Detecting Erlitou site using the temperature/vegetation dryness index (TVDI)

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Abstract: Nowadays, the main technologies of remote sensing application in archeology are microwave and optical remote sensing technology. But Erlitou site is a very old site and it located at the east of China, the moist soil and cultivated land limited the application of microwave and optical remote sensing technology. So this thesis put forward a new method of archeological remote sensing technology to detect archeological site like Erlitou site. The method is using the normalized difference vegetation index (NDVI) and land surface temperature (LST) retrieved from ASTER and MODIS data to construct an $NDVI\text{-}T_s$ feature space, then based on the temperature/vegetation dryness index (TVDI) designed by the $NDVI\text{-}T_s$ feature space as an indicator of soil moisture content to study Erlitou site's soil moisture distribution at May 10, 2001. Studies have shown that the soil water content of the ruins site was significantly lower than non-ruins areas in the period of May 2001when the land surface was covered by vegetation. The use of TVDI that is a combination of the vegetation cover index and land surface temperature information as a detection indicator of ancient ruins is reasonable and effective.

Key Words: Erlitou site, NDVI, T_s, NDVI/T_s feature space, TVDI

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1 INTRODUCTION

Because of the remote sensing detection of archeology have three characteristics as: weak information, low spatial resolution and complex factors. Currently, the study that applied remote sensing technology to detect the ancient ruins information is still in its infancy. However, the researchers of remote sensing archaeology have also done a lot of useful exploration in the ancient ruins detection by remote sensing technology, such as Rosa Lasaponara, et al (2007) applied data fusion and edge detection technology to process Quick Bird multi-spectral data of two ruins sites of southern Italy, which successfully probe to the archaeological crops flag; Sheets and Sever (1998) have used thermal infrared remote sensing image in Costa Rica to identify and analyses the roads that approximately 2500 years ago, which got the ancient road network that under the lush vegetation; M. Pipan, et al. (1999) has used radar remote sensing technology to detect the ancient ruins of Aquileia in northern Italy, it identified the potential ruin sites in the interested region of these regions; Zhu, et al.

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(2008) have detected Ming dynasty's Great Wall in NingShan region by radar remote sensing . In these studies, because of the penetration of microwave remote sensing, the use of microwave remote sensing in the detection of ancient ruins relatively large. Erlitou site is located at Henan Luoyang basin in the territory of eastern China, here is a transition region that climate between subtropical and warm temperate, and the climate is more humid. At the same time, Chinese civilization originated from here. The early life of the Chinese nation lived besides the Yangtze River and the Yellow River, so there are a large number of ancient ruins distributed in the more humid soil areas like these. In these areas, because the soil moist limited the depth of penetration of microwave remote sensing, this article attempts to achieve the purpose of remote sensing detection by the method of detection different soil properties between ancient ruins and non-ruins. Since ancient ruins withstood the impact of human activities, such as the palace buildings, roads, as well as the walls, etc., the soil density is relatively larger than non-ruins; and the soil moisture is relatively lower. Therefore, differences in soil moisture become the indirect signs of the ancient ruins of remote sensing archeology in this area.

Found in a lot of research at domestic and abroad that the combination of the land surface temperature and normalized difference vegetation index (NDVI) can retrieve the soil moisture successfully. In 2002, Sandholtet, et al. (2002) used the normalized difference vegetation index and land surface temperature to construct an $NDVI\text{-}T_s$ feature space, and then he used the temperature vegetation dryness index (TVDI) that calculated through this feature space as indicator to retrieve the soil moisture content. In recent years, many scholars (Qi, et al., 2003; XIN, et al., 2006) applied the theoretical models to monitor surface soil moisture, and achieved very good results. It stands to reason that soil water status evaluation either can use NDVI and surface temperature data as water stress indicators in the remote sensing data of vegetation covering period, but the study (Moran, et al., 1994; Goetz & S J, 1997; Sandholtet, et al., 2002) found NDVI or surface temperature alone as an evaluation indicator of soil water status have certain limitations, and there is a great relevance between TVDI that the combination of NDVI and LST and soil moisture conditions. Therefore, this article adopted the temperature vegetation dryness index to retrieve the soil moisture conditions, and launch the study of detecting the archeology ruins areas.

2 THE PRINCIPLE AND METHOD

Temperature vegetation/dryness index is extracted from a simplified $NDVI\text{-}T_s$ feature space by Sandholt. In the $NDVI\text{-}T_s$ feature space, NDVI is vegetation coverage indicators, T_s is the land surface temperature data, and all the remote sensing image pixel point from the naked land to completely vegetation covered land can be expressed in this $NDVI\text{-}T_s$ feature space that use NDVI as the horizontal axis and T_s as the longitudinal axis. Some scholars (Nemani & Running, 1989; Price, 1990; Carlson, et al., 1995) found that there is the negative relationship between NDVI and T_s, so pixel point triangular distribution in the $NDVI\text{-}T_s$ feature space. As shown in Figure 1, this simplified $NDVI\text{-}T_s$ feature space set wet edge $T_{s\text{-}min}$ as a straight line parallel with NDVI shaft, and the dry edge $T_{s\text{-}max}$ doing a linear relationship with NDVI value.

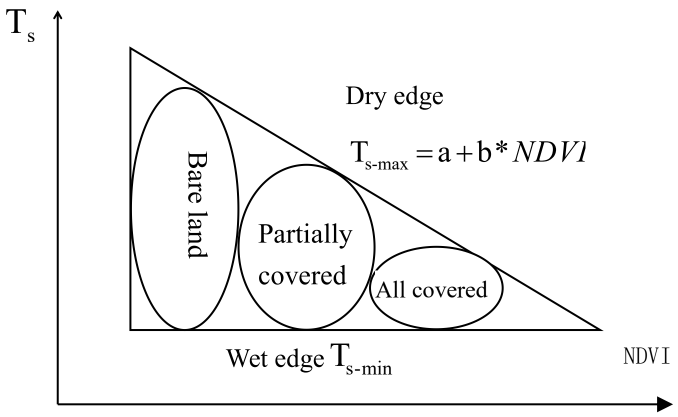

Fig.1 Simplified NDVI-T_s feature space

In the figure above, the triangle area is the land surface temperature values which corresponded with each NDVI value of remote sensing image. The regional NDVI values become larger from bare land to full coverage of vegetation land, when the land surface temperature values become higher from vegetation full coverage to the area of bare. This is a simplification to the normal land surface area. The TVDI calculation expression that through the describing of the NDVI-T_s feature space is (Becker & Li, 1990):

$$\text{TVDI}=\frac{T_s - T_{s\text{-}min}}{T_{s\text{-}max} - T_{s\text{-}min}}$$

In the above formula, T_s is the land surface temperature value which corresponded with an NDVI value. $T_{s\text{-}min}$ is the wet edge, and the dry edge is $T_{s\text{-}max}$. As can be seen from this figure, the value of dry edge needs to be expressed by a linear expression. Be described in the simplified graph of the above, the wet edge is a straight line parallel to NDVI shaft, so it is direct expressed as $T_{s\text{-}min}$, but in the actual land surface area, both dry edge and wet edge is not a straight line that parallel to NDVI shaft, and they are linear expression which are approximately fitted by the maximum and minimum points of the NDVI-T_s feature space. That is, the first step to calculate the value of TVDI is that you must build an NDVI-T_s feature space. Then extract the points of the dry edge and wet edge, these points are on behalf of the maximum land surface temperature value and the minimum land surface temperature value which corresponded with the NDVI value. And then calculate the coefficient “a” of the dry edge equation and coefficient “b” of the wet edge equation through the linear fitting of these points. After the coefficients of these two equations have been got, we can substitute the calculated result values into the TVDI formula to calculate the value of the temperature vegetation/ dryness index.

3 THE DATA PROCESSING AND CALCULATION

Wheat and corn are the major vegetation cover of Luoyang basin where Erlitou site located in. Because wheat is relatively sensitive to soil moisture content, and wheat growth to mature and have deep roots in May, this article selected the ASTER data at May 10, 2001 and the MODIS data at the same time and on the same satellite as research data to retrieve the land surface temperature and vegetation index value. ASTER data has four spectral channels in the thermal infrared band and all the spatial resolution of them are 90m. Because the 13-band and 14-band were less affected by the atmosphere, this article selected the two thermal infrared channels to retrieve the land surface temperature data. That first step is using the visible red band and near infrared band after atmospheric correction of ASTER data to calculate the NDVI values in the studied region. And then to calculate the land surface emissivity value of the two spectral channels through the relationship between the NDVI value and the land surface emissivity value (Sobrino & Raissouni, 2000). MODIS data is a parameter to be used for the estimation of atmospheric transmittance in the process of land surface temperature retrieving (Sobrino, et al., 2003). After the brightness temperature value was calculated by the Planck function, we can set these three parameters which are the brightness temperature, atmospheric transmittance and land surface emissivity into the multi-channel spilt-window algorithm formula (Mao, et al., 2006) to retrieve the land surface temperature data. Then with the extracted NDVI data and land surface temperature data to construct the $NDVI\text{-}T_s$ feature space, and then use this feature space to linear fit the dry edge equation and the wet edge equation. Finally, we can calculate the TVDI value through the TVDI formula.

Data processing of this article is as follows:

(1) Use the value of the visible red band and near infrared band from ASTER data to calculate the normalized difference vegetation index value of the study area;

(2) Calculate the land surface emissivity value of ASTER data channels 13 and 14 based on the empirical relationship between NDVI and land surface emissivity, retrieve the atmospheric transmittance value that is at the same area and the same time with the ASTRE data through the MODIS data, calculate brightness temperature value through Planck function ;

(3) Set atmospheric transmittance, land surface emissivity and brightness temperature values as the parameters into the spilt-window algorithm to retrieve the land surface temperature;

(4) Construct an $NDVI\text{-}T_s$ feature space use the NDVI data and T_s data and extract the maximum and minimum land surface temperature values corresponding with different NDVI values through the ENVI / IDL programming in this region;

(5) Linear fit the equation of the dry edge and the wet edge by the point data extracted in the previous step;

(6) Substitute the Ts, $T_{s\text{-}min}$ and $T_{s\text{-}max}$ values into the TVDI formula to calculate the value of the TVDI, and form the soil moisture distribution map, then detect ancient ruins of the study area through this map.

4 RESULT ANALYSES

In this paper, it uses the NDVI image and land surface temperature image of the study area through above calculation to construct a $NDVI\text{-}T_s$ feature space. And then use the maximum and minimum land surface temperature values corresponding with different NDVI values from the $NDVI\text{-}T_s$ feature space to regression fit the linear equation of the dry edge and the wet edge. This $NDVI\text{-}T_s$ feature space diagram and the dry edge and wet edge of the study area are as follows:

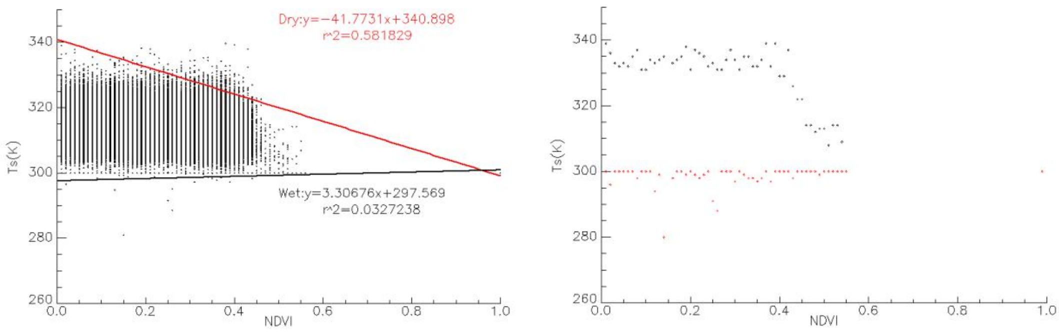

Fig. 2 NDVI - T_s feature space and the dry and wet edge in the period of vegetation cover

Substitute above equation of the dry edge and wet edge into the TVDI formula and add the land surface temperature map and NDVI map as the parameter, we can obtain the TVDI value by calculation. The numerical size of TVDI value can reflect the status of the soil moisture in this region. As shown in the following figure, is the Erlitou soil water content distribution.

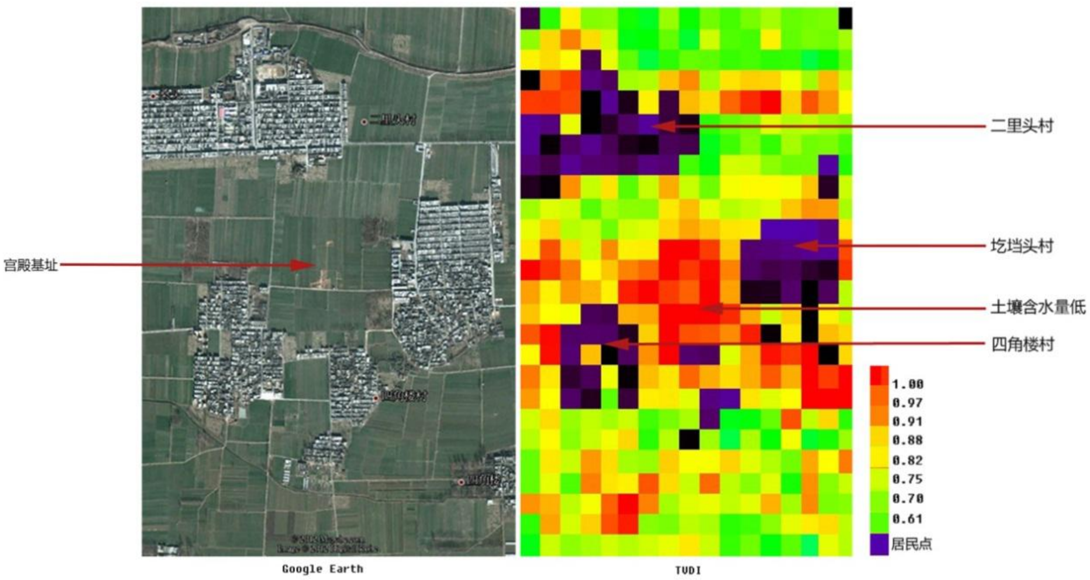

Fig.3 TVDI value distribution of Erlitou site

As can be seen from the figure above, there is an area where among the Erlitou Village, Gedangtou village and Sijiaolou village have larger TVDI value than the other areas, its color is red. This means that the soil moisture here is lower than the other. And we found that this address is precisely the region where the foundation of Erlitou site palace located at from the comparison with the Google Earth image. This shows that the soil moisture content of ancient ruins is lower than the surrounding area. And the ancient ruins detection method that uses TVDI as indicator to retrieve the soil moisture is feasible. Good results can be obtained after the processing of land surface temperature images through the TVDI model, and it can reflects the difference between the region of ancient ruins and other regions very well.

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