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EFFECTS OF RAINFALL CHARACTERISTICS, TILLAGE SYSTEMS AND SOIL PHYSIOCHEMICAL PROPERTIES ON SEDIMENT AND RUNOFF LOSSES FROM MICRO-EROSION PLOTS

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EFFECTS OF RAINFALL CHARACTERISTICS, TILLAGE SYSTEMS AND SOIL PHYSIOCHEMICAL PROPERTIES ON SEDIMENT AND RUNOFF LOSSES FROM MICRO-EROSION PLOTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

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* * * * *

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Dedicated to my parents:

Chief Anwana Mba Esu Mba

and

Mrs. Eme Mba (Nee Eme Okpo Etim-Ebito)

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INTRODUCTION

Runoff and sediment losses are two critical factors that prevent continuous economic crop production on sloping agricultural lands. Runoff occurs when rainfall rate exceeds the rate of water intake by soil. Sediment losses on the other hand are a result of the disintegration of soil aggregates by raindrop impact followed by the transport action of water. Both runoff and sediment losses carry with them not only the irreplaceable detached topsoil and water essential for crop growth, but also fertilizer and herbicides from farmlands into valley bottoms and streams.

Sediment and runoff losses also enhance the degradation of soil structural components and the reduction of soil fertility and thus represents a permanent economic loss to the farmer. A considerable amount of soluble and adsorbed plant nutrients may be removed from an agricultural land during the erosion process. Of prime importance is the selective removal of the finer soil particles and low specific gravity soil components, particularly organic matter, all of which constitute most of the inherent soil fertility status.

Considerable retention of rain water in the soil and the reduction of the rate of soil aggregate disintegration by rainfall action have been achieved by protecting the soil surface with vegetation. This management technique has not been totally successful in the tropics because most of the high intensity and long duration rains occur when the soil surface is dry and devoid of all vegetal cover.

The slot mulching and slot trenching soil profile modification techniques provide considerable potentials for the reduction of runoff and sediment losses during major storm events. The effectiveness of these management techniques on erosion control depends on their potential ability to increase soil water storage during storm events and subsequently decrease the amount of water avaliable for runoff. The total amount of rainfall for a particular location or growing period is usually assumed to give an indication of soil moisture conditions. In reality, rainfall amount does not serve as a reliable index of the amount of water available for plant use because most of the rain water may be lost as runoff. It is anticipated that the increased soil moisture associated with slot mulching and slot trenching management systems will be reflected by an increased crop yield particularly in locations where annual rainfall is low.

The response to the soil erosion problem in most parts of the world has been to leave the more erodible areas under limited cultivation and concentrate farming activities in valleys and more level areas. This solution is in a very rapid decline as increased population and desperate need for food is forcing people, especially in the tropics, to farm easily degradable and erodible soils such as those on sloping lands. There is therefore an increasing demand, particularly in the developing countries, for improved, inexpensive short-term, soil loss and runoff research which is directed towards landuse planning and other soil management programs. Often the urgency and need for a direction, funds and personnel prohibit carrying out the elaborate studies as outlined in the Universal Soil Loss Equation (USLE) methodology. Nevertheless, qualitative and quantitative results are expected as rapidly as possible. 'Micro-plot technique' as used in this study might provide the framework for meeting these goals.

LITERATURE REVIEW

Rainfall Characteristics and Soil Erosion

The characteristics of rainstorms which influence the rate and amount of soil loss are key factors that must be known in any attempt to understand and solve erosion problems. It is also vital to relate how and to what extent erosion is affected by each of these rainfall characters.

Wischmeier and Smith (1958) indicated that soil erosion is a mechanical process that requires energy and that much of this energy is supplied by falling raindrops. In a subsequent paper (1962) these workers noted that a study of rainfall momentum and energy in relation to erosion requires knowledge of the determining factors, enumerated as: raindrop mass, size, size distribution, shape, velocity, and direction. Lal (1975) indicated that rainfall amount, intensity, distribution of storm intensity, kinetic energy, and momentum and drop size are important parameters affecting soil erosion.

Studies of drop-size distribution of natural rainfall have shown a high degree of correlation between drop size and rainfall intensity, Wischmeier and Smith,(1958). Laws and Parsons (1943) described the relationship of median drop size to intensity by the equation:

$$D_{50} = 2.21\ I^{0.182}$$

in which I = intensity (inches/hr.),

D_{50} = 50% of the rainfall volume with drop diameters greater than median drop size.

Best (1950) described an equation relating the two parameters as:

$$D_{50} = 0.69^{1/n}\ A^{PI}$$

in which n, A, and P are empirically derived constants, and I = intensity (in/hr). The relationship between dropsize and intensity was later shown to vary with types of rain (orographic vs. nonorographic) (Hudson, 1961).

The shape of raindrops as they strike the surface of the earth is not spherical owing to differential air pressure created by the falling drop. The resultant shape approximates an ellipsoid flattened on the bottom (Smith and Wischmeier, 1962). The change in shape of a raindrop is significant from an erosion standpoint in that it affects the velocity (Laws, 1941) and the impact force per unit area of soil (Ekern, 1951).

The fall velocity of raindrops was studied by Laws to assist in understanding the action of rain in the eroding of soil (Laws, 1941). He used photographic equipment to measure drop velocity. His values were in good general agreement with terminal velocities of water droplets in stagnant air that Grunn and Kinzer (1949) measured by inducing an electric charge and producing pulses on an oscillograph record.

In natural rain, air turbulence can act either to increase or to decrease rain drop velocity. Smith and Wischmeier (1962) indicated that a horizontal wind increases terminal drop velocity by the reciprocal of the cosine of the angle of inclination of the rain with the vertical. These workers showed that in a heavy, driving rain with a 3 mm median drop size and a 30-degree angle of inclination, the velocity would be increased 17% and the kinetic energy would be increased 36%. Lyles et al. (1969) also reported from their findings that wind driven rain considerably increased the rate of soil loss. Hudson (1961) indicated that in detailed erosion studies where rain intensity, momentum or kinetic energy are related to soil movement, air turbulence or the wind factor in the erosion process should not be neglected.

Kinetic energy of rainfall is important in erosion studies since erosion is a work process and the energy required to dislodge and detach soil particles in the erosion process is provided by the falling raindrops. Mihara (1953) attributed soil erosion less to running water, and more to raindrop impact. Wischmeier (1966) reported that the combination of rainfall energy and quantity of rainfall was the most important variable affecting soil erosion. Further analysis by Wischmeier et al. (1958) showed that the correlations between both soil loss and total rainfall of individual storms and rainfall in 5-, 15-, or 30-minute intervals were poor. The product of the kinetic energy of the storm and the 30-minute maximum intensity (EI_{30}) was most significantly correlated with the soil loss. Wischmeier and Smith (1958) gave a regression equation for calculating the kinetic energy of individual storms by:

$$Y = 916 + 331 \log_{10}X$$

where Y is the kinetic energy in foot tons per acre inch, and X is the rainfall intensity in inches per hour. Rogers et al. (1967) indicated that calculating the kinetic energy of rainfall from rainfall intensity was satisfactory.

Hudson and Jackson (1959) found from their studies in Rhodesia (Zimbabwe) that although the EI_{30} index provided an accurate measure of erosivity of rainstorms in temperate America, it was less effective in tropical Africa. Hudson developed an alternate procedure based on the concept that there is a threshold intensity value at which rainfall becomes erosive (25 mm per hour). This index is referred to as KE > 1.

Lal (1975) pointed out that the kinetic energy values (KE) from EI_{30} index grossly underestimates KE for tropical storms. He pointed out that the intensity of temperate rainstorm rarely exceeds 50 mm/hr while it is not uncommon for tropical rainstorm intensities to exceed 100 mm/hr. Lal (1975) proposed a new index, the AI_m index, which is the product of the maximum intensity (I_m) in cm/hr and total rainfall (A). He calculated the weighted mean average correlation coefficient (r) for the various erosivity indices for a storm under tropical conditions with the following results:

	Correlation Coefficient (r)	
Erosivity index	Runoff	Soil loss
KE > 1	0.32	0.60
EI_{30}	0.34	0.65
AI_m	0.37	0.69

Although the AI_m index shows slight improvements in both runoff and soil loss and is easier to compute, it requires testing in many other locations before it can be widely adopted.

Ahmad and Breckner (1974) also found in their studies in Trinidad that correlations of soil loss with the EI_{30} index were generally low.

Since rainfall energy is a function of rainfall intensity, many workers have found high correlation between rainfall intensity and the amount of eroded soil (Mookerjee, 1950; Lal, 1975). Tamhane et al. (1959) reported that rain is designated as erosive or non-erosive if the intensity limit is above or below the energy sufficient for the destructive action on soil particles. Free (1960) showed that the relationship of the ratio of infiltration to runoff with rainfall energy was exponential and of the hyperbolic type. Ekern (1954) related storm erosivity exponentially to rainfall intensity. Rose (1960) found that the rate of soil detachment per unit area was influenced more by the momentum which is the product of the rainfall mass and linear velocity than the kinetic energy of the storm per unit area and time.

The intensity distribution within a storm has a significant effect on the erosive nature of rainfall. Lal (1975) indicated that some storms have their highest intensities at the beginning and lowest intensities at the later stages. Other storms begin with medium intensity and reach their peaks in the middle. There are also composite storms with peak intensities within 2 to 3 hours of one another. Each intensity distribution presents a different soil-erosion hazard. Lal (1975) indicated that interpreting the erosion data from composite storms is more difficult.

Erodibility of Soils in Relation to Physical and Chemical Properties

Soils differ in their inherent susceptibility to erosion and this intrinsic property is referred to as soil erodibility. Several early attempts were made to determine criteria for classification of soils according to erodibility (Browning, et al., 1947; and Peele et al., 1945) but classifications used for erosion prediction were only relative rankings. Bryan (1968) indicated that most studies on soil erodibility have been based on two indices. The first index is soil properties affecting dispersion and the second index is soil properties affecting water transmission. Similarly, Smith and Wischmeier (1962) in an attempt to classify the soil properties that influence soil erodibility grouped the properties into two areas. In the first group are the soil properties affecting infiltration rate and permeability and in the second group are the soil properties affecting the transporting forces of rainfall and runoff.

Ruben and Gray (1977) remarked that despite its importance, the erodibility factor has been experimentally derived for only a few benchmark soils. A major obstacle being that direct measurements of the K factor in the field or laboratory are both time-consuming and costly. Lindsay and Gumbs (1982) inferred that further attempts to simplify and hasten erodibility evaluation have resulted in the use of empirical indices such as dispersion ratio, erosion ratio, surface aggregation ratio, clay ratio and silica-sesquioxide ratio. These indices have been tested and found to be limited in determining soil erodibility (Smith and Wischmeier, 1962; Wischmeier and Mannering, 1969).

Kandiah (1979) indicated that several physical, chemical and physiochemical soil properties are reported to be key factors influencing soil erodibility. These properties include density, porosity, permeability, soil structure, clay mineralogy, organic matter content and interparticle cohesion and dispersion. As yet no one soil characteristics or index provides a satisfactory means of predicting erodibility.

Wischmeier and Mannering (1969) proposed a complex erodibility equation utilizing 15 soil properties and their interactions. This equation was later superceded by the USDA erodibility nomograph of Wischmeier et al. (1971)

which utilizes four soil properties, namely, texture, organic matter content, structure and permeability.

Soil erodibility factor, K, in the Universal Soil Loss Equation (USLE) is the most difficult factor to evaluate in the equation (Romkens, et al., 1977). The K factor is a quantitative value experimentally determined for a particular soil and 'it is the rate of soil loss per erosion index unit as measured on a unit plot' (USDA, 1978). USDA (1978) further indicated that a unit plot is arbitrarily defined as a plot 72.6 ft long with a uniform length-wise slope of 9%, in continuous fallow, tilled up and down the slope. Continuous fallow, for this purpose, is land that has been tilled and kept free of vegetation for more than 2 years. During the period of soil loss measurements, the plot is plowed and placed in conventional corn seedbed condition each spring and is tilled as needed to prevent vegetative growth and severe surface crusting. USDA (1978) indicated that direct measurement of the erodibility factor is both time consuming and has been feasible only for a few major soil types.

Bruce-Okine and Lal (1975) proposed a modified raindrop technique for determining soil erodibility. This simple technique was developed with potential usefulness in tropical areas. Lindsay and Gumbs (1982) reported that the raindrop technique for assessing the stability of aggregates and therefore the erodibility of soils showed marked variability in the number of drops required to destroy soil peds. Soil moisture content at the time of determination played an important role in the result of the raindrop method.

The New South Wales (Australia) Soil Conservation Service (Charman, 1978) proposed a soil erodibility index, K, of the form

$$K = \frac{TSD}{(IK'\ C)^{\frac{1}{2}}}$$

The variables in the numerator are texture (T), structure (S), and aggregate stability (D), which are parameters in the soil detachability component. The denominator is the water transmission factor, which is a function of the square root of the infiltration (I), horizontal permeability (K'), and water holding capacity (C). Lindsay and Gumbs (1982) reported from their findings that the Australian index places too much emphasis on soil texture and perhaps not enough emphasis on infiltration and permeability. Lindsay and Gumbs (1982) also indicated that the Australian index seems to be particularly sensitive in predicting erosion hazard of clay soils.

Many previous attempts on the evaluation of soil erodibility have mostly focused on soil physical factors.

Only few workers have included soil chemical properties (Singer et al., 1978; Trott and Singer, 1979). USDA (1978) indicated that a soil's erodibility is a function of complex interactions of a substantial number of its physical and chemical properties and often varies within a standard textural class.

Trott and Singer (1979) indicated that the USDA nomograph may not yield accurate estimates of the soil erodibility factor, K, when applied to western upland soils. From their study, they found that the nomograph overestimated the erodibility of soils high in dithionite iron. Trott and Singer (1979) found a positive relationship between low observed erodibility and dithionite Fe. They also found that the amount and form of Fe and Al are important factors of soil erodibility. Singer et al. (1978) found that exchangeable sodium percentage, dithionite extractable iron and aluminum and oxalate extractable iron and aluminum are additional useful indices in predicting the erodibility of ten California soil series.

Romkens et al. (1977) evaluated the relationship between erodibility factor, K, and 13 soil physical parameters, 6 chemical properties, 10 mineralogical properties and 6 interaction factors of physical, chemical and mineralogical properties for both surface and subsoils. The correlation coefficient for each of the four groups of variables are represented for some of the parameters evaluated (Table 1).

Table 1. The relationship between soil erodibility and soil physical, chemical and mineralogical parameters.

Variable	Correlation Coefficient	
	Surface Soils	Subsoils
Physical Properties:		
New Silt (very fine sand + silt) - (sand) (Wischmeier et al., 1971)	0.84	0.57
(Silt + very fine sand) x (silt + sand) (Wischmeier et al., 1971)	0.86	0.81
Permeability	0.64	-
Chemical properties:		
Total N	0.09	-0.82
Total organic carbon	-0.09	-0.46
Mineralogical properties:		
Fe_2O_3	0.19	-0.13
Al_2O_3	0.35	0.43
Kaolinite and halloysite	0.32	0.52
Interaction factors:		
$Fe_2O_3 + Al_2O_3$	0.22	-0.10
$(Fe_2O_3 + Al_2O_3)$ Montmorillonite	0.12	-0.61
Total % organic C x clay	-0.07	-0.77
Specific surface	0.12	-0.59

Romkens et al. (1977) suggested from their study that different soil properties were related to soil erodibility factors of surface and subsoils, respectively. Romkens et al. (1977) also indicated that the textural parameter and the percent of iron plus aluminum extractable with citrate-dithionite-carbonate (CDB), were significant prediction properties of erodibility of the clay subsoils examined. These authors further suggested that the CBD extractable percent of Al_2O_3 plus Fe_2O_3 be considered as a single variable influencing erodibility of soils since both constituents are thought to have soil binding characteristics.

Kandiah (1979) indicated that critical shear stress and cation exchange capacity (CEC) relationships are very valuable in predicting erosion potential of soils. He obtained a high correlation (r=0.99) between critical shear stress and CEC indicating a unique importance of CEC for soil erodibility. Kandiah (1979) further reported that in low organic mineral soils, CEC is an index of ion exchange capacity of clays which is intimately related to double layer repulsive forces. This author further stated that when other factors remain constant, interparticle forces are determined by the cation-exchangeable surface area of soils.

Wallis & Stevans (1961) indexed the erodibility of some California soils using the dispersion and surface-aggregation ratios, and tested values against concentrations of Ca, Mg and Ca + Mg. No significant correlation was found with K and Na.

Nutrient Losses in Surface Runoff and Eroded Sediment from Agricultural Lands

Nutrient elements in all forms may be removed from agricultural lands by the erosion process. The removal of nutrients by surface runoff tend to be selective in that the organic matter and finer particles of soil relatively high in plant nutrients are more vulnerable to erosion than are the coarser soil particles. These nutrients not only contribute to water quality deterioration but also represent an economic loss of fertility for the farmer. Holt et al. (1970) found that surface runoff from farm land can contribute appreciable phosphorus to waters even in the absence of fertilizer application. Verduin (1967), describing the relationships between eutrophication and agriculture, points out that less than half of the phosphorus enriching streams and lakes is derived from agricultural fertilizers.

Nutrient losses in surface runoff in Northern Nigeria have been reported by Kowal (1972). The average annual loss of calcium, magnesium and sodium in runoff water and eroded soil varied from 14 to 30 kg/ha. The average annual nitrogen loss ranged from 7 to 19 kg/ha. Barnett et al.

(1972) observed from studies on some Puerto Rican soils that the average concentration of nitrogen in surface runoff water ranged from 0.01 to 0.02 ppm and the average concentration of potassium varied from 0.01 to 2.29 ppm. Moe et al. (1967) reported that mineral nitrogen losses from fallow and sod plots established on an Indiana fragipan soil (13% slope) ranged from 2 to 15 percent of the applied NH_4NO_3 (224 kg/ha) after 12.7 cm of rainfall. In a subsequent study, Moe et al. (1968) reported that mineral nitrogen losses from NH_4NO_3 and urea treated plots (448 kg/ha) ranged from 2.4 to 12.7 percent with NH_4NO_3 being less susceptible to runoff loss than urea.

Thomas et al. (1968) observed that the highest concentrations of nutrients in the soil lost from various treatments were 633 ppm of calcium, and 104 ppm of potassium. The total loss of Ca was 1622 kg/ha while that of K ranged from 0.14 to 0.22 kg/ha.

Romkens et al. (1973) studied the influence of tillage methods on nitrogen and phosphorus composition of surface runoff. They reported losses of soluble nutrients for two successive simulated rainstorms in the order, coulter > till > chisel > double disk > conventional; whereas, sediment N and P losses were greatest from conventional and till systems. In a different study, Timmons et al. (1973) found that incorporation of broadcast fertilizer by plowing down and disking resulted in nitrogen and phosphorus losses in surface runoff equal to losses from unfertilized plots. In Georgia, White et al. (1967) found only 0.15 to 2.3 percent of broadcast nitrogen (224 kg/ha as NH_4 NO_3) in surface runoff from sandy loam soils with a 5% slope. Knoblauch et al. (1942) obtained loss of total K of 426 pounds per year from Collington Sandy loam. Losses were reduced to 98 pounds under cover crop receiving manure. Massey et al. (1973) reported an average loss of 192 kg of organic matter, 10.6 kg of nitrogen and 1.8 kg of exchangeable potassium per hectare on a Wisconsin soil of 11 percent slope.

Nutrient losses in surface runoff have also been determined on a watershed basis. Taylor et al. (1971) found that nitrogen and phosphorus losses from a farmland watershed were significantly greater than those from a woodland watershed at Coshocton, Ohio. Schuman et al. (1973) measured nitrogen losses in surface runoff for four agricultural watersheds near Treynor, Iowa. The 3-year average annual solution nitrogen losses were low from all watersheds and ranged from 0.42 to 3.05 kg/ha for the various conservation practices; whereas average annual sediment nitrogen ranged from 1.21 to 36.59 kg/ha. Schuman et al. (1973) also found that 92 percent of the total nitrogen lost in the runoff from contour-planted corn watersheds was associated with sediment. Frere (1971) found considerable variation in the nutrient contents of runoff from different watersheds. When a major storm was composed of more than one peak, the average nutrient concentration varied by as much as 200 percent between waterflow peaks.

Burwell et al. (1975) examined nutrient losses (nitrogen, phosphorus and potassium) in surface runoff under five soil cover cropping conditions from natural-rainfall erosion plots on Barnes loam soil (6% slope). Average annual losses of N in runoff and sediment ranged from 4.1 kg/ha for the hay treatment (alfalfa in rotation) to 150.3 kg/ha for the fallow treatment (continuous, clean-cultivated). Burwell et al. (1975) found that N transported by sediment accounted for 96% or more of the total losses of N from fallow, continuous corn, and rotation corn treatments. The average annual losses of total P in runoff ranged from 0.68 kg/ha for the hay treatment to 33.3 kg/ha for the fallow treatment. Burwell et al. (1975) also found that phosphorus transported by sediment accounted for 95% or more of the annual P losses for all soil cover treatments except hay. The average annual K losses in runoff ranged from 1.90 kg/ha for rotation corn to 8.41 kg/ha for the fallow treatment. Except for hay, K transported by sediment also represented a major portion of K lost annually in surface runoff.

Evaluation of nutrient losses in surface runoff from agricultural lands can become complex owing to the additions of soluble nitrogen and phosphorus from vegetative leaching (Timmons et al., 1970) and from precipitation. Daniel et al. (1938) demonstrated that the amount of N appearing annually in rainfall can be greater than that removed in surface runoff. Burwell et al. (1975) reported that average annual quantities of NH_4-N and NO_3-N contributed by precipitation exceeded the annual losses in surface runoff, but ortho-P losses in surface runoff were greater than the amount contributed by precipitation. Buckman and Brady (1960) suggest an average annual N return from rain and snow of 5 lb/ac under humid-temperate climate. Feth (1966), in a review of the N compounds in natural waters reported values in rainwater ranging from 0.56 to 12.66 kg/ha per year. Taylor et al. (1971) reported that N in precipitation averaged 20.3 kg/ha annually for a 2-year period and exceeded by six times the average annual nitrogen in runoff. During a 2-year period, Schuman and Burwell (1974) found that precipitation contributed an average of 7.26 kg/ha inorganic-N annually. This was four and seven times greater than the average annual surface runoff N from the high- and normal-fertility watersheds, respectively.

Burwell et al. (1975) observed that an average annual precipitation of 63.6 cm and 50.8 cm for each 12-month period respectively, contained 5.09 kg of NH_4-N/ha and 2.45 kg of NO_3-N/ha. Burwell et al. (1975) also found that the ortho-P content of average annual precipitation for a 2-year period was 0.125 kg/ha.

Burwell et al (1975) mentioned that under certain conditions leaching of the vegetative cover by surface runoff could contribute substantial amounts of N and P to surface waters. Timmons et al. (1970) reported that soluble P and N in leachates from alfalfa (*Medicago Sativa* L.) and blue grass (*Poa pratensis* L.) were greatly increased by drying or freezing, two processes which occur naturally in the field.

The Dynamics of Inorganic Orthophosphates in Soil and Surface Runoff

Under ordinary field conditions, phosphorus is one of the least mobile of the plant nutrients. Lal (1975) reported that although the literature indicates that most of the phosphorus losses occur through eroded sediments, the concentration of phosphorus in runoff water has been reported high enough to be a primary cause of eutrophication of water supplies. Nicholls et al. (1974) observed in their study that more than 90% of the total P in runoff is in the soluble form.

The amount of dissolved inorganic orthophosphate in flooded soils, swamp and marsh sediments, and shallow bodies of water depends on the capacity of the soil or sediment to release orthophosphate to a solution low in P and to sorb it from a solution high in P (Patrick and Khalid, 1974). Soils and sediments thus tend to have a buffering effect on solution P.

William et al. (1970) indicated that the capacity of lake sediments to retain or release P is one of the important factors that influence the concentrations of inorganic- and organic-P in lake waters. Patrick and Khalid (1974) remarked that the capacity of soils or sediments to sorb or release P into solution determines whether the P concentration in the interstitial and overlying water is adequate for the nutritional requirements of plants and whether the soils and sediments can remove enough P from solutions high in P to influence eutrophication. Thus the concentration of inorganic orthophosphate in surface runoff depends on the soil sorption-desorption capacity.

Syers et al. (1973) indicated that although the mechanism by which P is removed from solutions by sediment is not clearly understood, it is thought to be a sorption process rather than a precipitation process. This removal of dissolved P from interstitial water is therefore termed sorption, and its release from particulates is termed desorption. Factors that are associated with P sorption-desorption processes have been examined by many workers. These factors include oxidation-reduction status of the soil or sediment, concentrations of Ca^{2+} and Mg^{2+} (Patrick and Khalid, 1974, calcium carbonate content (Cole et al., 1953), pH (Hingston et al., 1972), iron and aluminum oxides (Hsu, 1964), and nature of clay minerals (Muljadi et al., 1966). Williams et al. (1971) attributed P sorption to a gel complex consisting largely of hydrated iron oxide. Patrick and Khalid (1974) found that under anaerobic conditions more P was released from the soil into the solution than under aerobic conditions. Patrick and Khalid (1974) further stated that the difference between reduced and oxidized soils in release and sorption of P suggests that under reducing conditions there is an increase of the solid material that reacts with P. The conversion of ferric oxyhydroxide to the more soluble and highly dispersed ferrous forms is implicated in increasing the activity and the surface area of the iron compounds reactive with P. Patrick and Khalid (1974) further stated that ferric oxyhydroxide is apparently capable of binding orthophosphate ions more firmly than the ferrous form, but probably has less surface area exposed to the solution P than the gel-like hydrated ferrous oxide or ferrous hydroxide.

Williams et al. (1958) reported on attempts made to correlate P sorption with the clay contents of soils. Correlation between P sorption and clay content after removal of Fe- and Al-oxides and hydrous oxides were often poor.

Phosphate adsorption studies on soils have been expressed by both the Freundlich isotherm (Kutz et al., 1946; Russell and Low, 1954) and the Langmuir isotherm (Olsen and Watanabe, 1957; Woodruff and Kamprath, 1965). The major advantage of the Langmuir equation over the Freundlich equation is that an adsorption maximum can be calculated. The Langmuir equation based on the kinetic theory of gases (Langmuir, 1918) to describe gas adsorption on solids is used in P adsorption studies and may be expressed in linear form as:

$$\frac{C}{X/M} = (1/kb) + (C/b)$$

where X/M = mg of P adsorbed per 100 g of soil,

b = the adsorption maxima

C = the equilibrium P concentration in moles/liter,

k = a constant related to the bonding energy of the adsorbent to the absorbate.

The Langmuir isotherm therefore provides a simple analytic procedure for the evaluation of soil and sediment capacity to sorb or release soluble P into surface runoff during a rainfall event.

The study of White and Beckett (1964) conducted at initial dissolved inorganic P concentrations comparable to those existing in soil-water ecosystem, provides a useful basis for understanding the interactions between aqueous and particulate phases of P in runoff and streams. This relationship is expressed in Figure 1.

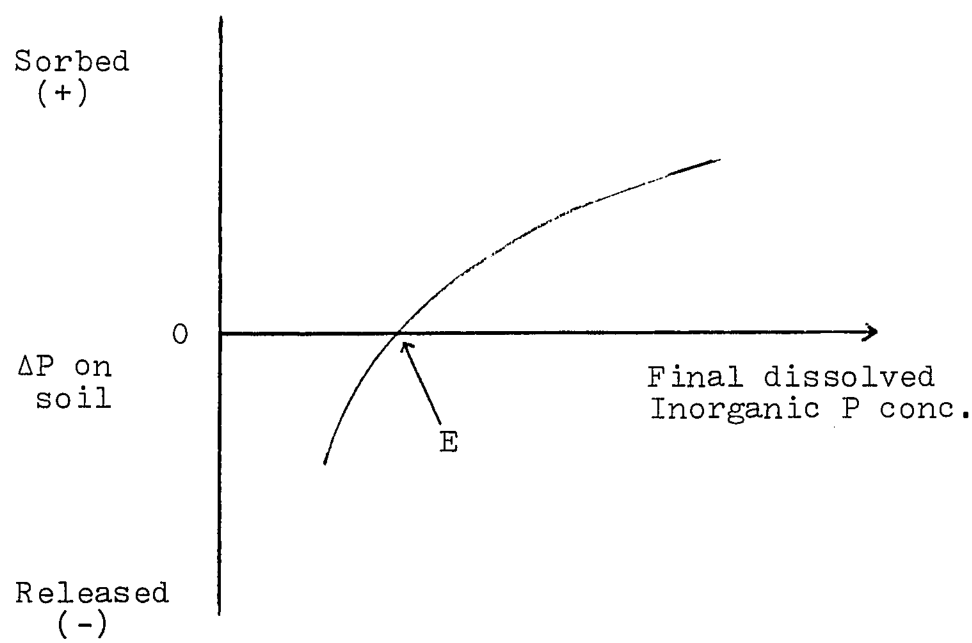

Fig. 1. Equilibrium P Concentration Curve (Schematic).

The equilibrium P concentration, E, in Figure 1 as defined by Taylor and Kunishi (1971) is equivalent to the inorganic

P concentration in the ambient aqueous phase when there is no net sorption or release of P i.e. $\Delta P = 0$. Ryden et al. (1973) indicated that this is a point of reference which provides a predictive estimation of sorption or release of P should the P concentration in solution change. Ryden et al. (1973) further indicated that the average slope of the sorption curve over a given P concentration range provides information on the ability of the soil to maintain the P concentration at the equilibrium concentration. The steeper the slope, the closer will be the final P concentration at the equilibrium P concentration. Ryden et al. (1973) further indicated that the slope of the curve, although not related to the total P sorbed, is related to the extent to which that soil may sorb P over the concentration considered.

Nutrient losses in surface runoff from agricultural lands are therefore principally a function of the inherent soil fertility status; intensity of rainfall and the quantity of transporting water; time, rate and method of fertilizer application; and the capacity of the soil to release the nutrient as in the case of inorganic phosphorus.

Slot Mulching and Slot Trenching Concepts: Alternative Tillage and Residue Management Techniques for Soil and Water Conservation

Slot Mulch Concept:

Saxton et al. (1981) developed and investigated a slot mulch concept of tillage and residue management to control runoff and erosion during major storms. The concept involves compacting crop residues into narrow continuous slots, with the crop residue well exposed above the soil surface. The slot is installed on the contour. Saxton et al. (1981) used slot widths of 5 to 10 cm and depths of 20-25 cm. These workers further indicated that they have not yet determined the best slot dimensions and spacings for optimum water infiltration and minimum energy use.

Saxton et al. (1981) further stated that during runoff, water will flow into the slot and downward through the residue. Water will penetrate the slot mulch only if the mulch is not covered by soil and if the slot can readily intercept free water on the surface. Covering the mulch with soil during subsequent tillage renders the slot mulch ineffective in most situations.

Slot Trenching Concept:

A number of workers (Bradford and Blanchar, 1980; Unger, 1970; Hauser and Taylor, 1964) have attempted different tillage methods such as trenching, deep chiseling and subsoiling as alternative techniques to achieve more efficient use of soils that restrict downward movement of water and plant roots. The general approach in alleviating this condition has been the disruption of the restrictive horizon by way of profile modification that results in creating a more desirable physical environment for biological activity and root growth. Unger (1970) mentioned that the modification of the slowly permeable Pullman soil can be an effective means of conserving the limited precipitation and irrigation water available for crop production on the Southern High Plains. Unger (1970) further stated that although the cost of modifying the entire soil mass to 90 or 150 cm is prohibitive at present, some form of limited profile modification, such as deep plowing or slot trenching may give benefits approaching those obtained with profile modification.

Previous Research on Vertical/Slot Mulch:

Spain and McCune (1956) were among the first to use a vertical mulch to enhance the effectiveness of subsoiling. They blew crop residues into the trench to keep it stabilized and open. This concept showed promise of increasing infiltration. Pebbler (1959) developed a machine for subsoiling and incorporation of crop residues that permitted a wider trial of the vertical mulch concept. Results of these trials were not impressive as the vertical mulch showed very little effect on infiltration because subsequent tillage covered the mulched trenches.

Clark and Hore (1965) used 74 cm deep channels with spacings of 0.9 m to 1.2 m apart and filled with chopped straw, to evaluate the effect of this treatment on soil water infiltration and storage. No measurable effects were observed. It should be noted that the experimental plots were plowed and tilled following the vertical mulch treatment.

Fairbourn and Gardner (1972, 1974) evaluated the potential of soil water storage with vertical mulch and nonmulch treatments with a micro-watershed in laboratory tests and field experiments. Their results showed that soil water evaporation was lowest on the microwatershed with vertical mulch, which concentrated runoff and enhanced deep percolation. Fairbourn and Gardner (1974) found that increased soil water storage associated with the vertical mulch was largely responsible for an increase in sorghum (Sorghum vulgare L.) yields ranging from 37% to 150% more than the control treatment.

Rao et al. (1977) observed a significant yield increase in vertical mulch plots on a vertisol with very low water intake rates, particularly in those years when water limited crop growth. Hauser and Taylor (1964) reported a considerable increase in water infiltration on vertical mulch plots under irrigation. Even after subsequent tillage free water was able to penetrate into the mulched trenches, probably through soil cracks.

Parr (1959) conducted a study on Crosby silt loam with an impermeable A_2 horizon to evaluate the influence of vertical mulching compared to subsoiling on soil physical properties at different channel depths and at different distances from the channel. He concluded that the bulk density values for vertical mulching were significantly lower than for subsoiling; in most cases the soil moisture values for vertical mulching were higher than for subsoiling; and aggregate index values were usually higher for the vertical mulch treatments.

Swartzendruber (1960, 1964) used mathematical solutions to investigate the effectiveness of vertically mulched channels. The summary of his finding states: If water enters the soil through the original soil surface as well as the channel surfaces, the increase in flow due to the channel is small. But if the original soil surface is sealed, the channels are relatively effective in restoring soil water flow to the level that occurs in the absence of the channels and surface sealing.

Since depth of wetting has an effect on soil water storage, a vertical mulch offers a possible way to get water into the soil readily at greater depths than by wetting downward from the soil surface, particularly in sloping areas where runoff occurs rapidly.

Swartzendruber (1960), in a mathematical solution developed a depth : spacing formula, $d_o = 0.28S$, which he presented as a tentative design criterion for the placement of vertical mulch channels. In the formula, d_o is depth and S is spacing interval between channels in feet. Spain and McCune (1956) used $S = 2.03$ meters and $d_o = 50.81$ cm. Saxton et al. (1981) used several spacings in their preliminary studies with $S = 2.44$m, 3.66m, 3.96m and 6.10m; and $d_o = 20$ to 25 cm. In another study, Rao et al. (1977) found that 30.5 cm deep trenches were as effective as 61 cm and 91 cm deep trenches for vertical mulch studies. Rao et al. (1977) recommended a 4 m spacing based on the result of their study.

These studies all indicate that vertical mulching does increase infiltration, especially where a restricting soil horizon occurs such as that caused by tillage, surface sealing and fragipan layers. Saxton et al. (1981) inferred that tillage across the mulched channels destroys the treatment by disconnecting the macroporosity of the mulch from the soil surface where free water is available for infiltration. Vertical mulch is therefore more adaptable to no-tillage plots and it is used in that fashion in the present study.

Previous Research on Profile Modification:

Burnett and Tackett (1968) grew cotton plants (*Gossypium hirsutum* L.) in Houston black clay soil (Udic Pellustert i.e. vertisol) that was modified by trenching to 120 cm. They found that root growth was increased as a result of trenching. This increase was probably associated with increased soil moisture, decreased soil bulk density and increased soil volume available to roots.

Bradford and Blanchar (1980) evaluated the effects of profile modification on a Hobson soil profile (Typic Fragiudalf) which restricted the downward movement of water and plant roots. Over a 3-year period, sorghum grain (*Sorghum vulgare* L.) yields were increased by 50% due to thorough mixing alone, and 150%

when lime and fertilizer were added prior to mixing. In another study, Bradford and Blanchar (1977) found that in the first year after soil profile modification by trenching of a Missouri Typic Fragiudalf, available water storage and yields of grain sorghum (Sorghum bicolor (L.) Moench) were increased. Within unmodified areas, sorghum yields averaged 1840 kg/ha. Deep trenching without chemical or physical additives increased yields to 4322 kg/ha. Bradford and Blanchar (1977) found that mixing lime, fertilizer and sawdust with the soil material within the trenches increased grain sorghum yields to 5987 kg/ha. From their observations, Bradford and Blanchar (1977) concluded that profile modification increased storage of water available to the plant roots by increasing total pore space (decreasing bulk density), by increasing the saturated hydraulic conductivity, and by decreasing the mechanical resistance to plant roots.

Unger (1970) evaluated the potential of profile modification for increasing water intake, retention, and storage. His result showed that profile modification to 90 and 150 cm effectively disrupted the slowly permeable horizon of a Pullman soil. Soil bulk density and strength were significantly decreased, and soil porosity was significantly increased. Unger (1970) found that unmodified soil retained more water on a volumetric basis than modified soil at 1/3- and 15-bar tension, but plant-available water as estimated from the 1/3- and 15-bar values was not altered by modification. Unger (1970) further indicated that the lower water contents of the modified soil at low tensions provided for potentially greater aeration. He found that water entered modified soil more rapidly than unmodified soil under field conditions.

Generally, trenching has been associated with increased soil porosity, increased water infiltration rates and decreased soil bulk density in the trenches. The enhanced infiltration rate, higher porosity and higher hydraulic conductivity of a trenched plot are therefore desirable characteristics that can directly retard the rate of surface runoff and soil erosion during a storm event because of the reduced amount of water available for runoff. On the other hand, since trenching reduces the cohesiveness of soil particles, it might also make the particles much more vulnerable to rainfall splash action which might result in accelerated soil detachment and sediment transport in storms of high intensity and long duration.

OBJECTIVES OF THE STUDY

1. To evaluate the relationship between the physical characteristics of rainfall (intensity, duration, kinetic energy and rainfall amount) and soil loss from a study site, knowledge of which is important for conservation practices.
2. To evaluate the effectiveness of different soil management systems (slot mulch and slot trenching) at variable intervals (91.4 and 182.9 cm spacings) on the reduction of sediment and runoff losses from micro-erosion plots.
3. To evaluate the potentials of the different soil management systems for increasing soybean yield through increased soil moisture storage.
4. To examine nutrient losses associated with sediment and runoff from microplots under different soil management systems.
5. To examine the phosphate sorption isotherms for Miamian and Celina soils and relate these with soluble phosphate content in runoff from these soils.

6. To examine the relationships between observed soil physiochemical parameters and sediment and runoff losses from the study site.

EXPERIMENTAL SITE

The study was conducted at the Ohio State University Agronomy Farm, Columbus, Ohio.

Soils.

Replicates 1, 2 and 3 were located on Miamian silty clay loam (fine, mixed, mesic Typic Hapludalf) while replicate 4 was on Miamian-Celina association. Celina silt loam is classified as fine, mixed, mesic Aquic Hapludalf.

The Miamian silty clay loam is well drained and has moderately slow permeability. The surface layer is brown, friable silty clay loam about 23 cm thick. The subsoil of dark yellowish brown and yellowish brown, firm and very firm clay loam extends to about 64 cm depth. The subsoil is higher in both clay and coarse fragment content than the surface horizon. The substratum that extends to about 178 cm depth is glacial till of yellowish brown, mottled, very firm clay loam and firm loam. The capability subclass for Miamian silty clay loam is IIIe i.e., severe limitations due to risk of erosion that reduces the choice of plants or requires special conservation practices (Soil Survey of Franklin County, Ohio, 1980).

Parts of the original soil surface at the site have been eroded and runoff from the unprotected soil surface is rapid.

Celina silt loam is a deep, moderately well drained soil with moderately slow permeability. The surface layer is dark brown, friable silt loam of about 18 cm depth. The subsoil is yellowish brown to dark yellowish brown, firm, silty clay loam and clay loam that extends to about 64 cm depth. The substratum is loam and it is high in coarse fragments. The substratum extends to about 178 cm depth and below this depth is glacial till. The capability subclass for Celina is IIe; i.e., the main limitation is risk of erosion unless close-growing plant cover is maintained (Soil Survey of Franklin County, Ohio, 1980).

Slope

The microplots were constructed such that the orientation of the slope in each microplot was from the south to the north. The percent slope in each individual microplot ranged from 1.8 to 10. The average slope values for the four replicates were as follows:

replicate one 8.4%
replicate two 8.6%
replicate three 7.6% and
replicate four 4.0%

The mean slope values for the treatments were:

control (no-tillage)	6.6%
slot mulch at 91.4 cm spacing	7.5%
slot mulch at 182.9 cm spacing	7.7%
slot trenching at 91.4 cm spacing	7.1%
slot trenching at 182.9 cm spacing	6.7%

The slope values for individual microplots are given in Appendix A.

Climate

Columbus, Ohio has a humid, temperate, continental climate. The 37 year average precipitation record (1931-1968) for Columbus (Port Columbus Airport) is given in Table 2. The rainfall record for the study period (May-November, 1982) is given in Table 3.

Table 2. Average monthly rainfall data (mm) for Columbus, Ohio (1931-1968)

Jan.	75.7	May	92.7	Sept.	63.7
Feb.	64.3	June	89.9	Oct.	56.6
March	105.9	July	93.5	Nov.	67.0
April	80.5	Aug.	78.0	Dec.	64.5

Table 3. Total monthly rainfall data (mm) at the study site during the field study period (May - Nov., 1982).

May	110.2	Sept.	81.3
June	67.8	Oct.	29.7
July	34.5	Nov.	160.3
Aug.	24.6		

Vegetation and Land-use

The section of the Agronomy Farm where the experimental plots were located has been under grass cover for many years as indicated in the 1939 soil survey of the farm. The grass cover has been mowed constantly and left in place. There has been no cultivation or soil disturbance recorded for the experimental site within the past half-century (1932-1982).

MATERIALS AND METHODS

Field Procedure

The field experiment was conducted in the summer and fall of 1982. The first and last runoff data collections were on September 2 and November 21, 1982, respectively. Additional runoff data were collected four times between these dates.

Glyphosate herbicide with a recommended rate of 1.68 $kg.ha^{-1}$ active ingredient was used in an attempt to kill all existing vegetation on the experimental site. The weeds were later mowed and left in place. Soybeans were first planted on May 3, 1982 but due to excessive weed growth and poor soybean stands as a result of very dry weather conditions, a second application of glyphosate with 3.36 $kg.ha^{-1}$ rate was sprayed on the site and the soybeans were reseeded on June 18, 1982. Soybeans were seeded directly into the weed residue using a "Tye" no-till drill. Five continuous rows of soybeans were seeded across the slope on the entire experimental site with 50.8 cm spacing between rows and about 12 seeds per 30.5 cm. The no-till drill planter created minimal soil disturbance in the study site. There were no other tillage operations performed on the site except the incorporation of treatments being examined.

The soybean variety used for the study was Williams 79, a variety that requires 141 days from planting to maturity in Central Ohio. Fertilization of the experimental site was by broadcast method at a rate of 224 $kg.ha^{-1}$ (5-20-35, P_2O_5 K_2O) on July 5, 1982.

When the soybean stands were fully established, the experimental plot was divided into 4 replicates, with each replicate measuring 3.04 m long up and down the slope and 6.1 m wide across the slope. Five micro-plots each measuring 1.22 m wide across the slope (i.e. on the contour) and 3.04 m long up and down the slope were constructed with fiber glass sheets within each replicate (Figure 2). Each of the 5 treatments under examination were randomly assigned to the

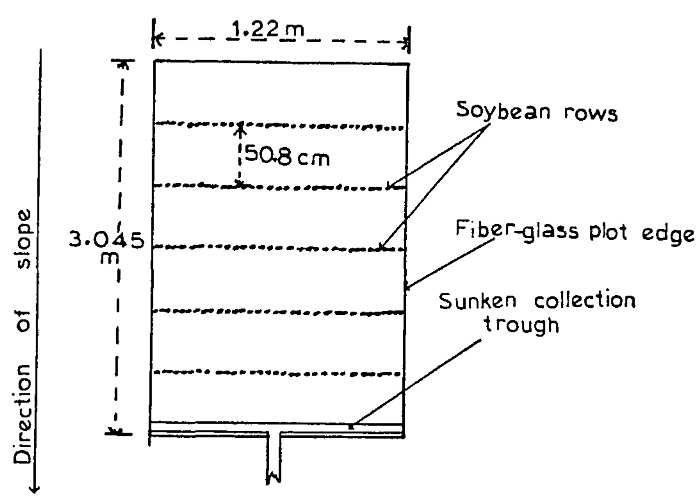

Fig. 2. Schematic representation of the size, shape, soybean row spacing and slope orientation for a single microplot.

micro-plots in each replicate using the table of "Ten thousand random digits" (Steel and Torrie, 1960). Each micro-plot had within its borders, the 5 rows of soybean as shown in Figure 2. There were two treatments at two spacing intervals of 91.4 cm and 182.9 cm and a control. The treatments were vertical or slot mulch and slot trenching, these were put in place on July 10, 1982.

An automatic recording raingage was installed at the site on July 12, 1982. The raingage recorded rainfall amounts, duration and intensity on charts. Rain water in the raingage collection bucket were retrieved during routine runoff sample collection and analyzed for nitrate- and ammonium- nitrogen addition to the site from the atmosphere.

Poast-sethoxydim, a grass killing herbicide was sprayed on all the micro-plots on July 19, 1982 at a rate of 0.22 $kg.ha^{-1}$.

Micro-Plot Design and Construction

Micro-plots were constructed with fiber glass sheets (Figures 3 and 4). The fiber glass edges extended 22.9 cm below ground surface and 20.3 cm above the ground surface. The plots were isolated so as to prevent the passage of water into or out of the plot both above ground and below. A 1.22 m long polythene pipe with 10.2 cm diameter cut lengthwise was sunken into the soil, covering the entire width of the down-slope edge of the plot. The pipe served as a collecting trough for runoff water and sediment. The trough was connected in the middle with flexible aluminum sheet to a 1 meter long polythene pipe (Figure 4). The latter was connected to a sunken catchment tank (113.55 liter drum) holding a graduated plastic bucket. The catchment tank had a detachable lid which when put in place prevented evaporation and direct rain-fall into the tank. Seepage of rain from each plot was prevented by sealing the edges of each connecting material (fiber glass, plastic pipes) with caulk during construction.

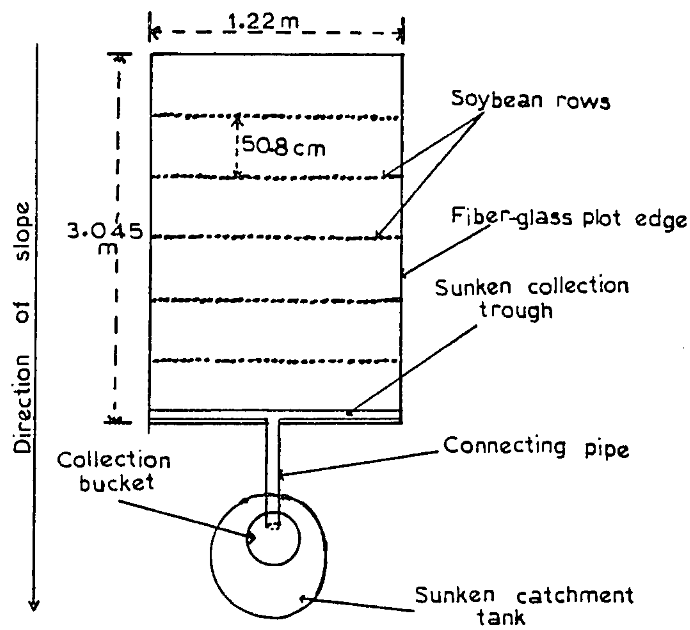

Fig. 3. Schematic representation of a microplot and the runoff collection device installed at the lower end of the plot.

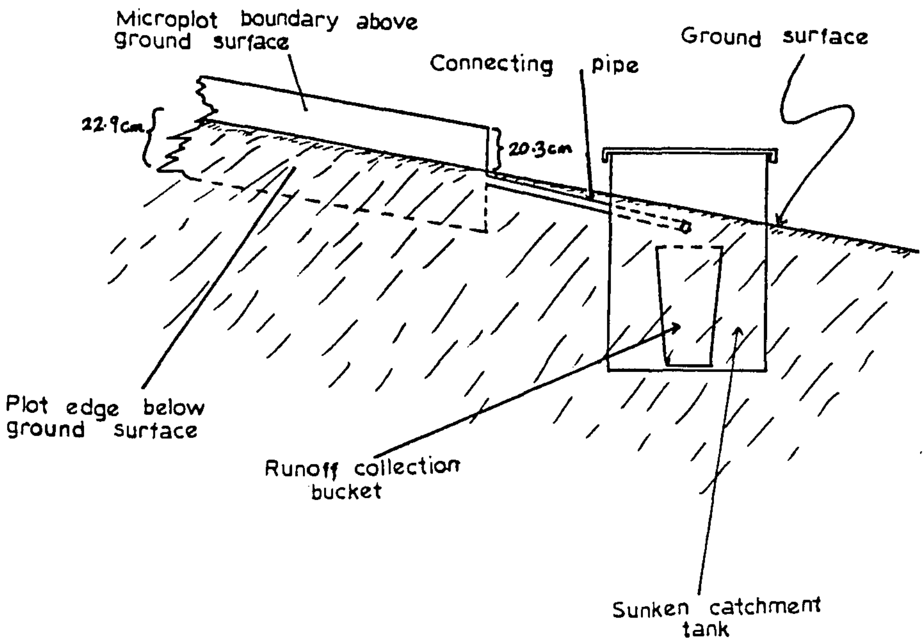

Fig. 4. Schematic representation of microplot elevation showing the sunken runoff catchment system and the vertical dimensions of the microplot boundary.

Treatment Forms:

Control:

When soybean stands were fully established and the micro-plot constructed, no more operations were carried out in this treatment except broadcast fertilization and Poast herbicide application that were given uniformly to all treatments. There was no soil disturbance in this plot through the entire duration of the study. The control in essence was a no-tillage plot with no further modification.

Slot Trenching:

In this treatment, narrow trenches measuring 10.2 cm wide and 30.5 cm deep were made along the slope on the entire width of the micro-plot. The soil particles dug out of the trench were collected on a plastic sheet outside the experimental plot, shattered, mixed thoroughly and put back into the same trench without being compacted (Fig. 5).

Slot trenching with 91.4 cm spacing had two trenches in the microplot while the treatment with 182.9 cm spacing had one trench in the micro-plot. The trenches were made between soybean rows.

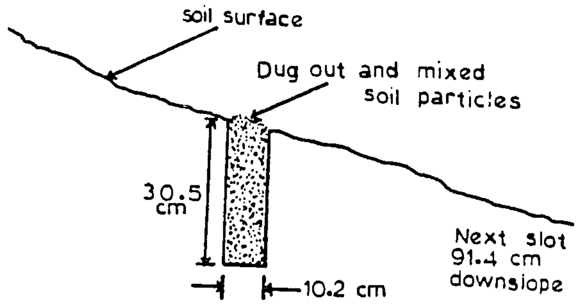

Fig. 5. Schematic of slot trenching treatment with the slot filled back with the crushed and thoroughly mixed soil particles dug from the same slot.

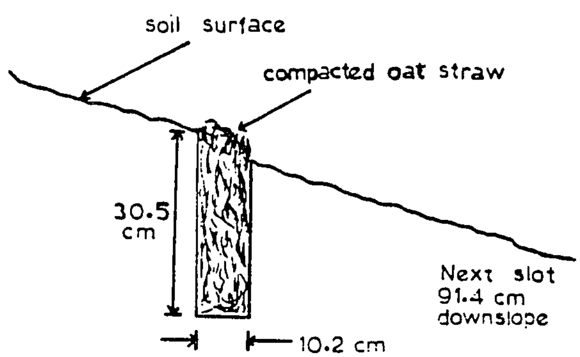

Fig. 6. Schematic of slot mulch treatment with the slot filled with oat straw.

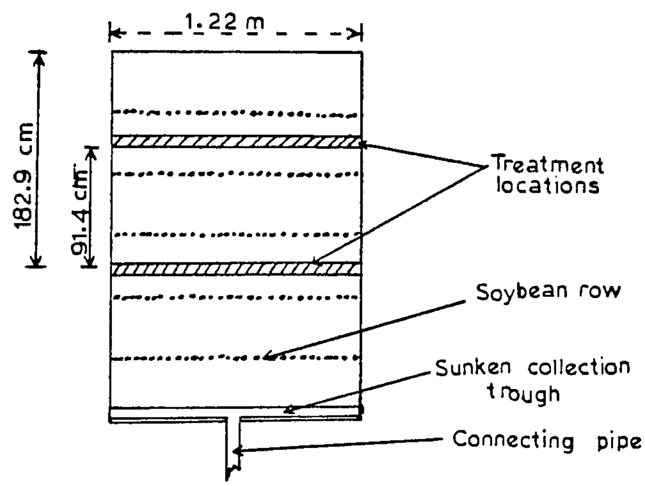

Fig. 7. Schematic representation of locations of treatment placement within a microplot.

Vertical or Slot Mulch Treatment:

The vertical mulch concept of tillage and residue management to control erosion and runoff consisted of dug channels 10.2 cm wide and 30.5 cm deep made along the slope and covering the entire width of the micro-plot. The channels were compactly and completely filled with oat straw and the straw was well exposed above the soil surface (Figure 6). The organic residue kept the soil from slumping into and filling the channels and at the same time provided an easy pathway for water to enter the soil through the surface of the channel.

Slot mulch comprised two treatments, the first had a distance of 91.4 cm between adjacent channels and the second treatment had a distance of 182.9 cm. The treatment with 91.4 cm spacing had two channels in a micro-plot. The slot mulch trenches were made between the soybean rows.

Each of the five treatments were replicated four times.

Sample Collection, Handling and Storage:

Runoff and eroded sediments collected in the receiving buckets were sampled within 24 hours after each storm event.

Two liters of the vigorously stirred runoff samples were taken in plastic bottles, labelled and stored in the cold-room (refrigerated) for future analyses. Each sample in the cold-room was vigorously shaken to disperse the sediment and a 200 ml aliquot was taken and the remaining 1.8 liter sample was left in the cold-room.

From the 200 ml sample of the sediment suspension, a 20 ml aliquot was filtered through a weighed 0.1 μm polycarbonate nucleopore filter. The filter and the sediment on it were dried in a micro-wave oven for 5 min and reweighed to determine the sediment weight. The filtrate was used to determine soluble phosphorus content of the runoff. The remaining sample from the 200 ml stock suspension was filtered with No. 5 Whatman filter paper and placed in polyethylene containers in the cold-room (5°C) for future analyses.

The remaining 1.8 liter suspension was left in the cold-room to settle. The supernatant was then syphoned off and the sediment transferred to a small aluminum can and left to dry at room temperature.

The rain samples collected in the rainguage were also refrigerated until they were ready to be analyzed for nitrate- and ammonium-nitrogen.

Soil Sample Collection:

Soil samples for routine laboratory analyses were collected during the construction of the microplots and trenching operation. Samples were randomly collected from 0-15 and 15-30 cm depths. Subsamples from the same depth obtained from the same microplot were thoroughly mixed to obtain a bulk sample that was representative of the respective depths. The bulk samples were air dried, crushed and sieved through a 2 mm sieve. The coarse fractions (> 2 mm) were discarded while the < 2 mm fractions were preserved for laboratory analyses.

Soil samples for phosphorus sorption studies where collected in late November, 1982, after the soybeans had been harvested and all runoff sample collections were completed.

Two representative samples from microplots located on Miamian soils and one representative sample from microplots on Miamian-Celina soils association were used for phosphate sorption studies. The soil samples for P-sorption studies were collected from a 0-1 cm depth, representing the zone of interaction between runoff water and the soil.

Laboratory Procedures

Soil Chemical Parameters

Soil Reaction

Ten g of soil sample were placed in a paper cup and 10 ml of distilled water were added, stirred and left for 30 minutes. The suspension was stirred again and left to equilibrate for another 30 minutes. The pH in the 1:1 soil-water mixture was determined using a Beckman SS-2 pH meter.

The pH of the soil sample was also determined using 0.10 M $CaCl_2$ solution with a soil - $CaCl_2$ solution ratio of 1:2.

Organic Carbon

Organic carbon content of the soil sample was determined by the dry combustion method (Post, 1956; Robinson, 1930). Two grams of sample were placed evenly in a porcelain boat containing about 0.25 g powdered manganese dioxide (MnO_2). The boat was placed in a preheated Lindberg furnace at a temperature of 1000°C for 10 min while CO_2- free oxygen was passed over it. The evolved carbon dioxide (CO_2) was collected in a Nesbitt adsorption bulb containing ½ inch fiberglass, ½ inch $Mg(ClO_4)_2$, 2 inches Ascarite and ½ inch fiberglass placed in that sequence from bottom to top. The bulb was weighed before and after passing the O_2 current through it. The difference in weight was used to calculate the percent organic carbon in the sample.

Cation Exchange Capacity

Cation exchange capacity of the soil sample was determined by ammonium saturation at pH 7.0 (Chapman, 1965). One hundred ml of 1.0N NH_4OAc was added to 20 g of soil, shaken and left to stand overnight. The sample was filtered with gentle suction and washed with two 25-ml portions of 1N NH_4OAc. The filtrate was saved for the determination of exchangeable calcium, magnesium and potassium.

The soil sample was washed with 200 ml of 95% ethyl alcohol and the leachate discarded. The soil sample was then leached with 10% NaCl solution acidified to 0.005N with HCl. The filtrate was diluted to 250 ml with 10% NaCl solution. Five ml of the NaCl leachate and approximately 0.1 g of MgO were added to a Kjeldahl flask and distilled into 5 ml of 2% boric acid solution containing methyl red and bromocresol green indicators until about 30 ml of the solution was collected. The resulting solution was titrated with a standard HCl solution with the end point being a change from blusih-green to pink. Cation exchange capacity was then calculated from the data.

Extractable Calcium, Magnesium and Potassium

Extractable Ca, Mg and K were determined in the leachate of ammonium acetate used for CEC determination. The leachate was made up to 250 ml with 1.0 N NH_4OAc and saved. Extractable potassium concentration in the leachate was determined directly on the 250 ml extract by atomic emission spectroscopy.

To 1 ml of the 250 ml extract was added 10 ml of 20,000 mg K/ml solution and then diluted to 100 ml with 1.0 N NH_4OAc solution. The addition of excess easily ionizable K enhanced the efficiency of the flame breakdown of Ca and Mg into free ground state atoms by eliminating interference resulting from ionization and formation of stable inert compounds. The addition may also eliminate the variable effects of small amounts of easily ionizable substances that may be present in the sample.

Calcium and magnesium concentrations in the leachate were determined from the 100 ml extract by atomic absorption spectroscopy.

Total Soil Phosphorus

Total phosphorus on the soil sample was determined by $HClO_4$ digestion method (Bray & Kutz, 1945). Three ml of 70% perchloric acid was added to 0.3 g of soil in a pyrex digestion tube and the sample was digested on an aluminum block at 203°C for 75 min. Twenty ml of the clear extract was neutralized with 5N NaOH using P-nitrophenol indicator. The sample was then analyzed for total phosphorus by the method of Murphy and Riley (1962) as modified by John (1970).

Available Phosphorus

Available phosphorus content of the soil sample was determined by the Bray-P1 method (Bray and Kutz, 1945). One g of air dried soil sample was placed in a 50 ml polyethylene extracting bottle. Ten ml of the Bray-P1 extracting solution (0.025N HCL in 0.03N NH_4F, pH adjusted to 2.6 ±0.05) were added to the sample and shaken in a reciprocating shaker for 5 min at 200 oscillations per min. The extract was then filtered through Whatman No. 2 filter paper into an air vented funnel tube. A 2-ml aliquot of the clear extract was transferred to a test tube and 8 ml of the acid molybdate ascorbic acid color developing solution added, and the mixture shaken. The solution was allowed to develop color for 10 minutes and absorbance reading was taken with a Beckman 24 Spectrophotometer at 730 mm wavelength. The phosphorus concentration was determined from a standard curve.

Extractable Iron and Aluminum

The contents of iron and aluminum in the soil materials from the experimental plots were determined by the sodium dithionite-citrate extraction method of Holmgren (1967) with some modifications. Two g of sodium dithionite and 20 g of sodium citrate were added to 2.0 g of air dried soil sample in a 200 ml extraction bottle. About 100 ml of distilled water was added to the bottle and the bottle was shaken overnight in an oscillating shaker at 120 oscillations per min. Five drops of 0.4% superfloc solution were added and the bottle was then filled with distilled water to the 200 ml precalibrated mark. The bottle was shaken by hand and allowed to stand until the solution was clear. Five ml of the extract was diluted to 100 ml with distilled water and used for the determination of both aluminum and iron. The concentrations of iron and aluminum were measured on the atomic absorption spectrophotometer.

Phosphorus Sorption Isotherms for Celina and Miamian Soils

One g of air dried representative soil sample was placed in each of 6 labelled 50 ml polyethylene tubes. Phosphorus solutions with concentrations of 0.0, 0.2, 0.5, 1.0, 5.0 and 10.0 μgP/ml were added to each of the tubes, respectively. Each tube was duplicated. To the tubes were added 2.5 ml of 0.1M $CaCl_2$ and 0.5 ml of chloroform. The chloroform was used to suppress microbial activity during the sorption period. The volume of each tube was made up to 25 ml with a precalculated volume of distilled water to maintain the assigned P concentration in each tube. Fifty percent air volume was maintained in each tube for aeration. The tubes were placed in an end-over-end shaker and shaken for 24 hr. The extracts were filtered through No. 1 Whatman filter paper into air vented funnel tubes. Two aliquots of the clear extracts were transferred to test tubes and 8 ml of acid molybdate ascorbic acid color developing solution added. The mixtures were shaken and allowed to develop color for 10 minutes. Absorbance readings were taken with a Beckman 24 Spectophotometer at 730 mm wavelength and the phosphorus concentration in each extract was determined from a standard curve.

Phosphorus sorbed/desorbed versus equilibrium P concentration was plotted for each soil.

Soil Physical Parameters

Particle Size Analysis

Particle size distribution was determined on the <2 mm soil fraction by the pipette method (Kilmer and Alexander, 1949). To 10.0 g of sample in a 450 ml square sedimentation bottle was added 5 ml of dispersing solution (sodium hexametaphosphate + sodium carbonate). Distilled water was added to the bottle until it was about 2/3 full. The bottle was stoppered and shaken overnight on a horizontal reciprocating shaker at 120 oscillations per min. The preweighed sedimentation bottle was placed on a torsion balance and a total of 395 g of distilled water were added at room temperature. The sample was dispersed and the <20μ, <5μ and <2μ fractions were determined by pipetting (after different predetermined sedimentation period at depths of 8-, 5- and 5 cm, respectively) and oven drying. The sedimentation times for the three fractions varied according to temperature. The <0.2μ fraction (fine clay) was determined by pipetting after centrifugation. The sand was separated from silt and clay by washing the sample through a 300 mesh sieve. The various sand fractions were determined by dry sieving, oven drying and weighing.

Samples with organic carbon content in excess of 1.72% (3% organic matter) were pretreated with hydrogen peroxide

(30% H_2O_2) to remove organic matter, in which case corrected sample sizes were used as shown in the formula:

Corrected sample size = 10.0 +0.1{(%org. C)(1.74) - 3}

Soil samples obtained from 0-15 cm and 15-30 cm depths from each microplot were analyzed for particle size distribution.

Bulk Density Determination

Bulk density determination at 1/3 atm were made by the Clod Method (Brasher et al., 1966). Single determinations were made for the 0-15 and 15-30 cm depths for each microplot.

Clods were coated in the field with a saran mixture (saran + acetone at 1:6 ratio) and suspended on a line to dry. Each clod was then wrapped in aluminum foil and packed separately in soil cans for transportation to the laboratory. The clods were assigned laboratory numbers and weighed in air. Each clod was again coated three times with saran, allowing enough time for drying between coatings. The clod was then weighed in air and in water. A flat surface was cut from the clod with a knife and the weight of the clod in air recorded. The cut edge was covered with gauze and held in place with a rubber band. The clod was saturated in water for two days. The saturated clod was weighed and placed on a ceramic plate for desorption with the cut end in contact with the plate. The clod was pressurized at 60 cm H_2O (4.5 cm Hg) and 1/3 atmosphere (26 cm Hg). After each equilibration the clod was weighed and after the 1/3 atmosphere desorption, two more saran coatings were applied to the clod. The clod was then weighed in air and in water, oven dried at 105°C for 4 days and reweighed. Two more saran coats were added to the clod and the final weight in air and water were determined.

The clod was broken and coarse fragments >2 mm were washed, oven dried and weighed. Fifteen atmosphere water retention was determined from the aggregate sample of the <2 mm fraction.

Determination of 1/3 atmosphere bulk density was made with a Fortran computer program with formula:

$$B.D.\ 1/3 = \frac{WTODTR}{VTHIRD}$$

where WTODTR = (weight of oven dry cut clod) - (Tag) - (correction factor for coats) - (weight of coarse fragments).

VTHIRD = (wt. of clod and coats after 1/3 atm) - (wt. in water) - (volume of saran + volume of coarse fragments).

Aeration Porosity

Data from the clod bulk density determination was used for the calculation of aeration porosity, represented as the percent volume of clod occupied by air at field capacity.

Aeration porosity was calculated with the formula:

Aeration porosity = (% moisture at saturation - % moisture at 60 cm) x bulk density at 1/3 atmosphere.

Void Ratio

Void ratio data was also calculated from the bulk density determination data. Generally, void ratio is given by the formula:

$$\text{Void Ratio} = \left(\frac{\text{Volume of void spaces}}{\text{Volume of solid particles}}\right)$$

An assumption is made that the density of soil particles is 2.65 $g.cm^{-3}$.

$$\text{Void Ratio} = \left(\frac{2.65}{\text{Bulk density 1/3 atm}}\right) - 1$$

Moisture Holding Capacity

Moisture contents at field capacity and wilting point were obtained from the clod bulk density analyses for 0-15 and 15-30 cm depths in each microplot.

Moisture at field capacity was obtained from the Fortran program as percent moisture content at 1/3 atmosphere while the percent moisture at the wilting point was equated with the moisture content at 15 atm. Available water was then calculated as the difference between field capacity (0.3 bar) and permanent wilting percentage (15 bar) x 1/3 atm bulk density.

Volumetric Soil Moisture Content

Water content measurement in each microplot were determined gravimetrically. A 2.54 cm diameter soil probe was used to obtain soil samples at 0-15 cm, 15-30 cm and 30-45 cm depths. The samples were not taken directly from the slot trenches but from undisturbed soil. Care was taken to ensure that the sampling locations were of the same distance to the slots in all plots with slot mulch and slot trenching treatments. The soil samples were placed in aluminum cans with tight fitting lids and taken to the laboratory. The samples were weighed in air and placed in a preheated oven at 105°C for four days with the cans' lids taken off and reweighed after oven drying. Water content on a dry mass basis was obtained by dividing the difference between wet and dry masses by the mass of the dry sample. Volumetric soil moisture content was determined by the equation:

$$\theta_{vb} = \left(\frac{D_b}{D_w}\right) \theta_{dw}$$

where:

D_b = soil bulk density $gm.cm^{-3}$ ($Mg.M^{-3}$)

D_w = density of water $gm.cm^{-1}$

θ_{vb} = moisture content on volume basis

θ_{dw} = moisture content on dry weight basis

Soil moisture contents for each of the microplots were determined periodically at 5 sampling dates, namely, September 10, September 19, September 29, October 11 and November 8, 1982.

Saturated Hydraulic Conductivity of Undisturbed Soil Samples

The constant-head method (Klute, 1965) was used for the laboratory determination of saturated hydraulic conductivity of undisturbed soil core samples. Undisturbed soil cores were obtained by pressing metal cylinders that fit into sampling tubes into the soil. After the samples were taken, the cylinders served as retainers for the soil samples during the conductivity determination.

Four soil cores were taken from each microplot with depths of 7.62 cm each such that the total soil depth in each microplot evaluated for conductivity was 0-30.48 cm. Each soil core was marked during sample collection for the identification of the upper and lower soil layers. The soil cores were placed in soil cans immediately after collection to prevent drying and then taken to the laboratory. Only one sample per depth per microplot was taken.

Once in the laboratory, the lower end of each core was covered with gauze held in place with a rubber band. To get the soil completely wet by capillary action, the gauze-covered end of the core was placed in a tray filled with water to a depth just below the top of the sample for three days. The soil cores were finally saturated by com pletely submerging them in a tray of water.

An empty cylindrical sample holder was placed on top of each core and a large rubber band was used to put it in place. The soil core sample was then placed on the wire screen support of the conductivity equipment and water was added to the empty cylinder sample holder to about 2/3 full. The siphon was quickly started to maintain a constant head of water on the sample. When the water level on top of the sample was stabilized, a stop watch was started at the same time that a beaker was placed beneath the sample to collect the percolate. The volume of percolating water (V) was measured after one hour (T), and the hydraulic head difference ($d\phi$) was measured.

Hydraulic conductivity (K) was calculated from Darcy's equation:

$$v = V/AT = Kd\phi/dL$$

$$K = \left(\frac{V}{AT}\right)\left(\frac{dL}{d\phi}\right)$$

where
- K = hydraulic conductivity (cm/hr)
- dL = length of soil core (7.62 cm)
- $d\phi$ = hydraulic head difference (cm)
- A = cross sectional area $\left(\frac{\pi D^2}{4}\right)$ (cm^2)
- T = time (hr)
- V = volume of percolating water (cm^3)

The assumptions in calculating K were as follows: only laminar flow occurs (no turbulence), the soil sample is homogeneous (not layered), the soil sample is isotropic with respect to its hydraulic conductivity (K is the same in all directions) and water drips from the bottom of the sample at atmospheric pressure ($h = 0$) (Baver et al., 1972).

Runoff and Eroded Sediment

Extractable Calcium, Magnesium and Potassium in Sediment

Sediments from the rainfall of Sept. 3 were the only ones analyzed for nutrient losses. All other rainfall events during the study period did not produce enough sediment to warrant similar analysis.

The cations, calcium, magnesium and potassium, were extracted from air dried sediments by leaching 10 g of sediment with 50 ml of 1N NH_4OAc solution adjusted to pH 7.0. The extracts were brought to 100 ml volume with 1N NH_4OAc. One ml of this solution was added to 10 ml of 20,000 μgK/ml solution and then diluted with 1N NH_4OAc to 100 ml volume. The latter solution was used for the determination of Ca and Mg concentrations by atomic absorption. Potassium concentration was determined from the original soil extract by flame emission on a Varian Techtron Spectrophotometer.

Soluble Basic Cations (Ca, Mg, K) in Runoff

Thoroughly dispersed runoff sample was filtered with No. 5 Whatman filter paper and 3 ml of the filtrate was made up to 100 ml volume with double deionized distilled water. Calcium and magnesium concentrations in the sample were measured by atomic absorption. Potassium concentration in the solution was determined by flame emission on a Varian Techtron Spectrophotometer.

The concentrations of the soluble basic cations in runoff from all microplots were determined for all six rainfall events.

Soluble and Total Phosphorus Contents in Runoff and Eroded Sediment

Total phosphorus and soluble phosphorus contents of the runoff samples were determined by the perchloric acid ($HClO_4$) digestion method. The runoff sample with sediments was very thoroughly shaken and a 2-ml aliquot was pipetted into a pyrex digestion tube for total phosphorus determination. For the filtered or soluble phosphorus content determination, 20 ml of the runoff sample was filtered through a 0.1 μm polycarbonate filter paper and 10 ml of this filtrate was pipetted into the digestion tube for perchloric acid digestion.

Total phosphorus and soluble phosphorus contents of runoff and eroded samples were then determined by Bray and Kutz (1945) method.

Ammonium- and Nitrate- Nitrogen in Runoff and Rainfall

Ammonium- and nitrate-nitrogen (NH_4-N and NO_3-N) contents in runoff and rainfall samples were determined by the Kjeldhal distillation method. Twenty ml of the sample was distilled, with a small amount of MgO added for the determination of NH_4-N. Devardo's alloy (Cu 49%, Al 45%, Zn 6%, N 0.004%) plus MgO was used to determined NH_4-N plus NO_3-N.

The distillate was collected into 5 ml of 2% boric acid in combination with mixed indicator (methyl red and bromocresol green) and titrated with a standard HCL of accurately determined normality until the blue color turned pink.

NH_4-N content of the sample was then obtained through direct calculation while NO_3-N content was obtained by the difference between (NO_3-N + NH_4-N) - NH_4-N. Total nitrogen contents of the runoff and rainfall samples represent the sum of NO_3-N plus NH_4-N.

Mineralogical Parametrs

Clay mineralogy of the total clay fractions were determined on two microplots located on Miamian soils, one microplot on Celina, and on sediments from the same microplots resulting from two rainfall events. The sediments were obtained from the first and last rainfall events (Sept. 3, Nov. 21) sampled. Soil samples analyzed were obtained from 0-15 and 15-30 cm depths.

Sample Prepararion

Thirty g of soil sample and sediment from the rainfall event of September 3 and the entire sample from the rainfall event of November 21 were treated to obtain the total clay fraction. Organic carbon was removed by hydrogen peroxide treatment (30% H_2O_2). The sample was washed with 100 ml of 1N NaCl solution and twice with 100 ml of 60% methanol. Thirty ml of 0.5N Na_2CO_3 was added to the soil sample and the suspension was thoroughly dispersed with a sonifier probe. The sand fraction was separated by wet sieving through a 300 mesh sieve. The remaining clay and silt fractions were separated with a fractionator. The clay fractions (<2 µm) were flocculated with 1N $MgCl_2$ solution. Excess Mg salt was removed by distilled water and 60% methanol washes.

An aliquot of the Mg-clay previously determined to contain 45 mg clay was transferred to a centrifuge tube and washed three times with 20 ml of 1N KCl. Excess salt was removed with distilled water and 60% methanol washes. Both the K- and Mg-saturated clay suspensions were thoroughly dispersed with an ultrasonic probe and 30 mg of Miamian and 15 mg of Celina samples were plated on 27x46 mm glass slides to air dry. The difference in clay amount was necessary to prevent curling which was observed on Celina samples.

Clay Mineralogy

The specimens were scanned as follows:

Treatment	Scanning range
Mg - 25^{o}C	3-30^{o} 2θ
K - 25^{o}C	3-15^{o} 2θ

The Mg-saturated clay slide was glycolated by placing it in an ethylene glycol pot at 40^{o}C for 12 hours. The K-saturated clay slide was x-rayed after both 350^{o}C and 555^{o}C heat treatments. The scanning ranges were:

Mg-glycolated	3-15° 2θ
K-350	3-15° 2θ
K-550	3-15° 2θ

A Philips Electronic Instrument x-ray generator (XRG 3100), diffractometer, and electronic control panel were used for the x-ray diffractometric analyses. The instrument settings were as follows:

tube type	Cu
tube voltage	35 kv
tube amperage	20 mA
time constant	2
counter rate	1000 cps
scan speed	2° 2θ/minute
monochromator	graphite
detector	scintillation

RESULTS AND DISCUSSION

Rainfall Characteristics and Soil Erosion

The six recorded rainfall events were composite storms with different intensity distribution patterns. Each of these intensities represents different potential for soil erosion. The interpretation of the erosion data from these composite storms were not clear cut. Because of this problem, the rainfall distribution patterns obtained from the automatic raingauge recorder were divided into segments. A cessation of rain in excess of 6 hours was taken as the end of one rainfall pattern and the begining of another pattern. The different rainfall characteristics, namely, rainfall erosion index (EI), rainfall duration, amount of rainfall, 30-minute maximum intensity, and kinetic energy, were computed for each rainfall distribution pattern. The computational process is adapted from Wischmeier and Smith (1958) and USDA Handbook No. 537 (1978). Rainfall energy (E) was computed in the metric system with the equation:

$$E = 210 + 89 \log_{10} I$$

where I represents rainfall intensity (cm hr^{-1}) and E is the computed rainfall energy in metric-ton meters ha cm^{-1} of rain.

Table 4. The characteristics of the six rainfall events and the mean weights of eroded sediments (g) from the control plots.

Rainfall Date	Rainfall Sequence	Mean wt. of Eroded Sediment(g)	Rainfall Duration (min)	Intensity (cm/hr)	Kinetic* Energy	Erosion Index	Rainfall Amount (mm)
Sept. 3	1	237.95	405	3.94	1068.0	42.10	43.81
Sept. 26	2	0.81	60	0.09	28.0	0.05	1.90
Oct. 10	3	1.36	990	0.09	260.4	0.23	20.32
Nov. 4	4	0.33	60	0.63	121.0	0.76	6.35
Nov. 13	5	2.48	120	5.08	371.0	18.85	16.51
Nov. 21	6	2.33	450	1.00	368.0	3.68	20.32

* metric-ton meters hectare per cm of rainfall.

The characteristics of the six recorded rainfall events and the mean weight of eroded sediment from the control plots for the respective rainfall events are shown in Table 4. The eroded sediment attributed to a storm event is the total sediment from a single rainfall consisting of all the storm composite parts.

In the computation of rainfall characteristics, the maximum 30-minute intensity and rainfall energy were computed for each segment of the storm. The segment that gave the highest values for these components was chosen to represent the erosive part of that particular rainfall. All the other rainfall characteristics, namely, rainfall amount, duration, kinetic energy and erosion index were subsequently computed from that segment. This is based on the premise that it is the higher values of the rainfall characteristics that contributes most to soil detachment during the erosion process.

Statistical Analysis:

A step wise multiple regression analysis was used to evaluate the relationship between the physical characteristics of rainfall and soil loss for the study site. The independent variables were the characteristics of the six rainfall events, namely, rainfall duration (min), intensity (cm hr^{-1}), kinetic energy, erosion index, and rainfall amount as shown in Table 4. The dependent variables were the eroded sediments from the six rainfall events. Both the dependent and independent variables were coded by log transformation, i.e. $1 + X\log_{10}$, where X represents the original data.

A comparison was made between the observed eroded sediment and predicted values based on the developed regression equation. Linear regression analyses of eroded sediment were subsequently performed on two rainfall characters identified as significant rainfall erosion parameters. Additional analysis was the determination of correlation coefficients between eroded sediment and computed rainfall parameters (Table 7).

A listing of the transformed variables used in the regression procedure is given in Table 5. Regressions were performed according to the SAS User's Guide 1979.

Table 5. The transformed variables used in the multiple regression analysis.*

Rainfall Sequence	EROD	DUR	INT	KE	EI	AMT
1	5.47206	6.00635	1.59736	6.97448	3.76352	3.80243
2	0.59333	4.11087	0.08618	3.36729	0.04879	1.06471
3	0.85866	6.89871	0.08618	5.56605	0.20701	3.05964
4	0.28518	4.11087	0.48858	4.80402	0.56531	1.99470
5	1.24703	4.79579	1.80500	5.91889	2.98820	2.86277
6	1.20297	6.11147	0.69315	5.91080	1.54330	3.05964

* Log transformation i.e. 1 + $X\log_{10}$, where X is original data.

EROD = weight of eroded sediment (g)

DUR = rainfall duration (min)

INT = rainfall intensity (cm/hr)

KE = kinetic energy (metric ton-meters per cm of rain)

EI = total rainfall energy x 30 min maximum intensity i.e. erosion index (metric ton-meters per cm of rain)

AMT = rainfall amount (mm)

Table 6. Rainfall variables that explain the stepwise relationship between sediment losses and rainfall parameters.

Rainfall Character (Variable)	R^2
Erosion index (EI)	0.63*
Intensity (I_{30})	0.92
Duration (DUR)	0.94
Amount (AMT)	0.94
Kinetic energy (KE)	0.94

* The addition of the next variable improves the accuracy of the prediction.

Ninety two percent of eroded sediment could be explained by erosion index and maximum 30-minute rain intensity. Erosion index alone accounts for 63% of this value. By definition, rainfall erosion index is the product of total storm energy (E) times the maximum 30-minute intensity (I_{30}). Erosion index reflects how total energy and peak intensity are combined in each storm. This relates how particle detachment is combined with transport capacity. Wischmeier and Smith (1958) indicated that median raindrop size increased with rain intensity. These authors further indicated that since the energy of a given mass in motion is proportional to velocity-squared, rainfall energy is directly related to rain intensity. Raindrop erosion therefore increases with intensity and the I_{30} component indicates the prolonged rates of soil detachment and runoff.

It is therefore apparent that the energy times intensity interaction term provides an outstanding common denominator for rainfall classification on the basis of erosion-producing capacity. No more improvement in the R^2 was observed by the addition of other rainfall parameters.

Substantial differences exist between rainfall characters in the correlations of rainfall characteristics and eroded sediment (Table 7). Erosion index had the highest correlation with eroded sediment. Rainfall energy, amount and I_{30} have fairly good correlation with eroded sediment. Rainfall duration was not an important contributory factor in the erosion process. This is probably due to the fact that a long duration rain of very low intensity might not reach the threshold of soil detachment and transport while a short duration rain of high intensity might be more effective in the erosion process.

The similarity between observed and predicted eroded sediment from the regression model indicate that the major rainfall parameters involved in the erosion process are the interactive terms of rainfall energy and maximum 30-minute intensity (Fig. 8).

Table 7. Rainfall characters used in the regression analysis and their correlation coefficients with eroded sediment.

Variable	Correlation Coefficients
Rainfall duration	0.37
Maximum 30-minute intensity	0.62
Kinetic energy	0.71
Erosion index	0.79
Rainfall amount	0.69

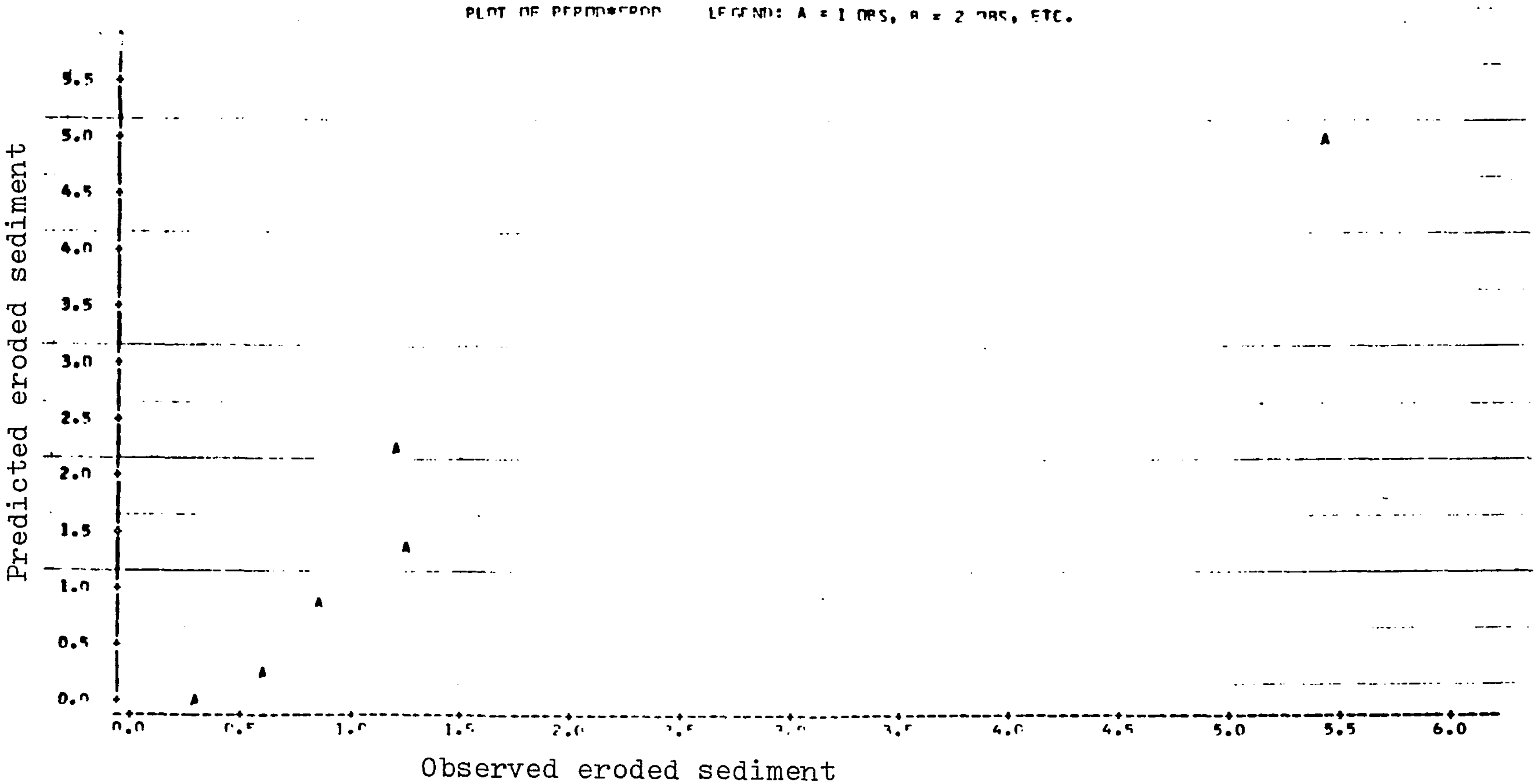

Figure 8. Plot of observed eroded sediment against predicted eroded sediment based on the linear regression analysis of eroded sediment vs. rainfall energy and 30-minute maximun intensity.

The Effectiveness of Vertical Mulching and Slot Trenching As Erosion Control Techniques

Analysis of variance for the randomized complete block design experiment was carried out to highlight any possible significant differences between no-tillage control plots and profile modification treatments in the reduction of runoff and sediment losses from the microplots. In addition, four independent comparisons of the profile modification treatments were carried out to identify the more effective of the two profile modification treatments in runoff and sediment losses reduction. The orthogonal comparison also provided information on the more suitable slot spacing for optimum reduction in runoff and sediment losses.

Effects of Soil Profile Modification on Runoff

From the analysis of variance, treatment response to soil profile modification occurred in two of the six rainfall events. These were the rain events of September 3 and November 4. There were no other observed differences in runoff volume from the microplots with the different treatments for all other rainfall events (Tables 8 to 13).

With the rainfall event of September 3, runoff from the control plots, vertical mulching (91.4 cm spacing) and slot trenching (91.4 cm spacing) were significantly different from runoff obtained from the control plots, slot trenching (182.9 cm spacing) and vertical mulching (182.9 cm spacing) (Table 8). With this rainfall event, slot trenching at 91.4 cm spacing reduced runoff by 8.93 liters compared to the same treatment at 182.9 cm spacing. Similarly, vertical mulching at 91.4 cm spacing reduced runoff losses by 7.52 liters compared to the same profile modification technique at 182.9 cm spacing.

With the rainfall event of November 4, the runoff from slot trenching at 182.9 cm spacing was significantly different at the 5% level from all the other treatments examined. Slot trenching at 182.9 cm spacing was therefore the most effective runoff reduction measure (Table 11).

Table 8. Mean runoff volume (liters) from plots with different treatments for the rainfall event of September 3, 1982.

Treatment	Mean runoff (liters)
Slot trenching at 182.9 cm spacing	22.38
Vertical mulching at 182.9 cm spacing	21.33
No-tillage control plots	16.27
Vertical mulching at 91.4 cm spacing	13.81
Slot trenching at 91.4 cm spacing	13.45

$LSD_{.05} = 7.32$

Table 9. Mean runoff volume (liters) from plots with different treatments for the rainfall event of September 26, 1982.

Treatment	Mean runoff (L)
Slot trenching at 91.4 cm spacing	1.87
No-tillage control plots	1.86
Vertical mulching at 182.9 cm spacing	1.80
Vertical mulching at 91.4 cm spacing	1.56
Slot trenching at 182.9 cm spacing	1.40
$LSD_{.05} = 0.75$	

Table 10. Mean runoff volume (liters) from plots with different treatments for the rainfall event of October 10, 1982.

Treatment	Mean runoff (L)
Slot trenching at 182.9 cm spacing	2.76
Slot trenching at 91.4 cm spacing	2.41
No-tillage control plots	2.35
Vertical mulching at 182.9 cm spacing	2.26
Vertical mulching at 91.4 cm spacing	2.14
$LSD_{.05} = 1.01$	

Table 11. Mean runoff volume (liters) from plots with different treatments for the rainfall event of November 4, 1982.

Treatment	Mean runoff (L)
Vertical mulching at 182.9 cm spacing	1.57
Vertical mulching at 91.4 cm spacing	1.38
No-tillage control plots	1.17
Slot trenching at 91.4 cm spacing	1.12
Slot trenching at 182.9 cm spacing	0.79
$LSD_{.05} = 0.49$	

Table 12. Mean runoff volume (liters) from plots with different treatments for the rainfall event of November 13, 1982.

Treatment	Mean runoff (L)
Vertical mulching at 182.9 cm spacing	2.40
Control plots (no-tillage)	2.18
Slot trenching at 91.4 cm spacing	2.06
Vertical mulching at 91.4 cm spacing	1.93
Slot trenching at 182.9 cm spacing	1.90
$LSD_{.05} = 0.72$	

Table 13. Mean runoff volume (liters) from plots with different treatments for the rainfall event of November 21, 1982.

Treatment	Mean runoff (L)
Vertical mulching at 182.9 cm spacing	6.92
Slot trenching at 182.9 cm spacing	6.26
No-tillage control plots	5.77
Vertical mulching at 91.4 cm spacing	5.76
Slot trenching at 91.4 cm spacing	5.72
$LSD_{.05} = 3.86$	

The four independent comparisons made are shown in Table 14. The coefficients for the partitioning of the sum of squares into orthogonal comparisons and the results of all the comparisons are shown in the Appendix (Table 45, 46-51).

Table 14. Orthogonal comparisons made for runoff and sediment losses from plots with different profile modification treatments.

(1) Response to profile modification (i.e. no-tillage control plots vs. treatments).

(2) Vertical mulching (91.4 cm + 182.9 cm spacings) vs. slot trenching (91.4 cm + 182.9 cm spacings).

(3) Vertical mulching at 91.4 cm spacing vs. vertical mulching at 182.9 cm spacing.

(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing.

Independent comparison of the control plots versus treatments for all rainfall events in effectiveness to control runoff losses showed no significant difference at the 5 percent level (Tables 46-51, Appendix).

With the rainfall event of Nov. 4, the slot trenching technique was more effective in the reduction of runoff than the vertical mulching technique (Table 49, Appendix).

With the rainfall event of September 3, vertical mulching at 91.4 cm spacing interval was more effective in runoff reduction than the 182.9 cm spacing of the same treatment. The 91.4 cm spacing of slot trenching was also more effective than the 182.9 cm spacing of the same treatment.

Vertical mulching and slot trenching were not consistent in reducing runoff losses in all the six rainfall events. The closer slot spacing of 91.4 cm in both profile modification methods were more effective in increasing soil water intake and consequently reduced the amount of surface water available for runoff.

The effectiveness of slot trenching and vertical mulching treatments in the reduction of runoff appear to depend on the rainfall characteristics. The rainfall of September 3 had a 405-min duration, 3.94 cm. hr^{-1} intensity and a total amount of 43.81 mm, and this was the most erosive rain during the study period. Similar characteristics of the rest of the recorded rain events were much lower in magnitude. It therefore appears logical to expect the effectiveness of the profile modification techniques as runoff reduction measures to be clearly evidenced only when there is enough surface water to create the potential for runoff losses.

Effects of Soil Profile Modification on Sediment Losses

Sediment losses during the six rainfall events from microplots receiving different profile modification treatments are shown in Tables 15 to 20. Sediments from each rainfall event were analyzed separately. With analysis of variance, differences in treatments effect were observed only in sediment losses during the rainfall event of September 26 (Table 16). All other rainfall events did not produce sediments that were significantly different among the treatments.

Sediment losses on September 26 from the control plots, vertical mulching plots at 182.9 cm spacing, and slot trenching plots at 91.4 cm spacing were significantly different from losses obtained from vertical mulching (182.9 cm spacing), slot trenching (91.4 cm spacing), slot trenching (182.9 cm spacing) and vertical mulching (91.4 cm spacing) plots at 5% level with LSD (Table 16).

Table 15. Mean sediment weight (g) from microplots with different treatments for the rainfall of September 3.

Treatment	Mean sediment weight (g)
Vertical mulching at 182.9 cm spacing	400.93
Vertical mulching at 91.4 cm spacing	384.92
Slot trenching at 182.9 cm spacing	356.07
Control plots	237.95
Slot trenching at 91.4 cm spacing	170.84
$LSD_{.05}$ = 245.07	

Table 16. Mean sediment weight (g) from plots with different profile modification treatments for the rainfall event of September 26.

Treatment	Mean sediment weight (g)
No-tillage control plots	0.81
Vertical mulching at 182.9 cm spacing	0.63
Slot trenching at 91.4 cm spacing	0.63
Slot trenching at 182.9 cm spacing	0.54
Vertical mulching at 91.4 cm spacing	0.47
$LSD_{.05}$ = 0.27	

Similar orthogonal comparisons made for runoff losses as shown in Table 19 were made for sediment losses from microplots receiving the different treatments. Significant differences were only obtained for sediment losses of the rainfall events of September 26.

Independent comparison of the control versus treatments for the rainfall event of September 26 showed that sediment losses were significantly higher in the control microplots than microplots that received soil profile modification treatments at the 5% level (Table 53, Appendix). All other comparisons did not show any significant differences between the treatment forms for this rainfall event.

Vertical mulching and slot trenching profile modification techniques were not consistent in the reduction of sediment losses during the six rainfall events. In only one rainfall event did the profile modification techniques prove superior to the no-till control in the reduction of sediment losses. Sediment losses from the other five rainfalls were similar between the control and the treatment forms. Vertical mulching and slot trenching did not show any higher effectiveness in controlling sediment losses between 91.4 cm and 182.9 cm slot spacings. Vertical mulching and slot trenching were not significantly different in their effectiveness to reduce sediment losses.

Table 17. Mean sediment weight (g) from plots with different treatments for the rainfall event of October 10.

Treatment	Mean sediment weight (g)
Slot trenching at 182.9 cm spacing	1.44
Vertical mulching at 182.9 cm spacing	1.39
Control plots	1.36
Vertical mulching at 91.4 cm spacing	1.26
Slot trenching at 91.4 cm spacing	1.20

$LSD_{.05} = 1.19$

Table 18. Mean sediment weight (g) from plots with different treatments for the rainfall event of November 4.

Treatment	Mean sediment weight (g)
Vertical mulching at 182.9 cm spacing	0.45
Slot trenching at 91.4 cm spacing	0.41
Vertical mulching at 91.4 cm spacing	0.35
Control plots	0.33
Slot trenching at 182.9 cm spacing	0.22

$LSD_{.05} = 0.035$

Table 19. Mean sediment weight (g) from microplots with different treatments from the rainfall event of November 13.

Treatment	Mean sediment weight (g)
Control plots	2.48
Vertical mulching at 182.9 cm spacing	2.02
Slot trenching at 182.9 cm spacing	1.94
Vertical mulching at 91.4 cm spacing	1.72
Slot trenching at 182.9 cm spacing	1.62
$LSD_{.05}$ = 1.63	

Table 20. Mean sediment weight (g) from microplots with different treatments for the rainfall event of November 21.

Treatment	Mean sediment weight (g)
Vertical mulching at 182.9 cm spacing	4.18
Slot trenching at 182.9 cm spacing	3.54
Control plots	2.33
Slot trenching at 91.4 cm spacing	2.31
Vertical mulching at 91.4 cm spacing	1.59
$LSD_{.05}$ = 3.29	

Effects of Soil Profile Modification on Soybean Yield and the Relationship Between Yield and Soil Moisture

Soybean Yield

Soybean yield data from the different profile modification treatments are given in Table 21. Analysis of variance on soybean yield was computed on a randomized complete block design.

Soybean yields from both spacing intervals of slot trenching treatments (91.4 cm and 182.9 cm) and yield from the control plot were higher than yields obtained from vertical mulching plots at both spacing intervals at the 5% level of significance.

The magnitude of yield increase expected from soil profile modification techniques depend greatly upon the amount and distribution of rainfall during the growing period. The nonresponse of yield to profile modification treatment in this study is attributed to inadequate rainfall during the growing period. Rainfall distribution and amount at the study site were below average during the 1982 growing period (Tables 2 and 3). Rainfall amounts from planting (June 18) until harvesting (Nov. 6) was only 18.95 cm and also unevenly distributed. This inadequate rainfall not only prevented the realization of profile modification potentials, it also reflected on the general performance of the soybean crop. Soybean stands on replicates 1, 2 and 3 (Miamian silty clay loam) exhibited water stress particularly at the early stage of soybean growth. The soybean stands on Miamian soils were shorter, with some of the lower leaves turning brown and drying out. Yields from these replicates were considerably lower than those obtained from the Celina soil with an aquic moisture regime.

The unusually dry growing period that occurred during this study eliminated any potential for soil moisture storage associated with the profile modification treatments. This created a general poor growth condition for the soybean crop.

Table 21. Mean yield of soybean (kg/ha) obtained from plots receiving different soil profile modification treatments.

Treatment	Soybean Yield (kg/ha)*
Slot trenching (91.4 cm spacing)	1467.30
Control	1443.76
Slot trenching (182.9 cm spacing)	1168.59
Vertical mulching (182.9 cm spacing)	1069.02
Vertical mulching (91.4 cm spacing)	1065.66
$LSD_{.05}$ = 312.93	

* Field weight;

Relationship Between Yield and Soil Moisture Condition

The volumetric water content determination (%) made for the experimental plots on September 10, September 19, September 29, October 11, and November 8 are presented in Table 59 (Appendix) and Figures 9 to 11. Mean available soil water contents (%) for 0-15 and 15-30 cm depths for plots under different treatments are shown in Table 22.

Available moisture contents at both 0-15 and 15-30 cm depths are similar for all plots with the different management systems. All the experimental plots receiving the different treatments also exhibited similar volumetric soil moisture distribution trend within 0-15, 15-30 and 30-45 cm depths, respectively.

A stepwise multiple regression analysis was computed to determine which depth or depths of soil volumetric moisture content contributed more to the soybean yield. The analysis were made for soil volumes comprising 0-15, 0-30 and 0-45 cm depths.

From Table 43 (Appendix) the R^2 value suggests that 53 percent of soybean yield is attributed to the moisture content in the 0-45 cm depth. The contributions (R^2) of the soil moisture content in 0-15 cm and 0-30 cm depths to soybean yield were low (Table 59). The low R^2 value of 0.53 suggests that apart from the soil moisture condition, other major factors account for the remaining 47 percent

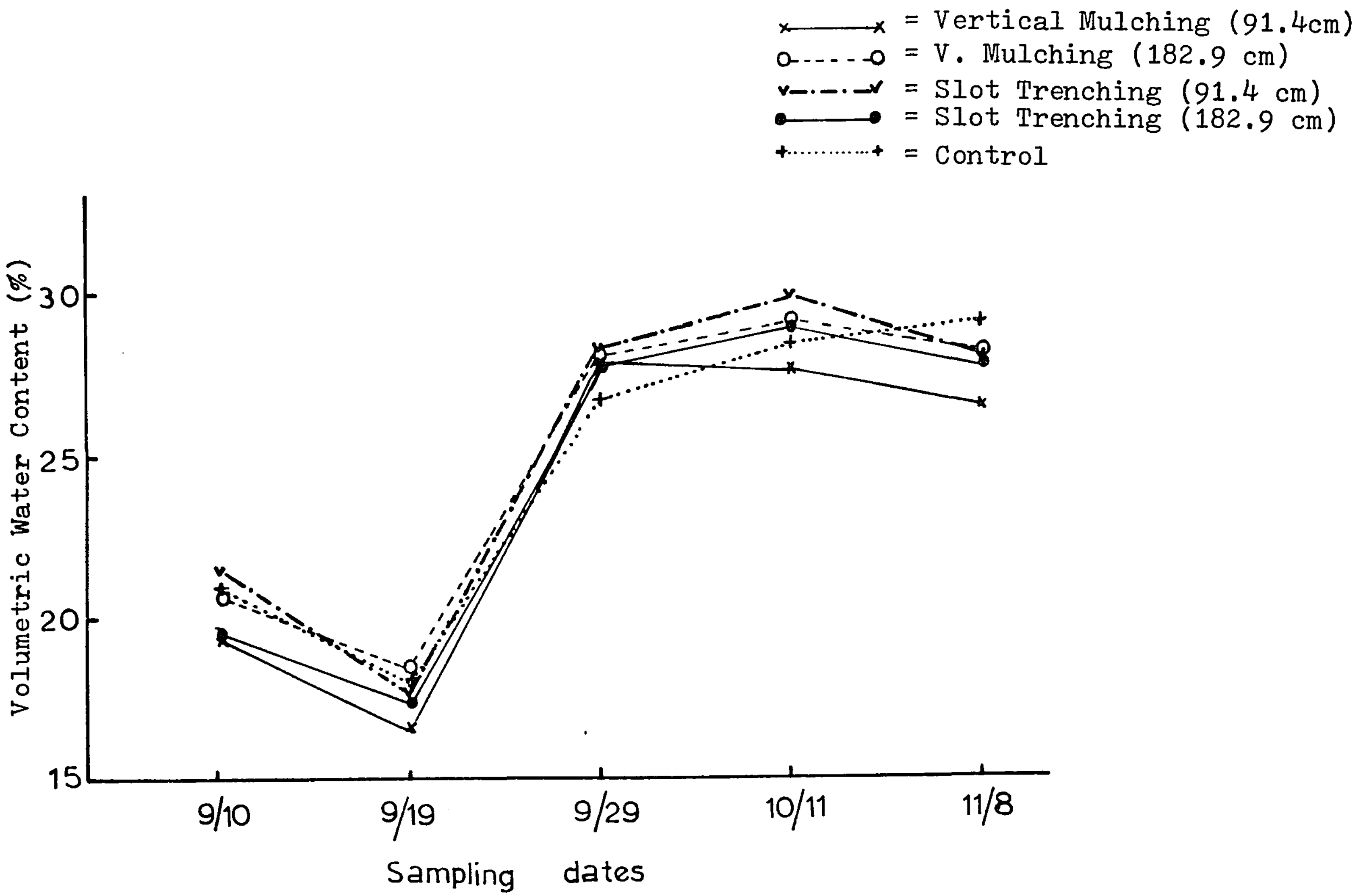

Figure 9. Volumetric Soil Moisture Content (%) at 0-15 cm Depth for the Different Treatments and the 5 Sampling Dates.

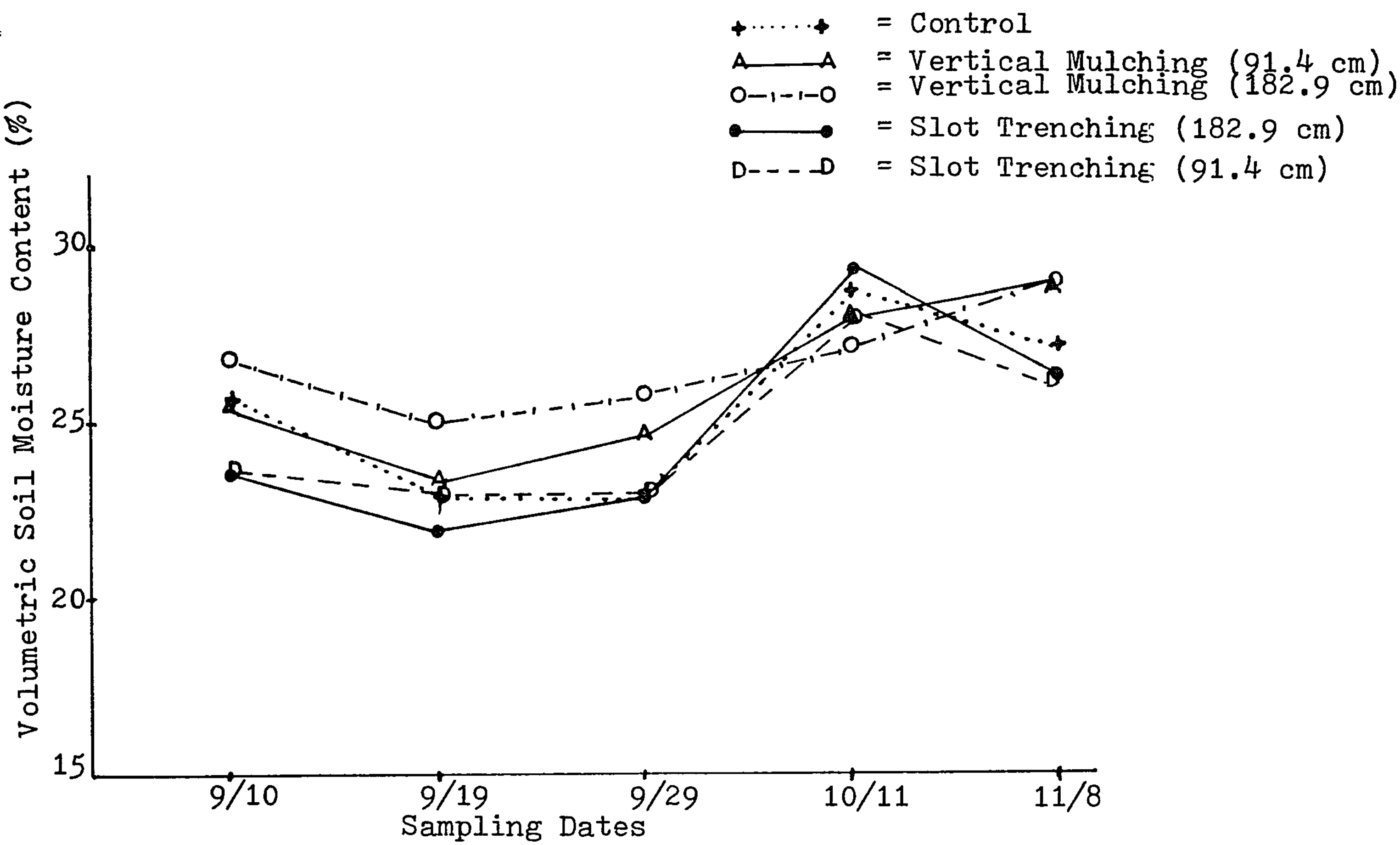

Figure 10. Volumetric Soil Moisture Content (%) at 15-30 cm Depth for the Different Treatments and the 5 sampling Dates.

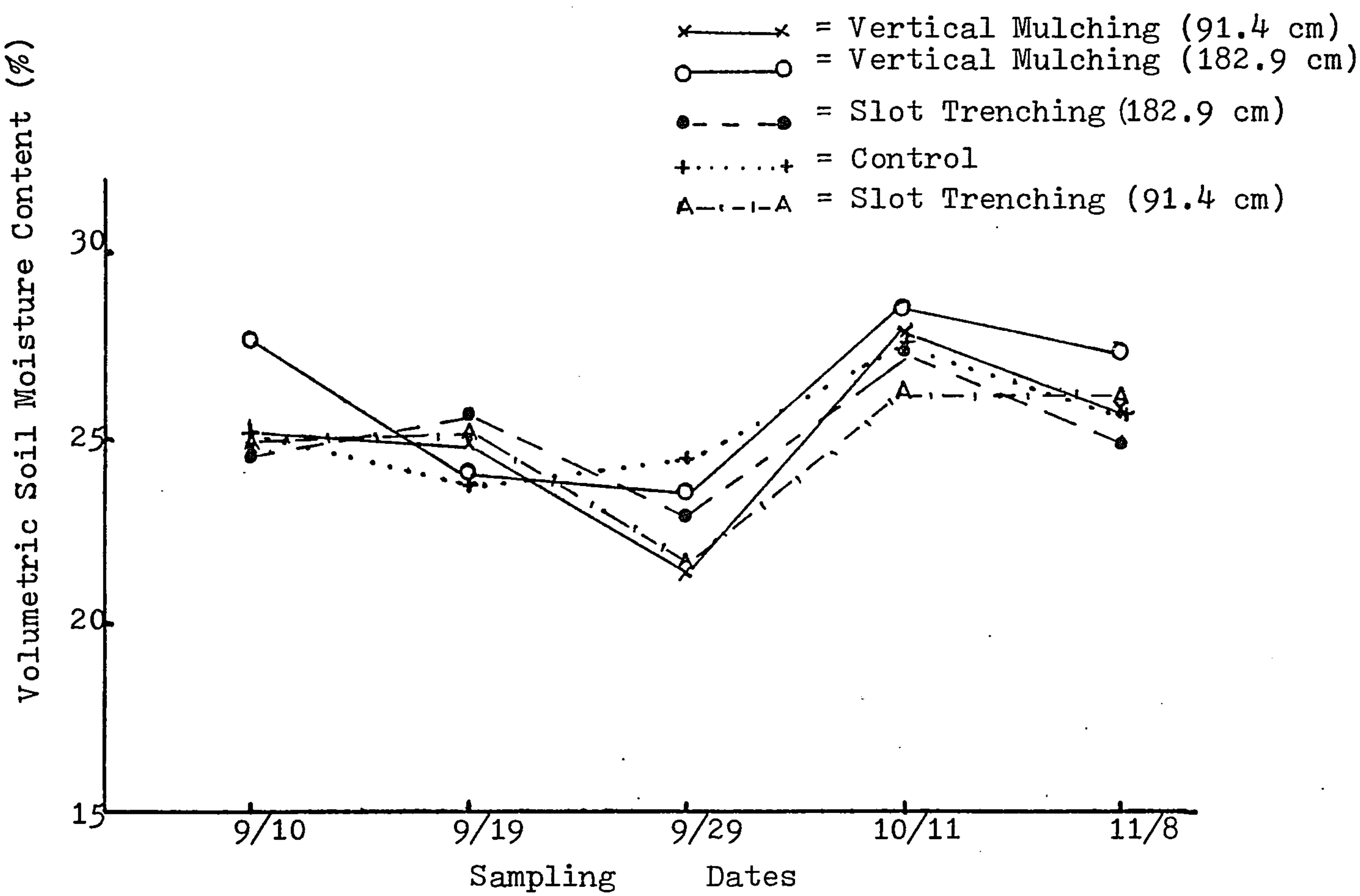

Figure 11. Volumetric Soil Moisture Content (%) at 30-45 cm Deth for the Different Treatments and the 5 Sampling Dates.

contribution affecting soybean yield in this experiment. The greater response of yield to the largest soil volume (0-45 cm) is probably due to a higher volume of water that is associated with a higher soil volume in the 0-45 cm depth relative to the volumes in 0-15 and 0-30 cm depths.

Figure 15 (Appendix) is a plot of predicted yield (PYIELD) vs. yield and Figure 16 (Appendix) is a plot of residual yield (RYIELD) vs. predicted yield (PYIELD). Both figures are based on the R^2 relationship of soil moisture and yield at 0-45 cm depth.

The correlation coefficient between soybean yield and soil moisture content in 0-15, 0-30, and 0-45 cm depths are poor (Table 44, Appendix). The correlation between yield and moisture content in 0-15 cm is 0.14 while the corresponding values for 0-30 and 0-45 cm depths are -0.64 and -0.73 respectively.

Table 22. Mean Available Moisture Content (%) for the Plots with Different Treatments.

Treatment	Depth cm	% Available H_2O
Vertical Mulching (91.4 cm spacing)	0-15	6.24
	15-30	5.67
V. Mulching (182.9 cm spacing)	0-15	7.17
	15-30	5.85
Slot Trenching (91.4 cm spacing)	0-15	7.93
	15-30	6.53
S. Trenching (182.9 cm spacing)	0-15	5.57
	15-30	6.04
Control	0-15	6.80
	15-30	5.82

Properties of Eroded Sediments in Relation to the Original Soil

Particle Size Distribution

Particle size distribution data for the original soil sample and sediments collected from the rainfall event of Sept. 3 are given in Tables 22 and 23. The textural classification for all plots are similar. The upper 15 cm depth is silt loam and the lower 15-30 cm depth is clay loam.

The particle size distribution of the surface 0-15 cm soil depth for each treated plot is very similar to that of the eroded sediments. The sediments from vertical mulching and slot trenching treatments are classified as silt loam while that from the no-till control plot is loam. The difference between the sediment from the control plot and other treatments is due to a one percent decrease in silt content (49%) for the control plot. The erosion ratio (Table 24) indicates that silt + clay content of the eroded soil from all treatments were generally lower than that of the original soil. This might be attributed to the very high intensity rainfall of 3.94 cm/hr, high kinetic energy of 1068 metric-ton meters hectare/cm, and rainfall amount of 43.81 mm which disintegrated soil aggregates and transported them rapidly out of the field. The eroded sediments from all treatments were however higher in coarse + medium sand fractions than the field soil. The particle size distributions of the eroded sediments were not statistically different between the different treatments.

Table 23. Mean particle size distribution for plots receiving the different soil management treatments.

Treatment	Depth (cm)	Coarse + medium sand	Very fine + fine sand	Coarse + medium silt (50-5μ)	Fine silt (5-2μ)	Total clay (2-<.2μ)	Textural class
Vertical mulching (91.4 cm spacing)	0-15	9.9	16.3	44.8	8.1	21.1	Silt loam
	15-30	9.7	16.0	34.7	9.6	29.9	Clay loam
Vertical mulching (182.9 cm spacing)	0-15	10.1	16.1	43.5	9.2	21.0	Silt loam
	15-30	9.0	15.4	32.1	9.3	33.6	Clay loam
Slot trenching (91.4 cm spacing)	0-15	9.9	16.5	43.7	10.1	19.8	Silt loam
	15-30	9.7	15.4	35.1	9.8	29.6	Clay loam
Slot trenching (182.9 cm spacing)	0-15	9.9	16.6	43.6	8.9	20.9	Silt loam
	15-30	10.0	15.6	34.5	9.5	30.3	Clay loam
Control (no-tillage)	0-15	10.3	16.5	44.0	9.6	19.6	Silt loam
	15-30	11.0	16.3	39.6	10.8	22.3	Clay loam

Table 24. Characterization of eroded sediment from plots receiving the different soil management treatments for the rainfall event of Sept. 3.

Treatment	Coarse + medium sand	Very fine + fine sand	Coarse + medium silt (50-5μ)	Fine silt (5-2μ)	Total clay (2-<.2μ)	Textural class
Vertical mulching (91.4 cm spacing)	12.8	15.1	46.2	7.4	18.5	Silt loam
Vertical mulching (182.9 cm spacing)	13.0	16.7	43.7	7.6	19.1	Silt loam
Slot trenching (91.4 cm spacing)	14.4	16.1	44.1	7.5	17.9	Silt loam
Slot trenching (182.9 cm spacing)	13.1	17.2	43.5	7.7	18.5	Silt loam
Control	13.4	17.1	42.5	6.5	20.5	Loam

Table 25. Erosion ratio for the rainfall event of Sept. 3.

Treatment	Erosion Ratio
(1) Vertical mulching (91.4 cm spacing)	0.91
(2) Vertical mulching (182.9 cm spacing)	0.97
(3) Slot trenching (91.4 cm spacing)	0.82
(4) Slot trenching (182.9 cm spacing)	0.83
(5) Control (no-tillage)	0.83

Erosion ratio = $\frac{\text{silt + clay}}{\text{sand}}$ of eroded sediments/

$(\frac{\text{silt + clay}}{\text{sand}})$ of field soil.

Clay Mineralogy

Clay mineralogical analysis was made on sediments from the rainfall events of Sept. 3 and Nov. 21. Semi-quantitative clay mineralogy data is presented in Table 25.

Quantitative mineralogy of the samples (both soil and sediment) is quite similar. This would be expected. Sediment samples collected in early September are also quantitatively very similar in mineralogy to the surface soil samples. Sediment samples collected in November are much lower in expandables, somewhat lower in vermiculite, and somewhat higher in mica and quartz than the corresponding surface soil samples. Perhaps lower rainfall intensity failed to suspend aggregated material which would include the finer clay minerals.

Table 26. Clay mineralogy data.

Sample	Kaolinite	Clay mica	Expandables*	Vermiculite**	Quartz
<u>Miamian 1</u>					
0-15 cm	XX	XXX	XX	XXXX	XX
15-30 cm	XX	XXX	XXX	XXXX	X
Sediment Sept. 3	XX	XXX	XXX	XXXX	X
Sediment Nov. 21	XX	XXXX	X	XXX	XX
<u>Miamian 2</u>					
0-15 cm	XX	XXX	XXX	XXXX	XX
15-30 cm	XX	XXX	XX	XXXX	X
Sediment Sept. 3	XX	XXX	XXX	XXXX	X
Sediment Nov. 21	XX	XXXX	XX	XXX	XX
<u>Celina</u>					
0-15 cm	XX	XXX	XXX	XXXX	XX
15-30 cm	XX	XXX	XXX	XXX	XX
Sediment Sept. 3	XX	XXX	XX	XXX	XX
Sediment Nov. 21	XX	XXXX	-	X	XXX

X = < 5%, XX = 5-20%, XXX = 20-35%, XXXX = 35-50%.

* Expandables = interstratified smectite/clay mica as indicated by 10-14 Å diffraction band in Mg-25 patterns which expands to 14-16 Å with glycolation.

** Most vermiculites show minor evidence of hydroxy-Al interlayering as indicated by their failure to totally collapse to 10 Å with K-saturation at room temperature.

Soil Nutrient Losses in Runoff and Sediment

Sediment and runoff losses of Ca, Mg, K, P, NH_4-N and NO_3-N are presented in Tables 27 to 36. Amounts of nutrient losses were greatly influenced by rainfall intensity and amount. This is expected because high rainfall intensity causes greater disintegration of soil aggregates and also a high rainfall amount increases the potential for nutrient solubilization and transport. The highest nutrient losses occured on Sept. 3 where the rainfall intensity was 3.94 cm/hr and rainfall amount was 43.81 mm.

None of the treatment variables were consistent in producing the highest nutrients losses for all nutrients considered in all six rainfall events.

The mean soluble Ca losses in all plots and all six rainfall events ranged from 0.0882 to 0.2464 kg/ha for slot trenching (91.4 cm spacing) and slot trenching (182.9 cm spacing), respectively (Table 33). With the rainfall event of Nov. 4 (Table 30), soluble calcium losses were significantly lower in slot trenching (182.9 cm spacing) than all other treatments. Soluble calcium losses from all other rainfall events did not differ significantly among the different treatments at the 5% level.

Sediment Ca losses were highest for vertical mulching (0.0022 kg/ha) for the rainfall event of Sept. 3. This value was not significantly different from losses obtained from vertical mulching (182.9 cm spacing), slot trenching (182.9 cm spacing) and the control plots. The lowest sediment Ca losses of .0009 kg/ha occured from slot trenching (91.4 cm spacing) plots. This was not significantly different from losses obtained from the vertical mulching (182.9 cm spacing), slot trenching (182.9 cm spacing) and the control plots.

Combined total mean soluble Mg losses for all rainfall events were not significantly different between the treatments. The rainfall events of Sept. 3 and Nov. 13 ranked the treatments differently in the magnitude of soluble Mg losses. With the rainfall event of Sept. 3, 0.5771 kg/ha of soluble Mg was the highest loss obtained and this was from the slot trenching (182.9 cm spacing) plots (Table 27). On the other hand, the highest soluble Mg loss from the Nov. 13 rainfall event was from the control plots with a value of 0.0170 kg/ha (Table 31). Mg losses in sediments were not significantly different between the different treatments.

Combined data for soluble K losses for all six rainfall events did not show any significant differences between the treatments. Soluble K losses ranged from 0.0293 to 0.0721 kg/ha for slot trenching at 91.4 cm and 182.9 cm spacing intervals, respectively. On an individual rainfall basis, the rainfall events of Sept. 3 and Nov. 4

showed different trends of soluble K losses. On Sept. 3, the most soluble K loss of 0.3779 kg/ha occured from the slot trenching plot (182.9 cm spacing). These losses were not significantly different from losses obtained from the control plots (0.1965 kg/ha), and 0.2852 kg/ha obtained from vertical mulching plots (182.9 cm spacing). With the rainfall event of Nov. 13, soluble K losses were in the range of 0.0128 to 0.0065 kg/ha for control and slot trenching (91.4 cm spacing) plots respectively. The soluble K losses from the control plots were not significantly different from losses obtained from plots with both spacings of vertical mulching, and slot trenching at 182.9 cm spacing interval. Sediment K losses were not statistically different among the different treatment forms.

The different treatments did not show differences in the amount of soluble phosphorus lost. Instead, soluble P losses reflected the rainfall characteristics, particularly rainfall intensity and amount. With the rainfall event of Sept. 3 (intensity = 3.94 cm/hr, KE = 1068 metric ton-meters ha/cm and amount = 43.81 mm) soluble P losses ranged from 0.0072 to 0.0028 kg/ha while the rainfall of Sept. 26 (intensity = 0.09 cm/hr, KE = 28.0, amount = 1.90 mm) the soluble P losses were in the order of 0.0009 to 0.0005 kg/ha. Sediment or particulate P losses differed among the different treatments. Slot trenching treatment (182.9 cm spacing) showed the highest particulate P losses of 0.0038 kg/ha for the combined data for the six rainfall events. These losses were not significantly different from losses obtained from vertical mulching plots with both spacing intervals. The least particulate P losses were from the slot trenching (91.4 cm spacing) treatment, (0.0015 kg/ha) and this was also not significantly different from losses obtained from the vertical mulching treatments and the control plots.

Ammonium nitrogen losses were highest from the slot trenching treatment (182.9 cm spacing) (26.84 kg/ha) and the lowest losses were from the control plots (1.75 kg/ha). NO_3-N losses were fairly uniform for all treatments with the values ranging from 7.48 to 3.19 kg/ha. Total ammoniacial N addition in the 6 rainfall events were 0.15 kg/ha while nitrate nitrogen addition totalled 0.32 kg/ha.

The profile modification techniques did not appear to show any consistent trend in their effects on soluble and sediment nutrient losses at the study site. With only the sediments obtained from the rainfall event of Sept. 3 used in the determination of Ca, Mg and K losses, it was not possible to ascertain if there was any trend in the amount of these nutrients lost from the different treatments. Soluble P losses were remarkably higher than particulate P losses from the study site.

Decomposition and hydrolysis of organic matter throughout the study period might have contributed more of the nutrient losses than from the mineral soil. The combined losses of NH_4-N and NO_3-N for individual plots exceeded the amounts of NH_4-N and NO_3-N contributed by rainfall.

Table 27. Total mean soluble Ca, Mg, K and P losses from plots with different treatments for the rainfall event of Sept. 3.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Slot trenching (182.9 spacing)	1.3271 a	0.5771 a	0.3779 a	0.00049 a
Control	0.7451 a	0.3535 abc	0.1965 ab	0.0028 a
Vertical mulching (182.9 cm spacing)	0.6616 a	0.5052 ab	0.2825 ab	0.0072 a
Slot trenching (91.4 cm spacing)	0.6271 a	0.2256 c	0.1337 b	0.0042 a
Vertical mulching (91.4 cm spacing)	0.5486 a	0.2803 bc	0.1683 b	0.0043 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 28. Total mean soluble Ca, Mg, K and P losses from plots with different treatments for the rainfall event of Sept. 26.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Vertical mulching (91.4 cm spacing)	0.0127 a	0.0069 a	0.0019 a	0.0006 a
Vertical mulching (182.9 cm spacing)	0.0122 a	0.0066 a	0.0013 a	0.0009 a
Slot trenching (91.4 cm spacing)	0.0121 a	0.0060 a	0.0015 a	0.0009 a
Control	0.0115 a	0.0054 a	0.0016 a	0.0006 a
Slot trenching (182.9 cm spacing)	0.0090 a	0.0045 a	0.0016 a	0.0009 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 29. Total mean soluble Ca, Mg, K and P losses from plots with the different treatments for the rainfall event of Oct. 10.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Slot trenching (182.9 cm spacing)	0.0223 a	0.0148 a	0.0072 a	0.0024 a
Vertical mulching (182.9 cm spacing)	0.0203 a	0.0115 a	0.0085 a	0.0008 a
Vertical mulching (91.4 cm spacing)	0.0201 a	0.0133 a	0.0052 a	0.0015 a
Control	0.0166 a	0.0163 a	0.0060 a	0.0014 a
Slot trenching (91.4 cm spacing)	0.0155 a	0.0132 a	0.0026 a	0.0021 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level.

Table 30. Total mean soluble Ca, Mg, K and P losses from plots with the different treatments for the rainfall event of Nov. 4.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Vertical mulching (182.9 cm spacing)	0.0439 a	0.0249 a	0.0146 a	0.0005 a
Vertical mulching (91.4 cm spacing)	0.0433 a	0.0233 a	0.0156 a	0.0003 a
Slot trenching (91.4 cm spacing)	0.0429 a	0.0214 a	0.0111 a	0.0008 a
Control	0.0367 a	0.0203 a	0.0168 a	0.0007 a
Slot trenching (182.9 cm spacing)	0.0227 b	0.0129 a	0.0104 a	0.0009 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 31. Total mean soluble Ca, Mg, K and P losses from plots with different treatments for the rainfall event of Nov. 13.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Control	0.0306 a	0.0172 a	0.0128 a	0.0004 a
Slot trenching (182.9 cm spacing)	0.0266 a	0.0126 ab	0.0079 ab	0.0003 a
Vertical mulching (182.9 cm spacing)	0.0237 a	0.0127 ab	0.0104 ab	0.0003 a
Vertical mulching (91.4 cm spacing)	0.0200 a	0.0117 ab	0.0120 ab	0.0003 a
Slot trenching (91.4 cm spacing)	0.0179 a	0.0088 b	0.0065 b	0.0003 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 32. Total mean soluble Ca, Mg, K and P losses from plots with the different treatments for the rainfall event of Nov. 21.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Slot trenching (182.9 cm spacing)	0.0837 a	0.0441 a	0.0277 a	0.0015 a
Vertical mulching (182.9 cm spacing)	0.0778 a	0.0435 a	0.0283 a	0.0020 a
Slot trenching (91.4 cm spacing)	0.0567 a	0.0258 a	0.0206 a	0.0016 a
Vertical mulching (91.4 cm spacing)	0.0440 a	0.0321 a	0.0247 a	0.0010 a
Control	0.0398 a	0.0253 a	0.0108 a	0.0013 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 33. Total mean soluble Ca, Mg, K and P losses for all treatments for the six rainfall events.

Treatment	Soluble Nutrient Losses (kg/ha)			
	Ca	Mg	K	P
Slot trenching (182.9 cm spacing)	0.2464 a	0.1110a	0.0721 a	0.0112 a
Control	0.1366 a	0.0730 a	0.0408 a	0.0087 a
Vertical mulching (182.9 cm spacing)	0.1320 a	0.0820 a	0.0580 a	0.0078 a
Vertical mulching (91.4 cm spacing)	0.1148 a	0.0612 a	0.0379 a	0.0086 a
Slot trenching (91.4 cm spacing)	0.0882 a	0.0488 a	0.0293 a	0.0130 a

Means for a particular nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 34. Total N additions from rainfall and N losses in runoff from plots with the different treatments for the six rainfall events (kg/ha).

Treatment	N Losses		Rainfall N additions to the site		Net N Losses	
	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N
Vertical mulching (91.4 cm spacing)	9.66	3.99	0.15	0.32	9.51	2.67
Vertical mulching (182.9 cm spacing)	13.22	3.19			13.07	2.87
Slot trenching (91.4 cm spacing)	3.57	7.48			3.42	7.16
Slot trenching (182.9 cm spacing)	26.84	4.82			26.69	4.50
Control	1.75	4.59			1.60	4.27

Table 35. Mean Ca, Mg and K losses in sediment (kg/ha) for the rainfall event of Sept. 3.

Treatment	Sediment Nutrient Losses					
	Ca		Mg		K	
Vertical mulching (91.4 cm spacing)	0.0022	a	0.0004	a	0.0001	a
Vertical mulching (182.9 cm spacing)	0.0015	ab	0.0003	a	0.0001	a
Slot trenching (91.4 cm spacing)	0.0009	b	0.0001	a	0.0000	a
Slot trenching (182.9 cm spacing)	0.0016	ab	0.0003	a	0.0001	a
Control	0.0011	ab	0.0002	a	0.0000	a

Means for the same nutrient followed by the same letter are not significantly different at 5% level with DMRT.

Table 36. Mean phosphorus losses in eroded sediment for the six rainfall events (10^{-4} kg/ha).

Treatment	Rainfall Date 9/3	9/26	10/10	11/4	11/13	11/21	Total P Losses
Vertical mulching (91.4 cm spacing)	16.01 ab	0.04 a	0.07 a	0.02 a	0.08 a	0.16 a	16.22 ab
Vertical mulching (182.9 cm spacing)	33.01 ab	0.07 a	0.10 a	0.03 a	0.07 a	0.28 a	33.56 ab
Slot trenching (91.4 cm spacing)	14.95 b	0.04 a	0.07 a	0.02 a	0.05 a	0.23 a	15.36 b
Slot trenching (182.9 cm spacing)	38.23 a	0.03 a	0.09 a	0.04 a	0.07 a	0.24 a	38.70 a
Control	12.97 b	0.02 a	0.08 a	0.03 a	0.08 a	0.23 a	13.41 b

Means for the same date followed by a similar letter are not significantly different at 5% level with DMRT.

The Relationship Between Soil Physical and Chemical Parameters and Soil Erodibility

The relationship between soil erodibility and soil chemical and physical properties were evaluated by a stepwise multiple regression analysis. The erodibility predictors were determined from mean eroded sediment amounts obtained from six natural rainfall events at the study site. The soil parameters and their coded terms used for the analysis are as follows:

1/3 atmosphere bulk density (BD)
Saturated hydraulic conductivity (COND)
% silt + % fine sand (SFS)
% clay (CLY)
% sand (SAND)
% organic carbon content (OC)
% Al sodium dithionite citrate extractable (AL)
% Fe sodium dithionite citrate extractable (FE)
(% Fe + % Al) x % clay (FEALCLY)
(% Fe + % Al) x % organic carbon content (FEALC)
% organic carbon x % clay (OCCLY)

Values for the soil chemical and physical parameters represent the 0-15 cm depth. All 20 microplots in the four replicates were used for this aspect of the study.

The rationale for the selection of these soil parameters is based on the assumption that erodibility is inherently related to the combined effects of soil textural properties and soil binding agents. Romkens et al., (1977) stated that, in physical terms, soil erodibility is the combined effect of the infiltration capacity of a soil and the resistance to particle detachment and transport by rainfall and runoff.

From the stepwise regression analysis, the highest significant erodibility predictor was % Fe with a multiple coefficient of determination, R^2=0.46 (Table 37) This was significant at the 5% level. The second best predictor of erodibility was soil saturated hydraulic conductivity with the improvement of the R^2 to 0.55. The next best erodibility predictors and R^2 improvement were in the sequence, bulk density (R^2=0.63), % organic carbon content (R^2=0.68), (% Fe + % Al) x % clay (R^2=0.71), and % organic carbon content replaced by % organic carbon content x % clay (R^2=0.72). The rest of the parameters made insignificant contribution to the coefficient of multiple determination (R^2) as shown in Table 37. The six most significant erodibility predictors outlined above were combined into a regression prediction model and then plotted to show the relationship between predicted and observed erodibility (Figure 13), with R^2=0.73. Predicted erodibility was also plotted against residual erodibility to test the reliability of the model (Figure 14). Simple correlation coefficient analysis was also carried out between all the erodibility predictive soil properties (Table 39).

The stepwise multiple coefficient of determination given by all the soil properties examined was R^2=0.77. This indicates that the parameters tested probably accounts for about 77% erodibility at the study site. The fairly close observed and predicted eroded values given by the model suggests that the six best identified parameters were high predictors of erodibility at the study site.
The plot in Figure 13 suggests a fairly linear relationship between predicted and observed erodibility (R^2=0.73).

The result in this part of the study suggests the importance of sodium dithionite citrate extractable Fe and Al, % clay and % organic carbon content on soil erodibility for the surface soil of the study site. These constituents probably enhance the soil matrix potential, increases aggregate stability and improve soil structure. Sodium dithionite citrate extractable Fe and Al are derived from the hydrated and more crystalline oxides. Therefore the Fe and Al values approximate the combined contents of relatively amorphous Fe and Al oxides and more crystalline oxides of these elements. Although the quantities of Fe citrate dithionite and Al in the soil at the study site were low compared to quantities in soils in humid tropical regions, these constituents together with organic carbon and clay have vital roles of holding together soil primary aggregates into secondary aggregates. The aggregated soil constituents generally have a higher stability and can withstand a higher impact and transport action of rain water.

The correlation coefficients (r^2) between the different soil erodibility predictors are given in Table 39. The correlation coefficient between 1/3 atmosphere soil bulk density and the following soil parameters were as follows: % organic carbon content r^2=0.10, % Al r^2=0.09, saturated hydraulic conductivity r^2=-0.13, % silt + fine sand r^2= 0.12 Very low, insignificant correlations, were observed between % Fe and % organic carbon content r^2=0.04, % Al and % organic carbon content r^2=0.00 and % organic carbon and % clay content r^2=0.14.

The six soil chemical and physical parameters identified as important erodibility predictors can be categorized into two groups. The first group comprises % Fe, % Al, % organic carbon content and % clay. These constitute soil 'binding agents' while bulk density and saturated hydraulic conductivity constitute indices of soil permeability.

The relationship involving soil textural components and erodibility was not as effective in predicting erodibility as the combination of soil permeability indices and binding agents at the study site. When Fe and Al components were added to the % clay, an increase in the coefficient of multiple determination was obtained over that of Al or clay alone.

The result of this study is in partial agreement with the findings of Wischmeier et al., (1971) in which erodibility was related to soil parameters consisting of the product of size fractions, indices of soil structure and permeability and % organic carbon. As shown in the present study, the products of the size fractions and % sand did not prove to be effective erodibility indicators at the study site. Indices of permeability and % organic carbon were effective predictors in both this study and that of Wischmeier et al. The present study shows that soil binding agents are important variables that should be included in the list of erodibility predictors. The binding agents include amorphous and crystalline oxides and hydroxides of Fe and Al, organic carbon and clay contents. The role of the soil binding agents in soil erodibility prediction at the study site was probably due to the ability of the binding agents to hold together primary soil particles into secondary particles. This phenomena improves soil structure, reduces the potential rate of soil detachability and also improves soil structure. It should also be noted that the complexity and variability of soils makes it difficult to relate erodibility of different soils to a comperatively few basic soil parameters.

Phosphorus Sorption Isotherms and Fertility Status of Runoff from Celina and Miamian Soils

The equilibrium phosphorus concentration (EPC) for both Miamian and Celina soils were fairly high with values of 0.68 μg P/ml and 0.80 μg P/ml for Miamian and Celina soils respectively. This is shown in Figure 12. The EPC provides a predictive estimation of sorption or release of P should the P concentration in solution change.

Factors known to affect P sorption in soil are shown in Table 36. The correlation between organic C content and amount of P adsorbed by soils has been shown to relate to Al and Fe adsorbed by the organic colloids. Ca and Mg concentration of soil also affect P sorption. The presence of exchangeable cations of high valency and low hydration energy on the clay surfaces is known to suppress the diffuse layer potential. This enhances P adsorption because of the higher effective concentration of P at these sites. Miamian soil was relatively higher in Ca^{2+} and Mg^{2+} (11.76 and 3.99 C mol(+)$\cdot kg^{-1}$, respectively) compared to Celina with Ca^{2+} (10.9 Cmol(+).kg^{-1}) and Mg^{2+} (2.71 C mol(+)$\cdot kg^{-1}$). Amorphous oxides and hydrous oxides of Fe and Al are also known to react with P rendering it relatively insoluble. Miamian soil at the study site was relatively higher than Celina in Fe content, 2.06% as opposed to 1.76% for the latter. Al contents in both soils were similar (Table 36).

The relatively higher values of the soil constituents known to influence P availability in soil solution in Miamian soil indicates that there is a tendency for these components to react with P at a rate higher than would occur on Celina.

On Miamian soil, there would be a net adsorption of P on soil surface when EPC exceeds 0.68 μg/ml. In contrast, the P concentration must exceed 0.80 μg/ml in Celina before sorption takes place.

These results show that runoff from Celina should be more fertile in P than runoff from Miamian. Also Celina may release greater amount of P that would result in higher potential for eutrophication of streams than would occur from Miamian. Celina soils will also have a higher P concentration in the soil system available for plant use than would Miamian soil.

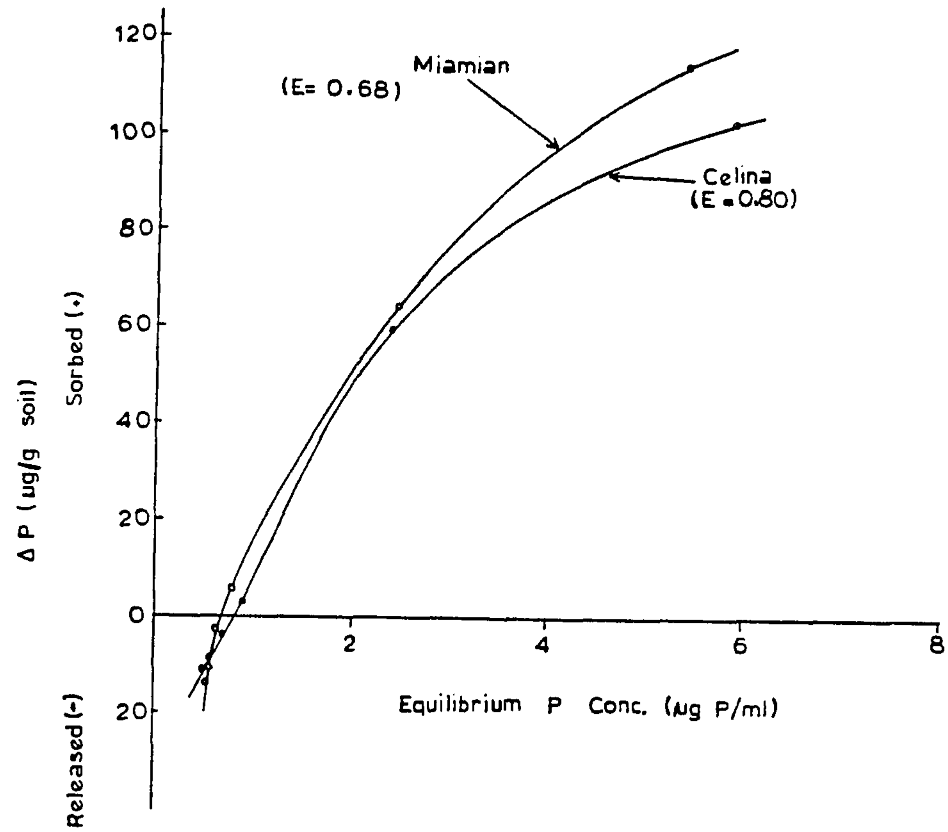

Figure 12. Equilibration studies of Miamian and Celina soils with solutions of varying phosphorus concentrations with EPC shown for each soil.

Table 36. Mean values of surface soil components known to influence the retention and release of phosphates in Celina and Miamian soils.

Soil	pH (H_2O)	% Organic C	Ca C mol(+) kg^{-1}	Mg C mol(+) kg^{-1}	% Al	% Fe
Miamian	6.4	1.86	11.76	3.99	2.06	0.23
Celina	5.8	1.70	10.19	2.71	1.76	0.20

SUMMARY AND CONCLUSIONS

This study was designed to evaluate the effectiveness of 'vertical mulching' and 'slot trenching' profile modification (PM) techniques on the reduction of runoff and sediment losses from micro-erosion plots. Nutrient losses in runoff and sediment from 6 rainfall events obtained from plots with the different management systems were also examined. Phosphate sorption isotherms for Miamian silty clay loam and Celina silt loam at the study site were compared and related to P fertility of surface runoff from these two soil. Other objectives of this study were the identification of natural rainfall characteristics that could be used to classify rainfall on the basis of erosion producing capacity. The relationship between soil chemical and physical parameters and soil erodibility were also evaluated in an attempt to identify the most important soil erodibility predictors for the study site.

The most important rainfall characteristic identified to classify rainfalls on the basis of erosion producing capacity at the site was the interaction of total energy and maximum 30-minute intensity designated Erosion Index. Stepwise multiple regression analysis showed that 63% of eroded sediment could be explained by the EI alone.

Rainfall duration was shown to be the least contributory predictor of rainfall erosion parameter.

'Vertical mulching' and 'slot trenching' profile modification treatments, were not consistent in runoff reduction in all rainfall events examined. The narrower slot spacing of 91.4 cm was more effective in reducing runoff losses than the wider spacing of 182.9 cm when there was enough water to create the potential for runoff losses. With the rainfall event of Sept. 3 that created the potential for considerable amount of runoff, slot trenching and vertical mulching at 91.4 cm spacing reduced runoff volume by 40% and 35%, respectively, when compared with similar treatments at 182.9 cm spacing. Slot trenching and vertical mulching treatments at 91.4 cm spacing also reduced runoff volume by 15 and 17%, respectively, when compared with the control.

Profile modification did not show superior effectiveness in sediment reduction over the control plots. There were no differences among the profile modification treatments in sediment reduction and no slot spacing was found to be superior in sediment reduction.

Yield improvement from profile modification was not observed. This was accounted for by the unseasonably dry period during the field aspect of this study. Rainfall total during the 5 months of soybean growth was only

18.95 cm. This was below the average value for that time of the year in Central Ohio.

Soil moisture contents at 0-45 cm depths in all treatments were found to be similar. This was also attributed to the low rainfall amounts and uneven distribution, which eliminated the potential effectiveness of profile modification in soil moisture storage. Soybean yield was more closely related to soil moisture content in the 0-45 cm depth than 0-15 or 0-30 cm depths.

Celina soil had a higher equilibrium phosphorus concentration (EPC), (0.80 ug/ml), than did Miamian of (0.68 ug/ml). These results showed that runoff from Celina would be higher in P than would runoff from Miamian. Celina will also generally have a higher P concentration in the soil system available for plant use than Miamian. Unavailability to plants of applied P fertilizer will occur first in Miamian since P sorption occurs at a lower EPC range, compared to Celina soil.

Soluble P losses in surface runoff from all treatments were higher than sediment adsorbed P. Total Ca, Mg and K losses for the six rainfall events were not significantly different among treatments.

Sediments obtained from Sept. 3 had lower silt + clay contents than the field soil. The eroded sediments were higher in coarse + medium sand fractions than the field soil. The mineralogy of eroded sediments of high intensity rainfall were identical to that of the field soil. Sediments from low intensity rainfall were much lower in interstratified smectite/clay mica, somewhat lower in vermiculite and somewhat higher in quartz.

Soil erodibility predictors for the study site were found to constitute 'binding agents' which included sodium dithionite citrate extractable Fe and Al, % clay and % organic carbon. Other important erodibility predictors found were 1/3 atmosphere soil bulk density and saturated hydraulic conductivity. Soil textural components were not important erodibility predictors at the site. Of these erodibility predictors, % Fe (amorphous + crystalline oxides and hydroxides) was the most important erodibility predictor for the study site. The role of the 'binding agents' was probably due to their ability to hold together primary soil particles into secondary particles and thus reduce the susceptibility of soil aggregate disintegration by raindrop impact and transport action of water.

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APPENDIX

Table 37. Stepwise multiple regression correlation of soil physical and chemical parameters and soil erodibility at the study site.

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 1 VARIABLE FE ENTERED R SQUARE = 0.46[illegible] C(P) = [illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	20138.44186562	20138.44186562	15.37	0.0010
ERROR	18	23590.20311938	1310.56694385		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-284.96287072				
FE	170.02585341	43.37421409	20138.44186562	15.37	0.0010

THE ABOVE MODEL IS THE BEST 1 VARIABLE MODEL FOUND.

STEP 2 VARIABLE COND ENTERED R SQUARE = 0.55444913 C(P) = -0.40191215

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	24245.30899195	12122.65449597	10.58	0.0010
ERROR	17	19483.33606305	1146.07859194		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-337.40850452				
COND	19.34455475	10.21905209	4106.94712633	3.58	0.0755
FE	185.13672147	41.33908673	22986.76107740	20.06	0.0003

THE ABOVE MODEL IS THE BEST 2 VARIABLE MODEL FOUND.

STEP 3 VARIABLE BD ENTERED R SQUARE = 0.63358347 C(P) = -0.91707479

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	27705.75325809	9235.25108603	9.22	0.0009
ERROR	16	16022.89179691	1001.43073731		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-19.27248920				
BD	-242.62734106	130.52216473	3460.44626615	3.45	0.0815
COND	18.10719599	9.57559397	3590.89738724	3.59	0.0769
FE	208.0[illegible]	4[illegible].56171359	2634[illegible]	[illegible]	[illegible]

THE ABOVE MODEL IS THE BEST 3 VARIABLE MODEL FOUND.

Table 37 (continued)

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 4 VARIABLE OC ENTERED R SQUARE = [illegible] C(P) = [illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	29826.78708230	7456.69677059	8.05	0.0011
ERROR	15	13901.85797262	926.79053151		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-74.49462092				
BD	-259.64809058	126.06696051	3931.44284798	4.24	0.0572
COND	20.49250554	9.34580099	4455.93300865	4.81	0.0445
OC	41.51342564	27.44135608	2121.03392428	2.29	0.1511
FE	209.30991463	39.03078604	26673.15241751	28.78	0.0001

THE ABOVE MODEL IS THE BEST 4 VARIABLE MODEL FOUND.

STEP 5 VARIABLE FEALCLY ENTERED R SQUARE = 0.71655903 C(P) = 0.65053903

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	31334.15540390	6266.83108078	7.08	0.0017
ERROR	14	12394.48965110	885.32068936		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-354.03536527				
BD	-234.21958767	124.74587907	3121.00866579	3.53	0.0814
COND	17.88921138	9.34965997	3241.09209520	3.66	0.0764
OC	45.52151489	26.99571454	2517.35446301	2.84	0.1139
FE	472.28912556	205.05939015	4695.31469021	5.30	0.0371
FEALCLY	-6.25569430	4.79419983	1507.36832153	1.70	0.2130

STEP 5 OC REPLACED BY OCCLY R SQUARE = 0.72359987 C(P) = 0.43565448

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	[illegible]	[illegible]	7.33	0.0014
ERROR	14	12086.60313004	[illegible]		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-343.10749150				
BD	-240.85077971	[illegible]	[illegible]	[illegible]	0.0714
COND	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FE	505.07796497	[illegible]	[illegible]	[illegible]	[illegible]
FEALCLY	-7.90194266	[illegible]	[illegible]	[illegible]	[illegible]
OCCLY	2.28719424	[illegible]	[illegible]	[illegible]	[illegible]

Table 37 (continued)

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

THE ABOVE MODEL IS THE BEST 5 VARIABLE MODEL FOUND.

STEP 6 VARIABLE CLY ENTERED R SQUARE = 0.7345[illegible] C(P) = [illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	32122.84019426	5353.80669904	6.00	0.0034
ERROR	13	11605.80486074	892.75422006		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-672.51613702				
BD	-286.33201551	139.92571621	3734.58405760	4.18	0.0616
COND	15.52889320	10.64120889	2135.17757631	2.39	0.1460
CLY	21.30885089	29.03651523	480.79826130	0.54	0.4761
FE	681.46397018	317.40150835	4113.20959360	4.61	0.0513
FEALCLY	-15.92793330	12.13664993	1537.60544663	1.72	0.2121
OCCLY	1.87547890	1.40277750	1595.80100330	1.79	0.2042

STEP 6 OCCLY REPLACED BY FEALC R SQUARE = 0.73500275 C(P) = 2.08764183

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	32140.67424734	5356.77905789	6.01	0.0034
ERROR	13	11587.97070766	891.38236213		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-705.13760462				
BD	-286.13105088	139.89532226	3728.95918625	4.18	0.0616
COND	15.47137426	10.01842829	2125.90112600	2.38	0.1465
CLY	26.02204442	27.78056459	782.10439967	0.88	0.3660
FE	665.39114193	319.55504799	3864.77535597	4.34	0.0576
FEALCLY	-16.64778525	11.99542770	1716.90194192	1.93	0.1885
FEALC	17.57278035	13.06600407	1613.63515638	1.81	0.2015

THE ABOVE MODEL IS THE BEST 6 VARIABLE MODEL FOUND.

Table 37 (continued)

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 7   VARIABLE CLYST ENTERED   R SQUARE = [illegible]   C(P) = [illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	[illegible]	[illegible]	[illegible]	0.0[illegible]
ERROR	12	[illegible]	[illegible]		
TOTAL	19	[illegible]			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	142.17737274				
BD	-298.42111270	162.10[illegible]	4014.[illegible]	[illegible]	[illegible]
COND	10.67136048	11.5799[illegible]	[illegible]	[illegible]	[illegible]
CLY	[illegible]	46.23147746	[illegible]	[illegible]	[illegible]
CLYST	-20.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FE	983.72093274	49[illegible]	[illegible]	[illegible]	0.069[illegible]
FEALCLY	-29.94090564	19.7266[illegible]	[illegible]	[illegible]	[illegible]
FEALC	33.50056741	[illegible]	[illegible]	[illegible]	[illegible]

THE ABOVE MODEL IS THE BEST 7 VARIABLE MODEL FOUND.

STEP 8   VARIABLE AL ENTERED   R SQUARE = 0.75492605   C(P) = [illegible].47955516

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	33011.89345755	4126.48668219	4.24	0.0151
ERROR	11	10716.75159745	974.[illegible]		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-41.[illegible]				
BD	-201.06[illegible]	167.11[illegible]	[illegible]	[illegible]	[illegible]
COND	10.04304026	12.05611791	676.[illegible]	[illegible]	[illegible]
CLY	74.03454935	61.31[illegible]	[illegible]	[illegible]	[illegible]
CLYST	-23.80[illegible]	[illegible]	[illegible]	[illegible]	0.3770
FE	1103.86731028	[illegible]	[illegible]	[illegible]	0.1049
AL	250.65423413	[illegible]	[illegible]	[illegible]	[illegible]
FEALCLY	-39.09[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FEALC	34.95[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

THE ABOVE MODEL IS THE BEST 8 VARIABLE MODEL FOUND.

Table 37 (continued)

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 9 VARIABLE SAND ENTERED R SQUARE = 0.75991142 C(P) = 7.2274[illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	9	33229.89659407	3692.21073267	3.52	0.0315
ERROR	10	10498.74846093	1049.87484609		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1727.60277031				
BD	-285.52384620	156.47540662	3495.66755396	3.33	0.0980
COND	10.71624255	12.60218666	759.15557247	0.72	0.4150
CLY	80.27871567	65.11200445	1595.93979530	1.52	0.2458
CLYSI	-44.71808263	53.20115224	742.42089859	0.71	0.4200
SAND	-16.73832992	36.73241803	219.00313652	0.21	0.6584
FE	1289.96287918	733.34123097	3248.47665475	3.09	0.1091
AL	324.11692117	601.56778196	304.76952[illegible]	0.29	0.6018
FEALCLY	-43.16252105	30.86728738	2052.83572857	1.96	0.1923
FEALC	40.80185327	27.87865669	2248.81444619	2.14	0.1740

STEP 9 AL REPLACED BY OCCLY R SQUARE = 0.76058747 C(P) = 7.30696336

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	9	33259.45946264	3695.49549585	3.53	0.0311
ERROR	10	10469.18559236	1046.91855924		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2442.88391509				
BD	-200.77023460	156.59579954	3345.14055640	3.[illegible]	0.1032
COND	9.62787362	13.87443262	595.46306133	0.56	0.4718
CLY	105.53722536	99.17817675	1195.47391630	1.13	0.3123
CLYSI	-52.40894047	58.68028639	835.10139476	0.80	0.3928
SAND	-21.50470603	39.35672460	312.56525451	0.30	0.5968
FE	1022.52846198	542.31894965	3721.[illegible]	3.56	0.0887
FEALCLY	-42.35466023	29.13311135	2212.70779324	2.11	0.1766
FEALC	189.71213878	270.77867197	513.99708720	0.49	0.4995
OCCLY	-15.52268173	27.46513440	334.33239123	0.32	0.5845

THE ABOVE MODEL IS THE BEST 9 VARIABLE MODEL FOUND.

Table 37 (continued)

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 10   VARIABLE SES ENTERED   R SQUARE = 0.76[illegible]   C(P) = [illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	10	33481.[illegible]	[illegible]	2.[illegible]	[illegible]
ERROR	9	10247.[illegible]	1138.[illegible]12581		
TOTAL	19	43728.64[illegible]			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3235.32034246				
BD	-228.05859248	202.31[illegible]	1446.[illegible]	1.[illegible]	0.[illegible]
COND	9.74371061	13.42[illegible]	[illegible]	[illegible]	0.[illegible]
SES	-1.77255276	4.01591977	[illegible]	0.19	0.6693
CLY	115.19268848	104.[illegible]	1311.[illegible]	1.1[illegible]	0.3110
CLYSI	-61.1145761[illegible]	66.[illegible]	1021.7[illegible]	[illegible]	0.3657
SAND	-27.66157616	43.[illegible]	[illegible]	[illegible]	[illegible]
FE	1029.91214815	[illegible]	[illegible]	[illegible]	[illegible]
FEALCLY	-44.63747440	30.81395909	2380.54640999	2.10	0.1814
FEALC	223.67907822	292.68213557	665.00504496	0.[illegible]	0.4443
OCCLY	-18.98607216	29.65452076	441.25705449	0.41	0.5401

STEP 10   OCCLY REPLACED BY AL   R SQUARE = 0.76614321   C(P) = 9.13724374

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	10	33502.40443094	3350.24044309	2.95	0.0594
ERROR	9	10226.24062406	1136.24895823		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2477.95323243				
BD	-226.65011443	202.36412802	1425.[illegible]	1.[illegible]	0.2917
COND	11.06489526	13.12[illegible]	[illegible]	0.71	0.42[illegible]
SES	-2.01530370	4.11[illegible]	[illegible]	[illegible]	0.6360
CLY	83.00759098	69.11[illegible]	1710.06776347	1.[illegible]	0.2498
CLYST	-53.62421746	[illegible]	[illegible]	[illegible]	0.3812
SAND	-22.97077463	40.[illegible]	[illegible]	[illegible]	0.5824
FE	1386.775004[illegible]	705.10[illegible]	[illegible]	3.1[illegible]	0.11[illegible]
AL	432.0996102[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FEALCLY	-47.03370176	33.[illegible]	2290.31[illegible]	[illegible]	0.1897
FEALC	43.16231534	29.40658034	2441.[illegible]	2.15	0.1761

THE ABOVE MODEL IS THE BEST 10 VARIABLE MODEL FOUND.

Table 37 (continued)

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE [illegible]

STEP 11 VARIABLE OC ENTERED R SQUARE = 0.77[illegible] C(P) = 11.[illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	33674.22[illegible]	3061.29[illegible]	2.44	0.1082
ERROR	8	10054.41[illegible]	1256.80206984		
TOTAL	19	43728.64[illegible]			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2921.91719033				
BD	-218.82843762	213.87742181	1315.66259005	1.05	0.3362
COND	11.72581273	13.92302028	991.32477285	0.71	0.4242
SFS	-1.93511800	4.33340193	252.62464850	0.20	0.6670
CLY	89.71[illegible]	73.[illegible]	1877.4[illegible]	1.49	0.2[illegible]
CLYSI	-58.52019642	62.677070[illegible]	1095.[illegible]	0.87	0.3777
SAND	-24.85253678	42.66442945	426.45819404	0.34	0.5763
OC	-108.68474739	293.94091980	171.92406534	0.14	0.7212
FE	1359.16011069	832.22002599	3357.71452309	2.67	0.1411
AL	406.26635040	702.22123054	420.66916719	0.33	0.5788
FEALCLY	-49.74164239	35.54340150	2461.43943540	1.96	0.1992
FEALC	95.33475484	144.45008011	547.43658953	0.44	0.5278

STEP 11 FEALC REPLACED BY OCCLY R SQUARE = 0.77062216 C(P) = 11.00654729

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	33698.26308048	3063.47846186	2.44	0.1074
ERROR	8	10030.38197452	1253.79774681		
TOTAL	19	43728.64505500			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2530.82179194				
BD	-218.65615048	213.57849042	1314.12251368	1.05	0.3359
COND	13.27233098	14.28535738	1082.29009954	0.96	0.3800
SFS	-1.84764258	4.33189441	228.09075512	0.18	0.6810
CLY	66.756786[illegible]	70.40[illegible]	1117.[illegible]	[illegible]	0.3715
CLYSI	-52.95962359	59.95137160	979.42[illegible]	0.78	0.4028
SAND	-20.86027198	41.76271907	[illegible]	[illegible]	0.6304
OC	-185.71790327	[illegible]	[illegible]	[illegible]	[illegible]
FE	1516.82957180	870.99071121	3802.54193433	3.03	0.1198
AL	602.26945275	747.18335798	814.61674827	0.65	0.4435
FEALCLY	-49.73731714	35.47204439	2471.97999400	1.97	0.1979
OCCLY	13.71898839	20.32070012	571.47117372	0.46	0.5186

THE ABOVE MODEL IS THE BEST 11 VARIABLE MODEL FOUND.

Table 37 (continued)

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE PROD

STEP 12   VARIABLE FEALC ENTERED   R SQUARE = 0.77[illegible]   C(P) = 13.[illegible]

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	12	33699.04722178	2808.25393515	1.96	0.1697
ERROR	7	10029.59793422	1432.79969046		
TOTAL	19	43728.64[illegible]			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2597.80525518				
BD	-218.53693412	228.37295600	1312.03628927	0.92	0.3705
COND	13.05132584	17.95699692	756.88052813	0.53	0.4909
SES	-1.86019125	4.66177244	229.11947538	0.16	0.7018
CLY	69.91383910	169.61814356	243.41915214	0.17	0.69[illegible]
CLYSI	-53.99812137	75.60869491	729.09701664	0.51	0.4990
SAND	-21.49585090	52.29751760	242.99054829	0.17	[illegible]
OC	-175.88706363	549.35019299	[illegible]	[illegible]	0.7777
FE	1493.79906840	1355.02601248	1741.30198362	1.22	0.3067
AL	573.28780511	1473.98462110	216.74295078	0.15	0.7089
FEALCLY	-49.79727750	37.95292245	2466.64262669	1.72	0.2309
FEALC	14.76818164	631.28002890	0.78414130	0.00	0.9820
OCCLY	11.70[illegible]	88.91257369	[illegible]	[illegible]	[illegible]

THE ABOVE MODEL IS THE BEST 12 VARIABLE MODEL FOUND.

Table 38. Statistical analysis of soil physical and chemical parameters used in the soil erodibility correlation.

STATISTICAL ANALYSIS SYSTEM

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
REP	20	2.50000000	1.14707867	50.00000000	1.00000000	4.00000000
TRT	20	3.00000000	1.45095250	60.00000000	1.00000000	5.00000000
EROD	20	52.87850000	47.97403003	1057.57000000	1.73000000	143.12000000
BD	20	1.49300000	0.05885754	29.86000000	1.27000000	1.63000000
COND	20	1.15900000	0.77450920	23.18000000	0.17000000	2.47000000
SFS	20	69.89500000	3.11321039	1397.90000000	63.30000000	77.90000000
CLY	20	20.50000000	1.75948567	410.00000000	16.60000000	23.80000000
CLYSI	20	73.66000000	0.79365908	1473.20000000	71.90000000	75.10000000
SAND	20	26.38500000	0.82543449	527.70000000	24.90000000	28.10000000
OC	20	1.81200000	0.25970834	36.24000000	1.19000000	2.19000000
FE	20	1.98700000	0.19147901	39.74000000	1.72000000	2.41000000
AL	20	0.21900000	0.03307090	4.38000000	0.15000000	0.30000000
FEALCLY	20	45.56700000	8.32815775	911.34000000	32.20000000	64.23000000
FEALC	20	3.99800000	0.69099166	79.96000000	2.27000000	5.56000000
OCCLY	20	37.20550000	6.48330932	744.11000000	22.01000000	50.93000000

Table 39. Linear correlation coefficients among soil physical and chemical parameters in the prediction of soil erodibility at the study site.

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 20

	REP	TRT	EROD	BD	COND	SFS	CLY	CLYSI	SAND	OC	FE	AL	FEALCLY
REP	1.00000 0.0000	0.00000 1.0000	-0.80230 0.0001	-0.38199 0.0965	-0.10425 0.6619	0.35888 0.1202	-0.67561 0.0011	-0.45093 0.0460	0.34742 0.1334	-0.20671 0.3819	-0.75961 0.0001	-0.44397 0.0499	-0.71336 0.0004
TRT	0.00000 1.0000	1.00000 0.0000	-0.16916 0.4759	0.23419 0.3203	0.20324 0.3901	0.16312 0.4920	-0.25564 0.2767	-0.37478 0.1035	0.47461 0.0345	-0.41901 0.0659	-0.16671 0.4824	-0.25229 0.2833	-0.22174 0.3474
EROD	-0.80230 0.0001	-0.16916 0.4759	1.00000 0.0000	-0.06868 0.7736	0.16965 0.4746	-0.48133 0.0317	0.55403 0.0113	0.33596 0.1476	-0.29532 0.2062	0.16431 0.4888	0.67863 0.0010	0.40015 0.0804	0.61872 0.0036
BD	-0.38199 0.0965	0.23419 0.3203	-0.06868 0.7736	1.00000 0.0000	-0.12646 0.5952	0.12245 0.6071	0.41980 0.0654	0.32156 0.1668	-0.28502 0.2232	0.10701 0.6534	0.32027 0.1686	0.09356 0.6948	0.34522 0.1360
COND	-0.10425 0.6618	0.20324 0.3901	0.16965 0.4746	-0.12646 0.5952	1.00000 0.0000	0.14210 0.5501	-0.22136 0.3483	-0.25605 0.2759	0.31344 0.1784	-0.17855 0.4513	-0.19310 0.4147	-0.33597 0.1475	-0.23249 0.3240
SFS	0.35888 0.1202	0.16312 0.4920	-0.48133 0.0317	0.12245 0.6071	0.14210 0.5501	1.00000 0.0000	-0.61350 0.0040	-0.28297 0.2267	0.28036 0.2312	-0.11957 0.6156	-0.56315 0.0097	-0.40063 0.0799	-0.59980 0.0052
CLY	-0.67561 0.0011	-0.25564 0.2767	0.55403 0.0113	0.41980 0.0654	-0.22136 0.3483	-0.61350 0.0040	1.00000 0.0000	0.45680 0.0429	-0.47799 0.0330	0.13649 0.5661	0.92358 0.0001	0.69014 0.0008	0.97048 0.0001
CLYSI	-0.45093 0.0460	-0.37478 0.1035	0.33596 0.1476	0.32156 0.1668	-0.25605 0.2759	-0.28297 0.2267	0.45680 0.0429	1.00000 0.0000	-0.95219 0.0001	0.70465 0.0005	0.38533 0.0934	0.09866 0.6790	0.38087 0.0976
SAND	0.34742 0.1334	0.47461 0.0345	-0.29532 0.2062	-0.28502 0.2232	0.31344 0.1784	0.28036 0.2312	-0.47799 0.0330	-0.95219 0.0001	1.00000 0.0000	-0.60652 0.0046	-0.38092 0.0975	-0.10662 0.6546	-0.39233 0.0871
OC	-0.20671 0.3819	-0.41901 0.0659	0.16431 0.4888	0.10701 0.6534	-0.17855 0.4513	-0.11957 0.6156	0.13649 0.5661	0.70465 0.0005	-0.60652 0.0046	1.00000 0.0000	0.03918 0.8697	0.00270 0.9910	0.06782 0.7763
FE	-0.75961 0.0001	-0.16671 0.4824	0.67863 0.0010	0.32027 0.1686	-0.19310 0.4147	-0.56315 0.0097	0.92358 0.0001	0.38533 0.0934	-0.38092 0.0975	0.03918 0.8697	1.00000 0.0000	0.74338 0.0002	0.98370 0.0001
AL	-0.44397 0.0499	-0.25228 0.2833	0.40015 0.0804	0.09356 0.6948	-0.33597 0.1475	-0.40063 0.0799	0.69014 0.0008	0.09866 0.6790	-0.10662 0.6546	0.00270 0.9910	0.74338 0.0002	1.00000 0.0000	0.77465 0.0001
FEALCLY	-0.71336 0.0004	-0.22174 0.3474	0.61872 0.0036	0.34522 0.1360	-0.23249 0.3240	-0.59980 0.0052	0.97048 0.0001	0.38087 0.0976	-0.39233 0.0871	0.06782 0.7763	0.98370 0.0001	0.77465 0.0001	1.00000 0.0000
FEALC	-0.56776 0.0090	-0.44726 0.0480	0.49598 0.0261	0.23866 0.3109	-0.28571 0.2220	-0.41346 0.0700	0.60896 0.0044	0.78566 0.0001	-0.70348 0.0005	0.83489 0.0001	0.57257 0.0083	0.43383 0.0560	0.58958 0.0062
OCCLY	-0.48064 0.0319	-0.47177 0.0357	0.39423 0.0854	0.27490 0.2408	-0.27669 0.2376	-0.39726 0.0828	0.57935 0.0074	0.80314 0.0001	-0.73583 0.0002	0.88302 0.0001	0.46481 0.0389	0.32003 0.1690	0.51005 0.0216

Table 39(continued)

STATISTICAL ANALYSIS SYSTEM

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 20

	FEALC	OCCLY
CLY	0.60896 0.0044	0.57935 0.0074
CLYSI	0.78566 0.0001	0.80314 0.0001
SAND	-0.70368 0.0005	-0.73583 0.0002
OC	0.83488 0.0001	0.88302 0.0001
FE	0.57257 0.0083	0.46481 0.0389
AL	0.43383 0.0560	0.32003 0.1690
FEALCLY	0.58958 0.0062	0.51005 0.0216
FEALC	1.00000 0.0000	0.97562 0.0001
OCCLY	0.97562 0.0001	1.00000 0.0000

	FEALC	OCCLY
REP	-0.56774 0.0090	-0.48064 0.0319
TRT	-0.44726 0.0480	-0.47177 0.0357
EROD	0.49598 0.0261	0.39423 0.0854
BD	0.23866 0.3109	0.27490 0.2408
COND	-0.28571 0.2220	-0.27669 0.2376
SFS	-0.41346 0.0700	-0.39726 0.0828

Table 40. Linear regression analysis for the six most important erodibility predictors against amounts of eroded sediments from the 20 microplots.

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: EROD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	6	32068.38644152	[illegible]	[illegible]	[illegible]	0.733350	56.6374
ERROR	13	11660.25861348	[illegible]		STD DEV		EROD MEAN
CORRECTED TOTAL	19	43728.64505500			[illegible]		52.87850000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
FE	1	20130.44186562	22.45	0.0004	1	[illegible]	5.74	0.0323
COND	1	4106.86713633	[illegible]	[illegible]	1	[illegible]	3.91	0.0729
BD	1	3460.44426615	[illegible]	0.0713	1	[illegible]	4.05	0.0653
OC	1	2121.03302428	[illegible]	[illegible]	1	[illegible]	0.48	0.5027
FEALCLY	1	1507.26832153	[illegible]	[illegible]	1	[illegible]	2.21	0.1607
OCCLY	1	734.23103761	0.82	0.3821	1	734.23103761	0.82	0.3821

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	-288.06706304	-0.99	[illegible]	[illegible]
FE	601.59330303	2.40	0.0323	[illegible]
COND	18.39627526	1.98	[illegible]	[illegible]
BD	-258.36398614	-2.01	[illegible]	128.36643116
OC	-150.67086211	-0.69	0.5027	218.54020602
FEALCLY	-12.41886439	-1.49	0.1607	8.34796265
OCCLY	9.37769454	0.90	[illegible]	[illegible]

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL
1	104.78000000	[illegible]	[illegible]
2	111.26000000	68.28498625	42.97501365
3	[illegible]	[illegible]	[illegible]
4	119.62000000	107.92666639	[illegible]
5	85.57000000	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	143.12000000	[illegible]	[illegible]
8	39.47000000	[illegible]	[illegible]
9	89.41000000	[illegible]	[illegible]
10	31.43000000	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	11.62000000	[illegible]	[illegible]
13	17.50000000	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	43.27000000	[illegible]	[illegible]
16	1.73000000	[illegible]	[illegible]
17	7.00000000	[illegible]	[illegible]
18	2.21000000	[illegible]	[illegible]

Table 40 (continued)

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: EROD

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL
19	10.15000000	41.05927908	-30.90927908
20	3.24000000	-21.42028134	24.66028134

SUM OF RESIDUALS	-0.00000000
SUM OF SQUARED RESIDUALS	11660.25851248
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000000
FIRST ORDER AUTOCORRELATION	-0.11597472
DURBIN-WATSON D	2.12487440

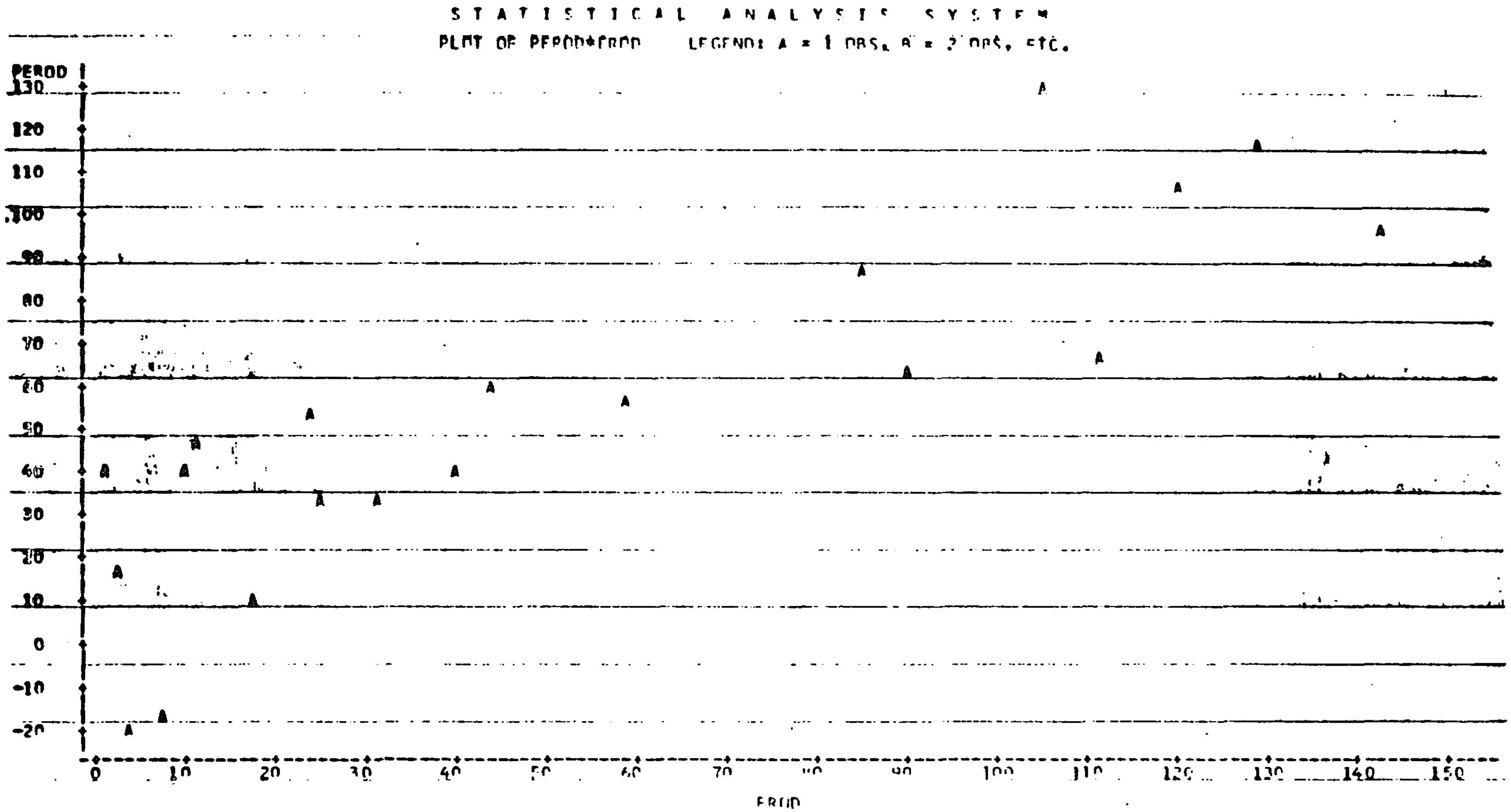

Figure 13. Plot of predicted and observed sediment loss based on regression model with the six most important erodibility predictors.

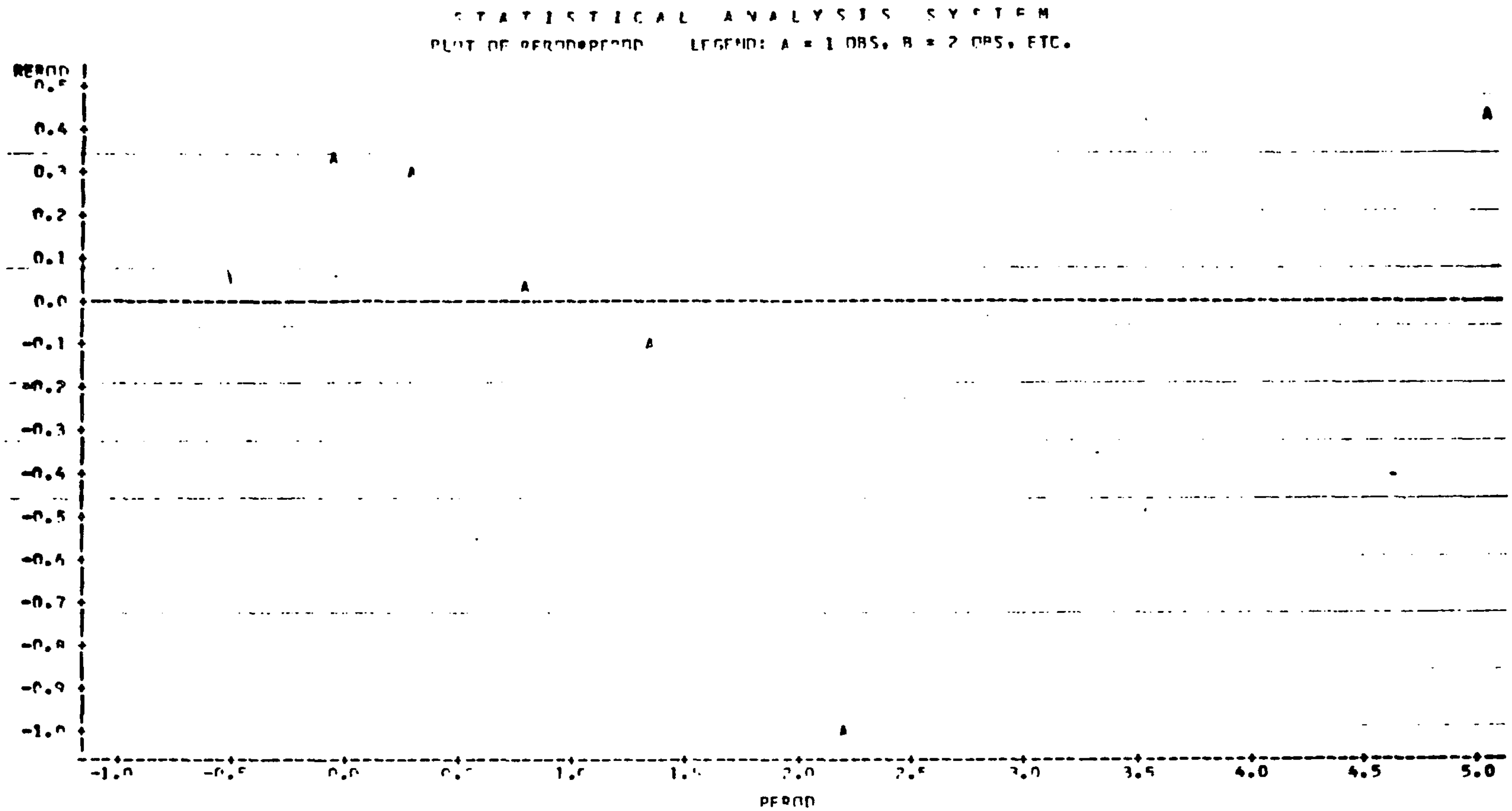

Figure 14. Plot of residual erode vs. predicted erode.

Table 41. Stepwise multiple regression analysis of rainfall characteristics and soil loss from the control plots.

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE EROD

STEP 1 VARIABLE EI ENTERED R SQUARE = [illegible] C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	11.75031815	11.75031815	6.90	0.0584
ERROR	4	6.81588755	1.70397189		
TOTAL	5	18.56620570			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.10573976				
EI	0.98998055	0.37699281	11.75031815	6.90	0.0584

THE ABOVE MODEL IS THE BEST 1 VARIABLE MODEL FOUND.

STEP 2 VARIABLE INT ENTERED R SQUARE = 0.92441707 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	17.16291745	8.58145873	18.35	0.0208
ERROR	3	1.40328825	0.46776275		
TOTAL	5	18.56620570			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.86523112				
INT	-5.11442769	1.50351200	5.41259931	11.57	0.0424
EI	3.35606917	0.72307158	10.07685136	21.54	0.0189

THE ABOVE MODEL IS THE BEST 2 VARIABLE MODEL FOUND.

STEP 3 VARIABLE DUR ENTERED R SQUARE = 0.94083476 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	17.46773175	5.82257725	10.60	0.0874
ERROR	2	1.09847396	0.54923698		
TOTAL	5	18.56620570			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.04857302				
DUR	-0.27268258	0.36603247	0.30481429	0.55	0.5339
INT	-6.05466561	2.06088078	4.74061138	8.63	0.0990
EI	[illegible]	[illegible]	7.92260867	14.42	0.0629

THE ABOVE MODEL IS THE BEST 3 VARIABLE MODEL FOUND.

Table 41. (continued).

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE FROD

STEP 4 VARIABLE AMT ENTERED R SQUARE = 0.94219197 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	17.49292992	4.37323248	4.07	0.3537
ERROR	1	1.07327578	1.07327578		
TOTAL	5	18.56620570			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.42519309				
DUR	-0.46558834	1.35897934	0.12597658	0.12	0.7899
INT	-6.20703037	3.04760911	4.45182149	4.15	0.2906
EI	3.78390672	1.43896554	7.42149490	6.91	0.2313
AMT	0.31893585	7.08083793	0.02519818	0.02	0.9032

THE ABOVE MODEL IS THE BEST 4 VARIABLE MODEL FOUND.

STEP 5 VARIABLE KE ENTERED R SQUARE = 1.00000000 C(P) = .

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	18.56620570	3.71324114	999999.99	0.0001
ERROR	0	0.00000000	0.00000000		
TOTAL	5	18.56620570			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	37.34473507				
DUR	-4.03395045	0	1.19788172	999999.99	0.0001
INT	-6.25690024	0	4.52257046	999999.99	0.0001
KE	-11.48730197	0	1.07327578	999999.99	0.0001
EI	3.73843284	0	7.23696061	999999.99	0.0001
AMT	18.35523836	0	1.09695608	999999.99	0.0001

THE ABOVE MODEL IS THE BEST 5 VARIABLE MODEL FOUND.

Table 42 Percent slope values for individual microplots.

Treatment	Replicate (% slope).				
	1	2	3	4	Mean
V. mulching (91.4 cm spacing)	8.0	10.0	8.5	1.8	7.1
V. mulching (182.9cm spacing)	8.0	9.0	7.5	4.8	7.3
Slot trenching (91.4 cm spacing)	9.0	9.5	7.5	4.8	7.7
Slot trenching 182.9 cm spacing)	9.0	7.5	6.5	3.9	6.7
Control	9.0	7.0	8.0	4.5	7.1

Table 43. Stepwise multiple regression analysis for the correlation of soybean yield with soil moisture content in 0-15cm (H1), 0-30 cm (H2), and 0-45 cm (H3) depths.

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE YIELD

STEP 1 VARIABLE H3 ENTERED R SQUARE = 0.53130425 C(P) = 6.82628762

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	392910.41044650	392910.41044650	20.40	0.0003
ERROR	18	346610.13955350	19256.11886408		
TOTAL	19	739520.55000000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2627.50785194				
H3	-86.58994630	19.16924824	392910.41044650	20.40	0.0003

THE ABOVE MODEL IS THE BEST 1 VARIABLE MODEL FOUND.

STEP 2 VARIABLE H1 ENTERED R SQUARE = 0.58456792 C(P) = 6.23225525

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	432299.99225897	216149.99612949	11.96	0.0006
ERROR	17	307220.55774103	18071.79751418		
TOTAL	19	739520.55000000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1845.18602460				
H1	35.58601524	24.10401291	39389.58181247	2.18	0.1581
H3	-90.05603713	18.71822182	418309.60549375	23.15	0.0002

STEP 2 H3 REPLACED BY H2 R SQUARE = 0.60866003 C(P) = 5.05892821

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	450116.60156565	225058.30078283	13.22	0.0003
ERROR	17	289403.94843435	17023.76167261		
TOTAL	19	739520.55000000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1426.35320316				
H1	75.13729510	25.55249745	147197.33146665	8.65	0.0091
H2	-112.20538106	22.16845131	436126.21480043	25.62	0.0001

THE ABOVE MODEL IS THE BEST 2 VARIABLE MODEL FOUND.

Table 43 (continued).

STATISTICAL ANALYSIS SYSTEM

MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE YIELD

STEP 3 VARIABLE H3 ENTERED R SQUARE = 0.67146949 C(P) = 4.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	496565.48325744	165521.82775248	10.90	0.0004
ERROR	16	242955.06674256	15184.69167141		
TOTAL	19	739520.55000000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1834.97481242				
H1	61.32706905	25.39180485	88577.46627061	5.83	0.0281
H2	-67.74798538	32.93142009	64265.49099847	4.23	0.0563
H3	-47.20102459	26.98775654	46448.88169178	3.06	0.0994

Table 44. Linear correlation coefficients of soybean yield and soil moisture content at depths of 0-15 cm (H1), 0-30 cm (H2) and 0-45 cm (H3).

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 20

	TRT	REP	YIELD	H1	H2	H3
TRT	1.00000	0.00000	0.23387	0.14710	-0.10029	0.04172
	0.0000	1.0000	0.3210	0.5360	0.6740	0.8614
REP	0.00000	1.00000	0.63876	-0.27324	-0.83816	-0.56513
	1.0000	0.0000	0.0024	0.2438	0.0001	0.0094
YIELD	0.23387	0.63876	1.00000	0.13754	-0.64001	-0.72891
	0.3210	0.0024	0.0000	0.5631	0.0024	0.0003
H1	0.14710	-0.27324	0.13754	1.00000	0.41827	0.12543
	0.5360	0.2438	0.5631	0.0000	0.0665	0.5983
H2	-0.10029	-0.83816	-0.64001	0.41827	1.00000	0.74804
	0.6740	0.0001	0.0024	0.0665	0.0000	0.0001
H3	0.04172	-0.56513	-0.72891	0.12543	0.74804	1.00000
	0.8614	0.0094	0.0003	0.5983	0.0001	0.0000

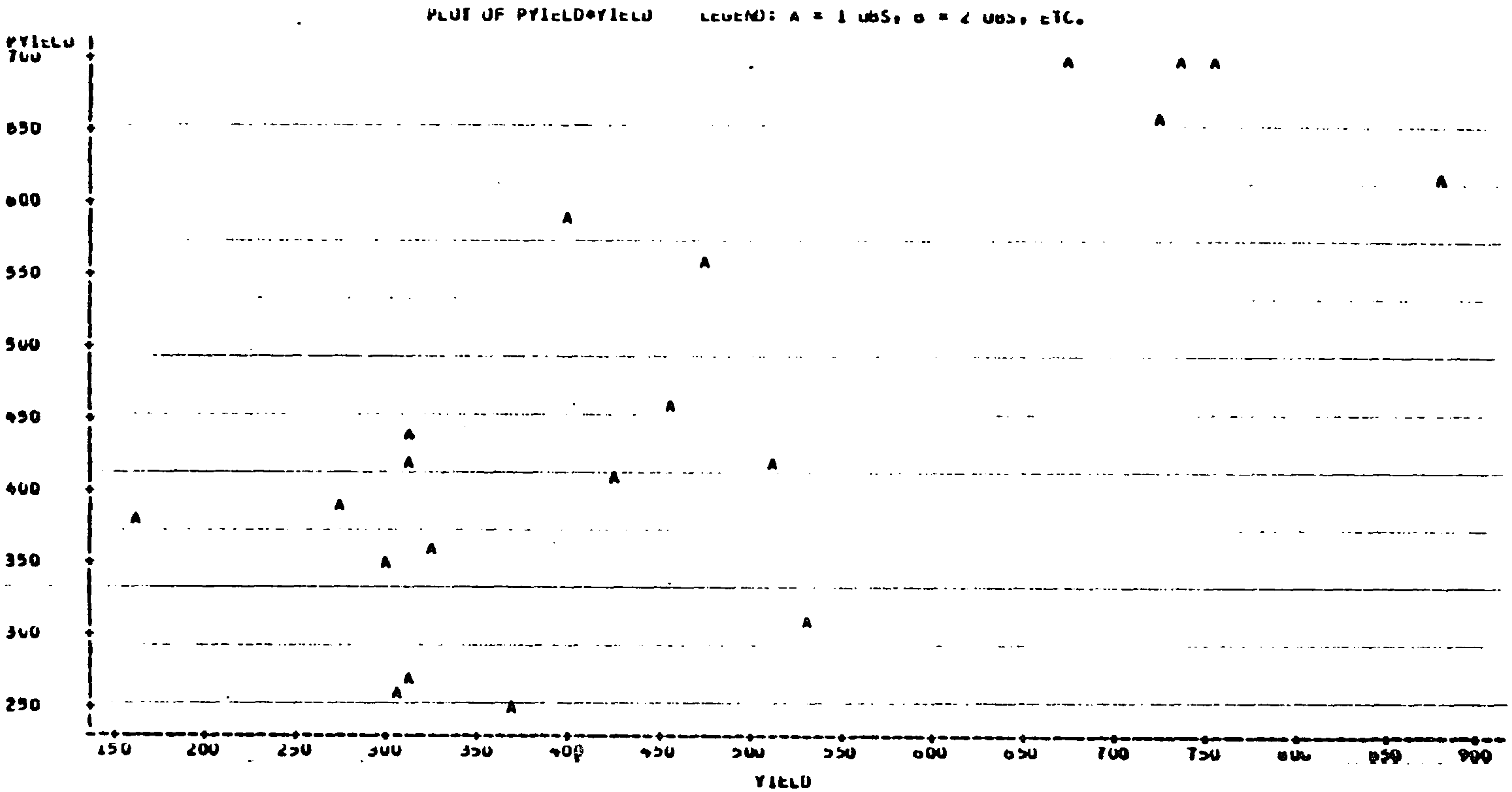

Figure 15. Plot of predicted soybean yield against observed yield based on the relationship between yield and moisture content at 0-45 cm depth.

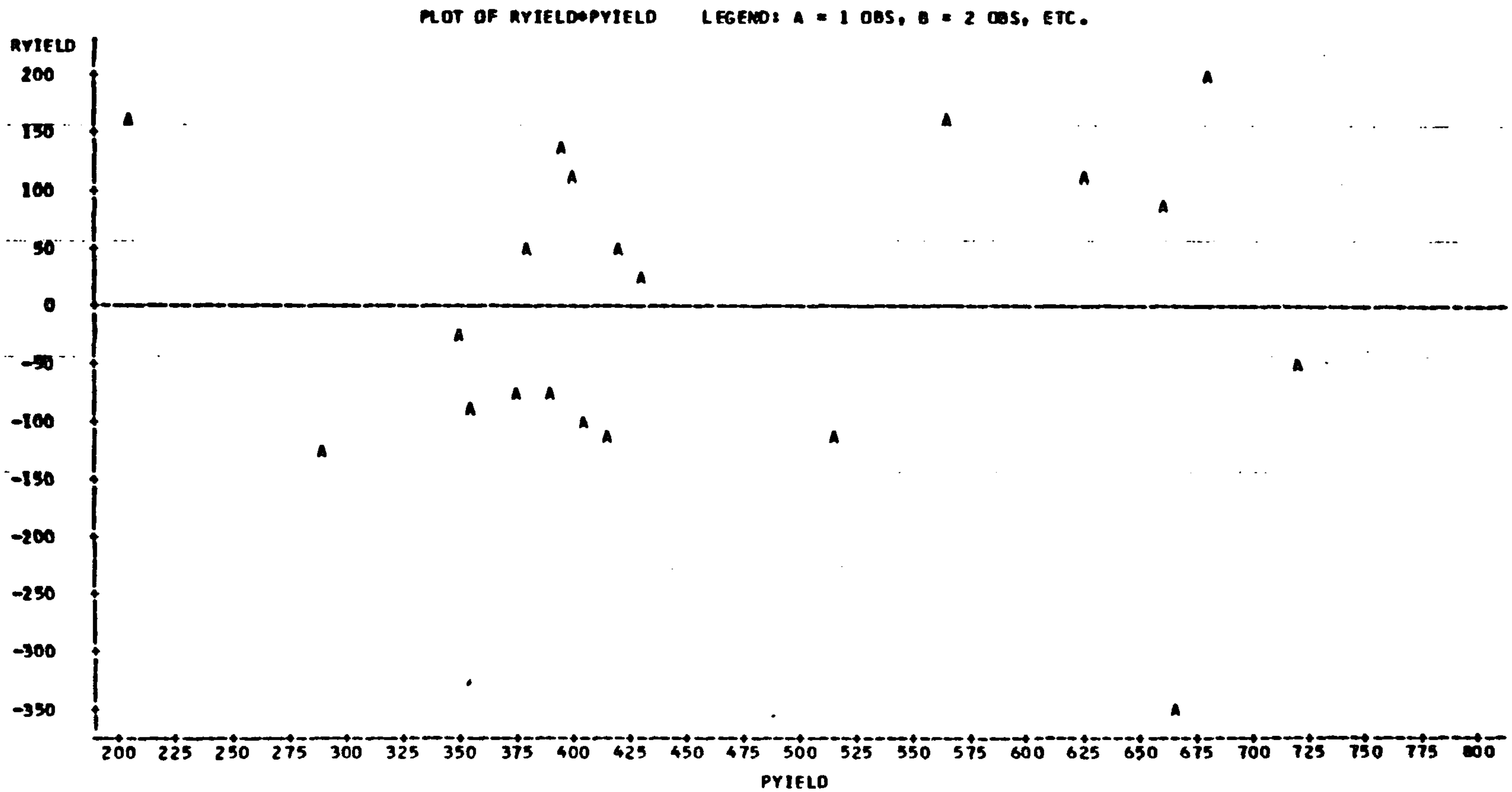

Figure 16. plot of residual soybean yield against predicted yield.

Table 45. Soil Chemical and Physical Characteristics of the study site.

Chemical parameters	Depth (cm)	Mean values for each treatment				
		Vertical Mulching		Slot trenching		Control
		91.4 cm spacing	182.9 cm spacing	91.4 cm spacing	182.9 cm spacing	
pH (H_2O)	0-15	6.2	6.1	6.3	6.2	6.2
	15-30	6.0	6.0	5.8	6.0	6.1
pH ($CaCl_2$)	0-15	6.3	6.3	6.4	6.4	6.3
	15-30	6.1	6.0	5.8	6.0	6.2
Organic C (%)	0-15	1.97	1.85	1.81	1.79	1.63
	15-30	1.0	1.20	1.06	0.97	1.29
Total P (%)	0-15	0.09	0.09	0.09	0.08	0.08
	15-30	0.07	0.08	0.08	0.07	0.07
Available P (µg/g)	0-15	91.02	105.05	98.26	78.40	99.48
	15-30	26.50	39.66	31.43	26.01	55.13
Exch. Ca	0-15	11.79	12.41	11.91	10.46	10.29
(c mol(+).kg^{-1})	15-30	12.60	11.61	11.24	10.91	9.81
Exch. Mg	0-15	3.86	3.57	3.75	3.70	3.47
(cmol(+).kg^{-1})	15-30	5.35	4.42	4.32	4.73	3.50
Exch K	0-15	0.37	0.44	0.38	0.33	0.28
(cmol(+).kg^{-1})	15-30	0.34	0.27	0.26	0.28	0.25
CEC (cmol(+).kg^{-1})	0-15	13.89	13.55	13.71	13.70	13.56
	15-30	15.64	16.30	15.47	15.85	13.03
Fe (%)	0-15	2.03	2.00	1.81	2.05	1.90
	15-30	2.59	2.53	2.63	2.74	2.13
Al (%)	0-15	0.22	0.23	0.22	0.22	0.20
	15-30	0.30	0.29	0.28	0.28	0.25

Table 45 (continued)

Physical parameters	Depth (cm)	Mean values for each treatment				
		Vertical mulching		Slot trenching		Control
		91.4 cm spacing	182.9 cm spacing	91.4 cm spacing	182.9 cm spacing	
1/3 atm bulk density (Mg m^{-3})	0-15	1.50	1.50	1.60	1.50	1.50
	15-30	1.51	1.50	1.50	1.52	1.51
Aeration porosity (%)	0-15	13.78	13.25	12.28	11.19	12.89
	15-30	14.43	12.67	14.26	12.82	13.01
Sat. Hydraulic cond. (cm hr^{-1})	0-8	1.33	1.40	2.10	2.26	1.26
	8-16	1.70	0.95	1.20	0.95	1.02
	16-23	1.15	2.05	0.50	2.36	0.95
	23-30	0.66	2.75	0.70	1.90	0.86

Table 46. Coefficients for the partitioning of the sum of square among the four treatments into four independent (orthogonal) comparisons.

Comparison	Treatments				
	No treatment (Control)	Vertical mulching (91.4cm)	Vertical mulching (182.9cm)	Slot trenching (91.4 cm)	Slot trenching (182.9 cm)
1. Response to profile modification (no-tillage control vs. treatments)	+4	-1	-1	-1	-1
2. Vertical mulching vs. slot trenching	0	+1	+1	-1	-1
3. Vertical mulching (91.4 cm) vs. vertical mulching (182.9 cm)	0	-1	+1	0	0
4. Slot trenching (91.4 cm) vs. slot trenching (182.9 cm)	0	0	0	+1	-1

Table 47. Orthogonal comparisons of runoff volume (ml) from plots with the different treatments for rainfall event of September 3, 1982.

Treatment Comparison	Mean square	F value
(1) No-tillages control vs. treatments	6891380.0	0.30 ns
(2) Vertical mulching (91.4 + 182.9 cm spacings) vs. slot trenching (91.4 + 182.9 cm spacings)	490000.0	0.02 ns
(3) Vertical mulching at 91.4 cm spacing vs. vertical mulching at 182.9 cm spacing	1.131008×10^8	5.00*
(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing	1.5966845×10^8	7.07*

* = significantly different at 5% level;
Tabulated F value with 12 degrees of freedom (error) and 1 degree of freedom (treatment) = 4.75.

Table 48. Orthogonal comparisons of runoff volume (ml) from the plots with the different treatments for rainfall event of September 26, 1982.

Treatment Comparison	Mean Square	F Value
(1) Control vs. treatments	123402.05	0.51 ns
(2) Vertical mulching (91.4 cm + 182.9 cm spacings) vs. slot trenching (91.4 cm + 182.9 cm spacing)	6972.25	0.03 ns
(3) Vertical mulching at 91.4 cm spacing vs. vertical mulching at 182.9 cm spacing	114242	0.47 ns
(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing	446512.5	1.85 ns

ns = not significant at 5% level.
Tabulated F with 12 df error and 1 df treatment = 4.75.

Table 49. Orthogonal comparisons of runoff volume (ml) from the plots with the different treatments for rainfall event of October 10, 1982.

Treatment Comparison	Mean Square	F Value
(1) Control vs. treatments	6771.2	0.01 ns
(2) Vertical mulching (91.4 cm + 182.9 cm spacings) vs. slot trenching 91.4 cm + 182.9 cm spacings)	586575.13	1.37 ns
(3) Vertical mulching at 91.4 cm vs. vertical mulching at 182.9 cm spacing	30628.12	0.07 ns
(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing	253828.13	0.59 ns

ns = not significant at 5% level.
Tabulated F value with 12 df error and 1 df treatment= 4.75.

Table 50. Orthogonal comparisons of runoff volume (ml) from plots with the different treatments for rainfall event of November 4, 1982.

Treatment Comparison	Mean Square	F Value
(1) Control vs. treatments	6845	0.07 ns
(2) Vertical mulching (91.4 cm spacing + 182.9 cm spacing) vs. slot trenching (91.4 cm spacing + 182.9 cm spacing	1081600	10.56*
(3) Vertical mulching at 91.4 cm spacing vs. vertical mulching at 182.9 cm spacing	74112.5	0.75 ns
(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing	214512.5	2.09

* = Significantly different at 5% level;
Tabulated F 12 df error and 1 df treatment = 4.75.

Table 51. Orthogonal comparisons of runoff volume (ml) from plots with the different treatments for rainfall event of November 13, 1982.

Treatment Comparison	Mean Square	F Value
(1) Control vs. treatments	37845	0.17 ns
(2) Vertical mulching (91.4 cm + 182.9 cm spacings) vs. slot trenching (91.4 cm + 182.9 cm spacings)	136900	0.63 ns
(3) Vertical mulching at 91.4 cm vs. vertical mulching at 182.9 cm spacings	456012.5	2.11 ns
(4) Slot trenching at 91.4 cm spacing vs. slot trenching at 182.9 cm spacing	46512.5	0.21 ns

ns = not significant at 5% level.
Tabulated F with 12 df error and 1 df treatment = 4.75 at 5% alpha level.

Table 52. Orthogonal comparisons of runoff volume (ml) from plots with the different treatments for rainfall event of November 21, 1982.

Treatment Comparison	Mean Square	F Value
(1) Control vs. treatments	494079.61	0.08 ns
(2) Vertical mulching (91.4 cm + 182.9 cm spacings) vs. slot trenching (91.4 cm + 182.9 cm spacings)	494560.56	0.08 ns
(3) Vertical mulching at 91.4 cm vs. vertical mulching at 182.9 cm spacings	2702812.5	0.43 ns
(4) Slot trenching at 91.4 cm vs. slot trenching at 182.9 cm spacings	593505.13	0.09 ns

ns = not significantly different at 5% level.
Tabulated F with 12 df error and 1 df treatment = 4.75 at 5% level.

Table 53. Orthogonal comparisons of sediment losses (g) from microplots with the different treatments for the rainfall event of September 3, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	26058.06	1.03 ns
(2) Vertical mulching vs. slot trenching	67051.22	2.65 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	512.96	0.02 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching 182.9 spacing	68622.16	2.71 ns

ns = not significantly different at 5% level.

Table 54. Orthogonal comparisons of sediment losses (g) from plots with the different treatments for the rainfall event of September 26, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	0.1901	6.62*
(2) Vertical mulching vs. slot trenching	0.0049	0.17 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	0.0496	1.73 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching 182.9 cm spacing	0.0136	0.47 ns

* = Significantly different at 5 percent level;
ns = Not significantly different at 5 percent level.

Table 55. Orthogonal comparisons of sediment losses (g) from plots with the different treatments for the rainfall event of October 10, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	0.0058	0.01 ns
(2) Vertical mulching vs. slot trenching	0.0002	0.00 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	0.0325	0.05 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching (182.9 cm spacing)	0.1128	0.19 ns

ns = Not significantly different at 5% level;
Tabulated F at 12 df (error) and 1 df (treatment) = 4.75.

Table 56. Orthogonal comparisons of sediment losses (g) from microplots with the differents for the rainfall event of November 3, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	0.0028	0.05 ns
(2) Vertical mulching vs. slot trenching	0.0297	0.57 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	0.0220	0.42 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching (182.9 cm spacing)	0.0666	1.28 ns

ns = Not significantly different at the 5 percent level.

Table 57. Orthogonal comparisons of sediment losses (g) from plots with the different treatments for the rainfall event of November 13, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	1.3676	1.22 ns
(2) Vertical mulching vs. slot trenching	0.0324	0.03 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	0.1711	0.15 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching (182.9 cm spacing)	0.2016	0.18 ns

ns = Not significantly different at 5% level;
Tabulated F at 12 df (error) and 1 df (treatment) = 4.75.

Table 58. Orthogonal comparisons of sediment losses (g) from plots with the different treatments for the rainfall event of November 21, 1982.

Comparison	Mean Square	F Value
(1) Control vs. treatments	1.0718	0.23 ns
(2) Vertical mulching vs. Slot trenching	0.0056	0.00 ns
(3) Vertical mulching (91.4 cm spacing) vs. vertical mulching (182.9 cm spacing)	13.7529	3.02 ns
(4) Slot trenching (91.4 cm spacing) vs. slot trenching (182.9 cm spacing)	3.0258	0.66 ns

ns = Not significantly different at 5% level;
Tabulated F at 12 df (error) and 1 df (treatment) = 4.75.

Table 59. Mean volumetric soil moisture content (%) at varying depths and different time intervals during the study period.

Treatment	Depth (cm)	Sampling Dates: Sept. 10	Sept. 19	Sept. 29	Oct. 11	Nov. 8
(1) Vertical mulching (91.4 cm spacing)	0-15	19.20	16.50	27.85	27.60	26.54
	15-30	25.40	23.30	24.61	27.78	28.87
	30-45	24.70	25.00	21.40	27.90	25.86
(2) Vertical mulching (182.9 cm spacing)	0-15	20.60	18.40	28.03	29.00	28.15
	15-30	26.70	25.00	25.70	27.06	28.91
	30-45	27.70	24.10	23.60	28.62	27.41
(3) Slot trenching (91.4 cm spacing)	0-15	21.42	17.53	28.11	29.82	28.02
	15-30	23.51	22.76	22.94	28.05	26.21
	30-45	24.79	25.25	22.46	26.29	26.27
(4) Slot trenching (182.9 cm spacing)	0-15	19.27	17.28	27.62	29.01	27.70
	15-30	23.31	21.88	22.89	29.19	26.17
	30-45	24.64	25.64	23.00	27.35	24.91
(5) Control	0-15	20.76	18.13	26.56	28.28	28.98
	15-30	25.49	22.80	22.66	28.62	26.96
	30-45	25.19	23.83	24.48	27.43	25.77