A method exploration on measuring the changes of sand ridges in exposed radial sand ridges area by means of remote sensing technology

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Present study took into account the relationship between surface soil moisture of intertidal zone and its spectral reflectance and the relationship between surface soil moisture and the relative elevation of intertidal zone to extract 'ridges'. It can represent the main morphological character of radial sand ridges, and find specific spectral bands to diagnose much 'drier' points of sand ridges in low tidal condition. This could be considered as much higher points of sand ridges. On that basis the ridges' changes were also discussed in this paper. Based on spectral analysis and comparison between extracted sand ridges and field measured elevation, the results demonstrated that the sensitive band centered at 224 nm has an excellent potential to extract sand ridges, furthermore the extracted sand ridges matched with field measured elevation accurately.

[Keywords: Radial Sand Ridges, Soil Moisture, Remote Sensing]

Introduction

The radial sand ridges of South Yellow sea lies in the middle coastal of Jiangsu, between Xinyanggang and Yaowanggang, which is between abolished Yellow River underwater delta and Yangtze River underwater delta. (Fig.1). Radial sand ridges stretch from south to north, 200 km long from south to north, 90 km wide from east to west, with Jianggang as its start point. The whole sea area is about 2×10⁴ km². About 70 sand ridges consist of the whole sand ridges group, 10 of which are above the ocean surface in low tide, expanding clockwise from north to south like a sector. To understand the evolution characteristics and laws, the technology of remote sensing is a good method admitted by many researchers. In the “research of the formation and evolution of the radial sand ridges in South Yellow Sea” executed by Ying Wang¹, her team retrieves shapes and calculates distribution area of the sand ridges, and then explain the characteristic of its morphology and revolution. For Haijun Huang,

![Fig. 1–The radial sand ridges of South Yellow Sea](image_url)
Renshun Zhang, Yongxue Liu, Haiyu Li, Jun Chen, they also make significant research and progress in field of the evolutions of radial sand ridges using RS techniques2–5.

This paper aims to analyze the historical evolution process of the radial sand ridges, using spectrum of the remote sensing images to measure tidal flat moisture, and then get the location and region of the sand ridges. The result of this method can not only be a new way to monitor the depositing of sand ridges and its dynamic migrations, which can better understand the evolution of sand ridges group scientifically and reasonably, but also extend a new application field of remote sensing.

Materials and Methods

Niluoheng is located at the northwest of the radial sand ridges (Fig. 2). There are only small plenty of shellfish inhabited on its surface and the development activity is simple. Since it is far away from the mainland, also by Dongsha main sand ridge as its barrier, human activity seldom change the geomorphology of the Niluoheng. As a result, the feasibility is apparent to draw the sand ridge line with soil moisture value measured by remote sensing.

Data

25 soil samples collected from the west of Dongsha tidal flat were put into 90 mm diameter culture dishes. Then distilled water was added into culture dish to enable the soil moisture reach its saturation. At the same time, the instantaneous moisture content and spectrum of sample were simultaneously measured by analytical balance and ASD FieldSpec® Pro FR spectrometer respectively. Finally, 398 curves of soil spectrum and their corresponding moisture content \( \theta \) were obtained.

The height measurement of Niluoheng flat

We performed the height measurement with leveling instrument in Niluoheng in June 2010 ebb (Fig. 3). One horizontal profile from west to east, including 50 stations was set in this area (Fig. 8). The positions of every station were located by GPS, with plane location precision 10 m and elevation precision 1 cm. Station 1 of this profile, which is base station its height is set with initial value 0 cm, and height of

![Fig. 2–Research area schemes(R for sand ridge and T for Tidal creek)](image)

![Fig. 3–Elevation measurements in Dongsha](image)

![Fig. 4–Section elevation measurements](image)
other stations are all based on the first one. Figure 4 shows the measured height of this profile and station 33 is the peak with the highest height 224 cm.

The Landsat/TM image captured on 28th February, 2008 was selected, as Dongsha Niliuheng was obviously exposed for a very long time.

The preprocessing of image data includes geometric correction of TM image by LGCP method, atmospheric correction with dark-object subtracting method and separation of tidal flat from the sea water via threshold method.

The waveband of TM7, whose central wavelength is 2215 nm, is most closed to the wavelength 2224 nm of Dongsha tidal flat surface sediment moisture and tidal flat moisture measured in spectrum measurement experiment, so we select band TM7 for extracting of sand ridge line.

The idea of exploring a new method to retrieve the evolution of radial sand ridges group with remote sensing technology is to get the relation between moisture and elevation value by testing the relation between the moisture and elevation of tidal flat and relation between moisture and its surface spectrum value, then find the peak of the tidal flat with the spectrum value provided by satellite image.

Relation between moisture and elevation of tidal flat

Moisture of the tidal flat varies regularly with the up and down of tidewater. As a result, on the ebb, the moisture of the tidal flat surface decreases gradually as the time going. The earlier the place is out of water, the higher its elevation is, and the lower its moisture is; the later the place is out of water, the lower its elevation is, and the higher its moisture is.

We here give the term of sand ridge line. Ridge is a terrain feature formed by two slopes, which meet at the ridge, with opposite directions and different degrees. The line connecting all highest points of the ridge is the line of the intersection of the two slopes, which is called a ridge line. Definition of a sand ridge line is derived from a ridge line, which is the connection of the highest point of sand ridge. Theoretically, the moisture along the tidal ridge line should be relatively lower than other places according to our hypothesis.

Relation between moisture and spectral value of tidal flat

Soil moisture spectral method is based on the relation between soil moisture and spectral value, as water in soil can be effectively diagnosed and its content can also be retrieved precisely by certain wavebands. As the researches of many experts show, reflectance of soil will be reduced when soil moisture increases. Spectrum of soil is affected by soil parent material, organic matter, moisture and other factors. In the same condition of soil parent material, the shape of soil spectrum and value of its reflectance are mainly affected and controlled by how much water contained inside, especially in those wavebands nearby water absorption peaks. Therefore, the soil moisture content can be determined and retrieved by the value of soil spectral reflectance. In another hand, relatively ‘drier’ places should be easily diagnosed by certain waveband which is sensitive to soil moisture.

Relation between spectrum value and tidal flat elevation

The position of sand ridge line is first exposed at low tide since its elevations relatively higher than other places the soil moisture of the sand ridge line, meanwhile, should be deservedly lower than its adjacent places. In order to extract sand ridge line automatically, the first step is to find the relatively ‘drier’ points of each line in remotely sensed imagery and then link above points to a line, which can represent sand ridge line. However, some parts of those ‘drier’ points have disorderly distribution and are impossible to be located in sand ridge line according to our priori knowledge. All of them should be deleted before generating the sand ridge line.

Results and Discussion

As mentioned before, it is the foundation for figuring out the relationship between moisture content and reflectance that to pick out those peaks with relatively higher height in our study area via remotely
sensed imagery. In our previous research, only Landsat-TM4 located in VNIR (visible and near infrared) domain has been proved with the highest correlation with moisture due to the limitation of VNIR spectrometer used before, which has a narrow spectral domain ranged from 325 nm to 1075 nm. However, we should try all the wavebands of TM imagery as we acquired spectra of soil by full-range spectrometer (350 nm-2500 nm) this time.

The determination of sensitive wavelength of tidal flat moisture

The previous study of the remote sensing retrieval method of soil moisture showed that, as for a certain soil sample, the spectrum reflectance increased relatively with the decrease of moisture.

It has been reported repeatedly in the literature that soil reflectance increases as soil moisture reduces over the visible light-SWIR (400-2500 nm) spectrum of, creating a possibility of retrieving moisture content over some regions of the spectrum.

Result based on our spectral analysis was also coincided with the trend of previous study. Sensitive band, however, of the soil moisture can varies with different soil types. Taking consideration of the complexity of soil deposit environment and turbulence of hydraulic conditions in intertidal flats, this study performed spectral analysis on 398 spectra of 25 samples which can represent the major characteristics of whole study area both geographically and in soil substances. The correlation analysis method was employed to determine which wavebands possess the highest $r$ with moisture content, that will be defined as sensitive waveband for tidal soil moisture and finally, we found that the spectrum reflectance at central wavelength 2224 nm showed a significant negative correlation $r = -0.89$ with soil moisture.

On the ebb in tidal flat, the moisture of soil reduces continuously due to water infiltration and surface evaporation after sea water left, but the variation value and rate of reflectance are not the same at different phase. According to our analysis, the results showed that at the beginning of ebb when $\theta$ is less than 35%, greater than 10%, the spectrum reflectance $R$ increases gradually within 0.10-0.15 at a lower increase velocity. As the ebb proceeding, the soil moisture decreases gradually, so the $\theta$ is less than 10%, $R$ increases from 0.15 with an obvious quicker velocity. As the result, as for the spectrum at wavelength 2224 nm, the negative relation is apparent between spectrum reflectance and corresponding soil moisture, which could be better for the obtaining of sand ridge line.

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So we also need to determine whether the peak is on the sand ridge according to the shape of the peak and the relation with its surrounding. As Fig. 6 showed, judging from the distribution of the splashes in the blue blank, the red peaks scatter here and there, contrary to the characteristic of sand ridge. So those points cannot be classified as sand ridge points and should be excluded.

(3) Extracting sand ridge line. We performed buffer analysis on those qualified peaks with GIS program (Fig. 7a), then calculated the axial line with ArcScan tool as sand ridge line of Niluoheng (Fig. 7b). The blue line of Fig. 8 showed the result of sand ridge line by remote sensing technique.

Given the comparison of actual measurement terrain data and the sand ridge line extracted in Niluoheng by remote sensing technique, the station 33 measured as peak in Niluoheng tidal flat is located near the sand ridge line. It can verify the above method to extract sand ridge line credible.

**Conclusion**

On the ebb, the soil moisture decreases gradually since seawater level goes down from surface of sand ridge group, which leads to spectral responses of soils. So we can detect the tiny variation by the soil reflectance measurement over intertidal surface. Present study discussed the feasibility of this method and made a beneficial trial. Based on spectral analysis of tidal flat soil in Dongsha Niluoheng, the sensitive wavelength centered at 2224nm had a close relationship with soil moisture. It could be used to extract sand ridge line in Niluoheng retrieved. Sand ridge lines of radial sand ridges group in historic
periods were extracted by means of the established moisture-based method. Validating with ground truth data, we found that the point located in sand ridge line is coincide with the elevation peak of transect, which crosses sand ridge line. Present study demonstrated that this method is credible.

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References: