Scientific and Technical Articles/ Articles scientifiques et techniques

An Introductory Comparison of Forest Ecological Conditions in Northeast China and Ontario, Canada

by

D. Burger¹ and Zhao Shidong²

Abstract

For two fairly similar areas, forest vegetation is compared in relation to broad features of the land. Items considered include location and land areas, history and forest resources, relief and climate, potential commercial tree species and vegetation regions, bedrock geology, soil parent materials and soil development. Ecological knowledge is considered important for the effective transfer of silvicultural technology and the exchange of plant material between the two areas.

Key words: China, Ontario, Vegetation regions, Tree species, Climate, Soils, Forest ecology, Forest history.

Résumé

Pour deux territoires assez semblables, la végétation forestière est comparée relativement à des caractéristiques général du terrain. Les comparaisons comprennent le lieux et l'aréa, l'histoire et les ressources forestières, le relief et le climat, les espèces d'arbre de potentiel commercial et les régions végétales, la géologie de roche, la matériel mère du sol et la pédogenèse. On considère la connaissance écologique comme essentielle pour transférer effectivement des techniques silvicoles et pour échanger des matériaux végétale entre les deux territoires.

Introduction

In recent years the People's Republic of China (PRC) and Canada have intensified relationships in several areas such as trade, science and technology including matters pertaining to forestry. Reciprocal missions have worked towards better understanding of conditions and potentials for development of forest resources. Rowe (1984) refers to several reports on such activities.

This paper compares two fairly similar areas — northeast China and Ontario. It provides background information on forest vegetation in relation to broad features of the land as a step towards a better understanding of the respective forest ecologies which is needed to improve an awareness of the potential for and limitations to information transfer and exchange of plant material between the two areas.

Location and Land Area

Northeast China considered here comprises the three provinces of Heilongjiang, Jilin and Liaoning and three eastern prefectures of the Neimongol (Inner Mongolia), between 38°40' and 53°30'N latitude and 115°30' and 134°48'E longitude (Fig. 1). Ontario, located between 41°55'N and 56°51'N and between 74°18' and 95°09'W is thus about three degrees further to the north with a slightly different photoperiod for plants, i.e. longer summer and shorter winter days. Latitudes of some major cities in northeast China compare with those in Ontario as follows: Harbin (45°50'N) with Ottawa (45°26'N) and North Bay (46°15'N); Changchun (44°00'N) with Toronto (43°15'N); Shenyang (formerly Mukden) (41°50'N) with Windsor (42°30'N). Important Ontario cities such as Thunder Bay and Timmins (48°30'N) are situated further north than even Harbin.

Land areas are compared in Table 1 (Han 1982, Canadian Forest Service 1986). The 474 000 km² of total forest land area in northeast China is about 35% of the forested area of China, whereas the 807 000 km² for Ontario is about 18% of that of Canada.

History and Forest Resources

In Ontario, destructive forces such as fires, insect pests and diseases have always been a natural component of forest

¹Principal Scientist, Ecology and Silviculture, Ontario Tree Improvement and Forest Biomass Institute, Ministry of Natural Resources, Maple, Ontario L0J 1E0
²Associate Professor and Assistant Director (Research), Institute for Forestry and Soil Science, Academia Sinica, P.O. Box 417, Shenyang, Liaoning, People's Republic of China

ecology. The effect of cutting to satisfy man's needs for construction timber started in the period 1783-1797 when thousands of settlers of European stock emigrated to the north shores of the St. Lawrence River and of Lakes Erie and Ontario as a result of the American War of Independence (Lambert 1967). These "United Empire Loyalists" saw the forests as a major obstacle to agricultural development; many groups followed to clear the land, mainly in the most southern part of Ontario. Cutting for *Pinus strobus* lumber started in the most eastern part of Ontario around 1810 and continued in a westward wave towards Lake Huron until about 1890 when supplies of large dimension lumber dwindled, but it was followed by cutting of *Tsuga canadensis*, *Betula alleghaniensis* and *Acer saccharum*.

In northeast China, the Liaodong Peninsula and the southern part of the Northeast Plain, because of the favourable climate and good land, have been used for centuries for agriculture and fruit crops. The forests there are now limited to the less productive lands. Records of government regulations regarding forests date back a

Table 1. A comparison of land areas in northeast China and Ontario

	Northeast China (000 km ²)	Ontario (000 km ²)
Total area	1 236	1 069
Total land area	1 234	891
Total water area	2	177
Total forest land	474	807
Total productive forest land	309	377
Total agricultural land	186	60
Other land	574	24

Table 2. Forest resources in northeast China and Ontario

	Northeast China		Ontario, 1983	
	000 000 m ³	national	000 000 m ³	national
Total growing stock	3 100	46	3 200	17
Annual roundwood production (logs, pulpwood, fuelwood)	23	58	24	15

Since the founding of the People's Republic of China in 1949 much more attention is being paid to proper forest management. Currently very large reforestation programs are underway and attempts are made to change the clearcutting of hardwoods to more (ecologically) appropriate systems to maintain productivity of the land.

The forest resources and the annual total roundwood production for northeast China (Han 1982) and Ontario (Canadian Forest Service 1986) are quite comparable (Table 2); those of northeast China are the most important forest resource on a national scale, whereas Ontario ranks third after the provinces of British Columbia and Quebec.

Relief

The two study areas are at somewhat comparable latitudes but they differ in relief patterns and in their position relative to landmasses and large bodies of water (Fig. 2). Altitudinal vegetation zones due to high relief occur in northeast China but not in Ontario.

Ontario has a relatively low relief (0-500 m) with only a few isolated higher areas of up to 690 m. To the north and south it borders on large bodies of water, i.e. Hudson Bay and the Great Lakes. There are very many small and large lakes.

In northeast China, the Northeast Plain with elevations of up to 200 m takes up about 29% of the study area. Mountains occur to the west, north and east, i.e. the Daxingganlin (main elevation 700-1100 m; highest peak 1400 m), the Xiaoxingganlin (300-800 m; 1160 m) and the Changbaishan (1000-1500 m; 2691 m). Only in the south is this area open to the influence of a large body of water, i.e. Bohai and Huanghai (Yellow Sea). There are few natural lakes.

Climate

Köppen's climate classification based on temperature and precipitation criteria provides a suitable basis for an initial intercontinental comparison of climatic regions and gradients (Fig. 3). The location of boundaries on published maps by Borchert (1947), Trewartha (1954), and Lu (1949, as quoted by Arakawa 1969) vary somewhat depending on the completeness of data, the selected period for computations and the minor amendments to Köppen's original classification criteria.

Both study areas have a cold snowy D climate, i.e. microthermal with the temperature of the coldest month below 0°C and that of the warmest month above 1°C. The most western edge of northeast China has a cold semi-arid steppe climate (BSk) which at times extends eastward halfway into the Northeast Plain causing so-called "steppe-years" (Borchert 1947). That BSk climate is not suitable for forestry.

Figure 2. Regional relief.

Table 3. Some climatic data for vegetation regions (see Fig. 4 and Table 5)

Vegetation region	Location	Temperature °C				Precipitation mm	
		Mean monthly ^a		Extreme		Mean	
		July	Jan.	Max.	Min.	annual ^a	summer ^a
Bb	Ontario	15	-23	38	-47	620	370
Bf	NE China	17	-33	39	-52	430	340
	Ontario	17	-21	41	-58	660	380
M1	NE China	23	-28	37	-45	550	410
M2	NE China	23	-20	37	-42	700	525
Mw	Ontario	18	-16	42	-49	660	380
Me	Ontario	19	-10	43	-49	860	380
D	NE China	26	-10	40	-37	800	600
	Ontario	22	-4	39	-30	840	370
S & Sf	NE China	21	-17	NA	NA	300	NA

^aMedian values of regional ranges.

There is no steppe climate in Ontario, but it does occur to the west in the adjoining province of Manitoba.

With respect to available summer heat there are also similarities. The northern half of Ontario and the Daxingganlin both have cool short summers with less than four months with a mean monthly temperature of over 10°C (c-type). Most of the southern half of Ontario and the Xiaoxinganlin and Changbaishan are warmer, but the mean temperature of the warmest month is less than 22°C (b-type). The most southwestern tip of Ontario and China's Northeast Plain and further south to the coast of the Yellow Sea are even warmer in

the summer; mean temperature is above 22°C in the warmest month (a-type). Table 3 provides some climatic data (Chapman and Brown 1966, Wu 1980) arranged by vegetation regions (as discussed below and see Fig. 4). Northeast China is generally colder in the winter than Ontario, especially in the south; the Chinese rivers are then frozen and their seaports are at times icebound. But summers are somewhat warmer in northeast China.

Annual precipitation is somewhat higher in Ontario, but summer rainfall is higher in northeast China, except in the Boreal Forest Region (Table 3). In Ontario precipitation is fairly

Figure 3. Köppen Climatic Types. Acc. to Lu (1949, quoted by Arakawa 1969) for China and Trewartha (1954) for Ontario. D = microthermal. BS = Semiarid steppe. a = hot summer; b = cool summer; c = cool short summer; k = cold; w = driest season in winter.

Figure 4. Vegetation Regions. Bb = Barren Boreal; Bf = Boreal Forest; M = Mixed Forest; D = Deciduous Forest; Sf = Forest Steppe; S = Steppe. Details in Table 5.

well distributed throughout the year (f-type), with a low peak in summer; prevailing westerly winds bring moist warm air from the southwest in the summer, and drier and cold air from the northwest in the winter. On the other hand, northeast China has a monsoon climate; the southeasterly summer winds from the Yellow Sea (Huang Hai) bring much rain in July and August but from October on, prevailing strong northwesterly winds from the dry high Mongolian Plateau and the Siberian Plain cause a fast drop in temperature starting the long bitterly cold and drier winter (w-type). Yellow dust occurs there everywhere in the winter, with dust storms in late winter and spring in southern areas (Kendrew 1953).

These broad climate patterns plus more local variations in temperature and precipitation due to altitude, proximity to water and position relative to land barriers affect the distribution of plant species.

Forest Flora

The forest floras of northeast China and Ontario have much in common as could be expected from similarities in climate discussed above. In our comparison we restrict ourselves to tree species that might be of major interest to forest management. Potential commercial tree species, i.e. species that will attain at least 15 cm diameter at breast height and 5 m total height, are listed in Table 4 (Hosie 1969, Liou 1955). Many smaller tree species which might be important as ornamentals or for wildlife are not included.

Fifty-nine genera with potential commercial tree species are represented in northeast China and Ontario; 25 of these

genera are common to both areas. There are 22 genera that occur only in northeast China; 19 of these have no representatives anywhere in North America. Twelve genera occur only in Ontario but of these eight (*Tsuga*, *Carya*, *Castanea*, *Fagus*, *Gymnocladus*, *Liriodendron*, *Nyssa* and *Sassafras*) occur somewhere else in China, although not in the northeast. The total number of potential commercial tree species in northeast China (123) is larger than in Ontario (76). This is true both for conifers (15 and 12 respectively) and deciduous hardwoods (108 and 64 respectively).

The shared genera and the large numbers of species suggest a potential for an exchange of plant material for hybridization or for direct use in plantations. However, to derive maximum benefits, better knowledge of the ecological requirements of the species is needed.

Vegetation Regions

Vegetation regions as delineated and described by Wu (1980) for China and forest regions by Rowe (1972) for Canada were selected for the initial comparison of regional distribution of forest vegetation in the two areas. In both publications, regions are considered as major geographic belts characterized vegetationally by broad uniformity in physiognomy and by the presence of selected species. A more detailed comparison of ecological relationships, with vegetation described in relation to specific landform positions as expressed for the Ontario Site Regions (Hills 1960, Burger 1972, 1976), is not possible since such information for northeast China is not yet available. Although descriptions and a map by Hou (1979, 1983) are more accessible to

Table 4. Potential commercial trees species in northeast China and Ontario, Canada.

Ontario Species		Northeast China Species	Ontario Species		Northeast China Species
Coniferous trees = Gymnosperms					
balsamea	Abies	holophylla nephrolepis	banksiana resinosa rigida strobis	Pinus	densiflora koraiensis sylvestris var. mongolica var. sylvestriformis tabulaeformis var. mukdensis var. umbraculifera takahasi
virginia	Juniperus	rigida			
laricina	Larix	gmellini olgensis		Platycladus	orientalis
				Taxus	cuspidata
glauca mariana rubens	Picea	jezoensis var. kamarovii var. microsperma koraiensis	occidentalis canadensis	Thuja Tsuga	koraiensis
Deciduous trees = Angiosperms					
negundo nigrum rubrum saccharinum saccharum	Acer	barbinerve ginnala mandshuricum mono pseudo-sieboldianum tegmentosum truncatum triflorum tschonoskii ukurunduense	crusgalli holmesiana punctata	Cornus Crataegus	controversa coreana dahurica maximowiczii pinnatifida
rugosa	Alnus	japonica mandshurica sibirica		Evodia Evonymus	daniellii bungeana maackii
triloba	Asimina		grandifolia	Fagus	
alleghaniensis papyrifera populifolia	Betula	costata dahurica ermanii platyphylla schmidtii	americana nigra pennsylvanica quadrangulata	Fontanesia Fraxinus	fortunei bungeana chinensis mandshurica rhynchophylla
caroliniana	Carpinus	cordata	triachanthos	Gleditsia	japonica
cordiformis glabra laciniata ovata tomentosa	Carya		dioicus	Gymnocladus	
dentata	Castanea		cinera nigra	Hemiptelea Juglans	davidii mandshurica
occidentalis	Celtis	bungeana jessoensis koraiensis		Kalopanax	septemlobum
canadensis	Cercis			Koelreuteria	paniculata
	Chosenia	arbutifolia	tulipifera	Lindera Liriodendron	obtusiloba

(Continued on next page)

Table 4. (cont'd)

Ontario Species		Northeast China Species	Ontario Species		Northeast China Species
	Maackia	amurensis var. buergeri		Rhus	chinensis
acuminata	Magnolia	siboldii		Salix	capitata
cooronaria	Malus	asiatica baccata manshurica sieboldii	amygdaloides nigra		dasyclados eriocarpa kangensis var. liocarpa korensis linearistipularis matsudana maximowiczii pierotii raddeana var. subglabra rorida var. roridaeformis sachalinensis triandra var. nipponica viminalis var. angustifolia var. gmelinii
rubra	Morus	bombycis			
sylvatica	Nyssa				
virginiana	Ostrya				
	Phellodendron	amurense			
	Picrasma	ailanthoides		Sassafras	
occidentalis	Platanus		albidum		
balsamifera deltoides grandidentata tremuloides	Populus	amurensis cathayana charbinensis davidiana girinensis koreana manshurica maximowiczii nakaii pseudo-simonii simonii suaveolens ussuriensis	americana decora	Sorbus	alnifolia var. lobulata pohuashanensis
	Prunus	asiatica davidiana maackii mandshurica		Styrax	obassia
americana nigra pennsylvanica serotina virginiana				Symplocos	paniculata
	Pteroceltis	tatarinowii		Syringa	amurensis pekinensis
alba bicolor macrocarpa muehlenbergii palustris prinus rubra velutina	Quercus	acutissima aliena dentata liaotungensis mongolica variabilis	americana rubra thomasi	Tilia	amurensis mandshurica mongolica
				Toxicodendron	verniciiflorum
				Ulmus	davidiana var. mandshurica japonica var. laevigata var. suberosa laciniata lamellosa macrocarpa pumila var. pendula
				Xanthoceras	sorbifolia
				Zelkova	serrata

readers of English, the descriptions are less detailed than those of Wu (1980).

The vegetation regions in both areas are shown in Fig. 4, in which new names and symbols have been assigned for ease of comparison. The relation between the new and original designations is given in Table 5.

Bb Barren Boreal Region

This region does not occur in northeast China. It is differentiated in Ontario as that northern part of the Boreal

Forest Region not suitable for commercial forestry. The barren boreal region is an area of low relief and poor drainage which rises southward to about 150 m above sea level. The horizontally stratified Palaeozoic bedrock is overlain with calcareous clay of marine and glacial origin and beach sand. Along the coast with its severe exposure to wind and cold is a belt of tundra "barrens" with scattered patches of stunted *Picea glauca* in protected locations. More inland and south of the tree line, extensive areas of patterned fens, bogs and muskegs occur with open woodlands of *Picea mariana* and *Larix laricina*. On the better drained riverbank levees there is

Table 5. Correlation of new and original names of vegetation regions.

New symbol and name on Fig. 4	Original designations	
	Wu <i>et al.</i> (1980) Northeast China	Rowe (1972) Ontario
Bb Barren Boreal region	—	Breal forest and barren
Bf Boreal forest region	Needle-leaf deciduous forest of southern cold-temperate zone	Boreal forest region
M Mixed forest region	Mixed broadleaved deciduous and needle-leaved evergreen in temperate forest zone	Great Lakes-St. Lawrence forest region
D Deciduous forest region	Broadleaf deciduous forest in temperate zone (or summer green forest)	Deciduous forest region
Sf Forest steppe	Temperate forest steppe	—
S Steppe	Temperate steppe	—

additional *Picea glauca* and *Betula papyrifera*, *Populus tremuloides* and *P. balsamifera*, but very little or no *Abies balsamea* or *Pinus banksiana*. Only the most southern part has exploitable timber along rivers. Also here are the most northern occurrences of *Ulmus americana*, *Fraxinus nigra* and *Thuja occidentalis*.

Bf Boreal Forest Region

This region is common to both areas. In Ontario the Boreal Forest Region stretches east-west from a humid to a moist subhumid cold climate. It is the major wood supply area for the pulp and paper industry and is characterized by mainly mixed, but also pure stands of *Picea mariana*, *P. glauca*, *Abies balsamea*, *Pinus banksiana*, *Larix laricina* and *Thuja occidentalis* and *Betula papyrifera*, *Populus tremuloides* and *P. balsamifera*. In protected valleys *Fraxinus nigra* and *Ulmus americana* occur. Towards the north, the closed forests become open woodland with large muskegs. In the south additional species occur including *Pinus strobus* and *P. resinosa*. Within the region, forest composition varies not only with local climate and soil moisture, but also as the macroclimate varies across the region. Natural forest fires have always played an important role in forest succession. Their somewhat more frequent occurrence in the drier western part of the region favours the establishment of *Pinus banksiana* stands.

In northeast China this forest region occurs at an elevation of about 480-1400 m in the northern part of the Daxingganlin — an old mountain range with gentle slopes, rounded peaks and wide valleys — where the continental climate is cold and dry. The dominant virgin forest from 480-820 m (in the north) and 600-1050 m (in the south) is of *Larix gmelini*, mixed with some *Pinus sylvestris* var. *mongolica*, in contrast to the *Picea*-dominated boreal forests in Ontario. In the northwestern part of this region in China — where elevations are lower and the climate is drier — small areas of valuable pure pine have been exploited extensively. At higher elevations (820-1100 m in the north and 1050-1380 m in the south) *Larix-Picea jezoensis* forests occur. Above this is an open forest zone of larch with *Pinus pumila* and *Betula ermanii* and above the timberline *Pinus pumila* occurs as dwarf trees. At lower elevations (below 480 m in the northwest and 600 m in the southeast) forests of *Quercus mongolica*, *Larix gmelini* and *Betula dahurica* occur with additional co- and sub-dominants of *Populus davidiana*, *Tilia amurensis*, *Fraxinus mandshurica* and *Phellodendron amurense*.

M Mixed Forest Region

In this forest region, characterized by stands composed of mixtures of conifers and tolerant hardwoods, the trees,

shrubs and herbs in northeast China belong to the same genera as those in Ontario. There are similarities in wildlife, both large and small species. This region in northeast China has less annual precipitation but more summer rainfall than the comparable region in Ontario.

In Ontario the Mixed Forest Region has as its characteristic species, *Pinus strobus*, but there are important differences in additional species in subregions Me and Mw. In the central and southern part of subregion Me, the main characteristic species are *Acer saccharum*, *A. rubrum*, *Betula alleghaniensis*, *Tsuga canadensis*, *Fagus grandifolia*, *Quercus rubra*, *Tilia americana*, *Fraxinus americana* and *Ulmus americana*, and in the southern fringe additional *Quercus alba*, *Juglans cinerea*, *Carya cordiformis* and *C. ovata*. In the northern part of subregion Me and Mw, additional species to *Pinus strobus* are *P. resinosa* and boreal species such as *Pinus banksiana*, *Picea glauca*, *P. mariana* and *Abies balsamea* and in Mw *Quercus macrocarpa*.

In northeast China the Mixed Forest Region is the most important forest resource occupying the Xiaoxingganlin and the Changbaishan; it extends eastward into the USSR and southeastward into Korea. Within China this forest region extends over 10 degrees latitude and two subregions, M₁ and M₂, are recognized on the basis of differences in tree species composition and climate.

The characteristic forest of this region as a whole is composed of *Pinus koraiensis* (up to 50% of stand volume) mixed with valuable tolerant hardwoods such as *Tilia amurensis*, *Betula costata*, *Fraxinus mandshurica*, *Ulmus japonica*, *Acer mono*, *Juglans mandshurica* and *Phellodendron amurense*. Neither *Fagus* nor *Tsuga* occurs here in contrast to Ontario. This forest occurs up to 900 m in elevation in the northern part of the region and up to 1100 m in the south. Pioneer species are *Betula platyphylla* and *Populus davidiana*. Floristically this region is very rich and includes some Tertiary (warmer pre-Pleistocene) relics such as *Phellodendron amurense*. At higher elevations *Abies*, *Picea* and *Larix* occur.

In the northern subregion (M₁) the mixed pine-tolerant hardwoods contain more boreal species such as *Picea jezoensis* and *Abies nephrolepis*. There are only half as many broadleaved species as in the southern subregion (e.g. five *Acer* species rather than 12). In the northeast corner, at the confluences of three major rivers, a large area with low relief and many swamps of *Carex* and shrubs occurs; on higher land, tree species include *Quercus mongolica*, *Tilia amurensis*, *T. mandshurica*, *Phellodendron amurense* and

Fraxinus mandshurica. Since 1949, swamp drainage has made agricultural land important for wheat and soybean.

In the southern subregion (M_2), with the somewhat warmer climate, the flora is more varied. *Pinus koraiensis* and a larger number of tolerant hardwoods are characteristic forest species; *Larix gmelini* is replaced by *L. olgensis* and *Abies nephrolepis* by *A. holophylla*. Much of the land below 500 m elevation has been cleared for successful agricultural crops such as corn, sorghum, soybean and rice.

D Deciduous Forest Region

In Ontario the Deciduous Forest Region occurs only in an area just north of Lake Erie, but it extends further south to occupy a large part of the eastern United States. There are fewer conifers here than in the Mixed Forest Region and the occurrence of *Pinus strobus*, *P. resinosa*, *Tsuga canadensis*, *Thuja occidentalis* and *Larix laricina* is scattered. This region shares many of the deciduous species with the Mixed Forest Region. However, there are other species that have their northern limit here, such as *Liriodendron tulipifera*, *Magnolia acuminata*, *Asimina triloba*, *Gymnocladus dioica*, *Nyssa sylvatica*, *Fraxinus quadrangulata*, *Sassafras albidum*, *Juglans nigra*, *Carya cordiformis* and *C. ovata*, *Quercus velutina*, *Q. bicolor* and *Q. palustris* and *Platanus occidentalis*. Much of this region has been developed for many agricultural crops, including fruit orchards (peaches, pears, grapes) and tobacco and for urban use.

The most southern part of northeast China is in the Deciduous Forest Region; this region as a whole extends southward somewhat beyond the Yellow River with tree species mostly belonging to the Fagaceae, Aceraceae, Tiliaceae, Oleaceae, Ulmaceae, Lugimonoseae, Juglandaceae, Betulaceae and Salicaceae, but also some conifers. The northeast China portion includes the Liaodong peninsula with its central ridge from 500 to 1000 m elevation, being the southern extension of the Changbaishan, and the Liao River alluvial plain and coastal bogs. The monsoon-like climate with hot rainy summers and cold but dry winters is still favourable to many species from milder southern regions. The Liaodong peninsula has typical forests of *Quercus* (*Q. acutissima*, *Q. liaotungensis*, *Q. variabilis*, *Q. aliana* and *Q. dentata*) and *Pinus* (*P. densiflora* and *P. tabulaeformis*) and also some species from the Changbaishan, such as *Pinus koraiensis*, *Abies holophylla*, *Quercus mongolica*, *Acer mono*, *Phellodendron amurense* and *Tilia amurensis*. There is no *Fagus*, a genus that does occur in similar regions in North America and Japan. In the Liao River plain important tree species include *Populus simonii*, *P. pseudo-simonii*, *Salix matsudana* and *Ulmus pumila*, but most of the area, especially at lower altitudes (< 450 m), has been changed into croplands (corn, sorghum, spring wheat, rice, peanuts and tobacco) and fruit orchards (apples, peaches, pears, grapes) by man's activities during a thousand years or more.

Sf and S Steppe Region

There is no steppe or Prairie Region in Ontario.

The western part of northeast China is a temperate forest steppe occupying the Northeast Plain, the southern part of the lower Daxinganlin and the Inner Mongolian plateau. From east to west the ratio of annual evaporation/annual precipitation changes from one to 3.5. In the Plain, the natural vegetation of mostly meadow-steppe with scattered open forests (Sf) of *Populus davidiana*, *Betula platyphylla* and

Quercus mongolica has been transformed into a very important agricultural area for corn, sorghum, spring wheat, soybean and sugar beet. The western steppe (S) is important grassland.

Bedrock Geology

Bedrock types are relevant to forest growth since they affect in a general way the nutrient and moisture characteristics of soil materials which have been derived from them through local weathering or as a result of geologic events such as glaciation, water and wind erosion, transportation and deposition. To provide a ready overview for comparison between northeast China and Ontario, the first author (D.B.) developed a new legend (Table 6) based on recent publications (Academy of Geological Sciences in China 1975, Freeman 1979, Ontario Geological Survey 1980) and drew new summary maps (Fig. 5) of major bedrock distribution patterns.

In Ontario, the central two-thirds of the province consists of Precambrian crystalline bedrock dominated by relatively nutrient-poor granite and granite gneiss resistant to weathering. There are many scattered areas of nutrient-richer ancient metamorphosed basic volcanics in the central and western parts, richer metamorphosed sedimentary rocks (e.g. schist, marble, amphibolite, conglomerate) in the southeast and also some basic intrusives. To the north and south of this Precambrian Shield are large contiguous areas of more easily weatherable fossiliferous Palaeozoic limestone, dolomite, shale and some sandstone.

In northeast China, granitic bedrock occupies large areas but it is not as dominant as in Ontario. Richer basaltic outcrops occur throughout, particularly large complexes in the Changbaishan. Sedimentary bedrock types, mainly of sandstone, shale and some limestone, with low to moderate resistance to weathering occur in all mountains and constitute a major portion of the higher parts of the Daxinganlin. In the other mountains these bedrock types usually occur at lower elevations.

Soil Parent Materials

In Ontario, the composition and distribution of soil materials has resulted from continental land ice which scoured the various bedrock types, transported materials and deposited these in various land forms, either as unsorted stony sandy loam and loam glacial till in ground moraines and drumlins or as water sorted sand and gravel such as in eskers, outwash plains and terminal moraines, or as silt and clay in pro-glacial lakes. Postglacial inundation by the sea and by major lakes also affected the distribution of soil material. Thus, for large areas the petrography of the parent soil materials may differ considerably from the underlying bedrock (Zoltai 1965, Boissonneau 1966, Burger 1967).

Although some mountain glaciers occurred in northeast China during the Pleistocene, continental glaciers did not reach this far south. Consequently, in northeast China the mineralogical composition of the soil materials above about 300 m altitude is fairly closely related to the underlying bedrock type. In-situ weathering of bedrock, even of granites, has yielded fine textured materials from loams to clay loams. The Quaternary alluvial deposits (Fig. 5) which occur mainly below 300 m are composed of clay, clay loam and loam. In the southwestern part of the Northeast Plain are large areas of sand with extensive sand dunes and a small area of deep,

Figure 5. Bedrock groups based on resistance to weathering and petrography. Igneous acid (1) and basic (2); metamorphic acid to calcareous (3); sedimentary Palaeozoic (4) and Mesozoic (5); alluvial Quaternary (6). Details in Table 6.

wind deposited loess. So-called carbonate and sodium pondings occur in the forest steppe portion of the Plain (Institute of Forestry and Soil Science 1980). Some areas, such as parts of the Changbaishan, are covered by pumice of sand and gravel size and finer volcanic ash of fairly recent origin.

Soil Development

Similarities in climate, vegetation and bedrock are reflected in similarities in the types of soil processes in well drained locations, that is, the leaching of iron, aluminum, humus and clay out of the A horizon and their deposition in the B horizon. However, the intensity of these soil processes seems to differ in the two study areas and probably affects soil fertility and potential site productivity.

In Ontario, these leaching processes vary, depending on climate and types of parent material and vegetation to produce podzolic, brunisolic or luvisolic soils (Canada Soil Survey Committee 1978). In the Boreal Forest Region, podzols with well developed Ae and B horizons occur, especially in coarse textured siliceous parent materials; but brunisols — having less pronounced horizons — are very common, especially in the finer textured materials. Where the substratum is calcareous, gray luvisols with a clay enriched B horizon and some organic matter accumulation have developed. To the north, there are extensive poorly drained areas, with considerable organic matter accumulation even on higher ground and permafrost is widespread. In the Mixed Forest Region, higher proportions of deciduous species have led to the development of brunisols, whereas podzols are found mainly under *Pinus* on acid sands and under *Tsuga* on

acid sandy loam. In the mostly calcareous materials of the Deciduous Forest Region, gray-brown luvisols — with a clay enriched B horizon but with good organic matter incorporation (Ah horizon) — are typical.

In northeast China leaching of iron and aluminum is less pronounced. In the Boreal Region of the Daxinganlin, "brown coniferous forest soils" with a humus enriched A, a relatively weakly developed eluvial Ae horizon and an iron enriched B occur in stony clay loams to loams. Above about 1 000 m are "podzolized brown forest soils", with more distinct Ae and B horizons (Inst. Forestry and Soil Science 1980). The area of

Table 6. Bedrock Groups. Numbers 1 through 6 refer to those in the legend of Fig. 5.

Resistant (Igneous)	
Plutonics, intrusives, lavas	
1.	Acid (granite, syenite, gneiss)
2.	Basic (Gabbro, basalt, andesite)
Moderately resistant (Metamorphic)	
Conglomerate, sandstone, shale, schist, crystalline limestone, iron formation	
3.	Acid to moderately calcareous
Moderately to weakly resistant (Sedimentary)	
Fossiliferous, mainly marine limestone, dolomite, shale, sandstone	
4.	Moderately resistant. Palaeozoic
5.	Low to moderately resistant. Mesozoic
Weakly resistant	
6.	Alluvial and marine clay, silt and sand, Quaternary

poorly drained soils is — in comparison with boreal Ontario — much smaller. Some permafrost occurs as "islands" at high elevations. In the Mixed Forest Region, "brown coniferous forest soils" occur only at higher elevations such as in the altitudinal zone of coniferous forests at 1 100–1 800 m of the Changbaishan. Above 1 800 m are shallow "soddy forest soils" comprising an Ah horizon over parent soil material developed under a birch-grass vegetation. Above 2 000 m on the summit near the North Korean border are "mountain tundra soils" of organic matter on top of the mineral soil with little humus incorporation (Ah) (Cheng Bo-rong *et al.* 1986). At lower elevations in this Mixed Forest Region, i.e. in the Changbaishan (below 1100 m) and in the Xianoxingganlin and lower Daxingganlin (below 800 m) are "dark brown forest soils". These soils, developed in basaltic as well as in granitic parent materials, have an Ah horizon high in organic matter (16–20%) over B and C horizons. Permafrost occurs locally in valley peat deposits deeper than 1 m. Further south in the mountains and hills of the Deciduous Forest Region are "brown forest soils" with an Ah horizon containing less (9%) of organic matter and a clay enriched B horizon but no distinct Ae (Cheng Bo-Rong 1981, Song Ta-quan 1986).

The Northeast Plain is characterized by black soils, the chernozems. Further to the west of the Plain and the Daxingganlin, chestnut soils are dominant in the much drier and colder climate.

In general, the profiles of forest soils in northeast China are deeper, probably as a result of the longer period of weathering in the absence of Pleistocene glaciation. Compared with Ontario, the Chinese soils have more humus incorporation (Ah horizon) and a less developed leached horizon (Ae) on comparable parent materials. This may be due to the drier climate and *Larix* rather than *Picea* forests in the Chinese Boreal Forest Region and to the generally higher clay content of the soils in the Chinese Mixed Forest Region. In the Deciduous Forest Regions of both study areas, forest soils have clay enriched B horizons.

Conclusions

The forests of northeast China and Ontario are important timber resources and have many genera in common that include potential commercial tree species, although in China there is a greater number of genera and species. In northeast China, the area occupied by the Mixed Forest Region of tolerant hardwoods and conifers is larger than in Ontario, but the Boreal Forest Region there is smaller.

Drier winters in northeast China favour *Larix* in the boreal forest rather than *Picea* and *Abies*, two genera that occur in more humid climates such as at higher elevations in China and throughout relatively humid northern Ontario. Forest soil profiles in northeast China are generally deeper as a result of long-term in-situ weathering of bedrock in the absence of continental Pleistocene glaciation. Those soils are also less leached, have a higher clay content and better structure, and may therefore be somewhat more fertile than Ontario forest soils.

For an effective exchange with Ontario of silvicultural technology and of plant materials, more detailed information and studies are needed of vegetation dynamics, species' distribution and growth in relation to land characteristics and of related silvics, diseases and insect pests in China. Establishment of seed zones and of site regions, such as recognized for Ontario, would be a useful component of such investigations.

Acknowledgements

We wish to thank Audrey Chui for drafting the maps for publication, G. Pierpoint for his thorough constructive review of an earlier manuscript and D.C.F. Fayle for his editorial comments.

References

- Academy of Geological Sciences in China.** 1975. Geologic map of Asia. Scale 1:5 000 000, Maps #7 and 11. Beijing. (In Chinese with English legend.)
- Arakawa, H.** 1969. Climates of Northern and Eastern Asia. World Survey of Climatology, Vol. 8. Elsevier Publ. Co., Amsterdam.
- Biossonneau, A.N.** 1966. Glacial history of northeastern Ontario. Can. J. Earth Sci. 3: 559–578.
- Borchert, J.R.** 1947. A new map of the climates of China. Assoc. Amer. Geogr. Annals 37: 169–176.
- Burger, D.** 1967. Distribution and origin of parent soil materials in part of the Ottawa and Bonnechere River Valleys, Ontario. Can. J. Earth Sci. 4: 397–411.
- Burger, D.** 1972. Forest site classification in Canada. Mitteil. Vereins forstl. Standortsk. Forstpfl. Zuchtung 21: 20–36.
- Burger, D.** 1976. The concept of ecosystem regions in forest site classification. Proc. 16th IUFRO World Congress (Norway) 1: 213–218.
- Canadian Forestry Service.** 1986. Selected forestry statistics, Canada, 1985. Information Report E-X-37. 161 p.
- Canadian Soil Survey Committee.** 1978. The Canadian System of Soil Classification. Can. Dept. Agric. Publ. 1646. 164 p.
- Chapman, L.J. and D.M. Brown.** 1966. The climate of Canada for agriculture. Can. Dept. Forestry and Rural Develop. ARDA Rep. 3. 24 p.
- Cheng Bo-rong, Xu Guang-shan, Ding Gui-fang, Zhang Yu-hua.** 1981. The main soil groups and their properties of the nature reserve on the northern slope of Changbai Mountain. p. 196–206 In Research of For. Ecosystem 2. Inst. Forestry and Soil Sci., Acad. Sinica. 268 p.
- Freeman, E.B. (Ed.).** 1979. Geological highway map, southern Ontario. Ontario Geological Survey, Map 2441, scale 1:800 000.
- Han, L.F. (Chief Ed.).** 1982. Forestry of Northeastern China. Beijing. 782 p. (In Chinese.)
- Hills, G.A.** 1960. Regional site research. For. Chron. 36: 401–423.
- Hosie, R.C.** 1969. Native Trees of Canada. 7th Ed. Can. For. Serv. 380 p.
- Hou, H.Y. (Chief Ed.)** 1979. The legend to the vegetation map of China, Scale 1:4 000 000. Inst. Botany, Acad. Sinica, Beijing. 12 p.
- Hou, H.Y.** 1983. Vegetation of China with reference to its geographic distribution. Ann. Missouri Bot. Garden 70: 509–549. With map 1: 14 000 000.
- Institute of Forestry and Soil Science.** 1980. Soils of Northeast China. Acad. Sinica, Shenyang. 549 p. With map 1:3 000 000. (In Chinese.)
- Kendrew, W.G.** 1953. The Climate of the Continents. 4th Ed. Clarendon Press, Oxford.
- Lambert, R.S.** 1967. Renewing Nature's Wealth, a Centennial History of the Public Management of Lands, Forests and Wildlife in Ontario, 1763–1967. Ont. Dep. Lands and Forests. 630 p.
- Liou, T.N. (Chief Ed.)** 1955. Illustrated Flora of Woody Plants of Northeastern China. Beijing. 568 p.
- Lu, A.** 1949. The climatic provinces of China. Collected Sci. Papers (Meteorology) Acad. Sinica, Peking 1954: 467–474.
- Ontario Geological Survey.** 1980. Geological highway map, northern Ontario. Ont. Geol. Surv., Map 2440, scale 1:600 000.
- Rowe, J.S.** 1972. Forest Regions of Canada. Can. For. Serv. Dep. Environ. Publ. 1300. 172 p.
- Rowe, J.S.** 1984. Some observations on forestry in China, 1983. For. Chron. 60: 96–100.
- Song Ta-quan.** 1986. On the genesis and characteristics of dark brown and brown forest soils in east Asia (Abstract). Proc. Intern. Symp. of Temperate Forest Ecosystem Management and Environmental Protection, Antu, Jilin Prov., PRC, July 5–12, 1986. In Press.
- Trewartha, G.T.** 1954. An Introduction to Climate. McGraw-Hill Book Co. Inc. New York. 402 p.
- Wu, Z.Y. (Chief Ed.)** 1980. Vegetation of China. Beijing. 1375 p. (In Chinese.)
- Zoltai, S.C.** 1965. Glacial features of the Quetico-Nipigon area, Ontario. Can. J. Earth Sci. 2: 247–269.