B.C. Agricultural Drainage Manual

Chapter 6

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Benefits of Drainage 6

6.0 Benefits of Drainage

Many of the benefits of improved drainage have been alluded to in previous discussions. Pulling all we have learned about soil, water, the impacts of poor drainage and solutions together, this chapter will cover the many benefits of improved drainage. Aside from the direct positive impact on measurable yield, there are many other benefits such as improvement of trafficability and timeliness, increased range of crops that can be grown and diminished danger of crop loss. All of these benefits translate into enhanced economic benefits. Improved soil and water conservation and reduced risk of environmental degradation are other impacts of improved water control that can be achieved with a drainage system.

6.1 Improved Trafficability

Increasing trafficability can benefit farmers who need access to plant, manage and harvest a crop. It can also be a benefit to livestock producers who require access to fields for grazing or pasturing purposes. Increased trafficability means livestock have longer periods to access forage and a reduced risk of incidence from injury or disease which can result from wet soil conditions.

A soil that is trafficable has sufficient strength to support traffic from machinery and/or livestock without compacting the soil beyond the point where water and roots have difficulty penetrating surface layers. There is a general relationship between trafficability and workability. A soil is said to be workable when cultivation will produce good soil tilth. Workability in soils that have a medium to fine texture usually occurs when the soil is below the plastic limit and the soil is friable.

Trafficability and workability depend on soil strength, which is largely determined by soil water tension. Soil water tension, as discussed in Chapter 3, is the cohesive force exerted on soil particles as the moisture level in the soil drops below field capacity. Higher tension creates stronger attraction between soil particles which strengthens the soil. In a well structured porous soil, with a high level of permeability, soil water tension and water table depth are closely related. A lower water table increases soil water tension and makes the soil more trafficable. Conversely, waterlogged soils have low soil strength and have a corresponding low trafficability. The cover of this manual shows the result of a farmer not paying attention to the trafficability of the field. Good trafficability should be obtained in most soils when the water table is 0.50 m below the soil surface.

Boundary Bay Water Control Project

Because this research project will be used as an example of the benefits of drainage several times in this chapter, some information on the setup may be useful. The project was initiated as a demonstration of the benefits of drainage and ten years of data were collected on various aspects of drainage. At the project site in East Delta, drained, subirrigated and undrained treatment areas where installed. The drainage system was installed on the Ladner Soil Series which is a poorly drained, silty clay loam derived from marine sediments. The system included subsurface drain pipes placed at a depth of about 1.2 m and a spacing of 14 m in the drained treatment and at a spacing of 7 m for the subirrigated treatment. All drains emptied into a small on-farm ditch that was pumped (float controlled) to the main regional drainage outlet. Subirrigation was provided by back-flooding a portion of the outlet ditch.

The following data on workable soil days were collected from the Boundary Bay Water Control Project. Over the span of two years, workable soil days where assessed for the spring planting period (April 15 to June 20, total of 66 days each year). The data indicates that each year drainage increased the number of workable soil days by about 40, in comparison to the undrained site. Over that same period there was an average of 24 days with measurable precipitation. Even with the water table lowered, the soil surface may remain unworkable if the soil moisture conditions are at or above field capacity due to recent precipitation.

6.2 Crops

The basic reason for improving drainage on a farm is to increase the profitability of the agricultural operation. In most instances, this means increasing the yield and quality of the crop. Land previously suitable to only water tolerant crops may now be suitable for other higher value crops. Table 6.1 shows varying damage levels for different flooding periods. Improvements in yield and quality may result from several factors including improved fertilizer use efficiency, longer growing season, reduced incidence of disease and improved cultural practices such as weed control or tillage. Other benefits with respect to crops include the ability to use a wider range of varieties or species of plants and the reduced incidence of soil damage from compaction or erosion of the topsoil layer.

6.2.1 Variety

Well drained soils offer a greater choice and flexibility in the range of crops which can be grown. For instance with drainage, potato varieties such as Warba may be grown in the spring where previously only mid-season varieties such as Russet Norkotah where suitable. This ability to use different varieties when drainage is improved applies to both annual and perennial crops. For tree fruits, some of the dwarfing rootstocks of apples or crops species such as pears will tolerate slightly higher water tables. However, by improving drainage, the range of rootstocks and fruit tree species available for use on the site will then only be limited by climate factors including air temperature, rather than soil factors such as a high water table.

The changes in grass variety that can be made as a result of drainage can be illustrated with an example from the organic meadows in the Interior of British Columbia. On these sites, with improved drainage and overall water control, tame species such as reed canary grass can be planted in place of the native species. On average, dry matter yields of tame species increases by 2 t/ha and dry matter digestibility increases by about 20%.

Table 6.1 Damages (in percent) to Crops as a Result of Surface Flooding

Month	December				April				June				September			
Days of Flooding	3	7	11	15	3	7	11	15	3	7	11	15	2	7	11	15
Potatoes	-	-	-	-	40	90	100	100	50	100	100	100	50	100	100	100
Fall Cereals	0	5	10	15	10	25	40	70	20	50	80	100	-	-	-	-
Perennial Forage	-	-	-	-	20	80	100	100	10	40	75	100	0	10	20	30
Corn	0	0	5	10	10	25	40	60	10	40	70	100	10	30	50	70

6.2.2 Rooting System

A well drained soil is necessary to allow the development of an extensive, healthy rooting system for most field crops. Drainage must at least control the water table to the crop rooting depth. In Chapter 11, Table 11.1 provides information on effective rooting depths for various crops in terms of subirrigation system design. They can be used directly as the appropriate minimum depth to water table. However, the actual desired depth to water table should be greater than those depths given in Table 11.1 particularly in terms of providing effective drainage. It is important to realize that trafficability or other drainage requirements will most likely exceed the water table control requirements of shallow rooted crops. For example in a peat soil, where shallow rooted vegetables crops are often produced, trafficability requirements would warrant a water table depth of approximately 40 to 50 cm. Whereas the effective rooting depth of a celery or lettuce plant is about 20 to 30 cm.

Compacted layers such as pans will also restrict root growth. Pan formation results from soil compaction caused by the movement of farm machinery or livestock under unfavourable conditions. The compaction may reach a depth of 50 cm, well below the bottom of the plow layer. A pan layer prevents plants from reaching their full potential rooting depth or water from percolating to the subsurface drainage system. Shallow rooting depths require earlier and more frequent irrigation during the growing season. Shallow rooting also reduces the effective soil volume that plants roots can explore for nutrients, thereby reducing fertilizer efficiency. A good drainage system, along with proper soil management, will reduce pan formation and potentially increase crop rooting depth. Figure 6.1 illustrates the impact of drainage on rooting depth of a crop.

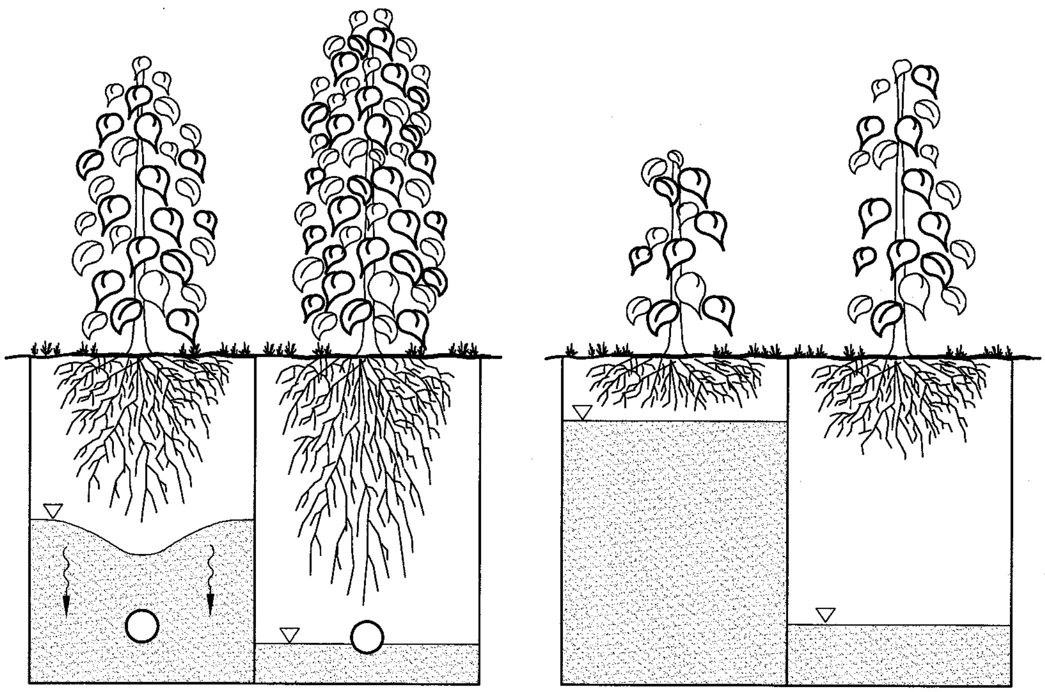


Figure 6.1 Rooting Depth of a Crop in Drained and Undrained Conditions

6.2.3 Growing Season

A drainage system improves the condition in the spring to allow earlier tillage and seeding operations. The basic agronomic requirements of a crop are achieved sooner, giving the plant a better chance to reach its potential during the growing season. The best way to illustrate how a drainage system lengthens the growing season is to use a measure of opportunity days. An opportunity day is said to occur when the water table is 50 cm or more below the soil surface between 0800 and 1600 hours. Table 6.2 shows the opportunity day data collected from the Boundary Bay Water Control Project. The opportunity day data for the drained site ranged from 76 to 90 days, while for the undrained site the range was 3 to 34 days.

Table 6.2 Opportunity Days at Ladner - Average of 10 years (1982 to 1991)

Total Days for Period (March 1 - May 31)	Opportunity Days		Increased Number of Days with Drainage	
	Drained	Undrained	Days	%
92	85	20	64	325

6.2.4 Yields

Plants use fertilizer more efficiently in well-drained soils. Most essential plant nutrients are more readily available under well drained and aerated conditions. Since nutrient uptake efficiency is improved, it may be possible to adjust nutrient application rates. Drainage allows the plant's root system to develop properly. Plants are able to draw moisture from a larger volume of soil and are therefore better equipped to withstand drought. Well-drained and aerated soils warms up faster, aiding in seed germination and crop establishment and are less prone to plant diseases. In particular, a crop is less likely to be infected by root rot caused by soil fungi such as *Pythium* or *Fusarium*. In Chapter 2, Figure 2.18 indicates how drainage improves the temperature levels of the soil over the growing season.

Yield data from the Boundary Bay Water Control Project are presented in Table 6.3. The data show a range of crops and the impact of both drainage and subirrigation.

Table 6.3 Yield Response Data - Boundary Bay Water Control Project

Crop (variety)	Yield (tonnes/hectare)			Years of Data
	Drained	Undrained	Subirrigated*	
Potatoes				
Main Season (Russet)	33.4	33.5	39.3	5
Early Season (Warba)	24.0	0	-	1
Forage Grass (perennial ryegrass or orchard grass hay) (dry matter yield)	8.9	6.8	9.1	7
Corn (silage) (dry matter yield)	17.5	9.2	18.2	4
Strawberries	6.6	0.7	4.6	2
Winter Wheat (Monopol)				
Grain	6.8	0.5	8.5	3
Straw	10.2	0.6	12.9	3
Blueberries (Bluecrop)				
year 2 (5 yr. old plants)	5.6	0.9	5.5	1
year 3	11.1	1.2	11.4	1
survival after 1 winter	100%	70%	100%	1
survival after 5 winters	100%	17%	100%	1

* note drain spacing for subirrigated site was 7 meters as opposed to the 14 m spacing for the drained site.

Of particular note is the effect on yield of main season potato crops. The undrained site had a higher yield which in part can be attributed to the higher soil moisture conditions during the growing season. Subirrigation was not able to overcome the moisture removed by drainage in the early spring. The undrained site was not suitable for early potatoes, because when the planting window for that crop closed, the site was still not trafficable.

The two perennial crops planted on the site indicate the impact of winter wetness on yield and survival. The number of blueberry plants that survived the high water tables and surface ponding in the undrained area is indicated. After one year, there was a 30% loss in plants. The forage grass data indicate an increase in yield due to both drainage and subirrigation. Forage crop quality measurements also indicated that drainage improved protein content by about 3% and acid detergent fiber (ADF) by about 10% in relation to the undrained crop. This improvement in quality was directly attributable to the species composition of the two treatments. The undrained area had a significantly higher percentage of weedy species.

The growth of winter wheat was one of the most dramatic crop responses observed at the project site. The undrained was drowned by surface ponding. Weed control was next to impossible due to a high water table that prevented timely access. Once the undrained area was trafficable, the weeds had overwhelmed the severely stressed winter wheat plants. Figure 6.2 shows the undrained (left) and drained (right) crop in mid June.

Figure 6.2 Winter Wheat at Boundary Bay

6.3 Soil and Water Conservation

Soil and water are vital resources for the continued well being of the human race. In light of the predicted population growth, crop production will need to increase to meet foodstuff demand. Therefore, conservation of these resources is of utmost importance. Soil and water conservation is achieved by utilizing these resources sensibly to produce crops and livestock in a sustainable fashion. Good farm management is reflected in a strong commitment to stewardship of soil and water resources and responsible approaches to the environmental issues. Although farming activities occur on private land, Federal and Provincial laws protect the land, water and air resources from contaminants and detrimental practices which may result from farming operations.

6.3.1 Water Quality

The two principal ways of increasing land based food production are: developing new land not already in production, and improving the productivity of existing farm operations. The development of new land is usually achieved by drainage, irrigation or land clearing. Agricultural development influences the volume of flow on the land as well as the quality of the water.

Agricultural development slightly increases total annual flow volumes. Some research has indicated that agricultural development, using only surface drainage, increases annual outflow by 5 to 10%. Subsurface drainage systems increase total annual outflow when compared to surface systems. The increase is usually minor. Some research has indicated increases of 5% while others have reported a 20% reduction in flow. However, what is clear, is that peak outflows from surface drainage systems are much higher than those from subsurface drainage systems.

Surface runoff is often the principal culprit for the deterioration of water quality in agricultural areas. Drainage water from surface runoff contains higher concentrations of organic nitrogen, phosphorus and soil-bound pesticides than drainage water from subsurface drainage systems. This is mainly due to the fact that these substances are mainly associated to sediment and organic particulate matter. Sediment loads from subsurface drainage water are much smaller than from surface water flows. Surface runoff is often "uncontrolled" and causes erosion which worsens the problem. The murky water resulting from soil erosion changes the water quality for aquatic organisms. This can clearly be seen in Figure 6.3. Water flowing from the surface of the field on the top of Figure 6.3 will deteriorate water quality in the ditch. In contrast, the "relatively clean" water flowing from the subsurface drainage outlet on the bottom of the picture will not affect water quality.

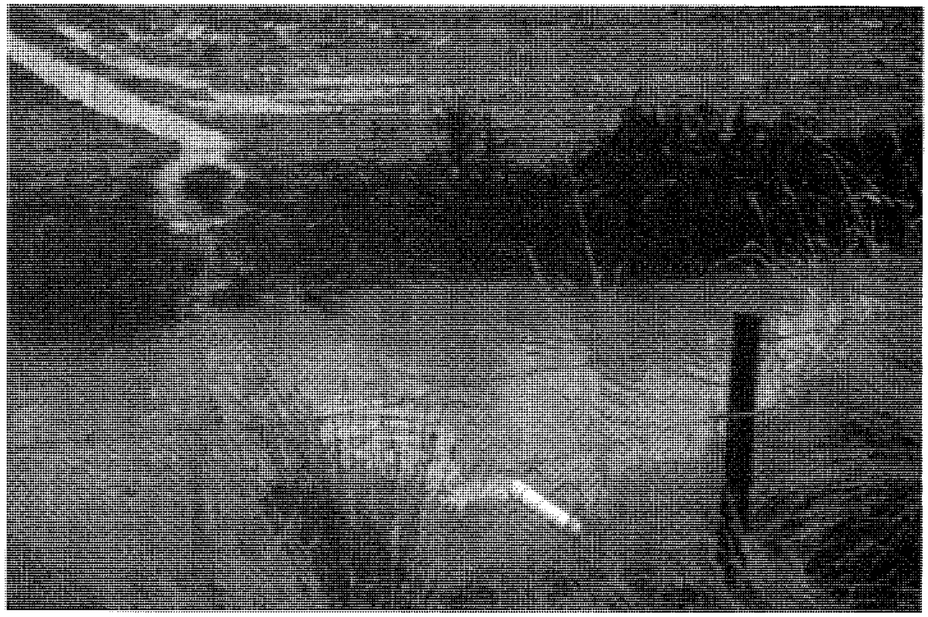


Figure 6.3 Surface vs. subsurface outlets

Like many substances nitrogen (N) is essential to life, but is a problem when found in large quantities in the wrong place. In particular, when nitrogen is in the nitrate form (NO_3-N) it can have negative impacts on water quality. Many factors affect the concentration of nitrate in drainage water: drainage volumes, differences between nitrogen input and removal, the rate of mineralization and denitrification, and tillage systems. Nitrogen mineralization is the process of converting organic nitrogen to mineral nitrogen (Soil Organic Matter-N to NO_3-N and NH_4-N).

Under high water table conditions nitrate can be denitrified by bacteria. The process of denitrification occurs when oxygen is no longer available to soil microbes when they decompose organic matter. When oxygen is depleted (i.e. under waterlogged conditions), nitrate is converted to nitrogen gas (N_2 or N_2O) and released to the atmosphere. Under natural conditions, the denitrification process usually occurs in short bursts after rainfalls. It occurs most rapidly at soil temperatures around of 20 °C. Any soluble nitrate not denitrified will leach to the groundwater or to surface waters by natural flow patterns. Since there is no bacteria present at the depths where groundwater is found, nitrate can easily accumulate and become a major problem in groundwater. By contrast, waterways and ditch bottoms have plenty of bacteria that can transform nitrate into harmless nitrogen gas.

Although subsurface drainage reduces the opportunity for natural denitrification of nitrate in the soil, it has many other advantages that outweight this disadvantage. By lowering the water table, soil aeration is increased which improves nitrogen utilization by both plants and soil microorganisms. Proper drainage increases nitrogen immobilization, which is beneficial. Nitrogen immobilization is the process of converting mineral nitrogen to organic nitrogen (NO_3-N and NH_4-N to Soil Organic Matter-N). Any soluble nitrogen that is not utilized or immobilized will leach out to surface waters via the subsurface drainage system. By increasing the water table depth, the reactive volume of the soil is greatly increased and sediment, phosphorus and nitrate losses are minimized.

Although subsurface drainage systems usually improve overall water quality, increased drainage volumes and increased nitrate transport to surface waters via a subsurface drainage system can have a negative impact on water quality. The manner in which water flows to drains has a direct impact on the distribution and concentration of nitrate throughout the soil profile. Increasingly, researchers have been reporting the importance of by-pass or preferential flow as a major path for water to move to subsurface drainage systems. This has many implications with regard to water quality. Methods and timing of soil amendment applications (inorganic fertilizer, manure, compost etc.) have a direct impact on concentrations of nitrate or ammonium (NH_4-N) in drainage waters. Best Management Practices (BMP's) should be used to minimize the impact of by-pass flow to drainage systems. The most critical BMP that can be used, is to ensure that the soil surface is uniformly tilled or cultivated after the installation of a subsurface drainage system and prior to the application of soil amendments or pest control products. This creates a soil barrier which minimizes the risk of direct discharge of nutrients or pesticides to surface water via the drainage system.

Another BMP that can be used, is controlled drainage. Many research studies have shown that controlled drainage and water table management can improve water quality when properly designed and managed. Controlled drainage benefits both crop production and water quality. Controlled drainage reduces nitrogen and phosphorus transport to surface waters, primarily because of a reduction in outflow. More details on controlled drainage can be found in Section 11.4.

6.3.2 Erosion Control

Soil erosion by water occurs whenever water fails to percolate into the soil and begins to move across the land as runoff. Well-drained soils have the ability to absorb rainfall providing some reduction in the risk of runoff. Poorly drained soils do not have this ability to store additional water and have low infiltration rates which increase the risk of runoff. Rainfall, on poorly drained waterlogged soils, causes overland flow or runoff which can detach and carry soil particles with it. Runoff during both severe rainstorms and lower intensity long duration storms will erode surface soil from many sloping lands in B.C. Soil erosion will be greatest under prolonged or intense rainfall conditions or with rapid snow melt on frozen ground.

A properly designed subsurface drainage system is an effective mean of reducing severe soil erosion problems. Bare cultivated soil is the most susceptible to erosion. Erosion decreases as the density of the crop increases. Fields planted to cover crops or to a permanent grass or grass-legume mixtures have a greater resistance to erosion.

Blind surface inlets, grassed waterways and cover crops, coupled with a subsurface drainage system, will provide effective soil erosion control. This is particularly true for upland sloping sites, but can also be effective on lowland sites where water may collect on soils that have low infiltration rates. Uncontrolled soil erosion can bring about substantial, permanent damage to many soils, so that soil productivity and manageability are greatly reduced and the livelihood of the land user is threatened. For more information on erosion control on sloping land refer to the Soil Management Handbooks for either the Okanagan-Similkameen or the Lower Fraser Valley available from the the Resource Management Branch (MAFF).

The general principles of soil management for water erosion control are:

- Runoff water must be controlled rather than allowing it to erode the soil. This may require properly designed and located ditches, interceptor drains or permanently grassed waterways.

- Vegetation cover must be maintained to protect the soil from the impact of falling rain, to allow better infiltration of water, and to reduce the velocity of runoff water. Use cover crops and crop rotations which include low growing or densely rooted crops. Crop residues should be left on fields over periods of high runoff risk rather than working the land.

- Soil structure must be maintained or enhanced to create large pores and good internal drainage which permit more infiltration of water. Avoid excessive tillage and compaction.

- Carry out tillage and seeding across the slope of the land, preferably on the true contour, rather than up and down the hill diverting any overland flow to grassed waterways or blind inlets.

6.3.3 Cover Crops

The use of cover crops has been mentioned repeatedly in this manual as a means of improving soil structure, protecting against soil erosion and aiding in the improvement of trafficability. None of these benefits will accrue to the land if surface ponding, resulting from high water tables or flooding, is allowed to occur. Cover crops, like any other crop, require some degree of drainage in order to grow. This is particularly true for cover crops grown in the South Coastal Region where relatively warm air temperatures stimulate plant growth during the wet winter period. Note the dramatic effect of improved drainage on a winter wheat crop shown in Figure 6.2. Winter wheat is a covercrop which is recommended for the many benefits it can provide in terms of soil and water conservation. These benefits will only be provided with adequate drainage during the winter period.

If cover crops, are to provide the additional benefits of nutrient capture, sediment trapping and fodder or habitat for wildlife, then they must be provided with suitable growing conditions. In general, these growing conditions could include flooding periods of less than 5 days and about 30 cm of freely drained soil most of the time. If fall planted cover crops are to be used for early spring application of manure, the land must be drained. This will allow the crop to survive the winter and the site to be trafficable in spring when manure application can occur.

6.3.4 Soil Organisms

In Chapter 2, there was a discussion of soil organisms. Table 2.6 illustrates the increase in earthworm biomass that resulted from improved drainage. By improving drainage, many beneficial soil organisms including insects, worms, aerobic bacteria and fungi go to work. Some provide nutrients to plants by decomposing organic matter, while others burrow deep in the soil improving the soil's porosity. Soil organisms also enhance soil aggregate stability which can improve infiltrability and reduce the potential for puddling.

Data collected from Westham Island, indicate that deep burrowing worms, in conjunction with a drainage system, can dramatically decrease the soil water content. Soil water content above the drains was 8% lower when worms were present one day after the end of a rainfall event. The same effect could be seen 7 days later midway between the drains.

6.3.5 Soil Compaction

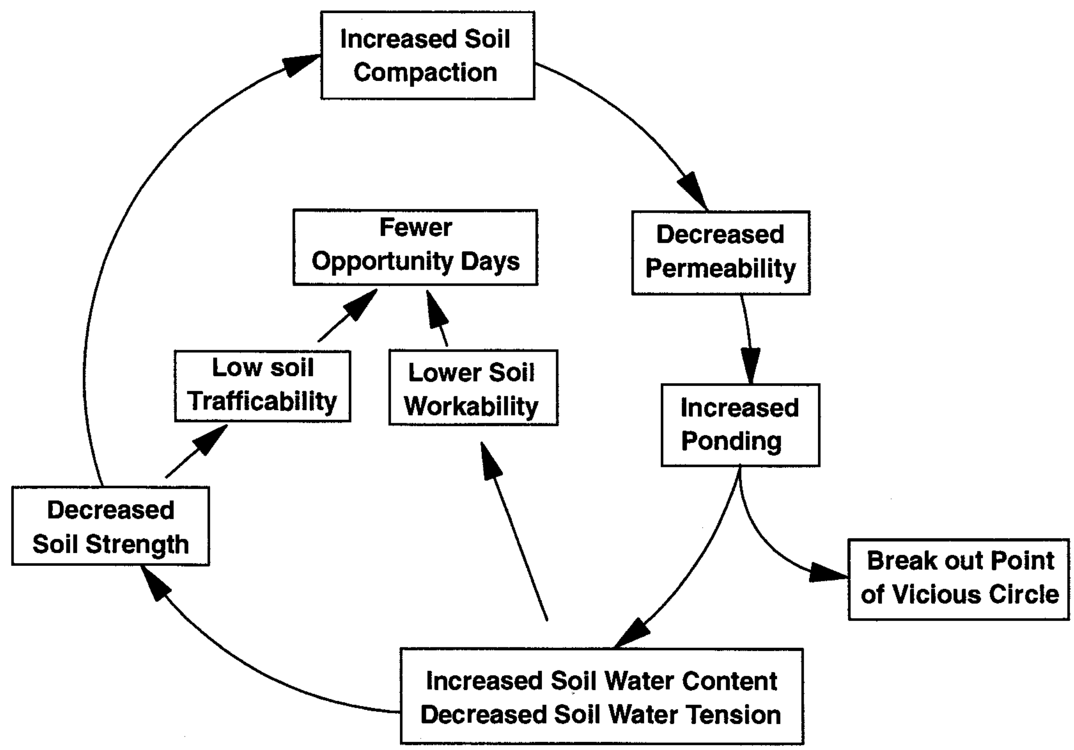
Soil compaction is best described as layers in the soil which have increased bulk density or reduced permeability. Compaction usually results from manipulation or pressure on the soil when it has low strength. Low strength occurs when the soil is wet. Good water control on a site due to the use of a drainage system will minimize the risk of wet soil conditions which could lead to compaction. Soil compaction and poor drainage are entangled in a cycle. Figure 6.4 is an illustration of the vicious cycle which can result from inadequate drainage, wet soils, and compaction. When adequate drainage is supplied the cycle changes to one where the many benefits mentioned in the preceding sections are realized. Escape from the vicious cycle of degradation to a positive cycle of improved soil tilth is illustrated in Figure 6.4.

6.4 Subirrigation

When a site is suitable, subirrigation may be an appropriate system of supplying irrigation water to a crop. With limited additional cost the system can also be used for drainage during periods of excess moisture. Some other benefits of subirrigation include reduced labour, capital and operational costs, and less water loss due to evaporation. Subirrigation systems provide water conservation benefits as a result of reduced nutrient leaching into the surface water system and greater water use efficiency.

Table 6.3 (Page 89) provides yield results from the Boundary Bay Water Control Project that indicate a slight benefit to using subirrigation on crops such as main season potatoes or silage corn. This could be seen as a true subirrigation benefit as the crops are grown during a moisture deficit period. For crops such as perennial forage grass and winter wheat this benefit may be derived more from the increased drainage provided by the tighter drain spacing which was used on the subirrigation treatment. Winter wheat in particular shows a dramatic increase in yield when grown on a drained, plus subirrigated site. In this case, subirrigation may have also provided adequate soil moisture at the critical dough stage, thereby improving the grain yield. The responsiveness of the silty clay loam to raising the watertable and soil water content through the use of subirrigation was somewhat restricted. This soil and site may have been better suited to the use of controlled drainage. The design parameters for these two types of systems are discussed in Chapter 11.

Vicious Cycle of Inadequate Drainage, Wet Soils and Compaction



Good Cycle of Adequate Drainage and Improved Soil Tilth

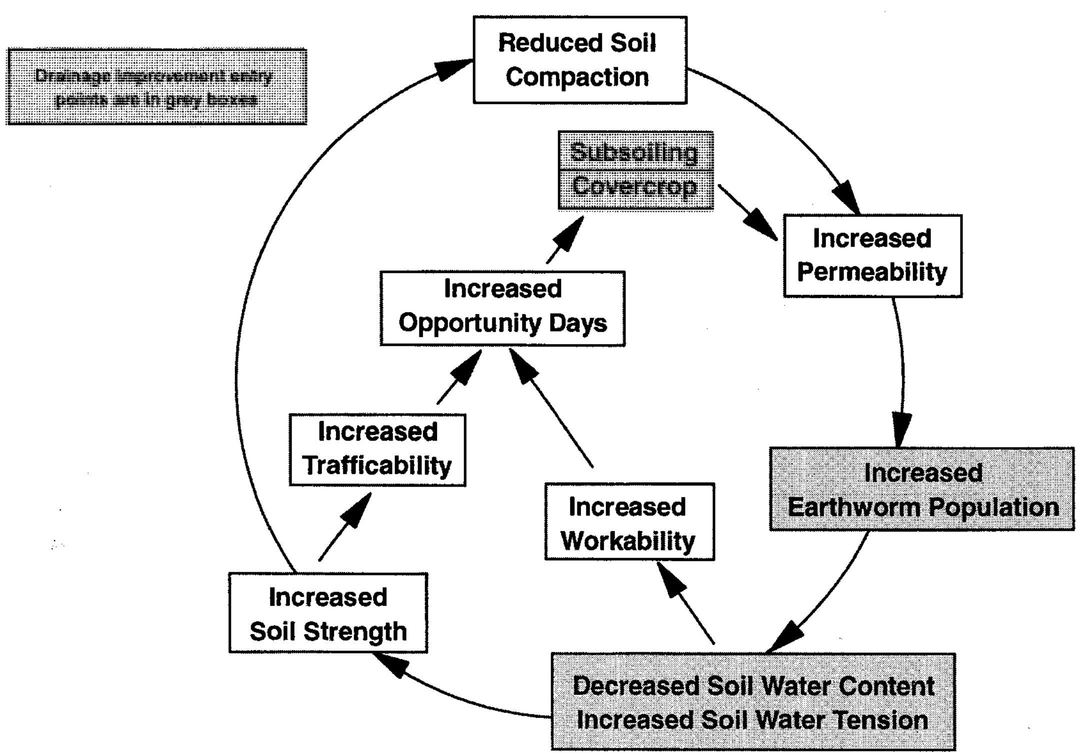


Figure 6.4 Soil Management Cycles With and Without Drainage