EPA-430/9-73-015

METHODS and PRACTICES for CONTROLLING WATER POLLUTION from AGRICULTURAL NONPOINT SOURCES

. S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

FOREWORD

This report is issued in response to Section 304(e)(2)(A) of Public Law 92-500. This Section provides:

> The Administrator, after consultation with appropriate Federal and State agencies and other interested persons, shall issue to appropriate Federal agencies, the States, water pollution control agencies, and agencies designated under section 208 of this Act, within one year after the effective date of this subsection (and from time to time thereafter) information including . . . (2) processes, procedures, and methods to control pollution resulting from -- "(A) agricultural . . . activities, including runoff from fields and crop . . . lands . . ."

This report, prepared under contract by the Economic Research Service, United States Department of Agriculture, for the Environmental Protection Agency, provides general information on alternative control measures and cultural practices. It is intended to provide information that, when considered in the light of local conditions, will give an indication of the kinds of measures that may be useful in a program to control pollutants from agricultural activities. Expertise, well-founded in the utilization of such measures, must be brought to bear in the final design of the control plan.

Russell E. Train
Administrator
Environmental Protection Agency

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METHODS and PRACTICES for CONTROLLING WATER POLLUTION from AGRICULTURAL NONPOINT SOURCES

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Program Operations
Water Quality and Nonpoint Source Control Division
Washington, D. C. 20460

OCTOBER 1973

PREFACE

This report provides information on methods and practices that will control or reduce water pollution from nonpoint agricultural sources.

Nonpoint agricultural pollutants are organic and inorganic materials entering surface and ground water from nonspecific or unidentified sources in sufficient quantity to constitute a pollution problem. They include sediment, plant nutrients, animal wastes, and pesticides from cropland, rangeland, pastures, and farm woodlots.

Both economic and environmental considerations are important in controlling nonpoint sources of water pollution. This report does not provide sufficient detail for selecting practices for specific regions, watersheds, or individual farms. Methods selected by farm operators will depend on local climate, soil, topography, and livestock and cropping patterns. The report does not evaluate the economics of alternative methods, nor does it discuss methods for controlling pollution associated with irrigation, soil salinity, feedlots, and commercial forests.

General information, research results, and technical assistance for water pollution control are available from the local, state and regional offices of the Soil Conservation Service, Extension Service, and Forest Service of the U.S. Department of Agriculture; Soil and Water Conservation Districts; state agencies; and the Regional and Headquarters Offices of the U.S. Environmental Protection Agency. Technical research results are available from agricultural experiment stations at land grant colleges and universities; from USDA's Agricultural Research Service; from the Environmental Protection Agency; and from state agencies. Additionally, various programs of the Agricultural Stabilization and Conservation Service, Soil Conservation Service, and Farmers Home Administration provide economic incentives for carrying out certain conservation and water pollution control practices.

Appreciation is expressed to the many individuals, both inside and outside the Government, for their critical review and relevant suggestions for this report. Special appreciation is given to the land grant colleges and universities, Regional Offices of EPA, and to USDA agencies, namely: Agricultural Research Service, Agricultural Stabilization and Conservation Service, Animal and Plant Health Inspection Service, Cooperative State Research Service, Extension Service, Forest Service, and Soil Conservation Service.

The photographs in this report were used through the courtesy of the Soil Conservation Service.

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Potential nonpoint agricultural sources of surface and ground water pollution include sediment, pesticides, fertilizer, and plant and animal wastes and residue from cropland, grazing areas, and farm woodlots. Sound management practices are the key to achieving acceptable water quality.

Water and wind erosion, use of plant nutrients and pesticides, livestock management, cultivation practices, and leaching are important factors to consider in controlling water pollution. Because of the wide variations in topography, climate, types of soil, and patterns of crop and livestock production, no one method or practice is universally applicable. A combination of practices must be designed and selected to meet the situation for any particular farm or region.

Water Erosion

Erosion occurs as a natural geological process, but may be accelerated by man's actions--including agricultural activities. Water erosion is the basic factor in nonpoint pollution of the Nation's water. Sediment is the major nonpoint pollutant.

Soils are protected naturally by vegetation and vegetative residue. If moisture or fertility is too low, the land is subject to periodic erosion. Tilling the soil, overgrazing, crop harvesting, and burning of vegetation remove or bury portions of the protective organic material and may bring about more erodible conditions. This is particularly serious in areas of high rainfall.

Proper land use and agricultural management practices will keep soil, plant nutrients, and organic matter on the land, rather than allow them to become part of the water-borne pollutant load. Erosion may be reduced by means of conservation tillage, terraces, diversions, stripcropping, contouring, grassed waterways, and crop rotations, and by more efficient range, pasture, and woodlot management.

Wind Erosion

Wind erosion is a relatively minor problem from the standpoint of water pollution, accounting for only a small fraction of the sediment loads in waterways. Major factors affecting wind erosion are soil cloddiness, surface roughness, soil moisture, vegetative cover, wind velocity, and field length along the prevailing wind direction.

Successful wind erosion control involves a combination of the following practices: (1) stubble mulch or conservation tillage practices to prepare land for crop production; (2) cover crops; (3) appropriate crop rotations; (4) controlled grazing; (5) wind barriers and shelterbelts; (6) artificial barriers; (7) hauled-in mulches; (8) emergency tillage; (9) deep plowing and (10) land forming and benching. These practices also conserve moisture and control water erosion.

Plant Nutrients

Plant nutrients are an environmental concern from the standpoint of increasing eutrophication of surface waters and the high concentrations of nitrates in both surface and ground waters. Agricultural operations have been identified as a potential contributor of nutrients to water resources. It is extremely difficult to identify the extent to which natural and applied plant nutrients may contribute to water pollution.

Factors influencing nutrient losses are precipitation and other sources of water, temperature, kind of soil, kind of crop, nutrient mineralization, and denitrification. Reducing nutrient losses from agricultural operations can be accomplished by three general approaches: (1) determining the proper amount, time, and method of plant nutrient applications to ensure efficient use by plants, (2) adopting approved cultural practices, including tillage and crop rotations, that minimize nutrient losses, and (3) reducing soil and water runoff by conservation measures such as contours and terraces.

Pesticides

The potential movement of chemical pesticides into water is of environmental concern. Most pesticides fall into three major categories: insecticides, herbicides, and fungicides. There are several approaches to reduce the quantity of pesticides entering surface and ground water. These include: controlling erosion and minimizing wind drift; reducing the quantity of pesticides used by applying minimum amounts needed, and/or substituting nonchemical methods of pest control; and using biodegradable rather than persistent pesticides, to the extent possible.

Animal Wastes

Disposal of animal wastes on land is a potential nonpoint source of water pollution. Animal wastes applied to land come from (1) wastes removed from feeding facilities, (2) contained runoff from feeding areas, and (3) excretion from animals on pasture and rangeland. Proper application of animal wastes provides nutrients for crop production and also reduces surface runoff. Appropriate animal and land management practices should be followed. These include: (1) spreading acceptable rates of manure uniformly on land; (2) applying feedlot runoff effluent on land as recommended for specific site conditions; (3) maintaining an adequate land-to-livestock ratio on pastures; and (4) locating feeders and waterers a reasonable distance from streams and water courses.

CHAPTER I - INTRODUCTION

Agricultural activities are widely dispersed over the 0.93 billion hectares (2.3 billion acres) of the Nation's land. Approximately 25 percent of the land is used for grazing and nearly 20 percent for crop production. A major concern is the movement of plant and soil materials from agricultural and other land areas into streams, lakes, and the ground water.

Nonpoint agricultural pollutants are organic and inorganic materials entering surface and ground water from nonspecific or unidentified sources in sufficient quantity to constitute a pollution problem. They include sediment, plant nutrients, pesticides, and animal wastes from cropland, rangeland, pastures, and farm woodlots. Sediment is the major pollutant in terms of volume, and may be a carrier of some pesticides and plant nutrients.

CONTROL METHODS

Pollution from nonpoint sources can be controlled by the use of appropriate production methods and practices. For the most part, methods and practices currently used are technically and economically feasible from a production rather than an environmental standpoint. Considerable progress is being made in adapting water and wind erosion control measures so they are compatible with modern agricultural practices. Equipment, plant varieties, fertilizers, pesticides, and production practices are being developed that will be consistent with environmental needs and will maintain high soil productivity. Practices that have been developed vary from area to area because of differences in soil and climate throughout the country.

Land use patterns and practices largely determine the degree of pollution of surface and ground water. Crop rotations are used to control erosion, improve tilth, and provide plant nutrients to row crops in the rotation. Conservation tillage aids in controlling erosion and runoff, but may require additional use of chemicals for pest control, depending on the crop and geographic location. Crop residues and cover crops increase the permeability of soils, reduce the velocity of runoff, and provide vegetative cover. Contouring, stripcropping, and terracing, practiced alone or in combination, are effective in reducing erosion.

Chemical residue and plant nutrient losses can be reduced by keeping these materials in place--on plants and in the soil--where they are beneficial. Control of runoff and leaching is a basic requirement in reducing losses of pesticides, plant nutrients, and animal wastes. Proper timing, rates, and methods of application will increase the efficiency of these materials.

A farm management program for minimizing nonpoint pollution may require the use of many measures and practices. For example, the sequence of crops within a system can be varied; tillage methods and conservation practices can be selected to control erosion and runoff; crop residue can be removed, left on the surface, incorporated near the surface, or plowed under; and seedbeds can be left rough to provide greater capacity for surface storage of runoff. Combinations of these alternatives will have varying effects on runoff, soil loss, productivity, and net farm returns. Control measures and practices must be blended into an economic program that is suited to local conditions.

SCOPE OF THE REPORT

This report provides general information on the problems, factors affecting, and methods for controlling water pollution from nonpoint agricultural sources. Because of the wide variation in climate, topography, soils, crops, and economic factors throughout the country, this report does not provide specific information on which to select methods and practices suitable to local conditions.

CHAPTER II - WATER EROSION

INTRODUCTION

Erosion and sedimentation are naturally and continually occurring geological processes. Over long periods of time they have reshaped the earth. Soils are protected naturally by vegetation and vegetative residue. In areas where moisture is too limited or fertility too low to sustain close-growing vegetation, the land is subject to periodic erosion from intense rains. In areas of higher precipitation, some agricultural activities, particularly row crop production, tend to increase the rate of erosion. Tilling the soil, overgrazing, crop harvesting, and burning of vegetation remove or bury portions of the protective organic material. Additionally, construction and mining activities often remove all of the vegetation in localized areas. Removal of this protective cover allows the forces of wind and water to act more directly and forcefully on the exposed soil particles.

Sheet, rill, or gully erosion (Figures 1-4) occurs when increasing amounts of water collect and move across the surface of the soil. Massive soil movements, in the form of slides and slippages, can occur when steep soils are tilled. These erosive actions carry away plant residues, soil and associated plant nutrients, and pesticides.

Erosive actions may decrease the productive capacity of the land through: the loss of valuable topsoil; changes in the soil structure, which reduce aeration, infiltration, and drainage; exposure of unproductive soil materials; or the intrusion of undesirable species of plants. Farm operations are slowed and mechanical problems develop due to excessive roughness of the fields, resulting from rill and gully erosion.

Downstream effects of erosion may include excessive quantities of sediment that obstruct drainage, fill reservoirs, make streams turbid, and transport plant and soil associated pollutants. Wise land use and management which control erosion and runoff are the keys to reducing pollution from nonpoint sources.

In 1967, approximately 97 percent of privately owned, non-Federal rural land had soil limitations or conservation problems. Erosion was a limitation on 51 percent or 286 million hectares (706 million acres). On cropland only, erosion was a dominant limitation on 55 percent or 89.5 million hectares (221 million acres). (3)1/

1/ Figures in parentheses refer to reference list at end of the various chapters.

Figure 1.--Sheet erosion on a cultivated bean field with about a 2 percent slope

Figure 2.--Rill erosion

Figure 3.--Gully erosion, 15.2 to 18.2 meters (50 to 60 feet) deep in places

Figure 4.--Gully erosion showing bank slough

The following sections discuss factors affecting water erosion and measures for controlling erosion on agricultural land.

FACTORS AFFECTING WATER EROSION

Water erosion, the major source of sediment, is a complex process. Climate, topography, and kind of soil are important factors and generally are uncontrollable. Land use, conservation tillage, and other conservation measures are subject to management decisions and control.

The form, volume, intensity, and distribution of precipitation are important determinants of erosion. Erosion of sloping land increases as volume and intensity of rainfall or runoff from snowmelt increase. Volume and intensity of rainfall vary widely among areas of the Nation. Perhaps even more important is the distribution of precipitation throughout the year. Rainfall of a given volume and intensity, occurring during periods when ground cover is inadequate, is more damaging than a similar rainfall when the ground is protected.

Length and gradient of slopes affect erosion. The erosion hazard increases as slopes become longer and steeper. Slope shape determines whether soil will move off the field or be deposited on the field at a point farther down the slope. Complex topography makes installation of erosion control practices difficult.

Soils vary in their susceptibility to erosion. Many factors are involved in determining the erodibility of a particular soil. The most important of these are particle-size distribution (texture), organic matter content, soil structure, and soil permeability. If these four factors are known, the erodibility of any given soil or subsoil can be predicted. (9)

The canopy protection of crops depends not only on the types of vegetation and the quality of growth, but it also varies over the months and seasons. Therefore, the overall erosion-reducing effectiveness of a crop depends directly on how much protection the crop or management practices provide during those portions of the year when most of the erosive rainstorms usually occur.

The interaction of the factors discussed above has been studied in many locations for several decades, and scientists have devised ways of measuring this interaction in order to predict erosion losses. The effects on soil losses of various combinations of erosion control practices can also be predicted. (8) Soil loss estimates can be used along with estimates of sediment delivery ratios to determine the amount of sediment delivered to streams. Research is continuing to refine and improve these techniques.

CONTROL METHODS

There are many known control measures for reducing erosion resulting from raindrop impact and surface runoff. These range from management of surface cover and tillage to mechanical conservation measures or a combination of measures. (4, 6, 7) This section discusses measures for controlling erosion.

Tillage Alternatives

Tillage systems are often used in combination with other erosion control measures and in many cases may be the only control measures needed. Tillage, in which the soil is inverted, generates the highest possible potential for erosion by water and wind. This is the practice used in many areas.

A number of alternative systems have been developed over the years to reduce the erosion potential of tillage. These systems have been identified under several different names--minimum tillage, mulch tillage, stubble mulching, and conservation tillage. Conservation tillage is the term used in this report to describe tillage practices that reduce erosion potential below that of conventional tillage. With some systems, a surface configuration is achieved that will retain water and increase infiltration. With others, residue from the previous crop is left on the soil surface to break raindrop impact and reduce the flow velocity of the runoff. (2)

The conservation tillage system that best fits a farm operation depends on the crops grown, soil characteristics, and climate of the area. Significant progress has been made in developing successful conservation tillage systems for a number of climatic areas and crop sequences. Research results and farmer experience are available for the selection of the system that best fits each situation. (9)

The systems listed below have all been used and have been shown to be effective in reducing water erosion. (1)

1. No-tillage or zero tillage (Figure 5)--This system uses a fluted colter or double-disk openers to cut through residues of the previous crop, ahead of the planter shoe. No seedbed preparations precede this operation. This system leaves a maximum of residue cover.

2. Ridge plant--This system gives a row configuration similar to listing (see item 7), but planting is done on the ridges year after year, with no seedbed preparation preceding planting. This system has the most promise for controlling erosion in straight-row farming. Rain falling on the ridge must run down the ridge into the residue which has collected in the furrow. Most of the sediment is deposited in the residue and is kept near the point of detachment.

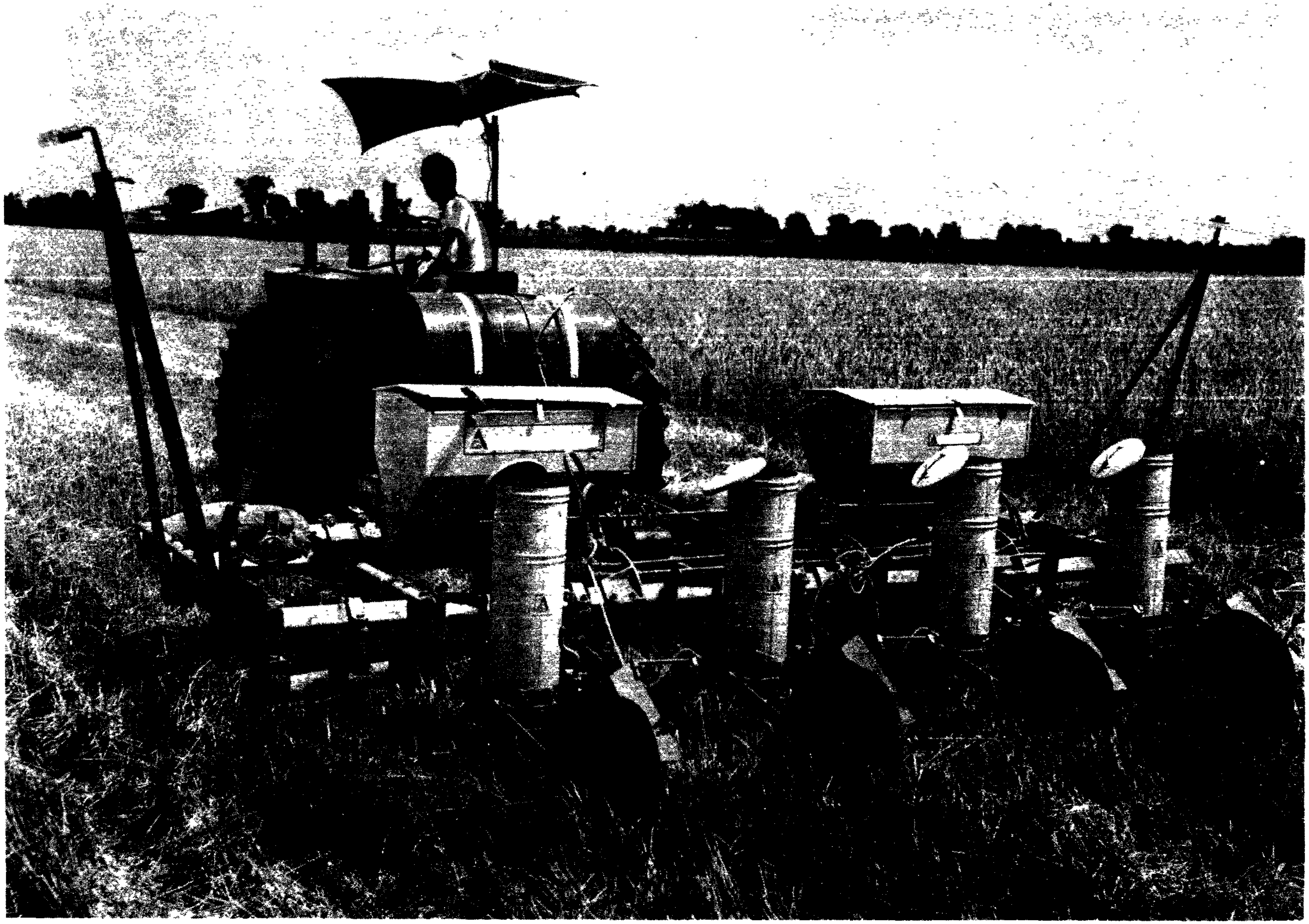

Figure 5.—Zero tillage equipment. Seed will be planted in the wheat stubble.

3. Till-plant (Figure 6)--With this system, wide sweep and trash bars clear a strip over the old row, and a narrow planter shoe opens a seed furrow into which seed is dropped. A narrow wheel presses the seed into firm soil; covering disks place loose soil over the seed. This system controls erosion most satisfactorily when done on the contour or across the slope.

4. Strip tillage--A narrow strip is tilled with rototiller gang or other implement. Seed is planted in the same operation. This system is applicable on soils where some tillage is desirable in the row zone.

5. Sweep tillage--This practice is used on small-grain stubble to kill the early fall weeds. It shatters and lifts the soil, thus enhancing infiltration while leaving the residue in place for water and wind erosion control.

6. Chisel planter (Figure 7)--This system breaks or loosens the soil without inversion. Most of the crop residue remains on the surface for control of water and wind erosion.

7. Listing (Figure 8)--Plowing and planting are done in the same operation. Plowed soil is pushed into ridges between rows, and seeds are planted in the furrows between the ridges. When operated on the contour, this system conserves soil and water.

8. Plow-plant (Figure 9)--Planting is done directly into plowed ground with no secondary tillage. This system increases infiltration, water storage in the plow layer, and surface storage. Surface sealing is delayed because of the large clods in the interrow zone.

9. Wheel-track plant--This system is similar to plow-plant, but is not restricted to freshly plowed ground. Planting is done in wheel tracks of the tractor or planter. Advantages are the same as for plow-plant.

<u>Terraces</u>

Terracing is generally applied to fields where contouring, stripcropping, and tillage operations do not offer adequate soil protection. Terraces break the length of the slope into shorter segments. The volume and velocity of water are effectively reduced when one or more terraces intercept the flow of runoff.

Terraces usually consist of a ridge, or a combination of ridges and channels, constructed across the slope. These ridges are placed high enough on the slope to collect the expected volumes of surface runoff from above. Some terraces on more permeable soils are designed to stop runoff and hold the

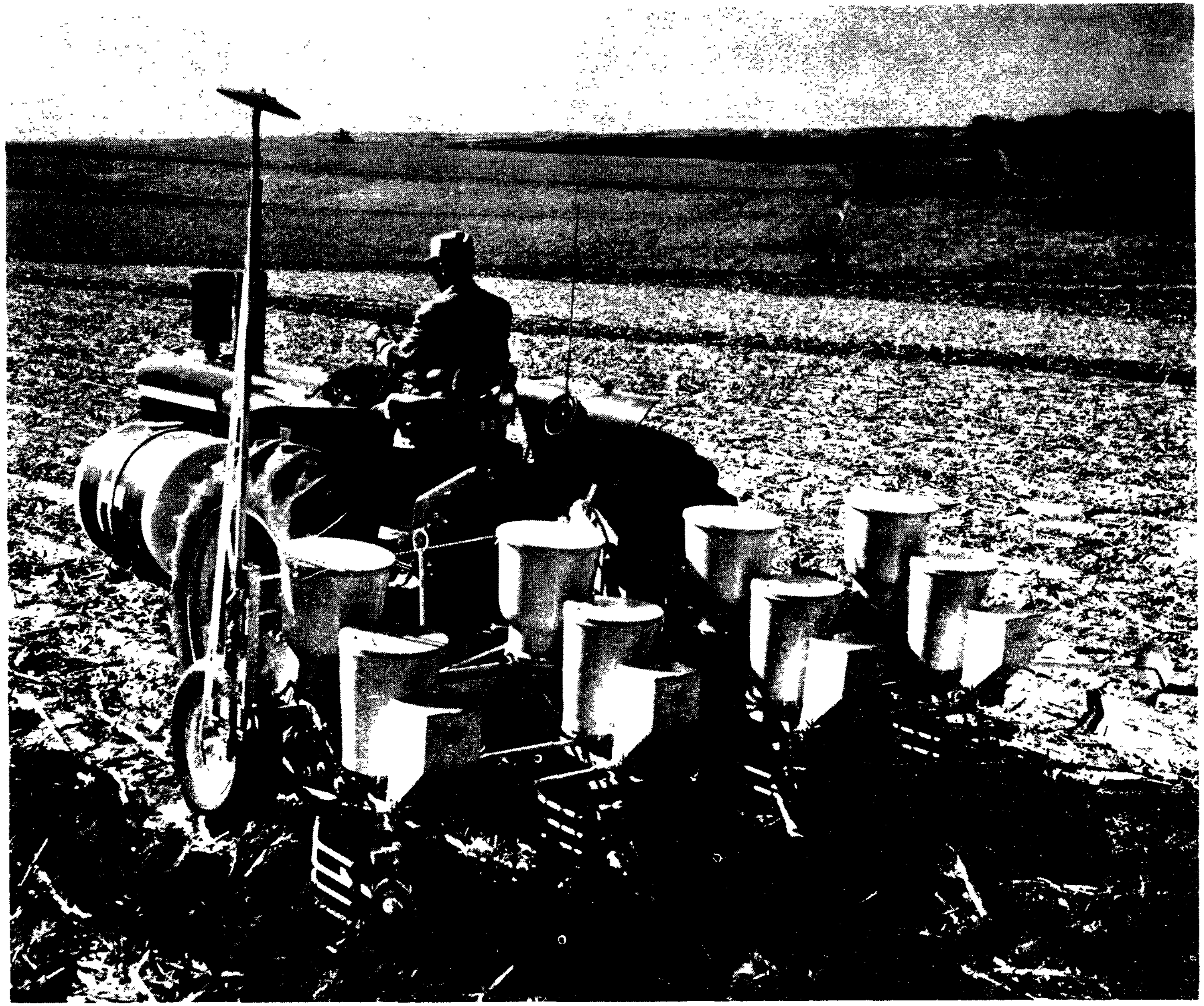

Figure 6.--Till-planter, planting in old corn residue. No plowing is done prior to planting.

Figure 7.--Chisel planter and 4-wheel-drive tractor. Surface is left rough to hold and absorb surface moisture.

Figure 8.--Planting corn in a blue lupine field, using lister-planter

Figure 9.--Plow-planting

water until it is absorbed. Others on less permeable soils are designed to intercept and divert runoff in a controlled manner. Terrace design requires detailed knowledge of probable rainfall totals and intensity, soil characteristics, and cropping systems.

Terraces often require the adoption of new management practices to maintain their desired effects. They should be planned to permit farming with large, modern equipment. If terraces are improperly designed, or used with poor cultural and management practices, they may increase rather than reduce soil losses.

Diversions

Diversions (Figure 10) are large, individually designed terraces, constructed across the slope to intercept and divert excess runoff to a stable outlet. They are generally constructed above cropland fields, gully headcuts, or other critical erosion areas. By reducing the volume of runoff water entering the problem area, soil erosion is reduced.

Widely spaced diversions may be used to reduce the length of slopes in conjunction with the planting of erosion-resistant crops or contour stripcropping. Diversions may also be useful in breaking up concentrations of water on long, gentle slopes and on undulating or warped land surfaces generally considered too flat or irregular for terracing.

Stripcropping

Stripcropping (Figure 11) is practiced as a means of reducing erosion on tilled soils. The intent is to break the length of the slope into segments by laying out strips across the natural slope of the land. Strips of close-growing crops or meadow grasses are planted between tilled row crop strips to serve as sediment filters or buffer strips in controlling erosion. The practice effectively reduces the velocity of the water as it leaves the tilled area. Additionally, water runoff is absorbed and soil particles are retained in the buffer strip.

The system of cropping where the strips are laid out nearly perpendicular to the direction of the slope is referred to as contour stripcropping. The buffer strips can vary in width across the field to make them compatible with modern farm equipment use.

Contouring

Performing tillage operations on the contour, in a direction perpendicular to the slope of the land, provides more protection from water erosion than tilling parallel to the slope. The contour rows collect and hold water during rainstorms and reduce runoff velocity, thereby increasing the time for infiltration and reducing erosion. Contouring, practiced alone on gentle slopes, or in combination with stripcropping or terracing on moderate slopes, can effectively reduce erosion.

Figure 10.--Diversion terrace draining after heavy rain

Figure 11.--Contour stripcropping

Grassed Waterways

Grassed waterways (Figure 12) are natural or constructed outlets, shaped to required dimensions and established with erosion-resistant vegetation. They are used for safe disposal of runoff from fields, diversions, terraces, and other conservation measures. Grassed waterways are a basic conservation practice commonly used by farmers. Stable outlets to transport concentrated runoff are vital to the functioning of most conservation systems.

The most satisfactory location for a waterway is a well-vegetated natural draw. Some shaping or enlarging may be required to handle the increased flow. In this case, the design and construction should provide a stable channel.

A pasture or meadow strip may be used in lieu of a constructed or natural waterway. A design check should be made to ensure that the strip is wide enough to carry the volume of flow, and that the type and density of vegetation is adequate to withstand expected flow velocities.

Pipe Outlets

Many modern diversion and terrace systems utilize buried pipe rather than grassed waterways for outlets. Terrace channels are graded to the outlet. However, the terrace ridge is built level to provide sufficient detention capacity to store the expected storm runoff.

Water enters the pipe through an outlet placed in the terrace channel. The outlet is designed to remove the runoff gradually, but soon enough to prevent crop damage from standing water. The combination of detention storage and slow release provides greater opportunity for water to infiltrate into the soil and for soil deposition.

Crop Rotations

In a crop rotation system, different crops are grown in a sequential pattern on the same field. Combinations of soil conserving and depleting crops provide opportunities for maintaining soil productivity and reducing soil erosion.

Continuous row cropping can deplete the organic matter (the decaying plant and animal residue) in some soils and thereby increase soil erodibility. Sod-forming grasses and legume crops, used in rotation with row crops, are highly effective in maintaining the soil structure and tilth and in reducing soil and nutrient losses by erosion. In addition, the rotation of crops often provides for the planting of both shallow- and deep-rooted plants; this pattern improves the physical condition and the internal drainage of both the surface soil and the subsoil.

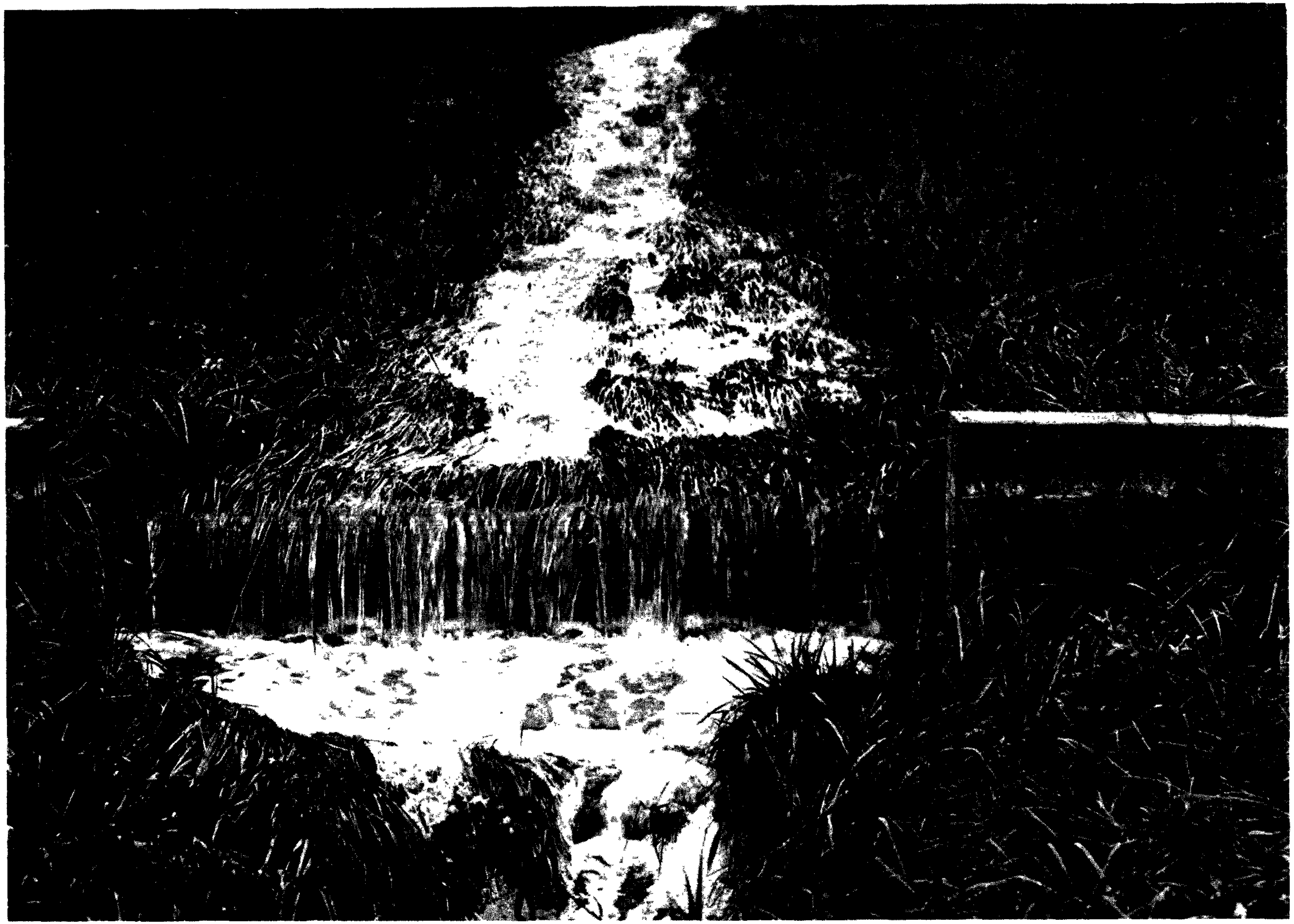

Figure 12.--Clear water flowing through grassed waterway

Cover Crops

Grasses and other close-growing crops provide more soil protection than row crops such as corn and grain sorghum. Crops that leave large quantities of residue after harvest offer more soil protection than crops with small quantities of residue.

Cover crops are grown when there would otherwise be no growing plants and/or residues to protect the soil from leaching and erosion. An example is winter rye seeded immediately after a corn crop is harvested for silage. The growing rye protects the soil during the fall, winter, and early spring when the field would otherwise be bare and subject to erosion. Many cover crops are left on the soil to serve as a protective mulch, or are plowed under for soil improvement.

Cover crops may be special crops planted specifically to provide soil cover and protection, or they may be crops typically found in the rotation but planted at a different time, in some cases. An example is spring oats, which are seeded in the fall, following a row crop. The growing oats freeze in the winter and the tops protect the soil. In all cases, use of cover crops provides better protection from the erosive effects of precipitation than continuous intertilling of crops.

Other Practices

Trees, shrubs, grasses, and man-made structures may be needed to handle severe erosion problems. Each alternative is adaptable to specific situations. These alternatives are usually permanent and may require a conversion of cropland to grass or trees.

Structural measures include drop spillways, box inlet spillways, chute spillways, pipe drop inlets, sod flumes, debris basins, and other grade-control structures. These structures supplement sound conservation measures, reduce the grade in water courses, reduce the velocity of flowing water, trap sediment, and reduce peak water flows.

Range and Pasture Management

Lands used for grazing are characterized by a diversity of climate, topography, soils, vegetative type, and vegetative condition. This diversity, coupled with varying intensities of livestock use, creates the potential for varying degrees of water erosion.

Prevention and control of erosion from grazing land is accomplished through management practices that control the intensity of livestock use, and/or increase the density and productivity of the vegetation (Figure 13). Overgrazing results in soil structural changes because of soil compaction and reduction of soil permeability. It also changes the density, vigor, and species composition of vegetation and reduces the protective soil cover afforded by vegetation. (4)

Figure 13.--Range pasture management. Lightly grazed pasture in upper right; overgrazed rangeland in lower left.

Grazing management practices that restrict livestock use to the carrying capacity of range or pasture reduce water erosion and sedimentation. Some of these practices are:

1. Rotation grazing permits intensive use of fields or portions of fields on an alternating basis. The nonuse period encourages vegetation recovery and renewed vigor prior to the return to livestock use.

2. Water supply dispersal provides better distribution of livestock use, reduces overuse or overgrazing in the vicinity of water supplies, and reduces erosion hazard.

3. Seasonal grazing that is compatible with the most productive period for the particular vegetation permits recovery and reseeding.

4. Range revegetation and pasture improvement increase the density, vigor, and desirable composition of the vegetative cover, thereby reducing runoff and erosion.

5. The dispersal and occasional relocation of salt, mineral, and feed supplement sites avoids concentrated overuse of these areas.

6. Ponds in pastures conserve water while providing water for livestock.

Farm Woodlot Management

Compared with most other agricultural land uses, erosion and the associated sediment from farm woodlots is relatively insignificant. Farm woodlots, in general, produce less sediment per area unit than other agricultural land.

Grazing of farm woodlots increases susceptibility of the land to erosion (Figure 14). However, this hazard will be minimized if livestock use is managed to preserve ground cover. Animal access to tree seedlings should be restricted. Browsing or trampling may destroy the seedlings and increase erosion hazards.

Timber harvesting should be scheduled to coincide with low rainfall periods to reduce erosion and the delivery of sediment and other inorganic materials to streams. Selective tree cutting, the usual practice on farm woodlots, generates low levels of sediment yield during harvest operations and for a short period thereafter. Logging access roads and trails should be planned, constructed, and stabilized so as to minimize the erosion runoff. (5)

Figure 14.--Woodland management. Pastured woods at upper right; protected woodland at lower left.

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CHAPTER III - WIND EROSION

INTRODUCTION

Wind erosion results in water pollution when materials eroded by wind are blown into drainage ditches, streams, lakes, and reservoirs, or are dropped back to the earth's surface where they become more susceptible to water erosion. It increases susceptibility of land to water erosion, but as a factor in water pollution, wind erosion generally is a minor problem compared to water erosion. It may be more significant in localized geographic areas.

Less than 1 percent of the sediment entering the world's oceans is delivered directly by the wind. (5) There are no estimates of the proportion of wind-blown materials going into inland waters, but it is believed to be small when averaged over the Nation. Wind deposition of soil on land areas has been measured in quantities ranging from more than 15.7 metric tons per hectare (7 tons per acre) per year near sites of severe erosion to less than 112 kilograms (100 pounds) in areas hundreds of miles from these sites. (8) Similar amounts would be deposited in bodies of water. In addition to soil particles, associated materials may include plant nutrients, animal wastes, residues from trash burning, and pesticides. (10)

Wind erosion is a problem in any area of low, variable precipitation, where drought is frequent, and temperatures, evaporation, and windspeeds are high. (14) It is the dominant problem on about 28 million hectares (70 million acres) or approximately 3 percent of the land in the United States--an area that includes 22.3 million hectares (55 million acres) of cropland, 3.6 million hectares (9 million acres) of rangeland, and 2.4 million hectares (6 million acres) of "other" land. (9)

Wind erosion is most serious in the Great Plains, but it also occurs around the Great Lakes in Michigan, Wisconsin, and Ohio, along the eastern seaboard, in the southeastern coastal areas, in California, and in the Northwest, especially in newly irrigated areas. (14)

Good farming practices, such as crop rotation and controlled grazing, adequately protect about 34 percent of this land, but specific wind erosion control is needed on about 18.6 million hectares (46 million acres). Each year about 1.9 million of these hectares (4.8 million acres) undergo moderate to severe damage from wind erosion. (9)

Successful systems of wind erosion control involve a combination of practices. Most of the recommended practices are consistent with practices to conserve moisture and control water erosion. The following sections discuss factors affecting wind erosion and measures for controlling it.

FACTORS AFFECTING WIND EROSION

Major factors affecting the amount of wind erosion from a given field are soil cloddiness, surface roughness, windspeed and direction, soil moisture, field length, and vegetative cover. (1, 14) The cloddiness of a given soil largely indicates whether it is susceptible to wind erosion. Soil clods prevent erosion because they are large enough to resist the forces of the wind and they shelter other erodible materials. Clods are formed during tillage. Their firmness and stability depend on soil moisture, compaction, microbial activity, and content of organic matter, clay, and lime. Clods are broken down by weathering, tillage, implement and animal traffic, and abrasion. Coarse-textured sandy loams and loamy sands are the least likely to form stable clods and therefore are the most susceptible to erosion.

Ridges and depressions formed by tillage alter windspeed by absorbing and deflecting part of the wind's energy. Rough surfaces also trap moving soil particles. This reduces abrasion and the normal buildup of eroding materials downwind. While the general effect of surface roughness reduces wind erosion, it also increases wind turbulence and exposes smaller areas to greater wind force. Therefore soil should not be too rough.

Wind erosion decreases as soil moisture increases. Air-dry soil erodes about one and a third times more rapidly than soil with moisture at the approximate wilting point for plants.

Windspeed and direction both affect wind erosion. The amount of soil lost from a given field is determined by the width or length of field, the distance across the field along the direction of the prevailing wind, and the windspeed. The rate of erosion from a 48.4 kilometer-per-hour (30-mile-per-hour) wind is more than three times that for a 32.3 kilometer-per-hour (20-m.p.h.) wind.

Living or dead vegetative matter protects the soil surface from wind action by reducing windspeed and by preventing much of the direct wind force from reaching erodible soil particles. It also reduces rates of erosion by trapping soil particles; this, in turn, slows the movement of soil material downwind.

Interaction of the factors discussed above has been under study for several decades in many wind erosion areas. An equation has been developed to express the relationship between these factors and annual wind erosion losses from a given field. (6, 12) The equation is a useful management tool in (1) determining potential wind erosion on any field under existing conditions, (2) determining conditions of soil cloddiness, surface roughness, vegetative cover, and the sheltering or width and orientation of the field necessary to reduce wind erosion to a tolerable amount, and (3) predicting the effects of single or combinations of wind erosion control practices.

PRINCIPLES AND METHODS OF CONTROL

Five basic principles of wind erosion control are: (14)

1. Establish and maintain vegetative or nonvegetative cover to protect the soil.

2. Produce, or bring to the soil surface, aggregates or clods large enough to resist the wind forces.

3. Roughen the land surface to reduce wind velocity and trap drifting soils.

4. Reduce field width along the prevailing wind direction by establishing wind barriers or trap strips at intervals to reduce wind velocity and soil avalanching.

5. Level or bench the land, where economically feasible, to reduce effective field widths and erosion rates on slopes and hilltops where wind forces are maximum.

These principles apply everywhere, but the usefulness of each varies with local climate, soil, and land-use conditions. For example, it is usually difficult to form stable clods on coarse-textured soils. For this reason, control of wind erosion by producing and maintaining clods or by roughing the surface is, at best, temporary. Maintaining vegetative cover is a far better way to control erosion on these soils. Erosive situations may also arise where there is no way of providing vegetative cover. In these situations, emergency tillage should be used to roughen the land surface and produce clods.

The principles of wind erosion control can be applied by following a number of practices--some permanent, some temporary. Methods and practices for applying each of the principles are discussed below. (14)

Establish and Maintain Vegetative or Nonvegetative Cover

Establishing and maintaining cover is the cardinal rule of wind erosion control. Cover can be maintained by:

a. Using stubble mulch or conservation tillage practices to prepare land for crop production (Figure 15). The amount of vegetative residues needed for control is related to the five factors affecting wind erosion and can be calculated for a particular situation using the wind erosion equation. (4, 6) Minimum quantities of standing wheat stubble needed under Central Great Plains conditions are 840, 1,400, and 1,960 kilograms per hectare (750, 1,250, and 1,750 pounds per acre) for silty clay loam, sand loam, and loamy sand-textured soils, respectively. However, the general goal is to maintain as much residue on the land

Figure 15.--Stubble mulching to maintain vegetative cover as protection from wind erosion

surface in a standing or near-erect condition as is compatible with seed planting procedures. Subsurface sweeps, chisels, rotary tillers, and other types of implements that do not invert the tillage layer leave residues on the surface and are preferable over moldboard plows or tandem or one-way disks. (19) Conservation tillage methods, combined with herbicides to control weeds, are also effective in providing vegetative cover for wind erosion control. (11)

b. Planting cover crops when land is bare between regular crops. A cover crop is any crop planted solely to control erosion. Winter and spring wheat, rye, oats, sorghums, winter peas, and vetch are excellent cover crops. If soil moisture must be conserved, the crops may be prevented from maturing by selecting a crop that winter kills, e.g., oats; or the crop may be killed by herbicides after growth is sufficient to control soil blowing.

c. Using crop rotations in which two or more crops or one crop and fallow are alternated on a given area in a regular sequence. This prevents leaving large blocks of land bare during the wind erosion season. Common rotations in some wind erosion areas include wheat-fallow, wheat-sorghum-fallow, and cotton-sorghum.

d. Controlling grazing of both rangeland and winter wheat to prevent complete denuding of vegetation and pulverizing of the soil. Control on grazing lands can be attained by (1) limiting livestock numbers on any given area, (2) providing reserves of harvested forage for use during drought periods, (3) dividing pastures and using rotational grazing, (4) supplying several watering and salt box sites and moving them from time to time, (5) fencing animals away from highly erosive spots, and (6) providing wind barriers to protect permanent watering sites and lanes.

e. Regrassing and reforesting areas such as sand dunes, blowouts, and other unproductive land to prevent the spread of the erosion problem to more productive land. Seeds and/or culms or stems of adapted grasses can be planted, preferably with mulch, adhesive soil stabilizers, or other protective material. Adapted trees and shrubs can also be planted in some dune areas.

f. Applying hauled-in mulches or nonvegetative and processed covers to areas of severe erosion or to areas with high economic return potential. It is most economical to grow cover in place; if this cannot be done, artifical cover can be applied. Vegetative mulches and application rates include cotton gin trash at 11.2 metric tons per hectare (5 tons per acre), straw or hay at 2.2 to 4.5 metric tons (1 to 2 tons), corncobs at 9 to 11.2 metric tons (4 to 5 tons), and manure at 33.7 to 67.4 metric tons (15 to 30 tons). Straw or hay mulches should be anchored with a disk packer. Several spray-on adhesives of petroleum, chemical, and organic origin are available for use as temporary covers for wind erosion control. Amounts needed vary from 533.3 decaliters per hectare (570 gallons per acre) for fermented corn extract to 1,123 decaliters per hectare (1,200 gallons per acre) for anionic asphalt emulsion, with respective costs of $24.72 and $130.91 per hectare ($10 and $53 per acre).

Roughen the Land Surface

The most effective roughness height for soil is 5.1 to 12.8 centimeters (2 to 5 inches). Minimum and stubble-mulch tillage leave the soil in a rougher condition than conventional tillage. Special planters, such as deep-furrow or hoe drills, produce a roughness in the 5.1 to 12.8 centimeters (2 to 5 inches) range and are especially effective in providing wind-resistant surfaces. Emergency tillage, in which land is roughened with chisels or listers, is used as a last resort when vegetative cover is not adequate to provide control.

Produce Soil Clods or Aggregates

Soil clods or aggregates larger than 0.84 mm. in diameter are not moved by winds under 48.4 kilometers per hour (30 m.p.h.). The degree of cloddiness needed to control wind erosion depends on the levels of the other factors that affect wind erosion. The size of clods required under various circumstances can be calculated with the wind erosion equation. (4, 6) For example, a field at Dodge City, Kansas, might require 1.25 mm. clods while a similar field at La Crosse, Wisconsin, would require 0.92 mm. clods.

The degree of cloddiness produced by tillage depends on such factors as soil texture, soil moisture, speed of operation, and kind of tillage tool. Generally, the most cloddiness is achieved by using 5.1 centimeter (2-inch) chisels and 82 centimeter (32-inch) sweeps, followed in order by disks, rodweeders with shovels, and large V-sweeps. (13) Soil aggregation and cloddiness are also affected on a long-term basis by crop residue management (Figure 16). An additional 1,120 kilograms per hectare (1,000 lbs/acre) of residue per cropping period, within the range of 0 to 6,720 kilograms per hectare (6,000 lbs/acre) will reduce the wind erodible soil fraction about 4 percent.

Figure 16.--Soil cloddiness reduces wind erosion

Reduce Field Widths Along the Prevailing Wind Direction

Wind erosion is an avalanching process. The rate of soil flow is zero at the windward edge of an eroding field and increases to a maximum that a given wind can carry. Therefore, any measure that reduces field length along the prevailing wind direction will reduce erosion.

Stripcropping, where strips of erosion resistant crops are alternated with strips of erosion susceptible crops, wind barriers, and shelterbelts can be used to reduce field widths along the prevailing wind direction. Erosion resistant crops are small grains and other closely seeded crops that rapidly produce a cover. Erosion susceptible crops include corn, cotton, tobacco, sugarbeets, peas, beans, peanuts, asparagus, and most truck crops. In the Great Plains, alternate strips of wheat and grain sorghum, or fallow wheat stubble and newly seeded wheat, can be used. Permanent strips of tall perennial grasses can be planted on fallowed wheat land to reduce erosion. In vegetable growing areas, alternate strips of rye and vegetables are commonly planted.

Stripcrops should be run at right angles to the prevailing winds (Figure 17). The actual width of strips varies with factors affecting field erodibility, e.g., soil texture, cloddiness, roughness, and wind velocity and direction. The strips may range in width from a single row of grain sorghum or corn to several meters. Information on widths needed for different soils can be calculated with the wind erosion equation, or can be obtained from research publications or from specialists in the Soil Conservation Service and Extension Service.

In addition to their use in reducing field lengths, wind barriers and shelterbelts reduce wind erosion by lowering windspeed in their lee, thereby decreasing soil movement. (2) They also help retain moisture on the cropland by holding snow that might otherwise be blown into gullies and roadside ditches. Trees and shrubs in 1 to 10 rows, narrow rows of field crops, snow fences, solid wooden or rock walls, and earthen banks--all are useful as wind barriers.

The effectiveness of any barrier depends on the wind velocity and direction, and on the shape, width, height, and porosity of the barrier. (7) The speed of wind blowing at right angles to the average tree shelterbelt is reduced 70 to 80 percent near the belt, about 20 percent at a distance 20 times the height of the belt, and only about 2 to 5 percent at a distance 30 times the height of the belt. (14)

Barriers used for wind erosion control provide protection for distances ranging from 1 to 18 times their height, depending on the type used. These relatively short distances require close spacing of barriers, which reduces field size and is objectionable where large equipment or mobile irrigation systems are used. For this reason, tree shelterbelts are usually planted at 402 meter (80-rod) intervals along field boundaries, at 105- to 135-meter (350- to 450-foot) intervals on highly erosive soils, or at 150- to 195-meter (500- to 650-foot) intervals on moderately erosive soils (Figure 18). Other wind erosion control practices, such as stubble mulching, are then applied to the land as supplemental control.

Figure 17--Stripcrops planted at right angles to direction of prevailing winds

Figure 18.--Spaced shelterbelts of willow trees protect the fields from wind erosion

Tree shelterbelts planted in the 1930's were generally wide--consisting of 10 to 12 rows. Experience and research indicate, however, that narrower belts of medium porosity are equally effective and take less land out of production. The ideal is a 1-row belt; however, in the more arid areas, 3 rows should be planted to insure protection in the event that some trees die.

Nearly any plant that reaches substantial height and retains its lower leaves can be used as an annual crop or grass barrier. These include pampas, tall wheat, plains bristlegrass, hybrid forage sorghum, kenaf, corn, and sunflower. Spacing between annual crop or grass barrier ranges from 3 to 18 meters (10 to 60 feet), depending on soil texture, control required, and other factors.

Artificial barriers (snow fencing, boardwalls, and earthen banks) provide temporary protection for highly erodible areas such as livestock watering sites and traffic lanes. They can also be used to protect high-value crops, and can help stabilize sand dunes. They provide a relatively short zone of protection; a 1.2 meter (4-foot) snow fence protects for a distance of about 12 meters (40 feet), and a 0.6 meter (2-foot) earthen bank protects for about 9 meters (30 feet). These artificial barriers are costly to construct.

Level or Benched Land

Land is sometimes leveled or benched for purposes of irrigation, water erosion control, and moisture conservation. These land modifications affect the rate and amount of wind erosion.

Research information on the relationship between land modification and wind erosion is meager. Estimates for average Great Plains conditions indicate that shortening field lengths from 300 meters to 30 meters (1,000 to 100 feet) by benching, reduces potential soil loss by wind 50 percent. Another calculation concerning a 360 meter (1,200-foot-long), 4 percent slope, benched with a series of 72-meter-wide (240-foot-wide) level benches, shows that soil loss from wind erosion was reduced 60 percent.

It is unlikely that land will be extensively modified to control wind erosion, but it will doubtless be increasingly modified for irrigation and to control water erosion. These land modifications will also provide substantial wind erosion control.

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CHAPTER IV - PLANT NUTRIENTS

INTRODUCTION

Agriculture is concerned with producing an adequate supply of food and fiber for domestic and export needs, with a minimum of water pollution. Nitrogen and phosphorus needed to meet production goals may, under certain conditions, adversely affect water quality through high accumulations of nitrate in surface and ground water and eutrophication, which can lead to excessive algae growth.

The extent of the water quality problem associated with losses of nitrogen and phosphorus varies from region to region. The need for and/or success of particular methods for controlling or reducing nutrient concentrations also vary. For example, almost all runoff from precipitation contains sufficient nitrogen (1-2 mg/1) to permit algal blooms unless the precipitation runs off grass or forest land. Control of phosphorus in runoff sediment and seepage is much more important on land near tributaries to lakes and ponds than on lands draining into fast-flowing rivers that run directly to the sea. Similarly, in areas with high rainfall and well-drained soils, the potential for nitrate accumulation in groundwater increases.

Most soils used for crop production need fertilizers to maximize yields and profits. Before World War II, fertilizers consisted mainly of animal byproducts, plant wastes, and some superphosphates. In 1972, 37.2 million metric tons (41 million tons) of commercial fertilizers were applied to crops in the United States, compared with 12 million metric tons (13.2 million tons) in 1945. Future trends in fertilizer use can be influenced by a number of factors, including changes in domestic and foreign demand for agricultural products, relative cost of fertilizer to other inputs, and environmental considerations.

The sources of nitrogen and phosphorus, both natural and from fertilizers, are numerous and interdependent. It is difficult and often impossible to estimate the contribution of each source to surface water. Major sources of nitrogen and phosphorus are precipitation, sediment, municipal and industrial effluents, urban storm water drainage, and natural organic and inorganic materials.

This chapter discusses factors affecting plant nutrient losses and alternative methods and practices for keeping the nutrients on the land where they can be effectively utilized.

FACTORS AFFECTING PLANT NUTRIENT LOSSES

The composition of phosphorus and nitrogen substances in the soil/water system and the way they are lost from soils differ greatly, as do control practices. Most of the phosphorus in soil, whether it comes from organic or inorganic sources, is contained within, or is tightly attached to, soil particles. Soluble phosphate content of surface runoff is usually very low, but concentrations may be significant in runoff from dead vegetation. Most of the phosphorus lost from land is associated with sediment. Thus, control of phosphate pollution depends largely on control of soil erosion.

Organic or humus nitrogen lost from soils into water is associated with sediment, and erosion control is, again, an important control mechanism. However, most nitrogen lost from the soil is in the form of nitrate, which is not absorbed into the soil particles. It is completely soluble in water and moves where water moves. Control of nitrate movement to surface water or to aquifers depends on the control of runoff and leaching.

Precipitation and Soil Moisture

The amount and rate of precipitation and/or irrigation water applied to the soil are important factors in determining the amount of runoff and nutrient losses. Infiltration rates are influenced by the properties of the soil. These rates can be changed to some degree by management. If rainfall or water application exceeds the rate of infiltration, runoff will result.

Nitrogen in the water percolating below the root zone may contribute to nitrogen concentrations in aquifers, whether the water is from rainfall or irrigation. The nutrient content of rainfall and irrigation water varies with local atmospheric conditions and the source of the water.

Irrigation can be controlled to reduce the leaching of nutrients. Prevention of leaching from excessive precipitation must be controlled by surface drainage and other management practices.

Type of Crop

The type of crop or land use has a major effect on nutrient losses through erosion and leaching. Erosion of soil and loss of phosphorus and organic nitrogen associated with sediment are much lower for sod crops such as pasture and range grasses, than for row crops such as corn and soybeans. Erosion control through land use practices is a well-established soil conservation principle.

The kind and amount of vegetative growth, as well as the length of the growing season, influence the amount of water available for leaching of nitrate. When more water enters the soil than is lost by evapotranspiration of the crop, the excess water can leach nitrate. Hence, nitrate loss is greater in the fall or spring, when water demands of crops are low.

Temperature

Temperature affects the mineralization or ammonification of nitrogen, which influences the nutrient content of runoff and leached waters. During cold periods, plant activity is retarded, thereby reducing the rate of nutrient utilization and water consumption. Variability in temperature is also important. If frozen land is thawed at the surface by rainfall, leaving a frozen sublayer that prevents percolation of water, surface runoff and erosion occur. Freezing of plant material tends to rupture plant cells, and nutrients are then subject to leaching during spring thaw.

Soil

The nutrient content, permeability, and structure of agricultural soils are important factors that may have a bearing on the nitrate in ground and surface water. The nutrient accumulation in the soil and substrata is a function of basic soil properties, geologic deposits, decomposition of organic matter and peat, presence of nitrogen-fixing plants, soil organisms, animal and human wastes, and inorganic sources such as fertilizer and precipitation. (7)

The energy associated with the impact of falling raindrops affects the amount of sediment in runoff and the rate of water infiltration. Adequate ground cover will absorb the raindrop impact and protect the surface cover. Forests and grasslands generally have higher rates of water infiltration than plantings of agricultural row crops when soil and slope conditions are otherwise equal.

Permeability and water retention characteristics of soil affect the amount of water passing through the root zone. If nitrate is present, it will move with the water and may eventually enter the groundwater. The concentration of nitrate in the groundwater depends on the amount of nitrate leached, the volume of water passing through the soil profile, and the transit time of the leachate from root zone to water table. Transit time is related to the hydraulic conductivity of the soil profile, depth of the water table, and degree of soil saturation. In some areas it may take 20-30 years for the leachate to pass from the root zone to the water table. (5) A sandy soil will not retain as much water in the root zone as a loam soil, and so has a higher leaching hazard. Therefore, less nitrogen is utilized by plants and more nitrogen is leached below the root zone in sandy than in less permeable soils.

Geologic materials underlying soils may restrict the downward movement of water. Under such circumstances, nitrogen will not contaminate deep aquifers, but may accumulate in perched water tables.

Mineralization and Nitrification

Mineralization (or ammonification) is the breakdown of organic nitrogen to ammonium. Nitrification is the oxidation of this ammonium, or ammonium from fertilizers, to nitrate. Factors affecting this process are soil characteristics, water content, aeration, and temperature. The rate of nitrification tends to decrease sharply when the oxygen content of soil falls below 2 percent or when soil air space is nearly saturated with water. The maximum rate of nitrification occurs in soil temperatures of about 30° C. and is very slow at 7° C. Nitrate can be used by plants, denitrified, leached to groundwater, or remain in the soil and be available for subsequent crops.

Denitrification

Denitrification is the microbial reduction of nitrate to harmless nitrogen gas. It is an important factor in determining the amount of nitrate available for leaching to groundwater. Denitrification generally takes place in soils when anaerobic conditions prevail and an energy source such as decaying organic matter is present. Organic nitrogen and ammonium forms must be oxidized to nitrate before denitrification takes place.

Under favorable conditions, a substantial amount of denitrification occurs in or near submerged tile drains. This decreases the amount of nitrates present in the tile drain effluent. Denitrification also removes nitrate from the root zones of crops, such as rice, that are submerged in water for extended periods of time.

CONTROL METHODS

Reducing nutrient losses from agricultural nonpoint sources can be accomplished by three general approaches: (1) determining and applying appropriate amounts of plant nutrients at the proper time and in the proper place, (2) adopting improved cultural practices, including conservation tillage and crop rotations, that minimize nutrient losses, and (3) controlling soil and water losses by conservation practices such as contouring and terracing. Control measures should be selected in light of their economic and technical feasibility, as well as their effect in reducing nutrient losses.

Fertilization

The timing and placement of fertilizer affect the efficiency of plant utilization of nutrients. Slow-release fertilizers have been developed to improve the efficiency by providing nutrients as plants require them.

Timing--The timing of application is much more important for nitrogen fertilizers that are easily leached than for phosphorus, which is adsorbed by soil particles. The leaching of nitrates below the root zone may be more prevalent on sandy soils during periods of precipitation. During cooler periods of low evapotranspiration, unused nitrates move downward within the soil profile. These factors should be considered in timing fertilizer applications to maximize the efficiency of utilization by crops, and to minimize nutrient losses by erosion and leaching.

In general, phosphate and potash fertilizer must be applied at seeding time or earlier for satisfactory results. Nitrogen may be applied in the fall, or in the spring for fall-sown green crops. For row crops, a portion of the nitrogen may be applied at planting time. Additional amounts may be side-dressed. The best time should be determined on the basis of soil, climatic conditions, and the crop being grown. In areas of high winter precipitation, where leaching or denitrification losses may occur, spring application usually is best. Nitrogen fertilizer should never be broadcast on frozen land.

Placement--The method of application and placement of fertilizers in relation to root distribution and moisture is important in increasing the effectiveness of fertilizers. General methods for applying fertilizer include: broadcasting and disking, plowing before planting, and top dressing after the crop has been established. The placement of phosphate fertilizer with respect to the plant root system is critical because of its limited movement. If the phosphorus is not utilized by the plant, it is subject to erosion with soil particles.

On soils of low or moderate fixing capacities, broadcasting the fertilizer on the surface and plowing it under is one of the most economical methods of application, but nutrients may be lost if the fertilizer is not plowed under. Fertilizers should be incorporated in the soil by such methods as disking and drilling.

Placement of fertilizer in bands under the surface is an efficient use of nutrients and minimizes losses by surface erosion. Top dressing of phosphate fertilizer is often the only method of fertilizing established pasture and some forage crops.

Slow-release fertilizers--Slow-release fertilizers may be used to minimize possible nitrogen losses on soils subject to leaching. Chemical inhibitors that can be incorporated with nitrogen fertilizer have been developed to delay nitrification. The technical feasibility of this approach has been demonstrated. (2) Presently, the general use of these inhibitors in agriculture is restricted by the high cost.

As mentioned in a previous section, nitrification is very slow at lower soil temperatures. Hence, anhydrous ammonia can have slow-release properties if the soil temperature is low. (4)

A "slow-release" nitrogen fertilizer is also a "long-release" fertilizer; therefore, this may not be the total answer to controlling nutrient pollution. If nutrients are not adequately used by a crop during the growing season, high levels of nitrate may remain in the soil during noncrop months and nutrient pollution may result. These materials are most effective on pastures, or with plants having a long growing season.

Soil Testing and Plant Analysis

Soil testing is a laboratory method of estimating the amounts of various plant nutrients that may become available to a crop. When properly correlated with field fertilizer trials, the tests help determine how much fertilizer is needed to produce a specified yield. To determine application rates, it is important to know whether nitrogen, phosphorus, and potassium are in correct proportions in the soil. Application rates should not be based on crop requirements alone. For example, in many soils the level of available phosphorus, as measured by soil tests, has gradually risen. In such a situation, fertilizer application based on crop requirement without any knowledge of soil fertility could lead to over fertilization and possibly excessive nutrient loss.

Plant analysis measures the total nutrient uptake and determines nutrient status. It has been used extensively for many tree crops. The presence of sufficient nutrients in the soil at the start of the growing season does not mean the plant will be able to use them, or that adequate nutrients will be available throughout the season. (1) Consequently, plant analysis provides information that can be used to adjust fertilizer application rates and timing, or to adjust other cultural practices.

Plant nutrient composition is closely related to soil fertility, climatic factors, and methods of management. Hence, soil and plant analyses are useful in developing fertilizer recommendations. (6) If fertilizer is applied at rates determined by these methods, crops will have adequate nutrients at the least cost, and nutrient losses via leaching and runoff will be minimized.

Tillage

Some type of tillage is necessary in the production of most crops. It is important to select a tillage method that will provide for high productivity, and will also reduce soil and nutrient losses. Inadequate tillage results in large soil aggregates and pore spaces that prevent adequate seed-to-soil contact. Excessive tillage compacts the soil. The soil tends to seal or crust, promoting water runoff and erosion. See Chapter II for a discussion of conservation tillage.

Crops and Crop Rotation

The selection of appropriate crops and crop rotation systems that help control erosion and prevent leaching is important in reducing nutrient loss. Rotation is more important in soil systems maintained at high fertility levels. Rotation of corn and soybeans with cover crops has been long recognized as a good erosion control method. Similarly, winter cover crops are useful in reducing soil and water loss.

Grasslands generally have the lowest nitrate loss because of the plant's extensive root systems, which can absorb nitrate over a long growing season. Legumes may fix nitrogen in their root nodules which adds nitrogen to the soil in organic form that is not readily susceptible to leaching. Alfalfa can effectively remove nitrate that has accumulated below the root zone of more shallow-rooted crops such as wheat or corn.

Contouring and Terracing

Contour planting and tillage can control runoff by retaining water until it can be absorbed by the soil. The crop rows are oriented on the contour to pond the runoff and allow more time for penetration of water into the soil, and to reduce the velocity of water flow and thereby reduce soil erosion.

Ridges and terraces, established across the slope of the land, reduce the slope length and retain the water for removal from the land via surface or subsurface outlets. Terracing used with contour cultivation provides maximum protection against soil erosion. See Chapter II for a discussion of conservation practices.

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CHAPTER V - PESTICIDES

INTRODUCTION

In 1971, production and sales of synthetic organic pesticides amounted to 0.5 billion kilograms (1.1 billion pounds). The use of pesticides has increased production and improved the quality of foods and fibers. However, there are environmental problems associated with chemical control of crop and livestock pests.

Most pesticides fall into three major categories: insecticides, herbicides, and fungicides. Discussion here refers primarily to the use of pesticides on crops. Some pesticides are also used on livestock and farm woodlots. The following table indicates the extent and use of pesticides on selected crops in 1966:

Pesticide Use for Selected Crops in the United States, 1966

Crops	Proportion of Crop Acres Treated		
	Insecticides	Herbicides	Fungicides
		Percent	
Cotton	54	52	2
Tobacco	81	2	7
Corn	33	57	2
Peanuts	70	63	35
Rice	10	52	0
Wheat	2	28	0.5
Soybeans	4	37	0.5
Pasture, hay, and range	0.5	1	0
Potatoes	89	59	24
Apples	92	16	72
Citrus	97	29	73

Source: Pimentel, D. Compilation of U.S. Department of Agriculture data.
Quoted in: (2)

This chapter discusses methods that can be used to reduce the quantity of pesticides moving into the aquatic environment. There are several approaches: (1) reduce the movement of pesticides into water by controlling erosion and minimizing wind drift, (2) reduce the quantity of pesticides used by applying minimum amounts needed to control the pests or by substituting non-chemical methods of pest control, and (3) substitute biodegradable for persistent pesticides to the extent possible.

PATHWAYS AND CONTROL METHODS

Agricultural pesticides enter the Nation's waterways by several means: (1) erosion, (2) runoff water, (3) escape of pesticides during application, (4) volatilization and redeposition of pesticides, and (5) accidents and incorrect container disposal. An obvious but fundamental means of reducing potential water pollution from pesticides is correct usage. It is essential that users follow recommended application techniques and not exceed prescribed dosages for specific pest problems. Methods of controlling pollution from various sources are discussed below.

Erosion

The major route of pesticides to the waterways is via erosion.

> Because of the tight binding characteristics of pesticide residues to soil particles, it is suggested that the general pollution of waters by pesticides occurs through the transport of soil particles to which the residues are attached. (4, p. 118)

Suspended plant particles or leachates from crop residue also carry pesticides to waterways. Since most pesticides adhere readily to soil, any cropping pattern or practice that is likely to cause erosion is also likely to foster entry of pesticide materials into lakes and streams. Limiting the use of pesticides on erosion-prone soil will reduce the pollution potential. Water and wind erosion control measures are discussed in Chapters II and III.

Nonpersistent pesticides pose only short-term problems from erosion or runoff. Persistent pesticides are a more serious threat to waterways from water and wind erosion. However, the threat of polluting waterways is reduced by practices that minimize soil erosion.

Pesticide persistence depends primarily on the structure and properties of the compound and, to a lesser degree, on location in or on the soil and soil particles. There is wide variation in persistence among different pesticides. For example, the highly toxic phosphate insecticides are relatively nonpersistent in soils. In contrast, some of the chlorinated hydrocarbon insecticides may persist 4 to 5 years under normal rates of application. The longer a pesticide remains in the soil, the more likely it is to move from target sites to nontarget areas by **water or wind erosion.**

Runoff

Pesticides also enter waterways through surface runoff and groundwater supplies. As a group, pesticides have low solubility in water, but small amounts are transported in solution. Herbicides are generally more water soluble than insecticides, and a few are freely soluble. Frequently, a choice can be made between two chemicals of varying degrees of solubility. It is easier to prevent runoff of pesticides in arid regions, where crops are irrigated and application of water can be controlled.

Application Methods

The amount of pesticides entering lakes and streams is influenced by the method of application and the solubility and volatility of pesticides. Pesticides incorporated into the soil, rather than left on the surface of soil or plants, are less subject to movement by runoff waters and to evaporation.

Pesticides are applied in liquid form as a spray or in solid form as a dust or granule. Present methods of application are imperfect in that some of the pesticide reaches nontarget organisms. The major reasons are lateral displacement (i.e., wind drift) and volatilization of the water carrier and the pesticide. In each case, the pesticide material may enter open bodies of water directly, or after fallout and washout from nontarget areas.

Dusted and sprayed pesticides are subject to considerable drift. Drift is related to particle size, wind speed, climatological inversion, and height of pesticide emission. In certain circumstances, such as application on dense foliage, where the underside of the leaves must be treated, a certain amount of drift is needed to provide complete coverage. However, such drift may result in the movement of pesticides into neighboring fields and open bodies of water. Drifting can be reduced by spraying and dusting when wind and other weather conditions are suitable.

Research shows the potential of engineering techniques that will produce particles of more uniform sizes and thus reduce the number of small particles that are apt to drift. Various emulsifiers and oils can be added to the spray to increase droplet size and thereby reduce drift. The table on the following page shows the relationship between drift and particle size.

Of the various forms of pesticides used, granules drift the least. Their value in certain above-ground uses is limited, however, because they do not provide as complete physical coverage as a spray or dust.

Drift Pattern in Relation to Particle Size

Particle Type	Drop Diameter	Drift[1/]	
	Microns	Meters	Feet
Aircraft spray:			
Coarse	400	2.6	8.5
Medium	150	6.7	22
Fine	100	15	48
Air carrier sprays	50	54	178
Fine sprays and dusts	20	338	1,109
Usual dusts and aerosols	10	1,352	4,436
Aerosols	2	33,795	110,880

1/ Distance a particle would be carried by a 4.8 km/h (3 mph) wind while falling 3 meters (10 feet).

Source: (1)

Volatilization

For certain pesticides, volatilization can be a significant means of introducing pollutants into the environment. This applies to volatilization after application, as well as to evaporation between nozzle and ground during application. Small spray droplets result in high rates of evaporation of the water carrier. This leaves small particles of dry pesticides to drift into nontarget areas. Amine stearates and other additives can be used to decrease the evaporation and drift potential, thus reducing pollution from pesticides.

Container Disposal

Pesticides can enter the environment through careless or improper disposal of containers and unused materials. If these items are deposited or buried near waterways, the groundwater may become polluted. If they are burned, pollution may result through washout or fallout. Section 19 of the Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1972 (Public Law 92-516) directs the Administrator of the Environmental Protection Agency to issue procedures and regulations governing the disposal of pesticide containers. Implementing regulations were published on May 23, 1973 (40 CRF, Part 165). Further dissemination of these regulations, and continuing education on the problems of incorrect disposal and on the dangers of accidental poisoning, can be expected to reduce pollution from these sources.

Livestock Pest Control

Insecticides used to control livestock pests are applied by various means, such as feed additives, backrubbers, sprays, pour-ons, liquid dips, or barn fumigations. Pesticide exposure to the environment is minimal with correct use. Barring dumping or accidental spillage, the potential for environmental pollution from this source is minimal.

Farm Woodlots

Pesticides are not used extensively on farm woodlots. Because of the relatively small size of tracts, aerial application is seldom used. Herbicides are perhaps the most frequently used pesticide on farm woodlots. They are selectively applied, frequently on stumps or at the base of trees. In the case of many pests, losses can be reduced through good farm woodlot management.

Control techniques are specific to each disease. Some examples are the timely removal of infected trees, pruning of infected parts, and elimination of alternate plant hosts in the case of rusts. Careful logging practices minimize mechanical injuries to trees. Injuries may serve as entry points for fungi.

ALTERNATIVES TO CHEMICAL PESTICIDE USE

Non-chemical methods of pest control can reduce the use of pesticides and thus their entry into the environment. However, for the foreseeable future, there will be a continuing need for pesticides in combination with these methods.

> Non-chemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are economically feasible and effective for the control or elimination of pests. When non-chemical control methods are not tenable, integrated control systems utilizing both chemical and non-chemical techniques will be used and recommended in the interest of maximum effectiveness and safety. (3, p. 1)

Cultural Practices

A number of cultural practices can partly substitute for pesticides to prevent or reduce crop damage from insects, nematodes, weeds, and diseases. These practices include changes in methods of cultivating and harvesting crops that make the environment less hospitable to pests. Cultural practices are most successful if applied at a vulnerable stage in the pest's life cycle. Examples are the removal of crop debris to eliminate host sites, and adjustments in planting schedules to minimize pest influence on the crop. Tobacco stalks remaining after harvest support large numbers of tobacco hornworms, budworms, diseases, and several nematodes. Destruction or removal of the stalks immediately after harvest aids in controlling these pests.

Mechanical weed control is a generally accepted farm management practice. Such measures as row cultivation, proper seedbed preparation, and mowing of weeds on uncropped land reduce the production of weed seeds. Herbicides can then be applied at lower levels than under conservation tillage methods. Conservation tillage may increase certain disease and insect problems which could require increased use of pesticides. A higher level of pesticide use under these conditions may not increase water pollution, however. A reduction in tillage means a reduction in soil erosion, a major source of pesticide movement and water pollution.

Biological Control

Natural enemies can be a major factor in controlling pests. A substantial number of devastating and extensive pest problems have been resolved by introducing or conserving natural pest enemies. Some examples are the control of Klamath weed in the Pacific Northwest, alligator weed in Florida, Comstock mealybug on apples in the Eastern United States, purple scale on citrus in Texas and Florida, citrophilus mealybug on citrus in California, alfalfa weevil in mid-Atlantic States, Rhodesgrass scale in Florida and Texas, European pine sawfly and European wheat stem sawfly in the East, larch casebearer in the Northeast, and satin moth in New England and the Pacific Northwest. But, in general, the augmentation of natural populations of insect enemies with programmed releases of mass-reared specimens is still largely in the research stage.

The conservation of natural enemies is receiving considerable attention in the United States. This approach is currently fostered by a federally assisted program of 39 pest management projects in 29 states, and the program is expanding each year. Commodities involved include tobacco, cotton, alfalfa, field corn, grain sorghum, fresh market and processing corn, peppers, beans, potatoes, apples, citrus, and pears.

Boll weevils are controlled on several million hectares of cotton by means of cultural methods and fall insecticide applications, in order to delay spraying in the spring. In this way, natural enemies of other insect pests will not be destroyed by early spraying for boll weevils.

At the present time, biological methods of controlling diseases, nematodes, and most weeds do not appear reliable.

Insect Sterilization

The use of sexual sterility is one of the most selective and environmentally acceptable methods of suppressing insect populations. Although the development of this approach has not received significant support from the private sector, it is operational in four instances: (1) the management of screwworm populations in the Southwestern United States and Northern Mexico, (2) protection of California citrus by release of sterile Mexican fruit fly pupae in Northwestern Mexico, (3) the protection of 364,372 hectares (900,000 acres) of cotton in the San Joaquin Valley (California) from incipient populations of the pink bollworm, and (4) the suppression of pink bollworm on wild cotton in the Florida keys. The method was recently employed against the boll weevil in an areawide test in Mississippi, and holds potential, when integrated with other techniques, for eliminating this pest from the United States.

Insect Toxins and Pathogens

Over 363,636 kilograms of the toxin of *Bacillus thuringiansis* were marketed in 1972 in the United States for the control of caterpillars on lettuce, cole crops, tobacco, and ornamentals. With improved efficiency of the toxin and a reliable and adequate supply, the toxin could be marketed for wide use in controlling pests on cotton, forests, and other large-volume crops. A number of insect viruses are also being developed. For example, the *Heliothis* virus was recently registered for control of bollworms on cotton. However, the virus is not yet sufficiently persistent.

Insect Attractants

Various insect attractants have been developed to aid in insect control. International airports, harbors, and other ports of entry into the United States are ringed with light and other traps to attract various foreign species of insect pests. These devices are valuable in attracting alien insects, and have reduced the need for scheduled insecticide spraying for these pests. In orchards, sex attractants are being used in traps to determine pest levels and the need for pesticide application. In pilot tests, a sex attractant is being applied to the forest canopy in gelatin microcapsules in an attempt to prevent male gypsy moths from locating females. This same approach is being developed for the codling moth and other major moth species. Commercial use of these methods awaits further development.

Resistant Crop Varieties

Use of plant varieties that are resistant to diseases, insects, and nematodes is one means of solving pest problems in an economical and relatively desirable manner. Many crops could not be profitably grown in numerous locations except for the use of insect resistant varieties. These crops include alfalfa, corn, cotton, tobacco, small grains, clovers, and grasses. Soybeans, wheat, and sugar crops would not be commercially profitable in the United States except for the use of disease and nematode resistant varieties. The use of resistant varieties has been the only practical method found to suppress a large number of disease and insect pests of wheat, corn, barley, oats, grain sorghum, and rice. Many tolerant varieties of crops are available. Absolute resistance to pests is rare. However, even modest resistance can greatly reduce the need for pesticides. Resistant varieties are not available and cannot be foreseen for all pests that attack major crops in the United States.

Crop Rotation

For centuries, farmers have used crop rotation to control pests. Rotations can be designed to partially reduce populations of a wide variety of diseases, insects, and nematodes. They are most effective in controlling pests on cultivated annual crops in areas of mixed agriculture.

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CHAPTER VI - ANIMAL WASTES

INTRODUCTION

The management of animal wastes has received considerable attention in recent years because of their water and air pollution potential. Much of the concern has resulted because of a major trend toward large confined livestock and poultry operations. Even so, as much as 40 percent of all livestock is produced on pasture.

Confined feeding operations result in vast accumulations of wastes in localized areas. There is potential for the movement of animal waste in runoff from these operations, and systems for control have become a necessary and required part of the facilities. Runoff from these areas is usually applied to the land, since there is no practical treatment to render it acceptable to stream discharge. Solid wastes must be removed from these installations and the most widely used disposal practice is to spread them on agricultural land. (3, 11, 17, 33)

Land is a nonpoint source of pollutants to water systems, mainly by means of erosion. The application of animal wastes to land can increase pollution if proper practices are not followed. When animal wastes are properly applied to land, the practice is a highly effective and acceptable means for disposal. The wastes can be beneficial to the land in providing nutrients for growing crops and organic matter for improving the physical properties of the soil, thereby reducing soil erodibility. (6, 16, 18, 25, 34) Animal wastes applied to agricultural land come from three basic sources: (1) waste removed from feeding facilities, (2) storm runoff and snowmelt captured as it leaves feeding areas, and (3) excretion from animals grazing on pasture and rangeland. Feedlot facilities, per se, will not be discussed in this report because they are considered point sources of water and air pollution.

The following sections discuss alternative management practices for applying various animal wastes to land.

WASTES REMOVED FROM ANIMAL CONFINEMENT FACILITIES

The wastes removed from confinement facilities vary greatly. Many dairy operations and some beef cattle and swine operations utilize slurry or other systems that involve regular removal of wastes. On the other hand, wastes are generally removed from cattle feedlots and loose housing barns only once or twice a year. Water accounts for 50 percent or more of the total weight of most animal wastes.

The nutrient content of animal wastes is highly variable. The major factors influencing nutrient content include animal species, feed ration, storage conditions, and rainfall. Poultry waste generally contains the highest concentration of nutrients. (17, 19)

The most common and ecologically accepted method for disposing of wastes from feeding facilities is application to the land. This is also the lowest cost method of disposal for most systems.

In general, where land is readily available and transportation is not a major problem, manure is applied to land. This practice emphasizes utilization of the wastes as primary plant nutrients in a recycling process. The waste produced per animal unit can be applied on less land than is required to produce feed for an animal unit. The application rate is determined largely on the basis of the nitrogen content of the waste and the plant species grown. Weed seeds, salt content, and toxic substances may become limiting factors under some conditions. (9, 13, 14, 22, 28, 29)

When sufficient cropland is not available, large amounts of manure are sometimes applied to land with emphasis on disposal rather than plant utilization. Although this practice can alleviate disposal problems, it can create other problems. Nitrate, salts, and other compounds may accumulate to undesirable levels in the soil profile, or leach into underground water supplies. Yields and quality of crops may also be adversely affected. The loading rate should be based on the characteristics of the waste, kind of soil, climatic conditions, plant species, and depth to water table. (14, 20, 30)

Methods of Waste Application

The alternative methods of applying solid waste on cropland consist of surface application followed by (1) no incorporation into the soil, (2) immediate incorporation, or (3) incorporation at a later date prior to planting a crop. The frequency of spreading solid manure on land varies from daily, in the case of many dairy operations, to periodically, such as after marketing of beef cattle. The preferred method for reducing the pollution potential is to incorporate the manure with the soil as quickly as feasible after spreading. This practice greatly reduces the possibility of pollution from runoff, and also prevents loss of nitrogen compounds through volatilization. Losses through volatilization can be great and should be minimized, especially when the waste is applied as a source of plant nutrients. Adverse weather and soil conditions, crop stage, and the inability to direct necessary labor and machinery to this effort are potential constraints. (4, 5, 23)

Slurry wastes (a mixture of solid and liquid materials) are also commonly applied to the land surface, although some soil injection systems are used. The surface application methods include surface and sprinkler irrigation techniques, and tank spreaders. Wastes applied by irrigation cannot be immediately incorporated with the soil because of the wet condition. If precipitation occurs shortly after irrigation, runoff will increase. The tank spreader methods require more labor than irrigation methods, but generally the wastes can be incorporated into the soil sooner. The injection system has a distinct advantage from a pollution abatement standpoint in that the waste is immediately incorporated into the soil,thereby reducing odor and largely eliminating the possibility of polluted runoff. (1, 2, 8, 27)

Runoff Control from Waste-Treated Land

Rates and methods for applying animal waste on agricultural land are so diverse that specific recommendations cannot be given that will apply in all cases. However, some good management practices are:

1. Estimate the plant nutrient value of the waste, and apply it on land uniformly in accordance with crop requirements. (The nitrogen requirement of the crop is often a convenient basis for determining the amount of waste to be applied.)

2. Schedule the time and frequency of manure applications for maximum nutrient utilization by plants.

3. Incorporate manure into the soil as quickly as feasible following application, or inject the liquid wastes into the soil.

4. Ensure enough land is available at the appropriate time for disposal of manure. For example, to maximize the utilization of waste, approximately 1 hectare (2.4 acres) of land will be required for every 3 to 6 dairy cows, 5 to 10 beef animals, 20 to 40 hogs, and 400 to 800 layers.

5. When large amounts of wastes are applied to the land, a highly productive crop should be planted to utilize the nutrients, reduce runoff, and reduce the amounts of nitrate and other pollutants that may reach the gound water.

6. Wet land, steep land, frozen or snow-covered land, and grassed waterways generally should not be treated with wastes since the material will not be readily absorbed and may result in polluted runoff.

7. Use good water erosion control practices, as outlined in Chapter II, to control runoff.

LAND DISPOSAL OF RUNOFF FROM CONFINEMENT AREAS

Most confined animal facilities must include a system for capturing and disposing of storm runoff. This problem is greatest in areas of high rainfall. Generally, about one-fourth to one-half of the annual precipitation ends up as runoff. However, the percentage may be smaller in arid and semi-arid areas because the drier conditions of the soil in feeding pens permits more absorption of the moisture. (4, 21, 25)

The runoff from a confinement area can contain high concentrations of organic matter and salt. The degree of concentration is primarily determined by the amount of precipitation, number of animals, size of the confined area, and management practices. Other important factors include the intensity, duration, and frequency of rainfall, size and topography of the drainage area, and type of facilities. (10, 12, 15, 26, 31)

Retention ponds or basins are used to store runoff prior to land disposal. Runoff effluent should be removed from the retention pond and applied on land as soon as possible after a runoff event, or additional storage should be provided for runoff from subsequent storms.

Methods to Dispose of Runoff

There are basically two conventional methods for land disposal of feedlot runoff. First, runoff can be pumped, hauled, and spread. The second method is by irrigation, using one of the conventional methods such as sprinklers, ditches, or flooding. The method used depends on the kind of soil, slope, crops being grown, climate, and costs. The pump, haul, and spread method is restricted to the smaller operations; irrigation is suitable for larger operations.

The composition of the runoff should be known before it is applied to land. In many cases, the effluent may have minimal value as a source of plant nutrients. Some effluent may have salt concentrations that are detrimental. In this case, some dilution is necessary before the waste is applied to land, especially when growing crops are present. (7, 20, 24)

Evaporation ponds are an alternate method of disposing of runoff effluent. However, this method is restricted to areas of the country where evaporation exceeds precipitation.

Practices to Minimize Surface Runoff

Good land use management is essential to prevent water pollution from feedlot runoff applied on land. General practices to minimize pollution include:

1. Use recommended irrigation management practices.

2. Ensure that enough land is available for disposing of runoff applications. The amount of land required depends on whether the land is used as a disposal site (applying the maximum permissible amount without causing surface runoff or ground water pollution) or for growing crops (applying the amount of effluent to provide enough water for optimum crop growth).

3. Attempt to maintain a cover crop that utilizes large quantities of water. Since feedlot runoff generally contains a low concentration of nutrients, it is not normally a major source of nutrients for growing crops.

4. Apply effluent uniformly to minimize the possibility of surface runoff or ponding, which may result in leaching.

5. Use recommended water erosion control practices outlined in Chapter II to control runoff. Avoid spreading feedlot runoff on land after heavy rains, on frozen or snow-covered land, and on grassed waterways.

PASTURE PRODUCTION OF LIVESTOCK

Pasture Operations

The use of pastures and ranges is a major component of livestock production. Feeder calves are produced almost exclusively from cow-calf enterprises on pasture and range systems. A substantial portion of hog production is a pasture operation, handled with portable facilities and mobile equipment. Most dairy farms, except for certain areas of the country, use pasture when seasonal conditions permit, but probably all use confined areas for milking. Winter housing is necessary in many major milk producing states. Sheep production is also mainly a range and pasture operation. Confinement operations dominate the production of fed beef cattle, broilers, turkeys, and eggs. (32)

In pasture production, manure is deposited directly on the land by grazing animals. Even though a relatively large land area may be available to animals on pasture, they tend to concentrate around feeding, watering, and resting sites. Concentration of wastes at these sites can be quite high, creating potential water pollution. (6) Good drainage around these sites is essential, but may increase the possibility of contaminated runoff. Flowing streams also attract animals, particularly in hot weather, which can lead to contamination of water.

Practices to Minimize Water Pollution

Good management is the best insurance against pollution of water from pasture or range systems of livestock production. The relative importance of production practices differ by types of livestock and regions of the country, but the following generally apply:

1. Maintain an adequate land-to-livestock ratio. Avoid concentrations of animals that will create holding areas rather than grazing areas.

2. Maintain a highly productive forage on the land to retard runoff, entrap animal wastes, and utilize nutrients.

3. Plan a stocking density and rotation system of grazing to prevent overgrazing and eroding of the soil.

4. Locate feeders and waterers a reasonable distance from streams and water courses. Move them to new locations often enough to avoid creating erodible paths through repeated trampling by livestock.

5. Provide an adequate land absorption area downslope from feeding and watering sites, preferably with a filter strip of lush forage growth between such sites and the streams.

6. Provide limited access to streams and ponds. Use fencing to keep livestock from entering critical stream reaches.

7. Provide fences to prevent animals from wading in streams at points where they may concentrate for drinking. Fencing may be impractical, however, for many pasture operations.

8. Pump water from a stream, farm pond, or well to watering troughs or tanks where the number of animals or the characteristics of land present critical pollution problems.

9. Provide summer shade, using trees or artificial shelters to lessen the need for animals to enter the water for relief from the heat. The same precautions used in locating feeders and waterers should be followed in locating shelters.

10. Install and maintain a good overall program of water erosion control, as described in Chapter II.

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GLOSSARY

The glossary consists of selected terms and definitions from the Resource Conservation Glossary published by the Soil Conservation Society of America, Ankeny, Iowa, 1970.

absorption - The movement of a chemical into a plant.

adsorption - Adhesion of a chemical to a soil particle.

agricultural land - Land in farms regularly used for agricultural production. The term includes all land devoted to crop or livestock enterprises; for example, the farmstead lands, drainage and irrigation ditches, water supply, cropland, and grazing land of every kind in farms.

agronomic practices - The soil and crop activities employed in the production of farm crops, such as selecting seed, seedbed preparation, fertilizing, liming, manuring, seeding, cultivation, harvesting, curing, crop sequence, crop rotations, cover crops, stripcropping, pasture development, etc.

ammonification - The biochemical process whereby ammoniacal nitrogen is released from nitrogen-containing organic compounds.

ammonium fixation - The adsorption or absorption of ammonium ions by the mineral or organic fractions of the soil in a manner that they are relatively insoluble in water and relatively unexchangeable by the usual methods of cation exchange.

animal unit - A measure of livestock numbers based on the equivalent of a mature cow (approximately 1,000 pounds live weight). An animal unit is roughly one cow, one horse, one mule, five sheep, five swine, or six goats.

application rate - Rate that material is applied to a given area.

arid - A term applied to regions or climates that lack sufficient moisture for crop production without irrigation. The limits of precipitation vary considerably according to temperature conditions, with an upper annual limit for cool regions of 10 inches or less and for tropical regions as much as 15 to 20 inches.

available nutrient - That portion of any element or compound in the soil that readily can be absorbed and assimilated by growing plants.

available water-holding capacity (soils) - The capacity to store water available for use by plants, usually expressed in linear depths of water per unit depth of soil. Commonly defined as the difference between the percentage of soil water at field capacity and the percentage at wilting point. This difference, multiplied by the bulk density and divided by 100, gives a value in surface inches of water per inch depth of soil. See field capacity.

blowout - An excavation in areas of loose soil, usually sand, produced by wind.

buffer strips - Strips of grass or other erosion-resisting vegetation between or below cultivated strips or fields.

canopy - The cover of leaves and branches formed by the tops or crowns of plants.

check dam - Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

chiseling - Breaking or loosening the soil, without inversion, with a chisel cultivator or chisel plow.

clean tillage - Cultivation of a field so as to cover all plant residues and to prevent the growth of all vegetation except the particular crop desired.

climate - The sum total of all atmospheric or meteorological influences, principally temperature, moisture, wind, pressure, and evaporation, which combine to characterize a region and give it individuality by influencing the nature of its land forms, soils, vegetation, and land use.

compaction - To unite firmly; the act or process of becoming compact, usually applied in geology to the changing of loose sediments into hard, firm rock. With respect to construction work with soils, engineering compaction is any process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the weight of solid material per cubic foot.

conservation - The protection, improvement, and use of natural resources according to principles that will assure their highest economic or social benefits.

conservation district - A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries; usually a subdivision of state government with a local governing body and always with limited authorities. Often called a soil conservation district or a soil and water conservation district.

conservation plan for farm, ranch, or nonagricultural land unit - The properly recorded decisions of the cooperating landowner or operator on how he plans, within practical limits, to use his land in an operating unit within its capability and to treat it according to its needs for maintenance or improvement of the soil, water, and plant resources.

contour - (1) An imaginary line on the surface of the earth connecting points of the same elevation. (2) A line drawn on a map connecting points of the same elevation.

contour farming - Conducting field operations, such as plowing, planting, cultivating and harvesting, on the contour.

contour furrows - Furrows plowed approximately on the contour on pasture or rangeland to prevent soil loss and increase infiltration. Also, furrows laid out approximately on the contour for irrigation purposes.

contour stripcropping - Layout of crops in comparatively narrow strips in which the farming operations are performed approximately on the contour. Usually strips of grass, close-growing crops, or fallow are alternated with those in cultivated crops.

cover crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards.

cover, ground - Any vegetation producing a protecting mat on or just above the soil surface. In forestry, low-growing shrubs, vines, and herbaceous plants under the trees.

cover, vegetative - All plants of all sizes and species found on an area, irrespective of whether they have forage or other value. Syn. plant cover.

cropland - Land used primarily for the production of adapted cultivated, close-growing, fruit, or nut crops for harvest, alone or in association with sod crops.

crop residue - The portion of a plant or crop left in the field after harvest.

crop residue management - Use of that portion of the plant or crop left in the field after harvest for protection or improvement of the soil.

crop rotation - The growing of different crops in recurring succession on the same land.

debris - A term applied to the loose material arising from the disintegration of rocks and vegetative material; transportable by streams, ice, or floods.

debris dam - A barrier built across a stream channel to retain rock, sand, gravel, silt, or other material.

degradation - To wear down by erosion, especially through stream action.

denitrification - The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

deposit - Material left in a new position by a natural transporting agent, such as water, wind, ice, or gravity, or by the activity of man.

deposition - The accumulation of material dropped because of a slackening movement of the transporting agent--water or wind.

desilting area - An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water, located above a stock tank, pond, field, or other area needing protection from sediment accumulation. See filter strip.

detention dam - A dam constructed for the purpose of temporary storage of streamflow or surface runoff and for releasing the stored water at controlled rates.

dispersion, soil - The breaking down of soil aggregates into individual particles, resulting in single-grain structure. Ease of dispersion is an important factor influencing the erodibility of soils. Generally speaking, the more easily dispersed the soil, the more erodible it is.

disposal field - Area used for spreading liquid effluent for separation of wastes from water, degradation of impurities, and improvement of drainage waters. Syn. infiltration field.

diversion terrace - Diversions, which differ from terraces in that they consist of individually designed channels across a hillside, may be used to protect bottomland from hillside runoff or may be needed above a terrace system for protection against runoff from an unterraced area. They may also divert water out of active gullies, protect farm building from runoff, reduce the number of waterways, and are sometimes used in connection with stripcropping to shorten the length of slope so that the strips can effectively control erosion. See terrace.

drainage - The removal of excess surface water or groundwater from land by means of surface or subsurface drains.

drop-inlet spillway - Overall structure in which the water drops through a vertical riser connected to a discharge conduit.

drop spillway - Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

duckfoot - An implement with horizontally spreading, V-shaped tillage blades or sweeps which are normally adjusted to provide shallow cultivation without turning over the surface soil or burying surface crop residues.

duff - The more or less firm organic layer on top of mineral soil, consisting of fallen vegetative matter in the process of decomposition, including everything from pure humus below to the litter on the surface. Duff is a general, nonspecific term.

environment - The sum total of all the external conditions that may act upon an organism or community to influence its development or existence.

erosion - (1) The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. (2) Detachment and movement of soil or rock fragments by water, wind, ice, or gravity. The following terms are used to describe different types of water erosion.

accelerated erosion - Erosion much more rapid than normal, natural, or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophies that expose base surfaces; for example, fires.

geological erosion - The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building of floodplains, coastal plains, etc. Syn. natural erosion.

gully erosion - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depth, ranging from 1 to 2 feet to as much as 75 to 100 feet.

natural erosion - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Syn. geological erosion.

normal erosion - The gradual erosion of land used by man that does not greatly exceed natural erosion. See natural erosion.

rill erosion - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently cultivated soils. See rill.

sheet erosion - The removal of a fairly uniform layer of soil from the land surface by runoff water.

splash erosion - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

erosive - Refers to wind or water having sufficient velocity to cause erosion. Not to be confused with erodible as a quality of soil.

eutrophication - A means of aging of lakes whereby aquatic plants are abundant and waters are deficient in oxygen. The process is usually accelerated by enrichment of waters with surface runoff containing nitrogen and phosphorus.

fallow - Allowing cropland to lie idle, either tilled or untilled, during the whole or greater portion of the growing season.

farm management - The organization and administration of farm resources, including land, labor, crops, livestock, and equipment.

farm operator - A person who operates a farm either by performing the labor himself or directly supervising it.

fertility, soil - The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil, are favorable.

fertilizer - Any organic or inorganic material of natural or synthetic origin that is added to a soil to supply elements essential to plant growth.

field capacity (field moisture capacity) - The amount of soil water remaining in a soil after the free water has been allowed to drain away for a day or two if the root zone has been previously saturated. It is the greatest amount of water that the soil will hold under conditions of free drainage, usually expressed as a percentage of the oven-dry weight of soil or other convenient unit.

field stripcropping - A system of stripcropping in which crops are grown in parallel strips laid out across the general slope but which do not follow the contour. Strips of grass or close-growing crops are alternated with strips of cultivated crops.

filter strip - Strip of permanent vegetation above farm ponds, diversion terraces, and other structures to retard flow of runoff water, causing deposition of transported material, thereby reducing sediment flow. See desilting area.

flume - An open conduit on a prepared grade, trestle, or bridge for the purpose of carrying water across creeks, gullies, ravines, or other obstructions. It may also apply to an entire canal where it is elevated above natural ground for its entire length. Sometimes used in reference to calibrated devices used to measure the flow of water in open conduits.

furrow dams - Small earth dams used to impound water in furrows.

grade - (1) The slope of a road, channel, or natural ground. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction like paving or laying a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

grade stabilization structure - A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further headcutting or lowering of the channel grade.

gradient - Change of elevation, velocity, pressure, or other characteristics per unit length; slope.

grassed waterway - A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from cropland.

groundwater - Phreatic water or subsurface water in the zone of saturation.

gully - A channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains or during the melting of snow. A gully may be dendritic or branching or it may be linear, rather long, narrow, and of uniform width. The distinction between gully and rill is one of depth. A gully is sufficiently deep that it would not be obliterated by normal tillage operations, whereas a rill is of lesser depth and would be smoothed by ordinary farm tillage. Syn. arroyo. See erosion; rill.

gully control plantings - The planting of forage, legume, or woody plant seeds, seedlings, cuttings, or transplants in gullies to establish or reestablish a vegetative cover adequate to control runoff and erosion and incidentally produce useful products.

herbicide - A chemical substance used for killing plants, especially weeds.

humus - That more or less stable fraction of the soil organic matter remaining after the major portion of added plant and animal residues have decomposed; usually amorphous and dark colored.

impoundment - Generally an artificial collection or storage of water, as a reservoir, pit, dugout, sump, etc. See reservoir.

infiltration - The flow of a liquid into a substance through pores or other openings, connoting flow into a soil in contradistinction to the word percolation which connotes flow through a porous substance.

infiltration rate - A soil characteristic determining or describing the maximum rate at which water can enter the soil under specified conditions, including the presence of an excess of water.

intensive cropping - Maximum use of the land by means of frequent succession of harvested crops.

land capability class - One of the eight classes of land in the land capability classification of the Soil Conservation Service. These eight land capability classes, distinguished according to the risk of land damage or the difficulty of land use, are:

Land suitable for cultivation and other uses.

I. Soils in class I have few limitations that restrict their use.

II. Soils in class II have some limitations that reduce the choice of plants or require moderate conservation practices.

III. Soils in class III have severe limitations that reduce the choice of plants or require special conservation practices, or both.

IV. Soils in class IV have very severe limitations that restrict the choice of plants, require very careful management, or both.

Land generally not suitable for cultivation (without major treatment).

V. Soils in class V have little or no erosion hazard but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife food and cover.

VI. Soils in class VI have severe limitations that make them generally unsuited for cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.

VII. Soils in class VII have very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife.

VIII. Soils and landforms in class VIII have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or esthetic purposes.

land leveling - Process of shaping the land surface for better movement of water and machinery over the land. Also called land forming, land shaping, or land grading.

leaching - The removal of materials in solution from the soil.

manure - The excreta of animals, with or without the admixture of bedding or litter, in varying stages of decomposition.

mechanical practices - Soil and water conservation practices that primarily change the surface of the land or that store, convey, regulate, or dispose of runoff water without excessive erosion.

minimum tillage - That amount of tillage required to create the proper soil condition for seed germination, plant establishment, and prevention of competitive growth.

mulch - A natural or artificial layer of plant residue or other materials, such as sand or paper, on the soil surface.

nitrification - The biological oxidation of ammonium salts to nitrites and the further oxidation of nitrites to nitrates.

no-tillage - A method of planting crops that involves no seedbed preparation other than opening the soil for the purpose of placing the seed at the intended depth. This usually involves opening a small slit or punching a hole into the soil. There is usually no cultivation during crop production. Chemical weed control is normally used. Also referred to as slot planting or zero tillage.

overgrazing - Grazing so heavy that it impairs future forage production and causes deterioration through damage to plants or soil or both.

pesticide - A chemical agent used to control pests.

plant nutrients - The elements or groups of elements taken in by a plant which are essential to its growth and used in elaboration of its food and tissues. Includes nutrients obtained from fertilizer ingredients.

plant residue - See crop residue; humus.

plow layer - The soil ordinarily moved in tillage; equivalent to surface soil.

plow-plant - Plowing and planting a crop in one operation, with no additional seedbed preparation.

pollution, water - Any change in the character of water adversely affecting its usefulness.

rainfall intensity - The rate at which rain is falling at any given instant, usually expressed in inches per hour.

reservoir - Impounded body of water or controlled lake in which water is collected or stored.

rill - A small, intermittent water course with steep sides, usually only a few inches deep and, hence, no obstacle to tillage operations.

rotation pasture - A cultivated area used as a pasture 1 or more years as part of crop rotation.

row crop - A crop planted in rows, normally to allow cultivation between rows during the growing season.

runoff (hydraulics) - That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, groundwater runoff, or seepage.

sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

sediment discharge - The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended and load and bedload.

sheet flow - Water, usually storm runoff, flowing in a thin layer over the ground surface. Syn. overland flow.

slope - Degree of deviation of a surface from the horizontal, usually expressed in percent or degrees.

soil-conserving crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

soil erosion - The detachment and movement of soil from the land surface by wind or water. See erosion.

soil management - The sum total of all tillage operations, cropping practices, fertilizer, lime, and other treatments conducted on, or applied to, a soil for the production of plants.

soil organic matter - The organic fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil sample passed through a 2-millimeter sieve.

soil structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades, respectively.

soil texture - The relative proportions of the various soil separates in a soil. The textural classes may be modified by the addition of suitable adjectives when coarse fragments are present in substantial amounts; for example, gravelly silt loam. Sand, loamy sand, and sandy loam are further subdivided on the basis of the proportions of the various sand separates present. The limits of the various classes and subclasses are as follows:

sand - Soil material that contains 85 percent or more of sand. The percentage of silt plus 1.5 times the percentage of clay shall not exceed 15.

coarse sand - 25 percent or more very coarse and coarse sand and less than 50 percent any other one grade of sand.

sand - 25 percent or more very coarse, coarse, and medium sand and less than 50 percent fine or very fine sand.

fine sand - 50 percent or more fine sand, or less than 25 percent very coarse, more fine sand, or less than 25 percent very coarse, fine sand.

very fine sand - 50 percent or more very fine sand.

loamy sand - Soil material that contains, at the upper limit, 85 to 90 percent sand, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15. At the lower limit, it contains not less than 70 to 85 percent sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

loamy coarse sand - 25 percent or more very coarse and coarse sand and less than 50 percent any other one grade of sand.

loamy sand - 25 percent or more very coarse, coarse, and medium sand and less than 50 percent fine or very fine sand.

loamy very fine sand - 50 percent or more very fine sand.

stabilized grade - The slope of a channel at which neither erosion nor deposition occurs.

stubble - The basal portion of plants remaining after the top portion has been harvested; also, the portion of the plants, principally grasses, remaining after grazing is completed.

stubble mulch - The stubble of crops or crop residues left essentially in place on the land as a surface cover during fallow and the growing of a succeeding crop.

subsoiling - The tillage of subsurface soil, without inversion, for the purpose of breaking up dense layers that restrict water movement and root penetration.

summer fallow - The tillage of uncropped land during the summer in order to control weeds and store moisture in the soil for the growth of a later crop.

terrace - An embankment or combination of an embankment and channel constructed across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope. Terraces or terrace systems may be classified by their alignment, gradient, outlet, and cross-section. Alignment is parallel or non-parallel. Gradient may be level, uniformly graded, or variably graded. Grade is often incorporated to permit paralleling the terraces. Outlets may be soil infiltration only, vegetated waterways, tile outlets, or combinations of these. Cross-sections may be narrow base, broad base, bench, steep backslope, flat channel, or channel.

terrace interval - Distance measured either vertically or horizontally between corresponding points on two adjacent terraces.

tillage - The operation of implements through the soil to prepare seedbeds and root beds.

transportation - The movement of detached soil material across the land surface or through the air. May be accomplished by running water, wind, or gravity. Soil erosion.

undergrazing - An intensity of grazing in which the forage available for consumption under a system of conservation pasture management is not used to best advantage. Contrast with overgrazing.

universal soil loss equation - An equation used for the design of water erosion control systems: A = RKLSPC wherein A = average annual soil loss in tons per acre per year; R = rainfall factor; K = soil erodibility factor; L = length of slope; S = percent of slope; P = conservation practice factor; and C = cropping and management factor. (T = soil loss tolerance value that has been assigned each soil, expressed T/A/Year.)

water control (soil and water conservation) - The physical control of water by such measures as conservation practices on the land, channel improvements, and installation of structures for water retardation and sediment detention (does not refer to legal control or water rights as defined).

weed - A plant out of place.

wheel-track planting - Plowing and planting in separate operations with the seed planted in the wheel tracks.

windbreak - (1) A living barrier of trees or combination of trees and shrubs located adjacent to farm or ranch headquarters and designed to protect the area from cold or hot winds and drifting snow. Also headquarters and livestock windbreaks. (2) A narrow barrier of living trees or combination of trees and shrubs, usually from one to five rows, established within or around a field for the protection of land and crops. May also consist of narrow strips of annual crops, such as corn or sorghum.

wind erosion - The detachment and transportation of soil by wind.

wind erosion equation - An equation used for the design of wind erosion control systems. E = f (IKCLV) wherein E = average annual soil loss, expressed in tons per acre per year; f = a function of; I = soil erodibility; K = soil ridge roughness; C = climatic factor; L = unsheltered distance across the field along the wind erosion direction; and V = vegetative cover.

wind stripcropping - The production of crops in relatively narrow strips placed perpendicular to the direction of prevailing winds.

woodland - Any land used primarily for growing trees and shrubs. Woodland includes, in addition to what is ordinarily termed "forest" or "forest plantations," shelterbelts, windbreaks, wide hedgerows, containing woodland species for wildlife food or cover, stream and other banks with woodland cover, etc. It also includes farmland and other lands on which woody vegetation is to be established and maintained.

woodland management - The management of woodlands and plantations that have passed the establishment stage, including all measures designed to improve the quality and quantity of woodland growing stock and to maintain litter and herbaceous ground cover for soil, water, and other resource conservation. Some of these measures are planting, improvement cutting, thinning, pruning, slash disposal, and protection from fire and grazing.