

PREDICTING THE EFFECTS OF AGRICULTURAL LAND MANAGEMENT CHANGE ON SOIL QUALITY AND PRODUCTIVITY

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Much of New Zealand's income derives directly from agriculture, and for decades individual New Zealanders, the New Zealand public, and agricultural industries have invested heavily in innovative farming practices to increase efficiency and to produce high quality products, and in scientific research to enhance the productivity and product quality of agricultural production systems. One aspect of this is ongoing scientific research into the characteristics, health or quality of the soil itself and its importance to sustaining high levels of agricultural production.

Soil quality can be defined as the fitness of soil for a specific land use. The farming management practices employed under a given land use – including the type of farm, the crops grown, and the tillage methods employed, the fertiliser and irrigation applied, and the grazing practices used – can affect the quality of the soil and the resulting economic outputs and environmental impacts. Farming practices can also damage the soil stability, putting it at risk of erosion. The focus of the MISG problem was to examine factors that affect seven important measures of soil quality – measures relating to both short-term productivity and long-term sustainability of the soil. The MISG study formed one chapter in an ongoing study programme being undertaken by researchers from Crop & Food Research and the Sustainable Soil Management Promotion Group. The eventual aim of the study programme is to produce a land management index that can be used by farmers to assess the likely effect of their farming practices on the soil and future productivity. An example would be the possible benefits or otherwise of replacing conventional ploughing with minimum-tillage techniques.

The seven soil measures under study reflected: soil compaction (BD15, the bulk density of the top 15 cm of soil); organic matter (C%15, the carbon percentage in the top 15 cm; and HWC, the biologically available carbon); the amount of phosphorous available in the soil (measured by Olsen's P); and the size and stability of soil aggregates (measured in terms of mean weight AgStabMWD and the percentage of very small or very large aggregates, ASD<0.85 and ASD>9.5 - both of which are related to erosion). Predictors of the soil measures included the soil order

(i.e. soil classification), soil texture (silt, sand or clay), the geographic region (Auckland/Waikato, Hawke's Bay, Canterbury, or Southland) and the land use or type of farming practiced (intensive cropping, mixed cropping, vegetable production, dairy farming, conventional sheep/beef farming, or high-tech intensive beef production). The effect of land management practices was summarised by a tillage index calculated from 10 years of management data (tillage index high for many years of intensive cultivation, zero for undisturbed grass) and a crop index reflecting the crop types grown.

The MISG contributed to the analysis of the soil data in several ways.

Exploratory data analysis was used to investigate the inter-relationships between the soil measures and to conclude some variables should be analysed on a logarithmic scale.

Preliminary regression models were fitted to each soil measure in terms of the categorical variables land use (farm type), soil order, soil texture and geographic region. These indicated between 31% and 78% of the variation in soil measures was "explained" by the categorical variables, with BD15 the best explained and ASD>9.5 the worst explained. The amount explained was somewhat higher when data from the cropping land uses alone was considered. Adding in the crop index and tillage index scores gave a significant improvement in the model for AgStabMWD, logHWC, logC%15, logOlsenP and ASD<0.85. The crop and tillage index did not add significantly to the model in the case of ASD>9.5 or BD15. Although these numbers would change with more development of the model, they broadly indicate which soil variables are the most/least responsive to the crop and tillage indices. In particular, bulk density and high compaction (ASD>9.5) do not appear to be affected much by the activities measured by the crop and tillage indices.

The crop and tillage indices, however, could be tweaked. They are based on empirical weightings of both the type of activity and how long ago the activity occurred. The weights were based on earlier experiments coupled with informed guesswork. An alternative approach was suggested at MISG, using Structural Equation Modelling to determine the weights. This approach was tried, using AMOS, and looks promising.

Significant regional differences were found in the soil measures even after adjusting for land use, soil order and soil texture. The strength of regional differences after these adjustments was surprising. The LENZ database (Land Environment of New Zealand) was interrogated to identify possible explanations for the regional differences. LENZ categorises sites according to a variety of measures, and data can be found to describe most agricultural locations. Climatic variations (annual rainfall, mean temperature and solar radiation) offered a partial explanation, significantly related to carbon mass, but not sufficient to explain all regional differences. Other components of LENZ may help explain soil order differences. LENZ data could well provide a useful component of a Land Management Index.

There appear to be interactions between the effects of region, land use, soil order and soil texture on the soil measures, for example the effect of land use on the soil measures may not be the same for all soil textures. Unfortunately the categorical data was unbalanced: each categorical variable had at least one category that was not present at all levels of some other categorical variable. For example each region had at least one missing soil order, land use or texture. This made the exploration of interactions difficult. A graphical method was proposed and used to identify those interactions that seemed to be the most important. These were tested in a regression model, but the procedure needs to be repeated with more developed models including more variables e.g. LENZ data. The intention would be to only include interactions when absolutely necessary, as for prediction purposes one needs to avoid over-fitting to the sample data. Also some alleged interactions may just be the result of data errors, and the technique aided in identifying these unusual cases.

An additional question concerned penetration resistance, a measure of soil compaction and therefore the difficulty roots have in entering the soil. Penetration resistance is an important soil measure in its own right, and the data are currently collected, but the results are greatly affected by the moisture content of the soil. The MISG group were asked to consider methods of correcting the penetration resistance data for differences in soil moisture content. A simple model was proposed and calculations suggest the model is plausible.

Finally suggestions were given as to how one could better express the data in a regression model for computation in Excel with new farmers' data, and how to present the results in a way easy to communicate to farmers.
