Economics and Temporal Sustainability of Soil Fertility at two Northern Cropping Region sites in New South Wales

Robert John Farquharson

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Certification

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that, to the best of my knowledge, any help received in preparing this thesis, and all sources used, have been acknowledged.

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Abstract

Wheat production has been a successful and profitable enterprise in northern NSW due in part to favourable soils and the development of technologies and management practices adapted to the particular cropping environment. However, a number of adverse issues associated with natural resource outcomes have emerged for this activity. Some of these (eg soil erosion) have been mitigated by new concepts of tillage and stubble management, but others have only recently become apparent and are still being addressed by farmers and researchers in cooperative research and development processes. Soil fertility decline is a problem which is still causing concern, and is the subject of this thesis.

Some of the natural resource problems in northern NSW are characterised by changes in biological or biophysical outcomes due to farm management decisions, and have been incremental and cumulative in nature. These changes can be characterised as a depletion of stocks of natural resources that have been used as 'free' inputs to the production processes. In light of this, concerns have been raised about the sustainability of crop production. While sustainability has many meanings, one element is the notion that the production process or system must be able to last for 'a long time', or be in a long-term equilibrium. One possible definition of sustainability is an improvement in the productive performance of a system without depleting the natural resource base upon which future performance depends.

Grain farmers make decisions in response to many factors such as economic (eg prices), agronomic imperatives, available technologies, their own knowledge and expectations of underlying biophysical processes, as well as their preferences for types of management. Past decisions by grain growers may have been made without knowledge of likely future impacts on natural resources. The profitable use of a natural resource for agricultural production is an economic problem of inter-temporal stock management. This thesis has combined these strands of thinking to analyse an important contemporary issue in the northern cropping region of New South Wales – the economics and temporal sustainability of soil fertility used in wheat production. A case study approach was used for two sites in the region.

Context for the development of the study was provided by considering the meanings of sustainability and farming systems. A review of soil fertility concepts, and of nitrogen and carbon processes in the soil, allowed the problem to be described in terms of managing stocks of soil fertility by appropriate farming methods. Economic theory and methodology were used to treat the problem in the 'stocks and flows' framework of optimal inter-temporal crop and soil management. The issue tested is whether the extra effort and complexity in such analyses is worthwhile compared to the simpler static economic framework. Wheat is treated as a multi-output product, priced according to protein content, with fertility carryover between crops. Climatic variability is also included, affecting outputs and outcomes in the crop and fallow periods. The model developed allows for potential non-convexities in crop response.

A two-stage process was used to evaluate direct and indirect soil fertility management for wheat production. The first question was 'how much' nitrogen to apply when carryover effects are considered. The results included an optimal stock of soil nitrogen at sowing, which accounts for grain removal at the expected profit-maximising input level and carryover effects in the subsequent fallow, and an optimal application to the crop. The sum of these is the strategic target of total crop available nitrogen in the soil at time of sowing. A tactical approach to dealing with annual fluctuations in soil nitrogen and moisture levels is developed.

The second question addressed in this study refers to soil fertility in the context of soil organic carbon. This measure accounts for the benefits of improved soil structure, water holding capacity, and a range of nutrients besides nitrogen. A hypothesised advantage of improved soil water holding capacity was analysed and fertiliser, tillage and stubble management options were evaluated based on the objective of maximising long-term profit. Associated with the best management strategy is an optimal long-term level of soil organic carbon. In this two-stage approach, the development of optimal organic carbon rules did not affect the optimal nitrogen rules from the first stage.

The main result for nitrogen was that if soil moisture at sowing was 'medium', the strategic target of soil available nitrogen for the wheat crop was 205 kg/ha for a

Vertosol soil at Gunnedah. Ideally this would be made up of an application of 81 units at sowing to an optimal stock of 124 units. However, if measured soil nitrogen was different from the 124 units in any season the tactic would be to apply the difference to make the level up to 205 kg/ha. Similar rules were developed for other levels of soil moisture at sowing.

The main carbon result was that if enhanced soil organic carbon was associated with improved soil water-holding capacity, then it was possible to build up organic carbon by using the above fertiliser rule, retaining stubble and using no tillage. Moreover, an optimal minimum level of soil organic carbon of 2% was indicated as a desirable long-term target.

These results and analyses will be directly useful to farmers for crop nutrient management and to soil scientists and agronomists for developing new research hypotheses. The use of dynamic stochastic bio-economic analysis in a two-stage approach to soil fertility analysis has provided new information and may be useful in answering other questions of contemporary interest. The sustainability of soil fertility in its application to crop production in Australia has not recently been discussed in an economic context. However, questions such as 'what are the optimal levels of carbon and nitrogen for sustainable crop production' lend themselves to economic analysis because of the optimising framework. This study has demonstrated an approach to answering such questions.

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