Remote sensing of insect pests in Larch forest based on physical model

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Abstract: In the recent ten years, great research progresses have been made on the remote sensing application in the forest pest monitoring area, especially on the monitoring model. However, most monitoring models were developed based on statistical analysis, which is highly depending on specific field data. Therefore, these models are limited for only small regions and not suitable for other research areas. Hence, it is necessary and urgent to develop more general models. Meanwhile, most researchers used two physiological characteristics -- defoliation and the change of the leaf color -- to monitor forest health status after the trees being attacked. Although they are suitable for the loss assessment, these researches are not so good to detect the insect pests during the early stage. That is because it's usually at the middle and late stage of the insects attacking when the two physiological characteristics changes are detectable by remote sensing data. Moreover, most VIS and NIR data were applied in the pest monitoring research, while, the application of TIR data are rare. The objective of this paper is to combine the theories of the ecology, forest protection and quantitative remote sensing to monitor the forest insect pests. There are mainly four parts in our paper:

(1) Index selection: through the analysis on the physiological characteristics changes right after the attacking, three indicative factors of the early forest insect pests monitoring were brought forward, which are CWC (representing the total water content of forest canopy), TVDI (Temperature/Vegetation dryness Index representing the relative water content of soil) and LAI (leaf area index). In order to evaluate the feasibility of the CWC inversion from the Landsat data, the sensitivity of the reflectance characteristics of coniferous needles on the needle water content was studied based on the filed data and the LIBERTY (Leaf Incorporating Biochemistry Exhibiting Reflectance and Transmittance Yields) model. The results show that three spectrum indices, which are MSI (Moisture Stress Index), NDWI (Normal Difference Water Index) and GVMI (Global Vegetation Moisture Index) were highly correlated with the water content. Especially, GVMI is not sensitive to whether the needle is clustered or not. Moreover, GVMI uses

two broad bands (NIR and SWIR), which can be calculated from Landsat TM/ETM+ data. Therefore, it is confirmed that Landsat TM/ETM+ data is feasible to inverse the forest canopy water content, which lays a solid theoretical foundation for the following research. Then, the inversion research on the three indicative factors was performed using VIR, NIR and TIR data, combined with physical-based RT (Radiative Transfer) model and ANN (Artificial Neural Network).

(2) Index inversion: the inversion method (RT-ANN) for LAI and CWC by combining the 5-scale radiation transfer (RT) model and back propagation (BP) artificial neural network (ANN) was put forward. And the method was customized on Landsat data to inverse the two indicative factors. TVDI is determined by using the Ts/NDVI feature space. Pre-analysis results show that the Landsat TM_6 data must be corrected to remove atmospheric effects and emissivity effects before retrieving TVDI.

(3) Index assessment: By combining the field rainfall data, the inversed TVDI image series show that this index is good to indicate the soil dryness and useful for monitoring soil relative water content. Field data and MODIS data were used to validate the index inversion of LAI and CWC.

(4) Decision rule for pest monitor: based on training samples of health/attacked pixel with the three indices, a decision tree was build to classify the pest-infected pixels.

(5) Demonstration and evaluation: The whole decision rule was test over Larch forest in the YIERSHI forest farm of Inner Mongolia, northeast of China. Twelve Landsat images from 1990 to 2000 at summer were used to derive indices of LAI, CWC and TVDI. The decision rules for the Larch forest insect pests monitor were performed based on historical material and field sample data. Results show that the insect pest forest compartments which extract from the images is highly consistent with the ground field data.

(6) Quick method: Considering practicability, a general and physically-based forest insect pest monitoring model is developed by speeding the inversion algorithm.

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