7

Soil Aeration and Temperature

The naked earth is warm with Spring.
–Julian Grenfell, Into Battle

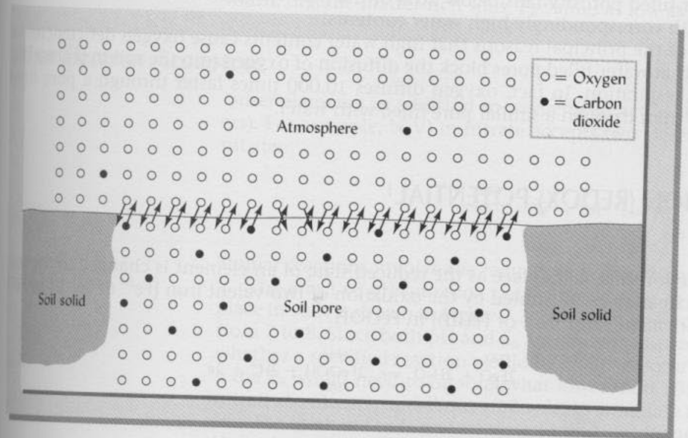

FIGURE 7.2 The process of diffusion between gases in a soil pore and in the atmosphere. The total gas pressure is the same on both sides of the boundary. The partial pressure of oxygen is greater, however, in the atmosphere. Therefore, oxygen tends to diffuse into the soil pore where fewer oxygen molecules per unit volume are found. The carbon dioxide molecules, on the other hand, move in the opposite direction owing to the higher partial pressure of this gas in the soil pore. This diffusion of O_2 into the soil pore and of CO_2 into the atmosphere will continue as long as the respiration of root cells and microorganisms consumes O_2 and releases CO_2.

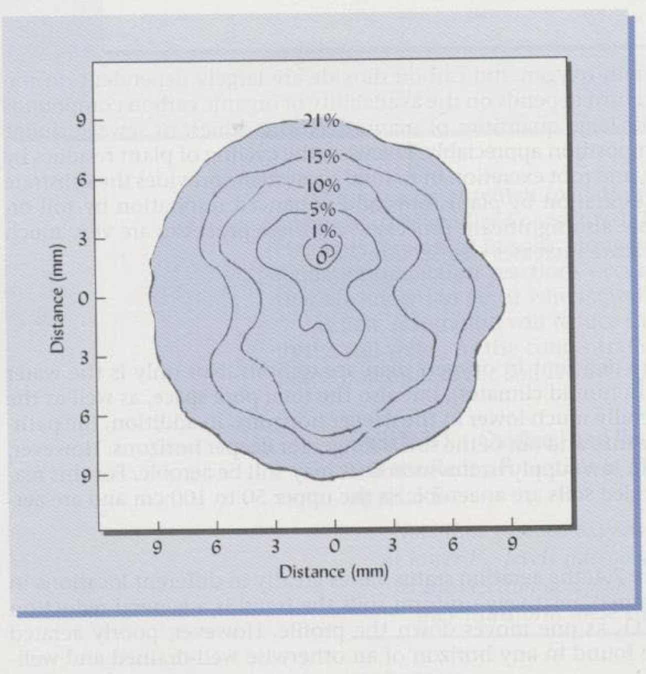

FIGURE 7.5 The oxygen content of soil air in a wet aggregate from an Aquic Hapludoll (Muscatine silty clay loam) from Iowa. The measurements were made with a unique microelectrode. Note that the oxygen content near the aggregate center was zero, while that near the edge of the aggregate was 21%. Thus, pockets of oxygen deficiency can be found in a soil whose overall oxygen content may not be low. [From Sexstone et al. (1985)]

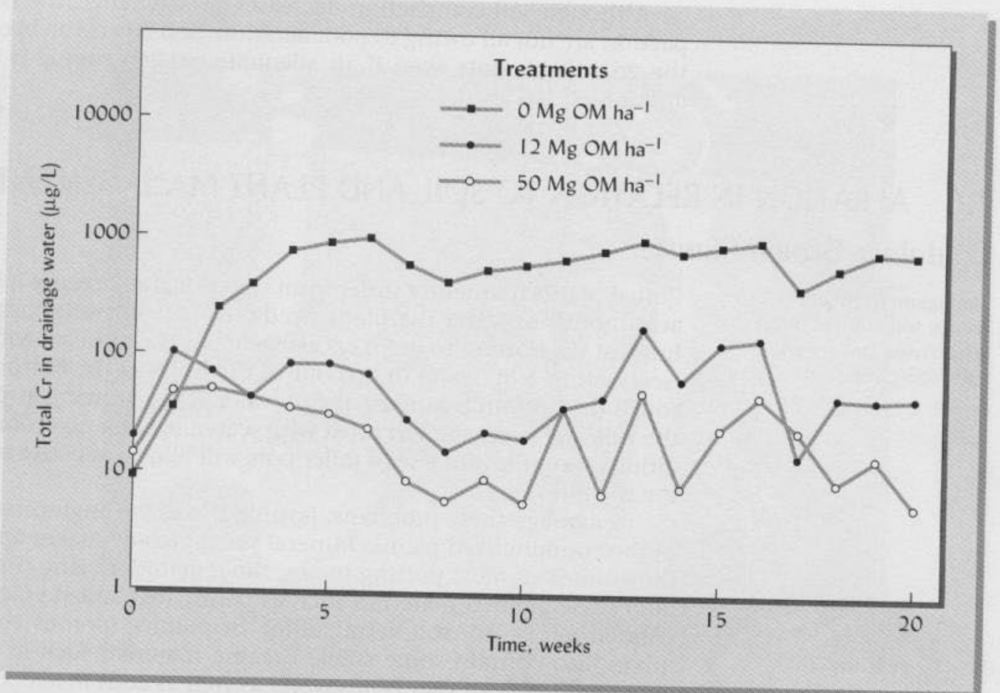

FIGURE 7.6 Effect of adding decomposable organic matter (OM) on the concentration of chromium in water draining from a chromium-contaminated soil. Here dried cattle manure was added as the decomposable OM. As the manure oxidized, it caused the reduction of the toxic, mobile Cr^{6+} to the relatively immobile, nontoxic Cr^{3+}. Note the log scale for the Cr in the water, indicating that the high level of manure addition caused the Cr level to be lowered approximately 100-fold. The coarse textured soil was a Typic Torripsamment in California. [Data from Losi et al. (1994)]

TABLE 7.3 **Examples of Plants with Varying Degrees of Tolerance to a High Water Table and Accompanying Restricted Aeration**

The plants in the leftmost column commonly thrive in wetlands. Those in the rightmost column are very sensitive to poor aeration.

Plants adapted to grow well with a water table at the stated depth				
<10 cm	*15 to 30 cm*	*40 to 60 cm*	*75 to 90 cm*	*>100 cm*
Bald cypress	Alsike clover	Birdsfoot trefoil	Beech	Arborvitae
Black spruce	Black willow	Black locust	Birch	Barley
Common cattail	Cottonwood	Bluegrass	Cabbage	Beans
Cranberries	Deer tongue	Linden	Corn	Cherry
Duckgrass	Eastern gama grass	Mulberry	Hairy vetch	Hemlock
Fragmites grass	Ladino clover	Mustard	Millet	Oats
Mangrove	Loblolly pine	Red maple	Peas	Peach
Pitcher plant	Orchard grass	Sorghum	Red oak	Sand lovegrass
Reed canarygrass	Redtop grass	Sycamore		Sugar beets
Rice	Tall fescue	Weeping lovegrass		Walnut
Skunk cabbage		Willow oak		Wheat
Spartina grass				White pine
Swamp white oak				
Swamp rosemalow				

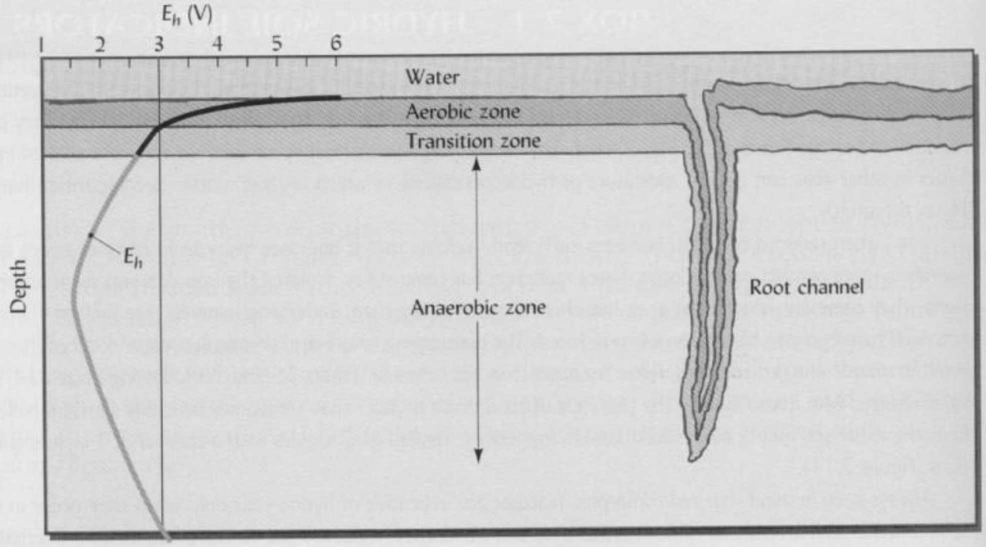

FIGURE 7.12 Representative redox potentials within the profile of an inundated hydric soil. Many of the biological and chemical functions of wetlands depend on the close proximity of reduced and oxidized zones in the soil. The changes in redox potential at the lower depths depend largely on the vertical distribution of organic matter. In some cases, low subsoil organic matter results in a second oxidized zone beneath the reduced zone. (Diagram courtesy of R. Weil)

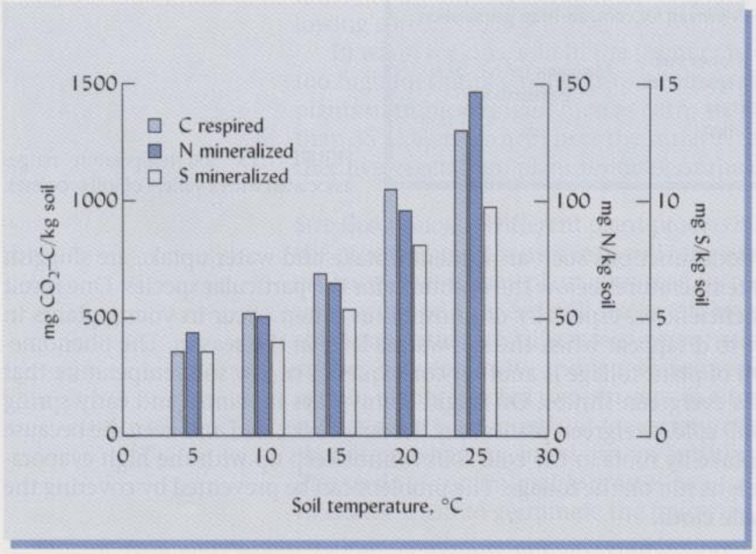

FIGURE 7.14 Effect of soil temperature on the cumulative microbial respiration (CO_2 release) and net nitrogen and sulfur mineralization in surface soils under hardwood forests over a period of 32 weeks during which the soil water content was adequate for microbial activity. Note the near doubling of activity with each 10°C increase in temperature. Data are averages of four sites in Michigan. From MacDonald et al. (1995).

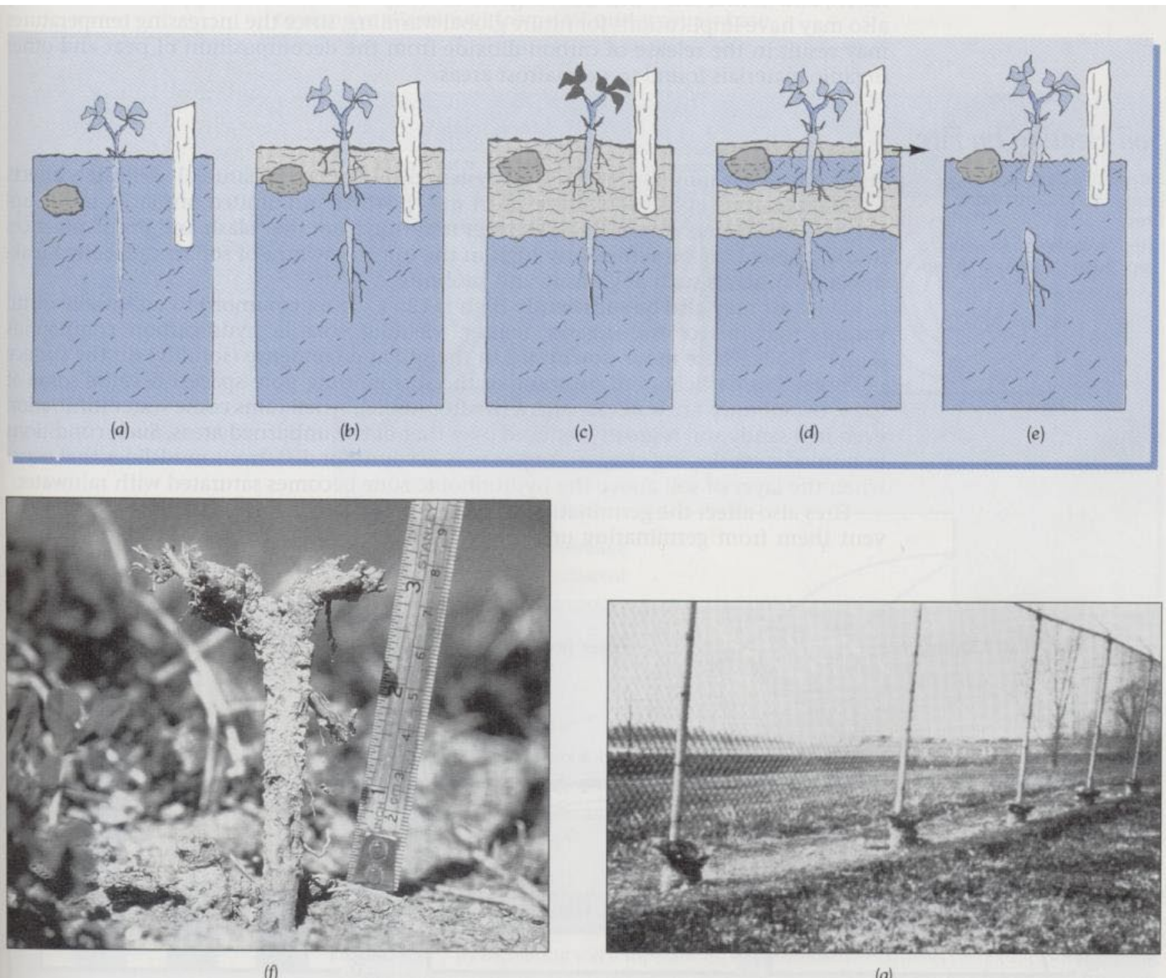

FIGURE 7.15 How frost heaving moves objects upward. (*a*) Position of the object (stone, plant, or fence post) before the soil freezes. (*b*) As lenses of pure ice form in the freezing soil by attraction of water from the unfrozen soil below, the frozen soil tightens around the upper part of the object, lifting it somewhat—enough to break the root in the case of the plant. (*c*) The objects are lifted upwards as ice-lens formation continues with deeper penetration of the freezing front. (*d*) As for freezing, thawing commences from the surface downward. Water from thawing ice lenses escapes to the surface because it cannot drain downward through the frozen soil. The soil surface subsides while the heaved objects are held in the "jacked-up" position by the still-frozen soil around their lower parts. (*e*) After complete thaw, the stone is closer to the surface than previously (although rarely at the surface unless erosion of the thawed soil has occurred), and the upper part of the broken plant's root is exposed, so that is likely to die. (*f*) Alfalfa plants lifted out of the ground by frost action. (*g*) Fence posts encased in concrete that have been progressively "jacked out" of the ground by frost action over several years. [Photo (*f*) courtesy of R. Weil; photo (*g*) courtesy of R. L. Berg, Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, N.H.]

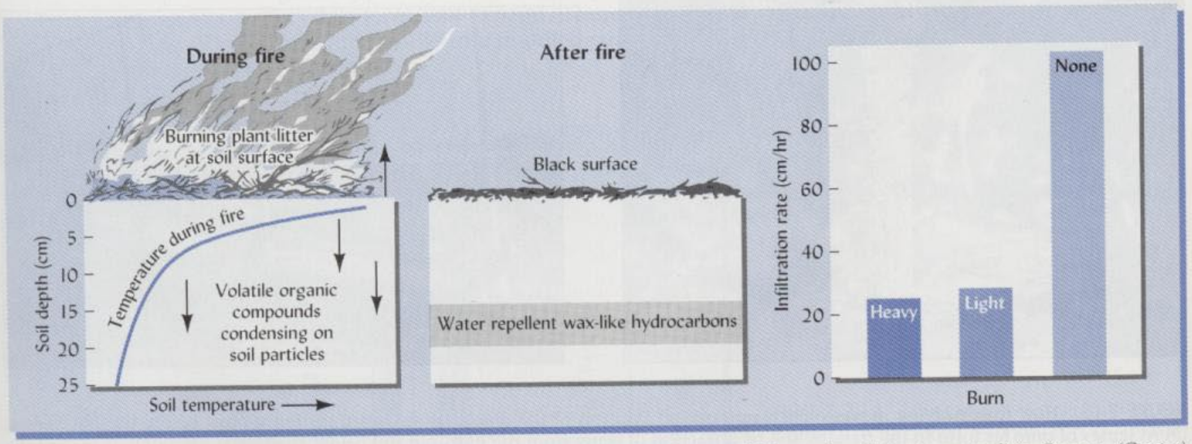

FIGURE 7.16 (Left) Wildfires of a lodgepole pine stand heat up the surface layers of this sandy soil (an Inceptisol) in Oregon. (Center) Note that the soil temperature is increased sufficiently near the surface to volatilize organic compounds, some of which then move down into the soil and condense (solidify) on the surface of cooler soil particles. These condensed compounds are waxlike hydrocarbons that are water repellent. As a consequence (right) the infiltration of water into the soil is drastically reduced and remains so for a period of at least 6 years. [From Dryness (1976)]

[5]For a recent article on permafrost in Alaska, see Wuethrich (2000).

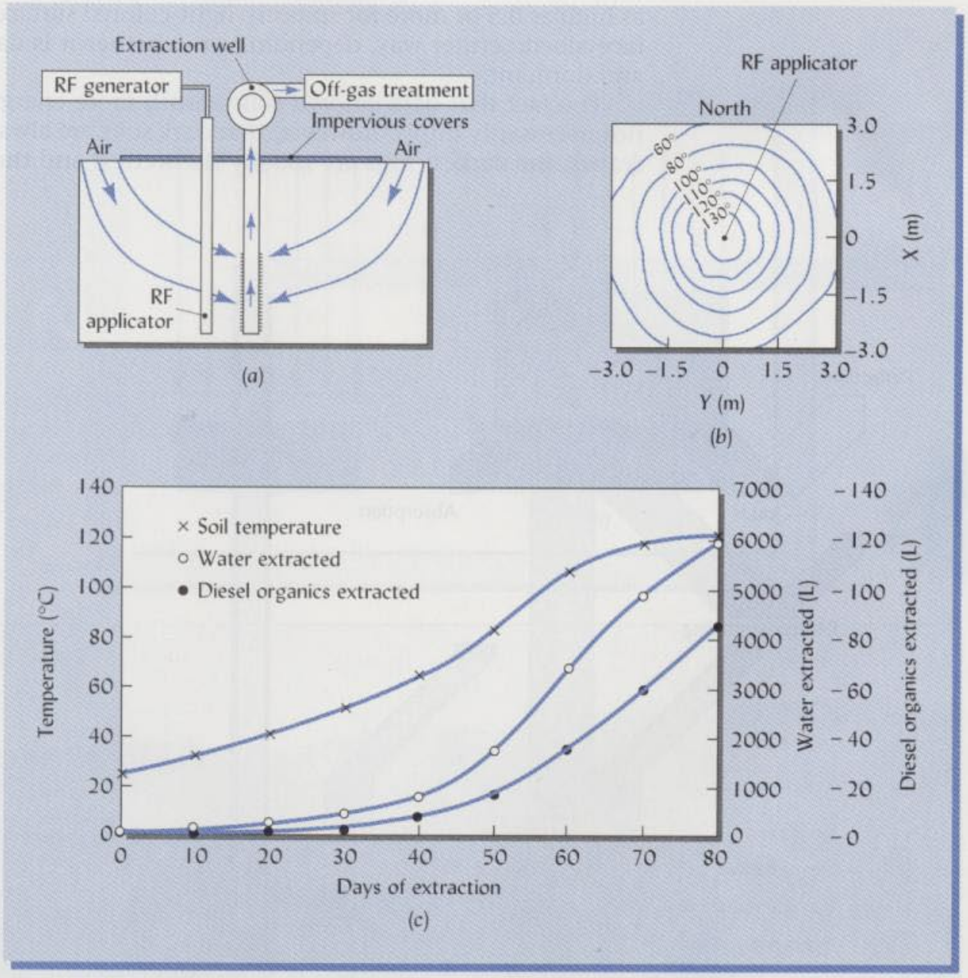

FIGURE 7.17 By increasing soil temperatures, environmental engineers can extract some organic pollutants from soils. (*a*) Electromagnetic radiation from radio frequency (RF) was used to supply the energy to gradually increase temperatures in a block of soil containing diesel fuel at the Kirkland Air Force Base near Albuquerque, New Mexico. At the higher temperatures the organic hydrocarbons were vaporized (along with water). The vapors were then extracted from the soil using an extraction well, and were subsequently removed from the air (off-gas treatment). (*b*) The effect of 80 days' radiation on soil temperatures outward from the RF applicator in a small block of polluted soil at the Kirkland AFB site. Note that extremely high temperatures did not prevail. (*c*) Soil temperature increase with time near the RF applicator, along with the quantity of organic compounds and water extracted from the soil. While this procedure is rather expensive, it permits remediation of the soil without having to remove it from its natural setting, and does not result in extremely high temperatures as the soil is heated. [Modified from figures in Lowe et al. (2000)]

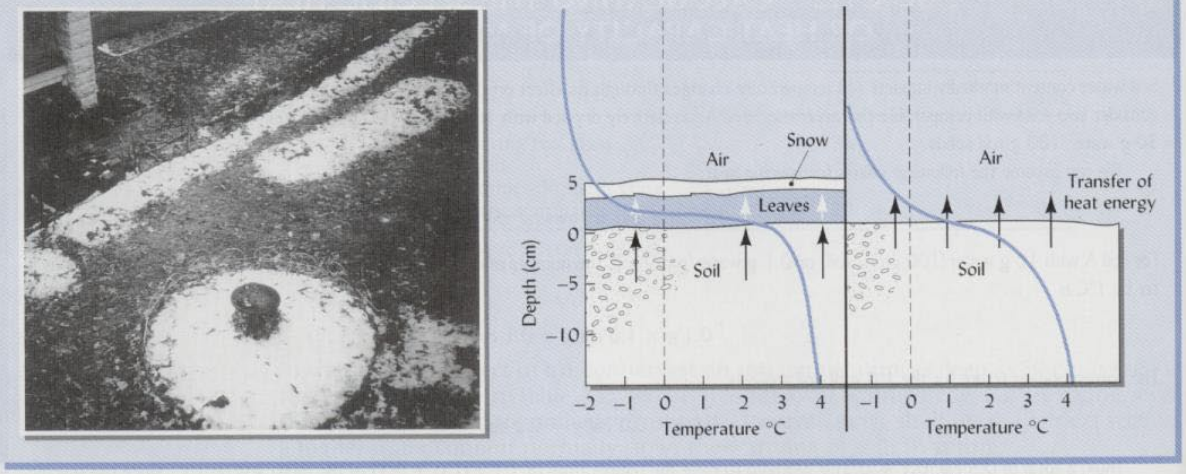

FIGURE 7.20 Transfer of heat energy from soil to air. The scene, looking down on a garden after an early fall snow storm, shows snow on the leaf-mulched flower beds, but not on areas where the soil is bare or covered with thin turf. The reason for this uneven accumulation of snow can be seen in the temperature profiles. Having stored heat from the sun, the soil layers are often warmer than the air as temperatures drop in fall (this is also true at night during other seasons). On bare soil, heat energy is transferred rapidly from the deeper layers to the surface, the rate of transfer being enhanced by high moisture content or compaction, which increase the *thermal conductivity* of the soil. As a result, the soil surface and the air above it are warmed to above freezing, so snow melts and does not accumulate. The leaf mulch, which has a low thermal conductivity, acts as an insulating blanket that slows the transfer of stored heat energy from the soil to the air. The upper surface of the mulch is therefore hardly warmed by the soil, and the snow remains frozen and accumulates. A heavy covering of snow can itself act as an insulating blanket. (Photo and diagram courtesy of R. Weil)

Heat of Vaporisation of Water: 2.26 Mega joules /Kg of water

Specific Heat of Soils – the amount of heat needed to raise the temperature 1 degree C

Water = 4.8 J/g ; Soil Solids 0.8 J/g

Thermal Conductivity

$$\mathbf{Q = K \times \Delta T/X} \qquad \text{Fourier's Law}$$

Where, Q is the Heat Flux (energy/area/time)

K is Thermal Conductivity

T is temperature

X is distance