Controlling Flooding and Water Pollution with Upland and Streamside Vegetation Systems

Michael Dosskey

U.S. National Agroforestry Center

Substantial research and development effort in the U.S. is being spent on developing strategies that address flooding and water pollution problems in agricultural areas. Concerns have been raised about the costs of flood damage, degradation of productive farm land, and declining water quality that are now recognized as unintended consequences of intensive, high-yield agricultural methods. These concerns have brought into question our ability to maintain future capacity for producing food and clean water. The focus of research and development has been to look for ways to lessen these environmental problems while maintaining high production.

A prominent strategy has been developed that uses special vegetation systems, called "vegetative buffers", to reduce water runoff, stabilize soil, and filter pollutants from runoff water. When used extensively within watersheds, vegetative buffers can help reduce flooding and erosion, and improve water quality in streams and rivers. Vegetative buffers can be used alone, but can achieve even greater effectiveness when used in combination with adjusted farming methods. This paper discusses our experience with using vegetative buffers to lessen flooding, erosion, and water pollution on farmland in the U.S.

Unintended Consequences of High-Yield Agricultural Methods

Intensive agricultural methods have been devised and refined over many years that have enabled U.S. farms to be among the most productive in the world. Intensive agriculture systems typically utilize tillage to control weeds and provide suitable soil conditions for planting and seed germination. Fertilizers are applied to enhance crop growth. Pesticides are applied to further suppress weeds, and to prevent losses to insects and diseases. In wet areas, drainage improvements are constructed, such as ditches and subsurface pipes, to quickly convey excess rainwater away from crop fields to streams. In drier regions, irrigation water is applied in measure to supplement crop needs.

Unfortunately, widespread use of these intensive agricultural methods also set the stage for subsequent environmental problems. Tillage has reduced the capability of soils to infiltrate rainwater causing greater amounts of rainwater to runoff quickly to streams. Tillage also reduces soil cohesion and exposes soil to the erosive force of rainfall and runoff which contributes to rapid erosion of productive topsoil. Fertilizers and pesticides are also exposed to rainfall and are washed from fields along with the topsoil. Over-application of irrigation water can create the same problems as rainfall.

Consequences of intensive agricultural methods include more-frequent floods, field soil and stream bank erosion, and water pollution. Broader problems for agriculture include loss of productive streamside farmland and reduced productivity of remaining land because of topsoil loss. Downstream problems include sedimentation of water storage reservoirs, declining drinking water quality, and low fish populations. In some regions, lower rate of groundwater recharge leads to reduced streamflow during dry periods.

These problems are a particular concern in the central U.S. farming region, where intensive farming covers a very high proportion of the land area. In this region, the climate and soils of this region are particularly well-suited to high-yield, intensive agriculture. This region contains the most productive agricultural land in the U.S. Our concern is that without some change to agricultural methods, the high productivity of these lands may not be sustainable, putting our food production systems at risk.

Using Vegetative Buffers to Protect Soil and Water Resources

We now recognize the critical need to protect soil and water resources in agricultural areas. Our approach is to seek a balance between methods that protect soil and water and the methods that enable high-yield crop production.

A major advance in this endeavor has been the development of vegetative buffer technology. Vegetative buffers are strips of permanent vegetation strategically located in and around farm plots. Vegetative buffers may be installed at field margins, between fields and streams, or within cultivated field plots, depending upon local conditions. They work by stabilizing soil and improving its structure, promoting water infiltration, retarding runoff flow, and by trapping sediments and other chemicals from the runoff water. Vegetative buffers may also remove nutrients from shallow groundwater that interacts with surface soils and plant roots. If employed extensively throughout a watershed, vegetative buffers can significantly reduce peak flooding and the amount of sediment and pollutants in stream water. Vegetative buffers are now being widely installed in U.S. farming regions.

Vegetative buffers take many forms. Basic forms include grass hedges, contour buffers, grassed waterways, filter strips, and forest buffers. Each of these basic forms is designed to be employed in a different situation, but all of them function to protect soil and water resources. For example, grass hedges and contour buffers are placed within fields to reduce water runoff and soil erosion. Grassed waterways are employed to convey water runoff from fields while protecting the soil from gully erosion. Filter strips act as infiltration zones and sediment filters. Forest buffers serve multiple purposes-as filter strips, and to protect stream banks from erosion by streams. In the U.S., forest buffers are also values highly for their ability to enhance stream habitat for fish and other desirable aquatic animals.

Four Elements of Design for Effective Vegetative Buffers

Vegetative buffers must be carefully designed in order for them to achieve a high level of effectiveness. Important considerations are location, size, vegetation composition, and maintenance of each vegetative buffer.

Location: Buffers work only if they intercept runoff water. They must be placed downhill from cultivated areas. They can be placed within fields to break up long distances of unrestricted water flow across fields; along the bottom of field swales where water flow converges as it moves toward streams and ditches; along the downhill margins of field areas; and along streams and ditches-anywhere that field runoff water may flow before entering a stream. The effectiveness of vegetative buffers on stream water will be limited if most runoff flow bypass the buffers in ditches, gullies, and pipes.

Size: The right amount of area to maintain in permanent vegetation must properly balance soil and water protection with the need for high crop production. In the U.S., recommended proportions of farm land to maintain in vegetative buffers generally fall into the range of 3 – 10 percent. Below 3% there may be unacceptably small benefit, and above 10% there is likely to be a low marginal benefit to increasing size. Among the basic kinds of vegetative buffers, strips of grass hedges typically are designed to be about 1 – 2 m wide; contour buffers and grassed waterways about 5 – 10 m wide; filter strips range from 10 – 30 m; and forest buffers often are 30 – 90 m wide. Larger sizes are recommended where high runoff loads occur, where fertilizer nutrient control is a priority goal, or where an overall greater level of control is desired.

Vegetation Composition: Selection of the proper vegetation type for the buffer area is critical to obtain desired runoff and pollution control functions. Tall, stiff grasses and forbs are recommended for use in hedges, contour buffers, and filter strips. Grassed waterways are composed of low growing grasses that enable rapid conveyance of excess water, but taller grasses may enhance their pollutant trapping benefits. Forest buffers contain shrubs and trees, but also have a health ground cover of grasses and forbs.

A useful model for a streamside buffer combines a forest strip close to the stream with a grass filter strip adjacent to the agricultural field. In this design, this dense grass the filter strip is better able to slow and disperse field runoff flow while and the forest vegetation is better able to stabilize and protect the area adjacent to the stream.

Selection of species may be important. The vegetation can be composed of plants that produce alternative crops such as forage, fruits and nuts, spices, fuel wood, or high quality lumber. The most important quality is that they be perennial plants. For streamside buffers, consideration of site moisture and flooding conditions is critical to select the proper species that will survive and thrive there. In some locations, the hydrology of a streamside area may be so altered that species of trees and shrubs that would naturally occur there may no longer be suitable. This can happen in areas where receding groundwater no longer supports the base flow required by water-loving plants during dry periods.

Maintenance: Vegetative buffers will lose their effectiveness if not properly maintained. Vegetative buffers work best when runoff water flow is dispersed evenly over the entire buffer area. Sediment accumulations can bury portions of a buffer and divert runoff water to rills and gullies. Sediment removal and smoothing of the buffer is necessary to maintain dispersed water flow. Accumulating nutrients in the vegetation may slow subsequent plant uptake. Periodic harvest of buffer vegetation may be required to maintain vigorous new growth and nutrient uptake.

Synergy Between Vegetative Buffers and Conservation Farming Methods

The efficiency of vegetative buffers is greater where field runoff loads are smaller and well-dispersed. Employing farming practices that reduce runoff load and disperse runoff flow will enable new vegetative buffers to work better and require less frequent maintenance. Complementary farming practices include residue management and reduced tillage that help protect the soil from erosion, improve soil structure and cohesion, and promote runoff infiltration. Nutrient management that limits fertilizer inputs to the amount needed only by the soil and crop will reduce the amount exposed to runoff. Similarly, integrated pest management will limit the amount of pesticide applied and expose to runoff. Contour tillage practices and other subtle land shaping practices can be employed discourage concentrated runoff flows into vegetative buffers. The benefits of vegetative buffers can be even greater when combined with conservation farming practices.

Create Balance Between Crop Production and Resource Protection

Vegetative buffers are now viewed in the U.S. as an important component of sustainable agriculture. Their primary role is to function for the protection of soil and water resources. Their strategic application on U.S. farmlands can improve environmental conditions while allowing for high-yield crop production.