ART
AGRICULTURAL RESEARCH TRUST

Independent Evaluation Report

Long-term commercial cropping systems trial

Supported by	Agricultural Partnerships Trust, Oak Foundation
Trial Season	Winter 2022 – Summer 2024-5
Location	Harare, Zimbabwe
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Highlights

- Long-term regenerative cropping systems were evaluated against conventional systems under irrigated and rainfed conditions in Zimbabwe.
- Regenerative practices improved yields and enabled fertiliser reductions in irrigated systems, particularly following winter cover crops.
- Gross profits were lower in regenerative systems over three years due to cover crops replacing cash crops, despite yield gains in subsequent seasons.
- Regenerative practices did not improve yields or profitability in rainfed systems within the three-year evaluation period.
- Grazing a winter cover crop provides cash relief from the loss of a winter crop, and whether this is enough depends heavily on the livestock and cropping system

1 Introduction

Commercial agricultural systems in Zimbabwe must continually develop to reduce land degradation and maintain a profitable agricultural sector. Part of the solution is Regenerative agriculture, a concept which places focus on improving soil health over time. In the context of commercial agriculture, which uses a high level of inputs, the aim is to replace some of these inputs with natural processes. Importantly, yields must be maintained or improved to improve profitability. While commercial agriculture has prioritized short-term productivity, it has often done so at the expense of long-term soil health. In contrast, regenerative agriculture seeks to reverse these trends by rebuilding soil organic matter, enhancing soil microbial functions, and promoting holistic farm management practices that sustain both productivity and environmental integrity. The design and management of regenerative cropping systems for different contexts is very important. This includes use of principles such as reduced- or no-tillage, cover cropping, plant diversity, year-round living roots, and livestock integration figure 1.1, all aimed at enhancing soil structure, nutrient cycling, water retention, and biodiversity. Despite growing interest and application of these principles to cropping systems in Zimbabwe, there remains a critical need to evaluate how different cropping systems perform when principles of regenerative agriculture are applied.

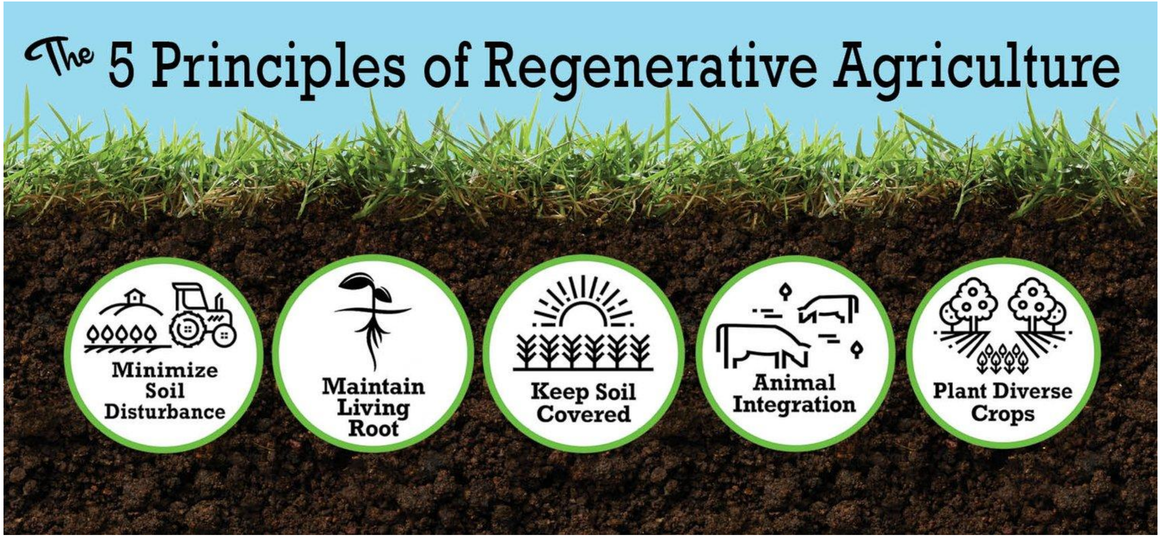

Figure 1.1: Principles of Regenerative Agriculture

This long-term experiment systematically compares a range of conventional and regenerative cropping systems. By evaluating essential metrics such as soil health, yield, pest suppression, and gross profit, the study will provide evidence on the relative benefits and trade-offs associated with each system from the perspective of the farmer.

2 Methodology

2.1 Experimental Design

A randomized split-plot design was used. The main factor was cropping system, with 5 systems evaluated which were designed to suit the red clay loam soil type at ART Farm: (1) A conventional irrigated system which used full cultivation on a 2 year maize-wheat-soya-wheat rotation; (2) A regenerative irrigated system which employed no-till and strip-till on a 2 year maize-cover-soya-wheat rotation (Winter multispecies cover crop); (3) A regenerative irrigated 3 year rotation of maize-wheat-cover-wheat-soya-wheat (summer multispecies cover crop), (4) A Conventional rainfed 2 year rotation of maize-soya with tillage, and (5), a Regenerative rainfed system with a 3 year cover-maize-soya rotation. Both winter and summer cover crops replaced a cash crop in the regenerative systems. This is because there is no time in the cropping calendar (in Maize-Wheat-Soy systems) for a true 'cover' crop to maintain soil cover and living roots where it normally would be bare. The treatment diagram and rotation for each treatment is shown in figure 2.1. Additionally, in the final two seasons of the trials, each cropping system was split into a full and a reduced fertilization rate.

	CONVENTIONAL IRRIGATED		REGENERTIVE IRRIGATED WINTER COVER		REGENERATIVE IRRIGATED SUMMER COVER		CONVENTIONAL RAINFED		REGENERATIVE RAINFED	
	Full Fert	Reduced Fert from W24	Full Fert	Reduced Fert from W24	Full Fert	Reduced Fert from W24	Full Fert	Reduced Fert from S24-5	Full Fert	Reduced Fert from S24-5
W22	Wheat		Cover		Wheat		-		-	
S22-3	Maize		Maize		Cover		Maize		Cover	
W23	Wheat		Cover		Wheat		-		-	
S23-4	Soya		Soya		Soya		Soya		Soya	
W24	Wheat		Wheat		Wheat		-		-	
S24-5	Maize		Maize		Maize		Maize		Maize	

Figure 2.1: Treatment diagram, rotation calendar, and colour codes

2.2 Site Description

The site is located at ART Farm, Harare, on red clay loam soils. This lies in Agroecological zone IIb, and has an annual rainfall average of 830mm. It is important to note that this soil type represents approximately 10% of Zimbabwe's arable land, with the remainder being often much more sandy.

2.3 Plot Management

All crops were kept weed-free using chemical control. Crops were planted at standard populations and were kept pest-and disease free using chemical control. Best management practices were applied for use of chemicals, including the use of them only if absolutely necessary to achieve a commercially profitable crop. Irrigation was done using overhead sprinklers. Standard recommended fertilisation rates were applied to each crop. For maize this was 250 Kg/ha of 6:23:23 N:P:K basal fertiliser, with 400 Kg/ha Ammonium Nitrate applied in two stages. For wheat 400 Kg/ha 6:23:23 N:P:K was applied as basal and 400 Kg/ha Ammonium Nitrate applied as a top dressing split application. For Soya, 250 Kg/ha N:P:K was applied as a basal application. Summer and Winter cover crops received no fertiliser. The trials were started in winter 2022 after a summer crop of sugar beans under full cultivation.

3 Results and discussion

3.1 Irrigated cropping system and Fertilisation rates

Figure 3.1 shows the yields of each of the three full irrigation treatments. Where columns are missing in years, this is because a winter or summer cover crop was planted in place of the cash crop. When reduced fertilisation rates were introduced in winter 2024, the full and reduced basal (6:23:23) rate was set at 400 Kg/ha and 175 Kg/ha respectively, and the top dressing rate (Urea) was set at 400 Kg/ha and 300 Kg/ha respectively. Summer 2025 Maize was fertilised with 250kg/ha in full fertilisation, and 200kg/ha in the reduced treatment. Error bars are shown from Winter 2024, when the experiment was replicated.

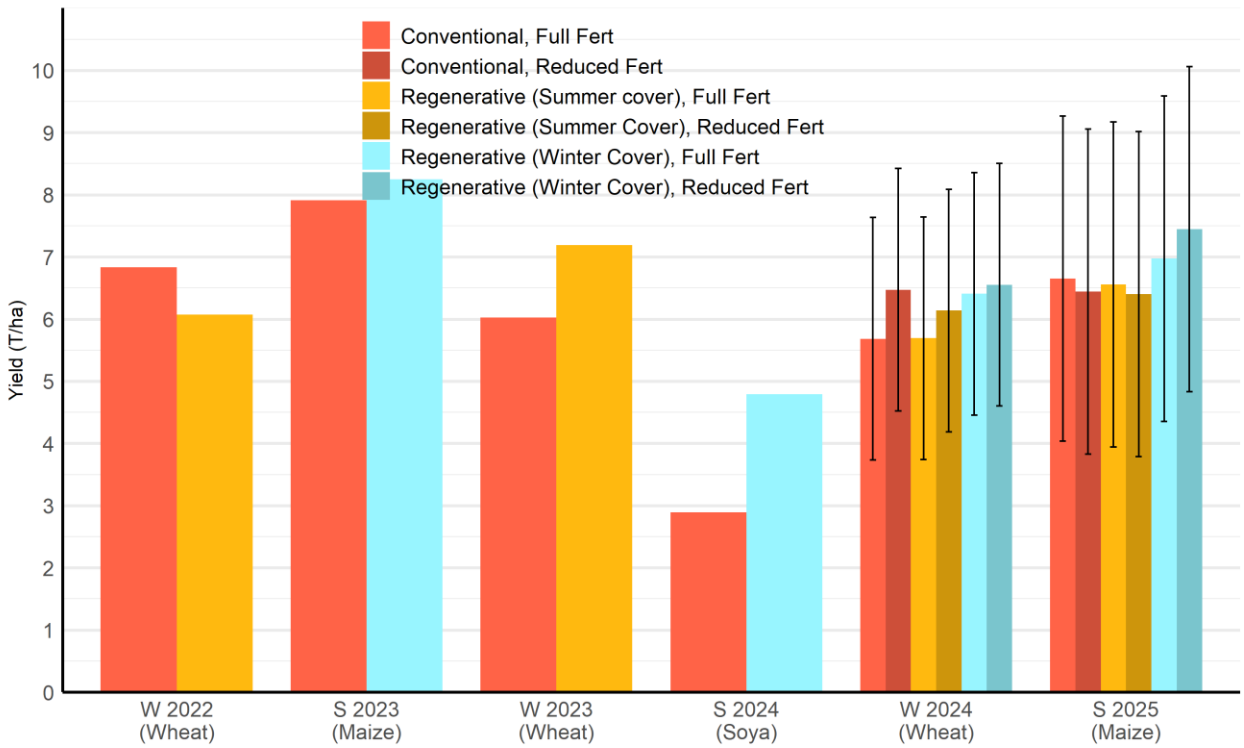

Figure 3.1: Irrigated yields of cash crops. Error bars represent confidence intervals.

3.1.1 Winter 2022 Wheat

The Winter 2022 wheat yields showed a reduced Regenerative yield compared to the conventional system. The regenerative wheat was drilled into the residue of a grazed a summer cover crop, which did not receive any fertilisation. This is likely to be the main factor in causing the reduced yield of the following wheat crop, in addition to possible nitrogen lock-up from the thick layer of surface residue. The Regenerative Summer cover actually performed better than the conventional in Winter 2023, when it was following a maize crop with far less surface residue.

3.1.2 Summer 2022/3 Maize

Maize grown under the regenerative system in Summer 2023 yielded slightly higher than its conventional counterpart, despite following a winter cover crop that also received no fertilisation. This suggests that maize may be better able to tolerate or recover from reduced nutrient availability in regenerative rotations, possibly benefiting from improved soil structure or microbial activity.

3.1.3 Winter 2023 Wheat

In contrast to the previous seasons wheat, regenerative wheat yields in Winter 2023 outperformed the conventional system. In this case, the regenerative wheat followed a maize crop, which left behind less surface residue and had received fertiliser. This outcome highlights the importance of previous crop type and residue load in influencing the success of regenerative wheat, particularly under direct-drilling and low-disturbance systems.

3.1.4 Summer 2023/4 Soya

The Soya crop in 2024 showed the greatest yield response to a regenerative system. Soyas are known to perform very well under no-till, and following the 2023 Winter cover crop likely added further yield benefits. The yield rose from 2.89 T/ha in the conventional to 4.79 T/ha in the Regenerative winter cover treatment, an increase of 66% in yield.

3.1.5 Winter 2024 Wheat with fertilisation split

In winter 2024, wheat was grown in all treatments, after the summer cover and winter cover regenerative systems had had two years of cover crops each. The fertiliser was also reduced in half of each of the plots in order to observe the effect on yield. Overall there were no significant differences. The full fertilisation rates all performed similarly, and interestingly they all performed worse than the treatments with reduced fertiliser. Because this difference was observed in conventional and regenerative treatments, the factor causing the difference must have been due to something applied the same across all treatments. Contributing factors may be the low amount of irrigation applied in early growth stages, causing higher salt content in the soil at the higher fertilisation rate.

3.1.6 Summer 2024/5 Maize with fertilisation split

In this season, maize was grown in all irrigated systems. Only the Regenerative winter cover was improved over the other treatments, but the difference was not significant. Interestingly there was no drop in yield with reduced fertiliser application, and it was even increased in the Regenerative winter cover treatment, but this difference was not significant.

3.1.7 Economics of Irrigated systems

The economics of cropping systems are probably the most important metric with regard to the feasibility of the systems in Zimbabwe. The inclusion of cover crops in place of cash crops is of most significance, as there is no direct income from sale of a crop when a cover crop is grown. When livestock are included in the system, there are benefits to using the cover crop as fodder beyond simply weight gain that are not readily quantifiable on ART in monetary terms. For example, with a breeding herd, grazing cows on the green fodder is likely to improve cycling and result in higher pregnancy rates. If weight gains are taken into account, then the faster turnover of cattle also plays an important role in the profitability of a system. Whether the value from livestock grazing the winter cover are enough to warrant replacing a winter cereal such as wheat or barley, is a highly context dependent question. Frequency of electricity shortages, reliability of water supply, reliability of markets, and financial risk of investing in the inputs required for winter cereals, are all important considerations. Similarly, cattle markets, winter feed availability and prices, herd nutrition requirements, also need to be considered.

Here, it is assumed simply that the cover crop directly substitutes for winter maintenance feed. Using data from previous trials, it is estimated that one hectare of cover crop has a cumulative stocking rate of 1441 a.u. days / ha. This is because in one cycle of grazing the stocking rate is 576 a.u.days /ha, but the cover crop can be grazed twice plus a third cycle of half stocking rate (2.5 cycles total). Cattle in this system are provided for approximately 15 minutes in the morning and 15 minutes in the afternoon, with an allowance of $17.5m^2$ / a.u. each day. Cattle in both systems maintain a constant weight. The expenses and incomes of the different systems are compared in table 3.1.

Over the three years, gross profit sharply dropped due to regenerative practices. However, in the third year, clear yield and input reduction benefits were seen, an indication that this drop in gross profits was becoming less and less. Experiments from similar studies, such as the long-term trial at Langgewens in the Western Cape, show that after approximately 5 years, similar yield and input reduction benefits result in an increase in gross profit compared to the conventional systems. To acheive the same profitability with conventional systems, cumulative profits could be measured, which would be longer than 5 years at Langgewens. In the context of ART, to make equivalent profits to the conventional system would certainly be longer than 4 years, and likely longer than 6 years, if the regenerative system profits started to exceed conventional profits in the 4th year. Additional experimentation would be needed to verify the exact time this would occur, and the extent to which cumulative regenerative profits would exceed conventional after this time.

Table 3.1: *Income and expenditure for each irrigated system tested for each year. A summary of all years is shown at the bottom of the table. All costs in USD. All costs are variable costs only and do not include overheads. Labour, repairs and maintenance, and diesel costs are included.*

year	season	name	Conventional	Regenerative (Summer Cover)	Regenerative (Winter Cover)
2022	Winter	Cattle feed cost	515.88	515.88	0.00
		Crop cost	1186.87	1186.87	270.53
		Crop revenue	2868.60	2549.40	0.00

		Gross profit	**1681.73**	**1362.53**	**-270.53**
2023	Summer	Cattle feed cost	0.00	0.00	0.00
		Crop cost	675.02	240.00	675.02
		Crop revenue	2530.88	0.00	2640.00
		Gross profit	**1855.86**	**-240.00**	**1964.98**
2023	Winter	Cattle feed cost	515.88	515.88	0.00
		Crop cost	1186.87	1186.87	270.53
		Crop revenue	2531.05	3019.23	0.00
		Gross profit	**1344.18**	**1832.36**	**-270.53**
2024	Summer	Cattle feed cost	0.00	0.00	0.00
		Crop cost	1208.00	240.00	1208.00
		Crop revenue	1432.20	0.00	2394.01
		Gross profit	**224.20**	**-240.00**	**1186.01**
2024	Winter	Cattle feed cost	515.88	515.88	515.88
		Crop cost	1186.87	1186.87	1186.87
		Crop revenue	2385.99	2350.64	2485.88
		Gross profit	**1199.12**	**1163.77**	**1299.01**
2025	Summer	Cattle feed cost	0.00	0.00	0.00
		Crop cost	1208.00	1208.00	1208.00
		Crop revenue	2393.32	2359.31	2509.27
		Gross profit	**1185.32**	**1151.31**	**1301.27**
All	**All**	**Cattle feed cost**	**1547.64**	**1547.64**	**515.88**
		Crop cost	**6651.63**	**5248.61**	**4818.95**
		Crop revenue	**14142.04**	**10278.58**	**10029.16**
		Gross profit	**7490.41**	**5029.97**	**5210.21**

3.2 Rainfed Cropping systems

The rainfed systems have been evaluated for three years of data. The regenerative system included a summer cover crop in Summer 2023/4, followed by soya and then maize. The conventional system followed a Maize (2023/4), Soya (2024), Maize (2024/5) Rotation. Figure 3.2 presents the yield of the crops grown. Summer 2022/3 and 2023/4 do not show major differences in yield, yet for maize grown in Summer 2024/5, the conventional treatments had a slightly improved yield in 2023 and 2025, and a much greater yield in 2024. This contrasts with the irrigated systems, in which regenerative systems generally outperformed conventional. Similarly to the irrigated plots, the reduced fertiliser treatment performed better than the full fertilisation plots in regenerative systems but not in conventional systems. This is an indication of improved soil health. It is possible that the increase in soil health from regenerative practices has led to the improved yields under reduced fertiliser, an example of ecological processes substituting for human inputs.

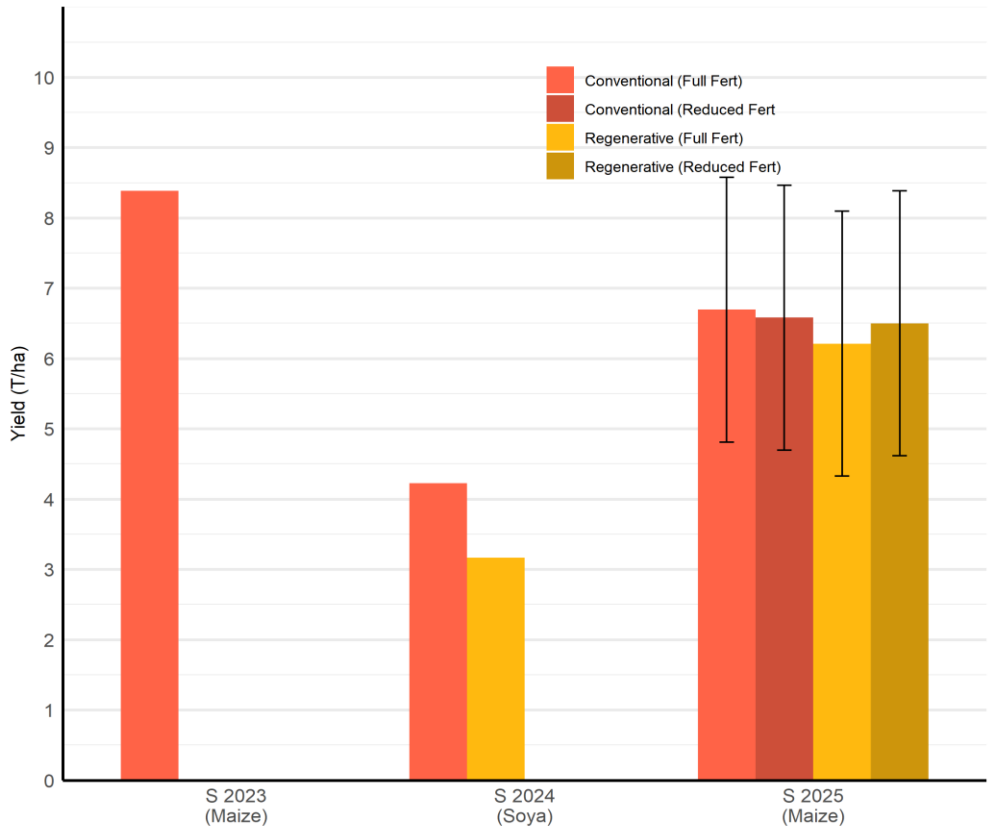

Figure 3.2: Yields of Rainfed cash crops. Error bars represent confidence intervals.

3.2.1 Economics of dryland systems

Table 3.2 shows that the conventional treatment had a higher gross profit than the regenerative. This is also the case for the reduced fertiliser treatment, because the saving of 50kg/ha basal fertiliser in Summer 2024/5 ($38/ha) made a negligible difference to the overall gross profit, considering that in 2022 an entire seasons income was lost.

Table 3.2: Income and expenditure for each dryland system tested for each year. A summary of all years is shown at the bottom of the table. All costs in USD. All costs are variable costs only and do not include overheads. Labour, repairs and maintenance, and diesel costs are included.

Year	Season	Name	Conventional	Regenerative
2023	Summer			
		Crop cost	675.02	219.00
		Crop revenue	2683.20	0.0
		Gross profit	**2008.18**	**-219.00**
2024	Summer			
		Crop cost	675.02	675.02
		Crop revenue	2090.28	1582.28
		Gross profit	**1415.26**	**907.26**
2025	Summer			
		Crop cost	1208.00	1208.00
		Crop revenue	2410.30	2235.22
		Gross profit	**1202.30**	**1027.22**
All	**All**			
		Crop cost	**2558.04**	**2102.02**
		Crop revenue	**7183.79**	**3817.51**
		Gross profit	**4625.75**	**1715.49**

4 Conclusions

This project was established to evaluate the integration of regenerative agriculture principles into Zimbabwean maize, wheat, and soya row cropping systems, in both rainfed and irrigated contexts. Regenerative systems were designed to apply principles of increased crop diversity, livestock integration, minimum soil disturbance, and ground cover.

4.1 Irrigated systems

In irrigated systems, yields in regenerative systems were improved compared to the conventional systems over three years. The winter cover and no-till resulted in the best increase in yield for the subsequent crop. Most notably so in the Soyas in 2023/4, which produced almost 2t/ha more than the conventional system. This is evidence that employing regenerative principles improves yields of subsequent crops in this context. Furthermore, the reduced fertiliser interestingly contributed to greater yields in the regenerative system, but not in the conventional, which shows that the regenerative practices enabled input reduction.

The economics of the irrigated systems show a different result. Yields were improved and fertiliser was reduced with the cover crops, providing better gross profits for the regenerative systems in cash crop years. However, in cover crop seasons, the land produced no direct income. The only income would be from cattle condition improvement, translating into potentially better pregnancy rates in the summer, faster turnover of cattle, and possible health benefits. Due to the nature of these benefits, they are not readily converted into monetary income. Because of this, they have not been included in costings, but it is noted here that integration of livestock, especially a breeding herd on winter cover crops, would alleviate some of these losses, although likely not all of them.

Overall, from three years of experimentation, the gross profit was greatest on the conventional system. Since it could be expected that the regenerative system profits would exceed the conventional system profits after a minimum of 4 years, a longer time frame than this would be required for cumulative profits of both systems to be equal. Therefore, it is only recommended to grow winter cover crops in place of a winter cereal if the benefits from the livestock are perceived to be great enough that they can outweigh the loss of direct profit from growing fewer cash crops. If there is no livestock integration, a in profit for 4 years at a minimum is simply not a possibility for many commercial medium and large-scale farmers in Zimbabwe, especially considering the land tenure situation in the country. If there is livestock integration, the time that regenerative system would take to match the profits of the conventional would be shorter, but likely still more than 2 years, which would heavily vary with the estimates and livestock system of individual farms.

4.2 Rainfed systems

In rainfed systems, there was no improvement in yield form regenerative practices, and in some years conventional systems performed better. This shows similar results to the summer cover irrigated system, and indicates that the cover crop grown in summer did not have the intended effect on soil health in order to improve the growth of a subsequent crop. This may be due to the species mixture used (80% grass, 18% legumes, 2% other species, total 7 species), since the main objectives were grazing production and soil health.

This is reflected in the gross profits of each system. The regenerative system both had lower yields and had no income for 1 out of 3 years. Therefore, it is not recommended to miss a seasons cash crop a summer cover crop in rainfed systems, since yields did not rise to alleviate the losses of the cover crop. in addition, direct benefit from cattle grazing would be less, since the fodder is available at a time when cattle have good natural grazing. Silage making would be more optimal for nutritive value, but the potential benefits from direct grazing lost. More research would be require to determine if the regenerative system would provide yield benefits and ultimately improved profits on a period longer than 3 years.

4.3 Future research

In light of these results, future research will need to focus on the improvement of soil health through practices which result in maintained or improved profits, as well as maintained or improved yields. Possible options to explore include intercropping, because a cash crop can be grown at the same time as soil health crop, and biological products, which require no changes to the crop rotation, but have potential to improve soil health and reduce fertilizer inputs.