Forest Canopy Moisture Content Monitoring Method Using HJ-1B IRS Data

X. L. Qin [a,*] , G. Deng[a] , Z. Y. Li[a] ,

[a] Research Institute of Forest Resource Information Technology, Chinese Academy of Forestry, Beijing, China
(noaags, dengg, lizy)@caf.ac.cn

Abstract – Forest canopy moisture content is an important factor in determining forest fire risk and forest fire behaviour. In Dargon 2 project, to develop a suitable regional early warning technique to predict forest fire risk, a Normal Difference Water Index (NDWI), which has been calculated by using the reflectance of SWIR and NIR band of HJ-1B IRS, has been used to retrieve forest canopy moisture content in our experiment region. The results showed that the value of forest canopy moisture content by using the reflectance of SWIR band and NIR band had the similar trend to the locate observation. This method can provide efficiently fuel moisture content spatial distribution in forest fire risk prediction.

Key word: Forest Canopy Moisture Content, NDWI, HJ-1B IRS, Forest Fire Risk, Early Waring Technique

1. INTRODUCTION

Forest Canopy Moisture Content is an important parameter in determining forest fire ignition and forest fire behaviour (E. R. Hunt et al., 1989; E. Chuvieco et al., 2004; Dasgupta et al., 2007). Estimation of fuel canopy moisture content is central to the understanding of biomass burning processes. The most practical, objective, and cost-effective way to monitor vegetation canopy moisture from a local to global scale is the use of earth observation technologies. They also provide information on remote areas where ground measurements are impossible on a regular basis. Many researches have demonstrated that multiple sensors currently onboard earth observation satellites are suitable for the monitoring of vegetation canopy moisture content (G. W. Jacquemoud et al., 1990; R. E. Burgan et al., 1997; Susan et al., 1998). According to the used satellite data, the instruments can be classified into the following three categories: (1) By using the reflectance of Visible and Short Wavelength Infrared (SWIR, spectrum between 400 and 2500 nm) channel, which provide information on vegetation biophysical parameters such as the chlorophyll content, the leaf area index, and the vegetation water content. Water has several absorption maxima throughout the infrared region of the spectrum. (2) Long Wavelength Infrared sensors (spectrum between 6.0 and 15.0 mm), which offer information on the thermal dynamics of vegetation cover, hence has been used to estimate the evapotranspiration of vegetation canopies, a parameter that is closely related to water stress. (3) Radar sensors (spectrum between 0.1 and 100 cm), which give information on the dielectric constant related to vegetation water content.Various models utilizing optical and thermal infrared measurements have been studied. Typically, these methods have attempted to measure foliage moisture content, which is a sensitive indicator of vegetation canopy water content. Most of them have used indices to assess vegetation canopy moisture status (R. E. Burgan et al., 1997; E. Chuvieco et al., 2002). More models for vegetation water estimation have typically utilized signals from liquid water absorption channels in the near infrared (NIR) or Shortwave Infrared (SWIR). Several indices based on the reflectance of SWIR and NIR have been proposed. Such as, Normalized Difference Water Index (NDWI) (B. C. Gao, 1996; X. L. Qin et al., 2005, 2008); the Leaf Water Content Index (LWCI) (E. R. Hunt et al., 1987); the Global Vegetation Water Moisture Index (GVMI) (P. Ceccato et al., 2001; P. Zhang et al., 2004). The Live Fuel Moisture Content (LFMC) (S. Dasgupta et al., 2007). Surface temperature (ST) has also been used as an indicator of vegetation moisture, since vegetation temperature increases in drier plants on account of reduced evapotranspiration (X. N. Song et al., 2004). More recently, the inversion of coupled leaf and canopy radiative transfer models have offered a more physically based approach to vegetation moisture estimation (P. J. Zarco-Tejada et al., 2003). Forest Canopy Moisture Content can be estimated by using these vegetation indices since they depend on the correlation to vegetation greenness and moisture content. But, this relation between Forest Canopy Moisture Content and chlorophyll content is not always simple. In fact, it will depend on plant species.

The Infrared Sensor carried by HJ-1B (HJ-1B IRS) is one Chinese satellite instruments. It has been launched with HJ-1A satellite in September 6, 2008. The HJ-1B IRS sensor has one Near Infrared band (0.92μm) and one Shortwave Infrared band (1.65μm), their spatial resolution is 150 meter. At the same, the sensor has also with the characters, such as 720km swath wide, 2 days repeat temporal resolution. In this paper, A Normal Difference Water Index (NDWI), which has been calculated by using the reflectance of SWIR and NIR band of HJ-1B IRS, has been used to retrieve typical forest canopy moisture content in the experiment region.

2. STUDY AREA AND DATASET

2.1. Experiment Area

The experiment area locates between 128°47′8″ - 128°57′19"E, 47°6′49" - 47°16′10″N. It belongs to Liangshui national reserve region of Heilongjiang province of China from administration. Its' climate belongs to temperate zone. The main trees include larch, Asian white Birch (*Betula platyphylla*) and Korean Pine (*pinus koraiensis*). The total area is 12,133 hm^2.

2.2. Dataset and Processing

The HJ-1B IRS L1B images have been used for the analysis of forest canopy moisture content in the experimental area. The selected data with a total of 10 scenes have been supplied by China Centre for Resources Satellite. Table A is about some charters and application of HJ-1B IRS sensor.

Table A. Part of characters of HJ-1B IRS

Band Name	Wavelength (μm)	Spatial Resolution (meter)	Application
NIR	0.75-1.10 (0.92)	150	Vegetation Index
SWIR	1.55- 1.75 (1.65)	150	Vegetation Index, cloud mask
MIR	3.50 - 3.90 (3.70)	150	Surface temperature, burning monitoring
TIR	10.50 - 12.50 (11.50)	300	Surface temperature, cloud mask

The method from raw digital to reflectance conversion and bright temperature of HJ-1B IRS images were based on X. L. Qin (X. L. Qin et al., 2010). At the same times, in order to use the TIR channel to cloud mask, it has been interpolate to 150 meter by using Nearest Neighbor method.

2.3 Field Work

The typical forest type, include Larch, Asian white Birch and Korean Pine in the experimental region have been harvested to be canopy leaf sample during August 10^{th} to 26^{th} of 2009. Every kinds of tree had been sampled more than 30 trees. At the same times, the locations where samples were measured were recorded by a GARMMIN Global Positioning System (GPS) having approximately 5m precision after differential correction. The sampled live leaf moisture content had been measured using desiccation method under the 105℃.

3. METHODOLOGY

Figure 1 shows the flowchart of forest canopy moisture content by using HJ-1B IRS.

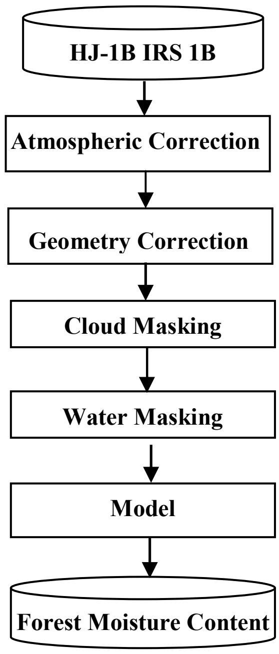

Figure 1. Flowchart of forest canopy moisture content estimation by using HJ-1B IRS images

3.1. Atmospheric Correction

Atmosphere usually causes error when using satellite to estimate the fuel moisture content. The Simplified Method for Atmospheric Correction (SMAC) has been used to modify the reflectance of NIR and SWIR channel of HJ-1B IRS. This algorithm has been developed by H. Rahman (H. Rahman et al., 1994).

3.2. Geometric Correction

Geometric corrections of daily data and multi-temporal matching were based on 1:50000 Atlas by manual control points.

3.3. Samples Test

In order to get the forest canopy moisture content estimation model with HJ-1B IRS data, the parameters of vegetation, soil and cloud have been sampled from the four channel of HJ-1B IRS L1B image. For reducing the potential noise caused by the great differences within the area covered when comparing HJ-1B IRS images and field measurements, the average value of a 3*3 pixel window was extracted from each image to correlated against field measurements. More than 100 pixels of every kinds of type have been sampled.

3.4. Algorithm Description

It shows that there are one absorb apexes at the near 1.65μm, however, high reflectance at the NIR bands for vegetation. According to the HJ-1B IRS charters, the approach retrieve of Forest canopy moisture content with HJ-1B IRS measurement include water mask, cloud mask, NDWI calculation and Classifying etc.

3.4.1. Water Masking

Water pixels in HJ-1B IRS images have been masked by using the river layer in 1:50000 digital map. Pixel will be identified as water class if the pixel at the same position in 1:50000 digital Map belongs to water.

3.4.2. Cloud Masking

According to the samples analysis, here, cloud detection was performed using a threshold. The Daytime pixels are considered to be cloud if one of Eqs.1-3 condition is satisfied.

$$R_{SWIR} > 90\% \qquad (1)$$

$$T_{TIR} < 265K \qquad (2)$$

$$\begin{cases} R_{SWIR} > 80\% \\ T_{TIR} < 285k \end{cases} \qquad (3)$$

Where R_{SWIR} is the reflectance of SWIR channel of HJ-1B IRS;

T_{TIR} is the bright temperature of 11.5 μm central channel of HJ-B IRS.

3.4.3. Forest Moisture Content Calculation

The forest moisture content could be calculated with the normalized ration of SWIR and NIR channel. Here, the Normal Difference Water Index (NDWI) has been used to evaluate the forest moisture content. The NDWI is defined as Eq. 4.

$$NDWI = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}} \times 100\% \qquad (4)$$

Where NDWI is Normal Difference Water Index;

ρ_{nir} is the reflectance of NIR channel of HJ-1B IRS;

ρ_{SWIR} is the reflectance of SWIR channel of HJ-1B IRS;

4. RESULTS AND DISCUSSSION

The forest moisture content was respectively calculated as the algorithm description in '3.4' by using HJ-1B IRS L1B images. Parts of results have been listed in Figure 2 and Figure 3.

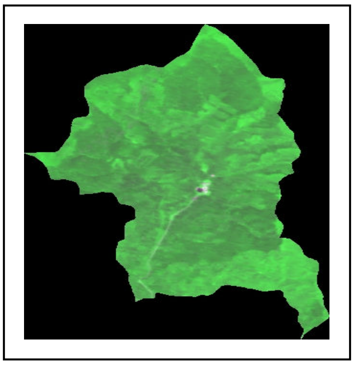

Figure 2. HJ-1B IRS images (Aug. 12, 2009)
(R=1.65μm, G=0.92μm, B=1.65μm)

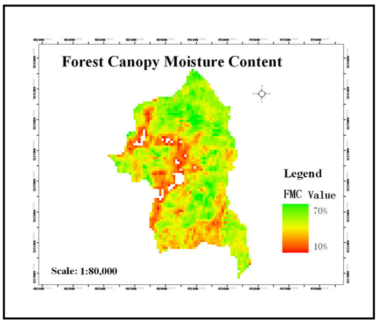

Figure 3. Estimated result of forest canopy moisture content
(Aug. 12, 2009, HJ-1B IRS, Spatial Resolution is 150m)

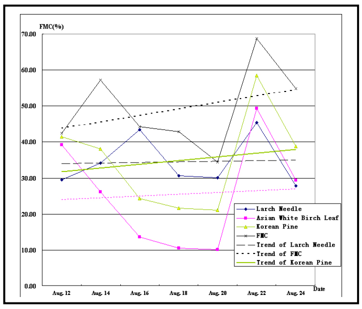

Figure 4. Change curves of forest canopy moisture content with times data come from HJ-1B IRS images

Comparing the same location pixels from Figure 4, it shows that the NDWI has the similar tendency distribution to the field observation. It shows that the NDWI is an effective index factor of FMC, which can be calculated by using the SWIR and NIR channel of satellite data.

5. CONCLUSIONS

Forest canopy moisture content is an important factor to forest fire risk prediction. How to estimate the dynamic forest canopy moisture content in larger area is a problem in forest fire risk prediction system. In this study, NDWI, which is defined as the indictor of forest canopy moisture content, has been estimated by using the NIR and SWIR band of HJ-1B IRS L1B images. The results showed that the NDWI has a sensitive indictor to typical forest canopy moisture content in broad area. In other words, the forest canopy moisture content in broad scale can be estimated by using the SWIR and NIR channel of satellite data.

In fact, forest canopy moisture content has been affected by many factors, such as tree type, soil, leaf, atmosphere, canopy structure and topography etc. In this study, the SMAC has been used to correct atmosphere effect of HJ-1B IRS images, but the others' affection hasn't been removed. These would cause error to estimate NDWI by satellite data.

ACKNOWLEDGEMENT

The fund of this work has been supported by the "863"project, the science fund of Chinese Academy of Forestry Project 'Study on Important Resources and Forest Fire Monitoring Techniques (CAFYBB2007003)', and MOST-ESA Cooperation Project 'Dragon Project-Early warning and damaged assessment for forest fire (Dragon Proposal id 5258)'.

Thanks X. Q. Wu, D. Zhao, Y. Guo, Qi Feng, Chen Li, Tian Fu, Lijuan Liu had taken in the field work. Thanks China Centre for Resources Satellite has supplied HJ-1B IRS data for the study.

REFERENCE

B. C. Gao, "NDWI – A normalized difference water index for remote sensing of vegetation liquid water from space," Remote Sensing of Environment, 58, P.P. 257−266, 1996.

C. C. Hardy, and R. E. Burgan, "Evaluation of NDVI for monitoring live moisture in three vegetation types of western U.S. ," Photogrammetric Engineering & Remote Sensing, 65, P.P. 603−610, 1999.

E. Chuvieco, D. Riano, I. Aguado, and D. Cocerro, "Estimation of fuel moisture from multi-temporal analysis of Landsat Thematic Mapper reflectance data: applications in fire danger assessment," Int. J. Remote Sensing, 23, P.P. 2145−2162, 2002.

E. Chuvieco, D. Cocero, and P. Riaño, etc., "Combining NDVI and surface temperature for the estimation of live fuel moisture content in forest fire danger rating," Remote Sensing of Environment, 92, P.P. 322−331, 2004.

E. R. Hunt, B.N. Rock, P. S. Nobel, "Measurement of leaf relative water content by infrared reflectance," Remote Sensing of Environment, 22, P.P. 429−435, 1987.

E. R. Hunt, and B.N. Rock, "Detecting of changes in leaf water content using near and middle-infrared reflectance," Remote Sensing of Environment, 30, P.P. 43−54, 1989.

H. Rahman, and G. Dedieu, "A simplified method for the atmospheric correction of satellite measurements in the solar spectrum," Int. J. Remote Sensing, 15(1): P.P. 123-143, 1994.

L. U. Susan, A. R. Dar, and P. Jorge, etc., "Estimating canopy water content of chaparral shrubs using optical methods," Remote Sensing of Environment," 65: P.P. 280–291, 1998.

M. Alonso, "Estimating Temporal Dynamics of Fuel Moisture Content of Mediterranean Species from NOAA-AVHRR Data," Earsel Advances in Remote Sensing, 4(4): P.P. 9−24, 1996.

P. Ceccato, S. Flasse, and S. Tarantola, etc., "Detecting vegetation leaf water content using reflectance in the optical domain," Remote Sensing of Environment, 77, P.P. 22−33, 2001.

P. J. Zarco-Tejada, C. A. Rueda, and S. L. Ustin, "Water content estimation in vegetation with MODIS reflectance data and model inversion methods," Remote Sensing of Environment, 85, P.P. 109−124, 2003.

P. Zhang, and Sh. X. Wang, "Research on estimating vegetation water content from MODIS data," Remote Sensing Information, (1): P.P. 19−23, 2004.

R. E. Burgan, R. A. Hartford, "Live vegetation moisture calculated from NDVI and used in fire danger rating," 13th Conf. on fire and Forestry Met., Lorne, Australia, P. P. 27−31, 1997.

S. Dasgupta, J. J. Qu, X. J. Hao, S. Bhoi, "Evaluating remotely sensed live fuel moisture estimations for fire behavior predictions in Georgia, USA," Remote Sensing of Environment, 108: P.P. 138–150, 2007 .

X. L. Qin, "Study on forest fire early warning and monitoring methodology using Remote sensing and Geography Information System techniques," PhD Thesis, Chinese Academy of Forestry, 2005.

X. L. Qin, Z. Y. Li, and H. R. Yi, etc., "Fuel moisture content estimation using satellite data," European Space Agency, Beijing, China, 21-25, 4, 2008.

X. L. Qin, Z. H. zhang, and Z. Y. Li, "An automatic forest fires identification method using HJ-1B IRS data," Remote Sensing Technology and Application, 25(4): P.P.700−706, 2010.

X. N. Song, and Y. S. Zhao, "Study on vegetation –temperature-water synthesis index using MODIS satellite data," Geography and Geo-Information Science, (2): P.P.13-17, 2004.