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Managing erosion and water quality in agricultural watersheds by small detention ponds

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Abstract

Terrace-contouring systems with on-site water detention cannot be installed in areas of complex topography, small parceling and multi-blade moldboard plow use. However, field borders at the downslope end may be raised at the deepest part where runoff overtops to create detention ponds, which can be drained by subsurface tile outlets and act similar to terrace-contouring systems. Four of such detention ponds were monitored over 8 years. Monitored effects included the prevention of linear erosion down slope, the sediment trapping from upslope, the enrichment of major nutrients in the trapped and delivered sediments, the amount of runoff retained temporarily, the amount of runoff reduced by infiltration, the decrease in peak runoff rate and the decrease in peak concentrations of agrochemicals due to the mixing of different volumes of water within the detention ponds. The detention ponds had a volume of 30–260 m^3 ha^{-1} and trapped 54–85% of the incoming sediment, which was insignificantly to slightly depleted (5–25%) in organic carbon, phosphorus, nitrogen and clay as compared to the eroding topsoil, while the delivered sediment was strongly enriched (+70–270%) but part of this enrichment already resulted from the enrichment of soil loss. The detention ponds temporarily stored 200–500 m^3 of runoff. A failure was never experienced. Due to the siltation of the pond bottom, the short filled time (1–5 days) and the small water covered area, infiltration and evaporation reduced runoff by less than 10% for large events. Peak runoff during heavy rains was lowered by a factor of three. Peak concentrations of agrochemicals (Terbutylazin) were lowered by a factor of two. The detention ponds created by raising the downslope field borders at the pour point efficiently reduced adverse erosion effects downslope the eroding site. They are cheap and can easily be created with on-farm machinery. Their efficiency is improved where they are combined with an on-site erosion control like mulch tillage because sediment and runoff input are reduced. Ponds had to be dredged only after the first year when on-site erosion control was not fully effective.

Keywords: Detention ponds; Sedimentation; Flood control; Pesticide; Nutrient enrichment

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1. Introduction

Storm water detention and retention ponds or basins (referred to as detention ponds in this paper) are common features in storm water management, to retain storm runoff for a certain time and to reduce peak discharge to a level that is bearable for the drainage system (Verstraeten and Poesen, 1999). Besides the reduction of peak runoff rates, there are several additional purposes, like sediment trapping, prevention of downstream linear erosion, or water quality management, which have been addressed in a variety of detention pond sizes, constructions and storage strategies.

In agricultural areas (dry) detention ponds, which typically hold water only during storms, are used to protect infrastructure and private properties from flooding and damages by muddy floods (Boardman et al., 2003; Verstraeten and Poesen, 1999, 2000). These ponds compensate on-site erosion in the fields, but create high costs for construction, area and maintenance. Especially regular dredging is cost intensive (Boardman et al., 2003). The size of these ponds, for example, in Central Belgium, where they are widely established, reaches volumes of several thousands of m^3 (Verstraeten and Poesen, 1999). Besides these flood protection measures, ponds are also constructed to treat agricultural runoff (Rushton and Bahk, 2001). These ponds typically maintain a permanent pool of water between storms to improve water quality by the settling of suspended solids and sediment bound substances.

A similar strategy but with completely different dimensions and layout are terrace-contouring systems with temporary water storage behind the terraces and a controlled, dampened drainage by underground tile outlets (Schwab et al., 1993). This system catches runoff shortly after the source area. Hence, only small volumes of water have to be retained behind each length unit of terrace, which causes little construction costs. A major advantage is that the retention area can still be farmed because water storage will only be shallow and occur during short periods of time, which will not be harmful to the crops as long as sediment input is reduced by additional on-site erosion control measures like mulching. This strategy, however, requires that field layout can be adapted to the landscape morphology. This is only possible in slightly undulated landscapes with large fields. This type of runoff control can hence be widely found in US American and in Australian agriculture, while it cannot be applied in areas where the land is owned by many farmers and with a steep and complex morphology as it is found in Middle Europe and many other areas in the world. In these cases, field borders running perpendicular to the main slope may be reshaped to serve similar purposes as the terrace-contouring systems.

This study investigates the performance of such small dry detention ponds (220–490 m^3 in size) established at field borders along the drainage ways of hill slopes. The objectives were to evaluate: (i) the on-site effects on linear erosion in the down slope fields; (ii) the trapping efficiency of sediments and sediment bound pollutants; (iii) the reduction of runoff volumes and peak runoff rates coming from the fields; and (iv) the reduction of peak concentrations of water soluble pollutants by water mixing in the ponds.

2. Materials and methods

2.1. Test site

The test site was part of the Scheyern Experimental Farm of the Munich Research Association for Agricultural Ecosystems (FAM), which is located about 40 km north of Munich. The area is part of the Tertiary hills, an important agricultural landscape in central Europe. The test site covered approximately 22 ha of arable land at an altitude of 461–486 m a.s.1. (48°30′50″ N, 11°26′30″ E). The mean annual air temperature was 8.4 °C (for 1993–2001). The average precipitation per year was 834 mm (for 1993–2001) with the highest precipitation occurring from May to July (average maximum 106 mm in July) and the lowest occurring in the autumn and winter months (average minimum 29 mm in October).

The test site consisted of four small adjacent watersheds 1.6–7.8 ha in size (Table 1). The management in the fields followed the principles of integrated farming in combination with an intensive soil conservation system (mulch tillage) (Auerswald et al., 2000). Field sizes ranged from 1.9 to 6.5 ha. The crop rotation consisted of potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.),