# EFFECTS OF PARTICLE-SIZE DISTRIBUTION, ORGANIC MATTER AND CALCIUM CARBONATE ON WATER RETENTION OF TEXAS HIGH PLAINS SOILS

by

TAN PIOW MENG, B.S.

A THESIS

IN

SOIL SCIENCE

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCE

Approved

Accepted

May, 1985

905
T3
1985
No.51
cop.2

# ACKNOWLEDGEMENTS

I am deeply indebted to my major professor, Dr. Howard M. Taylor, Rockwell Professor of Soil, for providing the direction, patience and knowledge during the course of my study and in the preparation of this thesis. I sincerely also want to thank Dr. B.L. Allen, Professor of Soil, and Dr. Billie E. Dahl, Professor of Range and Wildlife Management, for serving as graduate committee members.

I would like to extend my gratitude to Miss Jessica M. Davis, Mrs. Kokila Parmar, and Mr. Derek Gamradt for their help in the soil analyses for this thesis. And, special thanks to Mr. Luke Celentano for his help in computing the statistical analyses.

I am especially grateful to the Government of Malaysia for sponsoring my study.

TABLE OF CONTENTS


ACKNOWLEDGEMENTS ii

LIST OF TABLES iv

LIST OF FIGURES v

CHAPTER

I. INTRODUCTION 1

Objectives 5

II. LITERATURE REVIEW 6

III. METHODS AND MATERIALS 18

Mathematical Analyses 28

IV. RESULTS AND DISCUSSION 29

Water Retention at -10 kPa Matric Potential 32
Water Retention at -33 kPa Matric Potential 34
Water Retention at -100 kPa Matric Potential 36
Water Retention at -1500 kPa Matric Potential 38
Plant Available Water 52
Deep Plowing
Standards 64
Specifications 64
Rainfall Characteristics 66
Estimates of Precipitation Effectiveness 66
Deep Plowing Recommendations 71

V. CONCLUSIONS 73

LITERATURE CITED 76

LIST OF TABLES


1. Samples of Ap horizons collected from 15 counties on the Texas High Plains 19

2. Water contents at 4 matric potentials, organic matter content and calcium carbonate equivalent for 50 soil samples collected on the Texas High Plains 30

3. Clay, silt and sand subfraction percentages for 50 sandy soil samples collected on the Texas High Plains 31

4. Multiple regression equations and "R" values for the one to nine variable models at -10 kPa water retention 35

5. Multiple regression equations and "R" values for the one to nine variable models at -33 kPa water retention 37

6. Multiple regression equations and "R" values for the one to nine variable models at -100 kPa water retention 39

7. Multiple regression equations and "R" values for the one to nine variable models at -1500 kPa water retention 40

8. Multiple regression equations and "R" values for the one to nine variable models with plant available water 53

9. Total precipitation events in various quantity classes percentage of total events with precipitation within various quantity classes, total millimeters of precipitation within each quantity class and percentage of total precipitation within each class for the period 1971 to 1983, inclusive, at Lubbock, Texas 67

LIST OF FIGURES

1. Relationships among clay content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 33

2. Relationships among organic matter content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 42

3. Relationships among calcium carbonate equivalent and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 43

4. Relationships among silt content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 45

5. Relationships among coarse sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 47

6. Relationships among medium sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 48

7. Relationships among fine sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 50

8. Relationships among very fine sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains 51

9. The effect of organic matter content on the volumetric water content difference between -10 and -1500 kPa matric potentials 55

10. The effect of calcium carbonate equivalent on the volumetric water content difference between -10 and -1500 kPa matric potentials 56

11. The effect of clay content on the volumetric water content difference between -10 and -1500 kPa matric potentials 57

12. The effect of silt content on the volumetric water content difference between -10 and -1500 kPa matric potentials 58

13. The effect of coarse sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials 59

14. The effect of medium sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials 61

15. The effect of fine sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials 62

16. The effect of very fine sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials 63

17. Cumulation precipitation frequencies at Lubbock, Texas for the period 1971 to 1983, inclusive 68

# CHAPTER I

# INTRODUCTION

Soil is mankind's most important heritage, and must be conserved in order to provide sufficient food for future generations. We tend to neglect the vast areas of land where damage by wind and water erosion are occurring. Frequently, we can see bare land being exposed to severe soil erosion, but unfortunately few programs are carried out to conserve such land. Bennett and Lowdermilk (1938) stated that soil loss from erosion was perhaps "the most potent single factor contributing to the deterioration of productive land."

Wischmeier and Smith (1978) envisaged that there is a limit to soil erosion, beyond which the soil will not be productive. They defined the T - value (soil loss tolerance) as "the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely." The soil is a natural biological medium containing organic matter, beneficial flora and fauna and, if this medium is lost due to soil erosion, the soil will be difficult to replenish to the natural state again. The soil will not be improved to the natural state merely by adding organic matter.

The Soil Conservation Service considers land as

damaged if enough soil has been removed or deposited to subject the land to further erosion or to impair its capacity to produce.

While erosion may not have caused the downfall of nations, it certainly can be said that accelerated erosion has had—and is still having—adverse effects on human welfare (Dregne, 1982). The high velocity winds of the High Plains of Texas, at 80 to 100 km per hour, accompanied by low rainfall annually, blow off many tons of exposed soil each year. The seasonally strong wind dries the soil surface, blows away the clay and silt, and leaves behind the sand. The Soil Conservation Service had determined that soil aggregates less than 0.84 mm are erodible by wind erosion.

The 10 affected states on the Great Plains are Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wyoming. About 80 percent of the damage in the 10 states is to cropland. Contributing to the increased wind erosion are frequent, long windstorms, inadequate crop residue cover, excessive tillage, and inadequate soil moisture. Erosion damage in the Plains is greatest from November through May, when high winds are most frequent (Soil Conservation Service,

1977).

Under a dry, wind-blown environment, a Canadian loamy sand under virgin conditions lost virtually all its clay and silt in less than 60 years (Chepil, 1949). Clay and silt fractions are removed first, leaving the coarser sand and gravel. This sorting action over many years makes soil progressively coarser textured until nothing remains but infertile skeletal material forming shifting sand dunes and gravelly pavements (Chepil, 1962).

The organic matter, clay and silt content mainly determine the field capacity and permanent wilting point. The higher the organic matter and clay, the higher the field capacity and the permanent wilting point (H.M. Taylor, personal communication, 1984).

Farmers of the Texas High Plains have been plowing for three decades to counter wind erosion. According to H.M. Taylor (personal communication, 1984), sandy soils of Texas High Plains in native condition often have a subsoil layer (Bt horizon) with a clay content greater than that of the surface horizon (Ap horizon). Several hundred thousand hectares (possibly millions) have been plowed sufficiently deep to bring some of this higher clay material to the surface layer. The increase in clay

reduces, but does not eliminate, the wind erosion hazard on these soils. Fortunately, it is possible to bring up the more clayey layer to the surface by deep plowing on some of the sandy soils in the Texas High Plains. Wisner (1955) reported that soil to a depth of 100 cm had been plowed for the purpose of turning over the sand and developing a better soil structure.

Deep plowing the sandy soils of the Texas High Plains often will reduce erodibility of these soils but the higher clay, organic matter and calcium carbonate also will alter their water retention characteristics. These altered retention characteristics, in turn, will alter precipitation effectiveness in this 380- to 500-mm rainfall area and may adversely affect yield (H.M. Taylor, personal communication, 1984).

## Objectives

The overall objective of the research program was to provide data that will allow the prediction of the probable effectiveness of precipitation when deep plowing has altered the texture of the plow layer.

Specific objectives were to:

1) Obtain, by multiple linear regression techniques, models that account for at least 80% ($R^2$ = 0.80) of the deviation between measured and calculated water contents at -10, -33, -100 and -1500 kPa matric potential;
2) Obtain, by multiple linear regression techniques, models of "available" water (defined as the difference in water content at -10 and -1500 kPa matric potential);
3) Obtain, from precipitation records, the accumulation frequency of precipitation amounts and total number of storms for a minimum of 10 years;
4) Provide an example of calculation to illustrate use of the data to estimate precipitation effectiveness.

# CHAPTER II

# LITERATURE REVIEW

The study included 15 counties of the Southwestern Texas High Plains which comprise 3,781,700 ha. (14,595 sq. miles). The counties were Lubbock, Lamb, Bailey, Cochran, Hockley, Yoakum, Terry, Lynn, Gaines, Dawson, Andrews, Martin, Howard, Midland, and Glasscock.

About 56.8% (2,148,006 ha.) of the soils found in these 15 counties are suitable for deep plowing in order to bring up the subsoil clay to the surface to resist wind and water erosion. Some of the sandy soil series suitable for deep plowing are the Amarillo, Arvana, Patricia and Brownfield. These soils have a sandy clay loam layer within the 50 to 60 cm depth and are practical for deep plowing. Some examples of the soil series of the area which are not suitable for deep plowing are the Acuff, Arch, Berda, Bippus, Estacado, Friona, Kimbrough, Lofton, Midessa, Mobeetie, Olton, Posey, Pullman, and Randall. These soils either do not have a sandy clay loam layer below 50 to 60 cm in the profile, have shallow calcareous layers, or have soil textures such as clay loam, loam or sandy clay loam which already are suitable for agriculture.

According to H.M. Taylor, (personal communication, 1984) farmers deep plowed much of the sandy areas of the

Texas High Plains in the 1950's and 1960's. However, there are still large areas where very little or no deep plowing has been practiced, and such areas can be deep plowed in order to reduce wind erosion damage and maintain soil productivity for agriculture.

Soil Survey Staff (1960) reported that deep plowing is effective only if one-fourth to two-thirds of the furrow slice is clayey material. Mixing the clayey material with the sandy surface layer forms a fine sandy loam plow layer. Soils that have been deep plowed must be protected with crop residues or must be kept rough and cloddy; otherwise, they will start to blow and drift again. Deep plowing can be repeated, but it is effective only as long as clayey material is within reach of the plow.

Deep plowing should be carried out regularly to improve the resistance of the sandy soil against wind erosion, and also to avoid clay pan formation. Bryant (1977) reported that the B2 horizons of most Texas High Plains soils show evidence of clay translocation. Regular deep plowing will prevent the formation of clay pans which will hamper root growth. A root girdling study on cotton by Mathers and Welch (1964) and field studies by Taylor, Locke, and Box (1964) with cotton and grain sorghum on

compacted Amarillo fine sandy loam soil showed reductions in yields when roots were girdled or restricted due to excessive soil strength in plow pans. Taylor and Burnett (1963) observed that pans occur in soils of nearly all textures, but they occur most frequently on fine sandy loam, loamy fine sand, or sandy clay loam soils.

By having a sufficient amount of clay and silt through deep plowing with surface sand, there is higher water storage capacity. Unger (1975a,b) reported that there is greater water retention by sieved than undisturbed soil at -33 kPa and little change in retention at -1.5 megaPascals for fine-textured soils, which suggests that deep tillage and profile modification treatments may increase the water storage capacity of fine-textured soils.

However, excessive cultivation can cause aggregate instability. As expected, cultivation had a pronounced detrimental effect on aggregate stability, particularly in the larger size classes (Bryant, 1977). Repeated mechanical disaggregation is primarily responsible for the reduced infiltration and increased runoff, resulting in overall lower water availability. In areas of dryland farming the differences in water intake may become

critical. Increase in the moisture content of sandy clay loam will help to reduce wind erosion damage. Chepil (1953) found that the application of 2.5 millimeters (mm) of water sprayed on the soil followed by drying produced a surface crust and a cementation of the soil body that greatly reduced the erodibility by wind. The crust was easily recognizable by its platy structure.

Bisal and Hsieh (1966) reported that at a wind velocity of 7.6 meters (m) per second the fine sandy loam, loam, and clay soils required 4.0 , 4.1 , and 11.8 percent moisture, respectively, to prevent erosion. At a wind velocity of 12.5 m per sec. the requirements were 7.9 , 10.8 , and 15.7 percent moisture, respectively.

Soil texture has a very considerable effect on the available water-holding capacity because the water is held as films on the surfaces of soil particles and in the small pore spaces between the particles. Fine-textured soils have high water-holding capacities because their many small particles have a large total surface area and there is a large total volume of small pore spaces located between soil particles. Finer-textured soils therefore hold more water than coarser-textured soils.

Soil texture is the amount of clay, silt, and sand.

The proportion of the soil size fractions is responsible for the amount of moisture the soil can hold. It is important that the precipitation and irrigation water be stored in the soil efficiently for plant growth, rather than being lost through evaporation, runoff, or leaching. Different soil types will have different moisture retentive capacities for plant-available water, and simultaneously different resistances to wind drift in wind prone areas.

Clay particles are able to absorb water actively and swelling occurs in some clays as a consequence. Clay not only has a large surface area, but it is also electrically charged. The charge gives clay the capacity to hold cationic nutrients on its surface in forms available to plants. Bryant (1977) reported that water retention measurements for the upper three horizons of each profile are highly correlated with clay content. He specified that clay content may be used for prediction of water retention with a high degree of accuracy on Texas High Plains soils.

Chepil (1955) reported that the mechanical stability of clods, that is, the relative resistance of clods to breakdown by mechanical forces such as tillage or abrasion by wind-blown soil materials, increased directly with the

proportion of silt and clay. The clay fraction evidently offered a much greater resistance to breakdown of clods than did silt. Chepil reported that about 20 percent of clay, when mixed with silt, formed the greatest degree of cloddiness and resistance to wind erosion. Considerable clay increases beyond this limit were detrimental in that, under the influence of wetting and drying, and especially freezing and thawing, clay formed a substantial proportion of small granules as erodible as fine grains of sand. But, Chepil stated that no proportion of clay to silt produced a greater erodibility than that of mixtures containing more than 75 percent fine sand.

The proportion of silt in the sandy soil of the Texas High Plains also influence the wind and water erodibility. Silts occurring in the soil have an adhering film of clay, possess some plasticity, cohesion (stickiness), and adsorption, but to a much lesser degree than the clay separate itself. Brady (1974) reported that the influence of silt is such as to make it a rather unsatisfactory soil constituent physically unless supplemented by adequate amounts of sand, clay, and organic matter. The presence of silt and especially clay in a soil imparts to it a fine texture and slows water and air movements. The expansion

and contraction on wetting and drying usually are great and the water-holding capacity of clayey and silty soils generally is high.

Sands, mostly composed of quartz, are not so reactive and only limited surface adsorption can occur in sand. Clods formed with clay and sand are stronger than those formed with silt and sand, and are less subject to abrasion by wind (Chepil, 1955).

Unger (1975b) reported that organic matter also influences the water retention on sandy soils of the Texas High Plains in native conditions. Thompson and Troeh (1978) reported that organic matter can influence the water-holding capacity of a sandy soil, and one percent organic matter in a soil at field capacity will hold about 1.5 percent water on a soil volume basis. They reported that organic soils have field capacities of 100 to 150 percent water, and some, such as sphagnum moss peat, hold as much as 500 or 600 percent water by weight. It may be feasible but not economical, to improve soil structure and the water infiltration rate by the addition of reasonable amounts of organic matter on sandy soils.

Calcium carbonate may be a factor influencing the water retention of soil. Calcium carbonate can cause the

flocculation of soil. It can also cause increased stability by cementing particles together. Hopkins (1935) suggested that this factor may be responsible for the development of a weak, fine soil structure susceptible to erosion by wind. Wind erosion is associated with a deficiency of moisture, since only relatively dry particles of soil are susceptible to movement by wind (Bisal and Hsieh, 1966).

Mulching helps to protect the soil from evaporation and from erosion. The Texas Conservation Needs Committee (1962) reported that wheat stubble left on or near the surface prevents wind and splash erosion and increases organic matter and water-holding capacity.

Harrold et al., (1959) reported that evaporation directly from soil is responsible for losses not only from completely bare soil but also from soil incompletely covered by leaves of a crop growing on it. During the whole growing period of an annual crop, as much as half of the water evaporated to the atmosphere may come directly from the soil. Bond and Willis (1969) also agreed that mulches of straw or other materials covering the surfaces as in stubble mulching or minimum tillage reduce the potential evaporation at the soil surface by reducing the

amount of radiant energy absorbed and by minimizing air turbulence. The rate of evaporation during the constant rate stage is therefore reduced and much water can be saved over periods of one or two weeks.

Russel (1976) suggested that, besides mulching, mulch tillage is a method of improving the soil structure. He stressed that since the advent of stubble mulch tillage in the Great Plains, no one has disputed the value of maintaining crop residues on the soil surface for wind and water erosion control.

Any treatment that ensures deeper penetration of water in the profile helps protect it from evaporation. Thus, much of the extra water saved by adding straw mulches to fallows was at a greater depth than 60 centimeters (cm) in the experiments of Greb et al., (1970). Similarly, a given amount of water penetrates further into a coarse than into a fine textured soil and is less readily lost in semi-arid areas (Alizai and Hulbert, 1970). By forming a mulch of large aggregates that had been treated to make them water repellent, Fairbourn and Gardner (1975) caused less water to be retained at the surface and so decreased the rate of evaporation, especially in the first day after water was applied. Hillel and

Berliner (1974) showed that for this purpose the hydrophobic aggregates need to be large enough, 2 to 5 millimeters (mm), to allow water to infiltrate freely.

Thus, improvement of the sandy soil of the Texas High Plains will help to retain the water for plant growth under irrigated conditions. Precipitation and irrigation water are not readily lost through leaching or runoff. The water storage capacity of a soil determines to a large extent how efficiently precipitation and irrigation water are used for crop production.

The topsoil should not be plowed excessively; otherwise, water will not infiltrate to a greater depth. In this manner, water is easily lost from the surface. To make use of structure in controlling evaporation, Hadas (1975) also suggested that surface soil should be brought to the desired condition with water-stable aggregates of the right size by incorporating with organic matter before it is wetted. Greacen (1960) and Gurr (1962) found that evaporation from soil subjected to radiation and wind was greater for both untilled and cloddy soil than for soil of fine tilth containing aggregates mainly about 2.5 mm in diameter. Marshall and Holmes (1979) also suggested that controls devised to reduce the rate of evaporation

directly from soil must depend primarily on: 1) reducing the potential rate of evaporation at the surface by modifying atmospheric conditions there or 2) reducing the amount of water retained near the surface when water is added to soil. If the evaporation rate can be reduced in either of these ways, plants will be able to make use of the water before it is lost and water added to bare fallow will have the opportunity to move to a greater depth, where it will be preserved longer.

The physiochemical and biochemical growth processes of plants are closely related to the moisture characteristics of soil water systems. Soil-moisture tension affects plant elongation, the increases in fresh and dry weight, the movement of nutrients from the soil, the uptake of nutrients and the translocation of water and nutrients in the plant (Danielson and Russell, 1957; Gingrich and Russell, 1956; Hagan, Vaadia, and Russell, 1959; McCune, 1958; Pallas and Williams, 1962; Peters, 1957).

By having a suitable amount of sand, silt, clay, and organic matter, the soils on the Texas High Plains will have higher plant available water, which is ideal for irrigated agriculture. Henao (1976) evaluated the effects of 95 soil factors on corn yields with multiple regression

techniques over a wide range of soil conditions in 17 Iowa counties. He found that available water-holding capacity of the soil was highly correlated with corn yields.

# CHAPTER III

## METHODS AND MATERIALS

Fifty samples were collected from the sandy areas of the Texas High Plains. Two or more samples were collected from each of Lubbock, Lamb, Bailey, Cochran, Hockley, Yoakum, Terry, Lynn, Gaines, Dawson, Andrews, Martin, Howard, Midland, and Glasscock counties (Table 1). These samples were collected from the surface 10 cm of cultivated fields.

Each sample was air-dried and crushed to pass a 2-mm, square hole screen, thoroughly mixed and stored.

Water retentions were determined on each sample at -10 kPa (-0.1 bar), -33 kPa (-0.33 bar), -100 kPa (-1 bar), and -1.5 megaPascals (-15 bars) matric potential. The -10 kPa retention was determined by the tension table method, and -33 kPa, -100 kPa, and -1500 kPa were determined by the pressure-plate apparatus method. The sample was filled close to the brim of each soil-retainer ring with a plastic spoon. The samples were allowed to stand for at least 16 hours with an excess of water on the ceramic plate or membrane. The samples were then placed in the pressure apparatus and the required air pressure was applied. The sandy soil samples usually reached equilibrium in 5 to 6 days at -10 kPa and -33 kPa, 4 to 5 days

Table 1. Samples of Ap horizons collected from 15 counties on the Texas High Plains.

| Sample Number | Soil Series | County | Soil Survey Sheet Number | Legal Description |
|---|---|---|---|---|
| 1 | Amarillo fine sandy loam | Cochran | 26 | SW¼ Section 52, Block 136, Armstrong County School Land |
| 2 | Brownfield fine sand | Lamb | 25 | Section 16, League 244, Dickens County School Land |
| 3 | Brownfield-Tivoli fine sands | Cochran | 58 | NW¼ Section 15, Block P, Public School Land |
| 4 | Amarillo loamy fine sand | Hockley | 51 | Labor 16, League 42, Maverick County School Land |
| 5 | Brownfield fine sand | Bailey | 14 | SE¼ Section 15, Block Y |
| 6 | Springer loamy fine sand | Glasscock | 1 | SW¼ Section 3, R.R. Wade |
| 7 | Brownfield fine sand | Yoakum | 9 | NW¼ Section 450, Block D, John H. Gibson Survey |
| 8 | Brownfield fine sand | Yoakum | 24 | SW¼ Section 878, Block D, John H. Gibson Survey |
| 9 | Amarillo fine sandy loam | Midland | 7 | J.T. Murphy Survey, Block 37, TWP 2-S |
| 10 | Amarillo loamy fine sand | Terry | 26 | SW¼ Section 107, Block T, Dallas & Wichita R.R. Co. |

Table 1. Continued.

| Sample Number | Soil Series | County | Soil Survey Sheet Number | Legal Description |
|---|---|---|---|---|
| 11 | Amarillo loamy fine sand | Hockley | 37 | Labor 40, League 68, Hardeman County School Land |
| 12 | Amarillo fine sandy loam | Cochran | 25 | SE¼ Section 5, Block Y, Public School Land |
| 13 | Amarillo fine sandy loam | Cochran | 4 | NE¼ Section 30, Block 105, Fisher County School Land |
| 14 | Amarillo loamy fine sand | Bailey | 25 | Labor 1, League 187, Swisher County School Land |
| 15 | Amarillo loamy fine sand | Cochran | 22 | SW¼ Section 93, Block 100, Brewster County School Land |
| 16 | Faskin and Douro soils | Andrews | 22 | Section 12, Block A-44, Public School Land |
| 17 | Amarillo fine sandy loam | Midland | 1 | Section 1, Block 41, T & P R.R. Co., TWP 1-S |
| 18 | Springer and Brownfield soils | Gaines | 60 | Section 253, Block G, Waxahachie Tap R.R. Co. Survey |
| 19 | Triomas and Wickett soils | Andrews | 12 | Section 8, Block A-48, Public School Land |
| 20 | Brownfield fine sand | Yoakum | 22 | Section 35B, Block AX, John H. Gibson Survey |

Table 1. Continued.

| Sample Number | Soil Series | County | Soil Survey Sheet Number | Legal Description |
|---|---|---|---|---|
| 21 | Brownfield fine sand | Gaines | 41 | Section 38, Block G, C & M .R.R. Co. Survey |
| 22 | Triomas and Wickett soils | Andrews | 6 | Section 15, Block A-33, Public School Land |
| 23 | Brownfield fine sand | Gaines | 108 | Labor 317, League 22, Parmer County School Land |
| 24 | Amarillo fine sandy loam | Martin | 43 | SE¼ Section 8, Block 36, T & P R.R., TWP 1-S |
| 25 | Brownfield fine sand | Terry | 27 | SW¼ Section 3, Block T, Dallas & Wichita R.R. Co. |
| 26 | Brownfield fine sand | Terry | 50 | SE¼ Section 3, Block DD, John H. Gibson Survey |
| 27 | Miles loamy fine sand | Martin | 10 | SW¼ Section 73, Block B, Bauer & Cockrell School Land |
| 28 | Amarillo fine sandy loam | Glasscock | 1 | NW¼ Section 5, Block 35, T & P R.R. Co., TWP 2-S |
| 29 | Amarillo loamy fine sand | Terry | 31 | SE¼ Section 3, Block D-12, John H. Gibson Survey |
| 30 | Amarillo loamy fine sand | Terry | 29 | SW¼ Section 34, Block K, Public School Land |

Table 1. Continued.

| Sample Number | Soil Series | County | Soil Survey Sheet Number | Legal Description |
|---|---|---|---|---|
| 31 | Triomas and Wickett soils | Andrews | 7 | Section 11, Block A-33, Public School Land |
| 32 | Brownfield fine sand | Gaines | 56 | Section 23, Block A-9, Public School Land |
| 33 | Brownfield fine sand | Gaines | 42 | Section 94, Block H, Dallas & Wichita R.R. Co. |
| 34 | Brownfield fine sand | Dawson | 21 | Site 1. Section 127, Block M, EL & R.R. Co. Survey |
| 35 | Brownfield fine sand | Dawson | 21 | Site 2. Section 125, Block M, EL & R.R. Co. Survey |
| 36 | Amarillo loamy fine sand | Dawson | 2 | Section 10, Block C-4, Public School Land |
| 37 | Brownfield fine sand | Lynn | 57 | Section 15, Block O, H & O.B. R.R. Co. |
| 38 | Amarillo fine sandy loam | Lynn | 36 | Section 9, Block Y, EL & R.R. Co. Survey |
| 39 | Amarillo fine sandy loam | Dawson | 32 | Labor 4, League 276, Glasscock County School Land |
| 40 | Brownfield fine sand | Yoakum | 11 | NW¼ Section 436, Block D, John H. Gibson Survey |

Table 1. Continued.

| Sample Number | Soil Series | County | Soil Survey Sheet Number | Legal Description |
|---|---|---|---|---|
| 41 | Amarillo loamy fine sand | Howard | 35 | Section 23, Block 33, T & P R.R. Co., T-1-N |
| 42 | Amarillo fine sandy loam | Martin | 5 | SW¼ Section 17, Block 34, T & P R.R. Co., TWP 3-N |
| 43 | Acuff loam | Lubbock | 62 | SW¼ Section 23, Block 20, Lubbock County |
| 44 | Brownfield fine sand | Lynn | 66 | Section 2, Block H, EL & R.R. Co. Survey |
| 45 | Arch fine sandy loam | Lynn | 65 | Section 8, Block H, EL & R.R. Co. Survey |
| 46 | Brownfield fine sand | Howard | 36 | Section 42, Block 31, T & P R.R. Co., T-1-N |
| 47 | Amarillo fine sandy loam | Lubbock | 47 | NW¼ Section 24, Block CB, Lubbock County |
| 48 | Amarillo fine sandy loam | Lamb | 69 | SE¼ Section 14, Block 1, R.M. Thompson |
| 49 | Brownfield fine sand | Yoakum | 19 | SE¼ Section 694, Block D, John H. Gibson Survey |
| 50 | Brownfield fine sand | Gaines | 29 | Section 81, Block G, Waxahachie Tap R.R. Co. Survey |

at -100 kPa, and 3 to 4 days at -1.5 megaPascals matric potential. Before releasing the air pressure in the chamber, a pinch clamp was fixed to prevent the backflow of water to the samples after the pressure was released. To avoid changes in the water content of the samples after opening the chamber, the samples were transferred quickly to metal containers for drying. The water content was determined by drying in the oven at 105°C for 24 hours and expressed in terms of percentage on a dry-weight basis.

Water retention is difficult to measure under field conditions. Therefore, the capacity of a sandy soil to store water for plant use is often approximated from -10 kPa and -1.5 megaPascals water retention values determined in a laboratory with pressure plate equipment. The -1.5 megaPascals retentivity value has a reasonably close linear correlation with the permanent wilting percentage (Lehane and Staple, 1960).

It has been found that the -1.5 megaPascals percentage is a fairly definite lower limit for wilting point values (Richards and Weaver, 1943). That is, for approximately 160 nonsaline soils on which comparisons have been made, practically all of the wilting percentages were in the range of 0 to 2 percent of moisture above the -1.5

megaPascals percentage, and the majority of the wilting percentage values were less than one percent of moisture above that value. How generally this may be true is not yet known, but it provides a convenient method for estimating the lower limit of water available to plants in non-saline soils.

The organic matter determination was carried out by the wet combustion method. A 0.5-gram sample of soil was weighed out for each sample and transferred to a 125-ml Erlenmeyer flask. A 10-ml aliquot of 0.4 N chromic acid ($K_2Cr_2O_7$) was added from a burette to the sample. At the same time, 10 ml of the acid were added to an empty 125-ml flask to serve as a blank. The flask containing the soil was then twirled gently to get the soil in suspension. Small funnels were placed in the top of the flasks to act as condensers. The soil-acid mixture was then placed on a hot plate and boiled gently for five minutes. After the flasks had cooled sufficiently, the contents of the flasks were transferred to 400-ml beakers and deionized $H_2O$ was added to make a volume of approximately 250 ml. Five ml of concentrated $H_2SO_4$ and 5 drops of orthophenanthroline indicator were added to the beaker. The suspension was then titrated with standard ferrous ammonium sulfate

solution $\left[Fe(NH_4SO_4)_2 \cdot 6H_2O\right]$, to the end point, which is marked by a reddish tinge following a bright green.

The wet combustion method makes use of a strong oxidizing agent ($K_2Cr_2O_7$) to oxidize the organic matter. The quantity of organic matter was determined by reducing the amount of oxidizing agent remaining after the oxidation of the organic matter (Texas Tech University Soils Laboratory).

Calcium carbonate equivalent ($CaCO_3$) was determined by acid neutralization of the alkaline-earth carbonates. A 10-gram sample of the soil was placed in a 150-ml beaker, and 50 ml of standardized 0.5 N HCl were added. The contents in the beaker were covered with a watchglass, boiled gently for 5 minutes, and then cooled. The mixture was filtered through a Whatman 42 filter paper, and the soil was washed thoroughly with deionized water to remove the excess acid. The amount of unused acid was determined by titrating to the phenolphthalein endpoint with 0.25 N NaOH.

The calculation gives the $CaCO_3$ equivalent. This is the amount of $CaCO_3$ required to react with the acid by removal of $CO_2$ to the atmosphere.

Particle size distributions were determined by the

hydrometer method for the clay, silt, and sand fractions. Sand fractions (very coarse sand, coarse sand, medium sand, fine sand, and very fine sand) were determined by weighing separates obtained from a graded sieve stack and then converted to a percentage basis.

$$\% \text{ sand} = 100 - \left( \frac{\text{corrected 40 second hydrometer reading}}{\text{Weight of oven-dry soil}} \times 100 \right)$$

$$\% \text{ clay} = \frac{\text{corrected 2 hour hydrometer reading}}{\text{Weight of oven-dry soil}} \times 100$$

$$\% \text{ silt} = 100 - (\% \text{ sand} + \% \text{ clay})$$

Approximately 50 g soil were weighed into a dispersion cup. Five ml of 10% Calgon solution (sodium hexametaphosphate), $Na_6(PO_3)_6$, were added to the contents. The cup was filled to the two-thirds level with distilled water and the contents were stirred for 10 minutes.

After dispersion, the contents of the cup were transferred to the hydrometer jar. Distilled $H_2O$ was added into the jar to the 1000-ml mark. A plunger was used to mix the contents thoroughly until all the sediment was off the bottom of the jar. The hydrometer was placed in the suspension and the hydrometer reading was taken at the end of 40 seconds. The temperature measurement was recorded within five minutes. The temperature correction

was made by adding 0.36 for every degree above 20°C to the hydrometer reading, or, conversely, 0.36 was subtracted for every degree below 20°C. After two hours, the hydrometer reading and temperature were again recorded. The silt and clay were then washed through a 300-mesh sieve. The sand, which was retained by the sieve, was then oven dried, and separated using a nest of sieves of appropriate mesh.

The diameter limits of the soil separates were very coarse sand 2.00 - 1.00 mm; coarse sand 1.00 - 0.50 mm; medium sand 0.50 - 0.25 mm; fine sand 0.25 - 0.10 mm; and very fine sand 0.10 - 0.05 mm (Soil Survey Staff, 1951).

## Mathematical Analyses

Multiple regression equations were developed for -10 kPa, -33 kPa, -100 kPa, and -1.5 megaPascals soil water potential. These equations related water content (dependent variable) to $a_1$(organic matter) + $a_2$($CaCO_3$) + $a_3$(clay) + $a_4$(silt) + $a_5$(very coarse sand) + $a_6$(coarse sand) + $a_7$(medium sand) + $a_8$(fine sand) + $a_9$(very fine sand).

# CHAPTER IV

## RESULTS AND DISCUSSION

Results of analyses on 50 soil samples for 4 water retention levels, organic matter content and calcium carbonate equivalent are presented in table 2. Clay, silt and sand fractions for the 50 samples are presented in table 3.

The range in gravimetric water contents retained at -10 kPa matric potential was from 20.6 to 38.3% while the range at -33, -100 and -1500 kPa were 3.1 to 14.6%, 1.9 to 10.5% and 1.1 to 6.8%, respectively. There was only one sample with an organic matter content greater than 1% and the other 49 samples had contents of less than 0.5%. There were only 2 samples with $CaCO_3$ equivalents greater than 2% and the other 48 had equivalents of 0.7% or less. Clay contents ranged from 4.0 to 17.6% while those of silt ranged from 0.5 to 17.3%. Very fine sand fractions ranged from 9.1 to 28.7 of the total sample while those of fine sand ranged from 31.6 to 73.2%. There were only relatively small quantities of coarse and very coarse sand while medium sand ranged from 2.6 to 37.2%.

Table 2. Water contents at 4 matric potentials, organic matter content and calcium carbonate equivalent for 50 soil samples collected on the Texas High Plains.

| Sample Number | -10kPa % | -33kPa % | -100kPa % | -1500kPa % | OM % | $CaCO_3$ % |
|---|---|---|---|---|---|---|
| 1 | 28.5 | 10.5 | 7.6 | 5.0 | 0.36 | 0.43 |
| 2 | 28.1 | 6.4 | 3.9 | 2.6 | 0.35 | 0.20 |
| 3 | 28.5 | 4.5 | 3.4 | 2.4 | 0.33 | 0.37 |
| 4 | 27.7 | 4.8 | 3.1 | 2.2 | 0.20 | 0.25 |
| 5 | 36.0 | 7.2 | 5.9 | 3.9 | 1.12 | 2.01 |
| 6 | 24.4 | 4.1 | 2.7 | 1.5 | 0.28 | 0.22 |
| 7 | 25.5 | 5.7 | 3.4 | 2.4 | 0.19 | 0.20 |
| 8 | 28.9 | 7.6 | 6.2 | 4.3 | 0.26 | 0.36 |
| 9 | 20.6 | 8.3 | 5.2 | 2.9 | 0.25 | 0.31 |
| 10 | 32.1 | 8.6 | 6.1 | 3.8 | 0.36 | 0.39 |
| 11 | 29.7 | 6.2 | 3.7 | 2.2 | 0.14 | 0.18 |
| 12 | 29.2 | 8.5 | 5.5 | 3.8 | 0.47 | 0.69 |
| 13 | 36.9 | 14.6 | 9.8 | 6.2 | 0.46 | 0.48 |
| 14 | 25.9 | 5.6 | 3.9 | 2.6 | 0.26 | 0.35 |
| 15 | 33.3 | 8.8 | 7.2 | 4.5 | 0.38 | 0.54 |
| 16 | 31.3 | 10.2 | 7.1 | 4.9 | 0.22 | 0.43 |
| 17 | 35.1 | 13.5 | 10.0 | 6.8 | 0.24 | 0.50 |
| 18 | 28.7 | 7.5 | 6.5 | 4.5 | 0.36 | 0.37 |
| 19 | 26.9 | 6.5 | 4.3 | 3.0 | 0.25 | 0.25 |
| 20 | 28.1 | 7.0 | 4.4 | 2.9 | 0.24 | 0.23 |
| 21 | 33.9 | 13.1 | 7.9 | 6.1 | 0.24 | 0.46 |
| 22 | 26.8 | 6.6 | 4.6 | 2.9 | 0.15 | 0.20 |
| 23 | 29.7 | 7.7 | 5.6 | 3.5 | 0.26 | 0.32 |
| 24 | 29.9 | 7.7 | 6.4 | 4.1 | 0.34 | 0.47 |
| 25 | 26.5 | 3.5 | 2.7 | 2.2 | 0.12 | 0.15 |
| 26 | 27.9 | 9.4 | 6.5 | 4.5 | 0.25 | 0.33 |
| 27 | 31.9 | 10.0 | 7.1 | 5.3 | 0.29 | 0.49 |
| 28 | 27.0 | 10.4 | 6.4 | 4.4 | 0.32 | 0.35 |
| 29 | 31.9 | 10.2 | 7.7 | 5.3 | 0.31 | 0.22 |
| 30 | 31.5 | 10.6 | 7.1 | 4.7 | 0.32 | 0.45 |
| 31 | 25.5 | 3.8 | 2.5 | 1.8 | 0.12 | 0.19 |
| 32 | 26.3 | 5.7 | 3.4 | 2.5 | 0.21 | 0.22 |
| 33 | 28.3 | 6.0 | 4.5 | 2.7 | 0.16 | 0.20 |
| 34 | 31.8 | 8.0 | 6.7 | 3.8 | 0.27 | 0.29 |
| 35 | 26.6 | 4.6 | 3.7 | 2.3 | 0.22 | 0.20 |
| 36 | 30.8 | 7.3 | 5.4 | 3.4 | 0.22 | 0.26 |
| 37 | 27.4 | 5.1 | 3.4 | 2.3 | 0.17 | 0.21 |
| 38 | 33.0 | 11.4 | 7.9 | 3.8 | 0.34 | 0.55 |
| 39 | 33.0 | 10.8 | 7.3 | 4.2 | 0.27 | 0.61 |
| 40 | 31.8 | 10.5 | 6.1 | 4.1 | 0.33 | 0.36 |
| 41 | 26.0 | 4.1 | 3.5 | 2.0 | 0.12 | 0.24 |
| 42 | 33.0 | 11.7 | 8.6 | 5.0 | 0.40 | 0.61 |
| 43 | 38.3 | 14.1 | 10.5 | 6.2 | 0.48 | 0.54 |
| 44 | 28.8 | 6.7 | 4.3 | 2.7 | 0.14 | 0.29 |
| 45 | 30.0 | 5.1 | 3.9 | 2.7 | 0.15 | 2.21 |
| 46 | 23.8 | 3.1 | 1.9 | 1.1 | 0.07 | 0.11 |
| 47 | 35.5 | 11.3 | 8.1 | 5.3 | 0.45 | 0.47 |
| 48 | 32.3 | 11.9 | 7.7 | 4.6 | 0.47 | 0.36 |
| 49 | 30.2 | 9.1 | 5.3 | 3.5 | 0.23 | 0.37 |
| 50 | 28.2 | 7.0 | 5.9 | 3.6 | 0.29 | 0.27 |

Table 3. Clay, silt and sand subfraction percentages for 50 sandy soil samples collected on the Texas High Plains.

| | CLAY % | SILT % | VCS % | CS % | MS % | FS % | VFS % |
|---|---|---|---|---|---|---|---|
| 1 | 15.6 | 11.5 | 0.04 | 1.5 | 10.6 | 41.8 | 19.0 |
| 2 | 8.5 | 3.6 | 0.01 | 1.5 | 25.9 | 49.1 | 11.4 |
| 3 | 8.0 | 2.0 | 0.00 | 0.5 | 8.6 | 62.4 | 18.5 |
| 4 | 6.8 | 3.8 | 0.00 | 0.5 | 8.8 | 61.8 | 18.3 |
| 5 | 8.5 | 5.8 | 0.02 | 3.5 | 23.7 | 49.4 | 9.1 |
| 6 | 5.1 | 2.6 | 0.04 | 3.9 | 34.7 | 43.0 | 10.8 |
| 7 | 8.3 | 2.7 | 0.01 | 0.8 | 9.5 | 60.1 | 18.6 |
| 8 | 10.4 | 5.7 | 0.00 | 0.6 | 9.0 | 53.4 | 20.9 |
| 9 | 8.8 | 3.8 | 0.03 | 4.9 | 35.6 | 31.6 | 15.2 |
| 10 | 9.8 | 8.2 | 0.01 | 0.4 | 3.7 | 52.4 | 25.6 |
| 11 | 7.4 | 1.2 | 0.00 | 0.5 | 7.6 | 66.3 | 17.1 |
| 12 | 10.5 | 5.2 | 0.01 | 0.2 | 2.6 | 58.8 | 22.7 |
| 13 | 17.6 | 9.7 | 0.20 | 2.3 | 3.3 | 43.2 | 23.7 |
| 14 | 8.8 | 2.3 | 0.00 | 1.2 | 9.0 | 61.3 | 17.5 |
| 15 | 13.5 | 3.1 | 0.05 | 0.9 | 4.9 | 58.5 | 19.2 |
| 16 | 14.2 | 3.4 | 0.13 | 1.3 | 17.0 | 49.1 | 14.9 |
| 17 | 17.5 | 9.4 | 0.04 | 1.6 | 14.2 | 33.4 | 23.9 |
| 18 | 11.5 | 4.8 | 0.00 | 2.0 | 12.6 | 51.0 | 18.1 |
| 19 | 8.3 | 4.0 | 0.04 | 2.3 | 15.1 | 55.0 | 15.3 |
| 20 | 8.4 | 0.9 | 0.01 | 1.6 | 11.8 | 62.5 | 14.9 |
| 21 | 14.5 | 7.2 | 0.00 | 0.6 | 7.6 | 50.5 | 19.6 |
| 22 | 9.5 | 0.6 | 0.01 | 0.9 | 15.8 | 58.1 | 14.1 |
| 23 | 9.7 | 4.2 | 0.01 | 0.4 | 6.7 | 54.3 | 24.7 |
| 24 | 10.8 | 6.1 | 0.06 | 2.4 | 19.1 | 36.8 | 24.8 |
| 25 | 5.2 | 1.6 | 0.01 | 0.6 | 12.2 | 64.4 | 15.9 |
| 26 | 12.3 | 2.2 | 0.01 | 1.0 | 14.3 | 55.2 | 14.6 |
| 27 | 13.8 | 4.7 | 0.03 | 1.3 | 17.0 | 46.6 | 16.7 |
| 28 | 12.4 | 4.7 | 0.03 | 1.4 | 20.5 | 39.6 | 21.5 |
| 29 | 13.9 | 10.1 | 0.00 | 0.5 | 6.9 | 44.6 | 24.0 |
| 30 | 13.1 | 3.8 | 0.01 | 0.5 | 9.4 | 50.4 | 22.9 |
| 31 | 5.2 | 0.5 | 0.02 | 1.8 | 4.0 | 73.2 | 15.4 |
| 32 | 7.6 | 1.5 | 0.01 | 2.5 | 11.8 | 63.0 | 13.6 |
| 33 | 8.2 | 3.0 | 0.00 | 0.5 | 10.5 | 54.5 | 13.2 |
| 34 | 9.7 | 4.7 | 0.00 | 0.3 | 7.7 | 59.4 | 18.2 |
| 35 | 6.8 | 2.1 | 0.00 | 0.3 | 14.5 | 62.0 | 14.3 |
| 36 | 10.3 | 4.7 | 0.01 | 0.6 | 6.3 | 58.1 | 20.0 |
| 37 | 6.2 | 4.5 | 0.00 | 0.2 | 6.4 | 64.6 | 18.0 |
| 38 | 11.5 | 6.8 | 0.02 | 0.2 | 2.8 | 50.0 | 28.7 |
| 39 | 13.0 | 9.3 | 0.11 | 2.6 | 6.1 | 41.3 | 27.6 |
| 40 | 11.0 | 5.6 | 0.00 | 0.5 | 10.0 | 50.9 | 22.1 |
| 41 | 6.7 | 3.0 | 0.06 | 1.8 | 19.5 | 54.4 | 14.5 |
| 42 | 13.5 | 14.3 | 0.11 | 3.4 | 9.9 | 33.6 | 25.3 |
| 43 | 17.1 | 17.3 | 0.00 | 0.6 | 3.2 | 34.0 | 27.9 |
| 44 | 7.6 | 3.9 | 0.02 | 0.4 | 7.3 | 65.1 | 15.7 |
| 45 | 6.5 | 2.2 | 0.00 | 0.9 | 2.7 | 73.1 | 15.5 |
| 46 | 4.0 | 2.1 | 0.03 | 4.0 | 37.2 | 43.5 | 9.1 |
| 47 | 13.9 | 14.3 | 0.00 | 0.5 | 4.9 | 42.2 | 24.3 |
| 48 | 13.8 | 7.5 | 0.00 | 2.1 | 15.2 | 39.9 | 21.5 |
| 49 | 10.9 | 4.3 | 0.01 | 1.1 | 12.2 | 55.6 | 15.9 |
| 50 | 9.7 | 4.2 | 0.00 | 0.5 | 9.2 | 58.0 | 18.4 |

## Water Retention at -10 kPa Matric Potential

There is no general agreement on the water potential value that best represents field capacity in a sandy soil. However, some water potential near -10 kPa is the most frequently used value.

Gravimetric water content as a function of clay content is presented in figure 1. This relationship accounted for 54% of the deviations in water content at -10 kPa. Two data points are highlighted by arrows. The arrow at (a) indicates the sample with the greatest organic matter content and the arrow (b) indicates the sample with the greatest coarse plus very coarse sand. A model containing clay, organic matter, coarse sand and very coarse sand accounted for 75% of the deviation in water content.

Other single value correlations between the dependent variable and gravimetric water contents at -10 kPa were R=0.70 for silt, 0.59 for very fine sand, 0.57 for organic matter, -0.50 for medium sand, 0.41 for calcium carbonate, -0.34 for fine sand, 0.26 for very coarse sand and -0.25 for coarse sand.

There was a 6 variable linear regression model that provided a $R^2$ value greater than 0.8. These variables

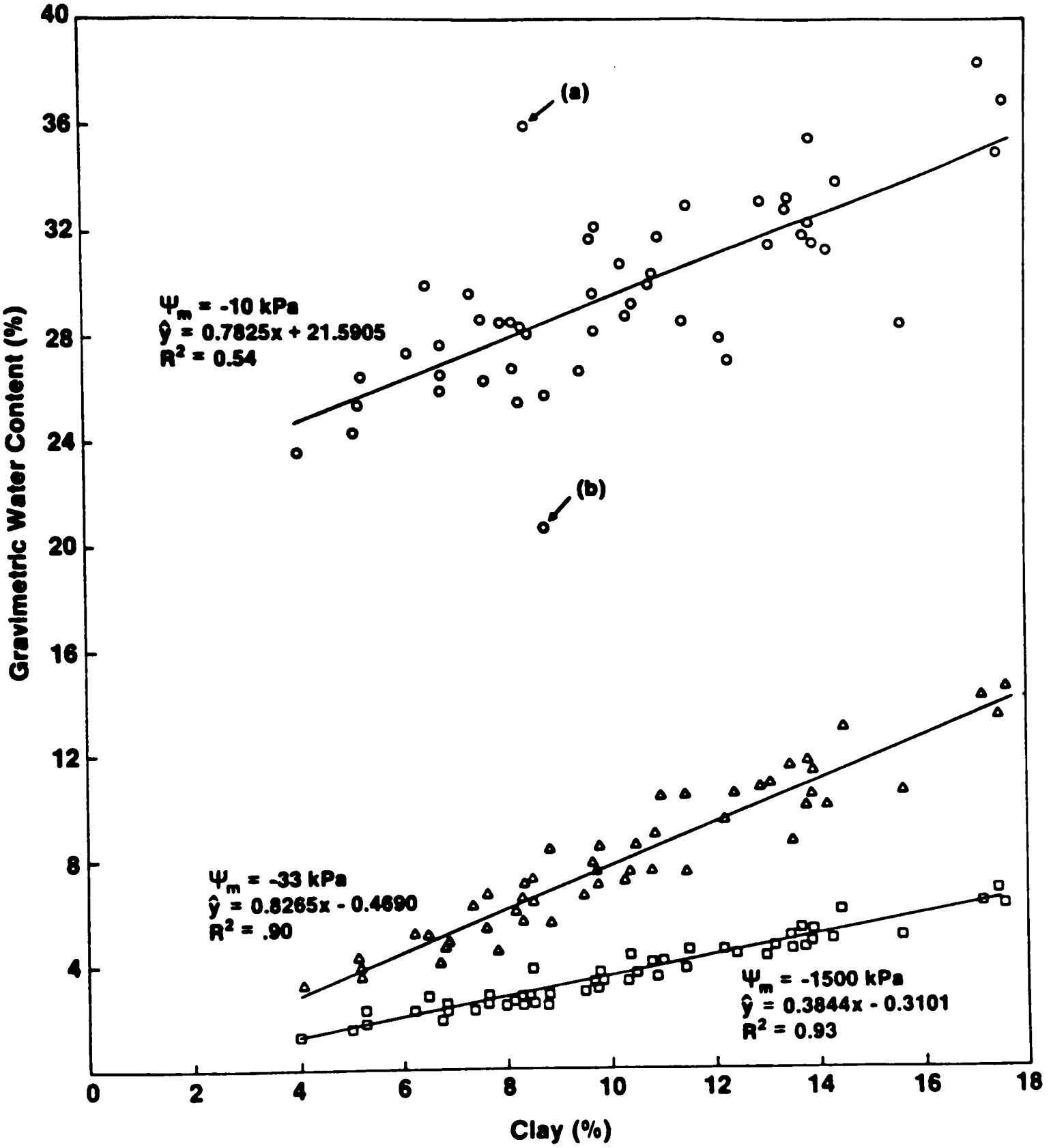


Fig. 1. Relationships among clay content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

were organic matter, $CaCO_3$, clay, silt, very coarse sand, and coarse sand. The nine variable model had a $R^2$ value of 0.81. The models with the greatest R values are presented in table 4 for the one to nine variables.

## Water Retention at -33 kPa Matric Potential

Many authors use the -33 kPa matric potential as a field capacity value. At -33 kPa, clay content had the greatest (R=0.95) and silt had the second greatest correlation (R=0.75) with water content. Very fine sand had a "R" value of 0.68 while fine sand was negatively correlated (R=-0.66). Correlation coefficients (R) were 0.40, 0.36, -0.29, 0.14 and -0.04 for organic matter content, very coarse sand, medium sand, calcium carbonate equivalent and coarse sand, respectively.

Clay content alone accounted for 90% of the deviations ($R^2$=0.90) in gravimetric water content at -33 kPa matric potential (Figure 1). The 6 variable model with the greatest $R^2$ value in the -10 kPa matric potential model accounted for 91% of the deviations at -33 kPa matric potential and the nine variable model had a $R^2$

Table 4. Multiple regression equations and "R" values for the one to nine variable models at -10 kPa water retention.

| Number of Variables | Coefficients of Soil Variables | R value |
|---|---|---|
| 1 | Y = 21.59 + 0.78 clay | 0.737 |
| 2 | Y = 20.63 + 3.21 calcium carbonate + 0.75 clay | 0.810 |
| 3 | Y = 23.73 + 8.81 organic matter + 0.51 clay - 0.16 medium sand | 0.869 |
| 4 | Y = 23.27 + 6.54 organic matter + 1.51 calcium carbonate + 0.54 clay - 0.14 medium sand | 0.879 |
| 5 | Y = 23.73 + 5.50 organic matter + 1.60 calcium carbonate + 0.43 clay + 0.18 silt - 0.14 medium sand | 0.887 |
| 6 | Y = 23.57 + 6.58 organic matter + 1.73 calcium carbonate + 0.32 clay + 0.27 silt + 18.12 very coarse sand - 1.25 coarse sand | 0.896 |
| 7 | Y = 18.59 + 6.51 organic matter + 1.51 calcium carbonate + 0.41 clay + 0.34 silt + 15.64 very coarse sand - 0.88 coarse sand + 0.06 fine sand | 0.900 |
| 8 | Y = -64.51 + 6.47 organic matter + 1.51 calcium carbonate + 1.25 clay + 1.14 silt + 15.64 very coarse sand + 0.83 medium sand + 0.89 fine sand + 0.84 very fine sand | 0.900 |
| 9 | Y = -53.88 + 6.49 organic matter + 1.52 calcium carbonate + 1.14 clay + 1.04 silt + 15.65 very coarse sand - 0.11 coarse sand + 0.72 medium sand + 0.79 fine sand + 0.74 very fine sand | 0.900 |

value of 0.92. The models with the greatest R values at -33 kPa water retention are presented in table 5 for the one to nine variable models.

## Water Retention at -100 kPa Matric Potential

Some soil scientists are interested in intermediate points between -33 and -1500 kPa in the water retention-water content relationships. One such point frequently used is the -100 kPa value.

Clay content was more highly correlated with water content at -100 kPa matric potential than any other measured variable (R=0.96) and silt content had the second greatest correlation (R=0.80). Other correlation coefficients (R) were very fine sand (0.70), fine sand (-0.66), organic matter (0.46), very coarse sand (0.35), medium sand (-0.32), calcium carbonate (0.20) and coarse sand (-0.06).

The six variable model with the greatest correlation at -10 kPa matric potential accounted for 95% of the deviations at -100 kPa matric potential as did the nine variable model. The specific models that provide the

Table 5. Multiple regression equations and "R" values for the one to nine variable models at -33 kPa water retention.

| Number of Variables | Coefficients of Soil Variables | R value |
|---|---|---|
| 1 | Y = -0.47 + 0.83 clay | 0.949 |
| 2 | Y = -1.15 + 0.76 clay + 0.07 very fine sand | 0.954 |
| 3 | Y = 6.04 + 0.64 clay - 0.06 medium sand - 0.07 very fine sand | 0.957 |
| 4 | Y = 0.78 + 0.45 calcium carbonate + 0.69 clay - 0.03 fine sand + 0.08 very fine sand | 0.958 |
| 5 | Y = 7.67 + 0.39 calcium carbonate + 0.62 clay - 0.05 silt - 0.08 medium sand - 0.09 fine sand | 0.958 |
| 6 | Y = 7.99 + 0.41 calcium carbonate + 0.62 clay - 0.06 silt - 1.99 very coarse sand - 0.08 medium sand - 0.10 fine sand | 0.959 |
| 7 | Y = 1.66 + 0.39 calcium carbonate + 0.69 clay - 2.64 very coarse sand + 0.13 coarse sand - 0.02 medium sand - 0.04 fine sand + 0.06 very fine sand | 0.959 |
| 8 | Y = 1.57 + 0.08 organic matter + 0.37 calcium carbonate + 0.69 clay - 2.57 very coarse sand + 0.12 coarse sand - 0.02 medium sand - 0.03 fine sand + 0.06 very fine sand | 0.959 |
| 9 | Y = 1.89 + 0.08 organic matter + 0.37 calcium carbonate + 0.69 clay - 0.0032 silt - 2.57 very coarse sand + 0.12 coarse sand - 0.03 medium sand - 0.04 fine sand + 0.06 very fine sand | 0.959 |

greatest R value between actual and calculated water retention at the -100 kPa are presented in table 6 for the one to nine variable models.

## Water Retention at -1500 kPa Matric Potential

Water content at -1500 kPa matric potential usually is considered to be about permanent wilting percentage. The correlation coefficient between clay content and gravimetric water content (R) was 0.96 while R was 0.74, 0.62, -0.60, 0.44, -0.31, 0.31, 0.21, and -0.10 respectively for silt, very fine sand, fine sand, organic matter, medium sand, very coarse sand, calcium carbonate and coarse sand.

The single variable model with clay as the dependent variable accounted for 93% of the deviations in water content at -1500 kPa matric potential (Figure 1). The six variable model with the greatest correlation at -10 kPa only accounted for 95% of the deviations at -1500 kPa matric potential as did the nine variable model.

The specific models that provide the greatest R value between actual and calculated water retention for the one to nine variables are presented in table 7 for the -1500 kPa measurement.

Table 6. Multiple regression equations and "R" values for the one to nine variable models at -100 kPa water retention.

| Number of Variables | Coefficients of Soil Variables | R value |
|---|---|---|
| 1 | Y = -0.44 + 0.59 clay | 0.958 |
| 2 | Y = -0.07 + 0.50 clay + 0.12 silt | 0.969 |
| 3 | Y = -0.24 + 0.48 calcium carbonate + 0.50 clay + 0.11 silt | 0.973 |
| 4 | Y = -0.74 + 0.54 calcium carbonate + 0.48 clay + 0.08 silt + 0.04 very fine sand | 0.975 |
| 5 | Y = -0.87 + 0.76 organic matter + 0.39 calcium carbonate + 0.47 clay + 0.07 silt + 0.05 very fine sand | 0.976 |
| 6 | Y = -1.23 + 0.66 organic matter + 0.45 calcium carbonate + 0.47 clay + 0.07 silt + 0.01 medium sand + 0.06 very fine sand | 0.976 |
| 7 | Y = -0.21 + 0.63 organic matter + 0.46 calcium carbonate + 0.47 clay + 0.05 silt - 0.66 very coarse sand - 0.01 fine sand + 0.05 very fine sand | 0.977 |
| 8 | Y = 5.39 + 0.64 organic matter + 0.46 calcium carbonate + 0.41 clay - 0.59 very coarse sand - 0.06 coarse sand - 0.06 medium sand - 0.07 fine sand - 0.003 very fine sand | 0.977 |
| 9 | Y = 18.38 + 0.65 organic matter + 0.46 calcium carbonate + 0.28 clay - 0.13 silt - 0.68 very coarse sand - 0.19 coarse sand - 0.19 medium sand - 0.20 fine sand - 0.13 very fine sand | 0.977 |

Table 7. Multiple regression equations and "R" values for the one to nine variable models at -1500 kPa water retention.

| Number of Variables | Coefficients of Soil Variables | R value |
|---|---|---|
| 1 | Y = 0.3101 + 0.3844 clay | 0.964 |
| 2 | Y = -0.43 + 0.41 calcium carbonate + 0.38 clay | 0.970 |
| 3 | Y = -0.49 + 0.42 calcium carbonate + 0.39 clay - 2.47 very coarse sand | 0.972 |
| 4 | Y = -0.42 + 0.40 calcium carbonate + 0.37 clay + 0.02 silt - 2.43 very coarse sand | 0.973 |
| 5 | Y = -0.43 + 0.09 organic matter + 0.38 calcium carbonate + 0.37 clay + 0.02 silt - 2.41 very coarse sand | 0.973 |
| 6 | Y = -0.43 + 0.41 calcium carbonate + 0.37 clay + 0.02 silt - 2.13 very coarse sand - 0.03 coarse sand + 0.004 medium sand | 0.973 |
| 7 | Y = -0.43 + 0.12 organic matter + 0.38 calcium carbonate + 0.37 clay + 0.02 silt - 2.03 very coarse sand - 0.03 coarse sand + 0.004 medium sand | 0.973 |
| 8 | Y = -26.97 + 0.40 calcium carbonate + 0.64 clay + 0.29 silt - 1.93 very coarse sand + 0.23 coarse sand + 0.27 medium sand + 0.27 fine sand + 0.26 very fine sand | 0.974 |
| 9 | Y = -26.52 + 0.10 organic matter + 0.38 calcium carbonate + 0.64 clay + 0.28 silt - 1.85 very coarse sand + 0.22 coarse sand + 0.26 medium sand + 0.26 fine sand + 0.26 very fine sand | 0.974 |

The relationship among organic matter, calcium carbonate, clay, silt, and the sand fractions with gravimetric water content at -10, -33, and -1500 kPa matric potentials are described below.

The graph of organic matter and gravimetric water showed positive correlation at the three matric potentials (Figure 2). There was only one soil sample greater than one percent organic matter and the other 49 soil samples had organic matter less than 0.5 percent. When only the 49 samples are considered gravimetric water increased substantially as organic matter increased. The soil sample with greater than one percent organic matter appeared to have high gravimetric water content at -10 kPa, but had low gravimetric water at -33 kPa and -1500 kPa.

There were only two samples with $CaCO_3$ equivalent values of greater than two percent. The other 48 samples had $CaCO_3$ equivalents less than 0.8 percent (Figure 3). These 48 samples were related to clay content [$CaCO_3$ equivalent (%) y = 0.1394 + 0.0205 clay content (%) with a $R^2$ correlation coefficient of 0.3079]. There was low correlation between calcium carbonate equivalent and gravimetric water content, especially, at -33 kPa and -1500 kPa matric potentials.

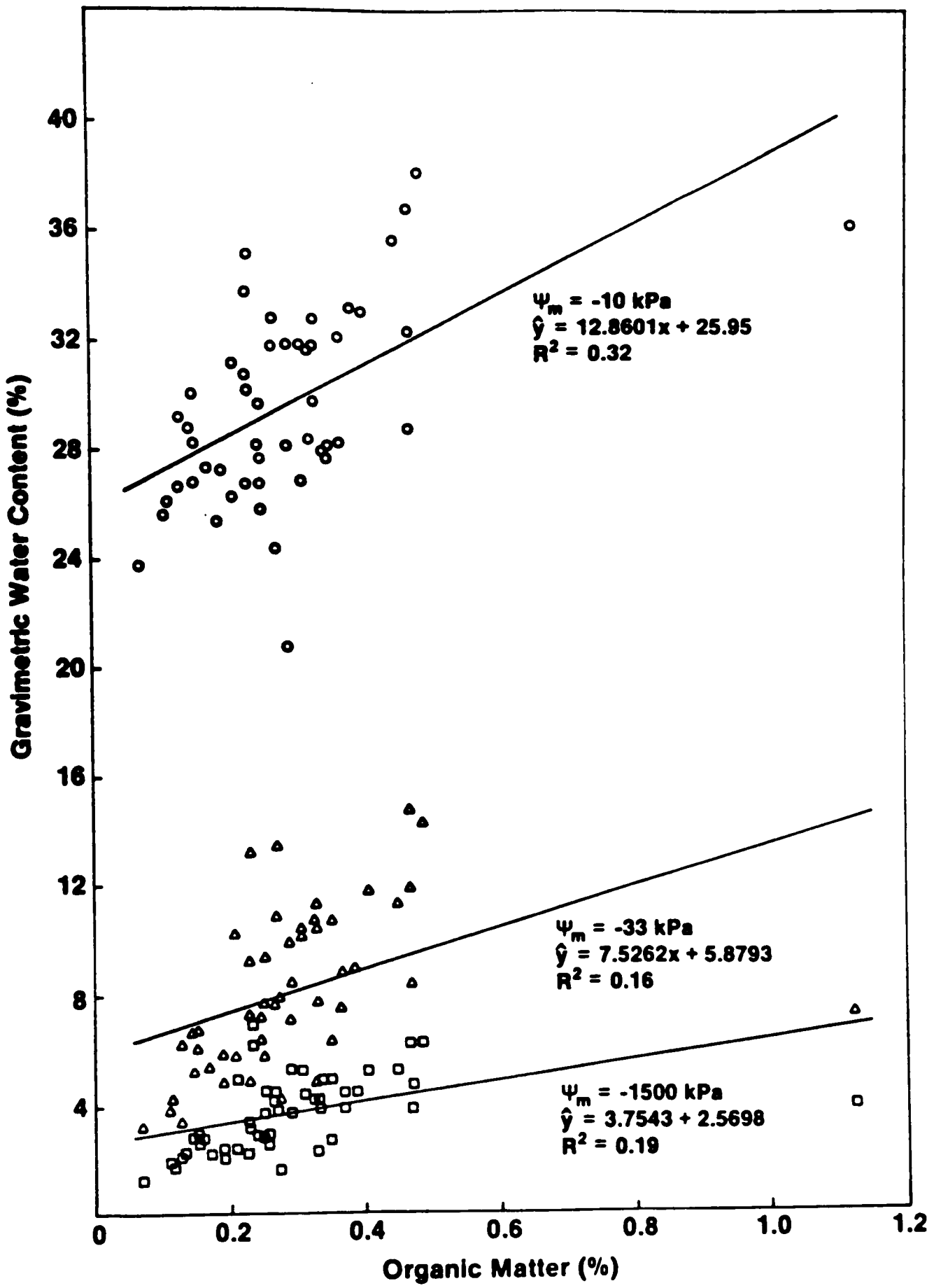


Fig. 2. Relationships among organic matter content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

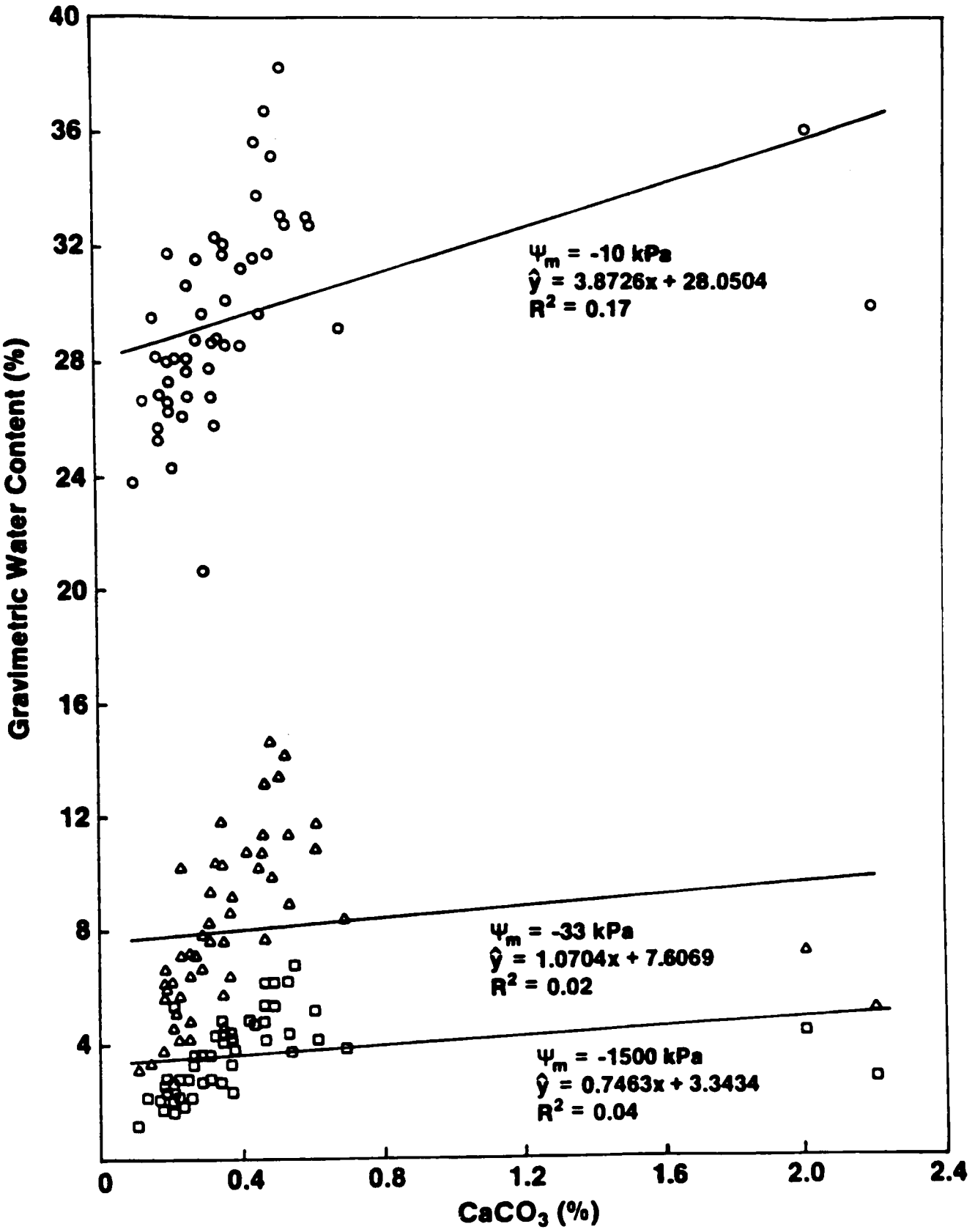


Fig. 3. Relationships among calcium carbonate equivalent and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

Clay ranged from 4.0 to 17.6 percent (Figure 1). There were positive correlations at the three matric potentials. High correlation coefficient values were found at the -33 kPa and -1500 kPa matric potentials.

The graph of silt content and gravimetric water content showed positive correlation at the three matric potentials (Figure 4). Silt had the second, besides clay, greatest correlation coefficient value with gravimetric water content.

The graph of coarse sand and gravimetric water content showed slight negative correlation at the three matric potentials (Figure 5). Coarse sand content ranged from 0.2 to 4.9 percent. The samples with about four percent or greater coarse sand tend to have a low gravimetric water content.

The graph of medium sand and gravimetric water content showed a negative correlation at the three matric potentials (Figure 6). Medium sand ranged from 2.6 to 37.2 percent. The graph showed that samples with high medium sand content tend to have low gravimetric water contents. On the average, medium sand ranked third in proportion among the five sand-sized fractions (very coarse sand, coarse sand, medium sand, fine sand, and very fine sand).

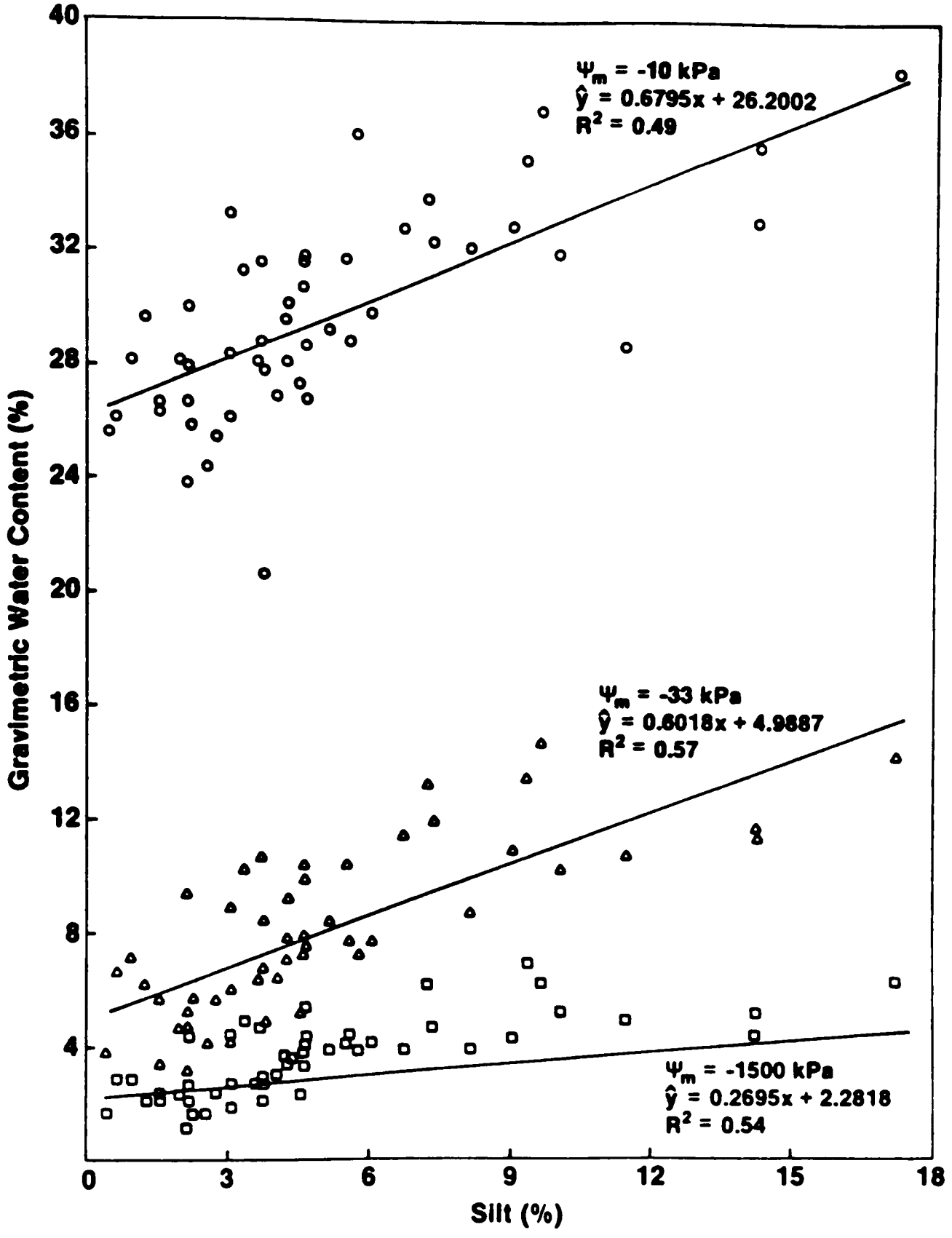


Fig. 4. Relationships among silt content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

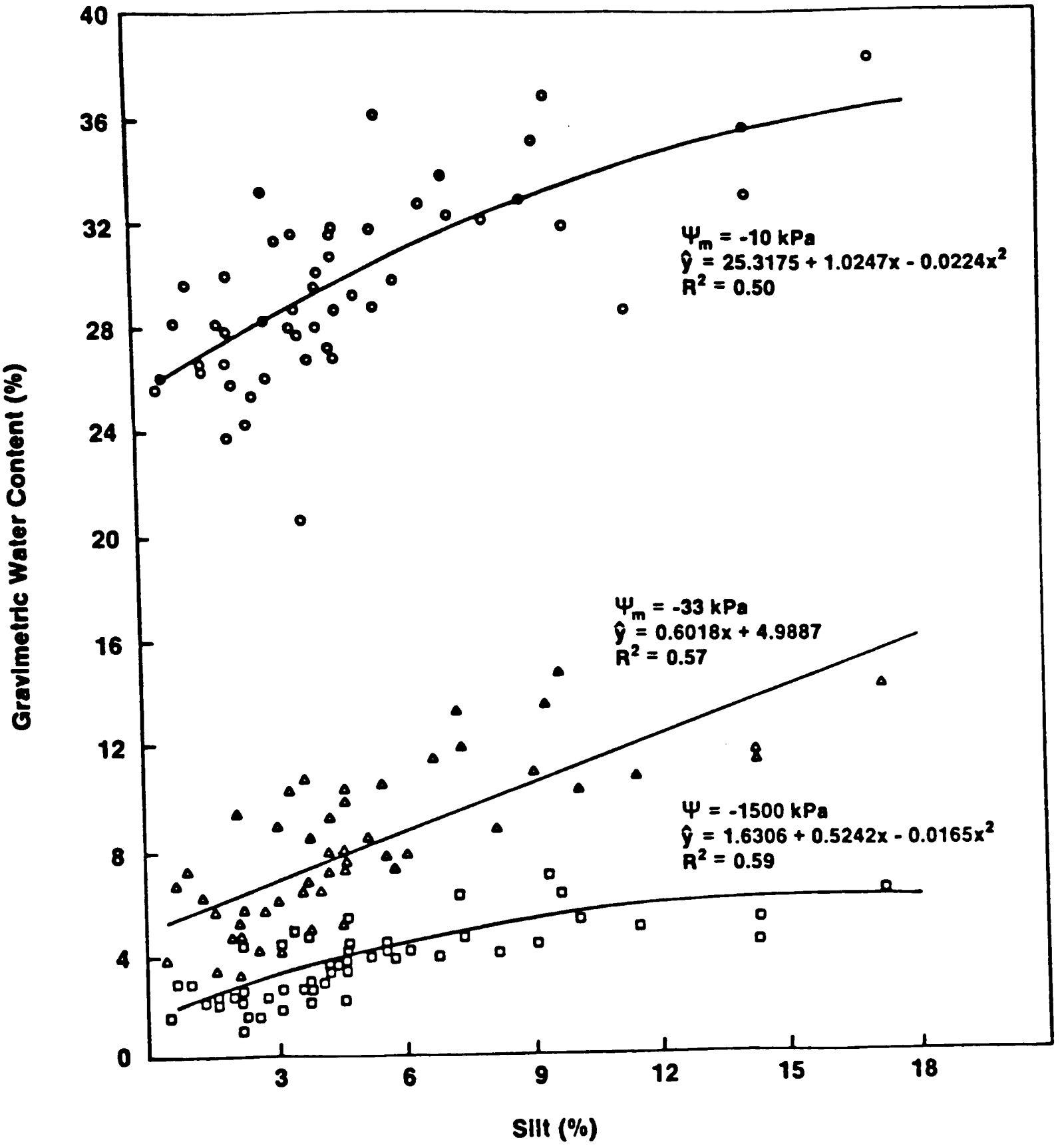


Fig. 4. Continued.

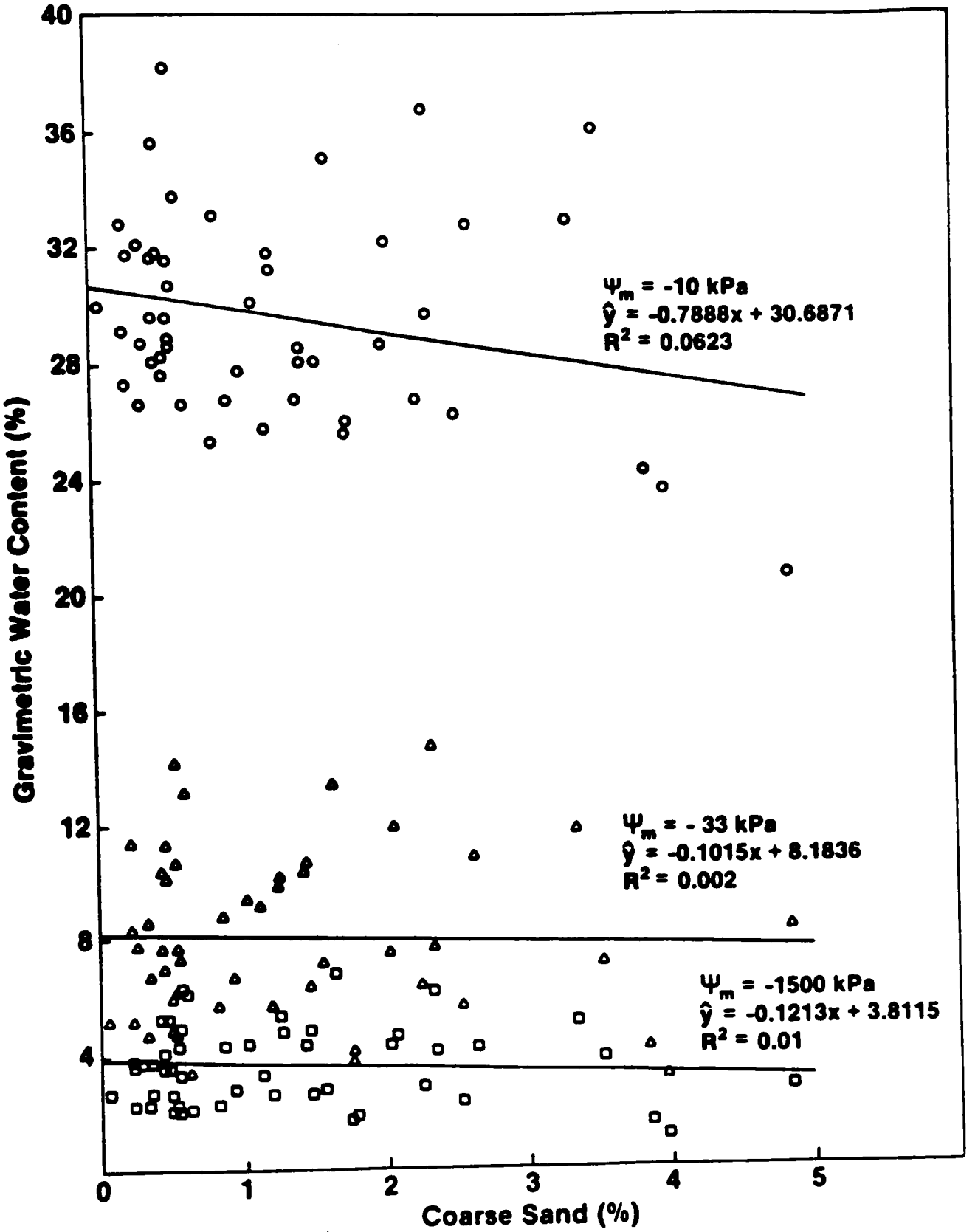


Fig. 5. Relationships among coarse sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

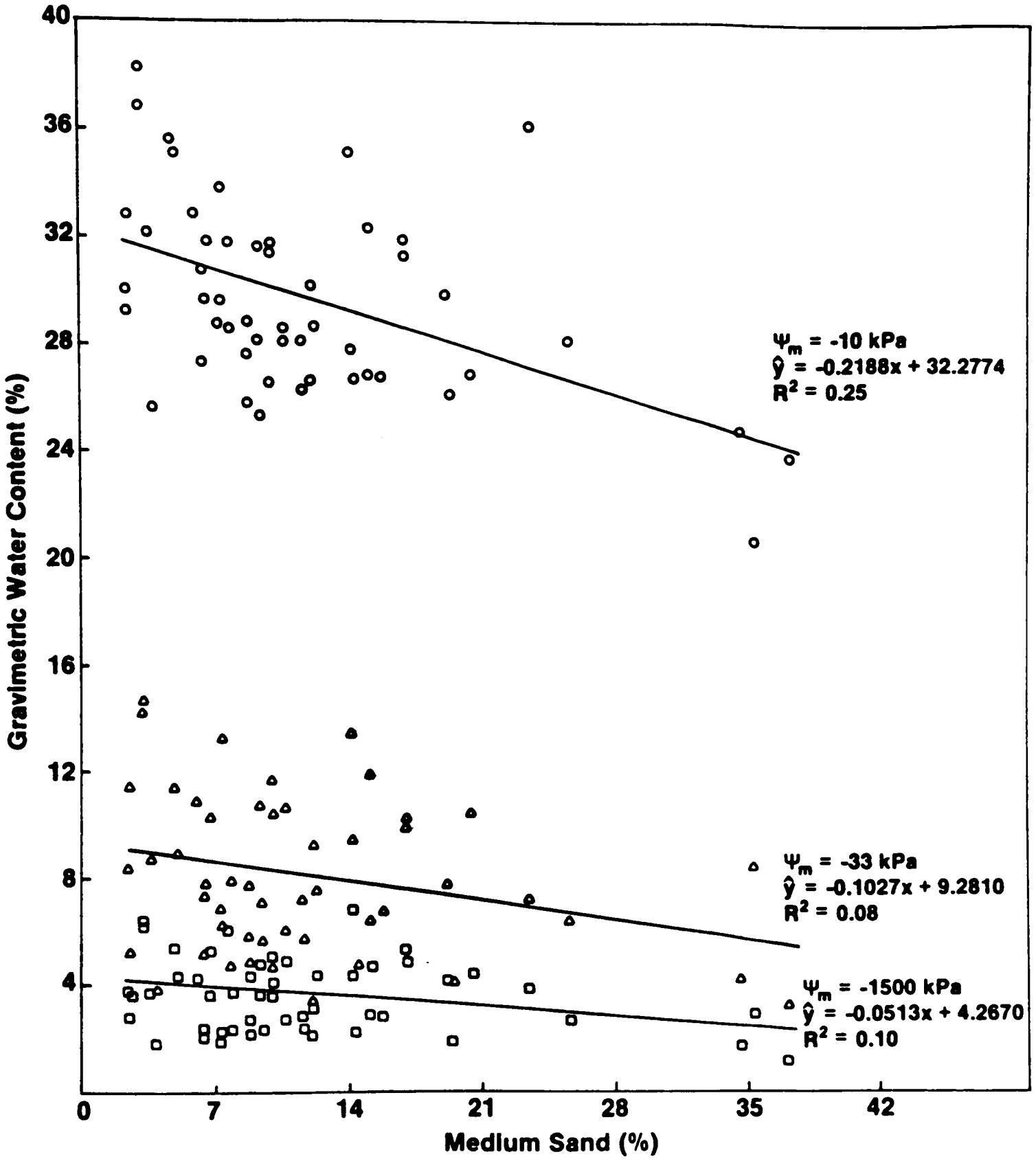


Fig. 6. Relationships among medium sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

Fine sand content ranged from 31.6 to 73.2 percent. The graph of fine sand and gravimetric water content showed negative correlation at the three matric potentials (Figure 7). Soil samples with high fine sand contents tend to have low gravimetric water contents. However, the sample shown on the graph with an arrow had the lowest fine sand content, but had a very low gravimetric water content. The sample had a very high percentage of medium sand (35.6%), which caused the low gravimetric water content. On the average, fine sand was the greatest in proportion among the sand-sized fractions. Fine sand was 2.8, 4.4, and 40.5 times greater than very fine sand, medium sand, and coarse sand, respectively.

The graph of very fine sand and gravimetric water content showed a positive correlation at the three matric potentials (Figure 8). Very fine sand ranged from 9.1 to 28.7 percent. It appeared that the greater the very fine sand content, the higher the gravimetric water content. However, the sample as shown on the graph with an arrow had the lowest very fine sand content (9.1%) but had very high gravimetric water content; the soil sample had the highest organic matter which accounted for the high gravimetric water content. On the average, very fine sand,

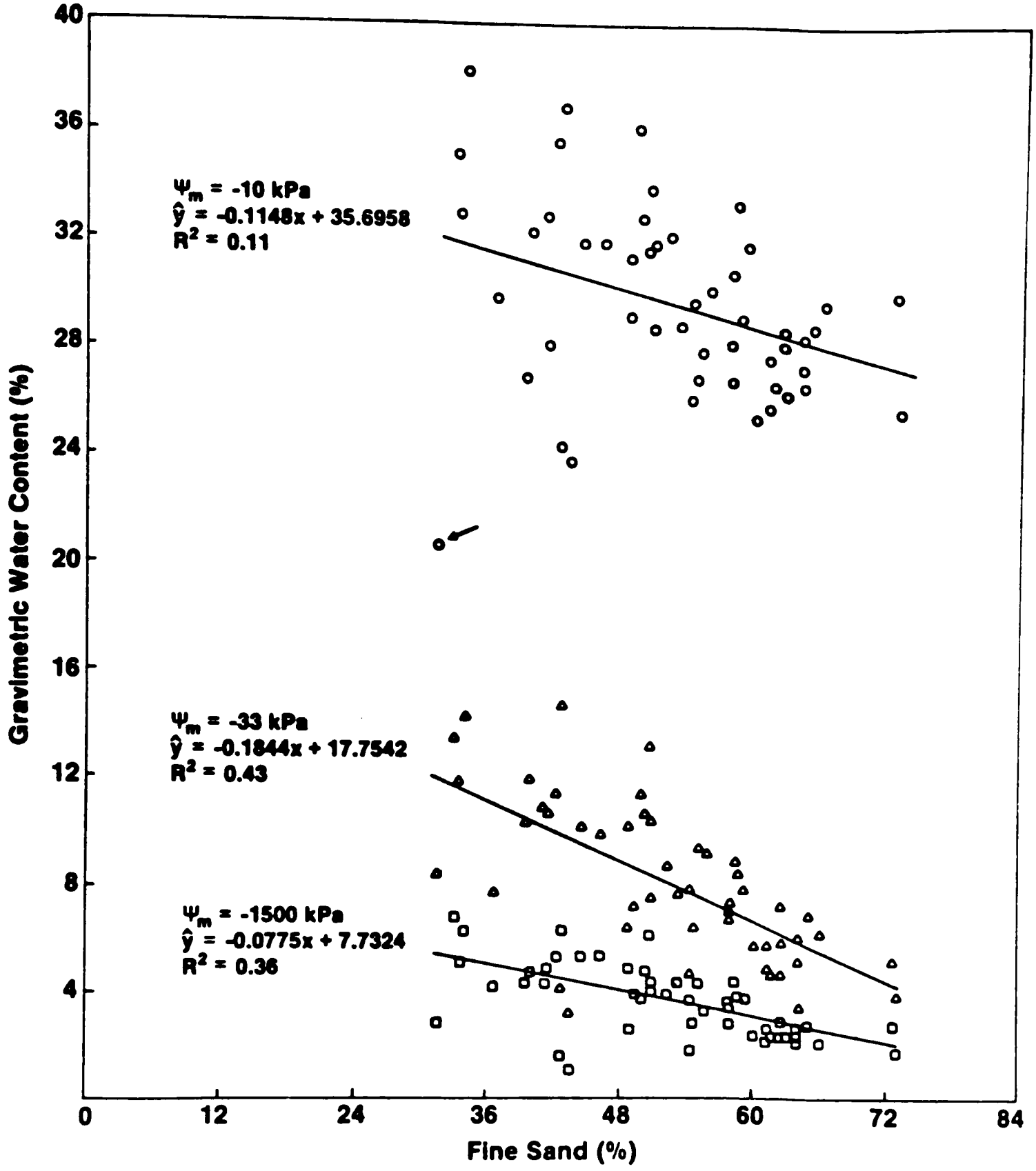


Fig. 7. Relationships among fine sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

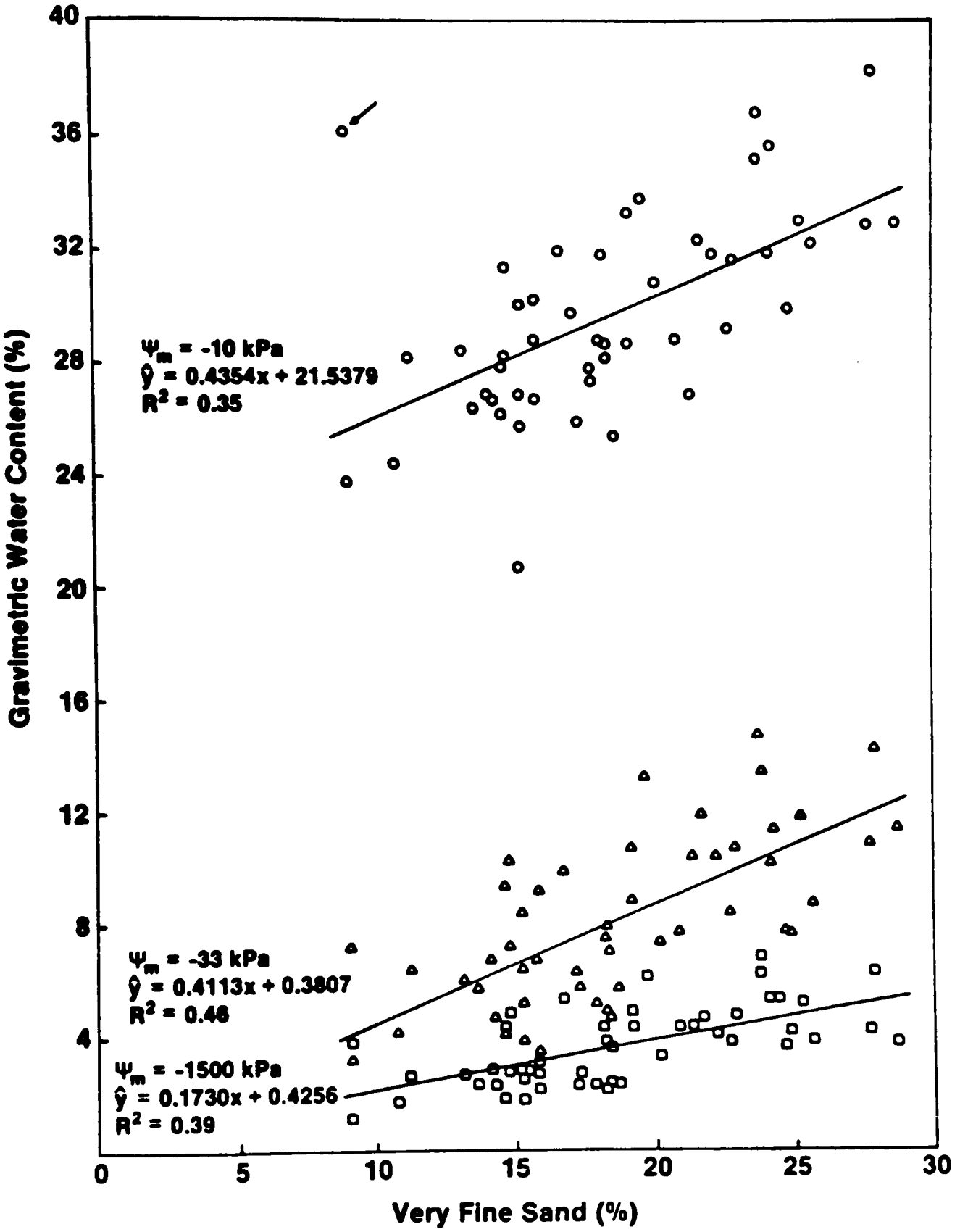


Fig. 8. Relationships among very fine sand content and gravimetric water content at 3 matric potentials for 50 Ap soil samples collected from 15 counties on the Texas High Plains.

besides fine sand, ranked second in proportion among the sand subfractions.

## Plant Available Water

Plant available water often is approximated as being the difference in water content between that held at -10 and at -1500 kPa matric potential. Plant available water, as defined in the previous sentence, was converted to volumetric water content by multiplying by an assumed bulk density of 1.55 grams/$cm^3$. These volumetric water contents ranged from 27.4 to 49.6%. Clay content alone accounted for 25.6% of the deviations in available water (Figure 11, page 57) and silt content alone accounted for 32.3% of the deviations (Figure 12, page 58).

The best nine-variable model of plant available water was y = -27.365 + 6.392 O.M. + 1.135 $CaCO_3$ + 0.503 clay + 0.759 silt + 17.493 very coarse sand - 0.337 coarse sand + 0.455 medium sand + 0.525 fine sand + 0.480 very fine sand (Table 8). The $R^2$ value for this model was 0.677.

The effects of organic matter, $CaCO_3$, clay, silt, and the sand-sized fractions on the volumetric water

Table 8. Multiple regression equations and "R" values for the one to nine variable models with plant available water.

| Number of Variables | Coefficients of Soil Variables | R value |
|---|---|---|
| 1 | Y = 23.92 + 0.41 silt | 0.568 |
| 2 | Y = 25.38 + 9.20 organic matter - 0.17 medium sand | 0.753 |
| 3 | Y = 24.75 + 7.32 organic matter + 0.18 silt - 0.15 medium sand | 0.781 |
| 4 | Y = 24.56 + 5.53 organic matter + 1.19 calcium carbonate + 0.20 silt - 0.14 medium sand | 0.793 |
| 5 | Y = 23.58 + 6.22 organic matter + 1.414 calcium carbonate + 0.22 silt + 18.73 very coarse sand - 1.19 coarse sand | 0.814 |
| 6 | Y = 19.72 + 6.52 organic matter + 1.13 calcium carbonate + 0.33 silt + 18.97 very coarse sand - 0.93 coarse sand + 0.06 fine sand | 0.822 |
| 7 | Y = 21.26 + 6.47 organic matter + 1.14 calcium carbonate + 0.28 silt + 17.38 very coarse sand - 0.83 coarse sand - 0.03 medium sand + 0.04 fine sand | 0.823 |
| 8 | Y = -59.24 + 6.34 organic matter + 1.13 calcium carbonate + 0.83 clay + 1.07 silt + 17.46 very coarse sand + 0.77 medium sand + 0.84 fine sand | 0.823 |
| 9 | Y = -27.37 + 6.39 organic matter + 1.14 calcium carbonate + 0.50 clay + 0.76 silt + 17.49 very coarse sand - 0.34 coarse sand + 0.45 medium sand + 0.52 fine sand + 0.48 very fine sand | 0.823 |

content difference between -10 and -1500 kPa matric potentials (plant available water) are described below.

There was a positive correlation (R=0.541) between organic matter content and the available water (Figure 9). The sample shown with an arrow had the highest organic matter and the plant available water was high. Organic matter ranked second in the correlation coefficient value with plant available water.

There was a positive correlation (R=0.444) between $CaCO_3$ equivalent and available water (Figure 10). However, there were only 2 samples with $CaCO_3$ equivalent percentages greater than 0.8%.

Clay had the fourth highest correlation coefficient value (R=0.506) with available water, after silt, organic matter, and medium sand. Figure 11 showed a positive correlation of clay content with available water.

Among the soil components, silt had the highest correlation coefficient value (R=0.568) with plant available water (Figure 12). Silt contents ranged from 0.5 to 17.3 percent.

Coarse sand ranged from 0.2 to 4.9 percent. Figure 13 showed a slight negative correlation between coarse sand content and available water.

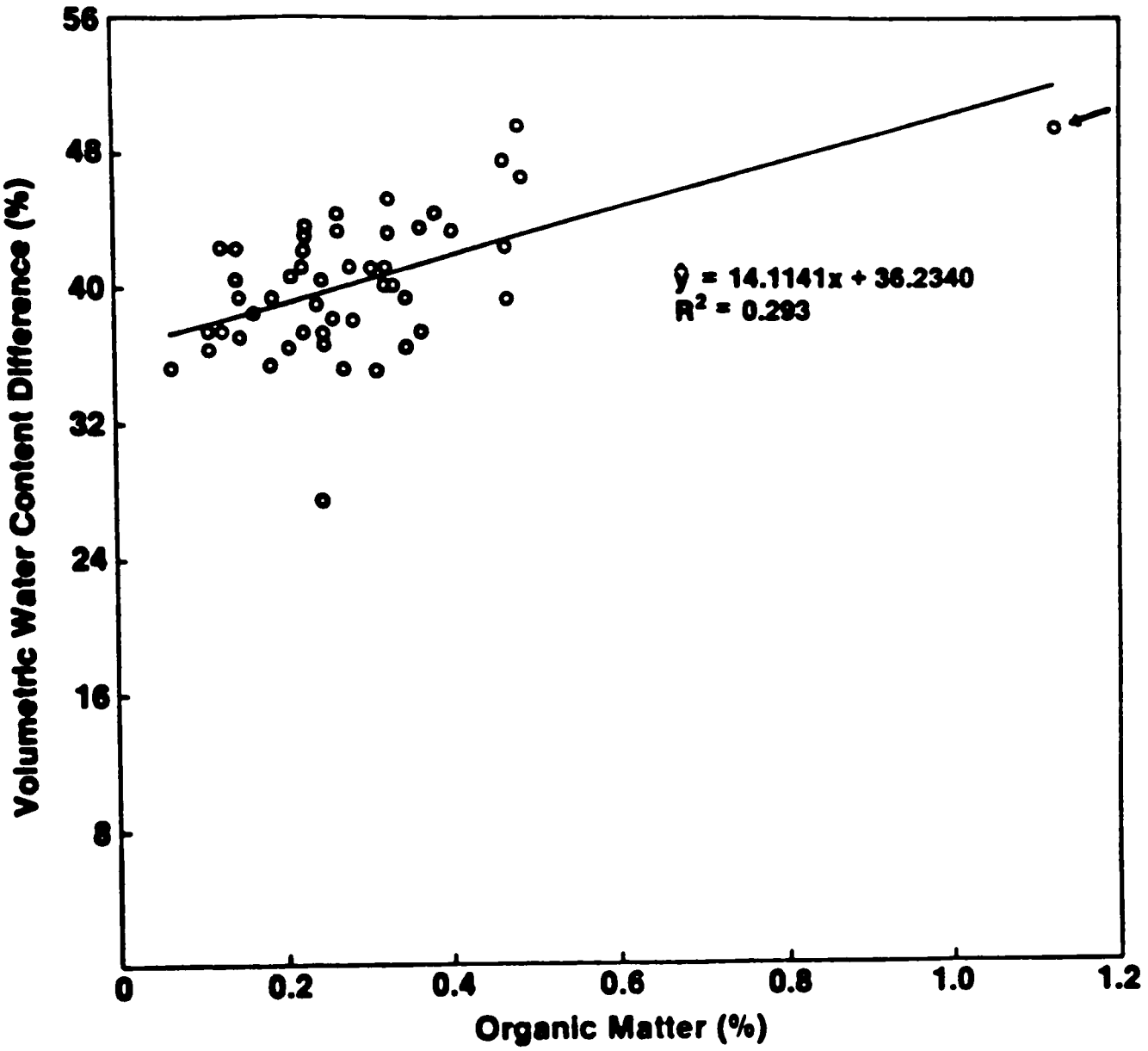


Fig. 9. The effect of organic matter content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

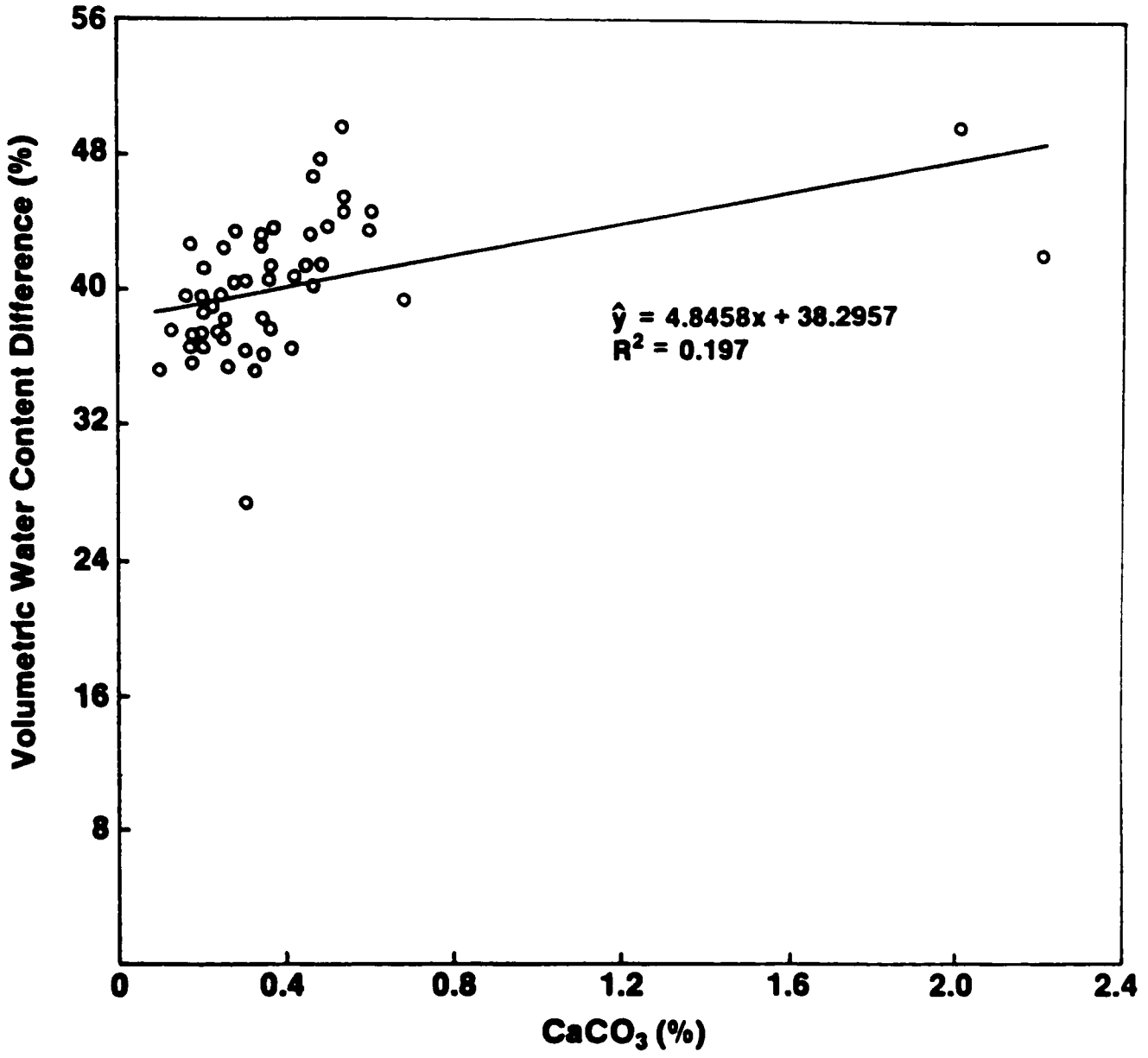


Fig. 10. The effect of calcium carbonate equivalent on the volumetric water content difference between -10 and -1500 kPa matric potentials.

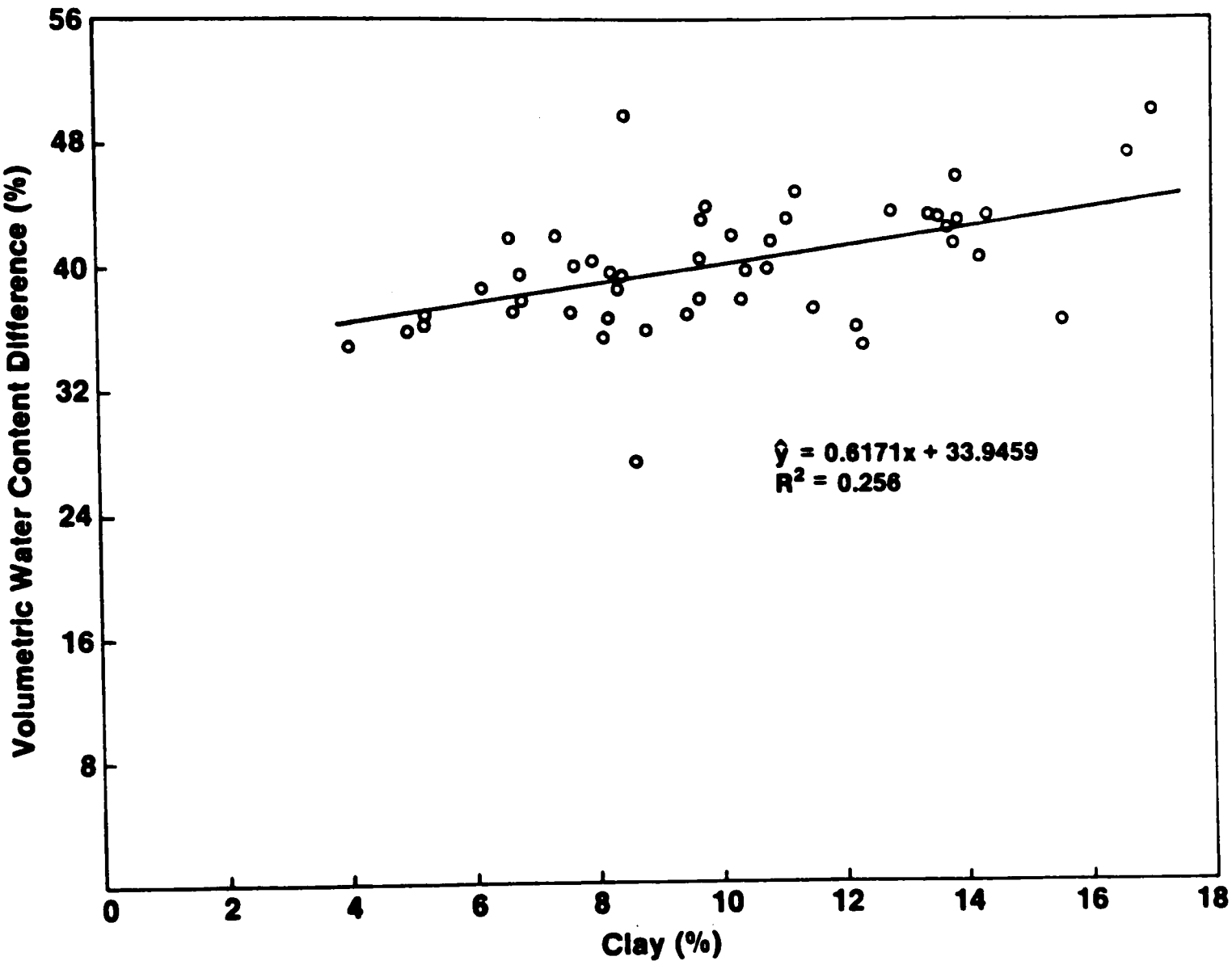


Fig. 11. The effect of clay content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

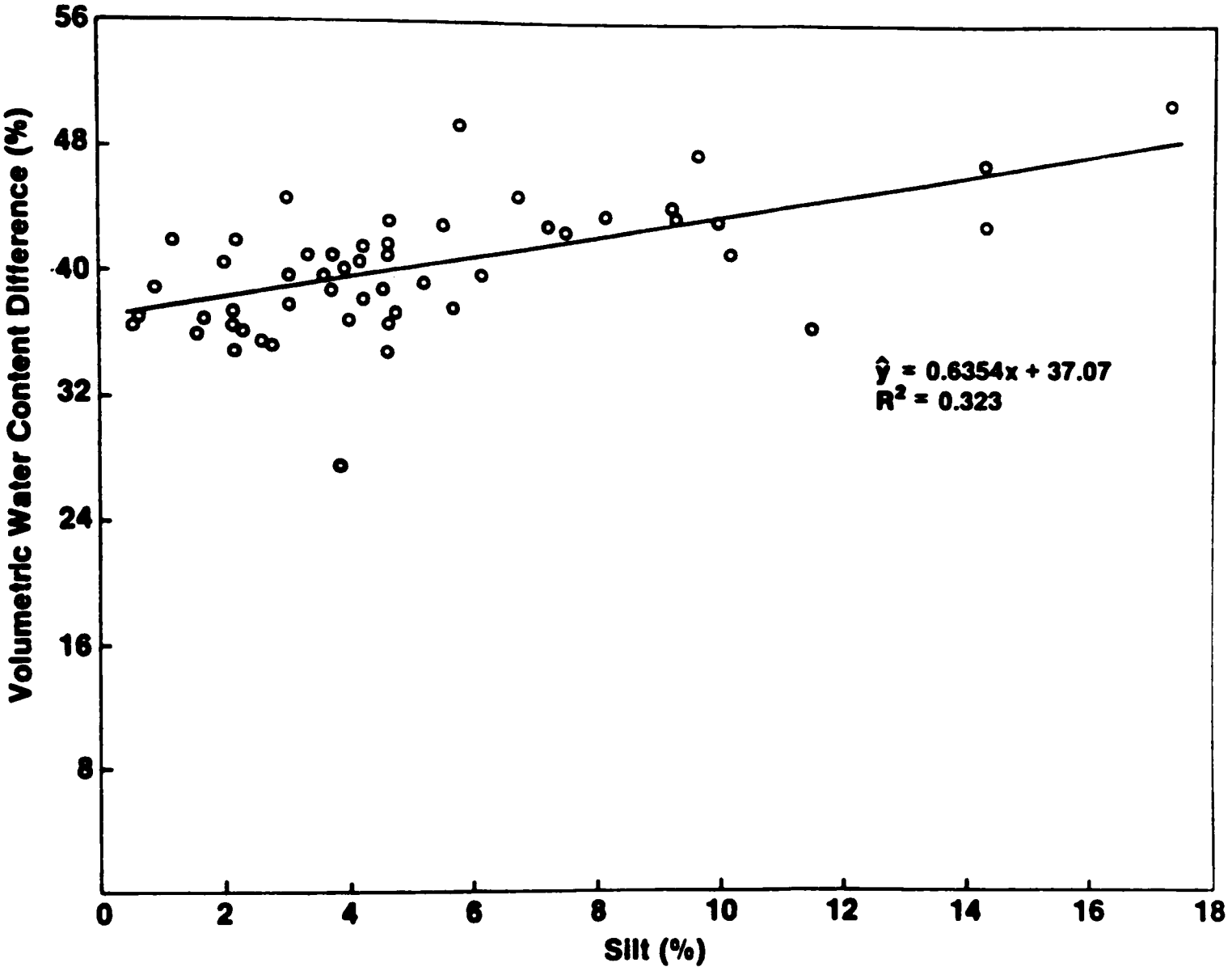


Fig. 12. The effect of silt content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

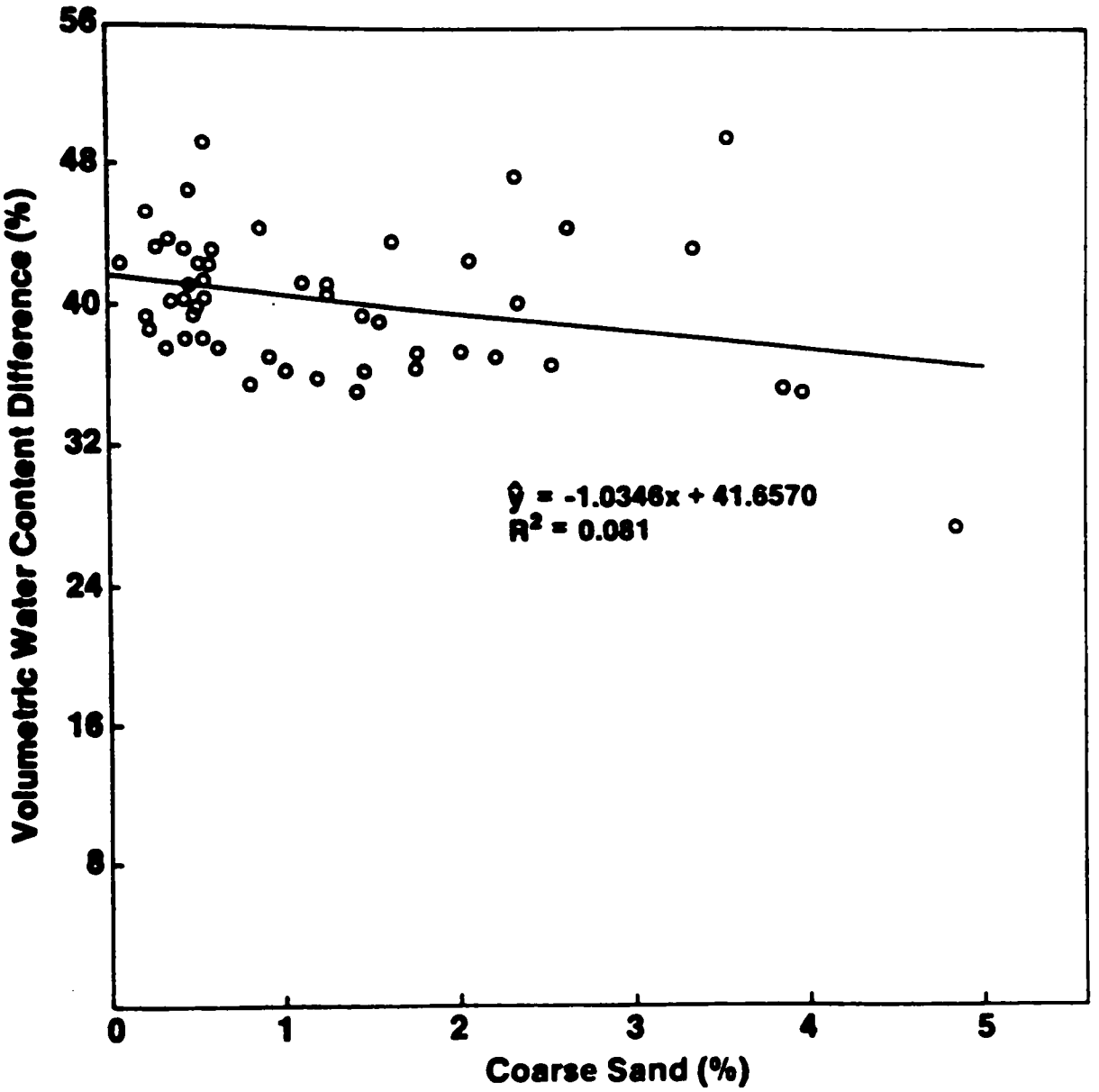


Fig. 13. The effect of coarse sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

There also was a negative correlation between medium sand and available water (Figure 14). Medium sand ranked third in correlation coefficient value (R=0.518) with available water. Medium sand contents ranged from 2.6 to 37.2 percent.

Fine sand had the greatest proportion among the sand-sized fractions, ranging from 31.6 to 73.2 percent. Figure 15 shows a slight negative correlation, such that as the proportion of fine sand increases, the available water slightly decreases. The correlation coefficient value between fine sand and plant available water (R=0.147) was the lowest when compared with the other soil components.

Very fine sand ranged from 9.1 to 28.7 percent and had the second greatest proportion among the sand-sized fractions. However, Figure 16 shows a positive correlation between very fine sand content and available water (R=0.480). As the proportion of very fine sand increases, the available water tends to increase. Very fine sand ranked fifth in correlation coefficient values with plant-available water.

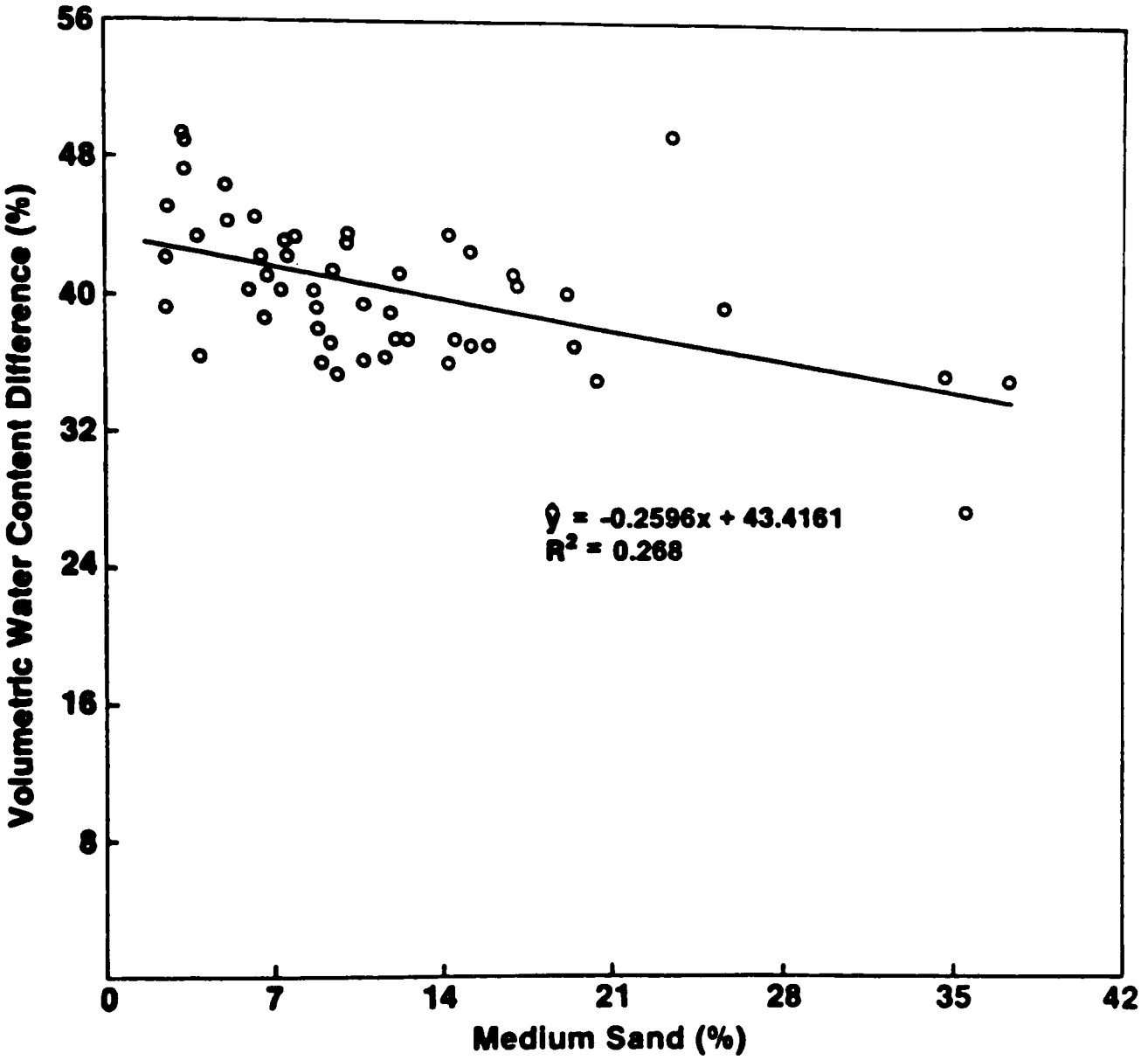


Fig. 14. The effect of medium sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

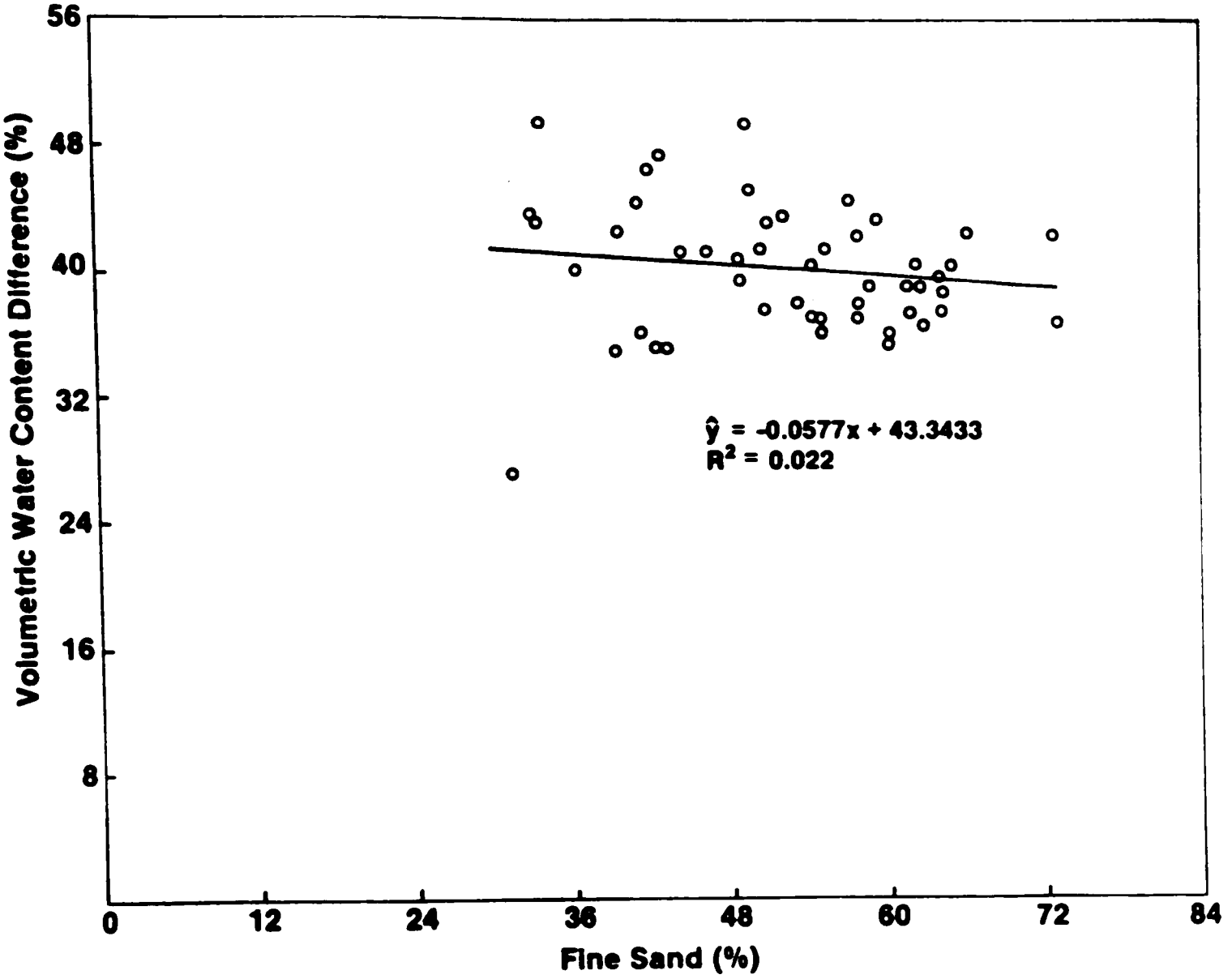


Fig. 15. The effect of fine sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

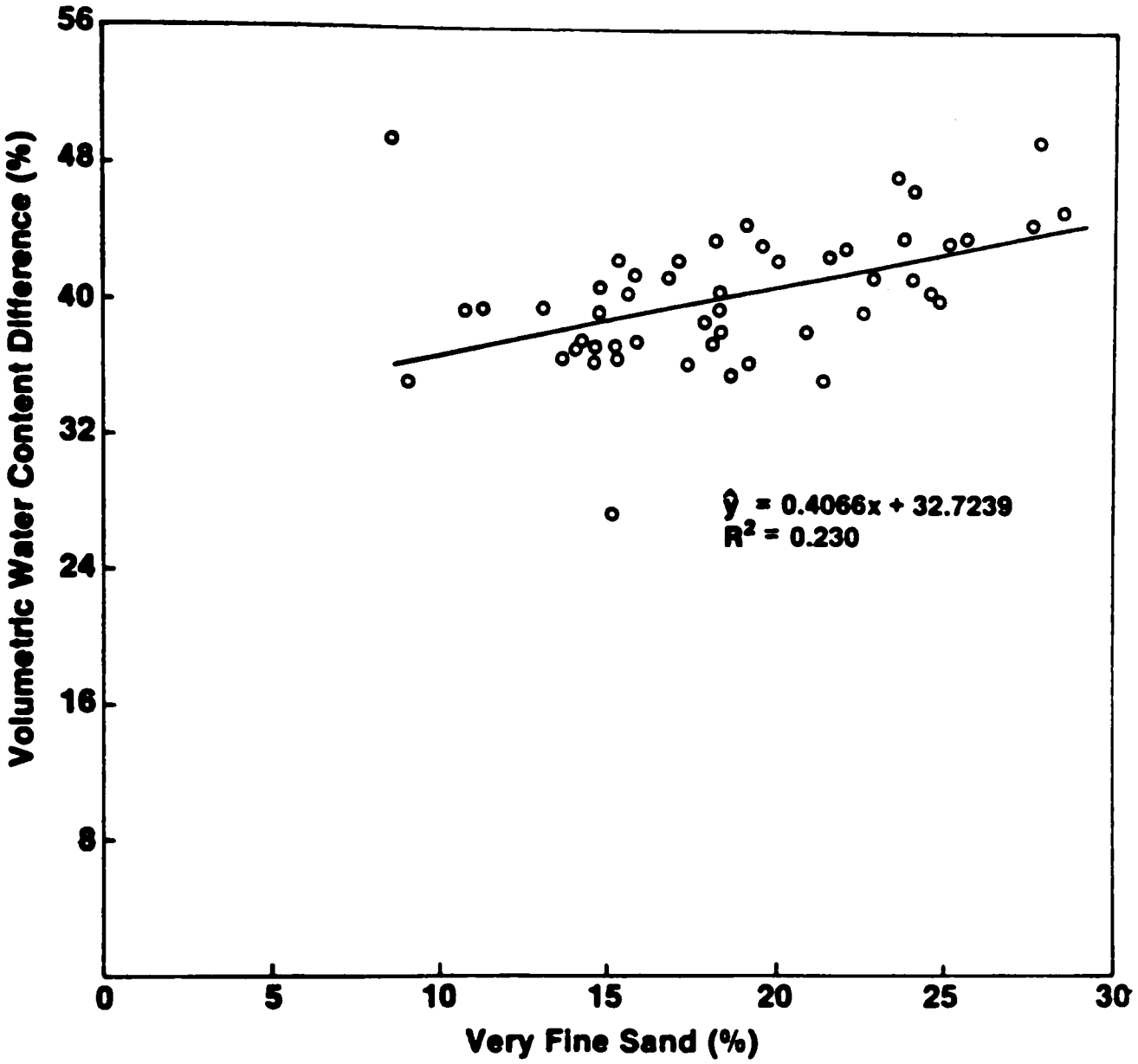


Fig. 16. The effect of very fine sand content on the volumetric water content difference between -10 and -1500 kPa matric potentials.

## Deep Plowing

### Standards

The Soil Conservation Service (1974) has stated that the purpose of deep plowing coarse textured soils is to bring clay materials to the surface. Deep plowing is applicable on Patricia loamy fine sand and fine sand, on Miles and Amarillo loamy fine sands, and also on fine sandy loam soils of Amarillo, Patricia and Miles series where wind winnowing has resulted in a thin loamy fine sand plow layer. These fine sandy loam soils, however, require a shallower plowing depth. This practice is applicable only where from 1/4 to 1/3 of the furrow slice will be of finer textured material. Less than this amount does not provide sufficient cloddiness to appreciably affect wind erosion control. More than this amount increases surface runoff and water erosion.

### Specifications

The Soil Conservation Service (1974) suggested that deep plowing be carried out according to the following specifications.

1. Sandy hummocks or accumulations, should be smoothed or

levelled before deep plowing to insure a plow depth that will reach adequate amounts of clay.

2. Slopes in excess of 3 percent are not adapted to deep plowing because of the increased water erosion hazard.
3. The subsoil material must not contain a high percentage of calcareous material. This material will not form clods that are resistant to wind erosion.
4. The subsoil should contain more than 20 percent but less than 45 percent clay. The mixture of the surface soil after deep plowing should contain about 12 to 15 percent or more of clay. (Twenty-six percent clay content offers the most resistant clods for wind erosion protection. Clod resistance decreases upon increasing or decreasing clay content from this point. For wind erosion control only, this percent of clay may be desired; however, considering moisture conservation and water erosion control it is more desirable to seek a surface clay content ranging from 25 to 26 percent clay).
5. Deep plowed soils should have an agronomic program designed to prevent further wind erosion. Use of adequate amounts of high residue crops, and management of their residue at an intensity which will accomplish this is a greatest importance.

## Rainfall Characteristics

Some characteristics of precipitation at the Lubbock, Texas National Weather Service location are presented in Table 9 for the period January 1, 1971 through December 31, 1983. There were 833 days in which at least 0.25 mm of precipitation occurred. In 43.4% of these events, the precipitation was 2.54 mm or less (Table 9). Total precipitation for this period was 6326.9 mm or an average of 486.7 mm/year. The greatest amount of precipitation during a 24-hour period was 137.9 mm in October 1983. Cumulation precipitation frequencies are presented in Figure 17.

## Estimates of Precipitation Effectiveness

Wiegand (1962) has shown that: (a) moisture distribution with soil depth is parabolic, (b) moisture content at given depths in a soil layer can be expressed by $\theta = a\ t^{-b}$ value where $\theta$ is the moisture content, t is time in days, a is the moisture content one day after water is added to the profile and b is the slope of plots of moisture content versus time on a log-log coordinate

Table 9. Total precipitation events in various quantity classes percentage of total events with precipitation within various quantity classes, total millimeters of precipitation within each quantity class and percentage of total precipitation within each class for the period 1971 to 1983, inclusive, at Lubbock, Texas.

| Rainfall Amount (mm) | Rainfall events | % of events within class | Total mm Precipitation | % precipitation within class |
|---|---|---|---|---|
| 0.25 to 2.5 | 361 | 43.4 | 381.8 | 6.0 |
| 2.6 to 5.1 | 142 | 17.0 | 533.9 | 8.4 |
| 5.2 to 7.6 | 81 | 9.7 | 506.5 | 8.0 |
| 7.7 to 10.2 | 55 | 6.6 | 489.5 | 7.7 |
| 10.3 to 12.7 | 41 | 4.9 | 476.2 | 7.5 |
| 12.8 to 15.2 | 25 | 3.0 | 353.8 | 5.6 |
| 15.3 to 17.8 | 26 | 3.1 | 432.8 | 6.8 |
| 17.9 to 20.3 | 18 | 2.2 | 343.2 | 5.4 |
| 20.4 to 22.9 | 13 | 1.6 | 278.1 | 4.4 |
| 23.0 to 25.4 | 22 | 2.7 | 534.4 | 8.5 |
| 25.5 to 31.8 | 16 | 1.9 | 453.1 | 7.2 |
| 31.9 to 38.1 | 13 | 1.6 | 452.9 | 7.2 |
| 38.2 to 44.4 | 6 | 0.7 | 247.9 | 3.9 |
| 44.5 to 50.8 | 7 | 0.8 | 334.0 | 5.3 |
| 50.9 to 57.2 | 3 | 0.4 | 163.1 | 2.6 |
| 57.3 to 63.5 | 1 | 0.1 | 59.4 | 0.9 |
| 63.6 to 69.9 | 1 | 0.1 | 69.1 | 1.1 |
| 70.0 to 76.2 | 0 | 0 | 0 | 0 |
| 76.3 to 82.6 | 1 | 0.1 | 79.2 | 1.3 |
| 82.7 to 88.9 | 0 | 0 | 0 | 0 |
| 89.0 to 95.2 | 0 | 0 | 0 | 0 |
| 95.3 to 101.6 | 0 | 0 | 0 | 0 |
| 101.7 to 108.0 | 0 | 0 | 0 | 0 |
| 108.1 to 114.3 | 0 | 0 | 0 | 0 |
| 114.4 to 120.6 | 0 | 0 | 0 | 0 |
| 120.7 to 127.0 | 0 | 0 | 0 | 0 |
| 127.1 to 133.4 | 0 | 0 | 0 | 0 |
| 133.5 to 139.7 | 1 | 0.1 | 137.9 | 2.2 |

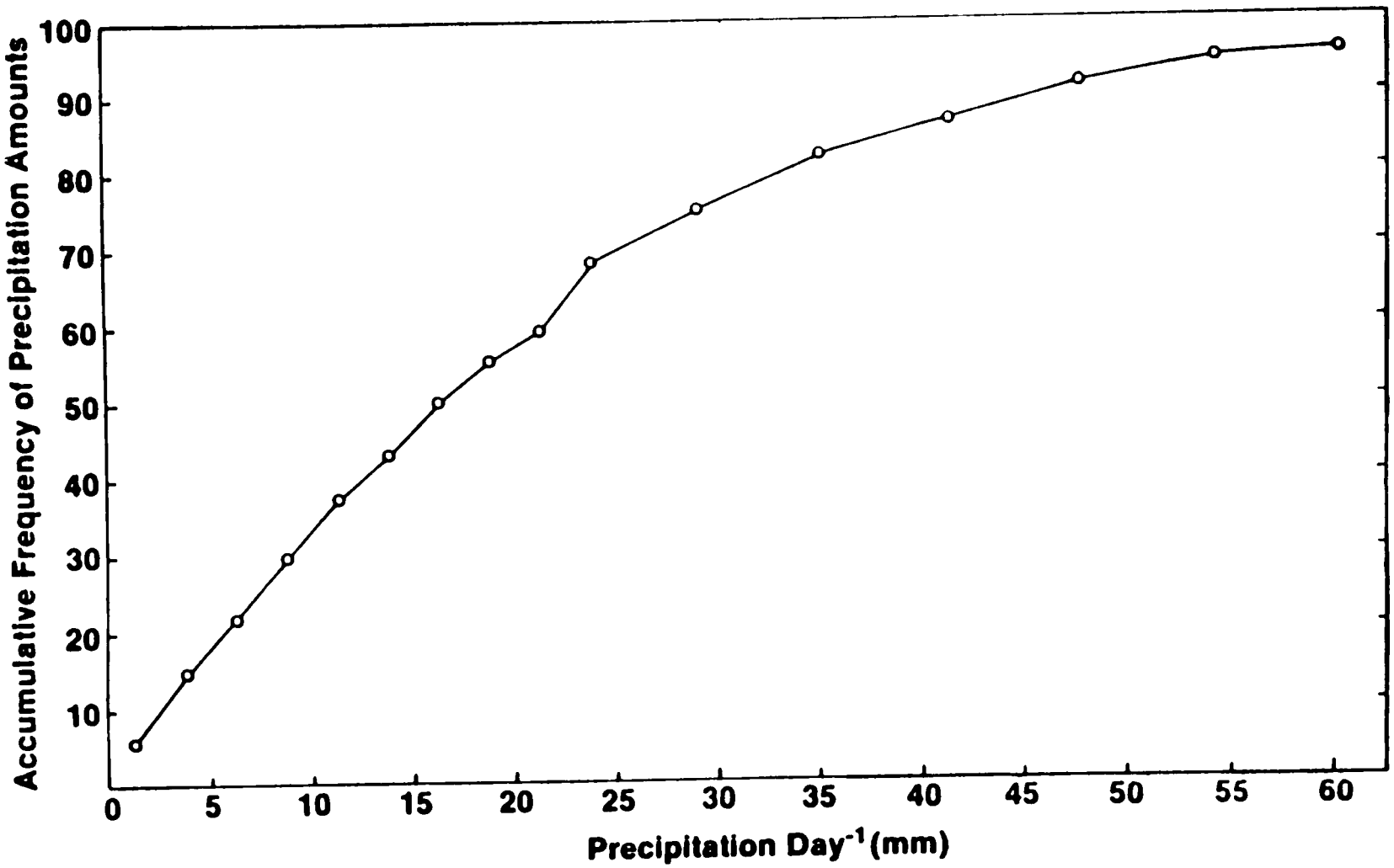


Fig. 17. Cumulation precipitation frequencies at Lubbock, Texas, for the period 1971 to 1983, inclusive.

system, and (c) planes of equal moisture content advanced into the soil linearly with time. Therefore, any analysis of precipitation effectiveness will depend on the length of time between precipitation events. Dugas (1983) has provided information about precipitation and dry period probabilities at various Texas locations.

Because of these length-of-time effects between precipitation events, this thesis will simply illustrate usefulness of the data in estimating precipitation effectiveness.

Assume that a deep plowing operation on the Texas High Plains increases the clay content of the upper 100 mm of the profile from 4% to 14%. Further assume that the bulk density of this 100-mm depth of soil is 1.55 $g/cm^3$ and that the surface 50 mm is oven dry and the depth of 50 to 100 mm is at wilting percentage (-1500 kPa matric potentials). How much rainfall will be required to wet the soil profile to a depth of 100 mm at each of the clay contents?

Figure 1 indicates that a soil with 4% clay will retain a gravimetric water content of 0.247 g/g and a volumetric water content of 0.383 $mm^3/mm^3$ at -10 kPa matric potential. Thus, 19.2 mm of water will be required

to wet the upper 50 mm of soil to field capacity (-10 kPa). At 14% clay, the gravimetric water content will be 0.325 g/g and a volumetric water content of 0.504 $mm^3/mm^3$. Thus, 25.2 mm of water will be required to wet the upper 50 mm of soil when the clay content has been increased to 14%.

Figure 1 also indicates that (0.247 - 0.012) 1.55 $g/cm^3$ or 0.364 $mm^3/mm^3$ will be required to wet the 4% soil layer at 50- to 100-mm depth to field capacity (-10 kPa) and (0.325 - 0.051) 1.55 or 0.425 $mm^3/mm^3$ will be required to wet the 14% clay content soil layer to field capacity from wilting point. Thus, 0.364(50) or 18.2 mm will be required to wet the 50-mm thick layer of 4% clay content from wilting point to field capacity and 0.425(50) or 21.2 mm will be required to wet the 14% clay layer.

The difference in precipitation amounts to wet the upper 100 cm of soil under the stated conditions is (25.2 - 19.2) + (21.2 - 18.2) or 9 mm of precipitation. It would take 37.4 mm of precipitation to rewet the upper 100 mm of soil containing 4% clay and 46.4 mm to rewet 100 mm layer containing 14% clay. About 84% of the daily precipitation events are less than 37.4 mm and about 90% are less than 46.4 mm (Table 9, Figure 17). Under the assumed

conditions, 16 percent of daily precipitation events will rewet the upper 100 mm of the 4% clay content profile but only 9 percent of the events will rewet the 14% clay profile.

## Deep Plowing Recommendations

The primary purpose of deep plowing sandy soils of the Texas High Plains is to help control wind erosion damage when there is insufficient cover during the windy season. The clay added to the surface few centimeters of soil is more coherent when dry and will form a rougher surface than the sandier surface that has not been deep plowed. This rougher land surface reduces wind velocity and carrying capacity for soil particles. The added clay content also will retain more water and may increase water flow in the vicinity of seeds and seedling roots.

The present research has shown that more water is retained in the surface 100 mm of soil after deep plowing than before it. This additional water retention usually will reduce effectiveness of the precipitation or irrigations on the Texas High Plains.

Whether or not the farmer should deep plow his sandy soil depends on the land characteristics and on the subsequent management he intends to follow. First, the farmer should deep plow only if the soil fits the standards and specifications described on pages 64 and 65. Second, the farmer or rancher should not deep plow if he intends to plant perennial crops, either irrigated or rainfed. The permanent cover will provide erosion protection. Deep plowing is costly and will reduce effectiveness of rainfall and of irrigation water if applied. Third, the farmer should not deep plow if a cold-resistant winter crop, such as wheat, is planted and irrigated. The growing wheat will provide the erosion protection. However, the farmer should deep plow if rainfed cereals are planted. If cereals are planted without any irrigation capability, stand establishment will be insufficient to control erosion during dry years without some emergency tillage to provide surface roughness. Fourth, the farmer should deep plow sandy fields, both irrigated and dryland (rainfed), if the fields will be bare of vegetation during March, April and May. Under these conditions, protection from erosion and from sand damage to young seedlings is more important than the reduced precipitation effectiveness.

# CHAPTER V

# CONCLUSIONS

The conclusions of the research are as follows:

1. Clay accounted for 54%, 90% and 93% of the deviation in gravimetric water content at -10 kPa, -33 kPa and -1500 kPa matric potentials respectively (Figure 1). Of the soil components studied, clay had the highest correlation coefficient value at the three matric potentials.

2. Silt accounted for 49%, 57% and 54% of the deviation in gravimetric water content at -10 kPa, -33 kPa and -1500 kPa matric potentials, respectively. Silt had the second greatest correlation coefficient value with water retention at the three matric potentials.

3. Organic matter accounted for 32%, 16% and 19% of the deviation in gravimetric water content at -10 kPa, -33 kPa and -1500 kPa, respectively.

4. Calcium carbonate accounted for 17%, 2% and 4% of the deviation in gravimetric water content at -10 kPa, -33 kPa and -1500 kPa, respectively.

5. Coarse sand accounted for 6%, 0.2% and 1%; medium sand accounted for 25%, 8% and 10%; fine sand accounted for 11%, 43% and 36%; and very fine sand accounted for 35%, 46% and 39% of the deviation at -10

kPa, -33 kPa and -1500 kPa matric potential respectively. There was a very low level of very coarse sand. All the sand-sized fractions were negatively correlated with gravimetric water content, except very fine sand, which was positively correlated.

6. Silt accounted for 32.3% of the deviation in the available water. Silt had the highest correlation coefficient value among the 9 variables studied.

7. Organic matter accounted for 29.3% of the deviation in the available water. Plant available water was positively correlated with organic matter content. There was only one sample with greater than one percent organic matter content and forty-nine samples with less than 0.5 percent organic matter content.

8. Clay accounted for 25.6% of the deviation in the available water. Available water was positively correlated with clay content.

9. Calcium carbonate accounted for 19.7% of the deviation in the available water. However, there was only two samples with a $CaCO_3$ equivalent greater than 0.8%.

10. Coarse sand, medium sand, fine sand, and very fine sand accounted for 8.1%, 26.8%, 2.2% and 23% of the deviation in the available water, respectively. All the

sand fractions (Figure 13, 14, 15) were negatively correlated with available water, except very fine sand, which was positively correlated.

11. Deep plowing the sandy soils studied here will increase clay content of the surface soil and reduce the fraction of the rains at Lubbock, Texas that will rewet the upper 100 mm of soil to field capacity.

12. The increased clay brought to the soil surface through deep plowing will help form clods during emergency tillage. The cloddy surface will reduce wind velocity, soil movement and damage to seedling plants.

13. The increased clay brought to the soil surface will increase the proportion of rainfall or irrigation water that will rapidly evaporate from the soil, thus reducing effectiveness of precipitation.

14. The farmer should deep plow the sandy soils of the Texas High Plains if they meet certain standards, the deep plowing is carried out according to outlined specifications and if the fields will have insufficient protection during the critical months of March, April and May.

15. The farmer should not deep plow the sandy soils of the Texas High Plains if the soils will have an adequate vegetative cover during the critical months of March, April and May.

## LITERATURE CITED


Alizai, H.U. and L.C. Hulbert. 1970. Effects of soil texture on evaporative loss and available water in semi-arid climates. Soil Sci. 110: 328-332.

Bennett, H.H. and W.C. Lowdermilk. 1938. General aspects of the soil-erosion problem, in Soils and Men. 1938 Yearbook of Agriculture. USDA, Washington, DC. pp. 581-608.

Bisal, F. and J. Hsieh. 1966. Influence of moisture on erodibility of soil by wind. Soil Sci. 102: 143-146.

Bond, J.J. and W.O.Willis. 1969. Soil water evaporation: surface residue rate and placement effects. Soil Sci. Soc. Am. Proc. 33: 445-448.

Brady, N.C. 1974. The nature and properties of soils. 8th edition. Macmillan Publishing Co., Inc. New York. pp. 43-44.

Bryant, R.B. 1977. A comparison of physical and chemical properties of selected irrigated, dryland, and native range Texas High Plains soils. Thesis for Master of Science, Texas Tech University.

Chepil, W.S. 1949. Soil erosion by wind. Can. Dept. Agr., Ottawa, Ont.

Chepil, W.S. 1953. Field structure of cultivated soils with special reference to erodibility by wind. Soil Sci. Soc. Am. Proc. 17: 185-190.

Chepil, W.S. 1955. Factors that influence clod structure and erodibility of soil by wind: sand, silt, and clay. Soil Sci. 80: 155-62.

Chepil, W.S. 1962. "Mechanics of wind erosion and significance as a sediment source." Presented at ARS-SCS Sedimentation Workshop, Panguitch, Utah.

Danielson, R.E. and M.B. Russell. 1957. Ion absorption by corn roots as influenced by moisture and aeration. Soil Sci. Soc. Am. Proc. 21: 3-6.

Dregne, H.E. 1982. Historical perspective of accelerated erosion and effect on world civilization. In B.L. Schmidt et al., Editors, Determinants of Soil Loss Tolerance. American Society of Agronomy Special Publication 45: 1-14.

Dugas, W.A. 1983. Agroclimatic atlas of Texas. Part 5. Precipitation and dry period probabilities at Texas research and extension centers. Texas Agric. Exp. Sta. MP-1531.

Fairbourn, M.L. and H.R. Gardner. 1975. Water-repellent soil clods and pellets as mulch. Agron. Jour. 67: 377-385.

Gingrich, J.R. and M.B. Russell. 1956. Effect of soil moisture tension and oxygen concentration on the growth of corn roots. Agron. Jour. 48: 517-520.

Greacen, E.L. 1960. Water content and soil strength. J. Soil Sci. 11: 313-333.

Greb, B.W., D.E. Smika and A.L. Black. 1970. Water conservation with stubble mulch fallow. J. Soil Water Conserv. 25: 58-62.

Gurr, C.G. 1962. Use of gamma rays in measuring water content and permeability in unsaturated columns of soil. Soil Sci. 94: 224-229.

Hadas, A. 1975. Drying of layered soil columns under nonisothermal conditions. Soil Sci. 119: 143-148.

Hagan, R.M., Y. Vaadia and M.B. Russell. 1959. Interpretation of plant responses to soil moisture regimes. In A.G. Norman, Editor, Advances in Agronomy. Academic Press, New York. 11: 77-98.

Harrold, L.L., D.B. Peters, F.R. Dreibelbis and J.L. McGuinness. 1959. Transpiration evaluation of corn grown on a plastic-covered lysimeter. Soil Sci. Soc. Am. Proc. 23: 174-178.

Henao, J. 1976. Soil variables for regressing Iowa corn yields on soil management and climatic variables. Unpublished Ph. D. Dissertation, Library, Iowa State University, Ames, Iowa.

Hillel, D. and P. Berliner. 1974. Waterproofing surface-zone soil aggregates for water conservation. Soil Sci. 118: 131-135.

Hopkins, E.S. 1935. Soil drifting in Canada. Trans. 3rd Intern. Cong. Soil Sci. 1: 403-405.

Lehane, J.J. and W.J. Staple. 1960. Relationship of the permanent wilting percentage and the soil moisture content at harvest to the 15-atmosphere percentage. Can. J. Soil Sci. 40: 264-269.

Marshall, T.J. and J.W. Holmes. 1979. Soil Physics. Cambridge University Press. pp. 242-243.

Mathers, A.C. and N.H. Welch. 1964. Pans in the Southern Great Plains soils. II. Effect of duration of radial root restriction on cotton growth and yield. Agron. Jour. 56: 313-315.

McCune, D.L. 1958. Effect of moisture tension on the production and movement of carbohydrates in plants. Ph. D. Thesis, Purdue University.

Pallas, J.E. Jr. and G.G. Williams. 1962. Foliar absorption and translocation of $P^{32}$ and 2,4-dichlorophenoxyacetic acid as affected by soil-moisture tension. Bot. Gaz. 123: 175-180.

Peters, D.B. 1957. Water uptake of corn roots as influenced by soil moisture content and soil moisture tension. Soil Sci. Soc. Am. Proc. 21: 481-484.

Richards, L.A. and L.R. Weaver. 1943. Fifteen atmosphere percentage as related to the permanent wilting percentage. Soil Sci. 56: 331-339.

Russel, J.C. 1976. Some historical aspects of stubble mulch tillage. In Conservation Tillage, Proc. of Great Plains Workshop. Great Plains Agr. Council, Lincoln, Nebr. pp. 1-12.

Soil Conservation Service, USDA. 1974. Standards and specifications for deep plowing. (Unpublished report).

Soil Conservation Service, USDA. 1977. Severe wind erosion hits Plains. Soil Conserv. 42: 22.

Soil Survey Staff, USDA. 1951. Soil Survey Manual. Agric. Handbook No. 18, p. 207.

Soil Survey Staff, USDA. 1964. Soil Survey of Cochran County, Texas. p. 22.

Taylor, H.M. and E. Burnett. 1963. Some effects of compacted soil pans on plant growth in the Southern Great Plains. J. Soil and Water Conserv. 18: 235-236.

Taylor, H.M., L.F. Locke and J.E. Box. 1964. Pans in Southern Great Plains soils. III. Their effects on yield of cotton and grain sorghum. Agron. Jour. 56: 542-545.

The Texas Conservation Needs Committee, USDA. 1962. Texas soil and water conservation needs inventory. Soil Conserv. Serv., Temple, Texas.

Thompson, L.M. and F.R. Troeh. 1978. Soils and Soil Fertility. McGraw - Hill Book Co. pp. 99-101.

Unger, P.W. 1975a. Water retention by core and sieved soil samples. Soil Sci. Soc. Am. Proc. 39: 1197-1200.

Unger, P.W. 1975b. Relationships between water retention, texture, density and organic matter contents of West and South Central Texas soils. The Texas Agricultural Experiment Station, Miscellaneous Publication No. 1192C. pp. 1-20.

Wiegand, C.L. 1962. Drying patterns of a sandy clay loam in relation to optimal depth of seeding. Agron. Jour. 54: 473-476.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses - a guide to conservation planning. Agric. Handbook 537. USDA, Washington, DC.

Wisner, G.H. 1955. Deep plowing to fight the wind. Soil Conserv. 20: 276-277.