A framework for understanding the long-term value of pasture leys in cropping systems

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Summary. Farmers are often under financial pressure leading them to make decisions based mostly on a short-term outlook for profitability. When longer-term strategies, such as legume pasture leys, are incorporated into a model of soil nitrogen (N) in cropping systems, the improvement in the natural capital (i.e., soil) brought about by the ley increases grain yields, grain protein, and hence long-term profitability. By including discount rates in the model, the influence of incorporating a legume pasture ley in the cropping system can be measured in terms of long-term accumulated profits, providing information about conservative farming systems in a form relevant to farmers.

Introduction

In a world which is increasingly emphasising economic efficiency in the use of resources, and yet, is also increasingly concerned about environmental issues, it behoves us to grapple with the dilemma of achieving sufficient output without seriously degrading or depleting our natural capital. The sustainability of a productive agricultural system depends on there being adequate levels of economic output (profit) together with adequate maintenance of the natural capital stock (e.g., soil) over the long-term.

In the 1950s, Trumble (11) wrote that, following periods of exploitive cropping, there was ' a marked swing (in Australia) to long-term leys between intensive periods of cropping.' However, in the cropping boom experienced in Australia in the 1970s, little heed was paid to this prior understanding, with some farmers cropping to such an extent that they removed all fences and, with them, the option of a grazing livestock enterprise.

We contend that farm management decisions are usually based on a sequence of priorities, with financial criteria often being given pre-eminence. Next comes a consideration of technical criteria related to animal or cropping enterprises, then pasture resources, and finally soil resources. This ordering of priorities means that decisions are often made in favour of short-term financial profit without adequate regard for the importance of degradative processes related to the basic physical/chemical/biological resources which support future profit. In order to encourage decisions to be made which value the need for appropriate conservation of resources, there is a need firstly to understand the complex relationships which exist between those resources, and present and future profitability. Secondly, some form of (price) signal must be given to impact at the financial level of farmer decision making.

Although the literature contains evidence that farming practices are being examined in models (e.g., 1,2,3,4) which describe many of the long-term effects of cropping on the physical, chemical and biological properties of soil, the literature linking such long-term biological results with long-term economic data (e.g., 9) is scarce. If farmers are principally governed by financial considerations, then we must develop a means of using dollars to communicate the long-term effects of agricultural practices on a farmer's natural capital stock. An outline is given of a means of valuing changes in our resources in present-thy dollar terms, thus enabling the communication of resource implications to farmers in the most relevant terms (i.e., dollars).

Developing the framework

The case study chosen for this paper concerns soils in the Billa Billa region of southern Queensland which have had a continuous wheat cropping history over several decades. There has been substantial degradation of the quality of the soil resource, resulting in yields declining by 2.3% p.a. and grain protein content by 2.4% p.a. (1,2). Changes to soil properties which occur following continuous cereal culture include loss of total and organic carbon; loss of aggregate stability; and losses of total, mineralisable and inorganic N. Because many of these changes occur in parallel and, usually, follow an exponential decay curve, we chose to use as the basis of our calculations, the relationships found in the literature describing the available N supply in the soil (e.g., 1,2,3,4,5,6,8).

The most effective means of ameliorating such soil degradation involves the establishment of a pasture phase. Legumes are especially beneficial (e.g. lucerne), rapidly replenishing losses of available soil N. Holford (5) found the optimum duration of a grazed lucerne ley was 3.5 years. Such a legume phase was found to eliminate any response to N fertilizer for up to five years with a measurable increase in N availability for up to seven years.

A relatively simple model was constructed, based largely on the work of Dalal and Mayer (e.g., 1,2,3) and that of Littler and Whitehouse (8), to enable a budget of available N to be calculated for the 0-60 cm layer of soil. The budget takes into account N removal by the crop (2), N additions *as* fertilizer and through the legume phase (7,8), and the effects of N on grain yield (8), protein (8) and on price (4). The model is not exhaustive in its incorporation of processes; nevertheless it serves as a tool to demonstrate a method of valuing pasture leys in cropping systems by calculating the future value of the N status of the soil in dollar terms.

The exponential decay function for total N was converted to a decline of available N. When N became limiting under the continuous cropping regime, urea fertilizer was added in increasing increments in an attempt to maintain yield and grain protein. For the crop/pasture rotation option, N was depleted during a seven-year wheat cropping cycle, and then was accumulated linearly during the three years of the grazed lucerne phase (6). This 10-year cycle was repeated over 25 years. The gross margins calculated for wheat cropping and for weaner cattle production in the first year from the virgin soil were $198/ha and $105/ha respectively (12), thus suggesting that, at least in the short-term, continuous cropping appeared to be far more profitable. The objective of the analysis was to demonstrate the types of results that could be generated by the model by examining the impact of different cropping regimes on soils and therefore long-term profitability. The procedure adopted was to compare the present value of returns from two cropping regimes: (i) continuous cropping with N fertilizer added when available N was limiting and (ii) regular cycles of cropping for seven years interspersed with grazed lucerne phases of three years duration. The core of the model is shown in equation [1].

$$\text{Max. NPV} = \int_0^{\infty} [P(N_t) f_t(N) - Cn - V] e^{-rt} dt, \qquad [1]$$

subject to d(N,n)/dt = g(N,n, crop choice), and N(0) = N,

where NPV is the present value of returns; P is the output price which, for wheat, is a function of protein content and hence dependent on N available (sum of soil[N] and fertilizer[n]);f (N) is the crop yield as a function of available N; C is the unit cost of fertilizer; n is the quantity of N fertilizer applied; V is other production costs; g is a function describing N dynamics of the soil; and r is the discount rate. The solution of [1] requires that the dynamic profit in equation [21 be maximised in each time period.

$$\underbrace{\text{Dynamic Profit } (\pi_t) = \text{Price}^* f\, N_t)}_{\text{[- - - term 1 - -]}} \underbrace{- \text{Cn} - V_t}_{\text{[term 2]}} + \underbrace{\frac{(\text{future value of } N_t)^* \Delta N}{(1+r)t}}_{\text{[- - - - - - - term 3 - - - - - -]}} \qquad [2]$$

where 'It is the dynamic profit and N is the N content of the soil at time 't'; and N is the change of N status of the soil (which is +ve or -^{y}e during the pasture or cropping phases respectively). In the expression for dynamic profit, term 3 accounts for the future effects of current decisions. If farmers are not concerned about future effects, they will tend to maximise only the current profit which is given by the terms 1 and 2 in the RHS of equation [2]. Equation [2] shows that a decline in N caused by a current decision to deplete soil N reduces dynamic profit by the amount of future losses caused by such decisions.

The choice of cropping system is complicated by the problem of returns flowing in over a number of years. The discount rate is the percentage by which we reduce the value of a flow of income in year t + 1 to make it comparable to a flow of income in year t. Therefore, if the discount rate is 10%, one dollar today is considered the same value as $1.10 one year from now and $2.60 (= 1.1^{10}) 10 years hence.

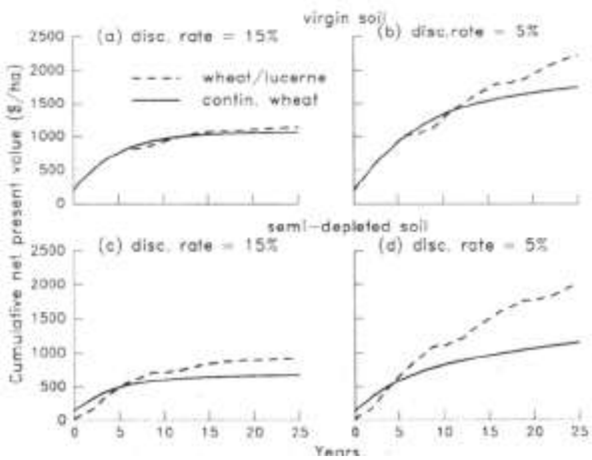

Figure 1. Prediction of 25-year cumulative profit (as NPV) derived from model of crop or crop/pasture systems incorporating either exploitive (r=15%) or conservative (r=5%) discount rates on virgin or semi-depleted soils.

There are strong arguments supporting the notion that society applies a lower discount rate than do individuals in their decision-making (7). Increases in farm debt levels and higher interest rates over recent years have increased the financial pressure on farms. Thus, there is a tendency for farmers to have short-term views (i.e., a high discount rate) often favouring continuous cropping over a crop/pasture rotation. This is in contrast to society which, with its lower discount rates, would favour cropping less, because it places a higher present value on the future losses from nutrient depletion thus favouring the adoption of a more sustainable use of natural capital (10).

Results and discussion

Typical model results are shown in Figure 1. A 15% discount rate might be used to represent farmers who take a shorter-term perspective in their farm decision-making than society typically does in such natural resource-sensitive areas. The 5% discount rate gives a societal decision-making perspective.

The results show that, although in all cases the short-term profitability of continuous cropping is at least as good as that from crop/pasture leys, the latter system leads to substantially increased cumulative profits, especially when the soil is already in a semi-depleted state and when a low discount rate is used. The fact that the curves of the crop/pasture ley system tend to continue to increase over the long-term indicates that both the product output and financial returns are more sustainable than with continuous cropping. This is due to the maintenance of the natural capital and avoidance of the severely reduced cropping gross margins which occur if continuous cropping is practised over the long-term.

Thus, the output of such a model provides a means of conveying to farmers, or to society, the dollar consequences of cropping systems which differ in the degree to which they exploit natural capital such as soil. In each of the four figures presented, any short-term losses experienced with the pasture ley system are far outweighed by the long-term gains brought about by the effects of the ley on the profitability of subsequent cropping. However, with high discount rates, the magnitude of the gains made in cumulative profit are necessarily small.

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