Acadia Research Forest: A Brief Introduction to a Living Laboratory

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Abstract

Forest research activities began at the Acadia Research Forest (ARF, then known as the Acadia Forest Experiment Station) in 1933. The ARF was the second in a series of research forests that were established by the Canadian government to develop and demonstrate sustainable forest management practices. It occupies approximately 9000 ha of forest in the Acadian Forest Region near Fredericton, New Brunswick, Canada. Presently, it serves as a living laboratory for the Atlantic Forestry Centre of Natural Resources Canada's Canadian Forest Service. A brief history of its establishment is provided. The climate, site conditions, long-term databases, collaborators, and facilities of the research forest are also described. Examples of past and present research activities are presented, with indications of their application to forest management.

Introduction

Forest research stations and demonstration areas have always been part of forestry practices in North America (Thirgood 1960, Anonymous 1992, Buckman 1992, Adams et al. 2004), but they vary in purpose and size because of different location, ecosystem type, availability and ownership of land, history, and available funds (Deitschman 1971, Place 1992). Before 1939, the only Canadian government agency involved in forest research was the Dominion Forest Service (Place 1992), and thus it was the first agency to establish areas on which to conduct research and demonstrate best forest management practices in Canada. This paper focuses on one of the oldest experimental forest research stations in Canada, the Acadia Research Forest (ARF). It provides: a brief history of the site and its facilities; describes the climate, geology, soils, elevation, drainage, and forest vegetation; discusses past and present research, and their applications; and lists relevant long-term databases, collaborators, research and recreational opportunities, and current contact information.

History

The federal government of Canada established the first experimental forest station at Petawawa, Ontario in 1919 and 1920 (Heaney 1947) amid concern about the exploitation and management of Canada's forest resources. Senior officers of the Forestry Branch of the Dominion Forest Service (forerunner of today's Canadian Forest Service (CFS), Natural Resources Canada) developed concepts and plans for forest experimental stations across Canada in 1931 (Place 1992). These additional forest research stations and the existing one at Petawawa were to demonstrate the premise that "good forest management would lead to greater productivity, sustained yield, and economic benefits"(Place 1992). Taking advantage of unemployment relief projects, the Department of the Interior set up four additional forest experiment stations in 1933 and 1934. The ARF (originally called the Acadia Forest Experimental Station) was the second forest experiment station, and was established near Fredericton, New Brunswick in 1933. The area was selected because it represented large parts of the Acadian Forest Region in New Brunswick and Nova Scotia (Heaney 1947). The other forest experiment stations were located in Valcartier, Quebec; Duck Mountain, Manitoba; and Kanaskis River, Alberta. A fifth forest experiment station was planned, but never established, in British Columbia. However, in 1940, fire destroyed the Duck Mountain station and it was replaced by a new forest experiment station in Manitoba's Riding Mountain National Park.

Administration of the ARF began in 1933 when the Dominion Forest Service began to inventory the forest, although the official establishment date is March 27th, 1934, when Chapter XVI (entitled "An act to enable the establishment of a military training area and a forest experiment station") of the Statutes of New Brunswick was passed (Heaney 1947). The Forestry Branch of the Dominion Forest Service created a Maritimes District, with its office located in Fredericton, NB (Thomson 1955). Initially, the Dominion Forest Service had control of 93 km^2 (36 $miles^2$) or 46% of the 202 km^2 (78 $miles^2$) of provincial land that was transferred to the Dominion of Canada. The remaining 54% of the land base was under the control of the National Department of Defence. In 1935, the area became part of the Burpee Game Management Area. The whole area temporarily came under the authority of the Dominion Forest Service, when the Department of National Defence abandoned its part of the area as a military training area. In 1942, the Province of New Brunswick redefined the boundaries of the research station and, in the final deed of 1945, the area was reduced by 3.1 km^2 to a total area of 91.6 km^2 (35.16 $miles^2$) (Heaney 1947, Thomson 1955).

In 1935, a station superintendent and a forester were hired (Thomson 1955). The number of staff at the ARF has varied since its establishment. At one time, service garages, a cook house, and residences for many of the field staff were in operation. Currently, the research forest is staffed by one Forest Manager, with support from the Atlantic Forestry Centre in Fredericton. The field records from various research studies show that many prominent forest managers, administrators, and researchers in both private industry and government have spent time at the ARF as summer students.

Various organizations have helped develop the infrastructure of the ARF over the years. In cooperation with the Department of National Defence and using labor from relief camps, buildings were constructed at the headquarters complex, and the road system for the research forest was begun in 1934.

During the winters of 1938–1939 and 1939–1940 (Thomson 1955), selected young farmers were offered a 9-week forestry training program. In 1939, a National Forestry Program called "Youth Training Short Courses in Forestry" began. Over the course of 3 months, upward of 60 men were "under canvas" studying and working in a forestry environment.

During the Second World War, the ARF was used by the Department of National Defence to house an internment camp. Many of the silvicultural research experiments, stand improvement projects, and maintenance of facilities were done by prisoners of war. The remnants of the Internment Camp can still be seen at the ARF, and a museum has been established in Minto, NB to house artifacts from the camp for public viewing. Another historic site found in the ARF, along Highway 10, is the site of a settler's cabin dating back to the 1850's.

The early silvicultural research on stand development, forest ecology, response to thinning, partial harvesting methods, nursery practices, reforestation techniques, and site classification were summarised by Thomson (1955). A tree improvement program was formalized and initiated in 1958, and has resulted in many experiments and associated projects with a variety of collaborators. Annual production at the nursery reached a high of 100, 000 seedlings in 1965.In 1987, in response to changing government priorities, the greenhouse and nursery were replaced by new facilities at the Atlantic Forestry Centre in Fredericton. However, the ARF continues to be used as a primary field research facility.

Large-scale timber sales for revenue began in 1962, and continue today. Revenue generated from the sustainable management of the forest resources currently supports the operation of the research forest. Starting in 2004, troops from the 4th Engineering Support Group from nearby Canadian Forces Base Gagetown have been using the ARF as a training area for road and bridge construction. For 20 days in 2004, this elite "horizontal" construction regiment had 120 engineers and support staff prepare for their next mission outside of Canada by improving the infrastructure at the ARF. They returned in 2005 to grade, ditch, and resurface roads, and replace culverts.

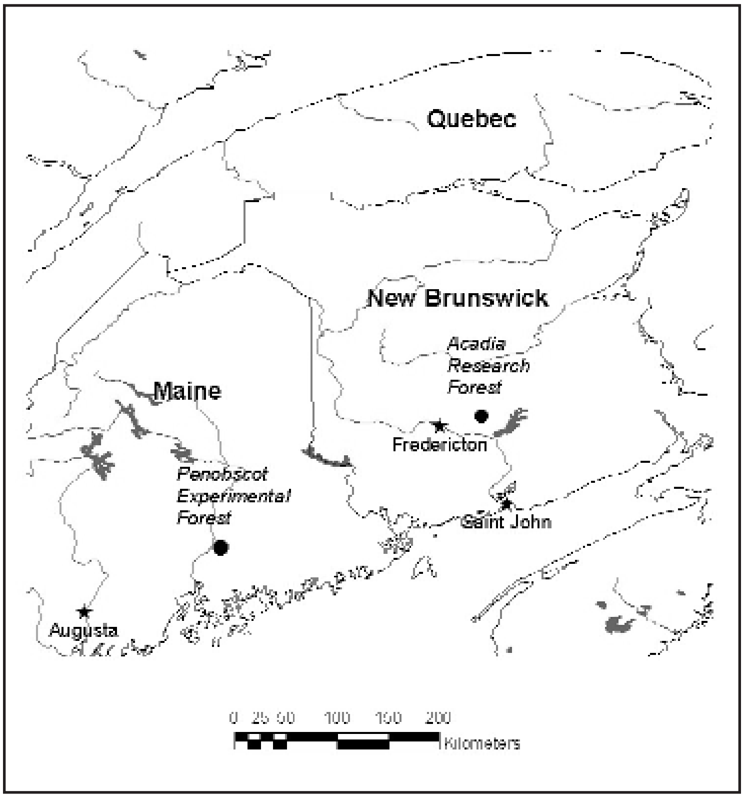

Figure 1. Location of the ARF.

Location

The ARF is located 25 km (16 miles) east of Fredericton along Highway 10 toward Minto in Sunbury County (45059' N, 66022' W, Figs. 1 and 2). It is 16.1 km (10 miles) north of the St. John River, and lies immediately west of Grand Lake, the largest lake in NB (Heaney 1947). The ARF derives its name from an early forest classification (Rowe 1972), the Eastern Lowlands of the Acadian Forest Region. Most of the ARF is located in the Grand Lake Ecodistrict of the Grand Lake Ecoregion of the present forest classification system (Ecological Classication Working Group 2003). The northern portion of the ARF lies in the southern portion of the Bantalor Ecodistrict of the Eastern Lowlands Ecoregion.

Climate

The research forest, situated between a maritime and continental climate, has a moderate climate. Its proximity to Grand Lake, the largest fresh water lake in New Brunswick, produces one of the warmest climates in the provinces for tree growth (Ecological Classification Working Group 2003). The Grand Lake Ecodistrict is characterized by warmer days and less precipitation than the Bantalor Ecodistinct. Mean annual temperature is 4.50 C, with a mean annual high of 18.40 C and a mean annual low of -9.70 C (Rees et al. 1992). Annual precipitation and snowfall averages 1143.5 mm and 267.4 cm respectively. The average frost-free period is 91 days, from early June to early September. Winter winds prevail from the west and northwest at speeds of 16 to 19 kph. In the summer, the wind blows predominantly from the southwest at 8 to 13 kph (Torrance and Associates Landscape Architects Limited 1991). More details on the climate of the research forest can be found in van Groenewoud (1983), Dzikowski et al. (1984), Rees et al. (1992), and Ecological Classification Working Group (2003).

Geology and Soils

Pennsylvanian sedimentary rock of red and gray sandstones of the Upper Carboniferous age underlay the entire site area, with minor components of red and /or gray-brown shale and conglomerates (Strobbe 1940, Rees et al. 1992). The soil is mainly acidic and nutrient poor. Clay or sandy loam textured tills form the surface tills, and red-brown compact clays form the subsoils. Podzolic soils occur in the drier portions of the research forest, whereas gleysolic soils are found in the wetter areas (Crampton 1971).

Elevation and Drainage

The landscape is characterized by a gently undulating terrain that ranges in elevation from 15 to 140 m (50–450 ft.) above sea level. Most of the ARF has an elevation of between 60 to 90 m (200–300 ft). Numerous small streams flow in a southerly direction toward Indian Lake, which is located outside the boundaries of the ARF. There are several bogs within the boundaries because of the horizontal bedrock formation, impermeable subsoils, and impeded drainage. Some of the wet areas are raised bogs and peat bogs.

Area Type	Hectares	Acres	Percentage of Land Base
Forest land	8214	20 288	91
Non-forest land	712	1759	8
Water	69	170	1
Total Land Base	8995	22 217	

Table 1. Land base classification.

Forest Vegetation

The ARF comprises approximately 9,000 ha (22,230 ac), with a cover type composed of softwood, hardwood, and mixedwood forests of the lowland type of the Acadian Forest (Table 1, Fig. 3). The four most common tree species are spruce (*Picea* spp.) at 41%, balsam fir (*Abies balsamea* (L.) Mill.) at 17%, red maple (*Acer rubrum* L.) at 19%, and white birch (*Betula papyrifera* Marsh.) at 9%. Red spruce (*Picea rubens* Sarg.), a characteristic tree species of the Acadian Forest Region, also occurs frequently in the research forest. It often hybridizes with black spruce (*Picea mariana* (Mill.) B.S.P.) in the eastern lowlands of New Brunswick (Manley 1972).

Remnants of the former eastern white pine (*Pinus strobus* L.) stands left after past sawlog harvests occur scattered or in clumps across the landscape. Tolerant hardwood stands tend to occur on the better-drained sites where rich calcareous nutrients leach to the soil surface. The following species also occur either in pure or as mixed-species stands: red pine (*Pinus resinosa* Ait.), white spruce (*Picea glauca (Moench) Voss*), eastern white cedar (*Thuja occidentalis* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), eastern larch (*Larix laricina* (Du Roi) K. Koch), yellow birch (*Betula alleghaniensis* Britton), white birch, grey birch (*Betula populifolia* Marsh.), sugar maple (*Acer saccharum* Marsh.), red maple, American beech (*Fagus grandifolia* Ehrh.), white ash (*Fraxinus americana* L.), black ash (*Fraxinus nigra* Marsh.), trembling aspen (*Populus tremuloides* Michx.), and largetooth aspen (*Populus grandidentata* Michx.). More recently, bur oak (*Quercus macrocarpa* Michx.) has been discovered and a protected area has been established. Past forest development has largely been influenced by fire (Videto 1943, Wein and Moore 1977) and epidemics of such pests as the spruce budworm (*Choristoneura fumiferana* Clemens), forest tent caterpillar (*Malacosoma disstria* Hübner), and eastern larch beetle (*Dendroctonus simplex* LeConte). According to Videto (1943), fire swept across most of the ARF at least five times in the 50 years before 1938. The two major stand-replacing fires occurred approximately between 1882–1885 and in 1895. Evidence suggests that smaller fires occurred in 1903, 1920–1923, and 1932. In recent times, with provincial fire suppression policies, forest and stand development has been influenced more by silvicultural practices than by fire disturbance. However, natural disturbances, such as hurricanes, have influenced stand development in the past. For example, in 1963, Hurricane Ginny blew down 42,500 m^3 of timber, which equated to 3 years' worth of wood for the allowable annual cut for that period.

Past and Present Research, and their Applications

The main purpose of the ARF is to provide an area for forest research, and thus it serves as a living laboratory for the science staff of the Atlantic Forestry Centre. Sustainable forest management is practised and demonstrated on the portion of the forest that is not designated for research. A variety of research programs and experiments have been conducted at the ARF since its establishment in 1933. Research activities at the ARF have covered most of the sectors in forestry at one time or another, responding to the changing research priorities of the Canadian Forest Service over time. Because the list of past and present research activities is extensive, only a brief summary and a few examples will be provided for a range of topics.

Even before the ARF was established, forest research was conducted in the area. Investigations with direct seeding of eastern white pine and white spruce were carried out on recently burned-over areas in 1924 and 1925 (Project M-5). Stands of evenly spaced, mature trees, the results of these reforestation experiments, grace the southwestern corner of the ARF today.

Nursery work began in 1934 to develop appropriate methods to raise seedlings for nursery culture, initiate a reforestation program in the Maritime provinces, and restore poor-quality hardwood stands to productive softwood stands (Thomson 1955). Some of the oldest plantations in the ARF and in the region were the result of nursery practices initiated in the 1930s (McLeod 1956, Webb 1966, Olive 1968, West 1984). Knowledge gained from the early work in nursery culture and plantation establishment has lead to adaptations that are now routine practice in the Atlantic Region and eastern Canada. An example of this research and technology work is the manual for greenhouse grafting of conifers in the Maritimes (Hallett et al. 1981).

Extensive tree-breeding programs and genetically improved stock have been developed at the ARF since the tree improvement program began in the late 1950s. A large number of provenance seed tests, using seed from various geographical locations around the world, are located in the ARF. These provenance tests form the basis for the tree improvement programs in the Atlantic provinces, and these advancements in tree improvement practices have led to implementation of somatic embryogensis techniques in commercial clonal forestry (Klimaszewska et al. 2001, Park 2004). Commercial clonal forestry will have a large impact on artificial reforestation programs in the future, as the technique allows: a) rapid development of clones adapted to potential climate changes, b) the ability to direct genetic diversity and gain, c) consistent production of the same genotypes over time, and d) greater genetic gains from seedlings than is possible with any conventional tree-breeding techniques. Seed orchards are a critical component of tree improvement programs, which in turn support reforestation activities. Research conducted in part at the AFR has developed refined flower induction treatments for operational procedures that are practised routinely throughout Atlantic Canada.

Industry in the Atlantic provinces is showing an increased interest in the practice and benefits of commercial thinning. Some of the older plantations that require thinning to reduce losses from natural mortality are being selected for demonstration and experiments involving commercial thinning. For example, a red pine plantation (M-280) that was established in 1944 has undergone several thinning treatments from the 1960s to the 1980s. More recently, this red pine plantation has been commercially thinned to demonstrate sustainable management for red pine utility poles. Only nine trees of the more than 3000 left after the thinning were damaged, a testament to the skill of the logger involved with the harvest operation. More recently, commercial thinning experiments have been extended to natural stands. In 2004, an experiment was established in a 38-year-old balsam fir stand that had received a precommercial thinning treatment in 1979 (Fullerton 2004). ALPHA Equipment Ltd. supplied a Ponsse Beaver wood processor to conduct the treatments as part of a demonstration. Close cooperation with industrial and provincial collaborators has been one key to the success of the ARF.

Labor from the relief camps (late 1930s) and Internment Camp (early 1940s) began with some of the earliest work on harvesting practices involving improvement cutting and thinning treatments. Starting in 1951, a number of demonstration woodlots were established throughout the Maritime provinces, including one at the ARF. The need to find alternative harvesting methods to replace clearcutting produced several projects in the early 1950s. One of the projects, M-321 (Swift 1997), is providing collaborative regeneration response information to a similar study established in the early 1950s by the USDA Forest Service at the Penobscot Experimental Forest in Maine (Fig. 1). Information from these and other partial harvesting studies will address recent provincial concerns about the impact of harvesting on the forest and stand composition in the Acadian Forest. More recently, a new long-term silvicultural study has been established to assess and monitor the impact of alternative forest harvesting systems on genetic, species, and stand diversity in a mature eastern spruce–balsam fir forest. The alternative harvesting treatments investigated are clearcut and plant red spruce, clearcut with natural regeneration, strip-cut, selective cut, and no harvesting (control).

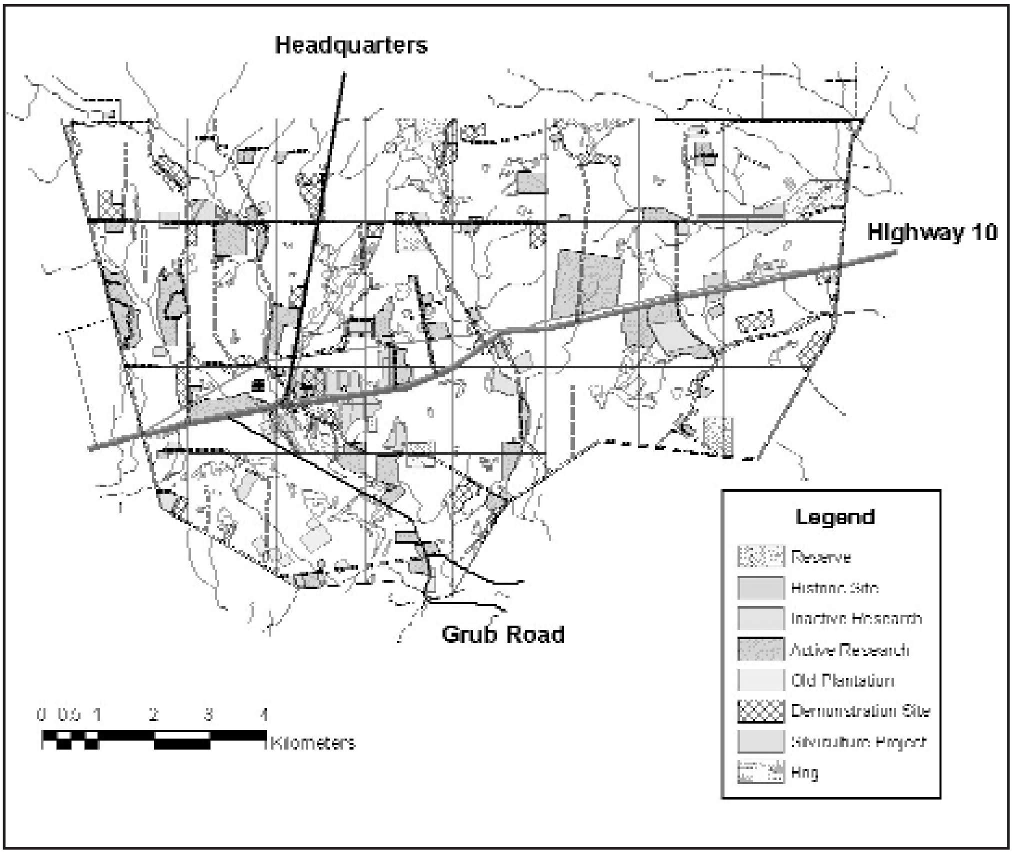

Figure 2. The ARF.

As part of a larger collaborative project for enhancing the establishment of red spruce, the abundance, diversity, and species composition of carabid and staphylinid beetles is being examined in the above-mentioned silvicultural study. Beetles were collected from pit traps that were established in clearcuts, strip-cuts, selective cuts, and residual forest (controls) The occurance and frequency of the different species of beetles will be used as indicator species to assess the impact of the different silvicultural treatments on ecological integrity.

Growth and yield information obtained from over 2800 permanent line plots that were established across the research forest in the 1930s and 1940s was used to develop the STAMAN stand growth model (Vanguard Forest Management Services Ltd. 1993). The model is widely used in New Brunswick and elsewhere as a major tool for forest management planning, and in research for stand-development scenarios (Norfolk 2004). The original purpose of these plots was to provide continuing data for management planning, for assessing forest development, and for growth and yield research.

Many of the existing hardwood research and demonstration sites located at the ARF were the result of an increased emphasis on hardwood management beginning in 1970s. A white ash reforestation project is an example of one of these sites (Lees 1988). Examples of commercial thinning and other partial harvest treatments in hardwood stands also exist at the ARF.

During the last spruce budworm epidemic (1950s to 1970s), the ecology of the pest was studied at two locations in the ARF to obtain more information on population dynamics in order to develop management strategies for control of the insect. Information from this study will assist in the development of control strategies for the next outbreak of this native insect of the eastern spruce–balsam fir forests (Strongman et al. 1997, Lucarottii et al. 2004).

Although fire is another major disturbance factor for forest development in the ARF, limited research has been conducted over the years. A direct seeding study of white spruce on a controlled burn (project M-317) was conducted in 1951 (McLeod 1951). More recently, Thomas (1984) examined conifer regeneration establishment on charred organic matter as part of the former Fire Research Area established in the AFR by the University of New Brunswick.

Air pollution and air quality studies have been conducted in the ARF. For example, mature red spruce branches were fumigated with sulfur dioxide in a manipulative experiment (Meng et al. 1994). Sulfur dioxide was shown to interfere with net photosynthesis, stomatal conductance, and general functions of the spruce foliage. In another experiment, the influence of light was shown to be a significant factor for modeling ozone damage to eastern white pine trees (Cox et al. 1996).

Baseline data on nutrient cycling were obtained from six softwood and three hardwood stand types from a long-term study located in the ARF (Mahendrappa and Kingston 1980). Information from this long-term study is assisting in the development of research and policy models that examine the potential impact of whole-tree harvesting and acid deposition on site productivity for New Brunswick.

Some of the earliest work in Christmas tree culture and management was conducted in the ARF (McLeod 1968, Smith and Newell 1968, Estabrooks 1986, 1987). Results from these studies and other publications have resulted in the production of a Christmas tree grower's manual for Atlantic Canada—the regional standard for this non-timber industry (Anonymous 2002).

Some of the bare-root seedling beds of the former nursery complex at the ARF are being used for experiments in the cultivation of ground hemlock (*Taxus canadensis* Marsh.). Naturally occurring chemicals—taxanes—in the bark, needles, and twigs of ground hemlock are in great demand for the treatment of more than 20 types of cancer and other diseases. To meet current and anticipated demand for taxanes, cultivated ground hemlock crops are needed to prevent over-exploitation of natural populations (Smith and Cameron 2002). Research with ground hemlock may lead to protocols for other potential medical plants.

Long-term Databases

Historical data sets from various projects have been stored in many formats, including original hard copies, computer data sets, and digital copies. A major effort is underway at the Atlantic Forestry Centre to collect and store information in digital format for the research, demonstration, and management activities at the ARF. Identification of legacy research projects is also part of the process.

Collaborators

Collaboration with industry and provincial forestry officials has been a basic tenet of the ARF since its establishment. The area has been used for forest research and demonstration by numerous agencies external to the federal government. The Faculty of Forestry and Environmental Management at the University of New

Brunswick was one of the first educational organizations to use the ARF for teaching forestry and conducting research. The Maritime College of Forest Technology also uses the ARF for forestry instruction and for its Continuing Forestry Education program. The Canadian Wildlife Service used the research forest as an outdoor laboratory during the early years. More recently, researchers associated with the Fundy Model Forest have used various sites in the ARF to support their research objectives for the model forest program in Canada. The New Brunswick Tree Improvement Council has tree improvement experiments, seed orchards, and a breeding garden located in the ARF. Industrial agencies in cooperation with staff from the Atlantic Forestry Centre have established research and demonstration areas for many forestry practices, such as vegetation control methods, alternative harvesting methods, and nursery production of medical plants. A high-resolution depth-to-water table map has been produced for the entire area in cooperation with the Nexfor /Bowater Forest Watershed Research Centre at the University of New Brunswick (Castonguay et al. 2004, Figure 4). Research experiments conducted at the ARF often involve scientists from other countries.

Research and Recreational Opportunities

Each year, several field tours are given to forestry professionals, research scientists, interest groups, and students from around the world by the ARF Forest Manager, study leaders of the different research projects, and others on various topics.

Because the ARF is located in the Burpee Game Management Area, regulations regarding "no hunting" are enforced, but sport fishing is permitted providing provincial regulations are followed. Staff of the ARF are allowed to control pests. Camping, unauthorized harvesting of trees and flora, and open fires are prohibited.

Facilities

Access to the ARF is obtained by Highway 10, a two-lane paved provincial highway that bisects the site in an east–west direction (Fig. 2). Grub Road, another public road, allows access to Indian Lake and properties south of the research station. The entire area of the ARF is served by a grid-like network of ditched and gravelled dirt roads that totals 275 km (171 miles). These roads are not plowed in winter and access is restricted during the spring thaw period.

Since the establishment of a headquarters complex on the north side of Highway 10 in 1934, a number of buildings have been constructed, renovated, and reallocated, and some have been destroyed by fire. Presently, the garage and workshop building also serves as the main administration office. For safety and security reasons, the ARF Forest Manager resides on site. The former headerhouse and greenhouse have been converted to a state-of-the-art forestry spray research wind tunnel complex, a cooperative project between the Canadian Forest Service, the University of New Brunswick, and Forest Protection Limited, with participation of other Spray Efficacy Research Group (SERG) members. The guest cabin that was built in 1936 has recently been renovated for meetings (Figure 5). A number of buildings are used for dry storage of equipment and field supplies. Some of these buildings have historical significance. A wide variety of equipment is available for research purposes, including a back-hoe, farm tractors, snowmobiles, GPS units, repair equipment, etc. The former bare-root seedling beds are available for experiments. Electrical power is also available throughout the headquarters complex.

Over 700 research plantations exist at the ARF. Some of the oldest plantations in the region were established either as operational prescriptions, silvicultural research trials, or tree improvement studies in the

1920s, 1930s, and 1940s. Permanent sample plots in some of these plantations and other silvicultural experiments are more than 50 years old. Eleven ecological reserves exist that cover a wide range of forest cover types (Wein and Jones 1975). Some of the cover types are red pine, black spruce, balsam fir, bur oak, and shade-tolerant and intolerant hardwoods.

Data on relative humidity, temperature, precipitation, barometric pressure, and evaporation have been recorded and collected on a year-round basis since the establishment of the ARF. The weather station is located at the ARF Headquarters.

Conclusions

Although emphasis on specific research subject areas may change over time, the ARF provides a field laboratory for forest research for the staff at the Atlantic Forestry Centre and other organizations. Located only 25 minutes by car from downtown Fredericton, the ARF bridges the gap between practice and theory for the forestry community and the general public. It also demonstrates on a practical scale the application of research results and long-term accepted forestry principles, which could not be observed elsewhere. The practice of forestry in Atlantic Canada is based on the permanent sample plots in the ARF, and the research forest itself is integral to professional forestry in the region.

Acknowledgments

We appreciated the editorial comments and suggestions from Caroline Simpson. We are indebted to those scientists, support staff, and students who have established, measured, and recorded the numerous experiments and demonstrations at the ARF. For without their efforts, the history and character of the ARF would not exist. Some of the major contributors to the establishment and continuity of the ARF are: O. Schierbeck (first superintendent, forester, and silviculture), E.G. Saunders (superintendent), H.G. McGillivary (tree improvement), D.P. Fowler and S.A.M. Manley (tree improvement), B.C. Wile (superintendent and silviculture), J.C. Lees (hardwood research), and Y.S. Park (tree genetics).

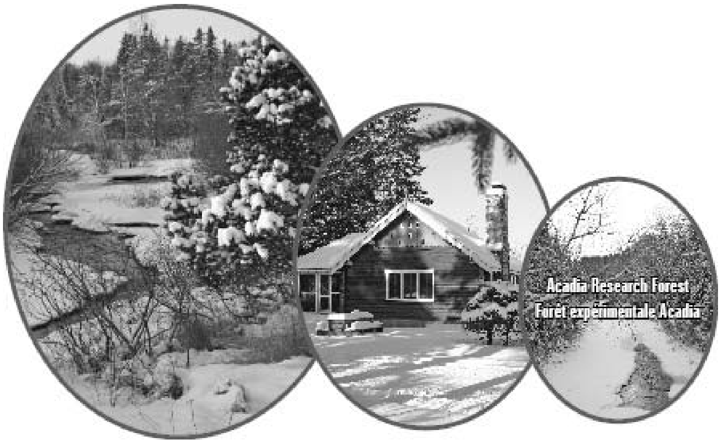

Figure 5. View of the guest cabin that was built in 1936 and surrounding landscape.

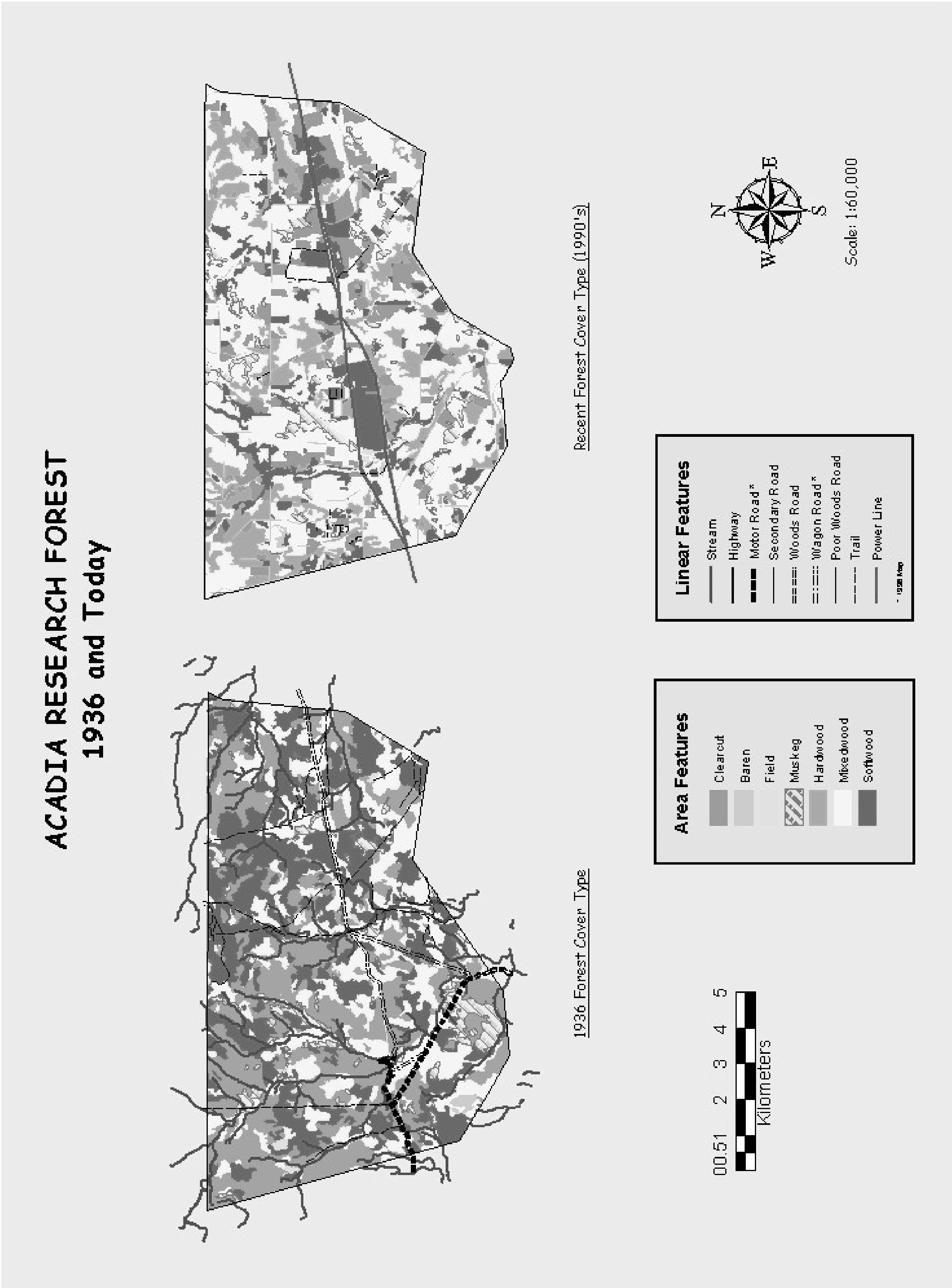

Figure 3. Forest cover changes for the ARF.

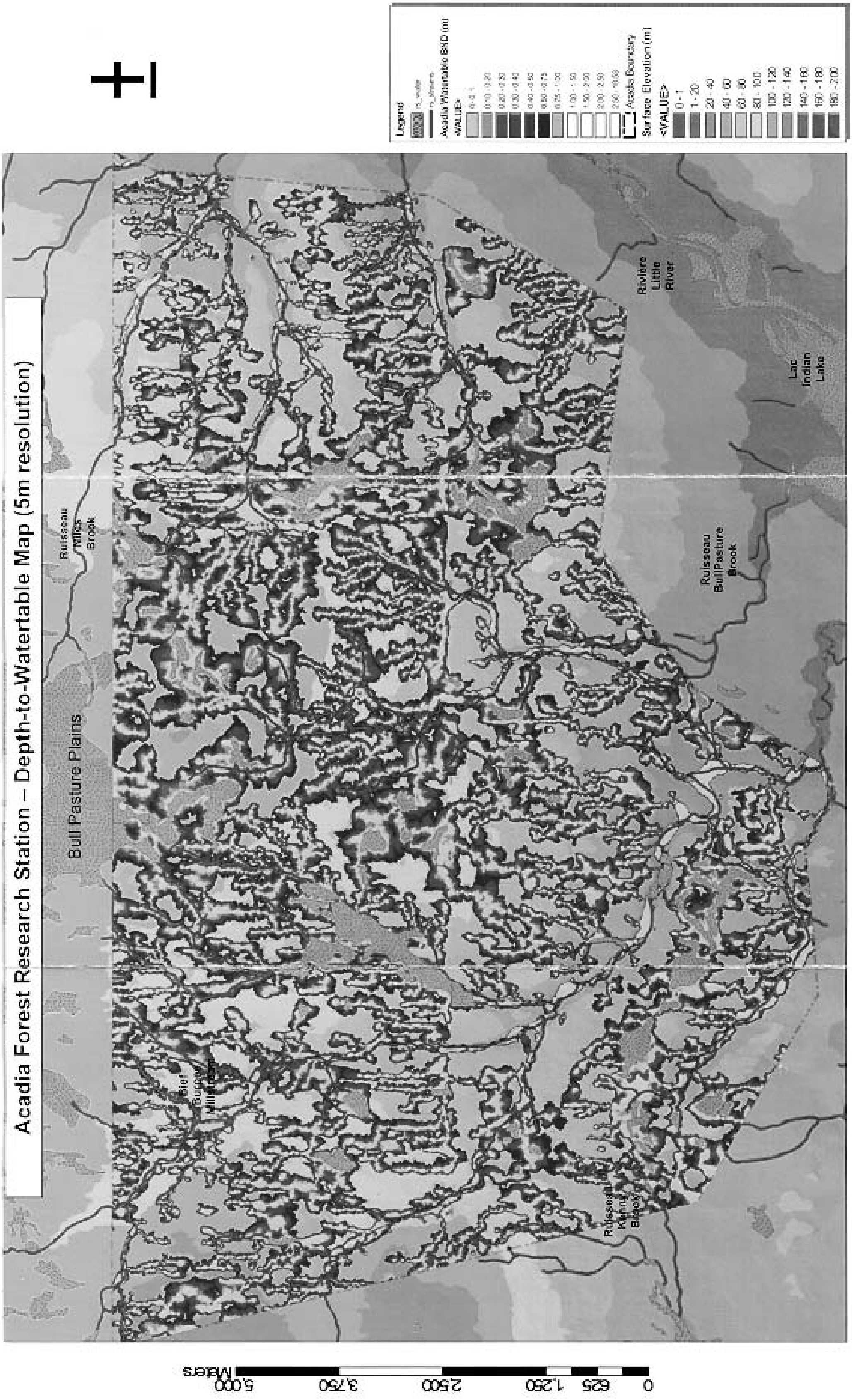

Figure 4. Depth-to-water table map for the ARF.

Contact Information

Additional information can be obtained from the following source:

Natural Resources Canada
Canadian Forest Service - Atlantic Forestry Centre
P.O. Box 4000
Fredericton, New Brunswick
CANADA E3B 5P7
http://www.atl.cfs.nrcan.gc.ca/index-e/who-e/role-e/acadia-e.html
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