Chapter III.

Development and Design of a Soil Erosion Collection System

Abstract

A simple, low cost soil erosion collection system was designed for use with small-scale replicated field plots. The described system was easily constructed, minimally disrupted equipment traffic in the study area, and was easily moved from season to season. The system utilized the natural slope of the study site, along with raised beds in the plot area, for operation, but could be modified for application to other types of erosion studies. Collected soil was removed from the soil collection box following significant rain events, allowed to air dry, and then utilized for physical analysis. Field results indicate the adequacy of this soil collection system for distinguishing differences in erosion due to varying production systems.

Introduction

The long-term sustainability of agricultural production in the sloping piedmont region of Virginia and North Carolina is a major concern due to excessive soil loss resulting from agricultural activities (Trimble 1974). Although producers in the region readily use conservation practices, including sod waterway and terrace formation, to reduce soil erosion, Langdale *et al.* (1979) indicated a minimal reduction in the observed soil loss. Kramer (1986) indicated a balance of production and use of conservation practices for this cropland must be established and maintained for the future of agricultural production.

Flue-cured tobacco, an important crop for the Southern Piedmont region of Virginia and North Carolina, is produced using intensive tillage of the soil prior to transplanting and subsequent row cultivation at multiple intervals. Soil erosion losses resulting from the conventional production system (Wood and Worsham 1986) are excessive, but considered acceptable due to the high income generated by the crop. The development of recent social and environmental concerns regarding the crop have led to a questioning of the long-term feasibility of conventional production methods and subsequently influenced the investigation of alternative production practices which reduce soil erosion. The intensive nature of tobacco production creates unique obstacles for the quantification of erosion.

Previous studies investigating soil erosion utilized expensive recording and sampling equipment (Zöbisch *et al.* 1996) designed for long-term placement and observation. Studies such as McGregor *et al.* (1975) and Langdale *et al.* (1979) relied upon soil collection systems similar to that of Carter and Parsons (1967) consisting of FW-1 water level recorders, H-flumes and N-1 Coshocton-type wheel sampling devices. Other authors, including Albets *et al.* (1985) and Kramer (1986), reported the use of calibrated collection tanks joined by a multislot divisor flume as described by Jamison *et al.* (1968). The collection systems described above effectively quantified soil erosion and water runoff, but their design hindered use with many research studies. Their application to replicated field studies investigating numerous treatments would be expensive and their use would be difficult with field crops requiring intensive land preparation prior to crop planting and intensive management after planting (i.e. row cultivation and multiple spray applications).

As part of a conservation tillage research study with flue-cured tobacco in Virginia (Chapter IV.), a need developed for a method to quantify soil erosion from 24 small-scale replicated field plots. Study design placed constraints on the erosion collection system, which included a minimal interference with equipment traffic in the plot area, easy reproduction, minimal maintenance of components, relative low cost, and the ability to relocate the system each year as the research plot area moved in an established tobacco crop rotation sequence. Study treatments examined the impact of varying cultivation frequency on the yield, growth, quality and resulting soil erosion of tobacco transplanted into a killed rye cover crop on pre-formed beds.

Hudson (1995) reported a soil erosion research plot area of approximately 100 m^2 was appropriate for trials investigating cropping practices, cover effects and crop rotations. McGregor *et al.* (1975) quantified erosion from an area of this size while Alberts *et al.* (1985) and Kramer (1986) utilized slightly smaller plots of approximately 88 m^2. Laflen and Colvin (1981) along with Dickey *et al.* (1984) examined areas of approximately 32 m^2 while Bui and Box (1993) investigated erosion from an area of only 1 m^2. The collection area utilized for this study was approximately 15 m^2 to remain consistent with earlier tobacco erosion work conducted by Wood and Worsham (1986).

Soil erosion is a dynamic process composed primarily of rill and interrill components. Foster *et al.* (1985) indicated that rill erosion occurs in erosion or tillage created channels that subsequently become the main pathways of downslope runoff.

Sharma (1996) indicated that interrill erosion occurs from spaces in between rill areas. Smaller research plots are usually utilized for determination of interrill erosion while larger plot sizes (~100 m^2) are more effective at quantifying rill erosion. Liebenow *et al.* (1990) investigated interrill erosion using very small erosion plots (<0.38 m^2) while Bui and Box (1993) used plots of approximately (1 m^2). The soil collection system for this study quantifies both rill and interrill erosion. This plot size (14.6 m^2) is more effective at quantifying interrill erosion but the formation of pre-formed beds effectively establishes a defined rill area. Huang and Bradford (1993) indicated that interrill and rill erosion processes describe a combination of erosion processes and cannot be used as though each describe a single set of activities.

Materials and Methods

The described erosion collection system (Figure 3.1) uses the natural slope of the study site, along with raised beds, to channel runoff water and suspended soil particles through a runoff flume (Figure 3.2), patterned after a modified Gerlach trough (Roels and Jonker, 1983), into a collection box (Figure 3). Water is pumped from each sediment collection box following rainfall (~12 hours) and the collected soil material is manually removed, air dried, weighed, and sampled for both chemical and physical analyses.

Collection system construction.

Necessary materials for construction are common and easily obtained. Components for the flume (Figure 4) include 1.4 m (4.6 ft) of treated 2x12 lumber, 1.4 m (4.6 ft) of treated 2x6 lumber, 0.2 m (7.9 in) of treated 4x6 lumber, 0.6 m (2.0 ft) of aluminum flashing, approximately 16-10d cement coated nails and ¼ tube of silicon caulking. The sediment collection box consists of 6.0 m (20 ft) of treated 2x8 lumber, 1.5 sheets of 0.02 m (0.63 in) exterior grade plywood, approximately 50-10d cement coated nails, 16-8x21/2-in wood screws, approximately one tube of silicon caulking and ¼ gallon of exterior grade house paint.

The collection box (Figure 5) is 1.2 m (4.0 ft) wide, 1.8 m (6 ft) long and 0.17 m (0.55 ft) deep with an effective storage capacity of 336 l (88 gal). This size was chosen to accommodate the inside clearance of the tires on a two-row tractor used for cultivation application. Caulking was applied to all joints of the collection box to improve water holding ability. Likewise, the joints of the flume received caulking to eliminate leaks and remove areas in which soil could collect. Boxes were covered with three individual pieces of plywood, providing easier removal and installation compared to a larger single piece. The entire box was covered except for a 0.026 m^2 opening to allow only plot runoff water to enter the box. Exterior grade house paint was applied to all exposed surfaces of the sediment collection box to reduce weathering damage.

Each plot consisted of four 1.2 m (4 ft) wide bedded rows with soil erosion collected from the area between the second and third row (1.2 m wide and 12.2 m long). The collection area (0.0037 A) was defined by adjacent row ridges, an earthen berm at the upslope edge of each plot, and the flume located at the downslope edge.

Box installation

The flume was centered between the two rows (1.2 m wide) of the sampled area and placed at the down slope edge of the plot. The use of hand digging tools was required to place the flume flush with the soil surface. Care was exercised to minimize unnecessary soil disturbance during installation. After proper positioning, soil was firmed along the wings of the flume. Flumes were checked extensively for approximately one week following installation with minor adjustments made for the settling of the packed soil.

The soil collection box was positioned directly down slope and below the runoff flume. The 1.8 m (6 ft) sides were placed perpendicular to and centered on the flume chute. A tractor mounted front-end loader was used to remove soil for sediment collection box placement. The hole depth had to allow for the top edge of the box to be below the flume chute. The slope of the test site (~5 percent) aided in box installment by limiting the amount of soil removal necessary for placement. Soil was packed around the box and drainage ditches constructed to eliminate water from collecting around the box perimeter.

Box sampling

Sampling of the sediment collection boxes was dependent on both the intensity and duration of each rainfall event. Sediment boxes were cleaned the next working day following rain events resulting in significant soil erosion for all treatments. This time lag (>12 hours) between storm event and sampling allowed sufficient time for settling of all but the finest soil particles.

A gasoline-powered water pump was used to remove water from each box. After pumping, boxes were scraped with a flat edge shovel and rubber squeegee. Collected soil was placed in 68.2 l (18 gal) plastic tubs lined with 125 l (33 gal) black plastic bags and placed inside a greenhouse to allow for air drying. After drying to a moisture content of approximately 2 percent, samples were weighed and moisture samples taken for adjustment to an oven-dry basis.

Results and Discussion

Eleven and nine rain events producing significant soil erosion were observed during the 1996 and 1997 growing season, respectively. Figure 6 illustrates the rainfall and subsequent soil erosion observed for a collection date in 1996.

Soil erosion quantified using the described collection system was significantly affected by the investigated tillage systems in both years of observation (Chapter IV). Erosion values resulting from conventional tillage tobacco production ranged from 20.37 tons per acre in 1996 to 13.28 tons per acre in 1997 while the non-cultivated conservation tillage production system exhibited erosion on the magnitude of 2.27 tons per acre and 0.60 tons per acre in 1996 and 1997 respectively. Erosion increased as the amount of row cultivation increased, but the increase was not significant. Soil disturbance during tobacco transplanting and collection system installation, along with the lack of a plant canopy, contributed to the soil erosion in each year. The first two collections of 1996 contributed 72 percent while the first collection of 1997 contributed 58 percent of the total soil erosion measured for the growing season.

The loss of soil particles in water pumped from each box was a major concern during the initial stage of this research study. Runoff water samples were collected immediately prior to the removal of water from collection boxes on the first collection date in 1996. Suspended soil material in this water was quantified using the hydrometer method of Day (1965) as modified by Laflen *et al.* (1978). No significant differences were observed in the quantity of soil particles contained in this runoff water, and the amount of soil material suspended was insignificant compared to the amount of sediment in the box. Due to time and labor constraints, quantification of this component was discontinued. Although the loss of soil material in the water removed from collection boxes was slight, an underestimate of the total soil erosion for the growing season would result. Therefore, values obtained with this collection system are a measure of the relative soil erosion rather than the absolute soil erosion. The values obtained are still effective for comparing different cropping systems and the impact on soil erosion.

Although the total quantity of runoff water was not quantified with this system, this was not a specific point of interest in this study. Zöbisch *et al.* (1996) noted the difficulty in runoff water quantification due to storage volume limitations. Soil particle loss resulting from collection box overflow during rain events would be low and would only affect the smallest of fractions. The heavier particles (i.e. sands) would immediately fall out of suspension and only clay and silt would be lost.

Conclusions

The described collection system was low cost, easily constructed, and interfered minimally with normal field operations. The design of system components allowed for easy repair, removal and repositioning from season to season. The system was designed for use with plots consisting of bedded rows oriented with the plot slope, but could be easily modified for use in other row-crop situations. A potential concern regarding the described soil collection system was a settling of eroded particles in the flume. The observed settling was limited and any material that settled was swept from each flume during sampling and included in the erosion sample.

The soil collection system is especially useful for researchers interested in quantifying soil erosion from small-scale replicated field plots requiring intensive cultural practices. Application to existing soil conservation studies where soil erosion is a secondary variable of interest can be accomplished with only minor modification to the system design.

Literature cited

Alberts, E.E., R.C. Wendt, and R.E. Burwell. 1985. Corn and soybean cropping effects on soil losses and C factors. Soil Sci. Soc. Am. J. 49:721-728.

Bui, E.N., and J.E. Box Jr. 1993. Growing corn root effects on interrill soil erosion. Soil Sci. Soc. Am. J. 57:1066-1070.

Carter, C.E., and D.A. Parsons. 1967. Field tests on the Coshocton-type wheel runoff sampler. Trans. of ASAE 10(1):133-135.

Day, P.R. 1965. Particle fractionation and particle size analysis. In: Methods of Soil Analysis, ed. By Black et al. Am. Soc. Agron., Madison, WI.

Dickey, E.C., D.P. Shelton, P.J. Jasa, T.R. Peterson. 1984. Tillage, residue and erosion on moderately sloping soils. Trans of ASAE 27(4):1093-1998.

Foster, G.R., R.A. Young, M.J.M. Romkens, and C.A. Onstad. 1985. Processes of soil erosion by water. In Soil Erosion and Crop Productivity. R.F. Follet, and B.A. Stewart eds.), ASA-CSSA-SSSA Publ., Madison, WI., pp. 137-162.

Huang, C., and J.M. Bradford. 1993. Analysis of slope and runoff factors based on the WEPP erosion model. Soil Sci. Soc. Am. J. 57:1176-1183.

Hudson, N. 1995. Erosion research methods. In Soil Conservation. Iowa State University Press. Ames, Iowa, pp. 154-189.

Jamison, V.C., D.D. Smith, and J.F. Thornton. 1968. Soil and water research on a claypan soil. Tech. Bull. No. 1379, U.S. Dept. Agr., Washington, D. C. 111pp.

Kramer, L.A. 1986. Runoff and soil loss by cropstage from conventional and conservation tilled corn. Trans. of ASAE 29(3):774-779.

Laflen, J.M., J.L. Baker, R.O. Hartwig, W.F. Buchele, and H.P. Johnson. 1978. Soil and water loss from conservation tillage systems. Trans of ASAE. 21:881-885.

Laflen, J.M., and T.S. Colvin. 1981. Effect of crop residue on soil loss from continuous row cropping. Trans of ASAE 24:605-609.

Langdale, G.W., A.P. Barnett, R.A. Leonard and W.G. Fleming. 1979. Reduction of soil erosion by the no-till system in the Southern Piedmont. Trans. of ASAE 22:82-86 and 92.

Liebenow, A.M., W.J. Elliot, J.M. Laflen, and K.D. Kohl. 1990. Interrill erodibility: Collection and analysis of data from cropland soils. Trans. of ASAE 33:1882-1888.

McGregor, K.C., J.D. Greer, and G.E. Gurley. 1975. Erosion control with no-till cropping practices. Trans. of ASAE 18(5):918-920.

Roels, J.M. and P.J. Jonker. 1983. Probability sampling techniques for estimating soil erosion. Soil Sci. Soc. Am. J. 47:1224-1228.

Sharma, P.P. 1995. Interrill erosion. In: Soil Erosion, Conservation and Rehabilitation. Menachem Agassi, ed. Marcel Dekker, New York. pp. 125-152.

Trimble, Stanley Wayne. 1974. Man-induced soil erosion on the Southern Piedmont 1700-1970. Department of Geography. University of Wisconsin-Milwaukee.

U.S. Soil Conservation Service. 1972. Hydrology. National Eng. Handbook., Sec. 4, Part I, Watershed Planning, Washington, D.C.

Wood, Sandra D. and Arch D. Worsham. 1986. Reducing soil erosion in tobacco fields with no-tillage transplanting. J Soil Water Cons. 41:193-196.

Zöbisch, M.A., P. Klingspor, and A.R. Oduor. 1996. The accuracy of manual runoff and sediment sampling from erosion plots. J Soil Water Cons. 51(3) 231-233.

Figure 3.1. Installation of soil collection system in one plot. Top sections of the sediment collection box are removed and soil has not been filled around box

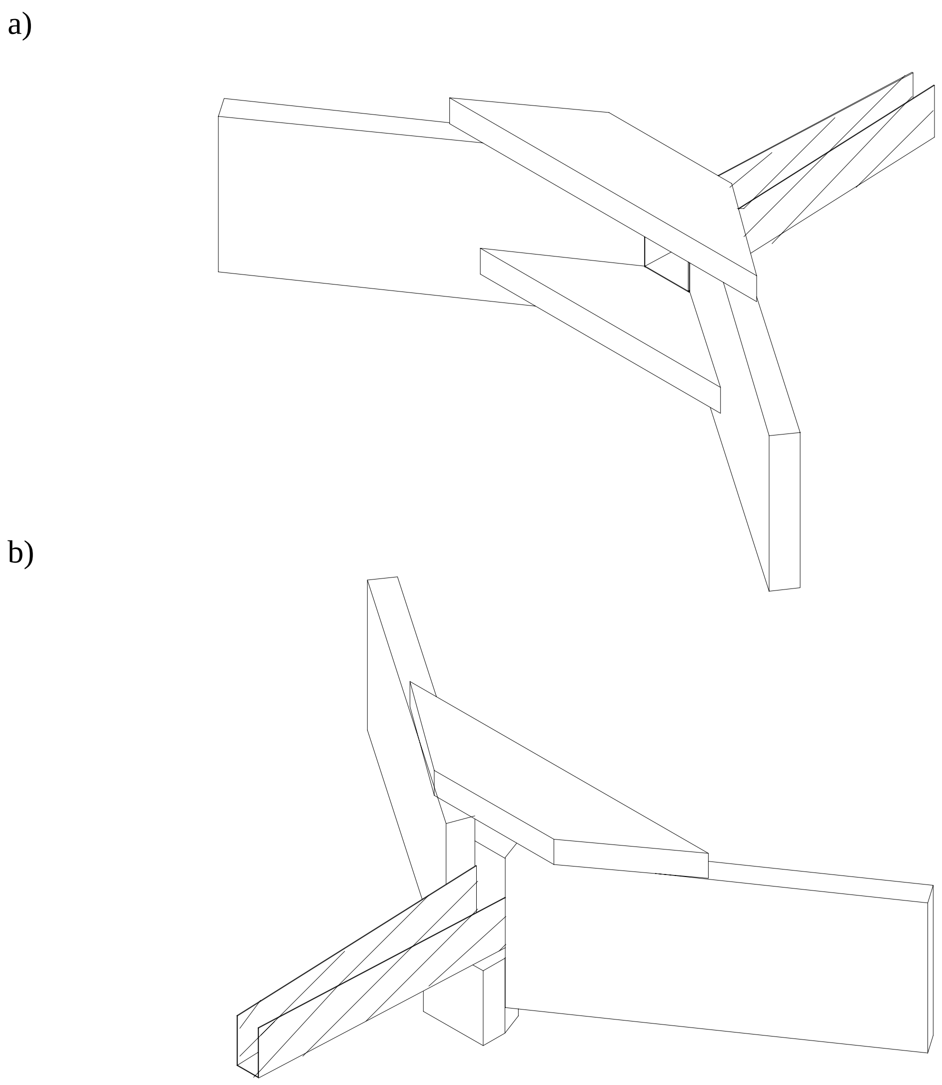


Figure 3.2. Anterior (a) and posterior (b) view of the runoff flume.

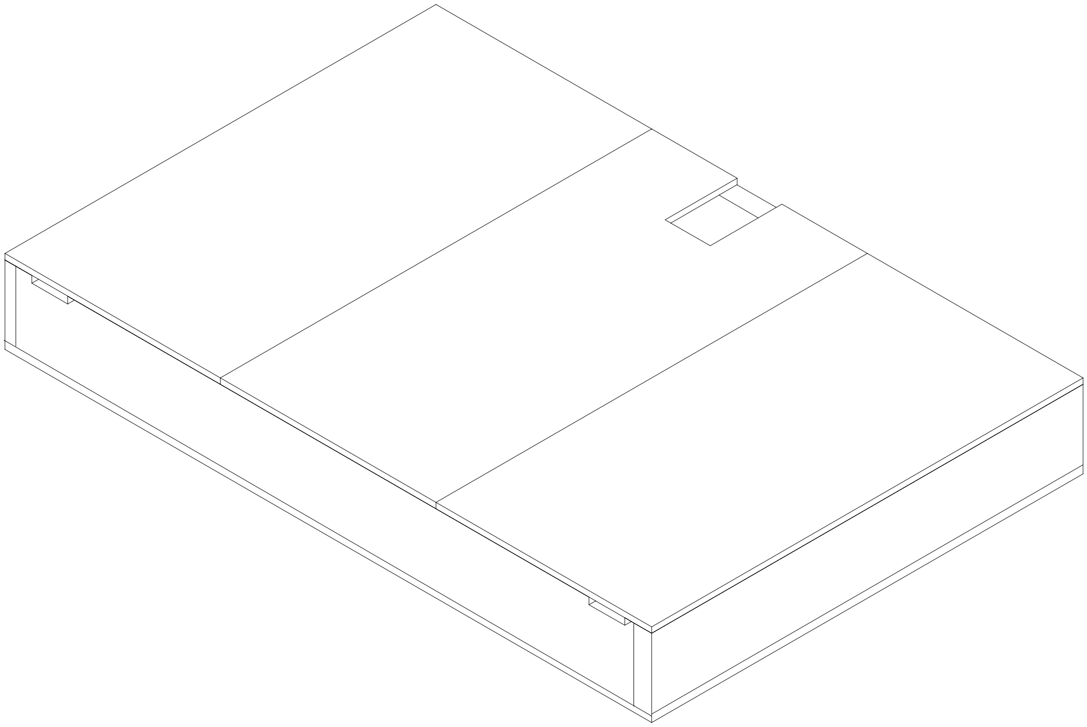


Figure 3.3. Sediment collection box

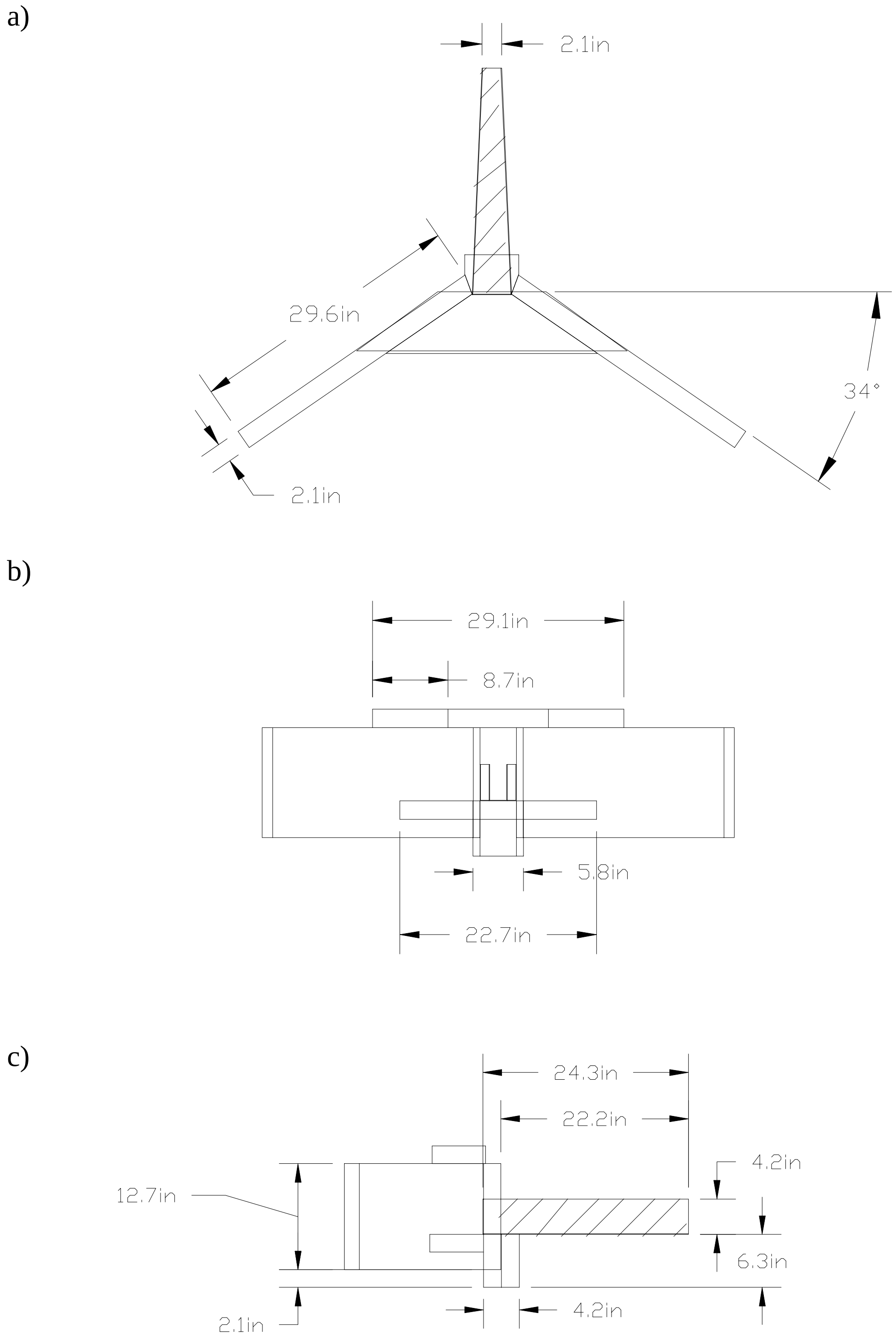


Figure 3.4. Design specifications of the runoff flume. Top view (a), anterior view (b), and side view (c).

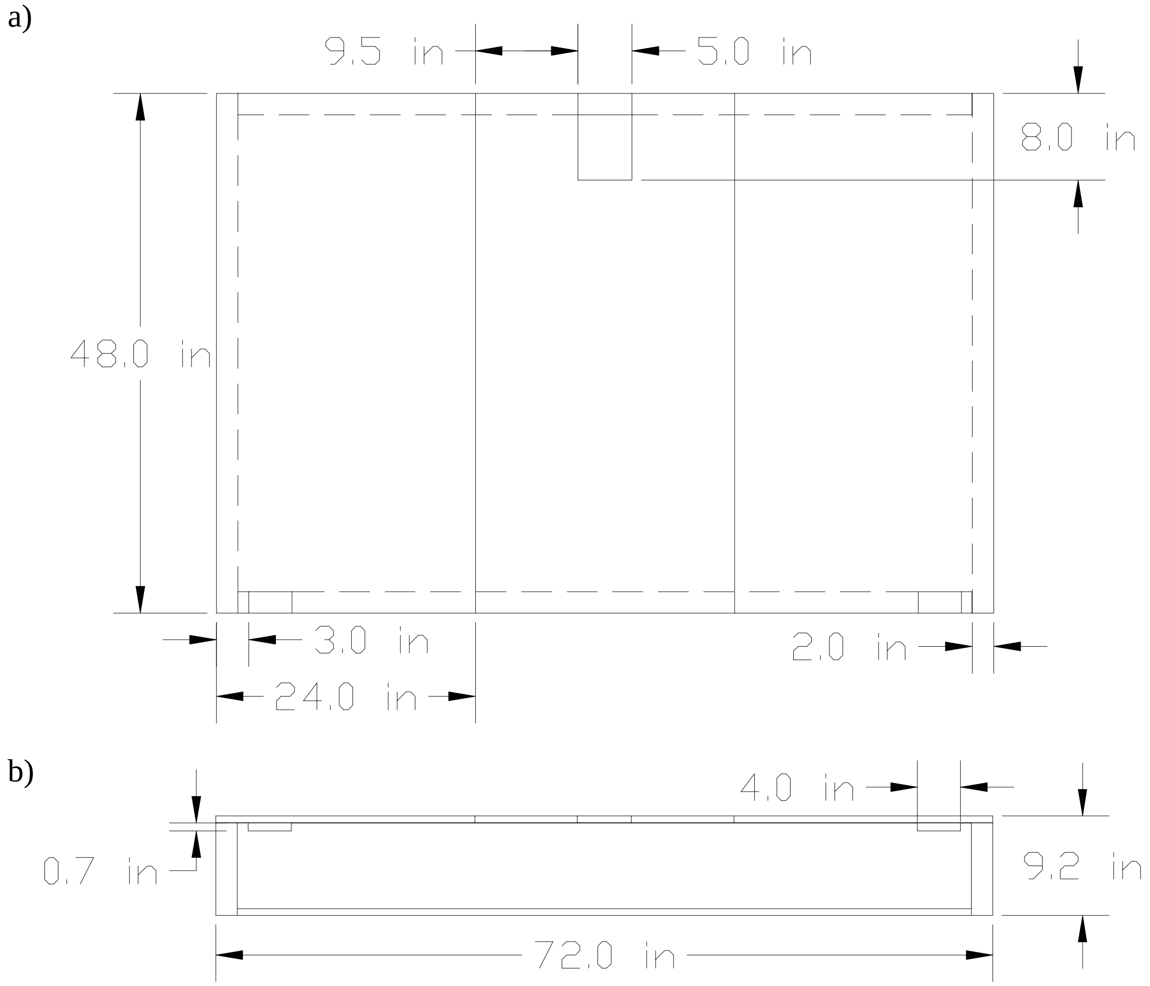
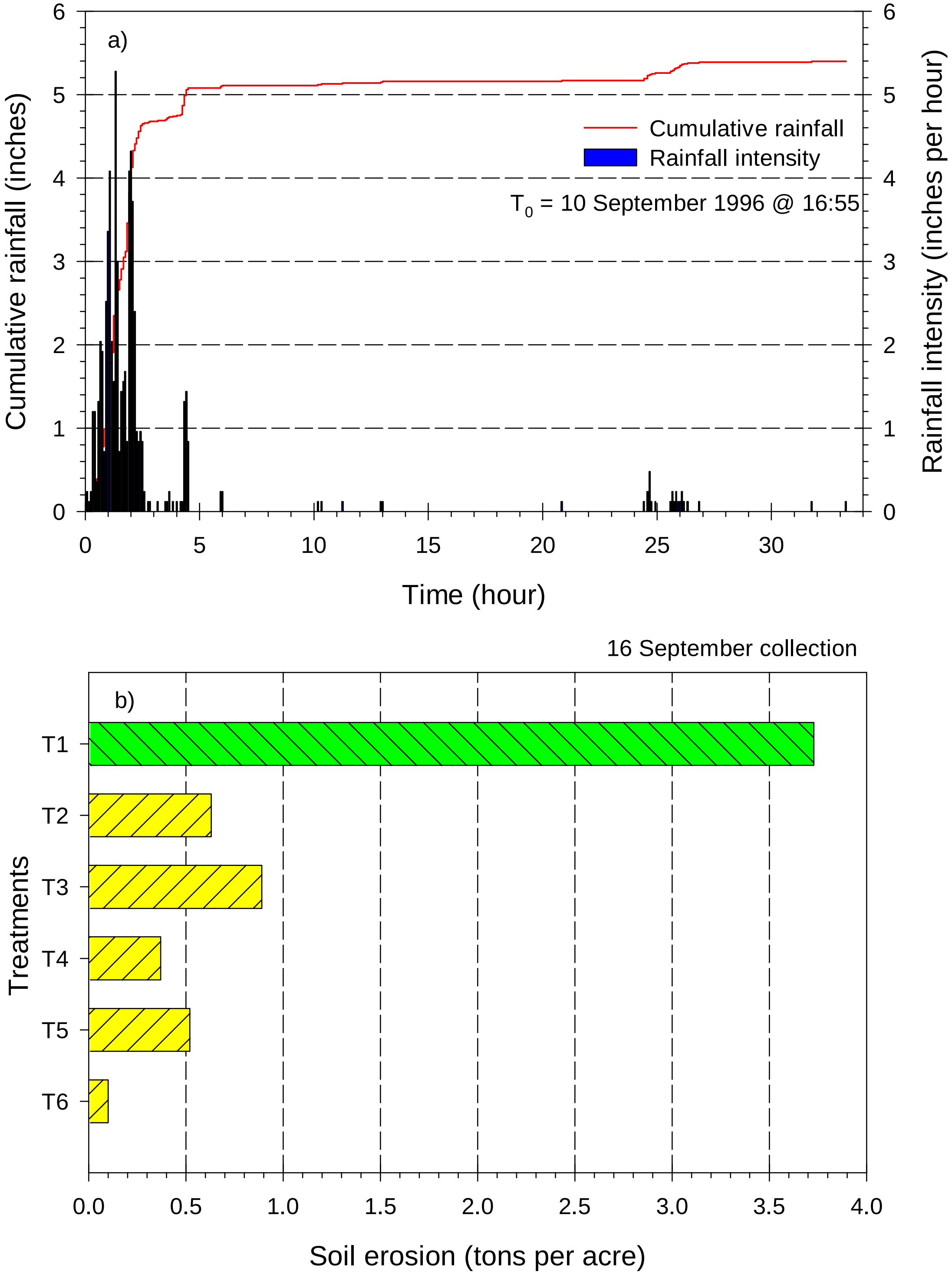


Figure 3.5. Design specifications of the sediment collection box. Top view (a) and rear view (b).

Figure 3.6a-b. Rainfall (a) observed from a high intensity storm on September 10, 1996 and the resulting soil erosion (b) quantified on September 16. Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6). Early cultivation was applied at 26 days after transplanting (DAT), late at 33 DAT and layby at 39 DAT.

a)
Cumulative rainfall (inches)
Rainfall intensity (inches per hour)
Cumulative rainfall
Rainfall intensity
T0 = 10 September 1996 @ 16:55
0
1
2
3
4
5
6
0
5
10
15
20
25
30
Time (hour)
16 September collection
b)
Treatments
T1
T2
T3
T4
T5
T6
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Soil erosion (tons per acre)