Remote Sensing of Forest Health: Current Advances and Challenges

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Abstract

In recent years, insect defoliators and drought-related dieback have been important natural disturbance agents in Canada's forests. While aerial and field surveys are the primary methods by which these disturbances are currently assessed, there is a need for more spatially precise, consistent mapping and monitoring of the area, severity and location of insect defoliation and dieback disturbances nationally. In response, Natural Resources Canada, in collaboration with the Canadian Space Agency, is developing methods applicable to the major insect defoliators in Canada and aspen dieback. The goal is to use multi-scale, remotely sensed change information as input to Canada's National Forest Carbon Monitoring, Accounting and Reporting System. Assessing the impacts of these disturbances is complicated because mortality and growth reductions vary by disturbance agent, region and year, resulting in highly variable patterns of impact severity across the landscape. This presentation highlights some of the advances and challenges associated with remote sensing of forest health.

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Résumé

Utilité de la télédétection pour l'évaluation de la santé des forêts : progrès récents et enjeux

Au cours des dernières années, les insectes défoliateurs et le dépérissement du à la sécheresse ont causé des perturbations importantes dans les forêts canadiennes. Les relevés aériens et les relevés sur le terrain sont les principales méthodes utilisées pour évaluer ces perturbations naturelles, mais il faut trouver une méthode spatialement plus précise pour cartographier et surveiller de façon systématique les zones perturbées et évaluer la gravité et la répartition des perturbations occasionnées par les insectes défoliateurs et le dépérissement à l'échelle nationale. Ressources naturelles Canada, en collaboration avec l'Agence spatiale canadienne, élabore des méthodes afin de surveiller l'activité des principaux insectes défoliateurs et le dépérissement du peuplier faux-tremble au Canada. L'objectif consiste à utiliser des données de télédétection multi-échelles sur les changements comme données d'entrée dans le système national de surveillance, de comptabilisation et de production de rapports concernant le carbone forestier. L'évaluation des impacts de ces perturbations soulève d'importantes difficultés, car les taux de mortalité et l'ampleur des réductions de croissance fluctuent selon l'agent de perturbation, la région et l'année, et l'ampleur des perturbations varie considérablement à l'échelle du paysage. Cette présentation expose certains des progrès récents et enjeux associés à l'application de la télédétection à l'évaluation de la santé des forêts.

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Extended Abstract: Presentation Summary
Remote Sensing of Forest Health: Current Advances and Challenges

Pest outbreaks caused by insect defoliation and climate-related drought resulting in dieback of trembling aspen (*Populus tremuloides*, Michx.) are considered natural disturbances that have carbon consequences (Volney and Fleming 2000; Hogg and Bernier 2005). Repeat severe defoliation and aspen dieback result in mortality, reduced growth rates, dead tree tops and loss of foliage, all of which will impact forest productivity, carbon stocks, and the reduced ability to sequester carbon

from the atmosphere (Hogg et al. 2002; Bhatti et al. 2003). There is also increasing concern that a changing climate will further enhance these impacts by altering the frequency and severity by which these natural disturbances occur (Volney and Fleming 2000; Hogg and Bernier 2005). Disturbance impacts in moisture-limited regions already appear to be underway in western Canada where observations of both dieback and mortality have been recorded (Hogg et al. *in press*).

To account for the impacts of natural disturbances caused by insects and drought, the Canadian Forest Service of Natural Resources Canada has developed the National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) (Kurz and Apps 2006). Outputs from NFCMARS will inform national policy makers and resource managers on the impacts of resource management, land-use change and disturbances on forest carbon stocks (Kurz et al. 2008). The system is providing data for annual reporting on greenhouse gas emissions provided to Environment Canada as part of Canada's report to the United Nations Framework Convention on Climate Change (Environment Canada 2007), Criteria and Indicators reporting, and to provide a framework for national level forest monitoring (Wulder et al. 2004).

At present, NFCMARS undertakes reporting for a select set of the major insect pests in Canada of which the defoliators include aspen defoliators (eg., large aspen tortrix, *Choristoneura conflictana* (Wlk.) and forest tent caterpillar, *Malacosoma disstria* Hubner), spruce budworm, *Choristoneura fumiferana* (Clem.), jack pine budworm, *Choristoneura pinus pinus* Freeman, and hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), and a pilot study is underway to incorporate drought as a natural disturbance within the Carbon Budget Model. Provincial forest health surveys are largely used for this purpose and there is a high desire for more spatially precise and timely mapping of insect and climate-related disturbances along with an assessment of their severity. With the support of the Canadian Space Agency, a project partnership between the Canada Centre for Remote Sensing and the Canadian Forest Service was devised to develop and demonstrate earth-observation based methods that could provide consistent, timely, and spatially precise mapping and monitoring of the location, extent and severity of insect defoliation and dieback disturbances. Project elements include a system framework for data management and reporting and methods for mapping disturbances caused by insect defoliation and aspen dieback that could be used to support Canada's national and international reporting requirements on environmental and sustainable development indicators and carbon accounting.

To meet the objectives of this study, the National Environmental Disturbances Framework (NEDF) is being developed whose purpose is to provide map products and a geo-spatial reporting system on national disturbance statistics. Many elements of the NEDF have already been developed, and it has been functioning operationally to provide information about national fire activity as part of the Canadian Wildland Fire Information System (de Groot et al. 2007). Information from the NEDF has been provided to NFCMARS to assist in its national reporting mandate the past three years. The intent of this incremental activity is to incorporate information about disturbances from insect defoliation and dieback into the NEDF. The NEDF is clearly a technology advancement that will facilitate the transfer of disturbance information to NFCMARS.

Research on remote sensing methods for mapping aspen defoliation, spruce budworm defoliation and aspen dieback is underway and while some success has been reported, operational challenges have also been identified (Arsenault et al. 2006; Hall et al. 2006a; Thomas et al. 2007). Some of the advancements in remote sensing include methods for multi-date image normalization, a modeling approach to map defoliation (Hall et al. 2006b) and dieback (Arsenault et al. 2006), and mechanisms by which these procedures could be applied to other sensors beyond the Landsat Thematic Mapper such as SPOT. One of the biggest challenges is generating annual estimates of defoliation and dieback activity nationally. Satellite remote sensing cannot map all disturbances at fine resolution due to the possibility of cloud cover at the critical time frames when disturbance events are most visible. Coarse resolution images from sensors such as MERIS could help identify where fine resolution remote sensing images should be acquired, and it may also serve as an alternate image data source for detection and mapping of large-scale disturbances (van der Sanden et al. 2006). As a result, the proposed solution is to invest in geospatial data integration of multisensor remote sensing, aerial survey and field data to generate a composite picture of defoliation and dieback disturbances.

With the support of the Canadian Space Agency, we are continuing development and validation of methods for mapping insect defoliation and aspen dieback, and we are intending to increase areas of mapping and to apply methods developed to other defoliators. We would welcome provincial agencies as collaborators through working partnerships. The annual products are feeding directly into monitoring and reporting in support of sustainable forest management in Canada.

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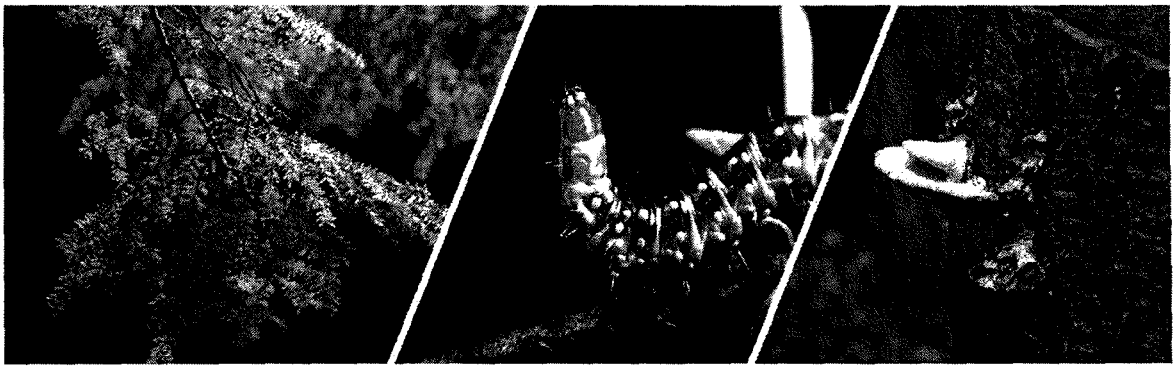

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