Evaluating the effects of land management systems on soil characteristics: some confounding problems in experimental design

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Abstract

A series of research projects over the last decade have had some unexpected outcomes, at least partly from the effects of confounding by uncontrolled variation in factors outside the experimental design. The most pervasive is the overarching effect of the land manager, their paradigm, commitment, motivation, competence and application. To compare land management systems, most experimental designs compare two or more adjacent or close by operations, and take great care taken to standardise the non variable biophysical factors (soil types underlying geology, etc) and system factors, (seed, fertiliser regimes, tillage, livestock type and number, overall grazing rates, etc), but how does the researcher standardise for land manager variation? Even fence line contrasts between systems on the same landholders land suffer from the attitudes and motivation of the land manager. The other, and an equally difficult issue to control relates to seemingly inconsequential differences not considered in the experimental design. For instance the contrast of two or more land management systems that examines the effects of grazing rotation, but the researcher finds that the ways in which grazing pressure are calculated is by different means; or a land management system contrast where a paddock in one system is cut for hay and in the other is grazed. In recent research all these effects have been felt and on some occasions the experiment was unable to be used to come to a sensible conclusion because of the confounding effect of uncontrolled variation.

Key Words

Land management systems, experimental design, confounding factors.

Introduction

The increasing interest in carbon (C) sequestration and the ever escalating political debate on the role of agriculture, not to mention inclusion or exclusion in a future protocol has led to a burgeoning interest among research students in soil C (SC). Interest amongst likeminded bodies such as Greening Australia and the NSW Government bureaucracy has led to a number of cooperative research projects, but the sites selected and the “treatments” led to a number of uncontrolled variations. Landholders are being encouraged to consider SC in roles as different as soil physical characteristics (soil water holding capacity, infiltration capacity, aggregate stability, to mention a few), soil chemistry (nutrient storage, buffering and uptake) and soil biology and ecology (as habitat, a substrate, a food source, plant exudates, VAM and other fungi, bacteria and viruses, and other micro organisms). The problem is that many of the more conservative and sustainable land management systems have little more than anecdotal evidence to back them and land managers are committing their financial future on decisions based on very little data, not to mention the dearth of analysis. Political discussion about long term C storage in soils with substances such as biochar and organic matter conversion in processes such as pyrolysis are examples where the validation experiments have not even been planned at this stage.

Addition of organic material as living organisms (agricultural and grazing management) and as already decomposing materials such as mulches and compost can be incorporated in already existing land management systems without large changes to landholder paradigms. These management systems seem to hold the greatest returns, because the changes made to increase C inputs, storage and cycling have huge benefits to the agricultural and grazing enterprises without risking returns and any additional financial returns from C sequestration would truly be cream on the cake. To this end projects examining a range of land management systems has been carried out. Each of those described turned up another example of an uncontrolled variation and a concomitant confounding of results, fortunately for the researcher in each case a rescue in the form of some more intricate statistical analysis, addition of extra data sets, or a careful redirection of the design and analysis brought home a worthy and viable project.

Methods

A range of projects conducted recently will be used to illustrate the examples of confounding factors.

Results and discussion

One example will suffice for the first set of issues – land manager commitment. In a recent study a researcher (Cheeseman 2006) set out to compare Biodynamic grazing systems with conventional systems on 5 different paired landholdings. In fence line contrasts Cheeseman set about comparing a range of soil attributes relevant to productivity and sustainability including; infiltration, bulk density, soil microbial respiration, SC and macro invertebrate counts. Cheeseman makes the point in his conclusions that he could explain the differences across the fence lines but being a Biodynamic manager or conventional operator ended up being only one of the explanatory variables. What is now called "operator variance" in our research circle has come to include the problem of land manager commitment to the system being managed, levels of competence in carrying out that system, levels of enthusiasm, financial commitment, and what many an innovative land manager has called "passion" on one side of the fence can often have a much greater effect than the actual system being implemented. The work of Cheeseman (2006) also had issues with land managers deciding to cut hay rather than grazing after agreeing to take part in the "experiment", forgetting that an area had been fertilised some 5 or more years earlier, limed or had a potent herbicide application, not to mention the inclusion or not, of rotational grazing without describing such likelihoods to the potential researcher.

In a project designed to examine the addition of C to the landscape by growing trees (deep rooted woody perennials) found in addition that direct seeded windbreaks and woodlots may have a C sequestration value, but a much more substantial return was from a "subsidiary effect" of the additional farm income that could be made available as a result of sheltering livestock and crops in the harsh weather conditions on the tablelands and slopes (Read 2008). The project also became an "effects of grazing", or not, of the windbreaks, when it turned out that some of the land managers regularly grazed their belts while others had only ever had stock in when fences went down. The effects were increased SC in the grazed belts, more than likely due to the more rapid decomposition of litter from the nutrients and microbes in excreta and from stock trampling and breaking up the litter. The incorporation of additional C into soils in pastures and crops resulting from hydration in flood plains under Natural Sequence Farming (NSF) techniques showed some benefits to SC but when the other benefits of increased biomass production, water retention on farm, increased yields of crops and pastures and the reduction in erosion by wind and water were all considered (Weber 2008), it appears that a difference in grazing rates had a greater effect than did "hydration". The saving grace was that one paddock on the NSF property was quite inaccessible and had a grazing history in the previous few years that was much more similar to the non NSF paddocks and in this one there were measurable and significant positive changes to a range of soil attributes, and a chance to make meaningful comparisons.

Changes to grazing systems such as Time Control Grazing not only benefit soil C but they allow sustainable increases in overall carrying capacity of livestock, reduced soil erosion, increased infiltration of rainfall, increased soil water storage, and better soil structure (Anderson 2004). There were however issues that were similar to Cheeseman (2006), but on this occasions all the fence line comparisons were within each of the 5 farms being studied. The issue then became the lack of commitment of the land manager to the conventional set stocking and because it had become abundantly clear to each of them that TCG was preferable, their commitment to maintaining set stocked paddocks faded over the 15 years of the experiment. The result was that ram and bull paddocks, paddocks near the house kept for the "killers" and others such as laneways had to be used. The problem was exacerbated because the overall grazing rate in these specialist paddocks was in general much lower then the TCG paddocks. Nevertheless, soil attributes were able to be discerned and concomitant increases in pasture perenniality came with carefully managed rotational grazing (Anderson 2004). The original project was unable to be completed and the benefits TCG brings in increased SC to considerable depth (anecdotally) have yet to be quantified.

The effects of pasture cropping (PC) have also been examined in detail by recent studies (James 2009; Warden, 2009) with on going research to examine the overall economics of the different systems. The general conclusion seems to back up widely held beliefs in the farmer and researcher communities that constant year round ground cover (living perennial plants and organic matter), absolutely minimal or zero tillage, short sharp grazing episodes with very long rest periods (ie ungrazed), and minimising inputs (fertiliser, a variety of biocides) all lead to not only increasing levels of soil C, better soil physical attributes, and more balanced soil nutrient levels in better buffered soil chemistry, but to increased profitability and reduced financial risk. The problem came in this research when those carrying out the research began to realise that although all land holders practised PC, PC itself was expressed in many forms, in fact in more forms that there were land holders, because two managers had two variants each operating on their properties. The researchers went on to note anecdotally, that a general reduction in levels of stress in the landholder community was observable, for those who are using these alternative systems and that may have also affected their results.

The techniques for measuring SC are currently many and varied and it appears that so are the results obtained by the variety of methods currently in use. There has been a glaring need to try and standardise these measurements because the politicians are currently quoting the lack of a consistent measurement technique as a very strong reason for not including agriculture in a C trading scheme. A recent study by McRorie (2009) has compared the Weil, Walkley-Black and Blair methods across a range of soils, and across a range of land management systems, while also comparing systems of representative sampling, problems of soil heterogeneity, sampling across and down slope positions and sample preparation techniques (McRorie 2009). Issues arose when data from otherwise reliable sources turned out not to be, and the experimental design had less soil types and systems covered and the reduction in what was to be variation led to a need for more intricate and complex statistical analysis. Nevertheless the Weil method turned out to be the most reliable, safe to use technique, and at the least cost for measuring SC, but sampling protocols, and sample preparation and sub-sampling protocols have to be used to get representative data to make decisions. In addition, the greatest disadvantage is that the Weil technique is marginally less able to be used to differentiate between land management systems, despite being very highly and significantly correlated with Walkley-Black (McRorie 2009).

Conclusion

Our conclusions after the last decade of work are that even greater care has to be used when working in the real world, with land managers operating real world businesses. On the other hand, research in these situations is rewarding and alternative agricultural and grazing systems do in general lead to better outcomes in a truly triple bottom line analysis. Grazing systems need to include rotations with long ungrazed spells; cropping should be carried out with continuous ground cover, and with zero tillage. Systems that combine the use of animals in a symbiotic relationship with cropping, and by doing so reduce or eliminate chemical inputs, have multiple benefits. They produce benefits on all of the (triple) bottom lines: better and more reliable profitability, with less land degradation and measurable rehabilitation of soils, and while the social factors are still being investigated anecdotal evidence to date suggests that communities will benefit too.

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