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Stand and landscape level applications of a forest ecosystem classification for northwestern Ontario, Canada

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Summary — Forest site classifications are used for a variety of resource planning and management objectives and as frameworks to address issues of biodiversity and sustainable development. The Northwestern Ontario Forest Ecosystem Classification (NWO FEC) is an ecologically based forest site classification system for northwestern Ontario, Canada. This article provides examples which show how the NWO FEC system has been applied for the purposes of ecological description at both the stand (*eg* 10 ha size) and landscape (*eg* 1:20 000 mapping scale) levels. At a stand level, the NWO FEC can be used to examine species autecologies, soil moisture requirements and wildlife habitat preferences. At a landscape level, the NWO FEC system is employed to construct landform toposequences, correlate interpreted climatic features with forest humus forms and develop spatial models of ecosystem processes. In the future, classification systems such as the NWO FEC will be used for advanced simulation modelling problems at various spatial scales.

boreal forest / Ontario / forest site classification / ecosystem modelling

Résumé — Applications d'une classification des écosystèmes forestiers au niveau du peuplement et de l'unité de paysage dans le nord-ouest de l'Ontario, Canada. *Les classifications des stations forestières sont des outils utilisés pour atteindre divers objectifs d'aménagement et de planification des ressources et servent de cadre pour aborder les questions de biodiversité et de développement durable. La classification des écosystèmes forestiers du nord-ouest de l'Ontario (NWO FEC) est un système de classification écologique des stations forestières utilisé dans le nord-ouest de l'Ontario, au Canada. Ce document présente des exemples illustrant comment le système de classification NWO FEC a servi à décrire les caractéristiques écologiques au niveau d'un peuplement (p ex, sur une superficie de 10 hectares) ou d'une unité de paysage (p ex, échelle cartographique de 1:20 000). Au niveau du peuplement, ce système permet d'étudier les relations des espèces avec leur milieu (autoécologie), les besoins en eau du sol et les préférences de la faune en matière d'habitat. Au* *niveau de l'unité de paysage, il sert à reconstituer les toposéquences des formes de relief, à corréler les caractéristiques climatiques décodées avec les formes d'humus du sol forestier et à élaborer des modèles spatiaux des processus écosystémiques. Les systèmes de classification comme le NWO FEC serviront à l'avenir à des simulations élaborées et permettront de modéliser des problèmes à diverses échelles spatiales.*

forêt boréale / Ontario / classification des stations forestières / modélisation des écosystèmes

INTRODUCTION

Some fundamental considerations in evaluating the land's potential response to management and resource production capability are 1) the nature of the land's biological and physical components and 2) the combination or integration of these components to represent ecological units (Hills, 1961; Rowe and Sheard, 1981; Jones, 1993). Forest site classification systems provide a framework for the organization of and communication of ecologically based information. By way of this structure, future responses of resource management activities may be anticipated or predicted, given the expectation that ecologically similar conditions will respond in similar ways to given sets of perturbations or effects (Bailey, 1985; Burger and Pierpoint, 1990). A precondition to addressing complex issues such as sustainable development and biodiversity conservation is the ability to identify, understand and delineate those ecological units which constitute the landscape. This may seem a trivial step, but presently it is a severe constraint to the process of bringing these concepts into some valid and usable form for resource applications and planning.

Ecosystem units (*ie* individual forest sites defined according to some combination of vegetation, soils, site and local climate, or some spatially contiguous aggregation of such forest sites) can be recognized at a range of scales; typically 1 set of ecosystem units is nested within others in a hierarchy of spatial scales (Bailey, 1985, 1987). The relationships among scales are such that one must be able to recognize and understand the aggregations upward and the subdivisions downward in the hierarchy in order to make informed decisions about ecosystem units at any given scale. Scale also implies a certain level of perceived detail (Hills and Pierpoint, 1960; Rowe and Sheard, 1981; Bailey, 1985). Ecological features and processes of primary significance at one scale are supplanted at other scales by different dominant features and processes.

There are various approaches devised to present land cover features within an hierarchical ecological framework. In Canada, a commonly accepted stratification is the Canada Committee on Ecological Land Classification's (CCELC) hierarchical ecological classification system which was originally devised during the early 1980s (Wiken *et al*, 1981). The CCELC system (table I) continues to provide a uniform nation-wide standard. Conditions described here are associated with the microscale levels (ecoelements, ecosites) of the CCELC stratification.

At the stand level (*eg* 10 ha size, CCELC ecoelements), quantitative, site-based environmental information can be used to classify and characterize forest lands in considerable detail. Variations due to slope, vegetational effects, site nutrient status, soil features (especially surficial landform patterns, bedrock controls, soil texture, drainage or moisture regime) may have major influences on the pattern and distribution of ecosystem units. In combination, these features serve to modify and affect the local climatic regimes and, hence, vegetation growing conditions. At the landscape level (*eg* 1:20 000 scale,

Table I. The Canada Committee on Ecological Land Classification's (CCELC) system for the hierarchical description and mapping of ecosystem units in Canada.

General level of resolution	*CCELC unit*	*Scale range*	*Primary controlling features*
Microscale			
Stand level	Ecoelement	< 1:10 K	Local relief, soil type,
Landscape level	Ecosite	1:10 K – 1:50 K	vegetation, elevation, *etc*
Mesoscale	Ecosections	1:50 K – 1:250 K	Landform patterns,
	Ecodistricts	1:125 K – 1:500 K	physiography, *etc*
Macroscale	Ecoregions	1:1 M – 1:3 M	Zonal climate, broad
	Ecozones	1:3 M+	geology, physiography

Modified from Wickware and Rubec, 1989.

CCELC ecosites), site classifications can provide the bases for detailed applications and planning, especially when spatial modelling techniques, using geographic information systems (GIS) and other technologies, are used in conjunction with the field-oriented classifications.

The science of forest site classification is changing rapidly. It is being aided by a number of new analytical approaches and technologies that can help us to effectively deal with increasingly complex ground-based and spatial data bases. This article provides a number of examples of how Northwestern Ontario's Forest Ecosystem Classification (NWO FEC; Sims *et al,* 1989) system has been recently applied, primarily in a research sense, for the purposes of ecological description at both the stand and landscape level.

MATERIALS AND METHODS

The northwestern Ontario study area

The NWO FEC study area extends throughout the range of commercial forest in northwestern (NW) Ontario, Canada (fig 1). Approximately 184 000 km^2 in area, it extends from the northeastern corner of Lake Superior in the east to the Ontario-Manitoba border in the west, and from the Ontario-US border in the south to just north of the physiographic limit of the Canadian Precambrian Shield. With the exception of a zone of strongly broken topography along the Lake Superior coast, the area is dominated by undulating, bedrock-dominated terrain. Surficial landforms and current drainage features strongly reflect the effects of 4 major glaciations (Zoltai, 1965, 1967; Sims and Baldwin, 1991), the last of which ended approximately 10 000 years BP.

The forests of the study area are predominantly within the Boreal Forest Region (Rowe, 1972) of Canada. In NW Ontario, these include pure or mixed stands of jack pine (*Pinus banksiana* Lamb), trembling aspen (*Populus tremuloides* Michx), white birch (*Betula papyrifera* Marsh), balsam fir (*Abies balsamea* [L] Mill) and white and black spruces (*Picea glauca* [Moench] Voss and *Picea mariana* [Mill] BSP). To the west of Lake Superior, along the US border, the forests constitute part of the Great Lakes-Saint Lawrence Forest Region (Rowe, 1972) of Canada. At one time, extensive communities of red pine (*Pinus resinosa* Ait) and eastern white pine (*Pinus strobus* L) dominated the landscape of this portion of NW Ontario. Over the past century, however, logging and fires have influenced the forest cover of this area; it is now represented more by widespread mixed wood forests containing some boreal elements together with scattered red and white pine stands of limited extent.

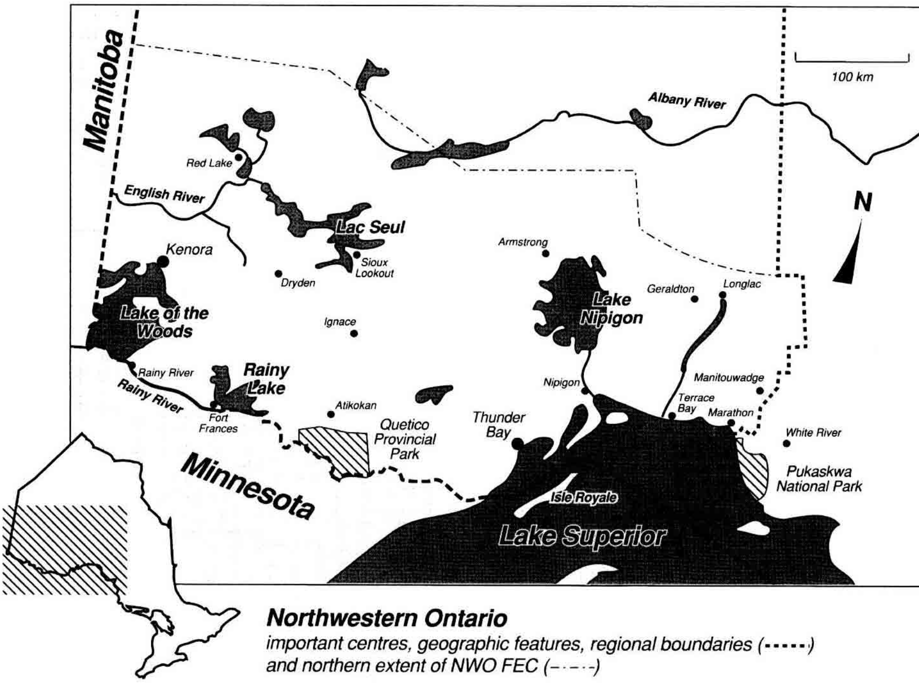

Fig 1. Map of the northwestern Ontario study area, Canada.

Derivation of the classification

The NWO FEC was developed as a standardized system to identify distinct forest vegetation and soil conditions in NW Ontario (Sims *et al,* 1989). It forms a framework for the organization, communication and application of forest management expertise (Racey *et al,* 1989a). It is relatively simple to apply in the field, and can help forest managers and others to better appreciate and understand ecological relationships within mature forest stands.

Data collection for the NWO FEC was conducted during the period from 1983 to 1988. Work was carried out cooperatively by the staff of the Canadian Forest Service and the Ontario Ministry of Natural Resources. Interim versions of the NWO FEC system were developed and field-tested annually for 5 years. The final version of the classification was based upon analysis of detailed soil, site and vegetation information from 2 167 10 m x 10 m plots located in mature forest stands throughout NW Ontario (Sims *et al,* 1989; Sims and Uhlig, 1992).

By applying a 2-step "keying" process, forest stands can be allocated among 38 vegetation types and 22 soil types. Once allocated by means of the field keys, stands are compared to corresponding modal descriptions of vegetation and soil types; these are provided as sets of "fact-sheets" in the NWO FEC field guide (Sims *et al,* 1989). Each of the types is named and associated with a suite of common overstory and understory vegetation species, and a defined range of soil and site attributes that serve to characterize it.

Computer-assisted ordination was conducted on NWO FEC vegetation data using detrended reciprocal-averaging analysis (Hill, 1979; Gauch, 1982). This technique has been used widely for the study of ecological relationships in boreal and northern mixed wood forest communities (Corns and Annas, 1986; Stanek and Orloci, 1987; Zelazny *et al,* 1989; Meades and Moores,

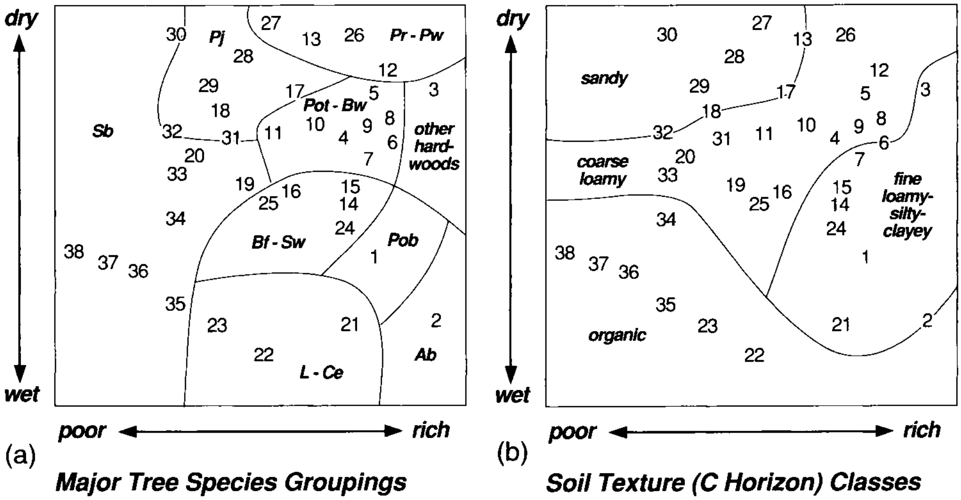

Fig 2. NWO FEC vegetation type ordination overlain with (a) major forest cover-type groupings, and (b) dominant soil-texture classes (parent material) (after Sims *et al*, 1989).

1990). The resulting NWO FEC vegetation types ordination (fig 2) was based upon abundance information for all vegetation species recorded within NWO FEC plots. Each of the 38 plotted points in this ordination (fig 2) represents an average vegetational composition for a vegetation type. The distance between any 2 points is a function of the relative degree of similarity or difference between those types. Two main gradients can be inferred along the axes of the vegetation type ordination: the horizontal axis represents a soil nutrient (poor to rich) gradient, while the vertical axis is the soil moisture (wet to dry) gradient.

Data base analyses

Statistics on stand level attributes reported here were prepared using the computerized NWO FEC data base described earlier. Species distributions within the NWO FEC vegetation types ordination (fig 3) were elucidated by developing overlays using occurrence frequencies for each species within each vegetation type. Parameters such as depth to mottling within the soil profile, depth to bedrock or texture of unweathered parent material can be employed to estimate the annualized index of site moisture conditions (Anon, 1985). This index, known as soil moisture regime, was assessed for each NWO FEC plot using observations from an excavated soil pit. Soil moisture regime measurements were summarized across 5 black spruce abundance classes (1–10, 11–20, 21–30, 31–50 and 51–100% cover) within those NWO FEC plots in which black spruce occurred within the tree layer (*ie* the vegetation layer which includes those trees which are >10 cm diameter at breast height and/or >10 m height).

Toposequences portraying soil and vegetational gradients across common landform features were constructed using a standardized approach, described by Baldwin *et al* (1990). Other landscape level summaries were based upon additional analyses of the NWO FEC data base, in conjunction with other spatial data bases, including a recently constructed digital elevation model (DEM) and mesoscale climatic surfaces developed for NW Ontario; the derivation of these spatial data bases is described by Mackey and Sims (1993) and Mackey *et al* (1994a).

RESULTS AND DISCUSSION

Stand level applications

Autecology of understory species

The NWO FEC ordination effectively provides a schematic representation within which the ecological ranges of vegetation species can be described. Figure 3 shows, for 2 *Cladina* spp (*C rangiferina* [L] Harm, *C mitis* [Sandst] Hale & Culb, *C stellaris* [Opiz] Brodo), the relative distributions of these species across the range of NWO FEC vegetation types. All 3 of these ground lichen species are widespread, occurring throughout many vegetation types in NW Ontario.

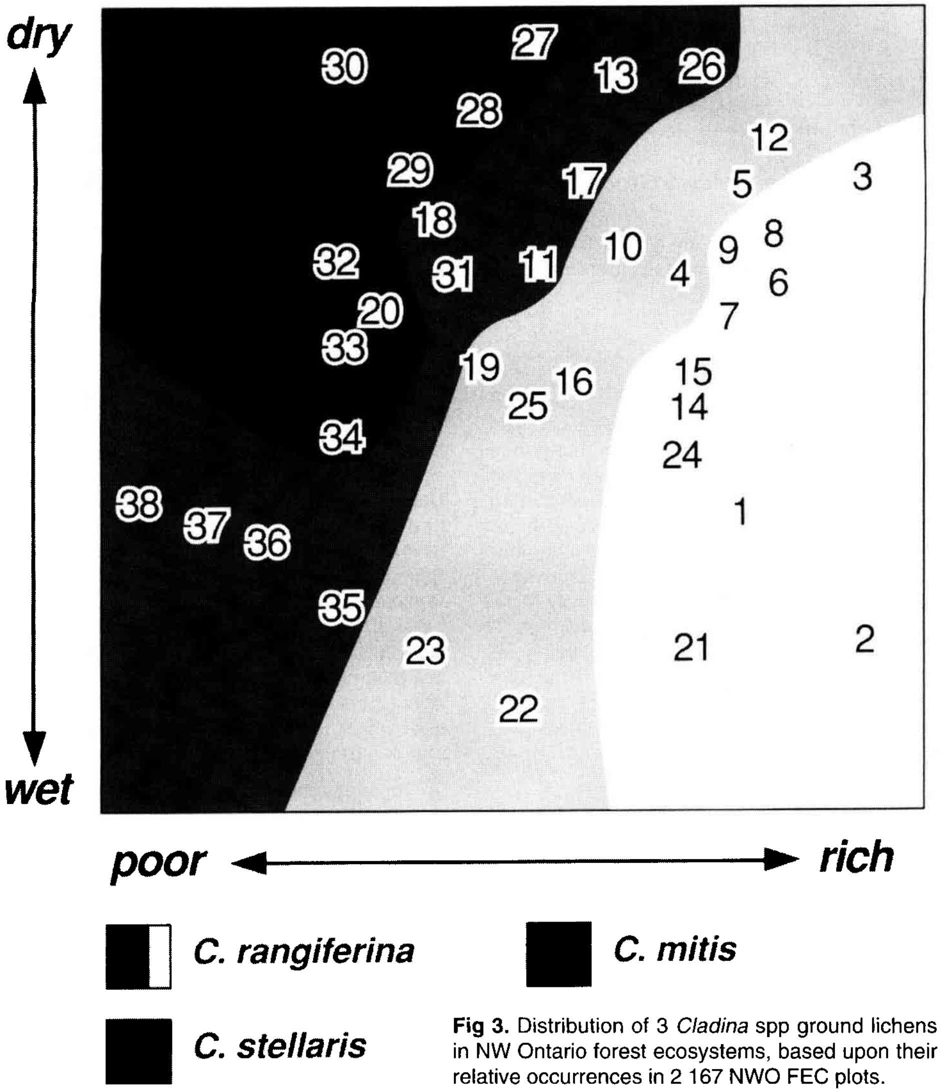

Fig 3. Distribution of 3 *Cladina* spp ground lichens in NW Ontario forest ecosystems, based upon their relative occurrences in 2 167 NWO FEC plots.

C stellaris is found on drier upland sites, especially those with infertile sand or bedrock substrates; it is restricted to the upper left-hand corner of the ordination (fig 3) which represents vegetation types characterized by nutrient-poor and dry growing conditions. By comparison, *C mitis* and *C rangiferina* are found across much broader ecological ranges. In NW Ontario, all 3 *Cladina* species are more frequently encountered in conifer-dominated stands, and may be typically found in exposed locations on bare rock, mineral soil or humus or, less frequently, on raised moss hummocks or dead wood (Harris, 1992; Hollstedt and Harris, 1992).

Similar information on the ecological range of other plant species is provided by Baldwin and Sims (1989). This field handbook provides identification aids and basic habitat information on 157 forest plant species, including common trees, shrubs, herbs, graminoids, ferns, mosses and lichens. Nontechnical language and simple line illustrations are used to simplify field identification of species. The publication includes individual NWO FEC ordination diagrams for each species, showing associated vegetation types and species distributions across the interpreted moisture/nutrient gradients.

NWO FEC data base information has also been used for clarification of ecological relationships among competitive understory species (Bell, 1990; Bell and Buse, 1992) and important overstory species (Sims *et al*, 1990). The companion reports by Bell (1990) and Bell and Buse (1992) describe the autecological features of common understory species that are serious competitors with crop trees in NW Ontario. Included for each species is a variety of descriptive information such as associated NWO FEC vegetation and soil types, life cycles, reproduction, soil/site characteristics conducive to growth, forestry practices that stimulate growth or establishment, forestry practices that reduce growth or establishment, wildlife relationships and other notes. Possible methods for controlling these competitor species are also summarized. Autecological descriptions of 12 commercially important tree species are considered by Sims *et al* (1990); the report summarizes biological, soil and site features, including NWO FEC units, related to the distribution of these species in mature forest stands in Ontario's North Central Region. The report includes background information including species' shade, frost, flood and fire tolerances, reproductive strategies, germination and establishment requirements and associated soil and vegetation parameters.

Soil moisture regime conditions for black spruce

Black spruce in NW Ontario is associated with a wide range of soil moisture regime conditions, thus it may be found on landscape positions ranging from hill crests to lowland depressions. For those 1 300 NWO FEC plots where overstory black spruce occurred, figure 4 shows the relationship between black spruce abundance class and soil moisture regime. For each of the 5 abundance classes, the histogram (fig 4) indicates the percentage occurrence of black spruce associated with each of the 11 soil moisture regime classes. The wide ecological tolerance of black spruce to moisture is reflected in its broad range of distribution.

In general, black spruce occurs less frequently at higher abundances (*eg* the 31–50 and >50% cover classes). In the >50% cover class, moisture regimes that were moist or wet were more frequently encountered in the field. This pattern shifts for lower abundance levels: in the 1–10 and 11–20% cover classes, for example, the most frequently encountered moisture regimes were classes 0, 1 and 2 (fig 4), representing dry and fresh conditions.

Table II compares the distribution of black spruce as a tree (1 300 NWO FEC plots), tall

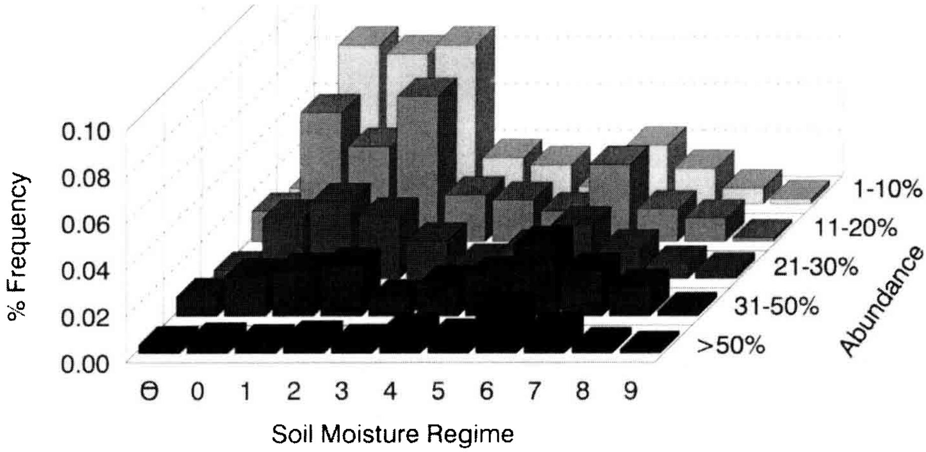

Fig 4. Histogram showing soil moisture regime classes for 1 300 NWO FEC plots where overstory black spruce (*Picea mariana* [Mill] BSP) occurred, summarized according to 5 categories of abundance: 1–10, 11–20, 21–30, 31–50 and 51–100% cover. The 11 soil moisture regime classes shown along the horizontal axis can be generally grouped as follows: dry (Ø, 0), fresh (1,2,3), moist (4,5,6) and wet (7,8,9).

shrub (879 plots) and low shrub (1 024 plots) across major groupings of soil moisture regime. Within all 3 strata, fresh soils were the most frequently encountered, a condition already confirmed for overstory black spruce in figure 4. Proportions falling into other soil moisture regime groupings were similar in all strata; however, the data indicate that shrubs may occur more frequently on dry soils, and less frequently on moist soils than overstory black spruce (table II).

White-tailed deer habitat preferences

White-tailed deer are restricted to the south-western corner of NW Ontario. With input

Table II. Soil moisture regime for black spruce (*Picea mariana* [Mill] BSP) in NW Ontario, based upon field measurements within soil pits at NWO FEC plots, where the species occurred either as a tree (>10 m height class and/or >10 cm diameter at breast height), tall shrub (2–10 m height class) or low shrub (<2 m height class).

	Dry	*Fresh*	*Moist*	*Wet*	*Total*
Tree	271 (21)	541 (42)	331 (25)	157 (12)	1 300
Tall shrub	216 (24)	368 (42)	181 (21)	114 (13)	879
Low shrub	256 (25)	442 (43)	203 (20)	123 (12)	1 024

Row percentages are shown in parentheses.

from wildlife biologists working within the study area, an "expert opinion" interpretation (fig 5) was prepared to identify NWO FEC vegetation types that are usually capable of producing preferred browse (food) species and winter shelter for the deer in areas to be managed for that purpose (Racey *et al*, 1989b).

The limiting factor for white-tailed deer in NW Ontario is usually considered to be winter severity; tree cover that offers some protection from severe cold and deep winter snow is essential. The value of this cover is enhanced if abundant winter browse, such as mountain maple (*Acer spicatum* Lam), trembling aspen, beaked hazel (*Corylus cornuta* Marsh), red-osier dogwood (*Cornus stolonifera* Michx) or black ash (*Fraxinus nigra* Marsh) exists in adjacent areas. White-tailed deer are generalist herbivores with critical energy requirements, particularly during winter; however, since most of their energy intake occurs during the snow-free

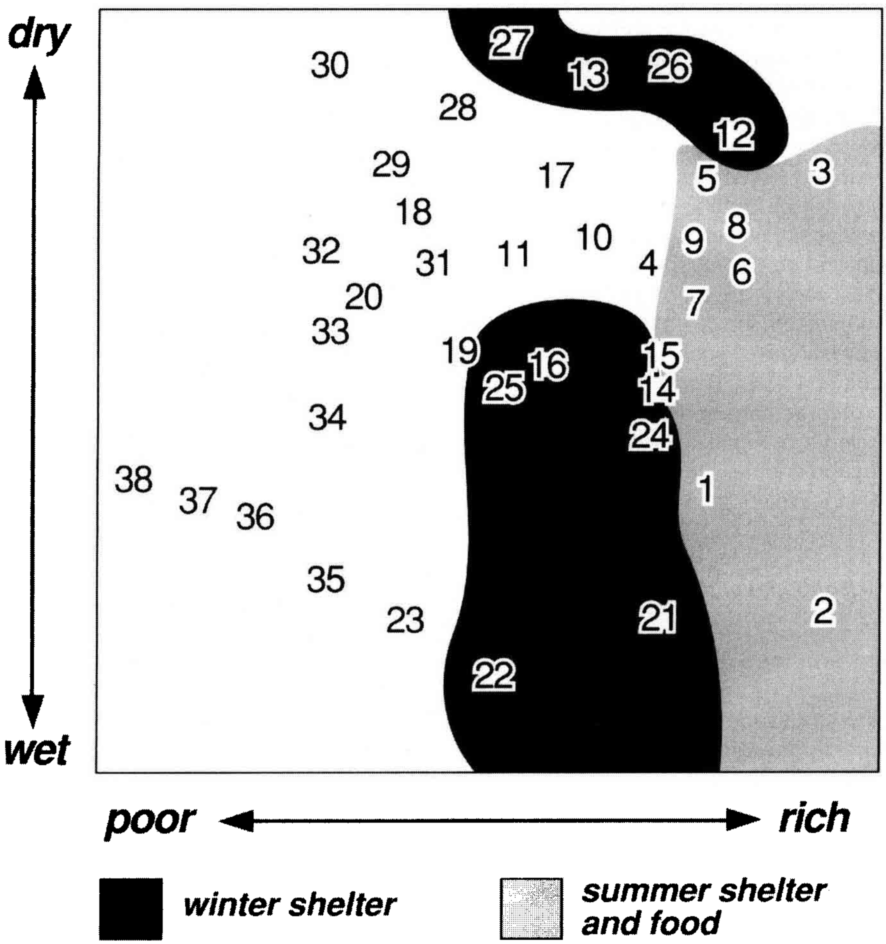

Fig 5. NWO FEC vegetation type ordination overlain with ratings of preferred winter and summer shelter and summer food for white-tailed deer (from Racey *et al*, 1989b).

period, good quality summer forage, especially grasses, deciduous leaves and a variety of herbaceous species, is essential. Figure 5 highlights those vegetation types in which most winter and summer shelter and food requirements are met for white-tailed deer. There are other factors that must also be considered, including the degree of habitat diversity, local topography and the general age-class distribution of forest stands in an area.

Since its introduction, the NWO FEC system has been well accepted by foresters and resource managers, and used for a variety of planning and operational activities. To assist in this process, suites of "forest management interpretations" at the stand level, including wildlife interpretations, were developed (Racey *et al,* 1989b; Sims and Uhlig, 1992). Similar interpretations have been constructed to describe moose habitat (Racey *et al,* 1989a) and woodland caribou habitat (Harris, 1992) in NW Ontario. Welsh (1993) related the distribution of various forest-dwelling bird species to the NWO FEC vegetation types, based upon listening station records throughout NW Ontario. More detailed investigations involving bird habitat usage and reproductive productivity are ongoing (Welsh, personal communication).

Landscape level applications

Landform toposequences

At the landscape level, landform features frequently play an important role in the definition and characterization of ecological units. Typically, there are observable topographic/geographic patterns which can be used to predict generally the characteristic landform features within an area (Mollard and Janes, 1984). In addition, most landform/surficial patterns (*ie* either individual landforms or complexes of 2 or 3 landform conditions) in a regional landscape have a standard set of vegetation communities that can be described along toposequences across them. Figure 6 shows a derived toposequence for a bedrock-controlled landscape in NW Ontario, showing common NWO FEC vegetation and soil types associated with slope positions (Baldwin *et al,* 1990).

When first introduced, the NWO FEC system was intended for use at the stand level and normally within mature forest stands of less than 10 ha. It was apparent, however, that mapping of ecosystem units at a landscape level of about 1:20 000 was also important, and this was subsequently pursued as a NWO FEC-related research topic. Some selected pilot studies were conducted to demonstrate the system's usefulness when applied within operational preharvest surveys (Towill *et al,* 1988), and in conjunction with mapping and photo-interpretation programs covering extensive forested areas (Wickware, 1990).

The NWO FEC system has been demonstrated to be valuable for conventional mapping activities that involve various forest management objectives. Vegetation and soil types may be aggregated into treatment units for regional forest inventories, or other extensive applications (Racey *et al,* 1989b).

Using a regional climate model to help characterize forest humus forms

A mesoscale climate model was used to generate estimates of long-term mean monthly climate at each of the 2 167 NWO FEC plots. The climate models consist of mathematical interpolation surfaces fitted to the regional network of 475 weather stations. The interpolation procedure uses thin-plate smoothing splines as developed by Hutchinson (1988; see also Nix, 1986; Mackay, 1993). The independent variables for the interpolated surfaces are the longitude, latitude and elevation (xyz) of each weather station. Hence, an estimate of a climate variable can be generated at any location at which the xyz geocode is known. Climate surfaces have been produced for minimum temperature, maximum temperature, total precipitation, potential evaporation and radiation. These data were further analyzed to produce a daily sequence of long-term mean daily minimum and maximum temperatures. The growing season (GS) was then defined as follows: 1) the start of GS is the first day after March 31

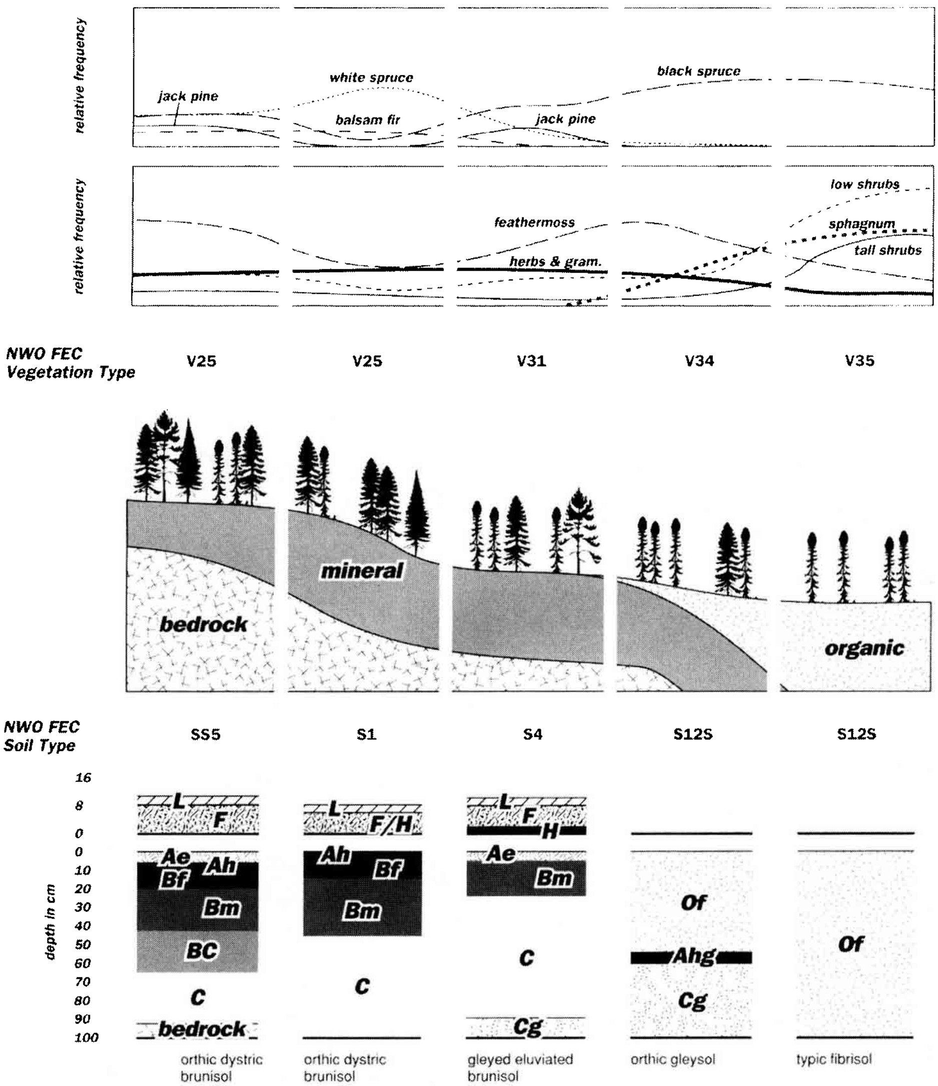

Fig 6. A derived toposequence for a deep coarse-loamy ground moraine landform in NW Ontario, schematically showing common vegetation types, soil types and other landscape features associated with slope positions. Nomenclature follows Anon (1985) and Baldwin *et al* (1990).

when the minimum temperature is greater than 5°C; 2) the end of GS is the first day after August 1 when minimum temperature is less than –2°C. By taking a base temperature of 5°C, it was possible to generate, at each of the NWO FEC plots, estimates of growing degree days (GDD) for the growing season.

By coupling the climate surfaces to a new digital terrain model of NW Ontario (see Mackey and Sims, 1993; Mackey *et al*, 1994a), it has also been possible to generate, for the entire region, gridded estimates of GDD for the growing season. Thus, a cell-based climatic data base can be generated and integrated with remotely sensed and digitized mapped thematic data within a GIS.

Recorded at all NWO FEC plots was the characteristic forest humus form, using the terminology and approach of Bernier (1968) and Anon (1985). For the example presented here (fig 7), only the order level of the humus form classification was used, which defines mors, moders and mulls. Cumulative percent occurrence plotted against GDD provides a characteristic response curve that describes the relative position along the gradient for each forest humus form.

In general, the 3 curves show a response that reflects their decomposition characteristics, the more highly active mulls occupying warmer climates, and responding between about 1 200 and 1 680 GDD, while

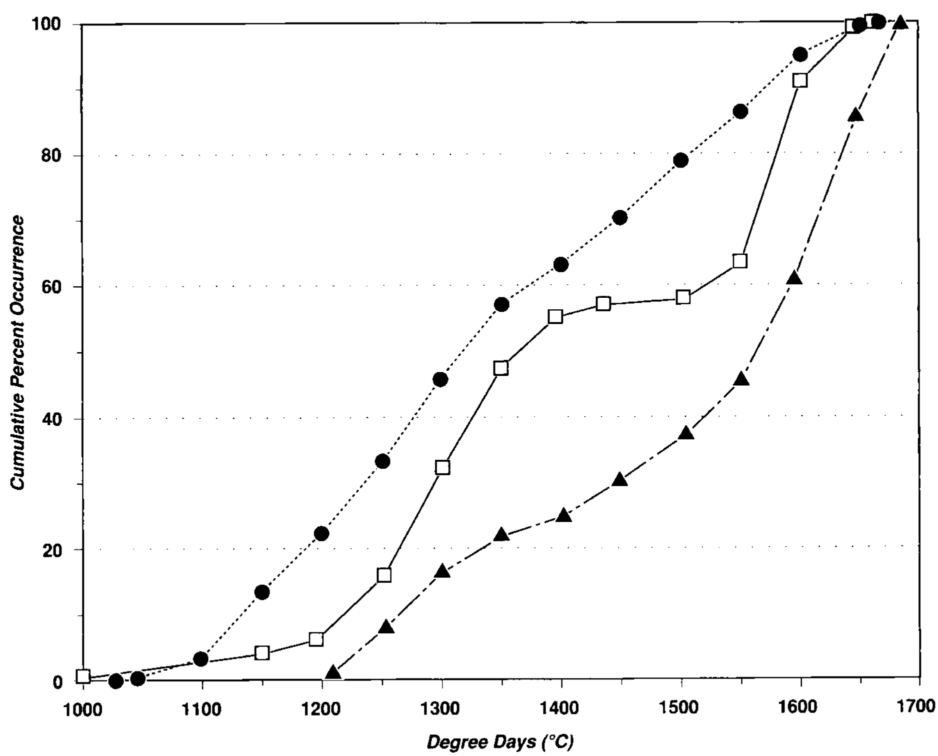

Fig 7. Cumulative percentage frequency curves for mor (solid circles), moder (open squares) and mull (solid triangles) forest humus forms in NW Ontario according to accumulated growing season degree days above a base temperature of 5°C.

the mors (primarily fibrimors in NW Ontario) respond across a generally colder gradient, between about 1 040 and 1 600 GDD. Moders are intermediate in their response and position. Fifty percent of each sample for mors, moders and mulls is acquired, respectively, at about 1 300, 1 380 and 1 570 GDD (fig 7).

Spatially based ecosystem modelling

Current research is using local environmental information from site classification systems to construct regional-level predictive models. Such models have considerable potential for improving our understanding of the dynamic processes which control forest growth and development in boreal forest conditions. Figure 8 outlines the major program components involved in the development of a spatially based ecosystem model in the Rinker Lake Research Area, a 900 km^2 pilot mapping area located about 100 km north of Thunder Bay, Ontario.

Of prime importance is the need to generate spatial predictions of the primary environmental regimes (energy, moisture, mineral nutrients). This requires integrating

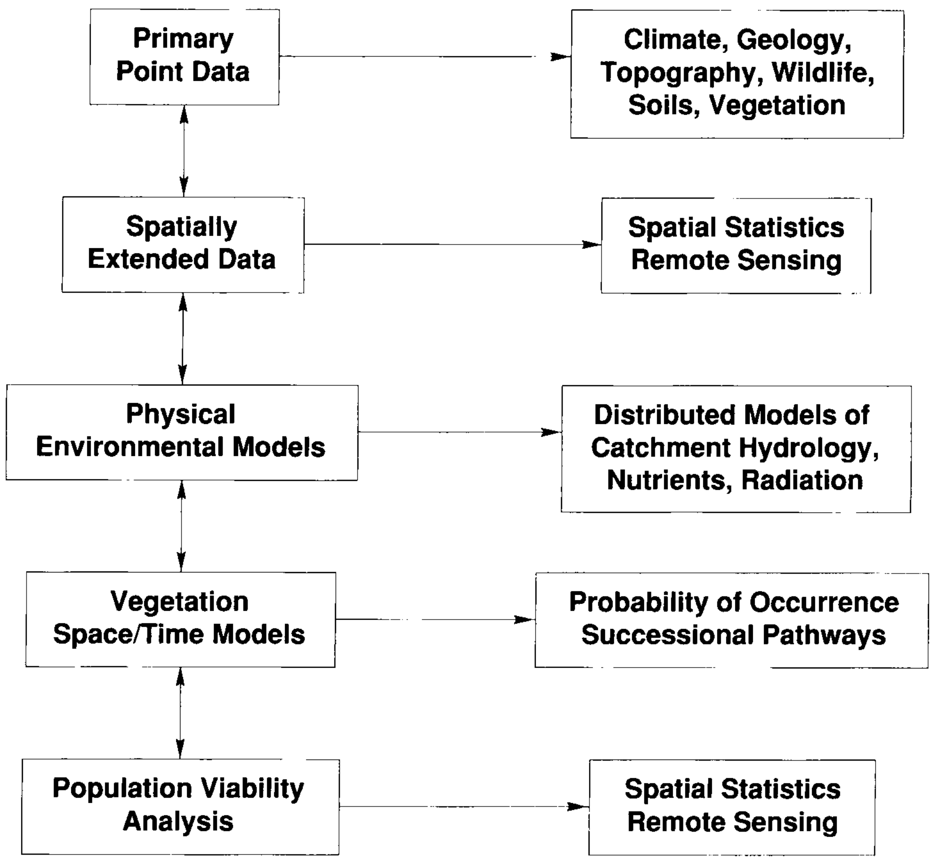

Fig 8. Diagram showing the data requirements and analytical components used to develop a spatially distributed ecosystem model for a NW Ontario pilot mapping area. The model is based upon Northwestern Ontario's Forest Ecosystem Classification system.

computer-based models that draw upon selected climatic, terrain and soil/geological attribute data. A fine scaled (20 m) DEM is used to spatially extend various compound terrain attributes and generate predictions of soil moisture and nutrient regimes (see Moore *et al*, 1991; Mackey *et al*, 1994a, b). Detailed ecological data from 142 plots within the Rinker Lake area (a subset of the NWO FEC plot network) are used to calibrate these landscape models, and predict potential vegetation distributions. All these analyses, together with extant land cover data from remotely sensed sources, are integrated within a GIS framework.

The research is aimed at defining functions that link local processes and regional resource management, in particular, the primary environmental regimes of soil moisture, nutrient status and climate (Mackey *et al*, 1994b; Sims and Mackey, 1994). At a landscape level, detailed ecological information from a portion of the NWO FEC plot network (142 detailed plots located within the Rinker Lake Research Area) has been linked to digital elevation, hydrology and climatology data using a computerized GIS (Mackey *et al*, 1994b; Sims and Mackey, 1994).

CONCLUSION

Site classification systems have an essential role to play in resource management, research and planning. The NWO FEC is an example of an ecologically based site classification system that may be employed to characterize and classify forest ecosystem units. This article has provided 6 examples of how the NWO FEC system has been applied in different ways for the purposes of ecological description at the stand (local, *eg* 10 ha size) and landscape (*eg* 1:20 000 scale) levels.

Future directions in ecological research at the stand and landscape levels in NW Ontario will continue to build upon the NWO FEC framework. Particularly at the landscape level, new technologies and capabilities that are now available will make the types of potential applications for forest site classifications fundamentally different from those of the past. Classifications will likely become more flexible and integrative across hierarchical levels, and computer approaches involving spatial modelling on a GIS and remote sensing data are providing new analytical opportunities.

Local environmental information, derived from forest site classification systems, will be increasingly used to construct or calibrate predictive spatial models at a variety of scales (*eg* see table I). Such models will seek to provide new information on, for example, specific regional effects of climate change and pollution, the distribution of ecological ranges for various species and communities, temporal responses due to succession and natural or anthropogenic disturbances, indices of biodiversity for conservation purposes and other dynamic mechanisms that link local-level ecological processes with resource management needs at other scales.

ACKNOWLEDGMENTS

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