EFFECTS OF LIVESTOCK MANURE DISPOSAL ON NITRATE ACCUMULATION IN A CLAY SOIL

by

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ABSTRACT

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Mankind is currently experiencing a period of increased ecological awareness. Agriculture is being affected by this concern partly because of the potential contribution of livestock wastes to environmental pollution. In the fall of 1971 the Departments of Agricultural Engineering and Plant Science undertook a groundwater and runoff water quality manure management experiment at the University of Manitoba Glenlea Research Station.

Approximately 3.2 ha were subdivided into 140, 7.6 m by 30.5 m plots. Five crops, alfalfa, barley, corn, reed canary grass, and a mixture of meadow fescue, brome, and alfalfa were seeded. Swine, beef, and dairy cattle manure were selectively applied at levels of 33.5, 67.0, and 201.0 kg ha^{-1} of N in the spring, fall, and winter. Inorganic fertilizer at levels of 67.0 and 201.0 kg ha^{-1} of N and a bulk application of sewage sludge were applied. Selected plots were monitored for percent nitrogen uptake and chemical analysis of soil samples was performed for these plots. Analysis of the runoff from selected plots was also included in the experiment. The data were analyzed statistically using a split-plot design.

Runoff from agricultural land can pose a serious threat to the environmental ecosystem. Nitrate and phosphate concentrations well in excess of the recommended standard critical values were recorded. The chemical oxygen demand (COD) of the runoff was, in some cases, recorded greater than that of domestic sewage.

Nitrate leaching and buildup of nitrate-nitrogen in the soil profile was not a serious problem at the manure application rates tested. A statistical analysis indicated a differential nitrogen uptake ability between alfalfa, barley, corn, and reed canary grass. Reed canary grass demonstrated the highest percent nitrogen uptake ability on a dry matter basis. There was no nitrate accumulation in the soil profile of the manured plots. Control and pre-treatment (1972) plots had greater nitrate concentrations in the surface layer than at any depth after manure treatment.

As part of the thesis the entire research project was assessed. Lack of a proper statistical design may be evidence enough to warrant discontinuation of the project on a long term basis. Consideration should be given to dividing the experiment into smaller and more controllable (statistically and operationally) projects.

Livestock wastes definitely can contribute to pollution of the environment if adequate management techniques are not developed. There is a need for on-going research in the area of agriculture and the environment.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Mankind is currently experiencing a period of increased ecological awareness. In the past, industrial wastes were discharged as cheaply as possible. Very often this involved discharge of raw wastes (chemicals, metals, liquids, solids) into the air, soil or water. In many cases the wastes were assimilated by the environment through processes such as mineralization, diffusion, or dispersion. However, as industrialization has progressed, discharge of environmentally degrading emissions (emissions that are so intense that assimilation is not possible and permanent or continuing damage results) into common property natural resources has become unfavourable. Concerned citizens realized that continued dumping of environmentally degrading emissions could not persist if mankind was to survive. It follows that many facets of human endeavour, including agriculture, have been influenced by this newly founded ecological revolution.

Agriculture is experiencing a period of rapid increased demand for its products. While the "green revolution" has supplied more food to the world's exploding population than ever before, a tremendous strain on agri-business to supply considerably more food still exists. Mechanization, advancements in chemical technology, developments in plant and animal genetics, and more intensive farming methods coincident with the "green revolution" are being employed to meet demands for food. Despite the significance of improved technology, production techniques, and the "green revolution" Barkley and Seckler (1972) believe that severe economic and environmental problems will result from these recent trends.

The Manitoba Institute of Agrologists in a 1973 publication, Agriculture and the Environment, indicated that present and future pollution hazards can be associated with fertilizers, pesticides, and livestock wastes. When dealing with livestock wastes, it is important to realize that animal manure contains valuable ingredients for crops and soils -- fertilizer and organic matter. Manure, when applied to a soil-crop regime, is a source of essential plant nutrients such as nitrogen, phosphorous, and potassium as well as micro-nutrients such as boron, manganese, copper, and zinc. Moreover, addition of manure to the soil contributes to the amount of organic matter which is important to soil structure and to the reservoir of potentially mineralizable plant nutrients. However, animal wastes (and by-products associated with the storage and decomposition of manure) may result in pollution of the air, soil, and water. Some related factors in environmental pollution from livestock wastes are quality and quantity of manure, frequency of disposal of manure, soil type and topography, land use or cropping practice, and urban-rural conflicts.

Allred (1969) indicated that there is a trend toward more concentrated and confined livestock production enterprises; and, increased amounts of manure produced in fewer locations would have an adverse effect on the quality of the environment. It has been stated that land disposal is the most feasible and most economic method of manure disposal (Manitoba Institute of Agrologists - 1973). In spite of the positive effect that the addition of manure can have on the crop and the soil, problems may be associated with the application of manure where the nutrient values of the manure applied exceed the crop utilization rate. This, for example, can result in an increased presence of nitrate-nitrogen in the soil and in the groundwater. An acceptable level of nitrate-nitrogen (NO_3^--N) in the ground water is 10 mg l^{-1} (Canadian Drinking Water Standards and Objectives - 1968) and concentrations above this level may be related to infantile methemoglobinemia. Surface runoff from areas where manure has been applied may transport particulate and soluble forms of manure nutrients and pathogens (for example, salmonella bacteria, entamoeba histolytica parasite, and infectious hepatitis virus, Bauer - 1969) into waterways adjacent to farm land in concentrations harmful to aquatic life and human health. Eutrophication of these waters may be increased as a result of carbon, nitrogen, phosphorus, or micro-nutrients which are associated with runoff from manured fields. Land application of manure may be offensive to individuals in nearby communities. Ammonia, hydrogen sulfide, indoles, skatols, mercaptans and other amine gases may be released to the atmosphere when manure that has existed in an anaerobic state is applied to the land; and, the environmental problem is the perception of these gases.

Essentially, the environmental problem in livestock production are a conflict between an ever-increasing demand for food and the handling of an undesirable by-product - animal manure. Research has been initiated to define and alleviate some of these conflicts in Manitoba. Crop response to the application of various types and rates of manure, soil profile and plant tissue analysis, and nutrient concentrations in runoff are being studied under the direction of the Department of Agricultural Engineering at the University of Manitoba.

The objective of this thesis, as a part of the research project, is to more clearly define the basis on which the experiment was established and to examine the results in hope of contributing to the understanding of some of the environmental aspects of manure management using soils and crops as a disposal media. Specifically, the objectives of this thesis are:

1. To assemble a complete background and analysis of the experimental design of the manure disposal experiment at the University of Manitoba Glenlea Research Station.
2. To interpret, where possible:
   a) the accumulation of nitrogen from manures, commercial fertilizers, and sewage sludge in the soil profile of the experimental plots at the Glenlea Research Station.
   b) the concentration of nutrients in the spring and summer runoff from selected plots at the Glenlea Research Station.
   c) the effectiveness of control techniques such as scheduling for the application of manure for Manitoba conditions.
   d) the uptake of nitrogen by those crops sampled in 1973.

CHAPTER 2

REVIEW OF LITERATURE

2.1 The Manure Problem in Manitoba

Heald and Loehr (1971) indicated that prior to the 1950's agricultural wastes could be disposed of without any consequence to the environment. During the 1950's, however, clear signs developed showing that the environment was being damaged by agricultural, industrial, and municipal wastes disposed of in the land and air. Heald and Loehr (1971) also suggested that the agricultural complex (production and processing of agricultural products) was the largest single source of pollution in the United States. Bayley (1971) indicated that the number one research priority should be the return of agricultural organic wastes, in particular manure, to the land. Similar trends have developed in Manitoba. On farms in Manitoba, livestock manure has traditionally been returned to the land; but, as livestock production facilities have increased in size, livestock manure has become a serious contaminant in the soil, air, and water (Buchanan - 1971). Hudek (1971) outlined the potential livestock pollution problem in Manitoba with a comparison to a human population equivalent in terms of biochemical oxygen demand (BOD) contained in the livestock wastes (Tables 2.1, 2.2). The livestock population equivalent in Manitoba in 1969 was approximately equivalent to three-fourths of the total Canadian population in terms of BOD equivalence.

Buchanan (1971) considered land application of animal manure as the most economic and feasible method of manure disposal subject to limitations

TABLE 2.1 Livestock Waste Quantities for Animals of Average Weights*

Animal	Wet Manure (Kg/Day)	Dry Manure (Kg/Day)	Population Equivalent
Cattle	29	4.54	11
Hogs	3.17	0.5	3
Chickens	.12	.03	1/12
Turkeys	.34	.09	1/4
Man	-	-	1

TABLE 2.2 June 1969 D.B.S. (Dominion Bureau of Statistics) Numbers of Livestock in Manitoba and Population Equivalent*

Animal	Livestock Numbers	Population Equivalent
Cattle	1,019,000	11,209,000
Hogs	612,000	1,836,000
Sheep	41,000	120,000
Hens	5,440,000	453,500
Turkeys	825,000	206,250
Horses	36,000	360,000
		14,184,750

* Hudek, E. P. 1971. Waste management problems in the primary agricultural industry, Unpublished report (seminar), Dept. of Agr. Eng., University of Manitoba, Winnipeg, Canada.

such as air pollution, ground and surface water quality, and crop utilization rates of nitrogen. Disposal of manure onto farm land has advantages as a source of nutrients and organic matter and is probably the most practical final placement for the manure (Klausner et al - 1971). Loehr et al (1973) also considered land application of farm animal manure as the most practical method of manure disposal and utilization if adequate management of methods was provided.

To this point, manure has been referred to in general terms. The 1973 edition of the Agricultural Engineers Yearbook defines manure as follows:

> "Manure is the fecal and urinary defecations of livestock and poultry. Manure may often contain some spilled feed, bedding, or litter".

However, quality and quantity characteristics of the manure vary between animal species. Similarily, amounts of spilled feed, bedding, and litter, spilled drinking water and washing water, and milk house wastes vary depending on the management practices of the particular farmer. Feed rations contain carbohydrates, proteins, fats, lignin, and inorganic nutrients such as nitrogen, phosphorous, potassium, and micronutrients; but, may vary from season to season, farm to farm, and region to region resulting in a variation in manure characteristics. For example, most farmers in the Nebraska region of the United States feed corn whereas the farmers of Manitoba are more likely to feed barley. Since the chemical characteristics of the manure depend primarily upon the chemical properties of the feed processed by the animal (McKinney - 1970) a variation in feed input (for example, a difference between corn feed and barley feed) will change the characteristics of the manure.

McCalla et al (1970) suggested that approximately 90% of the dry matter in manure is organic waste material from animal digestion of feeds; and, that manure retains about 60 to 70% digestible materials. As well, McCalla et al (1970) indicated that animal waste is more concentrated than the feed in lignin and minerals upon deposition in the feedlot or confinement and less concentrated in carbohydrates. If, as McKinney (1970) suggests, 70% of the feed consumed is excreted in the form of urine and manure, perhaps there is a case for re-feeding of manure to livestock.

It is a fact that the inherent variability in manure must be recognized when examining the implications of disposal of animal manure onto farm lands. Previously referenced, Buchanan (1971), Klausner et al (1971) and Loehr et al (1973), indicated that manure should be returned to the farm land provided that precautions ensured proper management techniques. When manure is applied to the soil (Figure 2.1) it may:

1. be mineralized by the soil biosphere,
2. be washed away by runoff or be leached into the hydrosphere,
3. volatilized into the atmosphere.

Regardless of the fate of the manure after land disposal, each of the aforementioned receptor media are unique in their relationship with the manure; and, each will be further discussed as soil biosphere, hydrosphere, and atmosphere.

2.2 Soil Biosphere

The intended final placement of manure during land application is the soil biosphere -- the soil and crop. Manure, as previously discussed,

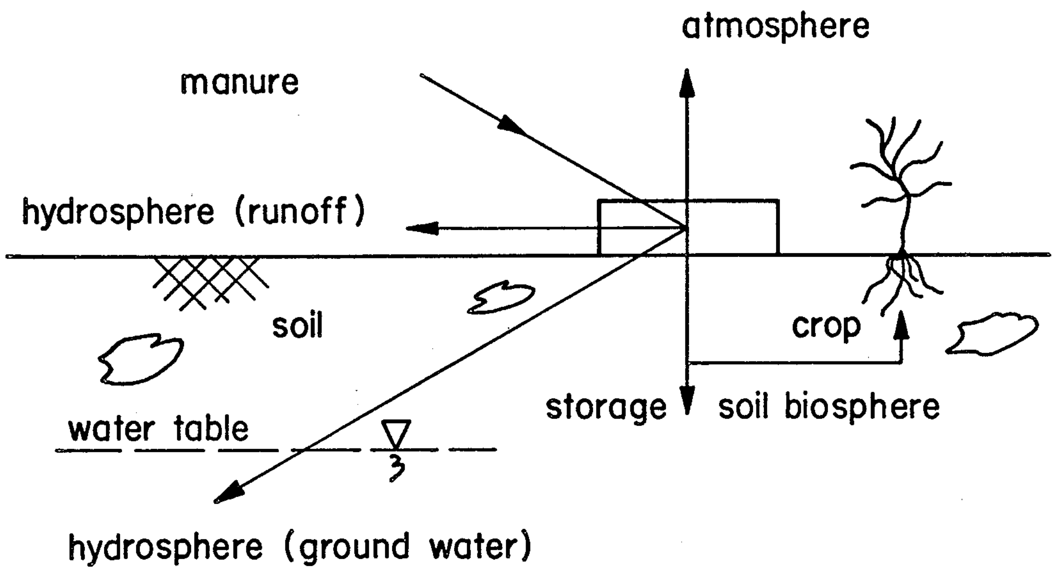

Fig. 2.1 Manure Applied to Farm Land

is a complex commodity in the crop-soil-manure regime. The soil is equally variable. Complex physical, chemical and biological properties are inherent to the many types of soil. Climate, parent material, living organisms, local topography, and time are factors that determine the kind of soil produced (Berger - 1972a). There are, for example, more than 500 types of soils recognized and mapped in Manitoba (Ehrlich et al - 1971). Upon formation, there are four components of soil that warrant consideration. Soil is a mixture of mineral matter, organic matter, water, and air. Although variable, an ideal combination of the four components for plant growth is approximately 45% mineral matter, 5% organic matter, 25% water, and 25% air (Foth and Turk - 1972a). Physical variability of soil relates to the proportioning of these four soil components with respect to flow and storage of water, movement of air, particle size, and structural aggregating ability (Berger - 1972b). Chemical variability is primarily due to the proportioning of the mineral materials (Berger - 1972c). Biologically, the soil supports innumerable forms of plant and animal life; from single celled organisms to large burrowing animals (Foth and Turk - 1972b). In fact, some soil microbiologists consider soil as a living tissue because of the heavy population of living organisms (Robinson - 1972).

Additions of manure to soil greatly increase the biological activity of the soil. The growth of bacteria, fungi, and actinomycetes is stimulated by addition of manure; and aerobic cellulose metabolizing bacteria are more numerous in manured fields (McCalla et al - 1970). Not only does the manure add organic matter to the soil, the manure stimulates the biological activity which contributes to the decomposition of the organic matter in the soil (i.e. mineralization of the soil organic matter). Robinson (1972) supports McCalla et al (1970) by indicating that many properties of soil, particularly those important to the decomposition of manure, are properties of the soil microflora. The ultimate disposition of manure, that is, the mineralization of the organic matter rendering the inorganic fraction available for storage in the soil and for crop utilization, depends on the interactions of the biological, chemical, and physical characteristics of the soil system with the surrounding soil environment.

Application of animal manure on to the soil surface or incorporation into the soil is followed by manure decomposition. Decomposition can be aerobic, anaerobic, or facultative. The factors contributing to the decomposition of the manure (i.e. organic matter) or the proliferation of micro-organisms favourable to decomposition are physical variables such as moisture content, clay content and type (Robinson - 1972), and oxygen, temperature, and micro-organisms already abundant in the soil (McCalla et al - 1970).

Like the organic matter in crop residues the manure organic matter (fats, carbohydrates, proteins, lignin) must be decomposed before the inorganic nutrients become readily available. The soil organisms that regulate decomposition have similar nutrient-element-physical requirements to that of the higher forms of life (Foth and Turk - 1972c). For example, temperature regulates some of the chemical and biological changes in the soil. Biological reaction rates increase two to three fold for every $10^{o}C$ temperature increase to a rough upper limit of $80^{o}C$ with the optimum temperature range around 35°C (Foth and Turk - 1972c). Autotrophic bacteria, which are capable of oxidizing ammonia, nitrite, sulfur, manganese, hydrogen, carbon monoxide, and methane, function within a temperature range of 5-55°C with production of nitrates greatest at 37°C (Donahue - 1965a). Moisture influences the numbers and activities of soil micro-organisms. The optimum amount of moisture for most soil organisms is between 50 and 70 percent of the water holding capacity of the soil (Foth and Turk - 1972c). Soil aeration is primarily governed by fluctuations in water content and is considered the inverse of moisture content. Aeration, therefore, increases with a decreasing water content; and, an increase in water content leads to the development of anaerobic conditions. Aeration may be reflected by the soil texture (Robinson - 1972). Texture refers to the fineness or coarseness of the soil and is determined by the relative proportions of sand, silt, and clay. Rates and extents of physical and chemical reactions are governed by texture because it determines the amount of surface area on which reactions can occur (Foth and Turk - 1972c). Concentration and rate of supply of gases affects the soils' micro-organisms (Foth and Turk - 1972c). Oxygen is used in the oxidation process; carbon dioxide as a source of carbon for autotropic organisms; and, nitrogen gas for the nitrogen fixing bacteria. Abundant oxygen will favour nitrite and nitrate formers, nitrogen fixers, fungi, and actinomyces which oxidize organic matter (Foth and Turk - 1972c). Initial populations have a decided influence on microbial activity. If numbers are small the mineralization process will be slower in commencing. If the aforementioned physical factors are conducive to soil microbial activity then the specific mineralization process may commence immediately (Robinson - 1972).

The conversion of nutrients in organic matter to the mineral inorganic form (i.e. decomposition) is termed mineralization. Mineralization of animal manure in the soil yields nitrogen, phosphorous, potassium, and micro-nutrients such as boron, copper, manganese, cobalt, zinc, and moylbdenum (McCalla et al - 1970). One of the factors affecting the ability of the soil to behave as a medium for the disposal of farm animal waste is the ability of the plants (cropping practice) to utilize the mineralized nutrients. The cropping procedure in this sense must be included as part of the soil biosphere since plants require sixteen essential nutrients for growth (Donahue - 1965b). Excessive mineralization of animal manure in the soil may lead to nutrient leaching into groundwater or nutrient loss (runoff) into ditches, streams, and lakes (McCalla et al - 1970). Runoff and leaching and problems associated with each are discussed in Section 2.3 - Hydrosphere. Excessive mineralization may result in the accumulation of nutrients in the soil or plant system. This accumulation may result in an unhealthy environment for the plants or possibly toxic concentrations for the plant consumers.

Yields of corn (for silage) were depressed by heavy applications of solid beef feedlot manure beyond a certain upper limit of between 556,000 and 740,000 kg ha^{-1} of manure. These depressed yields were attributed to the accumulation of soluble salts in the soil from large manure treatments. Toxic ammonium concentrations in the soil to a depth of 30 cm were partially responsible for poor germination and poor seedling vigor. Sodium and potassium accumulations in the soil were associated with poor yields (Murphy et al - 1972). However, Hensler et al (1971) suggested that for most soils, nutrients in manure (including N, P, K, Ca, Mg, S, Zn, Cu, Mn, Fe and B) can be used in crop production with little danger of plant toxicity; but, nutrient utilization efficiency decreases with increasing application rates thereby creating a pollution potential. Overman et al (1971) determined that oats grown with dairy manure measure up to those grown with commercial inorganic fertilizer in chemical composition, palatability, and digestibility. O'Callaghan et al (1973) suggested that animal manure spread on grazed areas may cause a health hazard to grazing animals. Nitrate poisoning where forages contain an excess of (0.4 - 0.5)% nitrate-nitrogen is also a possibility. Ukrainetz (1969) indicates that nitrate poisoning due to the accumulation of nitrates from nitrogen fertilizers may occur at levels as low as 0.14% nitrate-nitrogen. Over application of manure or under estimation of nutrient quantity associated with manure mineralization may result in conditions that are hazardous to the livestock or detrimental to the crops that have been manured.

2.3 Hydrosphere

Although the intended final placement of the animal manure during land application is the soil biosphere, the possibility of manure deposition in the hydrosphere exists. There are two distinct, but not separate, modes and locations by which the hydrosphere may become contaminated. Runoff from sloping fields may affect surface water courses and lakes. Leaching of nutrients may contaminate ground water reservoirs, surface water courses and lakes.

When precipitation, snowmelt, irrigation, or the like supplies water to a sloping surface at a rate exceeding the infiltration rate of water into the soil, runoff occurs (Holt - 1969). If infiltration is inhibited (for example, by an impervious layer or frost conditions) then runoff becomes an even more critical problem. Allred (1969) indicates that a large portion of stream and lake pollution that occurs during spring thaw is thought to have originated from fields where farmers have spread manure during the previous winter months. When manure is spread on frozen or snow covered fields, or when heavy rainfall occurs subsequent to land application of manure, considerable runoff resulting in nutrient loss is possible. Nitrogen losses may be as high as 3.34 - 4.45 kg ha^{-1} to over 25.6 kg ha^{-1} (Miner and Willrich - 1970). Klausner et al (1971) indicated that on a frozen grass sod field with a 20% slope, 16.15 kg ha^{-1} of nitrogen (expressed in N) and 4.65 kg ha^{-1} of phosphorus (expressed in P_2O_5) were lost.

Leaching can be associated with groundwater seepage or percolation (Armstrong and Rohlich - 1970). If the rate (total yearly rate in a bulk application) of fertilizer (manure) nitrogen does not exceed the nutrient requirements of the crop there should be little likelihood of nitrate-nitrogen leaching because of the lack of accumulation of nitrate-nitrogen (Power - 1970). A nitrate-nitrogen pollution potential exists when nitrogen supply exceeds the crop utilization requirement because of manure variability or over-application of manure to crop or fallowed lands.

Phosphorous and nitrogen are considered the two most serious contaminants in water quality degradation (Klausner et al - 1971). Phosphorous becomes fixed as insoluble compounds in the soil and is considered relatively immobile. The chemical process of fixation reduces the phosphorous concentration in solution. Loehr (1974) related increasing fixation of phosphorous to increasing clay content; and, phosphorous fixation was least with a high sand content. Klausner et al (1971) related phosphorous losses to erosion of the soil bulk. Similarily, Loehr (1974) suggested that, if soil erosion could be controlled, phosphorous losses could be controlled. Nitrogen, however, is not fixed in a manner similar to phosphorous. Nitrogen pollution problems are primarily associated with the nitrate ion (NO_3^-) form of nitrogen. Ammonia, through the nitrification process, is oxidized to nitrate (equation 2.1) which in turn is oxidized to nitrate (equation 2.2) (Pelczar and Reid - 1965):

$$2NH_3 + 3O_2 \longrightarrow 2HNO_2 + 2H_2O \quad (2.1)$$

$$HNO_2 + \frac{1}{2}O_2 \longrightarrow HNO_3 \quad (2.2)$$

The ammonia source is the decomposition (ammonification) of organic matter containing nitrogen such as animal manure. Since nitrate is an anion (NO_3^-) it is not readily absorbed onto the soil complex and is available for leaching or erosion losses (Weber and Lane - 1969).

There are two serious and topical reasons for being concerned with leaching and runoff -- infantile methemoglobinemia and eutrophication. The health of infants and animals may be impaired by drinking water containing more than 10 mg l^{-1} of nitrate N (Webber and Lane - 1969). The Canadian Drinking Water and Standards and Objectives (CDWS) - 1968 established an upper limit of nitrite plus nitrate of 10 mg. l^{-1} based on the relationship between nitrites, nitrates, and infantile methaemoglobinemia. Nitrate accumulation can be the result of runoff, leaching, or a combination of both of which feedlots, privies, and tanks are prime contributors as far as groundwater supplies, particularly wells, are concerned (Goldberg - 1970). Eutrophication, the addition of nutrient materials to the hydrosphere, the effect of which is the reduction of the oxygen supply (Smith - 1969), is a natural process (Allred - 1969). The question of significance, though, is to what extent does agriculture contribute to the acceleration of this natural process. Oglesby (1971) lists time of year, element form, and the nature of the receiving water as contributing factors in the way nitrogen and phosphorous speed the eutrophication process. Interest in eutrophication control is directed towards limiting the amount of nutrients entering the water (hydrosphere). The CDWS suggests 0.10 mg. l^{-1} as the upper limit for phosphates but sets no specific limits on nitrogen for eutrophication control. The aesthetic value of a lake may be lowered through excessive growth of aquatic weeds, algae, and algal floating scums; and, undesirable tastes and odours and the impairment of water treatment operations is possible if eutrophication is left unchecked (Armstrong and Rohlich - 1969).

2.4 Atmosphere

The extent to which manure becomes an air pollutant depends to a great degree upon the characteristics of the manure before field application. Manure decomposition in storage is normally anaerobic; and, malodourous and harmful gases are often associated with anaerobic decomposition. Some of the gases identified are hydrogen sulfide, ammonia, mercaptans, and amines (Ludington, 1971). Loehr (1974) adds hydrogen sulfide, two-to-five carbon organic acids, indoles, skatols, diketones, methylamine, ethylamine, methane and sulfides. Over twenty different compounds in the odours from animal manure have been separated but not all identified (Ludington, 1971). Upper threshold limits have been established for some of the aforementioned gases with respect to human and livestock populations (Taiganides and White - 1968). It is these odourous compounds from livestock operations that are responsible for many of the urban-rural confrontations with regards to air rights.

A difficulty arises in that air pollution from animal manures cannot be successfully controlled if the odourous compounds have already been produced (Ludington - 1971). The primary method of eliminating manure odours during field applications are those methods that inhibit odour or gas production. Ludington (1971) and Taiganides and White (1968) suggested some of the following procedures for the elimination of manure gas production:

1. Periodic and frequent removal of manure, bedding, and spilled feed from the manure storages and barns,

2. Control of moisture within the barn to eliminate wet bedding, wet feed, and generally damp conditions that contribute to production of manure gases,
3. Control of the level of manure in the storage pit and of the amount of water added to manure to maintain the manure in a condition that tends to eliminate noxious gases.

These good housekeeping policies are beneficial; but, are of little consequence to the farmer faced with handling anaerobically decomposed manure.

One method gaining acceptance as a manure handling technique (to eliminate losses of nutrients and gases to the atmosphere) is the plow-furrow cover (PFC) method of land application. Although there are variations, the principle of the PFC method is covering or burying of the manure (usually in slurry form) on application. Feldman and Hore (1970) indicated, even though odour measurements on field trials were difficult, that the odour during manure application using the PFC method was quite low. A citizens committee involved with the Feldman-Hore study were satisfied that the odour was controlled. There were, however, sources of exposed manure that created a potential odour problem with the PFC method such as:

1. Agitation of the manure in storage to facilitate handling and spreading,
2. Loading of the slurry into the distribution tank,
3. Manure exposed in the furrow before covering,
4. Manure spilled on the plow, tractor, or tank spreader.

Since the premise of the PFC method is to bury the manure or cover the manure with soil before losses can occur it would be interesting to note the pollution potential with respect to the soil biosphere and hydrosphere.

It should be the intention of livestock producers and environmentalists to eliminate the gaseous or odourous by-products of animal production. One method of odour elimination is aerobic treatment of animal wastes. Manure in storage will rapidly deplete the dissolved oxygen supply, Aeration (with diffusion aerators or mechanical aerators) can supply oxygen and mixing to maintain or exceed the necessary oxygen concentration level (Loehr - 1974). Aerobic treatment can remove much of the biological oxygen demand from the waste and allow for an acceptable effluent to be discharged to the field by sprinkler irrigation or tank spreader. Aerobic treatment is not an alternative to land application, but it eliminates objectionable odours which are normally associated with animal manure handling.

There are other manure handling techniques. Drying, anaerobic treatment, processing into commercially available fertilizers are examples. The urban community is becoming more aware of the contribution that agriculture is making to atmospheric pollution. As urban sprawl continues the urban-rural interface expands and a potential confrontation over air rights increases in likelihood. Hore (1971) outlined pollution legislation in Canada with respect to the livestock industry. Such legislation as the 1971 Alberta Clean Air Act implicates agricultural production to the current ecological awareness. If livestock production is to be maintained as a viable enterprise and the rights of the urban dweller protected; then, such practices as PFC and aerobic treatment will have to be expanded to eliminate nuisance and harmful odours from livestock operations.

CHAPTER 3

METHODS AND PROCEDURES

3.1 Location of the Experiment

The experimental site is located at the University of Manitoba Glenlea Research Station, approximately nineteen kilometers south of Winnipeg on Provincial Trunk Highway 75 in the Parish of St. Norbert immediately west of the Red River on river lots two through ten inclusive. The experimental plots are situated to the north and west within the bounds of river lot ten west of Highway 75.

3.2 Soil Description

A detailed soil survey of the Glenlea Research Station completed by W. Michalyna (Department of Soil Science, University of Manitoba) does not include river lot ten, the site of the experimental plots. However, the survey does include river lots two through nine inclusive. Personal communication with W. Michalyna with respect to the soil classification of river lot ten indicates that the following soil types of the Red River Association are located in the area of the experimental plots:

1. Gleyed Black - Scanterbury Series (moderately drained),
2. Gleyed Rego Black - McTavish Series (moderately drained),
3. Gleyed Rego Black - Dencross Series (moderately drained),
4. Rego Humic Gleysol - Osborne Series (poorly drained).

A comparative analysis of these soils shows two distinct groups. The Scanterbury, Dencross, and McTavish clays are grouped because of a slight to moderate problem associated with drainage, tilth, wind and water erosion, and stoniness. The three aforementioned clays are also subject to water-logging and have a characteristic slow permeability. A major soil problem associated with these clays is wetness and drainage. Osborne clay is distinct from the Scanterbury, Dencross, and McTavish soils because of its lower productivity status. Osborne clay has problems characteristically associated with low productivity such as poor drainage and water erosion, low fertility, salinity, stoniness, and soil drought. Ponding is likely if artificial drainage is not supplied due to the slow permeability of the Osborne clay. As with the Scanterbury, Dencross, and McTavish soils the major problem is wetness and drainage. The Osborne clay characteristics are very similar to those of the three aforementioned clays but are more pronounced. A more extensive analysis of the soils of the Red River Association and the methods of soil classification are available in a 1953 joint publication by the University of Manitoba, Provincial Department of Agriculture and Soils, and the Canada Department of Agriculture[1,2].

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1 Report of Reconnaisance Soil Survey of Winnipeg and Morris Map Sheet Area by W. A. Ehrlich, E. A. Poyser, L. E. Pratt and J. M. Ellis.

2 Appendix A - Analysis of the Cultivated Scanterbury, Dencross, McTavish, and Osborne Clays.

3.3 Plot Layout

Survey and land forming was initiated in the fall of 1971 and completed in the spring of 1972. Approximately 3.2 ha were subdivided into seven distinct blocks separated by alternating roadways and drainage ditches. Each of the seven blocks was subsequently divided into 20 plots. Each plot, surrounded by a low dyke, measured 7.5 m in width and 30.5 m in length with a uniform slope over the longest dimension (east-west) of 0.2 percent. The numbering system for the plots was based on the physical layout of the experiment. The seven blocks were designated as the 100, 200, ..., 700 series beginning with the most westerly block as the 100 series. Plots within the blocks were numbered one through twenty inclusive beginning at the northerly end of the blocks. For example, the plots in block 700 (the most easterly) were 701, 702, ..., 720 moving from north to south. Two half-block sections (i.e. plots 1, 2, ..., 10 and 11, 12, ..., 20) were designated on each block for experimental purposes[1].

3.4 Treatment Selection

3.4.1 Crops

Alfalfa, barley, corn, a mixture of alfalfa, brome, and meadow fescue (i.e. standard pasture grass), and reed canary grass were selected for study by Dr. K. W. Clark (Department of Plant Science, University of Manitoba). Crop selection was based on a variety of

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1 Appendix B - Diagram of the plot layout and numbering system.

factors. For example, corn and barley were selected as annual crops with differential nutrient input requirements. Corn has a higher nutrient requirement than barley and this could be a factor within the scope of a manure disposal experiment. Furthermore, both corn and barley feed grains are commonly associated with mixed crop-livestock operations. Reed canary grass was selected on the basis of its high nutrient uptake capability. The mixture (alfalfa, brome, and meadow fescue) was selected on the basis of its being a representative pasture grass. Alfalfa was selected for future considerations in an alfalfa dehydration project. Cropping was initiated subsequent to land forming in the spring of 1972 with each crop being replicated twice in each half-block. The crops were randomly allocated within the five-plot sections[1].

3.4.2 Amendments

The following animal manure, fertilizer, and sewage sludge amendments were initiated in the fall of 1972:

1. Spring application of manure,
2. Fall application of manure,
3. Winter application of manure,
4. Recommended application of inorganic fertilizer,
5. Activated sewage sludge treatment.

Amendments were based on both theoretical and practical considerations. Spring, fall, and winter applications of manure were chosen because

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1 Appendix C - Assignment of Crops to Plots

they conform to standard farm practice. Winter applications were implemented as some states (e.g. Wisconsin) and provinces (e.g. Ontario) prohibit winter application of manure in response to environmental concern. It is important to note that if winter spreading were prohibited large capital investment would be required by many farmers for construction of manure holding facilities.

Application of inorganic fertilizer was included in the experimental design because many farmers use inorganic fertilizer in accordance with Provincial Soil Test Laboratory (PSTL) recommendations. It was felt that such practice would provide a useful comparison to manure management practices on cropland.

The nutrient utilization rate of the five crops was based on the assumption that 67 kg ha^{-1} of N was approximately the nitrogen[1] requirement of each crop. Three levels of amendment were selected: 33.5 kg ha^{-1}, 67 kg ha^{-1}, and 201 kg ha^{-1} of N. Figure 3.1 illustrates the arrangement of the amendments and treatment levels on the experimental area. Manure selected for the treatments was based on availability at the Glenlea Research Station. Sewage sludge was selected as an amendment because of current interest in recycling municipal wastewaters through land. Activated sewage sludge was obtained from the Winnipeg North End Sewage Treatment Plant. A half-block was set aside as control.

Operational problems forced changes in implementation of the amendment design. Figure 3.1 indicates that 100.5 kg ha^{-1} of N was

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1 Principles and Practices of Commercial Farming, Department of Agriculture, University of Manitoba.

applied to the corn plots of the inorganic treatment block. As corn has a higher nutrient requirement than the 67 kg ha^{-1} of N assumed, 100.5 kg ha^{-1} of N was to be applied to all corn plots. After application of the inorganic fertilizer it was realized that it was an operational impossibility to vary the rate to 100.5 kg ha^{-1} of N on the manure treatments. Figure 3.1 indicates that sewage sludge was applied on three plots: 718, 719, 720. Sufficient activated sewage sludge was available; but, inconsistency in quality of the sludge (i.e. the clay content was extremely high) resulted in a decision to apply 44 metric tons of activated sewage sludge on the three plots. That is, at a rate of about 2000 kg ha^{-1} of N.

3.5 Treatment Establishment

Subsequent to the completion of field forming, cultivating and harrowing, barley was planted at 94 kg ha^{-1} on May 24, 1972 using a 1.85 m seed drill (Klapprat, Unpublished Report)[1]. Alfalfa was seeded May 29, 1972 at 5.6 kg ha^{-1}. On May 29, 1972 corn planting was completed at 63,000 seeds ha^{-1}. The mixture of alfalfa, brome, and meadow fescue was seeded May 31, 1972 at a 0.6 : 1 : 1 ratio, respectively, with alfalfa at 3.36 kg ha^{-1}, brome and meadow fescue at 5.6 kg ha^{-1}. The drainage ditches, roadways, and border dykes were seeded to Russian wild rye grass on June 2, 1972. On June 21, 1972 the barley and reed canary grass plots were sprayed with Buctril - M at 0.56 kg ha^{-1}. Corn

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1 Klapprat, Bob, 1972. Waste disposal plots - 1972. Unpublished report to the Department of Agricultural Engineering, University of Manitoba.

700's control no amendment	sewage sludge 718-720
600's beef - spring 33.5 kg ha^{-1} (N)	dairy - spring 201 kg ha^{-1}(N)
500's dairy - spring 33.5 kg ha^{-1}(N)	beef - spring 201 kg ha^{-1}(N)
400's inorganic 67 kg ha^{-1} (N)	fertilizer corn 100.5 kg ha^{-1}(N)
300's swine - spring 201 kg ha^{-1}(N)	swine - spring 67 kg ha^{-1}(N)
200's swine - winter 67 kg ha^{-1}(N)	swine - fall 67 kg ha^{-1}(N)
100's swine - fall 201 kg ha^{-1}(N)	swine - winter 201 kg ha^{-1}(N)

Fig. 3.1 Allocation of Fertilizer Amendments to Plots

plots and border dykes were sprayed with Banvil-3 July 4-5, 1972. On July 27-28, 1972 the legume plots were hand weeded. Barley swathing began on August 25, 1972. Due to the occurrence of fall rain the corn was chopped (forage chopper) and blown on the corn plots. The legume crops were not harvested because of lack of response. No fall tillage work was attempted because of an early snow fall. In November, 1972 both the fall and winter applications of swine manure were applied to the 100 and 200 blocks. The 201 and 67 kg ha^{-1} of N applications required approximately 58,800 and 19,600 l ha^{-1} of swine manure respectively (Phillips, Unpublished Report)[1]. Swine manure was applied as a liquid with a Lely tank, truck mounted, spreader. Manure spreading in November 1972 completed the 1972 field work program.

Lack of fall tillage in 1972 resulted in soil compaction and workability problems the following spring. Spring 1973 field work began with the 300 block application of swine manure following the same procedures as November 1972 (Phillips, Unpublished Report). On May 10, 1973 the 33.5 and 201 kg ha^{-1} of N applications of beef and dairy manure were completed at approximately 36.2 and 217.2 metric tons ha^{-1} using a box-type, pto-driven manure spreader (Buchanan, Personal Communication)[2].

Sewage sludge was applied at 44 metric tons[2] on plots 718, 719,

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1 Phillips, E. G., 1972. Manure Application. Unpublished report to the Department of Agricultural Engineering, University of Manitoba.

2 Buchanan, L.C., Department of Agricultural Engineering, University of Manitoba.

720 (2000 kg ha^{-1} of N). Although sufficient activated sewage sludge had been available for plots 710-720 only a portion of the sludge was found acceptable on the basis of quality. Much of the sludge discarded contained large clods of clay, presumably from the bottom of the holding lagoon. On completion of roto-tilling and harrowing, planting was started. Barley was planted May 29, 1973 at 80.5 kg ha^{-1}. On May 30, 1973 corn was planted at 2400 seeds per plot. Alfalfa was re-seeded June 2, 1973 at 13.5 kg ha^{-1}. The mixture was re-seeded June 7, 1973 at 3.46, 5.6, and 5.6 kg ha^{-1} respectively for alfalfa, brome, and meadow fescue. On June 7, 1973 inorganic fertilizer was applied with a pull type, axle driven, rotary spreader. The application rates for the 27-14-0 fertilizer were 67 kg ha^{-1} of N for all crops except corn which received 100.5 kg ha^{-1} of N. Ditches and roadways were re-seeded June 12, 1973. No pesticide spraying was attempted in the summer of 1973 as equipment availability and weather did not correspond. Alfalfa, reed canary grass, and the mixture were harvested as hay in June, 1973 and September, 1973. Barley was combined in September, 1973, and, the corn chopped for forage October 26, 1973.

Runoff collection equipment was installed on five plots in mid-summer 1972. Equipment consisted of five 910 l fiberglass tubs installed at the lower base of plots 116 to 120. Runoff was delivered to the tubs through a 10.2 cm diameter, 1.5 m long downspout between a weir in the plot dyke and the tubs. Due to lack of runoff, no samples were collected in the summer or fall of 1972. Frost heave and back-up water from a nearby main drainage channel disturbed the collection tubs and downspouts; and, no samples were obtained for the spring of 1973. The tubs were re-installed in mid-summer 1973 on plots 117, 118, 216, 217, and 318 in order to improve the sampling procedure. Several heavy rainfalls resulted in excellent runoff events being sampled.

3.6 Analytical Procedures

3.6.1 Sampling

3.6.1.1 Soils

Preliminary soil tests were completed in October 1971 under the direction of the Provincial Soil Test Laboratory (P.S.T.L.) before land levelling and shaping of the site. The preliminary sampling was investigative in nature; and, six locations were sampled to a depth of 3.66 m. A motor driven, truck mounted, auger was used for sampling. The samples were labelled, bagged, and delivered to the P.S.T.L. for analysis[1].

Prior to cropping in 1972, further soil samples were collected by the P.S.T.L. Representative plots were sampled to a depth of 3.66 m and some to a depth of 6.1 m.[2] The same sampling procedure and analysis was completed by P.S.T.L. The 1972 soil samples were stored in the event of future test requirements.

Following the 1973 crop harvest and prior to manuring, a soil test of selected plots was completed by P.S.T.L. Samples at the surface, 0.154,

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1 Appendix D - Location and Results of the 1971 Soil Sampling

2 Appendix E - Location and Analysis of 1972 Soil Samples

.31 m level and thereafter at .31 m intervals to 3.66 m were taken[1]. The samples were dried, ground, analyzed, and stored by the P.S.T.L. in a similar fashion to the 1972 samples.

3.6.1.2 Plant Tissue

Due to poor response of the crops in 1972, sampling of the crops was limited. Barley was the only crop sampled in 1972. Random samples were taken from the swath and a yield calculated (Klapprat, Unpublished Report).

In 1973, sampling of the crops was initiated with the legume crops (alfalfa, mixture, reed canary grass). Two samples, each one square meter in area, were cut from each plot. The samples were dried and weighed[2]. Legume sampling was completed on June 26, 1973. The samples were subsequently delivered to the Department of Plant Science for tissue analysis. Legume crops were not sampled prior to the second hay cutting. Barley was sampled from the swath. One 4.9 m sample was removed from one of the two swaths. Plots 100, 200, 300, 620, 704, 713, and 718 were sampled August 24, 1973 and the balance of the plots were sampled on September 17, 1973. The samples were threshed and weighed[3]. Corn was sampled before harvest on September 19, 1973. Two samples, each 4.9 m were cut from the corn rows and weighed[4]. In order to eliminate

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1 Appendix F - Location and Analysis of 1973 Soil Samples

2 Appendix G - Legume Yield

3 Appendix G - Barley Yield

4 Appendix G - Corn Yield

any boundary effects, outside rows were not sampled. Additional samples were taken from the forage chopped from each corn plot on October 26, 1973 and were forwarded to the Department of Plant Science for tissue analysis.

3.6.1.3 Runoff

Runoff samples, when available, were collected using the fiberglass tubs. The tub lids were removed, the runoff in the tub was agitated, and a representative sample gathered. The balance of the runoff was discarded. Samples were returned to the Department of Agricultural Engineering Wastewater Laboratory for analysis.

3.6.2 Chemical

3.6.2.1 Soils

Soil samples submitted to the P.S.T.L. were analyzed using a Technicon Auto Analyzer for extracts of NO_2, NO_3, and P*, and flame photometry for K. Texture and $CaCO_3$ were determined with a HCl solution and pH and conductivity were determined on the supernatant of soil and water (Fehr, Unpublished Report - 1971). Nitrate, nitrite, phosphorous, pH, and conductivity data were obtained for all samples. Texture, potassium, and calcium carbonate ($CaCO_3$) were measured only for surface soil samples.

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*0.5 M $NaHCO_3$ extractable P

3.6.2.2 Plant Tissue

Samples of 1973 corn and legume crops were forwarded to the Department of Plant Science for tissue analysis. A dry ash[1] method was used for heavy metals (Fe, Mn, B, Zn, Cd, Cr, Co), nitrogen, phosphorous, potassium, calcium, and magnesium. The Kjeldahl method was used for nitrogen determination. A Perkin-Elmer model 403 Atomic Absorption unit was used for the tissue analysis[2].

3.6.2.3 Runoff

Runoff samples were stored at approximately 4°C before being analyzed for chemical oxygen demand, phosphates, and nitrates according to the procedures outlined in Standard Methods[3,4].

Table 3.1 summarizes the parameters being analyzed in the soil, the plant tissue, and the runoff. It is important to note that the predominant chemical parameters being analyzed are nitrogen and phosphorous; perhaps the two most significant pollution parameters.

3.6.3 Statistical

Originally, a randomized complete block design was intended for the experiment. Operational problems such as fertilizer and animal waste applications and manpower shortages during the initial stages

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1 Methods of Analysis for Soils, Plants, and Waters by Homer D. Chapman, Parker F. Pratt, University of California, Division of Agricultural Sciences - 1961.

2 Appendix H - Plant Tissue Analysis

3 Appendix I - Runoff Analysis

4 Standard Methods - For the Examination of Water and Wastewater - 13th edition, 1971. American Public Health Association, Washington, D.C.

TABLE 3.1 Chemical Parameters Analyzed

Parameter	Soil	Runoff	Plant Tissue
Kjeldahl - N	-	-	x
Nitrate - N	x	x	-
Nitrite - N	x	-	-
% Phosphorous	-	-	x
Phosphate	x[1]	x[2]	-
% Potassium	-	-	x
% Calcium	-	-	x
% Magnesium	-	-	x
Iron	-	-	x
Manganese	-	-	x
Zinc	-	-	x
Cadmium	-	-	x
Cobalt	-	-	x
Cromium	-	-	x
Texture	x	-	-
Lime	x	-	-
pH	x	-	-
Conductivity	x	-	-
COD	-	x	-

[1] 0.5 M $NaHCO_3$ - extractable P

[2] PO_4 - P

of the project resulted in re-assignment of treatments (fertilizer) thereby eliminating randomization. However, with each of five crops randomized and replicated within any half-block section the experiment still lent itself to analysis as a split-plot or incomplete block design. The analysis of variance procedure was used to analyze the variation of a response and assign portions of the variation to specific independent variables. In the case of the parameters listed in Table 3.1 the analysis of variance procedure was used:

1. To analyze the nitrate level through the soil profile at .31 m intervals for 1972 and 1973 to determine if there was a significant difference in nitrate accumulation,
2. To analyze percent N (from plant tissue analysis) uptake in reed canary grass and corn to determine if there was a significant difference in nitrogen uptake.

It was hoped that any significant differences could be related to specific fertilizer or manure treatments thereby indicating a nitrogen control technique for manure applications.

A split-plot analysis of variance program, STATS II, written for IBM 360 using FORTRAN IV and available through the University of Manitoba Computer Center was used for the analysis of variance and standard errors of difference.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis of Variance

4.1.1 Soils Analysis

An analysis of variance was completed on nitrate levels of the spring, 1972 soil samples (Appendix E) at each .31 m of depth to a depth of 1.53 m (i.e. 6 trials). Eight mainplot factors (treatment blocks), 3 subplot factors (crops), and 2 replications (crops) were tested at a 95% confidence interval to determine if significant differences existed in the soil nitrate levels. The mainplots and subplots which were analyzed are outlined in Table 4.1. At all depths, the differences due to mainplots, subplots and interactions were insignificant (Tables 4.2 to 4.7). Figures 4.1 to 4.8 indicate the nitrate accumulation through the soil profile for the three crops on the eight treatments. All differences in nitrate level in the mainplots, subplots and interactions could be accounted for by random error. That is, there was no real difference. Figures 4.1 to 4.8 are representative of the nitrate level profile in spring 1972 before treatments. It is interesting to note the difference between the surface nitrate level and those of lower depths. The accumulation of nitrate in the surface layer is perhaps due to the cropping technique (or lack of same) in 1971. The lack of significant differences when comparing the spring 1972 nitrate levels between treatments infers that a zero base (no initial differences) had been established within the plot layout. Since the establishment of a zero base had been questioned; because of the importance of nitrate as a pollutional parameter; and because a zero base lends greater significance to real differences expected to occur after treatment; the establishment of a zero base for nitrate levels is a significant result of the 1972 soils data. No other chemical properties of the soil were analyzed statistically. With exception to the previously noted high surface nitrate value, Figures 4.1 to 4.8 indicate a decreasing nitrate level through the soil profile and no nitrate accumulation at lower depths.

A similar analysis of variance procedure was completed for the fall, 1973 nitrate data (Appendix F). The mainplots and subplots analyzed are outlined in Table 4.8. Table 4.9 to Table 4.14 indicates at which depths the blocks, crops, or interactions produced significant differences in nitrate levels. Figure 4.9 through 4.19 indicate the nitrate accumulation in the soil profile during October, 1973 after the treatment applications of fall, 1972 and spring, 1973, and the cropping of summer, 1973.

The statistically significant differences noted in Table 4.9 and Table 4.10 indicate that a real difference between nitrate levels was created by the treatments. Table 4.9 (surface sample) indicates a significant effect of subplots (crops). The analysis of variance procedure was followed by a two-tailed, least square difference (at $\alpha = 0.05$) test to calculate a confidence interval for the variable determined significant with the F-test. In the surface samples, the barley plot nitrate levels exceeded those of the alfalfa and reed canary grass plots. The alfalfa plot nitrate was significantly greater than the reed canary grass plot nitrate. Much information can be gleaned from the significant differences shown in Table 4.9 through Table 4.14. However, when each depth is analyzed and the information assembled a recurring trend develops. That is, soils analysis after manure treatments of fall, 1972 and spring, 1973 and cropping of summer, 1972 indicate a greater nitrate accumulation in the soil profile on the barley plots when compared to that of the alfalfa and reed canary grass plots. This nitrate accumulation, which occurred from summer 1972 to fall 1973, may be explained by the lower nitrogen demand by barley when compared to alfalfa or reed canary grass.

Mainplot and interaction differences at the 1.2 m depth are indicated by Table 4.13. The mainplot and interaction significance was due to the control and sludge treatment blocks (plots 710 - 720) and was probably due to the bulk application of sewage sludge on barley plot 718.

Figures 4.9 to 4.19 indicate the disappearance in the fall of 1973 of the high surface nitrate values apparent from Figures 4.1 to 4.9 in the spring of 1972. As crop production was visibly better in 1973 than 1972 the nitrogen loss can probably be accounted for by crop removal. Even on the barley plots where a lower nitrogen demand exists the surface values (with the exception of sewage sludge on plot 718) are negligible. The spring 1972 soil samples were taken prior to spring planting and the fall 1973 soil samples were taken following harvest.

4.1.2 Plant Tissue

Plant tissue analysis for 1973 was performed on the corn and reed canary grass samples only. The uptake of nitrogen was calculated on the basis of total dry matter (Appendix G) multiplied by percent nitrogen

(Appendix H). Table 4.15 outlines total nitrogen uptake for each corn and reed canary grass plot. Visual inspection of Table 4.15 outlines the differences between the corn and reed canary grass plots which were statistically significant according to the analysis of variance procedure. In all cases the corn value is greater for total nitrogen uptake. Corn, though, had a greater total dry matter yield than reed canary grass. The fact that the percent nitrogen of reed canary grass is always greater than that of corn suggests that the reed canary grass has a better capacity per unit dry matter for the uptake of nitrogen.

On the basis of the aforementioned results it is clear that corn is a superior crop from a total nitrogen removal point of view. However, the response (dry matter yield) of reed canary grass was visibly less than expected partly due to rooting establishment problems. Once established, the reed canary grass may be comparable to corn for nitrogen control because of its greater uptake capacity for nitrogen on a per unit dry matter basis.

It is difficult to recommend a crop from the five analyzed for nitrogen control. Corn has a high removal rate. Barley and alfalfa yields are usually considerably lower than corn; and, the barley has a low nitrogen requirement and alfalfa nitrogen removal depends on symbiotic fixation (Foth and Turk - 1972d). Therefore, corn appears to be the better crop to grow but is limited somewhat in the Red River Valley by growing season and investment capital for specialized equipment.

The point of interest, though, still is the lack of accumulation of nitrate in the soil profile. Manure should be applied until nitrate accumulation occurs in order to help determine the best crop for nitrogen removal.

4.2 Collection and Sampling

Runoff collection sampling and analysis was not a successful part of the experiment. Lack of samples in 1972 eliminated research efforts of that year. Even though sampling events and analysis were recorded for the 1973 crop year (Appendix I) the results are questionable. It was extremely difficult to estimate volume; to place any reliability in sample analysis because of field sampling techniques; or to draw any conclusion other than that the high chemical oxygen demand, nitrates and phosphates of the samples suggest that agricultural runoff can make a serious contribution to pollution of the hydrosphere. The range of values were 0.0 - 155.0 ppm, 0.1 - 20.0 ppm, and 28.8 - 742 ppm for the nitrates, phosphates, and chemical oxygen demand, respectively.

TABLE 4.1 Statistical Analysis - 1972 Nitrate Data

Mainplots			Subplots	
Number	Figure	Treatment Blocks	Number	Crop
1	4.1	Plots 101 - 110	1	Alfalfa
2	4.2	Plots 111 - 120	2	Barley
3	4.3	Plots 401 - 410	3	Reed Canary Grass
4	4.4	Plots 411 - 420		
5	4.5	Plots 501 - 510		
6	4.6	Plots 511 - 520		
7	4.7	Plots 601 - 610		
8	4.8	Plots 611 - 620		

TABLE 4.2 Analysis of Variance Surface - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	0.965	7	7	3.79	No
Subplots	1.949	2	16	3.63	No
Interaction	1.221	14	16	2.37	No

* F at $\alpha = 0.05$ (95% confidence)

TABLE 4.3 Analysis of Variance .31 m - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	1.151	7	7	3.79	No
Subplots	2.269	2	16	3.63	No
Interaction	1.221	14	16	2.37	No

TABLE 4.4 Analysis of Variance 0.62 m - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	2.663	7	7	3.79	No
Subplots	1.765	2	16	3.63	No
Interaction	1.293	14	16	2.37	No

* F at α = 0.05 (95% confidence)

TABLE 4.5 Analysis of Variance .92 m - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom v_1	Degrees of Freedom v_2	Table* F	Significant
Mainplots	2.101	7	7	3.79	No
Subplots	0.471	2	16	3.63	No
Interaction	1.267	14	16	2.37	No

TABLE 4.6 Analysis of Variance 1.22 m - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom v_1	Degrees of Freedom v_2	Table* F	Significant
Mainplots	0.855	7	7	3.79	No
Subplots	2.693	2	14[1]	3.74	No
Interaction	1.383	14	14[1]	2.48	No

* F at $\alpha = 0.05$ (95% confidence)

1 Estimated values indicate loss in the number of df

TABLE 4.7 Analysis of Variance 1.53 m - 1972 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	1.145	7	7	3.79	No
Subplots	1.557	2	13[1]	3.81	No
Interaction	1.268	14	13[1]	2.51	No

* F at $\alpha = 0.05$ (95% confidence)

1 Estimated values indicate loss in the number of df

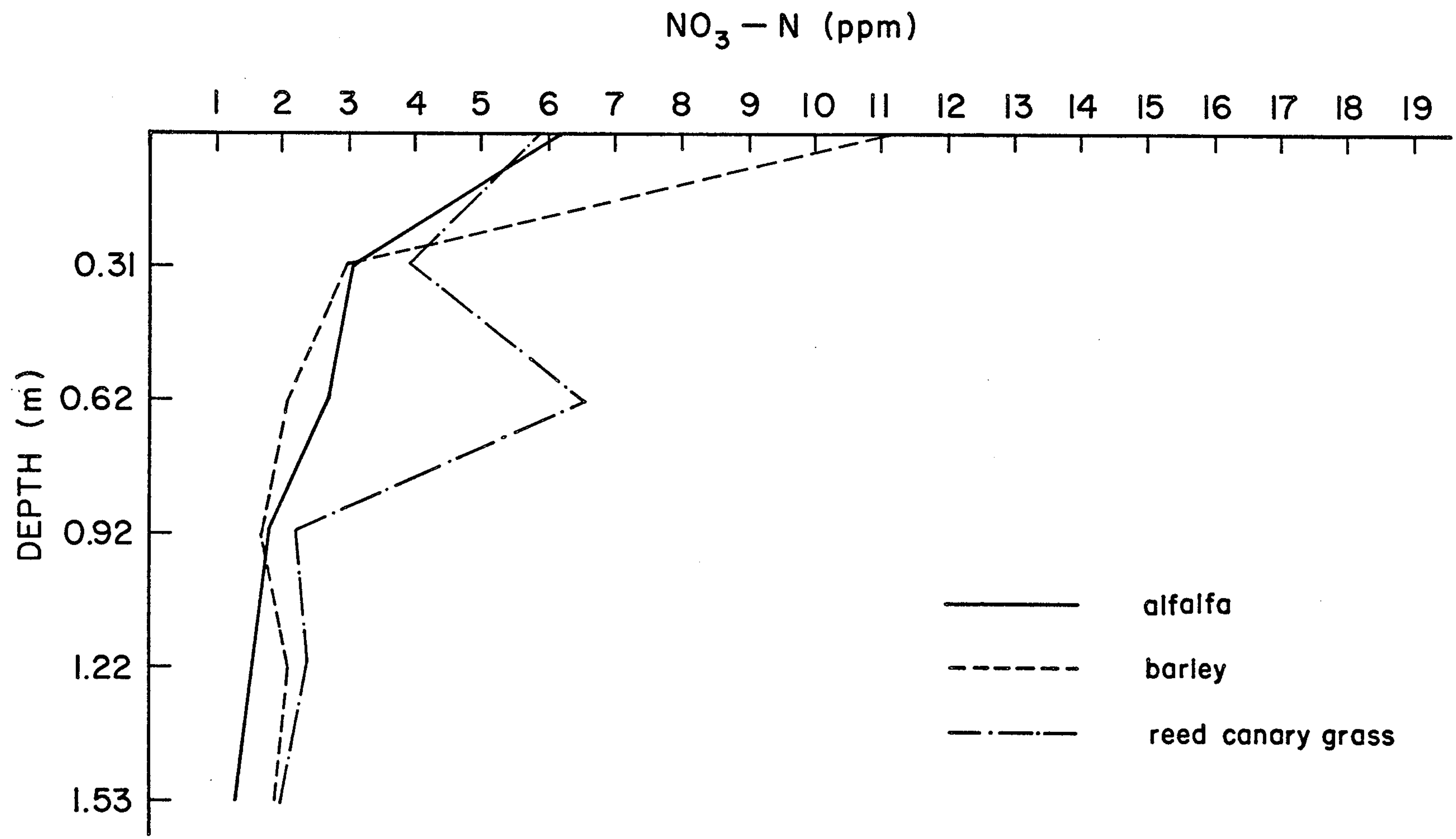

Fig. 4.1 Nitrate Profile for Mainplot One, Spring - 1972 Data
($201\ kg\ ha^{-1}$(N), swine manure)

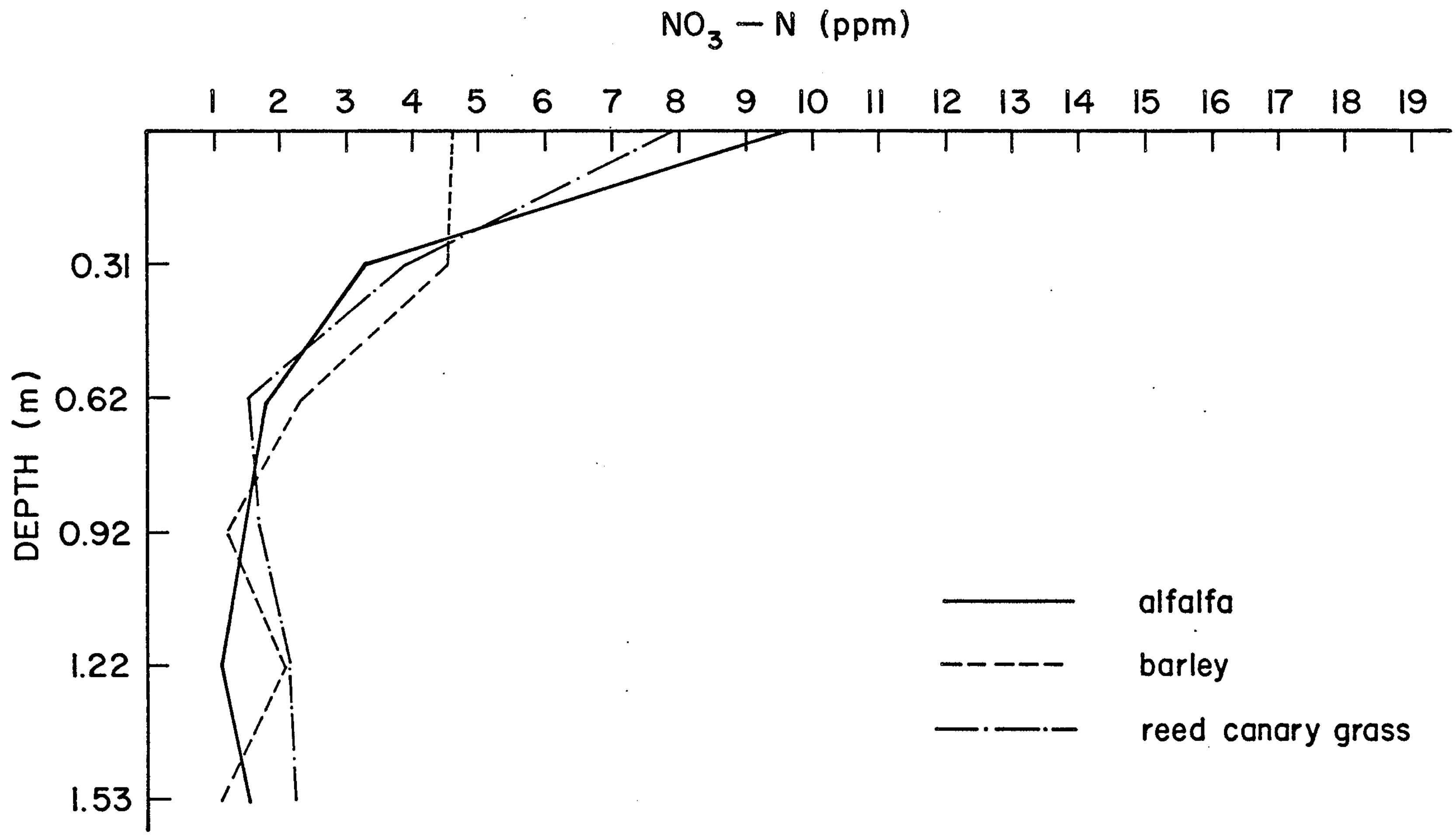

Fig. 4.2 Nitrate Profile for Mainplot Two, Spring - 1972 Data
(201 kg ha^{-1}(N), swine manure)

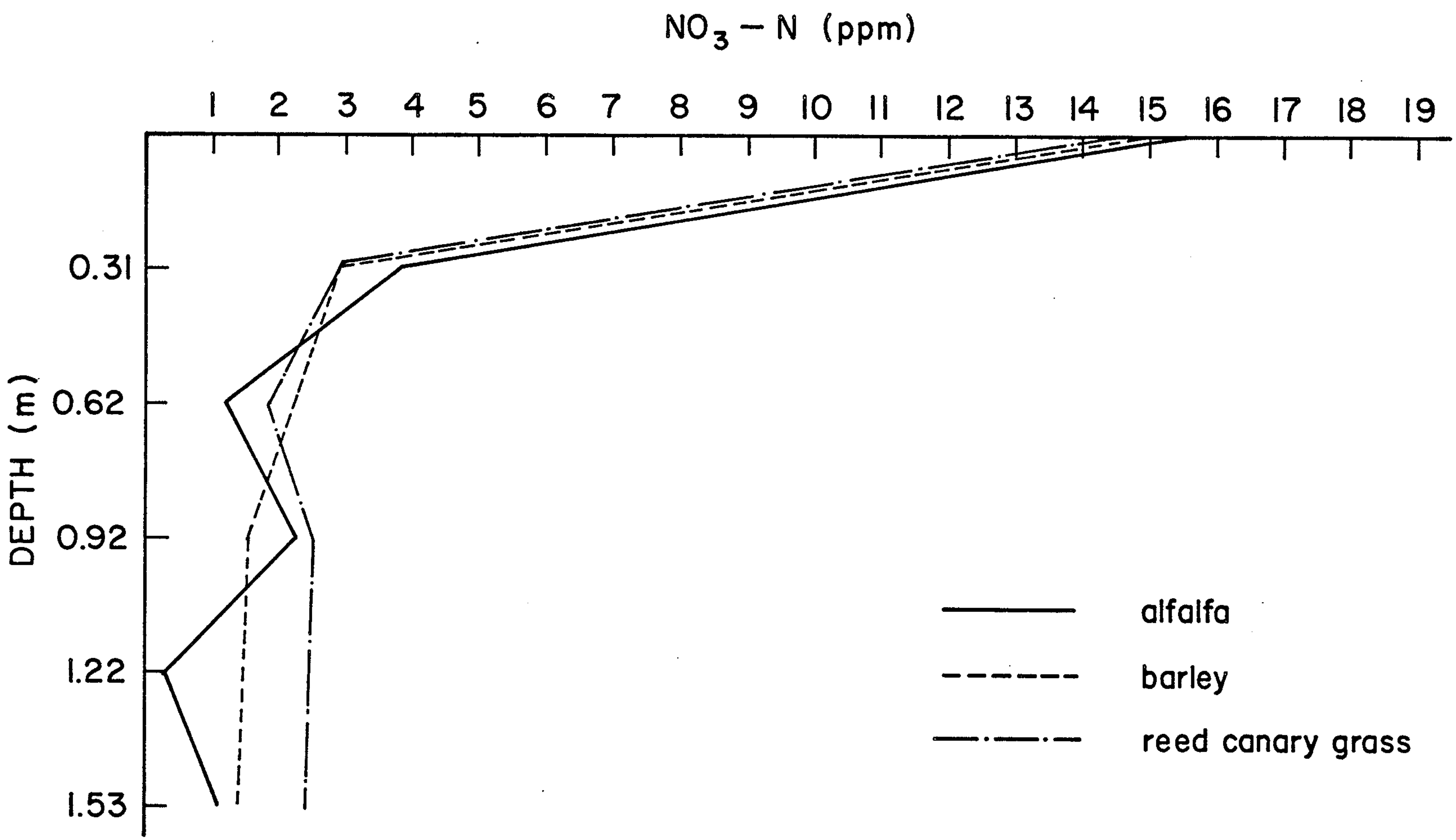

Fig. 4.3 Nitrate Profile for Mainplot Three, Spring - 1972 Data
(67 Kg ha^{-1}(N), inorganic fertilizer)

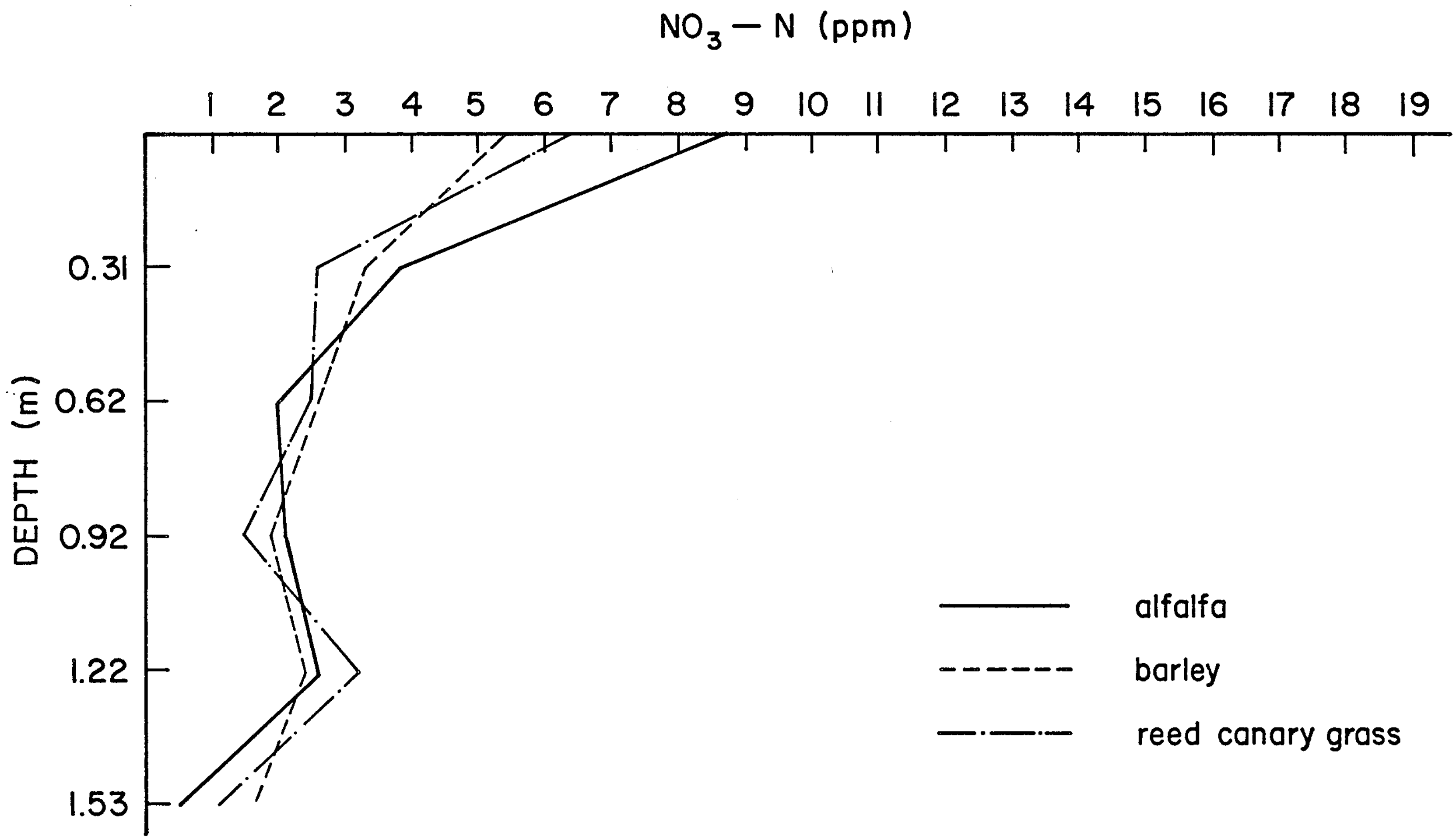

Fig. 4.4 Nitrate Profile for Mainplot Four, Spring - 1972 Data
(67 kg ha^{-1}(N), inorganic fertilizer)

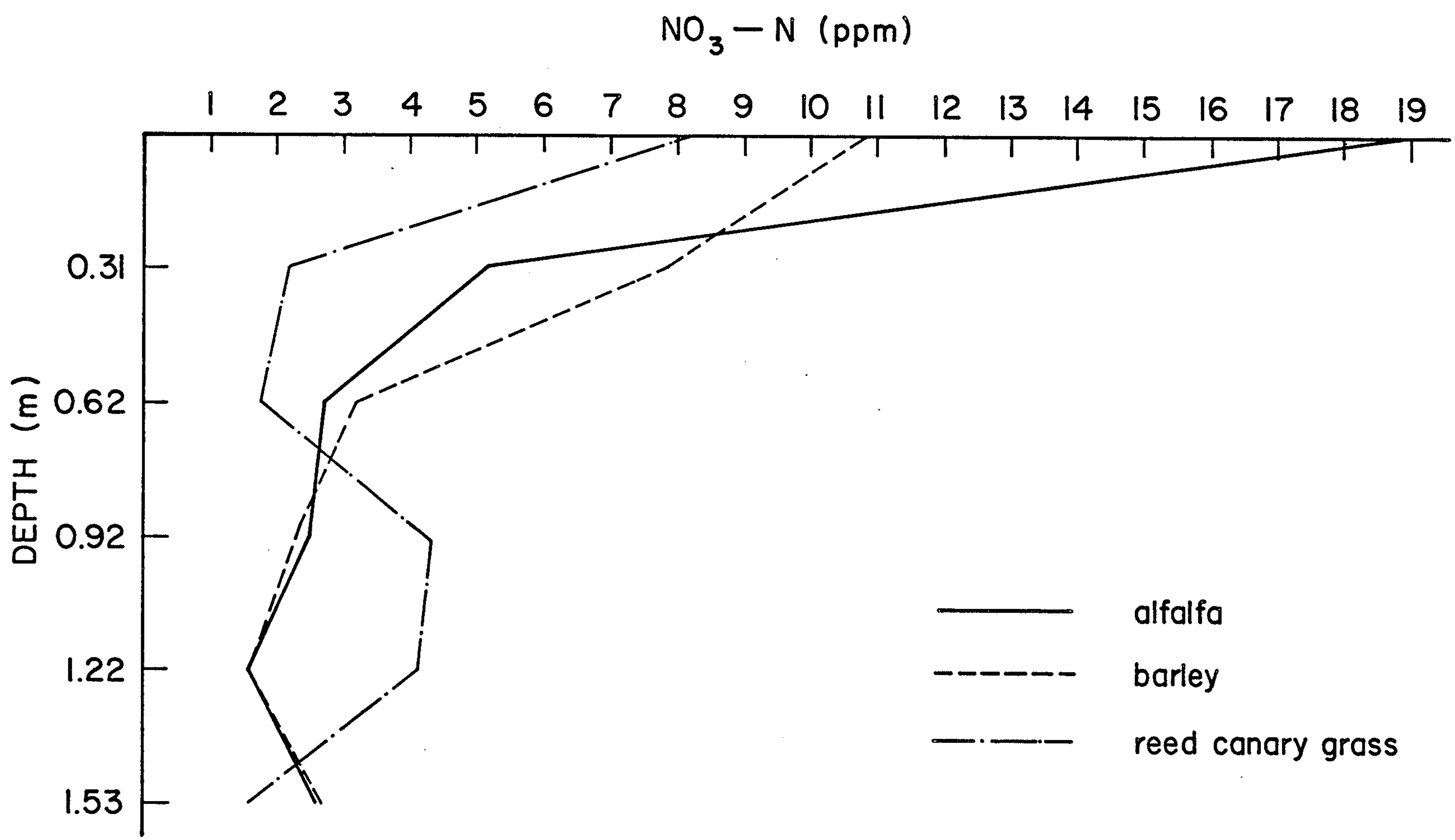

Fig. 4.5 Nitrate Profile for Mainplot Five, Spring - 1972 Data
(33.5 kg ha^{-1}(N), dairy cattle manure)

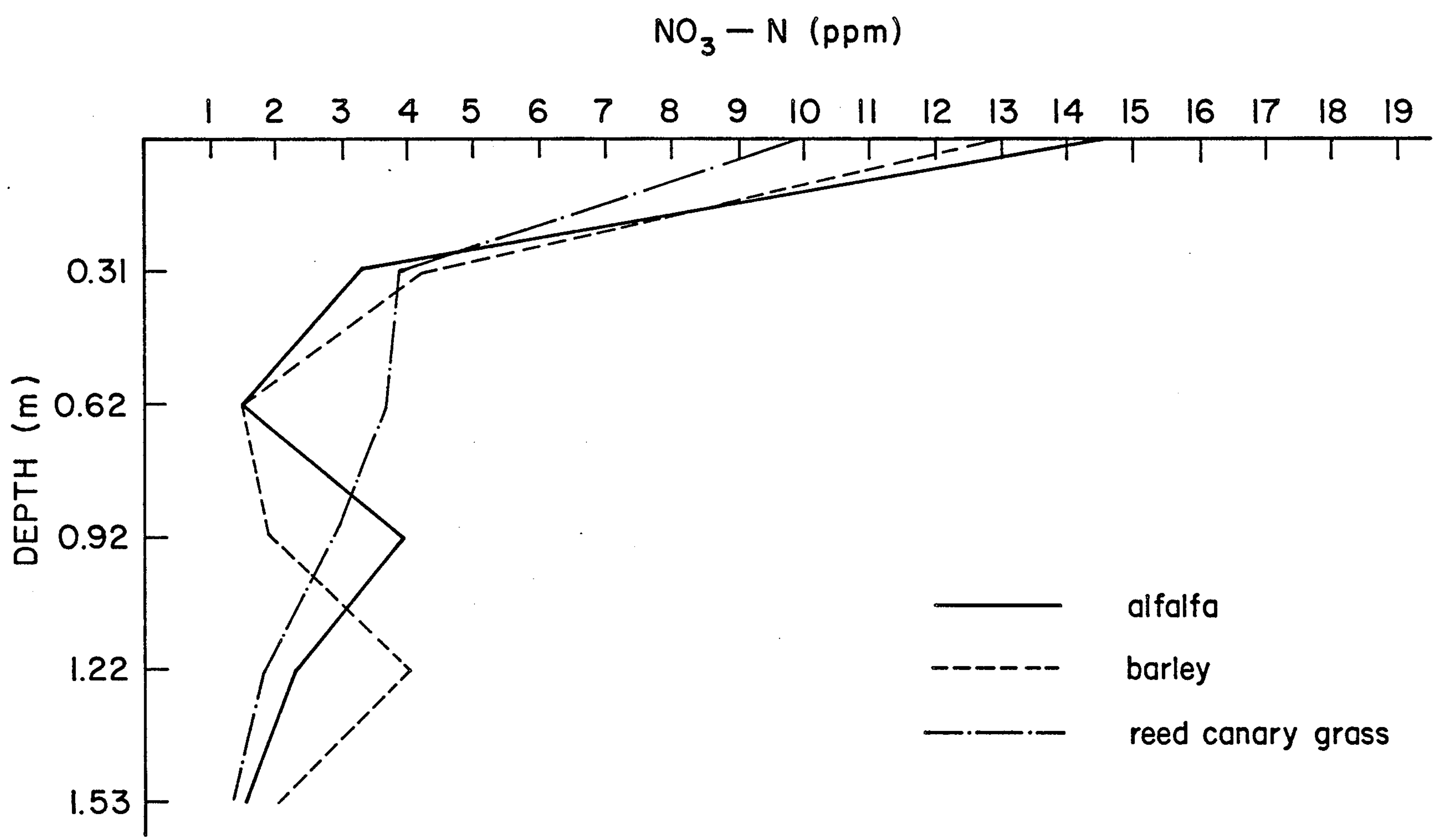

Fig. 4.6 Nitrate Profile for Mainplot Six, Spring - 1972 Data (201 kg ha^{-1}(N), beef cattle manure)

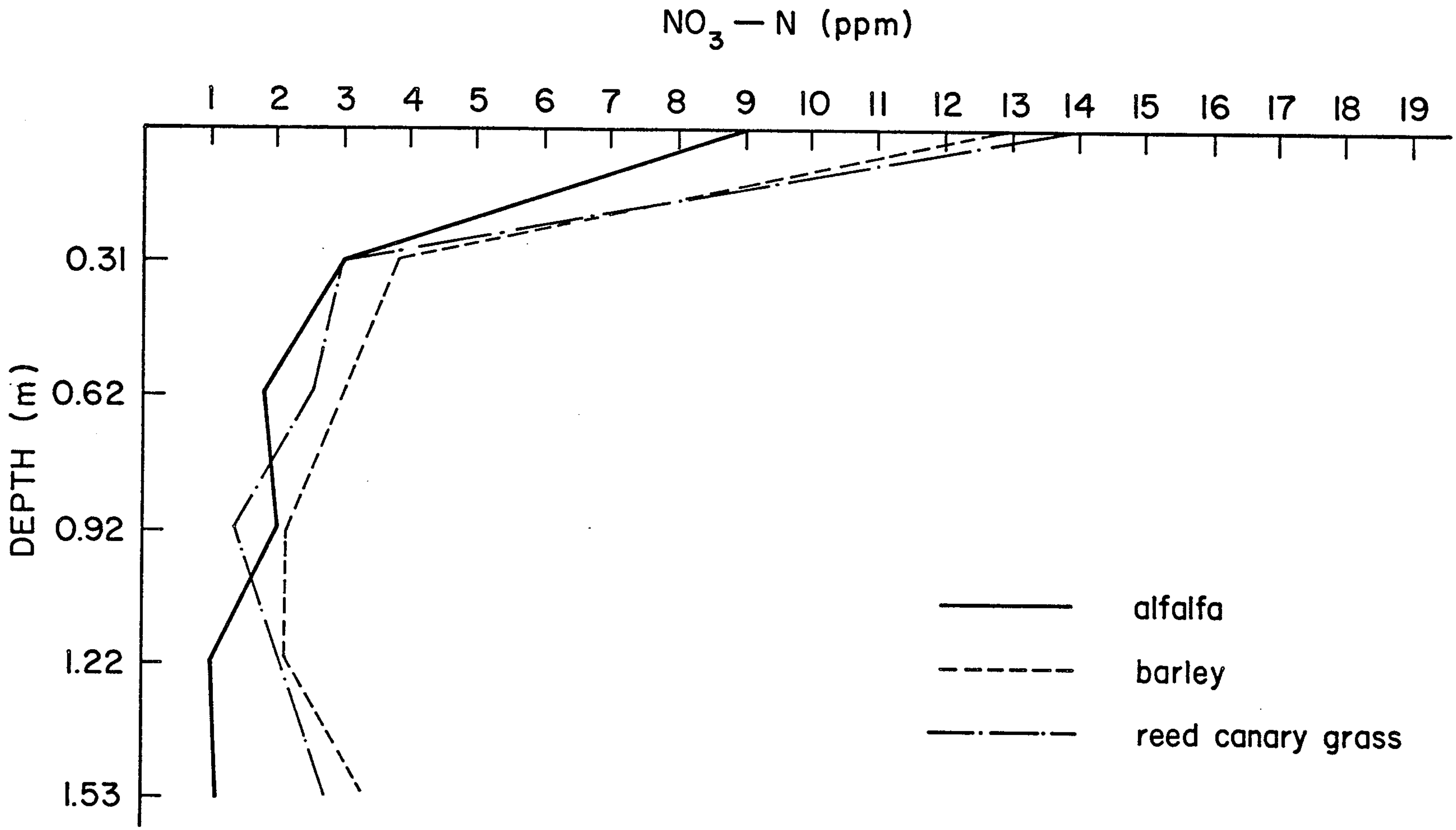

Fig. 4.7 Nitrate Profile for Mainplot Seven, Spring - 1972 Data
(33.5 kg ha^{-1}(N), beef cattle manure)

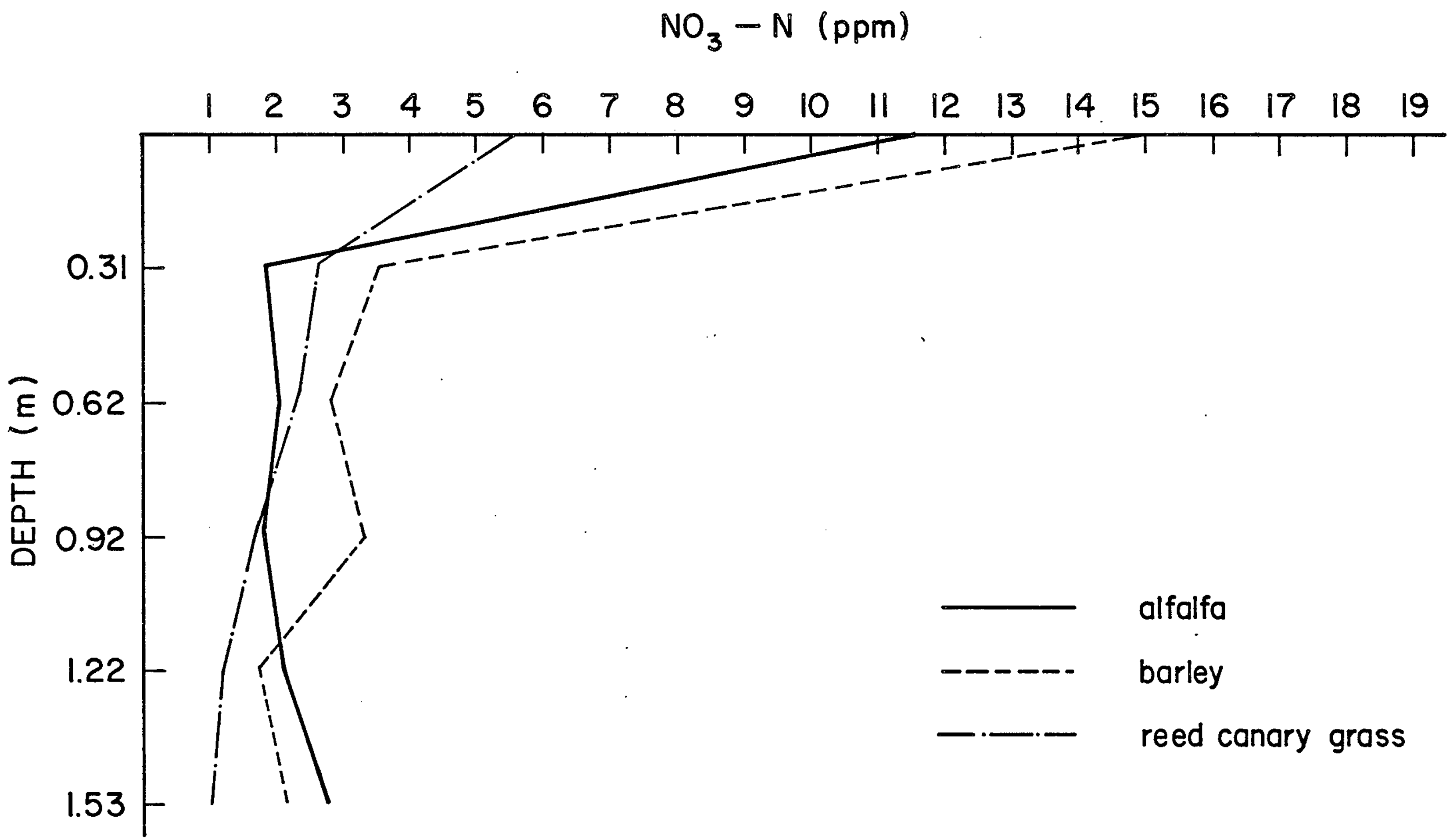

Fig. 4.8 Nitrate Profile for Mainplot Eight, Spring - 1972 Data
($201\ kg\ ha^{-1}$ (N), dairy cattle manure)

TABLE 4.8 Statistical Analysis - 1973 Nitrate Data

Mainplots			Subplots	
Number	Figure	Treatment Blocks	Number	Crop
1*	4.9	Plots 101 - 110 Fall - Swine - 201 kg ha^{-1} of N	1	Alfalfa
2*	4.10	Plots 111 - 120 Winter - Swine - 67 kg ha^{-1} of N	2	Barley
3	4.11	Plots 301 - 310 Spring - Swine - 20 kg ha^{-1} of N	3	Reed Canary Grass
4*	4.12	Plots 401 - 410 Inorganic		
5*	4.13	Plots 411 - 420 Inorganic		
6*	4.14	Plots 501 - 510 Dairy - Spring - 33.5 kg ha^{-1} of N		
7*	4.15	Plots 511 - 520 Beef - Spring - 201 kg ha^{-1} of N		
8*	4.16	Plots 601 - 610 Beef - Spring - 33.5 kg ha^{-1} of N		
9*	4.17	Plots 611 - 620 Dairy - Spring - 201 kg ha^{-1} of N		
10	4.18	Plots 701 - 710 Control		
11	4.19	Plots 711 - 720 Control and Sludge		

* Indicates same plots analyzed in 1972

TABLE 4.9   Analysis of Variance - Surface - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	0.831	10	10	2.98	No
Subplots	13.121	2	22	3.44	Yes
Interaction	1.1 0	20	22	2.07	No

TABLE 4.10   Analysis of Variance .31 m - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	0.727	10	10	2.98	No
Subplots	4.814	2	22	3.44	Yes
Interaction	1.209	20	22	2.07	No

* F at α =0.05 (95% confidence)

TABLE 4.11 Analysis of Variance .62 m - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	1.346	10	10	2.98	No
Subplots	4.199	2	22	3.44	Yes
Interaction	1.621	20	22	2.07	No

TABLE 4.12 Analysis of Variance .92 m - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	1.594	10	10	2.98	No
Subplots	3.731	2	22	3.44	Yes
Interaction	1.713	20	22	2.07	No

* F at $\alpha = 0.05$ (95% confidence)

TABLE 4.13 Analysis of Variance 1.22 m - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	4.051	10	10	2.98	Yes
Subplots	4.884	2	22	3.44	Yes
Interaction	2.625	20	22	2.07	Yes

TABLE 4.14 Analysis of Variance 1.53 m - 1973 Nitrate Data

Source	Calculated F	Degrees of Freedom		Table* F	Significant
		v_1	v_2		
Mainplots	1.725	10	10	2.98	No
Subplots	8.504	2	22	3.44	Yes
Interaction	3.187	20	22	2.07	Yes

* F at $\alpha = 0.05$ (95% confidence)

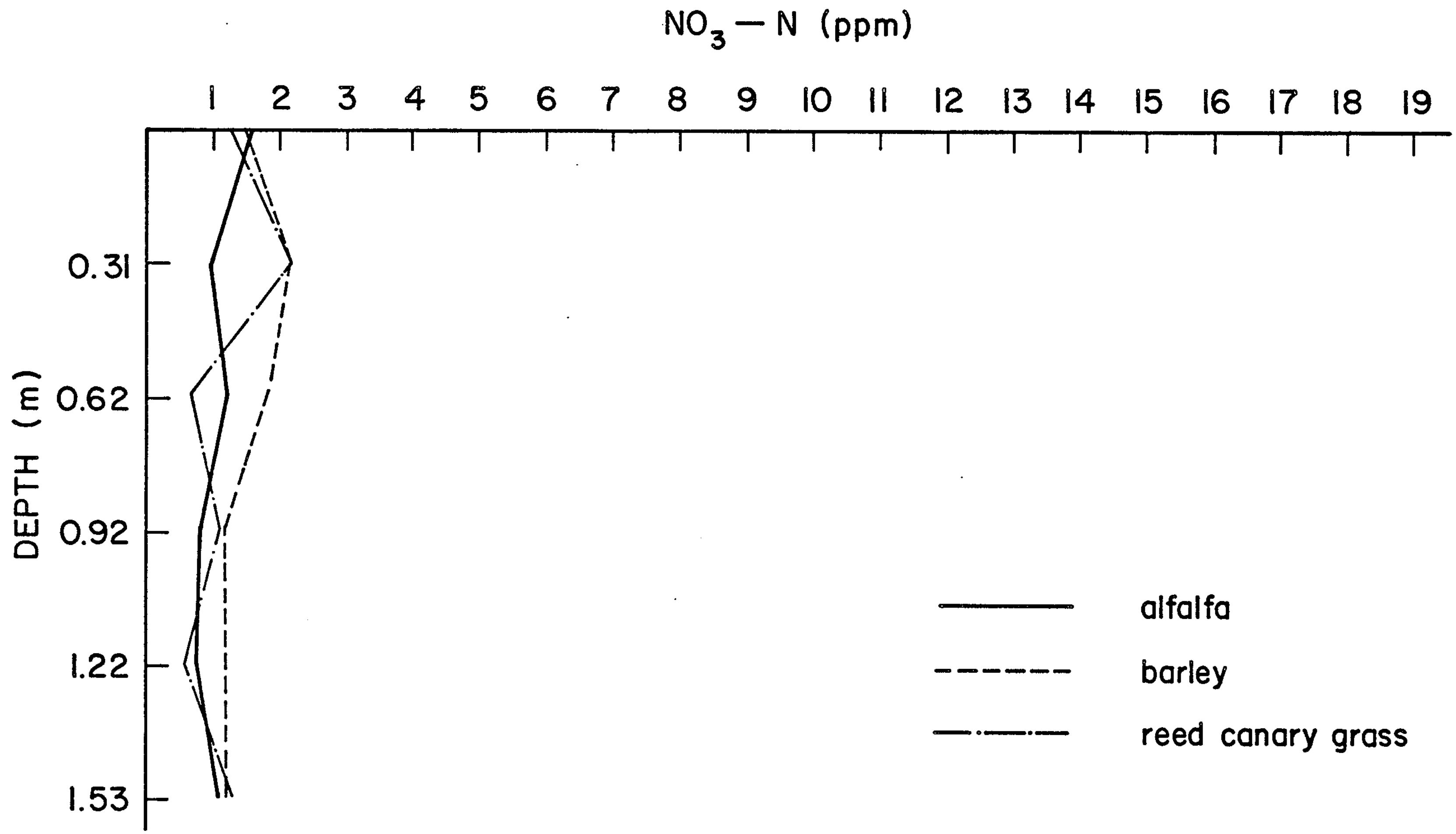

Fig. 4.9 Nitrate Profile for Mainplot One, Fall - 1973 Data
($201\ kg\ ha^{-1}$(N), swine manure)

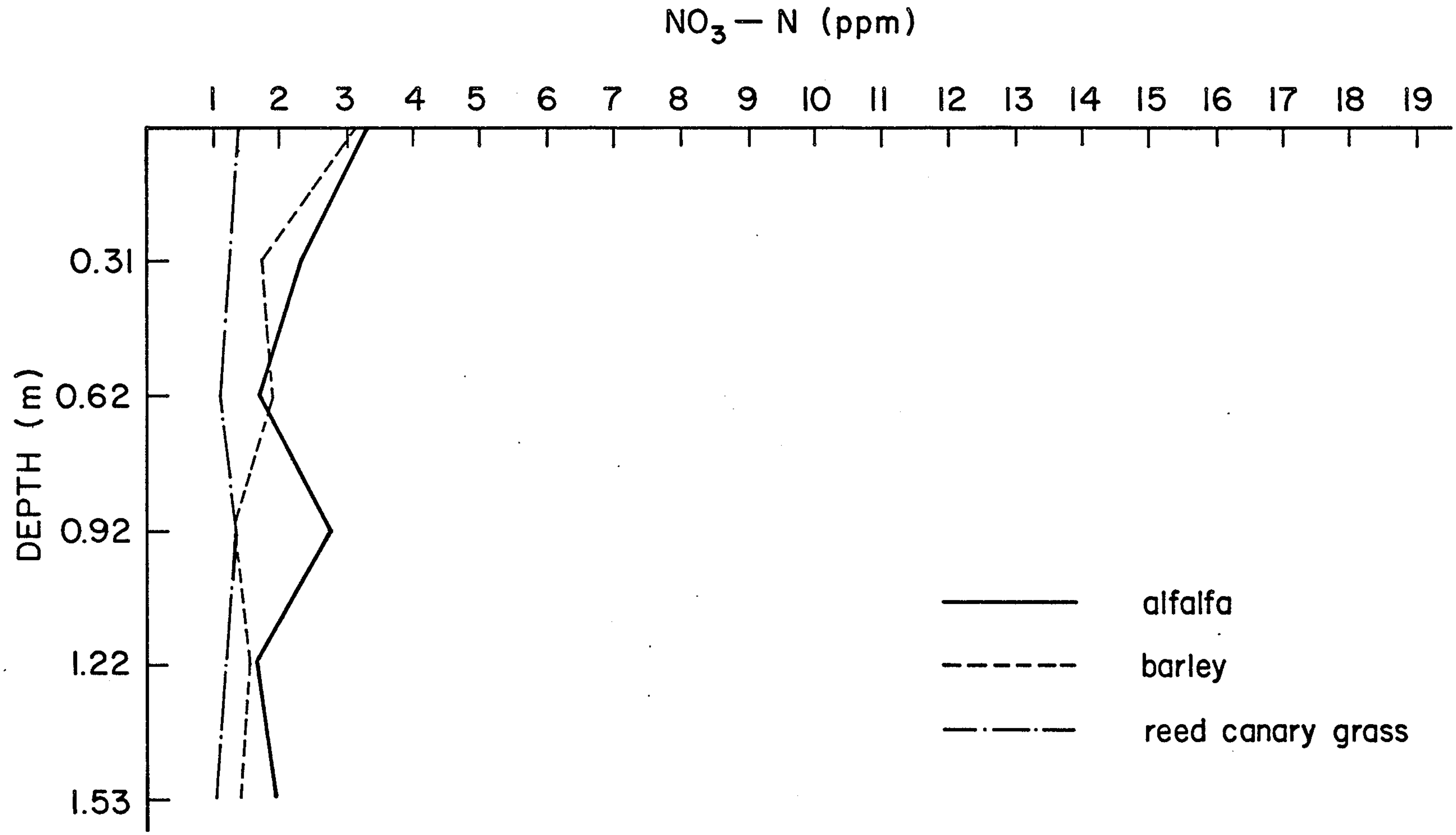

Fig. 4.10 Nitrate Profile for Mainplot Two, Fall - 1973 Data
(201 kg ha^{-1}(N), swine manure)

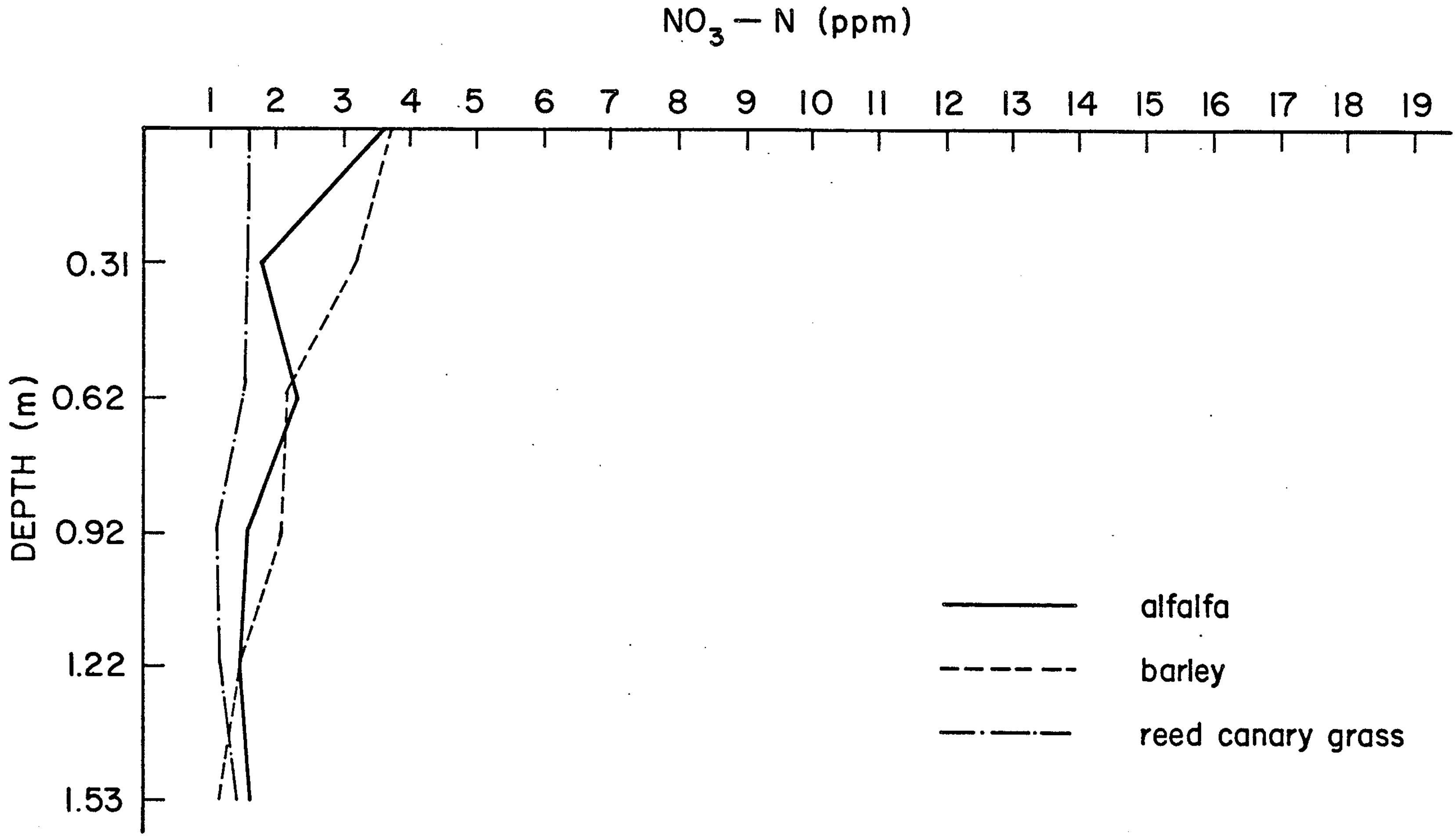

Fig. 4.11 Nitrate Profile for Mainplot Three, Fall - 1973 Data
(201 kg ha^{-1}(N), swine manure)

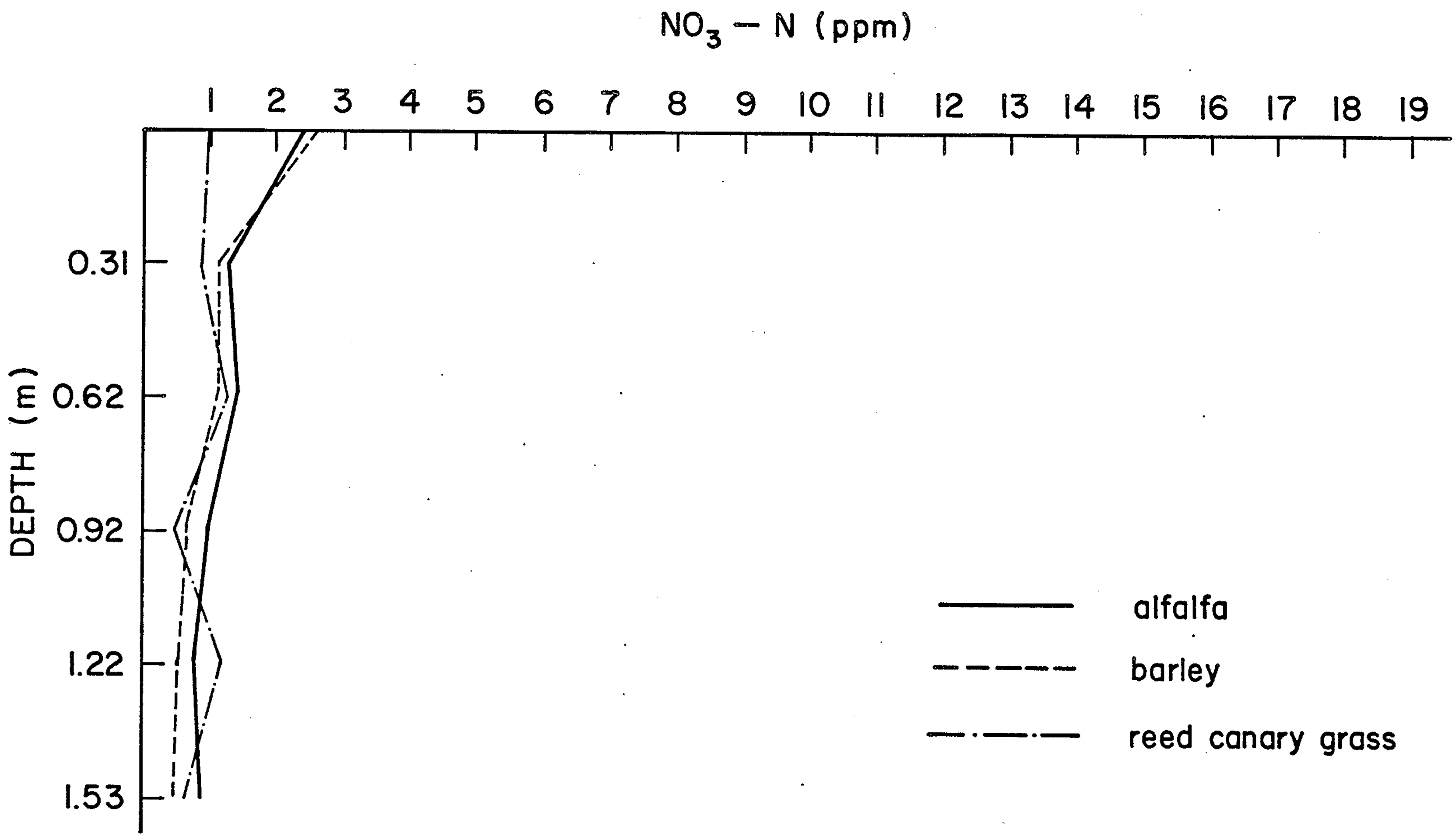

Fig. 4.12 Nitrate Profile for Mainplot Four, Fall - 1973 Data (67 kg ha^{-1}(N), inorganic fertilizer)

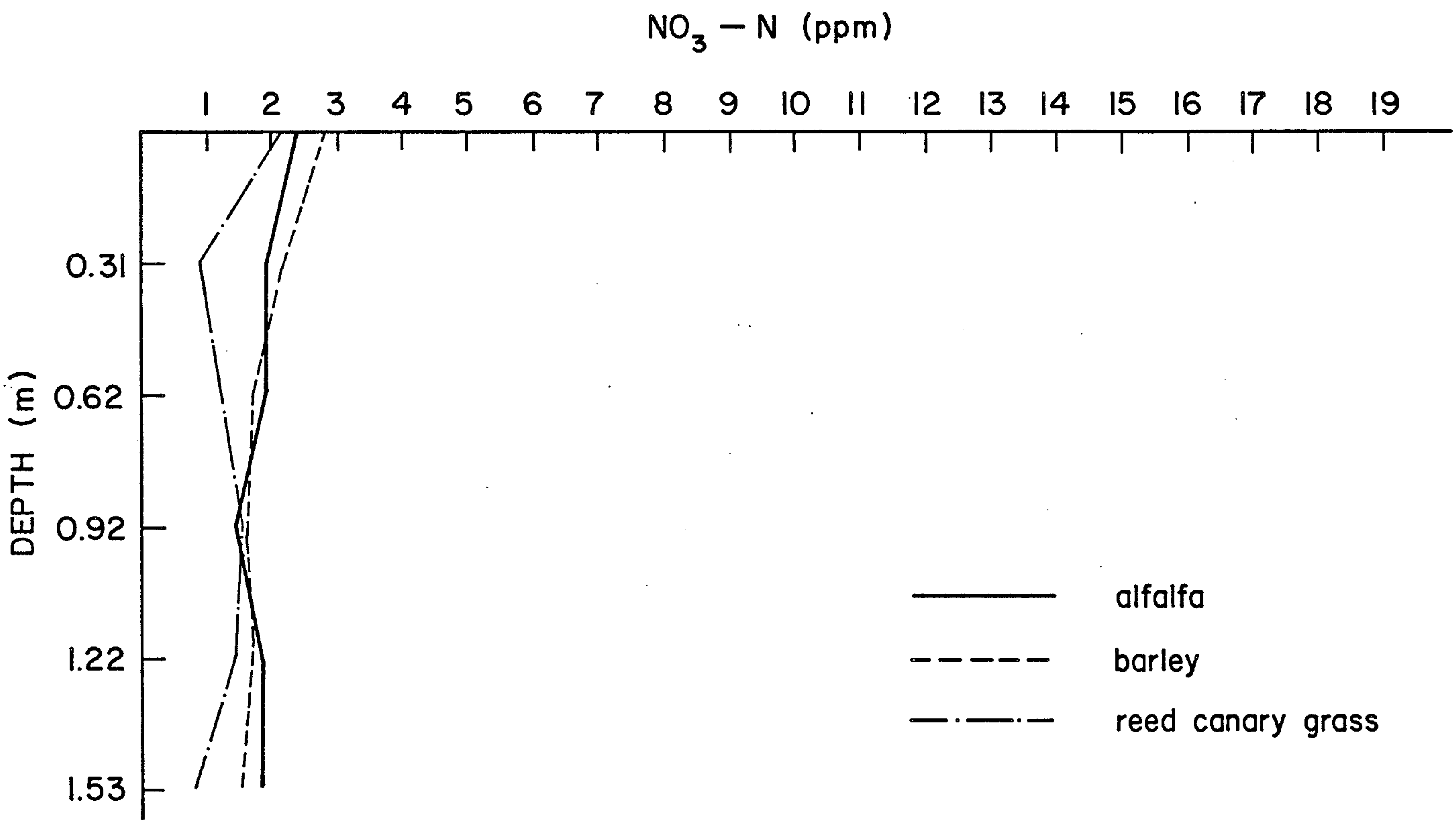

Fig. 4.13 Nitrate Profile for Mainplot Five, Fall - 1973 Data
(67 kg ha^{-1}(N), inorganic fertilizer)

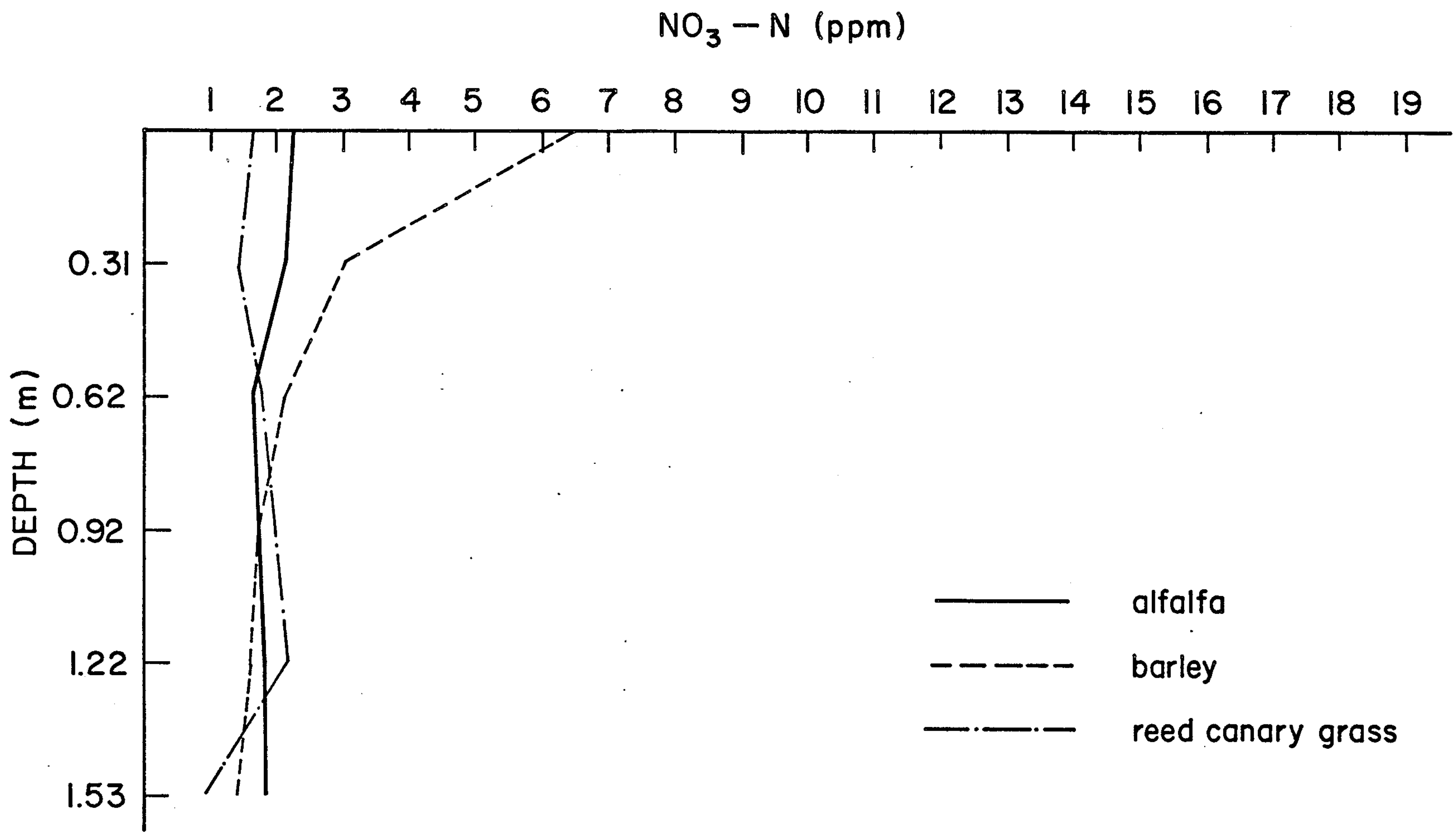

Fig. 4.14 Nitrate Profile for Mainplot Six, Fall - 1973 Data
(33.5 kg ha^{-1}(N), dairy cattle manure)

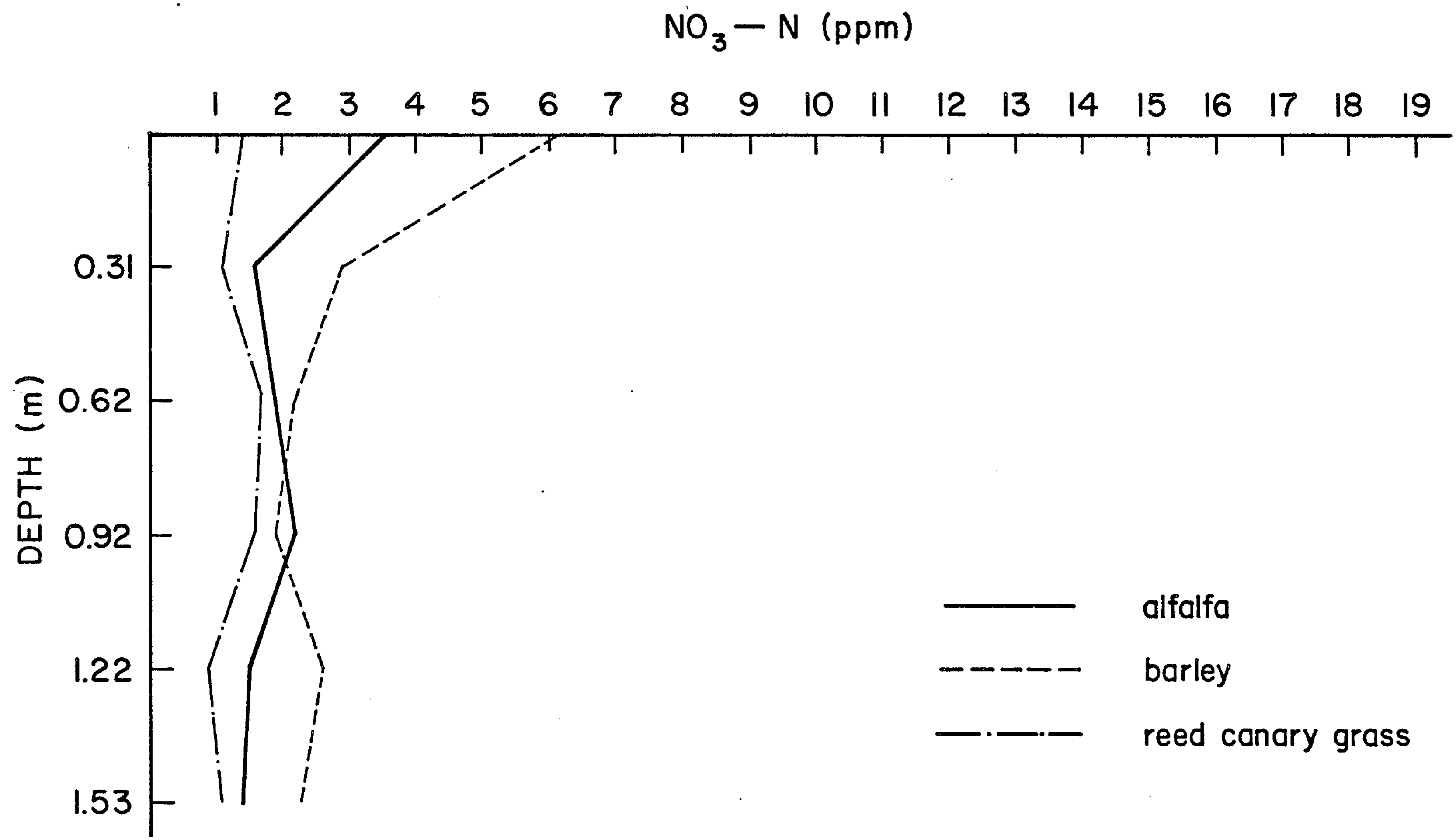

Fig. 4.15 Nitrate Profile for Mainplot Seven, Fall - 1973 Data
(201 kg ha^{-1}(N), dairy cattle manure)

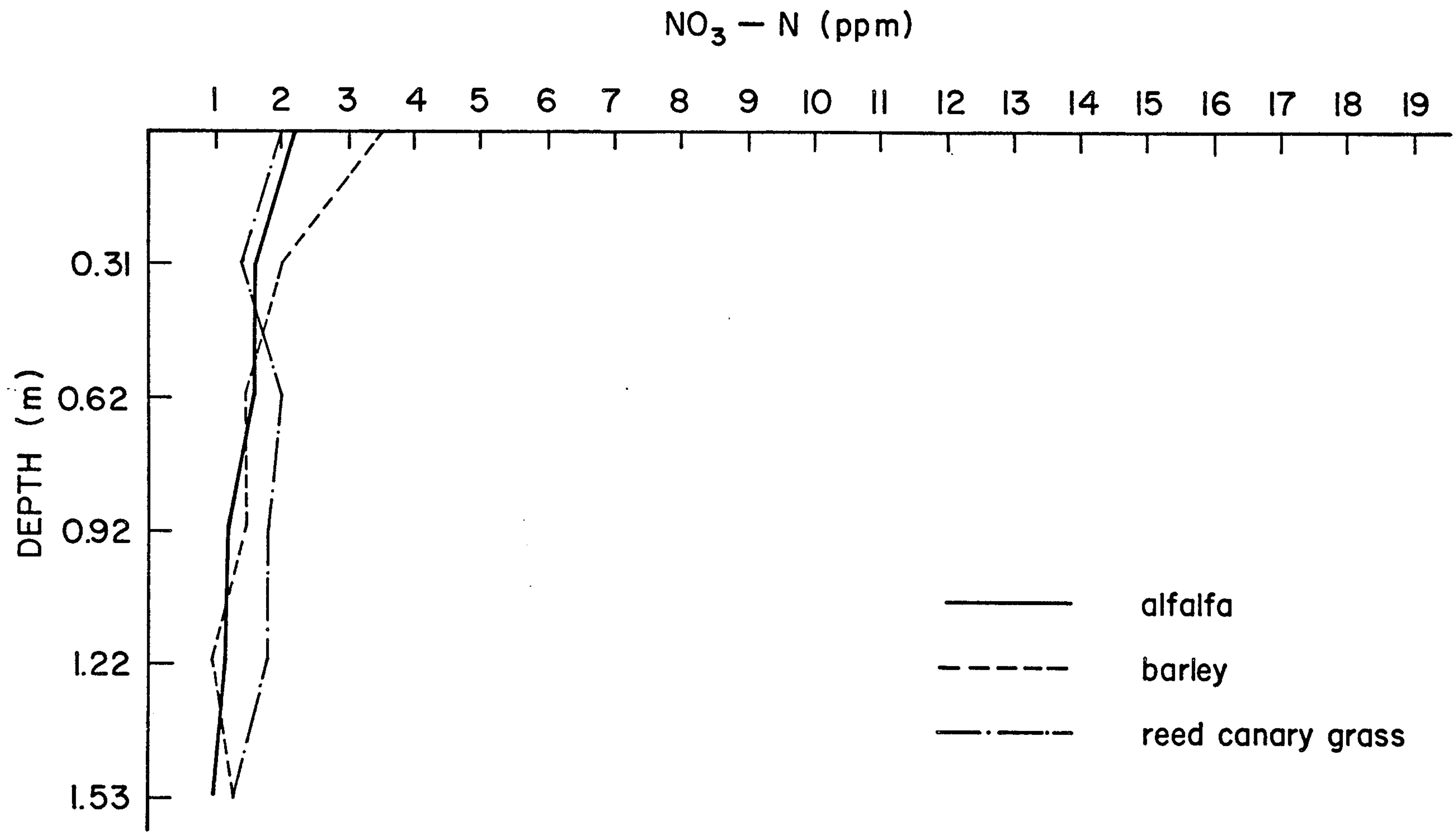

Fig. 4.16 Nitrate Profile for Mainplot Eight, Fall - 1973 Data
(33.5 kg ha^{-1}(N), beef cattle manure)

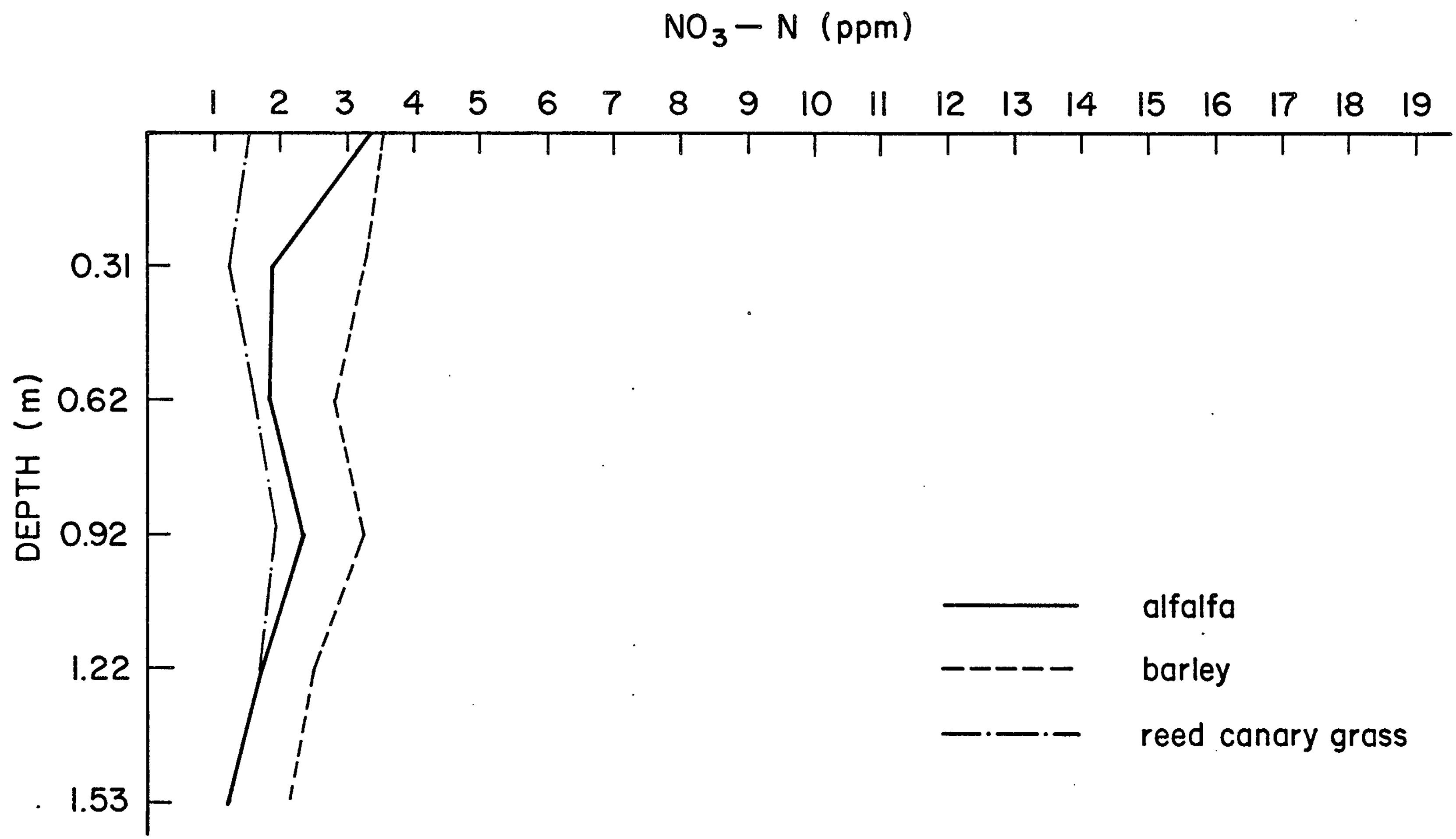

Fig. 4.17 Nitrate Profile for Mainplot Nine, Fall - 1973 Data
($201\ kg\ ha^{-1}$(N), dairy cattle manure)

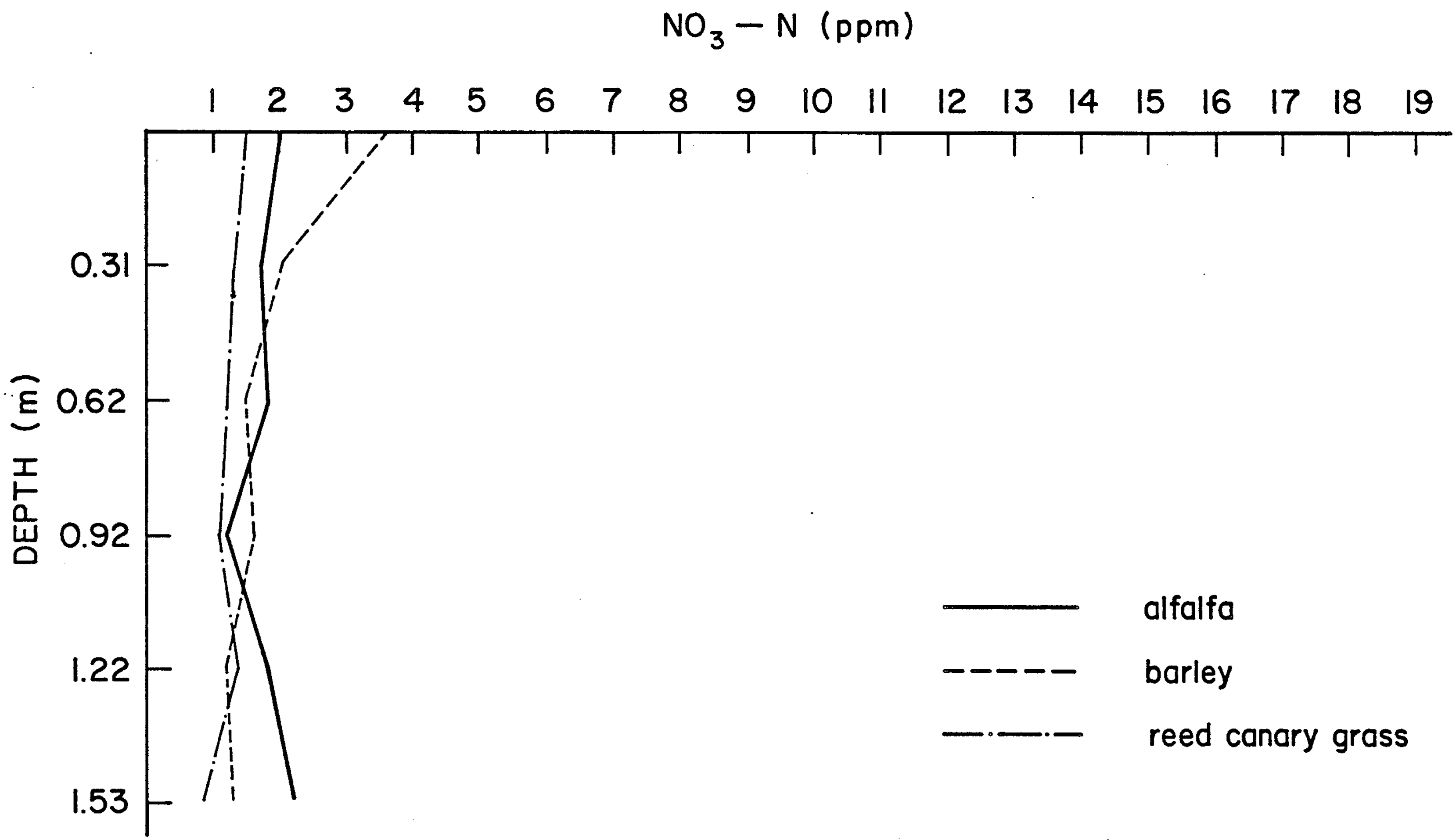

Fig. 4.18 Nitrate Profile for Mainplot Ten, Fall - 1973 Data
(control block)

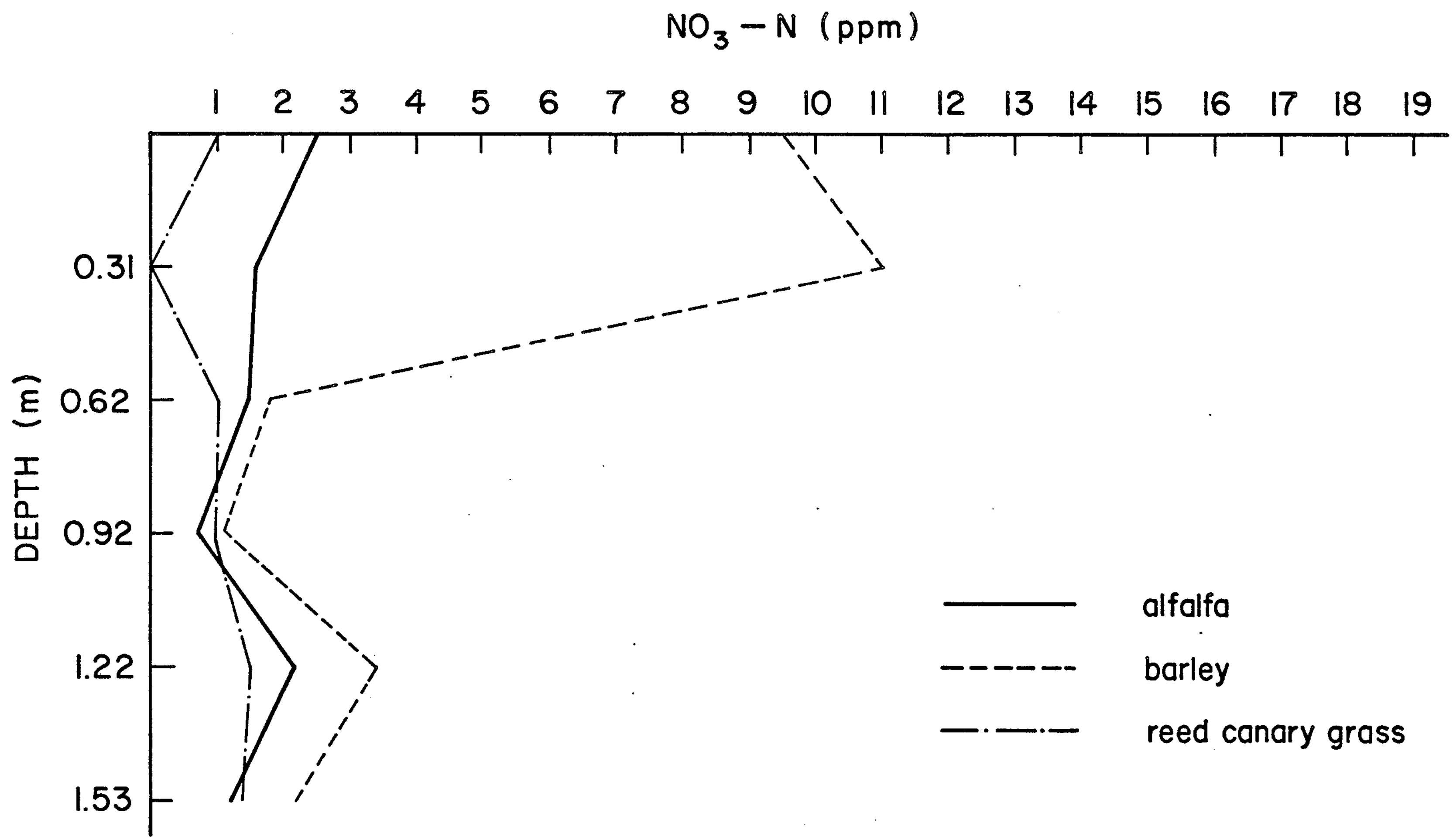

Fig. 4.19. Nitrate Profile for Mainplot Eleven, Fall - 1973 Data (control block, one barley plot sewage sludge)

TABLE 4.15 Nitrogen[1] Uptake

Corn				Reed Canary Grass			
Plot Number	Yield[2*] Kg/ha	% N	Uptake Kg/ha	Plot Number	Yield[3*] Kg/ha	% N	Uptake Kg/ha
102	4461.58	1.06	47.29	104	525	2.72	14.28
109	4188.06	1.02	42.72	107	385	2.64	10.16
114	4923.44	0.96	47.27	115	880	2.35	20.68
119	7129.56	0.83	59.18	116	560	2.81	15.74
203	5739.52	0.90	51.66	201	455	2.51	11.42
207	3555.81	1.06	37.69	206	805	2.11	16.99
214	6533.19	1.15	75.13	212	1015	2.69	27.30
218	5654.33	0.93	52.58	220	960	1.83	17.57
301	4923.44	1.12	55.14	303	560	4.39	24.58
310	8278.98	1.28	105.97	306	985	3.86	38.02
314	6143.08	1.22	74.95	315	845	2.64	22.31
320	6546.64	1.25	81.83	316	1005	3.00	30.15
403	7488.28	0.86	64.40	405	845	2.31	19.52
409	9954.48	0.86	85.61	410	720	3.68	26.50
413	6210.34	1.12	69.56	415	735	2.91	21.39
419	8766.22	0.99	86.79	418	540	2.93	15.82
503	3219.51	0.80	25.76	501	795	2.69	21.39
508	4004.21	1.02	40.84	507	415	2.47	10.25
514	1748.76	1.54	26.93	515	515	2.31	11.90
516	1555.95	1.34	20.85	519	430	2.06	8.86
603	4484.00	0.90	40.36	604	665	2.08	13.83
610	3170.19	1.25	39.63	608	445	2.39	10.64
613	3757.59	1.54	57.87	614	660	2.88	19.01
618	3506.49	1.63	57.16	617	1040	2.14	22.26
705	4690.27	0.83	38.93	701	670	2.41	16.15
710	4708.20	0.80	37.67	708	1115	2.03	22.63
714	5829.20	0.86	50.13	711	980	2.09	20.48
719	7308.92	1.02	74.55	717	1145	1.88	21.53

1 Total Kjeldahl nitrogen

2 Corn yield based on random samples removed from rows (September 1973)

3 Reed canary grass yield based on first cutting sample only

* Yield expressed as total dry matter (kg/ha)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Quantitative Conclusions

Analysis of the experimental data revealed several noteworthy trends:

1. The review of literature indicated that surface runoff from cropland manured in the winter season can be a serious contaminant to the hydrosphere. Although the experimental accuracy was questionable, the magnitude of the chemical oxygen demand (COD as high as 742 ppm), nitrates (NO_3 as high as 155 ppm), and phosphates (PO_4 as high as 20 ppm), from samples analyzed are evidence that runoff from fields manured in the winter can have a detrimental effect on environmental quality,
2. Lack of a significant nitrate accumulation in the soil profile suggests that agricultural manure disposal may not be a serious problem from a leaching (soil biosphere contamination) point of view at manure application rates tested. Specifically, Figures 4.11, 4.15, 4.17, the 201 $kg\ ha^{-1}$ applications of nitrogen of swine, beef cattle, and dairy cattle manure respectively, show nitrates values in the soil only slightly but not statistically greater than that of the control block (Figure 4.18). With the exception of one surface value in Figures 4.11, 4.15, and 4.17, the nitrate values in the soil in these three figures are less than 4 ppm. In fact, the 1972 nitrate values (no treatment) for the surface samples were all greater. From the review of literature

it appears that nitrate leaching can be a significant problem. Figures 4.9 to 4.19 suggest, however, that cropping can provide adequate nitrate control in the soil when animal manure is applied at the nitrogen application rates tested,

3. It is difficult to make recommendations based on the percent nitrogen uptake data. Even though corn and reed canary grass demonstrated good uptake ability, alfalfa, barley, and the mixture are unaccounted for. The percent nitrogen uptake for barley is low (because of the low nitrogen requirement) and is variable, depending on symbiotic fixation, for alfalfa. Since there was no nitrate accumulation in the soil profile, it can be said that all crops tested provided sufficient nitrogen removal from the soil to prevent nitrate contamination at the application rates tested. The lack of accumulation, though, could be due to less nitrogen applied than anticipated (i.e. errors in prediction of N content). It should be important to apply nitrogen until an accumulation occurs; then, determine percent nitrogen uptake. Greater application rates need to be tested,
4. The analysis of the accumulation of nitrate due to the bulk application of sewage sludge was not completed. The bulk application of sludge was to the detriment of the statistical design since only three plots were fertilized. Perhaps long term analysis of these three plots should be considered as a separate experiment.

5.2 Qualitative Conclusions and Recommendations

The quantitative conclusions of Section 5.1 indicate that this experiment has made a positive contribution to an improved understanding of animal manure management. Although nothing startling was uncovered, the experiment confirms that the agricultural sector can contribute to environmental degradation by mis-management of the disposal of agricultural wastes particularly through runoff from fields manured in the winter. Lack of an accumulation of nitrate in the soil suggests, however, that with proper management livestock manure can be used as a fertilizer without serious threat to environmental quality.

As part of the analysis of this field experiment, there are several points which should be raised:

1. The experiment is not statistically sound. The split-plot design only applies if the allocation of the treatments to the blocks is assumed random. The treatments were not randomly distributed but rather assigned. Sewage sludge in a bulk application also disrupts the statistical design. If the consequences of an improper statistical design cannot be rationalized then the project, as it exists, should be terminated,
2. If the project is to continue then there are a number of points to consider:
    a) Since the experimental results suggest that runoff from agricultural land is the most serious of the contributors to environmental degradation, then the experiment should be directed more towards measurement and analysis of runoff,

b) The cropping regime in the experiment provided adequate nitrate control against the manure treatments. As many farmers dispose of manure on fallowed land the experiment should be extended to include fallowed land,

c) Operational problems need to be eliminated from the project. Application of the manure treatments caused serious soil compaction and workability problems which hindered field work. Perhaps sprinkler application of liquid hog manure should be investigated,

d) The plot size (7.5 m by 30.5 m) caused farm equipment problems. Large equipment was awkward and garden size equipment underpowered for the field work. Purchase of adequate field equipment would eliminate many operational problems, and should be considered,

e) Sampling techniques need closer supervision. Closer supervision of field sampling techniques would eliminate, for example, runoff sampling and crop sampling errors. On such a long term project a procedure manual for field sampling should be prepared. A full-time project co-ordinator would be a benefit as well,

f) An objective of the experiment was to develop manure control techniques. The present combination of treatments, rates, and plots is awkward. If one manure at several treatment rates (for example, 65, 130, 200, 265, 650 $kg.ha^{-1}$ of N) then the critical point for nitrate accumulation and leaching could be established. The best crop, from a percent nitrogen uptake viewpoint, could be determined as well. Such information would be useful for the implementation of control guidelines for agricultural waste disposal.

Several alternatives now exist for this project. It may be continued, abandoned, or modified. Consideration should be given to dividing the project into several smaller and more controllable (operationally and statistically) experiments. An example of this being the bulk application of sewage sludge.

Agriculture manure mis-management can contribute to environmental degradation. Cropping is an adequate control technique for nitrate leaching, but to what extent is the question. Work must continue in order to monitor nutrient losses from runoff due to field manuring and to determine to what extent nitrate accumulation in the soil profile could contribute to leaching problems on farm land in the Red River Valley.

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APPENDIX A

APPENDIX A

Analysis of Cultivated McTavish, Osborne, Dencross, and Scanterbury Clays from Report of the Detailed Soil Survey of Glenlea Research Station by W. Michalyna

ANALYSIS OF McTAVISH CLAY (CULTIVATED)

Horizon	Depth (ins)	Sand %	Silt %	Clay %	Moist. Ret. 1/3 atm.	Org. C. %	Total N %	$CaCO_3$ equiv. %	pH	Cond. mmhos/cm.	Exch. Cap.	Exchangeable Cations meg/100 gms. O.D.S. Ca	Mg	K	Na	H
Ap	0-6	8.62	22.74	68.64	44.51	2.16	.242	0.0	6.65		51.06	28.24	17.22	1.23	0.31	0.0
Ah	6-9	9.91	20.40	69.69	42.21	1.97	.210	0.0	6.00		50.16	25.05	17.13	0.31	0.12	3.81
Ac	9-18	8.60	28.43	62.97	49.22	0.96	.108	0.0	6.92		51.25	24.34	21.75	0.08	0.0	0.00
C1	18-30	4.38	17.70	77.92	44.06	0.10	.063	15.39	7.82	3.02						
C2	30+	1.58	20.76	77.66	39.20		.053	13.78	7.95	1.11	39.81	24.48	24.75	0.08	0.02	

ANALYSIS OF OSBORNE CLAY (CULTIVATED)

Horizon	Depth (ins)	Sand %	Silt %	Clay %	Moist. Ret. 1/3 atm.	pH	Cond. mmhos/cm.	$CaCO_3$ equiv. %	Org. C. %	Total N %	Exchangeable Cations meg/100 gms. Ca	Mg	K	Na	H	CEC(NH_4)
Apg	0-4	3.68	23.39	72.93	50.54	7.05	0.38	0.34	2.08	.274	22.95	21.67	1.78	0.42		52.58
Cg1	4-12	4.05	25.19	70.76	45.94	8.00	0.33	1.52	0.31	.075	25.30	21.52	1.39	0.64		46.85
Cg2	12-24	4.46	25.21	70.33	45.79	7.80	0.32	4.70	0.00	.088						
Cg3	24+	3.85	21.95	74.20	46.37	7.88	0.61	9.91	0.14	.063	25.50	22.12	0.82	0.95		39.39
Ap	0-4	4.28	26.01	69.71	45.74	6.45		0.50	2.30	.250	19.85	21.07	1.50	0.67	3.72	47.79
Cg1	4-12	2.94	14.21	82.85	49.14	6.83		0.13	0.91	.102	19.42	23.52	1.49	0.96	2.32	51.46
Cg2	12-24	3.14	18.15	78.71	49.67	7.80	0.31	0.0	0.71	.068	21.53	30.92	0.13	0.17		51.11

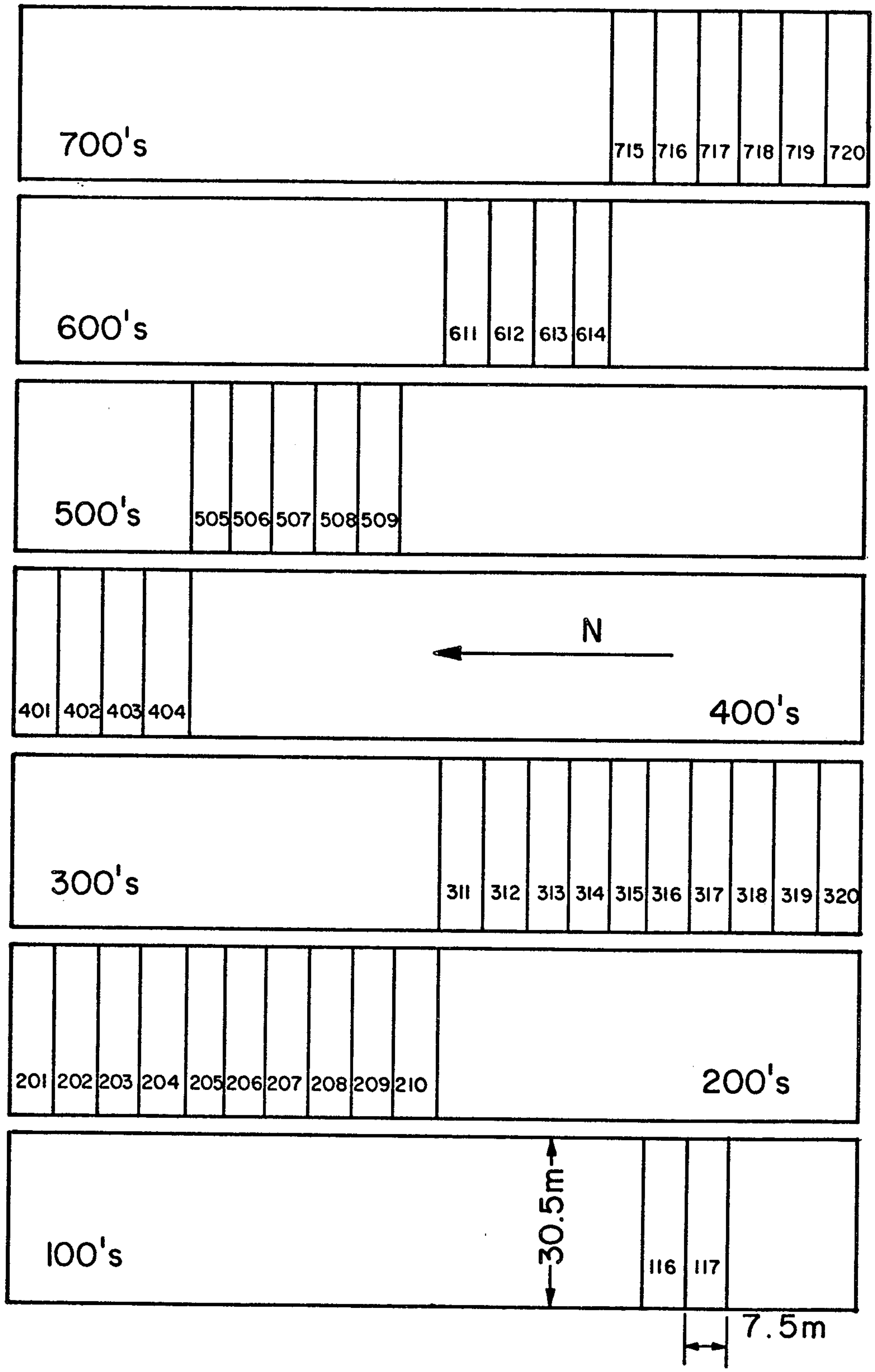
ANALYSIS OF SCANTERBURY CLAY (CULTIVATED)

Horizon	Depth (ins)	Sand %	Silt %	Clay %	Moist. Ret. 1/3 atm.	pH	Cond. mmhos/cm.	$CaCO_3$ equiv. %	Org. C. %	Total N %	Ca	Mg	K	Na	H	CEC(NH_4)
Ap	0-7	6.20	23.28	70.52	46.66	6.54	-	0.34	2.59	.305	30.04	14.94	0.83	0.18	2.64	52.75
Bm	7-22	9.17	15.89	74.94	47.78	7.20	0.41	0.18	1.48	.151	30.07	18.34	0.95	0.66	-	50.37
BCgj	22-28	6.86	17.08	76.06	47.33	7.72	0.47	2.25	0.49	.089	31.62	21.17	0.14	0.18	-	45.64
Cg	28+	1.66	14.18	84.16	47.83	8.05	0.53	11.71	0.60	.057	29.39	21.70	0.59	1.07	-	41.39

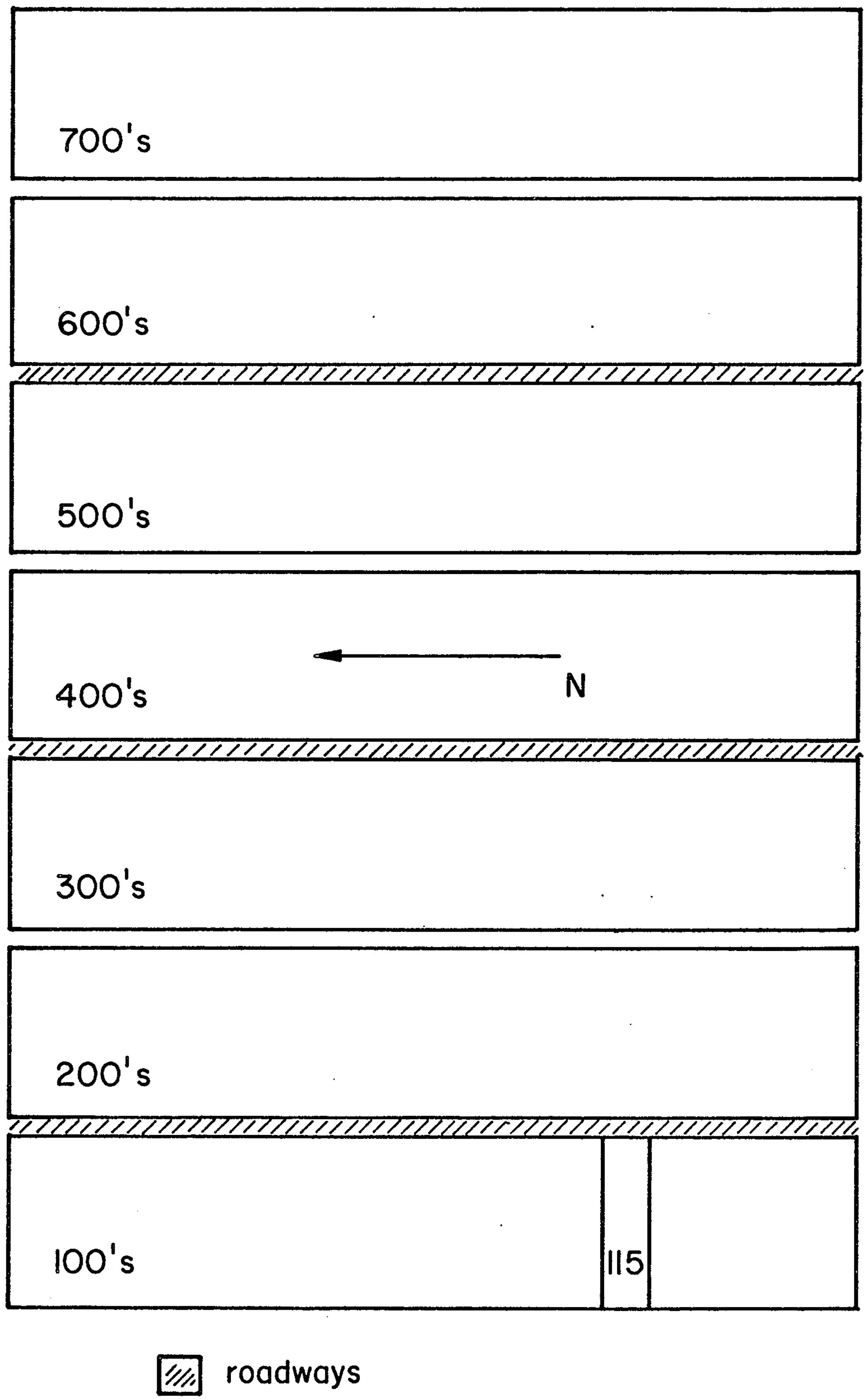
ANALYSIS OF DENCROSS CLAY (CULTIVATED)

Horizon	Depth (ins)	Sand %	Silt %	Clay %	Moist. Ret. 1/3 atm.	pH	Cond. mmhos/cm.	$CaCO_3$ equiv. %	Org. C. %	Total N %	Ca	Mg	K	Na	H	CEC(NH_4)
Ap	0-7	27.65	19.16	53.17	39.20	7.62	0.38	1.11	2.40	.241	26.25	18.38	0.70	0.19	-	43.29
Ac	7-9	31.57	21.17	47.26	29.33	8.10	0.35	22.17	0.79	.114						
IIC1	9-20	22.31	21.87	55.82	33.59	8.35	0.50	28.01	0.42	.076	19.50	18.43	0.53	0.41	-	26.70
IICgj2	201	36.59	19.96	43.45	30.28	8.16	0.74	19.94	0.05	.037						

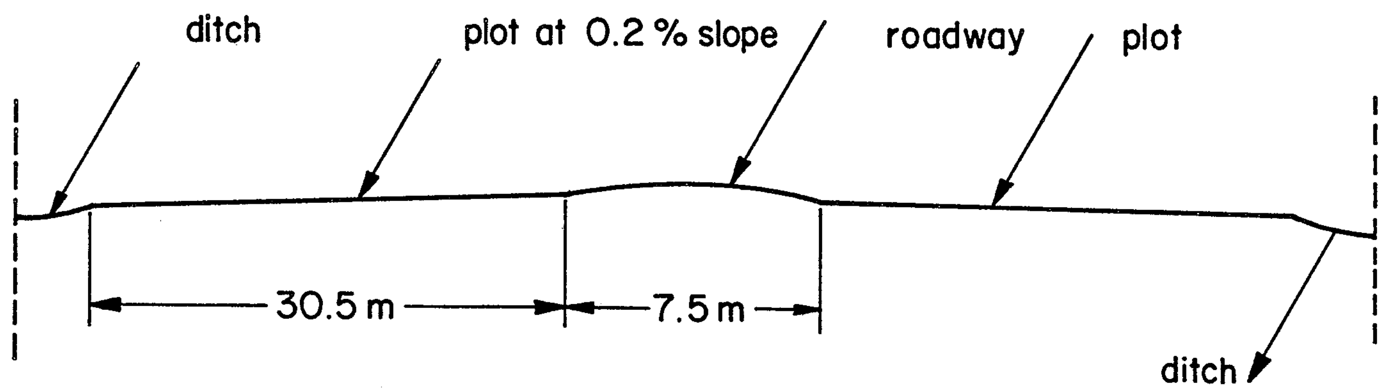
APPENDIX B



Plan View Plot Numbering System



Plan View of Block Sections Layout



Cross Cut View of Two Block Sections Illustrating Slope

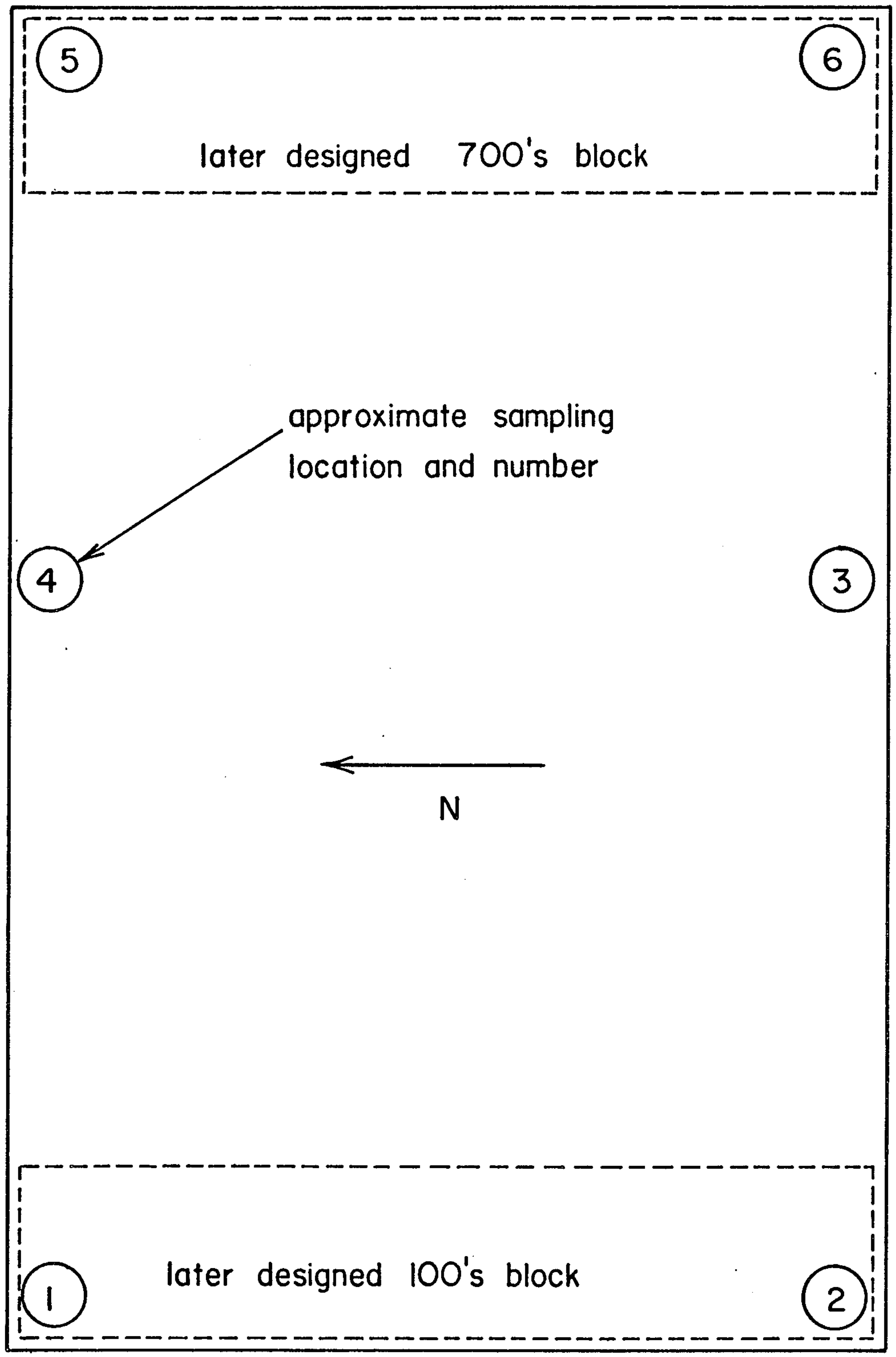
APPENDIX C

700's	R	A	M	B	C	A	M	R	B	C	R	A	B	C	M	A	R	B	C	M
600's	M	B	C	R	A	M	A	R	B	C	B	A	C	R	M	A	R	C	M	B
500's	R	A	C	B	M	M	R	C	B	A	B	A	M	C	R	C	M	B	R	A
400's	B	A	C	M	R	B	M	A	C	R	M	B	C	A	R	M	B	R	A	C
300's	C	M	R	A	B	R	A	B	M	C	B	A	M	C	R	R	A	M	B	C
200's	R	M	C	A	B	R	C	A	M	B	M	R	B	C	A	M	B	C	A	R
100's	M	C	A	R	B	A	R	B	C	M	M	A	B	C	R	R	M	B	C	A

A - alfalfa B - barley C - corn M - mixture
R - reed canary grass

Allocation of Crops to Plots - 1972, 1973

APPENDIX D



Plan View of Proposed Plot Area Showing
Six Preliminary Sample Sites

Preliminary Soil Test Analysis[1]

Site No.	Depth m.	NO_3+NO_2 (2) ppm	NO_3^- (3) ppm	NO_2^- (2) ppm	P ppm	K ppm	pH	Cond. (V/V) mmhos/cm.
1	0.154	4.0	3.6	0.4	8.0	700	7.2	0.7
	0.31	1.7	0.9	0.8	4.4	626	7.8	0.6
	0.62	1.5	0.9	0.6	4.2	562	7.9	0.6
	0.92	1.6	1.0	0.6	4.0	580	7.9	0.7
	1.07	1.4	0.7	0.7	5.0	571	7.9	1.0
	1.22	1.3	0.6	0.7	4.6	545	7.9	0.9
	1.53	1.4	0.7	0.7	5.0	545	7.8	1.2
	1.84	1.1	0.5	0.6	5.0	550	7.8	1.4
	2.17	1.3	0.6	0.7	5.4	547	7.7	1.7
	2.48	0.9	0.5	0.4	6.1	510	7.5	2.8
	2.79	1.0	0.4	0.6	6.6	549	7.4	2.9
	3.10	1.7	1.1	0.6	6.6	565	7.5	2.9
	3.31	1.8	1.2	0.4	7.4	590	7.7	2.2
2	0.154	8.2	7.4	0.8	8.0	636	7.7	0.9
	0.31	3.7	3.1	0.6	4.0	583	8.0	0.7
	0.62	2.6	1.8	0.8	4.0	635	8.0	1.1
	0.92	1.5	.9	0.6	5.6	505	8.0	1.6
	1.07	4.0	3.2	0.8	5.4	609	7.9	1.3
	1.22	1.7	1.2	0.5	5.2	500	7.8	2.2
	1.53	0.9	0.4	0.5	4.8	520	7.8	3.0
	1.84	1.0	0.4	0.6	4.6	531	7.7	2.9
	2.17	0.8	0.3	0.5	4.6	525	7.6	3.3
	2.48	0.8	0.3	0.5	6.6	545	7.6	3.3
	2.79	0.7	0.2	0.5	6.8	545	7.6	2.3
	3.10	0.6	0.2	0.4	7.4	562	7.6	3.3
	3.31	1.2	0.6	0.6	7.6	547	7.7	3.1
3	0.154	9.8	9.4	0.4	10.6	601	7.7	0.7
	0.31	4.9	4.3	0.6	6.2	481	7.9	0.7
	0.62	3.2	2.7	0.5	4.2	385	8.1	0.7
	0.92	2.6	1.8	0.8	4.0	350	8.1	1.2
	1.07	1.5	0.9	0.6	4.0	375	8.0	1.6
	1.22	1.5	0.8	0.7	4.0	404	8.0	1.6
	1.53	1.3	0.8	0.5	3.6	425	7.9	1.6
	1.84	1.3	0.6	0.7	4.6	449	7.8	1.7
	2.17	1.2	0.6	0.6	5.6	445	7.6	3.1
	2.48	2.2	1.6	0.6	5.2	454	7.6	3.2
	2.79	1.0	0.5	0.5	6.0	469	7.6	3.1
	3.10	0.9	0.1	0.8	7.0	455	7.8	3.0
	3.31	3.5	3.0	0.5	7.4	475	7.6	2.9

- continued

Preliminary Soil Test Analysis - continued

Site No.	Depth m.	NO_3+NO_2 (2) ppm	NO_3^- (3) ppm	NO_2^- (2) ppm	P ppm	K ppm	pH	Cond. (V/V) mmhos/cm.
4	0.154	6.1	5.7	0.4	9.0	585	7.1	0.9
	0.31	2.2	2.7	0.5	3.4	531	7.6	0.8
	0.62	2.1	2.6	0.5	3.4	475	7.8	1.2
	0.92	3.3	3.8	0.5	4.4	421	7.8	1.5
	1.07	1.2	0.7	0.5	5.0	392	7.8	1.9
	1.22	1.3	0.8	0.5	5.4	420	7.7	2.7
	1.53	1.0	0.6	0.4	6.1	475	7.7	2.0
	1.84	1.1	0.6	0.5	6.4	400	7.6	3.1
	2.17	0.4	0.0	0.4	6.2	465	7.4	3.4
	2.48	1.2	0.6	0.6	7.2	500	7.2	3.2
	2.79	1.5	0.5	1.0	7.2	475	7.5	3.4
	3.10	1.1	0.4	0.7	7.2	485	7.5	3.3
	3.31	0.9	0.3	0.6	7.6	483	7.2	3.3
5	0.154	12.1	11.8	0.3	14.3	635	7.6	0.9
	0.31	3.7	3.5	0.2	8.2	551	6.8	0.8
	0.62	1.6	1.1	0.5	4.6	495	7.2	0.7
	0.92	2.0	1.1	0.9	3.6	461	7.2	1.3
	1.07	0.7	0.1	0.6	4.4	425	7.8	1.5
	1.22	1.1	0.4	0.7	5.0	417	7.8	1.5
	1.53	0.9	0.2	0.7	5.6	470	8.1	1.6
	1.84	0.7	0.1	0.6	5.6	455	7.7	3.1
	2.17	0.6	0.0	0.6	5.8	470	7.6	3.1
	2.48	0.6	0.0	0.6	6.6	445	7.7	2.8
	2.79	0.7	0.0	0.7	7.0	515	7.5	2.8
	3.10	1.0	0.2	0.8	7.4	505	7.6	2.8
	3.31	1.0	0.4	0.6	7.6	497	7.5	2.9
6	0.154	15.6	15.0	0.6	16.2	595	7.4	1.0
	0.31	5.4	4.8	0.6	7.0	535	7.5	0.9
	0.62	3.8	2.8	1.0	5.6	427	7.7	0.9
	0.92	2.0	1.0	1.0	4.0	380	8.1	0.7
	1.07	1.1	0.5	0.6	4.0	352	7.7	1.1
	1.22	0.6	0.1	0.5	4.6	385	7.5	1.1
	1.53	0.9	0.2	0.7	5.4	420	7.7	1.3
	1.84	1.4	0.3	1.1	5.8	475	7.6	1.4
	2.17	0.6	0.0	0.6	6.0	490	7.7	2.9
	2.48	1.5	0.4	1.1	6.2	492	7.5	2.9
	2.79	0.8	0.0	0.9		513	7.5	2.9
	3.10	0.5	0.0	0.6	7.6	517	7.5	2.9
	3.31	0.6	0.0	0.6	7.4	529	7.5	2.7

(1) Samples taken October, 1971, by Bob Eilers, Man. Soil Survey, analyzed by P.S.T.L.

(2) NO_3^- + NO_2^- and NC_2^- done on same extract (0.5M NaHCO 1:2 soil:water ratio

(3) $NO_3^- - N = (NO_3^- + NO_2^-) - NO_2^-$

APPENDIX E

Nitrate Analysis from 1972 Soils Test Data
($NO_3 \cdot N$)

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
103	0-0.154	5.00	106	0-0.154	7.40
	0.154-0.31	2.80		0.154-0.31	3.40
	0.62	4.00		0.62	1.40
	0.92	2.20		0.92	1.60
	1.22	2.00		1.22	1.40
	1.53	1.40		1.53	1.20
	1.84	7.60		1.84	2.00
	2.18	0.80		2.18	0.40
	2.48	1.20		2.48	0.40
	2.79	1.00		2.79	0.80
104	0-0.154	4.60	107	0-0.154	7.00
	0.154-0.31	3.80		0.154-0.31	4.00
	0.62	7.80		0.62	5.20
	0.92	1.00		0.92	3.40
	1.22	1.60		1.22	3.40
	1.53	1.60		1.53	2.40
	1.84	2.20		1.84	3.20
	2.18	0.20		2.18	3.00
	2.48	1.00		2.48	3.80
	2.79	0.40		2.79	0.60
105	0-0.154	4.00	108	0-0.154	18.20
	0.154-0.31	2.20		0.154-0.31	4.00
	0.62	2.00		0.62	2.20
	0.92	2.20		0.92	1.40
	1.22	1.00		1.22	3.00
	1.53	1.20		1.53	2.60
	1.84	1.20		1.84	5.00
	2.18	1.20		2.18	0.60
	2.48	1.00		2.48	4.20
	2.79	0.60		2.79	1.00

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
112	0-0.154	11.20	116	0-0.154	10.20
	0.154-0.31	3.40		0.154-0.31	4.60
	0.62	0.60		0.62	1.00
	0.92	0.40		0.92	1.80
	1.22	0.80		1.22	2.40
	1.53	0.20		1.53	1.20
	1.84	4.40		1.84	3.00
	2.18	1.60		2.18	0.80
	2.48	3.40		2.48	0.80
	2.79	0.60		2.79	1.80
113	0-0.154	4.00	118	0-0.154	5.20
	0.154-0.31	6.20		0.154-0.31	2.80
	0.62	2.60		0.62	2.20
	0.92	1.00		0.92	1.60
	1.22	1.80		1.22	2.20
	1.53	1.00		1.53	1.20
	1.84	3.00		1.84	1.00
	2.18	1.60		2.18	1.60
	2.48	2.00		2.48	0.40
	2.79	2.00		2.79	1.60
115	0-0.154	5.60	120	0-0.154	8.40
	0.154-0.31	3.20		0.154-0.31	3.20
	0.62	2.20		0.62	3.00
	0.92	1.60		0.92	2.40
	1.22	1.80		1.22	1.60
	1.53	2.80		1.53	2.80
	1.84	-		1.84	1.20
	2.18	1.20		2.18	2.80
	2.48	2.20		2.48	2.60
	2.79	1.60		2.79	1.80

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
401	0-0.154	16.40	406	0-0.154	13.60
	0.154-0.31	3.40		0.154-0.31	2.40
	0.62	1.20		0.62	3.40
	0.92	2.20		0.92	0.80
	1.22	1.80		1.22	1.20
	1.53	0.80		1.53	2.00
	1.84	1.20		1.84	1.80
	2.18	1.00		2.18	1.40
	2.48	0.80		2.48	1.40
	2.79	0.60		2.79	1.00
402	0-0.154	12.60	408	0-0.154	18.60
	0.154-0.31	3.20		0.154-0.31	4.40
	0.62	1.60		0.62	1.00
	0.92	2.20		0.92	2.20
	1.22	0.20		1.22	0.40
	1.53	1.40		1.53	0.80
	1.84	1.00		1.84	0.60
	2.18	-		2.18	-
	2.48	0.40		2.48	0.80
	2.79	0.40		2.79	-
405	0-0.154	16.20	410	0-0.154	13.20
	0.154-0.31	3.00		0.154-0.31	2.80
	0.62	2.20		0.62	1.40
	0.92	1.20		0.92	3.80
	1.22	2.40		1.22	2.20
	1.53	2.80		1.53	1.60
	1.84	1.00		1.84	2.00
	2.18	1.80		2.18	1.80
	2.48	3.40		2.48	2.60
	2.79	2.60		2.79	0.40

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
412	0-0.154	5.00	417	0-0.154	5.80
	0.154-0.31	2.00		0.154-0.31	4.60
	0.62	3.40		0.62	2.00
	0.92	1.40		0.92	2.40
	1.22	1.80		1.22	3.40
	1.53	2.60		1.53	0.80
	1.84	1.00		1.84	4.80
	2.18	3.60		2.18	1.20
	2.48	1.40		2.48	4.40
	2.79	0.60		2.79	1.00
414	0-0.154	13.60	418	0-0.154	3.80
	0.154-0.31	5.00		0.154-0.31	1.80
	0.62	0.80		0.62	1.40
	0.92	1.80		0.92	1.80
	1.22	3.80		1.22	2.00
	1.53	1.00		1.53	0.80
	1.84	2.00		1.84	2.00
	2.18	2.40		2.18	1.60
	2.48	1.60		2.48	2.00
	2.79	1.60		2.79	2.00
415	0-0.154	8.80	420	0-0.154	3.60
	0.154-0.31	3.60		0.154-0.31	2.80
	0.62	3.80		0.62	3.20
	0.92	1.40		0.92	2.40
	1.22	4.60		1.22	1.60
	1.53	1.40		1.53	-
	1.84	1.20		1.84	1.60
	2.18	0.80		2.18	1.60
	2.48	0.60		2.48	0.20
	2.79	0.80		2.79	1.00

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
501	0-0.154	2.40	507	0-0.154	7.60
	0.154-0.31	1.60		0.154-0.31	2.80
	0.62	2.20		0.62	1.20
	0.92	2.80		0.92	6.00
	1.22	3.80		1.22	-
	1.53	1.40		1.53	1.80
	1.84	1.40		1.84	-
	2.18	0.80		2.18	0.60
	2.48	1.20		2.48	-
	2.79	0.20		2.79	2.80
502	0-0.154	9.60	509	0-0.154	15.80
	0.154-0.31	2.00		0.154-0.31	9.20
	0.62	3.40		0.62	5.00
	0.92	2.20		0.92	3.20
	1.22	1.40		1.22	2.00
	1.53	1.40		1.53	-
	1.84	2.00		1.84	2.60
	2.18	0.80		2.18	1.60
	2.48	1.20		2.48	3.00
	2.79	1.20		2.79	0.40
504	0-0.154	5.80	510	0-0.154	27.80
	0.154-0.31	6.60		0.154-0.31	8.20
	0.62	1.20		0.62	2.00
	0.92	1.60		0.92	2.80
	1.22	1.40		1.22	-
	1.53	2.20		1.53	3.80
	1.84	-		1.84	0.60
	2.18	1.60		2.18	0.80
	2.48	0.20		2.48	1.60
	2.79	1.20		2.79	-

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
511	0-0.154	17.80	518	0-0.154	8.20
	0.154-0.31	4.20		0.154-0.31	4.20
	0.62	1.60		0.62	1.40
	0.92	1.80		0.92	1.80
	1.22	1.40		1.22	6.60
	1.53	0.20		1.53	3.20
	1.84	0.80		1.84	1.20
	2.18	2.00		2.18	1.00
	2.48	3.20		2.48	-
	2.79	0.80		2.79	2.20
512	0-0.154	13.20	519	0-0.154	5.40
	0.154-0.31	2.80		0.154-0.31	2.80
	0.62	1.00		0.62	3.00
	0.92	2.60		0.92	3.00
	1.22	1.80		1.22	2.40
	1.53	0.80		1.53	1.00
	1.84	1.20		1.84	0.40
	2.18	0.20		2.18	2.60
	2.48	0.20		2.48	1.80
	2.79	0.60		2.79	-
515	0-0.154	14.20	520	0-0.154	15.40
	0.154-0.31	4.60		0.154-0.31	3.60
	0.62	3.80		0.62	2.00
	0.92	2.60		0.92	5.00
	1.22	1.00		1.22	2.80
	1.53	1.20		1.53	1.60
	1.84	0.80		1.84	1.20
	2.18	0.80		2.18	1.20
	2.48	0.40		2.48	0.80
	2.79	0.80		2.79	1.80

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
602	0-0.154	15.20	607	0-0.154	13.00
	0.154-0.31	5.40		0.154-0.31	3.20
	0.62	3.20		0.62	1.40
	0.92	2.00		0.92	1.80
	1.22	2.20		1.22	0.20
	1.53	-		1.53	1.40
	1.84	1.00		1.84	1.20
	2.18	1.60		2.18	1.20
	2.48	0.80		2.48	0.40
	2.79	1.00		2.79	0.80
604	0-0.154	16.60	608	0-0.154	11.60
	0.154-0.31	2.60		0.154-0.31	3.40
	0.62	3.20		0.62	1.80
	0.92	1.00		0.92	1.80
	1.22	2.00		1.22	2.00
	1.53	3.20		1.53	2.00
	1.84	2.40		1.84	2.80
	2.18	2.40		2.18	4.00
	2.48	0.20		2.48	-
	2.79	1.40		2.79	0.40
605	0-0.154	5.00	609	0-0.154	11.20
	0.154-0.31	2.80		0.154-0.31	2.00
	0.62	2.20		0.62	2.80
	0.92	2.20		0.92	-
	1.22	1.80		1.22	2.00
	1.53	0.80		1.53	3.00
	1.84	1.40		1.84	1.40
	2.18	2.20		2.18	0.80
	2.48	1.40		2.48	0.60
	2.79	2.00		2.79	2.20

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
611	0-0.154	12.80	616	0-0.154	10.40
	0.154-0.31	3.60		0.154-0.31	2.80
	0.62	2.80		0.62	2.20
	0.92	-		0.92	1.40
	1.22	1.80		1.22	1.80
	1.53	2.00		1.53	3.20
	1.84	1.20		1.84	0.40
	2.18	0.80		2.18	0.20
	2.48	-		2.48	2.20
	2.79	3.00		2.79	1.00
612	0-0.154	13.00	617	0-0.154	2.80
	0.154-0.31	0.80		0.154-0.31	2.40
	0.62	1.80		0.62	2.60
	0.92	2.40		0.92	1.40
	1.22	3.00		1.22	1.40
	1.53	2.20		1.53	1.00
	1.84	1.60		1.84	1.60
	2.18	1.20		2.18	1.00
	2.48	2.00		2.48	2.00
	2.79	2.00		2.79	0.80
614	0-0.154	8.40	620	0-0.154	17.00
	0.154-0.31	2.80		0.154-0.31	3.20
	0.62	2.00		0.62	2.60
	0.92	2.20		0.92	3.00
	1.22	1.20		1.22	1.80
	1.53	1.00		1.53	2.20
	1.84	0.60		1.84	-
	2.18	0.80		2.18	1.00
	2.48	0.40		2.48	0.80
	2.79	1.40		2.79	-

APPENDIX F

Nitrate Analysis from 1973 Soils Test Data
($NO_3 \cdot N$)

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
103	0-0.154	2.4	108	0-0.154	7.0
	0.154-0.31	1.2		0.154-0.31	1.2
	0.62	1.8		0.62	1.2
	0.92	0.8		0.92	1.0
	1.22	0.8		1.22	1.0
	1.53	1.4		1.53	1.2
104	0-0.154	1.2	109	0-0.154	2.2
	0.154-0.31	1.2		0.154-0.31	1.6
	0.62	0.8		0.62	2.0
	0.92	0.6		0.92	2.4
	1.22	0.8		1.22	2.0
	1.53	0.6		1.53	1.4
105	0-0.154	2.2	113	0-0.154	1.4
	0.154-0.31	3.4		0.154-0.31	1.2
	0.62	2.4		0.62	1.6
	0.92	1.6		0.92	1.2
	1.22	1.4		1.22	1.0
	1.53	1.2		1.53	1.4
106	0-0.154	0.8	114	0-0.154	2.4
	0.154-0.31	0.8		0.154-0.31	1.0
	0.62	0.6		0.62	1.6
	0.92	0.8		0.92	1.4
	1.22	0.8		1.22	1.6
	1.53	0.8		1.53	1.2
107	0-0.154	1.2	301	0-0.154	5.0
	0.154-0.31	0.8		0.154-0.31	3.2
	0.62	0.6		0.62	2.2
	0.92	0.8		0.92	2.2
	1.22	0.6		1.22	2.8
	1.53	0.6		1.53	1.6

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
112	0-0.154	2.6	302	0-0.154	1.8
	0.154-0.31	1.8		0.154-0.31	1.2
	0.62	1.4		0.62	2.0
	0.92	2.0		0.92	1.6
	1.22	1.8		1.22	2.2
	1.53	1.6		1.53	1.2
115	0-0.154	1.4	303	0-0.154	1.2
	0.154-0.31	1.4		0.154-0.31	1.4
	0.62	1.2		0.62	1.4
	0.92	1.2		0.92	1.2
	1.22	1.2		1.22	1.6
	1.53	0.6		1.53	1.2
116	0-0.154	1.4	304	0-0.154	3.2
	0.154-0.31	1.2		0.154-0.31	1.6
	0.62	0.8		0.62	2.2
	0.92	1.2		0.92	1.4
	1.22	1.0		1.22	1.4
	1.53	1.4		1.53	1.4
118	0-0.154	4.8	305	0-0.154	3.4
	0.154-0.31	2.4		0.154-0.31	2.6
	0.62	2.2		0.62	2.0
	0.92	1.2		0.92	1.6
	1.22	2.0		1.22	1.2
	1.53	1.4		1.53	1.2
120	0-0.154	4.0	402	0-0.154	1.6
	0.154-0.31	2.8		0.154-0.31	0.8
	0.62	2.0		0.62	1.2
	0.92	3.4		0.92	1.2
	1.22	1.6		1.22	0.8
	1.53	2.2		1.53	1.2

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
306	0-0.154	2.0	405	0-0.154	0.8
	0.154-0.31	1.8		0.154-0.31	1.2
	0.62	1.6		0.62	1.6
	0.92	1.2		0.92	0.4
	1.22	0.8		1.22	1.0
	1.53	1.6		1.53	0.6
307	0-0.154	4.0	406	0-0.154	2.6
	0.154-0.31	2.0		0.154-0.31	1.4
	0.62	2.4		0.62	1.4
	0.92	1.8		0.92	0.8
	1.22	1.6		1.22	0.6
	1.53	1.8		1.53	0.8
308	0-0.154	4.0	408	0-0.154	3.2
	0.154-0.31	3.6		0.154-0.31	1.8
	0.62	2.2		0.62	1.6
	0.92	2.6		0.92	0.8
	1.22	1.8		1.22	0.6
	1.53	1.4		1.53	0.6
401	0-0.154	2.6	409	0-0.154	4.6
	0.154-0.31	1.0		0.154-0.31	2.2
	0.62	1.0		0.62	1.0
	0.92	0.8		0.92	0.8
	1.22	0.6		1.22	1.6
	1.53	0.4		1.53	1.2
410	0-0.154	1.2	417	0-0.154	2.6
	0.154-0.31	0.6		0.154-0.31	2.2
	0.62	1.0		0.62	1.4
	0.92	0.6		0.92	1.6
	1.22	1.2		1.22	2.0
	1.53	1.0		1.53	1.6

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
412	0-0.154	3.0	418	0-0.154	1.8
	0.154-0.31	2.2		0.154-0.31	1.2
	0.62	2.2		0.62	1.6
	0.92	1.6		0.92	2.0
	1.22	1.6		1.22	1.8
	1.53	1.4		1.53	1.2
413	0-0.154	3.8	420	0-0.154	2.6
	0.154-0.31	1.8		0.154-0.31	2.0
	0.62	1.0		0.62	1.8
	0.92	1.6		0.92	1.8
	1.22	1.8		1.22	1.6
	1.53	1.8		1.53	1.8
414	0-0.154	2.2	501	0-0.154	2.2
	0.154-0.31	1.8		0.154-0.31	1.6
	0.62	2.0		0.62	1.4
	0.92	1.0		0.92	2.4
	1.22	2.2		1.22	2.4
	1.53	2.0		1.53	2.2
415	0-0.154	2.4	502	0-0.154	2.4
	0.154-0.31	1.2		0.154-0.31	2.2
	0.62	1.2		0.62	2.0
	0.92	1.0		0.92	1.8
	1.22	1.0		1.22	1.8
	1.53	0.6		1.53	1.4
504	0-0.154	5.6	511	0-0.154	7.8
	0.154-0.31	3.4		0.154-0.31	3.6
	0.62	2.2		0.62	2.0
	0.92	2.0		0.92	2.0
	1.22	1.4		1.22	2.8
	1.53	1.6		1.53	2.4

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
507	0-0.154	1.2	512	0-0.154	4.2
	0.154-0.31	1.2		0.154-0.31	1.8
	0.62	2.0		0.62	2.2
	0.92	1.6		0.92	2.8
	1.22	1.8		1.22	2.0
	1.53	2.0		1.53	2.0
508	0-0.154	5.0	514	0-0.154	9.6
	0.154-0.31	2.4		0.154-0.31	4.2
	0.62	2.6		0.62	2.6
	0.92	1.4		0.92	2.8
	1.22	2.4		1.22	2.0
	1.53	1.8		1.53	1.8
509	0-0.154	7.2	515	0-0.154	1.0
	0.154-0.31	4.6		0.154-0.31	1.0
	0.62	2.0		0.62	1.8
	0.92	1.6		0.92	2.2
	1.22	2.0		1.22	0.8
	1.53	1.6		1.53	1.6
510	0-0.154	2.0	518	0-0.154	4.4
	0.154-0.31	2.0		0.154-0.31	2.2
	0.62	1.2		0.62	2.4
	0.92	1.8		0.92	1.8
	1.22	1.8		1.22	2.4
	1.53	1.6		1.53	2.2
519	0-0.154	1.8	605	0-0.154	2.4
	0.154-0.31	1.4		0.154-0.31	1.4
	0.62	1.6		0.62	1.8
	0.92	1.0		0.92	0.8
	1.22	0.8		1.22	1.2
	1.53	0.6		1.53	1.0

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
520	0-0.154	3.0	607	0-0.154	2.0
	0.154-0.31	1.6		0.154-0.31	2.0
	0.62	1.6		0.62	1.6
	0.92	1.6		0.92	1.8
	1.22	1.2		1.22	1.4
	1.53	0.8		1.53	1.0
602	0-0.154	3.4	608	0-0.154	1.8
	0.154-0.31	1.6		0.154-0.31	1.0
	0.62	2.0		0.62	2.2
	0.92	2.0		0.92	2.0
	1.22	1.2		1.22	1.6
	1.53	1.6		1.53	1.0
603	0-0.154	4.4	609	0-0.154	3.6
	0.154-0.31	3.4		0.154-0.31	2.4
	0.62	2.0		0.62	1.2
	0.92	2.4		0.92	1.0
	1.22	2.8		1.22	0.8
	1.53	2.6		1.53	1.0
604	0-0.154	2.2	611	0-0.154	2.0
	0.154-0.31	2.0		0.154-0.31	1.6
	0.62	1.8		0.62	2.0
	0.92	1.6		0.92	3.8
	1.22	2.0		1.22	1.8
	1.53	1.6		1.53	1.8
612	0-0.154	1.1	620	0-0.154	5.0
	0.154-0.31	1.2		0.154-0.31	4.6
	0.62	1.8		0.62	3.6
	0.92	2.4		0.92	2.4
	1.22	1.8		1.22	3.2
	1.53	0.8		1.53	2.4

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
614	0-0.154	1.0	701	0-0.154	1.6
	0.154-0.31	1.4		0.154-0.31	1.2
	0.62	1.6		0.62	1.8
	0.92	2.0		0.92	1.6
	1.22	1.4		1.22	1.2
	1.53	1.0		1.53	1.2
616	0-0.154	4.8	702	0-0.154	2.0
	0.154-0.31	2.6		0.154-0.31	2.4
	0.62	1.8		0.62	2.0
	0.92	2.2		0.92	1.0
	1.22	1.6		1.22	1.8
	1.53	1.4		1.53	2.0
617	0-0.154	2.0	703	0-0.154	2.0
	0.154-0.31	1.2		0.154-0.31	1.8
	0.62	1.6		0.62	2.2
	0.92	1.8		0.92	1.6
	1.22	2.0		1.22	1.4
	1.53	1.2		1.53	2.2
618	0-0.154	2.8	704	0-0.154	4.8
	0.154-0.31	1.8		0.154-0.31	2.0
	0.62	1.6		0.62	2.2
	0.92	1.8		0.92	2.2
	1.22	1.6		1.22	1.4
	1.53	1.8		1.53	2.0
706	0-0.154	2.0	712	0-0.154	2.0
	0.154-0.31	1.0		0.154-0.31	1.4
	0.62	1.6		0.62	1.4
	0.92	1.6		0.92	1.0
	1.22	2.0		1.22	1.6
	1.53	2.4		1.53	1.4

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
708	0-0.154	0.8	713	0-0.154	2.8
	0.154-0.31	0.8		0.154-0.31	2.2
	0.62	1.0		0.62	3.2
	0.92	1.2		0.92	2.2
	1.22	1.3		1.22	2.4
	1.53	2.1		1.53	1.6
709	0-0.154	2.4	714	0-0.154	3.2
	0.154-0.31	2.0		0.154-0.31	1.8
	0.62	1.0		0.62	1.6
	0.92	1.0		0.92	1.8
	1.22	1.0		1.22	1.6
	1.53	0.6		1.53	1.4
710	0-0.154	4.0	715	0-0.154	2.6
	0.154-0.31	2.4		0.154-0.31	1.6
	0.62	2.0		0.62	1.6
	0.92	1.6		0.92	1.2
	1.22	1.6		1.22	2.0
	1.53	1.6		1.53	2.2
711	0-0.154	1.0	716	0-0.154	3.0
	0.154-0.31	0.6		0.154-0.31	2.0
	0.62	1.4		0.62	1.6
	0.92	1.0		0.92	1.4
	1.22	1.2		1.22	2.6
	1.53	1.0		1.53	1.4
717	0-0.154	2.8	719	0-0.154	3.0
	0.154-0.31	2.0		0.154-0.31	3.2
	0.62	1.0		0.62	2.2
	0.92	1.4		0.92	1.6
	1.22	1.8		1.22	2.0
	1.53	1.6		1.53	2.0

Plot	Depth m.	NO_3 ppm	Plot	Depth m.	NO_3 ppm
718	0-0.154	16.0	720	0-0.154	12.2
	0.154-0.31	19.8		0.154-0.31	6.8
	0.62	12.8		0.62	3.8
	0.92	8.2		0.92	2.0
	1.22	4.6		1.22	1.6
	1.53	2.6		1.53	5.0

APPENDIX G

Alfalfa, Barley, Corn, Mixture, and Reed Canary Grass Yields* (Kg/ha)

Alfalfa		Reed Canary Grass		Mixture	
Plot	Yield	Plot	Yield	Plot	Yield
103	565	104	525	101	775
106	635	107	385	110	850
112	625	115	880	111	770
120	1190	116	560	117	1215
204	1075	201	455	202	620
208	1085	206	805	209	1190
215	1285	212	1015	211	820
219	925	220	960	216	1080
304	535	303	560	302	680
307	705	306	985	309	615
312	595	315	845	313	1145
317	695	316	1005	318	675
402	535	405	845	404	785
408	1040	410	720	407	1225
414	1040	415	735	411	1340
420	1295	418	540	416	980
502	995	501	795	505	845
510	535	507	415	506	780
512	175	515	515	513	345
520	475	519	430	517	455
605	765	604	665	601	1165
607	935	608	445	606	695
612	330	614	660	615	930
616	1305	617	1040	619	1065
702	1510	701	670	703	1375
706	1385	708	1115	707	1080
712	1305	711	980	715	1305
716	1260	717	1145	720	1415

- continued

Barley			Corn	
Plot	Yield		Plot	Yield
105	1915		102	4462
108	1145		109	4188
113	893		114	4923
118	1013		119	3130
205	1783		203	5790
210	2299		207	3556
213	2434		214	6533
217	2145		218	5654
305	2242		301	4923
308	2125		310	8278
311	1716		314	6143
319	1803		320	6546
401	1492		403	7488
406	1630		409	9954
412	1276		413	6210
417	1478		419	8766
504	859		503	3219
509	534		508	4004
511	534		514	1749
518	168		516	1556
602	1069		603	4484
609	1066		610	3170
611	595		613	3258
620	1478		618	3507
704	1303		705	4690
709	932		710	4708
713	1085		714	5829
718	1452		719	7309

* Yield per plot reported in total dry matter per hectare except barley which is reported in kilograms of grain per hectare.

APPENDIX H

Nitrogen Uptake* as Taken from Tissue Analysis

Corn		Reed Canary Grass	
Plot	% N	Plot	% N
102	1.06	104	2.72
109	1.02	107	2.64
114	0.96	115	2.35
119	0.83	116	2.81
203	0.90	201	2.51
207	1.06	206	2.11
214	1.15	212	2.69
218	0.93	220	1.83
301	1.12	303	4.39
310	1.28	306	3.86
314	1.22	315	2.64
320	1.25	316	3.00
403	0.86	405	2.31
409	0.86	410	3.68
413	1.12	415	2.91
419	0.99	418	2.93
503	0.80	501	2.69
508	1.02	507	2.47
514	1.54	515	2.31
516	1.34	519	2.06
603	0.90	604	2.08
610	1.25	608	2.39
613	1.54	614	2.88
618	1.63	617	2.14
705	0.83	701	2.41
710	0.80	708	2.03
714	0.86	711	2.09
719	1.02	717	1.88

* Percent nitrogen is reported as total Kjeldahl nitrogen.

APPENDIX I

Runoff Sample Analysis - 1973

Date	Plot	COD ppm	PO_4 ppm	NO_3 ppm
June 14	117	-	-	-
	118	668	-	-
	216	257	-	-
	217	334	-	-
	318	-	-	-
June 18	117	106	-	-
	118	742	-	-
	216	73	-	-
	217	558	-	-
	318	791	-	-
June 20	117	53	-	0.886
	118	132	-	3.69
	216	49	-	0.886
	217	246	-	1.07
	318	322	-	3.1
July 4	117	196	5.0	1.55
	118	132	0.35	0.886
	216	77	1.0	0.66
	217	81	0.85	0.443
	318	461	0.375	2.2
July 6	117	-	-	-
	118	121	0.75	1.1
	216	72	0.35	0.22
	217	145	0.886	1.5
	318	408	5.0	0.31

- continued

Date	Plot	COD ppm	PO_4 ppm	NO_3 ppm
July 10	117	-	-	-
	118	32	0.1	0.8
	216	48	1.5	1.329
	217	383	0.67	0.7
	318	-	-	-
July 24	117	94	1.5	1.3
	118	356	1.0	1.5
	216	196	1.5	0.443
	217	192	1.5	0.9
	318	349	2.5	8.86
July 27	117	-	-	-
	118	290	3.0	2.2
	216	164	1.25	26.2
	217	117	0.55	1.772
	318	286	8.5	0.443
July 30	117	201	0.3	0.4
	118	122	0.625	4.43
	216	76	0.5	8.6
	217	91	0.3	1.6
	318	129	1.4	0.443
August 11	117	156	1.00	0.31
	118	52	0.4	13.3
	216	68	7.00	6.645
	217	164	1.25	2.215
	318	88	2.25	0.66

- continued

Date	Plot	COD ppm	PO_4 ppm	NO_3 ppm
August 20	117	167	1.0	0.866
	118	312	1.3	44.3
	216	145	2.0	66.45
	217	149	2.0	2.215
	318	264	2.5	0.22
September 5	117	268.66	2.5	13.29
	118	208	1.1	19.9
	216	82.82	1.87	0.443
	217	446.42	1.45	66.45
	318	107.6	20	0.664
September 27	117	455.8	2.75	44.3
	118	315.7	0.31	2.25
	216	90.87	2.0	110.75
	217	61.64	1.0	13.29
	318	173.72	0.2215	9.4
October 18	117	74.74	2.0	0.664
	118	28.8	0.5	0.443
	216	38.38	1.25	22.15
	217	36.36	0.29	155
	318	153.52	3.5	0

- NO_3 - N (ppm N)

- PO_4 - P (ppm)