Farm Site Development Method at a Livestock Farm

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Executive Summary

Bloemhoek Farm has identified the need for the application of the Farm Site Development Plan to concisely and clearly state the necessary resource acquisition at the specified times in the development process to the production saturation state of the business. The lack of a development plan results in avoidable cost and setbacks in reaching the saturation state of the farm.

The objective of the project is to give a clear and concise method to reach the production saturation state, identifying critical resources and constraints along the timeline and proposing a plan to develop and implement these resources. This method will be in the form of a Farm Site Development Method (FSDM). Extension points where added to the FSDM developed by Van Der Merwe et. al (2013) to accommodate a livestock farm. These extension points where documented and contributed to expanding the FSDM as a universally applicable method.

It was calculated that at saturation state, Bloemhoek farm will have 120 head cattle and 2607 head sheep in production. This is the combination of cattle to sheep that will ensure optimal utilisation of feed. There will be 5 Cattle Bulls and 115 cows, 18 sheep rams and 2589 ewes at saturation.

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1. Introduction and Background

The purpose of this project is to address one of the most prevalent issues faced by the Agricultural sector in South Africa: underutilization of potential productive farmland.

The project can be broken down into two broad stages:

1. Improve the current Farm Site Development Method (FSDM) by proposing solutions to already defined deficiencies by van der Merwe et al. (2014), and identifying and solving other deficiencies that are context specific to this project.
2. Applying the newly developed FSDM to Bloemhoek Farm to demonstrate its validity.

The impetus behind the FSDM is to develop a roadmap to the saturation state of the farm, allocating or developing tangible and intangible resources when existing resources have been depleted, to reach a stage where natural resources are optimally utilized, at saturation state, to the production of meat and wool.

There are a number of deficiencies in the current FSDM as reported by van der Merwe et al. (2014). Another project, executed parallel to this project will focus on the development of an "extended FSDM". The extended FSDM or FSDM 2.0 will address these deficiencies and propose solutions to improve the utility of the FSDM as a universally applicable tool in a specific context.

Extension points will be added to the FSDM 2.0, tailoring it to accommodate a livestock farm, this adapted method will be called the FSDM 2.1 (FSDM at a Livestock Farm).

Facility Background

A large part of the Eastern Freestate is mountainous terrain and is not suitable for cash crops but due to the climatic conditions and particularly the high rainfall, high potential grazing fields are abundant. One of the only ways to utilise this grazing potential and turn it into a marketable economic unit is through livestock farming. Because of the climatic conditions and the fertile soil, the lower lying arable land in this region has extremely good yields. Arable land is defined as "land under temporary crops, temporary meadows for mowing or pasture, land under market or kitchen gardens and land temporarily fallow"(The World Bank Group, 2013a).

Bloemhoek Farm, a livestock farm near the small Eastern Freestate town of Fouriesburg, was established in 2006 with the primary objective of farming with commercial cattle and to a lesser extent establishing and expanding an Nguni Stud to service the growing demand for bulls with exceptional quality genetics of this hardy cattle species in the Eastern Freestate, and surrounding intensive farming areas. The farm covers an area of 513 ha. At the moment there are 64 head commercial cows, 43 head stud cows and 5 stud bulls in production. Bloemhoek farm has diversified to include Lucerne production, with 28 hectares under annual production, and recently introduced 249 Dohne Merino Ewes and 13 Rams into the farming operation because of the potential cash flow benefits farming with sheep poses when managed correctly.

Because of the decline in farming profitability and water scarcity less than two thirds of the farms that was in production in the early 1990s are still in operation. Although the total area under production has declined significantly over the last 20 years the production output has remained relatively constant, indicating an increasing trend in intensified production (Goldblatt, 2014).

The Eastern Freestate is categorised as an intensive farming district. This means that the average farm size is small (usually less than 1000 ha), with an above average carrying capacity (grazing production potential, measured in livestock units per year, LU/year), unlike areas such as the Kalahari where the average farms are larger (in excess of 3000 ha) with a very low carrying capacity. Due to this fact it is of utmost importance that the available production farm area is utilized optimally and intensively.

2. Problem Statement

2.1 Macro Problem Statement

The world population was stated as 6.1021 billion in the year 2000, in 2012 it was 7.0464 Billion. It is estimated that in the year 2025 the population will be at 8.0038 Billion (The World Bank Group, 2013b). Considering the decline in available arable land due to erosion, mismanagement and desertification, and the rise in the human population, the available arable land per person is declining rapidly, this fact is indicated in Table 1, in the South African context.

Table 1 : Ha arable land/person in South Africa between 2009 and 2012(The World Bank Group, 2013a).

Year	Hectares of Arable Land per Person
2009	0.25
2010	0.24
2011	0.23

69% of the available land in South Africa is suitable for grazing, and livestock farming is by far the largest agricultural sector in the country (Goldblatt, 2014). It is clear that there is abundant potential for Livestock Farming in South Africa.

It is possible to meet the demand for protein rich food from locally produced meat if thorough planning is done using a tool specifically designed for long term planning in the agricultural sector, and if the developed plan is executed obediently. One of the planning phases in agriculture in South Africa that is lacking the most is financial planning. This is counterintuitive as this is one of the, if not the most important sections of planning.

There is a trend among farmers in South Africa, that generation after generation enter the agricultural sector, meaning that if my father farmed I will also most probably be a farmer. The consequence is that farming practice is taught down the generations, and rarely financial planning form part of this teaching. In the past this was not an issue as farmers did not farm to generate profit or to ensure food security, where financial planning is absolutely necessary, but rather applied subsistence farming. Considering the aforementioned there is a need for a method such as the FSDM in the South African agricultural sector.

2.2 Micro Problem Statement

Previous research addressed the need for a method to perform long term planning for facilities on farms, extending facilities according to a phased facilities development plan. A method-artefact, the Farm Site Development Plan (FSDM) was developed as a solution (Van Der Merwe et al., 2014) and applied to a crop growing farm. The problem is that the FSDM may not be useful to a livestock farm and need to be adapted to accommodate a new context.

In addition, several deficiencies have been identified by Van Der Merwe et al. (2014), which need to be addressed. This project is dependent on another project, which intends to address the deficiencies of the current FSDM to propose an extended FSDM or the FSDM 2.0.

3. Project Aim

The primary aim of this project is the validation of the FSDM 2.1.

This will be achieved by using the FSDM 2.0 and adding several extension points, tailoring the FSDM 2.0 to the application of a different context i.e. a livestock farm. By applying the FSDM to a different sector in the agricultural realm than previously tested on will add robustness to the FSDM as a universally useful tool.

Evaluation of the FSDM 2.1 will be in the form of a demonstration at Bloemhoek Farm. A further objective is to eliminate operational inefficiencies or develop best practice that restricts the optimal production of meat and wool on Bloemhoek Farm.

Validating the FSDM 2.1 is a step in the direction of having a tried and tested tool that can be applied throughout the agricultural sector to the applicable farms and yield a meaningful solution. If such a tool can be developed it can well be the solution to the food shortages in the not-so-distant future predicted by experts.

Furthermore, method engineering needs to be investigated to ensure that in the development of the FSDM, best practice is used. Literature on situational method engineering will provide insight into the development of method-artefacts.

4. Project Approach, Scope and Deliverables

The original FSDM was developed using the design cycle specified by Vaichnavi & Keuchler (2004). This project applied the same design cycle as follows:

1. Awareness of a problem: As indicated in the problem statement there exist a need to apply the FSDM to a livestock farm to address the inefficiencies in the long term planning of farms in this agricultural sector. The current FSDM does not accommodate the operational aspects and market drivers of livestock farming.
2. Suggestion: Suggesting extension points to the FSDM 2.0 to ensure that a generic FSDM is useful within different farming contexts.
3. Development: Extension points based on Industrial Engineering techniques and theories need to be added to the current FSDM to tailor the method to accommodate all aspects of a livestock farm. These techniques may include the following:
    a. Linear Programming
    b. Facilities Layout Design
    c. Situational Method Engineering
    d. Business Process Re-engineering
    e. Engineering Drawing
    f. Engineering Economics
4. Evaluation: Applying the FSDM 2.1 to Bloemhoek Farm to demonstrate the robustness and validity of this method
5. Conclusion: Interpreting and evaluating the results & reconnecting future work.

Table 2 is a summary of the steps in the FSDM, the Industrial Engineering techniques to be used in the specific step and the context specific deliverable that is expected from the FSDM 2.1 evaluation demonstration discussed in step 4.

Table 2 :Summary of FSDM steps, IE techniques and deliverables

FSDM 2.1 Steps	IE Techniques and tools	Demonstration Deliverables
1. Analyse the current state facility	One of the initial steps in BPR	As is analysis graphical display of layout and capacity
2. Calculate the saturation state of the facility	Linear programming	Combination of livestock Units
3. Determine production requirements and saturation date	Engineering economics, forecasting	Production driver (Cash Flow Constraint)
4. Identify RUSS and design criteria and evaluate.	Best practice	Identifying RUSS and appropriate design criteria.
5. Identify alternatives for RUSS replacement or extension	Engineering economics multi-criteria decision making	Net present value of alternatives
6. Compile the facility development Plan (FDP)	Cash flow and budgeting	Facility development plan (FDP)
7. Represent phase plans graphically	Engineering drawing	Phase development plans
8. Validate the FDP	Sensitivity analysis, verification methods	Validation

4.1 Interpretation of the FSDM at a livestock farm.

The Farm Site Development Method differs from conventional facilities planning in the sense that it provides a development plan over a time period to reach the saturation state of the facility. A long term development plan over a 5 to 15 year horizon encompassing facilities design and the accompanying cash flow constraints to acquire or develop new resources will be investigated to allow Bloemhoek Farm to reach its production saturation state.

Referring to the FSM steps in Table 2, the subsequent sections present suggested extension points for a livestock farm. The suggested extension points also guided the literature review that follows in section 5.

4.1.1. Analyse the current state of the facility

Applying the FSDM 2.0 to a livestock farm it becomes apparent that the current state of the facility needs to be analysed and benchmarked, this will indicate the start of the Facility Development Plan (FDP), and the current resources available. Feed yield sections and grazing camps need to be analysed.

4.1.2. Calculate the saturation state of the facility.

The purpose of calculating the saturation state of the farm is to estimate the maximum production rate of the farm given the area of land available to produce feed for livestock that can be converted through digestion to meat and wool.

Extension required:

The saturation state will be calculated as the combination of the amount of female cattle and sheep that will give the highest economic rate of return given the optimal utilisation of the natural resources on the farm. This optimal combination will be calculated using linear programming.

4.1.3. Determine the production requirements and saturation date

The current method developed (FSDM 2.0) where the forecast demand is used to determine the saturation date will not be applicable to a livestock farm or any farming sector where the demand for a certain product is not a production constraint. The problem in using the demand as a production constraint arises in that the production of one conventionally sized livestock farm will not saturate the demand for the product produced, in this case meat and wool, as the demand is much greater than the farm is able to produce, thus rendering the demand for the product as a production constraint invalid.

Extension required:

A new method will be used to calculate the rate at which the farm should develop, and the calendar date at which the farm will reach its saturation state. This new method will ultimately become universally applicable in the agricultural sector when using the FSDM, as a new constraint to the development rate of the farm.

The proposed new method is as follows:

Using historical data and market trends to calculate the cash flow of the facility will allow the farmer to determine what percentage of the Gross Profit (GP) can be allocated to growth. The percentage of the GP will determine the saturation date. The farmer may consider supplementing the business with cash from other sources, or he may supplement only from the profits of the farming business. Either of these will determine if the saturation date is reached at an early or later stage respectively, depending on the GP allocation.

The purpose of calculating the production requirement is to indicate the first time at which the optimal production of the farm will be reached. This will indicate the planning horizon to apply the FDP to.

4.1.4. Identify critical resources, utilities, services and structures (RUSS) and design criteria.

Applying the FSDM 2.0 to a livestock farm, leads to the identification of critical RUSS for livestock farming.

- Farming equipment (tractors, balers, hammer mills etc.) to produce feed for animals
- Fences, camps, support facilities and livestock handling facilities
- Arable land where cultivated crops are planted to produce animal fodder.
- Water resources

Design Criteria

The design criteria will be based on production requirements, technical feasibility, physical feasibility, financial feasibility and on the requirements specified by the farmer. If no production requirements are available best practice for the specific industry will be used.

4.1.5. Identify and evaluate alternatives for RUSS replacement/extension.

Applying the FSDM 2.0 the first saturation date of existing RUSS incremental replacement or extension should be planned, keeping in mind lead times, industry standards and best practice.

Alternatives for the restoration or replacement of RUSS should be identified. Using engineering economics and the time value of money the most economically viable alternative should be selected. If more than one alternative satisfies the requirements then the AHP method (Multi-criteria decision making) should be used.

4.1.6. Compile a series of phase plans, called the Facility Development Plan.

Applying this step ensures the logical grouping of replacement dates to form restoration phases. This enables the user to budget and plan for required restoration well in advance.

4.1.7. Represent the phase plans graphically in support of the FDP

Drawings of each phase in the FDP should be made starting at the current state facility layout and ending at the saturation state facility layout (SSFL).

This step will be relevant if parts of land are planted with crops that yield more feed than the existing crops.

4.1.8. Validate the facility development plan (FDP)

When identifying the alternative replacement of the critical RUSS certain inputs into the equations will be assumed. These inputs in the real world can most definitely vary from the assumed values. Scenario analysis will be used to test whether the selected alternative critical RUSS will be constant under varying conditions, and how sensitive the design is to change.

5. Literature Study

5.1. Introduction

The purpose of the literature study is to convey theoretical background regarding techniques and tools (listed in table 2) that are applied in this project.

In section 5.2 the process of method engineering is investigated. Google defines engineering as “the process of working artfully to bring something about”(Google Inc., 2014), and a method is defined by Merriam Webster as “a way, technique, or process of or for doing something (2) **:** a body of skills or techniques”(Merriam Webster, 2014). Thus it can be deduced that Method Engineering is the process of working artfully to bring a way, technique, or process of or for doing something towards improving a body of skills or techniques and ultimately improving the body of knowledge.

In section 5.3 the process of Facilities Planning is investigated. “Facilities planning determine how an activity’s tangible fixed assets best support achieving the activity’s objective”(Tompkins et al., 1984).

Sections 5.4 through 5.9 delves into detail pertaining to the practical aspects of the area of study that this project is focussed on. It is important that theoretical knowledge with regard to Industrial Engineering is connected to the practical components of livestock farming to facilitate the development of a practical, user friendly and relevant tool.

5.2. Method Engineering

“Method engineering is the discipline of developing, customising and/or configuring a situation-specific method from parts of existing methods”(Brinkkemper, 2006). Method engineering has been used for a number of years in the information systems design field, but the principles applied can be universally applicable in other fields of study.

According to Brinkkemper, a method is “an approach to perform a systems development project, based on a specific way of thinking, consisting of directions and rules, structured in a systematic way in development activities with corresponding development products” (Raylite et al., 2007). The idea is that many of the methods used in different fields share common features and if adapted or combined may be applicable to a new problem, thus a new method need not be specified or developed but a number sections of different methods can be used to construct a new method.

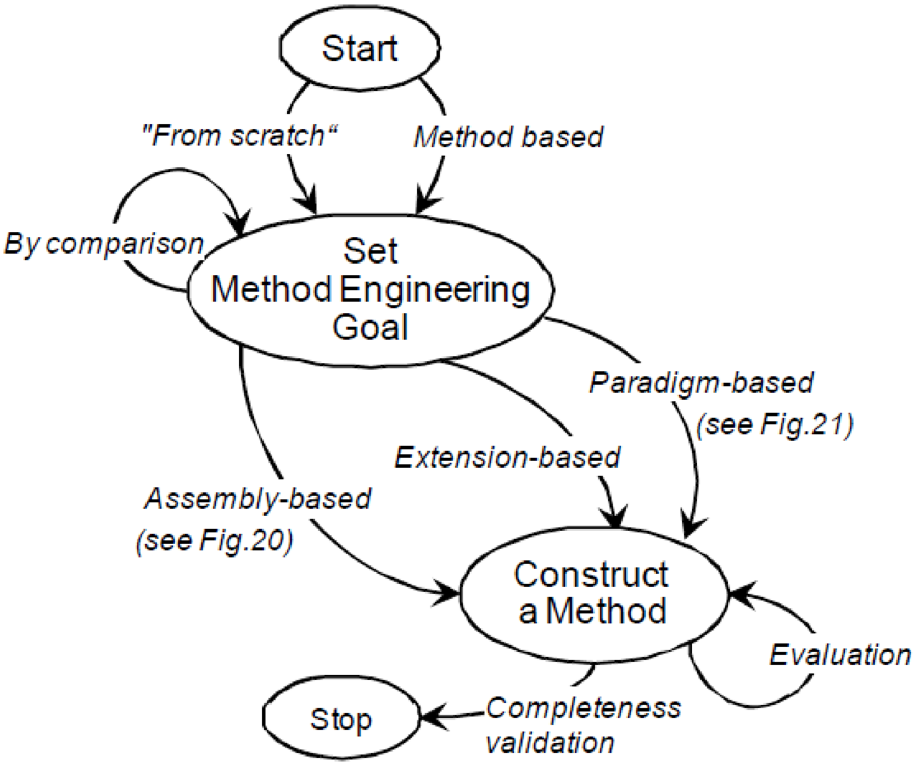
Situation method fragments are created and then selected depending on the situation specific requirements, these are then assembled into a project specific method. Most SME projects follow the abovementioned process of development.

A very important aspect of SME is the separation of method design from method use. The following two step approach is proposed by Raylite and Mirbel: “The first step builds a new method adapted for a project situation, while the second step allows the method users to configure further the obtained method for their particular needs."(Raylite et al., 2007). It is important to note that the system users do not design new method solutions to the project, rather selecting existing methods that are applicable.

The student dares to argue that, in the current context, the SME is a hierarchal process and that the user can utilise different methods on different levels of the hierarchy to solve a problem at hand. Customising a process by using different methods on different levels the hierarchy leads to the development of new methods and ultimately extension of the broad engineering application of methods and a contribution to the knowledge base. The development of the FSDM 2.1, applied at a livestock farm can be seen as one of these hierarchal extensions.

The generic process for Situational Method Engineering (SME) as can be seen in Figure 2 was used to develop the FSDM 2.1.

Figure 2: Generic Process for situational Method Engineering(Brian Henderson-Sellers and Raylite, 2010)



Facets from the FSDM developed by Van Der Merwe et al. (2013) and the FSDM 2.0 developed by Vos et. al (2014) where combined to form the foundation of the FSDM 2.1. Extension points where added from Industrial Engineering techniques, agriculture specific literature and practical experience to form the foundation of a development method applicable to livestock farming.

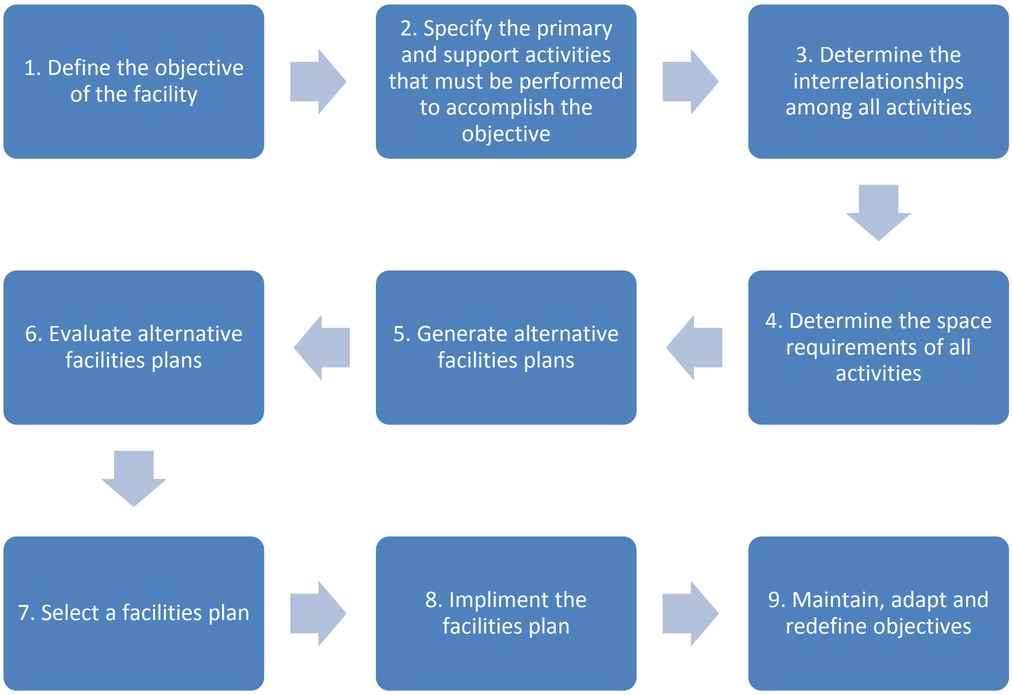
A method based solution was constructed. In the case of this project the goal is to develop a robust tool that will aid in the construction of a development plan to apply to a livestock farm that will facilitate growth to the saturation state of the facility. Because a method already exists to apply to a farm only extensions where needed to make it practically applicable to a livestock farm. The method was constructed and evaluated.

5.3. Facilities Planning

Facilities planning can be broken up into two broad sections, facilities location and facilities design. "Facility design involves how the design components of a facility support achieving the facility's objectives" (Tompkins et al., 1984). This project will focus mainly on the facilities design process.

According to Tompkins et al. (1984) the facilities design process is a continuous process of improvement of the facility. The basics steps of engineering design are adapted to be applicable to the facilities design context. The facilities design steps can be seen as set out below.

Figure 1 : Facilities Design Process (Tompkins et al., 1984)



1. Define objective of the facility: The output of the facility need to be quantified where possible.
2. Specify the primary and support activities that must be performed to accomplish the objective: the activities to be performed to meet the objective should be specified in terms of operations, equipment, personnel, and material flows.
3. Determine interrelationships between activities: Both quantitative and qualitative relationships between the various activities within the boundary of the facility need to be defined.
4. Determine the space requirements of all activities: All of the activities, including personnel, machinery, equipment and products need to be specified.
5. Generate alternative facility plans: In the case of this project only the facility design alternatives will be specified. The alternatives need to include material handling systems.

6. Evaluate alternative facilities plans: The respective plans should be ranked according to accepted criteria. A score system may be used where weights are given to certain attributes, the attributes are added and a overall score is calculated. The score system is used as qualitative factors need to be considered together with quantitative factors.
7. Select a facilities plan: Use the info gathered in the previous step to determine which the best alternative is.
8. Implement the facilities plan: sound project management principles need to be utilised when executing the selected alternative.
9. Maintain adapt and redefine objectives: Any plan will need to be adapted or changed slightly because of market fluctuations and other practical considerations.

Using the approach of Engineering Design (Keuchler and Vaichnavi, 2004) the user will be forced to investigate the problem from an analytical perspective. This process of thinking will yield a creative and sustainable solution based on factual, tried and tested method of constructing a solution.

5.4. Linear Programming

According to UCLA a linear program may be defined as the problem of minimising or maximising a linear function with linear constraints (UCLA Mathematics department, 2014). A number of linear constraints are defined, these constraints confine and define the state space in which the objective function may attain an answer.

The objective function will always be at a maximum or minimum where two of the constraint lines cross. Algorithms have been developed to find these intersection points, thereby identifying the maximum or minimum, subject to certain inputs.

5.5. Livestock Reproduction

Farming animals have different gestation periods. This can influence the choice of animal to farm with in the sense that some animals may be better suited for cash flow, some animals may be better suited for different climatic conditions and due to their reproduction time frame and the planning of pregnancy by the farmer, if cash flow is not an issue long term investment may yield a better income. A summary of the amount of offspring per year for a number of animals are given in table 4. The exact cycle length may differ from different breeds among the animals but a general average is used below.

The reproduction quantity is the amount of offspring a female animal delivers per year. This amount takes into account the gestation period, the time until the offspring is weaned and the time thereafter to grow to marketable age. Marketable age may differ from opinion to opinion, but for practical purposes the most predominant timeframe for marketable age will be used here.

Table 3 : Indicating the reproduction timeframe of different farming animals.

	Animal	Reproduction quantity (Offspring/ year)
1	Cow	0.67
2	Sheep	1.5
3	Swine	20
4	Horse	0.3

Using the information in Table 3 the user will be able to plan accordingly for the specific business situation, farming operation or market demand.

5.6. Ratio of male animals to female animals to ensure optimum breeding

Numerous opinions exist as to which is the ratio of male animals to female animals that deliver the optimum profit. This ratio depends greatly on the farming practice.

- Insemination purchased: Seed from the male animal is purchased and administered during the oestrus cycle of the female animal. No male animals are necessary.
- Synchronisation and self-collection of male seed: Seed from the males are collected from male animals on the farm and administered during the oestrus cycle of the female animal.
- Natural breeding: Male and female animals breed freely in a large area.

Table 4 : The ratio of male to female animals necessary for optimum breeding when applying different breeding techniques.

Animal	Insemination (Purchased Seed)	Synchronisation through self-insemination or pen mating	Natural breeding	Reference
Cattle	0:∞	1:200	1:25	(Thomas, 2013)
Sheep	0: ∞	1:150-200	1:40	(Schoenian, 2014)
Swine	0: ∞	1:4	-	(Coffey et al., 2012)

The driver for the ratio of male to female animals should not be the current state of affairs at the facility. The issue should rather be viewed from a profitability and an operational capability point of view, where the method chosen is the method that will deliver the maximum profit (Profit=income-expense) considering the current operational capabilities.

These capabilities will be externally influenced by things such as the cost of labour, climatic conditions, availability of good quality male animal genes (for insemination). It is important to note that these influences are not considered when the solution method was constructed, as these are extremely situational specific variables and will need to be considered by the applicator of the FSDM 2.1.

5.7. Livestock Units (LU), and the relationship between feeding habits of different animals.

“The ability to de-leaf a plant is conversely proportional to the animal size”(Snyman, 2012) The ratio of different animals is thus an important consideration to sustainable veld management. “Livestock can be divided into two broad groups, namely animals that utilise large mass roughage, these include cattle, and selective feeders such as sheep” (Snyman, 2012). Grazing posed to cattle need to be of high standard throughout to ensure sufficient nutrients are incorporated because a cow does not feed selectively .A sheep on the other hand will feed selectively on parts of a plant. This means that a herd of sheep can utilise a piece of land with low quality and will only select parts of the plants with high nutritive value, they may also leave parts of the plant with high nutritive value. Because of this it is essential that a combination of cattle and sheep utilise a piece of land to ensure that optimum utilisation of the plant material is achieved.

Do cattle and sheep compete for food?

According to Snyman (2012) the degree of competition depends on the amount of feed available and the amount of animals utilising this feed. He states in his book “The sustainable production of forage” that cattle and sheep should never utilise the same grazing camp at the same time because of the different feeding habits and management practice. Cattle utilise long grass whereas sheep prefer short grass (shorter than 20 cm). His solution is to allow the cattle to graze off the long grass to a point where sheep can utilise the remainder, take the cattle out of the grazing camp and allow the sheep to utilise the short grass in the camp.

The standard LU is calculated as an animal with a body mass of 450 kg, that gains 0.5 kg of weight per day on veld with digestible energy of 55%”(Snyman, 2012) This forms the basis of the infamous Meissner-tables.

Table 5: The LU relationship between different animals

Animal	Weight	LU	Amount of animals equal to 1 LU
Cattle	450	1	1
Sheep	55	0.122	8
Swine	65	0.144	7

The above values was be used in calculation the ratio of Animal 1 : Animal 2 : Animal 3 etc.

5.8. Lucerne production.

“Lucerne is the plant that is known to be longest grown specifically for animal feed.” (National Lucerne Trust, 2008). The use of Lucerne throughout the years has led to the development of a highly successful cultivated crop. Lucerne is known among livestock farmers as “Green Gold” due to the fact that it hold such a high economic value and high feed conversion ratio if converted through digestion to secondary animal products such as meat, wool and milk.

Plants need a number of chemicals to grow. These chemicals can be broken down into separate groups on the basis of where they are found. The first group of chemicals, hydrogen (H), carbon (C) and oxygen (O) is found from water and the atmosphere. The second group of chemicals, nitrogen (N), potassium (K) and phosphorus (P) is the macro elements and are used in relatively large quantities; these are derived from soil or fertiliser application.

When producing lucerne no nitrogen fertilizer application is necessary due to the its symbiosis with the nitrogen-fixing rhizobium bacteria which reduce the plant's dependence on soil nitrogen.(National Lucerne Trust, 2008). Constant rising fertilizer costs and the low dependence on nitrogen fertilization make lucerne an attractive cultivated crop to produce.

5.9. Natural grazing and cultivated crops

There is a saying among livestock farmers that reads as follows “We don’t farm with animals, we farm with veld”. This saying serves to enforce the importance of veld management when farming with livestock.

“Optimal feeding is necessary for animals to perform to their genetic potential” (McDowell, 2003). Table 6 summarise the yield potential of different types of veld. The yield potential of all types of veld is influenced by a number of factors, one of the largest contributors and a deciding factor is the amount of water the plant receives per year. This factor has been accounted for in Table 6, Table 6 which presents the yield potential of the Fouriesburg area. The annual rainfall used is 1100 mm/year.

Table 6: Yield potential of plant species.

Feed Type	Yield potential (kg./ha/mm/year)	Yield (kg/ha)	LU / ha	Reference
Corn	20	30000	3.1	(van Pletze, 1991)
Eragrostis Curvula	25.45	28 000	0.7	(Riveros, 2014)
Lucerne	27.27	30 000	1.9	(Moot, 2009)
Natural Grazing (Low lying)	14.45	16 000	0.5	(Botes, 2014)
Natural Grazing (Mountainous)	10.9	12 000	0.4	(Botes, 2014)

The above information will be used to calculate the capacity of the farm under consideration.

5.10. Calculating the size of irregular shaped areas on a map; The Planimeter.

“A planimeter is a table-top instrument used for measuring areas, usually the areas of irregular regions on a map or photograph”(Casselman and Eggers, 2014). The planimeter as a table top instrument is not a common occurrence today; they have been replaced by digital tools. These digital tools depend on the same principles as the first planimeters invented.

The concept is, that an area with known size is measured with the planimeter, this gives an indication of the ratio of planimeter units to actual size, and this is called the benchmarking area.

The irregular area for which the size is desired is then measured, on the same scale as the benchmarking area, with the planimeter. The ratio is then imposed and multiplied to the planimeter reading for the irregular shape and the size of the area is acquired.

Digital planimeters are in use today, and can be found as freeware on the internet.

5.11. Summary

The literature study serves to state the theoretical aspects of each topic used in the development to the solution of this project.

Method engineering was used to construct the different parts/segments of methods called situational methods, needed to solve the problem posed by inefficiencies and lack of planning on Bloemhoek Farm. These segments will be applied by the user where applicable to solve the problems at hand.

Facilities are the backbone of any farming operation. Facilities planning theory was used to efficiently solve the infrastructural issues on Bloemhoek Farm. From a macro lever, where the location and the orientation of the highest level tangible assets to the lower lever where operations and movement is concerned.

To obtain inputs where the maximum income can be generated it is necessary to use a linear program.

A factory is useless if there are no products manufactured. The animals and arable land was extensively investigated to strategically place Bloemhoek Farm on a profitable path.

6. Preliminary design of the FSDM 2.1

Table 7 indicate the steps of the FSDM developed by Van Der Merwe et. al (2013) and a summary of the extension points added to accommodate the requirements of a livestock farm. These extension points will be applied in subsequent sections, where each step and the purpose thereof will become clear to the reader.

The FSDM OT (Farm Site Development Method Optimisation Tool) should be used in conjunction with the below steps. Each step in the below table indicated either an input or calculation done by the FSDM OT.

Table 7 : FSDM and extension points required for a livestock farm

	FSDM 1.0 Van Der Merwe et. al (2013)	FSDM 2.1 with extension points
1	Analyse the current state of the facility	i. Benchmark facility by identifying areas with different feed yield potential and graphically indicate areas. ii. Identify and graphically indicate grazing camps. iii. Measure size of feed yield areas and grazing camps using a Planimeter. iv. Calculate the feed yield potential (total Livestock Units) of all of the feed yield sections using data in table 6 v. Calculate feed yield potential (LU) of grazing camps.
2	Calculate the saturation state of the facility	i. Identify all areas suitable for intensive feed production. ii. Graphically indicate areas and determine their size with a Planimeter. iii. Indicate what crop will be planted at saturation state and the yield potential (LU/ha) thereof. iv. Calculate total LU at maximum feed production. v. Calculate total cost of maximum feed production vi. Divide total cost of all feed production by total LU/year to get cost/LU/year vii. Determine income/animal/year by multiplying the market value of the offspring with the amount of offspring per year; see table 3 viii. Use table 4 to determine the LU relationship between animals. ix. Use LP in appendix 1 to calculate optimum combination of different animals to keep on the farm. x. Use table 5 to calculate ratio of male animals to females xi. Indicate saturation state as number of female animals in production
3	Determine the production requirements and saturation date	1. Calculate herd shortfall and the ratios at which the different herds of animals need to grow to reach saturation at the same time. 2. Develop basic cash flow spread sheet to indicate the growth of herds of different animals and obtain date at which maximum amount of animals are reached, saturation state.
4	Identify RUSS and design criteria	
5	Identify and evaluate alternatives for RUSS replacement/ extension	
6	Compile a series of phase plans (FDP)	Phase plans include the growth of livestock herds as this needs to be included in cash flow planning.
7	Represent the phase plans graphically	Phase plans don't necessarily include physical changes in infrastructure and consequently can't be represented graphically. Changes such as livestock quantities or improvement of feed processing equipment may be included into the phase plans because they need to be planned for when considering cash flows etc.
8	Validate FDP	

7. FSDM 2.1 Optimisation Tool

The FSDM, now, provides to the farmer a solution to the development timeline of the facility, at the current state. The solution is projected over a number of years, not considering adverse effects that external factors may have on the proposed development solution. These influences may be minor, but the consequences may be adverse. To better explain the problem it may be beneficial to look at an example;

At the moment it is more profitable to farm with sheep than it is to farm with cattle. The reason being comes down to the genetic ability of certain female sheep to produce multiple births. Thus, the cost to produce with one ewe per year stays constant whereas the income doubles if you are able to genetically exploit the ability through selective breeding. Cattle farmers have, to date, not been able to allow a cow produce multiple births where both calves where reared to a marketable age. Usually one or both of the calves are too weak to survive even the first day. If, however, through Genetic Modification (GM) this is achieved the profitability of cattle will go up, this will result in the solution of the FSDM achieved a number of years ago to be obsolete.

There exist a tremendous amount of external factors that may influence the development of a livestock farm. Because of this uncertainty there is a need for a dynamic tool that allows the user of the FSDM to tweak input parameters along the timeline of development, recalculate the output of the FSDM to better suit environmental, economic and financial conditions. The initial solution proposal for the FSDM will, however not be obsolete as this allows the farmer to plan for the coming year, with relative certainty.

The FSDM 2.1 OT was developed in Excel format for user friendliness and universal applicability. The tool, uses the inputs of the specific animals the farmer plans to farm with, details pertaining to the resources of the farm and operational constraints. The amount of Gross Profit allocated to growing the number of animals is specified. This information is then used to produce a cash flow calculation for the ensuing 15 years, stating the optimum amount of male and female animals to farm with under certain breeding conditions.

The amount of cash available is then proportionally divided, depending on the shortfall of animals between current and saturation state. This cash is then allocated to the purchase of a number of animals of a specific kind.

Please see the user manual for the FSDM OT in Appendix 4

The information for the FSDM 2.1 application to Bloemhoek farm is saved in the FSDM2.1 OT.

8. Demonstration of the FSDM 2.1 at Bloemhoek Farm.

8.1. Step 1: Current State Facility Layout

The current state facility layout will be broken down in a hierarchal list to demonstrate the different levels of the different sections of the farm.

The first level is the total area of the farm Bloemhoek. The farm can be seen in Figure 3.

Figure 3: First level layout of Bloemhoek Farm.

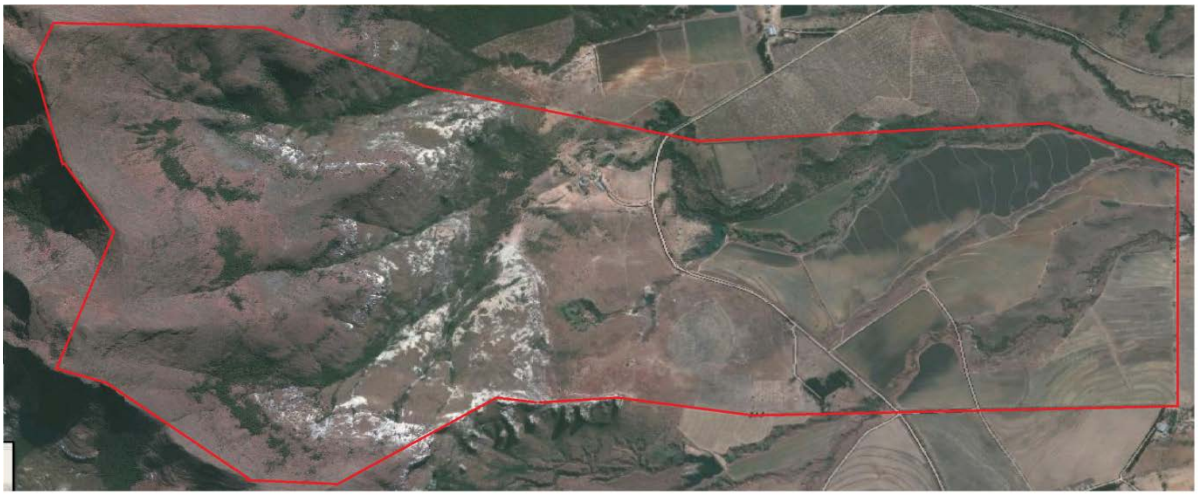


Figure 3 indicates the total area of the farm, 513 ha. The area in Figure 3 will be broken up into pieces on the basis of grazing capacity. The reason for this step is because some areas on the farm have a higher potential feed yield than other areas.

Figure 4: Different feed yield sections

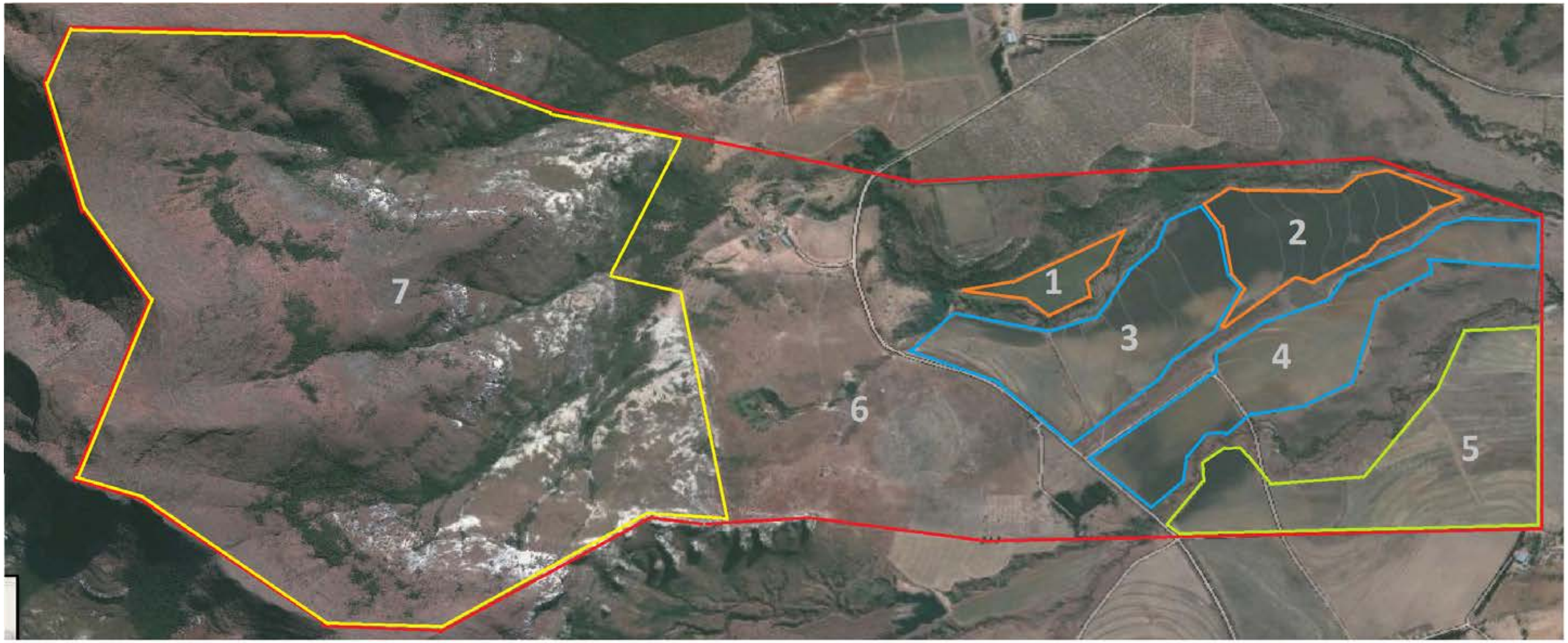


Figure 4 indicates the different feed yield sections on the farm. The below table indicates a summary of the relevant data. The yield capacity is given in livestock units per hectare (LU/ha), this is a standard unit used to measure the amount of animals that will be able to graze on one hectare annually. A fully grown cow of 450 kg is equal to one livestock unit.

Table 8: Table indicating the size and yield potential of different sections

Section	Size	Yield Capacity (LU/ha/year)
1	4.683	1.9
2	19.04	1.9
3	30.72	3.1
4	30.52	3.1
5	37.29	0.7
6	157.777	0.5
7	245.26	0.4
8	35.91	1.4
	564.343	

Sections:

1. Section 1 & 2:

Section 1 & 2 is currently used to produce lucerne. These lucerne fields have given exceptional yields over the past 4 years and constitute around 1.9 LU per hectare. The high yield can be ascribed to the fertility of the soil and the high rainfall. Lucerne fields have a lifetime of 4-10 years depending on the soil and other climatic conditions. Lucerne fields in this area have been known to reach roughly 7 years of age before they need to be ploughed out and planted with another crop. Wheat has been known to show good yield if planted after a Lucerne lifecycle, this will be considered when the RUSS calculations are done.

2. Sections 3 & 4

These sections are currently used for high yield cash crops such as maize and wheat. Both these cash crops, after harvesting are used to supplement animal feeds. At the moment there is not enough cash flow in the business to utilize these sections of land, they are rented out. The rent is paid in a yearly calculated amount of weight of either corn or wheat. This is used to supplement the feed for the livestock on the farm.

3. Section 5

Section 5 was planted with *Eragrostis Curvula* or commonly known as Weeping Lovegrass in 2011 due to the fact that the soil is extremely acidic. Weeping Lovegrass is able to withstand high acidity levels. This field is baled annually. The bales are kept in storage until the winter months when the quality of natural grazing drop to such an extent that the nutrient levels are negligible and supplementation with high quality hay is essential.

4. Section 6

Section 6 forms part of the low lying plains on the farm. These plains give an average yield consisting of natural grass, shrubs and bush.

5. Section 7

Section 7 is mountainous terrain. The grazing yield in this area is lowest.

6. Section 8

Section 8 is the total area of land that is not suitable for grazing. This includes farmhouses, storerooms, dams, roads and "dead ground". Dead ground is parts of the farm that is inaccessible to livestock on a practical level. Section 8 was taken as 7 % of the total area of the farm.

Grazing Camps

Currently there are 3 grazing camps on the farm. These grazing camps are indicated in Figure 5. Tables 9 summarise the details of each of the camps. The size of each yield potential section was multiplied by the yield potential and summed for all of the parts of the grazing camp to calculate the total grazing capacity in LU per camp.

Tables 9 : Tables indicating the size and grazing capacity of each natural grazing camp.

Camp 1

Sections	Size(a)	Yield Potential(k)	(a) x (k) [LU]
6	99.3	0.5	49.65
7	245.26	0.4	98.104
	344.56		**147.754**

Camp 2

Sections	Size(a)	Yield Potential(k)	(a) x (k) [LU]
6	28.9	0.5	14.45
	28.9		**14.45**

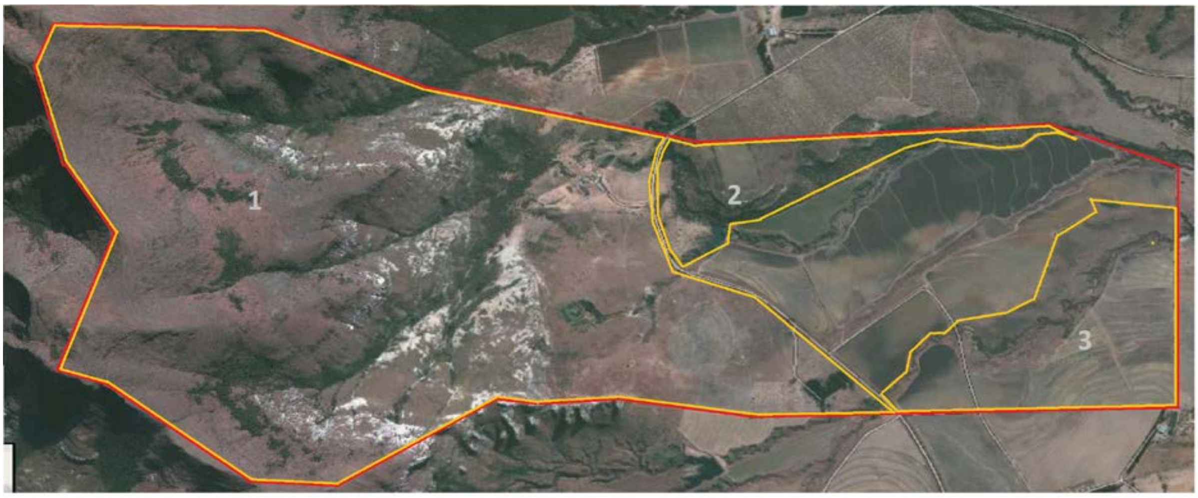
Camp 3

Sections	Size(a)	Yield Potential(k)	(a) x (k) [LU]
6	29.57	0.5	14.785
5	37.29	0.7	26.103
	66.86		**40.888**

Table 10: Summary of the yield potential of each of the natural grazing camps

Camp	Total Size	Yield Potential (LU)
1	344.56	147.754
2	28.9	14.45
3	66.86	40.888
	440.32	**203.092**

Figure 5: Demonstration of the layout and location of the grazing camps.



The grazing camps need to be utilised on a system called rotational grazing. Cattle and sheep are allowed to graze in a camp for durations between 2 months and 5 months depending on the condition of the grass. Cattle utilise different lengths of grass than sheep, thus together the maximum utilisation of natural grazing is achieved.

The possibility of ploughing out natural grazing on the farm and establishing pastures, because of the potential high yield of certain cultivars, was investigated. All of the possible parts of the farm that lends itself to arable land is utilised at this stage, thus no new pastures will be added to the current phase plan when the maximum capacity is calculated.

8.2. Step 2: Calculate the saturation state of the facility

The sections on the farm identified in step 1 were used to calculate the maximum surface utilisation. The size of the sections where measured using a digital planimeter. A screenshot of this freeware can be seen in Figure 6.

Figure 6: Screenshot of the ACME Planimetersoftware (Poskanzer, 2014)

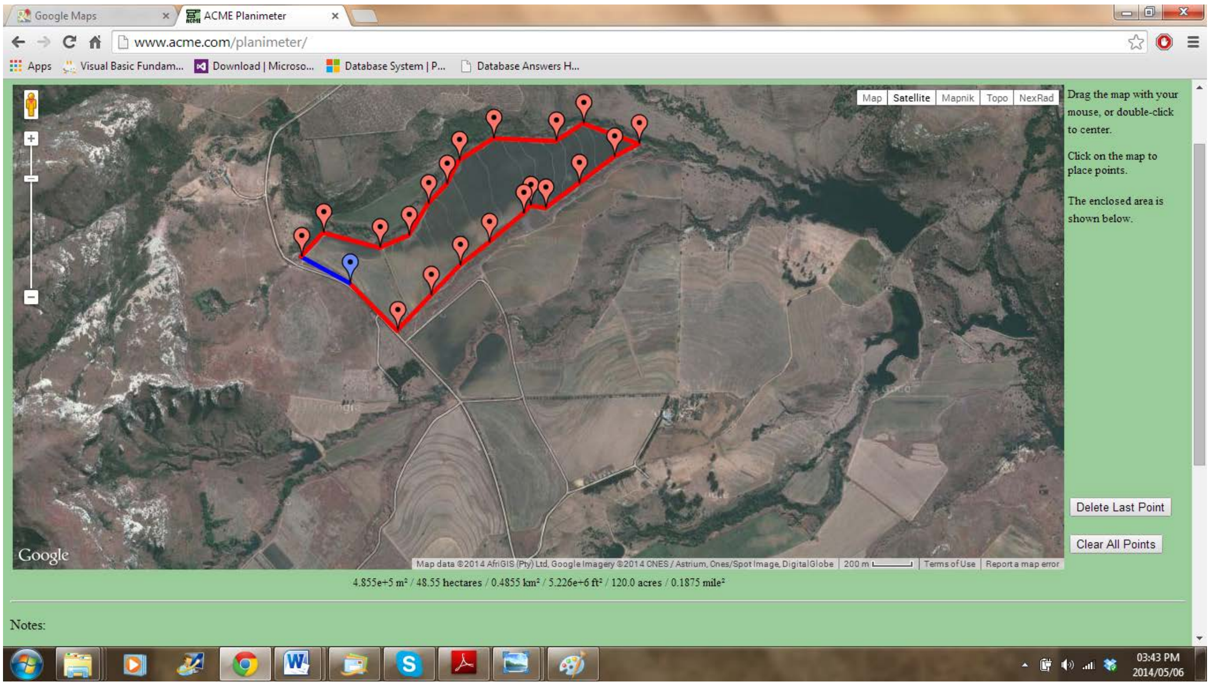


Table 11 indicates a summary of the cost per LU calculation. This cost is essential in the calculation of the saturation state as the objective function of the LP used in units of Rand. The LP will indicate the maximum Rand value that can be achieved subject to the conditions of the farm. The maximum Rand value will be linked to a combination of the number of sheep and cattle.

Table 11: Calculation of R/LU for Bloemhoek Farm

Section	Size	Yield Capacity (LU/ha)	Total LU	Kg Yield/ha/year	R/kg or R/ha	Total cost	R/LU/year
	A	B	C	D	E	F	G
1	4.683	1.9	8.8977	12000	1	56196	6315.789
2	19.04	1.9	36.176	12000	1	228480	6315.789
3	30.72	3.1	95.232	4000	1.2	147456	1548.387
4	30.52	3.1	94.612	4000	1.2	146496	1548.387
5	37.29	0.7	26.103	13000	0.4	193908	7428.571
6	157.777	0.5	78.8885	-	100 (Rent)	15777.7	200
7	245.26	0.4	98.104	-	100 (Rent)	24526	250
8	39.053	1.4	0	0	0	0	0
	564.343		438.0132			812839.7	**1855.742475**

Calculations for the above column headings are as follows:

A: Input value

B: Input Value

C: A x B

D: Input Value

E: Input Value

F: E x D x A

G: F/C

8.2.1. Calculate the maximum capacity of the farm(y)

No additional feed producing areas will be developed in the future. The farm has reached its saturation capacity in terms of utilisation of arable land.

The maximum capacity of the farm will be calculated by using the reasoning behind the conventional formula (Formula 1) in the FSDM developed by Van Der Merwe et. al (2013), multiplying the total area by the maximum surface utilisation and combining it with a linear program that will calculate the amount of cattle and sheep that will return the highest profit.

Formula 1

$$y = a * u$$

y = Maximum capacity of the farm

a = Total area

u = Surface utilisation

The equations used in the LP to calculate the optimum amount of cattle and sheep to keep on the farm that would give the maximum profit, considering the cost on one LU (Table 11) is indicated in Appendix 1.

The cost K_i (R/LU) including feed and the veterinary cost for one year to keep animal $i \in I$ on Bloemhoek Farm

The annual income generated P_i (R) for animal $i \in I$.

The amount of female animals L_i in production s.t.

$$\sum_{i=1}^{n} \frac{Li}{Yi} \leq X \qquad (1)$$

$$YiLi = Y(i+1)L(i+1)\ \forall i = 1,2,3 \ldots .i-1 \qquad (2)$$

Formula 2 ensures that the relationship of the number of different animals stay constant, eg. If there is one cow there must be 8 sheep.

K_1 = 2120.42 + 250 = 2105.74

K_2 = K_1/8 + 34 = 260.4

P_1 = 4200*0.67 = 2814

P_2 = 680*1.5 = 1020

X = 438.0132

Table 12: A summary of the constants fed into the LP

	1 Cattle	2 Sheep
K	2370.42	299.05
P	2814	1020
Y	1	8

The output of the LP can be seen in Tables 13. LU ratios where used as stated in table 6 to calculate the relationship of cattle and sheep to keep on the farm to generate maximum profit.

The respective grazing camps will be utilised in the same ratio as the total amount of animals on the farm. Thus as 10 cattle graze in a camp at any given time, 8 x 10 = 80 sheep need to graze the same camp after the cattle have utilised the longer grass.

Tables 13: Table indicating the maximum amount of Rand that can be achieved subject to a combination of sheep (2) and cattle (1).

Max Z	R327580.38
Total LU	438

	1	2
K	2370.42	299.05
P	2814	1020
L	120	2607

From the above output it can be seen that the amount of animals to keep are :

- Cattle = 120 head
- Sheep = 2607 head

Considering the above and the data displayed in table 5 the ratio of male animals to keep to female animals is displayed in table 14.

Table 14: Table indicating the ratio of male to female of animals kept on the farm.

	Cattle	Sheep
Male	5	64
Female	115	2534
Total	120	2607

8.2.2. Draw the saturation state facility layout

The saturation state facility layout will remain as is because no addition of arable land has been included in this FDP. There will be an increase in the amount of animals, and all of the feed produced on the farm will be utilised by the animals on the farm. The feed will not be sold as is the current case.

8.3. Step 3: Determine the production requirements and saturation date

Because there are two types of animals on the farm both types will not necessarily reach their saturation date at the same time. The growth of the number of animals on the farm will be linked to the cash flow of the business. The annual increase in the number of cattle and sheep will need to be proportional to the shortfall from the saturation amount of animals currently on the farm. This will ensure that both the cattle and sheep reach their saturation date at the same time thus optimising veld utilisation. The proportional annual increase in cattle and sheep can be seen in table 15

Table 15: Table indicating the ratio of increase needed for cattle and sheep to reach saturation at the same date.

	Cows	Ewes
Current	100	249
Saturation	120	2607
Shortfall	20	2358
Shortfall Ratio	1	117.9
Cost per animal	10000	1500
Total cost	10000	176850
Ratio	1	17.685
Percentage	5.35%	94.65%

Thus, for every cow purchased, 3.9 ewes need to be purchased over the planning horizon up to the saturation date.

The following assumptions where made during the cash flow calculations.

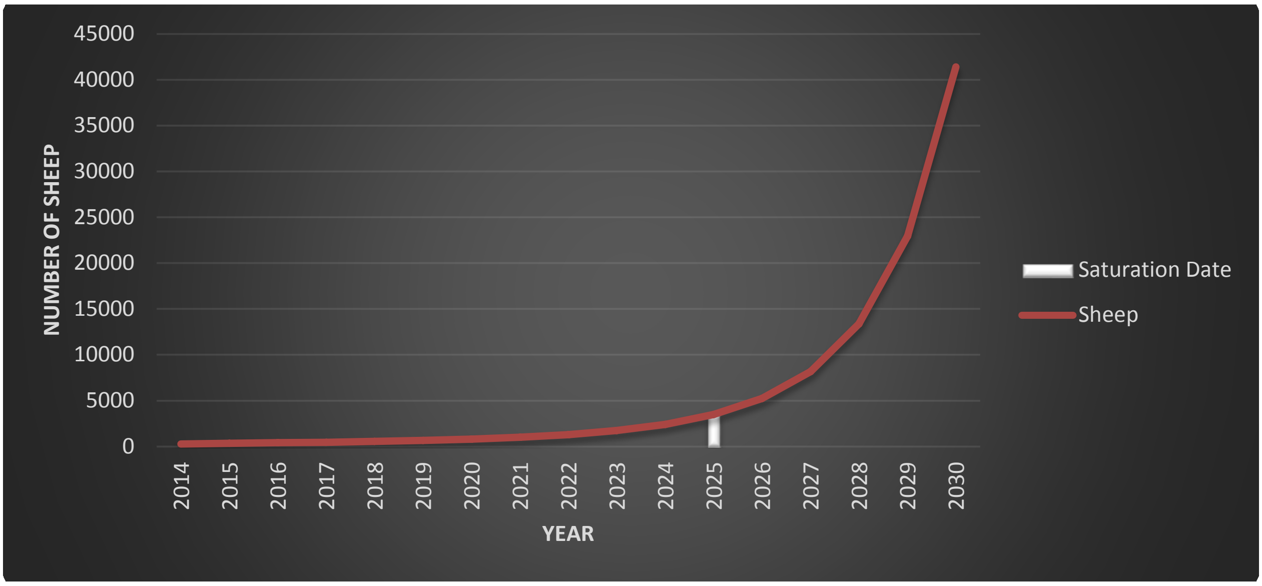
Table 16: Assumptions made in the LP calculation

	Cattle	Sheep
Reproduction potential percentage (Calves per female per year)	67.67%	150.00%
Price Growth	10.00%	10.00%
Percentage old females sold annually	7.00%	10.00%

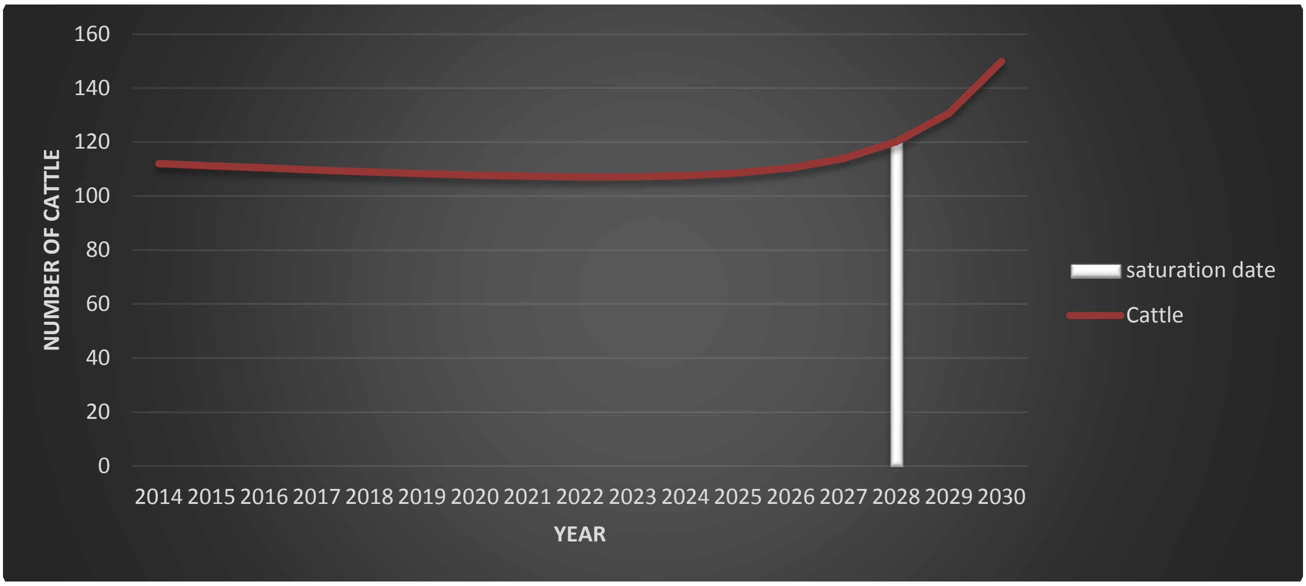
The percentage of the Gross Profit (GP) allocated to the growth of the herds of cattle and sheep is 40%. This number was obtained from the farmer as being appropriate for growth, taking into account all of the other expenses on the farm.

The saturation date was found to be at the start of year 2028. Below, Graph 1 & 2 display the growth in the amount of animals over the time period specified.

Graph 1 :The amount of sheep in production over the specified time period.



Graph 2: The amount of cows in production over the specified time period.



8.4. Step 4: Identify critical resources, utilities, services and structures (RUSS) and design criteria

The following RUSS where identified to be critical to the growth of the farming operation:

1. Livestock handling facilities
2. Sleeping camps for sheep
3. Feed processing equipment

Livestock Handling Facilities

The capacity of livestock handling facilities is directly proportional to the amount of animals on the farm, with a stepwise increase in capacity. The drawing in Appendix 3 indicates the current layout of the livestock handling facilities. These facilities, according to the owner are sufficient for the amount of animals currently on the farm.

The livestock handling facilities are used for stocktake purposes, administering medicine, branding the animals, castrating the young bulls and selecting animals to go to auctions.

A circular section can be seen with two moveable gates pivoting around the centre of the circle. This “kraal” is used for sorting. Animals are pushed into the “drukgang”, for the sheep and cattle respectively to keep the animals in single file, thus easy to inspect and work with. Animals then pass through the neck clamp where each animal is “caught”, this animal is then branded or medicine is applied, depending on the requirements of the animal. After the neck clamp a scale weighs each animal for record keeping purposes. The animals are then kept in the holding pens, or pushed back to the start if additional treatment is necessary.

At saturation state there will be a lack of holding pens before and after the sorting kraal and “drukgang”.

Sleeping camps for Sheep

Because of the major theft issue faced by sheep farmers in South Africa and the possibility of huge losses due to predators it is essential that animals sleep at a centralised location in a kraal, inaccessible to predators, where they can be supervised at night time.

The management of Bloemhoek farm prefer that the sheep sleep close to the house at night. At the moment there are a number of kraals on the farm as can be seen in Figure 7.

Figure 7: Layout of existing sleeping camps for sheep and the sizes of the camps (ha)

The total size of the sleeping camps are summarised below.

Table 17: Sleeping camp sizes

Camp	Size (ha)
1	0.438
2	0.3601
3	0.7556
4	1.343
5	0.3341
Total	3.2308

At saturation a total of 11 ha will be needed for sleeping camps. This was calculated by multiplying the amount of space needed per sheep per year with the total amount of sheep at saturation:

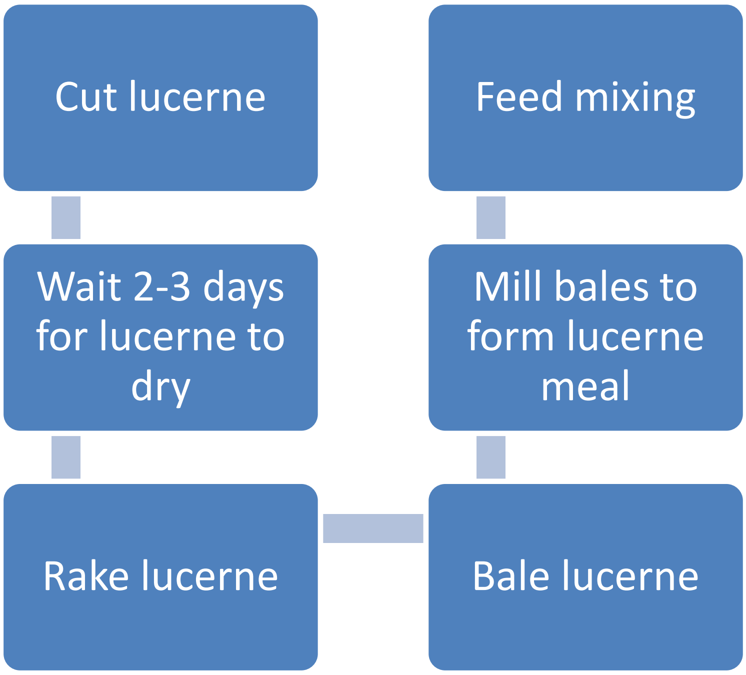
2607 sheep at saturation x 0.004 ha/sheep = 10.801 ha

Feed processing equipment

At saturation stage Bloemhoek farm will be operating at a very intensive level. This means that the animals will rely less on natural grazing and more on additional feeding from feeding troughs in the veld where produced feed is put out on a daily basis.

This practice will put extreme pressure on the capacity to produce different feed mixes for animals in the different production stages. These different mixtures of feed is commonly referred to as “lick”. Due to the high cost of manual labour it is essential that the feed production process is mechanised as far as possible. The process for feed production of the main ingredient, Lucerne is as set out below

Figure 8: Lucerne production process



The equipment needed to do the above at the volumes necessary on Bloemhoek farm are as follows:

Table 18: Equipment needed to produce lucerne on Bloemhoek Farm

Impliment	Capacity	Quantity	Cost	Reference
Tractors	41 kW; 55 hp	2	R 499548	(Agfacts, 2014)
Orbach 2.2 m mower	2,2 m wide 6.6 ha/hr	1	R57 000	
Enrossi bat rake	12 wheel	1	R18 000	
Claas Markant 55 square baler	Na	1	R 267895	
Staalmeester 6776 Hammermill	Na	1	R 45 499	
Drotsky vertical orital feed mixer turbomix	Na	1	R39 995	
Total Cost			R 927 937	

Currently the Orbach mower and the Claas Markant 55 square baler are available on the farm. The total sum of money needed to buy the rest of the equipment is R603 042.

8.5. Step 5: Identify and evaluate alternatives for RUSS replacement/extension

Livestock Handling Facilities

Plans for the extension to the current livestock handling facilities are indicated in Appendix 3. In this plan the holding pens have a dual purpose. Animals are pushed into the holding pens from the veld, small herds are then extracted from the holding pens, sorted and treated and put back into the same holding pen. This is done for the whole herd until all of the animals have been treated.

Building costs for a facility such as this is given in a per unit measure in Table 19.

The saturation dates are as follows:

1. February 2027 Need capacity for 115 cattle
2. April 2021 Need capacity for 994 sheep
3. November 2028 Need full capacity

Alternative 1: Build the entire livestock handling facility at once

Alternative 2: Build the facility as capacity is needed.

Table 19 : Future values of alternatives 1 and 2 to develop the livestock handling facilities for Bloemhoek Farm.

		Alternative1		Alternative 2					
		Feb-16		Feb-16		Apr-21		Nov-28	
Component	Cost per unit	Units	Cost	Units	Cost	Units	Cost	Units	Cost
Horizontal Posts, 110mm logs (per metre)	R 280	300	R 84 000	140	R 39 200	70	R 19 600	90	R 25 200
Vertical Posts including concrete	R 594	37	R 21 978	18	R 10 692	9	R 5 346	12	R 7 128
Bolts and nuts	R 5	500	R 2 250	250	R 1 125	110	R 495	150	R 675
Gates	R 900	8	R 7 200	3	R 2 700	3	R 2 700	2	R 1 800
Total			R 115 428		R 53 717		R 28 141		R 34 803
FV			R 129 817.28		R 60 413.37		R 40 031.66		R 59 049.03
FV Total			**R 129 817.28**						**R 159 494.06**
Inflation Rate	0.0605								

From Table 19 we can see that Alternative 1 imposes the least amount of cost to complete the project, and is thus the desired option.

The inflation rate was taken at the current rate of 6.05 % (Triami Media, 2014)

Sleeping camps for sheep

The first saturation date will be reached when there are 456 sheep on the farm. The current sleeping camps will need to be upgraded before then.

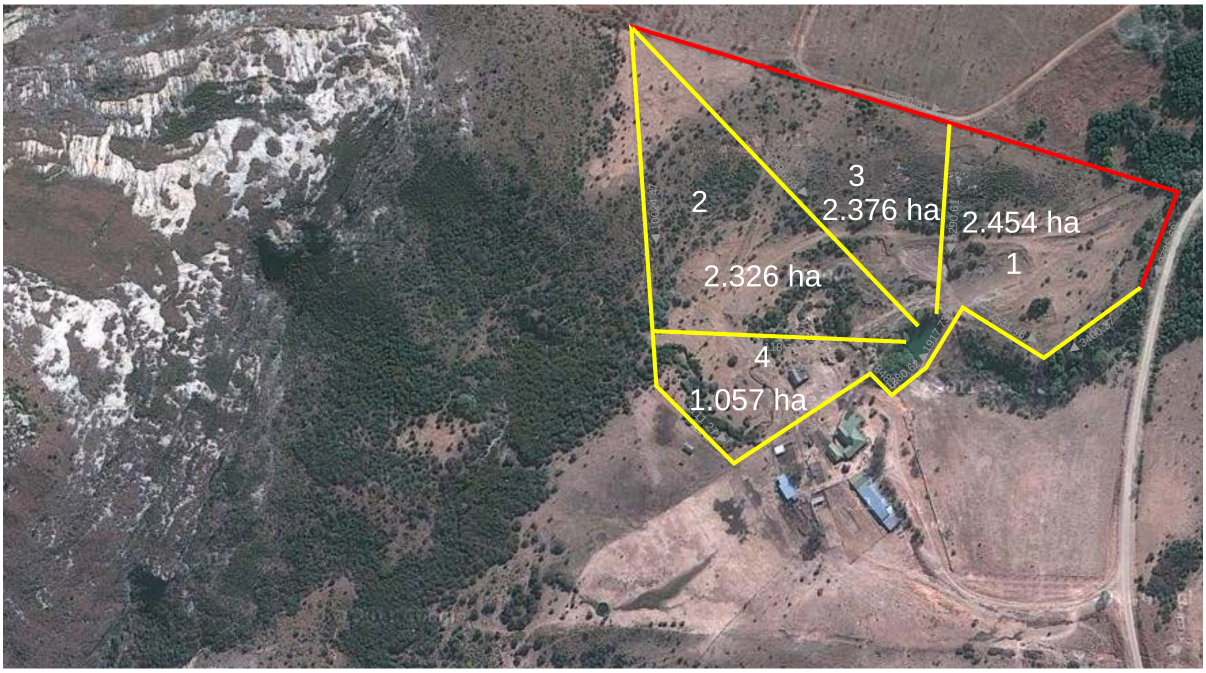
3.2308 (Current sleep camp size) / 0.004 (ha per sheep needed) = 807.7

The first saturation date is November 2020.

The total space needed thereafter is:

11 ha – 3.2308 ha = 7.7692 ha

Figure 9: Layout of future sleeping camps for sheep



The additional camps will be constructed as indicated above and cover an area of 8.213 ha. All of the camps are linked to a central point, a dam, supplying water to the animals. There is abundant bush for the sheep to use as shelter in the cold winter months. Two sides (indicated in red) are already fenced with the border fences of the farm. No fence will be needed here which will result in a large savings on materials.

Two alternatives for the construction of the above camps are suggested:

Alternative 1: Construct all of the camps before the end of November 2020

Alternative 2: Construct camps as the sleeping camp capacity runs out.

Depletion dates:

Table 20:Sleeping camp capacity depletion dates

Depletion Date	Solution
November 2020	Construct camp 1
July 2022	Construct Camp 3
June 2023	Construct camp 2
August 2024	Construct camp 4

Table 21: Future values for alternatives 1 and 2 to develop the sheep sleeping camps on Bloemhoek farm.

		Alternative1		Alternative 2							
		Nov-20		Nov-20		Jul-22		Jun-23		Aug-24	
Component	Cost per unit	Units	Cost	Units	Cost	Units	Cost	Units	Cost	Units	Cost
Support Posts including concrete	R 140	48	R 6 720	12	R 1 680	8	R 1 120	12	R 1 680	16	R 2 240
Vertical Posts including concrete	R 200	25	R 5 000	7	R 1 400	4	R 800	6	R 1 200	8	R 1 600
Fencing wire	R 2.43	13293	R 32 302	2790	R 6 780	4356	R 10 585	3690	R 8 967	2457	R 5 971
Droppers	R 5	1402	R 7 010	310	R 1 550	436	R 2 180	410	R 2 050	246	R 1 230
Y Irons	R 8	141	R 1 128	31	R 248	44	R 352	41	R 328	25	R 200
Binding wire	R 800	1	R 800	1	R 800		R 0		R 0		R 0
Total			R 52 960		R 12 458		R 15 037		R 14 225		R 11 041
FV			R 59 562		R 14 011		R 20 171		R 21 459		R 17 663
FV @ November 2023			R 59 562								R 73 304
Inflation Rate	0.0605										

Alternative 1 incurs the least amount of cost, thus is the best alternative.

Feed Processing Equipment

At the moment implements not owned by the farmer are hired from a neighbouring farmer to cut and process the lucerne, the feed is mixed with manual labour. Both these are extremely expensive. The result is that the saturation state for the feed processing equipment has been reached already. The feed processing equipment need to be replaced as soon as possible.

The cost of the feed processing equipment is R603 042.

8.6. Step 6: Compile a series of phase plans, called the facility development plan (FDP)

Table 22 : Phase plans of the FDP at Bloemhoek farm

Phase	Date	Description	Cost
1	Nov'14	• Purchase feed processing equipment • Expand Sheep herd by 94	• R603 042
2	Nov'15	• Expand Sheep herd by 106	
3	Feb'16	• Upgrade livestock handling facilities	• R129 817
4	Nov'16	• Expand Sheep herd by 97	
5	Nov'17	• Expand Sheep herd by 123	
6	Nov'18	• Expand Sheep herd by 159	
7	Nov'19	• Expand Cattle herd by 1 • Expand Sheep herd by 210	
8	Nov'20	• Expand Cattle herd by 1 • Expand Sheep herd by 398 • Construct sheep sleeping camps	• R261 360
9	Nov'21	• Expand Cattle herd by 1 • Expand Sheep herd by 573	
10	Nov'22	• Expand Cattle herd by 1 • Expand Sheep herd by 853	
11	Nov'23	• Expand Cattle herd by 1 • Expand Sheep herd by 1308	
12	Nov'24	• Expand Cattle herd by 2 • Expand Sheep herd by 435	
13	Nov'25	• Expand Cattle herd by 3	
14	Nov'26	• Expand Cattle herd by 5	
15	Nov'27	• Expand Cattle herd by 7	
16	Nov'28	• Expand Cattle herd by 1	

8.7. Step 7: Present phase plans graphically in support of the FDP

Phases 1 & 2 don’t constitute a change in physical infrastructure.

The change in phase 3, upgrade livestock handling facilities, can be seen in Appendix 3.

Construction of the sheep sleeping camps can be seen in figure 7.

Phases 5 through to 9 don’t constitute a change in the infrastructure.

8.8. Step 8: Validate facility development plan (FDP)

1. Scenario Analysis

The FSDM 2.1 Optimisation tool will be used to test a few scenarios and the effect that different input parameters will have on the output. The differing input parameters, possible reasons for the parameter to change and the result that was achieved are as follows:

Table 23: Scenario analysis indicating inputs, possible reasons for the input and the result obtained out of the FSDM 2.1 Optimisation tool.

Scenario	Input	Possible reason	Output
1	The price for animals at auction is stagnant or declines	Recently Namibia experienced such an effect, all exports to South Africa where subject to a quarantine procedure, increasing the export cost to such an extent that it is not a viable option, resulting in the flooding of young animals to slaughter in the Namibian market.	Cash flow will decrease, resulting in less GP contribution to growth which in turn will result in the postponement of reaching the saturation state, alternatively a cash injection may be needed to balance the need for cash to grow the number of animals.
2	An above average increase in input cost	Fuel price, labour cost, feed cost increase due to legislation	An increase in input cost will result in a decline in Gross Profit which in turn may render some farming operations non-profitable. The feasibility of these operations may have to be revisited. An example is the increase in the minimum wage for farm workers, this resulted in mechanisation where possible and profitable, but also disqualified numerous labour intensive farming operations as the market did not absorb the increased input cost.
3	A once off step in decline of the number of animals of a certain sort	A lethal outbreak of a certain disease, such as the Rift Valley Fever outbreak of 2012 and a subsequent loss of a large number of animals.	Because the number of animals of a certain kind suddenly drop the saturation state for the specific animal will be postponed. The sudden drop in the amount of animals of a certain kind will result in the recalculation of the animal ratio, resulting in a larger part of the GP to be allocated to the animal kind in question to balance the decrease out.

2. Questionnaire

2.1 Does the FSDM seem practically applicable to your livestock farm?*Yes, it does, it does however not give a lot of flexibility with regards to integration between livestock farming and crop farming. What I mean to say is that the FSDM 2.1 Optimisation tool does not consider the fact that I might want to sell Corn on the market, or start to plant certain crops where natural grazing is currently present. Considering these possibilities in the optimisation will result in an integration between Livestock Farming and Crop farming.*

2.2 Is the cash flow relevant and does it represent the probable obtainable values? *Yes it is relevant, in conjunction with the budget I use to manage the expenses on the farm it will be very meaningful. The stationary inflation rate may pose a problem as there are many external influences that may have an effect on the auction price, or the replacement cost of an animal for instance. These external influences are however of such a sort that there is no way to predict what they will be, positive or negative, so the average inflation rate is a good measure stick to use to represent the increase in cost, and income.*

2.3 Is the data specified, relating to offspring/animal/year, auction price, replacement cost etc accurate and relevant? *The data is most definitely accurate and relevant.*

2.4 Would you be willing to pay for the advice given during this project?*I am not certain that I would pay for the advice as it seems so obvious to me now. I think I will be more inclined to compensate for the advice if there was a case study where the solution has been proven to work.*

2.5 Do you think the infrastructure specified would suppliment the operational aspects of the farm in a positive way? *The infrastructure will depend greatly on the practice a specific farmer applies. The infrastructure development process in this case was pleasureable for me, and I am happy with the result. I think it is, as was the case with this project that there was a lot of collaboration between myself and the student with regards to the planning and layout of the infrastructure on the farm.*

9. Conclusion

The project as set out above, has the main purpose to add useful intellectual property to solving the imminent food shortage that experts predict. A short term goal is to add to the knowledge base with regards to the Farm Site Development Method developed by Van Der Merwe et al. in 2013 by expanding the application of this method to the livestock agricultural industry.

Through expansion of the knowledge base the project has addressed the shortcomings and inefficiencies in the development of Bloemhoek Farm. It is clear that the project will add value to the farm.

There are a tremendous amount of variables that influence the FDP. Attention needs to be given to the development of a tool in the form of an Excel spread sheet where changes to the variables can be made during the development timeline, when fundamental conditions change. For instance, it may not be viable for the farmer to allocate 40% of the GP to growth each year, he may need the cash during one year of drought and will resume the growth of 40% after the drought period. This channelling of the GP into another avenue will influence the FDP and changes to the timeframe of the plan will need to be made. Thus, ideally it will become a yearly iteration where the FSDM is adapted to the current conditions, optimising the relevance of the FDP and making it a robust tool for the user.
The first version of such a tool, imprinting the concept was developed as the FSDM 2.1 OT. This tool is a far cry from what the possibilities pose. It is a move in the right direction to the development of a tool that will encompass agriculture as a whole, where all possible variables are inserted to yield a valuable solution. This application will need to be dynamic and flexible, user friendly and scalable.

10. Recommendations and connecting future work

During the application of the FSDM to a livestock farm a number of deficiencies have been identified. These deficiencies, together with the deficiencies identified by Vos et. al (2014) during the application of the FSDM 2.0 have been combined to form the basis for future development to the FSDM artefact. The deficiencies have been addressed with recommendations below.

The Scope of the FSD have to be specified. There has to be a point where calculation and formulation of a solution is not “Automated” (Imposed by the FSDM steps) and human intervention and creativity takes over. A tool such as the FSDM should only address the tangibly definable and measurable variables, as these can be held to a certain achieveable standard. The FSDM should not venture into the human imposed creative solving of limitations and constraints.

During the application of the FSDM the user will venture into understanding and solving problems in the following domains:

- Cash flow calculation and planning
- Engineering economics, more specifically the time value of money and future trends in the particular agriculture sector. This ties in with cash flow calculation
- Operational requirements of the fixed (buildings) and moveable assets (tractors and equipment) used at the facility. These may also include Labour.
- The user will have to understand the product type and the market conditions to be able to creatively solve problems in the specific agricultural domain. The reason for this is because opportunities and trends will have to be identified to keep the user at the forefront of development and efficiency of the facility, optimising the process and profits.

The user will have to define a number of variables before the FSDM is applied, these variables are listed and explained below:

- Is the Cash Flow a constraint?
- Is the Demand a constraint?

The answer to the above questions, which are mutually exclusive would determine the steps to follow in applying the FSDM.

For a livestock farm, the following conditions need to be specified before the FSDM is initiated:

Animals
- What animals will be farmed with?
- LU for each animal kind (LU/ha/Year)
- Production potential of each animal (Offspring per year)

- Breeding technique to be used
- Additional cost (excluding feed)
- Auction price (when selling)
- Auction price (when buying)
- Price growth

Farm

- Yield section size
- Yield section production capacity (LU and kg)
- Cost of land/feed
- Other
- Miscellaneous expenses

All of the above data will serve as inputs to the FSDM 2.1.

The user of the FSDM will have to specify at the start of the process what the requirements and constraints are. This will aid in the development process, to addressing the initial need of the user. A certain condition has to be addressed for the FSDM to be successful. Specifying at the start what the need is will keep the FSDM artefact honest in solving a problem, meaning the moment that the FSDM does not solve the problem an opportunity arises to improve the utility, or limit the scope of the tool.

Typical users of the FSDM include Farm Owners and Farm Managers.

The extension points for each type of facility is specified in Appendix 6, providing a summarised update to the current FSDM. Appendix 5 indicate the pre-conditions and scope, input data, requirements and the users of the FSDM.

The saturation date can be omitted from future FSDM calculations. The reason for this is that the FSDM will not be applied once only, but rather used as a planning tool on a continuous basis. There is therefore no reason to assume a specific future date (especially long term >10 years) as the saturation date. Conditions may change significantly over time, the strategy of the business should be adapted to suit these conditions.

No multi criteria decision making was used in the FSDM2.1, and can be omitted from future applications where there is considerable bias towards a specific solution. The MCDC is not useful if applied by the user of the FSDM if he/she is not completely subjective. During the research considerable objectivity was experienced when communicating different solutions to the farm manager and owner. There are a multitude of reasons for the bias towards a specific solutions, some may include physical constraints, or even brand vendor specific decisions about equipment, regardless of the price or economic advantage.

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8. Appendices

8.1. Appendix 1

Linear Program to calculate optimum combination of animals to keep on a farm.

$$Max\ Z = \sum_{i=1}^{n} Li(Pi - Ki)$$

$$i \in I = \begin{matrix} Animal\ type\ 1 \\ Animal\ type\ 2 \\ Animal\ type\ n \end{matrix}$$

Constants:

X = Production capacity (LU/year) in standard units of LU of the farm under consideration

Y_i = Ratio of animals $i \in I$ to the standard unit of a cow equal to 1 LU.

P_i = The income generated from female animal $i \in I$ in one year.

K_i = The cost to keep animal $i \in I$ on the farm for one year.

Variables:

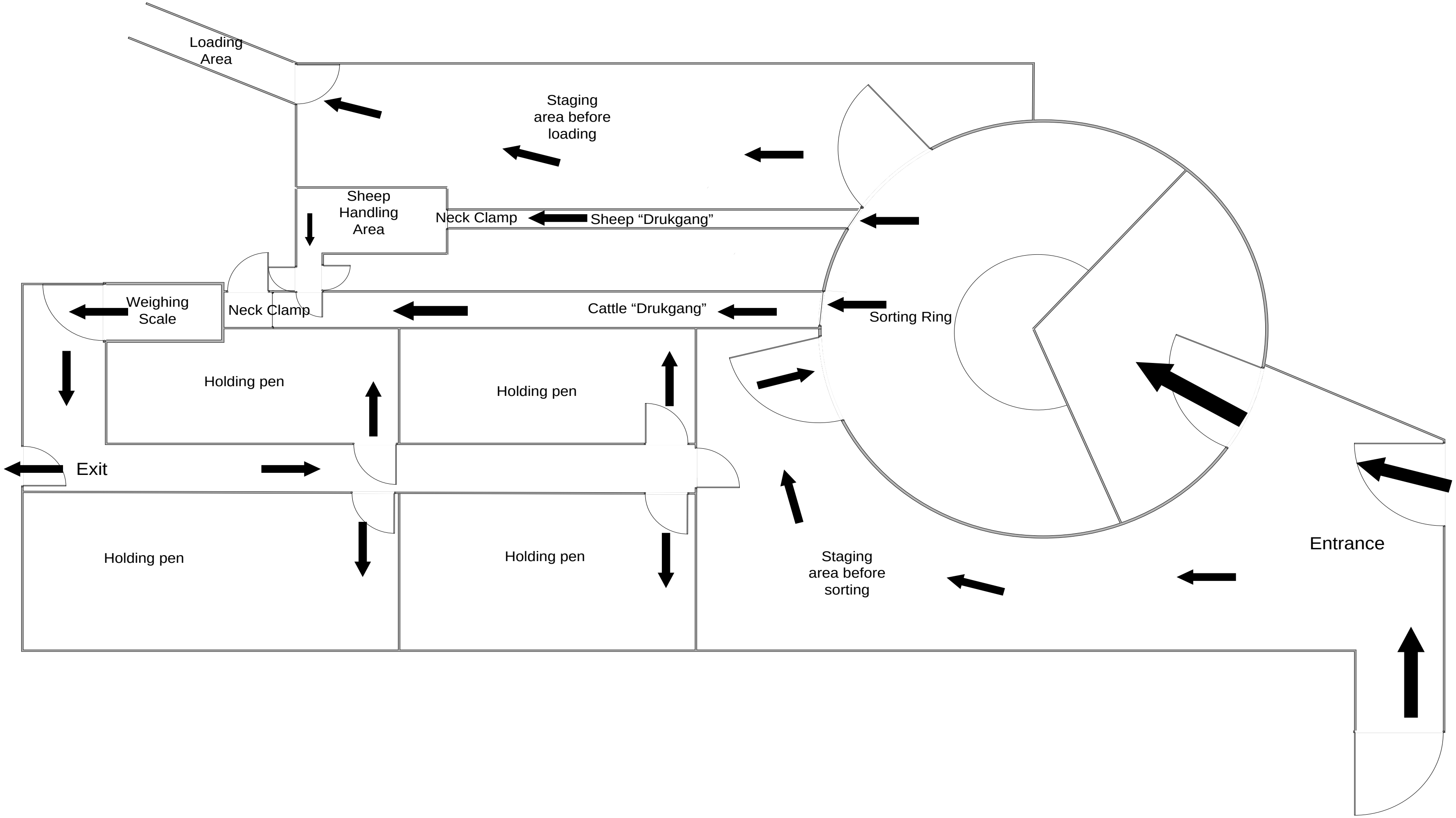
L_i = The amount of animals $i \in I$ to keep on the farm annually

s.t.

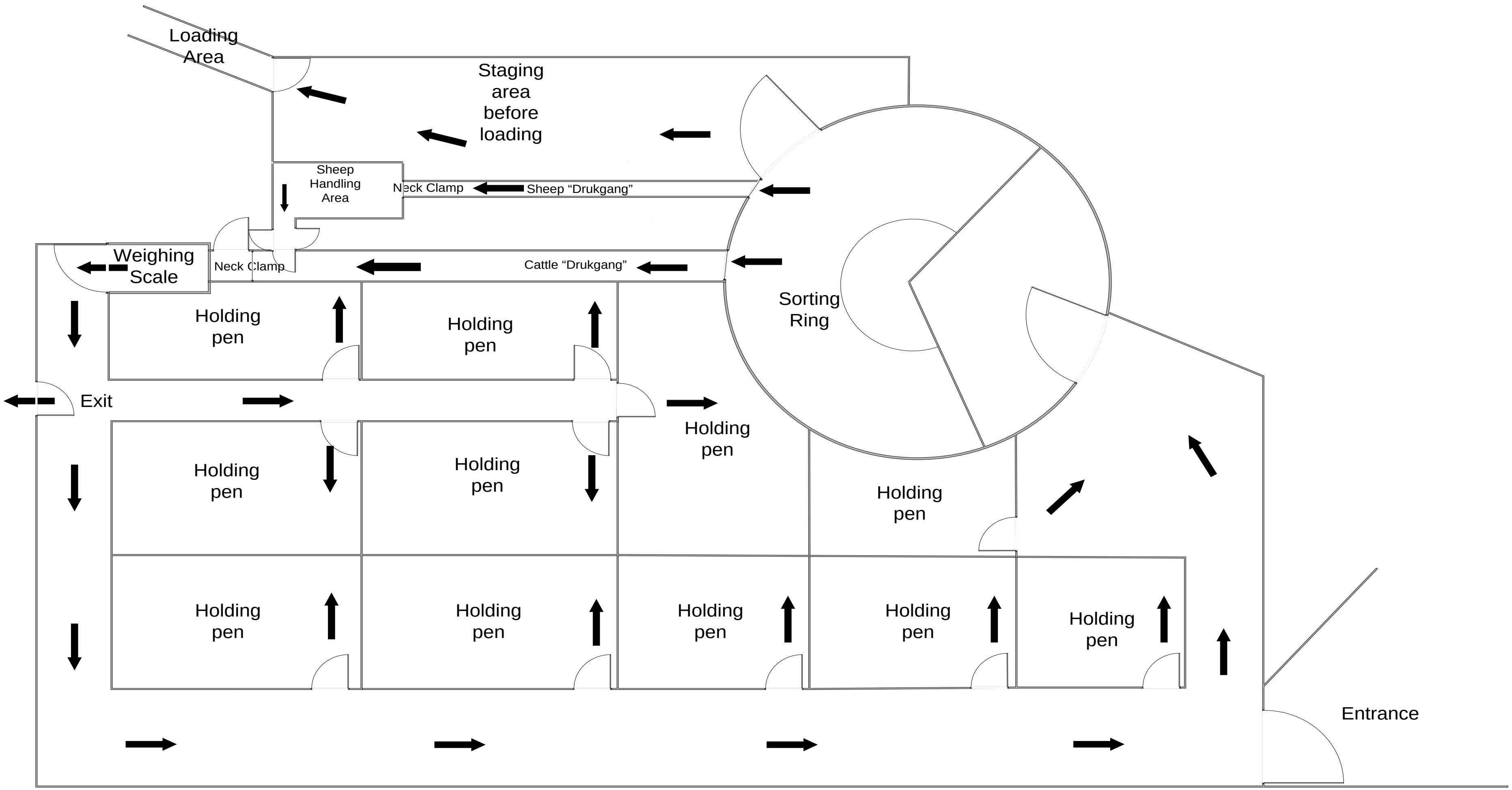
$$\sum_{i=1}^{n} \frac{Li}{Yi} \leq X$$

$$YiLi = Y(i+1)L(i+1)\ \forall i = 1,2,3 \ldots\ldots i-1$$

8.2. Appendix 2



8.3. Appendix 3



8.4. Appendix 4

FSDM OT User Manual

1. Select the Raw Data Tab.
2. Enter all the info for the animals that the user is planning on farming with, and select the tic box next to the relevant animal.
3. Note, do not change any info that is not in a white shaded area.
4. Enter the GP allocation to growth.
5. Select the Farm Info Tab.
6. Enter all the info describing the grazing and feed producing camps on the farm, fill in only the white shaded areas.
7. Select the LP tab.
8. Click the "Optimise solution" button to calculate the optimal number of animals of each kind to farm with.
9. If the solver returns an error, revise the minimum number of animals specified on the Raw Data Tab. The reason for this is that of the minimum number of animals is more than the least optimum amount for a certain animal the solver will return an error. Lower the minimum amount and click the Optimise Solution button. If the solver returns a value without an error the quantity specified is the optimal combination.
10. Select the Breeding Technique tab.
11. Tick the specific breeding technique that will be applied on the farm.
12. The table will return the number of male and female animals to keep on the farm at saturation state.
13. The Animal Ratio tab calculates the shortfall of the number of animals of each kkind from the saturation state, no values need to be changed here.
14. Select the Cash Flow tab.
15. Scroll down to where Misc Expenses and Misc Income is entered. Enter all misc expenses and Income not generated through revenue from the sale of animals.
16. The GP allocation may be changed for a specific year, if this is not changed the default value specified in the first tab will be selected.
17. The corresponding cash flow calculation will indicate the number of old animals to be sold each year, the number of new animals to be purchased, the cost, income and other self-explanatory information.
18. Select the FDP tab.
19. The graphs will indicate the number of animals of each kind on the farm at a specific year over the growth period.
20. The saturation state for a certain animal type is indicated with a white line on the corresponding year.
21. The global saturation date will be indicated and is assumed to be the date at which the last animal type reaches saturation.

8.5. Appendix 5

<table>
<tr><th colspan="2">Scope of Method</th></tr>
<tr><td rowspan="2">Financial :</td><td>Cash Flow Calculations</td></tr>
<tr><td>Engineering Economics</td></tr>
<tr><td rowspan="2">Operational Requirements:</td><td>Fixed Assets</td></tr>
<tr><td>Equipment</td></tr>
<tr><td>Production Requirements:</td><td>Product Type</td></tr>
<tr><td rowspan="2">Market Conditions</td><td>Demand as Constraint</td></tr>
<tr><td>Cash Flow as Constraint</td></tr>
<tr><th colspan="2">Pre-conditions and Input Data</th></tr>
<tr><th>Crop Producing</th><th>Livestock</th></tr>
<tr><td>Which crops are produced
Production expenses (R/ha):
Operating expense
Fertiliser cost
Input cost
Waste / cut rate (%)
Planting density
Arable area of farm
Yield
Growt times of crops
Inflation rates
% Split in production
Product selling price
% of profit to use in expansion</td><td>Animals
What animals to farm with
LU for each animal kind (LU/ha/Year)
Production potential of each animal (Offspring per year)
Breeding technique
Additional cost (Excl feed)
Auction price (When Selling)
Auction price (When Buying)
Price growth
Farm
Yield section size
Yield section production capacity (LU and kg)
Cost of land/feed
Other
Misc Expences</td></tr>
<tr><td colspan="2">If the demand is a constraint for expansion of the farm, historical sales data is required for forecasting.</td></tr>
<tr><th colspan="2">Requirements from Farmer and Constraints</th></tr>
<tr><td colspan="2">This include any constraints related to the farm expansion, production growth, facilities, assets, and equipment.</td></tr>
<tr><th colspan="2">Typical Users</th></tr>
<tr><td colspan="2">Farm owner
Farm manager</td></tr>
</table>

8.6. Appendix 6

Main Step	Preconditions	Extensions for FSDM	Input Data: Livestock Farm	Input Data: Crop Producing Farm	Farm Specific Extensions: Livestock Farm	Farm Specific Extensions: Crop Producing Farm
Step 1			Feed yield potential; section sizes		Calculate the feed yield potential (LU) of the farm using the input parameters.	
Step 2			Yield potential of intensive crop	Arable area Waste Planting density	Identify all areas suitable for intensive feed production. Determine production capacity of the areas using the input parameters Calculate the amount of LU of each kind of animal at saturation state using a LP.	
	Demand is constraint / demand is less than farm saturation state.					Calculate maximum capacity of farm. Calculate maximum possible production rate. Express maximum possible production rate in standardised units.
		Determine if additional requirements and constraints should be considered (from owner). If there are, first execute step 4 and step 5 before returning to step 3.				

Step 3		Not neccesary to calculate saturation date. Determine production requirements by using cash flow.		Expenses and Incomes Growth periods. Yield Inflation Production split % profit to use in expansion		
	Demand is constraint / demand is less than farm saturation state.	Calculate production requirements by using Holt's forecasting method. Use the future demand to limit the expansion while doing cash flow.	Historical sales data			
Step 4	Additional requirements / constraints from farmer.	Identify requirements / constraints from the owner (farmer-prioritised RUSS) with applicable design criteria.				
Step 5	Additional requirements / constraints from	Identify and evaluate alternatives for farmer-prioritised RUSS and then return to step				

	farmer.	3.				
Step 6					Phase plans include the growth of livestock herds as this needs to be included in cash flow planning.	
Step 7					Phase plans need to be indicated in the form of a table that group together logical dates of extension to ease in cash flow planning.	
Step 8		Redo the FSDM annually or when input data change.				