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Organic matter is a complex heterogenous soil component, a product of interactions between chemical and biological factors. Changes in management practices that alter decomposition rates and organic matter composition result in readjustments to the group composition of the soil's organic matter.

Soil organic matter characteristics were studied by determining total soil carbon and nitrogen, hot water extractable carbon and nitrogen. Humic acid, fulvic acid and humins were determined from a NaOH/Na-pyrophosphate extraction of soil organic matter. Humic acid optical densities were determined.

Paired pasture and cultivated grass seed sites were selected from a drainage association of four soils in Oregon's southern Willamette Valley.

Grass seed management practices combined with annual burning, winter fertilizing and infrequent cultivation, resulted in lower levels of total carbon compared to pasture sites with infrequent fertilization and no burning. Significant increases in carbon were found over a ten year period independent of management practices. No detectable buildup of straw ash residue was indicated in cultivated grass seed soils over a ten year period.

Total nitrogen values were significantly higher in pasture sites. Significant increases in total nitrogen were found after a ten year period independent of management practices. Soluble nitrogen values were significantly higher in pasture sites. Better drained soils contained higher levels of soluble nitrogen than poorly drained soils. No significant changes in soluble nitrogen occured over a ten year period.

Carbon:nitrogen ratios were significantly wider in pasture sites. No significant changes in C/N ratios occurred over a ten year period.

With the techniques used, no significant differences were detected in humic fractions between pastured and cultivated grass seed sites. Trends of lower humic acid, higher fulvic acid and humins in pasture compared to cultivated grass seed crop sites were detected. Optical density measurements indicated a smaller molecule for humic acids extracted from pasture sites than from cultivated grass seed crop sites.

Soluble carbon data indicated a significantly more humified organic matter in cultivated grass seed crop sites compared to pasture sites and over a ten year period.

Evaluation of the data indicated no significant difference in organic matter quality between pasture and cultivated grass seed crop sites. No single management practice could be identified as affecting the qualitative character of the organic matter in the soils used in this study.

# The Status of Organic Materials in Several Southern Willamette Valley Grassland Soils

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# INTRODUCTION

Soils in the Willamette Valley including soils in this study area have been subjected to burning from pre-settlement days to the present times. Indians used burning to assist in their hunting and gathering activities. Johannessen et al. (1971) contend that the Willamette Valley has been subjected to regular burning over the past 350 years. This has been sufficient time to allow this external input to characterize its presence on these soils and their mineral/organic components.

Since post-settlement times, widespread burning was restricted. In recent times, burning is again in widespread use for straw residue removal, disease and weed control and fertility requirements.

Many arguments for and against burning have been raised concerning its use as an agricultural management tool. Today, agriculture burning has become a political football. Few question its purpose and usefulness; for weed and disease control. Its physical side effects, namely visible and smellable air pollution, have been the major points of contention. Apparent soil quality deterioration, e.g. poorer drainage and possible loss or change in soil organic matter, is a more recent concern (Patching, 1975).

The purpose of this study was to investigate and compare the status of soil organic matter of several important grass seed producing soils that had been annually burned for at least ten years. The main objective was to document Patching's contention (Patching, 1975) that the soils in this study area are undergoing significant changes, e.g. resulting in taxonomic reclassification (Mollisols to Alfisols) as a result of management practices. The published information is deficient in this area. There is considerable literature on burning and its effects on the soil's chemical and physical properties. Total carbon and nitrogen are usually the only measure of the organic component that are studied (Wells, 1971).

Organic matter is an active dynamic component which is characterized by its group composition. To characterize organic matter, these compositional relationships must be identified and quantified. When the soil organic matter has been described, then conclusions can be drawn and management practices evaluated.

# LITERATURE REVIEW

## Grassland Burning

Grassland burning has a different and somewhat lesser impact on soil components and vegetative characteristics than forest burning. Under forest conditions, considerably greater quantities of fuel are available for combustion. Three dimensional fires occur more frequently in forests than in grasslands. Spot fires are also important propagative mechanisms in forest fires. Some "spotting" occurs in grass fires, but it is a relatively unimportant mechanism. Grasslands are exposed to the full force of all weather factors and, containing a finer fuel, react quickly to weather changes (McArthur, 1966). Higher burn temperatures and greater physiologic damage to vegetation occur in forests, whereas grasses have physiologically adapted to periodic burning.

Attitudes of South American scientists, as reported by Rosevear (1948), indicated an almost universal disapproval of grassland burning. Although quantitative data were absent, such views dominated reputable work reported by other scientists. Vincent (1935; cited in Rosevear, 1948) evaluated the premise that burning impoverished the soil by affecting humus and nitrogen contents and reducing soil fertility. He considered these claimed changes as unsubstantiated.

As quantitative data accumulates, it becomes increasingly apparent that fire is not always detrimental to the soil. Under the appropriate circumstances, desirable effects can be maximized while the undesirable effects are minimized or negated. Knowledge of the effects of agricultural burning is critical. If it is found that burning has no detrimental effects on soil, it justifiably can be used for fuel reduction, fertility needs, rangeland improvement, clearing new land or field sanitation. However, if burning has adverse effects on soil, then these effects must be major considerations in evaluating the use of fire as an agricultural practice. It must be recognized that there is no single answer concerning the effects burning has on soil physical and chemical properties. Critical evaluation of burning effects on soil properties requires consideration of fuel status, intensity and type of fire, soil type, topography and interacting environmental conditions.

Temperature

The effects of heat on soil properties and processes depend on the nature of the fuel, weather conditions and burn temperatures. The type, quantity and disposition of accumulated fuel since the previous burn are important factors of any fire (Hopkins et al., 1948). The type of fire is important. Byram (1958) reported slightly higher temperatures with backfires than with headfires. Soil surface temperatures depend on the amount of fuel and its character (standing, cut, compacted or scattered). It was found that temperatures 3 to 7 mm below the soil surface ranged from 150° to 175° C over a period of two to four minutes during and after a burn (Heyward, 1938). Soil temperatures of 65° to 75° C were recorded 15 mm below the soil surface (Tothill and Shaw, 1968). The temperature data show that grassland fires are seldom severe enough to directly oxidize substantial quantities of soil organic substances present more than a few millimeters below the soil surface.

Fire affects post-burn soil temperatures indirectly, by removal of plant and litter cover. Kucera and Ehrenreich (1962) observed soil temperatures 2.2° to 9.8° C higher on burned plots than on nonburned plots. Other workers (Aldous, 1934; Ehreneich and Aikman, 1963) reported higher post-burn soil temperatures up to 18 cm below the soil surface of burned compared to nonburned plots. A direct relationship between soil surface temperatures and vegetative cover was shown. Soil temperatures decreased as plot vegetative cover increased on burned plots and the temperature differences between burned and nonburned plots decreased.

## Physical Properties

Removal of vegetative cover by burning causes changes in soil physical properties. This exposes soil surfaces to rainfall impact and subsequent dispersion of the fine particles. Auten (1934) and Arend (1941) reported decreases in macro-porosity due to rainfall impact dispersion. They reported that the finer textured soils had increased bulk densities due to burning. Wahlenberg (1935) reported that bulk densities decreased and porosity increased in plots where fire had been excluded for several years.

It is apparent that the degree of vegetative cover removal by burning has a direct relationship to changes in porosity and bulk densities.

Heyward and Barnett (1934) reported structural changes from burning. Fine crumb structures were transformed into single-grained or massive structureless form. These structural changes subsequently decreased infiltration rates. Burgy and Scott (1952) concluded that ash deposited on soil surfaces did not render the soil impervious to water. They found that ash covered soil wetted as readily as soil on nonburned plots. They also reported a burn-induced trend towards a larger aggregate size distribution.

Chemical Effects

Both burn and natural decomposition of organic materials releases plant nutrients into the soil. Compared to slow natural release, burning results in a rapid release of nutrients. Part is lost to the atmosphere and part is converted into soluble forms which move down into the soil profile.

Burning, by releasing basic cations from plant material into the soil, generally raises the soil pH. Ehrenreich and Aikman (1963) pointed out that pH increases were not significant. Any pH increase usually persisted less than two years.

Several workers reported that total organic matter content was not reduced by repeated light burning durning twenty years of annual burning (Heyward and Barnette, 1934; Moehring et al., 1966; Wells, 1971). These authors indicated increased soil carbon values with burning. Greene (1935) felt that increased levels of organic matter were due to increased productivity and vegetative changes. Shantz (1947) as had Wahlenberg et al., (1939) reported that loss-on-ignition methods did not distinguish between forms of soil organic matter. Bremner and Jenkinson (1960a,b), using a wet-combustion method, indicated that organic matter increased on infrequently burned sites.

Most investigations of soil nitrogen levels reported increased nitrogen availability as a consequence of burning (Aldous, 1934; Norman and Wetslaar, 1960). Garren (1943) reported that nitrogen increases were the result of legume increases, resulting in increased nitrogen fixation. Kucera and Ehrenreich (1962) suggested that removal of surface organic materials by burning, may reduce soil C/N ratios, causing increased nitrogen availability.

Except for nitrogen and sulphur volatilization, low temperature grassland burning causes no direct nutrient losses from the soil ecosystem. Burning releases nutrients at the soil surface where they are subjected to erosion and/or leaching. Greene (1935) believed that burning returned the nonvolatile nutrients to the soil immediately after burning. Greene (1935) and Daubenmire (1968) regard the stimulative effect of burning on grassland soils as an indirect result of increased soil temperatures. Increased post-burn soil temperatures, as the active factor in producing earlier growth, causes greater vegetative stimulation rather than increased quantities of readily available nutrients from plant ash.

Soil Organic Materials

Soil organic materials consist of a series of products ranging from undecomposed plant and animal tissues, to stable amorphous substances. The system dynamics are determined by continous additions of organic materials (plant and animal residues) into the soil and their continual transformations by biological, chemical and physical processes.

Leibig (1842) described humus as "a brown substance easily soluble in alkalies but only slightly so in water and produced during the decomposition of vegetable matters by the action of acids or alkalies." During a span of well over 100 years, the basic description of soil humus has remained basically the same. Kononova (1966) best catagorized this soil organic system into two main groups. The first group of substances are "components of decomposing plant and animal residues, products of their decomposition and products of bacterial resynthesis." The organic substances within this group belong to protein decomposition products, organic acids, carbohydrates, fats, waxes and resins. The non-specialized compounds comprise approximately ten to fifteen percent of the total soil organic system.

The second group of substances, collectively labelled by Kononova as "humus substances",having undergone more extensive chemical and physical decomposition and condensation, have lost their former chemical identity. This group comprises 85 to 90 percent of the total soil organic system.

Kononova (1966) labeled the combination of these two groups as "soil organic matter."

## Humus Composition

### Humic Acids

In this review, the soil organic substances are classified into three operational groups: Humic acids, fulvic acids and humins. Each operational group, although composed of subgroups, is regarded as having different chemical and physical properties peculiar to each separate group.

Kononova (1966) refers to humic acids as substances "normally extracted from soil by solutions (NaOH, KOH, $NH_4OH$, $NaHCO_3$, $Na_2P_2O_7$, NaF, etc.) forming amorphous precipitates with acids." Bremner (1950) considered humic acids as an "operational definition" based upon certain chemical and physical properties. Humic substances are those which are extracted from organic tissues, removed from soil organo-mineral particulates or those in solution. The characteristics of that portion of humic substances which are insoluble in acid (humic acid) are controlled by the nature of the vegetation, soil type, aeration, pH, environmental factors such as temperature and rainfall (Waksman, 1952). Felbeck (1965) described humic compounds as "amorphous, three-dimensional polymeric, acidic substances of high molecular weight, with a more or less aromatic nature."

Humic acids result in part from microbial and chemical degradation of plant and animal residues. These degraded residues are subjected to secondary processes of condensation and some polymerization of phenolics, quinones and proteinaceous compounds from soil microorganisms acting on soil carbohydrates (Kononova, 1966; Steelink, 1963). Humic acids are characterized as complex, heterogenous, high-molecular weight heteropolycondensate molecules (Kononova, 1966). The elemental composition of humic acids from many soils, has been determined as being 50 to 60 % carbon, 30 to 40 % oxygen, 3 to 5 % hydrogen and 3 to 5 % nitrogen.

Fulvic Acids

Fulvic acids are characterized as "complex heterogenous low-molecular weight molecules composed of weakly expressed aromatic structural units with many side chains (sugars, amino acids, etc.)" (Kononova, 1966). A working definition of fulvic acids is a light yellow acid that is soluble in both alkalis and acids (Stevenson and Butler, 1969; Kononova, 1966). An elemental composition of 44 to 48 % carbon, 43 to 49 % oxygen, 5 to 6 % hydrogen and 1 to 3 % nitrogen typifies fulvic acids. The structural units are composed of weakly aromatized methoxyl, carboxyl and phenolic hydroxyl groups (Wright and Schnitzer, 1960, 1961).

No sharp division exists between humic and fulvic acids. Kononova (1966) regards the lower-molecular weight fulvic acids as simple representatives of humic acids, being less aromatic and condensed with an elemental composition differing from that of humic acids. Fulvic acids contain less carbon, nitrogen and more oxygen and hydrogen than humic acids. Schnitzer (1967) reported from studies conducted on Canadian organic soils, similiar relationships as those reported by Kononova. He concluded that fulvic acids were positively correlated with increasing humification whereas humic acids were negatively correlated. To him, this indicated that fulvic acids are probably condensation by-products of humic acids.

Numerous experiments conducted by Alexandrova (1966) on the decomposition of various organic residues, showed that at any stage of decomposition, a double-component system of both humic and fulvic acids existed. Alexandrova proposed a mechanism explaining the relationships between humic and fulvic acids. She hypothisized that in soil, break-down of high-molecular decomposition products occurs with the resulting products being separated by interactions with collodial mineral components. Thus, fulvic acids are separated from humic acids by organo-mineral interactions. This separation of fulvic acids from young humic acids continues with time.

Data presented by Mutaker and Wagner (1967) based upon $C^{14}$-labeled glucose added to soil, revealed that these classical fractions (humic and fulvic acids) did not represent successive stages of decomposition. Their data showed that these fractions did not vary in their contents with increased incubation times. Sorenson (1963), working with $C^{14}$-labeled barley straw, reported that the relative distribution of $C^{14}$ in humic and fulvic acids is dependent upon the type of plant constituent added to the soil. Water-soluble substances were shown to contribute largely to the fulvic and humic acid fractions. Lignin contributed largely to the humic acid and humin fractions.

Humin

Humin is the least studied of the classical humic fractions. Humin is defined as "that portion of the soil humus which is insoluble in alkali and acidic extracting reagents" (Kononova, 1966; Stevenson and Butler, 1969; Felbeck, 1965).

In soils, the humin group is represented by material bound to soil mineral components and by carbonized plant residues (These latter particles are not necessarily the result of burning). To some workers, humin in most soils is just humic acids, with some fulvic acids, insolubilized by association with soil mineral material (Kononova, 1966).

Other workers (Tyurin and Gutkina, 1940 and Khan, 1959; both cited in Kononova, 1966) have reported that humic acids isolated from the humin group contain lower carbon, and greater hydrogen and oxygen percentages than extractable humic acids. Based upon a narrower oxygen:hydrogen ratio, these same authors reported humic acids isolated from humins are less oxidized than extractable humic acids. From these indications, Kononova (1966) suggested that the humic acids isolated from the humin group have a less complex structural arrangement than the extractable humic acids. She further postulated that a stronger chemical bonding of humic acids to the mineral component results from this simplified structure. Kononova further indicated that the mineral component acting as a catalytic magnet, imparts a psuedostructure to young and simple humic acid fragments. This produces strongly bonded humic acids which are nonextractable under mild conditions. Williams (1939; cited in Kononova, 1966) pointed out that the conversion of humic acids into a nonextractable humic acid is an irreversible process. Schnitzer and Khan (1972) reported that humin is considered less humified than humic acids. However, from their work they believe that humic acids are less humified than humins which are less humified than fulvic acids. In their study, they pointed out that the data may be questionable due to purification procedures.

Other views are that humin may consist partly of carbonized plant residues. These probably result from small plant fragments subjected to conditions of poor or restricted aeration where carbonization processes occur (Najmr, 1960; cited in Kononova, 1966).

## Humus Quality

Humus materials play an active role in the biogeochemical processes of soil formation. Their role in soil fertility, nutrient recycling and aggregation are unique and important features in the soil ecosystem. In addition to their role as a source for plant nutrients and aggregation, soil humic substances have an active role in soil water-holding capacity, exchange capacity and buffering capacities.

Systematic classification of humus may show relative relationships to plant growth and development. Humus qualitative characteristics can be correlated to vegetative, climatic and biological regimes under which the organic materials accumulated. Other factors affecting humus development are soil pH, drainage and texture.

It has been inferred that soil organic matter has quantitative and qualitative components. The quantitative component is easily discerned by appropriate analytical methods. On the other hand, the qualitative component is not so easily discerned. No single analytical method can adequately describe quantitatively or qualitatively or both, those aspects of soil organic matter that relate to the soil ecosystem. Van Cleve (1974) stated that the organic matter produced on a particular site is "a product of the quality of that site as well as a product of particular species of plants and animals producing the organic matter." The average quality of soil organic matter is then an index of the organic materials that have undergone decomposition. Quantitative relationships of soil organic matter quality can be correlated with their functions and interactions effecting the soil ecosystem.

## Chemical Factors Relating to Soil Humus Quality

### Humus Composition

The contents and ratios of humic acids, fulvic acids and humins are used in distinguishing relative differences in humus composition under varying environmental conditions. The bulk of reported literature has dealt mainly with the humic acid fraction.

Humic acids are less acidic, as indicated by potentiometric titration curves (Khanna and Stevenson, 1962; Kononova, 1966), contain more carbon, nitrogen, sulphur, phosphorous and less oxygen than fulvic acids. Humic acids are more "condensed" than fulvic acids. This is based upon comparisons of carbon:hydrogen ratios which indicate relative molecular stability.

Recent data suggest that fulvic acids are more humified than humic acids. This concept was used to indicate the degree of humification and stability of organic matter present in a specific soil (Schnitzer, 1967). The relative contents of humic and fulvic acids are used to indicate relative degrees of humification. Schnitzer (1967) described the relationship between humic and fulvic acids by their degree of oxidative degradation. Based upon a study of Canadian organic soils, Schnitzer postulated that humification results in higher fulvic acid contents. The principle reaction mechanism governing humification was oxidative degradation of humic acids to fulvic acids by chemical and/or biological agents. Increased humification is therefore associated with increased fulvic acid content and a consequent decreased humic acid content. This is the reverse of others' conclusions.

Kononova and other European workers have done the bulk of the work on humic and fulvic acid relationships. Kononova (1966) regards increasing humic acid:fulvic acid ratios as indicating better quality soil organic matter, progressively from Podsols (Spodosols) to Chernozems (Mollisols). The humic acid:fulvic acid ratios vary from 0.6 to 0.8 in Spodosols to 1.7 to 2.5 for Mollisols. Kononova relates higher humic acid:fulvic acid ratios to a higher degree of humification. The development of humic and fulvic acid fractions is controlled by environmental factors, namely temperature and moisture regimes, microbial distributions, vegetative and mineral constituents. Generally speaking, Mollisols are formed under those conditions conducive to grass communities which result in decomposition of tremendous root residues. Associated with dryer conditions, dessication occurs, promoting formation of humic acids at the expense of the fulvic acid fraction. Under a higher and more uniform moisture regime conditions are less favorable for humic acid formation, hence accumulation of fulvic acids occurs. The humic acid:fulvic acid ratio is an indirect quantitative measure of qualitative humus composition. It is an expression of the ecosystem's ability to decompose and synthesize organic materials.

Determining the optical properties of humic substances is useful in evaluating their nature and properties. Regular differences between humic acids are evident from optical density data of differing soils. Past studies reported humic acids as showing a direct relationship between light absorption and aromaticity (Kumada, 1955; Kononova, 1966). Using the visible light spectrum, a ratio of extinction points are determined from absorption values determined at 465 and 665 nm. This is usually termed the $E_4/E_6$ ratio. From data presented by Kononova, the $E_4/E_6$ ratio decreases from between 5 to 6 in

Spodosols to 3 to 4 in Mollisols. Past literature suggested that this decrease in $E_4/E_6$ ratio represents an increase in the aromatic condensation of the humic acid molecule (Kononova, 1966; Schnitzer and Khan, 1972). Using only the $E_{465}$ value, Kononova attributed high values to an aromatic structure and lower values to structures with a high aliphatic content. The literature reported that humic acids are composed of strong aromatic structures while fulvic acids are more aliphatic in nature. Determining the $E_4/E_6$ ratio was considered a useful tool in determining the relative degree of humification of humic acids.

Recent work by Chen et al. (1977) (reported after this study was underway) showed results correlating the magnitude of $E_4/E_6$ ratios of humic and fulvic acids with the particle or molecular sizes and weights of these substances rather than degree of aromatic character. Less significant correlations were obtained by the authors between $E_4/E_6$ ratio and percent carbon (negative), COOH groups (positive) and total acidity (positive). Chen et al. explained their data by associating a low $E_4/E_6$ ratio with a large molecular size or higher molecular weight. Consequently, a high $E_4/E_6$ ratio is associated with a smaller molecular size or lower molecular weight. The larger molecular size, having a high carbon content, is low in oxygen, COOH groups and total acidity. Smaller molecular sizes, by contrast, have less carbon but higher contents of oxygen, COOH groups and total acidity. Chen and Schnitzer (1976) concluded from viscometric measurements that humic and fulvic acids behaved like flexible, linear, synthetic polyelectrolytes, in contrast to the structures composed of condensed aromatic rings with peripheral groups reported by Visser (1964) and Kononova (1966). It may be more appropriate at this time to associate the $E_4/E_6$ ratio to molecular size which still indicates some degree of relative humification.

Carbon:Nitrogen Ratio

Carbon:nitrogen ratios of soil organic matter have frequently been determined since many workers consider such values useful in assessing the influence of organic substances on plant growth. Results of the analysis suffer serious interpretation limitations.

The heterogenous nature of soil organic matter makes comparisons difficult. C/N ratios vary for plant residues in various stages of decomposition, from freshly deposited undecomposed material, thru humified material to charcoal. Nevertheless, Russell (1973) believed that soil C/N ratios gave as useful a characterization of soil organic matter as any other method known at that time. With a given agricultural management system, soil organic matter reflects a chemical composition that is characteristic for that particular management system. It is generally possible to predict the compositional change in organic substances resulting from changes in agricultural management (Russell, 1973). Practices which increase the decompositional rates in soil will tend to decrease the C/N ratios in grassland soils.

## Effects of Cultivation on Humus Quality

When organic materials decompose in soil, a great quantity of carbon is released as gaseous by-products but a large fraction remains in the soil. Part of this soil carbon joins the nutritive humus fraction with its rapid turnover rate and the remainder joins the more resistant forms of humus as a nutritive reserve.

The effects of cultivation on soil organic matter are many and varied. The dominating results are reductions in organic matter contents from levels established under pre-cultivation conditions. Cultivation was shown to increase oxidation rates in soil by increasing soil surface area and to accelerate aerobic decomposition by increasing gaseous exchange rates (Parr and Reusser, 1959; Greenwood, 1961). Cultivation also redistributes soil microorganisms (Neponiluev et al., 1960) and changes soil aggregation relationships (Rovira and Greacen, 1957). By increasing degradative systems, cultivation lowers the content of easily decomposable organic substances present in the soil and uses the more resistant and stable humic substances as a microbial energy source. This reduces the soil's dynamic biochemical systems and changes the soil from an active to a more passive ecosystem.

### Plowing

Plowing has a varied effect on soil. Aderikhin and Shevdienko (1968) reported decreases in the HA/FA ratio and water soluble substances. Kiryushia and Lebedeva (1972) reported a slight widening in the HA/FA ratio. Zbiec (1968) reported a temporary one-year increase in the HA/FA ratio.

Fertilizers

Several workers (Miftakhov and Taychinov, 1963; Lykov, 1968) reported decreases in soil organic matter or no significant changes resulting from applications of mineral fertilizers. Some workers (Miftakhov and Taychinov, 1963; Filipov, 1972) reported decreases in humic and fulvic acids. Other workers (Lykov, 1968; Khan, 1970; and Tan et al., 1972) reported increases in humic acid and the HA/FA ratio. The humin fraction was shown to increase with applications of mineral fertilizers (Miftakhov and Taychinov, 1963; Getmanets, 1969). Shevtsova and Sizova (1970) reported that NPK fertilizers had little affect on humus group composition but increased mobile carbon and nitrogen levels.

Manures

Animal manures consistently increased the humic acid content and widened the HA/FA ratio (Miftakhov and Taychinov, 1963; Kleszczycki et al., 1967; Filipov, 1972). Turski and Flis (1968) reported increases in the aromatic nature of humic acid. Humus quality was improved by adequate additions of organic fertilizers thereby increasing the humic acid content, free mobile humic substances and widening the HA/FA ratio (Getmanets, 1969).

## Lime

Lime usage increased the humic acid content, widened the HA/FA ratio and generally increased the humin content (Getmanets, 1969; Tan et al., 1972).

## Irrigation

Normal irrigation of agricultural soils was shown to increase the migration of humic acid and decrease that of fulvic acid (Ziyamukhamedov, 1970). Irrigation alters the seasonal wetting and drying cycles in soils which are important factors in formation of the humic acid molecule. Irrigation, by causing increased flushes of microbial activity upon wetting (Birch, 1958), tended to increase organic matter decomposition. Irrigation seemed to have no detectable effect on humus quality other than increasing the downward movement of humic acid in the soil profile.

# MATERIALS AND METHODS

## Description of Sampling Area

### Geographic Location

The study area was situated in the south-central portion of the Willamette Valley, west and east of the Willamette River. The larger area is east of Peoria and south of Tangent in Linn County. It extends over T. 12 and 13 S. and R. 3 and 4 W. of the Willamette Meridian (Figure 1). The smaller area is west of highway 99 W, north of Monroe and south of Greenberry, at the William L. Finley National Wildlife Refuge in Benton County. It extends over sections 21 and 28 of T. 13 S. and R. 5 W. of the Willamette Meridian (Figure 1).

### Physiography

The Willamette Valley in northwest Oregon is a broad alluvial plain, 160 km long and 30 to 65 km wide. The valley floor slopes from 120 m at its southern end to approximately sea level at its northern end. The average slope is 0.6 m per kilometer. There are numerous hills and buttes rising 100 m or more above the valley floor. The valley is drained by the north-flowing Willamette River and its tributaries.

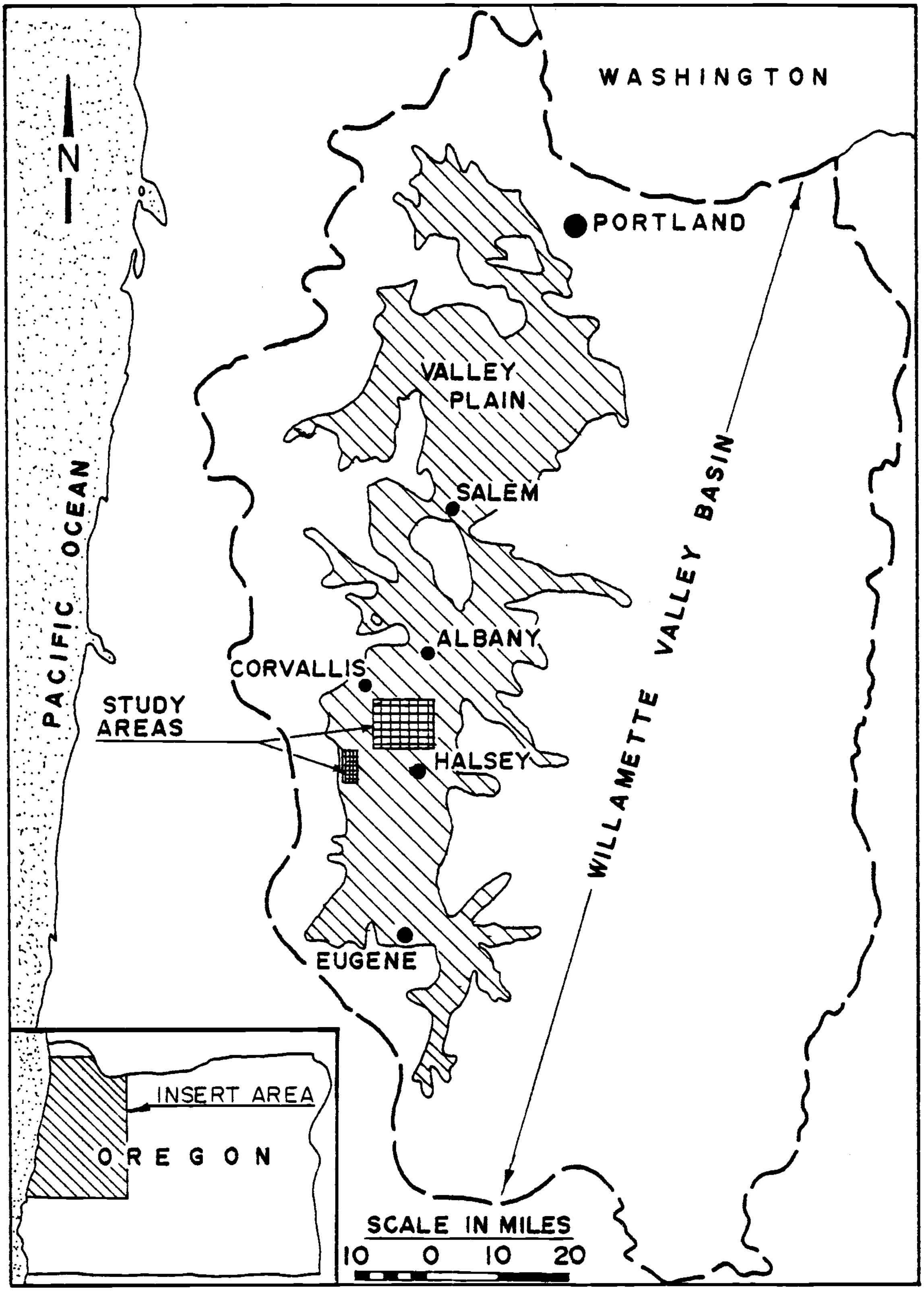


Figure 1. Geographic extent of the Willamette Valley Basin, valley plain and study areas.

## Climate

The Willamette Valley has a relatively homogenous climate, strongly influenced by marine air masses. This region has warm, dry summers (average July temperatures of 19° to 20° C) with cool, wet winters (average January temperatures of 4° to 5° C). The average annual precipitation is 103 cm of which approximately 70 percent occurs between the months of November and March. Most of the precipitation is in the form of rain although snow does fall most years.

## Vegetation

Before the migration of settlers into the Willamette Valley, (pre-1845), grasslands occupied extensive areas of the interior valley. Johannessen et al. (1971) concluded from travel journals kept by early explorers and settlers that the Willamette Valley was an artifically created and maintained prairie. They cite numerous early descriptions of the widespread grass burning that took place annually. The Indians, it was concluded, practiced game management through clearing land by using fire. The Indians also harvested sunflower seeds and wild wheat (Lamoro sappolil) after fall burning. Johannessen et al. (1971) cited strong evidence to indicate the annual nature of these widespread grass burns. It has only been since the arrival of settlers that widespread annual burning has been restrained. Now, much of the earlier prairie has been lost to woodlands, while new grassland areas have been created by clearing or burning. The nature of the original grassland vegetation has been conjectured from original land survey notes and other early written accounts. The original vegetation distribution included oak woodlands, coniferous forests and grasslands. The coniferous forests, containing Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandos*) and some big leaf maple (*Acer macrophyllum*), occurred on those uplands with adequate moisture. Oregon ash (*Fraxinus oregana*), black cottonwood (*Populus trichocarpa*), willows (*Salix* sp.), some grasses and forbs occurred in the wetter regions of the valley uplands and floor. Oregon white oak (*Quercus garryana*) and various grass communities were the principle vegetative types on the drier uplands and valley floor (Habeck, 1961). Extensive areas of the main valley floor were covered with *Quercus* savanna (Smith, 1949).

From historical records, numerous workers (Morris, 1934; Sprague and Hansen, 1946) reported that Indians (Klikitat) were responsible for the many fires occurring in the Willamette Valley prior to settlement. These authors noted that the controlled use of fire after settlement caused increased brush and tree development in grassland regions. Tree-ring growth studies by Sprague and Hansen (1946) showed frequent fires occurring in the Willamette Valley since 1647 but occurring less frequently after 1848, the time of settlement.

The early settlers raised cattle and only those crops for self needs. By 1879, wheat and oats became important cultivated crops with dairying, fruit and nut crops being introduced (Knezevich, 1975). Today, a highly diversified agricultural management system is in practice. The principle crops vary from cereal grains, horticultural and truck crops (Knezevich, 1975).

The present study was restricted to fields for grass seed crops, permanent pasture and some noncultivated weedy areas, all of which occur within the prairie communities.

## Soils of the Study Area

### Physical Relationships

The silty sediments, representing the principle parent material for soils of the Willamette Association, were deposited by glacial flood waters over an extended period of time (Allison, 1935). It has been postulated that ice jams west of the mouth of the Willamette River, within the Columbia River Gorge, caused overflow flooding to occur. These glacial waters were dammed up to depths exceeding 370 m. They were occasionally released into the Willamette Valley through topographic depressions. This overflow flooding was responsible for the deposition of gravels, sands and silts (Allison, 1935). Location of glacial erratics (Allison, 1935) indicated water depths up to 78 m above the present valley floor. The ponding of flood waters over extended time periods is indicated by the sedimentation pattern characteristic of summer-winter glacial lacustrine deposits. These periods of flooding and later depositional events have resulted in stratigraphic discontinuties which are responsible for many of the characteristics of the soils comprisong the Willamette Association.

Field Relationships

Field relationships between Woodburn, Amity, Concord and Dayton soils are related to stratigraphic discontinuties and landscape evolution (Balster and Parsons, 1986, 1968). These soils have been segregated into natural groups related by natural drainage characteristics but not entirely as reported by Pomerening and Knox (1962) who assumed an uniform deposit of parent material (Willamette Silts).

Dayton, Concord and Amity soils have similar surface horizons (A1, A2) but dissimilar subhorizons. Concord soils have a thinner IIB2t subhorizon than that prominent in Dayton soils (Parsons et al., 1968). Morphologically, Concord soils appear to represent a gradation between Dayton and Amity soils. This relationship may be considered in relating the degree of impeded internal drainage. Dayton and Concord soils occur on level to concave areas, while Amity soils occur on slightly higher convex "islands" having a somewhat improved drainage position. Parsons et al. (1968) suggest "clay deposition in swales surrounding knolls of higher elevations." They futher postulated that "during the deposition of the clay, knolls probably were islands in a shallow, marsh-like embayment or estuary."

Woodburn soils are related to Amity soils by also being topographically too high to have been mantled by the clay deposit characteristic to Dayton and Concord soils. Woodburn soils are often associated with overbank alluvial deposits forming natural levees and they show evidence of stratigraphic discontinuties below the overthickened surface horizons (Parsons et al., 1968).

Chemical Relationships

In a study by Pomerening (1961) soil acidity was shown to increase slightly (5.6 to 5.3) in the A1 or Ap horizons as the depth to water table decreased (Woodburn to Dayton). The soil pH increased from 5.7 to 6.0 in the B2 and from 6.0 to 6.7 in the B3 horizons as depth to water table decreased.

Pomerening found that carbon content within a single horizon (A1 or Ap) decreased as the soil became more poorly drained.

Mean nitrogen values did not vary significantly between soil series in surface horizons.

Pomerening (1961) reported narrower C/N ratios as depth to water table decreased. Mean C/N ratios in the A1 or Ap horizons were 14.5, 13.8, 12.1 and 11.1 for the Woodburn, Amity, Concord and Dayton soils, respectively.

## Field Procedures

Field work consisted of locating pairs of cultivated and burned grass seed crop and noncultivated and nonburned pasture sites. With the aid of Dr. G. Simonson and William R. Patching (SCS, Linn Co.), several areas in Linn County were examined and sites selected accordingly. Due to difficulties in selecting appropriate sites, two to three pairs of matched sites (grass seed crop:pasture) per soil series (Dayton, Concord, Amity and Woodburn) were selected. One criterion used in selecting sites was proximity to sites previously studied by Drs. Boersma and Simonson (1970). This enabled a ten year comparison of selected sites. Site locations and brief management histories are given in Appendix Tables 7 and 8 and accompanying Appendix Figures 1 and 2.

Sampling

Three auger cores per site were taken at 15 cm intervals from 0 to 75 cm depth using a 7.5 cm diameter core type soil auger. Soil horizon samples were taken on those sites previously sampled by Boersma and Simonson (1970).

Soil Preparation

The augered samples from the triplicate cores were composited and transported in wax-lined paper bags to the lab. Soil samples were air dried for 48 hours in a forced-draft drying cabinet on plastic trays at a temperature not exceeding 50° C. Samples were crushed and sieved by a Nasco-Asplm soil grinder to pass through a 14-mesh (1.40 mm) sieve. Portions not passing through the 14-mesh sieve were collected and recrushed three additional times. The greater-than 1.40 mm material (negligible) was then discarded.

Depth to Mottling

Depths to faint and distinct mottling were determined in situ. Soil pits and hand-probed cores were used in determining mottling depths. Faint mottling was determined by measuring to the depth below the soil surface where few, distinct and fine mottles occurred. Distinct mottling was determined by measuring to the depth where many to plentiful, distinct and large mottles occurred.

## Laboratory Procedures

### Chemical Analysis of Soil Samples

All chemical analyses were determined in duplicate on all samples.

#### Soil pH

Soil pH was determined by using a Corning model 7 pH meter with a glass electrode on a 2:1 (weight basis) soil-water paste (Kauffman and Gardner, 1976).

#### Organic Carbon

Organic carbon was determined by the Walkley-Black potassium dichromate method (Kauffman and Gardner, 1976; Allison, 1965). Organic materials were oxidized by $Cr_2O_7^{=}$ in a solution composed of two volumes 36 N $H_2SO_4$ mixed with one volume 1 N $K_2Cr_2O_7$. Excess $Cr_2O_7^{=}$ (that portion not reduced) was titrated with a 0.400 N solution of $Fe(NH_4)$-$(SO_4)_2 \cdot 6H_2O$ (159.6 gm plus 40 ml 36 N $H_2SO_4$ in 1 liter). Organic carbon content was calculated from milliequivalents of $Cr_2O_7^{=}$ reduced, using multiplying factor 1.33 to correct for the approximately 70 %

organic carbon recovery by this procedure (Peech et al., 1947; Bremner and Jenkinson, 1960a).

Total Nitrogen

Total soil nitrogen was determined using a standardized macro-Kjeldahl digestion and distillation method (Kauffman and Gardner, 1976). A 3 gm sample was digested until clear with concentrated $H_2SO_4$ (36 N) and a $Na_2SO_4$-$CuSO_4$-Se catalyst. The ammonium-N was distilled into a boric acid solution (40 gm $H_3BO_3$ in 1 liter). The ammonium-N in the distillate was determined by titrating with 0.0974 N HCl.

Water Extractable Carbon and Nitrogen

Soluble soil carbon and nitrogen were extracted by combining 60 ml distilled $CO_2$-free water with 25 gm of soil (< 2 mm) in a 250 ml Erlmeyer flask. The lightly stoppered flasks were placed in a stationary, constant temperature water bath at 80° C for 24 hours. The water solution plus soil mixture was transfered to 50 ml centrifuge polyethylene centrifuge tubes and centrifuged at 10,000 g for 15 minutes with a Sorvall RC 2-B centrifuge. The water solution was filtered with Whatman No. 5 filters. The soil was rinsed twice with $CO_2$-free distilled water, centrifuged and the extract brought to volume.

Soluble Carbon

Soluble carbon was determined using a spectrophotometric method developed by Orlov and Grindel (1967) and Nikitin (1972). One milliliter of extract was pipetted into a 10 ml test tube. One milligram of distilled, $CO_2$-free water was added followed by addition of 4 ml potassium dichromate-concentrated sulfuric acid solution (1.27 gm $K_2Cr_2O_7$ in 200 ml conc. $H_2SO_4$). The test tubes were placed in a wire basket 2 cm apart to ensure uniform heating. The test tubes were then placed in a preheated oven at 155° C for a 20 minute heating period. Heating time was counted from the moment the oven temperature returned to 155° C after placing the test tubes in the oven.

After 20 minutes of heating, the test tubes were removed from the oven and cooled for 30 minutes. The entire solution was transfered to a vacuvette cell and its optical density measured at 590 nm (Bausch and Lamb Spectronic 20 Colorimeter). Milligrams of carbon were determined from a calibration curve (0.0625, 0.125, 0.500 and 1.000 mg glucose) made with glucose as a carbon standard. The method works well in the range of 0 to 1.25 mg carbon per milliliter (Mangum, 1966). The blank consisted of 2 ml $CO_2$-free distilled water and 4 ml of $K_2Cr_2O_7$-$H_2SO_4$ solution.

Soluble Nitrogen

Soluble nitrogen was determined using a semi-micro-Kjeldahl digestion and distillation procedure (Kauffman and Gardner, 1976). A 25 ml extract sample was pipetted into standard digesting flasks and digested with sulfuric acid (36 N) utilizing a $Na_2SO_4$-$CuSO_4$-Se catalyst. After excess water was evaporated at low heat, digestion proceeded at high heat until clearing (pale green color) plus an additional 45 minutes. The ammonia-N was distilled into a boric acid solution (40 gm $H_3BO_3$ in 1 liter). The ammonium-N in the distillate was determined by titrating with 0.0203 N HCl.

Organic Matter Extraction

Five grams of soil (< 2 mm) were combined with 100 ml (1:20 weight:volume) of a 0.100 M sodium pyrophosphate-0.100 N sodium hydroxide solution (44.6 gm $Na_4P_2O_7 \cdot 10\ H_2O$ plus 20 ml of 5 N NaOH in 1 liter) in a 250 ml Erlmeyer flask. The flask was tightly stoppered and placed on an orbit shaker for 16 hours (Kononova, 1966).

The soil-extractant mixture was transfered into polyethylene centrifuge tubes, centrifuged at 10,000 g and the resulting solution decanted into a volumetric flask. The residual soil was washed twice with 30 ml extracting solution. Washings were combined with the previously extracted material and brought to volume.

A 50 ml aliquot of humus extract was acidified to pH 2.5 (with $H_2SO_4$ at 36 N) and left standing undisturbed in a covered beaker for 16 hours. The precipitated humic acid fraction was separated by centrifugation at 10,000 g for 20 minutes. The humic acid fraction was mechanically dispersed with a teflon stirrer and washed twice with dilute sulfuric acid. The acid soluble material (fulvic acid) and washings were discarded.

The washed humic acid precipitate was redissolved in 0.50 N NaOH and brought to volume in a 50 ml volumetric flask.

## Total Extractable Carbon

Total extractable carbon was determined in 10 ml aliquots of the original humus extract by the Walkley-Black wet-oxidation method (Kauffman and Gardner, 1976). Each 10 ml aliquot was combined with 5 ml of a 1.00 N potassium dichromate solution. Thirty milliliters of sulfuric acid (36 N) were quickly added to the potassium dichromate mixture, maintaining the 1:2 (water:acid) volume ratio to produce the necessary heat for reaction.

## Humic Acid Carbon

Humic acid carbon was determined in 10 ml aliquots of the redissolved acid by the Walkley-Black wet-oxidation method (Kauffman and Gardner, 1976). The same procedure as described under total extractable carbon was used to determine humic acid carbon.

## Fulvic Acid Carbon

Fulvic acid carbon was determined by difference. Milligrams fulvic acid carbon is the difference between the total extractable carbon and the humic acid carbon.

## Humin Carbon

Humin carbon was also determined by difference. Humin carbon represents the difference in mg-carbon between total soil carbon and total extractable carbon.

## Physical Analysis of Soil Samples

### Soil Color

Soil color was determined on noncrushed soil peds by removing two or three peds from each sample prior to grinding. Color was determined by using a standard Munsell color chart and an incandescent (white light) light placed six inches above the soil ped and color chip. A cream colored card with a centrally located hole was used to mask those color chips not matching the sample. Soil color determinations were done on samples chosen in a random sequence. Dry color was determined first followed by moist color determination. Each interval between color units was subdivided into four equal subdivisions (0.2, 0.4, 0.6 and 0.8). Estimates of value and chroma not matching one of the standards were determined by interpolation.

Soil color was also determined on chrushed samples passed through a 40-mesh sieve. The same procedures were used on chrushed samples as on noncrushed samples.

## Test to Determine Selectivity of Walkley-Black Wet-Oxidation Methodology

### Methodology

Numerous workers have been concerned with the various carbon methods used in relating organic carbon to microbial available organic materials. The question of appropriate methods is important especially when dealing with soils that have undergone a burning phase as part of their management practices. Soil carbon determined by dry combustion methods will indiscriminately combust all forms of organic carbon regardless of source. An appreciable addition of graminaceous straw ash (charcoal like) in soil can be erroneously identified as an active fraction of the soil organic materials. Wet-oxidation methods (Walkley-Black) selectively oxidize the more readily available materials. This selectivity results from the complex nature and relative resistance of organic materials to decomposition.

Various standards were used to distinguish how selected organic materials respond to the wet-oxidation method. Glucose, cellulose, starch, lignin and graminaceous straw ash were used as standards. Wet-oxidation carbon values were compared to either the theoretical or dry combustion values. Table 1 shows that glucose, starch and cellulose carbon were completely recovered while lignin carbon was substantially recovered. The high recovery rate of lignin by the wet-oxidation method is no doubt due to the nature of the lignin used. The lignin was a ligno-sulfate complex extracted from wood. Graminaceous straw-ash carbon (charcoal) was only slightly recoverable (12.4 %) using this method. The data indicate that burned graminaceous straw residue does not pose a large error source of organic carbon using the Walkley-Black wet-oxidation method. Secondly, the data indicate that glucose, starch and cellulose, representing the more readily available microbial substrates, are completely recoverable using the wet-oxidation method.

Table 1 Carbon recovery by Walkley-Black wet-oxidation compared to theoretical carbon values for various compounds.

| Material | % Carbon: Theoretical or Determined (Dry Combustion) | % Carbon: Walkley-Black (without factor) | % Recovery of Theoretical |
|---|---|---|---|
| Starch | 44.45 | 44.34 | 99.8 |
| Glucose | 40.00 | 40.22 | 100.6 |
| Cellulose (sol.) | 35.66 | 36.69 | 102.9 |
| Cellulose (insol.) | 44.45 | 44.00 | 99.0 |
| Straw Ash | 16.90 | 2.10 | 12.4 |
| Lignin | 46.40 | 45.04 | 97.1 |

Ash Accumulation

To test for accumulation of graminaceous straw-ash (charcoal-like) resulting from prolonged annual burning, comparative carbon analyses were made on soil samples from two sampling periods (1965 and 1975). Table 2 indicates that no significant difference (a=.05) occurs between carbon values determined by the Walkley-Black wet-oxidation and dry combustion methods.

Table 2 Determination of possible ash buildup in surface soil samples with time ( 1965 to 1975).

| Soil Sample | % Carbon: Walkley-Black (with factor 1.33) | % Carbon: Dry Combustion | % Diff. |
|---|---|---|---|
| Concord (GSC, 1965) | 1.76 | 1.48 | 15.9 |
| Concord (GSC, 1975) | 1.66 | 1.67 | 0.6 |
| Amity (GSC, 1965) | 1.92 | 1.96 | 2.0 |
| Amity (GSC, 1975) | 1.98 | 1.91 | 2.0 |

Note: GSC indicates grass seed crop sites.

Methodology Comparison

Surface soil samples were analyzed for carbon using both techniques, wet-oxidation and dry combustion methods. Table 3 indicates that wet-oxidation carbon values, using a factor of 1.33, are comparable to dry combustion carbon values. Neither method consistently gives higher or lower carbon values. This may result from the quantity of resistant undecomposed root material present in the soil.

Table 3 Comparison of two carbon methods, wet-oxidation and dry combustion, on surface soil samples.

| Soil Sample | % Carbon Walkley-Black (with factor 1.44) | Dry Combustion | % Diff. |
|---|---|---|---|
| Amity (GSC) | 1.78 | 1.69 | 5.1 |
| Amity (P) | 3.26 | 2.81 | 13.8 |
| Amity (F) | 3.39 | 2.96 | 12.7 |
| Woodburn (P) | 5.37 | 5.12 | 4.7 |
| Dayton (GSC) | 1.56 | 1.99 | 21.6 |
| Concord (GSC) | 1.66 | 1.67 | 0.6 |

Note: GSC indicates grass seed crop sites; P indicates pasture sites; F indicates Finley "virgin" sites.

Percent differences not significant (a=.05)

# RESULTS

## Soil Color and Mottling

My first procedure was to confirm or refute observations by soil scientists working in the Willamette Valley, e.g. lighter surface soil colors and deteriorating internal soil drainage (changes in depth to mottling) of these four valley soils (Dayton, Concord, Amity and Woodburn).

Soil color data (Appendix Tables 2 and 3) confirmed these above mentioned observations. Amity soils under grass seed crop management are apparently losing their mollic epipedons compared to soils under pasture.

The second observation, changes in depth to mottling, was confirmed by field measurements (Appendix Tables 4, 5 and 6). Amity soils under grass seed crop management showed common and distinct mottling closer to the soil surface than Amity pasture soil sites.

Appendix Figures 3, 4 and 5 show recent soil survey delineations compared to earlier soil surveys in this area. Differences in mapping do occur which can not be explained by differences in mapping criteria between soil scientists.

The above data document observations by soil scientists indicating that serious changes in at least Amity soils are occurring.

## Soil Carbon

### 1975 Data

The percentage organic carbon in soils is commonly used to estimate the quantity of accumulated organic matter. The percent carbon is multiplied by the Van Bremmelen factor (1.724) in converting organic carbon to organic matter. But, Broadbent (1953) reported that one conversion "factor" should not systematically be applied to both surface and subsurface organic material. Broadbent stressed the importance of recognizing that compositional differences occur between the surface and subsurface organic matter. The organic matter varies from residual litter material at the surface to illuviated organic substances in subsoil horizons. To minimize error associated with such factors, soil carbon data in this study are reported as percent organic carbon rather than organic matter.

### Dayton

Table 4 and Figure 2 show Dayton pasture sites having carbon values consistently higher that grass seed crop sites (sites I and II). The differences varied however, between paired pasture and grass seed crop sites. The Finley "virgin" soil site showed the highest carbon values of the Dayton sites.

Dayton pasture sites had significantly (a=.05) higher carbon values. Mean pasture carbon values (Table 5) were higher, but not significantly.

Table 4 Comparison of total carbon between pasture (P) and grass seed crop (GSC) sites from 1975 data.

| Soil Site | Depth cm | % Carbon P | % Carbon GSC | % Diff. from P | | Depth cm | % Carbon P | % Carbon GSC | % Diff. from P |
|---|---|---|---|---|---|---|---|---|---|
| Dayton | 0–15 | 4.27 | - | - | Concord | 0–15 | 2.38 | 2.24 | -6 |
| | 15–30 | 2.03 | - | - | | 15–30 | 0.96 | 1.61 | +67 |
| F | 30–45 | 0.72 | - | - | I | 30–45 | 0.57 | 0.74 | +30 |
| | 45–60 | 0.42 | - | - | | 45–60 | 0.30 | 0.29 | -3 |
| | 60–75 | 0.42 | - | - | | 60–75 | 0.15 | 0.31 | +106 |
| I | 0–15 | 1.55 | 1.49 | -4 | II | 0–15 | - | 1.67 | - |
| | 15–30 | 1.34 | 0.83 | -60 | | 15–30 | - | 1.25 | - |
| | 30–45 | 0.38 | 0.49 | +29 | | 30–45 | - | 0.50 | - |
| | 45–60 | 0.34 | 0.29 | -15 | | 45–60 | - | 0.36 | - |
| | 60–75 | 0.20 | 0.18 | -10 | | 60–75 | - | 0.28 | - |
| II | 0–15 | 3.13 | 0.56 | -50 | III | 0–15 | 1.53 | 1.66 | +19 |
| | 15–30 | 1.45 | 1.24 | -14 | | 15–30 | 0.44 | 0.65 | +18 |
| | 30–45 | 0.68 | 0.41 | -40 | | 30–45 | 0.30 | 0.33 | +10 |
| | 45–60 | 0.34 | 0.32 | -6 | | 45–60 | 0.36 | 0.35 | -3 |
| | 60–75 | 0.47 | 0.23 | -51 | | 60–75 | 0.28 | 0.23 | -18 |
| Amity | 0–15 | 3.39 | - | - | Woodburn | 0–15 | 4.19 | - | - |
| | 15–30 | 2.13 | - | - | | 15–30 | 2.09 | - | - |
| F | 30–45 | 1.50 | - | - | F | 30–45 | 1.46 | - | - |
| | 45–60 | 1.13 | - | - | | 45–60 | 1.14 | - | - |
| | 60–75 | 0.57 | - | - | | 60–75 | 0.55 | - | - |
| I | 0–15 | 3.26 | 1.78 | -45 | I | 0–15 | 4.10 | 2.41 | -41 |
| | 15–30 | 2.03 | 0.80 | -61 | | 15–30 | 2.26 | 1.81 | -20 |
| | 30–45 | 1.36 | 0.35 | -74 | | 30–45 | 1.57 | 1.03 | +34 |
| | 45–60 | 0.80 | 0.30 | -63 | | 45–60 | 1.12 | 0.57 | -49 |
| | 60–75 | 0.64 | 0.23 | -64 | | 60–75 | 0.55 | 0.34 | -38 |
| II | 0–15 | 2.52 | 2.43 | -4 | II | 0.15 | 5.37 | 2.44 | -55 |
| | 15–30 | 1.76 | 1.83 | +4 | | 15–30 | 2.01 | 1.67 | -17 |
| | 30–45 | 1.31 | 1.24 | -5 | | 30–45 | 1.30 | 1.08 | -14 |
| | 45–60 | 0.64 | 0.62 | -3 | | 45–60 | 0.87 | 0.60 | -31 |
| | 60–75 | 0.49 | 0.45 | -8 | | 60–75 | 0.68 | 0.40 | -41 |
| III | 0–15 | - | 2.08 | - | | | | | |
| | 15–30 | - | 1.57 | - | | | | | |
| | 30–45 | - | 0.73 | - | | | | | |
| | 45–60 | - | 0.27 | - | | | | | |
| | 60–75 | - | 0.24 | - | | | | | |

Note: Finley "virgin" sites are designated by the "F" symbol.

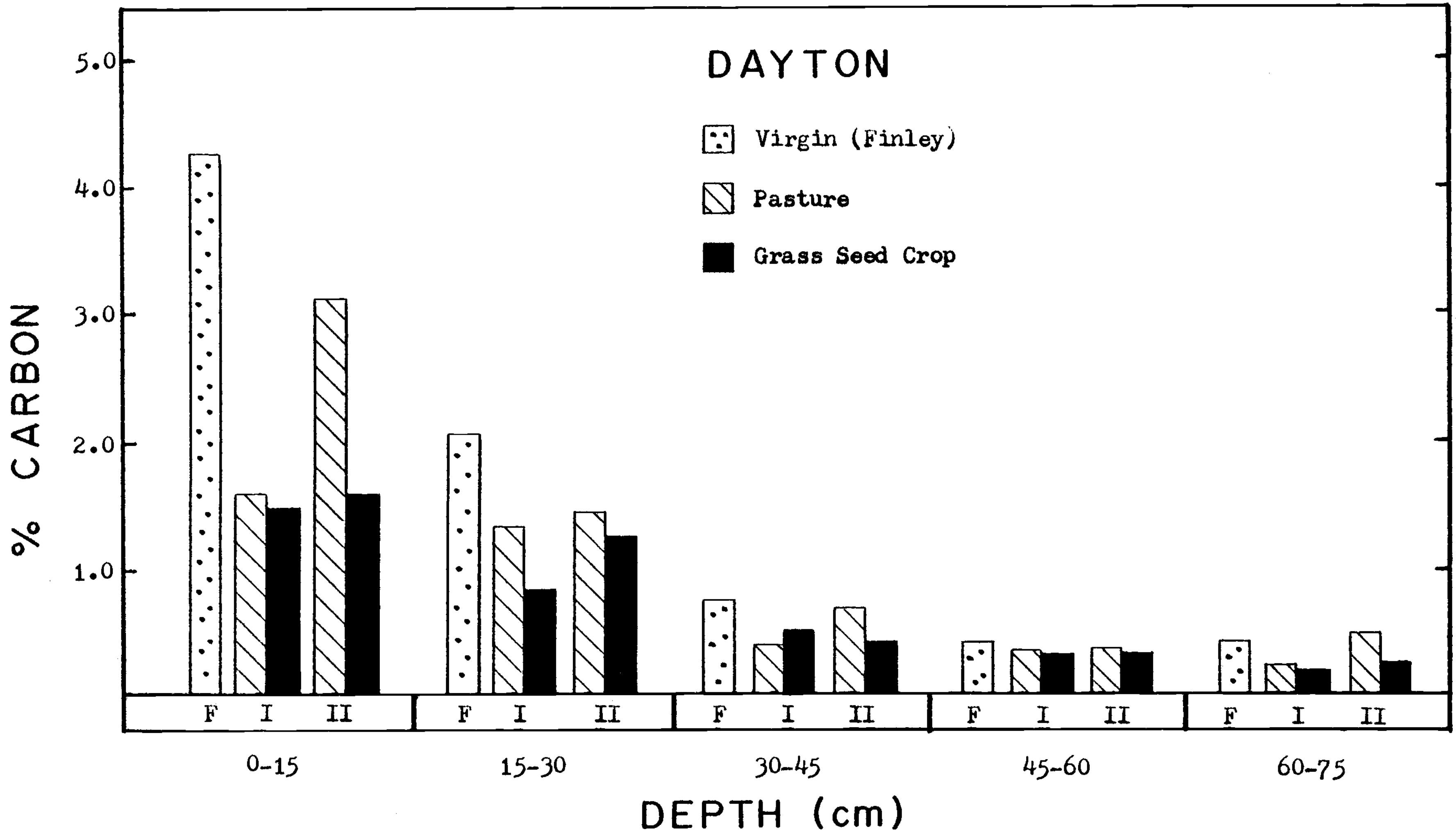


Figure 2. Comparison of total carbon between pasture (P) and grass seed crop (GSC) soil sites from 1975. See Table 4.

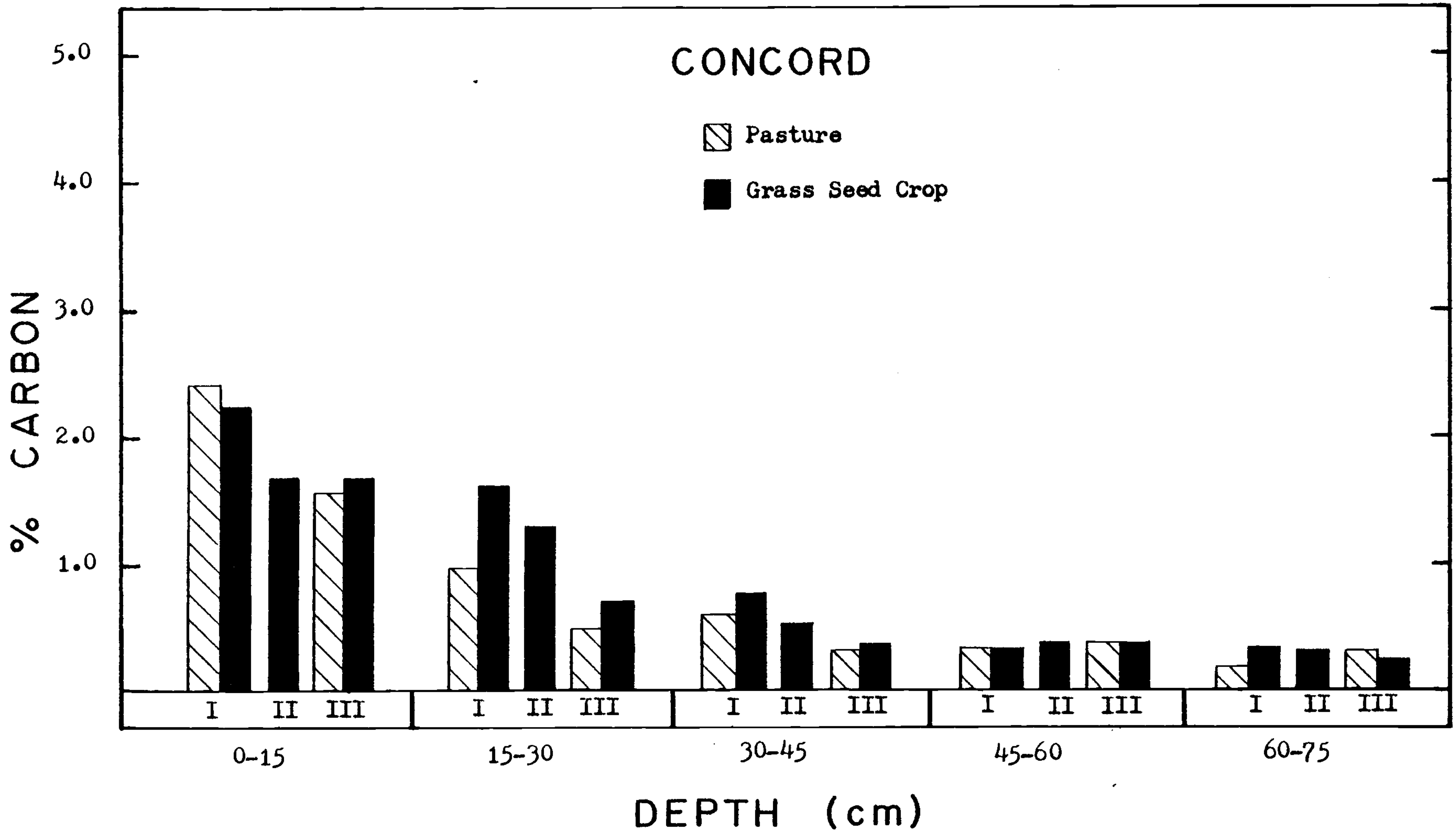


Figure 3. Comparison of total carbon between pasture (P) and grass seed crop (GSC) soil sites from 1975. See Table 4.

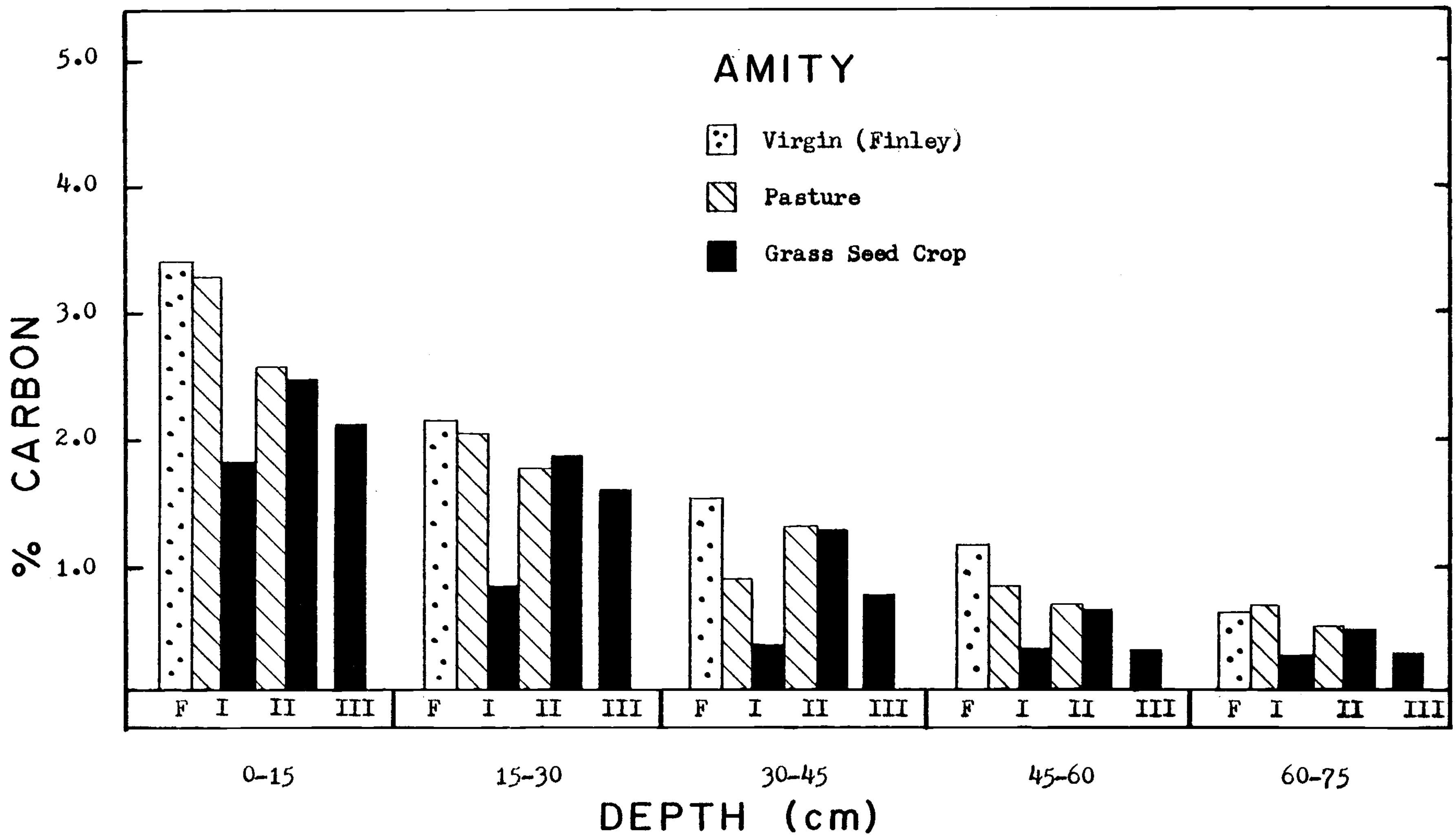


Figure 4. Comparison of total carbon between pasture (P) and grass seed crop (GSC) soil sites from 1975. See Table 4.

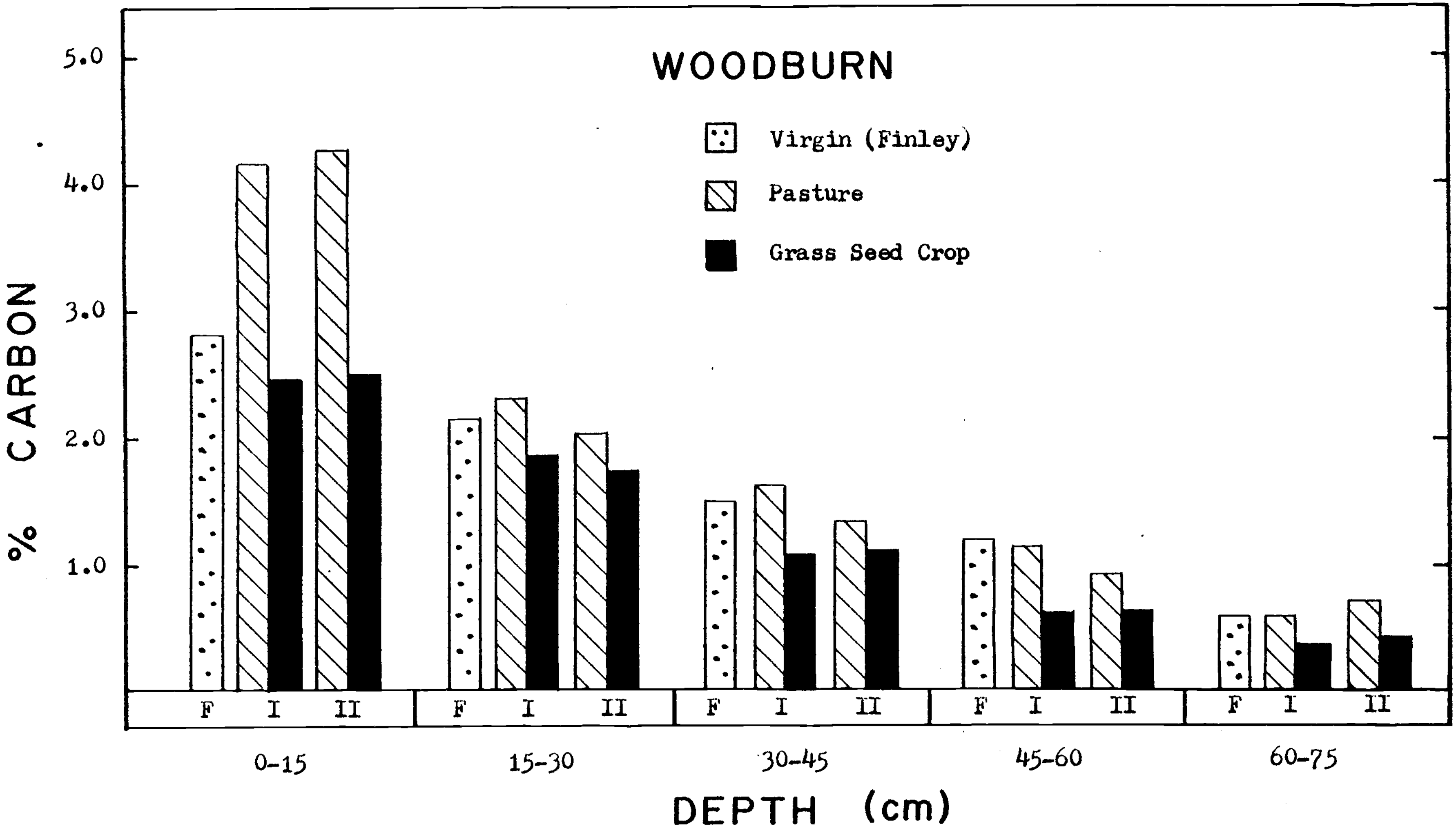


Figure 5. Comparison of total carbon between pasture (P) and grass seed crop (GSC) soil sites from 1975. See Table 4.

Table 5 Comparison of mean carbon data from pasture (P) and grass seed crop (GSC) soil sites (1975 data).

| Soil Series | Depth cm | % Carbon P | GSC | % Diff. bet. means |
|---|---|---|---|---|
| Dayton | 0-15 | 2.98 | 1.53 | -49 |
| | 15-30 | 1.61 | 1.04 | -35 |
| | 30-45 | 0.59 | 0.45 | -24 |
| | 45-60 | 0.37 | 0.31 | -16 |
| | 60-75 | 0.37 | 0.21 | -43 |
| Concord | 0-15 | 1.96 | 1.86 | -5 |
| | 15-30 | 0.70 | 1.17 | +67 |
| | 30-45 | 0.44 | 0.52 | +27 |
| | 45-60 | 0.33 | 0.33 | 00 |
| | 60-75 | 0.22 | 0.27 | +23 |
| Amity | 0-15 | 3.06 | 2.10 | +31 |
| | 15-30 | 1.97 | 1.40 | -29 |
| | 30-45 | 1.39 | 0.77 | -45 |
| | 45-60 | 0.86 | 0.40 | -53 |
| | 60-75 | 0.57 | 0.31 | -46 |
| Woodburn | 0-15 | 4.38 | 2.43 | -45 |
| | 15-30 | 2.12 | 1.74 | -18 |
| | 30-45 | 1.44 | 1.06 | -26 |
| | 45-60 | 1.04 | 0.59 | -43 |
| | 60-75 | 0.59 | 0.37 | -37 |

Amity

Paired Amity pasture and grass seed crop soil sites (Table 4 and Figure 4) showed significantly different (a=.05) carbon values, with pasture sites having the higher carbon values.

Site III, having no pasture comparison site, has carbon values comparable with the other grass seed crop sites. The Finley "virgin" site, showed the highest carbon values of any Amity sites sampled. Amity mean carbon data (Table 5) indicated significantly higher (a=.05) pasture carbon values.

Woodburn

Paired Woodburn pasture and grass seed crop carbon data, Table 4 and Figure 5, were significantly different (a=.05) with the pasture sites having the higher carbon values. Woodburn pasture site II had the highest carbon content of any sampled site (heavy perennial sod mat present). The Finley "virgin" site had carbon values comparable to Woodburn pasture sites and significantly higher than carbon values from grass seed crop sites. Woodburn mean carbon values, Table 5, for pasture sites were significantly higher.

Concord

Paired Concord sites (Table 4 and Figure 3) showed dissimilar trends to the Dayton, Amity and Woodburn soil sites. The pasture soil sites, in the surface sampling depth (0-15 cm), showed slight increases in carbon. The grass seed crop sites had slightly higher carbon values than the pasture sites in the 15 to 75 cm depth. Differences in carbon data between the pasture and grass seed crop sites were not statistically significant (a=.05).

The three Finley "virgin" sites ( Table 4) did not show a consistent trend in carbon content with increasingly better natural soil drainage. The Dayton site had the highest carbon content in the upper 15 cm with the Amity site showing the lowest value. The 15 to 30 cm depth contained fairly uniform carbon content for all three series. Below 30 cm, the Dayton carbon values were sharply lower. Amity and Woodburn carbon values below 30 cm, declined gradually and were similar.

Data from Two Sampling Periods, 1965 to 1975

Soil samples taken in 1965 (Boersma and Simonson, 1970) were analyzed simultaneously with recently (1975) taken samples. The 1975 samples were taken very close to the same site locations as used in the earlier study.

Dayton

Comparison of carbon contents of two Dayton pasture soil sites (both perennial grasses) showed a significant difference ($a=.10$) between the two sampling periods with the 1975 samples showing higher carbon values (Table 6 and Figure 6). The increases, although variable, were small. The Ap horizon of site II was an exception with a 138 percent increase in carbon which probably relates to a changed management. Prior to 1965, site II was an unimproved weedy area. Subsequently, one hundred pounds of ammonium sulfate per acre per year (spring application) have been applied. The increased nitrogen and improved pasture grasses should have substantially increased the soil carbon content.

Table 6 Comparison of total soil carbon as it varies with time, 1965 to 1975, in pasture (P) and grass seed crop (GSC) sites.

| Soil Series | Site | Horizon | Depth cm | % Tot. Carbon 1965 | 1975 | % Diff. From 1965 |
|---|---|---|---|---|---|---|
| Dayton | I-P | Ap | 0-18 | 1.30 | 1.28 | -2 |
| | | A2 | 18-33 | 0.63 | 0.88 | +40 |
| | | B21t | 33-48 | 0.38 | 0.59 | +55 |
| | | B22t | 48-74 | 0.25 | 0.35 | +29 |
| | II-P | Ap | 0-20 | 1.17 | 2.79 | +138 |
| | | A2 | 20-33 | 0.54 | 0.93 | +72 |
| | | B21t | 33-58 | 0.34 | 0.31 | -9 |
| | | B22t | 58-79 | 0.20 | 0.28 | +40 |
| Concord | I-GSC | Ap | 0-15 | 1.36 | 2.24 | +65 |
| | | A2 | 15-30 | 0.67 | 1.61 | +140 |
| | | B1 | 30-51 | 0.31 | 0.30 | -3 |
| | | B2t | 51-74 | 0.20 | 0.11 | -45 |
| | II-GSC | Ap | 0-13 | 1.36 | 1.72 | +26 |
| | | A12 | 13-26 | 0.90 | 1.23 | +37 |
| | | A2 | 26-48 | 0.43 | 0.49 | +14 |
| | | B1 | 48-66 | 0.27 | 0.28 | +4 |
| | III-GSC | Ap | 0-18 | 1.76 | 1.55 | -12 |
| | | A21 | 18-38 | 0.61 | 0.66 | +8 |
| | | A22 | 38-56 | 0.30 | 0.37 | -23 |
| | | B1 | 56-64 | 0.21 | 0.45 | +114 |
| | | B2t | 64-84 | 0.17 | 0.27 | +59 |
| Amity | I-P | A11 | 0-23 | 2.12 | 2.34 | +10 |
| | | A12 | 23-43 | 1.28 | 1.53 | +20 |
| | | A2 | 43-58 | 0.68 | 0.78 | +15 |
| | | B2t | 58-81 | 0.37 | 0.48 | +30 |
| | II-P | A11 | 0-36 | 2.12 | 1.84 | -21 |
| | | A12 | 36-56 | 1.14 | 1.23 | +8 |
| | | B2t | 56-71 | 0.36 | 0.53 | +47 |
| | III-GSC | Ap | 0-20 | 1.92 | 1.98 | +3 |
| | | A12 | 20-38 | 1.47 | 1.06 | -28 |
| | | A2 | 38-58 | 0.54 | 0.33 | -39 |
| | | B2t | 58-89 | 0.20 | 0.27 | +35 |
| Woodburn | I-GSC | Ap | 0-20 | 2.10 | 1.95 | -7 |
| | | A12 | 20-36 | 1.55 | 1.37 | -12 |
| | | B1 | 36-58 | 0.62 | 0.68 | -10 |
| | | B21t | 58-76 | 0.38 | 0.36 | -5 |

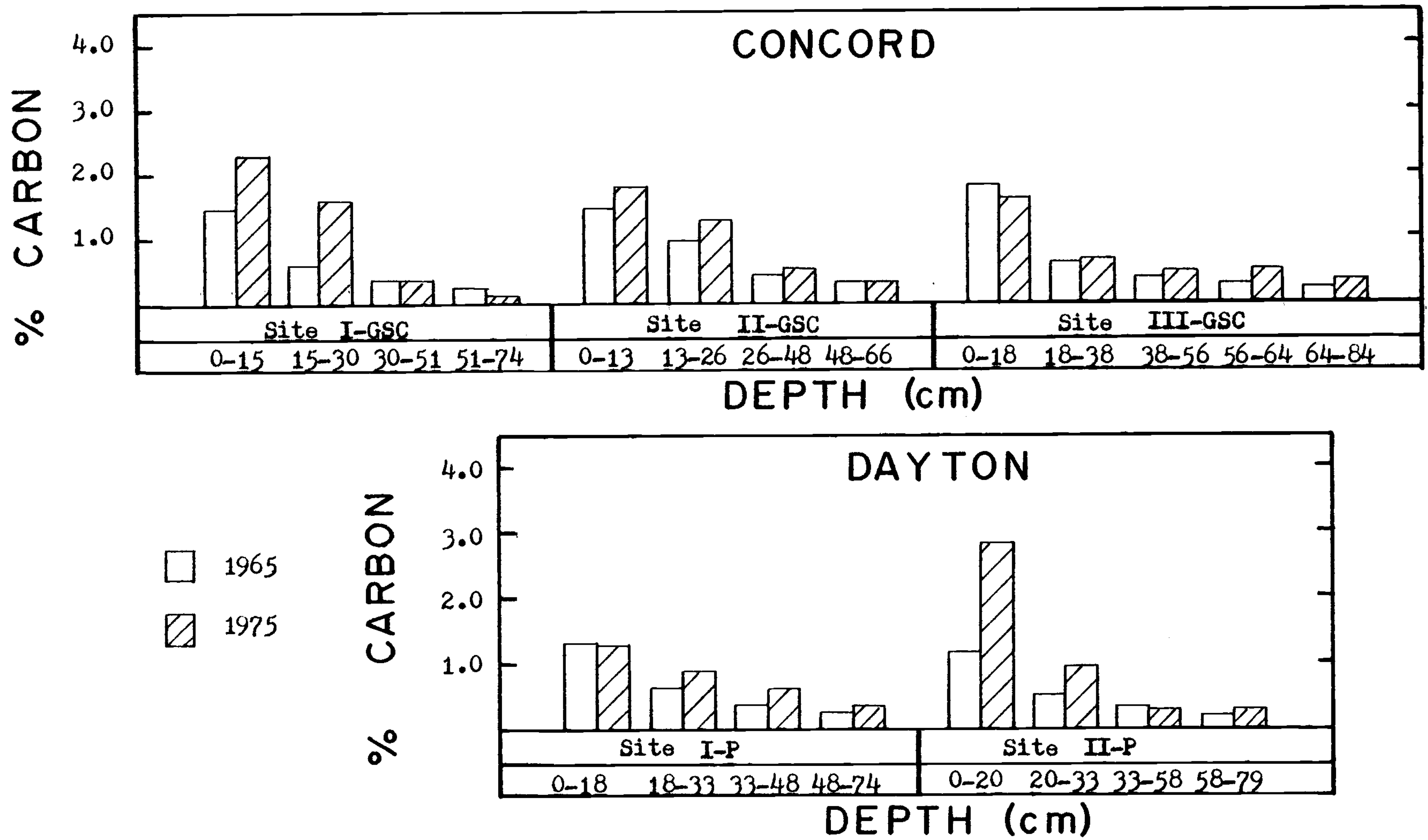


Figure 6. Comparison of total soil carbon as it varies with time, 1965 to 1975, in pasture (P) and grass seed crop (GSC) sites. See Table 6.

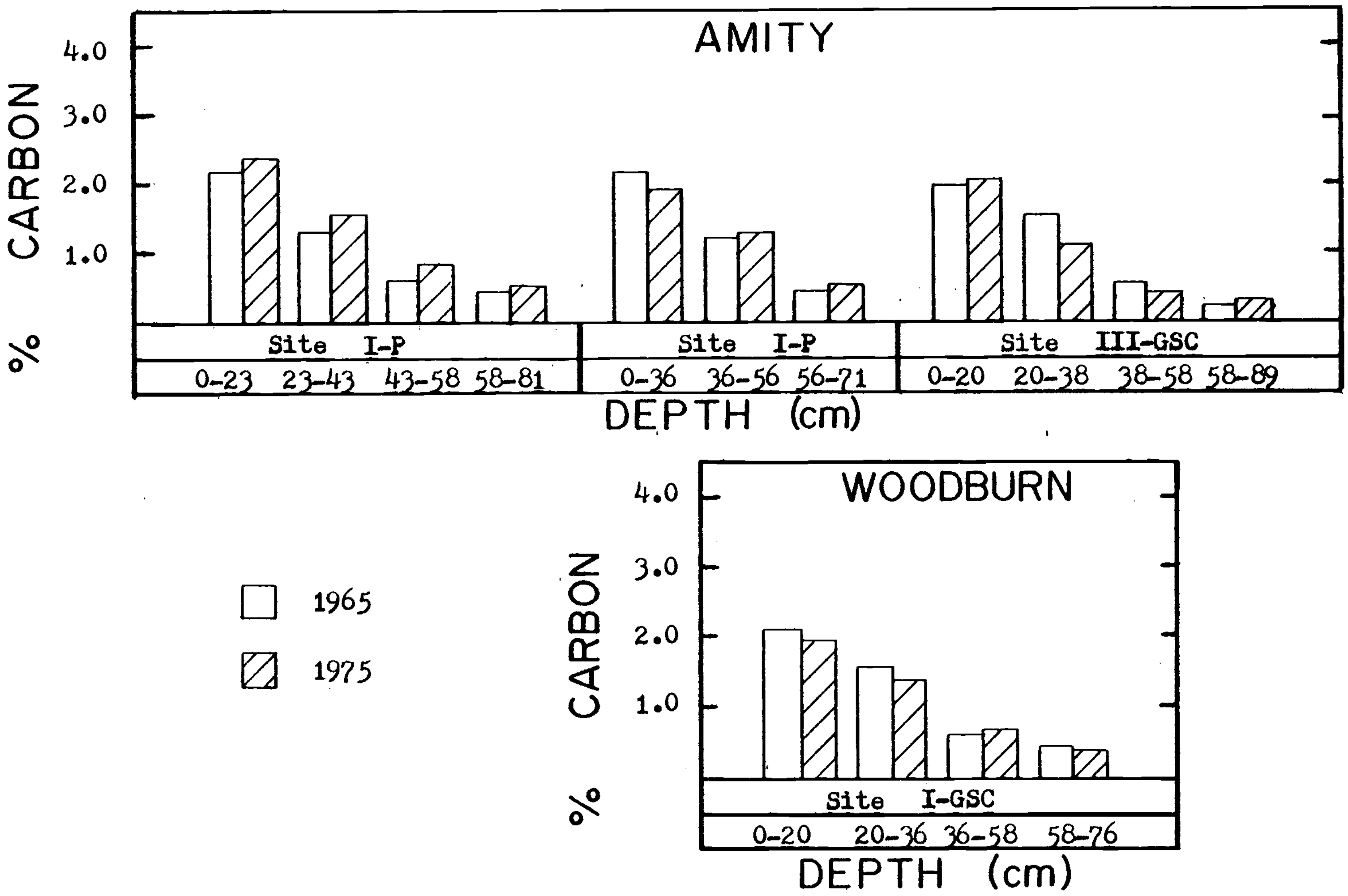


Figure 7. Comparison of total soil carbon as it varies with time, 1965 to 1975, in pasture (P) and grass seed crop (GSC) sites. See Table 6.

Concord

Carbon contents of three Concord grass seed crop sites were significantly higher (a=.05) in 1975 than in 1965 (Table 6 and Figure 6). Site I, with a 65 to 140 percent increase in the upper 30 cm, has been in annual ryegrass for 20 years. Three hundred to 400 pounds of ammonium sulfate were applied annually per acre.

Site II showed smaller carbon increases in the upper 26 cm (26-37 %) with lesser increases in the lower horizons (Table 6). This site was in annual ryegrass when sampled in 1965 but in 1967 was extensively leveled and seeded to perennial Kentucky bluegrass.

Site III shows a 12 percent decrease in carbon content in the upper 18 cm after ten years while the lower horizons showed increased carbon values (Table 6). This site has been in perennial ryegrass since 1965 and in annual ryegrass before that. The site was leveled prior to the 1965 sampling.

Amity

Amity carbon data (Table 6 and Figure 7) for one grass seed crop and two pasture sites showed no statistically significant differences (a=.05) in carbon values after ten years. The small gains in carbon (10 to 30 %) at site I reflect management practices. This nonburned, unplowed mixed-perennial pasture received 80 pounds of ammonium sulfate in 1970 and 1973 and hog manure in 1975.

At site II, carbon contents in the upper 36 cm were slightly lower after ten years. Site II, a perennial mixed pasture since at least 1945, was plowed in 1973 for the first time in 20 years with two 80 pound applications per year of 10-10-10 NPK since 1968.

Site III, an annual ryegrass field, showed little change in carbon content in the Ap horizon but some carbon losses (28 to 39 %) in the A12 and A2 horizons after ten years. Unfortunately only one grass seed crop site was sampled in 1965.

Carbon values in these Amity soils exhibited trends consistent with well-managed pastured soils by maintained or increased carbon contents while grass seed crop soils decreased in carbon content.

## Woodburn

Woodburn carbon data (Table 6 and Figure 7) for a single grass seed crop site generally decreased but showed no statistical significant difference (a=.05) over ten years. The lack of significant data probably results from a low degree of freedom used in the statistical analysis.

## Summary

The 1975 carbon values for pasture soil sites were significantly higher (a=.05) while the grass seed crop soil sites showed no statistical significant difference.

## Comparison with Pomerening's Carbon Frequency Distribution

Comparison of 1975 total carbon data (Table 7) with the carbon frequency distribution determined by Pomerening (1961) were made. The 1975 data fell within Pomerening's carbon frequency distribution for all sites except one: a Dayton A1 horizon at the Finley "virgin" site, had slightly more carbon than the highest carbon value determined by Pomerening. Pomerening found that carbon values above 3.4 percent were invariably from sites that had never been cultivated. He also indicated that carbon values above 4.1 percent were from sites that had recently been burned presumably after clearing a wooded area. Individuals with carbon values less than 3.4 percent were from cultivated sites. Few surface horizon carbon values (A1 or Ap) exceeded 3.0 percent (88 % had less than 3.0 % carbon). This might be a result of cultivation and other man-induced management practices. The A2 or A3 horizon carbon values are all less than 2.1 percent. The range in carbon content within a given horizon is such that it was not possible to differentiate between soil series using the carbon frequency distribution.

The range in carbon values was wider for surface horizons, A1 or A2 (0-30 cm) than for A2 or A3 (15-45 cm) horizons. This could be expected from differences in vegetation, management practices, reduced biomass and possibly qualitative changes in organic materials.

Table 7. Frequency distributions for percentage of organic carbon in two horizons of Woodburn, Amity, Concord and Dayton Soils, Pomerenings's 1961 Tabulation vs 1975 Data.

| | A1 or Ap | | | | A2 or A3 | | | |
|---|---|---|---|---|---|---|---|---|
| Percent Carbon | Wo | Am | Co | Da | Wo | Am | Co | Da |
| 0.2-0.3 | | | | | 1 | 3 | 2(2) | 10 |
| 0.4-0.5 | | | | | 3 | 11 | 4(1) | 3(1) |
| 0.6-0.7 | | | | | 4 | 6(1) | 4(2) | 5(2) |
| 0.8-0.9 | | | | 1 | 5 | 2 | 4 | 1(1) |
| 1.0-1.1 | | 1 | 2(1) | 6 | 3(2) | 6(1) | 2 | 1(1) |
| 1.2-1.3 | 1 | 2 | 1(1) | 4 | 0(1) | 4 | | 1 |
| 1.4-1.5 | 2 | 3 | 2(1) | 3(1) | 3(1) | 1(2) | | |
| 1.6-1.7 | 3 | 3 | 0(1) | 2(2) | 0(1) | 3(1) | | |
| 1.8-1.9 | 2 | 4(1) | 3(1) | 1 | 0 | 2(1) | | |
| 2.0-2.1 | 4(2) | 6(1) | 3 | 1 | 1 | | | |
| 2.2-2.3 | 0 | 4 | 2 | 0 | | | | |
| 2.4-2.5 | 3(1) | 6(2) | 2 | 1 | | | | |
| 2.6-2.7 | 1 | 3 | 1 | 1 | | | | |
| 2.8-2.9 | 2 | 1 | | 0 | | | | |
| 3.0-3.1 | 0 | 2 | 2 | 0(1) | | | | |
| 3.2-3.3 | 0(1) | 1(1) | | 0 | | | | |
| 3.4-3.5 | 1 | 1(1) | | 0 | | | | |
| 3.6-3.7 | 0 | 0 | | 0 | | | | |
| 3.8-3.9 | 0 | 0 | | 0 | | | | |
| 4.0-4.1 | 0 | 0 | | 1 | | | | |
| 4.2-4.3 | 0(1) | 1 | | 0(1) | | | | |
| - | | | | | | | | |
| 6.0-6.1 | 1 | | | | | | | |

Numbers in parentheses indicate 1975 data from both pasture and grass seed crop sites.

Soluble Components (1975 Data)

Soluble organic components such as sugars, amino acids, certain soluble proteins, organic acids, alcohols, starches and pectins are good substrates for microbes, hence they exert an important influence on the level of biological activity in the soil.

Hu et al. (1972) reported that soluble carbon determination is a valid measure of the decomposition and humification stage of the soil organic matter. Hu et al. (1972) concluded in forest litter layers, less than 12 mg C/gm litter indicated well decomposed and humified material, 12-20 mg C/gm litter indicated moderately decomposed and humified material and greater than 20 mg C/gm litter indicated relatively undecomposed material.

Data from the present study indicated that soil organic material has less milligrams of soluble carbon than forest litter but the same principles apply. Soluble carbon varied from 2.26 mg C/gm soil to 0.12 mg C/gm soil. The soluble carbon data are indicative of well decomposed and humified material. No apparent trends were indicated by the data between pasture and grass seed crop soil sites.

Table 8 shows that Woodburn soil sites have decreasing soluble carbon with depth. This indicates that the soil carbon is becoming more humified with depth (Hu et al., 1972). Statistically, the grass seed crop soil sites have a significantly (a=.05) more humified organic material than the pasture sites. The Woodburn Finley "virgin" site is slightly more humified at its surface (0-15 cm)

Table 8 Comparison of milligrams water soluble carbon per gram soil between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Site | Depth cm | mg C/gm Soil P | mg C/gm Soil GSC | % Diff. from P | Soil Site | Depth cm | mg C/gm Soil P | mg C/gm Soil GSC | % Diff. from P |
|---|---|---|---|---|---|---|---|---|---|
| Dayton | 0-15 | 1.31 | - | - | Concord | 0-15 | 0.24 | 0.31 | +29 |
| | 15-30 | 0.57 | - | - | | 15-30 | 0.07 | 0.11 | +57 |
| F | 30-45 | 0.43 | - | - | I | 30-45 | 0.22 | 0.17 | -23 |
| | 45-60 | 0.46 | - | - | | 45-60 | 0.17 | 0.10 | -41 |
| I | 0-15 | 0.53 | 0.70 | +32 | II | 0-15 | - | 0.62 | - |
| | 15-30 | 0.32 | 0.36 | +13 | | 15-30 | - | 0.30 | - |
| | 30-45 | 0.26 | 0.20 | -23 | | 30-45 | - | 0.13 | - |
| | 45-60 | 0.18 | 0.19 | +6 | | 45-60 | - | 0.21 | - |
| II | 0-15 | 1.41 | 0.73 | -48 | III | 0-15 | 0.31 | 0.37 | +19 |
| | 15-30 | 0.35 | 0.45 | +29 | | 15-30 | 0.08 | 0.08 | 00 |
| | 30-45 | 0.21 | 0.14 | -33 | | 30-45 | 0.17 | 0.16 | -6 |
| | 45-60 | 0.12 | 0.12 | 00 | | 45-60 | 0.21 | 0.20 | -5 |
| Amity | 0-15 | 1.09 | - | - | Woodburn | 0-15 | 1.30 | - | - |
| | 15-30 | 0.53 | - | - | | 15-30 | 0.67 | - | - |
| F | 30-45 | 0.35 | - | - | F | 30-45 | 0.47 | - | - |
| | 45-60 | 0.32 | - | - | | 45-60 | 0.33 | - | - |
| I | 0-15 | 1.14 | 0.50 | -56 | I | 0-15 | 1.64 | 0.58 | -65 |
| | 15-30 | 0.39 | 0.14 | -64 | | 15-30 | 0.70 | 0.33 | -53 |
| | 30-45 | 0.34 | 0.12 | -65 | | 30-45 | 0.47 | 0.16 | -66 |
| | 45-60 | 0.38 | 0.14 | -63 | | 45-60 | 0.33 | 0.06 | -82 |
| II | 0-15 | 0.81 | 0.56 | -31 | II | 0-15 | 2.26 | 1.20 | -47 |
| | 15-30 | 0.55 | 0.28 | -49 | | 15-30 | 0.46 | 0.23 | -50 |
| | 30-45 | 0.22 | 0.17 | -23 | | 30-45 | 0.25 | 0.23 | -8 |
| | 45-60 | 0.17 | 0.13 | -24 | | 45-60 | 0.11 | 0.07 | -36 |
| III | 0-15 | - | 0.73 | - | | | | | |
| | 15-30 | - | 0.44 | - | | | | | |
| | 30-45 | - | 0.39 | - | | | | | |
| | 45-60 | - | 0.29 | - | | | | | |

Note: Finley "virgin" sites are designated by the "F" symbol than both pasture sites.

Soluble carbon levels in the other three soil series, Amity, Concord and Dayton (Table 8) seem to be controlled by the water table rather than the degree of humification. These soluble carbon levels are indicators of humification only in the upper 30 cm of the soil.

In the upper 30 cm, the Amity grass seed crop soil sites exhibit greater humification than the pasture sites. The Amity Finley "virgin" site is comparable to the two pasture sites.

Concord and Dayton pasture sites seem to be more humified than the respective grass seed crop sites in the upper 30 cm.

These soils, ranked according to their soluble carbon contents (mg C/gm soil) are listed in order of increasing humification: Woodburn, Dayton, Amity and Concord for pasture soil sites. The grass seed crop soil sites are collectively ranked from Dayton, Woodburn, Amity to Concord. This ranking is for the surface 15 cm of the soil profile.

Soluble Components from Two Sampling Periods, 1965 and 1975

The soluble carbon data (Table 9) shows decreasing soluble carbon (mg C/gm soil) with depth. This indicates that the soil organic matter is becoming more humified with depth (Hu et al., 1972). There is no significant difference between sampling periods.

There is no trend in the degree of humification between the two sampling periods. Sixty-three percent of the 1965 samples indicated less humified organic matter as compared to 1975.

Table 9 Comparison of milligrams soluble carbon per gram soil as it varies with time, 1965 to 1975 in pasture (P) and grass seed crop (GSC) sites.

| Soil Series | Site | Horizon | Depth cm | mg C/gm Soil 1965 | mg C/gm Soil 1975 | % Diff. from 1975 |
|---|---|---|---|---|---|---|
| Dayton | I-P | Ap | 0-18 | 0.75 | 0.63 | -16 |
| | | A2 | 18-33 | 0.20 | 0.25 | +25 |
| | | B21t | 33-45 | 0.22 | 0.14 | +36 |
| | II-P | Ap | 0-20 | 0.38 | 1.15 | +203 |
| | | A2 | 20-33 | 0.16 | 0.21 | +31 |
| | | B21t | 33-58 | 0.18 | 0.15 | -17 |
| Concord | I-GSC | Ap | 0-15 | 0.56 | 0.31 | +45 |
| | | A2 | 15-30 | 0.18 | 0.11 | -39 |
| | | B1 | 30-51 | 0.13 | 0.11 | -15 |
| | | B2t | 51-74 | 0.10 | 0.05 | -50 |
| | II-GSC | Ap | 0-13 | 0.56 | 0.63 | +13 |
| | | A12 | 13-26 | 0.27 | 0.29 | +7 |
| | | A2 | 26-48 | 0.14 | 0.06 | -57 |
| | | B1 | 48-66 | 0.07 | 0.06 | -14 |
| | III-GSC | Ap | 0-18 | 0.88 | 0.65 | -26 |
| | | A21 | 18-38 | 0.17 | 0.33 | +94 |
| | | A22 | 38-56 | 0.17 | 0.11 | -35 |
| | | B1 | 56-64 | 0.06 | 0.13 | +117 |
| Amity | I-P | A11 | 0-23 | 0.84 | 0.68 | -19 |
| | | A12 | 23-43 | 0.41 | 0.24 | -41 |
| | | A2 | 43-58 | 0.15 | 0.19 | +27 |
| | II-P | A11 | 0-36 | 0.96 | 0.54 | -44 |
| | | A12 | 36-56 | 0.24 | 0.15 | -38 |
| | | A2 | 56-71 | 0.08 | 0.13 | +63 |
| | III-GSC | Ap | 0-20 | 0.66 | 0.63 | -5 |
| | | A12 | 20-38 | 0.29 | 0.27 | -7 |
| | | A2 | 38-58 | 0.10 | 0.13 | +30 |
| Woodburn | I-GSC | Ap | 0-20 | 0.83 | 0.57 | -31 |
| | | A12 | 20-36 | 0.43 | 0.22 | -49 |
| | | B1 | 36-58 | 0.20 | 0.13 | -35 |

## Total Nitrogen

### 1975 Data

Total nitrogen values in these four soil series did not follow a consistent trend. The Dayton, Amity and Woodburn pasture sites (Table 10 and Figures 8, 9, 10, 11) showed higher nitrogen values while the Concord pasture sites showed lower values. Overall, nitrogen values in the pasture sites were significantly (a=.05) higher than in the grass seed crop sites. Individually, Amity and Woodburn pasture sites showed significantly higher nitrogen values, while Dayton and Concord sites showed no significant difference between comparison sites.

Mean nitrogen data (Table 11) from the four soil series, showed significantly higher nitrogen values in the pasture sites.

It is generally assumed that nitrogen carry-over does not occur from the fertilization programs in this study area, due mainly to rainfall induced leaching and the high water table regimes. This is very pronounced in Dayton and Concord soils with high water tables saturating the surface horizons, but does not occur to the same degree in Amity and Woodburn soils.

Nitrogen data from the Finley "virgin" sites (Dayton, Amity and Woodburn) did not show a consistent relationship with drainage characteristics. The Dayton site showed the highest nitrogen values in the upper 15 cm of the soil profile. This may result from organic matter buildup caused by prolonged anerobic conditions. Below 30 cm, nitro-

Table 10 Comparison of total soil nitrogen between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Site | Depth cm | % Nitrogen P | GSC | % Diff. from P | | Depth cm | % Nitrogen P | GSC | % Diff. from P |
|---|---|---|---|---|---|---|---|---|---|
| Dayton | 0-15 | 0.35 | - | - | Concord | 0-15 | 0.20 | 0.19 | -5 |
| | 15-30 | 0.19 | - | - | | 15-30 | 0.10 | 0.14 | +40 |
| F | 30-45 | 0.09 | - | - | I | 30-45 | 0.06 | 0.07 | +17 |
| | 45-60 | 0.06 | - | - | | 45-60 | 0.04 | 0.04 | 00 |
| | 60-75 | 0.06 | - | - | | 60-75 | 0.03 | 0.04 | +33 |
| I | 0-15 | 0.14 | 0.13 | -7 | II | 0-15 | - | 0.16 | - |
| | 15-30 | 0.13 | 0.09 | -31 | | 15-30 | - | 0.13 | - |
| | 30-45 | 0.05 | 0.06 | +20 | | 30-45 | - | 0.07 | - |
| | 45-60 | 0.05 | 0.04 | -20 | | 45-60 | - | 0.05 | - |
| | 60-75 | 0.04 | 0.03 | -25 | | 60-75 | - | 0.04 | - |
| II | 0-15 | 0.26 | 0.15 | -42 | III | 0-15 | 0.14 | 0.15 | +7 |
| | 15-30 | 0.13 | 0.13 | 00 | | 15-30 | 0.06 | 0.08 | +33 |
| | 30-45 | 0.07 | 0.06 | -14 | | 30-45 | 0.05 | 0.05 | 00 |
| | 45-60 | 0.05 | 0.05 | 00 | | 45-60 | 0.05 | 0.05 | 00 |
| | 60-75 | 0.05 | 0.04 | -20 | | 60-75 | 0.04 | 0.04 | 00 |
| Amity | 0-15 | 0.26 | - | - | Woodburn | 0-15 | 0.24 | - | - |
| | 15-30 | 0.18 | - | - | | 15-30 | 0.19 | - | - |
| F | 30-45 | 0.13 | - | - | F | 30-45 | 0.14 | - | - |
| | 45-60 | 0.11 | - | - | | 45-60 | 0.12 | - | - |
| | 60-75 | 0.07 | - | - | | 60-75 | 0.07 | - | - |
| I | 0-15 | 0.25 | 0.15 | -40 | I | 0-15 | 0.33 | 0.20 | -39 |
| | 15-30 | 0.17 | 0.08 | -53 | | 15-30 | 0.20 | 0.16 | -20 |
| | 30-45 | 0.13 | 0.05 | -62 | | 30-45 | 0.14 | 0.10 | -29 |
| | 45-60 | 0.08 | 0.04 | -50 | | 45-60 | 0.10 | 0.07 | -30 |
| | 60-75 | 0.07 | 0.03 | -57 | | 60-75 | 0.06 | 0.05 | -17 |
| II | 0-15 | 0.20 | 0.19 | -5 | II | 0-15 | 0.50 | 0.19 | -70 |
| | 15-30 | 0.15 | 0.13 | -13 | | 15-30 | 0.16 | 0.15 | -6 |
| | 30-45 | 0.11 | 0.11 | 00 | | 30-45 | 0.12 | 0.10 | -17 |
| | 45-60 | 0.06 | 0.05 | -17 | | 45-60 | 0.08 | 0.06 | -25 |
| | 60-75 | 0.05 | 0.05 | 00 | | 60-75 | 0.07 | 0.06 | -14 |
| III | 0-15 | - | 0.17 | - | | | | | |
| | 15-30 | - | 0.14 | - | | | | | |
| | 30-45 | - | 0.08 | - | | | | | |
| | 45-60 | - | 0.04 | - | | | | | |
| | 60-75 | - | 0.03 | - | | | | | |

Note: Finley "virgin" sites are designated by the "F" symbol

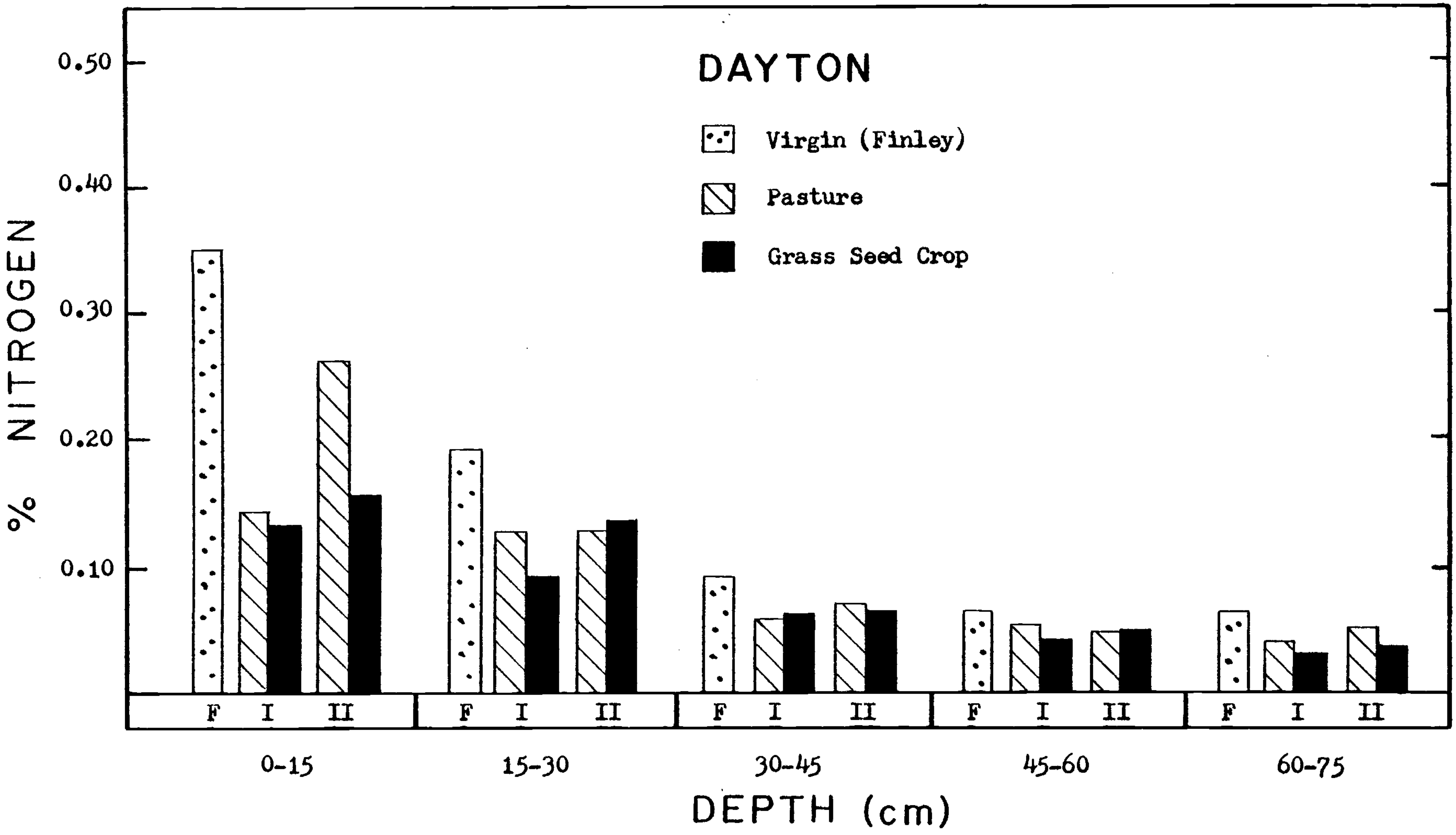


Figure 8. Comparison of total soil nitrogen between pasture (P) and grass seed crop (GSC) soil sites from 1975 data. See Table 10.

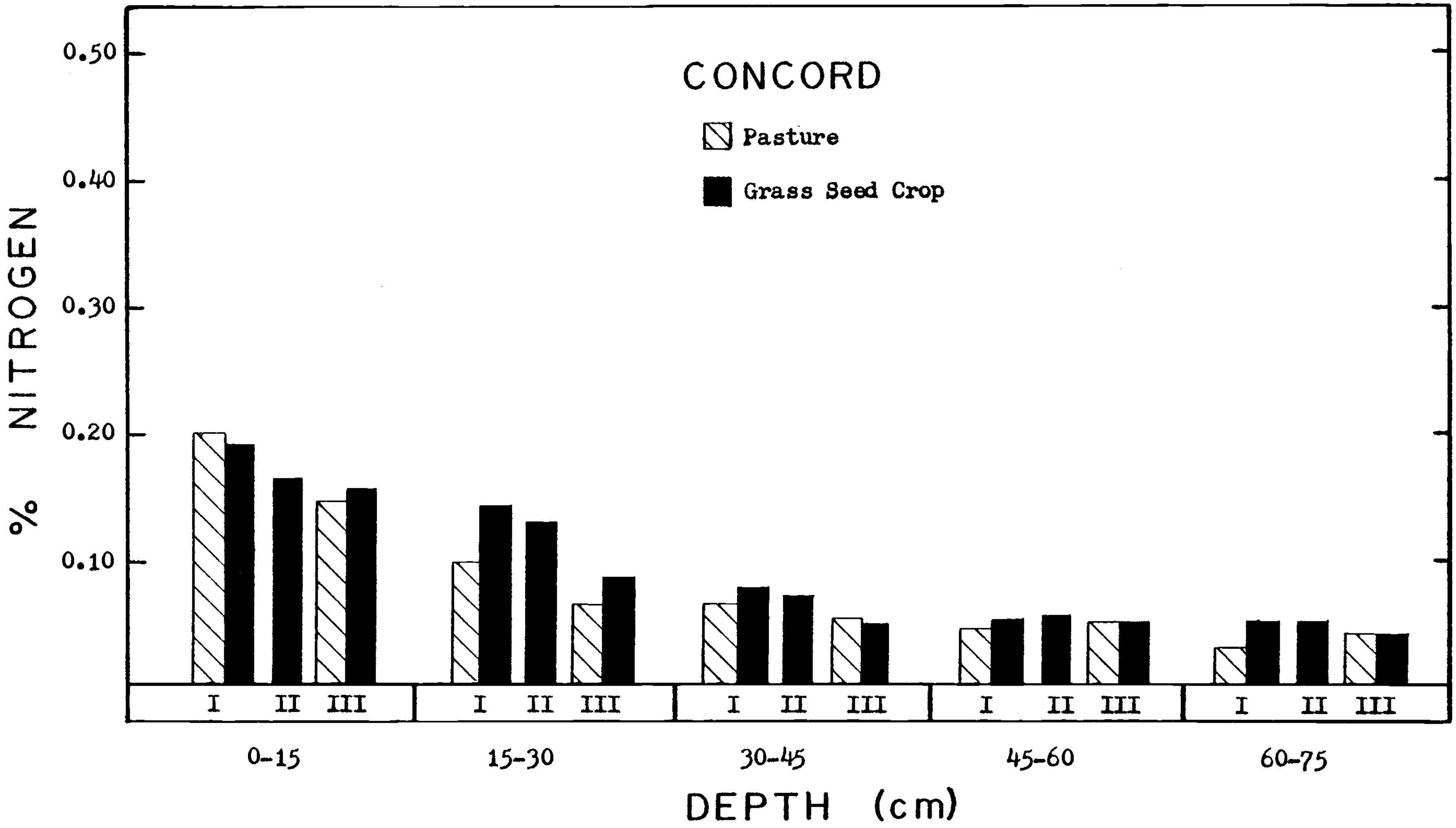


Figure 9. Comparison of total soil nitrogen between pasture (P) and grass seed crop (GSC) soil sites from 1975 data. See Table 10.

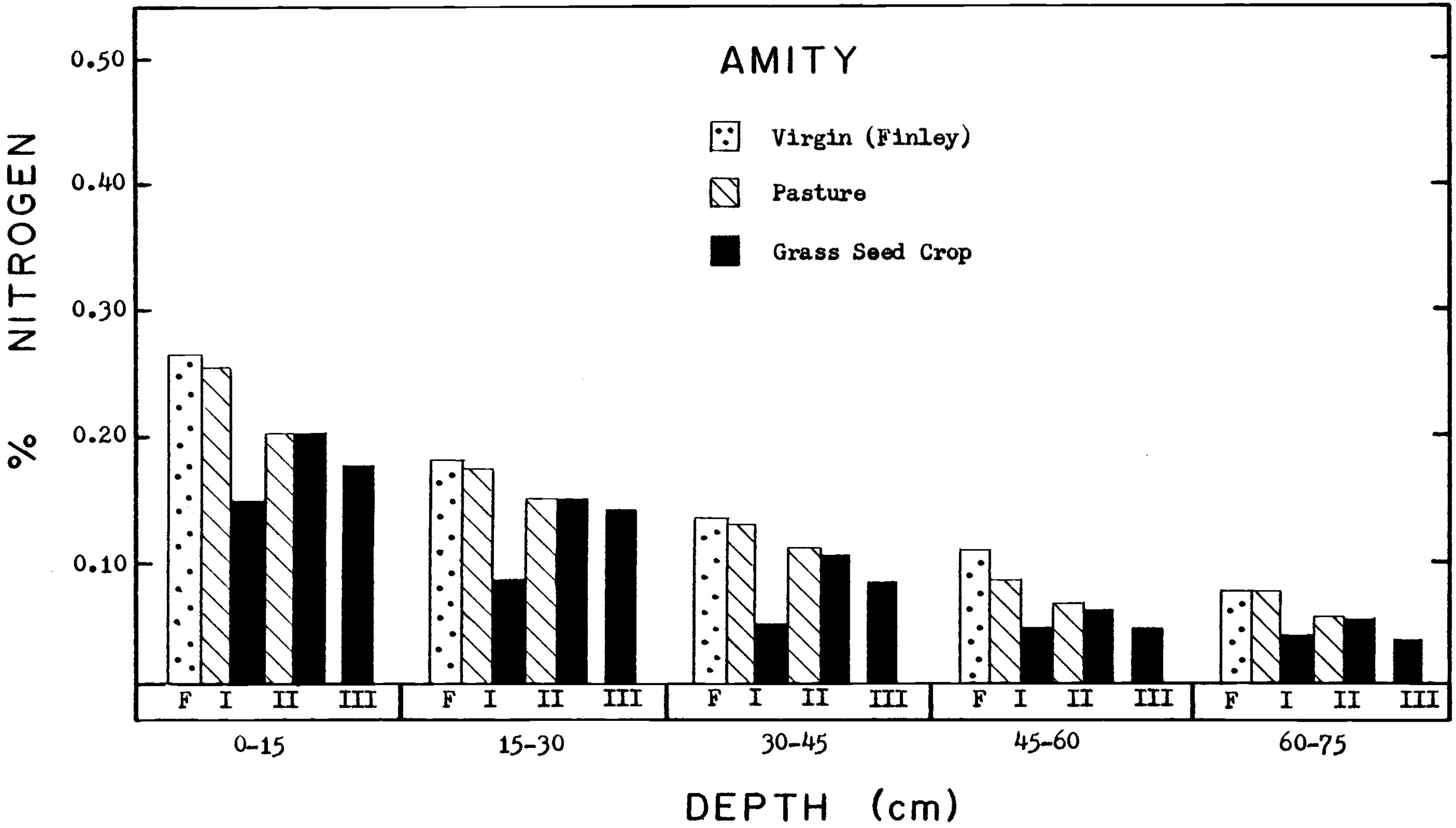


Figure 10. Comparison of total soil nitrogen between pasture (P) and grass seed crop (GSC) soil sites from 1975 data. See Table 10.

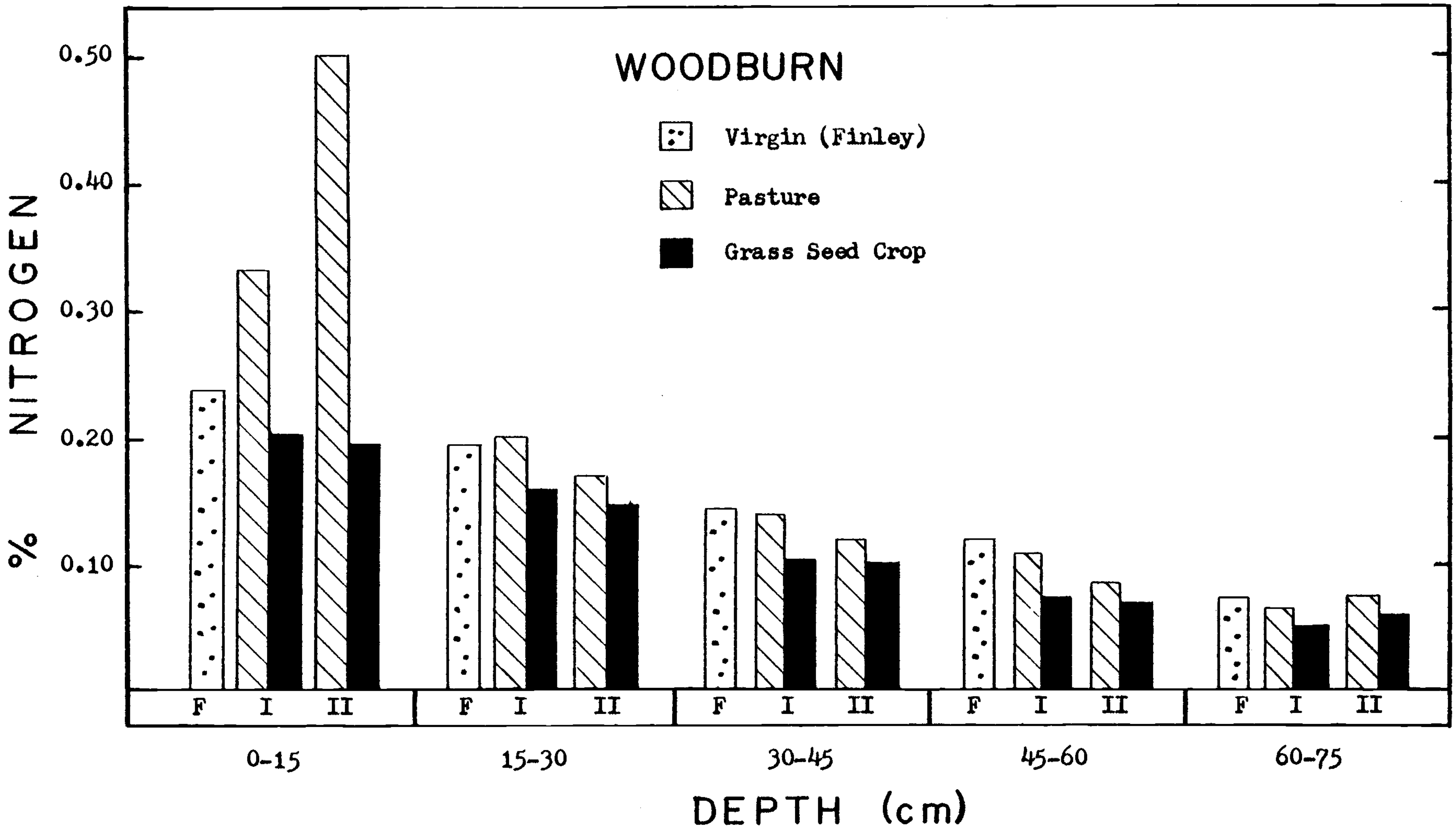


Figure 11. Comparison of total soil nitrogen between pasture (P) and grass seed crop (GSC) soil sites from 1975 data. See Table 10.

Table 11 Comparison of mean total soil nitrogen data between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Series | Depth cm | % Nitrogen P | % Nitrogen GSC | % Diff. from P |
|---|---|---|---|---|
| Dayton | 0-15 | 0.25 | 0.14 | -44 |
| | 15-30 | 0.15 | 0.11 | -27 |
| | 30-45 | 0.07 | 0.06 | -14 |
| | 45-60 | 0.05 | 0.04 | -20 |
| | 60-75 | 0.05 | 0.03 | -40 |
| Concord | 0-15 | 0.17 | 0.17 | 00 |
| | 15-30 | 0.08 | 0.12 | +50 |
| | 30-45 | 0.06 | 0.06 | 00 |
| | 45-60 | 0.04 | 0.05 | +25 |
| | 60-75 | 0.03 | 0.04 | +33 |
| Amity | 0-15 | 0.24 | 0.17 | -29 |
| | 15-30 | 0.17 | 0.12 | -29 |
| | 30-45 | 0.12 | 0.08 | -33 |
| | 45-60 | 0.08 | 0.05 | -38 |
| | 60-75 | 0.06 | 0.04 | -33 |
| Woodburn | 0-15 | 0.35 | 0.20 | -43 |
| | 15-30 | 0.18 | 0.15 | -17 |
| | 30-45 | 0.13 | 0.10 | -23 |
| | 45-60 | 0.10 | 0.07 | -30 |
| | 60-75 | 0.07 | 0.05 | -29 |

gen levels dramatically decreased below those found in Amity and Woodburn sites. Amity and Woodburn nitrogen values were very simiiliar except in the upper 15 cm, where the Woodburn site had the higher level.

## Data From Two Sampling Periods, 1965 and 1975

### Dayton

Data comparisons between the two sampling periods for two Dayton perennial pasture sites showed significant increases in nitrogen contents over time. All sampled horizons showed increases from 1965 to 1975 (Table 12 and Figure 12).

Concord

Nitrogen values from the 1975 sampling for Concord soils showed significant (a=.05) increases in nitrogen over the 1965 sampling period (Table 12 and Figure 12).

Amity

Nitrogen data from the 1975 sampling period showed no significant differences from the 1965 sampling period. Site I, a mixed perennial pasture, showed consistently higher values over time. Site II, a pasture site, showed consistent, although slight, decreases in nitrogen with time. Site III, an annual ryegrass seed crop site, showed no consistent trends in nitrogen values over time (Table 12 and Figure 13).

Woodburn

Site I, an annual ryegrass seed crop site, showed no significant increases in nitrogen values. Only one horizon (20-36 cm) showed a slight decrease (Table 12 and Figure 13).

There were significant increases in nitrogen contents in the 1975 sampling period independent of management practices (pasture or grass seed crop agriculture).

Table 12 Comparison of total soil nitrogen in pasture (P) and grass seed crop (GSC) sites from two sampling periods, 1965 and 1975.

| Soil Series | Site | Horizon | Depth cm | % Total Nitrogen 1965 | % Total Nitrogen 1975 | % Diff. from 1965 |
|---|---|---|---|---|---|---|
| Dayton | I-P | Ap | 0-18 | 0.10 | 0.12 | +20 |
| | | A2 | 18-33 | 0.07 | 0.09 | +29 |
| | | B21t | 33-48 | 0.06 | 0.07 | +17 |
| | | B22t | 48-74 | 0.03 | 0.05 | +67 |
| | II-P | Ap | 0-20 | 0.12 | 0.23 | +97 |
| | | A2 | 20-33 | 0.07 | 0.10 | +43 |
| | | B21t | 33-58 | 0.04 | 0.05 | +25 |
| | | B22t | 58-79 | 0.03 | 0.04 | +33 |
| Concord | I-GSC | Ap | 0-15 | 0.10 | 0.19 | +90 |
| | | A2 | 15-30 | 0.06 | 0.14 | +133 |
| | | B1 | 30-51 | 0.05 | 0.06 | +20 |
| | | B2t | 51-74 | 0.05 | 0.03 | -40 |
| | II-GSC | Ap | 0-13 | 0.12 | 0.15 | +25 |
| | | A12 | 13-26 | 0.09 | 0.12 | +33 |
| | | A2 | 26-48 | 0.06 | 0.07 | +17 |
| | | B1 | 48-66 | 0.04 | 0.05 | +25 |
| | III-GSC | Ap | 0-18 | 0.16 | 0.14 | -13 |
| | | A21 | 18-38 | 0.08 | 0.08 | 00 |
| | | A22 | 38-56 | 0.05 | 0.06 | +20 |
| | | B1 | 56-64 | 0.04 | 0.05 | +25 |
| | | B2t | 64-84 | 0.03 | 0.04 | +33 |
| Amity | I-P | A11 | 0-23 | 0.15 | 0.20 | +33 |
| | | A12 | 23-43 | 0.12 | 0.14 | +17 |
| | | A2 | 43-58 | 0.07 | 0.08 | +14 |
| | | B2t | 58-81 | 0.05 | 0.06 | +20 |
| | II-P | A11 | 0-36 | 0.18 | 0.17 | -6 |
| | | A12 | 36-56 | 0.11 | 0.10 | -9 |
| | | B2t | 56-71 | 0.04 | 0.06 | +50 |
| | III-GSC | Ap | 0-20 | 0.17 | 0.18 | +6 |
| | | A12 | 20-38 | 0.13 | 0.11 | -15 |
| | | B1 | 38-58 | 0.07 | 0.05 | -29 |
| | | B21t | 58-89 | 0.02 | 0.04 | +100 |
| Woodburn | I-GSC | Ap | 0-20 | 0.18 | 0.18 | 00 |
| | | A12 | 20-36 | 0.14 | 0.13 | -7 |
| | | B1 | 36-58 | 0.08 | 0.08 | 00 |
| | | B21t | 58-76 | 0.05 | 0.05 | 00 |

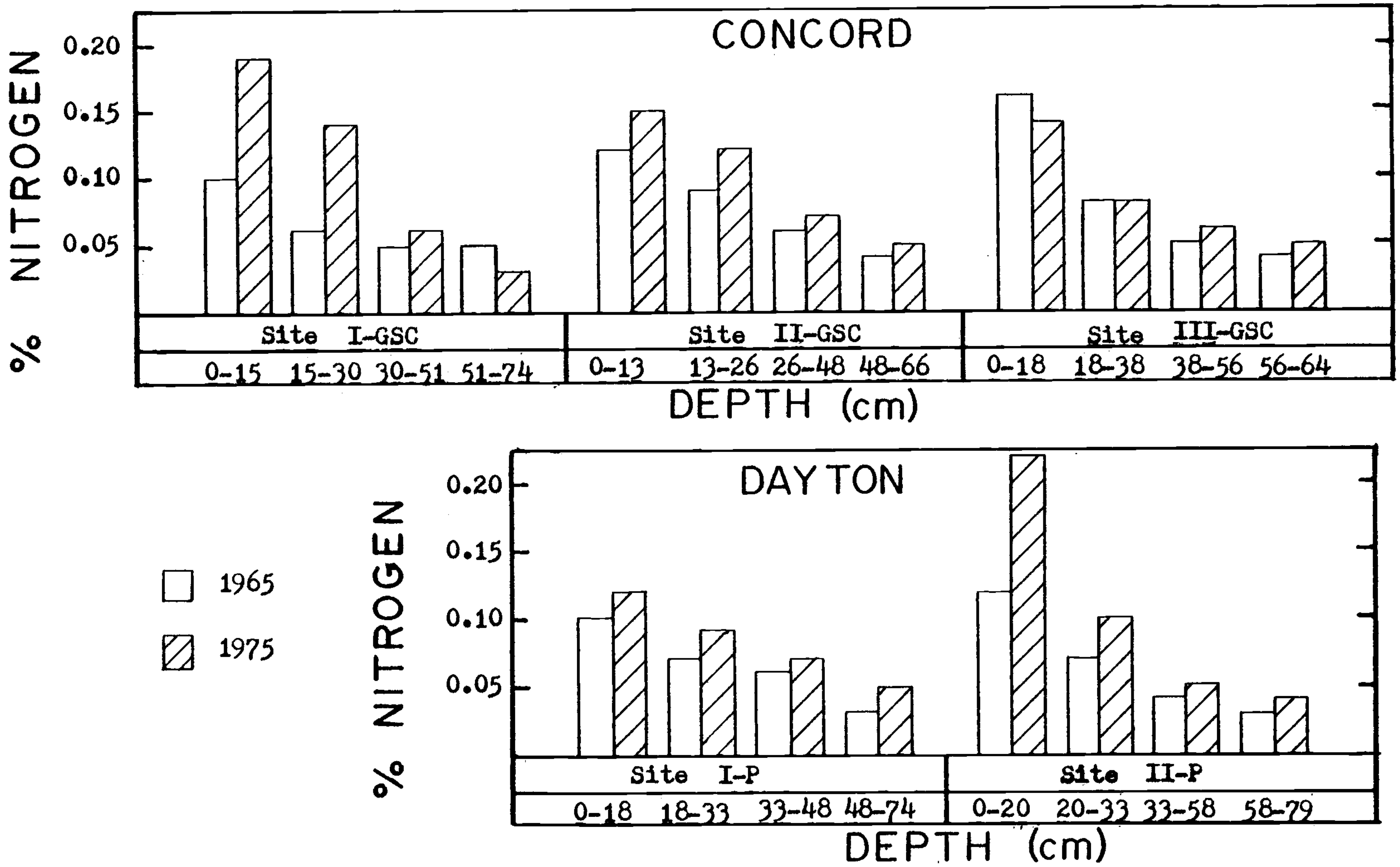


Figure 12. Comparison of total soil nitrogen in pasture (P) and grass seed crop (GSC) sites from two sampling periods, 1965 and 1975. See Table 12.

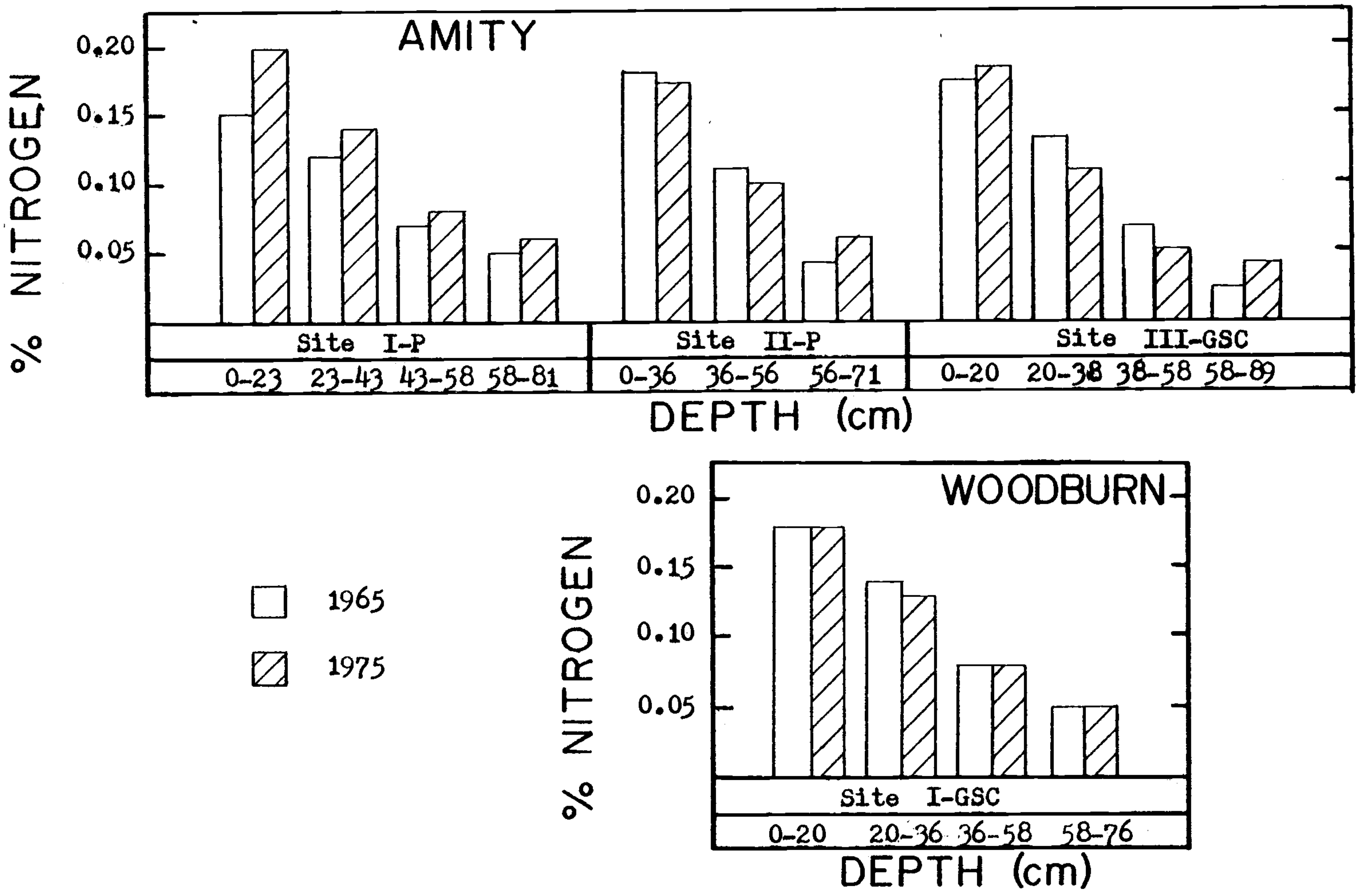


Figure 13. Comparison of total soil nitrogen in pasture (P) and grass seed crop (GSC) sites from two sampling periods, 1965 and 1975. See Table 12.

Nitrogen increases result from fertilization practices and the resulting increases in soil biomass. Increased biomass in turn increases nitrogen mineralization (Russell, 1973). The soluble nitrogen is leached and little soluble nitrogen is carried over from one year to the next.

Comparisons with Pomerening's Nitrogen Frequency Distribution

The recent total nitrogen data (Table 13) were somewhat on the higher end of Pomerening's (1961) total nitrogen frequency distribution. Two sites, a Woodburn and Dayton, had total nitrogen values above the range of Pomerening's frequency distribution for the A1 or Ap horizons. The Woodburn site is a noncultivated pasture site. The Dayton is the Finley "virgin" site.

The A2 or A3 horizons showed the same trend of being on the higher end of the distribution. There are two values above the range of this distribution, an Amity "virgin" site and a Dayton "virgin" site.

Total nitrogen frequency distributions were not particularly significant. Management practices and the unknown quantities of fertilizers that have been added, have not been taken into consideration.

Table 13 Frequency distributions for percentage of nitrogen in two horizons of Woodburn, Amity, Concord and Dayton Soils, Pomerening's 1961 tabulation vs 1975 data.

| Percent Nitrogen | A1 or Ap Wo | A1 or Ap Am | A1 or Ap Co | A1 or Ap Da | A2 or A3 Wo | A2 or A3 Am | A2 or A3 Co | A2 or A3 Da |
|---|---|---|---|---|---|---|---|---|
| .02-.03 | | | | | | | 1 | |
| .04-.05 | | | | | 5 | 11 | 3(2) | 12 |
| .06-.07 | | | | | 4 | 10(1) | 2(3) | 5 |
| .08-.09 | 3 | 1 | 1 | 1 | 6 | 5 | 9 | 2(2) |
| .10-.11 | 2 | 5 | 1(1) | 6 | 2(2) | 4(1) | 1 | 2(2) |
| .12-.13 | 2 | 5 | 3(1) | 5(1) | 2(1) | 3(2) | | 0 |
| .14-.15 | 4 | 4(1) | 1(2) | 4(2) | 0(2) | 5(1) | | 0(1) |
| .16-.17 | 1(1) | 8(1) | 4(1) | 2 | 0 | 0(1) | | |
| .18-.19 | 2(1) | 9 | 4 | 1 | 1 | | | |
| .20-.21 | 4 | 3(2) | 1 | 0 | | | | |
| .22-.23 | 1(1) | 2 | 1 | 1 | | | | |
| .24-.25 | 0 | 1(1) | | 0 | | | | |
| .26-.27 | 1(1) | 0(1) | | 0(1) | | | | |
| .28-.29 | 0 | | | 0 | | | | |
| .30-.31 | 0 | | | 1 | | | | |
| .32-.33 | 0(1) | | | 0 | | | | |
| .34-.35 | | | | 0(1) | | | | |

Numbers in parentheses indicate 1975 data from both pasture and grass seed crop sites.

## Soluble Nitrogen Data

### 1975

Water soluble nitrogen (% N/gm soil) showed inconsistent trends in poorly drained Dayton and Concord soils and somewhat poorly drained Amity soils (Table 14), in the upper 15 cm of soil. Below 15 cm, soluble nitrogen levels were below the level of analytical competency.

Soluble nitrogen in Woodburn soils (Table 14) ranged from 0.01 to 0.03 percent nitrogen in pasture soils, while grass seed crop soils contained 0.01 percent nitrogen. The higher soluble nitrogen levels are probably the result of considerably higher total carbon and nitrogen levels present in the pasture soils.

### 1965 and 1975 Samples

There were no measurable changes in nitrogen levels between the two sampling periods (Table 15). Soluble nitrogen (% N/gm soil) levels in the Ap or A11 horizons were 0.01 percent with three exceptions (trace amounts only; less than 0.01 percent).

Table 14 Comparison of soluble nitrogen (% N/gm soil) between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Series | Site | Depth cm | % Sol. N P | GSC |
|---|---|---|---|---|
| Dayton | F | 0-15 | 0.01 | - |
| | | 15-60 | Trace | - |
| | I | 0-15 | 0.01 | 0.01 |
| | | 15-60 | Trace | Trace |
| | II | 0-15 | 0.02 | 0.01 |
| | | 15-60 | Trace | Trace |
| Concord | I | 0-15 | 0.01 | 0.01 |
| | | 15-60 | Trace | Trace |
| | II | 0-15 | 0.01 | 0.01 |
| | | 15-60 | Trace | 0.01 |
| | III | 0-15 | Trace | Trace |
| | | 15-60 | Trace | Trace |
| Amity | F | 0-15 | 0.01 | - |
| | | 15-60 | Trace | - |
| | I | 0-15 | 0.01 | 0.01 |
| | | 15-60 | 0.01 | Trace |
| | II | 0-15 | 0.01 | Trace |
| | | 15-60 | Trace | Trace |
| | III | 0-15 | - | 0.01 |
| | | 15-60 | - | Trace |
| Woodburn | F | 0-15 | 0.01 | - |
| | | 15-60 | Trace | - |
| | I | 0-15 | 0.02 | 0.01 |
| | | 15-60 | 0.01 | Trace |
| | II | 0-15 | 0.03 | 0.01 |
| | | 15-60 | 0.01 | Trace |

Note: Finley "virgin" sites designated by the "F" symbol.

## Carbon:Nitrogen Ratios

### 1975 Data

#### Dayton

Data from paired Dayton pasture and grass seed crop soil sites (Table 16) showed no significant differences (a=.05) between C/N ratios. The Finley "virgin" site had C/N ratios that ranged between those of the two pasture soil sites. Mean C/N ratios (Table 17) showed wider ratios in the pasture soil sites.

#### Concord

Data from paired Concord pasture and grass seed crop soil sites (Table 16) and mean C/N ratios (Table 17) lack significant differences between ratios. There was no apparent trend between pasture and grass seed crop soil sites.

#### Amity

Data from paired Amity pasture and grass seed crop soil sites (Table 16) and mean C/N ratios (Table 17) indicated significantly wider (a=.05) C/N ratios for the pasture soil sites. The Finley "virgin" site had C/N ratios that ranged between those of the two pasture soil sites.

Table 16 Comparison of carbon:nitrogen ratios between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Site | Depth cm | C/N P | C/N GSC | % Diff. from P | Soil Site | Depth cm | C/N P | C/N GSC | % Diff. from P |
|---|---|---|---|---|---|---|---|---|---|
| Dayton | 0-15 | 12.2 | - | - | Concord | 0-15 | 12.0 | 11.9 | -1 |
| | 15-30 | 10.6 | - | - | | 15-30 | 10.1 | 11.3 | +12 |
| F | 30-45 | 8.0 | - | - | I | 30-45 | 9.3 | 10.1 | +9 |
| | 45-60 | 6.8 | - | - | | 45-60 | 7.7 | 6.6 | -14 |
| | 60-75 | 7.7 | - | - | | 60-75 | 5.8 | 7.1 | +22 |
| I | 0-15 | 11.0 | 11.3 | +3 | II | 0-15 | - | 10.5 | - |
| | 15-30 | 10.7 | 9.5 | -11 | | 15-30 | - | 9.9 | - |
| | 30-45 | 7.0 | 8.2 | +17 | | 30-45 | - | 7.4 | - |
| | 45-60 | 6.4 | 7.3 | +14 | | 45-60 | - | 7.1 | - |
| | 60-75 | 5.3 | 6.4 | +21 | | 60-75 | - | 6.4 | - |
| II | 0-15 | 12.0 | 10.1 | -16 | III | 0-15 | 10.9 | 10.9 | 00 |
| | 15-30 | 11.6 | 9.3 | -20 | | 15-30 | 7.2 | 8.0 | +11 |
| | 30-45 | 10.3 | 6.5 | -37 | | 30-45 | 6.0 | 6.9 | +15 |
| | 45-60 | 7.4 | 6.7 | -9 | | 45-60 | 7.8 | 7.8 | 00 |
| | 60-75 | 9.4 | 6.2 | -34 | | 60-75 | 7.4 | 6.6 | -11 |
| Amity | 0-15 | 12.8 | - | - | Woodburn | 0-15 | 12.7 | - | - |
| | 15-30 | 12.0 | - | - | | 15-30 | 10.9 | - | - |
| F | 30-45 | 11.5 | - | - | F | 30-45 | 10.4 | - | - |
| | 45-60 | 10.7 | - | - | | 45-60 | 9.9 | - | - |
| | 60-75 | 8.1 | - | - | | 60-75 | 8.1 | - | - |
| I | 0-15 | 12.9 | 12.2 | -5 | I | 0-15 | 12.5 | 12.1 | -3 |
| | 15-30 | 11.8 | 10.0 | -15 | | 15-30 | 11.5 | 11.7 | +2 |
| | 30-45 | 10.8 | 7.6 | -30 | | 30-45 | 11.5 | 10.2 | -11 |
| | 45-60 | 9.6 | 7.5 | -22 | | 45-60 | 10.8 | 8.4 | -22 |
| | 60-75 | 9.1 | 6.8 | -25 | | 60-75 | 8.9 | 7.2 | -19 |
| II | 0-15 | 12.7 | 12.2 | -4 | II | 0-15 | 10.7 | 12.8 | +20 |
| | 15-30 | 12.1 | 12.5 | +3 | | 15-30 | 12.3 | 11.5 | -7 |
| | 30-45 | 12.0 | 11.6 | -3 | | 30-45 | 11.3 | 11.0 | -3 |
| | 45-60 | 10.3 | 10.7 | +4 | | 45-60 | 10.6 | 9.2 | -13 |
| | 60-75 | 9.6 | 9.2 | -4 | | 60-75 | 10.0 | 7.9 | -21 |
| III | 0-15 | - | 12.0 | - | | | | | |
| | 15-30 | - | 11.2 | - | | | | | |
| | 30-45 | - | 9.2 | - | | | | | |
| | 45-60 | - | 6.8 | - | | | | | |
| | 60-75 | - | 7.1 | - | | | | | |

Note: Finley "virgin" sites designated by the "F" symbol.

Table 17 Comparison of mean carbon:nitrogen ratios between pasture (P) and grass seed crop (GSC) soil sites from 1975 data.

| Soil Series | Depth cm | C/N P | C/N GSC | % Diff. from P |
|---|---|---|---|---|
| Dayton | 0-15 | 11.8 | 10.7 | -9 |
| | 15-30 | 11.0 | 9.4 | -15 |
| | 30-45 | 8.5 | 7.3 | -14 |
| | 45-60 | 6.9 | 7.0 | +1 |
| | 60-75 | 7.5 | 6.3 | -16 |
| Concord | 0-15 | 11.4 | 11.1 | -3 |
| | 15-30 | 8.7 | 9.8 | +13 |
| | 30-45 | 7.7 | 8.1 | +5 |
| | 45-60 | 7.8 | 7.1 | -9 |
| | 60-75 | 6.6 | 6.7 | +2 |
| Amity | 0-15 | 12.8 | 12.1 | -5 |
| | 15-30 | 12.0 | 11.3 | -6 |
| | 30-45 | 11.4 | 9.5 | -17 |
| | 45-60 | 10.2 | 8.3 | -19 |
| | 60-75 | 9.0 | 7.7 | -14 |
| Woodburn | 0-15 | 12.3 | 12.4 | +1 |
| | 15-30 | 11.6 | 11.6 | 00 |
| | 30-45 | 11.0 | 10.6 | -4 |
| | 45-60 | 10.4 | 8.8 | -15 |
| | 60-75 | 9.0 | 7.6 | -16 |

Woodburn

Data from paired Woodburn pasture and grass seed crop soil sites (Table 16) and mean C/N (Table 17) indicated significantly wider (a=.05) C/N ratios for the pasture soil sites. The Finley "virgin" site had C/N ratios narrower than the two pasture soil sites except the surface horizon (0-15 cm) which had a slightly wider ratio.

Narrowing of the C/N ratios occurred with increasing profile depth (Table 16) for all soils. This narrowing results from increased mineral-nitrogen occurring with depth (Young, 1962). The relative importance of the data below 45 cm is slight compared to the surface data.

Carbon:Nitrogen Ratios From 1965 and 1975

Dayton

Data comparisons (Table 18) from two sampling periods, 1965 and 1975, for two pasture sites showed no consistent significant trends. Site I showed a narrowing C/N ratio in the Ap horizon while site II showed a widening in the surface Ap and A2 horizons.

Concord

Concord soil sites (Table 18) showed no significant trends for C/N ratios over time. Site I showed a narrowing C/N in the Ap horizon while both sites II and III showed no changes in the Ap horizons.

Amity

Amity soil sites (Table 18) showed significant (a=.05) narrower C/N ratios over time. Site I, in pasture, showed a narrower C/N ratio in the A11, while both sites II and III showed no relative changes in the A11 and Ap horizons, respectively.

Table 18 Comparison of carbon:nitrogen ratios for pasture (P) and grass seed crop (GSC) after ten years, 1965 to 1975.

| Soil Series | Site | Horizon | Depth cm | C/N 1965 | C/N 1975 | % Diff. from 1965 |
|---|---|---|---|---|---|---|
| Dayton | I-P | Ap | 0-18 | 13.0 | 10.4 | -25 |
| | | A2 | 18-33 | 8.6 | 10.0 | +14 |
| | | B21t | 33-48 | 6.8 | 8.3 | +18 |
| | | B22t | 48-74 | 7.6 | 7.6 | 00 |
| | II-P | Ap | 0-20 | 9.8 | 12.0 | +18 |
| | | A2 | 20-33 | 8.2 | 9.1 | +10 |
| | | B21t | 33-58 | 7.7 | 6.0 | -30 |
| | | B22t | 58-79 | 6.9 | 6.7 | -3 |
| Concord | I-GSC | Ap | 0-15 | 13.6 | 11.9 | -14 |
| | | A2 | 15-30 | 10.5 | 11.3 | +8 |
| | | B1 | 30-51 | 6.3 | 5.0 | -27 |
| | | B2t | 51-74 | 4.4 | 3.5 | -23 |
| | II-GSC | Ap | 0-13 | 11.2 | 11.2 | 00 |
| | | A12 | 13-26 | 9.7 | 10.2 | +5 |
| | | A2 | 26-48 | 7.7 | 7.0 | -10 |
| | | B1 | 48-66 | 6.4 | 5.7 | +13 |
| | III-GSC | Ap | 0-18 | 11.4 | 11.4 | 00 |
| | | A21 | 18-38 | 7.3 | 8.6 | +16 |
| | | A22 | 38-56 | 4.2 | 6.3 | +33 |
| | | B1 | 56-64 | 5.4 | 8.6 | +38 |
| | | B2t | 64-84 | 5.0 | 7.1 | +30 |
| Amity | I-P | A11 | 0-23 | 13.8 | 11.9 | -15 |
| | | A12 | 23-43 | 10.5 | 10.6 | +1 |
| | | A2 | 43-58 | 9.6 | 9.3 | -3 |
| | | B2t | 58-81 | 8.2 | 7.7 | -6 |
| | II-P | A11 | 0-36 | 11.7 | 11.2 | -4 |
| | | A12 | 36-56 | 10.5 | 12.2 | +14 |
| | | A2 | 56-71 | 9.0 | 8.3 | -9 |
| | III-GSC | Ap | 0-20 | 11.3 | 11.3 | 00 |
| | | A12 | 20-38 | 11.1 | 9.5 | -17 |
| | | A2 | 38-58 | 7.8 | 6.2 | -26 |
| | | B2t | 58-89 | 8.3 | 6.3 | -33 |
| Woodburn | I-GSC | Ap | 0-20 | 11.8 | 10.7 | -10 |
| | | A12 | 20-36 | 11.1 | 11.0 | -1 |
| | | B1 | 36-58 | 8.2 | 8.8 | +8 |
| | | B21t | 58-76 | 7.6 | 6.8 | -12 |

Woodburn

The Woodburn grass seed crop site (Table 18) showed no significantly (a=.05) changed C/N ratios after ten years. There is a narrowing trend in the C/N ratios over time.

Carbon:nitrogen ratios for all sites showed no significant differences between sampling periods regardless of management practices (pasture or grass seed crop agriculture). Carbon:nitrogen ratios generally decreased with depth for all sites with a few exceptions.

Comparisons with Pomerening's C/N Frequency Distributions

Carbon:nitrogen ratios (Table 19) calculated from the 1975 data of this study, indicated a slight narrowing compared to those determined by Pomerening (1961). Pomerening's frequency distribution reflects a majority of ratios in the 10 to 13 range (A1 or Ap) but with a few ratios higher than 14. Pomerening suggested that high C/N ratios were the result of vegetational differences (wooded vs grassland). The A2 or A3 horizon data of this study had relatively the same frequency distribution as Pomerening's data. The majority of the C/N ratios were between 8 and 11.

The carbon and nitrogen data should not be the sole factor in judging changes in organic matter quality (changes in humus composition) for a soil series. Individual soil sites need to be studied over an extended period of time in order to determine any significant shifts in the soil's humus composition. Soils of each series

Table 19 Frequency distributions for carbon:nitrogen ratios of two horizons of Woodburn, Amity, Concord and Dayton samples (Data taken from Pomerening, 1961).

| C/N Ratio | A1 or Ap Wo | A1 or Ap Am | A1 or Ap Co | A1 or Ap Da | A2 or A3 Wo | A2 or A3 Am | A2 or A3 Co | A2 or A3 Da |
|---|---|---|---|---|---|---|---|---|
| 4-5 | | | | | | | 1 | 6 |
| 6-7 | | | | | 1 | 4 | 3(3) | 6 |
| 8-9 | | | 0(1) | 1 | 4 | 15(1) | 6(1) | 5(4) |
| 10-11 | 0(1) | 2 | 5(3) | 14(3) | 8(4) | 11(2) | 5(1) | 4(1) |
| 12-13 | 12(4) | 22(6) | 9(1) | 6(2) | 5(1) | 8(3) | 1 | |
| 14-15 | 5 | 10 | 1 | | 2 | | | |
| 16-17 | 1 | 2 | 1 | | | | | |
| 18-19 | 0 | 0 | | | | | | |
| 20-21 | 1 | 0 | | | | | | |
| 22-23 | 0 | 0 | | | | | | |
| 24-25 | 0 | 1 | | | | | | |
| 26-27 | 1 | 1 | | | | | | |

Numbers in parentheses indicate 1975 data from both pasture and grass seed crop sites.

represented by Pomerening's frequency distributions, are composed of individuals with organic matter in various stages of humus composition. Pomerening made no distinctions between soil management practices except to explain the occurrence of a few high carbon values.

## Soil Humus Components

### Humic Acid (1975 Data)

Both Table 20 and Figure 14 show comparisons of humic acids between surface samples (0-15 cm) of pasture and grass seed crop sites. No significant (a=.05) differences were apparent but an apparent trend exists where grass seed crop soil sites showed higher humic acid values. Woodburn site I is the only grass seed crop site which showed a lower humic acid content than its comparison pasture site. The Finley "virgin" sites were comparable in humic acid contents to pasture sites.

### Fulvic Acid (1975 Data)

Grass seed crop soil sites showed a trend of higher fulvic acid levels than pasture sites (Table 20 and Figure 15). Woodburn and one Amity site (II) showed an opposing trend. The Finley "virgin" sites did not consistently compare to the pasture sites. Amity and Woodburn Finley sites showed lower fulvic acid contents than pasture sites. The Dayton Finley site was comparable to the pasture site.

Humin (1975 Data)

Humin percentages (Table 20 and Figure 16) showed no significant differences between pasture and grass seed crop sites. The general trend was for higher humin contents in pasture sites. The Woodburn site showed an opposite trend.

The Dayton Finley site showed a humin content comparable to the pasture site. The Woodburn and Amity Finley sites showed humin contents somewhat higher than their respective pasture sites.

Humic Acid/Fulvic Acid Ratios (1975 Data)

Humic acid/fulvic acid ratios (Table 20) revealed no significant ($a=.05$) differences in comparing pasture and grass seed crop sites. No consistent trend occurred among HA/FA ratios. A Dayton, one Amity and a Woodburn, all grass seed crop sites, showed greater HA/FA ratios than their respective pasture sites. Concord sites showed no differences in ratios. One Amity pasture site showed a slightly greater HA/FA ratio.

It is reported in the literature (Alexandrova, 1966; Kononova, 1966) that humic acid quantities present in soil can be used to indicate the relative degree of humification. Generally, the smaller the humic acid content, the greater is the degree of humification. Schnitzer (1967) reported FA positively correlated and HA negatively correlated with the degree of humification. The data indicated that the grass seed crop sites had a lesser degree of humification that

Table 20 Comparison of humic acid, fulvic acid, humin and the humic acid:fulvic acid ratio between pasture (P) and grass seed crop (GSC) soil sites from 1975 data (A horizon samples, 0-15 cm).

| Series Site | Humic Acid P | Humic Acid GSC | % Diff. from P | Fulvic Acid P | Fulvic Acid GSC | % Diff. from P | Humin P | Humin GSC | % Diff. from P | HA/FA P | HA/FA GSC | % Diff. from P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dayton | | | | | | | | | | | | |
| F | 19.4 | - | - | 18.5 | - | - | 62.1 | - | - | 1.0 | - | - |
| II | 18.4 | 25.0 | +36 | 18.4 | 22.4 | +22 | 63.2 | 52.6 | -17 | 1.0 | 1.1 | +10 |
| Concord | | | | | | | | | | | | |
| I | 25.0 | 29.8 | +19 | 20.3 | 22.5 | +11 | 54.7 | 47.7 | -13 | 1.3 | 1.3 | 0.0 |
| II | 24.0 | 24.7 | +3 | 35.3 | 38.3 | +8 | 40.7 | 37.0 | -9 | 0.7 | 0.7 | 0.0 |
| Amity | | | | | | | | | | | | |
| F | 22.7 | - | - | 19.0 | - | - | 58.3 | - | - | 1.2 | - | - |
| I | 24.7 | 28.2 | +14 | 23.5 | 29.9 | +27 | 51.9 | 42.0 | -19 | 1.2 | 1.1 | -8 |
| II | 21.6 | 31.4 | +45 | 28.9 | 21.6 | -25 | 49.6 | 47.1 | -5 | 0.7 | 1.5 | +114 |
| Woodburn | | | | | | | | | | | | |
| F | 25.8 | - | - | 20.4 | - | - | 53.8 | - | - | 1.3 | - | - |
| I | 28.6 | 23.4 | -18 | 24.5 | 17.5 | -29 | 46.9 | 59.1 | +26 | 1.2 | 1.3 | +8 |

Note: Finley "virgin" sites designated by the "F" symbol.

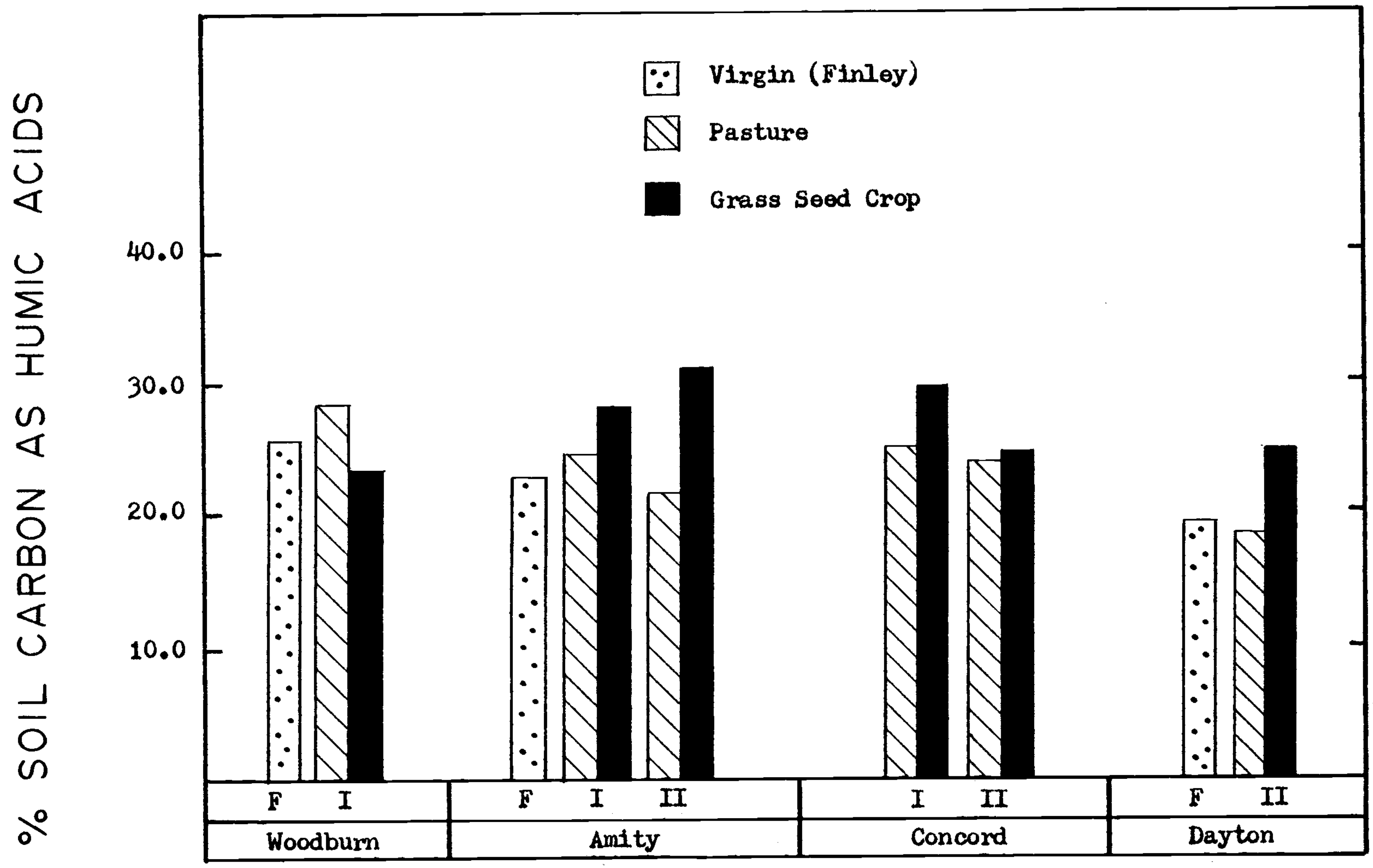


Figure 14. Comparison of percent soil carbon as humic acid between pasture (P) and grass seed crop (GSC) sites from 1975 data (A horizon samples, 0-15 cm). See Table 20.

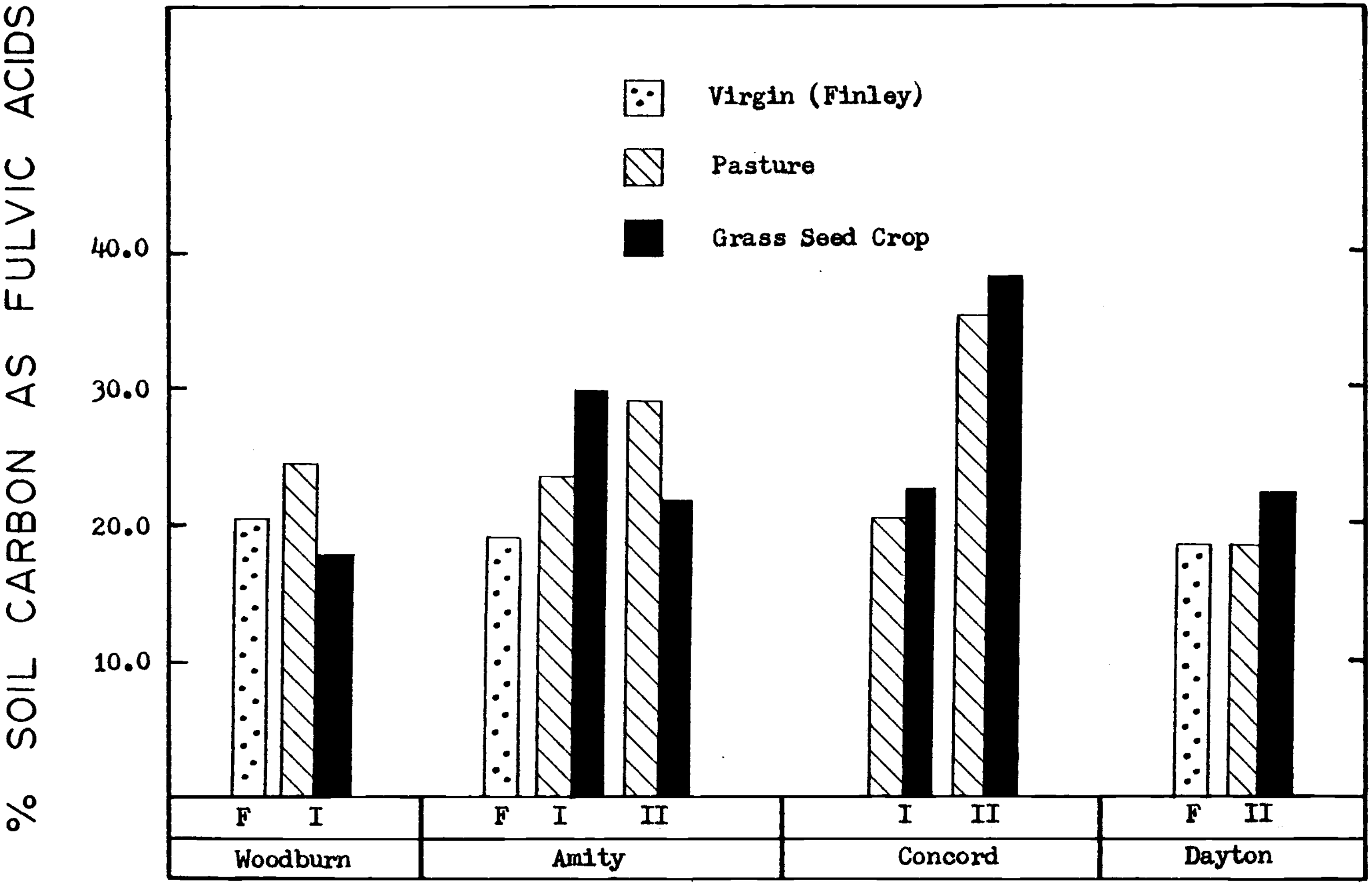


Figure 15. Comparison of percent soil carbon as fulvic acid between pasture (P) and grass seed crop (GSC) sites from 1975 data (A horizon samples, 0-15 cm). See Table 20.

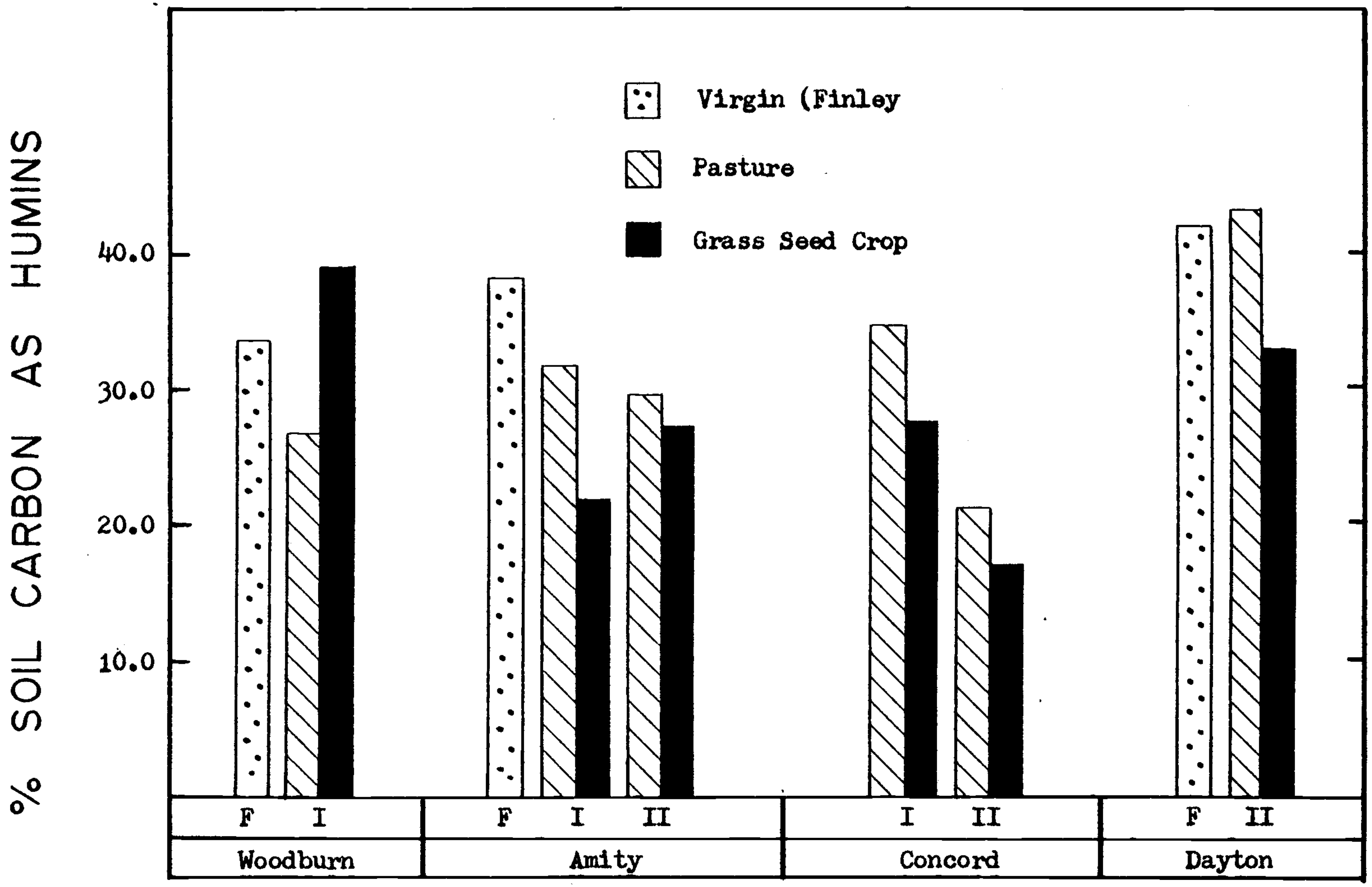


Figure 16. Comparison of percent soil carbon as humins between pasture (P) and grass seed crop (GSC) sites from 1975 data (A horizon samples, 0-15 cm). See Table 20.

the pasture sites. The grass seed crop sites generally had higher humic acid and fulvic acid and lower humin contents than the pasture sites. This is somewhat contrary to what Kononova (1966) has surveyed and reported. Kononova (1966) indicated that cultivated soils had less humic acid and more fulvic acid than noncultivated soils. The HA/FA ratio would be closer to unity in cultivated soils (Kononova, 1966). The differences which were apparent, although not statistically significant, resulted from agricultural practices imposed on the individual sites. Grass seed agriculture with its infrequent plowing (once every four years) and annual burning, is nearer to virgin conditions than annually (or more often) cultivated soils. Grass covering under seed production may be less than in the virgin condition, but burning compares to past practices (pre-settlement times).

Humic Acid, Fulvic Acid and Humin (1965 and 1975)

Table 21 shows comparisons of the humic acid, fulvic acid and humin contents after ten years (1965 to 1975). The 1965 samples, stored since the previous study (Boersma and Simonson, 1970), were analyzed at the same time as the 1975 samples. Collectively, no consistent shifts in proportions of humic acid, fulvic acid and humin fractions were evident. Four grass seed crop sites were analyzed, two Concord, one Amity and one Woodburn site. Three of these sites showed decreases in humic acid and fulvic acid contents but increases in the humin fraction. One of the Concord sites showed increases in

Table 21 Comparison of humic acid, fulvic acid, humin and HA/FA ratio data between two sampling periods, 1965 and 1975, from surface horizons.

| Series Site | Depth cm | Humic Acid 1965 | Humic Acid 1975 | % Diff. from 1965 | Fulvic Acid 1965 | Fulvic Acid 1975 | % Diff. from 1965 | Humin 1965 | Humin 1975 | % Diff. from 1965 | HA/FA 1965 | HA/FA 1975 | % Diff. from 1965 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dayton | | | | | | | | | | | | | |
| II-GSC | 0-20 | 25.9 | 18.2 | -30 | 31.0 | 21.2 | -32 | 43.1 | 60.6 | +41 | 0.8 | 0.9 | +13 |
| Concord | | | | | | | | | | | | | |
| I-GSC | 0-15 | 29.9 | 29.8 | 00 | 32.8 | 22.5 | -31 | 37.3 | 47.7 | +28 | 0.9 | 1.3 | +44 |
| III-GSC | 0-18 | 23.0 | 26.3 | +14 | 33.9 | 38.2 | +13 | 43.1 | 35.5 | +18 | 0.7 | 0.7 | 00 |
| Amity | | | | | | | | | | | | | |
| II-P | 0-36 | 30.8 | 37.3 | +21 | 23.5 | 26.6 | +13 | 45.7 | 36.1 | -21 | 1.3 | 1.4 | +8 |
| III-GSC | 0-20 | 31.4 | 28.4 | -10 | 33.5 | 31.5 | -6 | 35.1 | 40.2 | +15 | 0.9 | 0.9 | 00 |
| Woodburn | | | | | | | | | | | | | |
| I-GSC | 0-20 | 30.1 | 28.1 | -7 | 24.4 | 23.6 | -3 | 45.5 | 48.3 | +6 | 1.2 | 1.2 | 00 |

all three fractions. Two pasture sites, one Dayton and one Amity, did not show similar changes. Dayton showed decreased humic acid and fulvic acid proportions while the Amity showed increased proportions of the same fractions. The humin fraction from the Dayton site increased.

No general trends were detected in the humus subfractions after ten years regardless of soil treatment (pasture vs grass seed crop). If more sites had been sampled, possibly a statistical trend would have been apparent. There are too many factors to be considered which affect these humus fractions. Greater control over the sampled areas is necessary before a definite conclusion can be considered.

Optical Density Ratios ($E_4/E_6$)

Optical density ratios of dilute aqueous humic acid solutions determined at 465 and 665 nm have been used by soil scientists in characterizing humic substances. Kononova (1966) contends that this "$E_4/E_6$ ratio" varies for humic acids extracted from different soil orders. She believes that the $E_4/E_6$ ratio is related to the degree of condensation of its aromatic carbon framework. A low ratio supposedly indicates a relatively high degree of condensation in the aromatic structure while a high ratio reflects a low degree of aromatic condensation and a higher degree of aliphatic character.

Chen et al. (1977) presented data indicating that the magnitude of $E_4/E_6$ ratios for humic substances are related to particle or molecular sizes and weights. They concluded that there were no direct

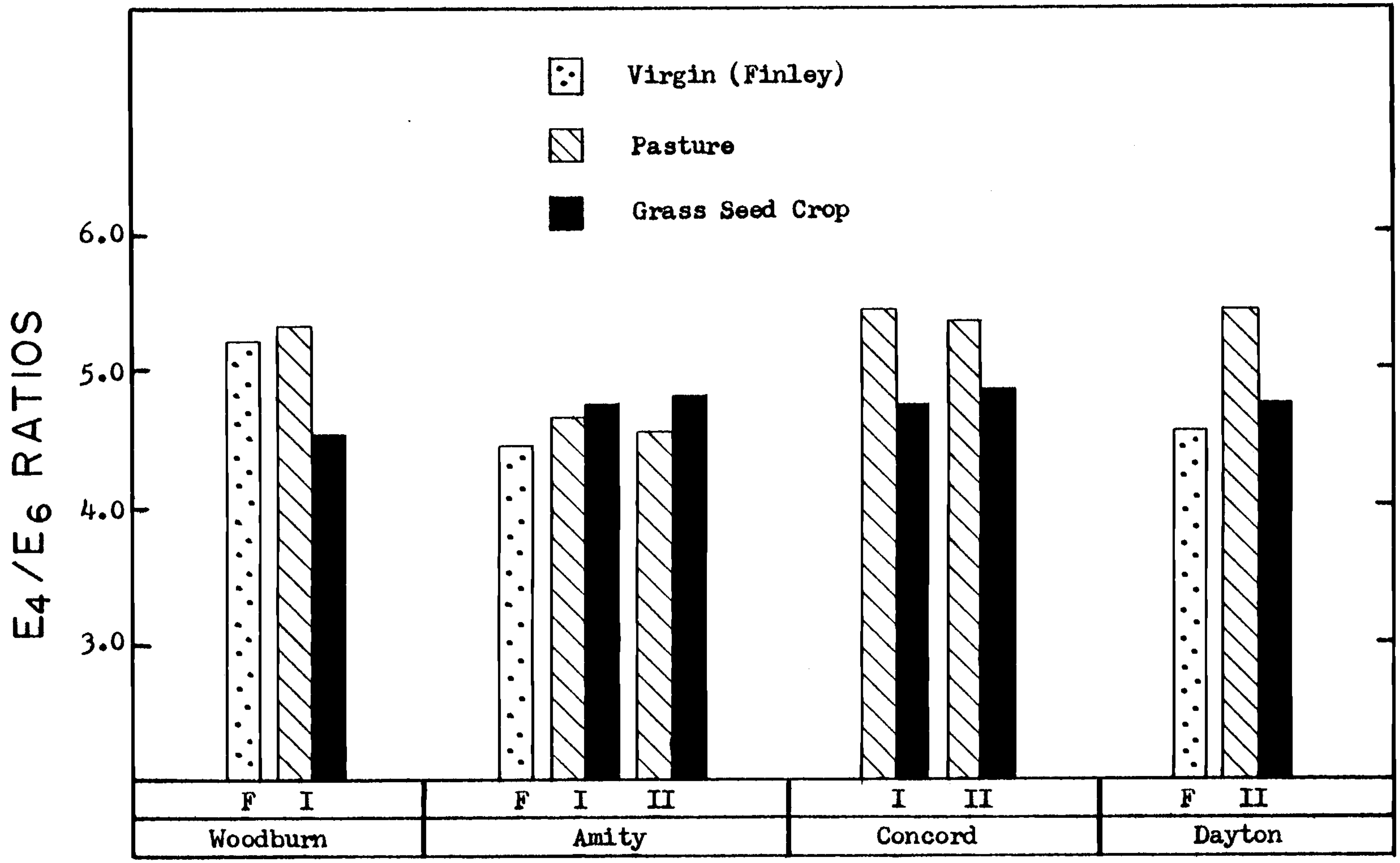


Figure 17. Comparison of humic acid $E_4/E_6$ ratios between pasture (P) and grass seed crop (GSC) sites from A horizon (0-15 cm) 1975 data. See Table 23.

relationships between $E_4/E_6$ ratios and aromatic condensation of humic substances.

These findings suggests that $E_4/E_6$ ratios and the degree of aromatic condensation of humic substances may be coincidental considering Kononova's work (1966). Recently, Schnitzer (1976) concluded from extensive chemical degradation studies that HA's and FA's do not contain appreciable concentrations of condensed ring structures. Kononova's work (1966) may be considered outdated by this recent work.

Considering this recent work, Schnitzer (1976) and Chen et al. (1977), $E_4/E_6$ ratios in this study will refer to the particle or molecular size of humic substances.

Figure 17 compares $E_4/E_6$ ratios between surface A horizons from paired pasture and grass seed crop sites. Collectively, no significant (a=.05) differences occurred between $E_4/E_6$ ratios for these paired sites. Individually and collectively, Dayton, Concord and Woodburn soils had higher $E_4/E_6$ ratios for pasture sites. Amity sites had higher ratios for grass seed crop sites. The general trend indicated that humic acid in pasture sites was of smaller particle or molecular size than from grass seed crop sites. Cultivation causes smaller molecular sized, younger and more easily decomposed humic acid to be lost from the soil. The Amity pasture site showed humic acid that had a slightly larger particle size than grass seed crop sites. Amity grass seed crop sites were similar to other grass seed crop sites. Amity pasture sites had lower $E_4/E_6$ ratios than the pasture sites of the other series.

There are several apparent inconsistencies portrayed in Figure 17. $E_4/E_6$ ratios from Amity pasture sites were lower than $E_4/E_6$ ratios from pasture sites of other soil series. This indicates a humic acid of larger particle size and higher molecular weight. The larger humic acid particles accumulate as the more mobile, smaller and younger humic acid is lost. There are two possible explanations. The first involves vegetational differences and inherited humic acid characteristics of that past vegetation. The second pertains to land leveling and removal of portions of the Ap horizon. This may impart in the organic matter less mobile, larger humic acid particles characteristic of the subsurface horizon. Work cited in Kononova (1966) shows decreasing $E_4/E_6$ ratios with depth. This is dependent on many variables including the soil, vegetation cover and land use.

The second inconsistency is shown by the Finley "virgin" $E_4/E_6$ data. The Dayton "virgin" site $E_4/E_6$ ratio is lower than the Dayton pasture site. The Amity "virgin" site ratio is slightly lower than either the pasture and grass seed crop sites while the Woodburn "virgin" site ratio is consistent with its pasture site. The poorly drained Finley sites had lower ratios; better drained soils had higer ratios.

$E_4/E_6$ ratios for grass seed crop sites showed no general relationship with drainage characteristics.

Optical Density Ratios (1965 and 1975)

Figure 18 shows time comparisons of $E_4/E_6$ ratios. Comparisons of pasture and grass seed crop sites indicated no significant (a=.05) changes or differences occurring as a result of agricultural practices.

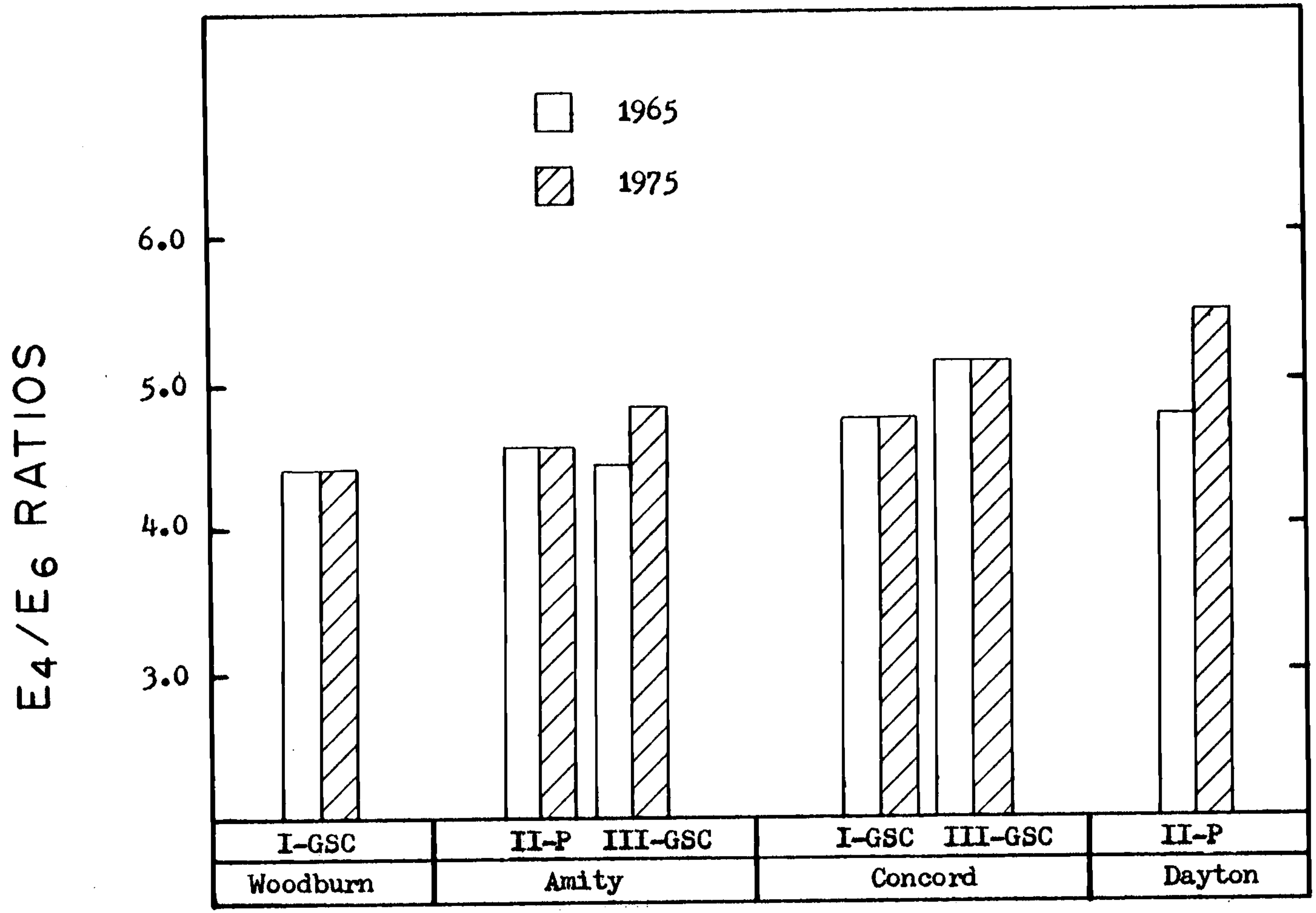


Figure 18. Comparison of humic acid $E_4/E_6$ ratios between two sampling periods, 1965 and 1975 from A horizons. See Table 24.

# DISCUSSION

## Carbon

Levels of organic matter in agricultural soils result from the decomposition rates of added vegetative materials and soil humus. Noncultivated soils typically have higher humus contents prior to cultivation. Russell (1973) attributes this to higher additions of organic matter in undisturbed soils resulting in high levels of organic matter. Soil organic matter is a dynamic system affected by changes in its input components. Any increase or decrease in these input components will correspondingly increase or decrease the net humus content. Under farming systems, the humus content trends towards a new equilibrium value for that system on that soil.

Carbon contents in these soils (Woodburn, Amity, Concord and Dayton) are representative of grass seed agriculture. Pasture sites used in this study include one derelict weedy site. The grass seed crop sites were characterized by annual burning, with plowing once every four years on the annual grass sites. The perennial sites have much longer periods without plowing. Burning reduces the surface residual straw to charcoal-like ash. Late summer burning, followed by a wet rainy winter could result in removal of the light hydrophobic straw ash by runoff. If so, little of the ash would be incorporated into the soil by natural means. Mechanical mixing would be necessary. Straw ash could be incorporated into the surface centimeter by raindrop/splash activity. Raindrop activity disperses and enables these straw ash particulates to be manipulated into soil pore spaces.

Organic carbon distributions indicated that Woodburn and Amity soils (Table 5) had higher mean carbon contents than Concord and Dayton soils. This occurred for both pasture and grass seed crop sites. Dayton pasture sites had higher carbon values than Concord pasture sites but Concord grass seed crop sites had higher carbon values than the Dayton grass seed crop sites. Higher Dayton pasture carbon levels may result from past vegetational differences. Concord soils were vegetated by grasses but were primarily forested with ash, alder and oak. Dayton soils were covered with open meadows with scattered Oregon white oak, red alder, shrubs of willow and wild rose (Franklin and Dryness, 1973). Carbon data indicated that higher carbon levels in Dayton soils may be a carryover from native vegetation. Restricted drainage in Dayton soils may also contribute to carryover through low decomposition rates resulting from reducing conditions within these soils.

There are relationships between soil carbon levels and both drainage characteristics and levels of soil disturbance. In well drained tilled soils, carbon distriubtion is strongly related to tillage processes, while poorly drained tilled soils are influenced more by drainage characteristics. In both well and poorly drained soils under pasture, carbon distribution is related to drainage characteristics.

Carbon values alone can not be used to indicate changes in internal properties of these soils. Table 7 shows overlapping frequency distributions of organic carbon from surface horizons. Each frequency distribution has carbon values concentrated toward the lower end of the distribution. Included with each distribution are individuals with disproportionally higher values. Carbon values obviously can not be used to distinguish between individual soil series. The 1975 data repeats approximately these same distributions. The data indicate a break between Amity and Concord sites which Pomerening's data do not indicate; but these are not sufficient data to determine its significance.

Pomerening's carbon frequency distribution, including the 1975 data, indicate a significant distribution break in surface horizon carbon values. This break, occurring at the 3.0 percent level, is apparent in each series. Woodburn and Amity soils have 76 and 82 percent respectively, of their sites with less than this value. Concord and Dayton soils showed 100 and 88 percent, respectively, of their sites with less than the 3.0 percent level. It is surmized that this level indicates a threshold between virgin and cultivated conditions. This threshold may indicate the upper limit of near steady state conditions acheived as a result of a particular soil management system under a particular climatic regime.

These carbon values probably reflect the nature of grassland soils instead of cultivated soils. Russell (1973) reported that grasses in a Nebraska soil produced 6.5 t/ha of roots in the upper 15 cm. Grasses can add over 2.5 t/ha dry matter to the soil per year from roots (Russell, 1973). Some grasses develop more dry matter below ground than above ground and greater below ground dry matter than general cultivated crops. Grass seed (annual and perennial) is a crop that apparently helps in maintaining a relatively constant organic matter level.

Water soluble components of soil organic matter are the most active, least resistant and first to be metabolized by soil microorganisms. As the more easily soluble materials are metabolized, the more resistant constituents (lignin, cellulose and hemicellulose) tend to accumulate and persist for increasingly longer periods of time as decomposition continues. Decomposition rates of various plant and animal residues are controlled by composition and structure which determines the availability of these various organic substances as energy sources for soil microorganisms.

Water soluble components are predominately free carbohydrates, sugars, bacterial by-products, organic acids and residues and humic substances (Gupta, 1967; Flaig et al., 1975). The dominant carbohydrates are the water soluble celluloses and starches. A wide variety of sugars are present in water extracts, predominately glucose, fucose and galactose (Gupta et al., 1963). Soluble bacterial by-products and residues contain sugars, organic acids and proteins.

A small portion of soil humus is water soluble, dominated by fulvic acids (Greenland and Oades, 1975). These soluble components exert an important influence on levels of biological activity in soils and high soluble carbon values are indicative of higher levels of microbial activity.

Soluble carbon can also indicate the level of humification of the residual organic material. Hu et al. (1972) reported that decreasing soluble carbon values are indicative of increasing humification. This same relationship existed in the soils from this study area. Soluble carbon values decreased with depth, mainly the result of decreasing total carbon. Generally, there was no significant difference in soluble carbon between pasture and grass seed crop sites although Woodburn pasture sites had soluble carbon values significantly higher than in the grass seed crop sites. Soluble carbon levels in grass seed crop soils significantly decreased over time (in approximately the upper 70 cm) while pasture soils showed no significant changes. Soluble carbon values did not distinguish between soil series.

There was no relationship between levels of soluble carbon (mg C/gm soil) and soil drainage characteristics in the upper 30 cm of soil. Dayton soils, with the poorest drainage, had the second highest mean soluble carbon level (Table 22). Woodburn soils had the highest mean soluble carbon content with Amity and Concord soils following Dayton soils.

Determining the percent of total carbon that was soluble (Table 22) indicated that soluble carbon percentages ranged between three to four percent in the upper 15 cm of soil for Woodburn, Dayton and Amity soils. Concord soils (Table 22) showed a lower percent, approximately two percent.

Mean total carbon and soluble carbon data (Table 22). from 0-15 cm, indicated that Concord soils had lower levels that the other three soil series. Concord's surface soil data were similar to subsurface data (15-30 cm) from Woodburn, Amity and Dayton soils. These results may reflect landleveling that has occurred to some degree throughout the study area.

Table 22 Mean total and soluble carbon data comparisons for the surface soil (30 cm) from 1975 data (both pasture and grass seed crop sites).

| Soil Series | Depth cm | Mean Sol. C mg C/gm soil | Mean Total C mg C/gm soil | % C that is Soluble |
|---|---|---|---|---|
| Woodburn | 0-15 | 1.40 | 37.0 | 3.8 |
| Amity | 0-15 | 0.81 | 25.8 | 3.1 |
| Concord | 0-15 | 0.37 | 19.0 | 1.9 |
| Dayton | 0-15 | 0.94 | 24.0 | 3.9 |
| Woodburn | 15-30 | 0.48 | 19.7 | 2.4 |
| Amity | 15-30 | 0.39 | 16.9 | 2.3 |
| Concord | 15-30 | 0.13 | 9.8 | 1.3 |
| Dayton | 15-30 | 0.41 | 13.8 | 3.0 |

## Nitrogen

Ensminger and Pearson (1950) reviewed the literature dealing with the effect of cropping practices on nitrogen levels in soil. As with soil carbon, nitrogen contents of most soils declined when the land was brought under cultivation. During the first few years, the losses are very rapid, then the rate of nitrogen loss decreases slowly with time until equilibrium levels characteristic of the climate, agrimechanical practices and soil type are reached.

Soil nitrogen reductions from cultivation practices do not result entirely from reductions in quantities of plant residues available for humus synthesis. Russell (1973) reported improved aeration from cultivation increased microbial activity and organic matter losses. Temporary increases in respiration rates occur when an air-dried soil is wetted (Birch, 1958). Rovira and Greacen (1957) reported that a major effect of cultivation in stimulating microbial activity was the exposure of organic matter not previously accessible to microbial attack. Other nitrogen losses occur through leaching, erosion, denitrification and chemical volatilization. Past studies have indicated that nitrogen contents of most soils can be maintained only when crops with sod characteristsic are a prominent part of the rotation (Stevenson, 1965).

The present study area consisted of sites under grass seed agriculture. These sites are fertilized with ammonium sulfate in both fall and spring applications. Fall applications are applied to establish the plants. Leaching from winter rainfall in addition to high water tables result in virtually no carry-over nitrogen. An additional 80 to 100 pounds of nitrogen per acre is applied in spring applications.

Dayton, Amity and Woodburn pasture sites contained significantly higher nitrogen than their corresponding grass seed crop comparison sites (Table 10). This occurred even with large bi-annual nitrogen fertilizer additions. Little carry-over nitrogen from winter/spring leaching and nitrogen volatilization from annual burning of surface straw residue are the primary factors responsible for lower nitrogen values in grass seed crop sites. Concord soils showed the reverse trend, although the higher nitrogen values in the grass seed crop sites are not significant.

Nitrogen increases with time are related to increases in the soil biomass. The major nitrogen increases are in the organic nitrogen fraction. Young (1964) showed that in surface horizons, the inorganic nitrogen accounts for about five percent of the total nitrogen. Inorganic nitrogen remaining in the soil after crop needs are satisfied is insufficient to cause significant increases in the total nitrogen. The effect of fertilization programs is to increase plant yields (dry matter) resulting in increased biomass and higher organic nitrogen levels. This is contrary to the many published reports showing decreasing nitrogen levels with continued cultivation. The increased nitrogen levels shown in this study probably result from the nature of the cropping system (sod or semi-pasture) and management practices.

Soluble nitrogen is an indication of the more readily dissolved (lysed) and probably more available nitrogen. A general trend of higher but not significant soluble nitrogen levels in pasture sites compared to grass seed crop sites occurred. These values indicate a relationship to the drainage characteristics of these soils. For moderately well drained Woodburn soils, pasture sites had significantly higher soluble nitrogen values. The poorly drained soils did not show significant differences in their soluble nitrogen data.

Comparisons for both pasture and grass seed crop sites after a ten year period show general trends of decreasing soluble nitrogen with time. These differences are not significant. This trend differs with the soil drainage characteristics. Woodburn and Amity pasture sites indicated significantly higher soluble nitrogen levels while Concord and Dayton pasture sites did not.

The time comparison data showed that while there were significant increases in both total carbon and nitrogen, soluble nitrogen levels mostly decreased. This indicated that the more resistant organic materials are accumulating at the expense of the more readily available materials. A change in humus quality may be occurring. Ashworth (1942) associated increased soluble nitrogen with better quality soils. This is synonymous with soils under long time grass/pasture cultivation.

## Carbon:Nitrogen Ratios

Although rather crude, C/N ratios according to Russell (1973), give a useful characterization of soil organic matter properties. Comparing C/N ratio differences (9 compared to 14) can indicate qualitative differences in humus composition. The C/N ratios in this study ranged from 10.1 to 12.9 in the surface 15 cm. Differences in C/N ratios between paired pasture and grass seed crop sites ranged from 0 to 1.9. These small values are not enough to indicate significant qualitative differences. They do indicate the general status of soil carbon and nitrogen. Comparison of mean C/N ratios showed wider ratios in the pasture sites. This indicated that humus nitrogen may be more limiting in pasture soils. Infrequent plowing may also be an important factor in preventing a significant decrease in C/N ratios. C/N ratios in pasture soils reflect conditions closer to the virgin state. This indicated that more decomposition of organic materials has occurred in grass seed crop sites. Lower C/N ratios may indicate increased humification in grass seed crop sites. Narrower C/N ratios can also occur from lower additions of organic material into the soil. Burning of straw is one method of reducing the carbon input. Also, perennial grasses in the pasture sites may increase carbon input more than annual grasses.

Changes in C/N ratios with depth indicate qualitative differences in the humus component. Young (1962) found some of these "apparent" differences to be the result of two factors:

(a) increases in relative amounts of mineral fixed $NH_4^+$ and

(b) increased quantities of nitrogen-rich, non-proteinaceous components of the fulvic acid fraction.

## Organic Matter Quality

M. Khononva, M. Schnitzer and many other workers have shown that components of soil organic matter vary in their proportions between soil orders and with profile depth. These relationships among the organic components are dependent upon soil, climate and vegetative characteristics.

Kononova (1966) and other European workers have reported changes in the soil's various organic components resulting from cultivation. Organic matter quality is a means to quantify these changes. Organic matter quality is associated with the decomposability of introduced organic materials and the soil's potential to decompose introduced organic materials (Van Cleve, 1974).

Kononova (1966) and others have reported that with cultivation, the humic acid fraction generally decreased while the fulvic acid increased. These humus components readjust to new equilibrium ratios established under cultivation.

Soluble Carbon

Other indices sometimes used in assessing organic matter quality include water soluble components, e.g. Hu et al. (1972), used to determine the degree of humification and the soil's potential to decompose introduced organic materials. Other workers have used soluble carbon values to indicate relative microbial activity. Low amounts of soluble carbon (high degree of humification) indicate a high degree of microbial activity but a low potential. Conversely, high amounts of soluble carbon indicate a low degree of microbial activity but a high potential.

The data (Table 9) indicate that the organic matter in grass seed crop soils is becoming more humified (reduction in soluble carbon) with time, while the pasture sites showed no significant changes.

Annual burning may not necessarily be a significant contributing factor. It has not been determined which management practice has the dominant influence on soil. Lower soluble carbon in grass seed crop soils may indicate that current agri-management practices are reducing the soluble carbon in these soils.

Individually or as a group, the four soil series do not show a significant relationship between soluble carbon levels and organic matter quality.

Raison (1976) indicated that applying external heat (burning) to the soil surface causes changes in the water solubility of soil organic carbon. Burning would cause small amounts of organic material present in the surface few millimeters of soil to solublize and be available as a microbial substrate. Raison reported that wetting of ash material results in hydrolysis of the basic cations present and the formation of an alkaline residue which may have a pH as high as 12.7. Swift and Posner (1972) reported similiar conclusions with autoxidation of humic acids under alkaline conditions. The degree to which these events occur has not been adequately investigated. For soils with sufficient buffering capacity, these mentioned processes are not considered significant (De Serra and Schnitzer, 1972; Jurgensen, 1973; Dormaar, 1971; Raison, 1976).

Humus Substances

The literature generally indicates that with cultivation, both fulvic acid and humin fractions increase while humic acid decreases

(Kononova, 1966). The changes may or may not be significant.

Data (Table 20) indicated that grass seed crop soils generally had higher humic acid and fulvic acid and lower levels of humin materials than pasture soils. The pasture sites have a greater organic reserve capacity.

Humin fractions for soils of this study are less than reported in the literature. It is probable that extraction and/or methodologies may be responsible.

Apparently the more resistant forms of organic matter are being brought into contact with soil microorganisms by burning and other agri-management practices causing further decomposition and increased humification. Extractable organic substances are increased.

The data (Table 21) suggest that humin contents generally have increased regardless of soil management practices. In the past ten years, the amount of more easily decomposed organic matter has been reduced. There were insufficient data to determine if the increase in nonextractable humus was due to increased decomposition rates or changes in the organic materials being introduced into the soil.

The humic acid and fulvic acid (Table 21) percentages generally were less, but humins increased during ten years.

Humic acid/fulvic acid ratios (Table 21) did not show significant ($a=.05$) differences between agricultural management practices or over time. Two pasture sites show increasing amounts of humic acid occurring over time.

The optical density ($E_4/E_6$ ratios) of humic acids (Table 23) investigated in this study indicated larger and heavier humic acid molecules in the grass seed crop sites. This suggested increased decomposition rates in the grass seed crop sites by eliminating the smaller humic acid particles.

Optical density ratios of humic acids did not show changes occurring over time for either pasture or grass seed crop sites (Table 24).

Table 23 Comparison of humic acid $E_4/E_6$ ratios between pasture (P) and grass seed crop (GSC) sites from A horizon (0-15 cm), 1975 data.

| Series | Site | $E_4/E_6$ P | $E_4/E_6$ GSC | % Diff. from P |
|---|---|---|---|---|
| Dayton | F | 4.5 | - | - |
| | II | 5.4 | 4.7 | -0.7 |
| Concord | I | 5.4 | 4.7 | -0.7 |
| | III | 5.3 | 4.8 | -0.5 |
| Amity | F | 4.4 | - | - |
| | I | 4.6 | 4.7 | +0.1 |
| | II | 4.5 | 4.8 | +0.3 |
| Woodburn | F | 5.2 | - | - |
| | I | 5.3 | 4.5 | -0.8 |

Note: Finley "virgin" sites designated by the "F" symbol.

The optical density data indicates qualitative differences between humic acids in pasture and grass seed crop sites. Differences were not detected in all sites when compared to the earlier sampling. Differences either existed but were not detectable by this technique

Table 24 Comparison of humic acid $E_4/E_6$ ratios between two sampling periods, 1965 and 1975, from A horizons.

| Series | Site | Depth cm | $E_4/E_6$ 1965 | $E_4/E_6$ 1975 | % Diff. from 1965 |
|---|---|---|---|---|---|
| Dayton | II-P | 0-20 | 4.9 | 4.9 | 0.0 |
| Concord | I-GSC | 0-15 | 4.7 | 4.7 | 0.0 |
| | III-GSC | 0-18 | 5.1 | 5.1 | 0.0 |
| Amity | II-P | 0-36 | 4.5 | 4.5 | 0.0 |
| | III-GSC | 0-20 | 4.4 | 4.8 | +0.4 |
| Woodburn | I-GSC | 0-20 | 4.4 | 4.4 | 0.0 |

or they did not exist for all sites.

Results from this study indicated qualitative differences in soil humus resulting from differing agricultural management practices, but no specific practices could be identified as those responsible for the changes. The types of management and experimental controls necessary for such conclusions to be made were not available for this study.

# CONCLUSIONS

## Carbon

Comparative total carbon analyses indicated no buildup of straw-ash residue in the soil after a ten year period of annual burning. This indicated that natural incorporation of ash particulates into the soil was not a significant phenomenon. Natural incorporation could occur in the surface few centimeters. Any surface accumulation of straw-ash residue would be subject to removal by wind and surface runoff.

Grass seed management practices with annual burning and infrequent cultivation (plowing), resulted in significantly lower levels of total carbon than in pasture sites, regardless of soil drainage characteristics.

Increased carbon was found after ten years for both nonburned noncultivated pastures and cultivated grass seed crop sites; the later was not statistically significant.

Comparison with Pomerening's frequency distribution of carbon contents indicated no significant shifts. Carbon data are too varied to be used as a general differentiation between soil series. A threshold carbon level, three percent, was indicated by the carbon distribution data. This threshold indicated a probable man-induced limit for carbon levels and decomposition rates for grass seed crop and pasture soils.

## Nitrogen

Total nitrogen values overall, were significantly higher in pasture sites. Both Amity and Woodburn pasture or weedy sites had significantly higher nitrogen levels. Dayton and Concord sites showed no significant differences in nitrogen between pasture and grass seed crop sites.

Significant increases in nitrogen were found in 1975 as compared to 1965 samples, independent of management practices. Comparisons with Pomerening's nitrogen frequency distribution showed no significant shifts in distribution for the four soil series studied.

Soluble nitrogen contents were higher but not statistically significant in the pasture sites. Better drained soils contained higher levels of soluble nitrogen than the poorly drained soils. No significant changes in soluble nitrogen were found during a ten year period.

## Carbon:Nitrogen Ratios

Carbon:nitrogen ratios overall, were significantly wider in the pasture sites. Comparing series, Amity and Woodburn pasture sites had significantly wider C/N ratios than grass seed crop sites. Dayton and Concord sites showed no significant differences in C/N ratios between management practices. After ten years, C/N ratios in either pasture or grass seed crop sites were not appreciably different.

## Organic Matter Quality

Differences in humic fractions between pasture and grass seed crop sites were not significant. Trends of lower humic acid, higher fulvic acid and humins in the pasture sites were apparent. These humic fractions indicated a more humified organic component in the pasture sites. No significant changes occurred in the humic fractions during ten years under either management practice.

Humic acid optical density differences, although insignificant, indicated smaller sized and lighter weight humic acid molecules extracted from pasture sites than from grass seed crop sites.

Soluble carbon data indicated a somewhat more humified organic soil component in the grass seed crop sites. During a ten year period, soluble carbon significantly decreased in the grass seed crop sites indicating increased humification and/or a change in the composition of introduced organic materials. The pasture sites showed no significant changes in humification with time.

It is apparent that discrepencies exist among the data for determining levels of humification. These may result from differences in drainage characteristics of each soil series. The Finley "virgin" sites indicated increasing quantities of humic acid and fulvic acids and decreasing humin contents with increasingly better drained sites. These trends in the humic fractions are probably related to differences in soil pH. The better drained soils had higher pH (see Appendix Table 1) which increases microbial activity.

Evaluation of the data indicated no significant differences in organic matter quality between pasture and grass seed crop sites. The pasture sites had an apparent higher site productivity resulting from higher carbon and nitrogen levels. No single management practice can be identified as affecting the qualitative nature of the soil's organic matter unless rigorous management and experimental controls are used.

The data document that significant changes have occurred in these soils as a result of differing management practices. Since no significant qualitative changes in the organic matter have occurred, other unidentified factors may be responsible, e.g. land leveling, winter fertilization (compaction) and/or rainfall induced soil compaction and aeration changes.

If it is decided that the documented changes in these soils are considered losses of a valuable natural resource, then a more detailed and better financed study will be needed.

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# APPENDIX

## Soil Descriptions

### Woodburn

Woodburn soils are deep, moderately well drained, silt loam soils with mostly 0 to 3 percent slopes. Their taxonomic class is Aquultic Argixerolls, fine-silty, mixed, mesic. Woodburn soils generally show evidence of impeded drainage between 61 and 91.5 cm. Permeability is slow. Runoff is slow to medium. Erosion hazard is none to slight. The winter and spring water tables are from 61 to 91.5 cm. The natural vegetation is Douglas-fir (Psuedotsuga menziesii), Oregon white oak (Quercus garryana), poison oak (Rhus sp.), wild blackberry and native grasses.

The following description of a Woodburn silt loam is of site I-GSC (site 226 from Boersma and Simonson, 1970). The site is a cultivated grass field. Soil profile description was compiled by Dr. Simonson.

| | | |
|---|---|---|
| Ap | 0-20 cm | Very dark grayish brown (10YR 3/2.4) silt loam; grayish brown (10YR 5/2) dry; moderate medium granular structure to structureless clods; slightly hard to hard dry, friable moist, slightly sticky and slightly plastic when wet; many large and medium pores except in massive clods; abundant fine grass roots; few very fine Fe-Mn concretions; large pores and granular structure appear to be mostly earthworm casts; abrupt smooth boundary. |
| A12 | 20-35 | Dark brown (10YR 3/3) fine silt loam; grayish brown (10YR 5/2) dry; weak fine granular to subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; common large pores and many fine pores; common |

worm casts; few very fine Fe-Mn concretions; abundant fine grass roots; upper 5 cm are compact and nearly massive in parts due to a tillage pan; gradual smooth boundary.

B1 35-58 Dark yellowish brown (10YR 3/3.6) fine silt loam; light grayish brown (10YR 5.6/2) dry; weak to moderate fine subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; common large and medium pores, and many fine pores; common worm casts; common fine grass roots; somewhat bleached appearance when dry due to abundant clear silt and sand grains on ped exteriors; few very fine Fe-Mn concretions; clear smooth boundary.

B21t 58-75 Dark brown (10YR 3.6/3.4) fine silt loam; pale brown (10YR 6/2.6) dry; weak fine prismatic breaking to moderate fine subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; abundant light gray patches of bleached silt coatings on peds; few thin patchy clay films on peds; common large and medium pores, and many fine roots; common very fine Fe-Mn concretions; few fine, faint grayer (10YR 4/2, 7/1 dry) mottles; clear smooth boundary.

B22t 75-95 Dark brown (10YR 4/3) silty clay loam; weak coarse prismatic breaking to moderate medium subangular blocky structure; hard dry, slightly firm moist, sticky and plastic wet; common patchy (10YR 3.4/4) clay films on peds and in pores; common bleached silt coatings on peds; common fine pores; less porous than above; few fine grass roots; few fine grayer (10YR 5/2, 7/2 dry) and yellowish (10YR 5/6) mottles; many very fine Fe-Mn concretions; clear smooth boundary.

B3t 95-118 Brown (10YR 4.4/3) light silty clay loam; weak coarse prismatic breaking to weak medium subangular blocky structure; hard dry, slightly firm moist, sticky and slightly plastic wet; common fine and medium faint grayish brown (10YR 5/2) mottles; few very fine soft Fe-Mn concretions; common patchy clay films on prism faces and in pores; few large and medium pores, common fine pores; few worm casts; few fine grass roots; gradual smooth boundary.

C    118-150    Brown (10YR 4.6/3) silt loam; few medium and large grayish brown (1Y 5/2) mottles, some with an outer zone of yellowish brown (10YR 5/6); massive; slightly hard dry, friable moist; slightly sticky and slightly plastic wet; common medium pores, few clay films in pores.

Note: This and all subsequent color notations are for moist soil unless otherwise indicated.

Amity

Amity soils are deep, somewhat poorly drained, silt loam soils with a 0 to 2 percent slope. Their taxonomic class is Argiaquic Xeric Agialbolls, fine-silty, mixed, mesic. Amity soils generally show evidence of impeded drainage between 30.5 and 61 cm. Permeability is moderately slow. Erosion hazards are slight. The winter and spring water table is from 30.5 to 61 cm. The natural vegetation is usually annual and perennial grasses, shrubs and scattered oak trees (Quercus garryana).

The following description of an Amity silt loam is of site I-P (site 228 from Boersma and Simonson, 1970). The site is a perennial pasture with mixed grasses. Soil profile description was compiled by Dr. Simonson.

All    0-23 cm    Very dark brown (10YR 2/2) silt loam; grayish brown (10YR 5/1.6) dry; weak medium and coarse granular structure, cloddy in parts; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; many large and medium pores; abundant grass roots; many worm casts; common fine Fe-Mn concretions; diffuse smooth boundary.

| | | |
|---|---|---|
| A12 | 23-43 | Very dark brown (10YR 2.4/1.6) silty clay loam; grayish brown (10YR 5.4/1.6) dry; weak to moderate medium subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; many large and medium pores; abundant worm casts; abundant grass roots; many fine Fe-Mn concretions; few fine faint grayer and browner mottles; clear wavy boundary. |
| A2 | 43-58 | Very dark grayish brown (10YR 3/1.6) light silty clay loam; light gray (10YR 7/2) dry; weak to moderate fine subangular blocky structure; friable moist, sticky and plastic wet; many large and medium pores; abundant worm casts; abundant grass roots; many fine and few medium Fe-Mn concretions; common fine faint grayer and browner mottles; clear wavy boundary. |
| B2t | 58-81 | Dark grayish brown (10YR 3.6/2) silty clay loam; (10YR 4.4/2) crushed; weak medium prismatic breaking to moderate subangular to angular blocky structure; friable moist, sticky and plastic wet; common thin patchy clay films on peds; common gray silt coatings on peds; abundant fine and few medium Fe-Mn concretions; many large and medium pores; common roots; common fine distinct brown (7.5YR 4/4) mottles and few fine grayish (1Y 4/2) mottles; clear wavy boundary. |
| B31t | 81-104 | Dark grayish brown (1Y 4/2.4) silty clay loam; weak coarse subangular structure; friable moist, sticky and plastic wet; many large and medium pores; common worm casts; common fine faint brown (1Y 5/3) and grayish brown (2.5Y 5/2) mottles; few thin patchy clay films and some dark gray (1Y 4/1.4) ped surfaces; many fine Fe-Mn concretions; gradual smooth boundary. |
| B32 | 104-132 | Brown (1Y 4.4/3) silty clay loam; coarse subangular blocky structure to massive; friable moist, sticky and plastic wet; few large pores, common medium and many fine pores; many very fine Fe-Mn concretions; common fine faint browner mottles, few grayer mottles; diffuse smooth boundary. |

| | | |
|---|---|---|
| C | 132-152 | Brown (1Y 4.4/3) silt loam; massive; friable moist, slightly sticky and slightly plastic wet; common fine pores, few medium pores; common fine faint browner and grayer mottles. |

Notes:

1. A2-B2 boundary could be a depositional boundary.
2. Some ped interiors of the B horizon appear similar to C horizon.
3. Textural differentation may partly reflect stratification.

Concord

Concord soils are deep, poorly drained soils with a 0 to 2 percent slope. They have silt loam surface horizons over silty clay loam subhorizons. Their taxonomic class is Typic Ochraqualfs, fine-montmorillonitic, mesic. Concord's poor drainage results from slowly permeable IIB2t and IIIB3t horizons 50 to 97 cm below the surface causing surface mottling. Permeability is slow. Runoff is very slow. Erosion hazards are none to slight. The winter and spring water tables are at or near the surface. The natural vegetation is rushes, sedges, wild blackberry, annual grasses and oak trees (Quercus garryana).

The following description of a Concord silt loam is of site II-GSC (site 235 from Boersma and Simonson, 1970). This site is in a perennial grass (Poa pratensis) field. Soil profile description was compiled by Dr. Simonson.

| | | |
|---|---|---|
| Ap | 0-13 cm | Dark grayish brown (10YR 3.6/2) silt loam; light grayish brown (10YR 6/2) dry; moderate fine granular structure; soft to slightly hard dry, friable moist, slightly sticky and |

| | | |
|---|---|---|
| | | slightly plastic wet; common fine faint dark yellowish brown mottles; many fine and medium Fe-Mn concretions; abundant roots; many fine and few large pores; abrupt smooth boundary. |
| A12 | 13-25 | Dark gray (10YR 4/1.4) silt loam; light gray (10YR 6/ 1.4) dry; weak to moderate fine subangular blocky structure; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; many medium Fe-Mn concretions; common fine distinct yellowish brown mottles; few worm casts; many fine and few medium pores; abundant roots; clear smooth boundary. |
| A2 | 25-48 | Dark grayish brown (1Y 4/2) silt loam; light grayish brown (1Y 6/2) dry; weak coarse prismatic breaking to moderate fine subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; many medium distinct yellowish brown (10YR 5/6-5/8) mottles; many fine and few medium pores; common roots; common worm casts; gradual wavy boundary. |
| B1 | 48-66 | Grayish brown (2.5Y 5/2) silty clay loam; light gray (2.5Y 7/1) dry; weak fine prismatic breaking to strong medium subangular blocky structure; slightly hard dry, friable moist, sticky and plastic wet; many medium distinct yellowish brown (10YR 5/6) mottles; many medium Fe-Mn concretions; many medium pores; common roots; clear wavy boundary. |
| IIB2t | 66-89 | Grayish brown (1Y 5/2) fine silty clay loam; moderate medium prismatic breaking to moderate coarse angular blocky structure; hard dry, friable moist, sticky and plastic wet; common thick patchy dark grayish brown (2.5Y 4/2) clay films; thick coatings of gray bleached silts apparent when dry; many medium distinct yellowish brown (10YR 5/6) mottles; few medium and common fine Fe-Mn concretions; few roots; smooth boundary. |
| IIIB3t | 89-112 | Brown (1Y 4/3) light silty clay loam; moderate coarse prismatic breaking to weak coarse blocky structure; hard dry, friable moist, sticky and plastic wet; moderate patchy dark brown (10YR 3/3) clay films on peds; many fine pores; gradual smooth boundary. |

IIIC 112-155 Brown (10YR 4/3) silt loam; massive; friable moist, slightly sticky and slightly plastic wet; many fine pores, common medium pores; few coarse grayish brown (10YR 5/2) mottles, few dark grayish brown (1Y 4/2) clay films in pores.

Dayton

Dayton soils are deep, poorly drained soils with a 0 to 2 percent slope. They have silt loam surface horizons over silty clay loam to clay subhorizons. Their taxonomic class is Typic Albaqualfs, fine-montmorillonitic, mesic. Dayton's poor internal drainage results from a clayey IIB2t horizon 25 to 50 cm below the surface causing surface mottling. Permeability is very slow. Runoff is slow to ponded. Erosion hazards are slight. The winter and spring water tables are ponded at the surface. The natural vegetation is grasses, shrubs and scattered oak trees (Quercus garryana).

The following description of a Dayton silt loam is of site I-P (site 227 from Boersma and Simonson, 1970). The site is a perennial pasture with mixed grasses. Soil profile description was compiled by Dr. Simonson.

Ap 0-18 cm Grayish brown (10YR 4/2) silt loam; light grayish brown (10YR 6/2) dry; weak medium granular structure; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; abundant roots; common fine and medium pores; many medium Fe-Mn concretions; many fine distinct yellowish brown to strong brown (9YR 5/4) mottles; abrupt wavy boundary.

| | | |
|---|---|---|
| A2 | 18-33 | Grayish brown (1Y 4.6/1.6) silt loam; light gray (1Y 7/1) dry; weak coarse prismatic breaking to moderate fine to medium subangular blocky structure; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; abundant roots; common fine and medium pores; many medium and few large Fe-Mn concretions; common fine distinct dark brown to yellowish brown (10YR 4/3-5/4) mottles; abrupt smooth boundary. |
| IIB21t | 33-48 | Olive gray (5Y 4.4/2) clay; moderate coarse prismatic breaking to weak coarse blocky structure, nearly massive when wet; very hard dry, very firm moist, very sticky and very plastic wet; medium continuous (5Y 4/2) clay films on ped faces; common fine roots between prisms, very few in ped interiors; few fine pores; common bleached silt coatings on prism faces in upper part; common fine and few medium Fe-Mn concretions; few fine faint olive (5Y 4/4) mottles in ped interiors; gradual smooth boundary. |
| IIB22t | 48-74 | Olive gray (5Y 4.6/2) silty clay; weak to moderate coarse prismatic breaking to weak coarse blocky structure; very hard dry, very firm moist, very sticky and very plastic wet; medium continuous (5Y 4/2) clay films; common roots between prisms; few fine pores; many fine and very fine Fe-Mn concretions; few fine faint olive (5Y 4/4) mottles; clear wavy boundary. |
| IIIB3t | 74-97 | Olive brown (2.5Y 4/3) silty clay loam; weak coarse prismatic breaking to weak coarse blocky structure, nearly massive; slightly firm moist, sticky and plastic wet; common patchy (5Y 4.6/2) clay films; many fine and few medium pores; few roots; common to abundant fine Fe-Mn concretions; common to many fine and medium distinct yellowish brown and grayish brown mottles; gradual boundary. |
| IIIC | 97-152 | Brown (1Y 4/3) fine silt loam; massive; friable moist, sticky and plastic wet; many fine and very fine Fe-Mn concretions; many medium faint dark brown (10YR 3/4) and distinct grayish brown (2.5Y 5/2) mottles, many of the grayish mottles are along pores, a few coarse zoned mottles are present. |

Appendix Table 1 Comparison of soil pH between pasture (P) and grass seed crop (GSC) sites from 1975 data.

| Soil Site | Depth cm | Dayton P | Dayton GSC | Concord P | Concord GSC | Amity P | Amity GSC | Woodburn P | Woodburn GSC |
|---|---|---|---|---|---|---|---|---|---|
| Finley | 0-15 | 5.1 | - | | | 5.5 | - | 5.3 | - |
| | 15-30 | 5.3 | - | | | 5.6 | - | 5.5 | - |
| | 30-45 | 5.4 | - | | | 5.7 | - | 5.7 | - |
| | 45-60 | 5.4 | - | | | 5.8 | - | 5.7 | - |
| | 60-75 | 5.1 | - | | | 5.8 | - | 5.8 | - |
| I | 0-15 | 4.6 | 4.5 | 5.1 | 4.5 | 5.2 | 4.9 | 5.5 | 4.5 |
| | 15-30 | 4.6 | 5.1 | 5.4 | 5.0 | 5.4 | 5.3 | 5.9 | 5.3 |
| | 30-45 | 5.1 | 5.5 | 5.6 | 5.5 | 5.6 | 5.4 | 6.4 | 5.7 |
| | 45-60 | 5.2 | 6.1 | 5.6 | 5.7 | 5.5 | 5.5 | 6.4 | 6.0 |
| | 60-75 | 5.7 | 6.8 | 5.7 | 5.9 | 5.6 | 5.7 | 6.6 | 6.1 |
| II | 0-15 | 5.5 | 4.2 | - | 4.5 | 5.2 | 4.8 | 6.2 | 5.1 |
| | 15-30 | 5.6 | 4.4 | - | 4.9 | 5.6 | 5.5 | 6.0 | 5.7 |
| | 30-45 | 5.7 | 4.9 | - | 5.1 | 5.7 | 5.8 | 6.1 | 5.7 |
| | 45-60 | 5.6 | 5.2 | - | 5.2 | 5.9 | 5.8 | 6.2 | 5.8 |
| | 60-75 | 5.6 | 5.5 | - | 5.4 | 6.0 | 5.8 | 6.1 | 5.9 |
| III | 0-15 | | | 5.3 | 4.6 | - | 4.7 | | |
| | 15-30 | | | 5.5 | 5.0 | - | 5.1 | | |
| | 30-45 | | | 5.6 | 5.1 | - | 5.3 | | |
| | 45-60 | | | 5.7 | 5.3 | - | 5.6 | | |
| | 60-75 | | | 5.7 | 5.6 | - | 5.6 | | |

Appendix Table 2 Comparison of 1975 Munsell soil colors between pasture (P) and grass seed crop (GSC) sites (artificial light, air dry and undisturbed peds).

| Soil Series | Site | Depth cm | Soil Color P | Soil Color GSC |
|---|---|---|---|---|
| Dayton | Finley | 0-15 | 10YR 5.8/2.4 | |
| | | 15-30 | 10YR 6.0/1.6 | |
| | | 30-45 | 10YR 6.4/2.4 | |
| | | 45-60 | 10YR 6.6/1.4 | |
| | | 60-75 | 10YR 6.4/1.4 | |
| | I | 0-15 | 2.5Y 6.4/1.0 | 10YR 6.6/2.0 |
| | | 15-30 | 10YR 6.6/1.2 | 10YR 6.4/1.6 |
| | | 30-45 | 10YR 6.6/1.0 | 2.5Y 7.0/1.0 |
| | | 45-60 | 2.5Y 6.0/2.0 | 2.5Y 7.0/1.0 |
| | | 60-75 | 2.5Y 5.6/3.0 | 2.5Y 7.4/2.0 |
| | II | 0-15 | 10YR 6.0/2.4 | 10YR 6.0/2.6 |
| | | 15-30 | 10YR 6.2/1.4 | 10YR 6.6/1.6 |
| | | 30-45 | 10YR 6.8/1.4 | 10YR 6.6/2.4 |
| | | 45-60 | 10YR 7.0/1.4 | 2.5Y 7.0/1.0 |
| | | 60-75 | 2.5Y 6.0/1.5 | 2.5Y 6.2/2.0 |
| Concord | I | 0-15 | 10YR 6.0/1.4 | 10YR 5.4/2.0 |
| | | 15-30 | 10YR 6.0/1.4 | 10YR 5.6/2.0 |
| | | 30-45 | 10YR 6.6/1.4 | 10YR 6.0/1.6 |
| | | 45-60 | 2.5Y 6.0/1.4 | 10YR 6.4/2.0 |
| | | 60-75 | 2.5Y 6.5/3.0 | 10YR 6.4/2.4 |
| | II | 0-15 | | 10YR 5.4/2.6 |
| | | 15-30 | | 10YR 6.4/2.0 |
| | | 30-45 | | 10YR 6.6/1.8 |
| | | 45-60 | | 2.5Y 7.0/1.0 |
| | | 60-75 | | 2.5Y 6.6/1.0 |
| | III | 0-15 | 10YR 6.4/2.0 | 10YR 6.4/2.0 |
| | | 15-30 | 10YR 7.4/1.4 | 10YR 6.6/2.0 |
| | | 30-45 | 2.5Y 6.0/1.0 | 10YR 6.6/1.0 |
| | | 45-60 | 2.5Y 6.0/1.0 | 10YR 6.6/1.4 |
| | | 60-75 | 2.5Y 6.2/1.0 | 2.5Y 6.8/1.0 |
| Amity | Finley | 0-15 | 10YR 5.4/2.4 | |
| | | 15-30 | 10YR 4.8/3.0 | |
| | | 30-45 | 10YR 5.8/3.0 | |
| | | 45-60 | 10YR 6.0/2.4 | |
| | | 60-75 | 10YR 5.6/3.4 | |

Appendix Table 2 (continued) Comparison of 1975 Munsell soil colors between pasture (P) and grass seed crop (GSC) sites (artificial light, air dry and undisturbed peds).

| Soil Series | Site | Depth cm | Soil Color P | Soil Color GSC |
|---|---|---|---|---|
| Amity | I | 0-15 | 10YR 5.4/2.4 | 10YR 6.2/1.8 |
| | | 15-30 | 10YR 4.8/2.4 | 10YR 7.0/1.4 |
| | | 30-45 | 10YR 5.0/2.4 | 10YR 6.8/1.4 |
| | | 45-60 | 10YR 6.4/1.4 | 10YR 6.4/1.0 |
| | | 60-75 | 10YR 6.4/2.0 | 2.5Y 7.0/1.0 |
| | II | 0-15 | 10YR 5.2/3.0 | 10YR 5.0/2.6 |
| | | 15-30 | 10YR 4.8/3.0 | 10YR 5.0/2.8 |
| | | 30-45 | 10YR 5.2/3.0 | 10YR 5.2/3.0 |
| | | 45-60 | 10YR 5.8/3.0 | 10YR 5.6/2.6 |
| | | 60-75 | 10YR 5.8/2.0 | 10YR 6.0/2.4 |
| | III | 0-15 | | 10YR 5.4/2.0 |
| | | 15-30 | | 10YR 6.0/2.4 |
| | | 30-45 | | 10YR 6.4/2.0 |
| | | 45-60 | | 10YR 6.6/1.4 |
| | | 60-75 | | 2.5Y 6.6/1.0 |
| Woodburn | Finley | 0-15 | 10YR 5.2/3.0 | |
| | | 15-30 | 10YR 5.0/3.2 | |
| | | 30-45 | 10YR 6.0/3.4 | |
| | | 45-60 | 10YR 6.0/3.4 | |
| | | 60-75 | 10YR 6.0/3.4 | |
| | I | 0-15 | 10YR 5.0/2.8 | 10YR 5.2/3.4 |
| | | 15-30 | 10YR 4.8/3.0 | 10YR 5.4/3.4 |
| | | 30-45 | 10YR 4.8/3.0 | 10YR 5.2/3.4 |
| | | 45-60 | 10YR 5.4/3.0 | 10YR 5.8/3.4 |
| | | 60-75 | 10YR 6.0/3.2 | 10YR 6.0/3.6 |
| | II | 0-15 | 10YR 5.4/1.4 | 10YR 5.0/2.6 |
| | | 15-30 | 10YR 5.0/2.8 | 10YR 5.4/3.0 |
| | | 30-45 | 10YR 5.2/2.8 | 10YR 5.0/3.0 |
| | | 45-60 | 10YR 5.4/3.0 | 10YR 6.2/3.4 |
| | | 60-75 | 10YR 6.2/2.6 | 10YR 6.2/3.0 |

Appendix Table 3 Comparison of 1965 and 1975 Munsell soil colors for pasture (P) and grass seed crop (GSC) sites (artificial light, air dry and crushed samples).

| Soil Series | Site | Depth cm | Soil Color 1965 | Soil Color 1975 |
|---|---|---|---|---|
| Dayton | I-P | 0-18 | 10YR 6.4/3.0 | 10YR 6.4/3.5 |
| | | 18-33 | 10YR 6.5/2.5 | 10YR 6.4/3.0 |
| | | 33-48 | 10YR 6.4/3.4 | 10YR 6.5/3.2 |
| | | 48-74 | 10YR 6.4/3.4 | 10YR 6.5/3.4 |
| | II-GSC | 0-20 | 10YR 6.2/3.4 | 10YR 4.8/2.8 |
| | | 20-33 | 10YR 6.8/2.5 | 10YR 5.8/3.0 |
| | | 33-58 | 10YR 6.8/3.0 | 10YR 6.5/3.0 |
| | | 58-79 | 10YR 6.8/3.0 | 10YR 6.4/3.5 |
| Concord | I-GSC | 0-15 | 10YR 6.0/3.0 | 10YR 5.5/2.0 |
| | | 15-30 | 10YR 6.4/2.5 | 10YR 5.6/2.0 |
| | | 30-51 | 10YR 6.8/2.5 | 10YR 6.2/3.0 |
| | | 51-74 | 10YR 6.8/3.4 | 10YR 6.5/3.5 |
| | II-GSC | 0-13 | 10YR 6.0/3.2 | 10YR 5.5/3.2 |
| | | 13-26 | 10YR 6.2/3.2 | 10YR 5.5/3.2 |
| | | 26-48 | 10YR 6.8/3.0 | 10YR 6.2/3.0 |
| | | 48-66 | 10YR 7.0/3.4 | 10YR 6.8/3.2 |
| | III-GSC | 0-18 | 10YR 6.2/3.0 | 10YR 6.2/3.0 |
| | | 18-38 | 10YR 6.4/3.4 | 10YR 6.4/3.2 |
| | | 38-56 | 10YR 7.4/2.5 | 10YR 6.4/3.2 |
| | | 56-64 | 10YR 7.4/2.4 | 10YR 6.5/3.2 |
| | | 64-84 | 10YR 7.2/2.8 | 10YR 6.5/3.5 |
| Amity | I-P | 0-23 | 10YR 5.0/3.0 | 10YR 4.4/3.0 |
| | | 23-43 | 10YR 5.0/2.8 | 10YR 4.2/3.0 |
| | | 43-58 | 10YR 6.0/2.5 | 10YR 5.2/3.0 |
| | | 58-81 | 10YR 6.8/3.0 | 10YR 5.6/3.2 |
| | II-P | 0-36 | 10YR 5.0/3.4 | 10YR 4.5/3.4 |
| | | 36-56 | 10YR 5.5/3.0 | 10YR 4.5/3.2 |
| | | 56-71 | 10YR 6.6/3.0 | 10YR 5.4/3.2 |
| | III-GSC | 0-20 | 10YR 5.0/3.0 | 10YR 5.2/3.0 |
| | | 20-38 | 10YR 5.4/3.5 | 10YR 5.6/3.0 |
| | | 38-58 | 10YR 6.4/3.5 | 10YR 6.5/2.8 |
| | | 58-89 | 10YR 6.8/3.5 | 10YR 6.4/3.4 |
| Woodburn | I-GSC | 0-20 | 10YR 5.0/3.8 | 10YR 4.2/3.8 |
| | | 20-36 | 10YR 5.2/4.0 | 10YR 4.4/3.8 |
| | | 36-58 | 10YR 5.8/4.0 | 10YR 4.8/3.8 |
| | | 58-76 | 10YR 6.0/4.0 | 10YR 5.2/4.0 |

Appendix Table 4 Mottling depths as evidence of impeded drainage for both pasture (P) and grass seed crop (GSC) soils, from 1975 data.

| Soil Series | Site | Surface Mottling | Depth to Commom Distinct Mottling[3] |
|---|---|---|---|
| Dayton | Finley | Few[1] | 5 cm |
| | I-P | - | 5 |
| | I-GSC | Few | 5 |
| | II-P | Few | 5 |
| | II-GSC | Few | 5 |
| Concord | I-P | Few | 8 cm |
| | I-GSC | Few | 8 |
| | II-GSC | Few | 8 |
| | III-P | Few | 8 |
| | III-GSC | Few, Faint[2] | 5 |
| Amity | Finley | Few, Faint | 41 cm |
| | I-P | Few, Faint | 30 |
| | I-GSC | Few, Faint | 20 |
| | II-P | Few, Faint | 30 |
| | II-GSC | Few, Faint | 10 |
| | III-GSC | Few, Faint | 18 |
| Woodburn | Finley | - | 91 cm |
| | I-P | - | 76 |
| | I-GSC | - | 84 |
| | II-P | - | 76 |
| | II-GSC | - | 66 |

1. Few denotes less than two percent.
2. Faint denotes that matrix and mottles are closely related.
3. Distinct denotes that matrix and mottles vary be one to two hues.

Appendix Table 5 Comparison of mottling as it varies with time, 1965 to 1975, in pasture (P) and grass seed crop (GSC) sites.

| Soil Series | Site | 1965 | 1975 |
|---|---|---|---|
| Dayton | I-P | 0-18 cm (many) | 5 cm (common) |
| | II-P | 0-20 cm (common) | 5 cm " |
| Concord | I-GSC | 0-15 cm (many) | 8 cm " |
| | II-GSC | 0-13 cm (common) | 8 cm " |
| | III-GSC | 0-18 cm " | 5 cm " |
| Amity | I-P | 42-58 cm " | 30 cm " |
| | II-P | 0-36 cm " | 30 cm " |
| | III-GSC | 20-38 cm " | 30 cm " |
| Woodburn | I-GSC | 97-119 cm " | 84 cm " |
| | II-GSC | 58-107 cm " | 66 cm " |

Note: 1965 data indicates a horizon where mottling occurred and not a specific depth.

Appendix Table 6 Comparative frequency distribution for depths to evidence of impeded drainage between data by Pomerening (1961) and recent 1975 data.

| Depth | Woodburn | | Amity | | Concord | | Dayton | |
|---|---|---|---|---|---|---|---|---|
| cm | 1961 | 1975 | 1961 | 1975 | 1961 | 1975 | 1961 | 1975 |
| 0-5 | | | | | 3 | | 9 | |
| 5-10 | | | | | 0 | 5-P,GSC | 0 | 5-P,GSC |
| 10-15 | | | | 1-GSC | 0 | | 0 | |
| 15-20 | | | | 1-GSC | 2 | | 4 | |
| 20-25 | | | | 1-GSC | 9 | | 6 | |
| 25-30 | | | | | 2 | | 2 | |
| 30-35 | | | 2 | 2-P | | | | |
| 35-40 | | | 3 | | | | | |
| 40-45 | | | 13 | 1-F | | | | |
| 45-50 | | | 10 | | | | | |
| 50-55 | | | 7 | | | | | |
| 55-60 | | | 3 | | | | | |
| 60-65 | | | | | | | | |
| 65-70 | 4 | 1-GSC | | | | | | |
| 70-75 | 3 | | | | | | | |
| 75-80 | 7 | 2-P | | | | | | |
| 80-85 | 3 | 1-GSC | | | | | | |
| 85-90 | 1 | | | | | | | |
| 90-95 | 2 | 1-F | | | | | | |

Note: Finley "virgin" sites designated by the "F" symbol.

Appendix Table 7    Locations of sampling sites.

| No. | Site | Location |
|---|---|---|
| 1 | Wo-F | William L. Finley Nat. Wildlife Refuge, Oregon; 11 miles south of Corvallis. NW1/4 NE1/4 SE1/4 Sec. 28 T13S R5W. |
| 2 | Am-F | William L. Finley Nat. Wildlife Refuge. Oregon 11 miles south of Corvallis. NE1/4 SE1/4 SE1/4 Sec. 28 T13S R5W. |
| 3 | Da-F | William L. Finley Nat. Wildlife Refuge, Oregon; 11 miles south of Corvallis. SE1/4 NE1/4 SW1/4 Sec. 21 T13S R5W. |
| 4 | Wo-I-GSC | Rasmussen Farm; NE1/4 NW1/4 NW1/4 Sec. 19 T13S R3W. |
| 5 | Wo-I-P | Davis Farm; NE1/4 NW1/4 NW1/4 Sec. 6 T13S R3W. |
| 6 | Wo-II-GSC | Davis Farm; NE1/4 SE1/4 NE1/4 Sec. 6 T13S R3W. |
| 7 | Wo-II-P | Davis Farm; SE1/4 NE1/4 NE1/4 Sec. 6 T13S R3W. |
| 8 | Am-I-GSC | NW1/4 NW1/4 NE1/2 Sec. 29 T12S R3W. |
| 9 | Am-I-P | NW1/4 NW1/4 NE1/4 Sec. 29 T12S R3W. |
| 10 | Am-II-GSC | Margason Farm; SE1/4 SE1/4 NW1/4 Sec. 6 T13S R3W. |
| 11 | Am-II-P | Margason Farm; SE1/4 SE1/4 NW1/4 Sec. 6 T13S R3W. |
| 12 | Am-III-GSC | Harold Miller, owner; SE1/4 SE1/4 SE1/4 Sec. 3 T13S R4W. |
| 13 | Co-I-GSC | Margason Farm; NE1/4 SE1/4 NW1/4 Sec. 6 T13S R3W. |
| 14 | Co-I-P | Margason Farm; NE1/4 SE1/4 NW1/4 Sec. 6 T13S R3W. |
| 15 | Co-II-GSC | SW1/4 NW1/4 NE1/4 Sec. 4 T13S R4W. |
| 16 | Co-III-GSC | Dobrinin Farm; SW1/4 SE1/4 NW1/4 Sec. 8 T13S R4W. |
| 17 | Co-III-P | NW1/4 NW1/4 SW1/4 Sec. 8 T13S R4W. |
| 18 | Da-I-GSC | Rasmussen Farm; SW1/4 NW1/4 SE1/4 Sec. 19 T12S R3W. |

Appendix Table 7 (continued)    Locations of sampling sites.

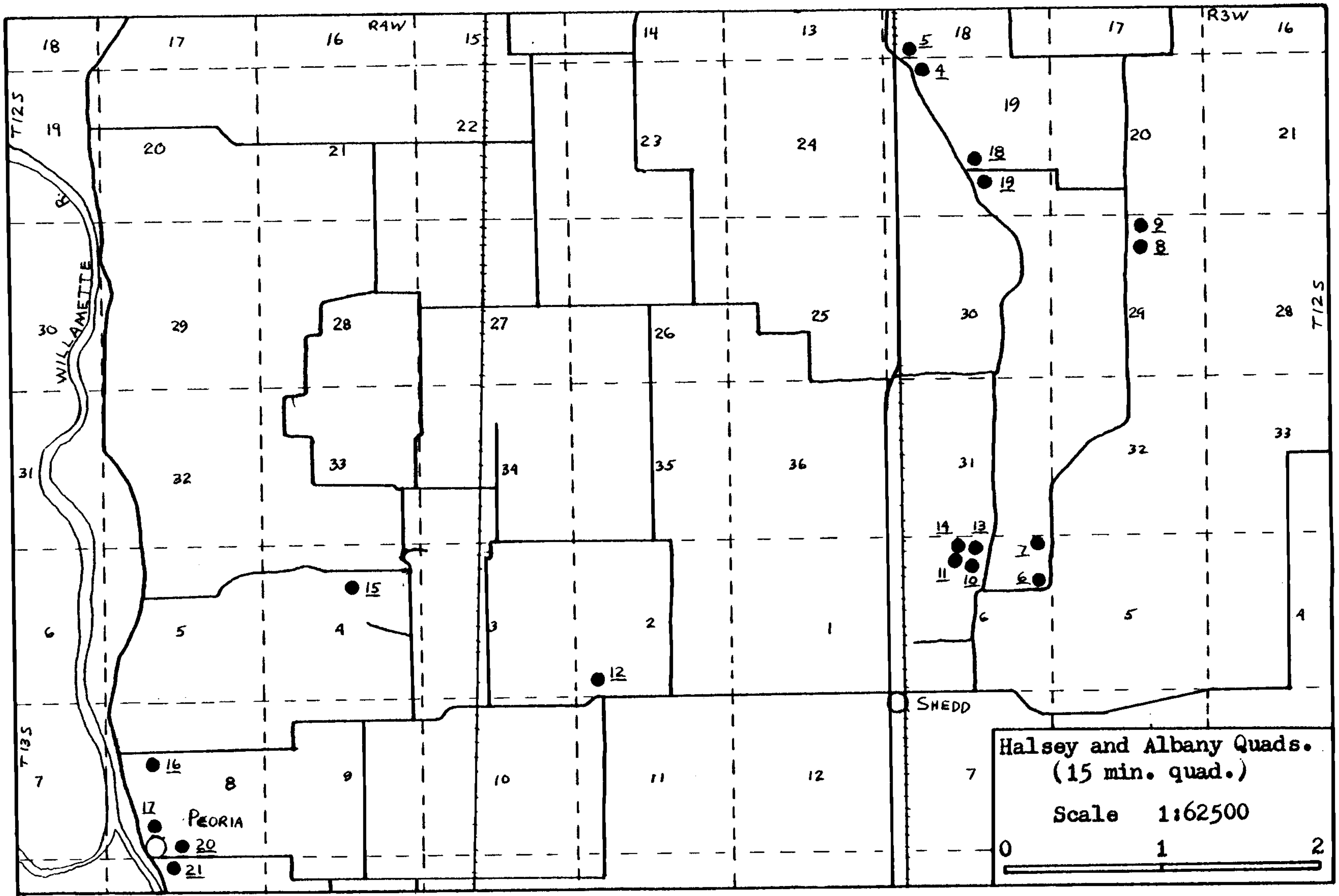
| No. | Site | Location |
|---|---|---|
| 19 | Da-I-P | Garland, owner; NW1/4 SW1/4 SE1/4 Sec. 19 T12S R3W. |
| 20 | Da-II-GSC | Lillian Curtis, owner; NW1/4 NE1/4 NW1/4 Sec 17 T13S R4W. |
| 21 | Da-II-P | Clifford Greg, owner; SW1/4 SE1/4 SW1/4 Sec. 8 T13S R4W. |

Appendix Table 8 Site histories.

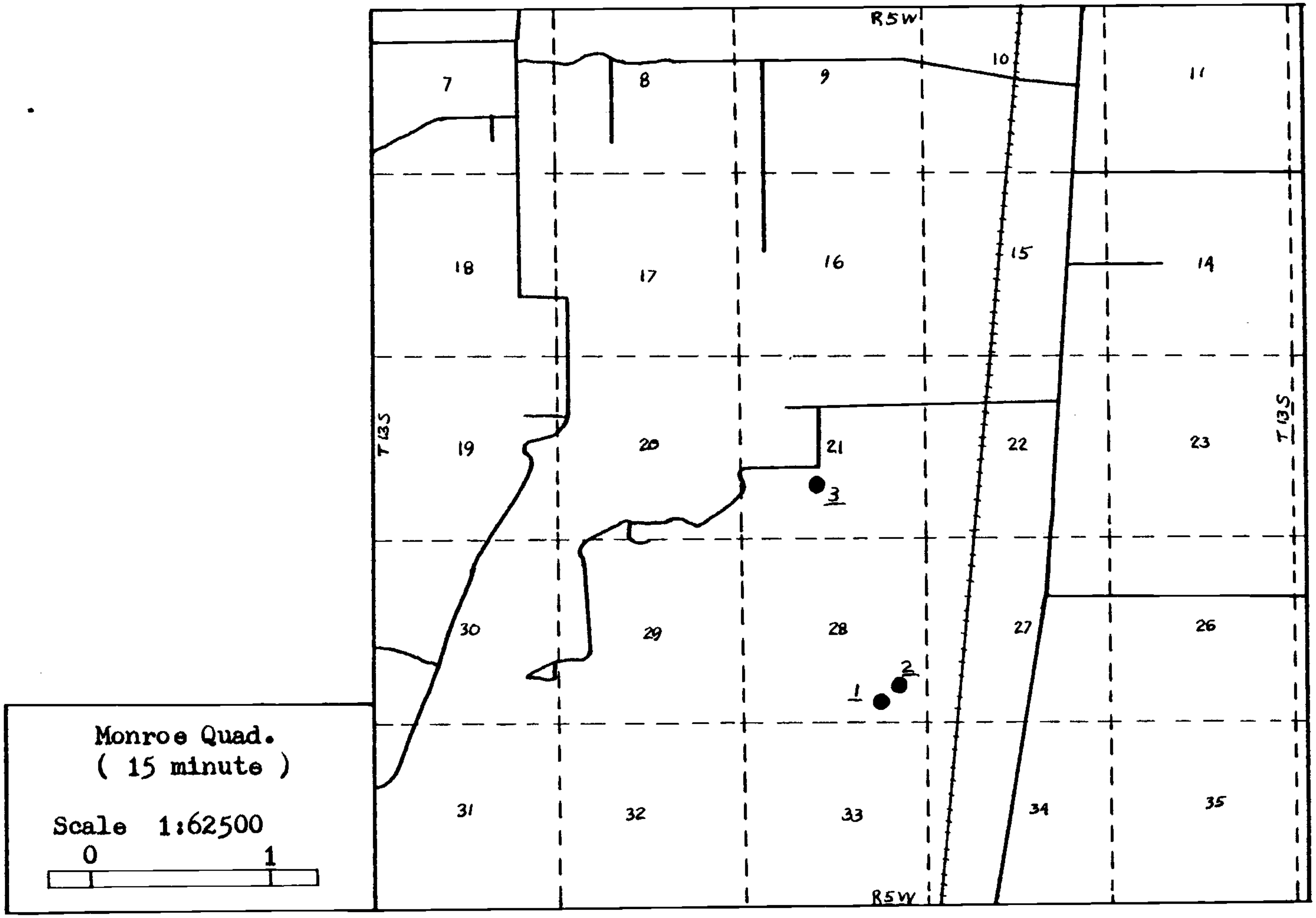
| Site No. | History |
|---|---|
| 1 | This Woodburn site (F) is part of the Finley Nat. Wildlife Refuge. This site is located in the Prairie Natural Area. It has never been subjected to cultivation and has been protected from burning. |
| 2 | This Amity site (F) is part of the Finley Nat. Wildlife Refuge. This site is located in the Prairie Natural Area. It has never been subjected to cultivation and has been protected from burning. |
| 3 | This Dayton site (F) is part of the Finley Nat. Wildlife Refuge. This site is located in the Prairie Natural Area. It has never been subjected to cultivation and has been protected from burning. |
| 4 | This Woodburn site (I-GSC) has been in annual ryegrass production for the past 30 years. It has been plowed once every four years and has been annually burned for the past 20 years. Annual fall application of 12-15-15, 100 lbs/acre, and annual spring application of ammonium sulfate, 525 lbs./acre. |
| 5 | This Woodburn site (I-P) is an old homestead site. It has been a weedy site for the past 20 years. |
| 9 | This Amity site (I-P) has been in pasture for the past ten years. It has not been plowed or burned over the past ten years. An 80 lb./acre application of ammonium sulfate was applied in 1970; 80 lb./acre in 1973. Substantial hog manure was applied in 1975. |
| 10 | This Amity site (II-GSC) has been in annual ryegrass for the past 20 years. It has been plowed once every four years and annually burned for the past 20 years. Three hundred to 400 lbs./acre of ammonium sulfate, in fall and spring applications, has been annually applied. Land leveling occurred in 1961. |
| 11 | This Amity site (II-P) has been in mixed pasture for the past 30 years. It was plowed in 1973 for the first time in 20 years, but never subjected to burning. Over the past seven years, two-80 lb./acre applications of 10-10-10 NPK have been annually applied. |

Appendix Table 8 (continued) Site Histories

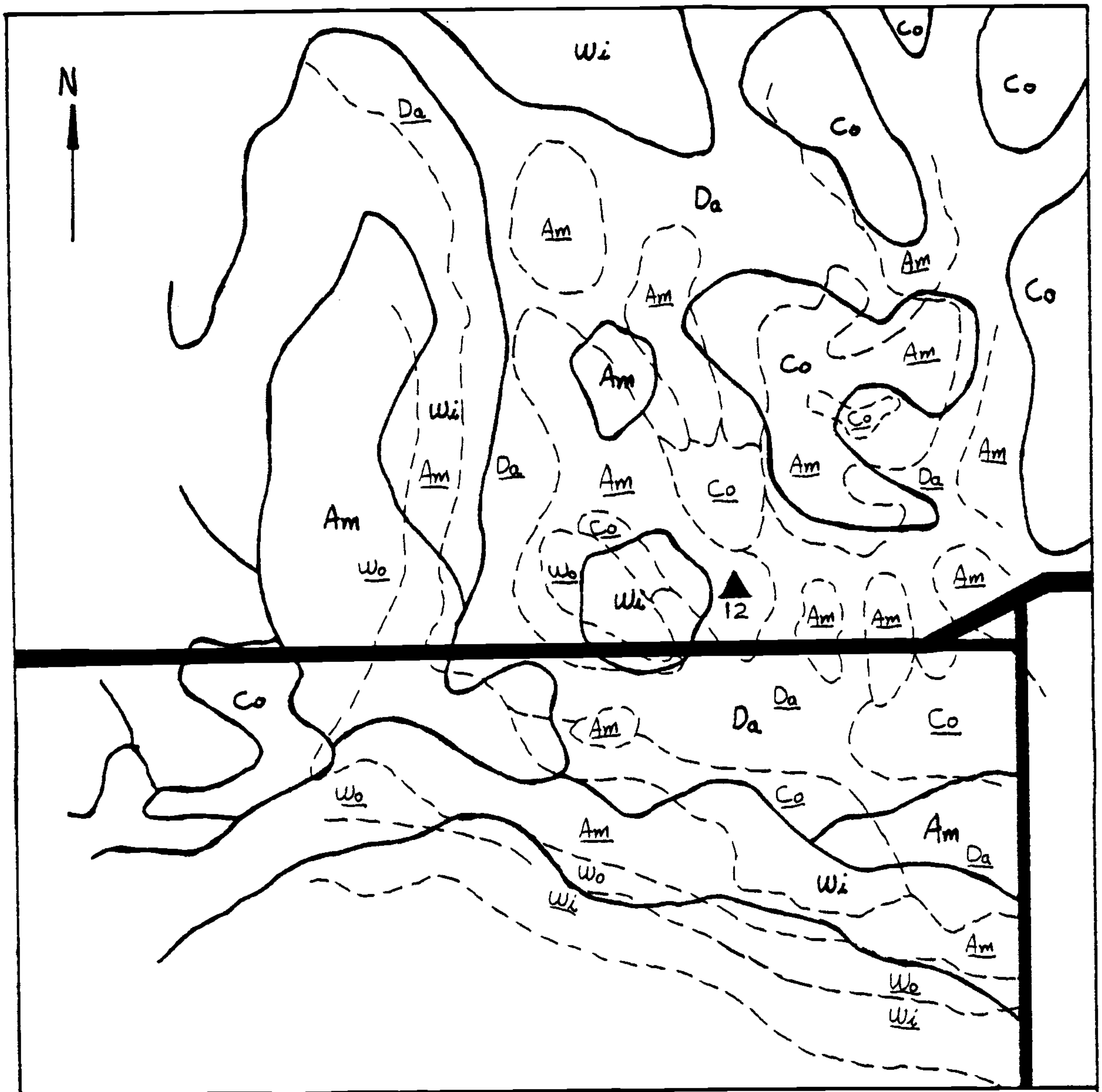
| Site No. | History |
|---|---|
| 13 | This Concord site (I-GSC) has been in annual ryegrass for the past 20 years. It has been annually burned and plowed once every four years. Three hundred to 400 lbs./acre of ammonium sulfate have been annually applied. Land leveling occurs when plowed. |
| 14 | This Concord site (I-P) has been in mixed pasture for the past 30 years. It has never been plowed or burned. Fall and spring applications of ammonium sulfate and 10-10-10 NPK has been annually applied (80 lbs./acre). |
| 15 | This Concord site (II-GSC) has been in perennial bluegrass for the past ten years. Prior to this, it has been in annual ryegrass or grain. No plowing has occurred for the past eight years. Prior to that, it was plowed once every two years. It has been burned annually for the past 20 years and occasionally before that. Spring applications (140 lbs./acre) of ammonium sulfate and urea have been applied. Twenty pounds of phosphate are annually applied. Land leveling occurred prior to the last bluegrass planting (approx. ten years ago). |
| 16 | This Concord site (III-GSC) has been in annual and perennial ryegrass over the past 30 years. It has been annually burned over the past 30 years and plowed once every four years. Annual applications of nitrogen (120 lbs./acre) have occurred. One 4000 lbs./acre application of lime was applied. Complete land leveling occurred in 1963. |
| 17 | This Concord site (III-P) has been in perennial fescue for the past 30 years. |
| 18 | This Dayton site (I-GSC) has been in annual ryegrass for the past 20 years. It has been annually burned for the past 20 years and plowed once every four years. Annual spring application of ammonium sulfate (525 lbs./acre) and a fall application of 12-15-15 NPK (100 lbs./acre). |
| 19 | This Dayton site (I-P) has been in pasture for the past ten years. It has not been burned for the past ten years and probably for longer. It has been plowed once every four years. Land leveling occurred in 1972. |




Appendix Figure 1 Site location map.




Appendix Figure 2 Site location map (continued).




Delineation of
Soil Series Boundaries

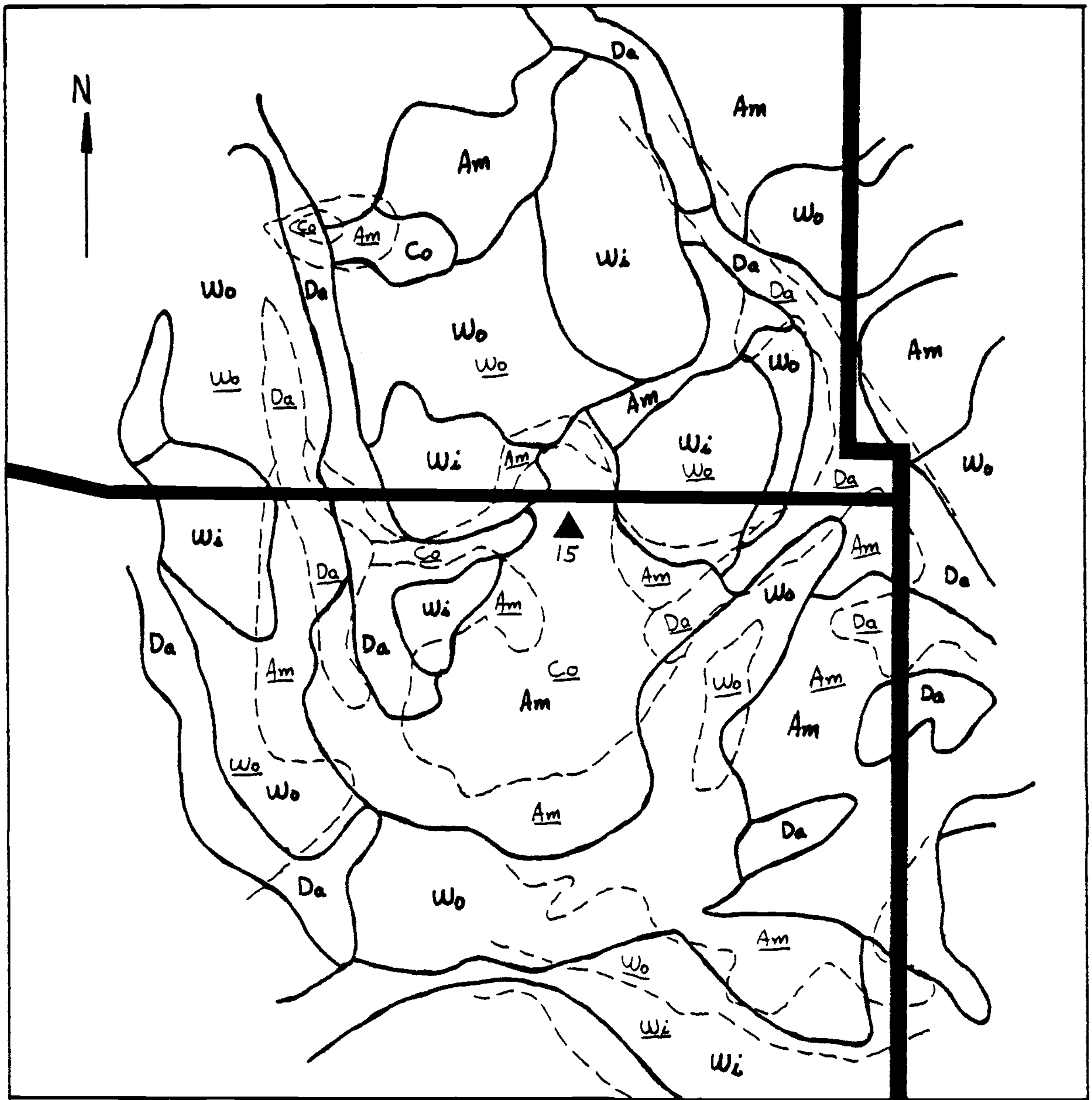
Note: Symbols Wi, Wo, Am, Co, and Da refer to soil series Willamette, Woodburn, Amity, Concord and Dayton, respectively.

Scale: 1 inch equals 725 ft.

1965 - - - -

1975 ———

Appendix Figure 3 Comparison of soil survey delineations between 1965 (Simonson) and 1975 (SCS, Linn Co.) for site 12.




**Delineation of**
**Soil Series Boundaries**

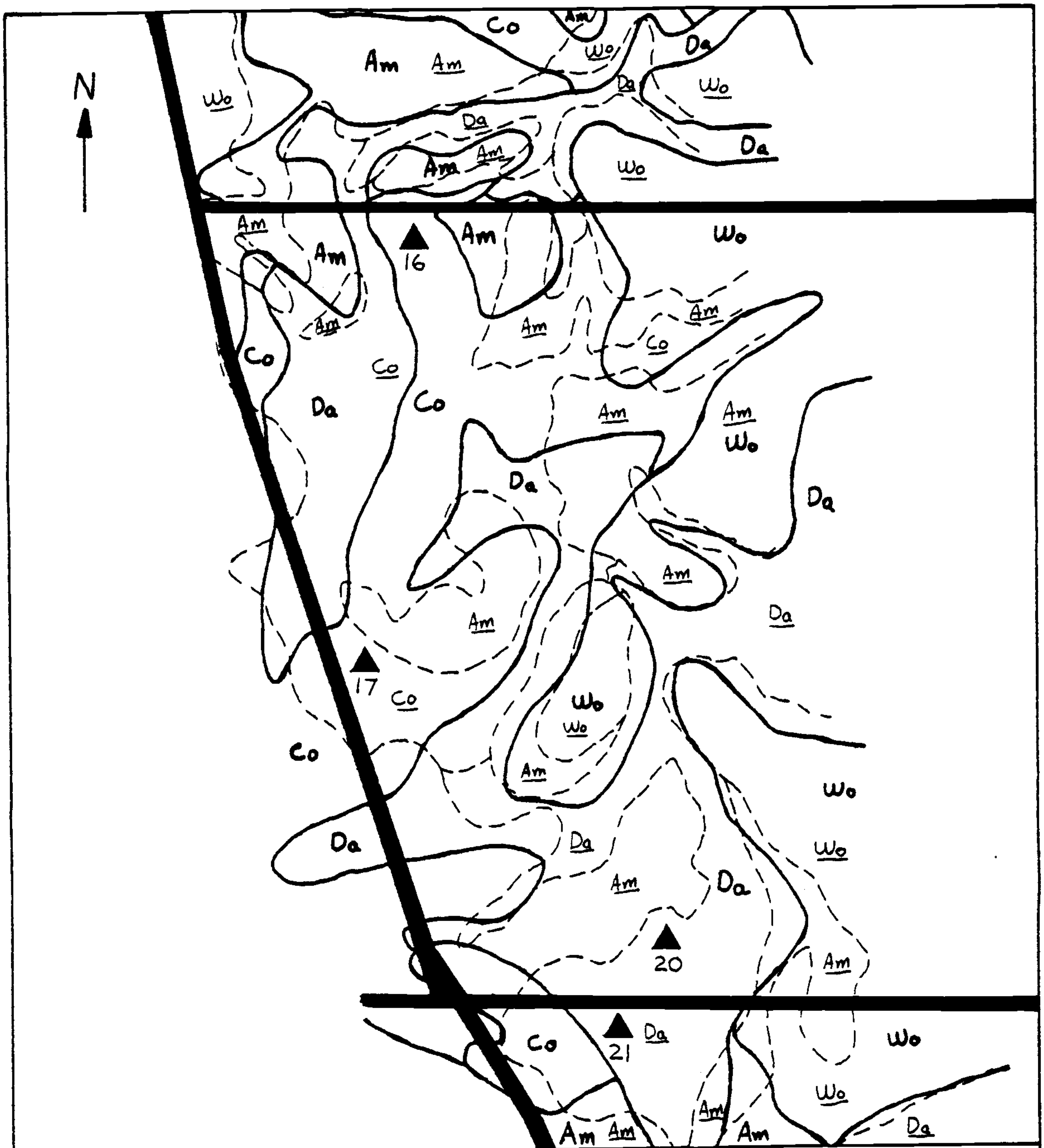
Note: Symbols Wi, Wo, Am, Co, and Da refer to soil series Willamette, Woodburn, Amity, Concord and Dayton, respectively.

1965 - - - - -

1975 ————

Scale: 1 in. = 725ft.

Appendix Figure 4 Comparison of soil survey delineations between 1965 (Simonson) and 1975 (SCS, Linn Co.) for site 15.




Delineation of
Soil Series Boundaries

Note: Symbols Wi, Wo, Am, Co, and Da, refer to soil series Willamette, Woodburn, Amity, Concord and Dayton, respectively.

1965 - - - - - -

1975 ————

Scale: 1 in. = 725ft.

Appendix Figure 5 Comparison of soil survey delineations between 1965 (Simonson) and 1975 (SCS, Linn Co.) for sites 16, 17, 20 and 21.