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GEO 240: Soil Resource Management.

Assignment Three: Soil Research Issue.

A report documenting the impact of different agricultural management actions; no till versus conventional till, on soil biological populations and diversity.

Abstract:

The comparison of different tillage regimes on two properties north of Gulgong, New South Wales, shows significant impacts of conventional tillage and no-till practices on soil biological populations and diversity.

Pasture cropping a no-till management strategy that involves sowing winter fodder crops into existing native perennial pastures; resulting in increased levels of soil biology associated with increased groundcover.

Additional benefits of pasture cropping include better soil structure associated with increased soil porosity, which in turn creates habitat for soil microbiology to benefit other predatory organisms. Consequently pasture cropping can be seen as a regenerative tool for sustainable agriculture.

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1.0 INTRODUCTION.

This report investigates the impact of different agricultural management practices, namely tillage regimes, on soil macro-biological populations and biodiversity. In this way, the use of basic experiments and assessment procedures have been applied to different tracts of land on neighbouring properties to assess the effect of no-till practices versus conventional till practices.

The biological assessments were carried out on two adjoining properties in the central west catchment, New South Wales; 'Winona' a merino and kelpie stud (840ha) and the adjoining property (no name) grazing merino sheep and some cropping (800ha). The properties are located north of Gulgong and are characterised by 'granitic loam' soils and sedimentary geology with exposed granite rock being common along sloping topography (Cluff, Seis and Jones (1998).

Colin Seis, the owner of 'Winona' manages his productive paddocks using a zero-tillage method known as pasture cropping where fodder crops such as oats, can be sown directly into native perennial pastures. Barry Seis manages his adjoining property conventionally and crops a percentage of his land with multiple passes followed by seeding. Consequently, the two properties provide a contrasting view of agricultural management practices and their impact on both soil biology and other soil health factors such as compaction, fertility and overall soil structure.

1.1 Pasture Cropping as an Ecologically Sustainable Alternative to Conventional Cropping.

The benefits of a grazing system such as pasture cropping can be measured in a variety of outcomes including economic, ecological and social arenas. It has been deemed as more than an agricultural land management practice by Seis (n.d.) who states “pasture cropping is more than a simple cropping technique…it is the combining of cropping and grazing into one land management system where each one benefits the other”. Furthermore, Cluff, Seis and Jones (1998) acknowledge “the intrinsic ecological benefits associated with permacropping provide a framework for addressing a suite of land degradation problems concurrently with cash flow”. In this way, pasture cropping exceeds the expectation of contributing to ecological sustainability and addresses valid concerns for economic profitability and in turn passes these benefits on to the agricultural community by being accessible, economically competitive and comparative to existing land management strategies.

According to Seis (2001) the management term of pasture cropping involves “high density short duration grazing (pulsed grazing) combined with cereal crops direct drilled into standing native perennial pasture (pasture cropping) on the same land in the same year”. Due to the nature of pasture cropping, many outcomes have been noted including increased percentage of groundcover (up to 100% coverage), increased grazing opportunity and reduced reliance on inputs such as fertiliser and herbicide (Seis 2001). From these outcomes multiple benefits have been noted as: a) increased biodiversity of native vegetation associated with 100% groundcover and zero tillage, b) increased profit margins associated with opportunistic grazing, and reduction of relance on inputs and c) improved ecological health associated with increased biodiversity and minimised alteration of the landscape. However, it is the ecological benefit associated with pasture cropping in conjunction with economic pressure as a reality that is seen as innovative and provides a possibility as an alternative to conventional cropping.

1.2 The Effects of Tillage Regimes On Soil Biological Health.

It has been established that conventional land use management practices involving heavy tillage regimes, removal of vegetation/groundcover and reduction of biodiversity through the advent of monoculture have contributed to a loss of soil structure, increased groundwater table in conjunction with salinity, increased soil and water erosion and associated environmental problems, to a certain extent, even resulting in a loss of income. Eijsackers and Quispel (1988) have ascribed detailed outcomes such as: the deterioration of soil structure and organic matter content, increased levels of toxic substances in the soil, high levels of nutrients in ground and discharge water, high risks of soil pests and diseases and the reduction of useful soil organisms such as mycorrhizal fungi and nitrogen-fixing bacteria, to the use of heavy machinery, short crop rotations, and injudicious draining, clearing and pest management associated with conventional agriculture and forestry.

In this way, conventional cropping practices to date, “have contributed to soil structural decline, markedly increased the risk of erosion and salinity and reduced the level of biological activity in the soil” (Cluff, et.al. 1998). Cluff, et.al. (1998) also concede that “there is neither diversity nor inter-connectedness in any type of annual cropping system currently practiced”. Therefore biological diversity and associated soil biological health may be seen as a lacking entity in current grazing/cropping systems.

On a deeper level, the effects of tillage on soil biological health can be seen as an alteration of soil pore space. Commonly a reduction of soil pore space can be associated with tillage machinery causing compaction; whereby “the number of macropores may limit habitat availability where there is a high degree of compaction” (Eijsackers and Quispel 1988). Similarly Eijsackers and Quispel (1988) cite ‘pore size distribution’ as a measure of predator-prey relationships between micro and mesofauna, and ‘the size of pore necks leading to pores' as a measure of specific habitat corresponding to specific organisms, for example microaggregates being a specific habitat for soil bacteria. Therefore the importance of adequate soil pore space and hence the importance of a well structured soil is seen by equating soil pore space with biological habitat. In this way, the optimal functioning of biological populations is desired in an agricultural sense, even more so in a cropping enterprise because of the nature of cropping (removal of stored nutrients in the form of grain from the soil). Consequently biological activity and good soil structure can be seen as an essential ecological interaction that contributes directly to soil health.

As a result of lack of biodiversity, alternative tillage management and corresponding soil health management may provide benefits in all areas of concern regarding agricultural management. In this way, "varying the tillage management and the management of organic matter residues will provide an efficient tool for manipulating the biological processes in the soil" (Eijsackers and Quispel 1988). Similarly, Sattler and Wistinghausen (1989) take an ecological perspective that "tillage should be as infrequent as possible…to minimise the compaction caused by machinery and give the soil adequate opportunity to develop structure and build up humus". However, Widdowson (1987) agrees with Eijsackers and Quispel (1988) by viewing the soil as a productive substratum where "the importance of ecological functioning soil organisms relates to the conversion of living matter to the colloidal state" and as such "husbandry methods must take note of their presence and try to provide conditions for their maximum performance". Consequently, it is agreed that the productiveness of the soil is implicitly connected to soil biological activity and as such the preservation of soil biological habitat through alternative tillage regimes is essential.

Therefore as the proposed ecological benefit of pasture cropping is recognised as increased biological activity associated with increased groundcover, then a series of specific assessments were employed such as the use of: pitfall traps to collect terrestrial organisms, SOILpak visual assessment of soil profile layers and topsoil/leaf litter sampling using Berlese funnels. In this way, the soil visual assessment is designed to indicate the overall structure of the soil by assessing compaction and porosity levels, while the other tests indicate species abundance and species diversity of available organisms living within the soil structure.

2.0 SAMPLING AND RESEARCH METHOD.

For the purpose of this report, a paddock from 'Winona' and a paddock from "" were chosen for their similar features; both paddocks had been cropped using the respective practices three years prior, both paddocks have north-east aspect, and both paddocks share the same soil type and characteristics and are adjacent to each other separated only by a laneway (see the following figures 2.1 and 2.2 below).

Figure 2.1 The Layout of Pitfall Traps in the Pasture Cropping Paddock

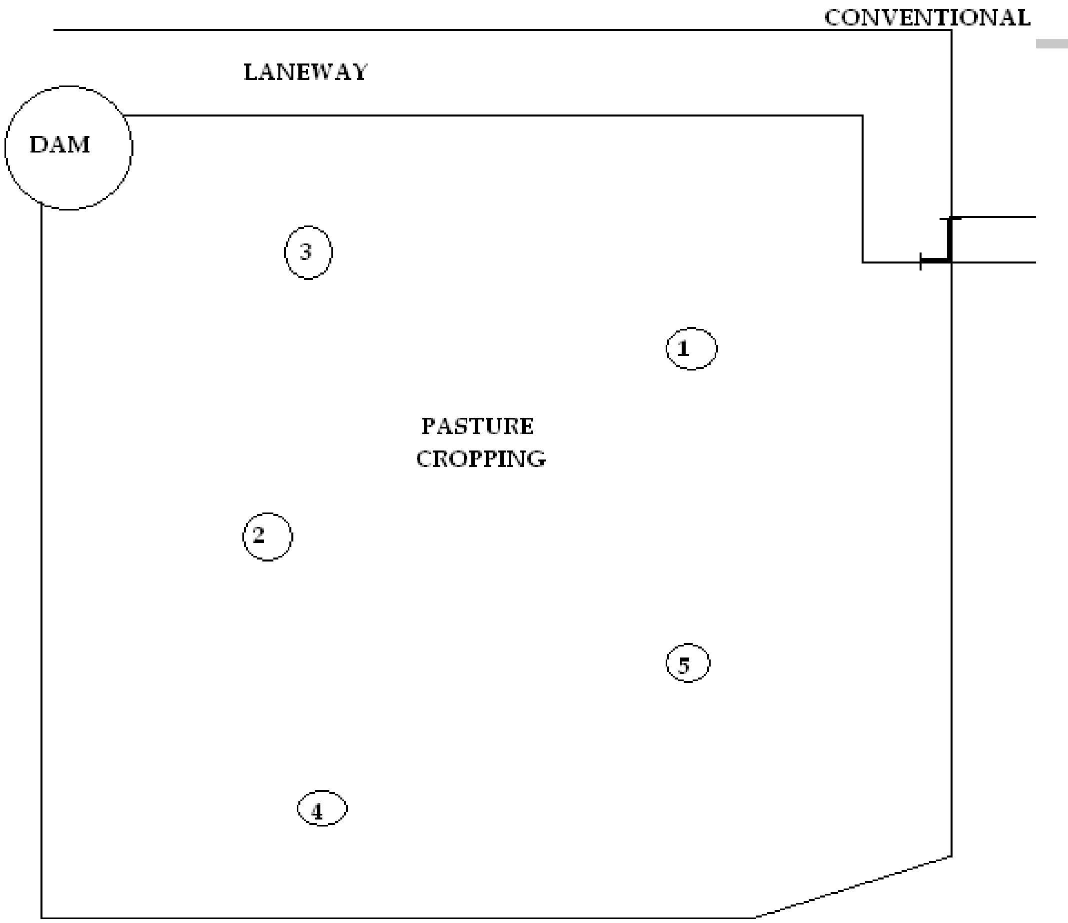


Figure 2.1 shows the configuration of sampling sites within the paddock..

As figure 2.1 shows, the random sample sites are spaced irregularly across the paddock in order to best encapsulate a biological view of these soils.

Figure 2.2 The Layout of Pitfall Traps in the Conventional Paddock.

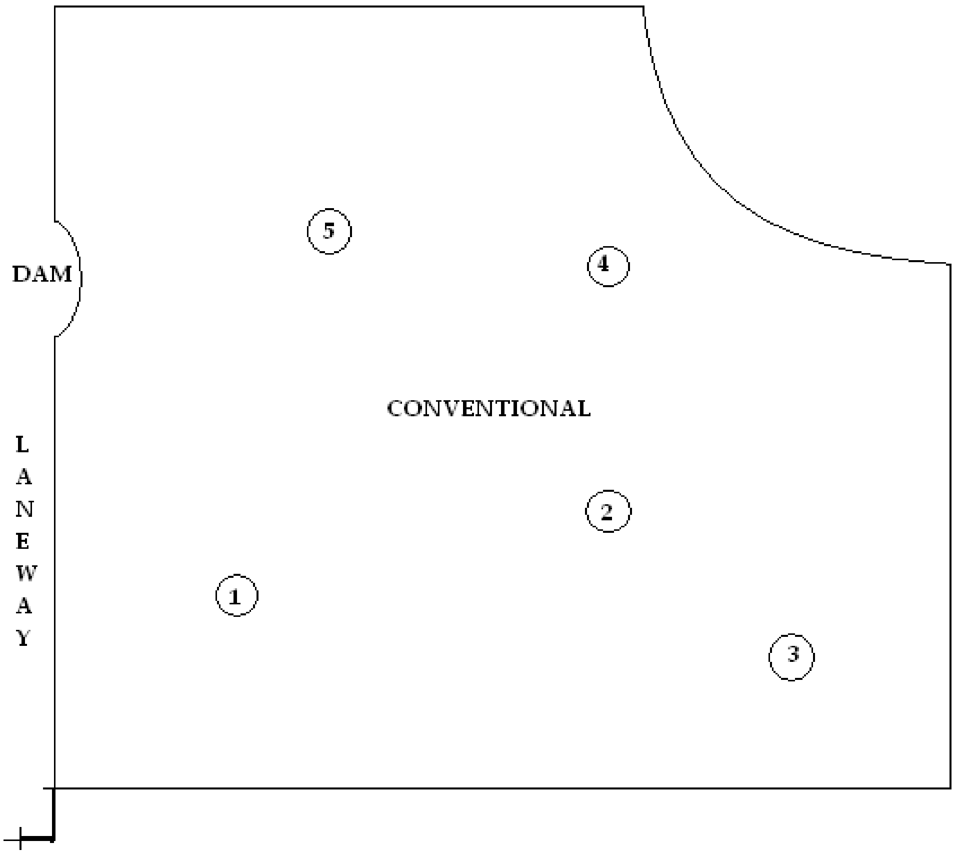


Figure2.2 shows the random spacing of samples in the conventional paddock.

As the above figures show, sample sites were randomly chosen as the sites for pitfall traps; designed to assess the population and diversity of above-ground organisms such as macro-arthropods and other mesofauna and macrofauna. For the SOILpak visual assessment a site was chosen in each paddock away from the disturbed areas of the pitfall traps and additionally a control sample was taken to compare the cropping area soil characteristics with an area on ‘Winona’ that had never been cropped. Similarly topsoil and leaf litter samples for Berlese funnels were collected during the excavation for the SOILpak visual scoring.

2.1 Sampling Methodology for Pitfall Traps.

The sampling methodology for pitfall traps was adapted from Discovering Florida Scrub (2000) and involved constructing 10 pitfall traps (5 for each paddock) to be sunk into the ground by excavating a hole and burying the trap to a sufficient depth so as the lip of the trap was in line with the soil surface level (see figure 2.3 and methodology below).

Figure 2.3 A Pitfall Trap.

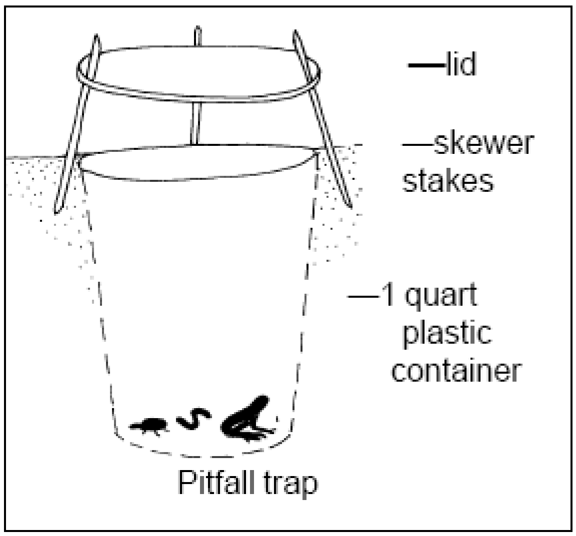


Figure 2.3 shows the design of a pitfall trap in the soil (after Discovering Florida Scrub 2000)

The construction of the traps involves:

1. collecting 10 recyclable containers with removable lids,
2. skewer 4 toothpicks through each lid to act as a prop,
3. attach the other end of the toothpicks with sticky tape to the outside of the containers,

4. bury the completed containers in the soil and mark with bright coloured ribbon for easy field identification (see figure 2.4),

5. leave traps for 24hrs undisturbed,

6. retrieve traps and trapped organisms after specified time and bag and label the contents of each trap for identification in laboratory.

<u>Figure 2.4 A Pitfall Trap in Use at 'Winona'.</u>

Figure 2.4 shows a completed pitfall trap in use at Winona.

2.2 Sampling Methodology for SOILpak Rapid Visual Assessment.

The SOILpak sampling methodology was adapted from (SOILpak pocket notes n.d.) and involves digging a soil profile to 40cms and analysing the information taken from the visual assessment of the soil profile and converting it into weighted values for different characteristics. The soil scores are assessed through characteristics such as: clod size, ease of breakage, clod shape, the proportion of primary clods within compound clods, and internal porosity of clods.

The method for SOILpak rapid visual assessment involves:

1. preparing a soil profile by digging to 40cms and extracting an intact block of soil, (photograph or note any distinctive features),

2. using the SOILpak scoring procedure, score each level of the soil profile according to different characteristics,

3. process raw scores to produce a ratified score for each layer of the soil profile.

2.3 Sampling Methodology for Leaf Litter using Berlese Funnels.

The leaf litter sampling methodology was adapted from Discovering Florida Scrub (2000) and involved taking leaf litter and small topsoil samples during the excavation of soil for SOILpak rapid visual assessment for analysis in the laboratory using Berlese Funnels.

Leaf litter sampling using Berlese funnels involves:

1. collecting leaf litter samples in bags,

2. in laboratory, empty each sample into a Berlese funnel and identify the organisms that are found subsequently.

3.0 RESULTS OF TESTING SOIL BIOLOGICAL POPULATIONS.

Upon primary investigation of the paddocks there were two general conclusions regarding subtle differences between different management strategies. An observation of the conventionally managed paddock showed very patchy, uneven distribution of groundcover per square metre compared with that of the pasture cropping paddock (see figure 3.1 below).

Figure 3.1 The Distribution of Groundcover in the Conventionally Managed Paddock.

Figure 3.1 shows an uneven distribution of groundcover that appeared in a striated pattern as a witness of tillage lines.

In figure 3.1 above, a relative comparison of groundcover versus bare soil per square metre shows that up to 30% of the conventionally cropped area is bare; indicating that this percentage of total area may not have recovered from cropping almost three years ago. In comparison, the pasture cropped paddock showed 100% groundcover or even distribution of groundcover per square metre (see figure 3.2 below).

Figure 3.2 The Distribution of Groundcover in the Pasture Cropped Paddock.

Figure 3.2 shows 100% distribution of groundcover per square metre.

As figures 3.1 and 3.2 show, the fundamental comparison between the two paddocks in terms of groundcover alludes to the increased percentage of perennial groundcover in the pasture cropped paddock and therefore indicates a fundamental outcome of tillage; the disturbance of perennial groundcover.

Secondly, a rapid assessment of the biodiversity levels in each of the paddocks showed a higher number of organisms found interacting (dwelling in or feeding from) within the pasture cropped paddock compared to the conventional paddock. In this case, during my time spent in each paddock (over 4hrs) setting the pitfall traps, I observed a range of insects such as soil-borne larvae, moths, butterflies and grasshoppers as well as three granivorous bird species within the pasture cropped paddock, whereas in the conventionally cropped paddock I observed only flies and one species of granivorous bird. Therefore from preliminary assessment and observation, a great difference in soil biological populations and diversity were noted.

3.1 Results of the SOILpak Rapid Visual Assessment.

The following results present general comments regarding the soil profile and additionally the tables present the SOILpak scores calculated in the field. The final row in each table shows the actual score for each horizon, which is calculation of raw scores against weighted values to provide an average score.

<u>Pasture Cropping</u>

General comments: soil very siliceous – high silica due to granite intrusive rock, good root depth down to 40cms, presence of larva and good overall porosity.

Soil Scores Table A:

Soil factors:	0-10cms	10-20cms	20-30cms	30-40cms
1) Clod size;	1.5	1	1	0.5
2) Ease of breakage;	1	0.5 – dry	1.5	1
3) Clod shape;	1.5	1.5	1.5	1.5
4) Clods within clods;	2	2	2	2
5) Porosity;	2	1.5	1.5	2
Actual score	1.5	1.1	1.4	1.1

<u>Conventional Cropping</u>

General comments: very hard, impervious, white/orange, clay/rock layer about 20cms below surface, little to no biological activity.

Soil Scores Table B:

Soil factors:	0-10cms	10-20cms	20-30cms	30-40cms
1) Clod size;	0.5	1	NA, Too hard	NA, Too hard
2) Ease of breakage;	0	1		
3) Clod shape;	1.5	1		
4) Clods within clods;	2	2		
5) porosity;	1	0.5 high silica – tight pore spaces		
Actual scores:	0.8	1.1	0	0

Control Area

General comments: high rock content.

Soil Scores Table C:

Soil factors:	0-10cms	10-20cms	20-30cms	30-40cms
1) Clod size;	1	0	0	0 rock
2) Ease of breakage;	0.5	1	0 rock	0 rock
3) Clod shape;	1	0.5	0 rock	0 rock
4) Clods within clods;	2	2	0.5 some clods	0.5 some clods

5) porosity;	2	1.5	0.5	0
Actual scores:	1.1	0.7	0.1	0.03

3.2 Results of the Pitfall Traps.

The following table present the results of the pitfall traps by listing organisms caught in their corresponding traps.

Management Conditions:	Pitfall Trap Sample no.:	Species collected:	No. of organisms collected
Pasture Cropping:	1	Spider sp. type a	1
	2	Ant sp. type a – 3mm long, shiny black thorax and abdomen Ant sp. type a – 3mm long, shiny black thorax and abdomen Collembola sp. (springtail) Pscocid sp. (booklouse) Coleoptera; Rhyzobius sp. (black ladybird)	13 adult 11 juvenile 1 2 2
	3	Ant sp. type a – 3mm long, shiny black thorax and abdomen Ant sp. type a – 3mm long, shiny black thorax and abdomen Ant sp. type b – 5-7mm long, brown thorax, shiny green abdomen Acarina; Halotydeus destructor Hemiptera; psyllid (plant louse)	7 adult 20 juvenile 2 1 1
	4	Spider sp. type b Ant sp. type a– 3mm long, shiny black thorax and abdomen Ant sp. type a– 3mm long, shiny black thorax and abdomen Acarina; tick sp. a (pea weevil) Nyssius sp.; (rutherglen bug) Coleoptera sp.	1 20 adult 18 juvenile 1 1 1 1
	5	Ant sp. type a – 3mm long, shiny black thorax and abdomen Ant sp. type a – 3mm long, shiny black thorax and abdomen	18 adult 1 juvenile
Conventional:	1	Ant sp. type a – 3mm long, shiny black thorax and abdomen Ant sp. type a – 3mm long, shiny black thorax and abdomen Spider sp. type b	1 adult 1 juvenile 1
	2	Coleoptera; possibly cryptophagidae	1
	3	Coleoptera; curculionoidea (weevil) Ant sp type b Coleoptera; possibly Pscocid (2-3mm)	1 6 1

		Ant sp. type a Ant sp. type a Diptera sp. spider sp. type c	1 juvenile 2 adult 1 1
	4	Nil – trap damaged by sheep	
	5	Spider sp. type c Spider sp. type c Ant sp. type a Ant sp. type b	1 juvenile 1 adult 1 adult 1 adult

3.3 Results of Leaf Litter Samples tested in Berlese Funnels.

The following table presents the results of organisms collected in leaf litter samples and processed in Berlese Funnels.

Management Conditions:	Species collected:	No. of organisms collected:
Pasture Cropping:	Coleopteran larvae, possible polyphagia sp. a) Dipteran (adult) a) Tick/mite species a) Woodlouse species a) (adult) Woodlouse species a) (juvenile)	1 1 1 1 1
Conventional:	Ant species a) (adult)	1
Control:	Nil	Nil

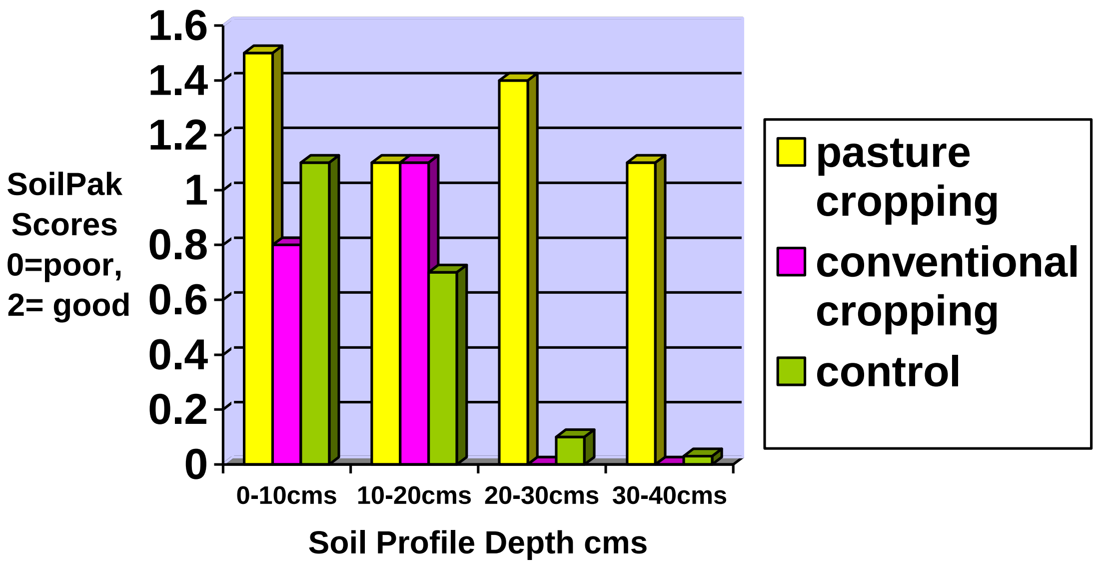
4.0 DISCUSSION.

Together, the results of each assessment showed a vast difference in both the populations of organisms and the diversity of organisms inhabiting the zero-till, pasture cropped paddock versus the conventional tilled paddock.

The results of the SOILpak tests showed higher scoring for pasture cropping in the topsoil (0-10cms) and in the subsoil (20-40cms) (see figure

4.1 below). The upper B horizon (10-20cms), shows conventional cropping and pasture cropping with the same score which can be accounted for by the overall soil structure; a harder clay layer appears (to a lesser extent in the pasture cropping paddock) in both paddocks yet the pasture cropping paddock scored higher on porosity and clod shape than the conventional paddock. Another factor mentioned in the SOILpak test is the moisture content of the soil. At the time of testing the soil was very dry and this could have affected factors such as ease of breakage.

Figure 4.1 Soilpak Scores For Different Management Units.

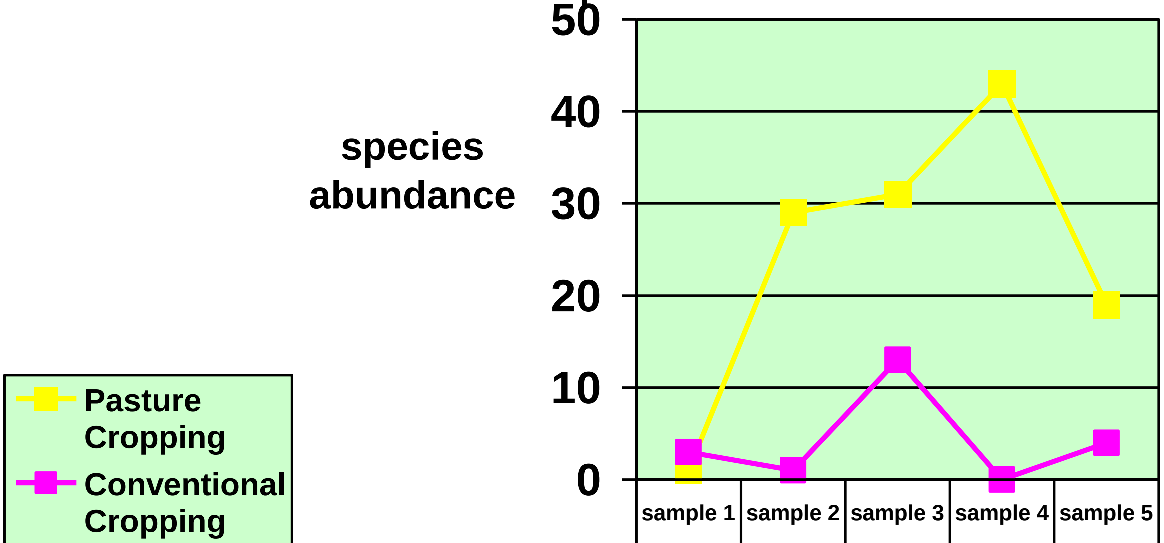


As the figure above shows the conventional paddock also scored 0 for the subsoil profile due to an impervious clay/rock layer; indicating a generally poor soil structure for the conventional paddock. Similarly the control samples show a general decline in SOILpak scores with depth which confirms the presence of rock in the profile.

Overall, the SOILpak scores indicate a better soil structure and less compaction in the pasture cropping paddock due to high porosity, ease of breakage and a high proportion of primary clods within secondary clods. It is this last factor of 'clods within clods' that provides macro and microporosity and thus a habitat for micro and mesofauna. As Eijsackers and Quispel (1988) show "the pores between microaggregates but within macroaggregates are large enough to accommodate small nematodes and protozoa and may be the chief habitat of fungi". Therefore this increased porosity is deemed desirable in any agro-ecosystem.

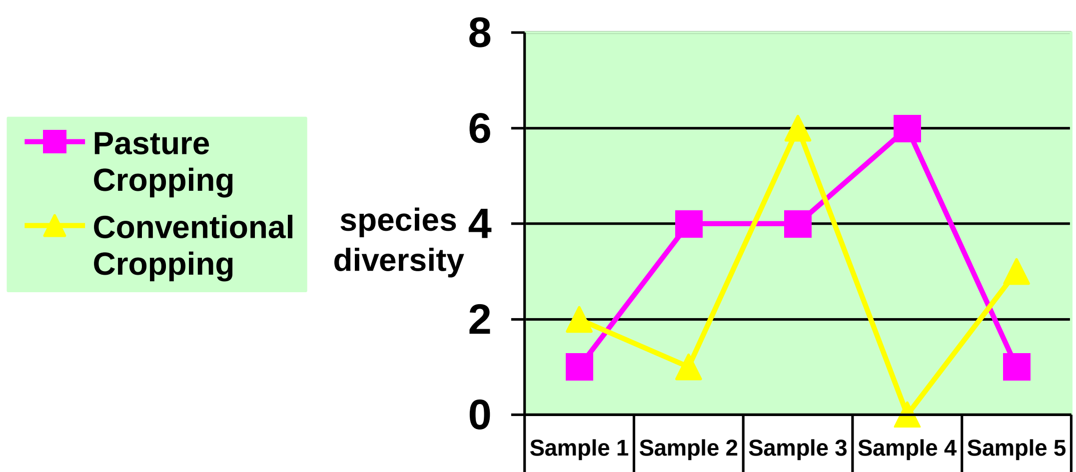
The assessment using pitfall traps provided a mixed outcome in terms of species diversity and populations. As figures 4.2 and 4.3 show (below) the abundance of organisms found in the pasture cropping paddock is clearly higher than those found in the conventional paddock. However, the diversity of species in each paddock varies. This variance could be attributed to the sampling method, for instance, the notion of the traps are designed to catch organisms that are in the vicinity of the trap and depending on the time of day, seasonality, food source and the presence and duration of grazing, the availability of organisms in one such area may change independently of the agroecosystem setting. At the time of setting and collection of traps, sheep were being grazed in the conventional paddock thus skewing the presence of coleopteran beetles, flies and possibly ticks. In this case the conventional paddock showed a general lack of biodiversity, yet one sample (sample 3) showed a high level of biodiversity; uncharacteristic of the other samples.

Figure 4.2 Abundance of Organisms Found in Pitfall Traps.



	sample 1	sample 2	sample 3	sample 4	sample 5
Pasture Cropping	1	29	31	43	19
Conventional Cropping	3	1	13	0	4

Figure 4.3 Diversity of Organisms Found in Pitfall Traps.

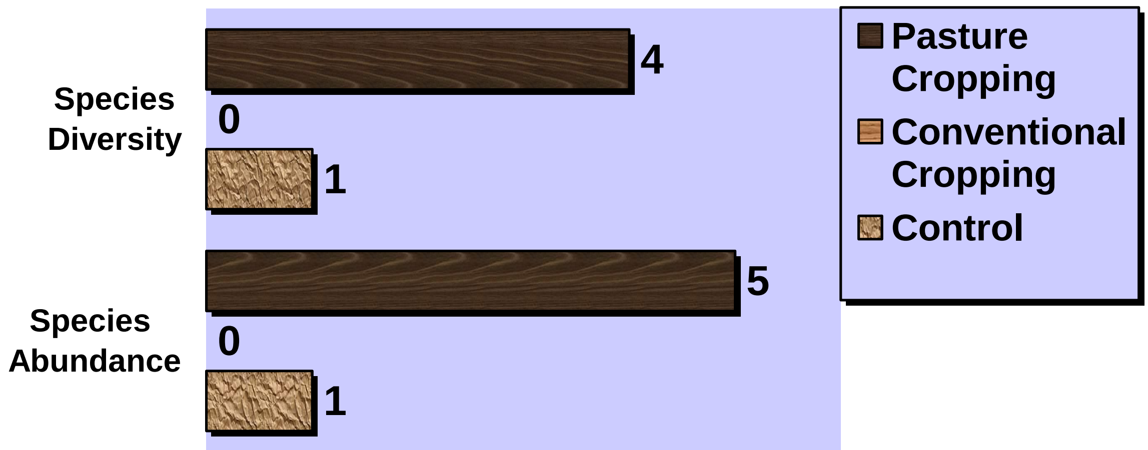


	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Pasture Cropping	1	4	4	6	1
Conventional Cropping	2	1	6	0	3

In addition to the ranging levels of diversity in each paddock, the different types of organisms present the system indicate the importance of different ecological functions. For instance in the pasture cropping paddock there were a number of significant species such as mites (predatory on other mites and nematodes), coleoptera (predatory on detritus and standing plant material), hemiptera (predatory on standing plant material) and collembola (predatory on standing plant material). However in the conventional paddock, there was a high presence of ant species and spider species with only coleoptera and diptera present in the third sample. This combination of organisms is also important in terms of spatial diversity; the presence of different types of species in the pasture cropping paddocks suggests that other untested elements such as soil-borne bacteria and mycorrhizal fungi should be present to support the predatory nature of these organisms. Therefore it could be presupposed that the pasture cropping paddock supports more microbiology (though untested) and hence the presence of meso and macrofauna in this system.

The following figure (4.4, below) shows a comparison of biodiversity under each management strategy and indicates that pasture cropping has higher species diversity as well as species abundance of organisms found in the leaf litter.

Figure 4.4 Biodiversity Levels Under Different Management Units.



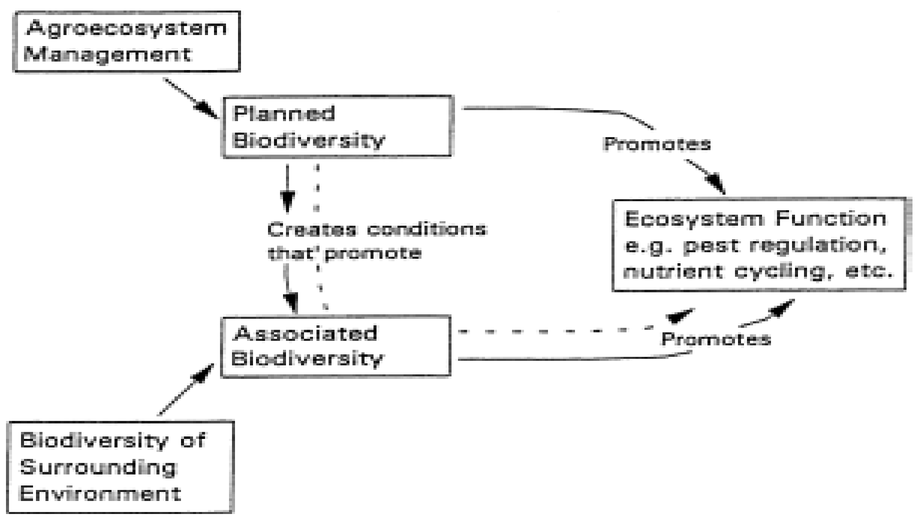
In this case, the conventional cropping paddock showed no presence organisms in the leaf litter. In comparison to the control sample and the pasture cropping sample, it indicates (in terms of biodiversity) that the conventional paddock has been mismanaged to the extent of zero biological population, yet the pasture cropped paddock has been managed in such a way to promote biodiversity. This promotion of biodiversity has then led to a higher number of organisms being present in the altered agro-ecosystem (pasture cropping) than in the natural system (the control), which is contrary to the fundamental ecological principle of natural ecosystems being superior, complex, dynamic and diverse systems. As Swift and Anderson (1993, as cited in Altieri 1999) explain "the net result of biodiversity simplification for agricultural purposes is an artificial ecosystem that requires constant human intervention, whereas in natural ecosystems the internal regulation of function is a product of biodiversity…and this form is progressively lost under agricultural intensification". Therefore it is acknowledged that agricultural ecosystems can result a loss of biodiversity, yet pasture cropping at 'Winona' has shown a promotion of biodiversity beyond levels found in local natural ecosystems; resulting in a highly diverse and complex agroecosystem.

Additional comments on the anomalies of this testing or assessment procedure include the time of testing; where a lack of organisms caught in soil and leaf litter samples (i.e. the conventional sample of nil) may be due to the time of collection. The day of collection of samples the temperature was hot 34'c and heavy dry winds may have prevented organisms from being active during the time of collection. However, organisms were collected in the adjacent pasture cropping paddock under the same conditions, and therefore results can still be considered representative.

5.0 PASTURE CROPPING AS A REGENERATIVE TOOL FOR SUSTAINABLE AGRICULTURE.

The above results have shown that conventional agricultural practices such a heavy tillage associated with cropping can have deleterious effects on soil biological populations and overall soil structure including compaction levels. Until recently agriculture and tillage management have been seen as "taking advantage of the ecological functions of the soil such as the turnover of organic matter, mediation of the transfer of nutrients to the plants, and filtering of the groundwater" (Eijsackers and Quispel 1988). However, pasture cropping seems to contrast this view of taking advantage of ecological function and rather, "it gives farmers and graziers a tool to effectively manage their properties whilst individually contributing to a healthier environment" (Seis n.d.). Also "appropriate management of microbial populations in soil could reduce leakage of excess nutrients from the rhizosphere and improve the efficiency of the fertilisers and so increase agricultural production…moreover the promotion of biological activity in soil will have a positive influence on soil porosity and thus preferential water flow" (Eijsackers and Quispel 1988). As a result of these outcomes pasture cropping has been referred to as "the difference between the poorly used term ‘sustainable’ and the better objective ‘regenerative’ agriculture” (Seis n.d.).

Figure 5.1 The Components, Functions and Enhancement Strategies of Biodiversity in Agroecosystems (after Altieri 1994).



As figure 5.1 (above) shows pasture cropping is a management strategy in an agroecosystem that plans biodiversity; hence ‘planned biodiversity creates conditions that promote associated diversity’ (Altieri 1999). As a result of this planned biodiversity that is contributing significantly on the on-farm soil biological populations, it is also contributing significantly to the biodiversity of the surrounding environment. Consequently, the observations made in this report regarding the benefits of zero till management practice may be carried further than the ‘Winona’ property boundary and may be indirectly benefiting surrounding paddocks such as the conventional paddock studied in this report.

6.0 CONCLUSION.

The results of this report have shown the impact of heavy tillage and no-tillage regimes on soil biological populations and diversity; indicating that pasture cropping is a zero-till management strategy that can enhance soil biological populations and diversity, while conventional till methods can inhibit soil structure and porosity and thus reduce levels of soil biology. In this way, pasture cropping may be considered as a regenerative tool to enhance soil biological population and diversity whilst improving soil structure and porosity.

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