FINAL REPORT 2016/17

DETAILS

PROJECT NUMBER		M106/13 (000352)
PROJECT TITLE		Comparison of insect complexes in conservation and conventional tillage systems
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	External	Farmers, North-West University, Central University of Technology (Free State)
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Final abstract

Conventional agriculture practices such as continuous tillage lead to the disruption of soil structure and loss of fertile top soil resulting in a reduction of soil productivity. Conservation Agriculture (CA) is recognised as a way to combat soil deterioration brought on by conventional cultivation crop production. CA farming practices not only alter the physical and chemical properties of soil but concomitant changes in pest species and arthropod populations may occur. CA provides a different habitat for supporting pests and may increase, decrease or have no effect on pest or beneficial insect populations. The aim of the study was to evaluate the effect of conservation agriculture on the arthropod biodiversity when practices change from conventional to CA farming. Arthropod data were sampled by using dry pitfall traps. Collections took place at six localities namely: Ottosdal, Vredefort, Hartbeesfontein, Sannieshof, Kroonstad and Bothaville. A total of 14 sites were selected where well-established CA and conventional farming systems are practised. Thirty traps per site were then monitored for two consecutive weeks over a 4-month period. Diversity indices as well as a T-test for the total number of arthropod morpho-species and individuals were calculated to measure the diversity in the different communities. A total of more than 40 000 arthropod individuals, comprising 179 morpho-species from 14 orders and 29 families were collected during this study. There was a significant difference in the mean number of individuals and morpho-species between CA and conventional farming systems. Arthropod biodiversity in CA systems are greater than in conventional farming systems. CA contributes to a healthier biodiversity and more stable agro-ecosystem. It is important to conduct further studies on ecosystem services provided by the increased number of arthropod groups recorded in CA systems. From the past seasons data, the potential of ecosystem services was observed and looked promising for the future of CA.

Keywords: Arthropod biodiversity, Conservation agriculture, ecosystem services, soil erosion.

INTRODUCTION

The ultimate aim of agriculture is to produce a sustained economic yield through crop produce, so it becomes of prime importance to understand the effect of insect pest population on subsequent yield. The total number of interacting factors responsible for determining crop yield is quite overwhelming, and any decision as to the probable effect of any single factor, such as the population of one insect pest species, is problematical (Hills, 1987). With future predictions of the world's human population being 50% higher than the current level by 2050, it is clear that food security will only be assured through greatly increased farmland productivity and yield. According to MacFadyen and Bohan (2010) ecosystem services, which result from species interactions directly support crop productivity and yield examples include services of pollination, natural enemy predation of crop pests and nutrient recycling by detrivores.

Arthropods are considered one of the most successful groups of all living biota on earth and along with other invertebrates make up about 80% of the total number of species in the animal kingdom (Frost, 1959). Insects are one of the most important groups in the natural world, which can affect the life and welfare of humans in many different ways. While some insects are referred to as pests, others are beneficial to humans i.e. insect may serve as natural enemies of harmful species, or as producers of valuable materials such as honey and silk. Several insect species, however, are not currently known as being harmful or beneficial. Nevertheless, insects are extremely important as essential components of both natural and modified ecosystems (You *et al*., 2005). The biodiversity of an agro-ecosystem is not only important for its intrinsic value but also because it influences ecological functions that are vital for crop production in sustainable agricultural systems and the surrounding environment (Hilbeck *et al*., 2006).

It has been realized that life on earth depends on the proper functioning of several large-scale ecological processes, many of which provide humanity with irreplaceable benefits, termed ecosystem services (Daily *et al*., 1996). Loss of biodiversity threatens these benefits, but exactly what type and amount of biodiversity is necessary for unimpaired, sustained ecological functioning and productivity is unknown (Loreau *et al*., 2002). To fully understand, manage and exploit biodiversity in agro-ecosystems, first the changes must be understood to the underlining structure of communities that result from interactions between species and how these changes affect overall productivity.

Soil erosion is a major environmental problem confronting soil and water resources in South Africa. Although soil erosion is a natural process, it is often accelerated by human activities, for example by the clearing of vegetation and soil tillage which involves the loss of fertile topsoil and reduction of soil productivity (Le Roux, 2014). Sand and dust storms are hazardous weather and cause major agricultural and environmental problems in many parts of the world. They can move forward like an overwhelming tide and strong winds taking along drifting sands to bury farmlands or blow out top soil (WMO, 2015). They also accelerate the process of land degradation and cause serious environment pollution and huge destruction to ecology and the living environment i.e. damage to crops through loss of nutrients and organic matter. A characteristic of most South African soils is that they are extremely vulnerable to degradation and have low recovery potential. Thus even small mistakes in land management can be devastating, with little chance of recovery. It is estimated that 25% of South Africa's soils are highly susceptible to wind erosion. These include the sandy soils of the North West and the Free State - the areas that produce 75% of the country's maize (Goldblatt, 2015).

As farming practices have been changed to reduce water and wind erosion there have been concomitant changes in pest species and populations. At the community level, invertebrates are more sensitive to habitat changes than plants and vertebrates (Burel *et al*., 1998). Conservation agriculture (CA) provide different habitat for attracting and supporting pests and may increase, decrease or have no effect on pest or beneficial insect populations (Ogg *et al*., 1999). One major constraint of the adoption of conservation systems is the possibility of pests and diseases surviving winter in crop residues especially when no crop rotation is practiced (Fowler, 1999). According to Van den Berg *et al*. (1998) crop residues in the form of stubble and stalks, form the primary source of border infestation in the following season i.e. larvae of *Busseola fusca* (Lepidoptera: Noctuidae) can spend the dry season in crop residues.

Agricultural soils under conservation systems are cooler and wetter in spring and summer and are warmer and wetter in fall and winter compared with soils under conventional systems. Thus, in terms of crop protection conservation systems provide a different habitat than conventional systems for attracting and supporting pests that can attack or interfere with the growth and yield of crops. Tillage or the lack of it influences arthropods and other invertebrates in three major ways, namely mechanical disturbance, residue placement and effects on weed communities. As farming practices have been changed to reduce water and wind erosion there have been concomitant changes in pest species and populations. Alterations in crop ecology are produced in conservation systems that may have significant effects on the bio-potential of certain arthropod pests and disease pathogens. Knowledge is lacking on population dynamics and control of pest complexes in CA systems (All *et al.*, 1977).

When a conservation maize cropping system was compared to a conventional one there was a significant increase in the amount of Johnson grass, (*Sorghum halepense*: Poaceae) and in the total leafhopper population in no-tillage, both of which are important factors in the epidemiology of maize chlorotic dwarf virus (MCDV). However, the yield loss from MCDV infection did not increase significantly in a conservation system compared to a conventional maize cropping system (All *et al.*, 1977). In maize grown in a no-till culture the armyworm, *Pseudaletia unipuncta* (Haworth) (Noctuidae) and the black cutworm, *Agrotis ipsilon* (Hufnagel) (Noctuidae) were more prevalent than in maize grown conventionally (Harrison, Bean, & Qawiyy, 1980). Hammond and Stinner (1987) reported that the amount of residue material influenced slug populations and higher amounts of residue will increase the incidence of slugs. Observations in Ohio indicated that slug problems are occurring in maize and soybean fields where residue convergence is great. There were also more slugs when soybean was the previous crop as opposed to maize (Hammond & Stinner, 1987).

Hammond and Stinner (1987) reported that seed-corn maggot does not have a high damage potential in conservation systems when only maize or soybean residue is present, especially when no-tillage practices are used compared with reduced tillage in Ohio. They also concluded that the potential for seed-corn maggot damage is greatest when green organic matter is present and incorporated into the soil. A study conducted by Barney and Pass (1987) to determine the influence of no-tillage planting on the foliage-inhabiting insects of alfalfa in Kentucky concluded that the pest populations did not increase significantly under CA conditions. In the case of the potato leafhopper, *Empoasca fabae* (Harris) (Cicadellidae), populations may have been reduced due to increased populations of grass weeds (Barney & Pass, 1987). Barney and Pass (1986) reported that lack of soil disturbance in CA plots did not increase numbers of species or abundance of Carabidae beetles. They concluded that species composition between tillage treatments became more similar over time. However, this may be due more to the potential prey community rather than an influence of tillage on soil conditions (Barney & Pass, 1986). More beetles were captured in conventional than in CA crops because of the dominance of *Poecilus scitulus* Linnaeus (Carabidae) in conventional systems, whereas species richness and biological diversity were generally higher in CA crops (Hatten *et al.*, 2007). Results of Foster and Ruesink (1984) demonstrated that flowering weeds as nectar sources associated with reduced tillage in maize are beneficial to *Meteorus rubens* (Hymenoptera: Braconidae), a black cutworm parasitoid.

Further research is needed to determine the effects of CA practices on the frequency of pest outbreaks and on the composition of insect communities. By determining the insect incidence, we need to consider pest management practices such as growing transgenic crops. Through monitoring field studies and conducting laboratory experiments one could determine whether pest populations can be suppressed in CA systems associated with transgenic crop production.

Thus, this study is important because the question remains whether conservation agriculture contributes in supporting the arthropod biodiversity especially when practices are changing from conventional to CA farming systems. The aims of the study were to compile a list of morpho-species that occur in conventional fields and CA fields, to compare diversity between these two farming systems, and to evaluate the potential of insect as an ecosystem service in CA.

MATERIALS AND METHODS

1. Annual arthropod sampling

Monitoring of insect complexes was conducted at four localities, which consist of 14 sites. Sites were selected where well established conservation farming systems are practiced and within each locality a farmer still practicing conventional farming systems was also included (Fig. 1 and Table 1). For well-established conservation farming systems reliable farmers who are willing to collaborate with researchers on CA farming were identified. It was also essential that these sites have a conventional system as control. The sites were monitored over time by means of pitfall traps.

For this study pitfall traps were used to compare the soil-dwelling species present in a conventional relative to a conservation system. The priority species are listed in Table 2. These priority species were categories in the different families and then in predators, pests and others (Fig. 2) for data analysis and to clarify interpretation.

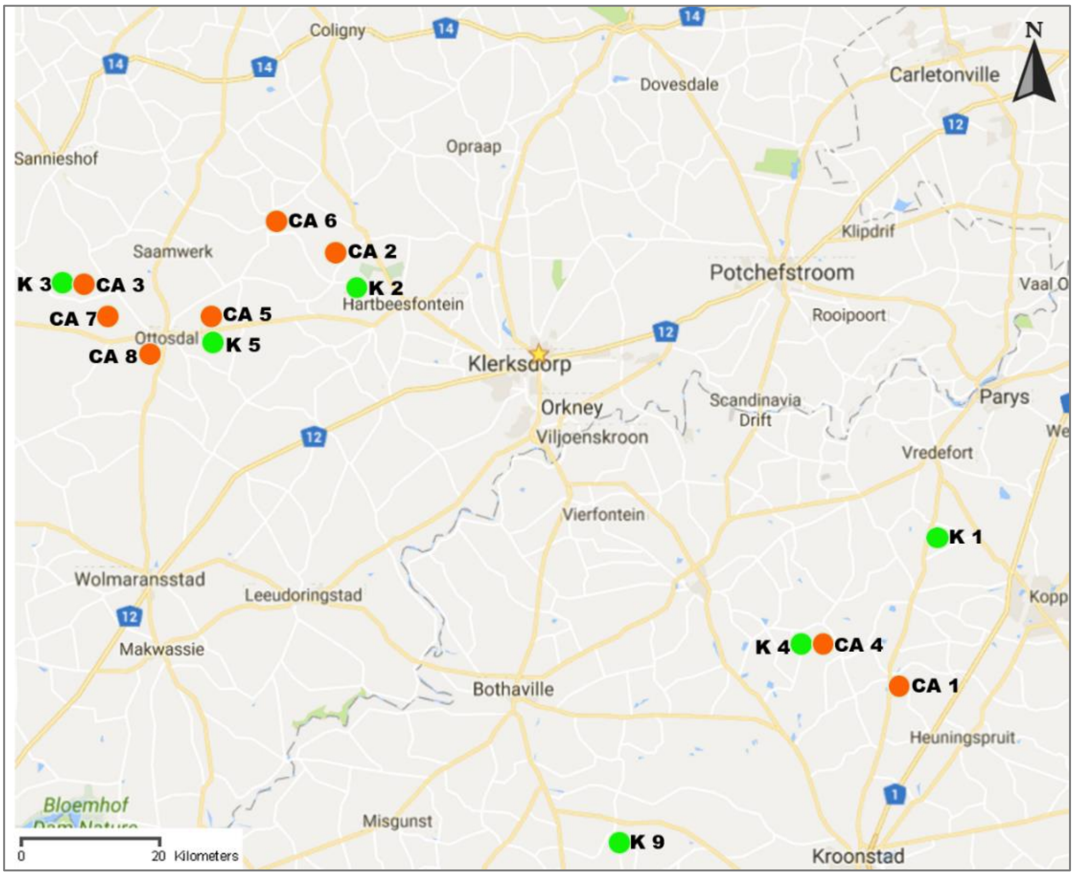

Figure 1. Sample sites of projects; orange being CA farmers and green conventional farmers as control.

Table 1. Numbering of sites and farmer names of each site.

Location	Site no.	Farmer	GPS Coordinates
1) Vredefort	CA1	Flip Van der Merwe	27°21'44.6"S 27°17'30.6"E
	K1	Johan Bronkhordts	27°09'01.0"S 27°20'57.3"E
2) Hartbeesfontein	CA2	Frik van Sitert	26°41'10.3"S 26°19'46.7"E
	K2	Frikkie Lemmer	26°45'12.9"S 26°22'33.0"E
3) Ottosdal - Sannieshof	CA3	Magnus Theunissen	26°45'09.7"S 25°48'53.6"E
	K3	(Neighbour)	26°45'09.7"S 25°48'53.6"E
4) Kroonstad	CA4	Kobus van Coller	27°19'08.0"S 27°08'34.4"E
	K4	Kobus van Coller	27°19'08.0"S 27°08'34.4"E
5) Hartbeesfontein - Ottosdal	CA5	Hannes Otto	26°48'33.8"S 26°04'56.4"E
	K5	(Neighbour)	26°48'33.8"S 26°04'56.4"E
6) Ottosdal - Colingy	CA6	Koos Vorendyck	26°38'00.6"S 26°11'14.1"E
7) Ottosdal - Sannieshof	CA7	George Steyn	26°46'51.5"S 25°53'16.4"E
8) Ottosdal - Wolmaransstad	CA8	Hannes Otto	26°49'45.2"S 26°00'02.1"E
9) Bothaville	K9	Bothaville	27°37'16.9"S 26°48'38.6"E

Table 2. Priority species that were monitored for presence in the field.

	Species	Order: Family	Common name
Soil dwelling pests	*Astylus atromaculatus*	Coleoptera: Melyridae	Spotted maize beetle / Bontmieliekewer
	Heteroderes flavostriatus	Coleoptera: Elateridae	Wireworms / Draadwurms
	Gonocephalum sp.	Coleoptera: Tenebrionidae	Surface beetles / Grondkewers
	Mesomorphus sp.	Coleoptera: Tenebrionidae	Surface beetles / Grondkewers
	Protostrophus spp.	Coleoptera: Curculionidae	Ground weevils / Doodhouertjies
	Somaticus spp.	Coleoptera: Tenebrionidae	Greater false wire worms / Groot valsdraadwurms
	Heteronychus arator	Coleoptera: Scarabaeidae	Black maize beetle / Swartmieliekewer
	Agrotis segetum	Lepidoptera: Noctuidae	Cutworms / Snywurms
Leaves	*Adoretus cribrosus*	Coleoptera: Scarabaeidae	Maize chafer beetle / Mielielentekewer
	Acantholeucania loreyi	Lepidoptera: Noctuidae	False bollworm / Vals bolwurm
	Helicoverpa armigera	Lepidoptera: Noctuidae	African bollworm / Afrika bolwurm
	Busseola fusca	Lepidoptera: Noctuidae	Stalk borer / Stamrusper
	Chilo partellus	Lepidoptera: Pyralidae	Chilo borer / Chilo-boorder

Stem	*Busseola fusca*	Lepidoptera: Noctuidae	Stalk borer / Stamrusper
	Chilo partellus	Lepidoptera: Pyralidae	Chilo borer / Chilo-boorder
	Sesamia calamistis	Lepidoptera: Noctuidae	Pink stem borer / Pienkstamrusper
		Isoptera: Termitidae	Termites / Termiete
Ears	*Astylus atromaculatus*	Coleoptera: Melyridae	Spotted maize beetle / Bontmieliekewer
	Acantholeucania loreyi	Lepidoptera: Noctuidae	False bollworm / Vals bolwurm
	Helicoverpa armigera	Lepidoptera: Noctuidae	African bollworm / Afrika bolwurm
	Busseola fusca	Lepidoptera: Noctuidae	Stalk borer / Stamrusper
	Chilo partellus	Lepidoptera: Pyralidae	Chilo borer / Chilo-boorder
	Sesamia calamistis	Lepidoptera: Noctuidae	Pink stem borer / Pienkstamrusper
Maize streak virus	*Cicadulina* spp.	Hemiptera: Cicadellidae	Maize leafhoppers / Mieliebladspringers
Parasitoids		Diptera: Tachinidae	Fly parasitising cutworms
	Cotesia sp.	Hymenoptera: Branconidae	Wasp parasitising stem borers
Predators	*Harpalus* sp.	Coleoptera: Carabidae	Ground beetles
		Coleoptera: Coccinellidae	Ladybird beetles
	Labidura riparia	Dermaptera: Labiduridae	Earwigs / Oorkruipers

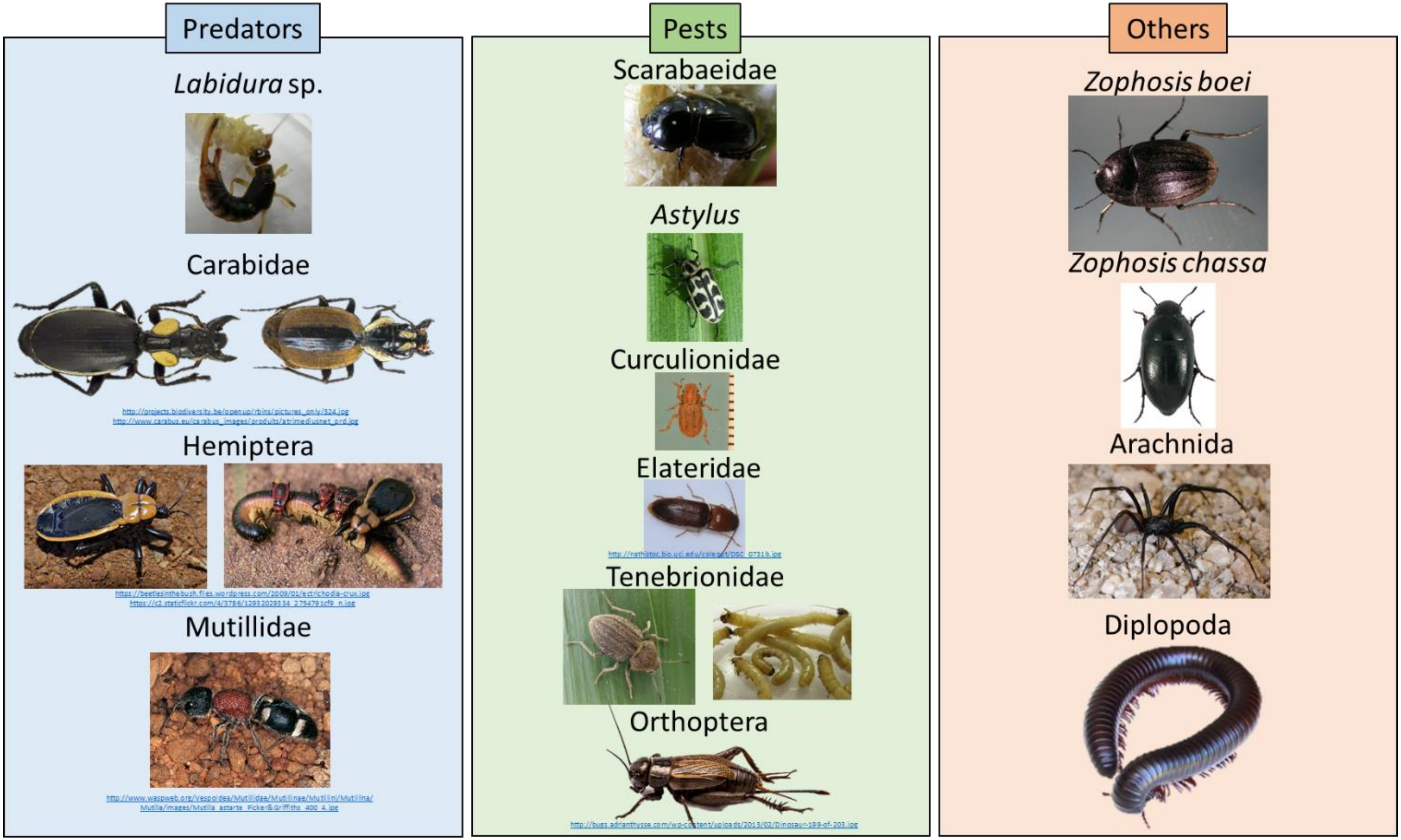

Figure 2. Categorizing of organisms in families and group (as used in graphs).

In each site thirty pitfall traps (10 x 3) were used which were monitored over time for four months, two weeks per month. These soil dwelling organisms were monitored by means of 240 pitfall traps at each site per season (14 sites x 30 traps x 4 months x 2 weeks per month = total traps 3360). For a more in depth study insect identification was also conducted by categorising insect species into morpho-species. A full time MSc student conducted this in 2015 - 2017. Therefore, each individual insect collected from pitfall traps was categorised into morpho-species by visual similarities (example of list, Table 3). As soon as all insect species are categorized, indices were conducted to compare biodiversity in the two systems. The number of individual species and the number of morpho-species were categorized in functional groups to compare between CA and conventional systems over the three seasons. Functional groupings are based on the feeding mechanisms ("functional feeding groups") of the insect. Functional groupings need make no taxonomic assumptions but use mouthpart morphology as a guide to categorizing feeding modes. The following functional groups were used: parasitoids, detrivores, pollinators, predators and herbivores.

Table 3. Example of categorising species into morpho-species.

	Plaas 1					
Class	**Orde**	**Family**	**common name**	**species/genus**		**Spesie nc**
Insecta	Coleoptera	Tenebrionidae	Surface beetle	Zophosis chassa	Klein volk	1
	Coleoptera	Tenebrionidae	Surface beetle	Zophosis boei	Groot volk	2
	Coleoptera	Carabidae		Harpalus	oranje bene, swart lyf	3
	Coleoptera	Melyridae	Spotted maize beetle	Astylus atromaculatus		4
	Coleoptera	Tenebrionidae	Tar Darkling Beetle	Somaticus aeneus	shiny black ridges	5
	Coleoptera	Tenebrionidae	Armoured Darkling Be	Gonopus tibialis	vet toktokkie	6
	Coleoptera	Curculionidae	Beaded weevil	Protostrophus	doodhouertjie wit/grys rond (het donkerswart bru	7
	Coleoptera	Elateridae	brown click bettle	Cardiotarsus acuminatus	Donker rooibruin (gestippel), ligbruin bene, kop sk	8.1
	Coleoptera	Elateridae			Oranje/bruin, kop knoppies, lyf knoppies in lyne, l	8.2
	Coleoptera	Elateridae			Minatuur elateridae swart, geel bene en 4 geel ko	8.3
	Coleoptera	Elateridae			Selfde as 8.1 net pik swart met geel bene ook ske	8.4
	Coleoptera	Scarabaeidae	Black maize beetle	Heteronychus trisis/arator		9
	Coleoptera	Scarabaeidae	Dung beetle		klein swart miskruirtjie	10
	Coleoptera	Carabidae	leaf-rolling weevels		klein + 2 oranje kolletjies, oranje kop, swart vlerl	11
	Coleoptera	Meloidae			Lyk soos astylus beetle met n stepe op n vlerk (ve	12
	Coleoptera	Scarabidae	Trox		klein miggie besies	13
	Coleoptera	Tenebrionidae	Mesomorphus		5mm swart gogatjie platter as volkies	14
	Coleoptera	Curculionidae	weevill		kleiner as doodhourtjie, bruin kolle, geriffeld	15
	Coleoptera	Scarabaeidae	Minature dung chafei	Aphodius	Goud bruin beetle	16
	Coleoptera	Scarabaeidae	Dung beetle		meroon shiny beetle lyk soos miskruier	17
	Coleoptera	Carabidae			pik swart + baie klein 2mm lyk soos minature leaf	18
	Coleoptera	Coccinellidae			swart met rooi/oranje/geel kolle	19
	Coleoptera	Meloidae			lyk soos astylus, groter met swart kollering strepe	20
	Coleoptera	Carabidae	Leopard tiger beetle	Lophyra	Geel met bruin/swart streep kolle	21
	Coleoptera	Curculionidae			miniture doodhouertjie donkerbruin lyk harig (sto	22
	Coleoptera	Tenebrionidae			rooi/bruin 4mm, strepe, stomp mond, glad	23
	Coleoptera	Carabidae			groundbeetle swart middel buite kant bruin	24
	Coleoptera	Curculionidae	snouted weevel		donker bruin, baie donkerder lang mondeel met 2	25
	Coleoptera	Chrysomelidae			ladu bird met swart en rooi strepe	26
	Coleoptera	Scarabaeidae			besie =oranje lyf met swart vlerke en oe	27
	Coleoptera	Tenebrionidae			luk soos harpalus, heeltemal swart met ligte wit l	28
	Coleoptera	Carabidae	leaf rolling weevel		oranje,Swart kop+2kolle bolyf,+2oranjekolle ond	29
	Coleoptera	Curculionidae	Prong-tailed weevil		Swart, klomp knoppies in reguit lyne, reghoekige r	30
	Coleoptera	Carabidae	starred ground beetle	Caminara	Swart met goud kolletjies, brons skynsel	31
	Coleoptera	Coccinellidae			oranje/geel, swart kop,5 swart kolle, 2hartjie koll	32
	Coleoptera	Coccinellidae	Ladybird larva		Geel met swartkolle, haartjies op kolle, wurm agt	33
	Coleoptera	Carabidae	Oogpister		swart met 2 geel koppe onder kop	34
	Coleoptera	Scarabaeidae			Lyk soos 10, swart, maar geel vlerkies met 2-4 sw	35
	Coleoptera	Curculionidae	weevill		Swart/geel kolle, ridges, met baie lang fyn hare	36
	Coleoptera	Curculionidae	weevill		Swart klein, reghoekige lyf, skerp langk mondeel (	37
Insecta	Hemiptera	Reduviidae	Millipede Assasin	Ectrichodia crux	geel/oranje + kruis	1
	Hemiptera	Cydnidae	Burrowing bug		swart bug met deurskeinende stukie op punt vlerk	2
	Hemiptera	Reduviidae			piercig suckimg mouth, ovaal agterlyf lig op kant (	3
	Hemiptera	Pyrrhocoridae			rooi met swart kol op anes +bo lyf, bene swart, p	4
	Hemiptera	Pyrrhocoridae	nimf		Swart+glad, lang dun piercing mond, ovaal ligg. 5r	5
	Hemiptera	Reduviidae			Pikswark met wit fyn haartjies oral piercing suckir	6
	Hemiptera	Pyrrhocoridae			oranje roooi met swart sterpe aan onderkant pie	7
	Hemiptera	Miridae			Lyk soos water goga, geel, swart kolletjies, deursk	8
	Hemiptera	Reduviidae			Oranje kop swat/bruin lyf (ovaal rond) kort pierci	9
	Hemiptera	Reduviidae			Swar met rooi/bruin gespikkeld, mondeel kort dik	10
	Hemiptera	Lygadeidae			Swart lyk soos 5 maar het rooi/bruin kolletjies en	11
Insecta	Hymenoptera	Mutillidae	Velvet ant	Polichomutilla sycorax	rooi swart mier-wit 2kolle+2strepe	1
	Hymenoptera	Formicidae	gewone mier		bruinmier, lang bene+voelers+swart prom. Agterk	2
	Hymenoptera	Mutillidae	Velvet ant		rooi swart mier-net wit strepe	3
	Hymenoptera	Formicidae	gewone mier		bruinmier,kortbene,2 stekeltjies op rug	4
	Hymenoptera	Formicidae	gewone mier		Bruin, kop (hartvorm) baie groter as agter kant (kl	5
	Hymenoptera	Sphecidae	Wasp	MESA sp	wasp-groen vlerke lig bruin pote swart agterlyf	6
	Hymenoptera	Vespidae	Wasp		wasp-swart, ligbruin vlerke, donker bruin bene fyr	7
	Hymenoptera	Formicidae	gewone mier		Klein bruin, agter kant aan steeltjie en donkerder	8
	Hymenoptera	Formicidae	mier		klein.pikswart.agertkant.ansteeltjie	9
	Hymenoptera	Formicidae	mier		Bruin, kop (hartvorm) grrot swart agter kant, baie	10
	Hymenoptera		Wasp?		lyk soos lang maer vlieg, 4pr duerskynende vlerke	11
	Hymenoptera	Vespidae	wasp		pikswart lyk soos 7, wit fyn hartjies oral, donker b	12
	Hymenoptera	Formicidae	African stink ant	Pachycondyla tarsata	swart, groot en lank (30mm) lang skerp abdomen,	13
	Hymenoptera	Formicidae	mier		Rooi/bruin, groot swart abdomen groter as kop, b	14
	Hymenoptera	Sphecidae	Wasp		Swart, bitjie haring, abdomen aan stingeltjie met (	15
	Hymenoptera	Apidae	Heuning by		Swarkop, goud/geel op abdomen, mond is ook ge	16
	Hymenoptera	Apidae	Wasp		Kort vet swart byq,wit haartjies, deurskynende ko	17
Diplopoda	Spirostreptida	Spirostreptidae		Doratogonus levigatus	Groot duisendpoot	1
	Spirostreptida	Spirostreptidae		Doratogonus levigatus	Klein duisendpoot	2
Chilopoda					Centipedes	1
Arachnida			spinnekop		ligbruin+harig,grys agter kant, swatr kol onder	1
			spinnekop		liggeel+ swart steek hare, 2 swart oe strepe(kop)	2
			spinnekop		ligeel+bruin kolle- klein+dun, oe is duidelik	3
			spinnekop		donker klein langbene(lyk soos plat bosluis)	4
			spinnekop		swart baie klein lyfie met geel voetjies	5
			spinnekop		bruin groot lyf, 2wit kolletjie naby oe, baie harig, g	6
			spinnekop		Ligg geel/bruin, klein abdomen, swart groot chelis	7
			spinnekop		rooi/bruin met 2 skerp tandjies skei van kop grys a	8
			spinnekop		Groot swartkop, 2 swart strepe oor abdomen, oo	9
			spinnekop		Donker bruin, chelisera lyk soos skerpijoen angel=	10
			spinnekop		Bruin met bitjie donker briun kolle, grys swart abd	11
			spinnekop		Pikswart+harig, lyk soos 8 met tande, 2 geel kolle	12
			spinnekop		Bruin groot plat kop, lyk soos geraamte omderkai	13
Insecta	Dermaptera	Labiduridae	long-horned earwing:	Labidura riparia	Groot oorknuiper- swartlyf, bruin agterknt, ligte b	1
	Dermaptera	Labiduridae			nimf klein oorknuiper	2
	Dermaptera	Labiduridae			Groot oorknuiper, kleiner lyf, groter angel	3
Insecta	Orthoptera	Gryllidae	common garden crick	Gryllus bimaculatus	Huis/tuin kriek volwasse	1
	Orthoptera	Gryllidae	Cricket		groot kriek donker met lig te streep op rug 15mm	2
	Orthoptera	Gryllidae	Cricket		Klein kriek donker met ligte streep op rug 3mm	3
Insecta	Isoptera	Hodotermitidae	termiet		reismier agtig goot doker kop, klein wit lyf	1
Insecta	Diptera	Muscidae			Swart vlieg oranje/geel oe, deurskynende vlerke	1
Insecta	**Neuroptera**		lacewing larf		Nimf wurm insek harig mondele prom. Buite	1
Unknown	Coleoptera	Staphylinidae			ant like beetle swart 10mm ligter op middel	1

2. BSc Environmental Science 3rd year project

This study was conducted to determine the potential of ecosystem services in CA. The experiment for the Arthropod predation on a weed seed and cutworms (*Agrotis segetum*) in the CA systems were done at CA2 and Conv2 (near Hartbeesfontein). Two different approaches were used to collect the necessary data.

Experiment 1: Weed seed feeding

Seeds of the weed, *Urochloa mosambicensis* were used. Double-sided sticky tape was used to fix the seeds onto the bottom of a petri dish. Fine sandy soil was used to cover the rest of the sticky tape to prevent the arthropods getting stuck to the sticky tape. The petri dishes were then placed into the specially constructed vertebrate exclusion cages, and the cages were placed on the ground and covered with soil up to the rim of the petri dish to level with the ground. Four cages per field were used with three petri-dishes per cage.

Experiment 2: Larvae predation

A cutworm larva was pinned onto a clay base and placed into the specially constructed vertebrate exclusion cage. Again, four cages with three larvae per cages were used per field.

Cages with weed seeds and cutworm larvae were left in the field for 24 hours before the predator activity was monitored

3. Ecosystem service trial

Three CA fields and the conventional field as control were identified as sites to evaluate the ecosystem service present. Five cages with two larvae per cage were used per field (Fig. 3 & Fig. 4). Larvae were pinned to a petri-dish with agar to prevent larvae from escaping. Although the larva was pinned, it was to such an extent that the larva was still alive to attract predators. Cages with larvae were left in the field for 24 hours before determining the predation percentage. This was repeated twice per season.

Figure 3. Larvae pinned to agar petri-dish.

Figure 4. Cage in the field to determine predation on larvae.

4. Evaluation of potential insect pests

Farms were visited only on request of farmers that have identified possible insect problems in the field. The fields visited were in the following regions: Mooirivier (KZN), Ottosdal (NW), Potchefstroom (NW), Parys (FS), Setlagole (NW), Koster (NW) and Settlers (Limpopo).

With arrival at each field, insect damage was identified and scouting was conducted to sample insect pests if possible. Percentage damages were recorded and insects were identified.

5. Statistical analyses

Data were analysed in GenStats 17th Edition applying the Student t-test to compare the number of individuals per group as described above for priority species as well as for morpho-species, between CA and conventional systems. Significance was declared for $P < 0.05$.

The Shannon diversity richness indices as well as the total number of species and the total number of individuals were used to compare these two systems. Like Simpson's index, Shannon's index accounts for both abundance and evenness of the species present. The Shannon diversity index (H1) describes diversity (species richness and evenness); whereas the Margalef richness index (d) describes species richness and Pielou's evenness (J1) describe the evenness of species. The indices were calculated using Primer 6 (Version 6.1.15) and statistical analysis was done with Statisica software (Version 12). Non-metric multi-dimensional scaling (NMDS) represent the composition of arthropod communities between the two treatments based on species richness and evenness. NMDS were calculated to test for significant differences between treatments, analyses were performed in Primer 6. A significant difference was observed when the P-value was lower than 5%.

For the purpose of the 3rd year project on ecosystem services only means were determined to evaluate the potential of this for future research. The ecosystem service trial was compared with each other by means of the Student t-test. Significance was declared for $P < 0.05$.

RESULTS

1. Annual arthropod sampling

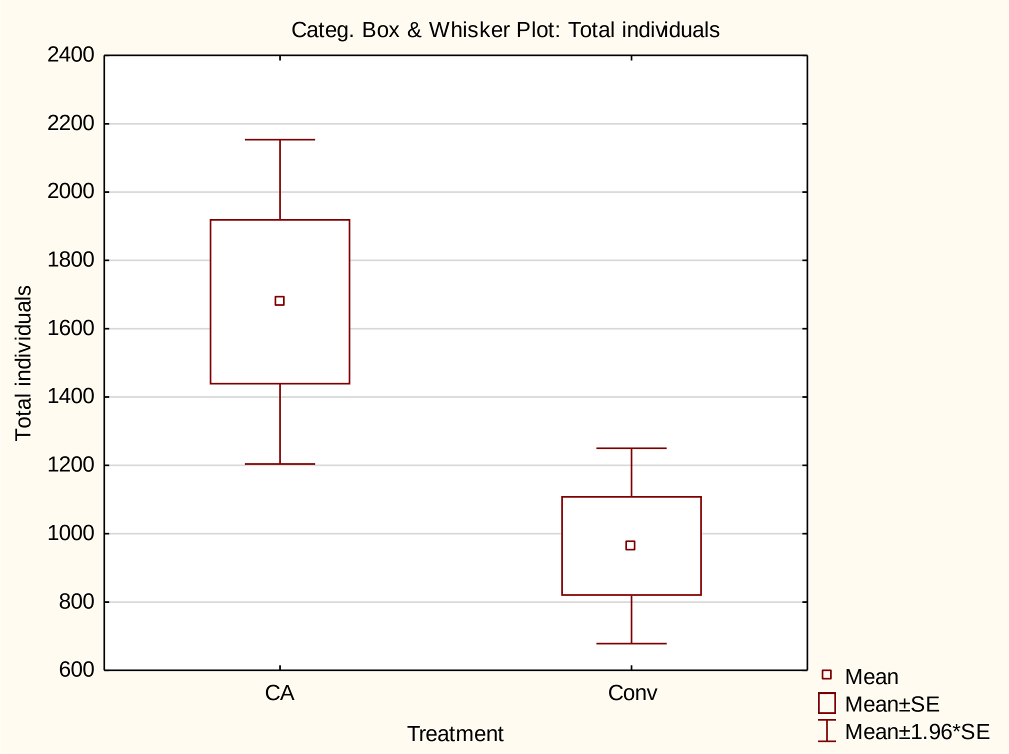

Figure 5. The mean number of individuals in CA and Conventional farming systems ($F_{(1;28)} = 6.39$; $P = 0.01$).

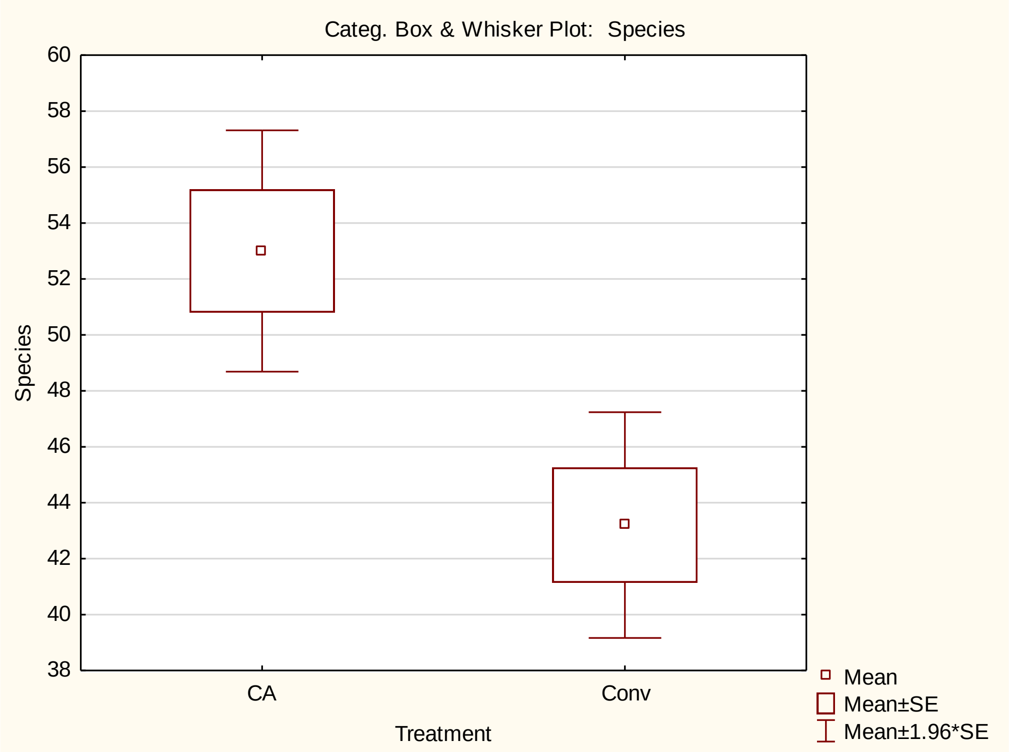

Figure 6. The mean number of morpho-species in CA and Conventional farming systems ($F_{(1;28)} = 10.57$; $P < 0.01$).

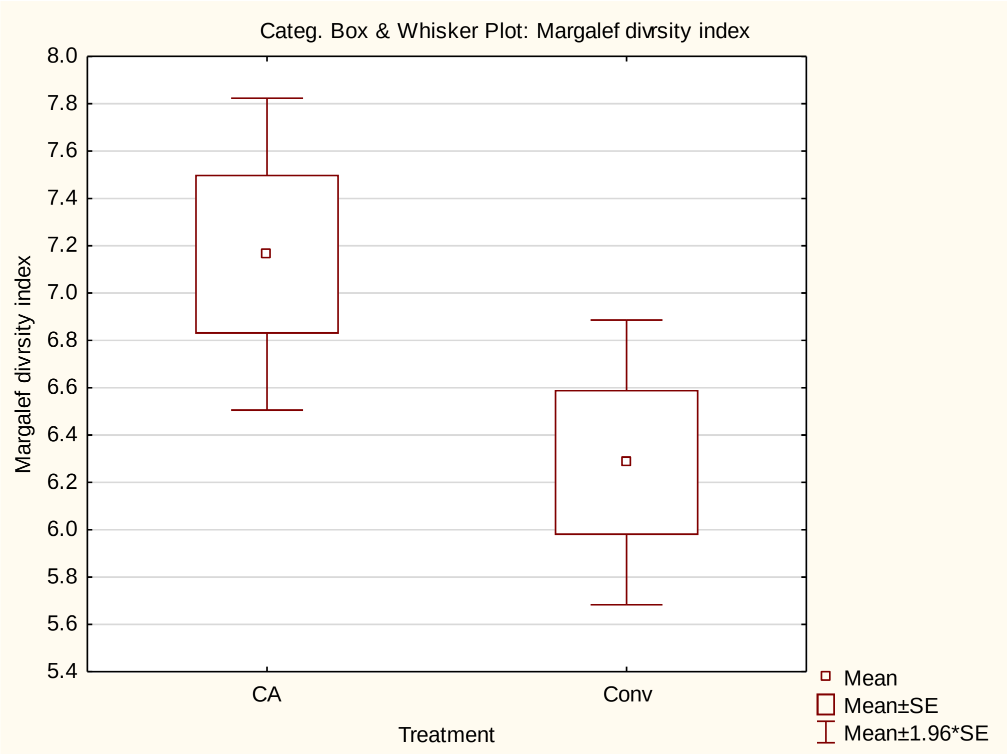

Figure 7. The Margalef diversity index in CA and Conventional farming systems ($F_{(1;28)} = 3.74$; $P = 0.06$).

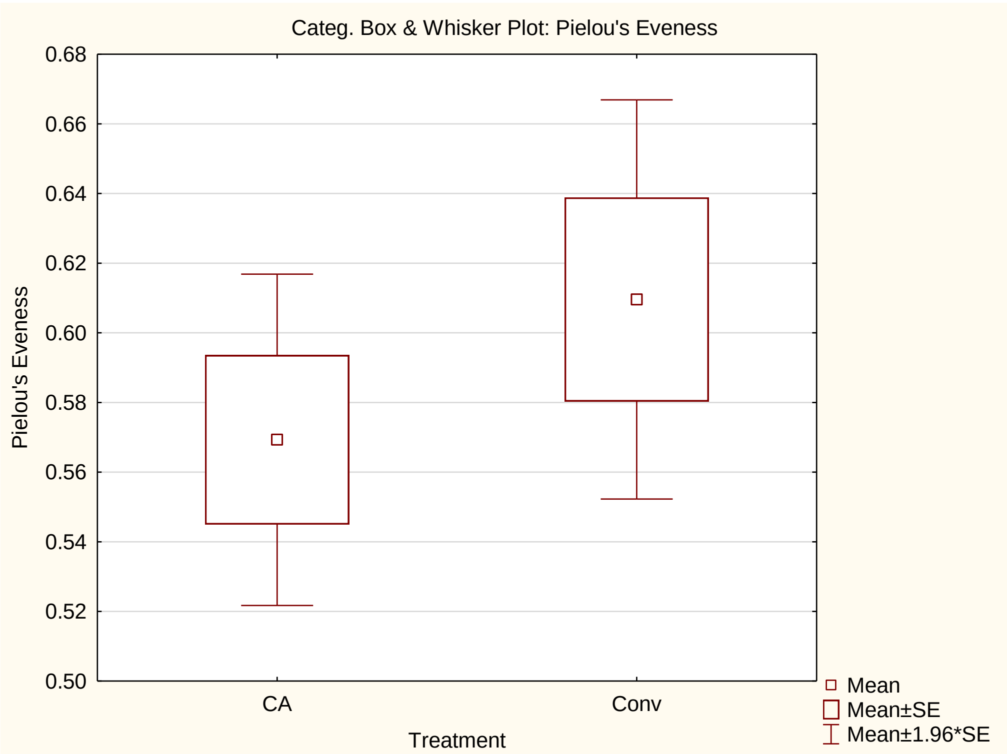

Figure 8. The Pielou's evenness index in CA and Conventional farming systems ($F_{(1;28)} = 1.12$; $P = 0.30$).

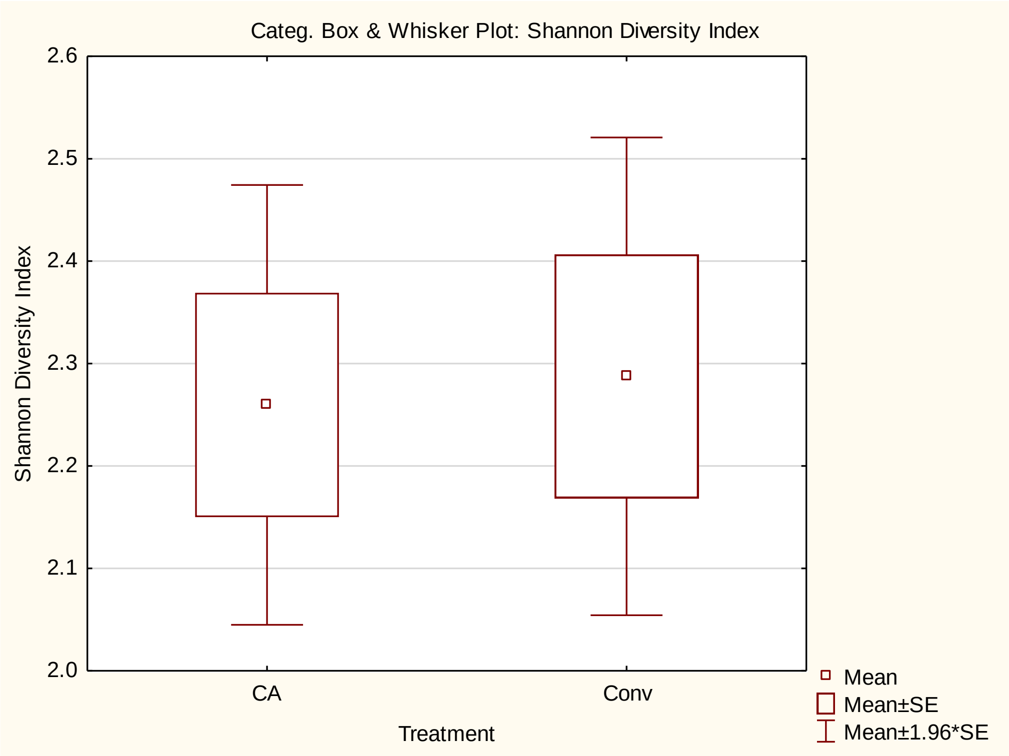

Figure 9. The Shannon diversity index in CA and Conventional farming systems ($F_{(1;28)}$ = 0.03; P = 0.86).

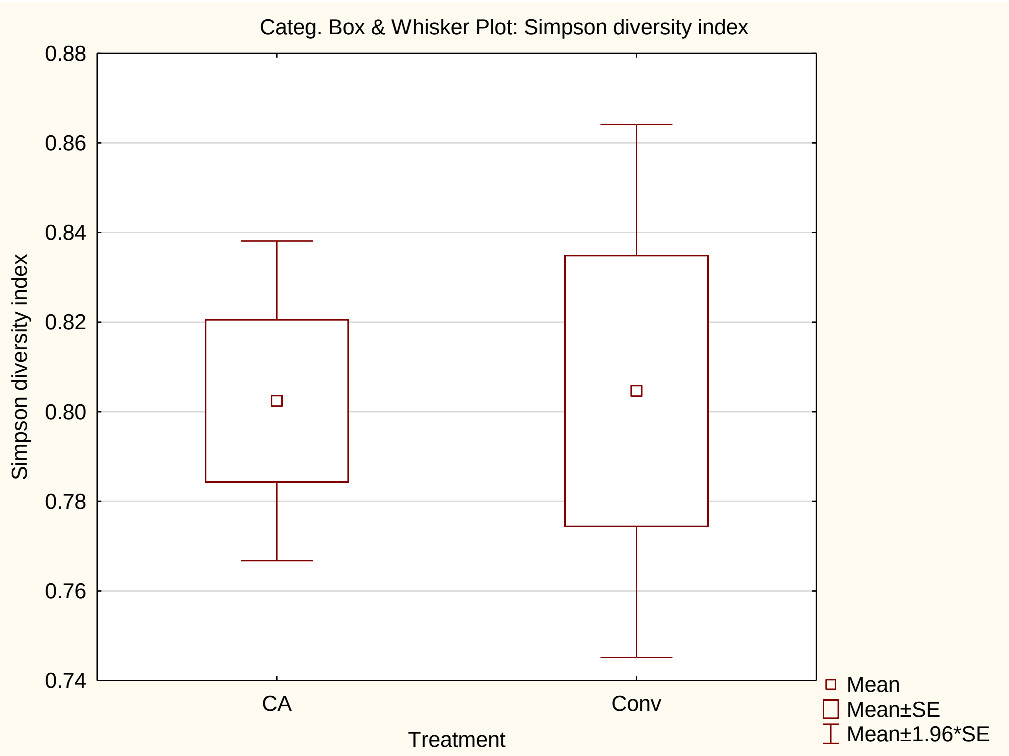

Figure 10. The Simpson diversity index in CA and Conventional farming systems ($F_{(1;28)}$ = 0.004; P = 0.95).

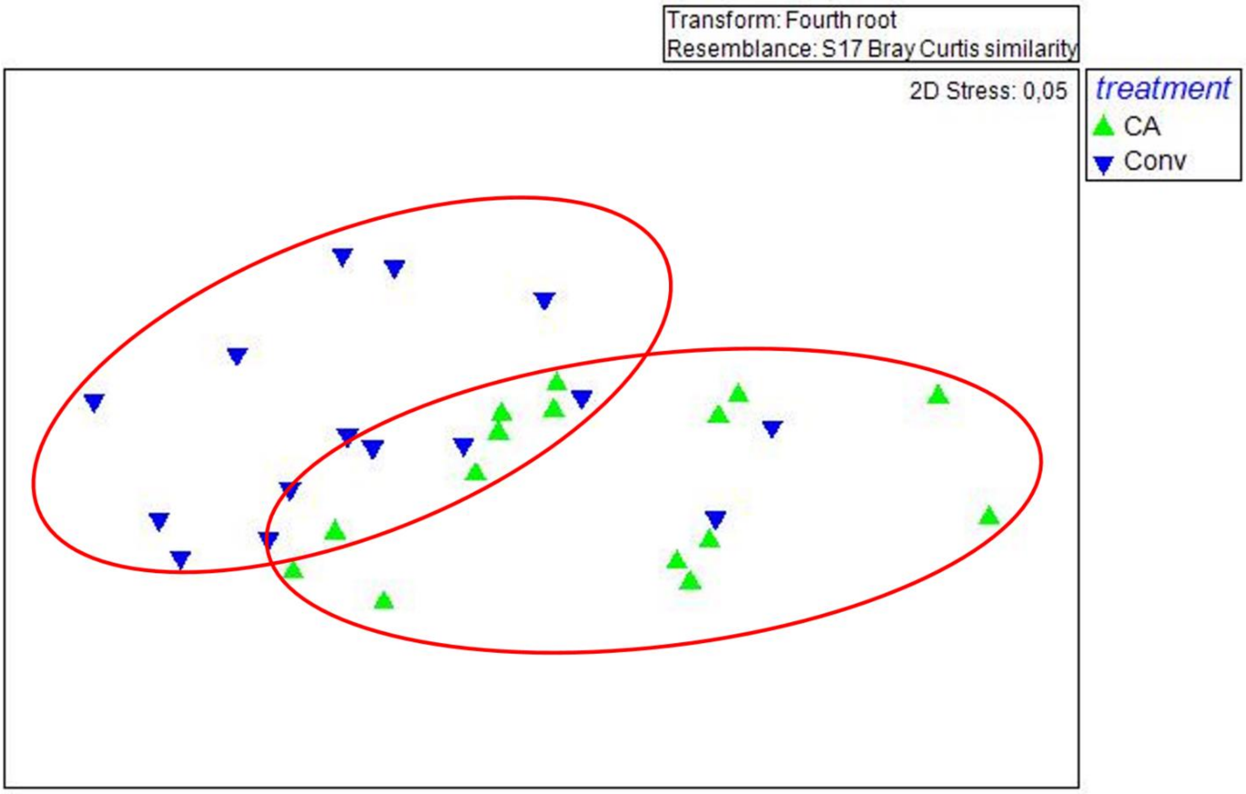

Figure 11. NMDS analysis graph for both CA and conventional community indexes.

From data collected in pitfall traps the number of individual species were always higher in CA sites compared to the nearest conventional site (Fig. 5). All CA sites within all three seasons had a significantly higher number of individual species compared to the nearest conventional site. The number of morpho-species from CA was also significantly higher compared to the conventional sites over the three seasons (Fig. 6). No significant differences were observed in diversity indices, Margalef, Simpson, Shannon and Pielou's evenness when the three seasons' data were pulled, however within seasons there were significant differences (Figs 7, 8, 9 and 10).

NMDS represent the composition of arthropod communities between the two treatments based on species richness and evenness. The two distinct habitat types, influence the pattern of arthropod species richness and abundance in the sites. Results confirmed that there was a significant difference between the two treatments (Fig. 11). Composition of arthropod community was significantly different, which was based on combined arthropod richness and abundance. Thus, the habitat type can be the main factor influencing both taxonomic and trophic community structure.

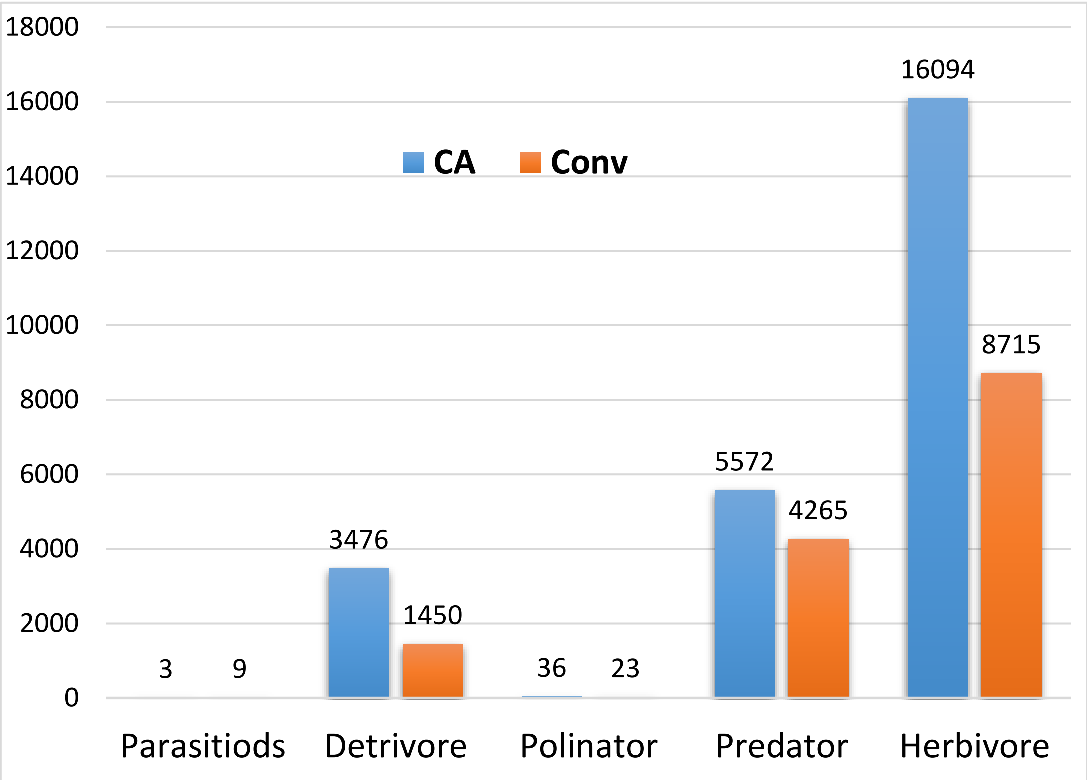

Figure 12. The number of individuals categorized in functional groups within CA and conventional sites over three seasons.

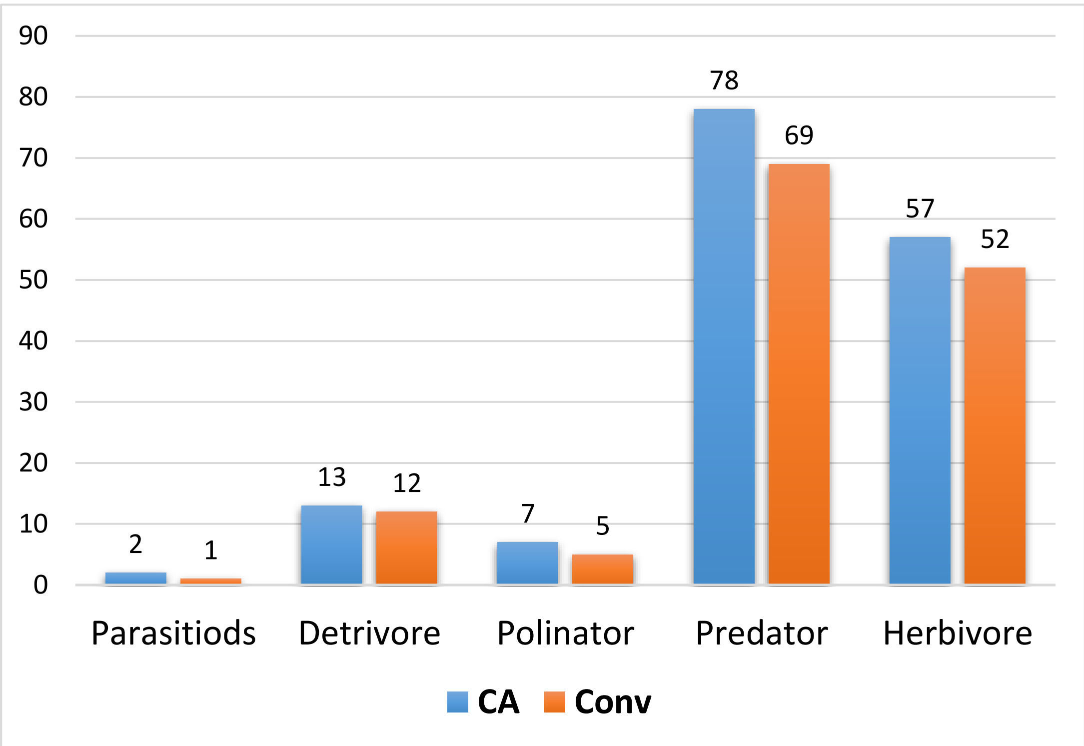

Figure 13. The number of morpho-species categorized in functional groups within CA and conventional sites over three seasons.

With the number of individual species when categorizing into functional groups the number was higher for all functional groups in CA compared to conventional sites except for the number of parasitoids (Fig. 12). The low number of parasitoids was expected since only pitfall traps were used to concentrate on the epigeal arthropods and not the flying parasitoids. The high number of detrivores indicate that organic plant material is consumed and transferred back to the soil, which contribute to nutrition value of the soils under CA. The same tendency was observed with the morpho-species in the functional groups, except that the number of morpho-species was also higher in CA compared to conventional sites (Fig. 13).

2. BSc Environmental Science 3rd year project

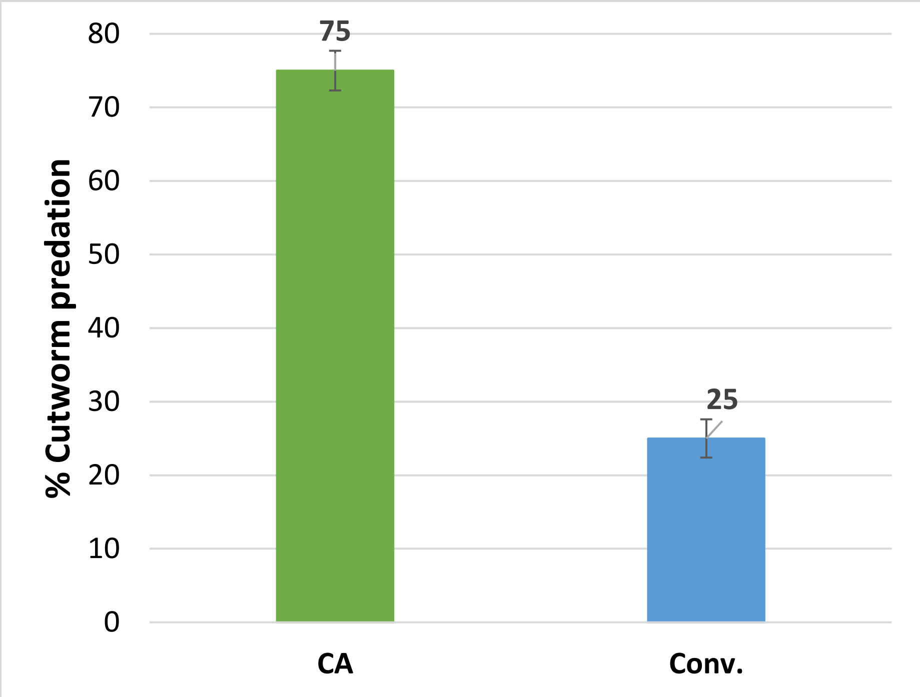

Figure 14. Percentage cutworm predation in CA compared to conventional system.

The potential of insect predators as an ecosystem service under CA was higher than in conventional field (Fig. 14 and 15). Ecosystem service provided by predation arthropods on insect pest, *A. segetum* and weed seeds (*U. mosabicensis*) was higher for the CA system because this system supports a higher abundance and diversity of arthropods. In CA the predation of cutworm was 75% compared to 25% in the conventional field. This means that the amount of crops damaged by pests and weeds can be reduced naturally by practicing conservation agriculture.

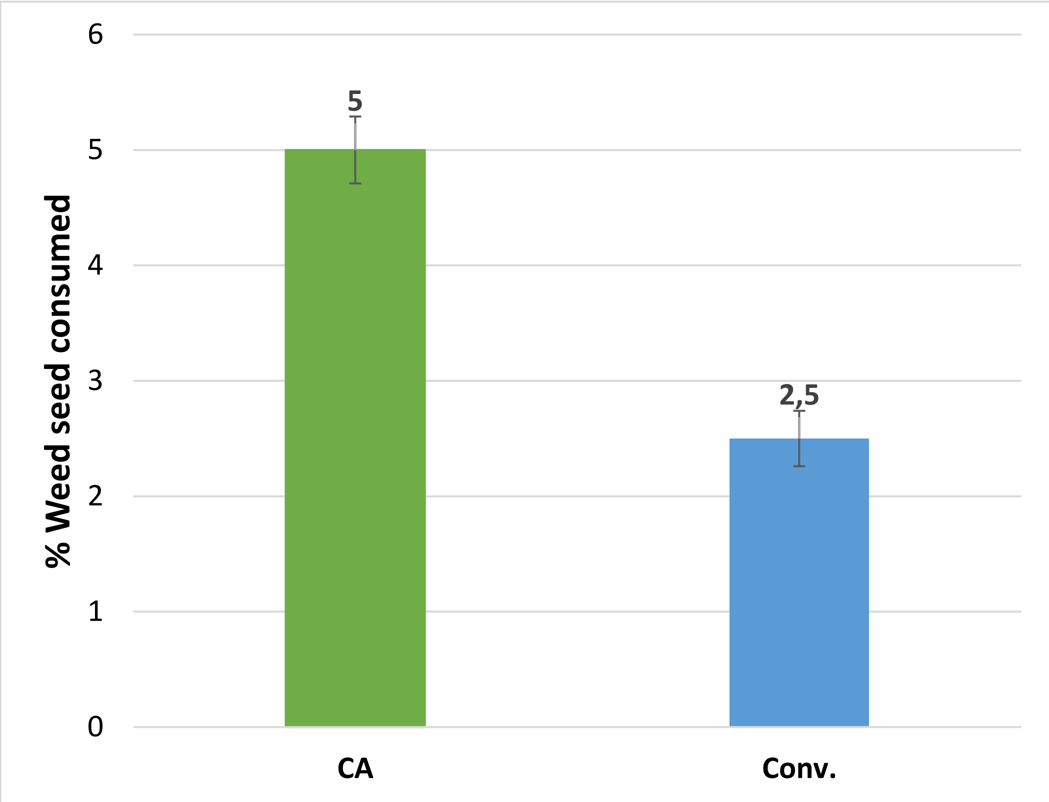

Figure 15. Percentage of weed seed consumed in CA compared to conventional system.

3. Ecosystem service trial

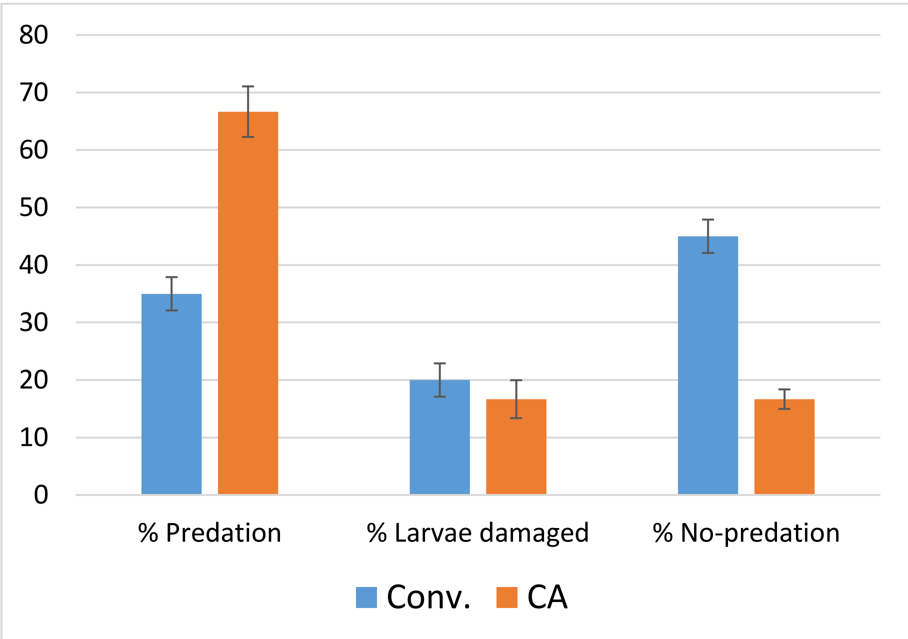

Figure 16. The percentage of larvae that were predated on, only damaged and not predated on in CA and conventional systems.

More than 60% of the larvae in the CA field were predated on compared to less than 40% in the conventional systems. The opposite was observed with the larvae that were not predated on, higher number of larvae were not fed on in the conventional fields compared to the CA field. Therefore, it correlates with the higher number of predators present in the CA field. This observation contributes to the fact that CA can provide an ecosystem service to the producer.

4. Evaluation of potential insect pests

Mooirivier (KZN) - *Classeya tenuistriga* (Hampson) (Lepidoptera: Crambidae)

Reports of localised outbreaks of an unknown pest of maize were received in the Kamberg, Mooi River area in KwaZulu-Natal (29˚19.394'S; 29˚47.310'E) during the 2008/09 growing season. Damage of a similar nature was again reported during the 2009/10 season. Since farmers reported serious damage to maize seedlings, the matter was investigated and the species identified as *Classeya tenuistriga* (Hampson) (Lepidoptera: Crambidae) (Fig. 17).

Fully-grown larvae of *C*. *tenuistiga* are between 10 and 15 mm long. Larvae curl up tightly when disturbed. Larvae develop into pupae inside pupal cells in the soil (Fig. 18). The pupal cell is constructed by spinning and by using soil, leaves and plant debris. Moths are typical of the Crambidae.

This species was described from South Africa during the 1880s (Günther et al. 1898). The original description was made by George F. Hampson as *Crambus* (*Propexus*) *tenuistriga* (Lepidoptera: Pyralidae) from specimens collected near Pretoria. In neither of these two publications were any host plants listed (Kroon 1999).

Damage to maize seedlings in the field is similar to that caused by the common cutworm, *Agrotis segetum* (Denis & Schiffermueller) (Lepidoptera: Noctuidae), and the black maize beetle adult, *Heteronychus arator* (Fabricius) (Coleoptera: Scarabaeidae). The larvae of *C*. *tenuistriga* emerge from soil during the night and sever seedlings at or just below soil surface level. Neat round holes (2-3 mm in diameter) are chewed into seedling stems. The damage can therefore not be mistaken for that of beetles or white grubs of which the feeding holes have frayed edges. Above ground symptoms are initial wilting of the central whorl leaf ("dead heart") which is followed by wilting of the entire plant (Fig. 19). As maize does not propagate vegetatively through tillering, this seedling damage means a cob-bearing stem is lost in the affected field ("stand loss"). This significantly reduces crop yield. At Kamberg, 22% of emerged seedlings were destroyed which means that cob bearing stalks were reduced by 22%. As stems normally bear more than one cob, substantial yield loss occurred. Further costs are incurred by the farmer if stand reduction was such that the maize field had to be replanted.

This field was under conservation practices however, the damage can rather be ascribed to the previous crop planted being a grass species. *Classeya tenuistriga* is known to feed on grass species. Since then the pest has not been reported again.

Figure 17. *Classeya tenuistriga* larva.

Figure 18. Pupae inside pupal cells.

Figure 19. Damage symptoms to maize seedlings.

Ottosdal (NW) - *Protostrophus* sp. (Coleoptera: Curculionidae)

With the first look at the field, it was clear that beetles have been feeding on the sunflower seedlings. Damage to the seedlings was higher that 90%. Ground weevil was identified as the problem species. In some instances, 3 – 4 weevils were present per seedling.

Although the field was not under CA, plant cover was observed from the previous season. The farmer had planted with a seed treatment and was tested by the company involved. The seed treatment concentration was not on standard and new seed was provided to the farmer for replanting.

Figure 20. Ground weevil.

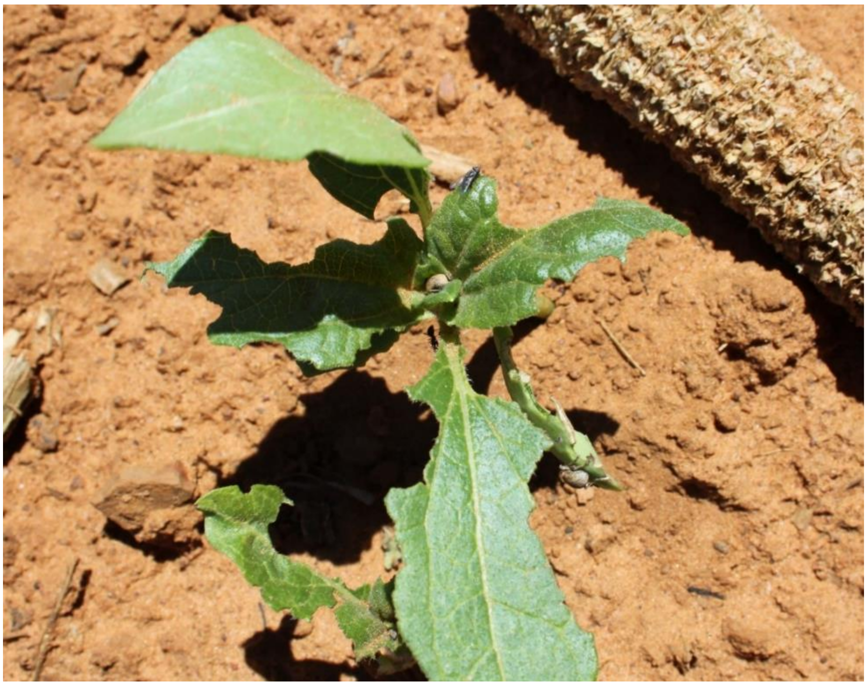

Figure 21. Ground weevil damage to sunflower seedling leaves.

Figure 22. Serious damage to sunflower seedlings.

Potchefstroom (NW) - *Spodoptera exempta* (Lepidoptera: Noctuidae)

The African Armyworm is widely distributed in Africa south of the Sahara, and is a serious pest in countries north of South Africa. A characteristic feature of armyworm outbreaks is their unexpected sudden appearance, and this has led to the common name of "mystery worm". Often, large areas of lawn, pasture or grass crops (like maize and sorghum) are seen to be covered in dense colonies of larvae, virtually overnight. Small outbreaks occur frequently in the high-rainfall areas of Mpumalanga and KwaZulu-Natal, but a large outbreak such as the one during 2013 occurs only once in every 6-10 years. The worst outbreaks in South Africa occur in seasons where there are "late summer rains" after drought conditions.

Moths have brown forewings and whitish hind wings with recognized dark brown patterns on the forewings. Moths are capable of migrating thousands of kilometers especially during outbreak years. The main migration flights of the moths start in early nighttime, and moths ascend to a height of anything between 300-1000m above ground level. Moths move downwind on prevailing air currents. In most parts of South Africa, the infestations are usually due to moths migrating from warmer, more northerly areas, often from Zambia, Zimbabwe or Mozambique to South Africa. The eggs are laid in groups of 100-400. A single female lays several egg masses and up to 1000 eggs. The eggs hatch within 3-6 days depending on temperature and humidity. Larvae can grow to about 25mm long, are blackish with green/yellow lines running along the length of the body and have a characteristic V-shape mark on the front of the head capsule. Fully-grown larvae pupate in the soil.

Figure 23. African armyworm larva.

For effective control measures, larvae need to be detected early. If larvae are discovered when fully grown, the use of insecticide control is often not recommended as most of the damage to crops will already have been done, and the likelihood that a second generation will emerge is very small. Where larvae move from one field to another, a furrow can be ploughed to create a pitfall where larvae can be trapped, ploughed under or controlled with insecticides. Damage observed in the Potchefstroom area was on grass fields and not on any crops. Occurrence of the African armyworm cannot be ascribed to CA.

Parys (FS) - *Bagrada hilaris* (Hemiptera: Pentatomidae)

An unknown insect pest on maize was recently reported in the North West province. The species was identified as the Bagrada bug (Bagrada hilaris). This species is usually a pest on cabbage crops with no reports of maize being attacked. Damage is only recorded in certain patches in the field (Fig.

24). The previous crop planted, radish, lucerne and oats, can explain the possible source of infestation.

Figure 24. Leaf feeding damage of the Bagrada bug.

The Bagrada bug has sucking mouthparts (Fig. 25). The primary host plants on which this bug feeds belong to the Brassicaceae family. It is also reported that this pest can attack other crops (secondary crops) where brassica crops do have high infestation levels. Hatchlings are 1 mm in length and develop quickly into adults that reach 5 - 7 mm. The bug is black with orange-red markings over the entire body. Adults have wings, but rarely fly and can walk considerable distances to infest new plants. Females lay their eggs on the ground or less commonly, on foliage. The eggs are white and then turn orange. A female bug can lay more than 100 eggs, which can hatch within a weeks' time. The nymphs take two to three weeks to reach maturity. A few generations may be produced per season if conditions are favourable.

Bagrada bugs are gregarious and feed in groups. The adults and nymphs attack aboveground plant parts. The bugs have sucking mouthparts with which plant fluids are sucked from green plant material. However, they do not inject toxins to the plant. Damage symptoms differ between different crops. Feeding result in white or yellow markings where feeding have taken place. The damage can usually been seen at the outer edges of the leaves (Fig. 26). The outer edges may dry out and turn brown if damage is severe.

Figure 25. Bagrada bug with pierce and sucking mouthparts.

The cultivation of soils where brassica crops have been planted may help reduce the viability of eggs that are laid on the soil. Old leaves or harvested crops should be destroyed which can be a source where nymphs survive. In the case of conservation farming where no or minimal soil disturbance take place the use of a contact insecticide being sprayed on the soil can be used to control nymphs and adult bug.

Figure 26. Damage to maize leaves after bugs have fed.

Koster (NW) - *Buphonella* sp. (Coleoptera: Galerucidae)

This less known pest has been recorded in KwaZula-Natal (Vryheid, Bloedrivier, Greytown and Howick) and Mpumalanga (Bethal and Piet Retief). Recently it was also recorded in the North West province, Koster district, with 42% damage to maize plants (Fig. 27). The environment played a role because the damage was reported in a new prepared field that previously was a grass field. As soon as the grass was destroyed, the only source of food was the maize plants which led to the rootworm attacking the crop.

The maize rootworm (Fig. 28) is the larval stage of a beetle. The beetle does not cause damage. The beetle is dark-grey and the female can become 7 mm in length and 2.3 mm in width. The male is usually smaller. Eggs are pale orange, oblong and on average 0.9 mm in length and 0.6 mm in width. The larvae are a butter-yellow colour and cylindrical in shape. The fully-grown larvae are about 10 mm long. The head and the last abdominal segment are dark brown, the rest of the body is covered with pale brown spots.

The eggs are laid singly or in clusters of up to 12, attached either to grass roots or just below ground level. The female beetle can lay up to 30 eggs and hatch in about 15 – 18 days. During the winter months, the eggs remain in a dormant state and hatch during spring. After hatching, the larvae start feeding and burrow into the subterranean stem of the maize seedling. The larvae moult three times after which pupal cells (Fig. 29) are constructed in the soil. The pupal stage (Fig. 30) is from seven to 19 days depending on weather conditions. There are three to four generations per year, and the beetle was dense in grass fields where the maize plants had been depleted earlier in the season by maize rootworm.

Maize rootworm could cause serious damage to maize seedlings and reduce plant density to such an extent that it might be necessary to re-plant. Plant density could be reduced by as much as 80%, but infestation usually only affects certain patches in the field. The pest becomes particularly serious during years when good spring rains are followed by a long, relatively dry period. The first visible damage symptoms observed (Fig. 31) are similar to those of maize infested by black maize beetles or false wireworms. Firstly, the whorl wilts and dries after which the entire plant wilts and dies. Some plants survive these attacks by producing many useless tillers. Damage symptoms under the soil include larvae burrowing a tunnel into the mesocotyl (Fig. 32) of the maize seedlings and feed a range of holes into the stem below the soil surface. When more than one larva is on a plant, some larvae may leave the plant, crawl over the soil surface and bore into neighbouring plants.

Maize rootworms only feed on plants belonging to the grass family. Therefore, it is important to keep fields free from weed grasses where maize will be planted. This can be accomplished by cultivation or in the case of conservation farming, with spray applications. The best chemical control that can be used is seed dressing insecticides, which can be applied as a preventative control. However, this is a difficult pest to control with insecticides when under soil surface damage has already taken place.

Figure 27. Damage in the field.

Figure 28. Maize rootworm.

Figure 29. Larva making pupal cell.

Figure 30. Pupa.

Figure 31. First visible damage symptoms observed.

Figure 32. Damage symptoms under the soil surface.

Setlagoli (NW) - Termites

Termite damage was observed to maize plants standing on the field. Although damage was present, no plant lodging was observed because of the termite damage. The field was under CA conditions and this could have contributed to termite damage since soil has not been disturbed. The recommendation was made that fiproniel is used to drainage patches where termite activity is seen.

Figure 33. Termite damage to maize stems after harvesting.

DISCUSSION

Crop losses due to harmful organisms can be substantial and may be prevented or reduced by crop protection measures. That is why it is important to evaluate the efficacy of present crop protection practices such as conservation agriculture (CA) to minimize losses due to the effect of pests whenever it might occur and to optimize productivity. CA promotes soils to have a richer bioactivity and biodiversity, soil erosion is therefore highly reduced, soil agronomic inputs transport slightly reduced, while pesticide bio-degradation is enhanced. It protects surface and ground water resources from pollution and mitigates negative climate effects (Bhan and Behera, 2014). Biodiversity of an agro-ecosystem is not only important for its intrinsic value but also because it influences ecological functions that are vital for crop production (Hilbeck *et al*., 2006).

It can be concluded that CA provides a different habitat to arthropods, which contribute to a higher biodiversity. If a higher biodiversity is present in the field, the ecosystem is more stable, and that decreases the risk of insect pest outbreaks. The diversity indices provided more information than simply the number of species present. To preserve biodiversity in a given area, it is important to be able to understand how diversity is impacted by different management strategies. Findings suggested that arthropod biodiversity in CA systems was higher than in conventional farming systems and contributes in supporting increased arthropod biodiversity.

The potential of predation on insect pest and weeds were also highlighted. Therefore, it can be concluded that insect predators in CA can provide an ecosystem service. By categorizing the different species into functional groups, biodiversity data is simplified to such an extent that more ecosystem services can be seen. The high number of detrivores and predators under CA correlate with the ecosystem service trial where high numbers of larvae were predated on. Detrivores provide an additional ecosystem service by contributing to soil nutritional value by feeding on organic plant and animal material.

During the duration of this project, no new insect pest can be ascribed because producers make use of CA. The only potential pest due to CA can be termite infestation. However, although termite damage was recorded in two CA fields no severe lodging was observed. The rest of the insect pests were not due to CA practises but rather of producers not making use of seed treatments or removing the original host plant.

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