Management and Conservation Practices for Vegetable Production on Peat Soils
Preface

The purpose of this document is to provide a basic guide for the sustainable use of peatland soils in Newfoundland for vegetable production. This guide was modelled after existing Best Management Practices handbooks published by the Ontario Ministry of Agriculture, Food and Rural Affairs and Agriculture and Agri-food Canada.

This document was developed in cooperation with Agriculture Canada, the Government of Newfoundland and Labrador’s Department of Forest Resources and Agri-food, and the major producer groups. Farmer’s experiences with conventional and alternative management practices are included wherever possible.

This guide examines: 1) the selection and development of peat bogs for vegetable production; 2) the maintenance of drainage systems after development; 3) the management practices used in vegetable production on peat soils, including the management of water, soil, crops, fertility, and pests; and 4) the conservation practices available to peatland vegetable producers to ensure agronomic, economic and environmental sustainability.

Many documents relating to vegetable production on peat soils have been published in the past. Most recently, Agriculture Canada published Vegetable Crop Suitability of Organic Soils in Newfoundland (E.F. Woodrow, 1990) which provides evaluation criteria for the selection of suitable peat bogs. This document, and others such as Guidelines for Peatland Management in Eastern Canada (L.E. Parent, 1981), are technical and provide essential background material for a management and conservation guide for vegetable production on Newfoundland peat soils.

Although this document is specific to vegetable production on Newfoundland peat soils, it could be applied to vegetable production on peat soils throughout Atlantic Canada with some limitation. Some of the information in this document may also be useful to producers of forage and sod on Newfoundland peat soils.

The Eastern Canada Soil and Water Conservation Centre produced this document with the best information available as of the publication date. The Centre assumes sole responsibility for the material presented. Since some of the information does not represent conventional practices, it may not reflect the programmes and policies of the supporting agencies.

David A. Lobb
Soil Conservation Specialist
Eastern Canada Soil and Water Conservation Centre
University of Moncton

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INTRODUCTION

Almost 6.8 million hectares of Newfoundland and Labrador are covered by wetland of which 6.4 million ha are peatlands. This constitutes about 17% of the province's total land area. In Newfoundland there are 1.1 million ha of peatland or 11% of the island. Consequently, peatlands represent a vast resource with potential for development in some areas while others provide a rich and unique wildlife habitat.

Historically, peat bogs in Newfoundland have had limited use in agriculture for grazing, forage and vegetable production. Non-agricultural uses include recreation, wildlife habitat, and extraction for horticulture and fuel. Peat has a very high capacity to hold liquids and gasses which makes it valuable commercially as an absorbent.

In their natural state peat bogs are unsuitable for crop production. They are very acidic, infertile, and saturated with water. However, these conditions can be overcome with proper development and management, and crop productivity can be sustained through soil conservation. Furthermore, many of the peat's physical properties benefit crop productivity. Some of the beneficial properties include high porosity and water holding capacity, good aeration when drained, and a structure that favours root penetration and mechanical cultivation with limited resistance. Peat soils are stone-free, whereas minerals soils can be limited for vegetable production by their stoniness.

Vegetable crop production research on peat soils has been on-going for many years at the Agriculture Canada research station at Colinet on the Avalon Peninsula. This research combined with growers’ experience has indicated that a wide range of vegetable crops perform equally well or better on peat soils than when produced on mineral soils. Peatland soils have attracted vegetable growers because they have the potential to produce excellent quality and high yielding crops.

Vegetable production on peatlands is not without its disadvantages. Peat bogs are complex natural ecosystems that require drastic changes to bring them to a state of successful agricultural production. Some of the difficulties in developing and maintaining a vegetable production system can affect the agronomic and economic sustainability of the farm. They include: initial development expenses (clearing, drainage, landforming, pH adjustment, fertilization); increased rate of decomposition when under production causing subsidence and compaction; increased
risk of frost since these areas are often low-lying; and more complex pH and nutrient management than on mineral soil. To date, establishment of a profitable commercial vegetable enterprise on the peat soils of Newfoundland has proved extremely difficult. Peat soils require special management because they consist of layers of organic matter of varying composition in varying degrees of decomposition that continue to change with time according to the management system used.

This comprehensive guide outlines basic management and conservation practices for vegetable production on peat soils, and has been developed to deal specifically with Newfoundland’s special conditions and needs.
UNDERSTANDING THE BASICS

Formation and Evolution of Peat Bogs

The formation of Newfoundland’s peatlands was initiated about 5000 to 10000 years ago following the most recent glacial retreat. Glaciation left much of the landscape with depressional features whose poor drainage resulted in ponds and lakes. Over time many of the shallower ponds and lakes filled with vegetation and formed peatlands. As well, vast areas of compacted or cemented glacial till on upland areas resulted in poor drainage that promoted the formation of peatlands on hilltops and sloping land.

A peatland is a wetland on which extensive organic material has accumulated. Peat soils are almost entirely organic matter, about 93 to 97 %. A soil that is more than 30 % organic matter is considered an organic soil. A minimum depth of 40 cm of peat is required before the wetland can be defined as an organic soil. In general, peat accumulation results when the primary peat production exceeds its decomposition for a prolonged period. On average, the rate of peat formation is about 0.6 to 0.7 mm per year. It is the relatively slow rate of decomposition, rather than the rate of production, that is responsible for the accumulation. The decomposition rate is slow because the peatland environment is unfavourable for growth and activity of many organisms capable of breaking down the peat. The older, deeper peat is more highly decomposed than the near-surface peat. Peat that is decomposed to a limited extent is called fibric, while increased decomposition is classified as mesic and advanced decomposition as humic (see PEATLAND SELECTION).

There are several morphological types of peatland in Newfoundland. These are: raised (eccentric, concentric or dome and plateau) bog, basin bog, blanket bog, string bog, slope bog, slope fen, ladder fen, and patterned fen. They differ in shape, but also in hydrology, acidity, fertility, and vegetation.

The naturally occurring plant communities vary considerably between peatlands. The physical and chemical properties of the peat depend primarily on the nature and origin of the plant remains that comprise the peat, and their degree of decomposition. In turn, the species of plants that contribute to peat formation and its properties, as well as the degree of decomposition of the residues, are all closely associated with the peatland’s water chemistry.
The Water Cycle

Peatlands are unique, dynamic ecosystems that continually evolve and change with time. The evolution of the wetland is regulated by complex interactions between climatic, biological, and hydrological factors.

Water is essential to the formation of a peat bog. Peat bogs develop because there is an excess of water within the landscape due to climate (i.e. high precipitation and cool temperatures) and restricted drainage. Newfoundland's mean annual precipitation varies from about 500 mm in the northwest to 1500 mm on the Avalon Peninsula. Most of this precipitation ends up as moisture surpluses. This has contributed to the formation of bogs up to 4-5 m in depth over much of Newfoundland's poorly drained landscapes.

The water in a peatland is either primarily derived from precipitation or it comes from a combination of precipitation and groundwater inflow. The source of water determines the type of peatland, its acidity, fertility, and vegetation. For example, water from groundwater inflow has a higher concentration of minerals (and therefore, nutrients) than does water from precipitation, and the resulting peatlands often have better fertility than those developed from precipitation alone.

The mineral content of the peatland is also very important to its fertility, as the mineral particles are a source of many nutrients. Clay minerals can also provide exchange surfaces for nutrients which will increase the nutrient availability of the peat. There is usually a very small amount of mineral material that washes or blows into the bog from the surrounding landscape. Peats that are on river flats, however, can have a much higher mineral content if sediments are deposited during flooding.

When the vegetation obtains its nutrients from the groundwater the peatland is termed minerotrophic. Fens are minerotrophic peatlands with the water table at or just above the surface of the peat. In general, the pH of a fen is very acid to alkaline (about 4.5 to 7.5). In Newfoundland, however, most of the bedrock consists of siltstones, slates, conglomerates, and acidic to intermediate volcanic rocks. As a result, the seepage water entering into these bodies of water is more likely to be acidic and nutrient poor. Fen flora may include sedges, grasses, reeds, brown mosses, certain Sphagnum species, ericaceous shrubs, and trees. Drained (to greater than 1.2 m), fens can become productive agricultural lands, but it requires a long time, as long as 100 years.
When the peatland and its surface vegetation obtain their water and nutrients primarily from precipitation the peatland is termed ombrotrophic. Bogs are ombrotrophic peatlands in which the water table occurs at or near the surface. Bogs are nutrient-poor with an extremely acid reaction (pH 3.5 to 4.5) resulting in a limited diversity of naturally occurring plant species. These conditions are suited to the establishment and growth of Sphagnum mosses and the subsequent development of Sphagnum peat bogs. Sundew and cranberry are also common. Because of their ubiquity and extent, Sphagnum peat bogs are the peatlands that are most commonly developed for vegetable production.

Because downward movement of water is restricted, water movement is limited to evaporation from the soil surface, transpiration from the plants, and lateral movement to depressions within the bog or outlets from the bog. Wind greatly affects the regional and local climate, but possibly equally important is its effect on the microclimate that exists on the surface of the bog. It is an agent of temperature and moisture change. Wind enhances moisture loss by increasing evapotranspiration. The amount of water removed from peat bogs by evapotranspiration can help offset precipitation moisture surpluses. For example, in central Newfoundland evaporation (483 mm) exceeds rainfall (406 mm) from May to September.

**The Effects of Vegetable Production on a Peatland**

**Decomposition**

In their natural state peat bogs are saturated with water. One of the first steps in agricultural development is to drain the bog. Ditches and subsurface drains are used to enhance the movement of water from the peat, thereby lowering the water table and aerating the peat soil. Aeration of the soil is necessary for plant growth, aerobic microbial processes, and to ease the operation of farm machinery. Before vegetable production can begin, the peat soil must also have its pH and fertility adjusted. The drainage, liming, fertilization and tillage required for vegetable production radically alter the physical, chemical, and biological properties of the peat. Under vegetable production the growth and accumulation of peat stops and decomposition is accelerated.

The characteristic physical properties of peat, such as the range of particle sizes and pore sizes, are a function of the peat’s degree of decomposition. At first, the peat soil is a very light material with high porosity and low bulk density. An undecomposed Sphagnum peat is estimated to be approximately 20 times lighter than an equivalent volume of mineral soil. However, as the peat soil decomposes through biochemical activity and pulverization by tillage, this difference diminishes, until a well decomposed organic soil is formed. A well, decomposed organic soil can be as little as 5 times
lighter than an equivalent volume of mineral soil, because as the soil decomposes it becomes more compact. The water holding capacity of a Sphagnum peat is extremely high (approximately 5 to 6 times that of a mineral soil). Water holding capacity also decreases as decomposition and drying progress. With advanced decomposition and drying, water movement also slows down dramatically. Drying traps air within the peat. Newfoundland farmers have observed these effects of decomposition within 5 years of development.

**Subsidence**

Once a peat bog is drained, tilled, limed and fertilized decomposition is accelerated and the volume of peat decreases. The result is a decrease in the depth or thickness of the peat soil. This process is called subsidence. The rate at which decomposition occurs after the land is developed will determine the loss of soil and subsidence of the surface.

Peat type, temperature, and depth of the water table have also been identified as major factors involved in the decomposition process. These factors are likely responsible for the different subsidence rates observed for organic soils in Eastern Canada. An average subsidence rate of 2.5 cm (1 inch) per year was measured at a cultivated farm in Sainte-Clotilde, Quebec after 35 years of cultivation. In southwestern Quebec mesisols, subsidence rate was found to be 5 to 8 cm per year during the first 6 to 8 years after development, but stabilized near 1 cm per year after 50 years. Biological decomposition and subsidence should be slower in colder climates and in humic peats. To date, relatively little subsidence has been observed under Newfoundland conditions.

**Compaction**

Associated with the subsidence is an increase in bulk density and a decrease in porosity and infiltration capacity, i.e. the soil is compressed or compacted and consequently the drainage is poorer. Most field operations cause some compaction. Increased wheel pressures enhance compaction but operations conducted in wet soil conditions can cause the most serious problems. As the soil becomes more compacted, its ability to drain is reduced causing wetter conditions at the soil surface, which may, in turn, cause more compaction.

A peat soil under production has a tendency to compact easily, especially if it has been over-tilled, and if a compacted crust forms on top, seedling emergence will be inhibited. Crusting, however, has not been identified as a major problem in Newfoundland.
Soil Erosion

A reduction in soil depth is often attributed to subsidence alone, but it can also be due to the loss of surface material due to erosion. Soil movement is caused by wind, water and tillage resulting in losses and accumulations of peat within the field and losses from the field. This redistribution of soil is considered to be a degrading process because it negatively affects crop productivity and the environment.

In the spring when the soil is still frozen and heavy rain cannot penetrate the soil surface, the water runs off the surface to the ditches. Runoff can carry considerable amounts of peat material from the field. Sediments in the ditches can reduce the effectiveness of the drainage system while sediments that are carried to a watercourse can have negative environmental impacts. The displacement of soil due to the action of tillage is another erosive process. Soil movement by tillage can cause levelling of fields reducing their desired crowned surface.

Cultivated peat soils are more susceptible to wind erosion than their natural counterparts. Although significant wind erosion rarely occurs in Newfoundland, it can be a concern. Wind erosion can be observed in the summer and winter. When there is no snow cover on the bog during the winter, dry winds can blow the peat. Brown snow is evidence of this process. In the spring and early summer, if the peat becomes dry at the surface and has little protective cover from vegetation, it becomes very sensitive to blowing. Wind erosion moves soil within the field, but wind also moves the peat to the ditches where it is washed away or blown out of the bog. Windbreaks can be established to reduce soil losses by wind, but by restricting wind flow they also reduce evapotranspiration which has a significant drying effect during the growing season.

It is unfortunate that the adjustments which facilitate plant growth also create conditions most favourable to biological oxidation and to the loss of soil. At an estimated rate of peat accumulation of 0.6 to 0.7 mm per year under natural conditions, peatlands can be considered non-renewable resources. Responsible management practices must be conducted to minimize soil loss if peat soils are to sustain vegetable production. The need for drainage, liming, fertilization and tillage must be balanced against long-term impacts of accelerated decomposition and soil erosion.
PEATLAND SELECTION

There are several features of a peat bog which are generally used to determine its suitability for vegetable production. They are the type of peat, depth of peat, content of wood in the peat, type of material underlying the peat, slope of the bog’s surface, presence of flashets and pools on the bog, and climate of the region. These features are described at the surface or near-surface to a depth of 160 cm (5 ft).

**Type of peat.** The origin of the organic material is important because it gives an indication of the nutrient content, the state of decomposition and the potential rate of decomposition.

There are two main sources of peat: those developed mainly from sedges and those developed mainly from Sphagnum mosses. More emphasis is generally placed on Sphagnum peat in Newfoundland because most of the organic soils are of Sphagnum material with lesser amounts of sedges. Sedge peat takes a long time for its fibres to break down, it is difficult to till and manage, and the fibres make it hard to maintain drainage ditches. As well, decomposed sedge material often impedes drainage.

There are three classes of peat materials based on decomposition: fibric, mesic, and humic.

**Fibric** peat material (light brown or blonde in colour) is at an early stage of decomposition (slightly decomposed). Much of the material can be recognized as to its plant origin. It is usually classified in the von Post scale of decomposition as class 1 to 4. A fibric peat is preferred for the initial drainage of the bog, because it is better able to support the drainage equipment, even when saturated. Very high rates of fertilizer, particularly nitrogen, are required for vegetable production on fibric peat. Once the peat is drained, accelerated decomposition causes a very high nutrient demand. The nutrient demand decreases as the rate of decomposition decreases and the degree of decomposition increases.

**Mesic** peat material (brown in colour) is at an intermediate stage of decomposition (moderately decomposed). It is usually classified in the von Post scale of decomposition as class 5 or 6. From a vegetable production standpoint, a mesic peat provides adequate drainage and does not require the extremely high rates of fertilizer that is needed for a decomposing fibric peat. This is the minimum state of decomposition for good soil to seed contact.

**Humic** peat material (dark brown to black in colour) is in an advanced stage of decomposition (well decomposed). This material contains few, if any, recognizable fibres and is usually classified in

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**von Post Scale**

The von Post Scale is an index used to describe the degree of decomposition of organic soil materials, such as peat. The degree of decomposition is determined by: squeezing a sample of peat within the closed hand; observing the colour of solution expressed between the fingers; the nature of the fibres; and the proportion of the original sample that remains in the hand.
the von Post scale of decomposition as class 7 to 10. The bulk density of humic peat is relatively high in comparison to the less decomposed peats. Consequently, below the till-layer humic peats can have very poor drainage capacity making both development and utilization difficult. Humic peat provides excellent soil to seed contact, but it is also very susceptible to soil compaction and erosion.

It is generally found that if development begins with a fibric peat, it will breakdown and become more like a mesic peat during the first few years of drainage, tillage and fertilization. If development begins with a mesic material, it will only be a couple of years before it reaches a humic state. Therefore, to sustain production, bogs of fibric peat (preferably classes 3 to 4 on the von Post scale) should be selected for development over those which are more decomposed. Since the mesic state of peat decomposition is preferred for vegetable production, once it has been reached, it is important to avoid over draining, over tilling, and over fertilizing.

- **Depth of peat soil.** Although vegetables can be grown on peat soils that are less than 1 m (3 ft) in depth, it is necessary to have greater depth to facilitate drainage: 1.6 m (5 ft) is needed for ditching. Decomposition and subsidence of the peat will reduce the soil depth over time. The regions of Newfoundland where rainfall is high and temperatures are cool, will have relatively slow rates of decomposition and subsidence. Roads and turning areas for field equipment can be located on areas that are too shallow to ditch or cultivate.

- **Wood content.** The presence of wood in the soil can hinder cultivation and ditching. It is ideal to have less than 5% wood content by volume in the top 1.6 m. Greater than 25% is considered a serious restriction to development. Wood content is based on the amount of wood exceeding 5 cm (2 in) in diameter to a depth of 1.6 m.

- **Underlying material.** Coarse textured material (sands) beneath the peat can improve the drainage, structure, and bearing capacity of the peat. Medium textured material (silt and loams) can create some problems in these areas, whereas fine textured materials (clays) can present severe drainage problems. Gravel, which ranges in size from pebbles to boulders, can be a problem in shallow bogs especially if it is tilled into the surface layers of the peat. Bedrock presents the greatest problem in developing and utilizing a bog. Most Newfoundland peat soils are underlain with stony material. Even when underlain with silts and sands, drainage can be severely impeded by naturally cemented layers known as placic horizons.

- **Slope.** Surface grade is an important consideration for draining,
developing and working with peat in Newfoundland. Peatland occurs on slopes that range from nearly level on blanket bogs to more than 10% on dome bogs. A slope of 1 to 3% is ideal because it will allow drainage without hindering the development of the bog and the operation of machinery.

< Flashets and Pools. Peat deposits in Newfoundland can range in size from less than a few hectares to over 100 hectares. Flashets or pools (shallow surface water that persists most of the year) occur on many peatlands, regardless of their size. They present potential problems to draining, developing and operating on peat bogs. They may also be significant wildlife habitats. Bogs, or sections of bogs, with extensive pools should be avoided. Even when drained and filled, pools may persist as wet spots causing difficulties in management.

< Climate. For vegetable production climate is characterized by the length of the growing season, the temperature (maximum, number of degree days and frost free days), the rainfall during the growing season, as well as the average annual precipitation (amount and distribution). All of these climatic characteristics differ significantly from the mainland and vary considerably across the island. The west coast is generally drier and the Avalon Peninsula is generally cooler and wetter. Considering the importance of wind as an agent of evapotranspiration, another useful descriptor of climate would be the drying capacity of the air, a drying index based on wind speed and frequency, the air’s moisture content, and barometric pressure.

This information is discussed in greater detail in Vegetable Crop Suitability of Organic Soils in Newfoundland where a rating system to assess suitability for vegetable crop production is presented. In the above mentioned report ‘suitability’ reflects, primarily, development and cultivation, and not fertility, crop productivity, maintenance or other management and economic considerations.

Many other factors should also be considered in the assessment of a peat bog before initiating development and utilization for vegetable production. There are relevant characteristics of peat soils in addition to those listed above such as mineral content. Clay, for example, is a source of nutrients and also contributes to the nutrient capacity of the peat soil. Although the mineral content of most peat soils is generally only a few percent, those situated along streams and rivers can be significantly higher due to flooding.

The acidity and fertility of a native bog can vary depending on the state of peat decomposition and the characteristics of the landscape in which it is situated. A poorly decomposed peat has a lower natural fertility, and hence greater nutrient requirements upon development,
than a well decomposed peat. When a bog is situated in a landscape where water enters as surface runoff, groundwater inflow or flood water, significant amounts of mineral material can be supplied which may increase fertility and decrease acidity (increase pH). Acidity and fertility may play a less important role in determining the suitability of a bog because they can be adjusted to optimum levels using proper management (see NUTRIENT MANAGEMENT).

During the selection process, consideration should also be given to several other factors which do not directly affect crop production, but can greatly affect the viability of the farm operation.

Possibly the most critical step in the selection process is the determination of land title and gaining the right to develop a proposed site. Agreements must be established where individuals or communities have the right to access the bog. Any land development which involves the alteration of a water body, including the draining of wetlands, or which is in a protected water supply watershed requires submission of an Application for Environmental Approval to the Department of Environment.

The size of the site and its potential production capacity must be considered when justifying capital costs for specialized equipment for use on the bog. Diversified farms which integrate crop or livestock production on mineral soils with crop production on bogs, can overcome this problem through innovations which increase the versatility of equipment.

Adequate maintenance of a bog may represent significant costs to an operation. A site which is expensive to develop will likely be costly to maintain.

The location of the site will greatly affect its accessibility to necessary services. If an access road or hydro must be installed, it can greatly affect the development cost. The location of a site will also affect availability of labour, distance to markets, and availability of storage.

All land development has the potential for negative environmental impacts. A bog developed for agriculture can have both on-farm and off-farm environmental impacts depending on its situation in the landscape. For example, when bog drainage water is diverted directly into a sensitive ecosystem such as fish spawning beds. It may be unlawful to develop a peat bog within protected areas or protected watersheds.

In general, peat bogs that are suited for vegetable production are also well suited for other uses, both agricultural and non-agricultural. These include: forage, grazing, extraction, etc. Peat bogs that are unsuited for vegetable production may be well suited for recreation or
preservation. It has been recommended by the Canadian Government that each province set aside at least 12% of each natural ecosystem, including wetlands, to sustain biodiversity.

Although some bogs may not be suitable for vegetable production as a whole, there may be sufficiently large areas within them that are. This gives rise to the concept of multipurpose development strategies.
PEATLAND DEVELOPMENT

After a peat bog has been selected there are many operations that must be carried out to prepare it for vegetable production. A topographical survey is necessary to determine suitability, but this information is probably more critical at the developmental stage for the design of the drainage system and field layout.

< Land clearing. Trees, brush, shrubs and other unwanted vegetative debris must be removed to allow for drainage installation and future management operations. This is done with tree pullers and brush cutters, and can be minimized by limiting development to the deeper, central area of a bog where large vegetation has not established. Raking should be done to remove roots from the bog’s surface layers.

< Primary drainage. Primary or surface drainage is required to remove water from the peat and lower the water table within the bog. Primary drainage consists of a perimeter ditch surrounding the development site and lateral ditches which cross the area within the perimeter ditch. The ditches allow the drainage water to move from the site to the drainage outlet. They also intercept snow, rainfall and surface runoff and remove this water from the site.

Lateral ditches can have straight walls (Healy ditcher), but the V-shaped ditches (DONDI ditcher) are preferred because they are more stable, resulting in less infilling. However, the V-shaped ditches take up about twice the land area. The recommended spacing of lateral ditches is 15 m (45 feet). As a general rule, ditch spacings should be reduced by 1 m from 15 m for every 100 mm annual rainfall above 1000 mm (e.g. 15 m spacings in Botwood and 10 m spacings in Colinet where annual precipitation is 1000 and 1500 mm, respectively). However, lateral ditches define the working width of the fields, therefore they must be compatible with the equipment available for tillage, spraying, etc. Subsurface drainage can be used to compensate for inadequate spacing of the lateral ditches.
The minimal grade for both types of primary ditches is 0.5 %, or 6 inches of fall for every 100 feet. The depths of the ditches is of less importance than the spacing, but they should be at least 1 m (3 feet) deep. The perimeter ditch must have sufficient capacity and grade to remove the water from the bog quickly. Therefore, it has to be wider and deeper than the lateral ditches. A backhoe is required to install the perimeter ditch.

_Drainage, through its impact on water levels and movement, is considered to be a major factor in crop productivity and profitability, profoundly affecting soil and nutrient management. The drainage system employed must ensure evacuation of surface water in the spring and after heavy rains in the summer. At the same time, the water-table must be maintained at a level that allows operation of farm equipment, as well as optimizing plant growth while minimizing subsidence caused by increased oxidation of the peat._

< Secondary drainage. Secondary or subsurface drainage is recommended to enhance the flow of water from the peat to the open ditches. Mole drainage is the most efficient drainage operation in humic peats. Mole drains are preferred over tile drains due primarily to the high cost of the plastic tile which must have a nylon sock to keep the fine peat particles out. Although rare, it is very expensive to replace tile drains if they fill with sediments, lose their grade with subsidence, or become too close to the surface as the bog subsides. Mole drains can be reestablished with relative ease. Mole drains are milled out or made by forcing a plug through the peat. Forced mole drains may close in and lose their effectiveness as the compacted peat around the drain expands over time. Mole drains should have 1 to 3 % grade.

< Drainage outlets. The placement of the drainage outlet is critical because the water in the bog can not drain below the level of the outlet. The drainage outlet is the point at which contaminants should be removed from the drainage effluent before it enters surface water bodies, such as lakes and streams. Settling ponds are recommended to remove sediments from the effluent, but they are ineffective in removing nutrients and other dissolved contaminants. A new practice to deal with the drainage effluent uses the peat as a filter by opening the perimeter ditch onto a low outlying area of the bog.

< Access roads and bridges. A main access road into the bog must be established to provide a reliable pathway for heavy equipment. A solid road base can be constructed with rock fill or timber corduroy. Geotextile fabrics can provide excellent additional support, but they are expensive. It is advantageous to build the road over areas where bedrock is near the surface. Permanent bridges using culverts should be used to cross the main ditch. Secondary roads within the bog and bridges to cross the
lateral ditches may also be required. Temporary bridges made of timber can be used to cross the lateral ditches. Roadways restrict subsurface water flow and can cause wet spots to develop by impeding water movement to the ditches. Therefore they should be strategically placed to minimize this problem.

< Draining pools and flashets. Pools or flashets within the area cleared for production should be drained if they interfere with field operations. However, pools, even after they are drained and filled, can cause management problems as they may develop into persistent wet spots. Therefore, areas which have many or very large pools should be avoided when laying out secondary drains and fields.

< Rotovating. During the development of the peatland, rotovation is done to cut the roots of trees and shrubs as well as loosen and mix surface materials. Less intensive rotovation is conducted as a tillage practice in regular soil management.

< Landforming. After the ditches are installed, the fields should be profiled and cambered to shape or crown the field surface. This will provide a more uniform depth to water table, enhance surface runoff to the ditches and eliminate depressions that may cause persistent wet spots. Aggressive profiling may eliminate the need for the initial rotovation.

< Ditch bank stabilization. By not cropping along the banks of ditches, a buffer zone is created for bank stabilization as well as safety. These buffers can be seeded with rye grass or another annual plant, which would provide additional stability and enhance evapotranspiration while suppressing weed growth along the ditches. As with intercrops (see SOIL AND CROP MANAGEMENT), such crops should be selected based on their potential to act as hosts for insects and diseases. Where ditch crossings are required, temporary bridges should be used rather than driving directly across the ditch.

< Safety precautions. Large open ditches pose a potential hazard to humans crossing the developed site. The perimeter of the site should be clearly signed indicating the danger.

< Controlled drainage. Intensive drainage systems can lead to over drainage in dry years. Although this may be a rare event in Newfoundland, it can result in crop stress and soil erosion by wind. Controlled drainage systems allow the restriction of drainage by blocking off ditches. The decomposition of peat soils
can be minimized by raising the water table as much as the crop will allow. Controlling the water table is probably the most inexpensive and effective means of reducing biological oxidation and the resulting subsidence of these soils. Controlled drainage may prove to be a method of controlling the frost layer during the winter and the movement of polluted drainage water from the bog.

Long-term drainage requirements. As the peat decomposes and becomes compacted after development and during utilization, the drainage requirements (ditch spacing) may increase as much as 3 fold (for example from 30 m after development to 10 m after 30 years of vegetable production). To slow the transition to a more decomposed and more compacted peat it is important to avoid over draining, over tilling, and over fertilizing once the bog has been developed.
WATER MANAGEMENT

The management of water in Newfoundland's peat soils, particularly in the surface layers, is critical to ensuring that the soil is suitably dry for vegetable growth while being stable enough for equipment traffic throughout the field season. The optimal depth to water table for vegetable production on peat soils is approximately 70 to 80 cm.

*It is of utmost importance to maintain an effective drainage system and employ field management practices that increase the ‘windows of opportunity’ to plant, manage and harvest vegetable crops by enhancing drainage and evapotranspiration (the combined evaporation from the soil surface and transpiration from the plants) of water.*

After the bog has been ditched and landformed, there are still many practices that should be carried out to **maintain the drainage system** to provide optimum moisture contents for plant growth and field operations.

<< Maintain the drainage ditches. Ditches should be cleaned of blockages and sediment regularly. Standing water or ponding indicates that the ditch is not draining effectively. Any obstruction to water flow should be removed immediately. If there is a lot of infilling a ditcher may be needed. It can be expected that the drains will need to be reditched about every 5 years.

≠ Inspect the drainage ditches regularly.

<< Maintain the subsurface drains. As with the ditches, the mole drains may need to be reopened periodically. As these drains fill in they become less effective. As the peat decomposes over time additional mole drains may be required. The outlets of subsurface drains should also be kept clean of all obstructions to outflow. Excessive vegetation should be removed from the outlets and outlets should have ‘rodent traps' to protect against blockages by animals.

≠ Inspect the subsurface drain outlets regularly.

There are also several **soil management and cropping practices** that can be carried out routinely by the grower to enhance both drainage and evapotranspiration.
<Raised beds, ridged beds and plough beds.> Because the soil in the bed is raised above the surrounding soil, drainage within the bed is enhanced and the surface area from which water can evaporate is increased. These soil conditions improve crop growth relative to flat beds which has the added benefit of increasing transpiration. When planning raised beds, sufficient bearing capacity should be provided in the inter-rows by peat fibres, drainage and/or possibly intercrops.

<Intercropping.> Establishing crops between the beds increases the amount of water removed from the soil by plants (for crop selection see SOIL AND CROP MANAGEMENT). In areas covered by vegetation, water loss by transpiration is usually two to five times greater than the loss by evaporation. Weeds can also enhance the removal of soil water but they are much more difficult to control than a well selected intercrop.

<Tillage.> Tillage is usually considered a practice to prepare the seedbed or to control weeds (see SOIL AND CROP MANAGEMENT). However, tillage can have an important impact on the soil moisture levels. Tillage increases evaporation of water from the soil by increasing the surface area and turning wet subsoil to the surface. Tillage can also create an air barrier which can restrict the movement of water from the wet subsoil to the surface (peat is like a sponge in that when the surface dries it sucks water up from the wetter subsoil). However, in reducing the weed population, tillage reduces the amount of water removed from the soil by transpiration which can remove larger quantities than evaporation.

The selection of appropriate field equipment can reduce the potential for problems arising from trafficking on wet peat soils.

< Floatation tires, dual wheels, tracks, half tracks.> These technologies can be used to increase trafficability on wet peat soils. The costs of these technologies varies tremendously. The costs may be greatly reduced if the farmer is able to modify an existing tractor.

For general use on bogs (i.e. ploughing, rotovating, planting, fertilizing, spraying, cultivating, harvesting and hauling) a four wheel drive tractor with dual tires on the front and back is adequate under most conditions. Tractors equipped with tracks and ATVs (all-
terrain-vehicles) can be used to reduce pressure applied at the soil surface from wheels. The three- and four-wheel ATVs have been found to cause a lot of damage to the soil surface when turning.
SOIL & CROP MANAGEMENT

Intensive vegetable crop production on Newfoundland’s peat soils creates a number of challenges for soil and crop management. The foremost is developing a soil and crop management strategy that provides adequate ‘windows of opportunity’ for necessary field operations.

Soil Management

Tillage is the common element in all soil management practices. Field operations that include some form of tillage are ploughing, discing, rotovating, cultivating, harrowing, and due to their impact on the soil, ridging or bedding and harvesting. One of the main functions of tillage is to prepare a suitable seedbed. As stated in the previous section (WATER MANAGEMENT), tillage can be used to provide a suitably dry and, therefore, warm soil for planting. Tillage is also necessary to incorporate lime and some fertilizers with tillage (see NUTRIENT MANAGEMENT).

All tillage operations provide some degree of weed control, but some, such as mid-season cultivation, are conducted specifically for that purpose (see PEST MANAGEMENT).

The soil is usually prepared for planting as raised beds and ridged beds. These beds are made through rotovation. They provide warmer, drier and better aerated soil for plant growth than flat beds. For small seed crops such as carrots the soil may have to be rolled after tillage operations to provide adequate soil-to-seed contact.

A well managed, productive soil allows for a vigorous root system which can resist crop stresses caused by adverse soil and climate conditions and pests. To produce a high yielding, healthy crop, peat soil should be managed in a way that:

< Maintains or improves the ability of water to move in (infiltration) and through the peat (drainage), or from the soil surface (evapotranspiration).

< Maintains or improves the plant’s ability to grow a good root system and take up nutrients (water table and pH control).

< Provides adequate soil aeration.

< Minimizes compaction, erosion and crusting of the soil.

Given the nature of peat and its tendency to decompose under vegetable production, achieving these objectives may be difficult to impossible over the long-term as the peat transforms physically and chemically. The integrated management of soil, crops, water, nutrients, and pests with minimal excesses is the most effective way to achieve sustainable, profitable vegetable production on peatlands.
Although peat soils require less tillage than mineral soils, **intensive tillage** is often associated with peatland vegetable production. Clearly, tillage is a necessary field operation on peat soils, but excess tillage should be avoided. Additional tillage may be a means of drying the soil surface, but it can also accelerate the decomposition of the peat which can result in long-term management problems.

**Crop Management**

There is a broad range of crops that can be grown on Newfoundland peat soils. The crops that have proven to be most successful historically include: cabbage, carrots, and celery. Crops such as asparagus, beets, broccoli, cauliflower, potatoes, and rutabaga can be grown on peat soils and have shown some potential on the local and regional markets. Tomatoes, peppers, cucumbers, corn, peas, beans, and eggplants are often avoided because the climate is not suitable for commercial production of these crops.

To optimize productivity and maximize profitability, it is important to select vegetable crops and varieties that are suited to the soil type and climate conditions. Selection is primarily based on crop yield potentials given the bog’s local and regional climatic conditions (precipitation, degree days, frost-free days, etc.). The profit potential for a crop is based on its yield potential, market value and cost of production. The total and marketable yields also depend on soil management (acidity, fertility, temperature, moisture content, depth to water table) and pressure from weeds, insects and diseases.

Other factors which must be considered in crop selection include:

- Market demands - fresh and processed.
- Storage and transportation requirements.
- Availability and cost of planting and harvesting equipment.

The method used to plant (seed or transplant) and harvest crops can vary greatly in technical complexity and cost. Manual techniques can still be cost effective, particularly for smaller operations. Manual methods provide significant environmental benefits over mechanical.

The sequence of crops can have an important impact on productivity. For example, beet crops are very sensitive to weed pressure. Therefore, if weed problems are anticipated as vegetable production on the bog progresses and effective weed control cannot be achieved, beets should be grown in the first couple of years after the bog’s development when weed pressures are lowest. The sequence of selected vegetable crops should be based on:
the stage of the bog’s development,
the previous crop and associated management,
the crop to follow and associated management.

### Vegetable Crops Suitable to Newfoundland's Climate

<table>
<thead>
<tr>
<th>Vegetable Crop</th>
<th>Plant Family</th>
<th>Optimum Temperature (°C)</th>
<th>Resistance to Cold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutabaga</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Radish</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Parsnips</td>
<td>Umbelliferae (carrot)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Beet</td>
<td>Chenopodiaceae (goose foot)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Spinach</td>
<td>Chenopodiaceae (goose foot)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Brussel sprouts</td>
<td>Chenopodiaceae (goose foot)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Asparagus</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>very</td>
</tr>
<tr>
<td>Rhubarb</td>
<td>Liliaceae (lily) Polygonaceae</td>
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<td>somewhat</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>(buckwheat) Compositeae (sunflower)</td>
<td>13-24</td>
<td>cold sensitive</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Compositeae (sunflower)</td>
<td>13-24</td>
<td>cold sensitive</td>
</tr>
<tr>
<td>Celery</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>somewhat</td>
</tr>
<tr>
<td>Carrot</td>
<td>Cruciferae (mustard)</td>
<td>15-18</td>
<td>somewhat</td>
</tr>
<tr>
<td>Potato</td>
<td>Umbelliferae (carrot)</td>
<td>15-18</td>
<td>somewhat</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Umbelliferae (carrot) Solanaceae</td>
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</tr>
<tr>
<td>Onions</td>
<td>Compositeae (sunflower)</td>
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<td>cold sensitive</td>
</tr>
<tr>
<td>Shallots</td>
<td>Compositeae (sunflower)</td>
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<tr>
<td>Leeks</td>
<td>(Amaryllis) Amaryllidaceae (Amaryllis)</td>
<td>13-24</td>
<td>cold sensitive</td>
</tr>
</tbody>
</table>

**Crop rotation** is a common practice although peat soils do not require crop rotations or additions of green manure to increase organic matter content. Rather, crop rotation is a desirable practice for preventing the build-up of soil borne pests. For example, clubroot in cabbage can be suppressed with rotation. Sclerotinia mould of carrot (which also affects lettuce, beans, and celery) may be controlled with a rotation including onion, beets, or spinach. Insects, nematodes, weeds and diseases (fungal, viral and bacterial) develop quickly and easily, both in the peat soil and in the crops produced. Radish, spinach and oat starve the northern root-
knot nematodes affecting carrot yield and quality. A typical peatland crop rotation is carrot-cabbage-carrot-cabbage. The inclusion of a sod crop in rotation may benefit pest control.

**Plant spacing and density** within rows and **row spacing** may be important factors to consider with respect to soil and air moisture management of the vegetable plants. In most cases, increasing the number of plants will increase moisture losses by increasing transpiration. However, plants that are too tightly packed (through high plant density and narrow row spacing) can reduce air circulation below the canopy and may result in persistent damp conditions where disease can take hold and spread.

**Intercropping** the alleyways between vegetable crop beds with annual crops such as barley, rye grass and oil seed radish could be useful for dealing with wetter soil conditions in these areas. Intercrops should be selected based on their ability to increase bearing capacity (trafficability) and evapotranspiration, suppress weeds, and their potential to act as a host for insects and diseases. Intercropping can also be used to control wind erosion.

**Strip cropping** may help to deal with variable water table depth, soil water content, fertility, etc. between the drainage ditches. As well, it can be used to control wind erosion.

A **cover crop** or **green manure crop** should be established whenever possible, ideally after the harvest of an early season crop. By keeping the soil continuously covered, these crops reduce wind erosion, particularly in the winter, and take up excess nutrients which can be made available to the following crop. The use of a grass, such as timothy or rye, as a cover crop is promising as it permits the use of selective herbicides to control weeds. Cover crops may require additional tillage to turn them under.

**Field Equipment**

To save on equipment costs, the equipment used on peat soils for field operations is often the same equipment used on mineral soils. There are two reasons for this: peatland producers also farm minerals soils on their operation; and the equipment developed specifically for peat soils is unavailable or very expensive.

**Adjustments and modifications** to equipment are usually required when moving from mineral to peat soils, just as when moving from sandy to clayey soils. Failure to make necessary modifications can result in the inability to conduct the required field operations, for example, spring tillage without dual wheels and front wheel assist on the tractor.
NUTRIENT MANAGEMENT

Nutrient management is a critical element of vegetable production on any soil. On peat soils, nutrient management is complicated by the soil’s naturally low fertility, high carbon content, and very acid pH. Poor nutrient management can result in crop failure or make the cost of producing a good crop economically unsustainable. An effective nutrient management system will:

- ensure crop productivity and marketability,
- optimize production inputs (lime, fertilizer, equipment, time) while eliminating any unnecessary production costs,
- minimize environmental impacts from vegetable production.

Nutrient management requires a systems approach as it is intimately linked to soil, pest, and water management. There are several nutrients required by each crop and the level of each, for optimal crop growth, depends on the crop being grown and the variety selected. To be best used by the plant, the nutrients must be kept in balance with each other. Nutrient availability and use is greatly affected by soil pH. A plant that is suffering from either a nutrient deficiency or excess is structurally weakened or under stress and, consequently, will be more susceptible to damage by insects and disease. Essential crop nutrients are also nutrients for weeds, therefore excess fertilization can result in weed proliferation rather than higher crop yields. Nutrient availability is also influenced by soil moisture. A poorly or excessively drained soil will be more difficult to manage for optimum soil fertility than one where drainage is good.

The peat bog must undergo significant changes before it is suitable for vegetable production. The physical and chemical properties of the peat soil continue to change for many years after it is brought into production and, therefore, nutrient management must change to accommodate this.

The Nutrient Cycle

A peat soil can be broken down into several components. These include the peat fraction, the soil solution (soil water and contained minerals), soil air, and the soil biota (microorganisms, macroorganisms, and plants). Their quantity and properties influence how the nutrients are cycled and how much is available to the crop. Climate also plays a major role in the nutrient cycle.

A Sphagnum peat bog has very low natural fertility. Nutrients are
supplied by snow, rainfall or water flowing into the bog. Levels are usually too low, or the nutrients are bound too tightly to the soil to be available for crop growth. Therefore, fertilizers must be applied for vegetable crop production.

**Commercial fertilizer** is the most common source of nutrients. The use of organic fertilizer (i.e. manure) for vegetable production on peat soils is uncommon due to more efficient use on mineral soils and due to concerns about the potential for increased weed and disease problems. Composted manure could be used to “inoculate” newly developed peatland with organisms which decompose organic matter.

Applied fertilizer has many fates. Only a portion of the fertilizer is used by the crop. Some of the nutrients may be taken up by weeds. The peat, as a source of organic matter, will bind many of the nutrients and hold them unavailable to the plants. The soil organisms will also consume a large proportion of the nutrients applied, particularly nitrogen, and to a lesser extent phosphorus. At harvest, only the nutrients retained in the produce are actually removed from the field, and their levels depend on crop yield. A substantial proportion of the nutrients will remain in the field to be used by subsequent crops or lost to the environment. **Crop residues and culls** will return nutrients to the soil unless they are removed from the field to control disease.

**Soil Acidity**

The first step in an effective nutrient management system is the adjustment of soil pH to a level which optimizes the availability of applied nutrients for crop growth, i.e. fertilizer efficiency. Sphagnum peat bogs are acidic. Their natural pH is often as low as 3.5. The optimal pH for most nutrients in organic soils is about 5.5, i.e. one pH unit lower than the optimum for mineral soils. As soil pH increases or decreases from this optimal value some nutrients become less available and can cause crop nutrient deficiencies. Similarly, other elements (i.e. aluminium) can reach toxic levels and cause crop damage.

The initial amount of lime required to bring the pH of the peat soil to such a level will be *much* greater than the amounts required to maintain that pH once it has been reached. In general, after the bog has been cleared and drained and before vegetable production is initiated, very high rates of lime are required - as much as 20,000 kg/ha - whereas later maintenance requirements may be more in the order of 2000 kg/ha. As peat decomposition then progresses, the amount of lime required to maintain the desired pH of a peat soil may increase due to the release of acidic products of decomposition.
The acidity of a peat soil is caused by the presence of peat acids which are associated with the organic matter. The acidity of organic soils consists of two distinct parts: active acidity (acid in the soil water), and potential acidity (acid held in reserve on the surface of the soil particles).

Routine pH determinations measure the active acidity of the soil. However, it is the potential acidity that is the much larger part of the total acidity. To increase the pH and decrease the acidity (neutralization), lime is added to the soil. Neutralization of the active acidity is accomplished with fairly small amounts of lime, but as time progresses, the potential acidity is released. Therefore, lime applications must be planned to neutralize both the active and the potential forms of acidity.

Decomposition produces acids which lower the pH of the soil solution but it also reduces the size of the organic soil particles. A given weight of soil made up of smaller particles will have an increased total surface area. A larger surface area means there are more places to hold acid in reserve, or an increased potential acidity. Lime must be added regularly to keep the soil from becoming too acidic.

Management of pH on a peat soil is further complicated because the addition of NH₄⁺-containing fertilizers [such as (NH₄)₂SO₄ (ammonium sulfate) and NH₄NO₃ (ammonium nitrate)] and the uptake of nutrients by plants both contribute to soil acidity. Vegetable production requires large nitrogen additions. If it is added in the NH₄⁺ form, it will contribute to soil acidity.

Soil pH and liming also influence the decomposition rates and subsidence of the peat. The activity of the soil microorganisms (microbiological oxidation) is believed to be responsible for most of the decomposition of organic soils. Microbial activity, like many biological processes, occurs at an optimal soil pH. Increasing the pH through liming not only improves nutrient availability and retention in the plough layer, but it also increases microbial oxidation (breakdown) of the peat.

Finely ground limestone is normally applied to acid soils. Superfine calcitic limestone (CaCO₃) is recommended when a rapid response of soil pH is required. For Newfoundland peat soils, which are low in magnesium (Mg), dolomitic (CaCO₃·MgCO₃) limestone is preferred. Calcite and dolomite are also important sources of Ca (calcium), and Ca and Mg, respectively. Both elements are essential plant nutrients.

When considering plant nutrition, the amount of calcium which is available to the crop is less important than its presence relative to other cations (positively charged nutrients). The addition of Ca in
the form of lime is intended to adjust the soil pH. However, the concentration of Ca in the soil solution is also related to the availability of several major and minor plant nutrients. The addition of lime increases the amount of available Ca, but it may decrease the availability of the macronutrients N (nitrogen), P (phosphorus), and K (potassium), as well as the micronutrients (except molybdenum). Therefore, the complex relationships between pH, Ca and plant nutrient availability makes mere analysis of pH of an organic soil insufficient for solving plant nutrition problems. As well, the relationships between pH and nutrient availability are not the same in organic soils as they are for mineral soils (e.g. there is often copper deficiency in organic soils but seldom in mineral soils in the same pH range).

Effective management of soil pH relies on accurate recommendations for the amount and type of lime applied. These recommendations require knowledge of the soil acidity as well as other chemical properties of the soil, including cation exchange capacity and buffer capacity.

Peat soils are able to hold many nutrients because there are negatively charged sites on the organic matter that the positively charged nutrients (cations such as Ca\(^{2+}\), Mg\(^{2+}\), K\(^+\), NH\(_4^+\)) are drawn to. These nutrients can be "pulled off" by plant roots but they can also exchange places with other cations in the soil solution. The soil's ability to hold and exchange nutrients is called the cation exchange capacity (CEC). Cation exchange capacity is pH dependant and largely determines the buffer capacity of a soil (or the ability of a soil to resist a change in pH). The buffering capacity of an organic soil is far greater than that of a mineral soil.
In practical terms, this means that far more lime is required to increase the pH of an organic soil than would be required for the same increase on a mineral soil. Crops grow in an organic soil at a lower pH than in a mineral soil without being affected by the higher degree of acidity because organic soils contain a small amount of exchangeable aluminum. Optimum plant growth in mineral soils is obtained at pH 6.5, compared to 5.5 for peat soils.

**Lime Application**

Lime applied to a peat soil has very little lateral or horizontal movement, therefore, it is very important to obtain good mixing within the till layer to avoid pockets or layers of high and low pH. Deep-rooting acid-sensitive crops (e.g. carrots) should have half the lime applied and incorporated to 15 to 20 cm (6 to 8 in), followed by ploughing to 36 to 45 cm. The remainder of the lime should then be applied and thoroughly incorporated to a depth of about 15 to 20 cm. The lime should be broadcast evenly over the surface prior to incorporation. It is also a good idea to apply the second portion of the lime after ploughing in case an acid layer gets turned with ploughing. An acid layer at the surface would threaten germinating seedlings.

The first application is ploughed deeply to form a barrier to the upward movement of acid from below. This barrier will greatly reduce acidity in the lower rooting zone and possibly extend the period between lime applications by several years. The remaining half is tilled (usually rotoated) into the top 15 to 20 cm. A uniform pH profile within the rooting zone is desired. This dual operation may be avoided in the first year by seeding an acid-tolerant crop.

Jerry Saunders

“We base our lime application on a pH of 6.5 to ensure that the whole field is greater than pH 5.5. If we don’t, we find problem spots in the crop.”

General recommendations for liming are:
Maintain soil pH at about 5.5 to ensure optimum availability of applied nutrients.

Test soil pH regularly since the response of pH to liming will vary with time. In general, soil pH should be tested every year, both for variability across the surface and with depth.

**Soil Fertility**

All of the major nutrients and many of the micronutrients must be added to make a Sphagnum peat bog productive. The common limiting elements are N, P, K, Ca, Mg, Fe, B, Cu, Mo, Zn, and Mn. Many of these elements react with each other, and some interactions can lead to nutrient deficiencies or toxicities. Deficiencies in both macro and micro nutrients are one of the long-term problems associated with vegetable production on peat soils.

During the initial stages of development, peat soils require heavy applications of nitrogen for vegetable production. This is because the fertilizer nitrogen has many fates. A large portion of the nitrogen is immobilized by soil organisms as they decompose the carbon-rich peat. As the peat becomes more highly decomposed (and nitrogen enriched) the demand for fertilizer nitrogen decreases. On a well developed peat soil under vegetable production, as little as half of the initial amount of nitrogen may be required. In wet, or oxygen limited situations, nitrate (NO$_3^-$) may be converted to gases (N$_2$, N$_2$O) by soil microorganisms, releasing nitrogen to the atmosphere by denitrification. Nitrate is also highly soluble and may be transported to groundwater through leaching or to surface waters via drainage tiles. Ammonium (NH$_4^+$) and urea (CONH$_2$) may be chemically converted to NH$_3$ and lost to the atmosphere through volatilization. Runoff and soil erosion may also transport nitrogen to surface waters within the sediments it carries. When considering Sphagnum peat for crop production, estimates of nitrogen requirements that will meet the crop’s needs must be made with an understanding of all its fates.

Potassium behaves quite differently in an organic soil than it does in a mineral soil. Potassium is tightly held in a mineral soil and highly immobile. In an organic soil, however, the strength of adsorption is weaker. Consequently, peat soils can lose considerable amounts of K in the drainage water if heavily fertilized. As well, organic particles hold Ca and Mg more tightly than K which has a smaller positive charge and, therefore, less affinity to the high CEC particles. When organic soils contain large amounts of Ca and Mg, the relative amount of K which is stored for the plants is small. This may require that high amounts of K be added, to ensure a reasonable balance for proper plant utilization. Therefore, highly acid soils that require substantial applications of
lime must also receive applications of potassium in order to establish an equilibrium between the soil cations. However, sometimes, heavy K fertilization can cause changes to the ratio of calcium to other cations in solution, enough to cause plant disorders. Potassium requirements tend to increase as peat decomposition progresses and CEC increases.

Under intensive cultivation a magnesium deficiency may occur if the soils have been heavily fertilized with muriate of potash and sulphate of ammonia. The soils will then require periodic application of amendments containing magnesium (i.e. magnesium sulphate). The calcium to magnesium balance is also very important. Therefore, when liming an organic soil to correct soil acidity, the use of dolomitic limestone rather than calcite would supply ample amounts of both Ca and Mg rather than Ca alone which would reduce the availability of Mg.

Peat soils are frequently low in the micronutrients Cu, Mn, B, Mo, Zn and Fe, and generally require supplements for normal plant growth. The need for micronutrient applications varies greatly depending on peat type, location, pH, mineral content, crop species and past treatment. There is a large range in micronutrient response with different crops. Micronutrients are commonly applied as Fritted Trace Elements - FTE or as sulfate salts. Some fungicides contain Mn, Zn or Cu.

Copper deficiency is a common problem in crops grown on newly developed peatland. Copper is strongly held by the soil complex so that once the deficiency is diagnosed, Cu application can have long-lasting effects. Copper slows the decomposition of peat by retarding biological oxidation. Regular application of 13 kg/ha of Cu (50 kg/ha of CuSO$_4$) is recommended for highly responsive crops (such as carrots). It has been observed that over-fertilization with copper can negatively affect Mo availability to the detriment of carrot production.

Fertilizer requirements not only change from one crop to the next but the levels of required nutrients change throughout the growing season and from one season to the next. There are several general recommendations for fertilizer use:

< Maintain a **proper balance of nutrients** to ensure optimum availability. The excess or deficiency of a single nutrient can affect the availability of other nutrients.

< Be able to **identify nutrient deficiencies**. Early identification of deficiencies may allow for corrective fertilizer application. Accurate identification of nutrient deficiencies in
vegetable crops grown on peat soils can be difficult (e.g. a calcium deficiency can appear very similar to nitrogen deficiency in some crops). Information and assistance is available through your crop specialist.

**Testing for Nutrients**

Fertilizer application rates are based on the amount of nutrients in the soil that are available to the crop prior to seeding, the crop nutrient requirements for yield goals, and for some in-season fertilizer applications, the nutrient content of the crop. To determine the nutrients in the soil and crop it is necessary to:

< Use **soil tests** to determine the existing soil fertility. Fertilizers can then be applied at appropriate rates where they are needed. When taking soil samples it is important to be sure they are representative of each field. Applying too much fertilizer is expensive and may also have an adverse effect on the environment. Too little fertilizer can cause nutrient deficiencies and reduced crops yields.

< Consult your soil and crop specialists for information on how, where and when to take soil samples.

< Use **plant tissue analysis** if available. Tissue tests can identify nutrient deficiencies and toxicities, and can be used to schedule in-season application of nutrients. Tissue analysis gives nutrient levels in the plants at the time they are sampled. Because it identifies problems that exist in the crop, it can be used to plan corrective nutrient applications, if possible, but it is best used to anticipate nutrient problems for the following cropping season.

< Keep **good records** to help you track each field’s fertility over time and assist in maintaining nutrient efficiency. Also record observations on crop growth, yield, quality, soil and weather conditions.

Annual soil tests are important, especially on newly developed bogs. Newly developed peat soils are highly acidic and very low in most nutrients. A complete soil analysis of the macronutrients and micronutrients is a good investment. Soil pH and levels of nutrients can change rapidly following development and initiation of vegetable production. After peat soils have been cropped for several years, levels of potassium and phosphorus will increase and, if applications do not change, may become excessive.

Traditionally, soil tests for pH and nutrient levels have been done
exclusively by provincial laboratories. There are increasing numbers of private laboratories and field kits now available for use by farmers, consultants and provincial staff. The field kits can include tests for pH, some nutrients, and tissue test kits. The reliability of soil test results should always be considered before using the information. Check to make sure the analysis being used is accredited.

**Fertilizer Recommendations**

There are a number of different approaches to interpreting fertility tests and making recommendations for fertilizer application. The traditional approach to fertility recommendation is based on the nutrient requirements for **maximum yield** under ideal soil and climate conditions.

A maintenance strategy is sometimes used for phosphorus and potassium, which will provide a build-up when soil tests are low, maintain desirable nutrient levels when soil tests are medium to high, and allow for gradual draw-down of available nutrient levels when soil tests are very high. A gradual build-up to optimal levels occurs in about five years. Applying more nutrients than recommended results in a more rapid build-up, but it may lead to nutrient balance problems and potential losses to the environment.

The more progressive approach is designed to produce **maximum economic yields** when accompanied by good or above-average management, soil and climate conditions. The worst approach to nutrient management and fertility recommendations uses maximum yields and assumes worst-case conditions (newly developed bogs and very high rainfall).
there is no available nitrogen in the soil. Considering the high rates of N being applied in Newfoundland, this assumption should be questioned, particularly after a number of years in production.

< Consult with soil and crop specialists regarding lime and fertilizer recommendations.

< Apply rates to achieve **maximum economic yields** rather than maximum yields. Economic yields maximize profits.

**Fertilizer Application**

Fertilizers are usually applied in a single spring application. Fall or early winter application of lime is acceptable, but fall application of fertilizers, particularly nitrogen, is not effective nor efficient. Multiple applications of fertilizer can be used to improve fertilizer efficiency, but may not be practical in all cases. Banding at planting can be used to supply part of the fertilizer requirement. Applications during the growing season ensure that the crop gets the required nutrients when it needs. This can be achieved with certain crops by side-dressing (e.g. ammonium nitrate and potassium) or foliar applications. Where these technologies can not be used and a single application is conducted (e.g. when using plastic mulches) it is possible to increase the nutrient efficiency by using slow release fertilizers. Broadcasting fertilizer is very inefficient, however incorporating broadcast fertilizer and windrowing the fertilized soil into ridges greatly improves the efficiency.

Application equipment, its use and timing can vary from crop to crop. Consult with soil and crop specialists for application methods for specific crops. There are few general best management practices:

< **Use variable application** methods to account for field variability where possible. Nutrient deficiencies often recur in the same areas of fields due to the variability of soil properties. Similarly, other areas of fields will need less fertilizer. Managing these areas accordingly will reduce fertilizer application.

< **Calibrate equipment** to ensure proper control of application rates. Poorly calibrated equipment can result in over-application or under-application of nutrients to the crop, or uneven application across the width of the applicator.

< If possible use **split applications** of nitrogen to reduce the possibility of loss by leaching. Although this will increase
fertilizer efficiency, it will increase management and application costs and may not be suited to all crops.

Use **slow release** fertilizers if available and cost-effective. Proper management of slow release fertilizers is very important because the release time will vary depending on the type of fertilizer, soil temperature and soil moisture. Slow release fertilizers can be an alternative to split applications.

If significant amounts of nutrients are presumed to be left in the soil after a crop is harvested, use a **cover crop**. Cover crops will consume residual nutrients which will become available to the following crop when ploughed under. This is particularly useful for excess nitrogen which would otherwise leach out of the soil. Cover crops are usually not feasible after late-harvested crops. However, fall rye can be established late in the year or it can be inter-seeded with some crops.

**Blend fertilizers** when efficient premixes are not available.

Use **alternative fertilizers** such as manure if possible. Manure should be composted to kill weed seeds and disease organisms although the nitrogen value of the compost will be less.

**Nutrient Management and the Environment**

Poor soil and fertilizer management can threaten water quality. Excessive applications of nitrogen may result in contamination of groundwater with nitrate. Nitrate, after prolonged consumption at high rates, can result in toxicity in humans and animals. Nutrients, particularly phosphorus, in streams and lakes can cause rapid algal growth (**Eutrophication**). This rapid growth robs the water of its oxygen making it an unsuitable habitat for fish and wildlife.

Carbon dioxide, NO and N$_2$O are greenhouse gases. Accelerated decomposition of peat and N-oxide losses to the atmosphere may contribute to the “greenhouse effect”.

Fertilizers are costly, they accelerate the decomposition of the peat, and they have the potential to pollute. Therefore, it is necessary to develop a management system that will ensure both economic and environmental sustainability.

**Approximate Amount of Nutrients Contained in Crops**
<table>
<thead>
<tr>
<th>Vegetable Crop</th>
<th>Harvested Yield per Hectare</th>
<th>N kg/ha</th>
<th>P₂O₅ kg/ha</th>
<th>K₂O kg/ha</th>
<th>Ca kg/ha</th>
<th>Mg kg/ha</th>
<th>S kg/ha</th>
<th>Cu kg/ha</th>
<th>Mn kg/ha</th>
<th>Zn kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage, early</td>
<td>20 tons</td>
<td>130</td>
<td>35</td>
<td>130</td>
<td>20</td>
<td>8</td>
<td>44</td>
<td>0.04</td>
<td>0.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Onion, bulb</td>
<td>7.5 tons</td>
<td>45</td>
<td>20</td>
<td>40</td>
<td>11</td>
<td>2</td>
<td>18</td>
<td>0.03</td>
<td>0.08</td>
<td>0.31</td>
</tr>
<tr>
<td>Potato</td>
<td>400 bu</td>
<td>80</td>
<td>30</td>
<td>150</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>0.04</td>
<td>0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Spinach</td>
<td>5 tons</td>
<td>50</td>
<td>15</td>
<td>30</td>
<td>12</td>
<td>5</td>
<td>4</td>
<td>0.02</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Turnip</td>
<td>10 tons</td>
<td>45</td>
<td>20</td>
<td>90</td>
<td>12</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Additions in fertilizer in excess of those listed above remain in the environment. The efficiency of applied fertilizers for each crop will vary depending on variety, and soil, crop and weather conditions.
PEST MANAGEMENT

Weed, insect and disease identification, monitoring and control are critical aspects of all production systems, particularly vegetable production where quality is highly valued. Effective management requires an understanding of the range of pests found in the environment, their life cycles, and the field conditions in which they proliferate. Efficient pesticide use and effective pest control are necessary for productivity and profitability, as well as environmental acceptability.

Pest Control Methods

There are several methods for pest control in vegetable crops. To be successful, it is necessary to take an integrated approach (Integrated Pest Management or IPM). This approach combines a number of control methods. There is rarely ever a single problem or a single solution, and the effectiveness of any one control method can vary.

There are several steps that can be taken to reduce pest risk:

< Buy certified, disease-free seed and transplants when possible. This eliminates the possibility of introducing diseases into the bog.

< Use disease-resistant or tolerant crop varieties when possible.

< Maintain optimal soil pH and fertility to reduce plant stress and vulnerability to disease.

< Avoid wet soil conditions at the surface by maintaining proper drainage. Wet conditions are favourable for the proliferation and spreading of some diseases.

< Maintain good air circulation. Don’t work when the foliage is wet. The moisture which is spread from plant to plant can carry disease. Air circulation can be enhanced by providing adequate spacing between plants and rows, or using temporary windbreaks for the winter months rather than permanent ones.

< Use good sanitation practices. Clean all equipment. Incorporate crop residues and culls immediately to reduce the potential for disease. Remove diseased culls and compost them, if possible, rather than burning them on the bog.

< Tillage operations conducted before, during or after the crop will reduce weed pressure and delay or prevent flowering and seed development. However, the ease with which re-rooting can occur in peat often makes tillage an unreliable method of control. Furthermore, tillage is not highly recommended to control weeds where other control methods are available, because tillage accelerates soil decomposition. Pulling, hoeing and cutting serve the same
purpose as tillage with less impact on the soil. If possible, weeds should be removed from the field following tillage to prevent re-rooting.

< Fallow fields where pest problems are too difficult to control. Taking selected fields out of vegetable production for a year can allow for more effective control of pests, not only during the fallow year but also the next cropping year. Fallowing provides an opportunity for multiple applications of herbicides, such as ROUNDUP, which is not possible during a cropping season. Tillage is much more effective for controlling weeds when it is not restricted by a growing crop. However, the additional tillage will contribute to soil decomposition. Fallowing should not be done where wind erosion is a concern.

< Use effective crop rotation. Rotate between crops that are not from the same family (e.g. turnips, cabbage and broccoli are from the cruciferae or mustard family and are susceptible to disease when grown frequently in succession - see page 24). Rotation breaks the life-cycle of some pests by introducing a non-host crop. Preventing crop disease problems through rotation can be more efficient than controlling an existing disease problem. A soil infested with the clubroot disease should not be planted to a cricifer crop, such as cabbage, broccoli, cauliflower, rutabaga, turnip or kale for 7 years.

< Intercropping with certain crops can suppress weed growth without interfering with the vegetable crop and benefit the following crop.

< Plastic mulches can be used to suppress weed growth in the beds. Additional weed control is required between the beds. Paper mulches are also available and have the advantage of being more environmentally friendly than plastic.

< Use pesticides (herbicides, insecticides, fungicides) when necessary (see Chemical Control).

< Biological control methods are a non-traditional means of controlling insects where predatory birds, insects, or bacteria are introduced (e.g. Bacillus thuringiensis [Bt]). These methods are not always practical.

Cost can also be a factor in selecting control methods - plastic mulch can cost as much as $1000 per hectare whereas three passes of tillage is about $400 per hectare. Vegetable growers can reduce the costs of pest control by Scouting fields for early identification and evaluation of problems.

**Chemical Control**

There are a few basic recommendations for using pesticides to increase their effectiveness and reduce the potential for human and environmental hazards.

< Follow instructions on labels carefully.
< Use a properly calibrated sprayer.

< Be aware of all federal and provincial **regulations** regarding the use, storage and disposal of pesticides and containers.

Where possible, pesticides should be applied by **spot spraying** rather than broadcast spraying. It can be more efficient and cost effective to apply pesticides only to the affected areas within fields. Similarly, herbicides can be directly applied to weeds with **contact applicators**. It may also be more efficient and cost effective to control pests to **tolerable limits** rather than attempting to eradicate them with excessive pesticide use. Excessive use can increase the pest’s resistance to the pesticide which will make further control difficult. By limiting the use of pesticides to only what is needed, the cost of producing a crop and the potential for environmental contamination can also be reduced significantly. However, applying pesticides at rates below those recommended can be ineffective, and very costly if crop quality and yield are compromised.

The greatest limitation to reliance on chemical control is the pesticide’s availability and permissibility. Pesticides react differently on organic soils than mineral soils. Therefore, there are different regulations for their use on peat soils. Glyphosate (ROUNDUP) provides excellent control of weeds on peat soils. However, it is not permitted to grow a crop the year this herbicide is applied. The treated field may require fallowing or rotation with sod crops. Many pesticides, which are available for use on organic soils in other countries, are not permitted on organic soils in Canada. This is primarily due to the cost of testing.

**Environmental Concerns With Pesticide Use**

By design, pesticides are toxic to selected forms of plant and animal life. They are used to prevent pests from damaging the desired crop. When used properly, pesticides pose negligible threats to other forms of life, in particular humans. Used carelessly they may not perform the desired function and can pose a health threat to the user. Most of the pesticides available do not persist for very long in the environment. The greatest damage by misuse of pesticides is usually herbicide induced damage to adjacent crops or valued vegetation which is sensitive.

**Controlling Weeds**

One of the principal limitations to growing vegetables on Newfoundland peat soils is the lack of consistent and effective weed control. There has been a recurrence of a few dominant species of weeds, particularly common chickweed and pineappleweed.

In their natural state, peat soils are often weed free due to saturation, acidity, and low nutrient content. After drainage, liming and fertilization the peat soils become an excellent medium for weed growth. Therefore, it is important that producers maintain recently developed peatland in weed-free state for as long as possible because establishment is rapid once the weed is introduced.
As indicated previously, there are a number of methods which can be used to control weeds. Tillage, plastic mulches, intercropping and crop rotation all help to reduce weed pressure, but there is still a strong reliance on herbicides for effective weed control.

Weeds are a much greater problem on cultivated peat soils than on mineral soils. More weed flushes occur during the season on peat than on mineral soils, and weed seedlings emerge from a greater depth (up to 10 cm). Chemical control of weeds on peat soils is also more difficult than on mineral soils because of greater adsorption (binding with soil particles) and a subsequent reduction in activity which occurs with many herbicides. Furthermore, the persistence of each herbicide may differ from that on mineral soil. Residual and foliar applied herbicides are being used increasingly on a wide range of crops. The main advantage of residual herbicides are that they allow crop seedlings to emerge in a relatively weed-free situation. Should they fail, however, a post-emergence herbicide may still be used. Unfortunately, many of the best and most widely used residual herbicides are strongly adsorbed to organic matter. The nature of the adsorption varies as does the degree of adsorption of each herbicide. As a result the amount of herbicide required for effective weed control is difficult to predict.

< Herbicides that are weakly adsorbed by organic matter can be of considerable value in tackling the weed control problem, but they are few in number. Contact your crop specialist for information on these types of herbicides.

Often more than one application of purely foliar-applied herbicide is required because of high weed populations and numerous flushes of weeds within the growing season. In general, foliar-applied herbicides should not be applied to wet foliage, when rain is imminent or when there is danger of drift to adjacent crops. Peatlands are often located in open, windy areas with high precipitation. Consequently, there are usually few days early in the growing season when ideal spraying conditions exist.

Pre-emergence contact herbicides are normally applied to weeds which have emerged before the crop and they usually have no residual effect. Their effectiveness depends on a large proportion of the weed population emerging before the crop. Unfortunately, prediction of crop emergence can be difficult. Contact herbicides can be used for post-emergence inter-row weed control using shielded nozzles, but tillage may often prove more attractive due to cost.

To obtain satisfactory results with contact herbicides, correct timing of the application is most important. The rapid growth of weeds on peat makes timing difficult as they can pass through the susceptible stage very quickly. Controlling as wide a weed spectrum as possible is essential on peat soils because of the ease with which uncontrolled species can establish and become dominant. For this reason the use of herbicidal
combinations is very important.

**Controlling Animals**

Wildlife, particularly moose, can cause serious damage to vegetable crops in Newfoundland. When crop damage is minimal, the most cost-effective approach to control may be toleration. When damage is beyond tolerable levels there are two ways to deal with animals. One would be to keep them out using fences or deterrents such as noise guns. The other would be to kill them when they get into the crops. Both can be costly and neither is guaranteed to solve the problem.
SUSTAINABILITY OF PEATLAND VEGETABLE PRODUCTION

Environmental Issues Facing Peatland Vegetable Producers

Historically, agriculture has been the cause of 85% of wetland loss in Canada. This loss has occurred mainly on the prairies and most of this loss was marsh, swamp and shallow open water wetlands (sloughs and potholes) with only a relatively low percentage of bogs and fens affected. Less than 0.2% of Newfoundland’s peatlands have been developed for agriculture, including pasture, forage, sod and vegetable production. To date, the overall impacts of peatland development are not extensively documented. However, development of any peatland must involve close consideration of several environmental issues and monitoring of key environmental indicators.

On a global scale, the importance of the wetland as a fragile, ecological niche which provides wildlife with a unique habitat, is being realized. The conservation of wetland areas for wildlife habitat and the protection of rare or unusual species that are specifically adapted to wetland conditions, are issues gaining public awareness. Rare or endangered bird and mammal species that are known to use peatlands in Canada include the Whooping Crane, Trumpeter Swan, Piping Plover and Wood Bison. Waterfowl usage of wetlands is generally directly proportional to the availability of open water and, therefore, swamps, marshes, and shallow open waters are favoured.

There are several species of plants which occur on typical peatland bogs that do not occur on mineral soil ecosystems. Pitcher plants, butterworts, and sundews are considered unique in some areas. They have adapted to peatland bogs because they can obtain nutrients by catching insects. However, many of Newfoundland’s wetland species are also widely distributed throughout Canada’s boreal wetland regions. The pitcher plant, for example, is the provincial plant for Newfoundland and Labrador, but it is also found across Canada’s entire boreal zone.

Beyond the more obvious plants, animals and birds, it is recognized that peatlands house a wider range of biota, including invertebrate species. A great deal of work still needs to be done to gain a full understanding of the biodiversity of peatlands. Given the vast quantity of peatland in Newfoundland, it is unlikely that agricultural development alone would threaten the extinction of
the province’s peatland ecosystem.

The Newfoundland and Labrador Wetlands Stewardship Program was created to advance the objectives of the Eastern Habitat Joint Venture of the North American Waterfowl Management Plan and The Newfoundland and Labrador Waterfowl Management Plan. This program focuses on the securement and enhancement of known significant freshwater and coastal wetlands through stewardship agreements with forest industry companies and municipalities. To date no peat bogs being utilized or considered for vegetable crop production are included in this program. Partners in the program include Wildlife Habitat Canada, the Government of Newfoundland and Labrador, Ducks Unlimited and the Government of Canada.

Another environmental issue that is gaining prominence is global warming. Carbon dioxide is a naturally occurring gas that has been implicated as a "greenhouse gas". Draining, tilling and fertilizing accelerates the decomposition process resulting in increased carbon dioxide being released to the atmosphere. However, undrained peatlands produce methane which may have a greater impact than the total contribution of all the carbon gases from the area once it is drained.

There are also environmental issues specific to each site being considered for development that must be addressed. These include water quality aspects such as suspended solid discharge, changes in water chemistry (reduction in pH and colour), and the potential for fertilizer and pesticide pollution, as well as air quality due to wind erosion in developed areas.

The potential effect on downstream aquatic ecosystems of drainage waters from developed peatlands is a significant environmental issue. Removal of surface vegetation results in exposed peat particles which may be transported into the drainage system and leave the bog. The initial development of a peatland soil requires very high rates of fertilizer. Therefore, the potential for transport of nutrients (i.e. nitrate and phosphate) and pesticides to surface waters via the drainage system is of major concern. Groundwater contamination, on the other hand, may be limited by the hydrologic nature of bogs.

When selecting a peatland area for agricultural development, all of the environmental impacts involved should be considered seriously. Due to the difficulty in establishing a sustainable, fertile peatland soil for agricultural production, most of the agriculturally related peatland research to date has focused on drainage, subsidence and fertility. However, if more peat soils are to be developed, it is imperative that environmental issues be further
explored so that we understand the ramifications of placing these unique ecosystems under intensive management.

The Government of Canada has announced the adoption of the Federal Policy on Wetland Conservation. The objective of this policy is to promote the conservation of Canada’s wetlands to sustain their ecological and socio-economic functions, now and in the future. Each province is encouraged to preserve at least 12% of their natural ecosystems (i.e. wetlands).

The Government of Newfoundland and Labrador, under the Department of Environment and Lands Act, requests the submission of an Application for Environmental Approval to ditch and drain peatlands.

**Long-term Sustainability of Crop Production**

Long-term agricultural productivity is affected by physical, chemical and biological changes in the peat soil (subsidence, soil moisture characteristics, nutrient requirements, contamination, etc.). After several years of drainage, tillage, and fertilization, peat soils become highly decomposed. Decomposition results in a peat volume reduction causing subsidence and poor drainage. The resulting wet soil conditions will reduce the ‘windows of opportunity’ necessary for field operations. Additional drainage may be required but it may not be practical. The depth to bedrock is reduced by subsidence causing potential problems for maintaining drainage ditches and, in extreme cases, tillage.

In drier climates if high rates of fertilizers are applied for many years, salts may accumulate at the soil surface and drastically reduce productivity.

There are three basic conservation practices which can be employed by the farmer to increase the longevity of the peat soil for vegetable production:

- Do not over drain.
- Do not over till.
- Do not over fertilize.

The objective is to slow the decomposition process to a rate that will sustain suitable soil conditions for crop production. These conservation practices not only increase the longevity of vegetable production on the bog, but they also reduce costs of production by increasing efficiency and, ultimately, they will increase profitability. Where soil loss is identified as a problem it is
important to establish and maintain protective vegetative barriers and covers (windrows, inter-crops and cover crops, etc.).

**Reclamations and Restoration of Peatlands Retired from Vegetable Production**

Once peat soils are no longer profitable, they may have to be retired from vegetable production. This raises the question “Can peat bogs after several years of vegetable production be restored to a natural state or used for alternative agricultural or industrial uses?” A retired vegetable peat bog may be suitable for forage crops or sod production or it may be possible to convert it for peat extraction. The simplest measure to restore the bog to more natural conditions would be to allow the water back by closing off the drainage ditches.
THE FUTURE OF PEATLAND SOILS FOR VEGETABLE PRODUCTION

Vegetable production on peatlands has the potential to be a viable part of Newfoundland’s agricultural industry. Higher yields on peat soils and the elimination of stone picking could outweigh the development and maintenance costs associated with water management on peat bogs. Vegetable production on peat soils is more complex with respect to water, nutrient and pest management, but these are challenges that are overcome through research, education and experience and should not be perceived as obstacles. Sound management and conservation practices should ensure agronomic and economic sustainability of this resource for continued agricultural use with limited impacts on the environment.

There are a number of factors involved in the production of vegetables on peatlands which will determine the future of the industry.

**Research.** There needs to be a better understanding of drainage requirements and technology, and the role of evapotranspiration in water management. There is a need for fundamental research in nutrient management, specifically, crop requirements, the fate of applied fertilizers and their impact on the environment. Soil test analyses and recommendations need to be developed specifically for peat soils which account for Newfoundland’s regional climates and the variability in soil conditions. Testing is required to determine the permissibility of herbicides and other pesticides which are currently available for use on organic soils in other countries. Integrated Pest Management (IPM) strategies must be developed to reduce the use of chemicals and improve pest control. Consideration must be given to the environmental impacts of vegetable production on peatlands, the longevity of this land use and reclamation of retired peatlands. Producers need to be involved in setting research priorities.

**On-farm testing.** Producers and extension personnel need to play a greater role in research. Research should be conducted on-farm under realistic conditions. Producers should be encouraged to develop innovations in production, conduct their own testing, and be given access to appropriate information and assistance. Adaptation of machinery is one area where producers can play a significant role. Others
include: variety trials, fertility trials, tillage trials and development of new cropping techniques, such as intercropping, and crop rotation strategies.

**Education.** Existing and prospective peatland vegetable growers need an enhanced educational system to provide information on both the conventional and innovative technologies and strategies for management and conservation. Interactive workshops and farm field tours are essential educational tools in addition to traditional extension materials and activities, such as newsletters, technical bulletins, research presentations, etc.

**Equipment availability.** Currently, there is insufficient equipment available in Newfoundland to adequately develop and maintain the drainage infrastructure of the peatlands. Equipment appropriate for use in crop production on peat soils is not accessible to farmers. The high cost of purchasing and shipping equipment and parts from the mainland may require the development and manufacturing of some equipment locally, or the modification of available equipment. Cooperation between producers may be necessary to make the purchase of some equipment economical.

**Industry.** The structure of the industry needs to be further developed to better enable vegetable producers to compete in the marketplace (e.g. more adequate storage and processing facilities). The solution to such problems can be found through the cooperative efforts of producer organizations and government agencies.

**Organization.** The existing organizations need to be more proactive to ensure necessary communication and cooperation amongst themselves and with other organizations.

**Monitoring and assessment.** With the expansion of vegetable production on peatlands there will be an increased need to monitor and assess the environmental impacts and sustainability of this land use. A cooperative initiative should be undertaken by producer organizations and government agencies to develop meaningful and useful agri-environmental indicators for this purpose.
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Writer: David Lobb, Soil Conservation Specialist, Eastern Canada Soil and Water Conservation Centre, University of Moncton


Contacts

Crops Specialist
Forest Resources and Agri-foods Regional Offices

Agricultural Representative
Forest Resources and Agri-foods Regional Offices

Soil Specialist
Forest Resources and Agri-foods Provincial Agriculture Building
Box 8700, St. John's NF A1B 4J6
Tel: (709) 729-6588 Fax:729-6046

Agricultural Drainage Specialist
Forest Resources and Agri-foods Agriculture Building
Box 8700, St. John's NF A1B 4J6
Tel: (709) 729-6588 Fax:729-6046

Horticulture Specialist
Agriculture and Agri-food Canada Provincial Agriculture Building
Box 7098, St John's NF A1E 3Y3
Tel: (709) 772-4619 Fax: 772-6064

Newfoundland and Labrador Peat Association

Peat Growers Association


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