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USE OF A LEVEL SPREADER TO ENHANCE INTERFLOW AND DELAY TIME TO PEAK IN A FORESTED FILTER ZONE

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The effectiveness of a modified level spreader to enhance interflow and delay time to peak was analyzed in a 0.2 ha. forested filter zone (FFZ). The level spreader was constructed on the contour to disperse storm flow uniformly across the upper edge of the FFZ. H-flumes were installed at the upper and lower edges of the FFZ. Stage height in the flume was measured with a float-driven potentiometer monitored by a data logger. The irrigated runoff was alternatively dispersed and concentrated under three soil moisture conditions - saturated, field capacity, and dry. Hydrograph analyses were performed to estimate interflow and time to peak. Dispersed flow considerably increased interflow and delayed time to peak at the lower flume even under saturated soil moisture conditions. The effectiveness of the dispersed flow increased as soil moisture content in the FFZ decreased.

INTRODUCTION

A forested filter zone (FFZ) is one of the most effective landscape features for improving interflow and reducing peak flow rate. In a FFZ, litter fall and surface roots increase hydraulic roughness and the organic matter from their decomposition binds both the litter layer and mineral soil. Forest debris along slope contours also significantly reduces peak flow rate and enhances water detention storage. In addition, the dense understory vegetation common in most FFZs increases turbulent flow to substantially reduce peak flow rate. Intensive and extensive root development promote soil porosity for deep percolation of water as well as interflow.

The development of interflow and turbulence is crucial to reduce the overland flow velocity and to delay time to peak in a FFZ. A small decrease in flow velocity can cause significant increases in sediment deposition because the sediment carrying capacity of runoff is proportional to the fifth power of the velocity (Alberts et al., 1981). However, flow velocity (rate) increases with drainage density (ratio of total hydraulic length of the flow channel to the area of the FFZ) because flow velocity is directly proportional to the hydraulic radius (ratio of cross sectional area of the channel to wetted perimeters) of the flow channels. In a recent study, conducted at the Oxford Tobacco Research Station in Granville County, North Carolina, Rajbhandari et al. (1998) found that when runoff is dispersed across the contour at the upper portion of a FFZ, it can significantly increase runoff reduction capacity and reduce peak flow rate over a wide range of soil moisture conditions. They found that the dispersed flow also functioned well where the drainage density was low. In this paper, as a continuation of that study, the effects of lateral dispersion on interflow and delayed time to peak are further evaluated.

MATERIALS AND METHODS

An agricultural watershed at the Oxford Tobacco Research Station in Granville County, North Carolina was utilized for this study. The watershed contained an upland agricultural field with a grass-vegetated waterway at the down slope edge and a FFZ below that. The FFZ was dissected by a main water channel with several side channels and received surface runoff drained from adjoining fields via grassed waterways (Figure 1). The physical characteristics of the FFZ are presented in Table 1.

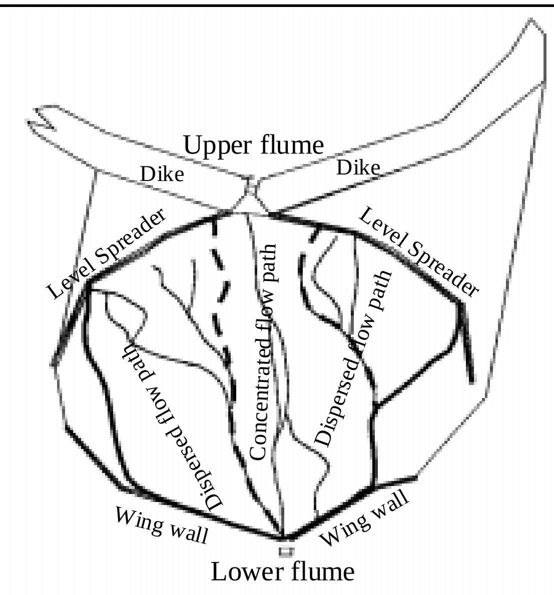

Figure 1. Schematic of the forested filter zone at Granville County, North Carolina (not to scale).

Table 1. Physical Dimensions of the Forested Filter Zone (FFZ) at the Oxford Tobacco Research Station, Granville County, North Carolina

Dimensions	FFZ
Forested filter zone area (ha)	0.12
Average slope of filter zone (%)	4.00
Average slope of grass pathway (%)	4.00
Maximum length of filter zone (m)	30.50
Maximum width of filter zone (m)	54.90
Average width of grass path (m)	17.00
Drainage density (m/ha)	5820.00

Soil in the FFZ consisted of Helena loamy sand (*Aquic hapludult, clayey, mixed, thermic*). The principal overstory species were loblolly pine (*Pinus taeda* L.), and white oak (*Quercus alba* L.) with an average diameter at breast height of 37.5 centimeters and average basal area of 11.2 square meters per hectare.

A level spreader was constructed on the contour to disperse storm flow uniformly across the upper edge of the FFZ. The level spreaders were a modified form of those described by Smolen et al. (1993), who originally recommended that level spreaders be constructed with soil, protected by an erosion-resistant material at the lip and stabilized with vegetation. Our modified level spreaders were made of wooden troughs extended on contour to ensure precise flow control. The level spreaders could be precisely situated and were easily cleaned of debris. A distribution box was constructed at the mouth of the natural ephemeral channel in each watershed to control water through the FFZ in either concentrated (direct) flow or flow dispersed through the spreader.

Two berms constructed at the downslope edge of each field channeled the runoff into a 61 cm H-flume (upper flume) for measuring flow. Stage height in the flume was measured with a float-driven potentiometer monitored by a Campbell CR-10 (Logan, Utah) data logger. Two wooden wing walls were constructed on either side of the natural topographic drainage at the downslope edge of each FFZ to channel runoff into a second H-flume (lower flume) for measurements of runoff through the FFZ. Plywood cutoff walls in both the field-edge berms and the FFZ wing walls intercepted overland flow and near-surface interflow. A base flow separation line method, as suggested by Barnes (1939), was used to estimate the total amount of interflow.

A standard hydrograph was designed according to Rajbhandari (1995) for generating irrigated runoff events. The hydrograph was designed for a one-year return period storm event with a total estimated rainfall of approximately 51 mm. For each flow mode, one irrigation event was performed at each of three levels of soil moisture status: near saturated (0.25 bars), field capacity (>0.25 and 0.35 bars), and nearly dry (>0.35 bars). A comparison between dispersed flow and concentrated flow in each soil moisture condition was then drawn by observing proportional changes in interflow and time to peak at the lower flume.

In this study, interflow is defined as that part of the runoff which flows in the upper horizon of the soil profile (near sub-surface flow). Time to peak is the time interval between the time of flow initiation and the time at the peak. Delayed time to peak is the time difference between the peak flow rates at the upper and lower flumes. Since flow velocity is inversely proportional to the flow travel time, a delayed time to peak indicates a reduction of overland flow velocity.

RESULT AND DISCUSSION

Interflow

As compared with concentrated flow, interflow was nearly five times greater under dispersed flow condition than with concentrated flow (Figure 2). When soil conditions were at their driest there was more than twice the amount of interflow as compared to the moister soil conditions for both the concentrated and dispersed flow. The contrasting performance of the two modes of dispersion could be due to the fact that concentrated flow moved mostly through channels (Figure 1). Interill flow (overland flow between channels) was limited to the concentrated flow areas only. Dispersed flow activated interill flow throughout the area and, hence, it could yield comparatively greater amounts of interflow.

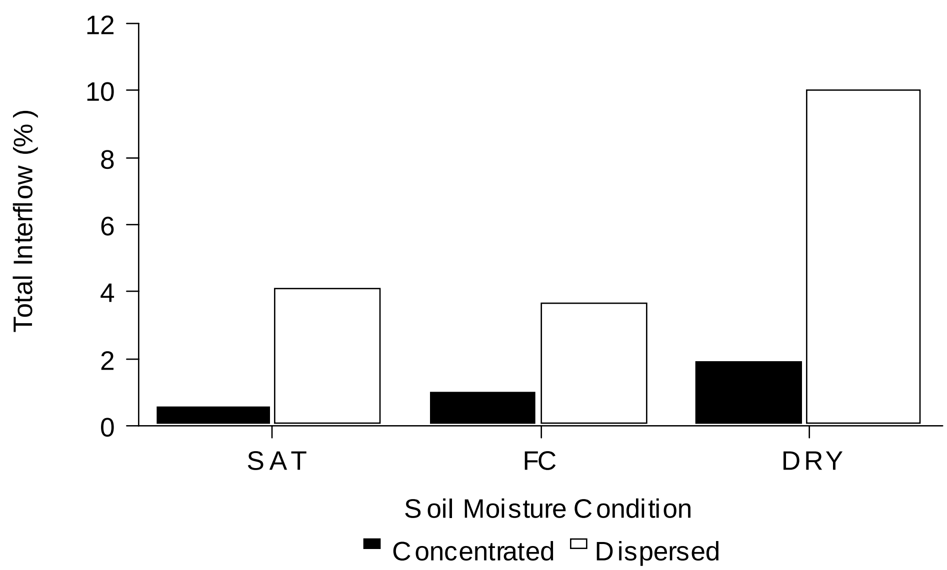

Figure 2. A comparison of dispersed and concentrated interflows under different soil moisture conditions: saturated (SAT), field capacity (FC), and dry (DRY) in the forested filter zone.

The interflow yielded by the FFZ in this study was comparatively very small (3 percent to 6 percent). However, Schellinger and Clausen (1992) obtained a 27 percent interflow when routing barnyard runoff over a grassed filter zone (GFZ). Such large differences may be due to the fact that the GFZ in their study was constructed with a 2 percent slope and with no channel flow system, whereas the FFZ in this study was selected from a watershed that had 4 percent slope and a definite channel flow system. The drainage density in the FFZ was estimated at 5820 m/ha (Table 1).

Delayed Time to Peak

Dispersed flow substantially delayed time to peak in the FFZ under all soil moisture conditions except when soil moisture was at field capacity (Figure 3). The lack of difference between the two modes of dispersion during the field capacity condition may have been due to an accumulation of forest floor materials in the channels. The two irrigation events at this soil moisture content were

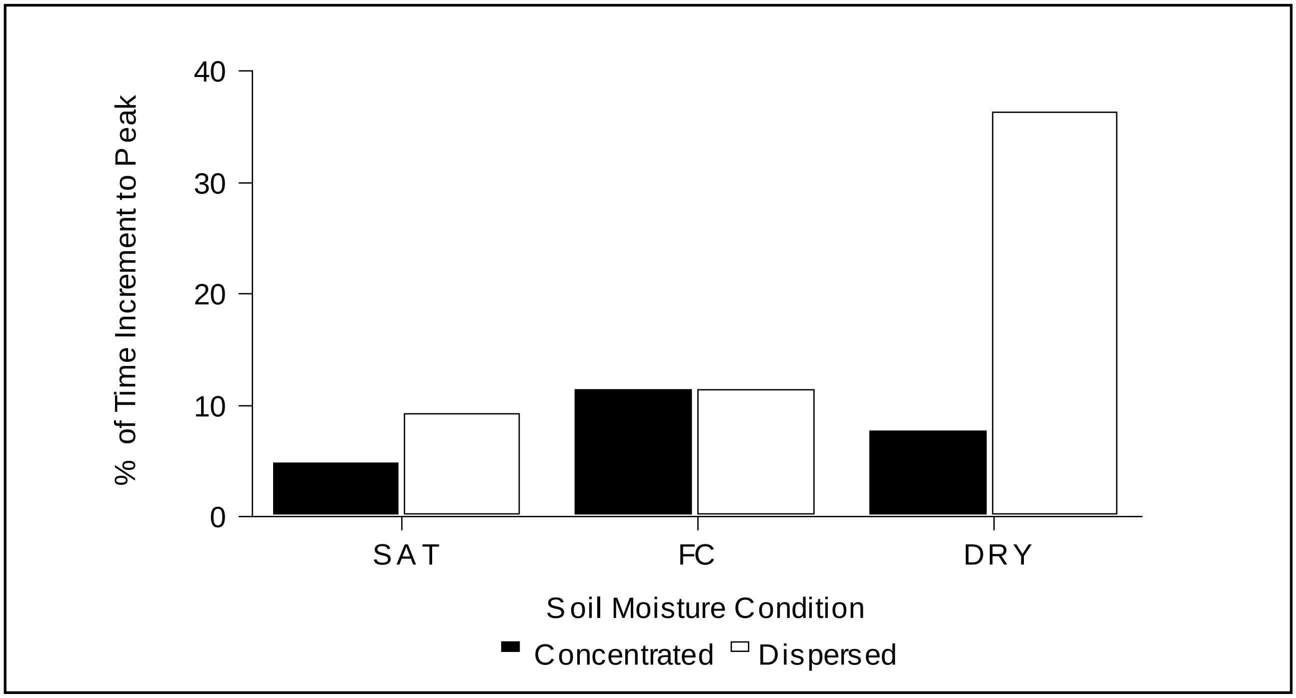

Figure 3. Effect of two modes of dispersion and different soil moisture conditions on time to peak in the forested filter zone.

conducted during mid-November when recent litter accumulations were at a maximum (from field records). However, there was a clear trend that the difference between the two modes of dispersion substantially increased as soil moisture decreased. This finding supports the general concept that as the soil moisture tends to saturation, rates of infiltration and interflow will decrease and rates of overland flow rate (flow velocity) will increase. Interestingly, in this FFZ, rapid interflow, as suggested by Gillham and Abdul (1986), Bonell et al. (1984), and Gilman and Newson (1980), was never found. The details of the hydrograph analysis for this and a number of related studies at this FFZ were well documented in Rajbhandari (1995).

CONCLUSIONS

Dispersed flow considerably increased interflow and delayed time to peak even under saturated soil moisture conditions. The effectiveness of the dispersed flow for increasing interflow and delaying time to peak increased as soil moisture content in the FFZ decreased. The use of a level spreader above the FFZ can play a significant role in reducing flow velocity, thus enhancing sediment deposition in all soil moisture conditions.

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