CLASSIFICATION OF FOREST STANDS AS FOREST FUELS ACCORDING TO THE CANADIAN FOREST FIRE BEHAVIOR PREDICTION SYSTEM

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PREAMBLE

This document combines two reports produced by the working group on forest fuels. This group, composed of representatives from the Société de protection des forêts contre le feu (SOPFEU) and the ministère des Ressources naturelles du Québec (MRN), published the first report in 1995. It contained the method used in Québec to classify forest stands according to the Canadian Forest Fire Behavior Prediction (FBP) System. In the second report, published in 1999, the group explained the changes introduced to the proposed classification guidelines.

1. INTRODUCTION

The desire to classify forest stands as forest fuels is not new. Back in 1948, in his fire protection manual *Manuel de protection des forêts contre le feu* the forest engineer, Georges H. Bernier, referred to a classification method proposed by an American forester by the name of L. G. Hornby. This method, based on the fire's rate of spread and its ability to resist fire fighting efforts, already made it possible to characterize certain types of fuels.

In the 1970's, a series of regional guides published in western Canada dealt with forest fire behavior indices. The fires' characteristics were described according to the fuel complexes widely found in that particular part of the country.

In Québec, the Maniwaki technology transfer centre developed a first forest fuel display program in the mid 1980's. The program was primarily based on a summary map prepared in the 1970's by the MRN's forest inventory service. The fuel types found in the Canadian Forest Fire Behavior Prediction (FBP) System were interpreted, then illustrated according to a 5 minute x 5 minute grid (average area of 54 km^2) that is used in Québec.

In 1992, Parks Canada mandated the forest engineering consulting firm of Del Degan, Massé et associés to prepare a fire management plan for the Mauricie National Park, which would take into account the classification of forest stands as forest fuels according to FBP System. This firm therefore established a classification table that took into account FBP System data and that could be applied to the forest stands surveyed during the second ten-year Québec forest inventory program.

In 1994, the seven Québec fire protection agencies, which had been created in 1972, merged to become the Société de protection des forêts contre le feu (SOPFEU). Before this merger, an in-depth reflection process was undertaken on the forest fire fighting methods used and the tools available. As a result, the new agency had to re-examine some of its practices. Among other things, the need to improve the forest fuel map system was expressed. The work, undertaken in March of 1994, was based on that of the firm of Del Degan, Massé et associés two years earlier.

The creators of the FBP System left it up to local forest fire officials to associate the available inventory data with the fuel types described in this system. In 1995, enough information had been compiled to enable the production of a provincial map of forest fuels. The resulting data made it possible to update SOPFEU's *Forest Fire Information System* (FFIS).

In 1995, the forest fuels working group tabled a first report containing the description of the chosen classification method along with recommendations and questions that would subsequently make it possible to improve the method.

As a follow-up to this report, we:

- created a databank with more accurate information, with raster cells of 15 seconds x 15 seconds (average area of 14 ha);
- revised the classification, following certain major fires;
- met with Marty Alexander, one of the creators of the FBP System, who gave us further information on forest fuels;
- used satellite imagery to classify areas that had been burned in the past;
- undertook a study to determine which variables now available in the database would enable us to distinguish between the two broad types of softwoods currently grouped in the fuel type C-2.

This report summarizes the method whereby forest stands are classified as forest fuels.

2. CLASSIFICATION OF FUELS

Considering the types of forests in Québec, three classes of forest fuels were determined:

– **fuels defined** in the FBP System;

– **fuels not defined** in the FBP System and which cannot be associated with those that are, such as burnt-over areas, dry bare areas, cedar bushes, etc.;

– **non-fuels**: this class includes several elements such as water, wet bare areas, farmland, etc.

The classification method takes into account many variables such as stand composition and density, tree height, etc. In the following pages, the area for each of the fuel classes will be given. A map of inventoried forest land will also be included, showing how the land is subdivided according to these same classes. These data are also given as a georeferenced digital file.

3. CANADIAN FOREST FIRE BEHAVIOR PREDICTION (FBP) SYSTEM

All organic materials, living or dead, buried in the forest floor, on the felling area and making up the various strata of stands, are flammable. They form what is called the "fuel complex". It goes without saying that the quantity of fuel, its size, shape, distribution, compactness and moisture content are extremely wide-ranging.

As a result, each fuel complex has its own distinctive characteristics in terms of rate of spread, intensity, height of flames, etc. The fire attack methods must therefore take these characteristics into account. The fuel complexes reflect both the influence of nature and humans since ecosystems are modified by wind, insects and fire and by human presence and activities.

The authors of the Canadian Forest Fire Behavior Prediction System studied the fuel complexes and grouped them into sixteen separate types (see Fire Danger Information Report, number ST-X-3).

> "Fuel type has been defined as an identifiable association of fuel elements of distinctive species, form, size, arrangement, and continuity that will exhibit characteristic fire behavior under defined burning conditions (Merrill and Alexander, 1987). More specifically, a fuel type is a fuel complex of sufficient homogeneity and extending over an area of sufficient size that equilibrium fire behavior can be maintained over a considerable time period." (ST-X-3, p.11)
>
> "Fuel types lacking sound Canadian fire behavior data have been included because of their significance to the Canadian landscape (e.g., boreal mixedwood and grass)." (idem)
>
> "The major distinguishing characteristics of each fuel type are described in more detail below; these will be used to classify fuel types from forest inventory type descriptions." (idem)

The sixteen fuel types are organized into five major groups.

Detailed Descriptions of FBP System Fuel Types

Coniferous Group

Type C-1 (Spruce-Lichen Woodland)

This fuel type is characterized by open, park-like black spruce (*Picea mariana* [Mill.] B.S.P.) stands occupying well-drained uplands in the subarctic zone of western and northern Canada. Jack pine (*Pinus banksiana* Lamb.) and white birch (*Betula papyrifera* Marsh.) are minor associates in the overstory. Forest cover occurs as widely spaced individuals and dense clumps. Tree heights vary considerably but bole branches (live and dead) uniformly extend to the forest floor and layering development is extensive. Woody surface fuel accumulation is very light and scattered. Shrub cover is exceedingly sparse. The ground surface is fully exposed to the sun and covered by a nearly continuous mat of reindeer lichens, averaging 3-4 cm in depth above mineral soil.

Type C-2 (Boreal Spruce)

This fuel type is characterized by pure, moderately well-stocked black spruce stands on lowland (excluding *Sphagnum* bogs) and upland sites. Tree crowns extend to or near the ground and dead branches are typically draped with bearded lichens (*Usnea* sp.). The flaky nature of the bark on the lower portion of stem boles is pronounced. Low to moderate volumes of down woody material are present. Labrador tea (*Ledum groenlandicum* Oeder) is often the major shrub component. The forest floor is dominated by a carpet of feather mosses and/or ground-dwelling lichens (chiefly *Cladonia*). *Sphagnum* mosses may occasionally be present, but they are of little hindrance to surface fire spread. A compacted organic layer commonly exceeds a depth of 20-30 cm.

Type C-3 (Mature Jack or Lodgepole Pine)

This fuel type is characterized by pure, fully stocked (1000-2000 stems/ha) jack pine or lodgepole pine (*P. contorta* Dougl.) stands that have matured at least to the stage of complete crown closure. The base of live crown is well above the ground. Dead surface fuels are light and scattered. Ground cover is feather moss over a moderately deep (approximately 10 cm), compacted organic layer. A sparse conifer understory may be present.

Type C-4 (Immature Jack or Lodgepole Pine)

This fuel type is characterized by pure, dense jack or lodgepole pine stands (10,000–30,000 stems/ha) in which natural thinning mortality results in a large quantity of standing dead stems and dead down woody fuel. Vertical and horizontal fuel continuity is characteristic of this fuel type. Surface fuel loadings are greater than in fuel type C-3 and organic layers are shallower and less compact. Ground cover is mainly needle litter and suspended within a low (*Vaccinium sp.*) shrub layer.

Type C-5 (Red and White Pine)

This fuel type is characterized by mature stands of red (*P. resinosa* Ait.) and eastern white pine (*P. strobus* L.) in various proportions, sometimes with small components of white spruce (*Picea glauca* [Moench] Voss) and old white birch or aspen (*Populus* sp.). The understory is of moderate density, usually red maple (*Acer rubrum* L.) or balsam fir (*Abies balsamea* [L.] Mill.). A shrub layer, usually beaked hazel (*Corylus cornuta* Marsh.), may be present in moderate proportions. The ground surface cover is a combination of herbs and pine litter, the organic layer is usually 5-10 cm deep.

Type C-6 (Conifer Plantation)

This fuel type is characterized by pure conifer plantations, fully stocked with closed crowns and no understory or shrub layer present. The forest floor is covered by needle litter with an underlying duff layer up to 10 cm deep. The rate of spread and crown fire relationships allow for variation in crown base height.

Type C-7 (Ponderosa Pine-Douglas-Fir)

This fuel type is characterized by uneven-aged stands of ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) in various proportions. Western larch (*Larix occidentalis* Nutt.) and lodgepole pine may be significant stand components on some sites and elevations. Stands are open with occasional clumpy thickets of multiaged Douglas-fir and/or larch as a discontinuous

understory. Canopy closure is less than 50% overall, although thickets are closed and often dense. Woody surface fuel accumulations are light and scattered. Except within Douglas-fir thickets, the forest floor is dominated by perennial grasses, herbs, and scattered shrubs. Within tree thickets, needle litter is the predominant surface fuel. Duff layers are nonexistent to shallow (< 3 cm).

Deciduous Group

Type D-1 (Leafless Aspen)

This fuel type is characterized by pure, semimature trembling aspen (*Populus tremuloides* Michx.) stands before bud break in the spring or following leaf fall and curing of the lesser vegetation in the autumn. A conifer understory is noticeably absent, but a well-developed medium to tall shrub layer is typically present. Dead and down roundwood fuels are a minor component of the fuel complex. The principal fire-carrying surface fuel consists chiefly of deciduous leaf litter and cured herbaceous material that are directly exposed to wind and solar radiation. In the spring the duff mantle (F and H horizons) seldom contributes to the available combustion fuel due to its high moisture content.

Mixedwood Group

Types M-1 (Boreal Mixedwood-Leafless) and M-2 (Boreal Mixedwood-Green)

These fuel types are characterized by stand mixtures consisting of the following coniferous and deciduous tree species in varying proportions: black spruce, white spruce, balsam fir, subalpine fir (*Abies lasiocarpa* [Hook] Nutt.), trembling aspen, and white birch. On any specific site, individual species can be present or absent from the mixture. In addition to the diversity in species composition, stand mixtures exhibit wide variability in stand structure and development, but are generally confined to moderately well-drained upland sites. Two phases associated with the seasonal variation in the flammability of the boreal mixedwood forest are recognized: the leafless stage occurring during the spring and fall (fuel type M-1) and the green stage (fuel type M-2). Rate of spread in both fuel types is weighted according to the proportion (expressed as a percentage) of softwood and hardwood components. In the summer, when the deciduous overstory and understory are in leaf, fire spread is greatly reduced with maximum spread rates only one-fifth that of spring or fall fires under similar burning conditions.

Types M-3 (Dead Balsam Fir Mixedwood Leafless) and M-4 (Dead Balsam Fir Mixedwood-Green)

These fuel types are characterized by mixedwood stands in which balsam fir grows, often as an understory species, in a heterogeneous mix with spruce, pine, and birch. These stands are found in the Great Lakes-St. Lawrence and Boreal Forest regions of Canada, and are not to be confused with the pure balsam fir stands typical of Nova Scotia and New Brunswick. Repeated annual defoliation (due to spruce budworm attack) causes balsam fir mortality, followed by peeling bark, draped lichen (Spanish moss or old man's beard, *Usnea* sp.) development, top breakage, and windthrow, peaking 5-8 years after mortality. The volume of down woody material is initially low, but increases substantially with progressive stand decomposition following mortality. The forest floor is a mixture of feather mosses, conifer needles, and hardwood leaves. The organic layer is moderately compacted and 8-10 cm deep.

After mortality, spring fires in this fuel type behave extremely vigorously with continuous crowning and downwind spotting, while summer fires are hampered by the proliferation of green understory vegetation resulting from the opening of stand canopy. As sufficient surface fuel accumulates through stand decomposition (usually after 4-5 years) during summer, fires will spread through the fuel complex, although not as vigorously as in spring. Forest fire behavior potential is greatest 5-8 years after mortality, decreasing gradually as the surface fuels decompose and the understory vegetation continues to proliferate.

Slash Group

Type S-1 (Jack or Lodgepole Pine Slash)

This fuel type is characterized by slash resulting from tractor or skidder clearcut logging of mature jack or lodgepole pine stands. The slash is typically one or two seasons old, retaining up to 50% of the foliage, particularly on branches closest to the ground. No post-logging treatment has been applied and slash fuels are continuous. Tops and branches left on site result in moderate fuel loads and depths. Ground cover is continuous feather moss mixed with discontinuous fallen needle litter. Organic layers are moderately deep and fairly compact.

Type S-2 (White Spruce-Balsam Slash)

This fuel type is characterized by slash resulting from tractor or skidder clearcut logging of mature to overmature stands of white spruce and subalpine fir or balsam fir. Slash is typically one to two seasons old, retaining from 10% to 50% of the foliage on the branches. No postlogging treatment has been applied. Fuel continuity may be broken by skid trails unless winter logged. Tops have been left on site and most branch fuels have broken off during skidding of logs to landings, resulting in moderate fuel loads and depths. Quantities of shattered large and rotten woody fuels may be significant. Ground cover is feather moss with considerable needle litter fallen from the slash. Organic layers are moderately deep and compact.

Type S-3 (Coastal Cedar-Hemlock-Douglas-Fir Slash)

This fuel type is characterized by slash resulting from high-lead clearcut logging of mature to overmature coastal British Columbia mixed confier stands. Predominant species are western red cedar (Thuya plicata Donn.), western hemlock (T. heterophylla [Raf.] Sarg.) and Douglas-fir. Slash is typically one season old, with the cedar component retaining all its foliage in a cured condition on the branches, while the hemlock and Douglas-fir components will have dropped up to 50% of their foliage. Slash fuels tend to be continuous and uncompacted. Very large loadings of broken and rotten unmerchantable material may be present, depending on degree of stand decadence. Slash fuel depths may range from 0.5 to 2.0 m. Ground cover may be feather moss or just compact old needle litter under significant quantities of recent needle litter fallen from the slash. Organic layers are moderately deep to deep and compact. Minor to moderate shrub and herbaceous understory components may be present. This fuel type may also be applied to wet belt decadent cedar-hemlock slash of coastal and interior British Columbia where the Douglas-fir component is absent.

Open Group

Type O-1 (Grass)

This fuel type is characterized by continuous grass cover, with no more than occasional trees or shrub clumps that do not appreciably affect fire behavior. Two subtypes are available for grasslands; one for the matted grass condition common after snowmelt or in the spring (O-1a), and the other for standing dead grass common in late summer to early fall (O-1b). The proportion of cured or dead material in grasslands has a pronounced effect on fire spread there and must be estimated with care.

(Fuel type descriptions are those found in the Information Report ST-X-3, pp. 11 and 14-16)

NOTE: In the case of fuel types associated with boreal mixedwood (M-1 and M-2), a number expressing the percentage of softwoods contained in the stands was included (e.g., M-1/70, 70% of softwoods). In the case of stands with M-3 and M-4 fuel types, this number corresponds to the percentage of softwoods that died following an insect epidemic (e.g., M-3/75, 75% of softwoods died).

4. AVAILABLE FOREST DATA

The way the forest data are collected is relatively unimportant. It is however important that these data be georeferenced. This is why a choice had to be made among the following three data acquisition methods when we started classifying the forest fuels according to the FBP System.

- **Satellite Imagery**

  Advantages: very precise view of the land and yearly updates.

  Disadvantages: difficulty in distinguishing fuel types and consistently obtaining quality images, delays in image processing and difficulty in obtaining similar results from one year to the next.

  Identification: according to the dominant stand.

- **Digital Forest Maps**

  Advantages: highly accurate outlines.

  Disadvantages: expensive, high number of vectors (unwieldy system on a wide scale) and unavailable.

  Identification: according to the centroid (central element of the polygon considered).

- **Raster Data Structure (Tessellation)**

  Advantages: low number of vectors, simple graphic representation and same grid as that of the FFIS.

  Disadvantages: manual data entry, delay caused by its dependency on the inventory system (updating of cuts and other disturbances), data sometimes outdated since taken from the map resulting from the second inventory program (1979-1990).

  Identification: according to the centroid of the raster cell.

  All things considered, the raster system appeared to be the best choice. We therefore opted for the raster data system called the **S**ystème d'**I**nformation **FOR**estière par **T**esselles (SIFORT), which is used by the MRN, SOPFEU and the Société de protection des forêts contre les insectes et maladies (forest insect pest control agency). The forest fuels were therefore classified according to raster cells of 15 seconds by 15 seconds, each cell representing an area of approximately 14 hectares.

SIFORT (Raster-Based Forest Information System)

The data from the second ten-year forest inventory are currently entered into SIFORT. A complete description of the inventory method used is found in the *Normes d'inventaire forestier* (forest inventory standards), published in 1984.

Geobase

In SIFORT, forest land is divided into a mosaic of polygons created mathematically. The creators of the system, inspired by a fire positioning method, subdivided Québec according to a grid where each square represents 15 minutes in latitude by 15 minutes in longitude. The numbering, which starts at the south-western limit of the province, goes toward the east and the north.

The basic grid is itself subdivided into nine equal zones of 5 minutes by 5 minutes. Each of these is again divided into 16 equal zones of 1 minute 15 seconds by 1 minute 15 seconds, and then divided into 25 cells of 15 seconds by 15 seconds.

The SIFORT system can be compared to Russian dolls: the smallest unit is the common denominator of the other units into which it can fit (Figure 1). The raster cells in SIFORT are saved in a file where the data are grouped according to 1/50 000-scale maps, ASCII format, and expressed as longitude and latitude.

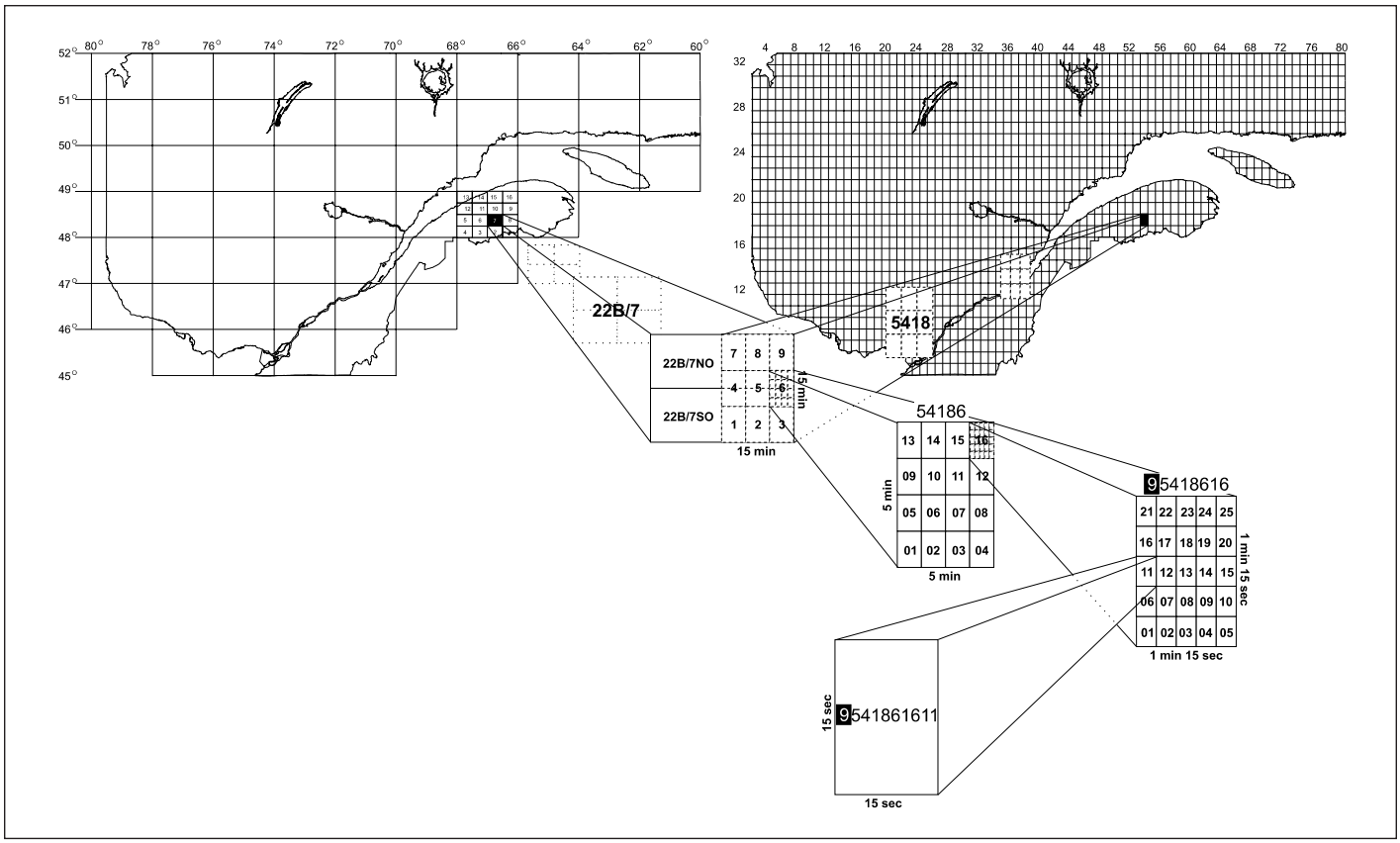


Figure 1: Québec subdivided according to the SIFORT system

FOREST INVENTORY DATA

The data entered into SIFORT come from the second ten-year forest inventory program, which can be described as a forest development or exploration inventory. The information entered into the database comes from two separate processes, albeit closely linked: photo interpretation and compilation of field survey results.

Photo interpretation makes it possible to draw the outlines and determine the composition of the forest stands seen on aerial photos. These data are transferred onto base maps that contain the boundaries of regions, municipalities and other territorial divisions. The result is planimetric base maps.

During the field surveys, measurements are taken in sample plots and along cruise lines. This operation makes it possible to determine the species that compose the stands and to collect all required mensuration data regarding the forest strata. These data are therefore used to calculate, among other things, the number of stems in each of the diameter classes, their basal area and the available volumes, both for merchantable and non-merchantable species. The stock tables are also established with these data.

In this report, all land in Québec has been classified, including productive and unproductive forest land as well as non-forest land.

5. PROJECT METHODOLOGY AND PROGRESS

The Canadian Forest Fire Behavior Prediction System and the raster cell system (SIFORT) are the two basic tools used for classifying forest stands in Québec according to fuel types.

The project included the following steps:

1. Acquisition of forest inventory data entered into SIFORT;
2. Development of guidelines for a preliminary classification (use of variables chosen by the forest inventory service);
3. Validation of classification guidelines;
   - selection of flyover zones;
   - classification of stands in selected zones;
   - selection of stands whose classification will be validated;
   - flyover of the selected zones;
   - verification of classification results through field trips;
   - compilation of results;
4. Modification of classification guidelines;
5. Application of the classification method throughout Québec.

About Validation

When a classification method is developed, it is always important to ensure that the results obtained using established rules conform with the actual conditions in the field. Should this not be the case, the method must be revised, at least in part.

We decided to validate our results from the air, since it is the technique that most resembles aerial photography (vertical view of stands and fuel characteristics). We also felt is was important to visit the stands that were flown over to confirm the fuel type recorded. During these field trips, the structure of the forest cover was examined and the herbaceous, shrub and tree strata composition was determined. Finally, photos were taken on the ground and in the air to confirm the composition of the forest stands and the fuel types observed.

To optimize the classification, we looked at several management units that overlap more than one ecological region. This enabled us to test the method and see how reliable it was before applying it to all of Québec. Since 1994, yearly flyovers are carried out to improve the classification of forest fuels.

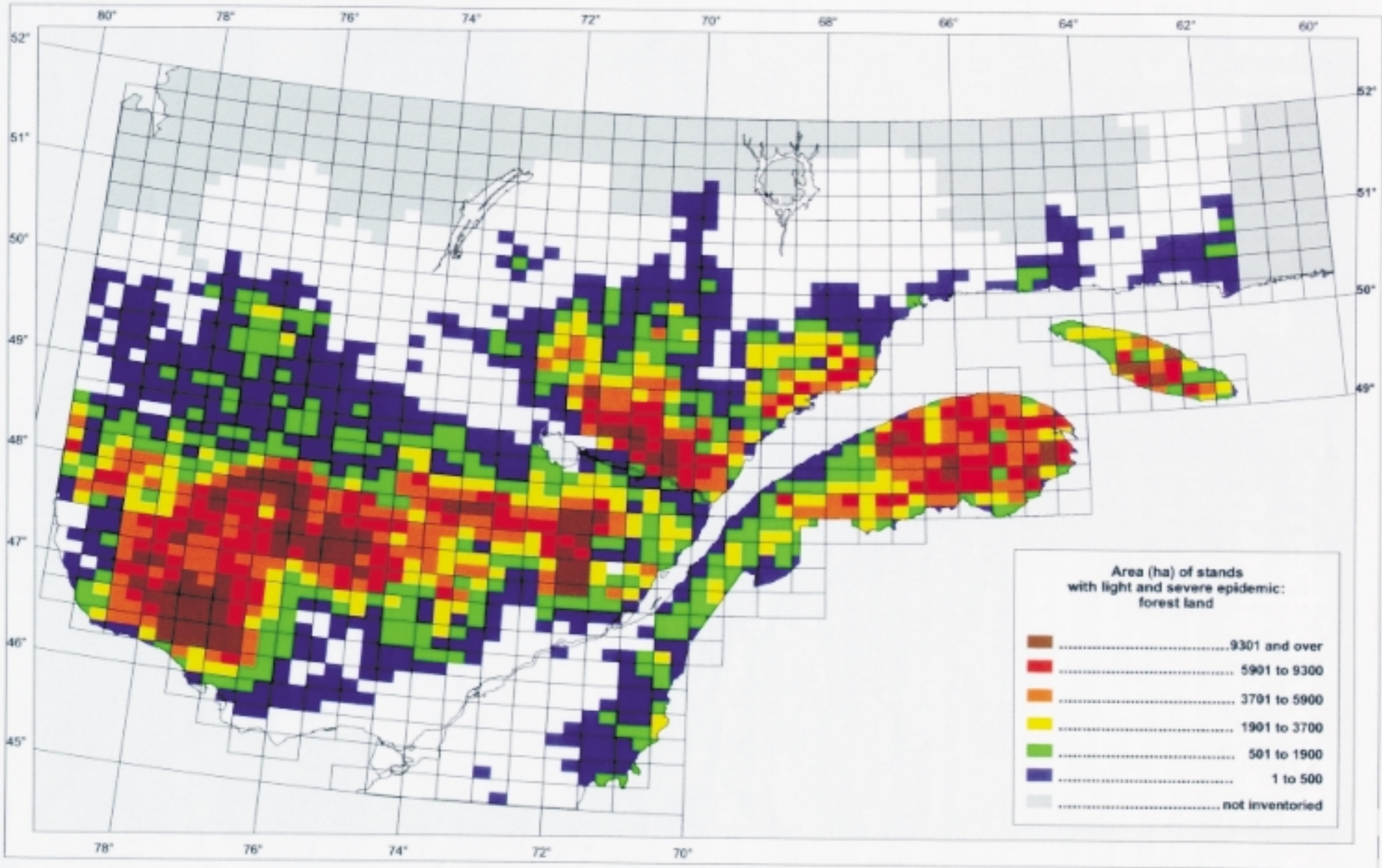


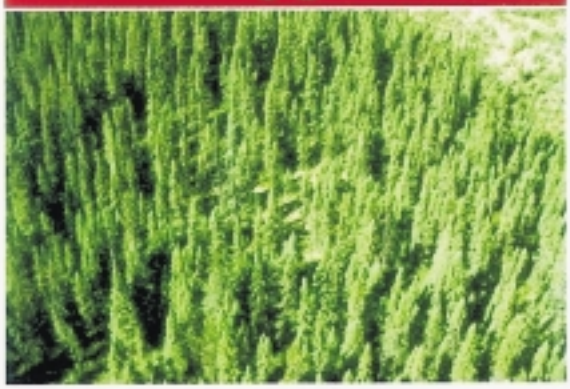
Figure 2. Territory affected by an epidemic

TYPES OF FOREST FUELS

AERIAL VIEW

GROUND VIEW

C-2



C-2

C-3

C-3

C-5

C-5

TYPES OF FOREST FUELS

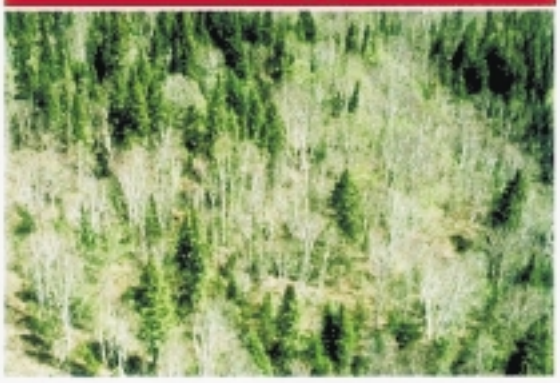
AERIAL VIEW

GROUND VIEW

S-2

S-2

M-1/35



M-1/35

BR

BR

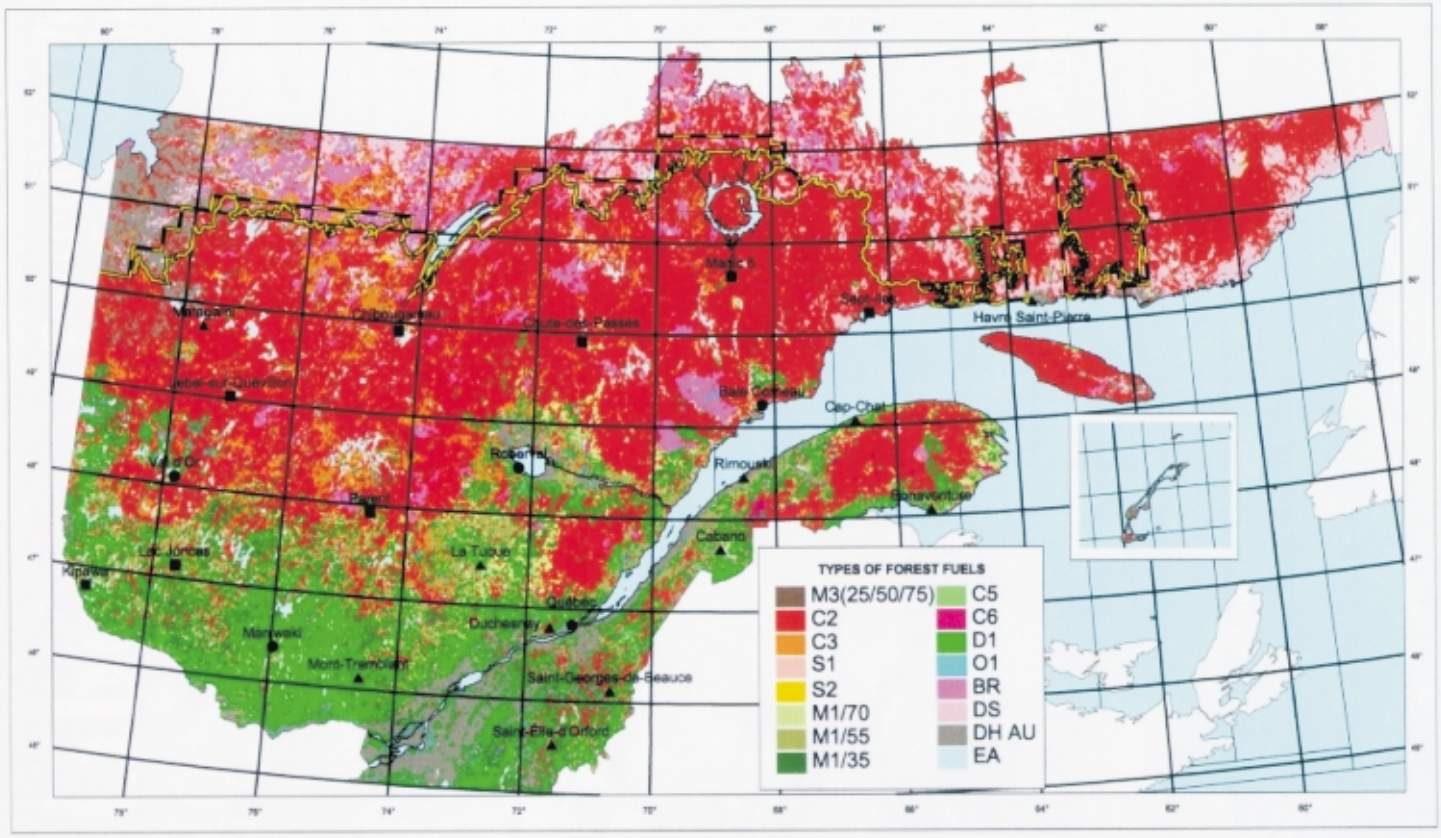


Figure 3. Forest fuels in Québec (2001)

6. CLASSIFICATION GUIDELINES

First it was decided to base our classification on the forest stratification established by photo interpreters (groups and subgroups of species, density classes, height classes, age classes, disturbances, origins and types of terrain, etc.). For even more accurate results, stand tables and the division of the area into ecological regions[1] were also taken into account.

To better classify some of the fuel types, certain additional variables were defined, such as the **ratio of softwoods** (number of stems of softwoods compared to the total number of stems), **mortality** (corresponding to the number of years that have gone by since an insect epidemic destroyed a stand) and the **age** (number of years or the period of time since the last disturbance other than an insect infestation).

It is worth noting that 10 to 20 years are required for the inventory data to be updated and that stands change considerably during this time. To take into account this change, the notion of evolution in the fuel types was introduced for classification purposes.

6.1 Detailed Descriptions of the FBP System Fuel Classes

Grass (O-1)

This class comprises two types of forest strata:

– strata without cover, for which the year of the original disturbance is known;

– wildland that is not dense enough to be classified.

The second forest inventory does not take into account ground vegetation, but validations in the field make it possible to associate it with certain species groups.

Slash Group (S-1 or S-2)

This fuel type is particularly widespread in Québec because of the logging methods used. For classification purposes, the following elements must be specified:

– type of intervention,

– stand composition before the intervention,

– year of the intervention,

– ecological region where the stand grows.

When a stand is greatly disturbed or is the result of a "disturbance of origin," the initial composition must be determined so it can be properly classified. In addition, the year in which the disturbance occurred (reference year) is also taken into account so the probable progression of the stand (i.e. fuel), which depends on the ecological region, can be estimated.

In recent years, forest companies have been practising the "cutting with regeneration and soil protection" method, especially in softwood stands. However, after such a cut, the remaining stand is very open. On-site visits have led us to classify these types of areas as type C-2, not only because of the opening, but also because of the fuel left behind.

Mortality (M-3/M-4)

Some insects, notably the spruce budworm, cause their hosts, and sometimes even entire stands, to die (Figure 2). When these stands are classified in terms of forest fuel, the mortality rate must be taken into account. This rate depends on the percentage of basal area made up of dead trees, the year of the disturbance and, in some cases, the ecological region in question.

In Québec, there are two categories of epidemics: severe epidemics and mild epidemics. During a severe epidemic, where more than 75% of the stand's basal area is

1. THIBAULT, M. *Les régions écologiques du Québec méridional*. Colour map – scale 1:1 250 000. Québec, ministère de l'Énergie et des Ressources, Service de la recherche forestière and Service de la cartographie, 1987.

destroyed, the disturbance is said to be "of origin" since it causes the formation of a new stand. If the basal area is reduced only by 25% to 75%, the epidemic is deemed to be mild.

The year of the disturbance is generally known and recorded in the database. Should the year be unknown, it is possible to consult the database on the recurrence of insect epidemics in archives kept by the MRN since 1938. The reference year chosen is determined by the mortality rate observed, which itself depends on the severity of the infestation and its duration.

Deciduous (D-1)

During the summer, the occurrence of fire in deciduous stands is rare. However, in the spring and fall, the leaves on the ground are flammable.

Mixedwood (M-1/M-2)

A stand is said to be mixed when it contains between 25% and 75% of softwoods. The classification of this type of stand as forest fuels must take into account subgroups of species, the percentage of softwood trees found in the stand and the ecological region.

It is the photo interpreter's responsibility to determine if the subgroups of species contained in mixed stands are predominantly softwood or deciduous. For instance, it is the photo interpreter who specifies if a white birch stand is dominated or not by softwoods. In terms of forest fuels, all mixed stands are classified as M-1. However, the class is followed by the number 35, 55 or 70, depending on the proportion of softwoods in the stand.

To classify young mixed stands whose composition is unknown, the ecological region in which they are established is taken into account.

Jack Pine Stands (C-3)

These stands are generally fairly homogenous. After having flown over several of these stands, we classified all stands containing jack pine and which have a structure similar to that of a jack pine stand in the C-3 category.

White or Red Pine Stands (C-5)

Like white or red pine stands, hemlock stands are grouped into a same fuel class.

Softwood Plantations (C-6)

In terms of fire behavior, plantations must be separated into two separate groups: jack pine plantations and the other plantations. In addition, plantation age and height must be taken into account for classification purposes.

The classification of jack pine plantations has already been validated. As for plantations of other species, they are currently classified according to their age: those under 8 years old are included in the O-1 fuel type, the others in the C-6 fuel type. This is based on the data published in *Performances des plantations établies dans les forêts publiques du Québec* (plantation performance in Québec's public forests) and our experience in differentiating such stands. It appears however that this classification criterion needs to be improved.

Boreal Spruce Stands (C-2)

Several types of stands are associated with this forest fuel type as defined in the FBP System:

- stand in the regeneration stage (cover currently unknown, which was composed of softwoods prior to the disturbance);
- softwood stand (several softwood species, without any predominating);
- black spruce stand;
- fir stand;
- softwood stand with unidentified species.

If the origin, species group, density, height and age of softwood stands are taken into account, some 28% of them belong to the C-2 class. By default, spruce stands, fir stands and softwood stands containing more than two species of softwoods are included in this same C-2 class. It would be important to develop new classification guidelines to better reflect the actual composition of Québec forests.

6.2 Fuel Types Not Defined in the FBP System

Areas Devastated by Fire and Not Regenerated (BR*)

Even after having visited several areas devastated by fire (surface or crown-type) fairly recently, we were not able to associate them with any of the fuel type classes of the FBP System. There was no choice but to include these areas in the "non-defined" class.

Satellite imagery was used to determine the classification of defined and non-defined fuel types in areas that were burnt-over at least ten years ago and of at least 112 hectares, which correspond to 8 raster cells of 15 seconds by 15 seconds.

** In French: brûlis*

Dry Bare Land (DS*)

As its name suggests, "dry bare land" is forest land characterized by the dryness of its ground. This land is considered unproductive since merchantable species are very rare and logging unprofitable. Plant species that grow on dry bare land can easily burn. However, in Québec, it is not possible to associate DS-type land to black spruce stands with lichens as defined in the Canadian FBP System. It is worth noting that most of these sites are found on cliffs, hilltops and flats which had previously been devastated by fire.

Power lines, cedar stands and larch stands are also associated to DS, even if fire in these areas has a specific type of behavior.

** In French: dénudé sec*

6.3 Non-Fuel Types

Wet Bare Land (DH*)

Land that is bare and wet is considered unproductive forest since it produces less than 30 m^3 of wood per hectare over a period of 120 years. Since it cannot be included in one of the FBP System fuel types, it was classified as a non-fuel type. The decision can be justified by the high moisture content of the sites in question.

** In French: dénudé humide*

Other Land (AU*)

All non-forest land was grouped together in the AU class, reserved for non-fuels. This type of land is used for purposes other than wood production. It includes:

- farmland;
- campgrounds;
- ski centres;
- roads.

** In French: autre*

Lakes and Rivers (EA*)

Lakes and rivers obviously do not burn. However, they must be classified like any other element that appears on a forest map.

** In French: eau*

7. FUEL CLASSIFICATION TABLE

The classification table used (2001) is subject to change since we must continually modify certain classification guidelines to take into account validations carried out in the field. The flexibility of this tool also allows for improvement on an ongoing basis. In the following tables, the M-2 and M-4 fuel types are not considered, for simplicity purposes.

Table 1. Fuel classification diagram

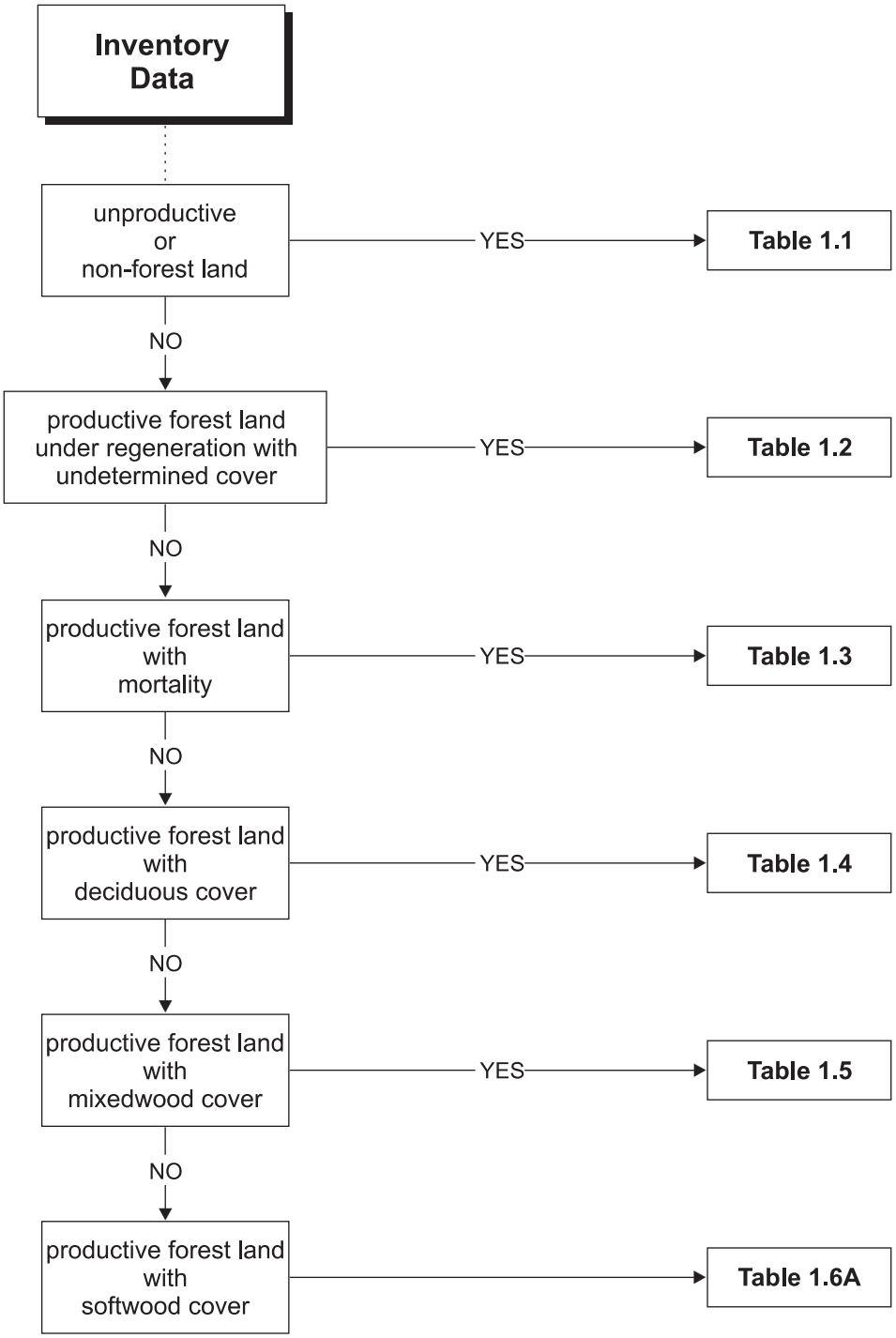


Table 1.1 Unproductive or non-forest land

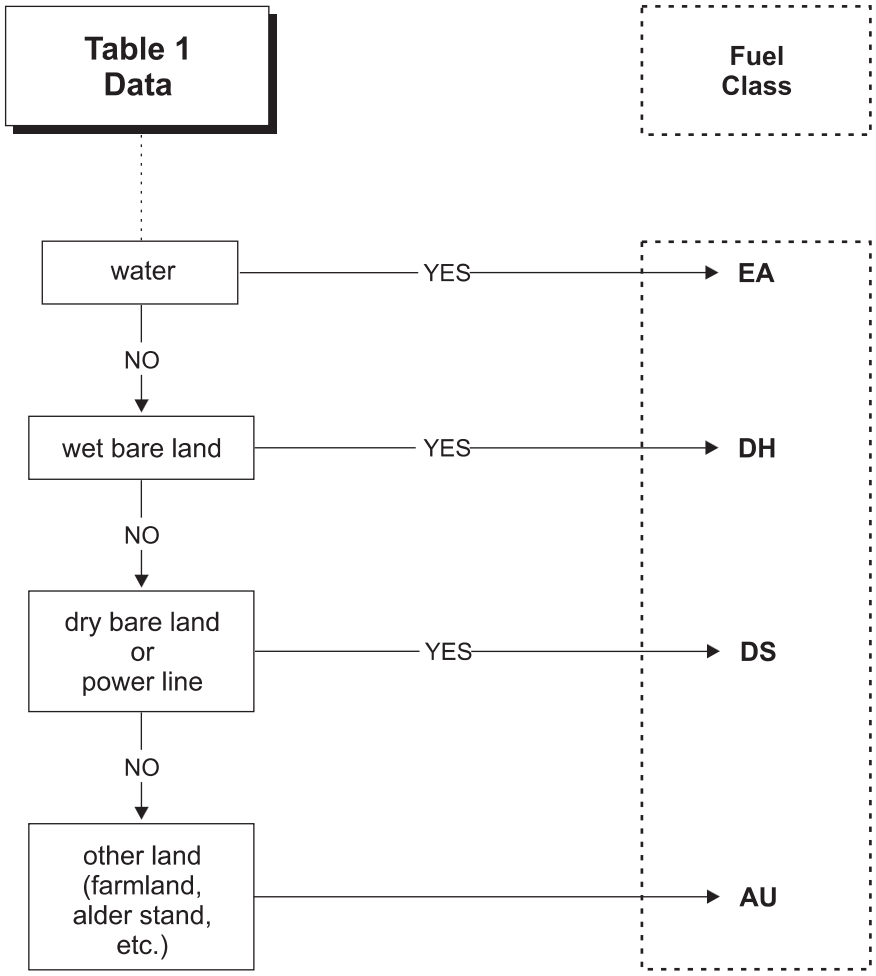
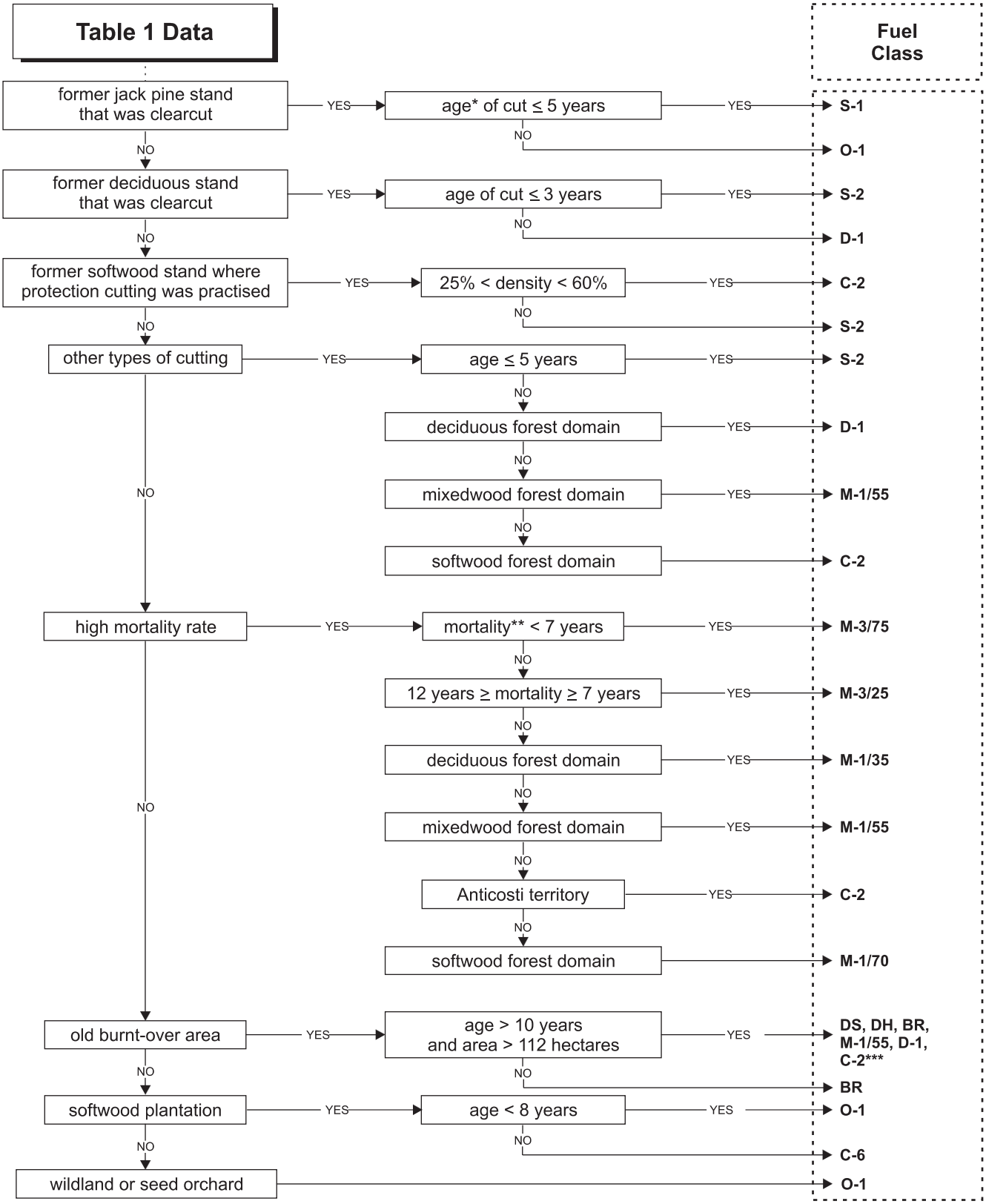


Table 1.2 Productive forest land under regeneration with undetermined cover



* age: number of years or period passed since the last disturbance other than an insect infestation
** mortality: number of years passed since an insect epidemic devastated tree stands.
*** This classification does not follow normal guidelines; it stems from satellite images.

Table 1.3 Productive forest land with mortality

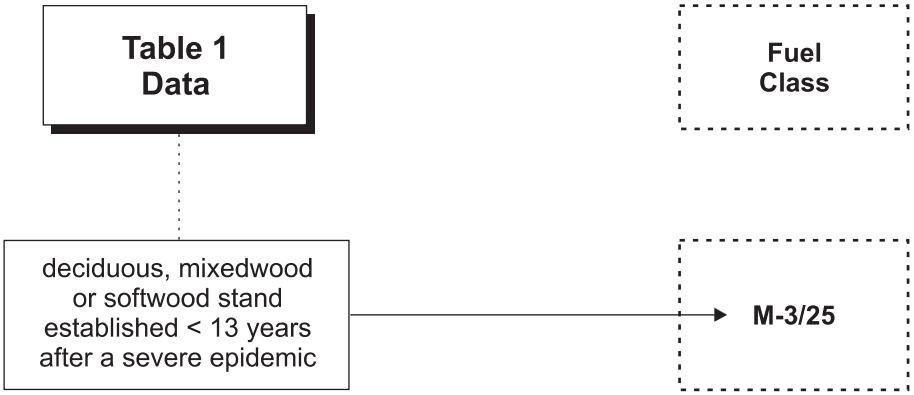
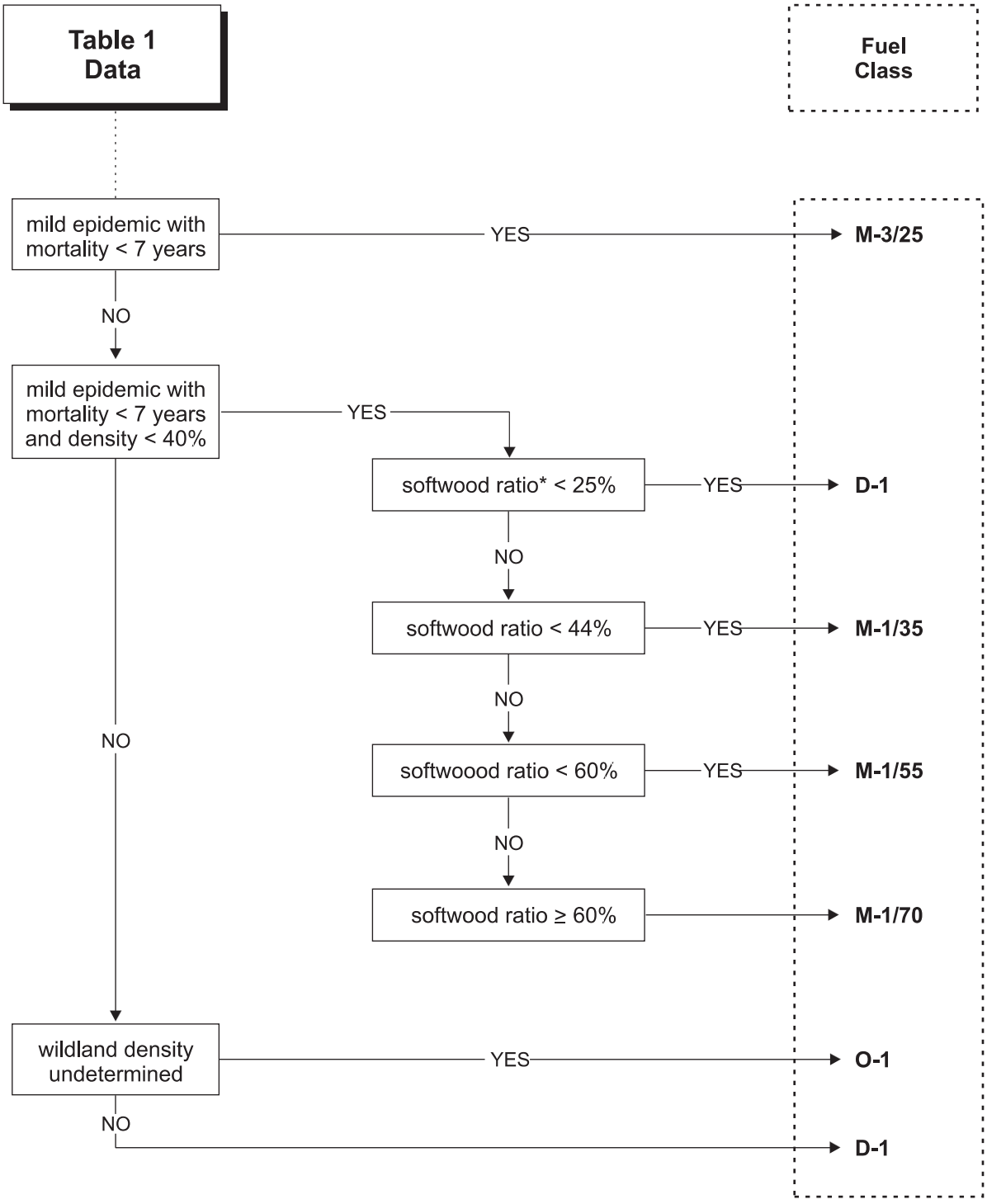


Table 1.4 Productive forest land with deciduous cover



* softwood ratio: number of softwood stems in relation to the total number of stems.

Table 1.5 Productive forest land with mixedwood cover

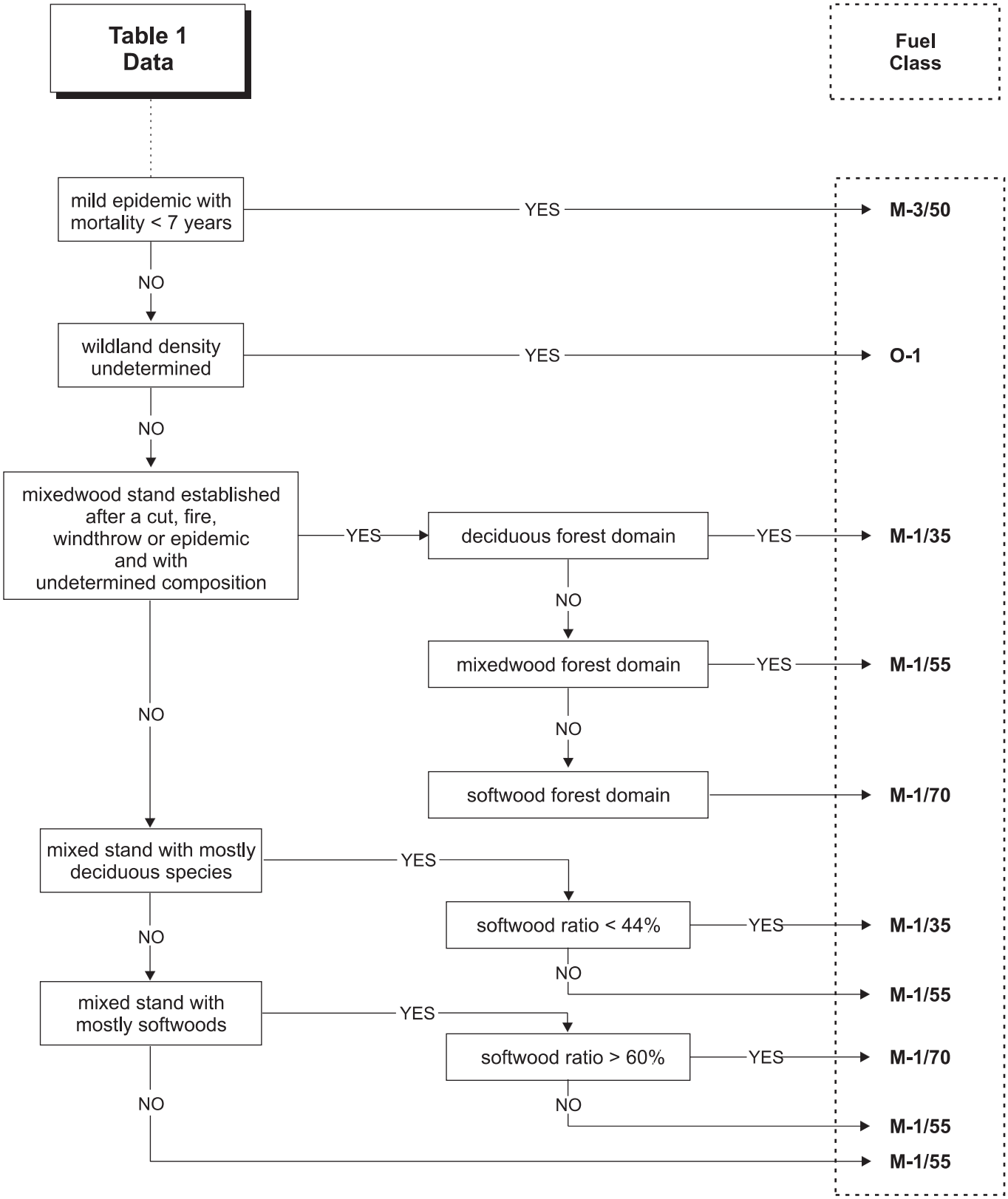


Table 1.6A Productive forest land with softwood cover

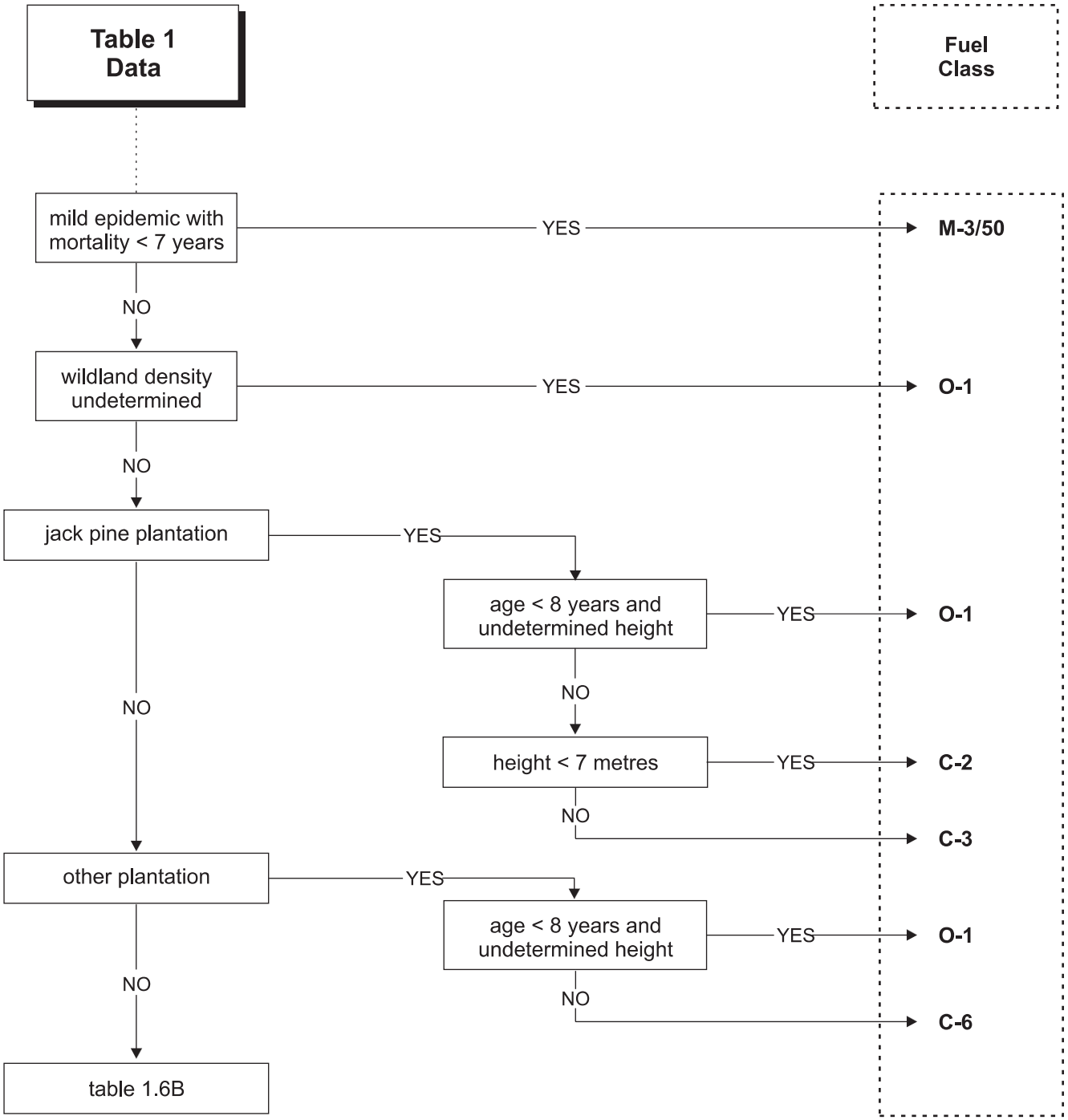
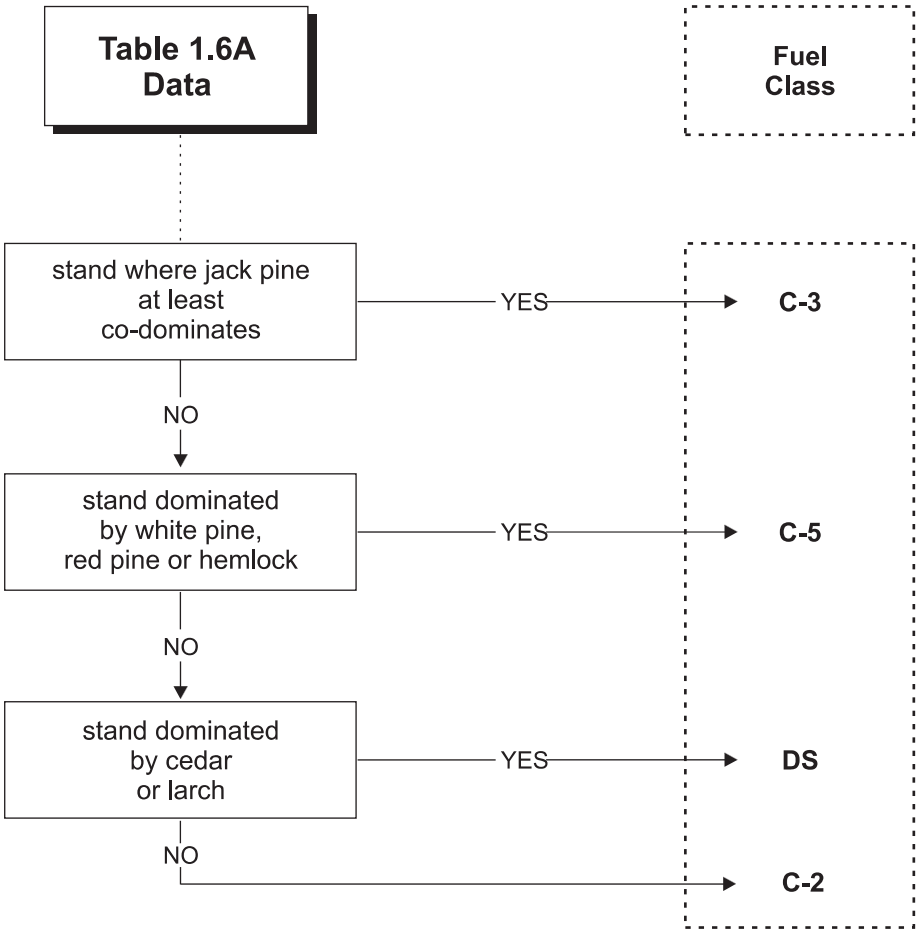


Table 1.6B Productive forest land with softwood cover



8. RESULTS AND STATISTICS

The classification of stands makes it possible to show the types of forest fuels found throughout the province. This fuel distribution could however be modified by human-caused or natural disturbances: logging operations, plantation, burnt-over areas, windthrow, etc. The updating of the forestry database has been temporarily interrupted to enable an eco-forest inventory system to be implemented. The portrait presented however takes into account recent disturbances caused by major fires and insect epidemics.

Figure 3 and Table 2 summarize the results for all of Québec.

Table 2: Areas with forest fuel classes in Québec in 2001

FUEL CLASS	NUMBER OF RASTER CELLS	AREA (hectares)
Fuels Defined in the FBP System		
C-2	2 011 128	27 752 826
D-1	462 793	6 755 079
M-1/55	395 998	5 718 675
M-1/70	243 562	3 467 802
C-3	197 870	2 747 936
M-1/35	113 936	1 665 599
O-1	58 358	847 207
C-6	32 558	467 826
S-2	13 179	184 666
C-5	8 089	119 661
M-3/25	3 443	49 021
M-3/50	3 401	46 375
S-1	1 783	25 348
M-3/75	470	6 421
Sub-total	**3 546 568**	**49 854 442**
Fuels Not Defined in the FBP System		
DS	463 587	6 269 694
BR	211 830	2 868 753
Sub-total	**675 417**	**9 138 447**
Non-Fuels		
EA	499 253	6 922 466
DH	445 807	6 131 387
AU	260 391	3 813 184
Sub-total	**1 205 451**	**16 867 037**
TOTAL	**5 427 436**	**75 859 926**

9. CONCLUSION

Since 1994, the field of fuel classification has progressed considerably in Québec. More than 90% of stands have been validated and classified according to established guidelines. The C-2 fuel type is the most complex because of the wide range of stands it encompasses and the large areas involved. Because of the FBP System's limitations, there is no choice but to include 38% of the stands that grow in Québec in this fuel class.

Over the years, we have collected a series of photos, aerial and ground, that show the various fuel types found in Québec. These photos are valuable pedagogical tools and are used for educational purposes.

SIFORT is the system currently used as a reference point. However, this system will be extended when the data from the third inventory program, soon to be completed, is added. It will then be possible to improve forest fuel classification, since this newest inventory will contain a major ecological component and take into account, among other things, the moisture regime, the type of deposit and the lichens present.

The classification method presented in this document is a work in progress. We are always on the lookout for new data to help further define or modify the choices involved so as to improve the classification of forest stands as forest fuels.

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