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Goodwin Creek Experimental Watershed – Effect of Conservation Practices on Sediment Load

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Abstract. *The Goodwin Creek Experimental Watershed, a benchmark watershed in the USDA-ARS Conservation Effects Assessment Project (CEAP), drains 2132 ha in the north central part of the state of Mississippi, USA. The watershed is characterized as having high sediment yield (13.2 t/ha/yr) and unstable channel substrate and banks. The effectiveness of management practices applied to the watershed will be evaluated as part of CEAP, and new practices and strategies for continued reduction in sediment loading will be explored using watershed computational models.*

Land use on the watershed has changed from 26 to 6 percent cultivated with corresponding increases in timber (26-38%) and pasture (48-55%) lands over the period of record. Annual concentrations of sediment have decreased from about 5000 ppmw in 1982 to about 2000 ppmw at the present. Sediment source tracking using naturally occurring radionuclides has indicated that channel processes are one of the main sources of sediment to the streams of the watershed. In addition to the reduction in sediment, a significant reduction has occurred in the relation between runoff and precipitation in the first part (April-July) of the land use year.

Simulations using AnnAGNPS have been shown to favorably compare to the relative trends of the measured rates of runoff and sediment concentration except for periods of cultivation on agricultural lands. Enhancements or applications with advanced channel erosion models are needed to better reflect ephemeral gully and channel erosion.

Keywords. experimental watershed, Conservation Effects Assessment Project (CEAP), water quality, conservation practices, sediment transport, channel-evolution models.

Introduction

The Goodwin Creek Experimental Watershed (GCEW) is a major research watershed of the Agricultural Research Service (ARS) and one of 12 benchmark watersheds of the Conservation Effects Assessment Project (CEAP), a cooperative project of the ARS and Natural Resources Conservation Service (NRCS). The principal focus of the CEAP effort is to produce an assessment of environmental effects and benefits derived from implementing USDA conservation programs. This study is a first cut at the analysis of the effect of conservation practices on the quality of the water in the channels of the GCEW. The results derived from measured data on the watershed will be considered first. This will be followed by a consideration of the accuracy of model simulations to reproduce the measurements of runoff and sediment loadings.

Goodwin Creek Watershed

The watershed is located in Panola County in the north central part of the state of Mississippi (Fig. 1). The 2132 ha drainage area is divided into 13 sub-watersheds which range in size from 28 to 1292 ha. Elevation ranges from 71 m (233 ft) to 128 m (420 ft) above sea level, with an average channel slope of 0.004. Average daily temperatures are 30^{o} C in summer and 10^{o} C in winter.

The soils on the watershed consist of two major associations. The Collins-Falaya-Grenada-Calloway association is mapped in the terrace and flood plain locations. These soils are poorly to moderately well drained and include much of the cultivated area in the watershed. The other soil association, the Loring-Grenada-Memphis association, is developed on the loess ridges and hillsides. These soils are moderately well to well drained on gently sloping to very steep

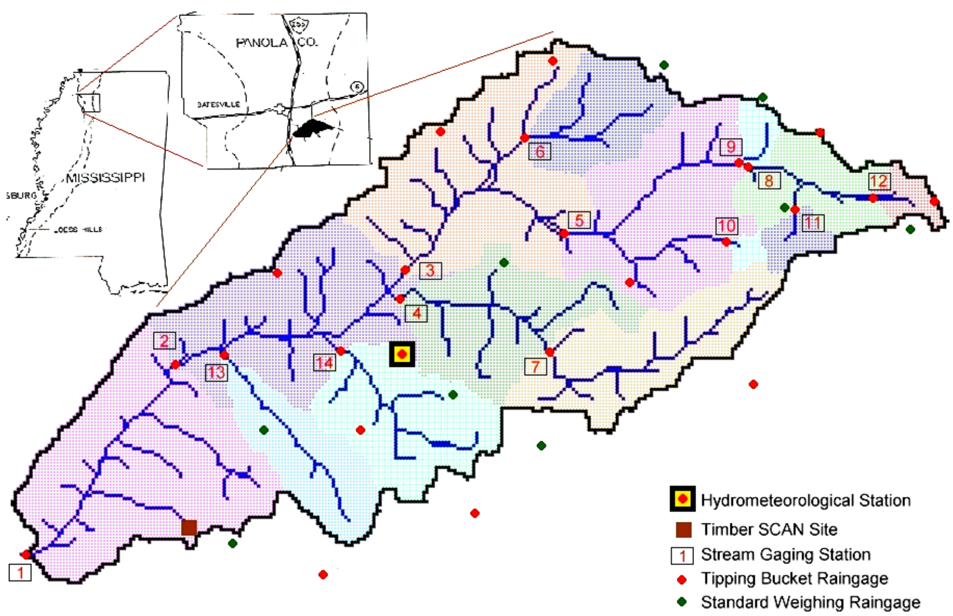

Figure 1. Goodwin Creek Experimental Watershed, Panola County, Mississippi.

surfaces and include most of the pasture and wooded area of the watershed. The soils are silty in texture and easily eroded when the vegetation cover is removed. More detailed information is provided about the watershed in Bowie and Sansom (1986) and Alonso and Bingner (2000**)**.

Land Use and Conservation Practices

Land use on GCEW has changed over the period of record of the watershed from 26 to 6 percent cultivated with corresponding increases in timber and other land use types (Fig. 2). Although there have been several types of conservation practices applied to the watershed over its history, the conversion of cultivated land to uncultivated uses, such as the conservation reserve program, are the main changes that have occurred on the watershed.

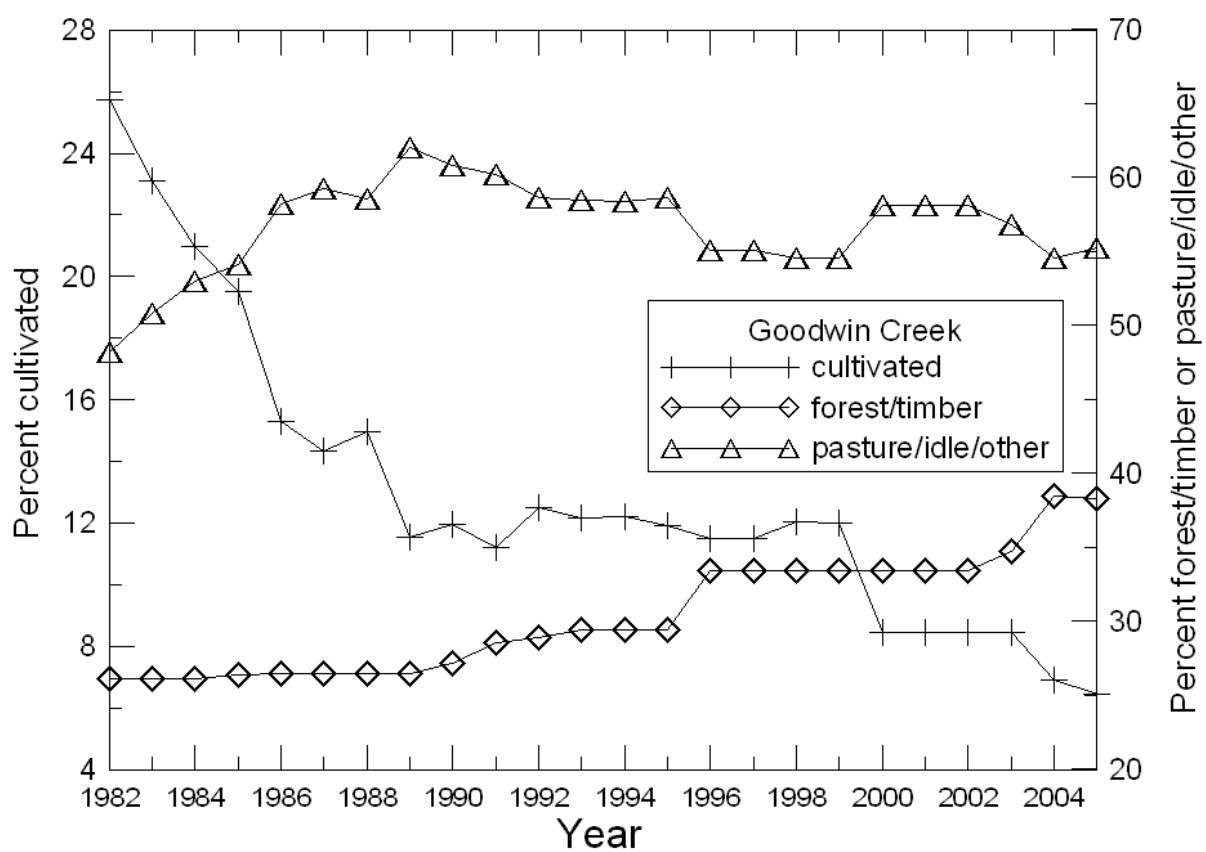

Figure 2. Change of land use with time on the GCEW.

Sediment Sources Determination

The sources of the sediment carried by the channels of the watershed are required to determine the effects of conservation practices. The channels of Goodwin Creek were highly unstable vertically before the construction of the combination supercritical measurement and grade control structures in the late 1970s and early 80s. Following the construction of the supercritical flow structures, lateral instability of the channels was still a major problem (Grissinger et al., 1991). Several indirect methods have been used to calculate sediment sources on Goodwin Creek (Grissinger et al., 1991; Kuhnle et al., 1996). These methods yielded values of 75% and 85% (Grissinger et al., 1991) and 64% and 79% (Kuhnle et al., 1996) for the fraction of fine (< 0.062 mm in diameter) and total sediment load which originated from channel sources, respectively. Recently a technique using signatures of naturally-occurring radionuclides of the sources and transported sediment has been applied successfully on the GCEW for fine sediments (Wilson and Kuhnle, 2006). This method employed a more direct measurement technique than the previous two studies and thus yielded a more defensible result. A determination that 78% of the fine sediment in the channel originated from channel sources is derived using the radionuclide signatures from samples collected during runoff events on April 22, 2004 and January 7, 2005.

Precipitation and Runoff

The pattern of precipitation on the GCEW is shown in Figure 3. The precipitation data is plotted in terms of land use years (April 1 to March 31) which correspond to the timing of agricultural practices used on the GCEW (Kuhnle et al., 1996). The land use year consists of three four-month periods which represent soil preparation and planting (April-July), tilling and harvesting (Aug-Nov), and minimal disturbance of the soil (Dec-Mar). These periods have been found to be useful to relate the runoff and sediment transport more directly to the effects of changing land use (Kuhnle et al., 1996).

Several above and below average periods of precipitation have occurred over the period of record on the GCEW (Fig. 3). It is important to take into account whether measurements were taken predominantly during periods of below or above average precipitation as the relation between sediment erosion and transport is highly non-linear and may bias a determination over whether sediment yield is increasing or decreasing at a particular site (Garbrecht, 2006).

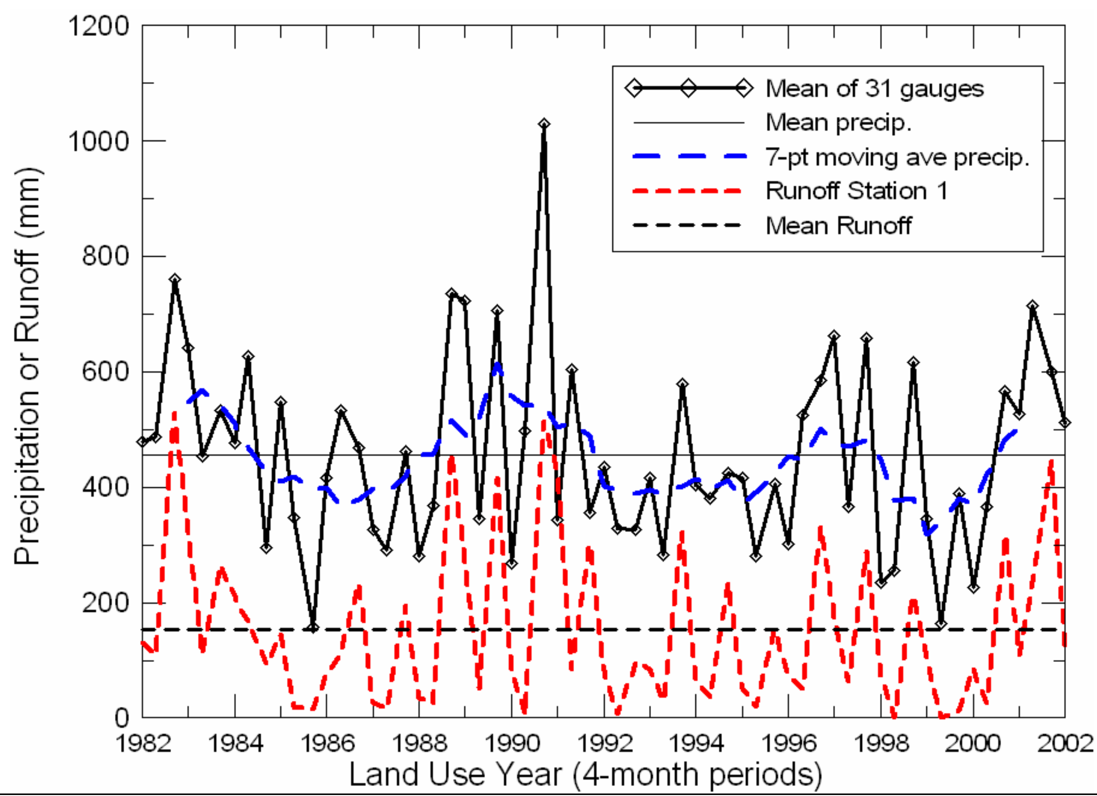

Figure 3. Mean Thiessen area weighted precipitation from 31 gauges and runoff at station 1

The relation of runoff versus precipitation has been found to change from the first part of the period of record (1982-1990) as compared to the second part (1992-2002). This difference was only present in the first period of the land use year (Apr-July). Figure 4 and Table 1 give the details of the difference in runoff for the first period of the land use year. The cause for this difference has been attributed to the change in land use between these periods. The amount of cultivated land is seen to have nearly stabilized by 1991. Presumably, the increase in forest/timber and pasture/other lands has caused the runoff to precipitation relation to change although a direct comparison between percent cultivated land and runoff to precipitation ratio yielded no evidence for a relation.

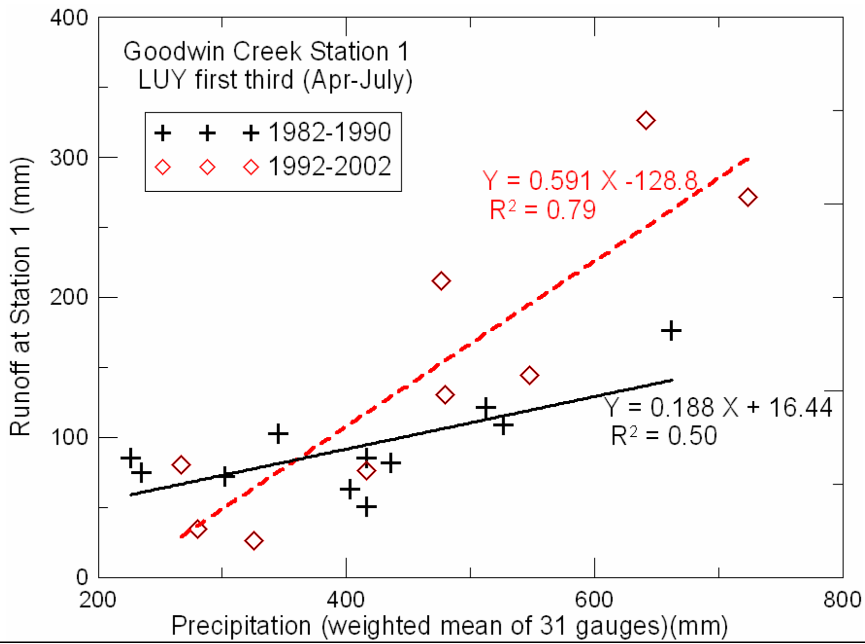

Figure 4. Runoff versus precipitation relations for 2 periods on GCEW.

Table 1. Slope, intercepts, and correlation coefficients for linear relations between runoff and precipitation for station 1 for four month periods.

Years and land use period	slope	y-intercept	R^2
1982-2001 LUY (Apr-Mar)	0.653	-430.2	0.73
1982-2001 (Apr-July)	0.427	-68.6	0.62
1982-2001 (Aug-Nov)	0.367	-92.2	0.69
1982-2001 (Dec-Mar)	0.672	-86.0	0.75
1982-1990 (Apr-July)	0.591	-128.8	0.79
1992-2002 (Apr-July)	0.188	16.44	0.50
1982-1990 (Aug-Nov)	0.409	-111.3	0.60
1992-2001 (Aug-Nov)	0.354	-86.4	0.74
1982-1990 (Dec-Mar)	0.672	-82.5	0.92
1992-2001 (Dec-Mar)	0.653	-79.7	0.41

Sediment Load

Over the period of record of the watershed large annual variations in precipitation and runoff have occurred (Fig. 3). To scale the sediment by the runoff, sediment concentration, rather than mass, was considered. The mean sediment concentration (C_{ma})(in parts per million by weight) was calculated as

$$C_{ma} = \left(\frac{Y_a}{R_a} \right) \times 10^6$$

where Y_a is the total mass of sediment moved past a given point in the channel over the time period, and R_a is the total mass of runoff measured for that period. The two primary variables measured on the watershed are sediment concentration and flow depth in the structures, which is directly related to flow discharge. The basic sediment parameter considered was sediment concentration.

Sediment concentration with time decreased appreciably from 1982 to about 1990 (Fig. 5). Concentrations decreased from 3000 to 1000 ppmw over that period and have been essentially flat from 1990 to 2002. This trend corresponds closely with the change in cultivated land use on the watershed (Fig. 2).

Simulations using AnnAGNPS

The assessment of the effects of conservation practices can be performed using the Annualized Agricultural Non-Point Source Model (AnnAGNPS) (Bingner and Theurer, 2001). The erosion engine within AnnAGNPS is based on the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997) with management described through a schedule of events that would be performed on any particular location. For GCEW, AnnAGNPS simulations were performed based on the climatic record from 1982-2002, as well as the management described through the annual landuse surveys. Based on information from NRCS, it was assumed that from 1992 to the present, reduced tillage conservation practices were implemented on cultivated areas of GCEW. This reduced tillage consisted of one cultivation per year.

Simulated sediment concentrations were compared with the measured results and show a similar trend of higher concentrations from 1982-1992, but lower concentrations afterwards (Fig. 5). If the results are analyzed seasonally by land use year thirds, sediment concentrations were much higher in the April to July portion then the others (Fig. 6). The effects of cultivation on erosion do not appear to be reflected by sheet and rill erosion only. One important feature that has been observed to occur on the watershed are areas of ephemeral gully erosion that could produce a significant amount of sediment during periods of cultivation. Enhancements to AnnAGNPS are currently being developed to account for this portion of the sediment source from the watershed. Other sediment sources include channel erosion that may describe the remaining differences in simulated and measured results.

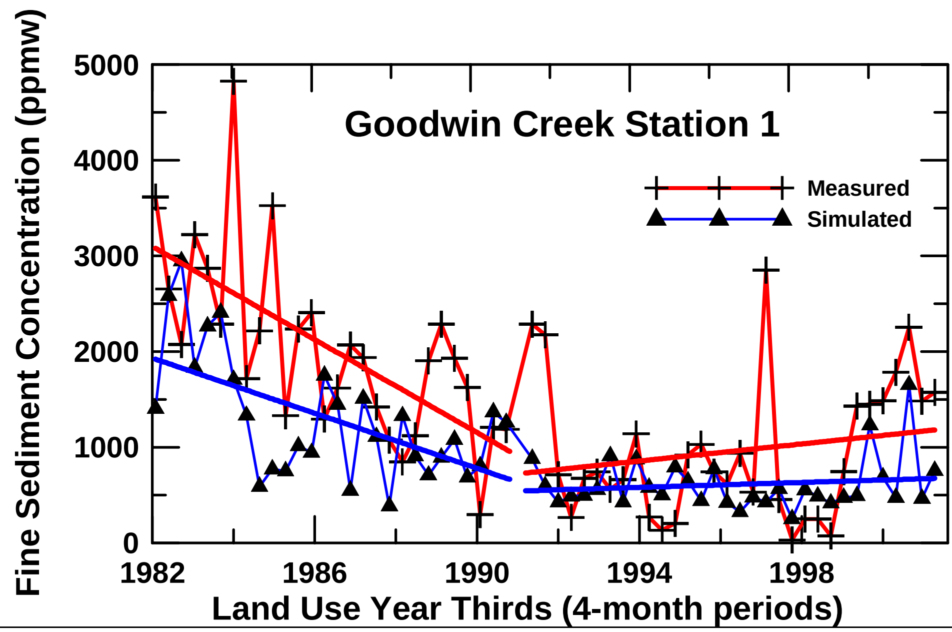

Figure 5. Fine (diameter < 0.062 mm) sediment concentration with time on GCEW. One period in 1991 was omitted because of errors with the runoff measurement.

Additional comparison between simulated and measured results show that the simulated runoff is somewhat underestimated (Fig. 7). Fine sediment simulated is also shown to be nearly 50% of the measured (Fig. 7). Additional simulations with more enhanced ephemeral gully and channel models may provide a better comparison with sediment production.

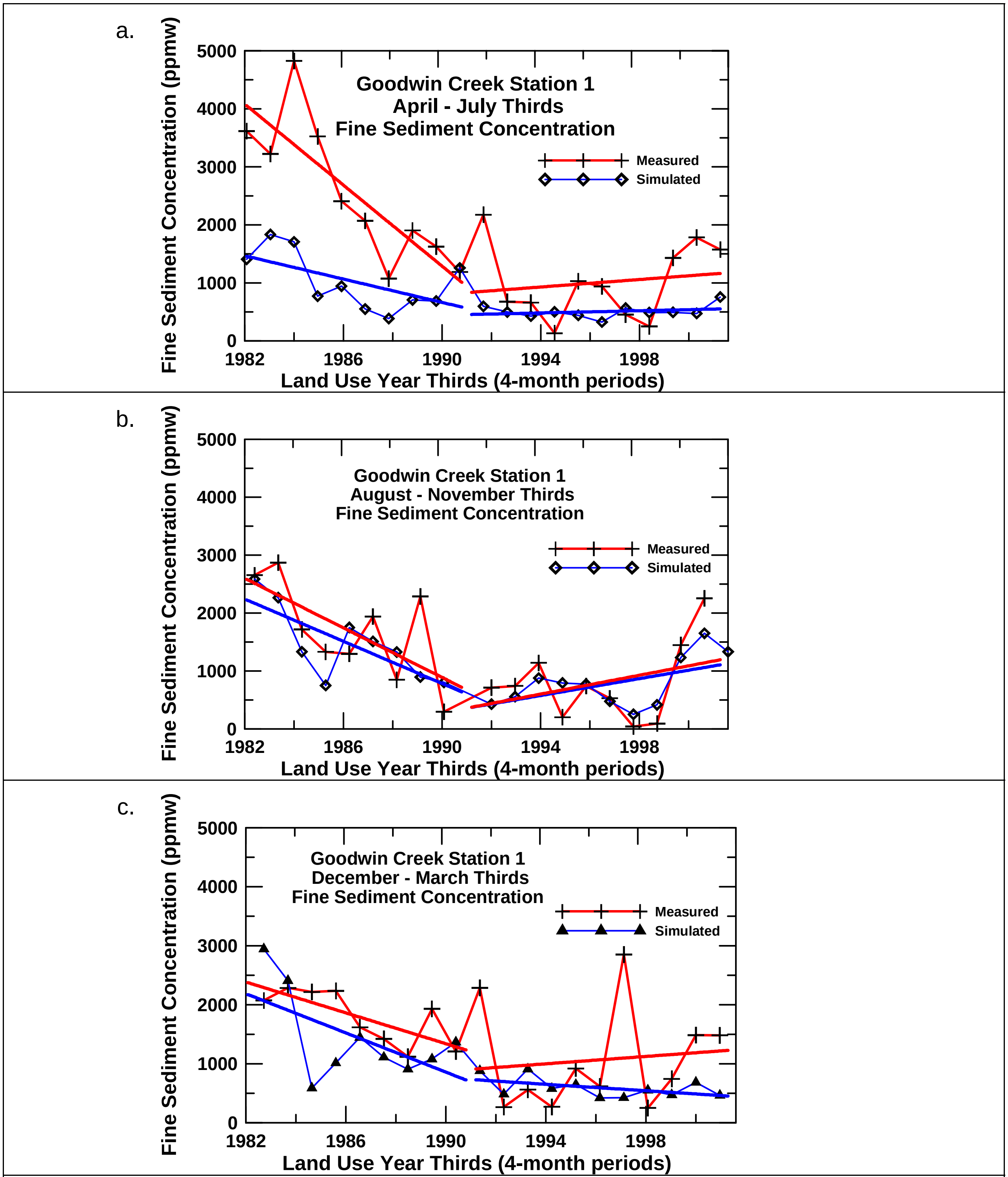

Figure 6. Fine (diameter < 0.062 mm) sediment concentration with time on GCEW as defined during April-July (a), August-November (b), and December-March (c). One period in 1991 was omitted because of errors with the runoff measurement.

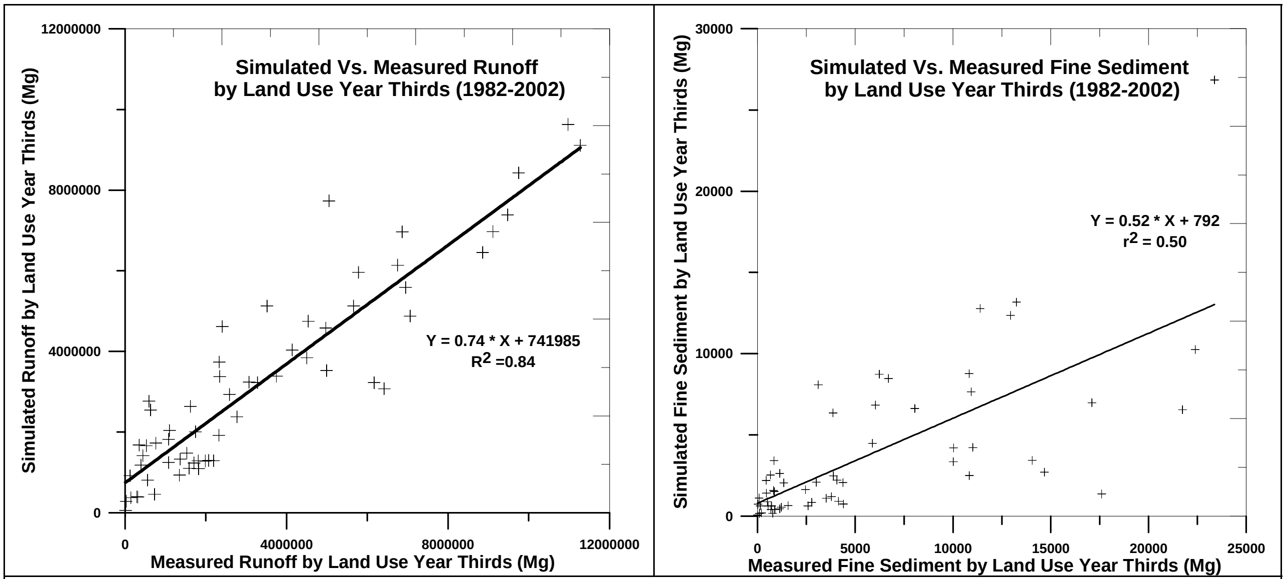

Figure 7. Comparison of simulated vs. measured runoff and fine (diameter < 0.062 mm) sediment on GCEW by land use year thirds from 1982-2002.

Conclusion

Land use on the Goodwin Creek Experimental Watershed has changed from 26 to 6 percent cultivated with corresponding increases in timber (26-38%) and pasture (48-55%) lands over the period of record. The resulting annual concentrations of sediment have decreased from about 5000 ppmw in 1982 to about 2000 ppmw at the present. Sediment source tracking using naturally occurring radionuclides has shown that channel processes are one of the main sources of sediment to the streams of the watershed. In addition to the reduction in sediment, a significant reduction has occurred in the relation between runoff and precipitation in the first part (April-July) of the land use year.

Simulations using AnnAGNPS have been shown to favorably compare to the relative trends of the measured rates of runoff and sediment concentration except for periods of cultivation on agricultural lands. Enhancements or applications with advanced channel erosion models are needed to better reflect ephemeral gully and channel erosion.

The evaluation of the effectiveness of management practices applied to the watershed is a critical component of CEAP. This information is vital in the development of conservation programs by action agencies that provide the best erosion control. New practices and strategies for continued reduction in sediment loading will need to be explored using watershed computational models. Further studies are needed to determine the sources of sediment and the processes that produce, transport and control sediment.

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