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Agriculture
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Evaluation of the Impact of the Long-Term Crop Rotation Trails at Langgewens

Main Document

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Acronyms

CWWW	Canola, Wheat, Wheat, Wheat
DPME	Department of Performance Monitoring and Evaluation
ha	Hectares
MWMC	Medic, Wheat, Medic, Canola
NEPF	National Evaluation Policy Framework
WMC/WM/C	Wheat, Medic/Clover, Wheat, Medic/Clover
WCG	Western Cape Government
WCWL	Wheat, Canola, Wheat, Lupins
WMWM	Wheat, Medic, Wheat, Medic
WWLC	Wheat, Wheat, Lupins, Canola
WWWW	Wheat, Wheat, Wheat, Wheat

Section 1: Introduction

1.1. Introduction

Urban-Econ, in collaboration with Social Systems Scanners (SOSSCA) and Agronomist, Christopher Yohane, has been appointed by the Western Cape Department of Agriculture to undertake an impact evaluation of the Swartland Community Crop Rotation project on Langgewens farm near Malmesbury. The purpose of the study is to determine what impact the study on Langgewens has had on the greater Swartland region. The project on Langgewens started in 1996 and the project will turn twenty in 2016. Finally the impact assessment provides recommendations for the future of the project.

1.2. Purpose of the Evaluation

The global population has doubled over the last 40 years from 3 billion to more than 6 billion people, and it is projected that it will exceed 9 billion by the year 2050. In order to provide sufficient food for this population, it is estimated that current food production must increase by 70% over the next 35 years (Knott, 2015). Although the economy of the Swartland is based on wheat production, due to a number of factors, this type of production has become increasingly risky to farms and as a result alternative crops and cropping systems have been identified as potentially financially viable alternatives. Despite this potential (i.e. canola, lupins and medics) no large-scale, long term evaluations have been conducted before the initiation of this long-term project to determine the long-term, on-farm potential of various crops and crop/pasture rotation systems. This evaluation therefore seeks to determine the impact of the knowledge generated by the project on the farms in the study area.

The project evaluated was launched in 1996 by the Western Cape Department of Agriculture. This project consists of eight rotation systems, which included four cash crop and four cash crop/annual pasture rotation systems. As such the evaluation needs to determine the short and long-term effects of these 8 rotation systems in terms of: crop yields; weed control; disease suppression; soil production; sheep production; and economically sustainable land-use in the Swartland. Therefore the goals and the objectives of this evaluation are:

GOAL: To provide a comprehensive evaluation of the impact of the long-term crop rotation trial, on the shift from monoculture cropping to rotation in the Swartland and of the sustainability of farming systems in the grain producing areas. The evaluation will allow discussions to be made on the future of the project and to utilise known results to take sustainable crop production and food security forward.

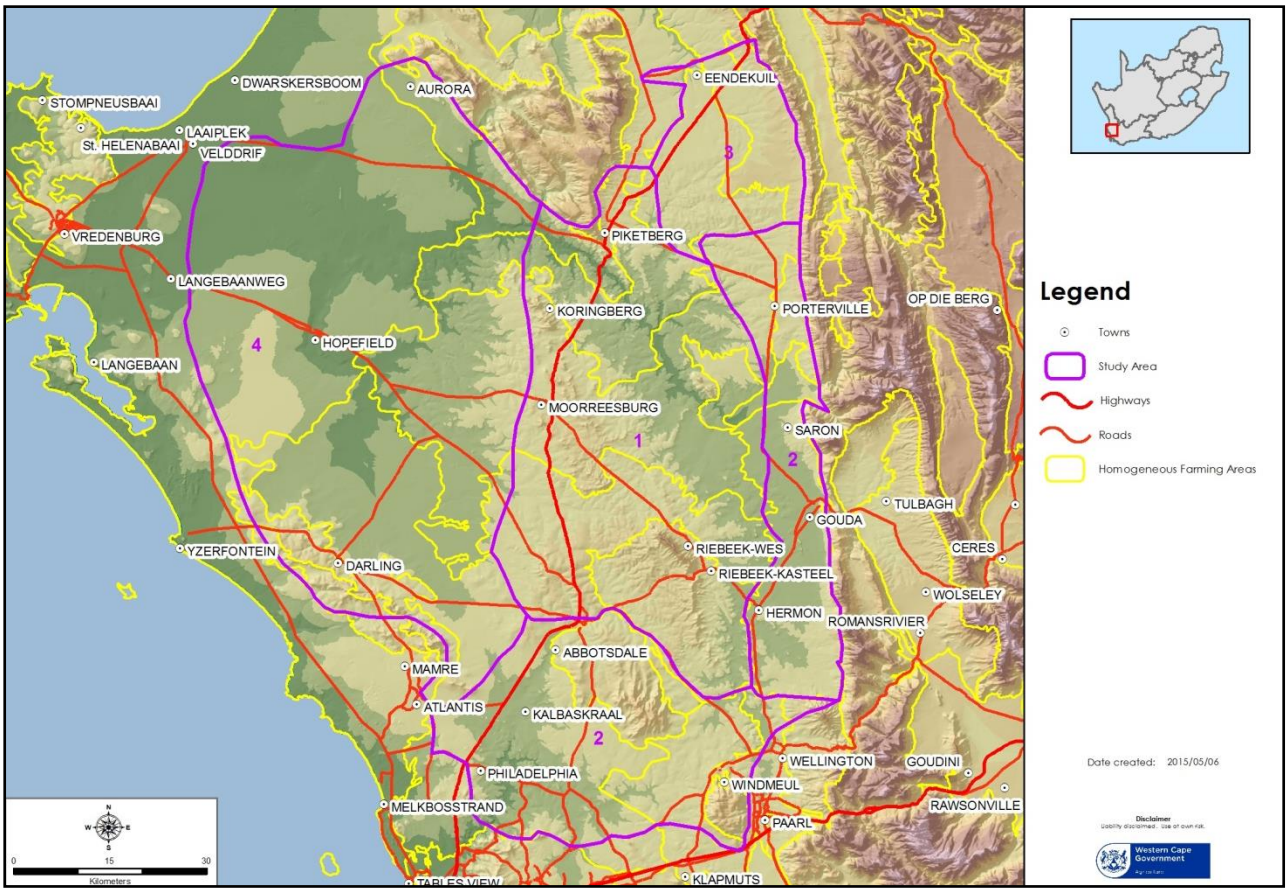
Based on this goal, the following objectives have been identified:

- To assess the impact of existing rotation systems on the sustainability of farming in the Swartland, with specific reference to crop yield and quality, weed control and weed seedbanks, carbon content of soils and the diversification of farming (including animal factor).
- To determine the long-term effect of crop and crop/pasture rotations on the financial and economic viability of farming systems in the Swartland, including an indication of improvements or declines in farm income as well as an indication of differences between farm sizes (economies of scale).
- To assess the adoption rates of crop rotation research amongst farmers in the Swartland and which factors influence these rates.
- To provide recommendations for design changes that should be made with regards to crop rotation research to enhance its impact per research expenditure. As such this should include an assessment of current research needs overall and in depth assessment of crop rotation and systems research relevant to the Swartland. Also a priority list of research needs to be relevant to crop rotation in the Swartland.

The evaluation was focused on the greater Swartland region (Map 1.2.1). The sample areas identified within the Swartland were:

- Rooi Karoo (low potential for agriculture) (number 3 on map)
- High Rainfall (high agriculture potential) (number 2 on map)
- Middle Swartland (med-high potential for agriculture) (number 1 on map)
- Sandveld (only wheat and lupin have potential) (number 4 on map)

MAP 1.2.1: STUDY AREA



1.3. Methodology

An inaugural meeting with the client and the project team was held to refine the scope of the brief and to obtain all the relevant background information relating to the study. Stakeholders and role-players were identified and consulted (i.e. WCG Department of Agriculture, role-players involved in the Langgewens Experimental Farm, farmers in the grain producing areas of the Swartland, Winter Cereal Trust, GrainSA, and agri-businesses). A survey questionnaire was designed in order to obtain information from farmers to understand crop yield and quality, weed control and seed banks; carbon content of soils, the diversification of rotational crop systems; and understanding the financial implications of the crop rotational systems.

The evaluation framework was developed based on the precise qualification and quantification of the objectives based on key performance indicators, norms and parameters. The evaluation framework is in a matrix format and weights were given to the criteria in terms of qualification and critical value. The main outcomes included: crop

yields, weed control, disease suppression, soil production potential, sheep production and economically sustainable land-use in the Swartland. The analyses make recommendations on 'how' the findings of the trial came to influence agricultural practices and develop an understanding of how the uptake and influence of future research could be improved upon. The report concludes with recommendations on what decisions need to be taken as to the future of the programme, how to improve on crop production and sustainable crop rotation and take the positive results forward and provide a suggested way forward concerning the particular needs of farmers with regard to sustainable farming systems for the area under evaluation.

1.4. Report Outline

The remainder of the report is broken down into the following sub-sections:

Section 2: Research Strategy & Overview of Study Area – this section outlines the research strategy used to collect data and provides an overview of crop rotation trials in the Swartland.

Section 3: Evaluation Framework – this section provides an overview of the evaluation framework, with criteria used to measure the objectives of the study and to illustrate the extent to which each objective has been met.

Section 4: Recommendations – this section provides an overview of recommendations.

Annexure A: Survey Questionnaire Analysis – this section outlines the analysis of the survey questionnaire.

Section 2: Research Strategy & Overview of Study Area

2.1. Introduction

This section provides an overview of the research strategy used in this study and outlines a short description of the trials at Langgewens.

2.2. Research Strategy

To ensure that government evaluation studies are carried out accordingly, specific government guidelines and standards had to be followed. The Department of Performance Monitoring and Evaluation's (DPME) Standards for Evaluation in Government (2014) have a set of standards that intend to support the use of evaluations conducted through the national evaluation system through setting benchmarks of evaluation quality. They are based on the National Evaluation Policy Framework (NEPF, 2011). According to the NEPF there are four main purposes of evaluation, namely:

1. Improving policy or programme performance (evaluation for continuous improvement). This aims to provide feedback to programme managers.
2. Evaluation for improving accountability e.g. where is public spending going? Is this spending making a difference?
3. Improving decision-making e.g. should the intervention be continued? Should how it is implemented be changed? Should increased budget be allocated?
4. Evaluation for generating knowledge (for learning): increasing knowledge about what works and what does not with regards to a public policy, programme, function or organisation.

Monitoring and evaluation is an intertwined concept and an essential part of every project or programme design. Monitoring entails a systematic and logical process of collecting information. It provides a platform to learn from experiences and improve activities in future and promotes internal and external accountability of resources. The data acquired through monitoring is used for evaluation. Evaluation systematically and objectively assesses a completed project or programme (or a phase of an on-going project that has been finalised). It helps to draw conclusions about the sustainability, relevance, effectiveness, efficiency and impact of the project.

The following data collection methods were used to complement the qualitative and quantitative research approaches:

- Document Review (secondary data source) – existing documents provided by the Western Cape Department of Agriculture and documents from scholars, the internet, etc.
- Interviews (primary data source) – face-to-face interviews and telephonic interviews
- Questionnaires (primary data source) – survey questionnaires conducted with farmers

The sample size for this study was to be between 20 and 25 farmers per region (i.e. Rooi Karoo, Middle Swartland, Sandveld and High Rainfall area). In total 85 farmers were interviewed in the greater Swartland. The sample was used to determine the adoption rate of crop rotation in the study area and the financial and economic impact crop rotation had on the farms. Table 2.2.1 indicates the number of survey questionnaires completed per region and the reasons why the target of 20 to 25 farmers was not reached in some regions.

TABLE 2.2.1: NUMBER OF SURVEY QUESTIONNAIRES COMPLETED

Region	Number of Survey Questionnaires Completed	Reasons for not reaching the target of 20 to 25 farmers per region
Rooi Karoo	6	The Farmers Association in this area did not want to disclose farmers contact details, but the Association did email the survey questionnaire to all of its members. GrainSA provided a few extra contact details.
Middle Swartland	43	The Farmers Association in these areas provided all the contact details of farmers in the area. All the farmers were contacted and all the farmers interested in taking part in the study were either interviewed or filled in the survey questionnaire electronically.
Sandveld	27	
High Rainfall	9	The Farmers Association in this area did not want to disclose farmers contact details, but the Association did email the survey questionnaire to all of its members. GrainSA provided a few extra contact details.
Total	**85**	

As with any research or study, limitations can be expected. Below is a summary of limitations experienced during the data collection:

- Some respondents' contact details were not made available to the research team (as mentioned above). The research team had to rely on farmers responding to the emails without being able to phone the farmers directly.
- Some respondents' were not willing to take part in the survey questionnaire. Some reasons were lack of time, not interested in contributing towards the study, etc.
- Many of the farmers were planting during this time and even though they were interested in taking part they could not find the time to do so. That said, some farmers found the time during planting even when it meant the research team had to interview the farmer in their field.

2.3. Langgewens Experimental Farm

The long-term crop rotation project was launched in 1996 by the Western Cape Department of Agriculture, with the support from industry (local business players) through the Winter Cereal Trust. The project consists of 8 crop rotation systems, which include four cash crop and four cash crop/annual pasture rotation systems. The experimental design encompasses eight crop rotation treatments, fully represented each year and replicated twice, in a random block design. The whole experiment operates under a no-tillage practice, with a total experimental area of 50 hectares divided up into 38 camps, each camp comprising a minimum or maximum size of 0.5ha or 2.0ha respectively. Each year there are ten medic camps with a grazing herd of 66 sheep, divided over the medic camps according to each of the pasture system requirements (Knott, 2015). The eight rotations selected for the experiment are:

1. System A – Wheat, Wheat, Wheat, Wheat (WWWW)
2. System B – Canola, Wheat, Wheat, Wheat (CWWW)
3. System C – Wheat, Canola, Wheat, Lupins (WCWL)
4. System D – Wheat, Wheat, Lupins, Canola (WWLC)
5. System E – Wheat, Medic, Wheat, Medic (WMWM)
6. System F – Wheat, Medic/Clover, Wheat, Medic/Clover (W M/C W M/C)
7. System G - Medic, Wheat, Medic, Canola (MWMC)
8. System H – Wheat, Medic/Clover, Wheat, Medic/Clover (With saltbush pastures) (W M/C W M/C)

Table 2.3.1 indicates the ranking of total wheat production per farm (800 ha) between different rotation systems, derived from average wheat yield (kg/ha) and the area of arable land under wheat production per system for the period 2002 to, and including, 2012 (Strauss&Hardy, 2014).

TABLE 2.3.1: WHEAT PRODUCTION IN DIFFERENT ROTATION SYSTEMS (LANGGEWENS 2002 – 2012)

System	Average Yield (kg/ha)	% Area Under Wheat Production	Total Amount of Wheat Per Farm (ton/farm)	Average Gross Margin (R/ha)	Difference Compared to Monoculture (R/farm)	% Improve-ment
WWWW	2 854	100%	2 283.2	R 2 022	-	-
CWWW	3 158	75%	1 894.8	R 2 684	R 528 115	33.6%
MWMW	3 942	50%	1 576.8	R 2 972	R 760 216	47%
McWMcW	3 843	50%	1 537.2	R 3 402	R 1 103 959	68.2%
LWCW	3 794	50%	1 517.6	R 3 051	R 823 401	50.9%
LCWW	3 664	50%	1 465.6	R 2 495	R 378 112	23.4%
MCMW	4 072	25%	814.4	R 2 985	R 770 553	47.6%

(Strauss&Hardy, 2014)

Monoculture production produces the most wheat per farm since it uses all the available arable land, but the impact of including alternative crops in rotation with wheat can be seen in the average gross margins in the whole cropping system (Strauss&Hardy, 2014). Management and production data from Langgewens is regularly presented to the local farming community in popular publications, on occasions such as farmer's days and at scientific conferences. The information is also made available to technical advisors of the various agri-businesses that operate in the area. The data suggests that crop rotation is having a positive impact on farms and this study will test these outcomes based on independent research done.

Section 3: Evaluation Framework

3.1. Introduction

This section indicates the steps involved in formulating the evaluation framework for the impact assessment and provides an analysis of the objectives of the evaluation framework for this study.

3.2. Objectives and Key Performance Indicators

The evaluation framework employed for the impact assessment was formulated based on the Langgewens Experimental Farm trials objectives. The following sub-section provides an overview of the objectives, performance indicators, rating and weighting of the indicators. The Logical Framework Approach (also known as the Log Frame) is a systematic, analytical process for project planning. It helps to present the project in a standard format to planners, decision makers and managers and serves as a reference for project cycle management. The Log Frame categorises objectives in such a manner that analyses linkages and determines whether the objectives are being achieved:

- **Objectives –** includes questions such as what has the programme achieved? Where has it failed or succeeded? What are possible explanations for this? Were there any unplanned or unintended changes?
- **Inputs –** specific tasks performed using resources and methods in order to achieve the intended outputs (i.e. what we do or what we use to do the work? Did the inputs/activities contribute to the expected outcomes?).
- **Outputs –** products and services produced or competencies and capacities established directly as a result of project activities.
- **Impacts –** improvements of a situation in terms of social and economic benefits which respond to identified development needs of the target population under a long-term vision (i.e. how we have actually influenced target groups. Has the project brought about any change or improvements since implementation?).
- **Outcomes –** intended situation at the end of or soon after the project's lifespan in terms of gains in performance (as a result of changes in knowledge and behaviour) (i.e. what we wish to achieve).

By understanding the objectives, baseline and outcomes of the crop rotation trials, it becomes easier to create linkages with performance indicators, stakeholders and guiding the evaluation. Table 3.2.1 indicates the objectives of the crop rotation trials at Langgewens and the key performance indicators used in the evaluation.

TABLE 3.2.1: CROP ROTATION TRIALS EVALUATION FRAMEWORK

Objective	Indicator	Key Performance Indicator
1. What is the impact of existing rotation systems on the sustainability of farming in the Swartland with specific reference to crop yield and quality, weed control and weed seedbanks, carbon content of soils, and the diversification of farming (e.g. canola and lupins)?	1.1. Crop yield and quality	1.1.1. With what percentage has the yields of the crops increased since the implementation of crop rotation systems?
	1.2. Sheep / cattle production	1.2.1. Has there been a difference in sheep/cattle grazing on medics, stubble or other feed at slaughter time?
	1.3. Weed control and weed seedbanks	1.3.1. Has the application of pesticides decreased since the implementation of crop rotation systems?
		1.3.2. What effect has crop rotation had on weed seedbanks?
	1.4. Disease control	1.4.1. Did crop rotation have an effect on the diseases the farm was struggling with?
		1.4.2. Has the application of disease control measures decreased since the implementation of crop rotation systems?
	1.5. Carbon content of soils	1.5.1. With what percentage did yields increase since the implementation of crop rotation systems?
		1.5.2. Was there a change in soil structure at the point of harvest after the implementation of crop rotation systems?
	1.6. Diversification of farming (e.g. canola and lupins)	1.6.1. What crop rotation system is being used on the farm (i.e. WWCW, WCWC, etc)?
2. What is the long-term effect	2.1. An indication of improvements or	2.1.1. Has the farmer's income increased since the implementation of crop rotation systems?

Objective	Indicator	Key Performance Indicator
of crop and crop/pasture rotations on the financial and economic viability of farming systems in the Swartland?	declines in farm income	
	2.2. The difference between farm sizes (economy of scale)	2.2.1. Has the size of the farm under production increased since the implementation of crop rotation systems?
3. What are the adoption rates of crop rotation research results amongst farmers in the Swartland and which factors influence these rates?	3.1. Adoption rates of crop rotation research results amongst farmers in the Swartland	3.1.1. Has the farmer adopted a crop rotation system?
		3.1.2. Has the farmer implemented crop rotation systems that are being used as trials on Langgewens?
	3.2. Has the adoption of crop rotation had a positive impact on weed control, increased yields, soil improvement, etc?	3.2.1. Which factors have caused farmers to adopt crop rotation systems?
4. What design changes should be made in crop rotation research to enhance its impact per research expenditure?	4.1. An assessment of current research needs and in depth assessment of crop rotation and systems research relevant to the Swartland	4.1.1. What research would farmers still like to see taking place at Langgewens?
	4.2. An assessment of the accessibility of the current research findings to farmers.	4.2.1. Do farmers think that research findings and documents on the project on Langgewens are easily accessible?
	4.3. A priority list of	4.2.1. Findings from 4.1.1 will be prioritised.

Objective	Indicator	Key Performance Indicator
	research needs relevant to crop rotation in the Swartland	

These objectives have weighting that help to assess the extent to which the objectives have been achieved.

3.3. Overview of Survey Questionnaire Results

Table 3.3.1 indicates an overview of the survey questionnaire results conducted with farmers in the study area. More details can be found in **Annexure A**.

TABLE 3.3.1: OVERVIEW OF SURVEY QUESTIONNAIRE RESULTS

	Rooi Karoo	High Rainfall	Middle Swartland	Sandveld
Farm Size	33.3% of farms are 601 – 800 ha in size; while 66.7% are larger than 1,000 ha.	81% of farms are larger than 800 ha.	53.5% of farms are between 200 – 1,000 ha; while 41.9% are larger than 1,000 ha.	92.6% of farms are larger than 800 ha.
Crop Produce	❑ Wheat ❑ Canola ❑ Lupin ❑ Medics ❑ Oats ❑ Maize	❑ Wheat ❑ Canola ❑ Lupin ❑ Medics ❑ Oats ❑ Potatoes ❑ Barley ❑ Vineyards	❑ Wheat ❑ Canola ❑ Lupin ❑ Medics ❑ Oats ❑ Peas ❑ Triticale ❑ Barley	❑ Wheat ❑ Lupin ❑ Medics (very little) ❑ Oats ❑ Triticale ❑ Barley ❑ Mealies
Livestock Produce	❑ Sheep (pastures)	❑ Sheep (pastures)	❑ Sheep (pastures)	❑ Sheep (pastures)

	Rooi Karoo	High Rainfall	Middle Swartland	Sandveld
	❑ Cattle	❑ Cattle	❑ Cattle	❑ Cattle
Practice Crop Rotation	100% 66.7% started crop rotation less than 10 years ago.	100% 77.7% started crop rotation 10-50 years ago.	100% 83.7% started crop rotation 10-50 years ago.	98.8% 70.4% have always practiced crop rotation.
Crop Rotation System	WMWM; WLWC; WLWL; WMWL; WLWO	WMWM; WOWW; WWWC; WOWC; WCLM; LWCW; MWMC; WWLW; WLWL; Eight year rotation of Wheat, Barley, Canola, Barley and Potatoes	WMWM; MWMC; LWCW; CWWC; MWWM; WLWL; WMWC; WLWO; WOWO; WCWL; CMWW; WLWL; WCWC	WLWL; WLWW; TOMT; CWLW; WMWM (only on clay & hard soil)
Planters	Majority (66.6%) use Knifepoint Planters & Disc Planters	Majority (77.8%) use Knifepoint Planters	Majority (93%) use Knifepoint Planters	Majority (92.6%) use Knifepoint Planters
Awareness of Trials at Langgewens	83.3% are aware	100% are aware	90.7% are aware	96.3% are aware
Crop Rotation Effect on Yields	83.3% indicate an increase	77.8% indicate an increase	97.7% indicate an increase	92.6% indicate an increase
Crop Rotation Effect on Seeds	Majority (50%) indicated no change	Majority (55.6%) indicated no change	Majority (51.2%) indicated a decrease	Majority (74.1%) indicated no change
Crop Rotation Effect on Weed	Majority (66.7%) indicated an	Majority (55.6%) indicated an	Majority (55.8%) indicated a	Majority (81.5%) indicated a

	Rooi Karoo	High Rainfall	Middle Swartland	Sandveld
Control	increase	increase	decrease	decrease
Crop Rotation Effect on Lowering the Weed Seed Bank	Majority (83.3%) indicated a lowering of the weed seed bank	44.4% indicated a lowering of the weed seed bank; while 44.4% indicated no lowering	Majority (76.7%) indicated a lowering of the weed seed bank	Majority (81.5) indicated **no** lowering of the weed seed bank
Crop Rotation Effect on Diseases	Majority (66.7%) indicated a positive impact on the diseases the farm was struggling with	Majority (55.6%) indicated a positive impact on the diseases the farm was struggling with	Majority (81.4%) indicated a positive impact on the diseases the farm was struggling with	Majority (74.1%) indicated **no** positive impact on the diseases the farm was struggling with
Crop Rotation Effect on Pesticide Inputs	Majority (50%) indicated an increase	Majority (44.4%) indicated no change	Majority (39.5%) indicated no change	Majority (74.1%) indicated an increase
Crop Rotation Effect on Mechanisation Costs	Majority (66.7%) indicated a decrease	Majority (44.4%) indicated a decrease	Majority (65.1%) indicated a decrease	Majority (70.4%) indicated an increase
Livestock on Medics, Stubble or Other Feed	Majority (33.3%) indicated livestock weighted more at slaughtering	Majority (66.7%) indicated livestock weighted more at slaughtering	Majority (88.4%) indicated livestock weighted more at slaughtering	Majority (96.3%) indicated livestock weighted more at slaughtering
Livestock Production & Crop Residues	Majority (100%) indicated livestock production is affected by the availability of crop residues	Majority (66.7%) indicated livestock production is **not** affected by the availability of crop residues	Majority (65.1%) indicated livestock production is affected by the availability of crop residues	Majority (96.3%) indicated livestock production is affected by the availability of crop residues

	Rooi Karoo	High Rainfall	Middle Swartland	Sandveld
Crop Rotation Effect on Soil	Majority (100%) indicated soil improvement	Majority (88.9%) indicated soil improvement	Majority (100%) indicated soil improvement	Majority (100%) indicated soil improvement
Crop Rotation Effect on Fertiliser Inputs	33.3% indicated a decrease; while 33.3% indicated no change	Majority (55.6%) indicated a decrease	Majority (74.4%) indicated a decrease	Majority (81.5%) indicated a decrease
Use of Organic Fertiliser	Majority (66.7%) do not use	Majority (66.7%) do not use	Majority (72.1%) do not use	Majority (88.9%) do not use
Economic Viability of Crop Rotation	Majority (83.3%) agree it is economically viable	Majority (77.8%) agree it is economically viable	Majority (97.7%) agree it is economically viable	Majority (100%) agree it is economically viable
Crop Rotation Effect on the Cost of Production	Majority (66.7%) indicate a decrease	Majority (55.6%) indicate an increase	Majority (72.1%) indicate a decrease	Majority (85.2%) indicate an increase
Crop Rotation Effect on Farm Income	Majority (100%) indicate an increase	Majority (100%) indicate an increase	Majority (79.1%) indicate an increase	Majority (100%) indicate an increase

(Source: Urban-Econ Survey Questionnaire 2015)

3.4. Analysis of Objectives & Impact Assessment

The purpose of the following section is to provide the results of the Evaluation Framework Assessment. The evaluation framework is based on an assessment informed by the score of the objectives and indicator. The framework also provides a motivation for the assessment provided. The assessment is based on the following:

- **Very Poor**: the indicator score is 0%. This means that the indicator has not been addressed/achieved.

- **Poor**: the indicator score is between 1% and 25%. This means that the indicator has not been addressed although some attempts were made in attempting to address the indicator.
- **Acceptable**: the indicator score is between 26% and 50%. This means that attempts are made to achieve the indicator and although some of the aspects are being met there is major room for improvement.
- **Good**: the indicator score is between 51% and 75%. This means that the indicator is being addressed; however with some minor changes the impact could be much higher.
- **Very Good**: the indicator score is between 76% and 100%. This means that the indicator is being addressed and the impact of the indicators in high.

TABLE 3.4.1: EVALUATION FRAMEWORK – ANALYSIS OF OBJECTIVES

Objective 1: What is the impact of existing rotation systems on the sustainability of farming in the Swartland with specific reference to crop yield and quality, weed control and weed seedbanks, carbon content of soils, and the diversification of farming (e.g. canola and lupins)?	
Indicator 1.1: Crop yield and quality – this indicator looks at whether the implementation of crop rotation has had an effect on crop yields and the quality of crops at harvest.	
In the evaluation of the research conducted the majority of farmers in the study area (92.9%) indicated that crop rotation has increased yields. In terms of seed inputs, the majority of farmers (52.9%) indicated that there has been no change in the amount of seed inputs while 37.6% indicated a decrease in about an average of 25% of seed inputs. South Africa is a net importer of potassium, a nutrient used in wheat fertilizers, and imports approximately 50% of its nitrogen requirements. Domestic prices of wheat fertilizers are therefore impacted by international raw material prices, shipping costs and the Rand/Dollar exchange rate (Bester, 2014). Soil fertility is improved by using legumes in the crop rotation that fixes nitrogen in the soil. Yield variations are thus reduced, and crops can better withstand a drought through increased and consistent soil moisture and structure. These factors all lead to higher yields over the long term that cannot be achieved through conventional agricultural practices (Knott, 2015). In conservation agriculture production systems planting can be done closer to optimal	Assessment: Very Good

planting time. There is no need to wait for ideal weather conditions to till and prepare the land (Hobbs, 2007). This is particularly relevant in years when there are years when the rain is late (like what is currently happening in the Swartland area).	
Indicator 1.2: Sheep / cattle production – this indicator looks at whether the implementation of crop rotation has had an effect on the weight of sheep/cattle at slaughter time.	
In the evaluation of the research conducted the majority of farmers in the study area (84.7%) indicated that the animals have weighed more at slaughter time due to grazing on medics, stubble or other feed and 74% of farmers indicated that the availability of crop residues has an impact on animal production. Other benefits included in livestock production include: bringing in animals into crop rotation systems allows for the maximum use of the land; the quality of the animal improves on medics; animals create increased cash flow; aids towards weed control; and animals provide diversity in the farm produce. According to Knott (2015) through diversification producers exposure to risk can be reduced, the cash flow can be stabilised by incorporating livestock, resulting in increased whole-farm profitability over the longer period (Knott, 2015). The evaluation of the research conducted indicated an increase cash flow due to the addition of animals in crop rotation systems.	Assessment: Very Good
Indicator 1.3: Weed control and weed seedbanks – this indicator looks at whether the implementation of crop rotation has had an effect on weed control and whether there has been a lowering in the weed seed bank.	
In the evaluation of the research conducted the majority of farmers in the study area (57.6%) indicated that there has been a decrease in weed control while practicing crop rotation; while 34.1% indicated that there has been an increase in weed control. Some farmers have experienced a decline in weed control because, especially with medics, farmers are struggling to kill broad-leaf weeds alongside crops that also have a broad-	Assessment: Acceptable

leaf. Around 54% of farmers indicated that there has been a decrease in the weed-seed bank[1]; while 42.4% of farmers indicated that there has not been a decline in the weed-seed bank. Of the 54% of farmers that indicated a lowering of the weed-seed bank, 10.6% saw a lowering less than 5 years after implementing crop rotation, 8.2% five to nine years after, and 7.1% ten to nineteen years after implementing crop rotation. Of the 54% of farmers that indicated a lowering of the weed-seed bank, 47.8% of farmers indicated that yields increased on the farm, 13% indicated it was too soon to tell, and 23.9% indicated that yields decreased. This indicates that a lowering in the weed seed bank has a positive effect on yield outputs on the farm. Weed resistance is a problem even with crop rotation. The only extension services the farmers get are from the seed and fertiliser companies (Coetzee, 2015). Through rotating differing plant species, specific herbicides can be used to target competing weeds in alternating crops. In the long-term this reduces the use of herbicides and reliance on specific herbicides (Knott, 2015). When the same herbicides are used continuously weeds develop tolerance or resistance to the active ingredients in the chemical. By alternating herbicides with crop rotations, the effective period of herbicides can be extended and the gene pool of tolerant and resistant weed seed can be reduced during the rotation crop phase (Knott, 2015). Problems with grass weeds were resolved with the introduction of broadleaf and/or pasture crop rotations (Knott, 2015) but farmers that were interviewed indicated that weeds with medics was still a major problem and farmers in the Sandveld indicated that weeds have never been under control.	
Indicator 1.4: Disease control – this indicator looks at whether the implementation of crop rotation has had an effect on the diseases the farm was struggling with and if the application of disease control measures decreased since the implementation of crop rotation systems.	
In the evaluation of the research conducted the majority of farmers in the	Assessment:

[1] The weed seed bank is the reserve of viable weed seeds present on the soil surface and scattered throughout the soil profile. It consists of both new weed seeds recently shed, and older seeds that have persisted in the soil from previous years. In practice, the soil's weed seed bank also includes the tubers, bulbs, rhizomes, and other vegetative structures through which some of our most serious perennial weeds propagate themselves.

study area (57.6%) indicated that crop rotation had a positive effect on the diseases the farm was struggling with. Almost 37% of farmers have had increased pesticide inputs since implementing crop rotation and 24.7% indicated a decrease in pesticide inputs (of an average of 19%); and 29.4% indicated that there has been no change in the amount of pesticide inputs since implementing crop rotation. By alternating broad-leaf crops with grasses, weeds and diseases can be isolated and controlled with agrochemicals. This reduces the seed bank, as well as fungal and bacterial diseases in the soil. By alternating herbicides, weed tolerance to specific chemicals can be reduced, thereby prolonging the effective life of herbicides (Knott, 2015). The costs of chemicals have increased significantly over the last few years and farmers need more evidence that certain chemicals are indeed effective (as chemical companies will always advertise that the chemicals are effective).	Good
Indicator 1.5: Carbon content of soils – this indicator looks at whether the implementation of crop rotation has had an effect on farm yields and whether there has been a change in soil structure at the point of harvest.	
In the evaluation of the research conducted the majority of farmers in the study area (98.8%) indicated that the soil on the farm has improved since implementing crop rotation, specifically in terms of soil structure; increased micro-organism activity; increased water retention; and less soil erosion. Most farmers (71.8%) have also seen a decrease in fertiliser inputs since the implementation of crop rotation, 20% noticed no change, and 4.7% experienced an increase in fertiliser inputs. Only 23.5% of the farmers in the study area applied organic fertiliser and indicated that results from organic fertiliser use cannot be seen in the short term. Those farmers that have used organic fertilisers for a longer term have noticed increases in yields and improved soil management. Some farmers stopped using organic fertilisers because no change was seen; while the farmers who do not use organic fertilisers indicated that the cost was limiting the uptake in the area. There are two interconnected aspects driving conservation agriculture: (1) the ecological and biological benefits from the improved soil fertility, moisture retention, and reduction in erosion – live crop cover or dead	Assessment: Acceptable

mulch provides food for soil biota, which acts as biological tillage replacing the need for conventional tillage; and (2) the financial benefits of reduced input costs and reduced exposure to production risk – as the soil structure and fertility increases, the requirements for certain inputs, such as fertilisers, decline (Knott, 2015). Improved moisture retention of the soil reduces the risk associated with climate change, and a diversified cropping system spreads the risk across the various enterprises. Soil aggregate stability is further improved as plant matter decomposes naturally in the soil under no-till. Legumes such as alfalfa and medics are known to increase soil fertility through nitrogen fixation (Knott, 2015). Crop rotation has resulted in improvements in the spoil (as mentioned above) but farmers have indicated the need for more research to be done on the effects of organic fertiliser and if the high costs justify the means.	
Indicator 1.6: Diversification of farming (e.g. canola and lupines) – this indicator looks at whether the implementation of crop rotation has resulted in a diversification of farming in the study area.	
Key: W=wheat; M=medics; L=lupin; O=oats; T=triticale; C=canola In the evaluation of the research conducted In the High Rainfall region farmers implement the following crop rotation systems: WMWM; WOWW; WWWC; WOWC; WCLM; LWCW; MWMC; WWLW; WLWL; and one farmer mentioned an eight year rotation of Wheat, Barley, Canola, Barley and Potatoes. In the Rooi Karoo region farmers implement: WMWM; WLWC; WLWL; WMWL; and WLWO. In the Sandveld region farmers implement: WLWL; WLWW; TOMT; CWLW; and WMWM (only on clay & hard soil). In the Middle Swartland region farmers implement: WMWM; MWMC; LWCW; CWWC; MWWM; WLWL; WMWC; WLWO; WOWO; WCWL; CMWW; WLWL; and WCWC. According to Knott (2015) at Langgewens wheat after medics achieves the highest yields throughout the period with wheat after lupins also showing higher yields than wheat monoculture. Many of the farmers are implementing these two crop rotation systems, with some adding oats in the fourth year. Rotation systems also depict less erratic responses to poor rainfall seasons experienced from 2009 to 2011 (Knott, 2015).	Assessment: Very Good
Additional observations	
Conservation agriculture is a knowledge-intensive practice. Producers need continued	

support in training, flow of information, and supply of necessary inputs, such as herbicides, throughout the adoption phase. Assistance in special term financial arrangements, machinery pools, and extension services can aid the adoption process (Knott, 2015). The Swartland area does not have problems with acidity and findings suggest the levels are closer to neutral (4.5-7ph). The trials do not use organic fertiliser but liquid fertiliser at planting time and then later granules as top dressing. At the moment Langgewens does not have the equipment to apply organic fertiliser. Crop rotation systems differ in carbon content. The carbon content in the Swartland has a ceiling, it goes up but it never goes higher than a certain level. This is because of the very hot dry summers (Laubscher, 2015). The main constraints to conservation agriculture adoption are: (1) inadequate tillage equipment; (2) build-up of diseases and subsequent drop in yields and quality; (3) high price of herbicides, such as glyphosate; (4) lack of passion and commitment to the concept; (5) farmers often tried no-till on problem fields (Knott, 2015).

Objective 2: What is the long-term effect of crop and crop/pasture rotations on the financial and economic viability of farming systems in the Swartland?	
Indicators 2.1: An indication of improvements or declines in farm income – this indicator looks at whether the implementation of crop rotation has had an impact on farmer's income.	
In the evaluation of the research conducted the majority of farmers in the study area (95.3%) indicated that crop rotation is economically viable. Almost 50% of farmers indicated that crop rotation has led to a decrease in cost of crop production (by an average margin of 20%); while 45.9% indicated there has been an increase (by an average margin of 23%). The directly allocatable variable cost for the wheat in rotation with canola and lupins systems are marginally higher than wheat with medics. It is, however lower than that of wheat monoculture. A contributing reason is that the canola year is used as a weed bank control year, whereby, effective and expensive herbicides are used to eliminate grass weeds (Knott, 2015). The majority of farmers in the study area (89.4%) indicated that the farm's income has increased since implementing crop rotation (increase of ±10-30%); while 2.4% indicated a decrease in farm income (mostly ±1-20%); 1.2% indicated no change; and 7.1% did not disclose the information. By	Assessment: Good

incorporating crop rotation and residue cover in the production system, the producer can optimise labour use and reduce agrochemical application levels over the long-term. The increased crop yields from rotations, combined with the reduced non-directly attributable variable costs, experienced under no-till, generate a significantly higher gross margin for the conservation agriculture system than that of a conventional system of wheat monoculture and conventional tillage (Knott, 2015). Almost half of farmers in the study area (49.4%) indicated that mechanisation costs have decreased (average of 27%); while 30.6% indicate an increase (average 13%). Input costs such as fuel and repairs and maintenance of tractors and implements are reduced in a no-till production system (Knott, 2015).	
Indicator 2.2: The difference between farm sizes (economy of scale) – this indicator looks at whether the implementation of crop rotation has had an effect on the size of the farm under production.	
In the evaluation of the research conducted the majority of the farms in the study area (60%) are larger than 1,000 hectares in size. The same amount of land is under production after the implementation of crop rotation, but less of the production consists of one certain crop (i.e. where 1,000 hectares was planted in wheat, now 800 hectares is under wheat and 200 under medics, etc). The farms have more diversification in terms of produce thereby stabilising the income returns of the farm.	Assessment: Good
Additional observations	
Improved agronomic practices, suited to the specific environment in the Middle Swartland, and improved yields through better seed varieties, have increased the attractiveness of canola as a rotation crop and a cash crop (Knott, 2015). According to interviews with farmers, canola has been over-produced and has become less economically viable. Farmers in windy regions in the Swartland cannot plant canola either. The phasing out of the Wheat Board in 1997, which led to the deregulation of South Africa's wheat industry, has exposed the market price of wheat to international market forces. Producers in South Africa argue that they are being pushed out of the market due to the competitiveness of international wheat resulting from government subsidies. The cost of transporting wheat in South Africa from storage to the market (milling industry) is	

determined by a location differential system when dealing with SAFEX future contacts. Each grain-producing area in South Africa has a location differential based on the cost of transporting wheat to a reference delivery point. Farmers in the Western Cape and Northern Cape, based the furthest from the reference delivery point of Randfontein, have been the biggest critics of the location differential system (Bester, 2014). According to studies the location differential system has the advantage of increasing transparency among producers and buyers when calculating the value of wheat at point of delivery and consumption. Another issue is the price the producer receives which is much lower than the price charged by millers and bakers for flour and bread (Bester, 2014).

Objective 3: What are the adoption rates of crop rotation research results amongst farmers in the Swartland and which factors influence these rates?	
Indicators 3.1: Adoption rates of crop rotation research results amongst farmers in the Swartland – this indicator looks at what crop rotation systems have been adopted in the study area and if the system is the same as systems at Langgewens.	
In the evaluation of the research conducted the majority of farmers in the study area (98.8%) implement crop rotation. The majority of farmers in the study area (92.9%) are aware of the 20-year crop rotation trials on Langgewens and the majority of farmers (60.6%) use the information that comes from the findings from Langgewens. Those farmers that do not use the information indicated that Langgewens' soil and climate differs from that of their farm (especially in the Sandveld region). The majority of farmers in the study area (95.3%) attend farmer's days and information sessions. Farmers that do not attend the farmer's days do still receive the information from the Framers Associations. Farmers have indicated that it is difficult to attend farmer's days when the farmer's days are scheduled on the same day as auctions. One hundred percent of farmers would recommend crop rotation to a friend farmer.	Assessment: Very Good
Indicator 3.2: Has the adoption of crop rotation had a positive impact on weed control, increased yields, soil improvement, etc – this indicator looks at which factors have caused farmers to adopt crop rotation systems.	
In the evaluation of the research conducted the majority (54.2%) started implementing crop rotation between ten to thirty-nine years ago. The reasons for starting crop rotation include increased weed control; to	Assessment: Very Good

increase returns; to decrease soil erosion; to improve soil fertility; and to improve cash flow. The majority of farmers in the study area (48.2%) indicated that crop rotation has led to a decrease in the cost of production (by an average margin of 20%); while 45.9% indicated an increase (by an average margin of 23%). In terms of farm income, the majority of farmers in the study area (89.4%) indicated that farm income has increased since the implementation of crop rotation (by an average of 10-30%); while 2.4% of farmers indicated there has been a decrease in farm income (by an average of 10%).	

Objective 4: What design changes should be made in crop rotation research to enhance its impact per research expenditure?	
Indicators 4.1: An assessment of current research needs and in depth assessment of crop rotation and systems research relevant to the Swartland.	
See *Chapter 5: Recommendations* where current research needs of farmers are unpacked. As discussed above there are many different crop rotation systems being implemented in the Swartland area and the majority of farmers are learning from the trials on Langgewens. The farmers feel that the trials are crucial and should never be stopped but variations in cultivars could be tested; as well as possibly establishing an additional research farm in the Sandveld.	Assessment: Very Good
Indicator 4.2: An assessment of the accessibility of the current research findings to farmers.	
In the evaluation of the research conducted The majority of farmers in the study area (77.6%) indicate that research findings and documents about Langgewens is easily accessible; while 15.3% indicated that they are not.	Assessment: Good

Section 4: Recommendations

The above report has provided and assessment of the crop rotation trials on Langgewens and the following are identified as the main findings:

- The majority of farmers in the region (98.8%) are implementing crop rotation.
- Farmers are in favour of continuation of the crop rotational trials and would like to see more technologies that would make their farming more sustainable.
- Crop rotation has had a positive impact on farming in the area as indicated by reduced disease and weed infestation and associated increases in farm incomes.
- Crop rotation is a long-term process and takes about ten to fifteen years to implement optimally on a particular farm (taking the farms unique climate into account).
- Consider introducing new crops into the rotational system to assist improving soil wellbeing, raise farm income and all positive attributes as set by the current crop rotation trials.

Table 4.1 indicates the research needs of the various stakeholders that could still be researched at Langgewens or by the WCG Department of Agriculture.

TABLE 4.1: RESEARCH NEEDS / RECOMMENDATIONS OF THE VARIOUS STAKEHOLDERS

	Research Needs / Recommendations
Continue with current research	❑ Keep up with the current trials ❑ Consider adding crop rotation systems that are being implemented by farmers but are not being tested at Langgewens
New cultivars / new cash crops	❑ Test genetically modified wheat ❑ Test wheat with higher proteins and higher returns ❑ Test new crop cultivars that have higher returns ❑ Test new alternative cash crops ❑ Research on the affordability and sustainability of wheat farming to legumes ❑ Test Wheat, Canola, Medics, Lupines, and Oats rotations ❑ Test the costs and economic viability of a wheat and lupin system ❑ Research on drought-resistant crops ❑ Test better crop rotation systems with lupins

	Research Needs / Recommendations
	❑ Research on silage crops ❑ Research on summer crops ❑ Find canola cultivars that binds with nitrogen in the soil ❑ Find more leguminous crops that can bind nitrogen in sandy soils (other than lupines) ❑ More effort with cutting methods for medics instead of only using medics for grazing ❑ Research on cover crops in cereal farming ❑ Need a crop that can see Sandveld farmers through the summer (especially considering how much sheep consume) ❑ Need a crop with a shorter growing period
Livestock Production	❑ Test more sheep and lamb systems ❑ There are problems with government distributing enough vaccines for animals (in particular the Blue-Tongue disease) ❑ With "Johne's Disease" the government keeps showing out dated trends from the 1960's, new trends need to be shown. ❑ Caracals are also a problem, especially in the Sandveld where caracals are being protected and breeding in the National Park
Planters	❑ More tests with the Knifepoint Planter; Disc Planter; and Zero-Till Planter ❑ Test the economic difference between sowing and planting ❑ Test WMWM via sowing ❑ Weed control with minimum till remains a huge problem
Pests	❑ Birds and mice (especially gerbils) in the wheat fields remain a significant problem, need research to determine solutions ❑ Geese eat the lupins and oats, need research to determine solutions ❑ The Blue Crane is a problem in Lupins but they are a protected bird, need research to determine solutions
Chemicals	❑ The cost of chemical control is at a point where it is no longer affordable, test for cost effective alternatives ❑ Research on chemical and organic fertilisers and the effects they have on crops and the environments

	Research Needs / Recommendations
	❑ Research on better weed control alternatives (especially in medics where limited weed chemicals are available and are very expensive; and weed control for the entire Sandveld region where weeds have not been under control) ❑ The grass-weed management capacity of WWMM in comparison with WMWM and WWCM ❑ There needs to be research on the impact that different pest poisons have on the biological life of the soil and what damage this causes and to what degree ❑ More research into curing plant illness and fungi. There needs to be more independent research to test the different fungi agents on the market ❑ Look at spraying the "Sakura chemicals", the farmers are too scared to test it because you need a certain amount of rain for it to work ❑ Does "Round-Up" even work? ❑ Do more testing of products advertised on the market such as spraying "Cocktails" and "Blaarvoedings". The marketing of the company shows how the product will help, but the marketing messages need to be tested and verified.
Fertilisers	❑ Test the effectiveness and economic viability of organic fertilisers ❑ How can cow dung be applied as manure? ❑ Conduct trials on long term economic viability of organic fertilisers versus inorganic fertilisers
Soil life and soil temperature	❑ The soil temperatures rise so much in summer that the heat of the soil kills microorganisms thus research the effectiveness of mulching on controlling soil temperatures in summer. ❑ Research from an environmental perspective on how crop rotation stimulates the life of microorganisms in the soil and the role they play in crop rotation ❑ Medics and lupines remove phosphate from the soil therefore research the withdrawal of phosphate from the soil as a result of crop rotation

	Research Needs / Recommendations
	❑ More research on soil conservation ❑ Research new methods for alkaline soil and how to rehabilitate it
Diversity research areas	❑ Test different regions and different rainfall scenarios ❑ Research how medics can be planted in the Eendekuil area as the soil there is different from the soil in Langgewens ❑ Needs to be trials of crops done on sandy soil ❑ A research farm needs to be established in the Sandveld region
Fuel and mechanisation costs	❑ Test the viability of bio-fuels ❑ Maintenance costs on tractors are high (especially considering the Dollar/Rand exchange rate), are there alternatives?
Market conditions and market information	❑ More research should be done on the calculation of the wheat price. Local farmers want to pay the same price as the farmers from America or Australia ❑ The government must look at the quality that is being imported and pay local farmers correctly for their quality of crops ❑ The transport differential is having an adverse impact on the farmers and the input costs remain high even if the diesel prices decrease ❑ Information regarding Langgewens and crop rotation should be distributed via email, not just at annual farmer's days

Based on the above, the five main recommendations going forward include: (1) continue with the current trails at Langgewens; (2) investigate new cultivars and alternative crops; (3) develop new parallel research trails for sandy areas (i.e. Sandveld); (4) investigate input costs and consider alternatives to the norm; and (5) conduct closer combined research with industry.

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