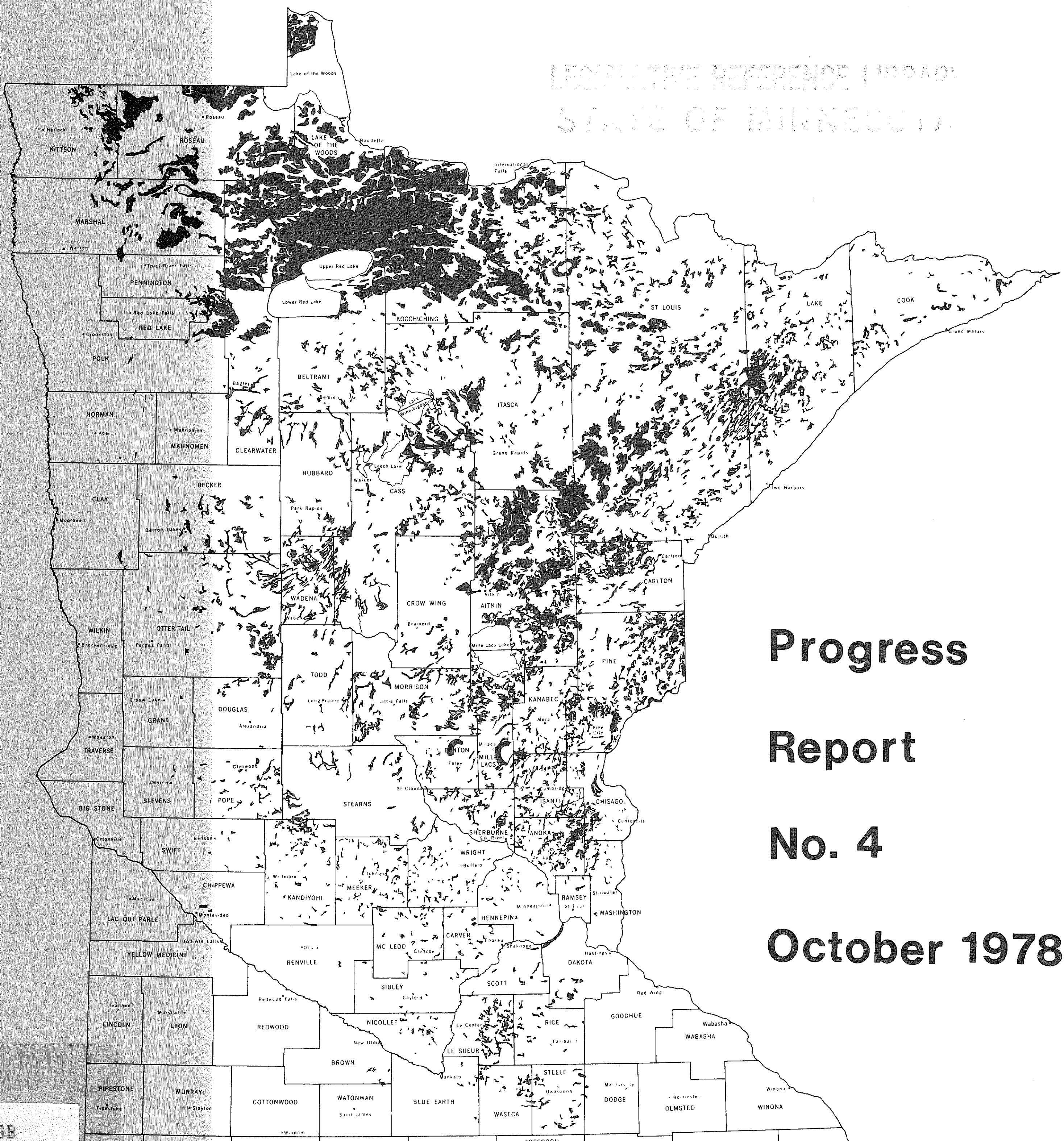
PEAT PROGRAM

1978-1979 BIENNIUM LEGISLATIVE APPROPRIATION



Progress Report No. 4

October 1978

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

MINNESOTA PEAT PROGRAM PROGRESS REPORT

OCTOBER 1978

Submitted by the

Minnesota Department of Natural Resources

Funded by the

Minnesota State Legislature

(1978 - 1979 Biennium)

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PEAT PROGRAM PROGRESS REPORT

1978 - 1979 Biennium Legislative Appropriation

FOREWORD

The studies in this part of the Peat Program are complementary, as well as supplementary, to those funded by the Upper Great Lakes Regional Commission in the Phase II -- Peat Program.

These studies cover such areas as water resources of peatlands, the plants and animals of Minnesota peatlands, forest and agriculture reclamation of peatlands, and the analysis of Minnesota peat for possible industrial chemical uses. The results of these studies will provide information necessary for the formulation of a policy governing the management of state peatlands.

Water Resources of Peatlands (Dr. Ken Brooks, University of Minnesota)

TASKS 1, 2, 3: COMPLETED

TASK 4: REVIEW LITERATURE

Reviewing the literature is a continuing process. A preliminary literature review has been done for the effects of drainage on streamflow. Approximately 60 articles have been reviewed on this subject. Water quality articles are much fewer in number. Searches are continuing in that area.

TASK 5: COLLECT FIELD DATA

The last progress report included a table of preliminary water quality results. Since that time results have been received for mercury, selenium, and arsenic. These are reported below:

Range in Values for Select Metals

Parameter	Toivola Outlet	Corona South	Corona North	Red Lake
Mercury, ppb	<1.3 to 1.9	<1.3 to 1.8	<1.3 to 2.2	<1.3 to 1.5
Selenium, ppb	0 to 2.1	0 to 1.9	0 to 2.1	0 to 1.9
Arsenic, ppb	0 to 4.8	0 to 5.3	0 to 4.7	0 to 1.7

Water balance studies have not been completed at the time this progress report was released.

TASKS 6 - 9: HYDROLOGIC MODELING

These tasks have not been initiated at this time.

The Importance of Peatland Habitats to Small Mammals in Minnesota

(Dr. Elmer Birney, University of Minnesota)

PROGRESS OF STUDY:

During the past quarter (June - September 1978) final field preparations were completed and crews began work on aspects of the peatland small mammal study. Two separate studies were conducted: 1) a second state-wide survey of small mammals in peatlands was organized and executed; and 2) preparatory work was completed and field work was initiated for a long-term study of small mammal populations in a single region.

SECOND SURVEY:

The second state-wide survey, conducted from 26 June through 16 September, returned to all the sites sampled during the first survey (30 August - 15 November 1977). Comparisons of changes in the small mammal densities and species diversities were obtained from this second trapping season. Data from the second survey are now being compiled. Specimen autopsies will be conducted this winter. Preliminary information will be described in the December progress report.

LONG-TERM STUDY:

Most of the effort for this portion of the study was spent building equipment. The unique conditions of peatlands necessitated designing traps that would capture and keep alive the variety of small mammals known to exist in the various peatland habitats. One thousand traps were constructed. In addition to traps, equipment to handle and process small mammals and to gather supplemental information of abiotic and biotic parameters were designed and built.

The Big Falls area, including Koochiching and Pine Island State Forests, was chosen as the location for the long-term study. The area provides a variety of larger peatland habitats, year-round accessability, and adequate lodging. A base of operations for both laboratory and field work has been established at Big Falls.

Following extensive reconnaissance, 10 peatland sites, representing the major peatland habitats of the area, and 2 adjacent non-peat sites were selected. On each of the 12 sites, the small mammal ppopulations will be monitored by live-trapping and marking individuals for later recapture. Rectangular grids, 4 x 10 trap stations each, encompassing 0.4 hectares are being live trapped. Separate from the live-trap grids, areas will be reserved for monitoring aspects of the physical and biological environment, and for removal of small mammals for additional laboratory analysis.

At this time, the live-trap grids and supplemental areas have been established. Logistical work, such as bridging ditches and clearing paths, has been completed, and equipment has been moved to the sites. Work currently is concentrated toward placing the traps, and trapping is expected to begin the 3rd week in September. The vegetation of all sites has been analyzed according to the releve' method used in the state-wide survey and by other peatland studies. Additional quantitative vegetational analysis and phenological work will be conducted later.

FUTURE WORK:

The long-term sites will be monitored for the next year. Immediate emphasis will be placed upon capture, identification, and marking of small mammals in the various sites. Later, laboratory analysis of the state-wide survey specimens will be done.

A third survey will be conducted 25 September - 10 October 1978 to examine the small mammals found in the peatland habitats of the Red Lake area. Ten sites will be surveyed (9 peat, 1 nonpeat). Trapping equipment and techniques will be the same as used in the two previous surveys. Data gathered from this survey will be discussed in the December progress report.

<u>Bird Population Structure and Seasonal Habitat Use as Indicators of Environmental Quality of Peatlands</u> (Dr. Dwain Warner, University of Minnesota)

PERSONNEL:

Ten persons were on the project from April 1 to June 10; eleven persons from June 10 to July 15; ten from July 15 to August 15; and nine from August 15 to September 15. In addition, the principal investigator was in the field nearly continuously from June 15 to September 15.

SCHEDULE OF WORK:

The following flow chart indicates major projects by time since April 1:

April	May	June	July	August	Sept. 15

transect establishment

Netting plot establishment

Woodcock, grouse, owl censusing

Insect collecting, keying

Transect censusing

Netting/bird banding

Plant relevés

Foliage density diversity

Tree, shrub counts

Data compilation

Special Study: Spruce Island/Palm Warbler/Bruce Fall

Flow Chart I

Examples of the amount of time spent on field projects are:

	Total person hrs.
Census transects	960
Bird netting--banding	2190
Plant relevés	132
Foliage Volume and Foliage Height Diversity	676
Tree-shrub Counts and Canopy Cover	298

Each person worked 6 days/week, with some days having as much as 10 work hours.

PROJECT ACCOMPLISHMENTS TO DATE:

The data compilation and analysis phase of this year's study is in progress but only tentative summary statements and a few examples can be included in this quarterly report.

TRANSECT CENSUSES:

Transect censuses identified the species and populations present in the 13 vegetation types sampled this year. The following is a summary of the total number of species found in each type and the number of species considered only casual visitors:

Summary	Open fen	Shrub fen	Open bog	Muskeg	Swamp-conifer-spruce	Swamp-conifer-spruce feathermoss	Poor swamp forest	Swamp conifer Tamarack	Swamp conifer Cedar-spruce	Swamp thicket	Clear-cut	Riparian hardwood	Mixed upland
# of species detected	24	11	5	7	15	30	20	27	41	44	24	31	37
# of casual species	12	5	0	3	7	16	8	12	26	21	12	14	19
# of censuses	9	11	12	11	11	10	12	10	13	11	10	5	11

The following is an example of population densities expressed as singing males per 100 acres that were determined by the transect counts in Muskeg and in Intermediate Spruce vegetation types:

	Muskeg	Intermediate Spruce
Palm Warbler	3.90 ± 1.60	3.33 ± 2.51
Savanna Sparrow	11.11 ± 6.19	
Lincoln's Sparrow	4.14 ± 3.14	
Nashville Warbler		4.96 ± 3.35
Yellow-bellied Flycatcher		4.34 ± 2.45
Myrtle Warbler		1.80 ± 2.43
Junco		6.27 ± 3.21
Chipping Sparrow	.05	4.91 ± 2.16
Connecticut Warbler		1.44 ± 1.44
Hermit Thrush		2.06 ± 1.23
Gray Jay		3.17
Spruce Grouse		2.11
Raven		.82
Cedar Waxwing		.58
Blackburnian Warbler		.38
Olive-sided Flycatcher		.28
Robin		.19
Blue Jay		.19
Cowbird	.19	.14
Solitary Vireo		.05
Sharp-tailed Grouse	4.71	
Brewer's Blackbird	.19	
Tree Swallow	.86	

From these transect data and the vegetation analyses (see below) population figures are being determined as well as such factors as Bird Species Diversity in relation to vegetation features (i.e. Foliage Height Diversity, Foliage Volume, etc.).

Transect data are also being used to determine the various reproductive time schedules among the bird species and their total time utilization of the various habitats.

An example of a very short term user of bog habitats was the very sudden disappearance of the Bobolink from scrub fen, open fen, and open bog after the first broods were raised. The Brewer's Blackbird did the same.

NETTING-BANDING:

Netting was done in the 4 netting plots on different schedules, depending on numbers of birds captured and the special needs for information. The total of 1600 Size 0 bands placed on the smallest birds captured gives some indication of the scope of netting activity, as does the figure 2190 person hours devoted to banding operations.

One finding of significance that has come out of the banding and color marking program is that the Palm Warbler breeds in rather high numbers in the spruce islands and this year, at least, raised 2 broods (i.e. a large percentage of pairs in Bruce Fall's special study area were double brooded).

There are many other kinds of data that may, after further study, show some new and significant features.

VEGETATION ANALYSES:

A. Plant relevés - Thirty-six relevés were done in all but the Riparian (Transect) habitat along the Rapid River. (This transect, 8,000' long, was established in late June. Vegetation studies will be done there next season).

B. Foilage Volume and Foliage Height Diversity - These measurements (based on R. MacArthur's system) were made along all transects except the Riparian Transect.

C. Tree-shrub counts - These measurements have been done on all but 9 of the 26 transects. These will be done this fall or next season.

INSECT COLLECTIONS:

Beginning in mid-June, insects were collected along selected transects in an attempt to obtain some quantity and kind (Family and Genus) of insects that were available as food for birds. These data are now in the process of final analysis.

SPECIAL NOTES:

Sharp-tailed Grouse - This species has a "muskeg population" breeding on the peatlands of the Red Lake Bog. Broods were found in several of the vegetation types; and in late summer broods showed high survival figures.

Palm Warbler - As reported above, this species was double brooded in the spruce island study area this year. This is probably the first case of a northern warbler demonstrated to raise 2 broods in one season.

Utilization of Minnesota Peatland Habitats by Large Mammals and Birds (Dr. John Tester, University of Minnesota)

From 1 July to 30 September 1978, field work in the Hubbard County study area included regular monitoring of radio-tagged animals, continued trapping and tagging efforts, and frequent animal track censusing. In addition, efforts were made to begin some phases of data analysis.

The number of radio-tagged animals regularly monitored this quarter varied from 17 to 13. Two hares, two ruffed grouse, and one spruce grouse were lost due to predation or transmitter failure. As a result, the current total of animals monitored includes four ruffed grouse, three spruce grouse, five hares, and two deer.

Track censusing has provided an additional source of information on deer movements through various habitats. Tracks were censused 17 times in this quarter, using a two mile stretch of graded road which cuts through the center of the study area. Tabulations are made of the numbers of times tracks are observed to enter or exit from each habitat type available. This data, like the radio-location data, will be submitted to statistical testing to provide more information on the subject of habitat selection.

In addition to censusing road tracks, careful records were made of other types of information on unmarked animals. In this quarter these records include 22 sightings of hare, 30 of spruce grouse (not counting young of the three radio-marked hens), 22 of ruffed grouse, and 15 of deer.

As in previous periods, sighting and sign records have been kept for many species other than those in the telemetry program. Among the mammals observed this quarter were black bear, porcupine, woodchuck, and striped skunk. Tracks, droppings, and/or vocalizations were recorded for coyote, porcupine, bear, skunk, raccoon, fox, and weasel. Avian species observed included goshawk, sharp-shinned hawk, red-tailed hawk, broad-winged hawk, great horned owl, saw-whet owl, and woodcock. Among the reptiles and amphibians recorded were red-bellied and garter snakes, leopard frog, Jefferson (?) salamander and tiger salamander.

Trapping efforts this quarter were primarily directed toward deer, hare, and spruce grouse. Throughout the summer a salt-soil mixture was used to attract deer to bait sites. Although deer utilized some of these sites, the animals never entered baited traps. Seventy-nine trap nights resulted in no captures.

Hare trapping was attempted in two habitat types not previously sampled. Forty-two trap nights resulted in one capture. Due to the recent loss of two radio-tagged hares, trapping will probably resume in early October.

Broods of radio-tagged spruce grouse hens were observed regularly in hopes of noosing and tagging some of the young when they reached adult size. Thus far, however, young have not been located in situations in which the noosing technique could be used safely. Efforts to capture and radio-tag grouse will continue.

Aside from field work, a great deal of effort has been made to initiate some phases of data analysis. Several months of radiolocation data on two spruce grouse hens were used to test various statistical approaches. Progress was made in this direction that should be useful in analyzing data on all of the radio-tagged animals.

The Relationship of Amphibians and Reptiles to Peatland Habitats in Minnesota (Dr. Philip Regal, University of Minnesota)

The first field season of the amphibian and reptile peatlands project is drawing to a close. The planned termination date is around September 30 (the date upon which the lease on the project truck expires). This third progress report will be brief. The important December 15 report will cover the first seasons's data as completely as possible given the time constraints involved.

The activities of the second half of the field season consisted essentially of a continuation of the activities outlined in the June 15 report. The main amphibian breeding period ended around June 30, hence breeding ecology experiments and frog call surveys were terminated. Drift fence trapping, water chemistry sampling and collecting surveys to the Pine Island, Waskish and Lost River areas have continued. No new species were found the second half of the season to add to the to the first given in the June 15 report.

New activities have included relevès. These were done at the drift fence locations. These will give a clear picture of the habitat type at the major collecting sites. Also an experiment to determine the tolerance of metamorphosed amphibians to bog water (acidic, highly colored, low ionic content) as compared to "normal" water was initiated. The experiment is in progress and will be described in the December 15 report.

Preparations have now begun to close out the season. Drift fences will be removed the last week of September. Drift fence sites for the second field season have been chosen and initial preparation of these sites has begun.

The second part of the field season has gone well. Substantial and interesting data on the peatlands herpetofauna has continued to be amassed. With the close of the first field season this month detailed analysis of this data will begin.

<u>Agricultural Reclamation of Peatlands</u> (Dr. Rouse Farnham, <u>University of Minnesota)</u>

The first week of this period (July 3 through 7) was spent weeding and cultivating each vegetable plot by hand. The vegetables were prepared for optimum growing conditions; such practices include raising onion plants to expose the crowns and hoeing to form raised rows on emerged plants. The following week (July 10-14) work continued on the sump area of the Field 8 excavation and the 100 gpm (gallon per minute) pump was installed. This pump was stationed near the permanent steel cistern submerged in the sump area and discharged into the N-S drainage ditches. The fence surrounding the garden was completed and the spinach, which germinated poorly, was reseeded. This reseeding was continued the following week (July 24-28). The weeding and other cultivating to improve tilth, which had previously been done by hand, was greatly improved with the arrival of the garden tiller. The entire weeding time was then reduced by two-thirds and the depth of till increased to about eight inches. Such continuous use is necessary to prepare a sufficient texture and to improve the physical properties that the crops require.

The onion plants which were originally planted shallow seem to have settled into the tilled surface peat due to the regular rainfall. Thus plants of about ½ inch diameter were raised. It was anticipated that this practice would have to be repeated; however, it may be detrimental to the root system and affect the quality of the vegetable due to a greenish crown. During this week the pea blossoms appeared and were very abundant indicating a good crop. Stakes were set with twine at a height of fifteen inches down the length of the pea rows to act as a climbing trellis. The plants responded overnight as the tendrils attached to the twine bearing the plant and blossoms upright.

This week (July 31-August 4) a weekly weeding-cultivating procedure continued. Intervals between the individual plants were still weeded by hand, however most inter-row lanes were done with the tiller. The broccoli was thinned, without wasting any plants, transplanting any removed to thinner areas. Thus, a general spacing of 6-9 inches on center was established. The carrots were also thinned, despite some opinions that the loose tilth of the peat allowed for heavy seedings. Growing conditions are optimized by proper populations per row, and thus intensive gardening requires such practices. With only maintenance practices remaining in the vegetable areas field preparation of the grain-grass plots began. This area, the width (ditch to ditch) of Field 7W and 120 feet deep, south of the garden plots was sprayed with a Round-Up solution required for quack-grass eradication. After the vegetative portions of the weeds were noticeably dead, the area was mowed. The area was contoured using the caterpillar and back-blading to the center, creating a crowned field. This convex surface was again rotovated successively and then rolled to reveal any low regions that needed to be filled. This procedure was repeated until the surface was contoured appropriately. A land-levelling machine is more suitable for this practice, though not available. The following week (August 7-11) furrows were hoed beside nitrate fertilizer was side-dressed to each vegetable crop. Thinning and blocking practices continued as did the weekly cultivation-weeding procedure. During this week the Legislative Committee of Minnesota Resources visited and toured the project. Hidden by the large foliage bean blossoms became apparent and flowered abundantly. A weekly dusting of sevin and rotenone was applied to the cold crops to prevent excessive pest damage. This dusting was performed again early in the next week (August 14-18) as the cabbage butterfly larvae became apparent. Rain and heavy dew tends to wash off the applications. Weeding-cultivation-thinning practices continued on the weekly basis. The vegetables were evaluated and results recorded (refer to Table A). The grain-grass plots were laid out (refer to Figure A). The individual beds were raised and fertilized with 300#/A 6-24-24 each. Following the fertilizer application the beds were hand-rolled, seeded and lightly raked to insure seed-soil contact. Each grass crop was seeded at a rate of 12 ounces/plot, the grains considerably more (approximately two pounds/plot). This seeding rate is considered excessive although it insures sufficient germination. At the end of this week the first pea harvest was completed, yielding 10 quarts of shelled peas from 360 feet of rows. The quality was excellent and the yield seemed phenomenal in respect to the size of the plants. The cabbage began to head and effects of the side-dressed fertilizer was very evident. This (August 21-25) was spent entirely in the garden area. The grains germinated within five days. General maintenance including cultivation, weeding and dusting continued. The first few cauliflower plants were tied to blanch the emergent heads. The potato plants were hilled to facilitate good tuber development. All of the cold crops indicated some measure of head emergence by this time. An entire green-up due to the side-dressing was easily observable. The final week of August (28 to September 1) was also spent in the garden area. Maintenance practices continued and the weeds converging on the fence were scythed. Potato blossoms were apparent though unopened. The broccoli plants were heading rapidly, promising an abundant yield. A second harvest of the peas was begun, yielding an additional 2-3 quarts of shelled peas. The supply of dust chemicals was exhausted and a liquid sevin emulsion was then used.

The first week of this month (September 4-8) was spent harvesting and removing spent plants. The pea crop was entirely harvested, the plants removed as well as the stakes and twine, the plot was tilled. The lettuce which appeared to be a leaf variety was browning rapidly and bolting. This crop had been spot-harvested periodically for about two weeks and now a few, soft heads were developing. The plot was afflicted with a wet rot and was removed (east plot only) and cultivated. The refuse pile was welcomed by the local deer family. The first harvest of green beans yielded in excess of 1.5 bushels from the east plots alone. The potential bean yield is shown in Table D. The quality was superb, sweet, and tender. Late in the week a light frost nipped the bean foliage, though was not serious. The first five heads of cauliflower tied were harvested. These heads averaged 5½ inches in diameter and were of saleable quality. The pest however were devouring much of the cold crop foliage despite two and three sevin sprayings. An additional twelve cauliflower plants were tied. The project was photographed during this week and some new potatoes were harvested. The second week (September 11-15) was plagued by inclement weather, restricting outdoor activity. The garden was cultivated and weeded. Spraying seemed futile as the rain merely washed the chemical off. A second harvest of the beans yielded about 1/8 bushel. These bean harvests were selective pertaining to choice size of the vegetable. Also the first heads of cabbage were cut, these averaged six inches in diameter. Several heads of cauliflower and the first broccoli were also cut. The final week of this report (September 18-22) was spent sampling soil, evaluating the growth, excavation preparations and other garden work. The south-adjacent area to the grain-grass plots to a depth of an additional 200 feet was sampled. This area is to be eradicated of weeds, and contoured for next season. The results of the second vegetable evaluation are available in Table B. Table C shows the evaluation of the grain-grass crops. The area around the grain-grass plots was rotovated. The two 10x100 foot grass plots in the excavation area were laid-out and bed preparation began. This area is inundated with undecomposed tree roots and stumps which are being removed. Further bed preparation, fertilizer application and seeding will be accomplished shortly. The excavation area continued to be pumped in lieu of permanent drain systems. The ditches (N-S) affecting the agricultural project are being renovated and the major ditching contract is being processed. The first major frost occurred the night of 9/20-21 followed by another severe frost of 9/21-22. The potatoes were burnt as well as the beans. The beans were finally harvested yielding ½ bushel, the plants removed, and these plots tilled. The crops remaining are the potatoes, caluliflower, cabbage, onions, heading lettuce (west side), reseeded spinach and carrots.

TABLE-A

AGRICULTURAL PEAT PROJECT - FIELD 7W
VEGETABLE PLOTS 8/17/78

Area	Crop	Germination	Height(inches)	Vigor(1-5)	Comments-Remarks
East Plots	carrots	G(good)	11	5	
	spinach	P(poor)	7-22	3	reseeded, three repititions
	lettuce	E(excellent)	6-8	5	
	brocolli	F(fair)	6-U	3	slight pest infestation
	peas	G	23	3	abundant, large (2" avg.) pods, well-filled
	beans	G	11	4	N chlorotic
	onions	P	9-15	3	leaves lacking
	cabbage	F	8	3	pests evident
	cauliflower	F	4-9	3	pests evident
	potatoes	G	10-15	3	slow emergence, small plants
West Plots	carrots	G	9	4	
	spinach	P	2-10	2	reseeded, three repititions
	lettuce	E	5	4	
	brocolli	F	7-10	3	general nutrient deficiencies, pests
	peas	P	4-9	1	few pods, small in size and fill, dwarfed
	beans	P	6	2	N chlorotic fewer blossoms
	onions	P	9-18	3	leaves lacking
	cabbage	F	3-10	2	general deficiencies
	cauliflower	F	3-12	2	general deficiencies
	potatoes	F	6-16	3	small plants

(* note: West plots much wetter)

TABLE-B

AGRICULTURAL PEAT PROJECT - FIELD 7W

VEGETABLE PLOTS 9/19/78

AREA	CROP	HEIGHT(inches)	VIGOR(1-5)	COMMENTS - REMARKS
East Plots	carrots	18-20	4-5	4½-6" long, 1¼ - 1½" diameter, multiple tap roots
	spinach	20-32	3-4	variable maturation, headed
	brocolli	18-28	4-5	4-8" heads, reheading from laterals where already cut
	beans	13-18	4	3-6" long beans, stunted plants
	onions	18-24	4-5	1-1½" diameter
	cabbage	12-14	4-5	4-7" diameter heads, pests
	cauliflower	14-22	4-5	3-6" diameter heads, pests
	potatoes	15-24	4	4 to russet-type tubers, 1½-1" diameter
West Plots	carrots	15-19	4-5	4-6" long, 1-1½" diameter, multiple tap roots
	spinach	10-15	4	more favorable crop, later reseeded
	lettuce	12-18	3	some soft heads, bolting, bitter
	brocolli	15-26	4-5	3-7" diameter heads, reheading where cut, pests
	beans	10-14	3-4	severely stunted, more mature beans
	onions	12-24	4	3/4-1½" diameter
	cabbage	12-14	4	4-6" diameter heads, some splitting, pests
	cauliflower	12-14	4	3-5" diameter heads, pest
	potatoes	12-17	4	4 to 8 russet-type tubers, 1-1½" diameter

Table-C

AGRICULTURAL PEAT PROJECT - FIELD 7W
GRAIN - GRASS PLOTS 9/19/78

Crop	Height(inches)	Vigor(1-5)	Comments-Remarks
Era Spring Wheat	10	4	generally 90%$^+$ germination and rapid
Lyon Oats	15	4	growth of all grains and grasses,
Larker Barley	12	4	forming a dense crop growth.
Park Kentucky Bluegrass	2	4	minimal weed occurrance.
Newport Kentucky Bluegrass	3	4	necessity of N top dress evident on
Merion Kentucky Bluegrass	1½	3	grasses and possible a heavier
Nugget Kentucky Bluegrass	2	4	N initially applied.
Alden Reed Canarygrass	10	4-5	some problem due to inept drainage, possibly
Frontier Reed Canarygrass	5	4	linked to partial N deficiency.
NK-200 Perennial Ryegrass	4	4	variable bluegrass color and texture.

Table-D - POTENTIAL PER ACRE BEAN HARVEST

based on actual 5 pound yield (single harvest) green beans per 10 feet of row.

Plot Size:

104' wide x 208' long = 21,632 square foot area.

Row Size:

1' wide x 10' long = 10 square foot area.

Yield:

5 pounds/10 square foot row.

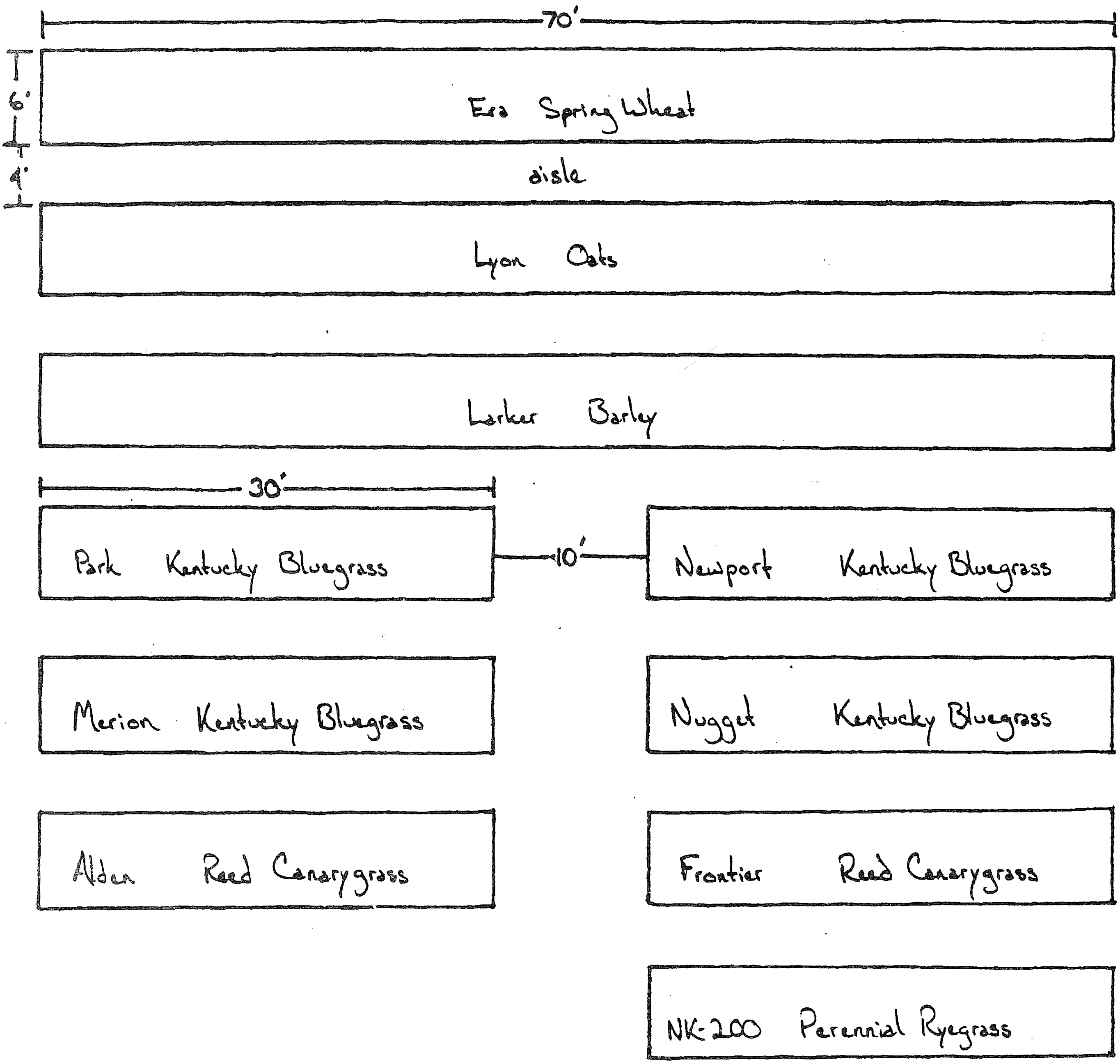
Potential:

2,163 x 5 = 10,815 pounds/Acre or in excess of 5 tons/acre

N

FIGURE - ~~(Type A)~~ A

AGRICULTURAL PEAT PROJECT
FIELD 7W GRAIN-GRASS PLOTS



Forestry Reclamation of Peatlands (Dr. Edwin White, University of Minnesota)

UNMINED PEATLANDS:

All plots were tallied for tree survival in late September 1978 by species, fertilizer treatment and replications. Of the five species tested, hybrid poplar exhibited the greatest mortality, especially on the fertilized plots. However, overall survival was acceptable. The somewhat greater mortality of the hybrid poplar may have been caused by the increased competition from grasses that responded to the fertilizers applied or possibly there may have been some damage from the herbicide used to control the quack grass. Survival data is attached.

LITERATURE REVIEW:

Attached is a paper summarizing selected literature concerning utilization of peatlands for wood production.

SECONDARY SUCCESSION ON DISTURBED PEATLANDS:

Nine areas that have been harvested for peat over the past five to forty years have been statistically sampled to ascertain secondary succession as a means of natural reclamation of disturbed peatlands. Areas sampled are near Cromwell, Hill City, Central Lakes, Zim and Floodwood, Minnesota. Sampling included the following parameters: (a) peat-bulk density, pH, nutrients conductivity, decomposition, (b) water samples, (c) vegetation - % cover, density and frequency by species and life form groups.

All samples and data are currently being processed in the laboratory.

GREENHOUSE - LABORATORY STUDY:

Preliminary plans have been developed to install a greenhouse-laboratory study testing peat type, drainage and fertilization effects on early growth and survival of several tree species. Surface peat samples are being collected from Fens, Tovoila and Cromwell bogs and potted in containers in the greenhouse. Fertilizers will be applied, pots seeded with selected tree species and treatment effects evaluated. The study is being duplicated with deep peat samples collected from the last foot of peat over the mineral substratum.

This study will allow better control of factors that make field experimentation relatively difficult. Plans are to field test the results of the greenhouse study.

Seedling Survival, Zim, Minnesota

September 1978 fertilized plots

Replication	Species	Fertilizer 0	N	P	K	NP	NK	PK	NPK
		% Survival							
I	White Spruce	100	100	100	100	100	100	100	100
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	94	100	100	100	63	94	100	81
	Norway Spruce	100	94	100	100	100	94	100	100
	Hybrid Poplar	75	81	63	94	81	75	75	63
II	White Spruce	100	100	100	100	100	100	100	100
	Black Spruce	100	100	100	100	100	94	100	100
	Scots Pine	100	100	—	100	94	94	100	100
	Norway Spruce	100	100	94/100	100	94	100	100	100
	Hybrid Poplar	94	88	100	94	88	100	100	31
III	White Spruce	94	100	100	100	100	94	100/100	100
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	100	100	100	100	94	94	—	100
	Norway Spruce	100	100	100	100	63	100	100	100
	Hybrid Poplar	94	100	100	81	100	94	94	100
Average	White Spruce	98	100	100	100	100	98	100	100
	Black Spruce	100	100	100	100	100	98	100	100
	Scots Pine	98	100	100		84	96	100	94
	Norway Spruce	100	98	99		87	98	100	100
	Hybrid Poplar	88	90	88	90	90	90	90	65

Seedling Survival, Zim, Minnesota

September 1978 non-fertilized plots

Replication	Species	Row 1	2	3	4	5	6	7	8
		% Survival							
I	White Spruce	100	100	100	94	100	94	100	100
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	100	100	100	94	100	94	94	94
	Norway Spruce	100	100	100	100	100	100	100	100
	Hybrid Poplar	94	94	100	100	100	94	94	88
II	White Spruce	100	100	100	100	100	100	100	100
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	100	100	100	100	100	100	100	100
	Norway Spruce	100	100	100	100	100	100	100	100
	Hybrid Poplar	100	100	100	100	100	100	100	88
III	White Spruce	100	100	100	100	100	94	100	94
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	100	100	88	100	100	100	100	94
	Norway Spruce	100	100	100	100	100	100	100	100
	Hybrid Poplar	100	100	100	100	100	100	81	100
Average	White Spruce	100	100	100	98	100	96	100	98
	Black Spruce	100	100	100	100	100	100	100	100
	Scots Pine	100	100	96	98	100	98	98	96
	Norway Spruce	100	100	100	100	100	100	100	100
	Hybrid Poplar	98	98	100	100	100	98	92	92

UTILIZATION OF PEATLANDS FOR WOOD PRODUCTION

by

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Abstract

UTILIZATION OF PEATLANDS FOR WOOD PRODUCTION:
With forest resources being projected to be in short supply in the next century, consideration is being given to intensive peatlands forestry in the United States. This paper evaluates the parameters that will need consideration for afforestation and reforestation of America's peatlands. Reviewed are the general characteristics of organic soils, techniques to determine peatlands suitability for forest improvement purposes, and silvicultural considerations for peatlands forestry. Techniques considered in the determination of desirable peatlands include: a) plant communities, b) physical and chemical properties, and c) drainability. Silvicultural considerations include: a) drainage, b) fertilization, and c) plant site interactions on drained and fertilized peatlands.

INTRODUCTION:

To meet the increasing demand for wood products in the United States on the ever decreasing land base allotted for forest production, intensive forest management practices have become essential. These intensive practices include such management procedures as artificial regeneration of forest sites, the utilization of genetically improved seedlings. and stand thinnings to enhance growth of desirable trees. Also included in intensive forestry is the enhancement of site productivity on lands considered poor for forest growth. Traditionally this enhancement has included fertilization and or drainage of mineral soils. However, with forest resources being projected to be in short supply by the year 2020 (Anonymous, 1972), the organic soils (peatlands) of the United States are now being considered for forestry purposes. Although the utilization of peatlands for wood production has been done successfully in Scandinavia, little has been done in the United States to test the feasibility of such operations. It will therefore be the purpose of this paper to evaluate the parameters that will need consideration for afforestation and reforestation of peatlands in the United States.

Before considering the factors associated with peatlands forestry, a brief discussion of peatlands themselves will be made.

ORGANIC SOILS:

Brady (1974) provides a general overview of the physical and chemical properties of organic soils as well as a review of their classification, origin, development and distribution. The following brief discussion of organic soils will be based on factors noted by Brady (1974) with supplementation from Moore and Bellamy (1974), and Heikurainen (1975).

ORIGIN, DEVELOPMENT AND DISTRIBUTION:

Moore and Bellamy (1974, page VII) define peatlands as "unbalanced systems in which the rate of production of organic materials by living organisms exceeds the rate at which these compounds are respired and degraded." The accumulation resulting from the undergraded portion of organic matter forms peat or organic soils. In the United States, the formation of swamps and bogs, where peatlands develop, are associated with high water tables that were formed by raised ocean levels, as in Florida or Louisiana, or impeded drainage in glaciated regions, as in the Lakes States. These flooded areas are normally characterized by an abundance of plant materials which provide a steady source of organic matter. The raised water tables prevent air from reaching the plant materials after death, resulting in the absence of rapid oxidation. Breakdown does occur by certain fungi, aquatic animals, algae and anaerobic bacteria, but decay is at a slower rate than accumulation.

Although water levels which prevent rapid oxidation of plant organic matter are the major reasons for the development of peat, cooler climates where decay rates are slower, also play a role in rates of peat accumulation.

As the accumulation of organic matter increases in swamps and bogs, the plant communities living in the ponded areas tend to change. These changes often progress from reeds and sedges in early stages of accumulation to woody vegetation such as shrubs and trees in later stages. The type of plant material comprising peat plays a role not only in its classification, but also in the type of utilization the peat can experience. These classification and utilization factors will be considered in more detail later in this paper.

The distribution of peat in the United States covers the non-glacial regions as well as the glacial ones. Non-glaciated states having sizable organic deposits include: Louisiana, (1,200,000 hectares), Florida, (>787,000 hectares), California, (118,000 hectares) and North Carolina. Glaciated states, which contain over 75 percent of the peat deposits in the mainland include: Minnesota, Wisconsin, Michigan (4,800,000 hectares combined); Washington (787,000 hectares); Indiana, Massachusetts, New York, New Jersey (approximately 158,000 hectares each); with smaller deposits in Iowa, Illinois, and Maine (Brady 1974). In terms of world distribution of peatland, Heikurainen (1975) has noted the follwoing (in millions of hectares); USSR, 245; Canada, 230; Alaska, 50; Finland, 10; USA (-Alaska), 10; Sweden, 7; Norway, 3; Great Britain, 3; Germany and France, 2; Poland, 2; and Ireland 1.

CHEMICAL PROPERTIES:

Although the chemical properties of peatlands are varied, the following factors are consistent for most organic soils. Calcium content is usually high, being related to the high lime content of the water that enters peatlands through subsurface flow. Although the calcium content is high, the cation adsorption capacity of organic soils is so great that low base saturations are often present. Unless influenced by underlying bog lime or marl, organic soils are acidic ($pH \sim 5.5$) with highly acidic conditions ($pH < 5.5$) often occurring. In terms of macronutrients, nitrogen, calcium and sulfur are relatively abundant, with phosphorus, potassium and magnesium considered at low levels. The levels of micronutrients will vary with different peat locations. Deficiencies have been noted for copper, zinc, boron, manganese, sodium, and chlorine. The availability of nutrients for plant growth varies with different locations especially for micronutirents, but in general, additions of phosphorus and potassium are necessary for successful crops on organic soils. Calcium is usually in adequate supply unless extremely acidic conditions are present. Nitrogen will be available unless excessive cropping has reduced decay and nitrification to a critical point.

PHYSICAL PROPERTIES:

The physical properties of peatlands are considered unique when compared to mineral soils. The soil color will be darker with variations in color from dark brown to pure black. The stage of plant decay will play a determining role in the intensity of peat color. The bulk density of peatlands are very low in comparison to mineral soils. Brady (1974) reports bulk density values of .20 to .30 for well-decomposed organic soils, and values of 1.25 to 1.45 for cultivated surface mineral soils. The water holding capacity of peatlands is very high, often retaining three times their own dry weight in water. Peat in less decomposed stages can hold even greater amounts of moisture, often in excess of 15 times their own dry weight. Although peatlands hold excessive quantities of water in relation to their dry weight, they provide plants with only a little more water than mineral soils in similar climatic conditions. The small release of water to plants by organic soils can be related to the fact that they have a higher proportion of unavailable water than mineral soils, and that comparisons of available water between the two soil types are often made on a dry weight basis, of which peat soils are considerably less. Attention will be given later in this paper to water relations of peat soils under drained, forested conditions. The structure of peat soils is considered to be good with low cohesion and plasticity. Peatlands are often porous, have openings and are fairly suitable for cultivation. The good structural quality of organic soils can be damaged by intensive cultivation and fire.

The colloidal nature of organic soils is important, and is considered along with the physical properties, because their surface area is greater than that of the expanding mineral clays, having higher cation exchange capacities. The higher cation exchange of organic soils increase their ability to adsorb greater amounts of calcium than mineral soils, and it increases their ability to exchange greater amounts of mineral elements. Since the pH of soils are largely controlled by their colloidal properties, the greater colloidal nature of organic soils result in lower pH's than comparable mineral soils. The high colloidal nature of organic soils also acts as a buffer against changes in pH.

CLASSIFICATION OF PEATLANDS:

A number of systems to classify peatlands have been developed and used throughout the world (Heikurainen, 1964, 1972). However, this brief review will only make reference to the Comprehensive Classification System, which places organic soils in the Histosols order. Histosols contain a minimum of 20 percent organic matter if a low clay content exists, and a minimum of 30 percent organic matter if a clay content of greater than 50 percent exists. The Histosols order has four suborders, three of which are based on their stage of decomposition (Fibrists-least, Hemists-intermediate, and Saprists-most), and the fourth (Folists) which is derived from leaf-litter, twigs and branches resting on or mixed in fragmental material in humid climates.

The classification of peatlands completes this brief consideration of organic soils. Attention will now be turned to the main emphasis of this paper, that being a review of the factors associated with establishing productive forests on peatlands.

PEATLANDS FOR WOOD PRODUCTION:

SITE SELECTION:

Although large quantities of peatlands exist in the world, only certain portions are suitable for forestry. Heikurainen (1964, 1972) has done extensive reviews on the factors associated with peatlands forest in Europe, including proper site selection, and his work will serve as the basic outline noted in this paper. The Canadian works of Jeglum et al. (1974), and Stanek (1977), will also be considered to provide specific reference to forestry related peatlands classification in North America. Heikurainen (1964) has noted three major factors utilized in the classification of peatlands for forestry purposes. These factors include: (1) the plant communities on the peatlands, (2) the physical and chemical properties of the peatlands including degree of humification, and (3) the drainability of the peatlands. The role of plant communities as forest site indicators will be considered first.

PLANT COMMUNITIES:

The different plant communities that occur on peatlands are a reflection of the environment in which they exist. Variations in such factors as nutrient availability, water tables, topography and climate will be reflected by the types of plants that occur. Through investigations, peatlands suitable for forestry can be determined on the basis of the presence (or absence) of certain plant communities. Plant communities are usually more reliable indicators of desirable sites, since they tend to reflect environmental conditions on a holistic basis.

Heikurainen (1964) has reviewed some of the forestry related plant classifications schemes used in Europe (Sweden, Russia, Great Britain) with particular emphasis on his native country of Finland. For Sweden, Malmstron's (1928, 1959) work was cited, with attention being given to the need to consider other factors such as climate and peat thickness when using plant communities to determine suitability for forest drainage. For Russia, Pjavtsdenko's (1955, 1958, 1959) papers were reviewed, with reference being made to the utilization of swamp (peatland) types based on one or more dominant plants. In British swamps complexes, where emphasis for forestry purposes center on structure and topography, Zehetmayr's (1954) work was noted. Warnings from Dicksons's (1962) publication as to the unreliability of plant communities on highly disturbed peatland sites, such as Britain's was also mentioned. For Finland, forestry related works cited, were by Lukkala (1929, 1935), Kukkala and Kotilainen (1945), and Heikurainen and Huikari (1960). The Heikurainen and Hüikari (1960) study, which is a good example of the Finnish classification system, consisted of dividing peatland swamps into three categories inclueing: open swamps, spruce swamps, (mostly spruce and hardwoods) and pine swamps. Subgroups were also noted, based on the plant species that occurred in assòciations within each of the main groups. A similar classification system to that of the Finnish one has been developed in Canada (Jeglum, et al., 1974), and will be discussed when site selection for peatlands forestry in North American is considered.

As noted in the beginning of this section, the types of vegetation that are found in an area will depend on such factors as the topography, climate, nutrient availability and edaphic conditions. Because these factors vary throughout the world and even within the regions of one country, plant classification schemes designed to identify peatlands for drainage and forestation are often limited to the area in which they were developed.

PEAT CLASSIFICATION:

The second technique outlined by Heikurainen (1964), for determining peatland suitability for forestry was based on the classification of peat. Most peat classification systems that have been developed are found on the degree of decomposition of plant materials. Other variables included in peat classifications are, origins of peat (on site or transported), percentages of plant types composing peat, nutrient content, and peat color and structure. The use of microscopic classifications was also mentioned, but those techniques that include only degree of decomposition, color and structure were considered the most effective. It was stressed that no system of peat classification would be considered adequate without measuring the degree of humification. This is true because of the significant influence humification has on peat characteristics. Notably this includes decreasing permeability and field capabilities for peatlands as humification increases. Schemes for determination of humification ranged from broad classes to microscopic analysis. Relationships derived between the peat types of classification schemes and suitability for forestry are normally restricted to forestry will vary with environmental changes.

DRAINABILITY OF PEATLANDS:

The final technique considered by Heikurainen (1964) to determine suitable peatlands for forestry, was based on the potential the peatlands had for drainage. Satisfactory drainage potential was determined only on the basis of increasing forest growth and was not related to any form of economic analysis. Drainage was considered as a way to either transform unforested areas into forested areas, or as a method to increase the productivity of areas that could or were already supporting forest vegetation.

The plant communities and peat types derived from the classification systems mentioned previously are often used to determine the suitability of organic soils for forest drainage. By measuring the growth responses of established forests on drained and undrained peatlands classified according to their peat, or plant communities (or combinations of both peat type and plant communities), relationships are often established between the peatland types of the classification systems and forest growth responses after drainage. Heikurainen (1964) cited several studies in his review that have utilized such an approach to evaluate drainage potential for peatlands (Buss, 1958; Thurmann-Moe, 1962; Lukkala, 1951; Heikurainen, 1959; Fraser, 1933; and Zehetmayr, 1954). It was also noted from these studies that the successfulness of forest peatland drainage is related to the peats fertility and its location or climate.

In relation to the utilization of site index (a measure of site productivity based on the height of the dominant or codominant trees in a timber stand at a base age) to estimate future growth on drained peatlands. Heikurainen (1964) took special efforts to point out that with the changes in site conditions that occur after drainage, such attempts are of little value. It was also noted that the variations in growth after drainage within some peat and plant community types are excessive, resulting in meaningless appraisals. On the whole however, the relationships between the peatland types of the classifications and growth after drainage were considered worthwhile within given regions.

FOREST PEATLAND SITE SELECTION IN NORTH AMERICA :

The application of peatland classification systems for forestry purposes in North America have been limited. As Stanek (1977, page 656) stated, "in Canada, the improvement of peatlands for forestry purposes is limited largely to regenerating stands after harvesting." He also noted that little information was available on growth responses after drainage,and that intensive forest management of peatlands in Canada was only on a small scale. Similar statements could be made for the United States.

Some of the work that has been done in North America includes Jeglum et al., (1974) efforts to classify swamp lands (peatlands) for forestry purposes, and Stanek (1977) use of Jeglum's classification system to compare difference in growth responses between undrained and artificially drained sites. Jeglum (1975, page 227) observed that the classification system he and his colleagues proposed tried to separate the peatlands (specifically the black spruce forest of the northern clay section in Ontario) into, "units that would (1) be relatively easy to recognize in the field, (2) relate to differences in tree growth, (3) relate to differences in regeneration, and (4) be interpretable from air photos." Jeglum's classification system is based on vegetation with physiognomy and dominance of plant communities being stressed. Productivity was derived from the site index of the dominant forest species within each site type identified. As was noted earlier in this paper, site index will not serve as an adequate base to predict future productivity for a site type if intensive practices such as drainage occurs. Because of this inadequacy Jeglum's system alone is deficient for selecting peatland sites for intensive forest management. To make Jeglum's classification applicable for intensive management practices, Stanek (1977) studied the differences in tree growth responses on undrained and drained peatland site types classified by Jeglum's system. Jeglum's classifications were however modified, by assigning the peatlands site types of Jeglum's classification to five trophic groups based on the macronutrient content of the peat. The results of Stanek's (1977) study showed that the five nutrient classes could be broken down into two major suitability classes, one being bogs and the other swamps plus fen-marsh complexes. Bogs showed an average improvement in growth of 6 meters after drainage and the swamp plus fen-marsh complexes showed an improvement of 4 meters. It is these differences in growth between peatland site types that make techniques to determine peatland suitability a desirable management tool in peatlands forestry.

SILVICULTURAL CONSIDERATIONS:

Although techniques to identify peatland suitability for forestry purposes are helpful, the major factors associated with peatlands forestry are the silvicultural considerations. These considerations can be broken into three major divisions, those being drainage, fertilization, and plantsite interactions.

DRAINAGE:

As was noted in the beginning of this paper organic soils often hold three times their own weight in water, with peat in less decomposed stages often holding in excess of 15 times their own dry weight. Heikurainen (1964) stated that peat in natural swamp conditions contain 90 to 95 percent water. Because of the excessive amounts of water associated with peatlands, drainage is normally a part of any type of intensive peatlands forestry. Publications by Payandeh (1973) in Canada, Efremov (1967) in Russia, Boggie and Miller (1973) in Great Britain, and Heijurainen, (1964, 1968) and Jenen et al., (1964) in Finland, demonstrate that drainage of peatlands will result in successful gains in forest growth. Some of the important aspects of peatland drainage in relation to forestry considered by this paper are: (1) water relations of peat soils, (2) the influence of drainage on physical properties, (3) techniques of drainage and their influence on forest growth, and (4) physiological responses in drainage.

WATER RELATIONS:

With site drainage being normal procedure in peatlands forestry, water relations noted here will be focused on drained conditions. Heikurainen (1964) has reviewed the main factors of water relations in peatlands forestry. Some of the parameters that he felt were important are noted as follows. Peat soils contain about 80 percent water in drained conditions, a percentage value not that different from undrained peat soils. Field capacity values for peatlands are high, with decreasing field capacity and permeability occurring for peatlands increasing in their degree of humification. Even at low degrees of humification, permeability of peatlands is still considered small. Oxygen content of peat soils will increase by the amount that water is removed from pore space by drainage. Depth and intensity of ditches are a major factor determining intensity of drainage or increases in oxygen content. It should be noted however, that intensive ditching alone is unable to bring the moisture content of peat much below that of field capacity (Boggie and Miller, 1973). The impermeable nature of peat to water causes slow water movement, and water holding capacities of peat in drained conditions is high. In terms of evapo-transpiration on unforested peatlands, drained areas tend to have less evapo-transpiration than undrained ones. However, on peatlands where drainage enhances the establishment or growth of the forest, the evapo-transpiration of the trees will increase total transpiration from peatlands. Heikurainen (1964) noted that many researchers feel that it is the increased transpiration from trees that bring about the major effects of drainage. Temperature changes after drainage are also important. The effects of drainage on peat temperature are two fold. First, a decrease in surface water after drainage reduces surface evaporation, yielding a favorable effect on temperature relations. Secondly, drainage results in a lowering of the thermal conductivity of peat. With freezing being directly related to temperature relations, drained peatlands tend to freeze deeper and remain frozen longer than undrained ones. This increased freezing can play a role in limiting the establishment of trees during normal planting times in the spring. However, the overall effects of drainage on temperature relations in peatlands are considered to be limited in their importance.

PHYSICAL PROPERTIES:

The effects of drainage on the physical properties of peat under forested conditions have received little attention. One study translated from Russian (Bel'skaya, 1961) was available and its content will be summarized to provide a general overview of the physical changes that occur. Drained forested peat soils experience greater aeration than undrained ones, increasing rates of peat decomposition. These increased rates of decomposition result in alterations of the peat's physical properties. These alterations include the following (Bel'skaya, 1961 page 8):

1) The bulk density of peat increases with the age of the drainage network.

2) The specific gravity of pure peat decreases with the increasing degree of its decomposition, but the profile of thin peat may exhibit the reverse pattern in horizons containing mineral admixtures.

3) Total porosity of peat decreases as it becomes more compact in the course of decomposition; nevertheless, water permeability increase through intensification of the first period of the penetration of water into the soil, i.e., the imbibition of

water by the peat on drained areas, on account of its lower moisture content.

Belskayas (1961) concluding remarks stated that changes in the physical properties on drained forested peatlands are slow, but noted that these changes favor tree growth.

TECHNIQUES OF DRAINAGE:

The factors associated with drainage techniques for peatlands forestry received attention from Stoeckeler (1963), Burke (1973) and Heikurainen (1964, 1973). Stoeckeler (1963) centered his review on drainage methods utilized in Northern Europe. Hand ditching and dynamite were considered, but major ditching operations were accomplished by mechanized ditchers. These mechanized ditchers included: bucket type-ditchers, plowed ditchers, cable and winch ditchers, direct pull ditchers, rotary ditchers, and endless chain ditchers. The type of mechanized ditchers utilized varied with different countries and management requirements. In Britain for example, a ditching plow was used that cut shallow furrows leaving excavated ridges on which seedlings were planted. In other areas where excavated ridges were not desirable, different types of ditchers were employed. New techniques such as plastic drains were also mentioned, but their utilization was still in pilot-stages. The major physical problems in drainage of peatlands noted by Stoeckeler (1963), were trafficability of equipment, and the necessity of ditch cleaning and maintenance. Equipment having low track pressure was emphasized to prevent mining, and warnings in terms of limiting excessive movement on peat surfaces were given.

Although beyond the scope of this paper, the major consideration determining the type of ditching machinery to utilize is economics, a factor that has received little attention for peatlands in the United States.

Heikurainen (1964, 1973) and Burke (1973) considered in their reviews, parameters involved with the intensity of drainage necessary to obtain optimum forest growth. Heikurainen (1964, page 67) noted the follwoing factors to be of importance in determination of runoff or drainage, "size of runoff area, percentage of open water surface inside the area, moisture content of snow before melting, types of land utilization, and shape of the runoff area." Because of the variations that exist in these factors, the exact intensity of drainage needed for the peatlands of the world will vary. Three principles of drainage that are consistent with peatlands forestry on a world basis are noted as follows. First, groundwater levels in peatlands play a major role in determining forest growth. The desired depth of groundwater after drainage will reach an optimum point below which plant growth will decrease. This optimum depth will vary with such factors as climate, tree species, and peat type. Second, ditch spacing has a significant influence on tree growth with closer spacings yielding better growth responses. Poor sites will respond better to closer ditch intensity and groundwater tables, Heikurainen (1964) noted Hainla's (1957) study, on infertile Sphagnum swamps, which demonstrated that closely spaced ditches, (a) lowered the groundwater table more than widely spaced one, and (b) they increased runoff. The third factor considered for world peatlands forestry application, is the effects of ditching depth. As in the control of water table depth, forest growth will improve with greater ditch depths until an optimum point is reached. Heijurainen (1973) reports that this optimum depth is very shallow. Reasons noted for this included the fact that the entire surface layer of drained peatlands is extremely thin, and that the distribution of roots is very superficial, with the bulk of roots occurring between 0-10 cm. Heikurainen (1973) considered ditch depth the least important of the factors considered.

Other parameters that should be considered in peatlands drainage have been noted by Burke (1973), and Boggie and Miller (1973). In terms of obtaining an optimum water table depth for forest growth, Burke (1973) pointed out that shrinkage of peat often occurs after drainage. This means that the peat surface will become closer to the water table surface, eliminating some of the depth of the lowered water table. Allowance for this shrinkage should be made when guidelines for obtaining optimum water table depths are determined. Boggie and Miller (1973) noted in their report that actual increases in forest growth after drainage may be more closely related to the increased downward movement of water, carrying dissolved oxygen and nutrients following rains, than to the limited changes in peat moisture content after drainage.

Because of the variations in responses to drainage that occur for different peatlands of the world, drainage techniques should be tried on an experimental basis in areas of concern. Research tends to indicate that numerous variations in results can be obtained from different drainage intensities, and that these variations can be of significance in obtaining optimum forest growth.

PHYSIOLOGICAL RESPONSES:

Heikurainen (1964) cited a number of reports dealing with tree growth responses after drainage on peatlands (Malmstrom, 1935; Lukkala, 1937, 1951; Elpatjevski, 1955; Hainla, 1957; Heikurainen, 1959; Buss, 1960; and Heikurainen and Kuusela, 1962). In general it was noted that smaller and younger trees responded better to drainage than older and larger ones. Stand thinnings were encouraged to eliminate older and larger trees unable to respond to drainage. The time it took trees to respond to drainage was as little as one year in some cases (Lukkala, 1937). Radial growth responded first to drainage, with height growth responding a little later. The responses of height growth lasted a longer period of time than did radial growth. Length of growth responses to drainage varied considerably between studies. Differences were related to such factors as site fertility before drainage, peat thickness, and intensity of drainage. In general, growth responses on poor sites lasted from 10 to 20 years, with better sites having responses as long as 40 years.

The physiological responses of roots to drainage were also considered by Heikurainen (1964), who noted the following points. First, rooting depths of trees on drained as well as undrained peatlands were considred very shallow. Reasons for this were related to a lack of oxygen in potential rooting zones. Second, drainage was reported to increase rooting depth and the amount of total roots developed. A general correlation of one centimeters increase in root development to 10 centimeters of drainage was noted. Third, Paavilainen's (1963) study reported the use of smaller ditch spacings to increase root development. These results in Paavilainen (1963) study can be explained by the increased effectiveness of drainage associated with closer ditch spacings. And fourth, Heikurainen (1964) noted the importance of increasing rooting depths for forest species susceptible to windthrow. Since drainage of peatlands is usually accompanied by site preparation and fertilization, Paavilainen (1967) and Kaunisto (1971, 1975) have studied the effects of these silvicultural practices on root systems. Paavilainen (1967) reported that applications of NPK increased the amount of roots in the upper 10 centimeters of peat soils. Increases in the length of roots were also observed, but short roots only increased in the first three centimeters of the profile. Kaunisto (1971, 1975) observed that fertilization on prepared sites resulted in the best root growth, and that rotavation favored root growth more than shoot growth.

FERTILIZATION OF PEATLANDS:

The general status of macro and micro-nutrients in peatlands were considered in the introduction of this paper and only those nutrients of commercial importance will be considered here. In terms of commercial fertilization of peatlands only nitrogen (N), phosphorus (P) and potassium (K) have been widely used. Atterson and Binns (1973) have considered some of the fertilization factors associated with these macronutrients and their findings are noted as follows: Nitrogen content was considered high in most peat soils with deficiencies being noted for P and K. Values to a depth of 30 cm were cited for N, P and K, they were: 2,000-10,000 kg N; 40-300 kg P; and 30-350 kg K. Bogs having high percentages of sphagnum moss, or an oligotrophic classification comprised the peatlands having the lowest nutrient content. It was noted that although peat normally has a high N content, large percentages of this N are tied up in organic compounds and are not available to plants. Phosphorous was considered to always be limiting to plant growth. Potassium was not considered limiting in early stages of plant growth, but was considered so in the later stages of development (Meshechok, 1968). Potassium and nitrogen were both reported to be in decreasing availability as the depth of peat increased (Paavilainen, 1972). Differences in the availability of K and P were also discussed. Since K content in rainfall often exceeds that of P by five times, K was considered to be more available to plants over the long term. Heikurainen (1964) has also reviewed some of the main characteristics of N, P and K in peatlands. His observations are similar to those of Atterson and Binns (1973).

Of the many articles dealing with commercial and experimental fertilization considered for this paper (Tamm, 1960; Jensen et al., 1964; Heikurainen, 1964; Meshechok, 1968; Viro, 1970; Kaunisto 1971, 1972, 1975; Paivanen, 1972; Paavilainen, 1972; Hauge, 1972; Seppala and Westman, 1976; MacCarthy and Davey, 1976; Kaunisto and Norlamo, 1976; and Kaunisto and Paavilainen, 1977) most were in agreement that applications of NPK or PK are necessary to obtain satisfactory forest growth on peatlands. Variations to this general rule were noted as in Seppala and Westman's (1976) study, in the unfavorable climatic conditions of north-eastern Finland, where little additional growth was obtained from applications of PK. A review of the studies revealed generally that sites considered poor in their overall nutrients status (oligotrophic) were in need of NPK and those sites considered phosphorus the most deficient nutrient limiting forest growth. Publications such as Hauge (1972) and Meshechok (1964) revealed that it is almost impossible to establish seedlings on organic soils without applications of P. Applications of lime in conjunction with normal fertilization of peatlands has also proven to enhance forest growth (MacCarthy and Davey, 1976; and Kauvisto and Norlamo, 1976). Part of this enhancement was related to a significant enlargement of biological activity that increased fixation of nitrogen after liming.

The publications on the fertilization of peatlands also noted other important factors that affected growth responses besides the additions of macronutrients. These other parameters included time of fertilization, methods of application and types of site preparation.

Viro (1970) has studied the best time to apply fertilizers and he states that early spring is the best for pines and that late summer is the best for spruce. Viro (1970) also noted that the variations in responses to time of application were not as significant as expected. Paavilainen (1972) did warn however, that nitrogen uptake was poorest when applied in winter on top of a snow cover. Methods of applying fertilizer were considered by

Mackenzie (1972), Meshechok (1968) and Hauge (1972). In general it was found that spot applications in the immediate area of the trees was better than broadcasting. Meshechok (1968) also noted that additions of phosphorus in planting holes besides the trees caused a definite increase in growth when accompanied by surface fertilizer applications. Hauge (1972) warned however, that additions of super phosphate to seedling roots resulted in increased mortality. In terms of types of site preparation used will effect seedling responses to fertilizers. He also stated that if fertilizers are worked into the substrate they will be better utilized by the plants, than if just applied in surface applications. Meshechok (1968) reported that the best growth responses in his studies have occurred on furrow slices. Because of the significant influences that time of application, site preparation, and methods of fertilization have on forest growth, these factors must be considered in any type of peatlands forestry.

Another area of interest in fertilizer studies is the uptake and utilization of the nutrients that are applied. For peatlands, this subject, is considered by Tamm (1960), Dickson (1973), and Atterson and Binns (1973). Tamm (1960) noted that only a small amount of the additions are used by trees. Dickson (1973) pointed out that much of the fertilizer added is used by competing vegetation. Considerable increases in growth were observed by Dickson (1973) when herbicides were used to control competing vegetation. The increases in growth were related to the increased availability of N. It was noted however, that where extremely large applications of fertilizers were made, little growth response was noted after the use of a herbicide.

The final aspect of peatland fertilization to be considered is the importance of a nutrient balance on drained peatlands. Heikurainen (1964) has considered this aspect in his review and notes some of the following nutrient relationships to be of importance: (a) additions of phosphorus can affect nitrogen mobilization, (b) applications of calcium can result in increased humification of peat, resulting in fixation of N and P in the protoplasm of microbes, and (c) additions of P can increase K deficiencies in peatlands. As can be seen from these examples, the application of fertilizers to peatlands is a matter that needs serious consideration before being carried out.

PLANT SITE INTERACTIONS:

SPECIES SUITABILITY:

Tree species will respond differently to the various types of peat soils, climatic conditions, drainage schemes and silvicultural practices that occur throughout the world. Because of the diverse influences of these factors, proper selection of tree species for peatlands forestry is often difficult, especially in regions where little research has been conducted to identify desirable species.

In Europe and Great Britain extensive work has been done to identify species suitable for peatlands forestry on a commercial basis. Heikurainen (1964) reviewed the countries of Europe and noted the following: In Western Europe, Norway spruce scots pine, and birch (Betula verucosa and B. pubesiens) were approved as suitable commercial species. Spruce was recommended in colder climates and on ombrotrophic swamps, with pines being recommended on minertrophic swamps. In Eastern Europe, spruce and pines were also approved, with the additions of larch and black alder. Species suitability work in Great Britain has been considered by Seal (1973), who noted the following species to be of importance. On fertile sites in the colder parts of Britain, Norway spruce and sitka spruce were recommended almost exclusively. Lodgepole pine and sitka spruce were noted as desirable species on Britain's deeper peat soils and infertile sites. On sites of extreme infertility, only lodgepole pine produced satisfactory results.

In the United States and Canada, little work has been done to determine species suitability for intensive peatlands forestry. In the southeast where some drainage has been done commercially on organic soils, Loblolly and slash pine seem to be the best species (Walker, et al., 1961). In the Lake States and Canada consideration is usually given to the species already occurring on organic soils, these being predominately black spruce, tamarack and Eastern white cedar. To identify which species would be best suited for intensive forestry on peatlands in the Lake States Dr. Ed White of the University of Minnesota, is currently investigating the growth responses of five species (black spruce, white spruce, a hybrid poplar, Norway spruce and scots pine) to drainage and fertilization. This type of research must be carried out in North America if intensive peatlands forestry is ever going to be considered on a commercial basis.

SITE PREPARATION:

The utilization of some form of site preparation is associated with most recent attempts to establish forest on organic soils.

This type of site preparation used varied with different locations, a point demonstrated by Neustein and Rowan's (1973) review of plowing schemes for site preparation in Great Britain, and Kaunisto's (1972) work on the utilization of rotavators and plows in Finland. Advantages and types of site preparation in peatlands forestry have been considered by Kaunisto (1971, 1972, 1975), and the results from his studies are noted as follows. First, Kaunisto (1971) reported that the utilization of site preparation equalled the effects of the best fertilization treatments without site preparation. He also noted that the use of site preparation and fertilization together increased seedling growth twice as much as when either treatment was used separately. Increased mobilization of nutrients after site preparation was believed to be the major reasons for the increased growth. In a later study using a rotavator in site preparation, Kaunisto, (1975) also noted that increased seedling growth after site preparation could be related to the reduction of competing vegetation. He reported that the use of a rotavator completely destroyed the ground vegetation. In terms of plows used in site preparation, Kaunisto (1972) stated that front plows were superior to tractor pulled plows. This was related to the fact that front plows pressed turf ridges closer to the original peat surface, allowing easier seedling access to nutrients and moisture. Precuations were noted in the use of rotary cutters where excessively shallow benches prevented adequate moisture contact by seedling. Shallow furrors at a depth of 15 to 20 cm on a single tree basis were recommended to control moisture levels in site preparation. In summary, the major objectives of site preparation in peatlands forestry are (1) to regulate the moisture and temperature to which seedlings are exposed, (2) to stimulate microbal activity, and (3) to eliminate competing ground vegetation, (Kaunisto, 1971).

PROBLEMS IN FORESTATION:

The majority of the major problems associated with intensive peatlands forestry were discussed when consideration was given to techniques of site selection, drainage, fertilization, and species selection. These problems can be noted by reviewing these topics and they will therefore not be considered again. Another major problem not adequately covered beforehand involves the intensive competition on peatlands from non-forested vegetaion during seedling regeneration (Maki, 1974). This competition competes with tree seedlings for both sunlight and nutrients. Heikurainen (1964) pointed out that competition not only occurs from plants that invade organic soils, but that loose sphagnum moss will compete with seedlings for sunlight. As was noted in the review of fertilization, the use of herbicides to eliminate competition for nutrients resulted in substantial increases in seedling growth after nutrient additions (Dickson, 1973). Although the use of herbicides to control competing vegetation is the best solution to the problem, Heijurainen (1964) warned that on well humified peat void of vegetation, heavy rains can splash peat mud on seedlings bending and breaking them. Although not a part of this review, it should also be remembered that tree species growing on organic soils will encounter the problems of fire, insect attacks, and diseases just as trees on mineral soils. Though the problems associated with peatlands forestry are important, most can be overcome or avoided with wise management practices.

CONCLUSIONS:

Although a great deal is known about peatlands forestry in Europe, little work has been done in the United States to evaluate the feasibility of intensive peatlands forestry. With timber supplies projected to be in a shortage by the next decade, now is the time to begin investigating the potential of America's peatland for forestry purposes. This investigation should include not only the specific biological requirements considered in this review, but an economic analysis should also be made that would identify when intensive peatlands forestry could be carried out on a profitable basis.

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Ecological and Floristic Studies of the Peatland Vegetation of Northern Minnesota (Dr. Eville Gorham & Dr. Herbert Wright, Jr., University of Minnesota)

ACCOMPLISHMENTS TO DATE:

1. More than 50 relevé plots have been analyzed for species cover and sociability, and notes on the habitat (aspect, slope, soil profile, etc.) have been made. These plots have been distributed over the full range of peatland habitats and landforms, except for transitional zones at the margins of the peatland. An account of the major vegetation types of the Red Lake peatland will be based on analysis of the relevé data.

2. Water samples have been collected at most of the plots, together with a few elsewhere. So far these have been analyzed for pH, specific conductance (a measure of dissolved ions), and absorbance at 320 nanometers (a measure of dissolved organic matter). Further analysis will follow, and plant distribution will be related to water chemistry.

3. A number of peat profiles have been examined, and a few peat samples have been collected for analysis.

4. Collections of vascular plants, bryophytes and lichens have been made from the peatland relevés, and from many other peatland sites. These are being placed in the herbarium of the University of Minnesota as voucher specimens for this project.

5. Lists of vascular plants, and of rare and endangered species, have been compiled, preparatory to producing a "Flora of the Red Lake Peatlands." Such a flora will be of great value to others studying the peatlands, particularly the animal biologists who must gather data on vegetation in the course of their studies.

Vegetation Analysis of Selected Beltrami, Koochiching, and St. Louis County Peatlands by Remote Sensing Methods
(Dr. Merle Meyer, University of Minnesota)

STUDY OBJECTIVES:

Phase 1 - Preparation of 100% site-specific vegetation classification of portions of 9 7½-minute USGS quadrangles in Beltrami/Koochiching Counties and portions of 6 7½-minute quadrangles in St. Louis County (an approximate total of 315 square miles). Classification to be accomplished from the most recent 1:15,840 summer B&W infrared aerial photography.

Phase II - A two-camera 35mm aerial photography camera system will provide color infrared photo samples along up to 35 miles of representative transects selected by the investigators. Continuous coverage of the transects will be flown at circa 1:84,000 and photo plots at circa 1:12,000 will be flown at selected intervals along the transects.

FINAL DELIVERY PRODUCTS:

1. Fifteen stable base orthophotoquads, board mounted and each with its individual registered stable film overlay bearing the interpreted detail.

2. Transects and photo samples will be located on the board adjacent to the corresponding orthophotoquad. Type lines and designations will be added where pertinent.

3. Final narrative report including acreage summaries.

WORK PERFORMED DURING THE PERIOD JULY 1 THROUGH SEPTEMBER 30:

1. All the necessary orthophotomaps, orthophotoquads and B&W photography have been ordered, recieved and categorized.

2. Effective areas and project boundaries have been completed on approximately 90% of the B&W contact prints.

3. Photo overlays have been prepared for approximately 60% of the B&W prints.

4. Selections of 35mm transect locations were made in mid-July with close cooperation of the Ecological and Floristic Studies investigator Paul Glaser.

5. Significant delays in 35mm photography accomplishment were encountered due to problems with weather and flight scheduling. Transect photography was accomplished as follows:

    - Koochiching/Beltrami transects were flown August 30.

    - St. Louis County transects were flown September 22.

6. 1:120,000 Scale 35mm C1R complete coverage (not specified in the contract) for the two study areas was accomplished as follows:

   - Koochiching /Beltrami area was flown on September 22

   - St. Louis County area was flown on July 24.

7. Initial field work has been done in both study areas.

WORK PLANNED FOR NEXT QUARTER (OCTOBER THROUGH DECEMBER, 1978):

1. Complete photo and overlay preparation for the 1:15,840 photography.

2. Complete ground truthing of the 1:15,840 B&W photography and the 35mm transect photography.

3. Finalize classification scheme.

4. Commence aerial photo interpretation of the 1:15,840 scale photography on alternate photographs.

5. Proceed with editing, transfer of interpreted detail, final drafting and area measurements.

6. Complete one or two key quadrangles by the end of December.

<u>Analysis of Minnesota Peat for Possible Industrial Chemical Use</u>
(Dr. Charles Fuchsman, Bemidji State University)

1. Samples have been received from the field crew working under Tom Malterer's direction. The samples received represent fibric peat sites within the "Pine Island Bog", located near the center of the Pine Island State Forest in Koochiching County. Each site was sampled over the depth range 1-5 ft. below the surface.

2. Laboratory work has been initiated on the preparation of samples from two of the above-noted sites. The samples are to be air-dried before subdivision into portions allocated to inorganic analysis (principally for phosphorus); and to organic analysis (principally for bitumens). Methods for accelerating the air-drying without significant alteration of the organic component of the peat are being investigated.

3. Analytical techniques for both the phosphorus and bitumen analyses are being tested in the labs to reveal and correct any procedural difficulties before embarking on the systematic testing of field samples.

4. A visit to one of the field sampling sites is being planned in conjunction with the forthcoming visit of Dr. Grumpelt of Germany.

5. A large number of analytical procedures appropriate to the project have been translated from the German and Russian literature.

AN INSTITUTIONAL VIEW OF MINNESOTA'S PEATLANDS

The peat program staff, in cooperation with the Department of Revenue is currently perfecting a computer program that will, it is hoped, allow the peat staff to predict the expected demand for horticultural peat in the United States. The program compares the follwoing variables from the years 1961-1976:

Commercial Sales of Sphagnum ($)

Commercial Sales of Reed-Sedge

Commercial Sales of Humus

Number of tons of peat produced

Number of tons of peat sold

Average price of peat sold (per ton)

New housing starts

Personal income

Preliminary investigation of the computer runs indicates that the variables chosen seem to be good indicators of peat demand. The program itself will be refined in the coming weeks to make its predictive capabilities more flexible.

Ability to predict expected demand for horticultural peat in the United States would be a useful tool in helping the project and the legislature to better understand the economic implications of peat development in Minnesota. Some reasonable predictions should be available in time for presentation to the Legislative Session.