Application of Hyper Spectral Remote Sensing for Urban Forestry Monitoring in Natural Disaster Zones

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***Abstract*—Urban forestry is the core resource used to achieve a virtuous cycle of urban ecosystems and the main subject of urban life support systems. Natural disasters appear in characteristics of high frequency, intensity, and often result in huge losses in their area of destruction. Therefore, the situation requires real-time, accurate and dynamic monitoring, which is an important guarantee for maintaining a healthy and low-carbon urban ecological environment. Hyper spectral remote sensing is a remote sensing technology which provides a new technological means for scientific urban forest monitoring. In this paper, our group tries to provide a data processing method for analyzing of hyper spectral remote sensing images, starting from radiometric correction for image enhancement processing, then adopting dimension reduction operation, and finally match the spectral information. Based on hyper spectral remote sensing technology, the authors do investigation, monitoring and evaluation of urban forests in natural disaster zones. Combined with specific examples like the forest fires in California, the dendrolimus superans disaster of urban forestry in Greater Khingan Prefecture, and the classification of Californian coniferous species, our group makes evaluation and analysis of the hyper spectral remote sensing images. Relying on the advantages of hyper spectral remote sensing images like narrow-band, multi-channel, union of image and spectrum for dynamic monitoring of urban forestry, we prove that hyper spectral remote sensing has broad application prospects in fields like forest fire monitoring, pest monitoring and investigation of changes of urban forest resources in natural disaster zones, and propose directions of hyper spectral remote sensing for further research.**

Keywords- hyper spectral remote sensing; natural disaster zones; urban forestry monitoring

I. INTRODUCTION

Urban forestry is the core resource used to achieve a virtuous cycle of urban ecosystems and is considered as a unique urban “green lung” as it is the main subject of urban life support systems. Natural disasters appear in characteristics of high frequency, intensity, and often result in decrease of urban biodiversity and destruction of regional ecological balance. Therefore, the situation requires real-time, accurate and dynamic monitoring, which is an important guarantee for maintaining a healthy urban ecological system and building low-carbon cities. However, application of traditional remote sensing technique for urban forestry monitoring in natural disaster zones is limited by spectral bands, data location and classification accuracy and little attention has been focused on application of hyper spectral remote sensing. By using hyper spectral remote sensing to make investigation, monitoring and evaluation of ecological benefits for urban forestry in natural disaster zones, we aim to provide a new technological means for scientific urban forest monitoring and construction of the green corridors and the ecological network system of urban forestry, and build a theoretical basis for urban forestry monitor and government decision-making.

II. DEVELOPMENT OF HYPER SPECTRAL REMOTE SENSING

Hyper spectral remote sensing is a new remote sensing technology developing rapidly in the late 20th century, which takes imaging of ground surface and surface features with nanometer ultraspectral resolution and dozens or hundreds wave bands simultaneity, and obtains the continuous spectrum information of surface features in natural disaster zones including every kind of forest resources. With the advantage of its rich spectrum information, hyper spectral remote sensing provides wide application prospects for the investigation of urban forest resources, the monitoring and evaluation of forest fires, pest monitoring and monitoring of changes of urban forest resources in natural disaster zones.

Traditional remote sensing technique is limited by spectral bands, and its data location and the classification accuracy will not be guaranteed. Compared with traditional remote sensing, hyper spectral remote sensing has unique advantages like narrow-band, multi-channel, union of image and spectrum. With such kinds of characteristics, hyper spectral remote sensing is good at precise recognition and classification for forest vegetation in natural disaster zones. It can also improve the precision of recognition and classification of types of vegetations, and enhance the estimation and inversion precision of vegetation variables, which provides convenience for the detection of plant morphology and activity, the monitoring of the land cover change and the estimation of ecosystem's biophysical and biochemical parameters, and becomes a powerful technical

978-1-4244-9283-1/11/$26.00 ©2011 IEEE

tool for spatial analysis of urban forestry and decision support. The timeliness of hyper spectral remote sensing is able to discover and solve problems in time, and guarantee the sustainable development of urban forest eco-network system.

III. Data processing method for analyzing of hyper spectral remote sensing images

Hyper spectral remote sensing is the inheritance and innovation of multi-spectral remote sensing technology. Therefore, most of the processing method for analyzing of multi-spectral remote sensing data can still be used to process hyper spectral data. However, as imaging spectroscopy and multi-spectral technology with different technical features, the conventional multi-spectral data processing method of urban forestry is not suitable for quantitative analysis of imaging spectrometer data of urban forestry. (Figure. 1)

A. Radiometric correction

Hyper spectral remote sensing information is liable to be influenced by external factors such as remote sensor aging, bi-directional reflectance distribution and terrain factors. These factors, especially the complex urban terrain in natural disaster zones, will weaken the sensitivity of distinguishing terrain by hyper spectral remote sensing data. Therefore, like ordinary RS, hyper spectral remote sensing information needs for radiometric correction to eliminate the influence of these factors.

B. Image enhancement processing

Spectral image enhancement technology can enhance the differences between pixels and spectrum. The main purposes of image enhancement are to change the gray scale of images, to improve image contrast, to eliminate the edge and noise, highlight urban forest edges or linear features.

C. Dimension reduction operation

In order to carry on comparative analysis of hyper spectral remote sensing data with common broadband data, it is necessary to reduce the dimensions. General dimension reduction methods are to get low spectral resolution data by convolution operation. The narrow band information of hyper spectral remote sensing images is transformed into the broadband information of conventional remote sensing images by convolution operation to make comparative analysis.

D. Spectral information matching

Spectral information matching by spectral databases utilization can direct identify components of various types of urban forest vegetation. Its advantage is the similarity of pixels and reference spectrum can be calculated without considering their relative brightness.

IV. Application of hyper spectral remote sensing in urban forest monitoring

A. Urban forest fire monitoring

Researchers need to consider at least two factors if they use RS technology to determine the possibility of forest fires. On the one hand, they must consider whether the detected high temperature on earth surface abnormal or not. On the other hand, they should consider whether the ground cover is combustible. Therefore, our group believes that it’s a good way to detect the location of forest fires and above-ground biomass, burning effects, surface material composition and the update status relevant with forest fires by combining ordinary RS data with hyper spectral remote sensing data. In recent years, satellites used for forest fire monitoring include FY-1 Meteorological Satellite of China, and NOAA series of meteorological satellites of US. And EOS / MODIS Satellite of US are currently used for forest fire monitoring.

Smoke from the outbreak of fires in Southern California can clearly be seen from NASA satellites. The left, photo-like, true-color image, taken by MODIS on Aqua satellite on November 16, 2008, shows the smoke drifting to the southwest from the Los Angeles basin over the waters of the Pacific Ocean. The right image shows measurements of aerosols -- tiny particles within smoke -- as observed by the OMI onboard Aura satellite, overlaid on top of the MODIS image. In the right image, aerosol concentrations are represented by an aerosol index, with the highest concentrations in pink, and the lowest in dark blue. The aerosol index is calculated based on the way the tiny particles absorb and scatter light. Specifically, the index is a measurement of the difference between the amount of ultraviolet light the smoke-filled atmosphere scatters back to the satellite compared to the amount of ultraviolet light that the atmosphere would scatter back if it were totally clear. The difference between these two measurements can effectively detect smoke that would otherwise be invisible in photo-like imagery. In the MODIS image, the smoke disappears when it moves over the bright surface of the low-level marine stratocumulus clouds. The OMI aerosol index measurement reveals, however, that smoke is present over the clouds. Such ultraviolet measurements from instruments like OMI are useful to scientists working to understand how aerosols affect clouds. (Figure. 2)

B. Urban forest pests monitoring

Forest space shapes in remote sensing images are related to actual forest shapes and structures, while the spectral information of the images is related to the physiological characteristics of forest vegetation. For example, chlorophyll content and spectral reflectance of green plants have obvious characteristics, and completely change with the change of wavelength. Affected by pests and diseases, strong reflection bands in spectral curve will shift to the direction of shortwave when the chlorophyll content of forest vegetation decreases, and when the forest vegetation leaves wither because of water shortages, strong reflection bands will shift to the direction of long-wave. Healthy green plants have typical spectral features. The spectral curve shape of plant will change as the plant growth status change. If plants affected by pests and diseases or crops with poor growth for lack of nutrition and water, the spongy tissue will be damaged and the proportion of leaf pigment will change, making the two absorption valley in visible light region become not obvious. Changes in near infrared region will be more obvious, the peak will be cut low, or even disappeared, the whole wave characteristics of reflectance spectral curve will be leveled. Therefore, with the comparison of spectral curves of damaged plants and healthy plants, we can determine the damaged extent of plants (Figure. 3).

Zhiming Liu and other researchers in Changchun Institute of Geography, Chinese Academy of Sciences used the ratio vegetation index (RVI) to make assessment and analysis of the *dendrolimus superans* disaster of urban forestry in Greater Khingan Prefecture. There was an outbreak of *dendrolimus superans* disaster in this region during 1989-1991. Their research selected the transit data from NOAA / AVHRR on May 25, 1990 and July 19 (the two-phase pre and post the outbreak of the *dendrolimus superans* disaster). Based on the census data of the *dendrolimus superans* disaster from local forestry department and combining with the actual sampling survey results in disaster zones, they found out the RVI critical value between the disaster zones and worst-hit disaster zones. RVI $\leq$ 2.6 means disaster zones while RVI $\leq$ 2.3 means seriously disaster zones. We can describe the distribution of disaster zones and worst-hit disaster zones (Figure. 4) from the results.

C. Changes of urban forest resources monitoring

Changes of forest resources monitoring is a kind of dynamic monitoring process which takes advantage of the multi-sensor and multi-temporal characteristics of RS, not only for the number and position of change information, but also for the change type of each pixel (for spatial distribution of forest resources dynamic change) by the extraction of change information of the same area's forest resources RS data in different phases. Forest resources dynamic changes include two parts:

1) Forest land turns into other land types, such as cultivated land, water, etc. or changes within forest land, for example, forest land turns into thin forest land, clear-cutting forestland and so on.

2) Non-forest land turns into forest land, for example, non-forest land turns into broad-leaf forestland.

Therefore, it is very important to make correct identification for forest tree species in the research of changes of forest resources monitoring. In the past two or three decades, large-area wood species recognization by application of digital RS data can only be divided to the level of species composition or simply divided into coniferous species and broadleaved tree species. It's mainly decided by two factors: one is the lack of hyper spectral resolution and plenty of spectral wavebands, since different species often have very similar spectral characteristics, namely, the phenomenon of "different objects with the same spectrum", their subtle spectral differences are undetectable with the broad band spectral RS data. The other is due to optical remote sensing relies on uncertain light conditions, which may lead to the same species have significantly different spectral characteristics, that is, the phenomenon of "same object with different spectrums". Compared with the application of digital RS data, the hyper spectral remote sensing can detect various objects with more subtle spectral differences, which greatly improve the accuracy of the identification and classification of vegetation.

According to the spectral reflectance of plant which under control of the biochemical substances, application of hyper spectral remote sensing technology can make the classification of forest tree species or forest types be more detailed. Peng Gong, who classified California's 6 major coniferous species with the spectral data field measured by high resolution imaging spectrometer (HRIS) proved that simple transformation of hyper spectral data can effectively improve the identification precision of species.

V. DISCUSSION

In this paper, relying on the advantages of hyper spectral remote sensing images like narrow-band, multi-channel, union of image and spectrum for dynamic monitoring of urban forestry, we confirm that hyper spectral remote sensing has broad application prospects in fields like forest fire monitoring, pest monitoring and investigation of changes of urban forest resources. The success of application of hyper spectral remote sensing for forest monitoring in natural disasters zones mainly depends on its ability of distinguishing forest tree species types and different forest growth status and evaluation of various forest physical parameters. Hyper spectral remote sensing images can be used for a large-area scale or a global scale real-time monitoring for forest with its unique advantages. However, it should be noted that we need further research in the following areas:

1) Many physiological parameters of the forest can not directly be obtained from the hyper spectral remote sensing images. Therefore, one of the key application of hyper spectral remote sensing for forest monitoring is to establish effective image processing technology and related object spectral analysis algorithm for quantitative acquisition of physiological parameters of the forest.

2) The development of imaging spectroscopy relies on the development of ground object spectroscopy. And study on spectral characteristics of ground objects is the basic work, which requires accurate and quantitative measurement of spectral information of ground objects in various continuous wave bands by application of hyper spectral remote sensing.

3) The amount of hyper spectral remote sensing data is enormous, the correlation extent of the spectral image data of each band is high and the data redundancy is large. Based on principal component analysis, we can merge data of different bands in a band group by taking advantage of correlativity of various bands of spectral image and transformational analysis to avoid the redundancy of different kinds of information, while retain the specific spectral information of forest vegetation of each narrow-band.

Figures:

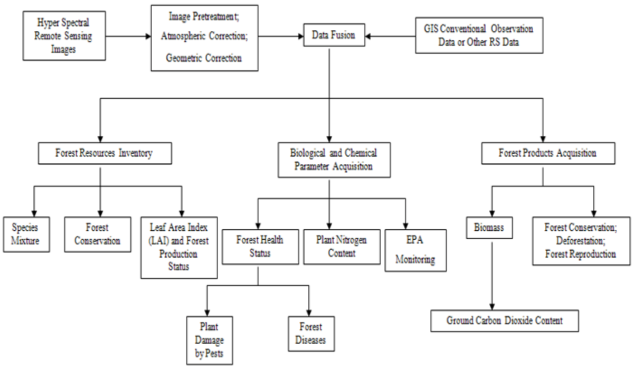

Figure 1. *Flow chart of forest information extraction by hyper spectral remote sensing in natural disaster zones*

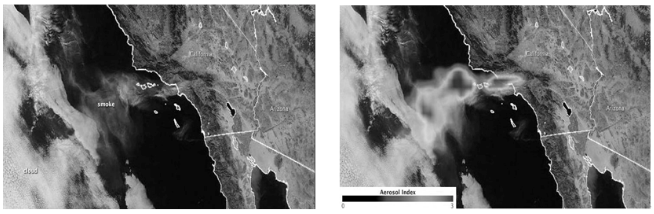

Figure 2. *RS images of the outbreak of fires in Southern California*

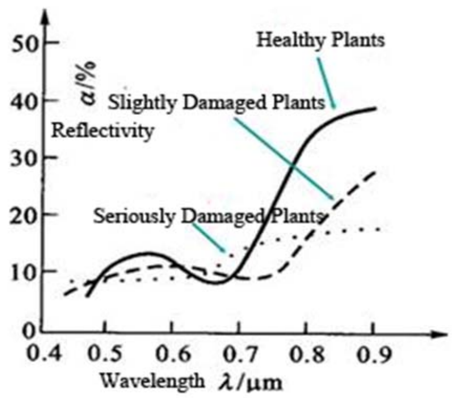

Figure 3. *Spectral curves of damaged plants and healthy plants*

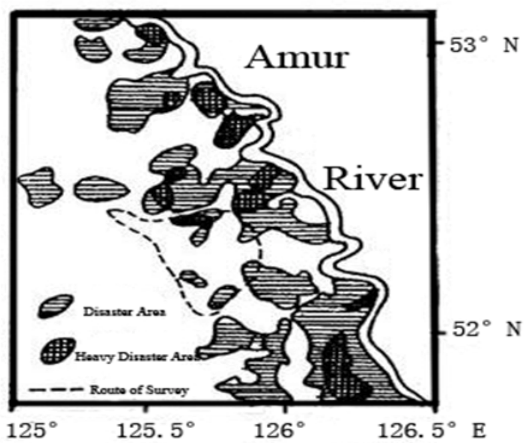

Figure 4. *Distribution of disaster zones and worst-hit disaster zones in Greater Khingan Prefecture*

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