves the spatial resolution. Since soil moisture retrieval by remote sensing is one of the main objectives of AMSR and AMSR-E, the soil moisture retrieval algorithms of AMSR and AMSR-E are studied and verified, and some achievements are obtained. In 2003, Wang Lei analyzed amsre data from five regions of China based on the inversion algorithm of microwave radiation transfer model. In this paper, the concept of microwave polarization index (MPDI) is introduced, and a method of automatic identification of soil vegetation is proposed. This provides the AMSR-E algorithm for the reversion of soil moisture in the covered area, improves the vegetation extinction coefficient formula proposed by richand, and improves the reversion efficiency. Even in the areas with higher vegetation biomass, the soil moisture value obtained by AMSR inversion is the same as PSR / Cx. Display dynamic range. The start of envisataar (2002) and the implementation of SMOs plan (2006) will further improve the accuracy of soil moisture recorded by microwave remote sensing.

3. Soil Moisture Retrieval and Analysis by Remote Sensing in Baiyin City

3.1. Overview of the Study Area

The research area is located in Baiyin City, Gansu Province, Gansu Province. Longitude 103 °33 '- 105 °34' e, 35 °33 '- 37 °38' n. The terrain of the area is mostly mountainous, with an altitude of 1275 to 3321 meters. The region has a dry to semi-arid monsoon climate. The middle temperate semi-arid to arid transition zone is characterized by sunny days, drought and light rain. Soil erosion and soil erosion are serious [10].

A good source of remote sensing data is very important for the use of remote sensing to extract soil moisture. Therefore, according to the actual needs of specific crops, topographic map is used to correct the shape of the image accurately, and the average error will be corrected within 0.5 pixels.

The temperature data is based on the average temperature of 15 weather stations in Baiyin and its vicinity. The average outlet temperature can be calculated as 20.28 °C.

3.2. Land Surface Temperature Inversion

In order to realize the inversion of land surface temperature in the study area, the spatial modeling module (spatial modeler) of envi software is used, and a series of spatial models are created according to the single window algorithm. Using these visual spatial models, we can easily realize the automatic calculation of remote sensing image data according to the designed algorithm, and output the target image to a specific directory.

3.2.1. Calculate the Normalized Vegetation Index

(NDVI). Through the normalization process of envi software, the gray value of each pixel in the hyperspectral image is integrated into the same total energy level, or the spectral value of each pixel is integrated into the average overall brightness. Eliminate or minimize differences due to albedo and terrain effects. Envi provides a vegetation index calculator, which can automatically list the vegetation index that can be calculated according to the input image book, and the biophysical cross check function can improve the calculation accuracy of vegetation index.

3.2.2. Calculate Surface Temperature (TS)

According to the modified terrain temperature distribution, the single window algorithm is used to reverse the surface temperature. With the support of envi software ENVI + IDL, the IDL language code is written to realize the single window algorithm.

4. Conclusion and Prospect

4.1. Conclusion

Drought has become a key problem that directly affects industrial and agricultural production and residents' daily life, and has been widely concerned by scientists at home and abroad. The application of remote sensing and GIS drought monitoring technology has achieved satisfactory results, but there are still some problems.

1) In order to realize the exchange of basic data, it is necessary to establish a complete basic database. Meteorological data and data for monitoring drought detection are stored in different departments. The main reason for the delay of monitoring and analysis is that the data exchange between departments is not smooth, and the lack of timely access to relevant information.

2) The development of remote sensing technology for drought monitoring is relatively mature, but there are still some problems to be discussed. For example, in areas with complex terrain, altitude can seriously affect vegetation, soil temperature and other parameters. In monitoring the drought in these areas, the impact of more terrain will be considered, multi-source satellites will be integrated, and resource remote sensing satellites and high-resolution sensors will be increased, and the quality and quantity of remote sensing data will be greatly increased. It provides an improved and extensive data source. The use of multi band and multi-image data fusion is drought detection. One of the development directions of surveillance.

3) Comprehensive application of 3S technology and weather data. The integration of 3S technology is the comprehensive development direction of RS, GIS and GPS technology, and also used for drought monitoring. The meteorological data obtained from the surface meteorological station records can accurately reflect the surface drought conditions, and can be used to effectively verify the data to obtain the surface temperature and other conditions. GPS technology can locate the ground and accurately distinguish the affected areas from different angles. Through the extensive use of remote sensing image interpretation results, DEM, water system, surface meteorological data, drought index and other data, GIS technology data can be used to design, construct, test and drought forecast model based on integrated 3S technology. By defining dynamics, a large number of geographic information can be processed. Monitoring system. The system provides real-time monitoring of weather and vegetation conditions, comprehensively simulates the drought situation in different regions, predicts the development area and drought intensity, evaluates the degree of drought disaster and corresponds to the early warning mechanism, which is helpful for decision-making of drought resistance and disaster relief, and evaluating the loss level of disaster situation.

The purpose of drought monitoring is not only to detect drought, but also to solve the problems caused by drought. Therefore, it is necessary to develop remote sensing and GIS drought monitoring in

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detail. The establishment of dynamic drought monitoring system based on 3S technology is not only the function of drought monitoring, but also the additional decision-making function of drought warning, disaster decision-making, damage assessment and even disaster recovery. Therefore, we should focus on solving the technical problems of drought monitoring and drought process, and strengthen the integration and application of 3S technology and meteorological data, and also develop in the direction of remote sensing and GIS drought monitoring.

4.2. Prospect

The methods and models of soil moisture retrieval by remote sensing have certain advantages and properties, and must have certain limitations, because they are defined in some regions and their respective application fields under certain conditions. There is also a big difference: the reflection method is easy to use and fast, but it is sensitive to the environment and its own components, so its relationship with soil moisture is given by quantitative inversion area: it cannot be simply expressed by linear equation. Because it is difficult to reach, the reflectance method is only suitable for flat terrain, single terrain and typical soil composition. Vegetation index method usually achieves better results in areas or periods with higher vegetation coverage. However, it is difficult to obtain the required data and ensure real-time performance by some vegetation index methods. Thermal inertia method is suitable for reversing soil moisture in bare land or early vegetation growth. Thermal vegetation can effectively overcome the influence of soil background. Full coverage of the area will bring better results. Microwave remote sensing has a wide range of applications and high accuracy. It can be monitored 24 hours a day, 7 days a week. However, it is expensive, and the relationship between radar parameters and target function parameters is very complex, so it has not officially entered the practical stage.

The development of microwave remote sensing technology and integrated "3S" technology will enable remote sensing of soil moisture to meet the actual needs, and will be more and more evaluated in the actual growth practice, and further develop into practicability and industrialization.

As one of the focuses and problems in the world, in addition to the theoretical defects of remote sensing soil moisture sensing, there are other exploration and improvement methods and application fields. Remote sensing of soil moisture increases terrain, slope and other elements for inversion monitoring, which greatly improves the accuracy of ground inversion and the applicability of the model (especially in areas with more difficult terrain conditions). With the advent of multiple satellite sensors, soil moisture can now be measured and monitored from multiple scales by capturing a variety of types of data. To better understand how soil moisture changes in a specific area, you can connect data of different sizes in the same area to get more benefits from multiple sizes.

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