



The Canadian Smoke Newsletter

Spring/Summer 2010

"Connecting diverse terrestrial, emissions, air quality and modelling communities."

Fuel-type mapping for the CWFIS: Past, Present, and Future

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Wildland fire is a frequent event in Canada's forests. Each year, approximately 7,000 forest fires burn over 1.7 million hectares [Natural Resources Canada, 2009]. Fire is a natural part of the landscape and has helped to maintain forest health and diversity for the past 10,000 years. On the other hand, these fires destroy valuable timber, disrupt forest-based communities and affect public health and safety. Understanding forest fires and fire behaviour is important in mitigating their effect on the Canadian landscape.

Countryman [1966] describes the fire environment as the conditions, influences, and modifying factors that control fire behaviour. The fire environment consists of three principal components: fuel, topography, and weather. Fuel represents any organic material – living or dead – that is available for combustion and thus is the driving force behind fire behaviour. Topography represents elevation characteristics of a landscape, such as slope and aspect, that can influence fire spread. Weather represents the atmospheric elements that directly affect combustion, such as wind and rain. Together, these three factors make up what is referred to as the fire environment triangle.

Of the three major components affecting fire spread, forest fuels represent the most spatially diverse and dynamic predictor of the three. Differences within fuels such as the height of the forest canopy above

ground or whether deciduous trees have leafed out can lead to variations in propagation rates of ten to a hundredfold. Mapping forest fuels is crucial to predicting potential fire growth on the landscape. With respect to smoke modelling, fuel characteristics have a significant impact by influencing fire behaviour and therefore the fuel consumption rate which in turn affects the amount of smoke emitted to the atmosphere. Other fuel characteristics can affect smoke chemistry, which may have an impact on health and safety. This paper summarizes efforts to map forest fuels and include them in fire management systems.

Canadian Forest Fire Danger Rating System

The Canadian Forest Fire Danger Rating System (CFFDRS) is a model developed by the Canadian Forest Service over the past 40 years to predict the potential impact of fire on the landscape [Stocks et al., 1989]. The CFFDRS consists of two principal sub-systems: the Canadian Forest Fire Weather Index (FWI) System and the Canadian Forest Fire Behaviour Prediction (FBP) System. The FWI is used to assess the impact of weather conditions on fuel moisture and fire behaviour [Van Wagner, 1987]. The FBP system provides quantitative estimates of potential head fire spread rate, fuel consumption, and fire intensity, as well as fire descriptions [Forestry Canada Fire Danger Group, 1992]. With the aid of an elliptical

fire growth model, the FWI and FBP systems together give estimates of fire area, perimeter, perimeter growth rate, and flank and back fire behaviour. Required input data include weather, topography, and fuels.

16 fuel types in the FBP system

1. C1 – Spruce-lichen woodland
2. C2 – Boreal spruce
3. C3 – Mature jack or lodgepole pine
4. C4 – Immature jack or lodgepole pine
5. C5 – Red and white pine
6. C6 – Conifer plantation
7. C7 – Ponderosa pine or Douglas fir
8. M1 – Boreal mixedwood - leafless
9. M2 – Boreal mixedwood - green
10. M3 – Dead balsam fir/mixedwood - leafless
11. M4 – Dead balsam fir/mixedwood - green
12. S1 – Jack or lodgepole pine slash
13. S2 – White spruce/balsam slash
14. S3 – Coastal cedar/hemlock/Douglas-fir slash
15. D1 – Leafless aspen
16. O1 – Matted (O1a) or Standing (O1b) grass

Canadian Wildland Fire Information System

The Canadian Wildland Fire Information System (CWFIS) is a computer-based fire management information system that monitors fire danger conditions across Canada

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(<http://cwfis.cfs.nrcan.gc.ca/>). Daily weather conditions and satellite hotspot data are collected from across Canada and used to generate fire weather, fire behaviour and fire occurrence maps in near real time.

The CWFIS has produced national maps of fuel types since 1995. Fuel type maps were developed for use in geographic information systems starting in the 1990s in order to produce maps of FBP outputs. Many of the provincial and territorial fire management agencies have also

produced fuel type maps based on forest inventory data. Recently, remote sensing has been used more extensively.

The first fuel type map (Figure 1) used by the CWFIS was a reclassification of land cover based on Advanced Very High Resolution Radiometer (AVHRR) imagery [Palko et al., 1993]. Although the fuel type classification was done in 1995, the imagery was acquired during the summers of 1988 to 1991. Of the 16 FBP fuel types, only five were used in

the map.

Classification was basic. Coniferous forest land was classified as C2, “transitional” forest land as C1, hardwoods as D1, all mixedwoods as M1, and cropland or grassland as O1. Because there was no way to distinguish tree species or stand age with coarse remotely sensed data, other coniferous or mixedwood fuel types could not be identified. For example, mature jack pine (C3) and immature jack pine (C4) could not be distinguished from boreal spruce (C2).

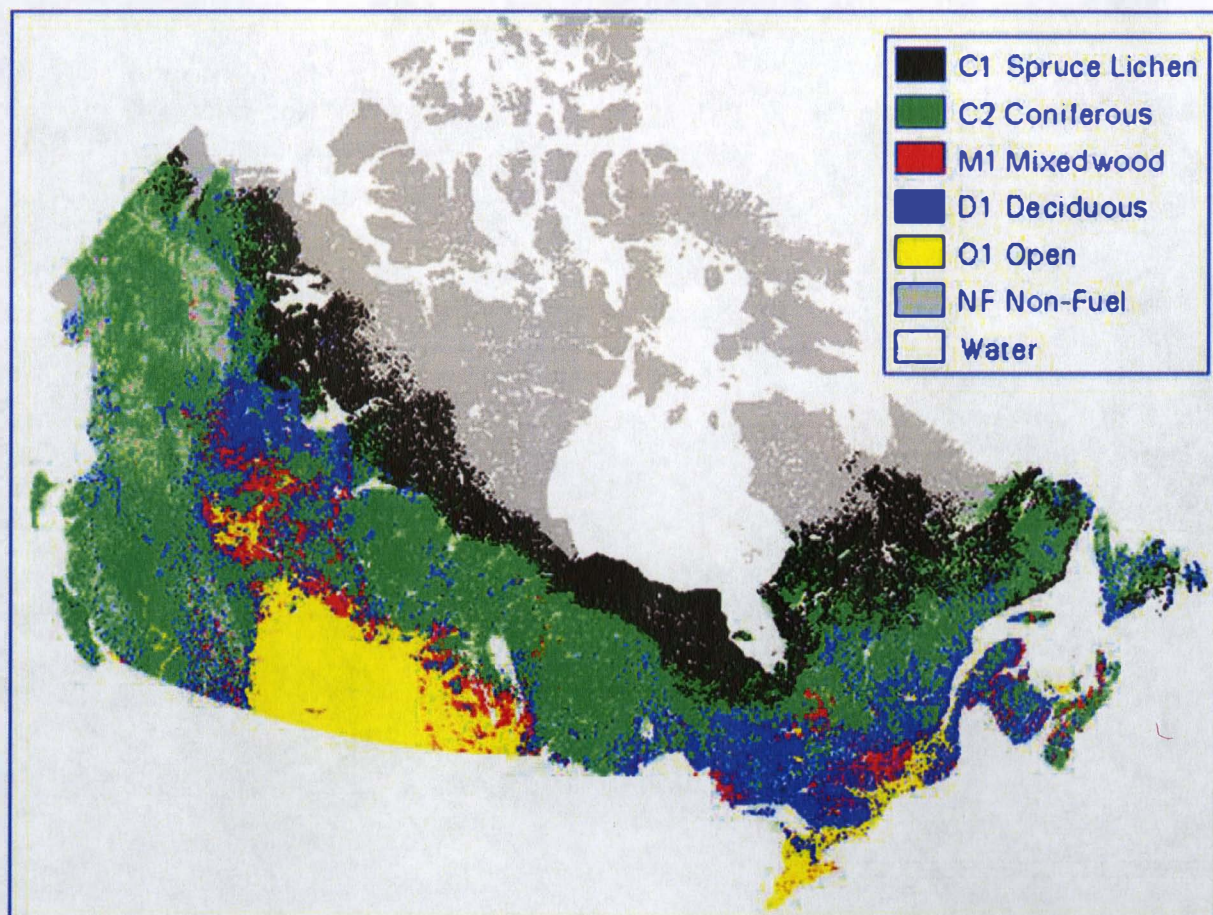


Figure 1. Original FBP fuel type map of Canada based on Cihlar and Beaubien (1998).

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The second fuel-type map used by the CWFIS was also a reclassification of AVHRR-based land cover [Cihlar and Beaubien, 1998]. The imagery was acquired from one of the Polar Operational Environmental Satellites operated by the National Oceanic and Atmospheric Administration (NOAA), called NOAA-14, during April to

October 1995. The CWFIS began to use this map in 2000.

The land cover map was produced by the Canada Centre for Remote Sensing (CCRS), a sector within Natural Resources Canada [1999]. This land cover map contained more detailed information about stand

density, which was used to distinguish C1 from C2. Shrublands were classified as deciduous (D1) and mixedwood (M) classes were distinguished by the percentage of coniferous trees they contained. Cropland and grassland were classified as O1 (Figure. 2).

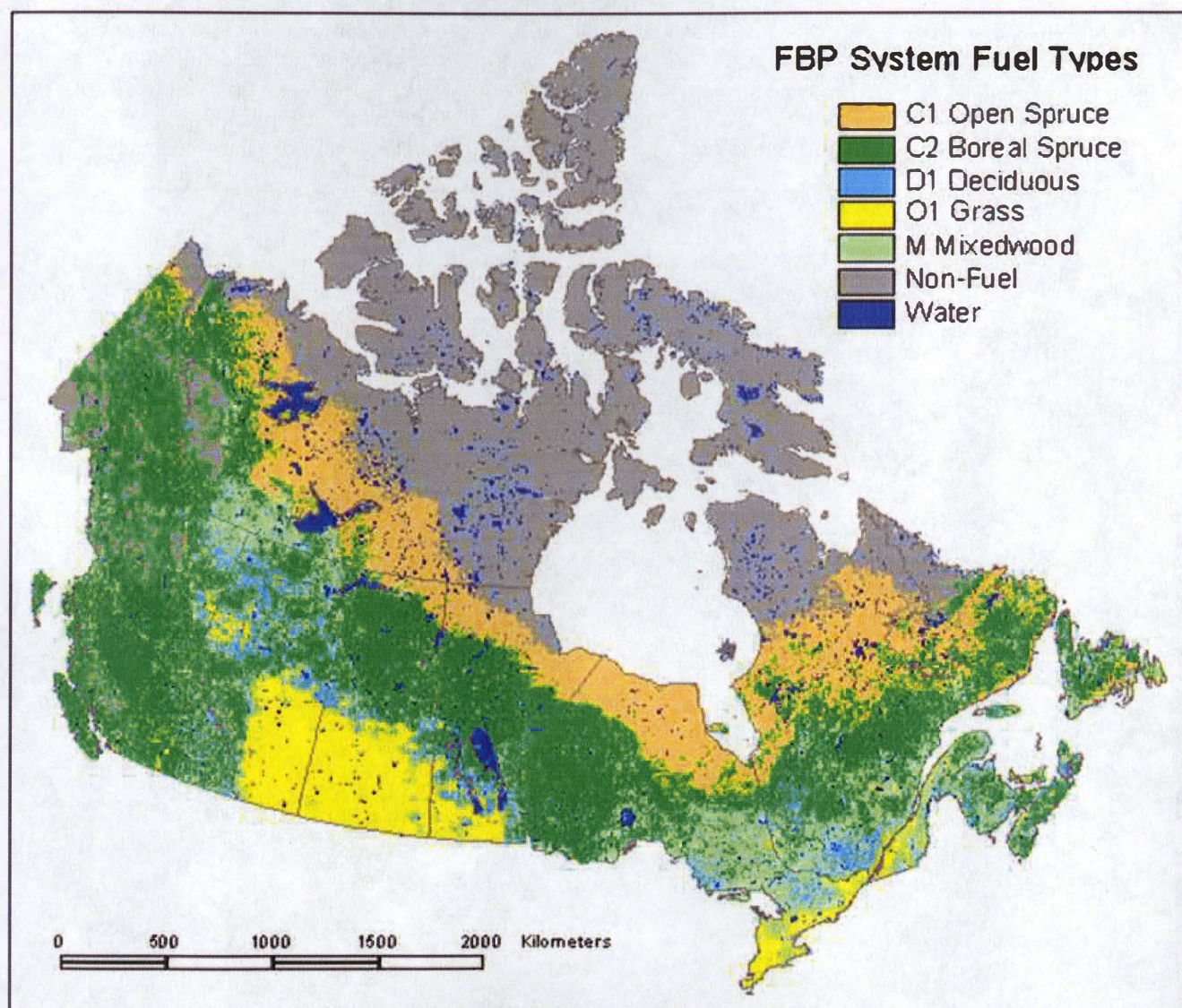


Figure 2. Updated FBP fuel type map of Canada based on reclassification of AVHRR land cover data.

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A third fuel type map began to be used by the CWFIS in 2005 [Nadeau et al., 2005], in which multiple sources of data were used to determine fuel types. Vegetation types were determined using a land cover map based on 2000 Satellite Pour l'Observation de la Terre (SPOT) VGT imagery [Latifovic et al., 2004]. Additional information was obtained from Canada's Forest Inventory (CanFI) 2001 [Natural Resources Canada, 2004a and 2004b].

In addition, the Terrestrial Ecozones of Canada [Ecological Stratification Working Group, 1996] were used as a guide for a reclassification scheme for each ecozone on the basis of local knowledge and expert opinion.

Because CanFI data includes species information, it was possible to separate spruce (C1 and C2) from pine (C3, C4, C5, and C7). In some cases, it was possible to use CanFI to

separate mature jack or lodgepole pine (C3) from immature jack or lodgepole pine (C4). Where this was not possible, the fuel type was designated as C3/4 (Figure 3). Also, for the first time, cropland and tundra were distinguished from grassland. For FBP calculations, the CWFIS considers cropland as O1 with low curing, and tundra as O1 with a low fuel load. The number of fuel types mapped has increased significantly from five to nine.

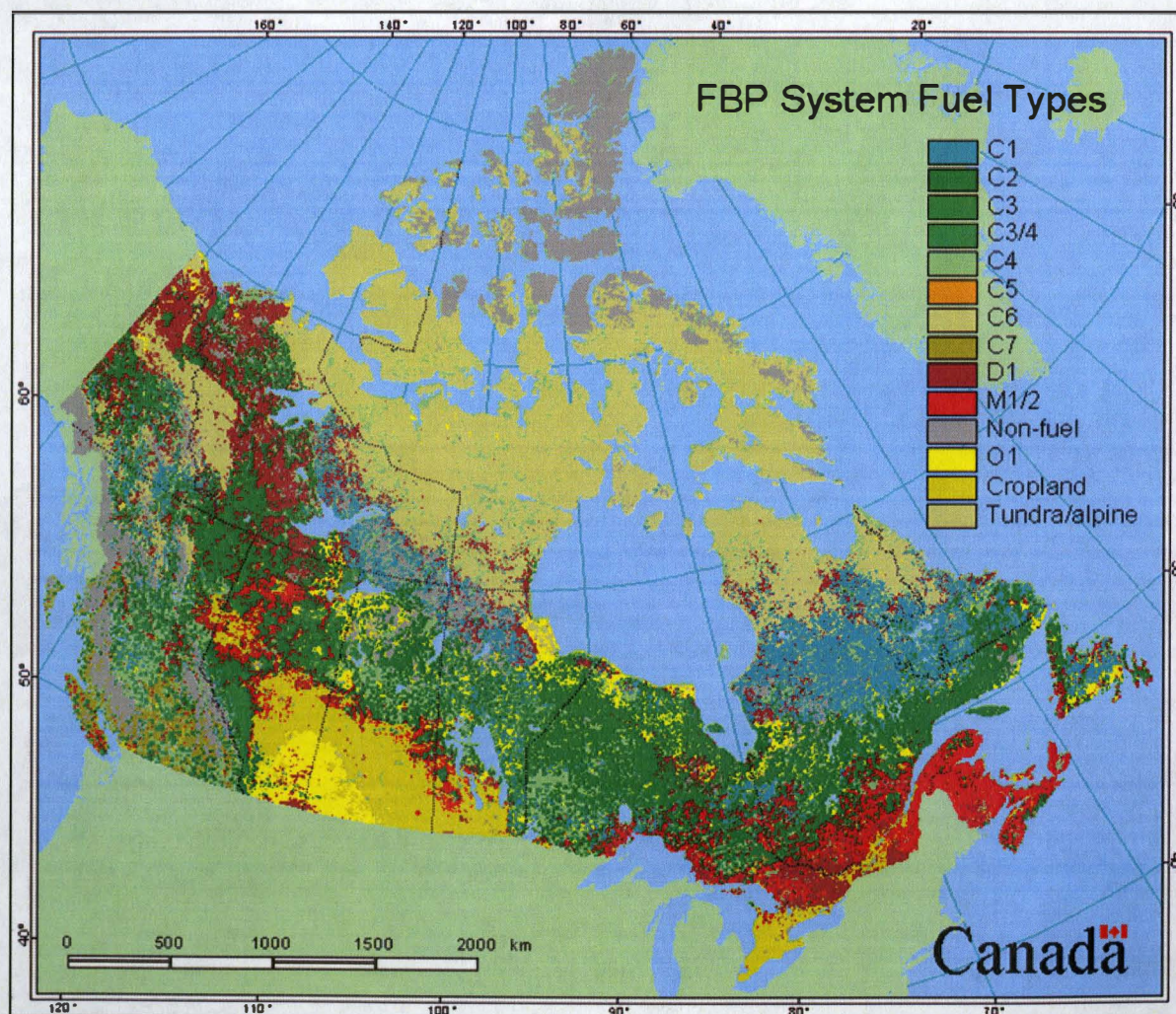


Figure 3. Third fuel type map of Canada produced with land cover and forest inventory maps using fuzzy logic.



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The Future

Although FBP fuel types have been and will continue to be widely used in Canada, future versions of the map will include a database of species and structural characteristics for each raster cell. Land cover data is more widely available now than in the past because of the development of new remote sensing technologies.

Despite the advances shown by successive progressive fuel type maps, there are several areas that can be improved upon. They are species assignment, resolution, and age of imagery.

Species assignment. The Canadian FBP system relies on a limited number of fuel types that – for mapping purposes – were primarily defined by species. However, the assignment of species to a fuel type was a substitute for some measure of structure. For example, a stand that has the characteristics of a C2 – Boreal Spruce stand might be assigned to that fuel type even if it were a different species, such as eastern larch. This is particularly true for those species (such as larch) that are not represented by an existing fuel type. Therefore it is very important to know not only the species, but also the structure of the stand. However, satellite land cover maps may not provide either.

Resolution. All three historical fuel type maps are rasters limited to a resolution of 1 km². Future fuel type maps will use additional data to increase the resolution to 250 x 250 m, resulting in a 16-fold increase in the number of grid cells. Although

higher resolution satellite products do exist, the number of freely available supplementary data sources that are high resolution, up to date and that cover all of Canada’s forests are limited. In the future, new landcover maps may allow for even higher resolution fuel maps for Canada’s forests should there be a need at the national scale for detailed fire growth modelling.

Age of imagery. A persistent problem with the production of national fuel type maps has been the age of the images used to generate the products. It takes time to acquire national cloud-free coverage from the various satellite sources, and still more time to use that data to generate a land cover map. Once the land cover map is available, it must then be converted to a fuel type map using other data sources to provide, for example, species information. The sources of species data have often been much older than the land cover map itself. Therefore, recent events like clearcuts, insect infestations, blowdown events and even wild fires might not be reflected in the fuel type map. Additionally, it is important that future disturbances – such as harvesting or wild fires – that affect fuels are recorded and accounted for in the fuels map. To date, CWFIS fuels maps have not been updated to reflect landscape level disturbances. Ideally, any future system will incorporate a mechanism to update the fuel type on an annual basis.

Many types of disturbances are currently mapped across Canada, on an ongoing basis. Fires are mapped in the National Burned Area

Composite (NBAC). Deforestation is tracked with a sampling protocol by the Deforestation Monitoring Group and updated annually for the National Inventory Report [Environment Canada, 2010]. Additionally, efforts are under way to produce a Canadian Forest Service nationwide insect outbreak atlas. Combined with national carbon accounting procedures [Kurz et al., 2009], they also offer a potential mechanism to refine estimates of fuel loads.

With currently available land cover products such as the MODIS land cover map produced by the Canada Centre for Remote Sensing [2008], it should be possible to achieve the desired levels of resolution and detection of changes to land cover. However, identification of tree species continues to be an issue when using satellite imagery. Additional sources of information are required to assign an FBP fuel type to each pixel.

Where they are available, provincial fuel type maps would be an ideal source for fuel type classification. Additional stand characteristics can be derived from supplementary sources such as standard polygonal forest inventory maps. For example, species, merchantable and total volume, basal area, height, and crown closure might all be available.

One area of particular interest is airborne LiDAR data; although current operational implementation of airborne LiDAR is limited in Canada it is becoming increasingly widespread and cost effective. One such study in Ontario [Woods et al., 2008] demonstrated that the stand

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characteristics described above can be directly measured or inferred with LiDAR data at landscape scales. Other information that might be available from LiDAR data includes vertical structure (e.g., number of stems by height class) and horizontal structure (e.g., gaps in the forest canopy).

As more data becomes available, additional products and tools will be able to make use of the fuel type map. Fuel consumption models such as CANFIRE [de Groot 2009] use parameters and fuel load values such as those described above. Information on stand structure could be used to model fuel treatments or fire behaviour in ways that are difficult with currently available data. In a static fuel type map, current FBP fuel types are difficult to apply in some situations such as successional changes following insect damage to a forest.

As these new tools become available, an improved fuels map will be produced for Canada. While past iterations were static, the future product should be dynamic, changing as new data becomes available. Finally, the new fuels map will include other information that will be of use to modellers and fire behaviour specialists in addition to just FBP fuel type. §

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Welcome to the 2010 Spring-Summer issue of The Canadian Smoke Newsletter. Please note that the Newsletter is published twice per year and that from this point on, issues will be labelled as Spring/Summer and Fall/Winter.

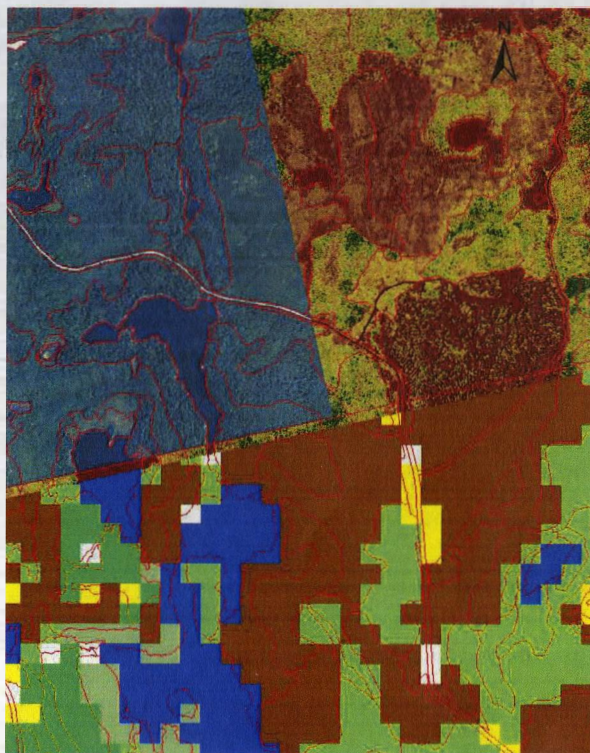
Of continuing interest to the smoke prediction community in Canada is the progress of the BlueSky Western Canada extension. The project came to a standstill in early 2009 due to severe funding limitations. Fortunately through partnered contributions by the British Columbia Ministry of Environment and Environment Canada, the final parts of the system were tied together. Under the leadership of Steve Sakiyama at the BC Department of Healthy Living and Sport, the BlueSky team together with staff at the University of British Columbia under Roland Stull as well as Sonoma Technologies Inc. have succeeded in setting up a Canadian version of BlueSky. The system has undergone test runs using selected fires from the BC interior in 2009. We will have an in-depth look at this project in the upcoming Fall/Winter 2010 issue.

The Fall (now Fall-Winter) issues of the CSN have usually filled this column with a listing of upcoming conferences around the world which are of interest to the smoke community. Since few of us have the wherewithal to attend each conference, I invite those of you who do attend to send a short email (to al.pankratz@tec.gc.ca) outlining the salient aspects of the conferences from the smoke point of view. Point form is fine. I will compile the results and add them to the next issue of the CSN. In this way, community input will assist those who are considering attending that particular conference in the future, and provide potentially valuable information for people who were unable to attend.

Cheers,

Al Pankratz

Disclaimer: This informal newsletter is produced by the Air Quality section of Prairie and Northern region of Environment Canada on behalf of the smoke community. It does not represent the policies of Environment Canada.



Composite image of remote sensing data: Air photo, LiDAR canopy height model data and FRI polygons courtesy of Chad St. Amand, Tembec. Fuel type map generated from Earth Observation for Sustainable Development of Forests (EOSD) land cover map of the forested area of Canada.

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