Nonpoint Source Pollution Control by Soil and Water Conservation Practices

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ABSTRACT

There has been a tendency to equate best management practices, as defined in water quality legislation, with soil and water conservation practices. The effectiveness of SWCP's at controlling potential pollutants other than sediment depends on the characteristics of pollutants. Pollutants have been categorized in groups having distinctly different soil adsorption properties which have been related to the effect of SWCP's on water and soil movement.

INTRODUCTION

One of the mandates of Section 208 of the Water Quality Act Amendments of 1972 is the development of long-term management plans to control potential water pollutants. To control nonpoint source pollution from agricultural activities, the US Environmental Protection Agency is supporting research to find "best" management practices for agricultural land. Here, "best" implies upgrading water quality without hampering production.

There has been an understandable tendency to assume that soil and water conservation practices (SWCP's) would be "best" practices. SWCP's were designed to control erosion and/or conserve water. Eroded soil and runoff are principal carriers of potential water pollutants. Thus, SWCP's should indirectly control movement of pollutants other than sediment.

However, pollutants vary in chemical and physical properties, and, consequently, take different paths out of the field. Similarly, SWCP's vary in their target. A SWCP which controls only sediment movement will not prevent pollution by solutes which leave the soil via runoff water or seepage. Most pesticides and nutrients leave the soil in this manner. There is a need for a classification of potential pollutants according to their mode of leaving the field, and a corresponding classification of SWCP's according to the pathways they block. Then, a logical assessment of the ability of SWCP's to control nonpoint source agricultural pollution can be made.

SOIL AND WATER CONSERVATION PRACTICES (SWCP's)

Any agricultural practice that reduces soil erosion and/or increases soil water retention can be considered a SWCP. In humid areas, conservation of soil has been the primary goal, while in dry areas, conservation of water has been given more emphasis. Since water and soil move together, controlling the movement of one sometimes means increased control over the movement of the other. Stewart et al. (1975) have compiled a list of SWCP's that are effective in reducing surface runoff and/or erosion as compared to conventional tillage practices. For purposes of this paper, conventional tillage includes moldboard plowing, secondary tillage to smooth and pulverize the soil, planting, and cultivating, where appropriate. Operations are assumed to be straight row. However, the concept of conventional tillage can vary with the crop grown and location.

SWCP's are designed on the following three principles to control the physical processes that lead to soil erosion or water loss:

Control of runoff by:

Reduction of runoff velocity. The velocity of surface runoff water is reduced either by decreasing land slope or by lengthening the flow path the water takes. Surface roughness is increased by reducing certain tillage practices, or by increasing vegetative or residue cover. A decrease in runoff velocity is usually accompanied by increased infiltration and settling out of some of the sediment load.

Increase surface storage. Practices that increase surface storage generally reduce the total volume of runoff and increase infiltration. The effectiveness of practices designed to reduce total runoff volume depend on the character of the storm producing the runoff. For instance, some practices are ineffective for large storms (Wischmeier and Smith, 1965).

Increased conductivity and moisture storage. Some practices increase the soil macropores connected to the soil surface, which can greatly increase infiltration and conductivity. Retention of moisture from an event can be increased by either draining or evaporating moisture between events.

Reduction of raindrop impact:

Splash erosion results from raindrops impacting the soil, detaching particles, and transporting them for short distances. Perhaps most importantly, because raindrops detach soil particles, the particles are more available to be transported in overland flow. Raindrop impact tends to break down aggregates into small primary clay and silt particles. Raindrop impact can also form a soil surface crust that is often the limiting factor in infiltration (Hillel and Gardner, 1969).

Article was submitted for publication in June 1978; reviewed and approved for publication by the Soil and Water Division of ASAE in December 1978. Presented as ASAE Paper No. 77-2506.

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Acknowledgements: Research reported in this paper is based in part on results of the project "Effectiveness of Soil and Water Conservation Practices for Pollutant Control" sponsored by the U.S. Environmental Protection Agency, Environmental Research Lab., Athens, GA. Special thanks to Lee Jacobowitz for editing of the manuscript.

834 © 1979 American Society of Agricultural Engineers 0001-2351/79/2204-0834$02.00

This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 22, No. 5, pp. 834, 835, 836, 837, 838, 839, 840, 1979) Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

TRANSACTIONS of the ASAE—1979
**TABLE 1. MECHANISMS BY WHICH SWCP'S AFFECT SOIL AND WATER LOSSES**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Direct effect on water losses*</th>
<th>Direct effect on soil losses</th>
<th>Primary physical process</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Increased vegetal cover</td>
<td>Increased ET</td>
<td>Greatly reduces splash and</td>
<td>Increased conductivity and moisture storage</td>
</tr>
<tr>
<td></td>
<td>Increased infiltration rate</td>
<td>interrill erosion</td>
<td>Reduction of raindrop impact</td>
</tr>
<tr>
<td></td>
<td>and capacity</td>
<td>Reduces rill erosion</td>
<td>Improved soil moisture</td>
</tr>
<tr>
<td>02 Increased surface residue</td>
<td>Decrease in runoff volume</td>
<td>Reduced transport capacity</td>
<td>Reduction of runoff velocity</td>
</tr>
<tr>
<td></td>
<td>Increased infiltration rate</td>
<td>Greatly reduced splash and</td>
<td>Improvement improved soil structure</td>
</tr>
<tr>
<td></td>
<td>and capacity</td>
<td>interrill erosion</td>
<td>Increased soil structure</td>
</tr>
<tr>
<td>03 Decreased slope length or</td>
<td>Reduced runoff velocity</td>
<td>Reduced rill erosion</td>
<td>Increased soil conductivity</td>
</tr>
<tr>
<td>steepness</td>
<td>Reduced runoff volume on</td>
<td>Reduced transport capacity</td>
<td>Increased surface storage</td>
</tr>
<tr>
<td></td>
<td>permeable soils</td>
<td>Reduced rill and gully</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased infiltration</td>
<td>erosion</td>
<td></td>
</tr>
<tr>
<td>04 Reduced tillage</td>
<td>Increased infiltration due to</td>
<td>Reduced transport capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduced surface sealing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05 Increase in surface-connected</td>
<td>Increased infiltration</td>
<td>Reduced rill erosion for</td>
<td></td>
</tr>
<tr>
<td>macropores</td>
<td></td>
<td>small storms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced transport capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>for small storms</td>
<td></td>
</tr>
<tr>
<td>06 Increased storage in place</td>
<td>Increased infiltration</td>
<td>Prevents gully erosion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced transport capacity</td>
<td></td>
</tr>
<tr>
<td>07 Increased storage at slope</td>
<td>Reduced runoff velocity and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bottom</td>
<td>volume at field edge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Effects relate to non-frozen soil only.

**Improvement in soil structure:**

Bulk density, porosity, and aggregate stability all affect soil erodibility and infiltration. Soils with stable aggregates tend to be less erosive. Those soils with low bulk density and high porosity have higher infiltration capacities.

The relationships between the principles given above and the mechanisms by which SWCP’s affect soil and water losses are summarized in Table 1. Specific selected practices and related physical effects on topography, soil and vegetation are listed in Table 2.

**EROSION AND WATER QUALITY**

In humid regions, SWCP’s are designed primarily to control erosion; they are not generally designed for sediment control. There is a subtle but important difference. Erosion control measures stress holding the soil in place on the field, while sediment control measures prevent sediment from entering surface water bodies. Presumably, controlling erosion will also partially control sediment. However, from a water quality point of view, on-field erosion control practices are not necessarily those best designed to control sediment, since only a fraction of eroded soil ever reaches a stream or lake. Even when SWCP’s do control sediment movement to surface waters, the impact on water quality is not clear. Background or natural sediment yield of a watershed is a critical parameter to consider in evaluating the relative effects of reducing the additional “man-made” sediment delivery to surface waters. The natural sediment loads of some streams are high enough to discourage many uses.

Many researchers have identified sediments as carriers of adsorbed substances that could become water pollutants (Stewart et al., 1975). One conclusion resulting from such research is that if erosion and sediment movement are controlled, then soil-adsorbed pollutants will also be controlled. However, this is not necessarily true. SWCP’s control sediment depending on particle size, density, and original location in the soil profile and the field. Adsorption of many substances also depends on these factors. The inter-relationships are important. For example, many SWCP’s are least effective at controlling the movement of small particles, or those with low density, which are the very ones that have the highest adsorption capacity. Many potential water pollutants are only partially or not at all adsorbed to soil particles, so control of erosion has limited effect on movement of these substances.

Sediments can have a dampening influence on nitrogen and phosphorus concentrations in surface waters (Holt et al., 1970). Black (1970) concluded that the adsorption of anions such as phosphate could be an important reaction that occurs in natural colloidal suspensions. Sediments have been shown to remove cesium-137, a major radioactive contaminant of natural

**TABLE 2. PRACTICES AND RELATED EFFECTS ON TOPOGRAPHY, SOIL, AND VEGETATION**

<table>
<thead>
<tr>
<th>Practice</th>
<th>Mechanism (see Key)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Terraces</td>
<td>17 23</td>
</tr>
<tr>
<td>2. Grassed waterways</td>
<td>21</td>
</tr>
<tr>
<td>3. Contouring</td>
<td>16 23</td>
</tr>
<tr>
<td>4. Graded rows</td>
<td>16 23</td>
</tr>
<tr>
<td>5. Contourist and ridge planting</td>
<td>16 23 32 31 41 51 55</td>
</tr>
<tr>
<td>6. Strip cropping</td>
<td>16 33 31 41 51 55</td>
</tr>
<tr>
<td>7. Minimum tillage</td>
<td>22 32 42</td>
</tr>
<tr>
<td>8. Winter cover crops</td>
<td>21 31</td>
</tr>
<tr>
<td>9. Soil-based rotations</td>
<td>21 31 41 51 55</td>
</tr>
<tr>
<td>10. Tile drainage</td>
<td>50</td>
</tr>
<tr>
<td>11. Surface drainage</td>
<td></td>
</tr>
</tbody>
</table>

Key:

10: Increased storage
15: Increased storage in place
17: Increased storage in reservoir at slope bottom
20: Reduced runoff velocity
21: Reduced runoff velocity by vegetative cover
22: Reduced runoff velocity by surface residue
23: Reduced runoff velocity by decreased slope or slope length
30: Reduced splash
31: Reduced splash by vegetative cover
32: Reduced splash by surface residue
40: Improved soil structure
41: Improved soil structure by vegetative cover
42: Improved soil structure by surface residue
44: Improved soil structure by reduced tillage
50: Increased hydraulic conductivity and soil moisture storage capacity
51: Increased hydraulic conductivity and soil moisture storage capacity by vegetative cover
55: Increased hydraulic conductivity and soil moisture storage capacity by increased macro pores
waters (Lomenick and Tamura, 1965). Frink (1969) found that potassium was fixed by sediment in lakes. Holt et al. (1970) refer to adsorption of lindane and parathion on the clay-organic complex as “chemical scavenging” of uncharged pollutants in natural waters.

The severity of a sediment problem depends on the nature of the sediment, the receiving water, and the water’s use. Some SWCP’s are designed to control sediment long-term, and are relatively ineffective at controlling runoff from large storm events. Depending on the particular type of sediment problem, learning to handle the runoff from single large-scale storms might be the key to solving the problem. In addition, the character of sediment controlled is an important consideration relative to the possible control of sediment-adsorbed substances.

WATER MOVEMENT

Water can flow above the soil surface (direct runoff), be stored in surface depressions, move vertically down toward the water table (percolation) or move within the soil above the permanent water table and parallel to the surface (interflow). Flow emerging from below the water table is termed base flow. Thus, surface runoff is the sum of direct runoff and subsurface flow that has re-emerged at the surface. Fig. 1 illustrates these concepts.

Direct overland runoff often contains dissolved materials such as nutrients or pesticides and may also carry a sediment load. The type and quantity of the dissolved chemicals depend on the soil, vegetation, organic residue, management, and soil conservation practice (Holt, 1969). The sediment load depends largely on rainfall characteristics, topography, vegetation, soil type, and prevailing soil conservation practices. Interflow and deep percolated water carry only dissolved matter. The path of water movement beneath the soil surface depends on vegetation, geology, weather, and soil type.

NUTRIENT AND PESTICIDE MOVEMENT

Water transport of a substance includes movement in the dissolved phase in the subsurface and surface flows, and in the adsorbed phase with the soil particles in the surface runoff (Nicholsen, 1970). The volume of runoff water is generally much greater than the quantity of sediment yielded from a watershed. Therefore, even if the concentration of a certain substance is greater in the sediment, the quantity of the substance lost in the water might be greater (Nicholsen, 1977; Mulkey and Falco, 1977). The distribution between dissolved and sediment-adsorbed phases determines the amount of substance that may be lost in a given storm runoff.

GROUPING OF POLLUTANTS BY ADSORPTION PROPERTIES

In studying pollutant losses in soil and water, it has proven useful to categorize the chemicals according to their relative concentrations adsorbed to soil particles and dissolved in the water surrounding the soil. These concentrations may be found from adsorption/desorption isotherms, which may be non-linear and multiphased. Therefore, the equilibrium partition coefficient, K (the ratio of concentration of chemical adsorbed to the soil versus that in solution), is generally not a constant. It remains possible, however, to loosely categorize specific pollutants (chemical forms) into three groups, based on the partition coefficient’s order of magnitude:

- Group A. K ~ 1,000, strongly adsorbed pollutants (e.g., solid phase organic nitrogen, DDT, paraquat)
- Group B. K ~ 5, moderately adsorbed pollutants (e.g., most currently used herbicides)
- Group C. K ~ 0 to 0.5, nonadsorbed or soluble pollutants (e.g., nitrate)

Table 3(a) and 3(b) list various agricultural pollutants according to the above classifications.

This classification was chosen to account for the different possible paths by which pollutants may leave the field. Strongly adsorbed substances are carried on the sediment eroded by overland flow. Non-adsorbed substances are dissolved in percolation and interflow. Moderately adsorbed substances may leave by either of the above means, or as solutes in the overland flow.

Table 4 shows how the different pollutant groups are affected by reducing runoff volume and by reducing soil loss. The strategy for deciding which SWCP to
TABLE 4. EFFECT OF REDUCED RUNOFF VOLUME AND SOIL LOSS ON POTENTIAL POLLUTANT LOSSES

<table>
<thead>
<tr>
<th>Reduced runoff volume</th>
<th>Strongly adsorbed nutrients and pesticides</th>
<th>Moderately adsorbed pesticides</th>
<th>Soluble nitrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced soil loss</td>
<td>Reduced approximately proportional to decrease in runoff volume</td>
<td>Increase to ground water and surface water (via base flow and interflow)</td>
<td>No effect</td>
</tr>
</tbody>
</table>

Use to control pollution is to match the SWCP control mechanism (Table 1) with the pollutant's mode of leaving the field (Table 4).

STRONGLY ADSORBED SUBSTANCES

Strongly adsorbed substances include organic phosphorus and nitrogen, as well as the chlorinated hydrocarbons. Losses of strongly adsorbed substances in deep percolation and interflow are extremely small, while losses in overland flow can be high and are closely related to the amount of sediment in the runoff. This is illustrated by the following studies. Paraquat and diquat were found to be strongly adsorbed to soil constituents (Knight and Tomilnsen, 1967; Burnes et al., 1973). As expected, paraquat and diquat losses were found to be associated with sediment (Smith et al., 1978). Nicholsen et al. (1966) found that DDT was associated with the suspended sediment at the outlet of a 400-square mile watershed.

Certain components of sediment carry a disproportionate amount of adsorbed substances. Casler and Jacobs (1975) and Barrows and Kilmer (1963) have reported that total phosphorus and total nitrogen losses are associated with eroded soil carried off the land. However, the concentrations of total phosphorus and total nitrogen in the sediment are much higher for storms producing small sediment loads than for those with large sediment loads. The smaller loads were found to be composed of the finer mineral particles and organic matter. Clay-sized soil particles, while not necessarily

TABLE 5. SUMMARY OF SELECTED SWCP'S AND EXPECTED EFFECTS ON POTENTIAL POLLUTANT LOSSES

<table>
<thead>
<tr>
<th>Practice</th>
<th>Effect on surface runoff</th>
<th>Effect on base flow and interflow</th>
<th>Effect on soil loss</th>
<th>Effect on losses of strongly adsorbed substances</th>
<th>Effect on losses of moderately adsorbed pesticides</th>
<th>Effect on phosphate losses</th>
<th>Effect on nitrate losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terraces</td>
<td>Reduced volume and velocity</td>
<td>Increased</td>
<td>Reduced transport capacity Prevents gully erosion</td>
<td>Reduced in as much as fines and OM settle out</td>
<td>Generally reduced</td>
<td>Increased proportional to decrease in runoff volume</td>
<td>No effect</td>
</tr>
<tr>
<td>Grasped waterways</td>
<td>Very little</td>
<td>Very little</td>
<td>Reduced soil erosion</td>
<td>Reduced transport capacity</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>Contouring</td>
<td>Slight decrease in volume and velocity</td>
<td>Slight decrease</td>
<td>Reduced soil erosion</td>
<td>Reduced transport capacity</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>Graded rows</td>
<td>Decrease in volume and velocity</td>
<td>Increase</td>
<td>Similar to contouring but more effective</td>
<td>Same as graded rows</td>
<td>Reduced moderately</td>
<td>Reduced moderately</td>
<td>Unknown</td>
</tr>
<tr>
<td>Ridge planting and contour listing</td>
<td>Both volume and velocity are reduced in grassed strip</td>
<td>Unknown</td>
<td>All forms of erosion greatly reduced</td>
<td>Reduced transport capacity in grassed strip</td>
<td>All forms of erosion reduced</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>Velocity greatly reduced, volume generally reduced dependent on soil condition</td>
<td>Generally increased</td>
<td>All forms of erosion reduced in fall, winter and spring</td>
<td>Red to water</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Winter cover crops</td>
<td>Velocity and volume are reduced in fall, winter, and spring</td>
<td>Unknown</td>
<td>All forms of erosion greatly reduced in sod-years</td>
<td>Greater reduced during years of sod; also reduced other years due to less pesticide application</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Sod-based rotations</td>
<td>Velocity and volume are reduced in sod-years</td>
<td>Unknown</td>
<td>All forms of erosion greatly reduced in sod-years; slight reduction other years</td>
<td>Greatly reduced during years of sod; also reduced other years due to less pesticide application</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Tile drainage</td>
<td>Volume decreased</td>
<td>Base flow and interflow (tile flow) greatly increased</td>
<td>Unknown</td>
<td>No effect or slight reduction</td>
<td>Slight reduction</td>
<td>Unknown</td>
<td>Increased</td>
</tr>
<tr>
<td>Surface drainage</td>
<td>Volume and velocity increased</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Slight increase</td>
<td>Increase</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>
the easiest to detach, are more easily transported than larger soil particles. Since organic matter is concentrated in the soil matrix and has low density, it is one of the first components of the soil to be removed (Holt et al., 1970). Thus the eroded sediment contains more organic matter, clay, and associated nutrients than the surface soil from which it came (Massey and Jackson, 1952; Bruce et al., 1975; and McElroy et al., 1976).

Massey and Jackson (1952) used the concept of enrichment ratio to characterize the quantity of a substance in sediment relative to that in the original soil. The enrichment ratio can be defined as the concentration of a substance in sediment compared to the concentration of the substance in situ in the soil. Enrichment ratios are typically greater than unity. Factors affecting the enrichment ratio include soil type, kind of erosion, sediment transport, and character of the storm producing the runoff.

To determine the effect of a SWCP on losses of strongly adsorbed substances, one must evaluate the effect of the practice on the particular soil particles to which substances are adsorbed. Strongly adsorbed substances are generally carried away on clay and organic matter particles which are distributed uniformly over the field surface. Therefore, those practices which control splash and interrill erosion will be most effective at controlling adsorbed substances. SWCP's that only reduce rill or gully erosion or rely on causing sediment to be filtered out will be less effective in this case. Practices that provide a mulch or a plant canopy are more effective at reducing splash and interrill erosion (Table 1). Minimum tillage, winter cover crops, and sod-based rotations are therefore obvious SWCP's for reducing losses of strongly adsorbed substances. However, winter cover crops have no effect for part of the year. Od-based rotations eliminate losses of strongly adsorbed substances during years with sod. Losses for other years will also be reduced, but to a lesser extent. Contour strip cropping will also reduce losses of strongly adsorbed substances, primarily in the grass or small grain strip, due to reduced rainfall splash and interrill erosion. If crops are rotated, less pesticide should be needed for the row strips as well. Inasmuch as fines settle out of overland flow in the grass strip, some additional reduction in loss of adsorbed substances might occur.

Contouring, graded rows, lister planting, ridge planting, and some forms of terraces (particularly level terraces) reduce loss of adsorbed substances by allowing eroded fine soil particles to settle out of overland flow. Reducing either the runoff volume or its velocity lessens the energy available to transport materials. If the overland flow is slowed enough for clay aggregates, clay-size particles or organic matter to settle out, adsorbed substances will settle out with them.

Minimum tillage can greatly reduce splash and interrill erosion, as well as runoff volume and velocity. However, as indicated in Table 6, minimum tillage requires the use of additional pesticide. Over the short term, even considering additional required pesticide usage, minimum tillage might well reduce losses of strongly adsorbed substances, but unless pesticides degrade (some of the strongly adsorbed pesticides used in the past have degraded very slowly), their concentration in the soil will continually increase.

Organic phosphorus is strongly adsorbed to soil particles in the spring, summer and fall. In areas with cold winters, phosphorus losses in the dissolved phase are high because plant cell walls rupture and the phosphorus leaks out (Martin et al., 1970; White, 1973). Thus, a SWCP that increases surface plant residue in an effort to decrease sediment loss might increase dissolved phosphorus losses.

MODERATELY ADSORBED SUBSTANCES

Although losses of moderately adsorbed substances are related to both soil loss and runoff loss, loss is predominantly in the runoff water because the quantity of water greatly exceeds that of sediment. The following studies illustrate this conclusion. In research on atrazine and GS15329, applied at rates of 2.2 and 4.5 kg/ha on Hagerstown silty clay loam on a 14 percent slope with corn planted, it was found that over eight times more atrazine was lost in runoff then on the sediment at the lower rate of application, and over four times more at the higher rate (Hall et al., 1972). Kearny (1972) found much higher losses of 2,4-D, 2,4,5-T, and picloram in runoff water than with the sediments. In Iowa, Ritter et al. (1974) found that most atrazine loss was in the water fraction. Studies in Georgia showed that pesticide loss was related to initial rainfall abstraction and infiltration as well as soil loss (Bailey et al., 1974). In another study in Georgia, the quantities of atrazine, 2,4-D, and trifluralin lost in the dissolved phase in runoff greatly exceeded the losses adsorbed to sediment, especially in the first runoff after pesticide application (Smith et al., 1978).

In winter, when soil losses are generally small, losses of weakly adsorbed inorganic nutrients tend to be high (Harms et al., 1974; Schreiber et al., 1976). Presumably nutrients leach out of plant residues that have been frozen over the winter (Martin et al., 1970; White, 1973; Timmons et al., 1968). Snowmelt events are normally of longer duration than rainfall events with the same quantity of runoff. For snowmelt events, therefore, more time is available for nutrients to leach from plant material into the melt water.

Solutes in subsurface waters exhibit different behavior than those in surface flow. Transport of substances in the soil matrix is slow relative to surface flow, allowing equilibrium between the dissolved and adsorbed phases. The literature indicates that moderately adsorbed pesticides do not, in general, leach below the root zone, particularly if precipitation is moderate to low, soil permeability is low, and temperature is conducive to biological activity. In a report by Hague and Freed (1974), pesticides were found to move downward no more than 50 cm in a loam soil at 25 °C under simulated annual rainfall of 150 cm. The greater danger of pesticide pollution in base or interflow is from very weakly adsorbed pesticides such as aldicarb (Porter, 1977). In situations where nutrients percolate to the
groundwater, their effect on groundwater quality must take into account existing natural (due to geologic processes) levels of the nutrients in the groundwater.

SWCP’s which control volume of runoff water will be the most effective in controlling moderately adsorbed pesticides. Any practice that reduces runoff by increasing infiltration should ultimately reduce loss of moderately adsorbed pesticides. If the pesticides listed in Group B in Table 3(a) infiltrated into the soil, they would typically degrade before they reached the groundwater. Therefore, a practice such as terracing could significantly reduce loss of moderately adsorbed pesticides. The loss should drop in proportion to the reduction in runoff.

Contour strip cropping and sod-based rotations seem well suited for control of pesticides because they reduce both overland runoff and the quantity of pesticide required. Minimum tillage could increase total net loss of moderately adsorbed pesticides because runoff may not be decreased as much as pesticide use is increased.

SUBSTANCES NOT ADSORBED TO SOIL PARTICLES

Non-adsorbed substance losses in direct surface runoff are minor. Nitrate contributions to surface waters by base and interflow are at least five times as high as direct overland flow contributions in humid regions (Jackson et al., 1973; Campbell, 1976; Booram and Asmussen, 1976). Soluble substances are found in very low quantities from small plots where direct overland flow accounts for all surface runoff. In larger areas, interflow and base flow, which can transport significant amounts of nitrates and other soluble substances, may emerge as surface flow and contribute to the surface flow pollutant load (Beasley, 1976; Chichester, 1976).

Nitrate is the major potential soluble water pollutant in humid regions. In general, any of the SWCP’s that increase infiltration may increase loss of nitrate to surface or groundwater. However, some practices increase infiltration by improving crop cover. These practices might increase evapotranspiration and nitrate uptake by plants enough to offset increased infiltration. None of the SWCP’s listed in Table 2 are obvious candidates for nitrate control. In fact, tile drainage would probably increase nitrate losses to surface water while terraces would increase losses to groundwater.

SUMMARY AND CONCLUSIONS

The effects of all the management practices discussed above on loss of pollutants (by group) are summarized in Table 5. These results are a collation of the findings and analysis of many published studies.

Strongly adsorbed pesticides and nutrients are controlled by SWCP’s inasmuch as the practices control splash and interrill erosion and loss of clay and organic matter originating at the soil surface. Losses of moderately adsorbed pesticides, which include most commonly used pesticides, are reduced by reducing direct overland runoff. Sediment control will not effectively reduce losses of moderately adsorbed pesticides. If the background levels of phosphate in groundwater are low, then reduction of surface flow by SWCP’s should reduce phosphate loss to surface water. None of the SWCP’s considered would be likely to reduce nitrate loss.

Some SWCP’s could have detrimental effects on water quality. Those practices that increase infiltration without increasing evapotranspiration or nutrient uptake will increase nitrate loss. Practices that increase surface residues have been found to increase phosphate levels in snowmelt runoff. Required increased inputs of pesticides or nutrients for adoption of some practices, such as minimum tillage, might easily offset the advantages of the on-field control of these pesticides. Table 6 lists some of the accompanying factors inherent in several SWCP’s that could adversely affect ultimate water quality.

The purpose behind categorization of pollutants is to allow a logical means of determining which, if any, management practice would effectively control a given pollutant. Problems occur within this categorization, when chemicals change their absorption behavior as they degrade or are transformed.

References

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