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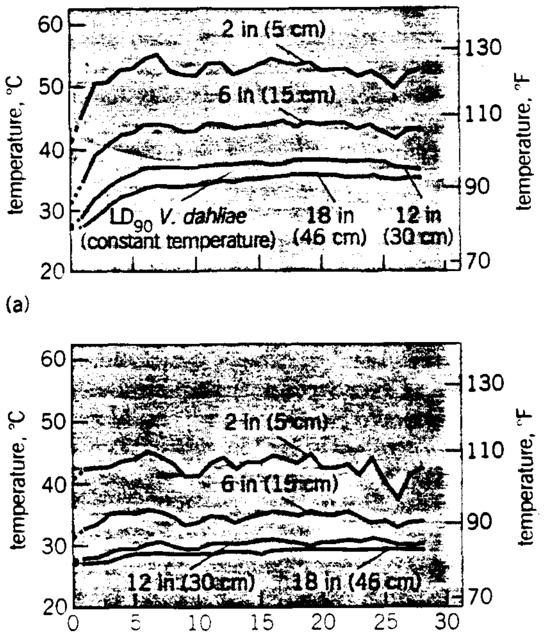

Fig. 3. Daily maximum soil temperatures (a) in moist soil during solarization with 25-μm clear polyethylene sheeting and (b) in dry nonsolarized soil at indicated depths. Each temperature value is an average of four experiments made during June and July at Davis and Shafter, California. (*After G. S. Pullman, J. E. DeVay, and R. H. Garber, Soil solarization and thermal death: A logarithmic relationship between time and temperature for four soil-borne plant pathogens, Phytopathology, 71:959–964, 1981*)

pathogens and pests, they are often highly beneficial to plant growth. In some soils, solarization causes biological changes that suppress the reestablishment of pathogens.

Chemical effects. Among the chemical changes that occur in soils during solarization are significant increases in soluble nutrients, such as nitrogen, calcium, and magnesium, which are associated with the increased growth response of plants grown in solarized soils.

Physical effects. The physical effects of soil solarization are largely unknown, but marked improvement in soil tilth occurs. During solarization soil moisture tends to rise to a cooler soil surface at night, whereas during the day the moisture tends to move toward a cooler temperature zone deeper in the soil. This diurnal cycling of soil moisture is believed to leach sodic layers and thus accounts for the reduction of salinity caused by solarization in some soils.

Applications. Soil solarization is a safe, nonchemical, and effective method for plant disease and pest control. When used in conjunction with agricultural chemicals and biological control agents, soil solarization can be extended to regions where environmental conditions are less suitable for it. Use of solarization is increasing in orchard, field, and truck crop farming as well as in greenhouse and nursery operations; it is also finding increased use for garden and landscape improvement. Considering the multiple benefits of soil solarization and its lasting effects, the costs are competitive with other methods for control of soil-borne diseases and pests.

For background information SEE AGRICULTURAL SOIL AND CROP PRACTICES; IRRIGATION (AGRICULTURE); MYCORRHIZAE; SOIL; SOIL ECOLOGY; SOIL MICROBIOLOGY; SOLAR RADIATION in the McGraw-Hill Encyclopedia of Science & Technology.

James E. DeVay

Bibliography. J. Katan, Solar heating (solarization) of soil for control of soil-borne pests, *Annu. Rev. Phytopathol.*, 19:211–236, 1981; J. Katan et al., Solar heating by polyethylene mulching for the control of diseases caused by soil-borne pathogens, *Phytopathology*, 76:683–688, 1976; J. J. Neeteson and J. A. van Veen, Mechanistic and practical modelling of nitrogen mineralization-immobilization in soils, *Advances in Nitrogen Cycling in Agricultural Ecosystems: Proceedings of the Symposium on Advances in Nitrogen Cycling in Agricultural Ecosystems*, Brisbane, 1988; E. A. Paul and J. N. Ladd (eds.), *Soil Biochemistry*, 1981; G. S. Pullman, J. E. DeVay, and R. H. Garber, Soil solarization and thermal death: A logarithmic relationship between time and temperature for four soil-borne plant pathogens, *Phytopathology*, 71:959–964, 1981; J. J. Stapleton and J. E. DeVay, Soil solarization: A non-chemical approach for management of plant pathogens and pests, *Crop Protect.*, 5:190–198, 1986; J. J. Stapleton and J. E. DeVay, Thermal components of soil solarization as related to changes in soil and root microflora and increased plant growth response, *Phytopathology*, 74:255–259, 1984; J. J. Stapleton, J. Quick, and J. E. DeVay, Soil solarization: Effect on soil properties, crop fertilization, and plant growth, *Soil Biol. Biochem.*, 17:369–373, 1985; J. A. van Veen and P. J. Kuikman, Soil structural aspects of decomposition of organic matter by micro-organisms, *Biogeochemistry*, 11:213–233, 1990; J. A. van Veen, R. Merckx, and S. C. van de Geijn, Plant- and soil-related controls of the flow of carbon from roots through the soil microbial biomass, *Plant and Soil*, 115:43–52, 1989.

Soil conservation

Erosion decreases the productivity potential of soil except in rare locations where soils are unusually deep and fertile. Crop yields are decreased as topsoil is removed by erosion. Lower crop yields provide less income to sustain farm families and less food for the world. Recent research has identified and defined factors causing soil erosion and has developed management alternatives to combat these factors and conserve valuable soil resources. The most significant recent progress involves controlling erosion caused by irrigation on highly productive lands.

Furrow erosion processes. When water enters the furrow, erosive forces are created by wetting and water flow that exceed cohesive forces holding soil

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particles together and in place. The condition of the soil in the furrow when it is contacted by water largely determines if erosion will occur. When soils are dry, oxygen and nitrogen are adsorbed on the internal surfaces of aggregates. If these soils are wetted suddenly, water molecules rapidly displace the molecules of oxygen and nitrogen, and these gases join the air entrapped in the gaseous phase of the soil, causing pressure forces sufficient to break apart the soil aggregates. The bursting of small clods resembles tiny explosions. When water is applied early in the morning following a cool night, much less erosion results than when the water is applied during or following a hot dry afternoon.

Other eroding forces are shear forces caused by flowing water and transported materials. The furrow stream size and slope along the furrow are factors affecting water velocity that cause shear forces on the perimeter of the furrow. Under slow velocities, there may be practically no detachment of particles. Bonds between primary soil particles hold soil aggregates together. The strength of these bonds represents the soil cohesion or stability, which varies with clay content and type, organic matter content, compaction, adsorbed cations, time and water content since the last disruption, the wetting rate, and the chemical components in the water that is wetting the soil. The processes of formation and disruption of soil bonds are not yet well understood, but recent research has provided considerable enlightenment about factors controlling bond strength and cohesive forces. For example, bond strength increases with time since the last disruption, with increasing clay content, and with increasing amounts of gums and resins from decomposing plant residues present in the soil.

Factors affecting furrow erosion. The greater the slope along the irrigation furrow, the higher will be the water velocity and the resulting shear forces. Recent research has shown that erosion is approximately a two- to three-power function of furrow slope. Also, erosion is about a 1.5-power function of stream size. These two factors give rise to the eroding forces. Factors that impede furrow erosion are crop residues in the furrows and surface roughness of the furrows, which slow down the water velocity and thereby reduce the shear or erosion forces. The amount of residue on and in the soil surface can be controlled by cropping sequences and the kind and number of tillage operations between crops. Furrow surface roughness can also be controlled by tillage operations, the previous crop, and the water content of the soil when tilled. Analyses of this information show that furrow erosion can be controlled because a number of these factors can be controlled.

Erosion and sediment loss. Most of the furrow erosion takes place along the upper one-third of the furrow length and along about the last 15 m (50 ft) immediately above the tailwater ditch (the channel made to carry runoff water from the field) where a convex field end has developed. The cause of this development, which is a condition of increasing slope toward the ditch, is that past management has kept the tailwater ditch 15 cm (6 in.) or more deeper than the furrow ends to facilitate drainage. This practice has caused accelerated erosion from the tailwater ditch, upslope along the furrows. The erosion along the upper one-third of the field exposes subsoils, which are generally less productive than topsoils. Usually, most of the eroded topsoil is subsequently deposited on the lower half of the field, but some of it may reach the tailwater ditch and be carried away in the drainage water.

These erosion processes are a natural consequence of the irrigation requirement, which is to supply enough water to meet crop needs over the entire length of run or furrow length. To meet this requirement, the size of the stream placed in the upper end of the furrow is often large enough to be erosive. As the stream progresses down the furrow, its size diminishes as a result of infiltration into the soil. Usually about one-third of the way toward the lower end of the field, the stream size has decreased sufficiently that it no longer has enough erosive energy to overcome cohesive forces; erosion ceases. A short distance farther, the stream becomes still smaller, and it no longer has enough energy to transport the soil that it eroded upslope. This soil is often known as sediment once it is suspended. At this point, sedimentation begins, and soil materials eroded from upslope areas are deposited in the furrows. The quantity of deposition depends upon the stream size and field slope, but generally most of the material is deposited before it reaches the lower end of the furrow. Hence, this process causes topsoil redistribution (**Fig. 1**), which seriously reduces crop yield on the eroded area and seldom increases it on the deposition area. This occurs because there is a critical requirement of topsoil depth for maximum crop productivity. When erosion decreases topsoil depths to less than this critical depth, crop yields are decreased. However, when topsoil is deposited onto areas that already have topsoil depths greater than the critical depth, crop yields are not changed.

Reducing erosion and sediment loss. Five years of intensive research has demonstrated that furrow erosion can be almost eliminated by changing cropping sequences and using conservation tillage practices on furrow-irrigated land. Studies have shown that cereals and corn can be grown without tillage following

Fig. 1. Aerial photograph illustrating the exposure of light-colored subsoils as a result of furrow erosion of the upslope one-third of the fields.

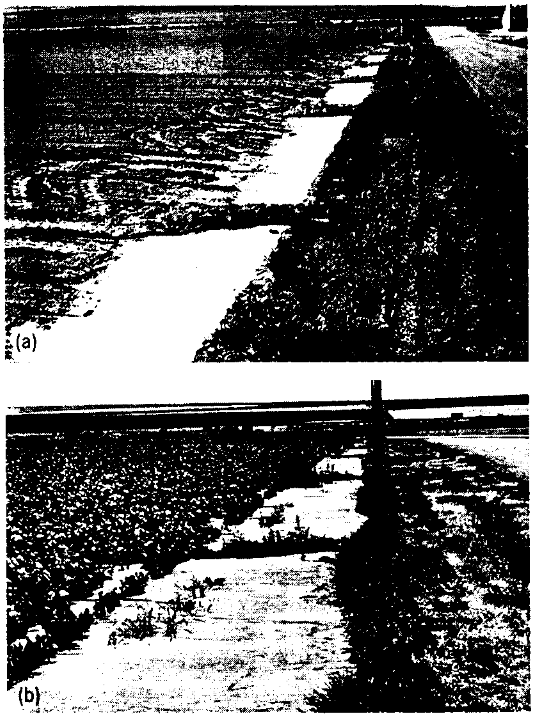

Fig. 2. Buried-pipe erosion and sediment-loss control system. (*a*) First irrigation after installation. (*b*) Basins filled with sediment after five irrigations.

alfalfa killed with herbicide, and that yields are maintained and requirements for nitrogen fertilizer are decreased. The same irrigation furrows used for alfalfa are cleaned and used to irrigate the cereal or corn. These furrows have uniform infiltration rates, and they erode very little, if any. Similarly, either cereal can be grown following corn or corn can be grown following cereal without tillage with the same effect of eliminating furrow erosion. When row crops such as dry beans or sugarbeets are to be grown, the smallest number of tillage operations possible to prepare a seedbed and plant the crop are used. This involves shallow tillage, generally only slightly deeper than the furrows from the previous crop, and it is done with equipment that leaves residue on and mixed into the soil surface. Studies have shown that furrow irrigation can be done successfully in the presence of crop residues on and mixed into the soil surface.

All of the tillage practices used in the newly developed management systems can be done without additional tillage implements. Some minor adaptations may be needed for seeding corn without previous tillage following alfalfa or cereal. Usually, mounting a cutting coulter (a serrated, sharp disk) or a small bull tongue shank (a vertical metal tool for cutting the soil) ahead of these seeders assures adequate seeding depth. Furthermore, results have shown that the number of tillage operations required over a 7-year cropping sequence can be reduced from near 40 to less than 10. Yields of the specific crops are not affected by their position in the sequence. The savings resulting from fewer tillage operations is reflected as a significant increase in net farmer income. Thus, farming to prevent or reduce erosion on furrow-irrigated land benefits the farmer economically in the short term as well as in the long term by protecting the productivity of the soil resource.

The loss of eroded soil or sediment from convex field ends can be almost entirely eliminated by installing a buried-pipe erosion and sediment control system. The pipe is buried along the lower end of the field, and it has vertical inlets at intervals. The tops of these intervals are set at the level desired to correct the convex end when sediment is accumulated to the tops of these inlets. Small earthen dams are placed on the downslope side of these inlets to form small sediment basins along the lower end of the field. As sediment from the upper part of the convex end and further upslope settles and fills the basins, the convex end is corrected. The pipe remains as a means to drain runoff water from the field, eliminating the need for a tailwater ditch. **Figure** 2*a* shows a newly installed system in operation, and Fig. 2*b* illustrates the same system after five irrigations with the convex end corrected.

Erosion control on sprinkler-irrigated land. The same erosion control principles apply to lands irrigated by sprinklers and by furrows. The differences are that sprinkler irrigation does not require furrows for water distribution and that it can be used on steeper lands than furrow irrigation. Greater amounts of residue can be tolerated under sprinklers.

The most serious erosion problem under sprinkler irrigation is on the steep slopes. In addition to conservation tillage systems to maintain residue on and in the soil surface, a new practice known as reservoir tillage has been developed and evaluated. This practice forms thousands of small water storage basins in the soil surface (**Fig. 3**). As water is applied by sprinkler systems, their reservoirs catch the water and store it temporarily until it infiltrates the soil. This prevents runoff from steep slopes, thus preventing erosion, and assures that adequate water infiltrates the soil to support the crop. These small reservoirs function best when they are depression-scooped (removing several shovelfuls of soil at a point) or pressed into the land surface rather than being formed by earthen dams in furrows. Erosion on sprinkler-irrigated land can be eliminated by using reservoir tillage and appropriately designed sprinkler systems.

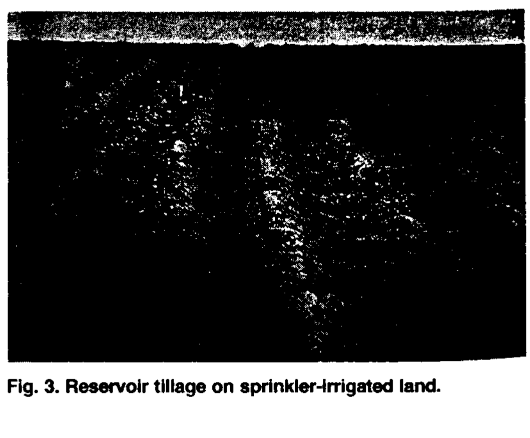

Fig. 3. Reservoir tillage on sprinkler-irrigated land.

For background information SEE AGRICULTURAL SOIL AND CROP PRACTICES; SOIL; SOIL CONSERVATION; SOIL MECHANICS in the McGraw-Hill Encyclopedia of Science & Technology.

David L. Carter

Bibliography. D. L. Carter, R. D. Berg, and B. J. Sanders, The effect of furrow irrigation erosion on crop productivity, *Soil Sci. Soc. Amer. J.*, 49:207–211, 1985; W. D. Kemper et al., Furrow erosion and water and soil management, *Trans. ASAE*, 28:1564–1572, 1985; B. A. Stewart and D. R. Nielsen (ed.), *Irrigation of Agricultural Crops*, 1990.

Soil ecology

Recent advances in soil ecology include development of quantitative methods for studying belowground ecosystems in forests, the sensitivity of forests to air pollution, and the role of nematodes in deep-rooting systems in desert environments.

Belowground Ecology of Forests

The belowground portion of terrestrial ecosystems has historically received less study than the aboveground. This has been due in part to methodological difficulties, the inability to see and measure objects and processes belowground, and the perception that it is possible to understand the whole ecosystem while remaining ignorant of this hidden realm. Since 1970, it has become apparent that studying only the half of the ecosystem that is aboveground can badly mislead workers seeking to understand how the system functions and responds to disturbances such as acid rain or heavy-metal contamination. Today, scientific studies emphasize the flow of matter and energy between the various components, the processes that control these flows, and the role of plant root systems in regulating the structure and function of the whole forest.

Belowground components. In the simplest view, a belowground ecosystem contains only two components: plant roots and the growth medium (soil). Typically, belowground is defined as the zone that starts at the surface organic layer on top of the mineral soil and extends down to consolidated rock (bedrock), in which biological activity is absent and no organic matter accumulates. A more realistic view recognizes the belowground ecosystem as a complex and extremely heterogeneous mosaic of many interacting components (for example, roots, microorganisms, soil animals, organic matter, and mineral particles). Each component can be subdivided into many types and structures with differing functions in the belowground.

This definition of the belowground is valid for temperate zone forests but not for wet tropical forests. In tropical forests, root growth is not restricted to the soil; roots may grow into and on top of freshly fallen leaves, over exposed rocks, into streams, or up the trunks of other trees (apogeous roots; **Fig. 1**). Apogeous roots are commonly found climbing up the trunks of trees (such as palms) that collect nutrients in rainwater more efficiently because of their branching form. Roots are also produced adventitiously from branch tissues when organic material collects in branch crotches and cavities. This type of root growth in the tree canopy resembles the standard air-layering technique used in horticulture to propagate ornamentals. In addition, epiphytes such as bromeliads and orchids have root systems growing along the branches of trees, a role played by mosses in cool, damp northern forests.

Much of past soil research concentrated on studying soil (bulk soil) that had low biological activity and from which roots were removed. But the most critical area in any soil is the very narrow region, less than 0.06 in. (2 mm) wide, that surrounds fine roots. It is in this region, known as the rhizosphere, that biological activity is most pronounced, so that this soil has distinctive characteristics. Much of the rhizosphere may be discarded when roots are separated from soil; thus, traditional methods of studying soils underestimate the level of biological activity.

In most soils, mineral particles make up the bulk of the soil, ranging from microscopic, chemically active clay to larger, more inert sand and gravel. These serve as the primary source for nutrients such as calcium, potassium, phosphorus, and trace minerals, which are released through chemical dissolution (weathering).

Organic matter includes all material from recently dead leaves, branches, and roots to advanced decay products such as humic acids. Dead organic matter serves as an important storage reservoir for many nutrients, especially nitrogen, in all but the youngest soils. It also provides energy for saprophytic organisms (those that derive energy from breaking carbon bonds in dead organic matter).

Humic acids are large (molecular weight 5000–1,000,000+) organic complexes that are highly resistant to decomposition. They serve as a long-term storage pool of slowly released nutrients, especially nitrogen and phosphorus. They also provide a signif-

Fig. 1. Apogeous root of guaba (*Inga vera*) with large cluster of nitrogen-fixing nodules growing up the stem of a Sierra palm (*Prestoea montana*) in Puerto Rico.