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**THE INFLUENCE OF CULTURAL PRACTICES ON  
SOIL ORGANIC MATTER, SOIL BIOMASS SIZE  
AND NITROGEN LEACHING**

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in partial fulfilment of the requirements for the Degree of  
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## ***ABSTRACT***

The effects of bare fallow, cultivation and nitrogen application on soil organic matter, soil biomass and nitrogen leaching were compared against the backgrounds of permanent grass pasture and grass/clover pasture. Cultivated plots were dug annually to a depth of 15cm. All plots received an annual dressing of 300kg ha<sup>-1</sup> of Potassic Super. The Nitrogen treatment was applied as two equal applications of 100kg ha<sup>-1</sup> Calcium Ammonium Nitrate in November and December each year.

The results indicated that both bare fallowing and cultivation reduced soil organic matter and soil microbial biomass. The use of N-fertilizer did not promote either the soil organic matter or soil microbial biomass; this is contrary to the general finding.

Legume nitrogen was found to leach as readily as the applied nitrogen and hence posed an environmental threat to groundwater quality. In all cultural practices the largest concentration of nitrate nitrogen (NO<sub>3</sub>-N) was observed at the 50 - 100m depth, below the root zone. Vertical movement of groundwater was estimated at 1m year<sup>-1</sup>. This confirmed the concern of possible groundwater pollution by nitrate nitrogen from agricultural activities.

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# **CHAPTER 1**

## ***1 General Introduction***

### ***1.1 Introduction***

Agriculture manipulates energy fluxes, nutrient dynamics and hydrological cycles. Such manipulation may involve clearing and burning to remove woodland, ploughing, fertilizer application and seeding to create crops and pastures and intensive grazing by domestic animals. Increasingly, farmers, agricultural scientist and environmentalists are turning their attention to considerations of the chemical and biological integrity of the cropping systems. The reasons for this are obvious. When man converts natural ecosystems into agroecosystems, he modifies many specific features of their structure and dynamics. These modifications affect two basic ecosystem characteristics. They tend to reduce the importance of detritus food chains and to increase the importance of nutrient and energy exports from the system (Cox and Atkins, 1979). In particular the nitrogen cycle has captured the interest of both environmentalists and agriculturalists. The environmental concerns stem from the fact that potable water pollution by  $\text{NO}_3^-$  in run-off or groundwater has been linked to carcinogenic nitrosamines from  $\text{NO}_2^-$  and the depletion of ozone layer by soil evolved  $\text{N}_2\text{O}$  (Crutzen, 1981 and Byrnes, 1990). From the agricultural point of view nitrogen cycling is of paramount importance in that it is one of the most limiting nutrients in crop yields. Furthermore, in economic terms N fertilizer constitutes a large monetary cost of crop production.

For more than a century now mankind has always been keen to know more about the impact of his agricultural activities on the environment since this has a bearing on the long-term sustainability of agricultural systems. Jenkinson (1991) reported on British experiments as old as 150 years in which inorganic nutrients, in various combinations, were compared with farmyard manure - the traditional source of fertility. These experiments provided a wealth of information with regard to long-term effects of inorganic fertilisers and organic manures on soil organic matter levels. Over the years

agricultural research has broadened its focus. To date several other issues have been incorporated into this historic research thrust. These include research on changes in soil pH over time and nitrogen cycling in these agroecosystems. This kind of research is no longer limited to more conventional cropping systems such as cereals but has been extended to pastoral systems as well. For example in New Zealand there is currently a strong interest in cycling efficiencies of many plant nutrients in grazed pastures. It is believed that the grazing animals aggregate many plant nutrients into dung and urine excretions. These excretions contain concentrated forms of many plant nutrients, with N and potassium (K) levels being potentially high (Hogg, 1981). Once urine has been applied onto the soil much of the organic forms of N are rapidly converted to ammonium ( $\text{NH}_4^+$ ) then nitrate ( $\text{NO}_3^-$ ) ions which are susceptible to losses through leaching and other soil processes such as volatilisation and denitrification.

Managed agroecosystems generally tend to have greater inputs of N than unmanaged systems. Because of this, greater N losses are incurred under intensively managed systems. The actual extent or severity of the losses of N in such systems will depend on several factors. Allison (1966) and Campbell and Paul (1978) pointed out that the amount of N loss is a function of timing and rate of application, cropping system and moisture regime. With good management, losses could be minimised. However, increased exports of N from disturbed and unmanaged natural ecosystems such as forests have long been appreciated. Likens *et al.*, (1970) noted that clear felling of trees alters the N cycle within the ecosystem, greatly increasing the N leakage from the watersheds and resulting in increases in nitrate levels in river waters. Bormann *et al.*, (1968) reported and stressed that the nutrient cycle in a forest is closely geared to all the components of the ecosystem and the balance between decomposition and the nutrient uptake influences the conservation of nutrients within the ecosystem. In the absence of forest vegetation the bulk of mineralized nutrients, and mainly N, are rapidly flushed out from the watershed-ecosystems.

### *1.2 Nitrate problem in the Environment*

The impact of nitrogen on the environment is now well appreciated and a more responsible attitude to the problem has been adopted. Research in crop production is aiming to provide a basis for acceptable compromise in conflicting goals of maximum yield, maximum profit and zero environmental pollution. Peterson and Russel (1991) gave some of the reasons for increasing studies in nitrogen cycling in agricultural production systems as:

- (a) depletion of the atmosphere's protective ozone layer.
- (b) high demands of energy required in the production of N fertilizers.
- (c) accumulating scientific evidence showing that some agricultural practices deposit N in both surface water and groundwater supplies.

The protection of groundwater quality from which both public and private wells draw drinking water is a high priority in most countries. In New Zealand the concentration of  $\text{NO}_3^-$  in bore and well waters in many areas exceeds the upper limit for potable water of 10mg per litre suggested by the World Health Organisation (Steele and Judd 1984). This problem of nitrate pollution is not being experienced in this country alone. Other countries, for example, the United Kingdom (Wild and Cameron, 1980a) and U.S.A. (Magette and Shirmohammadi, 1989) are facing a similar problem.

Nitrate leaching is a particular problem on cultivated agricultural lands and it is often the most important channel of N losses from field soils. Wild and Cameron (1980b) reported that such losses range from 2 to 100kg  $\text{ha}^{-1}$   $\text{year}^{-1}$  in the UK. This N originates from mineralisation of soil organic matter and fertilizer N not used by crop plants. Addition of N which is essential for obtaining high crop yields commonly increases leaching losses. When high fertiliser rates are combined with heavy irrigation regimes on light-textured soil, leaching losses of nitrate nitrogen ( $\text{NO}_3^-$ -N) can be large (Weil *et al.*, 1990). The processes involved in  $\text{NO}_3^-$  leaching and factors influencing losses have been studied extensively because of their economic and environmental significance (Cameron and Haynes 1986). However, data is needed on specific cultural practices and their impact on N leaching from the soils. Such studies could help develop

best management practices for agricultural land to protect groundwater. It has been found that nitrate moves downward through the soil profile at a rate of about 1 to 2m per year depending on soil type and the underlying rock (Young *et al.*, 1979). This kind of information may not only make it possible to predict when problems in drinking water may arise but may also help identify which cultural practices pose the greatest risk of N pollution to ground water.

The current rising levels of nitrate in groundwater is attributed to application of N-fertilisers by farmers. Because of this, calls for the control, or in some cases a ban, on the use of N-fertilisers by farmers have been put forward, particularly in Europe. Work by Powlson *et al.*, (1986) strongly points to the residual N from previous seasons and from the soil organic N. The work suggests that organically bound N can be a major source of nitrate pollution when it is finally re-mobilised by soil microbes. This microbially produced N is subject to leaching if the re-mobilisation rate is not matched with the plant uptake.

In order to investigate more closely the complexity of this issue, a six-year experiment was set up at DSIR Grassland, Palmerston North. The objective was to assess how cultural practices affect soil's N mineralisation potential and N leaching. In particular, the effect of cultivation, bare fallowing and legume N fixation was investigated. Additional investigation was to assess the impact of these cultural practices on soil microbial populations since the N mineralisation and soil biomass are closely linked. The soil biomass derives its energy and nutrient supplies through the decomposition process. The size of the biomass pool, therefore, reflect the amount of material available for decomposition (Carran 1983) and hence should reflect the long-term amount of C input to the soil (McGill *et al.*, 1986). Because of this close association between biomass and organic matter, biomass assessment can offer an alternative method of assessing the impacts of cultural practices on soil-plant systems. Past scientific work has established that the decline in soil biomass is far more sensitive to measuring effects of cultural practices on any change in organic inputs than is the measuring the total organic matter (Powlson *et al.*, 1987 and Powlson and Jenkinson,



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1981). The measurement of microbial biomass could thus be a valuable tool for understanding and predicting the long-term effects of changes in soil conditions.