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Profitability and competitiveness of grain handling at farm level

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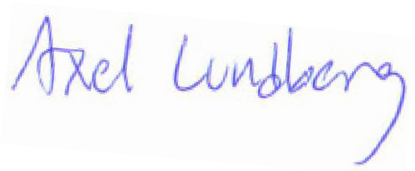
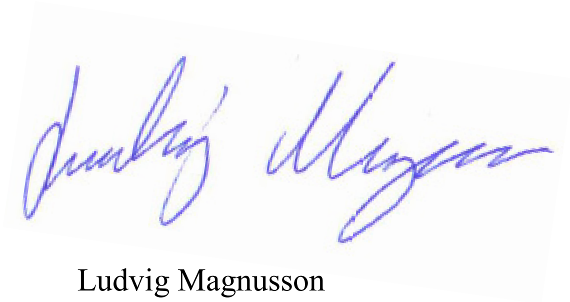
We look forward to use our knowledge, learned at SLU, in future employment.



Axel Lundberg



Ludvig Magnusson

Abstract

The Swedish agricultural sector is currently experiencing substantial structural changes, where the number of agricultural enterprises continuously decreases and the average farm size increases. In order to maintain competitiveness, it is important to be aware and adapt to changes concerning the surroundings of the company (Johnson *et al.,* 2011). Agricultural commodity prices sharply fluctuate on the global market in recent years, affecting the profitability of farmers. High volatility market requires tools to reduce price variations and increases the need of decision-making (Bouder & Beth, 2003). Farm-based grain handling facilities increases the sale options regarding agricultural commodities; a flexible strategy to get additional compensation for the storing the grain produced on the farm (Edling, 2002; Edwards, 2013). Storing and drying on farm is compulsory in order to manage seed production, which is not possible when selling to the grain trader at harvest (Pers. Comm., Gillsjö, 2015). A farm-based grain handling facility means streamlining the farm operations and gives the opportunity to achieve higher profitability.

The aim of this study is to investigate the profitability and competitiveness of farm-based grain handling facilities. The study accounts for the possibility of combining different investments and crop strategies. Profit maximization determines the optimal strategy of the farm with respect to limitations interpreted from empirical data. The strategy varies based on the possibility to segregate the quality of crops. The study uses mathematical programming, empirical data from statistics and interviews of knowledgeable people within the sector. A mixed integer linear programming model is developed in order to find the most profitable strategy.

The results that emerge from this study indicate economic feasibility of farm-based grain handling facilities when seed production is possible. Seed production is a crucial factor regarding the profitability of the optimal strategy of the farm. None of the optimal strategies on the fictitious farms includes an investment in a facility without seed production. However, in order for the farm-based grain handling facility to represent the optimal strategy of the farm, it has to be combined and supplemented by a grain trader at harvest. An investment in exclusively farm-based grain handling facility do not generate higher profitability than selling to the grain trader during the harvest period.

Sammanfattning

Den svenska lantbruksnäringen genomgår för närvarande stora strukturella förändringar där antalet lantbruksföretag kontinuerligt minskar medan den genomsnittliga gårdsstorleken ökar. För att bibehålla företagets konkurrenskraft är det viktigt att vara medveten och anpassa sig till de förändringar som uppkommer i dess omgivning (Johnson *et al.,* 2011). De senaste åren har spannmålspriserna fluktuerat kraftigt på världsmarknaden vilket har påverkat lönsamheten för lantbruksföretag. En marknad med hög volatilitet kräver verktyg för att reducera prisvariationerna och behovet av beslutfattande ökar (Bouder & Beth, 2003). Gårdsbaserade spannmålsanläggningar ökar antalet försäljningstillfällen och försäljningsalternativ för de producerade råvarorna i växtodlingen, d.v.s. en flexibel strategi för att få ytterligare ersättning för den producerade spannmålen (Edling, 2002; Edwards, 2013). Lagring och torkning på gårdsnivå är en förutsättning för att odla utsäde, vilket inte är möjligt vid direktleverans vid skörd (Pers. medd., Gillsjö, 2015). Den gårdsbaserade spannmålsanläggningen effektiviserar verksamheten och möjliggör högre lönsamhet.

Syftet med studien är att undersöka lönsamheten och konkurrenskraften kring gårdsbaserade spannmålsanläggningar på växtodlingsföretag. Studien beaktar möjligheten att kombinera olika investeringsalternativ och växtodlingsstrategier. Den optimala strategin gällande grödor och investeringsalternativ bestäms utifrån ett vinstmaximeringsproblem med beaktandet av empiriskt material. Utformandet av strategin baseras på möjligheten att särhålla olika kvaliteter av grödor. Studien baseras på matematisk programmering, empirisk data från statistik samt intervjuer med sakkunniga inom ramen för studien. I studien byggs en kombinerad linjär- och heltalsprogrammeringsmodell för att finna den mest lönsamma strategin gällande grödor och investeringsalternativ.

Studien visar att det är ekonomiskt möjligt att investera i en gårdsbaserad spannmålsanläggning när utsädesproduktion är möjlig på gården. Utsädesproduktion är en avgörande faktor gällande lönsamheten för den strategiskt optimala driften för gården. Utan utsädesproduktion är ingen gårdsbaserad spannmålsanläggning ekonomiskt optimal. Genom att sälja till en spannmålshandlare vid skörd uppnås högre lönsamhet än att enbart investera i en spannmålsanläggning på gården. Dock är en kombination av gårdsbaserad spannmålshantering kompletterat med direktleverans vid skörd den mest optimala strategin på större gårdar.

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1. Introduction

Regardless of industry, it is important to be aware and to adapt changes concerning the surroundings of the company in order to maintain competitiveness (Johnson *et al.,* 2011). There are several factors affecting the business environment; shifting market demand, technological development, new regulations and competitors taking market shares. It is essential to understand these changes and adapt a suitable strategy in order to survive.

The foundation of the Common Agricultural Policy (CAP) was a strategy to ensure food production and was constituted in 1957 (www, SJV 1, 2014). The purpose was to ensure Europe´s food production, i.e. improve efficiency in agriculture, stabilization of the markets, ensure reasonable prices to the people and guarantee the farmer a reasonable standard of living (Sarris & Freebairn, 1983). The strategy of CAP was to regulate commodities in order to achieve its purpose. Agricultural commodities are nowadays continuously deregulated, which affect the Swedish farmers. They become more risk exposed to market conditions, and thereby market risk (LRF, 2010). Moreover, factors that can increase the risk exposure are fluctuation in the energy market, changing oil prices or climate impacts (SJV 2010:33 & OECD-FAO, 2008). These factors affect the risk exposure and force the farmers to compensate for the structural changes. Through diversification, farmers can achieve risk compensation by producing alternative crops, increase flexibility of commodities/assets etc. (Hardaker *et al.*, 1997; Kandulu, 2011).

It is common for crop producers to store their grain in order to capture seasonal price improvements (Dhuyvetter *et al.,* 2007). The average spot prices of grain are expected to be lowest at harvest. Over time, the price of grain tends to increase as the supplies of grain are consumed. The fluctuations of world market prices of grain have a substantial impact on the Swedish grain market (SJV 2014:08). The price fluctuations tend to increase in the future due to the stronger connection between agricultural sector and the energy market (SJV 2010:33). Furthermore, expected climate changes and exposure to extreme weather conditions may affect future prices.

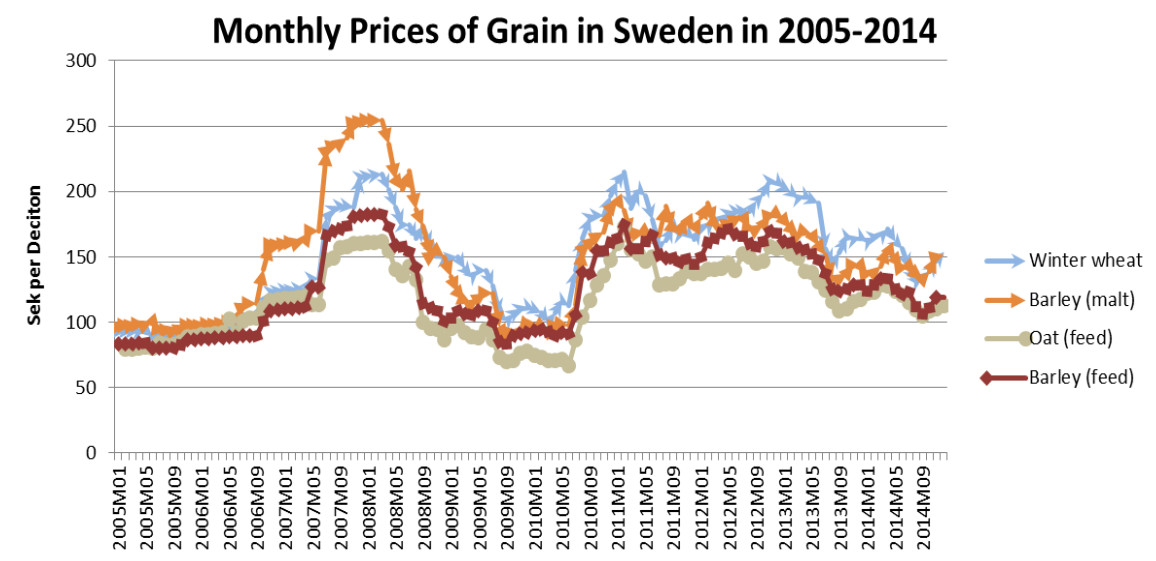
There are several grain traders on the Swedish grain market, prepared to buy the farmers harvested crops. They offer numerous of sale options for producer's commodities; sell directly, use price hedging or forward contracts. The producer's conditions and market environment determine which sale option is most profitable. A farm-based grain handling facility increases the sale options regarding agricultural commodities; a flexible strategy requires an investment (Edwards, 2013). Farm-based grain handling facilities provides the opportunity to separate the quality of grain, hence the opportunity to get an additional compensation for the storage (Edling, 2002). Moreover, increasing numbers of farmers choose to store and dry their grain themselves, which means streamlining the operations and an opportunity to achieve higher profitability (www, ATL, 2010). There are approximately 20 000 farm-based grain handling facilities in Sweden, both hot air dryers and air dryers are included (Sahlin *et al.,* 2014).

This study examines various investments of farm-based grain handling facilities from a microeconomic perspective. The optimization model built in this study accounts for segregation of crops when storing, different qualities of crops and seed production. These conditions, combining farm-based grain handling facilities and grain traders, are examined in the south of Sweden with land-related conditions in order to find most profitable strategy.

1.1. Problem Background

Swedish agriculture faces the challenge of continuously developing production to achieve profitability (Dahlqvist *et al.,* 2013). Today's farming requires large investments where the combine harvester, drying and storage are significant cost items (Westlin *et al.,* 2006). Agricultural commodity prices have sharply fluctuated at the global market in recent year, resulting in uncertain earnings and affecting the profitability for the producers (Olsson *et al.,* 2014).

Chart 1 presents the price of grain in Sweden between the year 2005 and 2014. The chart illustrates the world market's impact on grain prices in Sweden. Before the peak of grain prices in March 2008 the price of grain, in both Sweden and the world, was lower than current prices and less volatile (SJV, 2014:08). The record levels of grain prices in 2008 were a direct effect of the low yields in 2006/07 and 2007/08. The high prices contributed to an increase in supplies, which lowered the price. In 2010, the prices increased globally due to the dry weather in Eastern Europe. The next major increase of grain prices happened in 2012 because of the drought problems in US and South America. The current prices have decreased since the peak in 2012 due to the high forecasted yields in the rest of the world. A market with high volatility increases the importance of decision making and requires tools to reduce price variation (Bouder & Beth, 2003; SJV 2008:1).



Notification: The price presented in the figure refers to normal quality (transport included). The prices are an average of what commercial grains buyers are willing to pay.

Chart 1. Historical spot prices of grain in Sweden in 2005-2014. (Own modification from www, SJV 2, 2015)

The Swedish agricultural sector is currently experiencing substantial structural changes, where the number of agricultural enterprises continuously decreases and the average farm size increases (SJV 2011:33). The trend towards larger farm units and higher yield levels implies updating the grain handling facility at farm level (Jonsson, 2006). In the year 2005, a large grain trader reduced their grain depots from 92 to 15 plants (www, Lantmännen 1, 2006). Due to the closures, the research increased on grain handling facilities at farm level since the ability to deliver grain at harvest decreased (Westlin *et al.,* 2006). An investment in a farm-based grain handling facility is expensive and it is important to consider the right investment choice (Westlin *et al.,* 2006). Westman (2006) examines whether grain stir drying system is an alternative option to conventional drying plants from an economic perspective. The report shows economic benefits regarding a grain stir drying system because of its low investment cost. Ugander *et al.* (2012) find that storing grain at the farm level reduces the price risk. Grain producers are given the opportunity to choose the time of sale and contract farming becomes possible, such as seed production. This is an advantage for agricultural enterprises with great production value, in relationship to equity, since low grain prices may decrease the equity of the firm. Ugander *et al.* (2012) argue that an integrated analysis of crop rotation and storage systems may provide interesting aspects.

1.2. Problem

The Swedish crop producers are heading towards larger agricultural units, where market prices fluctuate substantially. The advanced grain handling facilities at farm level become more competitive against business environment (Ugander *et al.,* 2012). Farm-based grain handling facility is a substantial investment for a crop farm, which enables sales at desired time for the farmer. This study is based on previous studies and gathered empirical data to find a profitable combination of crops and investment alternatives for a crop producer through an optimization model.

Farm-based grain handling facilities include economic values and are hard to estimate in form of better logistics at harvest. These benefits are mentioned as timeliness effects (Gunnarsson *et al.,* 2012). Low machinery capacity decreases the timeliness effect and high machinery capacity increases it (Axenbom *et al.,* 1988). Timeliness effects are defined by having the capacity to conduct operations at the most favourable time. Timeliness costs occur when timeliness effects are lacking in terms of capacity. These effects differ between crops, operations and weather conditions. There are positive timeliness effects when using farm-based grain handling facilities compared to direct delivery at harvest. Direct delivery at harvest requires transport from field to grain trader, which is time consuming and reduces efficiency, which can be seen as a negative timeliness effect. However, in order to minimize timeliness costs at harvest, when delivering directly to grain trader, an investment of buffer storage is necessary on the farm.

Numbers of farm-based grain facilities are increasing since farmers assume they will achieve higher price for their commodities (www, ATL, 2010). There are approximately 20 000 farm-based grain handling facilities in Sweden, both hot air dryers and air dryers are included (Sahlin *et al.,* 2014). The recent publications from the Swedish institute of Agricultural and Environmental Engineering states it is rare to achieve profitability when investing in a farm-based grain facility (Westlin *et al.,* 2006; Jonsson, 2006; Ugander *et al., 2012*). This study uses a new perspective to analyse economic aspects of farm-based grain handling facilities. Earlier studies does not account for various strategies regarding the qualities of crops and segregation of crops.

This study is carried out to examine optimal dryer and storage systems concerning segregation and various crop strategies. This new perspective may form the basis of new conclusions regarding the motivation of an investment in farm-based grain handling facility.

1.3. Aim and Research Questions

The aim of this study is to investigate the profitability and competitiveness of farm-based grain handling facilities. The study accounts for the possibility of combining different investment and crop strategies. The study investigates several investment alternatives of farm-based grain handling facilities and a various qualities of crops within the crop rotation. The study aims to find the most profitable combination of qualities of crops and grain handling strategies for each fictitious farm. To reach the aim, these research questions have to be answered:

- ✓ Is an investment in farm-based grain facility economically feasible on 200-, 500- and 800- hectare farm?
- ✓ Which grain handling strategy is most profitable on 200-, 500- and 800- hectare farm?
- ✓ What are the economic impacts of seed production, discount rate and willingness to pay for additional land regarding farm-based grain handling facilities?

This study is based on previous research on grain handling systems. This thesis contributes with a new perspective of optimal dryer and storage systems combined with several qualities of crops. An optimization model is developed in order to examine the profitability for each fictitious farm. The applied optimization model provides the answer to the research questions. The study primarily targets grain producers and advisors in the agrarian sector.

1.4. Delimitations

Since this study investigates the profitability of farm-based grain handling facilities it requires fictitious farms growing grain. Livestock producers could be accounted for in this study as they grow feed grain to their livestock. A livestock farmer has other values than a crop farmer since there are synergies between the land grown and livestock produced. However, livestock production is excluded from this study and the focus is on "pure crop farms". The geographical area for this kind of thesis can be made where crop production is common. This particular study chooses to focus on Östergötland in Sweden. There are several geographical areas in Sweden where crop production is higher than the national average i.e. Uppland, Östergötland and Skåne (SCB, 2014). Moreover, the very southern part of Sweden grows industry crops, such as green peas, to a greater extent, which does not require a farm-based grain handling facility. Furthermore, many grain traders are located in Östergötland, which enables several marketing options for crops produced on the farms e.g. milling industry and animal feed industry

This study does not focus on certified cultivation such as Krav-certification and EU- organic since these crops represents a minority (15 percent) of the market shares (SJV, 2014). This study is limited to the conventional (non-organic) crop production since it represents a majority of the total tillable land in Sweden. The farm-based grain handling facilities are limited to the assortment of Tornum since they have more than a 50 percent market share in Sweden (Holm, 2011). They are a supplier of grain facilities for both agricultural and grain industries. The study excludes various types of risk and the individual is assumed to be risk-neutral. This means that the individual is assumed to choose the investment generating the highest expected profit regardless of the risk levels of the various investments. There are several risk factors, regarding the grain price, yields and quality aspects, affecting the profitability of a farm enterprise (Ugander *et al.,* 2012). Hence, these are difficult to estimate and thereby excluded from this study.

This study uses fixed grain prices irrespective of the farm size. Grain traders offer several types of contract for marketing grain; pool, depot, spot and forward or spontaneous delivery (www, Lantmännen 4, 2015; Pers. Comm., Wildt-Persson, 2015). Different marketing strategies could have been used in this kind of study but it is difficult to generalize and estimate the value. The value of these contracts depends on the specific situation for each decision maker of the farm. This study uses pool 1- and pool 2-prices since it is a generalizable measure when selling grain at different periods in time.

2. Literature Review

This chapter provides a historical background of the research on farm-based grain handling facilities.

2.1. Earlier studies of farm-based grain handling facilities

There are several foreign and Swedish studies related to farm-based grain handling facilities. Earlier research focus on both technical and economic aspects, which demonstrates the versatility of the factors studied.

2.1.1. International studies

A farm-based grain handling facility uses several resources such as different energy systems. Schoenau *et al.* (1995) investigates energy utilization systems and management strategies for in-bin drying of canola in North America. Different energy systems, moisture contents, annual costs and weather data are examined in a simulation model in order to find the most cost effective system for in-bin drying of canola. Solar panels are shown to be the most cost effective alternative for locations with good solar energy availability. In those areas where conventional energy systems are preferable to renewable energy systems, prophane and natural gas are the most cost effective. The study by Schoenau *et al.* (1995) highlights the effect of the weather condition at harvest and drying when evaluating energy systems. Patil & Ward (1989) examines solar and combined solar-natural air drying of rapeseed, similar to the research of Schoenau *et al.* (1995), using a simulation model. The study accounts for weather conditions, solar radiation, different harvesting dates and moisture contents. The study focuses on actual time for drying where the time increases with increasing depth of the layer and initial moisture content. The conclusion of the study shows faster drying with solar-natural air-drying.

A study by Jayas & White (2003) provides a review of low cost approaches for storage and drying of grain. The authors compare near-ambient drying systems to hot air dryers with regard of the safety of storing. The near-ambient drying system is the most cost efficient but is more time consuming. Furthermore, the hot air dryer is far more expensive per kilogram of grain. Sun *et al.* (1995) investigates how to model mass and energy transfer processes for grain drying systems using near-ambient conditions. Both Sun *et al.* (1995) and Jayas & White (2003) explore near-ambient drying systems. However, Sun *et al.* (1995) focuses on the mass and energy transfer process and uses a mixed set of non-linear modelling. Sun *et al.* (1995) and Jayas & White (2003) adds quality assurance and energy flow chart as new aspects to the research of farm-based grain handling facilities.

The studies mentioned above focus more on the technical aspects than the economic aspects. Khatchatourian *et al.* (2013) and Radajewski *et al.* (1988) combine economic and technical aspects. Khatchatourian *et al.* (2013) simulated the performance of cross flow grain dryers and cross flow dryers with energy saving. They use non-linear partial differential equations in order to express the mass and heat processes. The aim of the study is to improve the drying process to provide a significant economic benefit. Their conclusion state non-uniformity of the temperature in the different stages of a grain dryer may increase efficiency and provide economic benefits. Radajewski *et al.* (1988) develops a simulation model in order to investigate the economic benefits of microwave preheating system for continuous flow dryers.

The authors state that field losses are reduced when harvesting wheat at higher moisture contents than currently practiced. Since high moisture contents prolong the time of drying, a microwave heating system is investigated in order to achieve time efficiency and less field losses. The result of the study depended on the cost of microwave source, electricity and fossil fuel. In order for the preheating microwave system to be economically viable, the maximum cost cannot exceed 480 Australian dollars per kW. Khatchatourian *et al.* (2013) and Radajewski *et al.* (1988) demonstrate economic benefits with different techniques concerning drying grain on farm-level. However, the focus is to large extent on the technical aspects in these studies.

2.1.2. Swedish studies

The Swedish studies of farm-based grain handling focuses more on the economic aspects than the technical aspects. Earlier studies in the 70's and the 80's show similar results as recent studies. The capital costs are a significant cost element, which complicates an investment in farm-based grain handling facilities. Ånebrink (1980) examines different types of systems for drying and storage of grain with feed quality. The purpose of the study is to investigate which type of system generating the highest profit. The result reveals the need of an investment reduces if existing buildings can be used. Additionally, the capital cost is to a large extent affected by the level of the initial investment. Ekström's (1972) study examines several investment alternatives accounting for economy and labour requirements. Ekström stresses the consideration of several factors; size of farm, geographical area and which type of crop system. The study observes this through different yields and different moisture contents. The results regarding labour requirements show new types of grain handling system reduce the manual work concerning filling and outloading. Ånebrink (1980) and Ekström (1972) use fundamental microeconomic calculations to study their area. Westlin *et al.* (2006) contributes with a new factor, collaboration between farmers, compared to the studies by Ekström (1972) and Ånebrink (1980). Westlin *et al.* (2006) study aims to explore the possibilities to increase the profitability of crop production by collaborating at grain harvest, drying and storing. The calculations regarding harvest and drying costs are created based on four fictitious farms with sizes ranging from 100- to 1000 hectares. The method is based on calculations combined with existing data and qualitative interviews to explore if collaboration at harvest and farm based grain handling facilities is profitable. The results show benefits of collaboration, regarding harvesting and storage are substantial, particularly for the farms with little tillable land.

Recent studies use mathematical programming to analyse farm-based grain handling facilities. Wildt-Persson (2006) study is an evaluation of the economic impact of different grain handling facilities, and categorizes these based on financial results. The method of the study is based upon linear and integer mathematical programming together with empirical data, involving qualitative interviews and statistical data. The study examines three different farm sizes, 50-, 100- and 150- hectares, in three different production areas in Sweden. The result of five different systems for grain handling at farm level indicates two interesting alternatives of investments; low cost approaches such as slab or outloading bin. These alternatives generated the highest profitability compared to the other alternatives. The capital cost per kilo of grain was a major contributing factor to the result and the smaller farms have difficulties justifying more advanced investment options.

Ugander *et al.* (2012) analyses various aspects of investing in a farm-based grain handling facilities; the price volatility, yield risk and quality risks. The authors assume farmers as risk averse, since farmers have a financial interest in reducing the risks. Fictional farms in sizes of

100-500 hectares were created in different production areas in order to investigate if a farm-based grain handling facilities reduced the risks. Mathematical programming, existing data and qualitative interviews formed the basis of this study´s methodology. The results of the study show that price volatility increased sharply after year 2006, compared to previous years, and storage at the farm level is an interesting investment alternative to reduce price risks. However, smaller farms have difficulties justifying such an investment.

Collaboration and economies of scale are important factors in order for farm-based grain handling facilities to become more cost efficient. The Swedish studies reveal similar conclusions regarding smaller farms; an investment in a grain facility is not economical viable. However, Westman (2006) investigates low cost approaches for drying grain, which are found in the foreign studies. The study consists of a comparison of different silo drying systems, where a 200- and 400- hectares farms are compared in three geographical plain areas in Sweden. The author uses linear integer programming combined with empirical data and interviews to calculate the most optimal cropping systems for various investment alternatives. The study reveals that silo drying is the most profitable option. This study reveals lower capital cost per kilogram of stored grain for larger plants, which makes it easier to achieve profitability of an investment with larger farm size.

2.2. Summary of literature review

The literature review of this study shows research concerning farm-based grain handling facilities to focus on technical or economic aspects, often both. The literature review indicates different levels of parameters used to evaluate farm-based grain handling facilities. The technical aspect of farm-based grain handling facility enters deeply into weather factors, different moisture contents and efficiency of energy systems. The economic aspects focus on interest rates, grain prices, risk factors and the grain market. The technical and economic aspects are rarely combined since their area of focus is complex. Naturally, researchers would focus on their area of expertise when examining farm-based grain handling facilities. The economic research often uses linear programming, fictitious farms and existing data.

This study has similarities to earlier studies, especially the economic studies (Ugander *et al.,* 2012; Wildt-Persson, 2006; Westlin *et al.,* 2006; Westman, 2006). Moreover, this study uses fundamental microeconomic calculations similar to earlier studies. This study distinguishes itself from earlier studies since it considers segregation of crops, various grain strategies and equalizing timeliness effects between the grain trader and the farm-based grain handling facilities. Linear and integer programming is often used when investigating operation of a farm and decision making concerning storing and drying of grain. The earlier studies create a deeper understanding of the studied area and can help the researcher to increase their ability to analyse the result.

Table 1 presents a summary of the relevant studies mentioned in the literature review. The table shows subject, aspects, research method and geographical location. The literature review shows the width of the studied area and reveals an overlooked aspect, segregation of crops and various grain strategies.

Table 1. Overview of earlier studies within farm-based grain handling and their research methods.

Earlier studies	Aspect	Subject	Research method	Country
Ekström (1972)	*Economic / Technical*	Selection of grain dryer with respect to costs and labor requirement	Calculations, existing data and qualitative interviews	Sweden
Ånebrink (1980)	*Economic*	Different methods of preservation of feed grain - economic analysis	Calculations, existing data and qualitative interviews	Sweden
Radajewski *et al.* (1988)	*Economic / Technical*	Grain drying in a continuous flow drier supplemented with a microwave heating system	Simulation model	Australia
Patil & Ward (1989)	*Technical*	Simulation of solar air drying of rapeseed	Simulation model	New Zeeland
Schoenau *et al.* (1995)	*Economic / Technical*	Simulation and optimization of energy systems for in-bin drying of canola grain (rapeseed)	Simulation model	Canada
Sun *et al.* (1995)	*Technical*	Mathematical modelling and simulation of near-ambient grain drying	Mixed set of non-linear modelling	United Kingdom
Jayas & White (2001)	*Economic / Technical*	Storage and drying of grain in Canada: low cost approaches	Literature review	Canada
Westlin *et al.* (2006)	*Economic*	Collaboration when harvesting, drying and storing grain	Calculations , fictitious farms , existing data and qualitative interviews	Sweden
Westman (2006)	*Economic*	Investment in grain drying and storage on a farm-level	Mathematical programming (LP), fictitious farms and existing data	Sweden
Wildt-Persson (2006)	*Economic*	Farm-based grain facilities within the future organisation of Lantmännen	Mathematical programming (LP), fictitious farms, existing data and qualitative interviews	Sweden
Ugander *et al.* (2012)	*Economic*	Profitability in the drying of grain on small and medium-sized agricultural enterprises	Mathematical programming, fictitious farms, existing data and qualitative interviews	Sweden
Khatchatourian *et al.* (2013)	*Economic / Technical*	Modelling and simulation of cross flow dryers	Mathematical programming (non-linear)	Brazil

3. Theoretical Framework

The theoretical framework for this study is presented and motivated in this chapter. The theories presented in this chapter are used to evaluate the profitability and competitiveness of farm-based grain handling facilities.

3.1. Theoretical approach

The theoretical approach of this study is based and built upon fundamental microeconomic theory. Microeconomics is based upon several set of models with the aim to explain how restricted resources are used with regard to the role of prices and its market (Gravelle & Rees, 1992). The unit of analysis in microeconomics are the decisions makers or economic agents, usually categorized as consumers and producers. Assumptions between consumer and producer are made in order to draw conclusions about how the market should operate. This study analyses fictitious farms at micro level and their opportunities with farm-based grain handling facilities. In order to form accurate assumption several calculations are performed concerning the producer's conditions and the market environment. This thesis concerns a comparison between investing in a farm-based grain handling facility or selling directly to the grain trader at harvest. The outline of this study requires fundamental microeconomics basis where profit is generated by subtracting the total cost from total revenues *(ibid)*. Moreover, this kind of problem becomes complex since it consists of several farm activities, investments and strategies. By building an optimization model based on mixed integer linear programming with the aim to maximize profit, the most profitable way of operating the farm will be chosen.

3.2. Decision model

Simulation is the most commonly used quantitative method for decision making; a descriptive technique where a model is built to represent reality (Anderson, 2000; Turban *et al.,* 2005). The model is based on two types of inputs; probabilistic variables and controlled variables (Turban *et al.,* 2005). Probabilistic variables require a statistical distribution and the analysts choose control variables. The calculated outputs of the descriptive models are determined by the inputs. The researcher is able to understand how input affects the output by changing the control variables. This method creates a deeper understanding of how a decision affects the reality (Anderson, 2000). The strength of descriptive method is that it demonstrates the consequences of various decisions, where configuration of inputs and processes vary (Turban *et al.,* 2005). The descriptive technique does not optimize the performance of the system since it exclusively highlights differences in scenarios.

A distinction is made between descriptive method and normative method. The normative approach attempts to find the best outcome of all possible actions (Turban *et al.,* 2005). Mathematical programming is a normative method that tries to find the most efficient way of using restricted resources to minimize or maximize the chosen objectives (Sinha, 2006). Turban *et al.* (2005) states that the normative method is based on three assumptions about the decision maker: rational behaviour, knowing the consequences of all alternatives and has the ability to rank them according to preferences. The rationality of financial and economic behaviour is questionable since irrational behaviour occurs in the reality. Moreover, Turban *et al.* (2005) states that a lack of information, incorrect interpretation and incompetence are underlying causes for irrational behaviour.

3.3. Mixed integer linear programming

The fundamental theory of the applied optimization model is presented and explained in this section.

3.3.1. Optimization process

Optimization theory is a part of the applied mathematics including the use of mathematical models and methods to find the optimal alternative of actions in different decision situations (Lundgren *et al.,* 2001). Optimization models are often used to describe and analyse technical and economic decision problems where the aim is to achieve insights regarding the research questions. The optimization model requires research questions consisting of variables, something that can be controlled or influenced. The definition of optimizing is to determine the best possible values of the variables given the objectives specified. The objective function expresses the objective of the optimization problem and it depends on the variables that can either be maximized or minimized. A number of constraints restrict the variables. In order to use optimization models, the objectives and constraints are required to be quantifiable. Additionally, more advanced and complex problems require special optimization methods with help of computers to determine optimal use of resources (*ibid)*. Optimization theory is applied in both technical and economic research areas, and is used as a tool for analysing operative and strategic planning.

Figure 1 presents the five steps in the optimization process where an objective function is based on the actual problem and simplified (Lundgren *et al.,* 2001). The first step is to find and quantify parameters for the actual problem in order to find a solution using an optimization model (*ibid*). The second step is to simplify the actual problem; a complex process where the relevant and insignificant factors are excluded without influencing the relevance of the results. The third step is to identify the main problem and define the delimitations, which allows an optimization model to express the problem. It is important to verify previous steps in order to get a valid solution and result, as shown in figure 1.

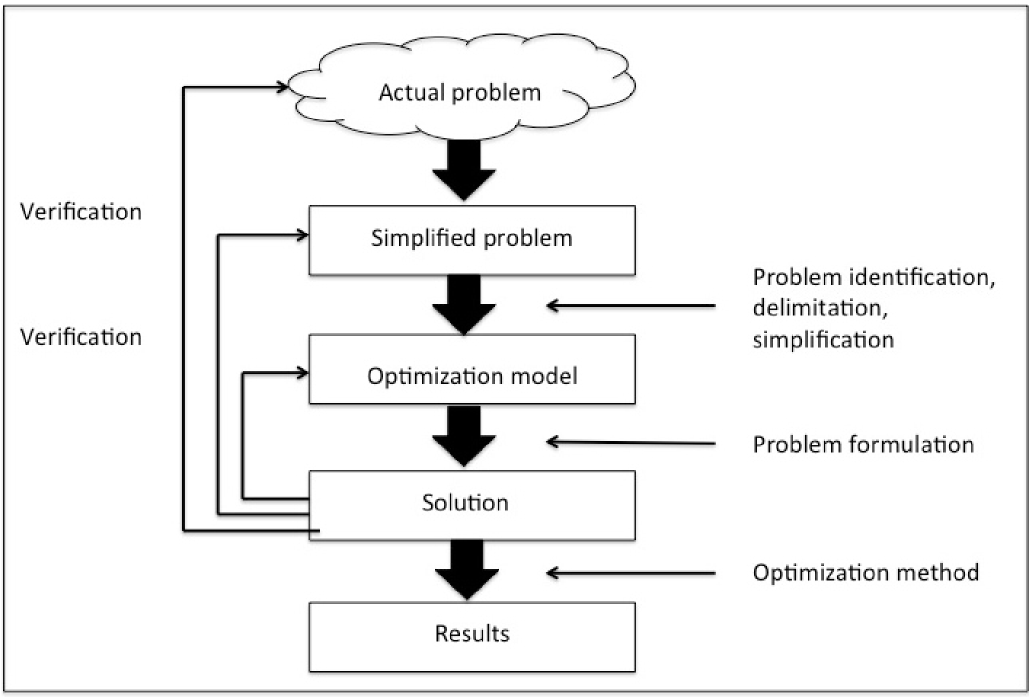


Figure 1. The five steps of the optimization process (Lundgren et al., 2001)

3.3.2. Optimization approaches

Mathematical programming is a suitable technique in order to find the best possible option among unique set of choices for system analysis (Yin, 2003). Linear programming is a technique appropriate for decision problems where limited resources are consumed (Lee & Olson, 2006). Problems characterized by maximization or minimization of a function, affected by restrictions, are typical mathematical programming problems (Debertin, 1986). Moreover, non-linear programming problems are defined by non-linear objective function, non-linear constraints or both. Hence, both the constraints and objective function have to be linear in order to define a linear programming problem. Linear programming is a profit maximization method, which determines the optimal use of resources with regard to the restrictions (Hazell & Norton, 1986). There are usually two ways to solve a linear problem: simplex method and graphical method (Cook & Russel, 1989). Simplex method is appropriate to use when solving major problems containing several decision variables and constraints. The method uses an iterative algorithm to find the optimal solution. This method is useful when performing a sensitivity analysis since it provides information about slack variables (unused resources) and shadow prices (opportunity costs). The graphical method is a simple method including less decision variables and a smaller amount of constraints due to the difficulty of graphing and evaluating more than two decision variables. The limitation of decision variables makes the geographical method difficult to adapt to real world problem. The computer-based simplex method is more adaptable to real-world problems than the graphical method since it provides the optimal solution to linear programming problems containing a large amount of decision variables and constraints (*ibid*).

Integer programming is often a type of linear programming where some or all of the variables are restricted to be integers (Lundgren *et al.,* 2001). Integers can either be integer values, $X_j \in \{0,1,2,\ldots\}$, or binary variables, $X_j \in \{0,1\}$. Mixed integer linear programming is basically integer linear programming where variables can be either integers or non-integers. Binary integer variables are beneficial when modelling yes or no decision, e.g. whether to build a facility or invest in equipment. This study uses mixed-integer linear programming since it combines non-integers (hectares) and binary integer values (investment alternatives; farm-based grain handling facility). The hectares regarding each crop on the fictitious farms do not need to be fixed, this allows optimal use of land. The investment alternatives of farm-based grain handling facilities are forced to be expressed in binary integer values, $X_j \in \{0, 1\}$, since the farmer, either invest or not.

3.3.3. Basic model formulation

Linear programming is a method to determine maximum profit in combination of possible activities with regard to the restrictions (Hazell & Norton, 1986). Three requirements needs to be fulfilled in a given situation order to use a linear programming model:

1. All possible activities available at the farm and their use of resources must be known. A unique set of restrictions concerning a special activity must be specified, e.g. rapeseed (activity) can only be grown every seventh year.
2. The fixed resources on the farm require specification, e.g. maximal arable land or storing capacity.
3. Accurate gross margins need to be calculated in order to obtain a valid result.

By fulfilling these three requirements, it is possible to formulate an objective function and restrictions, which can be optimized. The general expression of an objective function in a farm model is presented in equation (1):

$$\pi = \sum_{j=1}^{n} C_j X_j \qquad (1)$$

The objective function in this study represents the profit (π) of the fictitious farm. The control variable (X) expresses the units, e.g. hectares, of activity j. The gross margin of the farm activities are expressed as C_j. The summation extends from lower bound m and to upper bound n.

To maximize the objective function certain constraints has to be satisfied. The general expression for constraints is the following equation (2):

$$\sum_{j=1}^{n} \boldsymbol{a_{ij} X_j} \leq \boldsymbol{b_i} \qquad \forall\, j = 1, \dots n \qquad (2)$$

$$X_j \geq 0, \qquad \forall\, j = 1, \dots n \qquad (3)$$

The available quantity of the resources i are restricted by b_i and a_{ij} expresses the quantity of resource i required to produce one unit of the activity j. The level of control variable j is expressed in X_j. The summation extends from lower bound *1* and to upper bound n.

In summary, the problem is to find the operating plan generating the highest possible profit (1), but does not violate the resource constraints (2) or contain any negative activity levels (3) (Hazell & Norton, 1986; Lundgren *et al.,* 2001).

3.4. Investment appraisal

In order to determine which investment that maximizes the profitability of a company, a spectra of investment options needs to evaluated (Lumby & Jones, 2003). This study uses several techniques to determine accurate cost figures: net present value, annuity, discount rate, cash flow and calculation period.

Brealey *et al.* (2014) describes *the net present value* (NPV) as the difference between costs and revenues of the projects period. Since the value of money change with time, the cash flows are recalculated in respect to inflation (Grubbström & Lundqvist, 2005). The future cash flows are often discounted to present time through a selected discount rate, in order to achieve a common monetary value. Whether the investment is profitable or not is determined by the NPV i.e. if the value is greater than zero the investment is profitable and non-profitable if it is less than zero. It is important to do accurate estimations of future cash flow since it determines the net present value (Lee *et al.,* 1999). False forecasts of future cash flows create misleading conclusions. The advantage of this method is the consideration of risk and opportunity costs along with the timing of future cash flows.

The difficulty of evaluating an investment is to predict the uncertainty of forecasts, which makes it challenging to make an accurate estimation. Inaccurate estimations of *cash flows* can be reduced by being aware of environments influence on the companies´ cash flow (Brealey *et al.,* 2014). Brealey *et al.* (2014) present four respectable rules to follow in order to estimate future cash flow; only cash flows is of importance, be consistent in the treatment of inflation, approximations of cash flow should be on gradual basis and finally separation of the investment and financing decisions. These rules prepare the decision-makers estimation of future cash flow and upcoming problems, increasing the accuracy of the appraisal (ibid). Further, it is important to account for fixed and variable costs, since these can affect the cash flow.

The *annuity* is used to distribute cash flows evenly over time (Olsson, 1998). Annuity can be seen as a fixed cash flow each year for a specific set of time (Brealey *et al.,* 2014). In order to get the yearly payment (annuity) the annuity factor needs to be calculated and multiplied with NPV. The annuity method is preferable when different investment with various depreciations is compared (Löfsten, 2000).

The *discount rate* is determined by the preferences of the company; the required rate of return of the capital invested (Persson & Nilsson, 1999). The capital of a company is frequently a limited resource in businesses and the alternative use of the capital should be reflected in the discount rate. Hence, the discount rate is the alternative cost, which indicates the rate of return of an alternative investment (Brealey *et al.,* 2014). Risk, fluctuation of prices and inflation are factors influencing the discount rate (Persson & Nilsson, 1999). The required rate of return in the agricultural sector may be affected by the size and orientation of the farm (Lagerkvist, 1999). Discount rate is used to evaluate an investment and can be expressed in nominal or real terms (Wålstedt, 1983). The real interest rate does not take into account the inflation and is common when monetary value is necessary due to the uncertainty in future price. However, the nominal rate is expressed in current values and is not adjusted for inflation. Since figures frequently are received through the accounting system, nominal terms are commonly used in costing calculations. An accurate estimated discount rate reduces the risk of incorrect assessments (Olve & Samuelson, 2008).

There are two ways to estimate the *calculation period* of an investment: the economic lifetime and technical lifetime (Persson & Nilsson, 1999). The economic lifetime ceases if the investment no longer generates a surplus and becomes too expensive; the capital asset needs to be taken out of production. The technical lifetime of an investment is based on the functionality of the asset. Olve and Samuelsson (2008) stress the difficulty to estimate the time span of the functionality since upgrades are possible in the future. The economic lifetime cannot be longer than the technical lifetime, although it is possible the other way around. The profitability of an investment is determined by the economic lifetime (Persson & Nilsson, 1999).

3.5. Summary and motivation of theories

The aim of this study is to investigate the profitability and competitiveness of farm-based grain handling facilities based on empirical data. Profit maximization determines the profitability of the investment alternatives based on fundamental assumption. The decision model advocates a normative approach, such as mathematical programming, when the purpose is to find the most efficient use of resources. This approach is advantageous when maximizing profit. This particular study uses mixed integer linear programming to optimize the operation of the fictitious farms. Microeconomic theory and investment appraisal are used to determine the economic contribution of each activity to optimization model. This is possible since the decision maker in this particular study is risk-neutral. Consideration of various risk behaviour requires different techniques and methods. Expected utility can be used in order to evaluate impacts of risky choices on a farmer's wellness (Meuwissen *et. al.,* 2001). A study accounting for risk maximizes the utility function of the decision maker (Varian, 1992). This alternative study may use quadratic programming to determine the optimal farm operation in combination of risky prospects (Hardaker *et al.,* 1997). A study considering risk uses a descriptive method and requires probabilistic values for each activity affecting the operation of the farm. Studies, in consideration of risk, that accounts for maximization of utility and not profit maximization.

Yin (2003) stresses the benefits of using mathematical programming when maximizing the profit of an operation. Lee & Olson (2006) advocate linear programming for maximizing productions with restricted resources, assuming risk-neutral behaviour. This particular study is characterized by a normative approach using mixed integer linear programming to maximize the economic result of the fictitious farms. The study considers the vast complexity of separation of qualities and crops when the programming model is developed. The complexity occurs due to the segregation, where only on crop can be stored in one bin. The study accounts for 5 crops, 11 different qualities and 59 storage bins.

4. Method

This chapter presents the unique set of choices made for this study. The chosen method is explained and motivated.

4.1. Research design

The general aim of this study is to highlight economic aspects of farm-based grain facilities by combining earlier studies and collecting empirical data. A distinction is often made within social research designs in order to approach the problem; quantitative and qualitative research strategies (Bryman 2008; Rudestam & Newton 2007). Further, one way of explain these approaches are to mention them as *fixed* (quantitative) and *flexible design* (qualitative) (Robson, 2011). Before the collection of data is started, the fixed design aims to create a detailed and formal plan. The fixed design reduces the researcher's bias that may affect the result and outcome of the study, i.e. reducing the risk of that researcher's beliefs, values and expectations affect the result (Robson, 2011). Moreover, this approach demands more preparation and understanding of the study area than the flexible design. The complexity of individual human behaviour is not accounted for in the fixed design (Robson, 2011). The aim of the flexible design is to develop a preliminary plan before the collection of data but details may change during the time of the procedure. The researcher needs to be open-minded, have high responsiveness and lack of bias in order to explain the reality, since it is a fundamental part of flexible design. Therefore, the quality of the study is determined by the skills of the researcher. It is important to point out, fixed and flexible designs are not opposites since it is rather a matter of basic attitude towards the research project (Eisenhardt, 1989; Robson 2011). Furthermore, there are synergies to achieve between these designs.

The majority of this type of particular study use flexible design. Moreover, a literature study, collection of empirical data and mathematical modelling are performed in order to answer the research questions and reach the aim. The majority of the empirical data is collected by conducting qualitative interviews with crop advisors and manufacturers of farm-based grain facilities in the geographical area of the study. Hence, the flexible design is motivated for the research. Flexible and fixed designs determine how the data is collected and not how the study processes the problem. There are two ways to approach the problem depending on how the problem proves itself: *deductive* and *inductive approach.* Inductive research is based on a single event and gathers empirical data in order to determine general conclusions, usually without connection to the theory (Eriksson & Wiedersheim-Paul, 1997). A theory is developed through observations and experiences of the researcher. Deductive research use existing theory as a theoretical framework of the study. The applied theories are used to create a new perspective, which can be compared with reality. Moreover, the deductive approach requires organized empirical data within the theoretical framework and a theoretical pre-understanding influencing the research questions (Holme & Solvang 1991; Silverman 2005).

Qualitative studies usually apply an inductive approach since a theoretical pre-understanding may disturb the analysis of the empirical data (Bryman, 2008). However, Silverman (2005) states that the base of knowledge from earlier studies prevent the disturbance of the analysis.
This particular study is based on known theories and principles; hence, the orientation of the study is deductive. Thus, the study will collect empirical data through interviews to reconnect with the theoretical framework. This study uses fictitious farms in order answer the research

questions and draw conclusions. Hence, create perspective based on the empirical data and theories compared to reality.

4.1.1. Case study

A case study is preferable strategy when examining a phenomenon within in the framework of real life, which implies involving empirical data collection and using numerous sources of evidence (Yin, 2009). Bromley (1986) stresses that case studies or situation analysis is the basis for scientific research, case studies are in general a qualitative method (Robson, 2002). There are two ways to carry out a case study: single or multiple (*ibid*). Single case studies involve one individual, a group of individuals, an institution or an innovation. Multiple case studies are mainly theoretically and analytically generalizable but not statistically generalizable. The goal of case studies is to achieve an analytic basis and not to count frequencies (Yin, 2009).

Robson (2011) stresses the importance of developing a case study, due to strengthen the involvement of the investigators. The study applies case studies as a method in order to answer questions such as *how* and *why* (Yin, 2008). Case studies provide in-depth knowledge and information of the studied problem during real conditions. The strength of the case studies is the gathering of data from several sources of evidence (Yin, 2009). Through interviews, questionnaires and observations, the data can be collected and combined to the case study (Eisenhardt, 1989). Occasionally, researchers have been criticized the credibility of case studies since bias have influenced results and discoveries (Yin, 2009). Moreover, systematic procedures are not followed which makes the case studies time consuming and requires substantial amount of documentation. However, recent research proves that case studies can fulfil its purpose anyway.

Explanatory, descriptive and exploratory are the three examples of case studies (Yin, 2009). The researcher is allowed to explain and describe the reality-based situation with a descriptive case study. In order to design a case study it requires numerous of steps where the choice of case is fundamental. Yin (2009) emphasizes the importance of defining the “unit of analysis”, the pursuit for the suitable unit of analysis starts with the research questions and the objectives of the thesis. The general aim of this study is to investigate which investment of grain handling strategies, in combination with segregation and quality of crops, which generates the highest profit.

4.1.2. Case Farms

This study uses fictitious farms with different areas of arable land in Östergötland in order to answer the research questions. Östergötland is located in the production area Götalands Northern Plains (GNS), which is presented in figure 2. This geographical area is of interest, since the focus on grain is greater compared to the very southern part of Sweden (Pers. Comm., Lovang, 2015; SCB, 2014). Additionally, this part of Sweden grows industry crops, such as green peas, to a greater extent, which does not require a farm-based grain handling facility. Furthermore, many grain traders are located in Östergötland, which enables several sale options for crops produced on the farms e.g. milling industry and animal feed industry. The fictitious farms form the basis of the optimization model, which determines the most profitable use of the limited resources. Crop producers in Östergötland have a broader range of choices regarding grain varieties, legumes and oilseeds (*ibid)*.

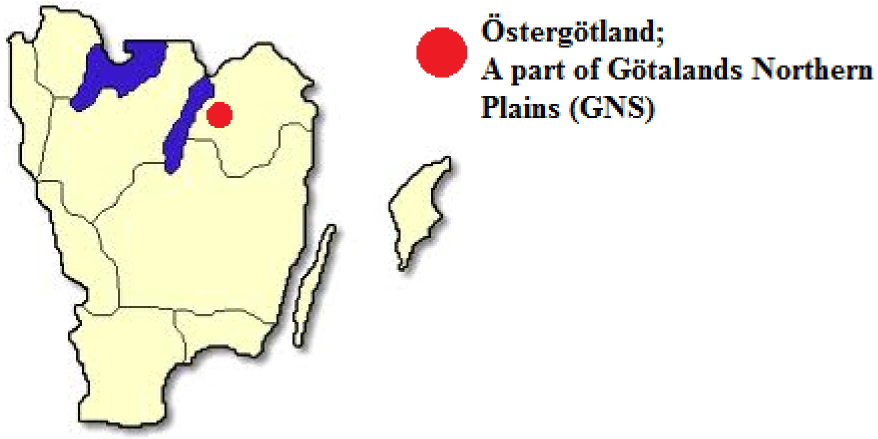


Figure 2. The figure presents a map of southern Sweden, which is the geographical location of the fictitious farms (own modification).

The fictitious farms experience the same biological conditions in terms of yields and arable crops. This study uses statistics from Agriwise for the fictitious farms in terms of direct costs and economies of scale regarding the years 2011-2013 (www, Agriwise 1, 2015). Agriwise is a program developed by SLU, agricultural consulting firms and banks in Sweden. The data has to be adjusted in order to reflect the current planning situation and the geographical conditions of the agricultural enterprises, such as yields, revenues of commodities and resource consumption. Each fictitious farm is a "pure crop producer", which excludes livestock and forestry production. However, there exists no farm-based grain handling facilities on the farms. Their options are to invest in a farm-based grain handling facility or sell to the grain trader at harvest (choosing one does not exclude the other). The study uses three fictitious farms with different areas of arable land; 200-, 500- and 800- hectares. These areas are common since a majority of grain is produced on farms larger than 100 hectares (SCB, 2014). Total tillable land in Östergötland consists to 45 percent of grain, which is higher than the average grain production in Sweden. The crop rotation for each fictitious farm is predetermined and is generalizable for crop farms in the geographical area of the study (Pers. Comm., Lovang, 2015). A seven-year crop rotation has been developed in consultation with Lovanggruppen: a consulting company for crop production in Östergötland. The crop rotation chosen for all the fictitious farms is presented in figure 3.

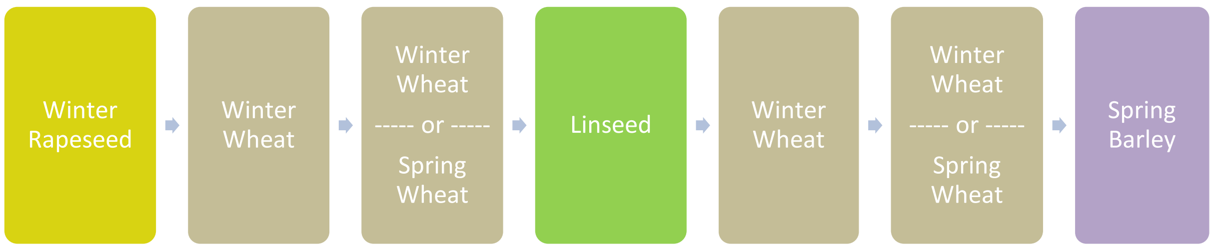


Figure 3. The predetermined crop rotation of the fictitious farms (Own modification).

There are different strategies/qualities for each crop i.e. spring barley can be sold as malting barley, feed barley or barley seed. The strategies require different inputs in advance in order to achieve the requirements of the selected outcome of the crop. Hence, the strategy is established in advance. Furthermore, some outcomes are not possible if there is no farm-based grain facility e.g. contract production of seed.

Seed production as a strategy is limited since it requires more supervision than conventional farming (Pers. Comm., Lovang, 2015). However, there are farms managing large areas of seed production because of long experience and good conditions. In consultation with Lovanggruppen, it is likely for a 200-hectare farm to manage seed production on its total area. In the case of larger units of land, it is difficult to operate the entire area as seed production. Therefore, the larger fictitious farms of 500 and 800 hectare it is possible to grow up to 50 percent of the total area as seed production.

The yields of the fictitious farms are based on average yields from Lovanggruppen's (crop advisor) internal statistics. The statistics are average yields from grain producers all over Östergötland, from both forest regions and the plains. Since the thesis has been limited to the plains, the crop yields were increased with 10 percent in order to create a more accurate result for the plains in the region. Yields are assumed not to differentiate between different qualities (Pers. Comm., Lovang, 2014). The statistics are based on 150 agricultural enterprises and most of the crop enterprises have similar crop rotations i.e. winter oilseed rape - winter wheat - winter wheat - variety crops - winter wheat - winter wheat - spring barley. Crop rotation affects crop productivity in a positive sense in terms of both crop yield and disease mitigation (Ohlander, 1996). Winter wheat is the main crop in the cropping system and its purpose is to generate money. Crop rotation is used to prevent plant pests and plant diseases, create preceding crop benefits and avoid depletion of the soil (Fogelfors, 2001). The preceding crop benefits are included in the statistics.

4.2. Gross margin

Gross margin (*GM*) calculation consists of revenues and separable costs of a production segment (Nilsson *et al.,* 1983). The calculations mainly intend to support operational planning of individual companies. Gross margin calculations is a commonly used method within agricultural firms since the production of different crops can use the same resources. The cost of these resources (common costs), e.g. maintenance costs and depreciation of machinery, are thereby difficult to allocate to a specific activity. Gross margin can be defined as the contribution of an activity and is expected to cover common costs and possibly generate a profit (Nilsson *et al.,* 1983). The *GM* is divided into different levels to create comparative measurements, depending on the share of the common costs allocated to a specific activity.

The gross margin is divided into three groups: *GM 1*, *GM 2* and *GM 3*. The revenues and specific subsidies subtracted by direct costs, such as seed fertilizer, fuel and lubricants, represents *GM 1*. This measure is less affected by the planning situation than *GM 2* and *GM 3*. *GM 2* is established by considering maintenance and interest on working capital, related to the enterprise, and subtracting them from the *GM 1*. Lastly, *GM 3* accounts for labour, depreciation and interest on invested capital related to the enterprise. *GM 3* is appropriate when allocating the highest proportion of possible costs related to branch of production. *GM 3* should cover the common costs of basic machinery, operational management etc. Buildings used by several crops are typical common costs.

The Cj-values used in the optimization model are equal to the gross margins per hectare for each farm activity *j*. The gross margin is based on calculations from Agriwise, a software program developed by SLU, agricultural consulting firms and banks in Sweden. This study uses *GM 3* in order to allocate the largest proportion of common costs. However, the study does not account for cost of land or subsidies. The gross margin are adjusted by statistical data gathered from the empirical collection i.e. grain prices, yields, interest rate and specific data for seed production. See appendix 1 for an overview of the enterprise budgeting concerning the gross margin for each crop. Appendix 2 illustrates the actual gross margin for each crop and quality used in this study. GM 3 is appropriate to use as a comparison between storing grain and selling directly at harvest since the discount rate affects the capital cost of storing.

4.3. Interviews

Interviews are a common method used for research and can be conducted in three ways; structured, semi-structured and unstructured (Robson, 2011). Studies characterized by a qualitative approach and case studies are commonly associated with interviews (Denscombe, 2000). Interviews do not require advanced equipment, however ethical and practical considerations are necessary to take into account. The choice of interview method is important since it should be compatible to the design of the project (Robson, 2011; Yin, 2009). This study is based on a flexible research design and uses semi-structured interviews when questioning crop advisors and the supplier of farm-based grain facilities. Flexible research design generally uses semi-structured interviews (Robson, 2011). This interview method is characterized through the predetermined questions where the interviewer allows modifying the order of the questions. This method brings flexibility to modify the questions according to the interviewer's interpretation of what is appropriate and gives the opportunity to ask follow-up questions.

Face-to-face interviews are a flexible way to explore phenomena (Robson, 2011). By collecting empirical data through face-to-face interviews, it is possible to receive underlying meanings and follow up on interesting replies. Non-verbal messages i.e. facial expressions and tone of voice offers the opportunity to understand verbal messages. However, it is important to be aware of the researcher's biases. Face-to-face interviews are a time-consuming approach comparison with other techniques. A considerable amount of preparations is necessary in advance. By avoiding jargon-based, biased and leading questions, the validity and reliability of the study increases.

The primary purpose of the interviews, performed in this study, is to collect empirical and technical data to complete the calculations. Secondary, the interviews intend to validate assumptions from earlier studies. Furthermore, the practical application and quality of the results might increase since the link between theory and reality is strengthening.

4.4. Applied mixed integer linear programming

This section includes a detailed description of the optimization model used in this study. The model is a generalisation and a development of the description in section 3.2. (Mixed integer linear programming).

4.4.1. Objective functions

This study uses mathematical programming as a main method; solving a problem through maximizing an objective function. Control variables or coefficients within the objective function are maximized or minimized in order to find the most optimal solution

(Boehlje *et al.,* 1984; Lundgren *et al.,* 2008). The objective function in farm models focus on the optimal strategy of the farm production (Glen, 1987). Furthermore, the objective function can be a result of an attempt to express a business objective in mathematical terms for use in a decision analysis (Lundgren *et al.,* 2008). This problem consists of 734 Xj-values and requires a complex-solving program. Due to the size of the optimization model, it is not possible to present the model in the appendix. Equation (4) expresses the objective function for the optimization of this study.

$$\boldsymbol{\pi} = \sum_{j=1}^{J}\sum_{q=1}^{Q} G_{jq} * AX_{jq} + \sum_{j=1}^{J}\sum_{q=1}^{Q} G_{jq} * AZ_{jq} - \sum_{d=1}^{D} FC_d * IF_d - \sum_{d=1}^{D}\sum_{j=1}^{J}\sum_{q=1}^{Q} VC_d * VZU_{jqd}$$

$$-\sum_{j=1}^{J}\sum_{q=1}^{Q} VCT * VXU_{jq} - \sum_{s=1}^{S} Islab_s * FCslab_s$$

$$IF_d = \{0,1\} \mid Islab_s = \{0,1\}$$

$$\begin{aligned} j &= \{1,\ldots\ldots..J\} \\ q &= \{1,\ldots\ldots..Q\} \\ d &= \{1,\ldots\ldots..D\} \\ s &= \{1,\ldots\ldots..S\} \end{aligned} \qquad (4)$$

Π =	Objective function defining profits of the farm.
G_{jq} =	Gross margin of crop *j* with quality *q*.
AX_{jq} =	Total hectares for crop *j* delivered to the grain trader at harvest with quality *q*.
AZ_{jq} =	Total hectares for crop *j* stored at the farm with quality *q*.
FC_d =	The fixed annual cost of farm-based grain handling facility *d*.
IF_d =	Binary value for a farm-based grain handling facility *d*.
VC_d =	Variable cost of dryer *d*.
VZU_{jqd} =	Total volume of crop *j* with quality *q* dried and stored at the farm-based grain handling facility.
VCT =	Variable cost per deciton for the drying contract with the grain trader at harvest.
VXU_{jq} =	Total volume of crop *j* with quality *q* delivered without drying to the grain trader at harvest.
$Islab_s$ =	Binary value for concrete slab *s* in order to deliver to the grain trader.
FCslab =	The fixed annual cost of the concrete slab *s*.

4.4.2. Restrictions

This section presents the restrictions of the optimization model, which must be taken into account when designing the model. The constraints are based upon the literature review and empirical background. These constraints affect the use of resources in order to attain a simplified interpretation of reality. In order to achieve the optimal solution of the farm all constraints need to be satisfied. The optimization model in this study is based on 86 restrictions and can be divided into four subgroups: land, crop rotation, farm-based grain handling facility and the grain trader. Figure 4 is a schematic presentation of the restrictions in the optimization model. The figure demonstrates the subgroups and the structure of the restrictions. Moreover, figure 4 shows the complexity and consideration of segregation and capacity of crops in each silo. The subgroups are explained below.

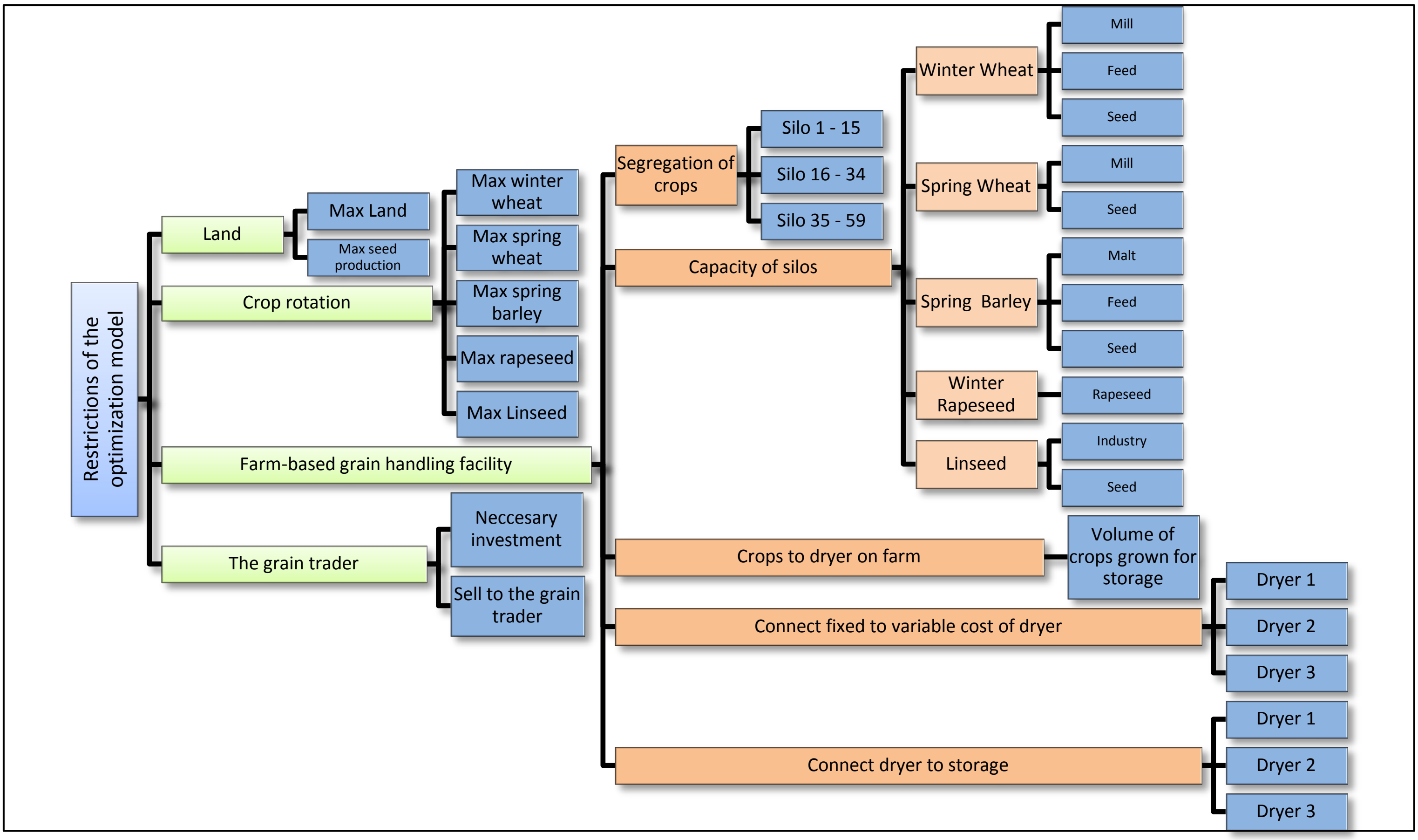


Figure 4. Schematic presentation of the restrictions in the optimization model (Own modification)

4.4.2.1. LAND

The arable land consists of the crops grown on the fictitious farms. The land can be used to grow winter wheat, spring wheat, spring barley, winter rapeseed and linseed. Each crop can be sold to the grain trader at harvest or stored on the farm. Nevertheless, each crop uses the land available for crop production. Equation (5) presents the acreage of crops allowed on the fictitious farms. The sum of hectares grown on the farm cannot exceed the total arable land for the farm. The total arable land differs between the farms: 200 hectares, 500 hectares and 800 hectares.

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} \boldsymbol{AX_{jq}} + \sum_{j=1}^{J}\sum_{q=1}^{Q} \boldsymbol{AZ_{jq}} \leq \boldsymbol{A_{tot}} \qquad (5)$$

A_{tot} = Total arable land of the farm.

4.4.2.2. CROP ROTATION

Restrictions concerning crop rotations are presented in equation (6) and determine the crop rotation of the fictitious farms; a seven-year crop rotation. The constraints cover both crops grown for sale to the grain trader at harvest and for storage on farm. Equation (6) presents the maximum share (α) of total land for crop *j* acceptable on the farm in order to satisfy the crop rotation. The restrictions for each crop in this study are presented in table 2.

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} AX_{jq} + \sum_{j=1}^{J}\sum_{q=1}^{Q} A\boldsymbol{Z}_{jq} \leq A_{tot} * \alpha_{jq} \qquad (6)$$

α_{jq} = The maximum share of the total land to be grown by crop *j* with quality *q*.

Table 2. Maximum share for each crop allowed in order to satisfy the crop rotation.

Crops	**Max share of total land (α)**
Winter wheat	4/7
Spring wheat	2/7
Spring barley	1/7
Winter rapeseed	1/7
Linseed	1/7
Seed production	100% on 200 hectare| 50% on ≥500 hectare

4.4.2.3. FARM-BASED GRAIN HANDLING FACILITY

There are several restrictions concerning the farm-based grain handling facility in the optimization model. This section contains several parts that affect the profitability of farm-based grain handling facilities. The following parts in this section are presented: segregation, capacity of silos, crops to dryer on farm and connects fixed and variable cost of dryer. Equation (7) concerns segregation of crops for storage on the farm. Each silo can only store one type of crop with a specific quality. E.g., there are three type of qualities of winter wheat: milling wheat, feed wheat and wheat for seed. Only one of these qualities can be stored in one silo.

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} S\boldsymbol{Z}_{jq} \leq \sum_{b=1}^{B} Ibin_b \qquad SZ = \{0,1\} \mid Ibin = \{0,1\} \qquad (7)$$

b = {1,……..B}

SZ_{jq} = Binary value for segregation of crop *j* stored at the farm with quality *q*.
$Ibin_b$ = Binary value for storing in silo *b*.

Equation (8) concerns available storage capacity for each crop. In order to determine the storage capacity of each silo, the volume of each silo has to be taken into account. Since each crop has different bulk densities and yields, they require various amount of storage per hectare. The crops grown for storage on farm are not allowed to exceed the capacity for storage.

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} AZ_{jq} * KZD_{jq} \leq \sum_{b=1}^{B} Ibin_b * V_b \qquad Ibin = \{0,1\} \qquad (8)$$

b = {1,……..B}

KZD_{jq} = Cubic content per hectare of crop *j* with quality *q* that are dried and stored at the farm.
$Ibin_b$ = Binary value for storing in silo *b*.
V_b = Storage capacity of silo *b*.

Equation (9) quantifies the volume dried in the farm-based grain dryer and later stored. The equation connects the crop grown for storage on farm to the various investment alternatives of dryers.

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} AZ_{jq} * KZU_{jq} = \sum_{d=1}^{D} VZU_{jqd} \tag{9}$$

KZU_{jq} = Cubic content per hectare of crop *j* with quality *q* that is dried and stored at the farm.

Equation (10) connects variable costs and fixed costs of each investment alternative for dryers. In order to dry the crop grown for storage on farm an investment is mandatory, which represents the fixed annual costs. The investment is required in order to dry the grain at the farm.

$$\sum_{d=1}^{D} VC_d * L_d \leq \sum_{d=1}^{D} IF_d \tag{10}$$

$$IF_d = \{0,1\}$$

L_D = Drying capacity of dryer *d*.

4.4.2.4. THE GRAIN TRADER

The opposite investment alternative to farm-based grain handling facility is to deliver to a grain trader at harvest. There are a few constraints regarding crop grown for delivering to the grain trader at harvest: the timeliness effect and the cost of drying. The volume of crops delivered directly at harvest to the grain trader is presented in equation (11).

$$\sum_{j=1}^{J}\sum_{q=1}^{Q} AX_{jq} * YXU_{jq} = VXU_{jq} \tag{11}$$

YXU_{jq} = Total deciton of crop *j* delivered undried to the grain trader at harvest with quality *q*.

Equation (12) exists in order to equalize the timeliness effects between farm-based grain handling facility and the grain trader. In order to achieve time efficiency with direct delivery to the grain trader; an investment in a slab is necessary and functions as buffer storage of harvested crops. The investment is required in order to sell to the grain trader at harvest.

$$VXU_{jq} * LT \leq \sum_{s=1}^{S} Islab_s \qquad Islab_s = \{0,1\} \tag{12}$$

LT = Drying capacity of the grain trader.

Islab = Binary value for a necessary investment in order to deliver to the grain trader at harvest.
Equation (13) expresses the number of silos available for storage when investing in dryer *d*. This equation is of importance since the number of bins and storage capacity differs between the facilities. The small-sized grain handling facility has 15 bins, the medium-sized has 19 bins and the large-sized facility has 25 bins. An example: if the optimization model chooses to invest in the medium-sized facility, 19 bins become available to store different grain qualities.

$$\sum_{b=1}^{B} Ibin_b = \sum_{d=1}^{D} IF_d * Totbin_d \tag{13}$$

$Totbin_d$ = Total number of silos b included in investment d.

4.5. Validity and reliability

If the purpose of a study is to provide support to the real world, it is important to strive towards the essence of validity (Pidd, 2009). Conclusions drawn from models, concerning "true" or "wrong", might influence people in the wrong way when making decisions. Hence, it is important for the authors of models to aim for validation. Pidd (2009) stresses the difficulty of complete validity since it might not be reachable. Validity can be explained as the conformity between what we are assumed to examine and what we really examine (Patel & Davidsson, 1991). Reliability is defined as the precision of the tool used and how it resists against random influences. The correlation between validity and reliability can be expressed as (*ibid*):

- Complete reliability is a condition for complete validity
- Low reliability creates low validity
- High reliability is no guarantee of high validity

It is important to consider several aspects when assessing an investment project due to the complexity and number of parameters (Persson & Nilsson, 1999). This study examines profitability and competitiveness of farm-based grain handling facilities including separation of crop qualities. This study does not account for variation in future market of commodities, the risk exposure and corporate social responsibility. Hence, the study makes assumptions based on theories, available empirical data and previous research.

The applied optimization model developed in this study is designed to increase the reliability and provide the same result regardless of the performer. Hence, there is a precision of the tool used. However, the model is influenced by restrictions shaped by the empirical data and the authors. The level of the initial investments of the farm-based grain handling facilities is consolidated with Tornum and studies from the Swedish institute of Agricultural and Environmental Engineering in order to obtain reliable results. The result of this study is based on the author's collection of empirical data. The data is validated by comparing results to earlier studies and interviewing knowledgeable people within the sector. The validation is important to establish operational measures for studied area. The results that emerge from this study are non-generalizable for any crop producer; it provides an indication of feasible decision-making. The lacking of generalizability may occur from homogenous conditions of the farms. In reality, farms are heterogeneous regarding the preconditions.

4.6. Ethical considerations

It is of importance to recognize and take into account ethical considerations when conducting a research project (Robson, 2011; Bryman 2011). Ethical aspects should early be considered and permeate the research project (Kvale & Brinkmann, 2009). The researcher should be proactive and prevent negative consequences causing harm or seen as offensive (Oliver, 2010). The participants may be concerned if the released information does not match with the reality. It is of importance to inform the interviewees concerning the project's aim, no intruding on participators privacy and no kind of deception towards participants or readers (Bryman, 2011).

Most of the information from this study is based on earlier publications and statistics. However, some data collection is conducted through interviews with people with expertise within the subject. All participants were informed about the study's aim and how their involvement can help to develop the study and its results. All participants were offered anonymity and given the opportunity to read and validate the recorded information to avoid misunderstandings and conflicts.

4.7. Summary of the method

The method presented in chapter 4 is used to answer the research questions of this particular study. There are several parts of the method contributing to the results of the study. The research design explains the strategy of the study. The study uses both qualitative and quantitative strategies through different aspects. The interviews and empirical collection are qualitative approaches used to investigate prevailing conditions for the case farms. However, the optimization is strictly a quantitative strategy to establish results. The objective function in the optimization model is partly based on the gross margins of different quality crops. The study uses a deductive approach since it does not operate outside the theoretical framework.

All parts mentioned above contribute to the empirical findings of the study. The empirical findings and analytical discussion provides a basis for conclusions. It is important to strive towards validity and reliability when drawing conclusions. Ethical consideration is necessary to prevent negative consequences when including expertise within the subject.

5. Background to the empirical study

This chapter presents information concerning the empirical background of the study. The purpose of this chapter is to provide an understanding about the study's research area and its problem. The sections presented in this chapter are fundamental parts of the study and the optimization model, which are summarized in the last section.

5.1. Farm-based grain handling facilities

Farm-based grain handling facilities consists of a dryer and storing bins or silos on a farm. Most of the present dryers on the Swedish market have been similar for more than 30-40 years (Jonsson, 2006). Drying is a critical step in the grain production in order to assure the quality of the grain (Naewbanij & Thepent, 1989). Drying provides optimal moisture content of grain for further processing and allows storage by avoiding mould growth. The drying process removes moisture from the grain, often through heated air penetrating the grain. There are different types of conventional dryers: batch and continuous dryers. Batch drying systems dries a certain volume of grain at a time to achieve specific moisture content. The batch is then cooled after drying in order to be stored. Continuous drying implies a continuous flow of grain to be dried without stopping. This system requires several buffer bins, both for continuously filling and holding the discharged grain.

This study investigates three types of farm-based grain handling facilities, presented in table 3. The capacity and initial investment cost originates from Weslin *et al.* (2006) in consultation with Tornum (Pers. Comm., Larsson, 2015). Tornum is a market leading supplier of grain handling facilities for agricultural and grain industries (www, Tornum 1, 2015). This study categorizes the different types of farm-based grain handling facilities as small-, medium- and large-sized, see appendix 3, 4 and 5. The alternatives are not fully adapted to the fictitious farms. The initial investments are based on Westlin *et al.* (2006) and adjusted upwards by indexes for buildings, see appendix 6. The investment alternatives from Tornum are complete buildings with dryer and several storage bins.

Table 3. Overview of the initial investment and storage capacity for different types of farm-based grain handling facilities investigated in this study.

Type of dryer	**Storage capacity**		**Number of storage bins**	**Initial investment**		
	m^3	**Ton wheat**		**SEK**	**SEK/kg wheat***	**SEK/m^3**
2*35,8 m^3 Double batch (Small-size)	2 260	1 740	15	6 049 678	3,5	2 677
31,5 m^3 Continuous drying (Medium-size)	3 630	2 795	19	7 559 529	2,7	2 083
50,4 m^3 Continuous drying (Large size)	7 350	5 660	25	12 048 000	2,1	1 639

**Based on: Bulk density Wheat 770 g/m^3*

Fundamental assumptions regarding cost of oil, electricity, labour and interest are made in order to achieve a generalizable result. These assumptions are based on historical view of each component. The electricity price used in this study is based on historical electricity prices for industries from 2007 to 2014 (www, SCB, 2015). The average price is then adjusted for tax refunds made in accordance with the Swedish tax agency. The tax refund consists of the tax on electricity minus 0,05 SEK/kWh (www, Swedish Tax Agency 1, 2015). The tax on electricity during 2015 is 0,294 SEK/kWh (www, Vattenfall, 2015) and the average price of electricity is 0,79 SEK/kWh, see appendix 7. These conditions provide an electricity price of 0,55 SEK/kWh.

The Swedish Petroleum & Biofuels Institute is the primary source of the fuel oil price, which is based on average prices from 2006 to 2013, see appendix 8. The price of fuel oil in this study is 7.15 SEK / liter after the restitution (www, Swedish Tax Agency 2, 2015: www, SPBI 1 & 2, 2015). The cost of labour is based on the hourly rate (including normal overtime), which amounts to 209.65 SEK / hour (www, Agriwise 2, 2015).

Lagerkvist (1999) calculates the user cost of capital in Danish and Swedish agriculture, a real discount rate of 5-7% was detected in the study during 1986 to 1995. However, this study takes into account the current policy rate and use a real interest rate of 5.2%, which is calculated based upon the fixed lending rate on 5 years added by 3 percentage points (Pers. Comm., Andersson, 2015). Wålstedt (1983) advocates the use of real interest rate due to the uncertainty of future markets. Hence, this study uses real interest rate since it is hard to estimate future price fluctuations on grain and inputs regarding agricultural enterprises. According to the long-term investigation by Sweden´s financial supervisory authority, the real interest rate in long-term is 5,2 percent for the energy market (Bergman, 2014). Several of the inputs in this market are similar to the agricultural enterprise. By using a real interest rate of 5,2 percent several aspects are accounted for; earlier studies, lending perspective and official services investigations.

This study uses calculation models from Westlin *et al*. (2006) in order to estimate the capital cost and volume cost for each type of dryer and storage, see table 4. The table displays assumptions made for calculating the capital cost and the variable cost of each farm-based grain handling facility. Consumption of oil and electricity, economic lifetime, maintenance cost and labour time originates from Westlin *et al.* (2006).

Table 4. Overview of assumption for calculating the capital and variable cost of farm-based grain handling facilities (Westlin et al., 2006)

Factor	Value	Unit
Interest	5,2	%
Labour cost	209,65	SEK/h
Economic lifetime Furnace	10	Years
Economic lifetime Building	25	Years
Economic lifetime Storage & Dryer	20	Years
Fuel oil price	7,15	SEK/liter
Maintenance cost	0,3	% of initial investment
Labour time	0,5	Min/dt
Electricity price	0,55	SEK/kWh
Fuel oil consumption	0,15	Liter oil per kilo water removed
Electricity consumption	1	kWh/dt

The annual costs of the farm-based grain handling facilities are presented in table 5. The assumptions in table 4 are used to calculate the net present value of each component (furnace, building, storage and dryer). The maintenance cost is viewed as a negative cash flow and is discounted to present value using the discount rate. The annuity factor calculates the annual cost including maintenance for the farm-based grain handling facilities and thereby the annual capital cost is determined.

Table 5. A presentation of the capital cost, variable cost and total cost of the farm-based grain handling facilities investigated in this study.

	Small-sized	**Medium-sized**	**Large-sized**
Annual capital cost (SEK)	528 190	641 986	1 025 287
Variable cost (SEK/m^3)	77,39	77,39	77,39
Total cost (SEK/m^3)	311,1	254,2	216,9
Total cost (SEK/kg wheat)	0,40 [1.]	0,33 [1.]	0,28 [1.]
Annual capital cost (SEK/ha)	2 641[2.]	1 284 [3.]	1 281 [4.]

1. *The total cost divided by total capacity of wheat with bulk density 770 g/m^3.*
2. *The annual cost is divided by 200-hectare.*
3. *The annual cost is divided by 500-hectare.*
4. *The annual cost is divided by 800-hectare.*

5.2. Drying Contract

The drying contract in this study symbolizes delivering to the grain trader at harvest. The drying contract is an agreement signed between a grain producer and a grain trading enterprise (www, Lantmännen 2, 2015). The contract is intended to hedge possible drying costs prior to harvesting and consists of a fixed cost for all upcoming deliveries of grain. The agreement implies a fixed cost of 95 SEK / ton for moisture content up to 24.0 %. The drying contract is not valid for deliveries with a moisture content of 24.1% and higher. Then drying costs will increase. The drying agreement covers the producer's spontaneous deliveries and contracts for grain and oilseeds (not corn, grain legumes and seeds) during the harvest period 1:th of July until 14:th of October. The drying contract is not valid for starch wheat and oilseeds refined for human consumption with required moisture content of 9 % *(ibid)*. The drying contract is suitable for producers without a farm-based grain facility or as a supplement to the own drying capacity on farm. The disadvantage of a drying contract is the limited choice of crops and the restricted time of sale. Furthermore, the drying contract becomes more attractive at high moisture contents (up to 24.0%).

5.3. Concrete slab

In order to equalize the timeliness effects, between investing in a farm-based grain handling facility and delivery to the grain trader, an investment is necessary for the delivery option. There are economic values with farm-based grain handling facilities that are difficult to predict in form of better logistics at harvest. These values are mentioned as timelines effects

(Gunnarsson *et al.,* 2012). To achieve comparable conditions, where timelines effects are accounted for, an investment is necessary when delivering to the grain trader at harvest. Delivering to the grain trader requires an investment in a concrete slab, which is assumed to make the alternatives comparable in terms of timeliness costs. These conditions provide an equal timeliness effect for all the investment alternatives.

The concrete slab is defined as buffer storage for those farms choosing to deliver their grain to the grain trader at harvest. In this study, the concrete slab consists of moulded concrete with reinforcement and supporting walls. The size of the concrete slab is based on two-day harvest regarding each fictitious farm, as shown in table 6. In order to handle the grain in the concrete slab, a variable cost of rental a loading machine is required. The economic lifetime is assumed to be 25 years (Pers. Comm., Johansson, 2015). Table 6 illustrates the size and cost of each concrete slab, customized for each farm (*ibid*). The variable cost is based on grain trader's recommendations and empirical data (www, Lantmännen 3, 2006; www, Agriwise 1, 2014).

Table 6. The size and cost of the concrete slab for each fictitious farm used in this study.

Farm-size	Width	Length	Height	Volume	Initial investment	Volume	Annual cost	Variable cost
(ha)	(m)	(m)	(m)	(m^3)	(SEK)	(SEK/m^3)	(SEK)	(SEK/kg)
200	12	16	1,5	285	228 000	792	16 503	0,008
500	14	22	1,5	428	328 000	710	23 741	0,008
800	16	22	1,5	500	356 000	674	25 768	0,008

5.4. Grain prices

This study uses prices of oilseeds and cereals (in this study referred as grain) from 2009 to 2013 in order to evaluate farm-based grain handling facilities. The grain prices are gathered through Lantmännen, a cooperative owned by farm members. Lantmännen offers several types of contract for marketing grain; pool, depot, spot and forward or spontaneous delivery (www, Lantmännen 4, 2015; Pers. Comm., Wildt-Persson, 2015). However, this study focuses on the pool contract, which implies Lantmännen markets the grain for the farmer of a contracted volume of grain. Trades of physical and financial commodities conducted by Lantmännen during different periods determine the pool price *(ibid)*. There are two types of pool contracts: pool 1 and pool 2. Farmers who want to deliver their grain at harvest signs pool 1- contracts, where the price is determined by Lantmännen's trades during the 1:th of July to 14:th of October. Those farmers who want to store their grain on the farm use pool 2-contracts. The grain price of pool 2 is determined by the trades made by Lantmännen during 15:th of October to 31:th of March.

This study uses the pool 1-contract as the price of grain for direct delivery at harvest and pool 2-contracts as the price of grain stored and dried at the farm, see appendix 9. In summary, an investment in farm-based grain handling facility is compulsory in order to obtain pool 2-prices. The grain prices used in this study is presented in table 7.

Table 7. The table presents the average prices of pool 1 and 2 from 2009-2013 (except linseed, no prices from 2012)

Crops: (SEK/ton)	**Winter Wheat**		**Spring Wheat**	**Spring Barley**		**Winter rapeseed**	**Linseed**
Quality:	**Feed**	**Mill**	**Mill**	**Feed**	**Malt**	**-**	**Industry**
Pool 1:	1520	1574	1636	1374	1484	3370	3813
Pool 2:	1690	1728	1754	1448	1588	3674	3945
Difference:	170	154	118	74	104	304	132,5

5.5. Seed production

Contract farming, in the form of seed production, is a type of cultivation practice that requires well-managed land (Pers. Comm., Gillsjö, 2015). Since the crop is grown as seed for future harvest, it is important to maintain good quality. Several grain traders offers seed production contract to farmers. This study focuses on seed production for Lantmännen. Storing and drying on farm is compulsory in order to manage seed production. An investment in a farm-based grain handling facility is required in order for seed production to be possible on a farm. The grain price of seed production is usually based on pool 2-prices of the crop grown. Furthermore, an additional premium and compensation for storing and drying of the grain is added to the pool 2-price for the crop grown *(ibid)*. Table 8 illustrates the increasing costs and revenues when growing seed. The additional value for seed production has been similar for five years (*ibid*). The additional cost of seed production includes increased cost of seed for planting, drying and storing. The seed production in Östergötland amount to 10 027 hectare in 2014, which is 5 percent of the tillable land (www, SJV 3, 2015; www, SJV 4, 2015).

Table 8. The table presents an overview of the increase of revenues from seed production and the increasing cost of seed for sowing (SEK/Ton).

Crop (SEK/ton)	**Additional premium**	**Compensation for drying and storing**	**Increasing cost of seed for sowing**
Winter wheat mill	160	25	-500
Spring wheat mill	220	25	-500
Spring barley malt	220	25	-500
Linseed industry	550	25	-500

5.6. Summary of the empirical background

The empirical background this study explains assumptions regarding the preconditions for the fictitious farms. There are three different sizes of farm-based grain handling facilities used in this study, as shown in table 3. Through an investment in a farm-based grain handling facility, storing grain becomes possible and a higher price is achieved. If the fictitious farm excludes an investment in a farm-based grain handling facility, they have to use the drying contract of the grain trader. This implies a lower investment cost, such as a concrete slab for buffer storage, and a lower price of the grain produced. Table 7 presents different prices of grain when using the drying contract (pool 1) and storing grain by investing in a farm-based grain handling facility (pool 2). Seed production provides additional premium to the pool 2-prices and is only possibly when investing in a farm-based grain handling facility.

Irrespective of the marketing strategy, an investment is required to generate profit. This study choose to look at the drying contract with grain trader as an investment, due to the required investment in a concrete slab for buffer storage when selling to the grain trader at harvest. In summary, there are four investment alternatives; Drying contract + concrete slab (Grain trader), small-, medium- and large-sized farm-based grain handling facility. It is possible for the most profitable strategy for the farm to include more than one investment. The assumptions presented in the empirical background and in figure 4, are all integrated in the applied optimization model.

6. Results

This chapter presents the empirical result from the applied mixed integer linear optimization model of this study. The chapter contains three sections, one for each fictitious farm. The sections present the highest profit and distribution of crops for each investment alternatives. The results emerged from this study is illustrated per hectare in order to make the interpretation easier. By presenting the results per hectare, it is easier to compare to earlier studies by Westlin *et al.* (2006), Westman (2006) and Ugander *et al.* (2012).

6.1. Profitability of investment alternatives

This section illustrates the profitability of each investment alternative and the most profitable strategy for the fictitious farms. The profit and optimal use of land are presented for each investment alternative on the fictitious farms. The distributions of crops are presented in table 9, 10 and 11 in the end of this section as a landscape orientation. The results are based on profit maximization, which explains the absence of negative numbers. If an investment option is too expensive and evokes a negative result, no land will be grown since zero profit is better than a negative result. The use of land is permeated by the crops with the highest gross margin with respect to optimal use of land and storage. As mentioned earlier in this study, there are four investment alternatives: using the drying contract with the grain trader (mentioned as trader in charts), small-sized, medium-sized and large-sized farm-based grain handling facility.

The grain handling strategy affects the optimal distribution of crops. The optimal solution of the farm consists of the optimal distribution of crops and investment alternative. Milling wheat, malt barley, winter rapeseed and industry linseed represents the most profitable quality crops, concerning the crop rotation, when selling to the grain trader at harvest. An investment in a farm-based grain handling facility changes the distribution of crops and quality. The distribution consists of crops grown as seed production, a quality generating a higher value through additional compensation for drying and storing. However, seed production entails greater risk exposure compared to other qualities of grain (Pers. Comm., Wildt-Persson, 2015). The applied optimization model assumes that the decision maker is risk-neutral, which implies choosing the activities (quality of crops) generating the highest profit.

6.1.1. Result of the optimization on 200-hectare

Chart 2 illustrates the profit of each investment alternative for the 200-hectare farm. Delivering directly to the grain trader at harvest generates the highest profit of 3 100 SEK/hectare. Investing in a farm-based grain handling facility is not economically optimal given the prevailing conditions on the 200-hectare farm. Although the grain trader provides the optimal strategy for the farm, the small- and medium-sized grain handling facility still generates a profit. Investing in a small or medium sized farm-based grain handling facility is economically feasible. However, investing in the large-sized dryer generates a negative result, which excludes cultivation of land.

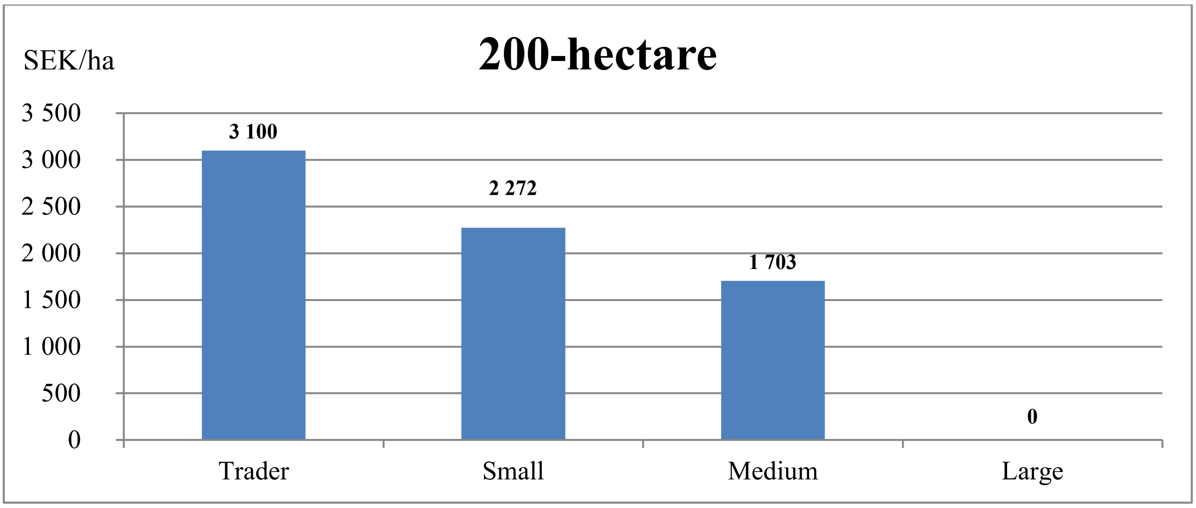


Chart 2. The optimal profit per hectare of each investment alternative on the 200-hectare farm.

Table 9 demonstrates the crop rotation for each investment alternative when maximizing the profit on the 200-hectare farm. The highest profitability is obtained when growing winter wheat, spring barley, winter rapeseed and linseed for the grain trader at harvest. Since selling to the grain trader excludes seed production, the optimal use of land consists of milling wheat, malt barley, winter rapeseed and industry linseed, as shown in table 9. Seed production provides the most profitable crop rotation when investing in a small or medium-sized farm-based grain handling facility. In the case of investing in the large-sized facility cultivation of land is terminated since the investment generates a loss.

6.1.2. Result of the optimization on 500-hectare

The profitability of each investment alternative is illustrated in chart 3 regarding the 500-hectare farm. The optimal strategy for the farm generates 3 576 SEK/hectare and is a combination of investing in a medium-sized grain handling facility and selling grain to the grain trader at harvest. Chart 3 illustrates a small difference between selling to the grain trader at harvest and investing in a medium-sized grain handling facility, with a slight edge to the grain trader. The medium-sized grain handling facility generates a marginally lower profit of 3 474 SEK/hectare. The small- and large-sized grain handling facility indicates a positive result and all investments are economically feasible.

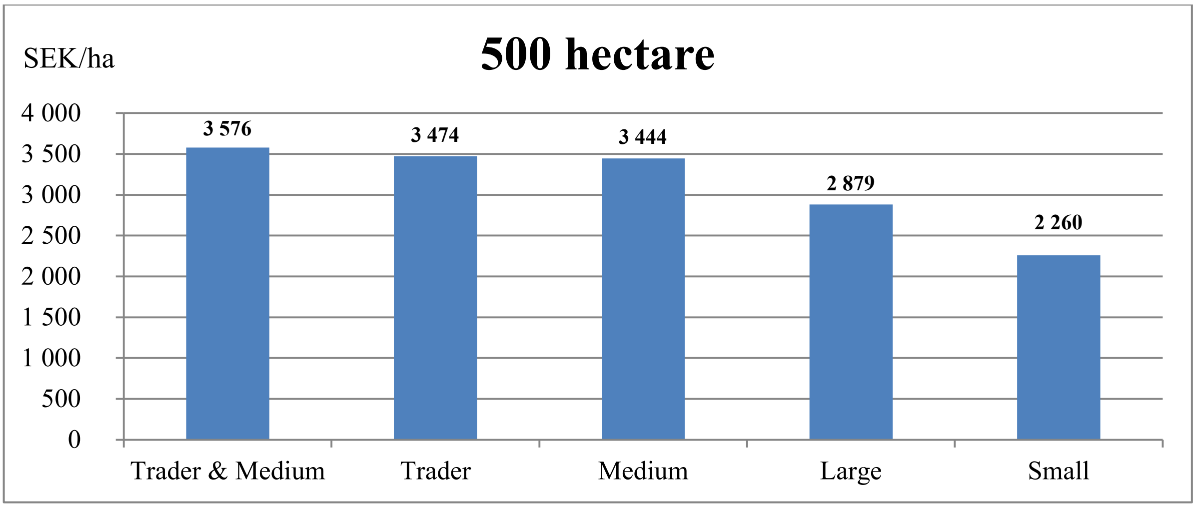


Chart 3. Optimal profit per hectare of each investment alternative on the 500-hectare farm.

In order to achieve maximum profitability on the 500-hectare farm, the grain is sold to the grain trader at harvest in combination with the medium-sized facility. Table 10 shows the optimal distribution of crops in this scenario. The highest profitability is obtained when maximizing the allowable area of winter wheat seed production. Remaining tillable land is determined by the crop rotation and consists of winter wheat mill, malting barley, rapeseed and linseed. Selling the grain exclusively to the grain trader at harvest is the second most profitable alternative. Solely investing in the medium-sized facility is the third most profitable solution and but this strategy is not using all available land, only 464 hectares is cultivated since the storage capacity is full. All the three alternatives of farm-based grain handling facilities maximize the volume of seed production. The large sized facility maximizes the availability of tillable land, but still contributes with a lower profit. The small facility uses its storage capacity to its maximum, which is not enough to store the yields from all available land. This investment alternative generates the lowest profit.

6.1.3. Result of the optimization on 800-hectare

The model reveals the highest profit when combining the grain trader and the medium-sized grain handling facility, as shown in chart 4. The combination generates a profit of 3 798 SEK/hectare and is the most profitable strategy for the 800-hectare farm. Investing in the large-sized grain handling facility provides the second most profitable solution for the farm. However, a small difference in profit is observed between the large-sized facility and the grain trader. All investment alternatives indicate a profit and are economically feasible.

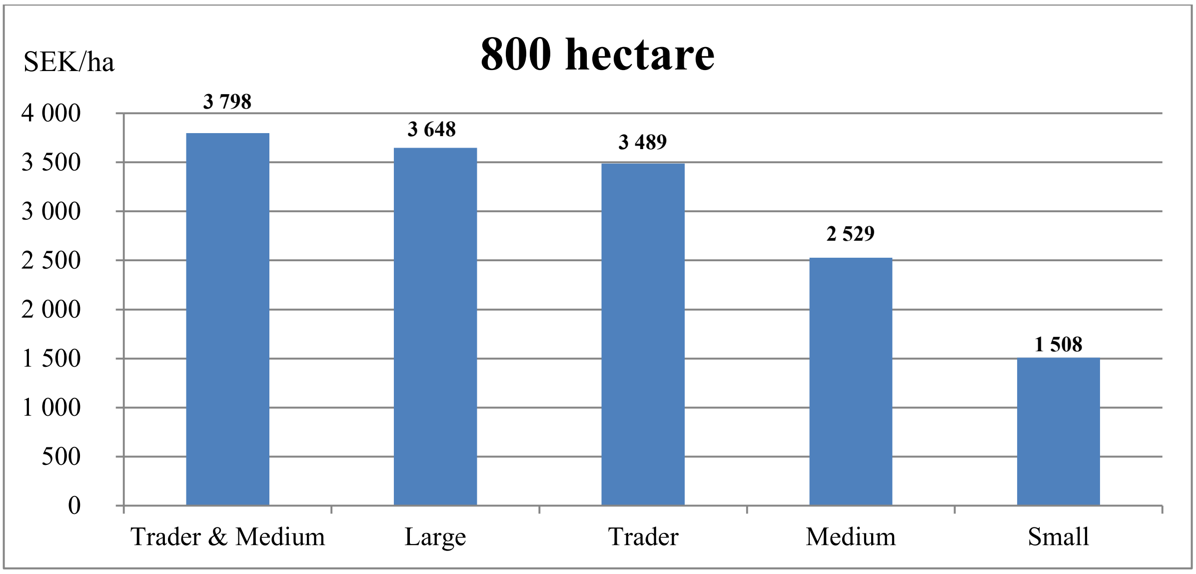


Chart 4. Optimal profit per hectare of each investment alternative on the 800-hectare farm.

Since the highest profit is generated by combining the medium-sized grain handling facility and selling grain to the grain trader during harvest, all tillable land is used. This combination enables seed production and optimal use of storage available on the medium-sized facility, see table 11. Crops stored at the farm consist of winter rapeseed and seed production of winter wheat and linseed. Since seed production is not permitted when delivering to the grain trader, the remaining land is grown by milling wheat, malting barley and industry linseed. The distributions of crops are similar for the second most profitable investment, the large-sized farm-based grain handling facility. However, seed production focuses on winter wheat. Remaining crops are malting spring barley, winter rapeseed and industry linseed. Given the third most profitable alternative, the grain trader, a smaller number of crops are grown consisting of milling wheat, malt spring barley, winter rapeseed and industry linseed. The alternative with the lowest profit, i.e. the medium- and small-sized grain handling facility, use its storage capacity to its maximum, which is not enough to store the yields from all available land.

Table 9. An illustration of the investment alternatives and their optimal crop rotation when maximizing profit for the 200-hectare farm.

Crop:	**Winter Wheat**			**Spring Wheat**		**Spring Barley**			**Winter Rapeseed**	**Linseed**		
Investment	Mill	Feed	Seed	Mill	Seed	Malt	Feed	Seed		Industry	Seed	**Total**
Trader (ha)	114	----	X	----	X	29	----	X	29	29	X	**200**
Small (ha)	----	----	114	----	----	----	----	29	29	----	29	**200**
Medium (ha)	----	----	114	----	----	----	----	29	29	----	29	**200**
Large (ha)	----	----	----	----	----	----	----	----	----	----	----	**0**

*The **X** indicates that seed production is not possible with the trader as a sale option.*

Table 10. An illustration of the investment alternatives and their optimal crop rotation when maximizing profit for the 500-hectare farm.

Crop:	**Winter Wheat**			**Spring Wheat**		**Spring Barley**			**Winter Rapeseed**	**Linseed**		
Investment	Mill	Feed	Seed	Mill	Seed	Malt	Feed	Seed		Industry	Seed	**Total**
Trader/Medium (ha)	36	----	250	----	----	71	----	----	71	71	----	**500**
Trader	287	----	X	----	----	71	----	X	71	71	X	**500**
Medium (ha)	36	----	250	----	----	42	----	----	71	71	----	**470**
Large (ha)	36	----	250	----	----	71	----	----	71	71	----	**500**
Small (ha)	----	----	178	----	----	----	----	----	71	----	71	**320**

*The **X** indicates that seed production is not possible with the trader as a sale option.*

Table 11. An illustration the investment alternatives and their optimal crop rotation when maximizing profit for the 800-hectare farm.

Crop:	**Winter Wheat**			**Spring Wheat**		**Spring Barley**			**Winter Rapeseed**	**Linseed**		
Investment	Mill	Feed	Seed	Mill	Seed	Malt	Feed	Seed		Industry	Seed	**Total**
Trader/Medium (ha)	169	----	288	----	----	114	----	----	115	3	112	**800**
Large (ha)	57	----	400	----	----	114	----	----	114	114	----	**800**
Trader (ha)	457	----	X	----	----	114	----	X	114	114	X	**800**
Medium (ha)	----	----	286	----	----	----	----	----	114	----	114	**514**
Small (ha)	----	----	141	----	----	----	----	----	112	----	114	**367**

*The **X** indicates that seed production is not possible with the trader as a sale option.*

6.2. Sensitivity analysis

The sensitivity analysis is a helpful tool to analyse the impact of variations in parameter values on the results (Bertsimas & Tsitsiklis, 1997). The model allows changes of variables, which reveals how sensitive the solution is to different assumptions (Quiry & Vernimmen, 2011). This section presents a sensitivity analysis regarding seed production, discount rate and the marginal value of land. These factors are difficult to estimate and may affect the optimal distribution of crops and investment alternatives. This section highlights how the optimal solution is influenced by seed production and interest rate. Moreover, the marginal value of additional hectares of land is illustrated.

6.2.1. Seed production

Crops grown as seed is the most profitable strategy when investing in a farm-based grain handling facility. Since seed production in Östergötland amounts to 5 percent of the total tillable land, it is important to highlight the effect on a farm operation without seed production. Chart 5 illustrates the optimal strategy for the fictitious farms when seed production is excluded. The optimal strategy for the 200-hectare farm is not affected by seed production, selling to the grain trader at harvest is the most profitable alternative. Seed production is not available when selling to the grain trader at harvest, which explains the non-existing difference of excluding seed production. Chart 5 reveals a difference of 102 SEK/ha when seed production is excluded on the 500-hectare farm. The elimination of seed production changes the most profitable solution for the farm. The decision maker chooses to sell the grain to the grain trader instead of investing in a farm-based grain handling facility. For the 800-hectare farm, profit is reduced by 309 SEK/ha when seed production no longer is available. Similar to the 500-hectare farm, the most profitable alternative for the farm is to sell to the grain trader at harvest instead of using combination of marketing grain at harvest and investing in a facility.

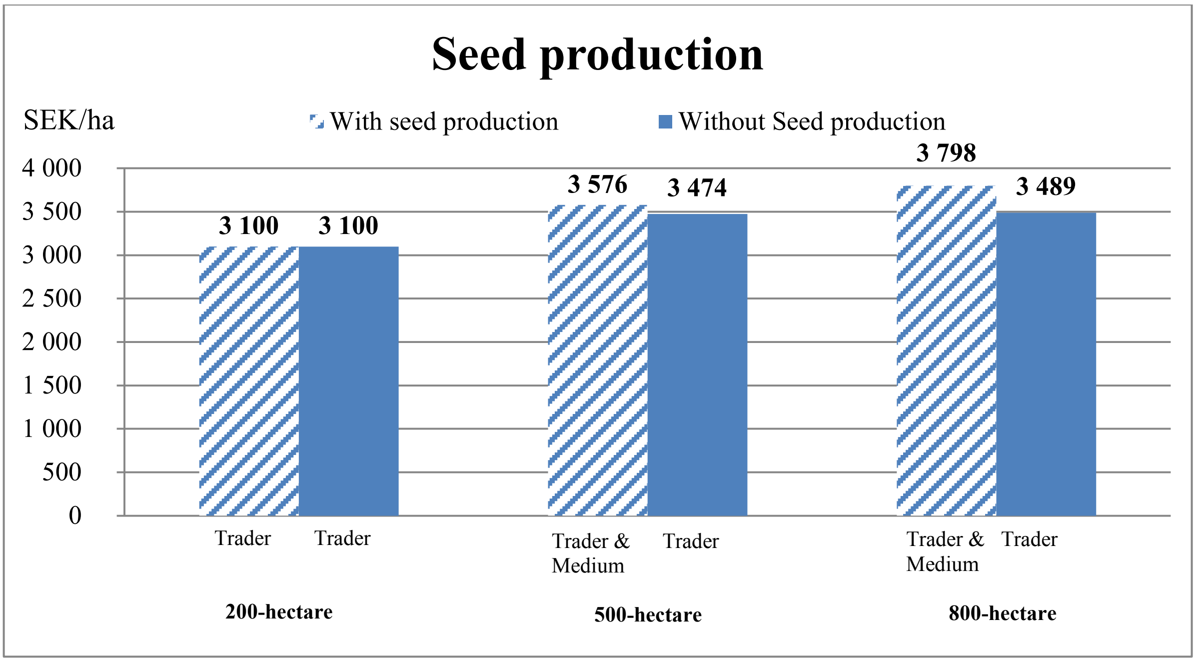


Chart 5. Optimal profit and investment alternative with and without seed production for the fictitious farms.

6.2.2. Discount rate

The discount rate affects the annuity factor and annual capital cost for the farm-based grain handling facilities and the concrete slab. The discount rate is determined by preferences of the company and is affected by risk, fluctuation of prices and inflation (Persson & Nilsson, 1999). An accurate estimation of the discount rate reduces the margin of error, which provides a basis for further investigation (Olve & Samuelson, 2008). Table 12 shows optimal strategy for each fictitious farm using the real discount rate from 1 to 9 percent. The outliers of discount rate are rarely occurred but highlight the differences in the annual capital cost. Moreover, these extreme values are not found in the study by Lagerkvist (1999). The optimal solution for the 200-hectare farm does not include investing in a farm-based grain handling facility until the discount rate is decreased to 1 percent. A combination of marketing to the grain trader and investing in a medium-sized facility is optimal until the discount rate is 7 percent or higher on the 500-hectare farm. Investing in the large-sized facility is the optimal solution for the 800-hectare farm when the discount rate is 1 percent. A discount rate of 3 to 7 percent implies combining an investment in the medium-sized facility and selling to the grain trader. Selling to the grain trader at harvest is the optimal strategy if the discount rate reaches nine percent. In summary, farm-based grain handling facilities become less profitable when the discount rate increase, as shown in table 12.

Table 12. An overview of how the discount rate affects the optimal strategy for the fictitious farms.

Discount rate	**Optimal combination 200-hectare**		**Optimal combination 500-hectare**		**Optimal combination 800-hectare**	
	Strategy	Profit (SEK)	Strategy	Profit (SEK)	Strategy	Profit (SEK)
1,0 %	Small	671 857	Trader & Medium	2 092 465	Large	3 410 853
3,0 %	Trader	630 038	Trader & Medium	1 952 161	Trader & Medium	3 222 917
5,2 %	Trader	619 963	Trader & Medium	1 788 236	Trader & Medium	3 038 186
7,0 %	Trader	611 719	Trader	1 717 213	Trader & Medium	2 879 223
9,0 %	Trader	602 560	Trader	1 695 304	Trader	2 724 704

6.2.3. Marginal value of additional land

The marginal value (shadow price) is the increases in profit if a resource restriction is relaxed. The sensitivity analysis focuses on the marginal value of land by changing the constraint of available land. The difference of profit, when changing the constraint, is equal to the marginal value of land. The implication of maximal profit is based on the marginal value being equal to the marginal revenue (Pindyck & Rubinfeld, 2009). Hence, there is no difference in profit for another unit of resources. The additional acreage of land implies increasing available land for the fictitious farms.

All assumptions remain unchanged for the farms when adding an additional hectare of land. Furthermore, seed production is possible on all land for the 200-hectare farm and 50 percent is possible on the 500- and 800-hectare farm.

Chart 6 illustrates the marginal value for an additional hectare of land for each farm, where the grain trader and farm-based grain handling facilities are compared against each other.

This implies that the comparison does not account for a strategy combining a facility and selling the grain at harvest. If a combination would be used in this sensitivity analysis, it would reveal the same marginal value as the trader since a combination often means that the facility storage capacity is already fully used. The marginal value is lower for the farms choosing to sell to the grain trader on 200-hectare and 800-hectare farms. The grain trader alternative on the 500-hectare farm has a substantial higher marginal value for additional land compared to the medium-sized facility. The facility on the 500-hectare farm does not use all available land since the storage capacity is maximized, which implies no further profit is attained if more land becomes available. Since the storage capacity is fully used, the additional land has to be sold to the grain trader at harvest, which would imply the same marginal benefit of an additional land as the trader. However, this strategy is a combination of marketing grain and investing in a facility is not accounting for in this analysis. Chart 6 reveals a difference between the marginal value of using the grain trader on 200-hectare compared to the other farms. The difference occurs due to economies of scale for farms larger than 200-hectare. The 200- and 800-hectare farms have a greater willingness to pay for additional land when investing in a farm-based grain handling facility compared to using the grain trader. However, the medium-sized facility on 500-hectare do not gain profit for an additional hectare.

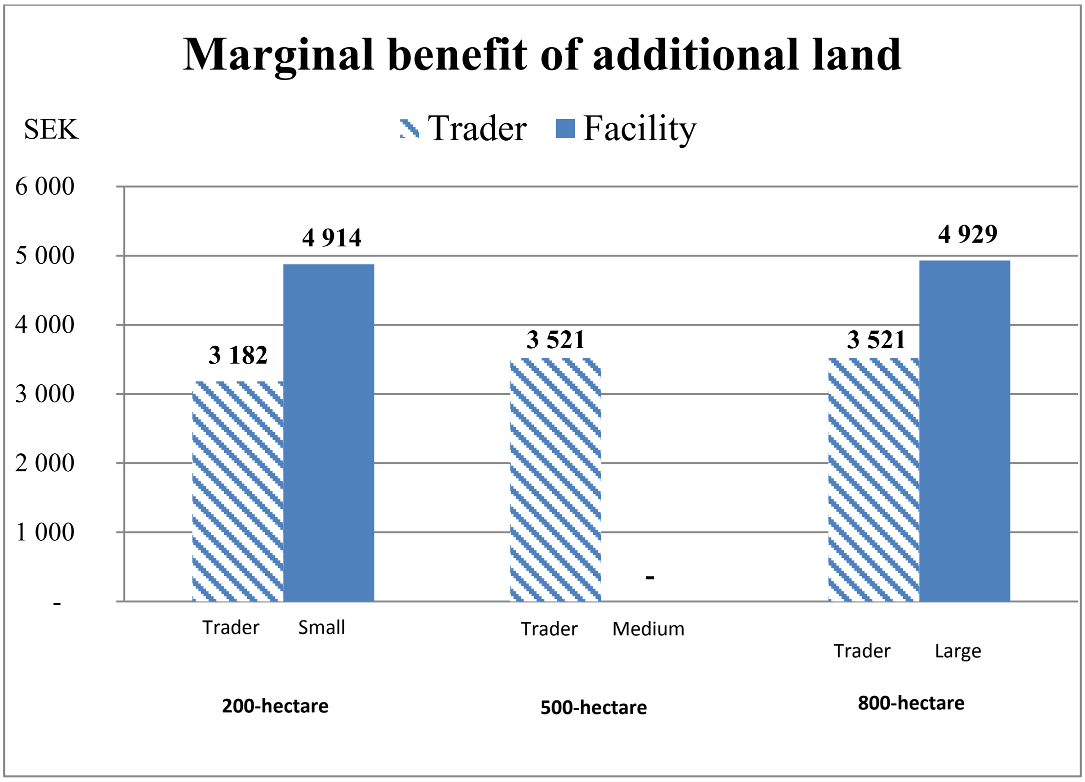


Chart 6. The marginal benefit of an additional hectare of land for the fictitious farms.

7. Analytical discussion

This chapter analyses and discuss the result of the model and the sensitivity analyses performed on seed production, discount rate and marginal value of land. The analytic discussion is based on earlier studies within the theoretical framework.

7.1. Profitability of investment alternatives

The results from the applied optimization model show different results depending on available land of each fictitious farm. Case studies provide an analytic basis and do not count frequencies (Yin, 2009). The different result of the fictitious farms provides an answer to *how* and *why* questions, due to developing of case studies (Robson, 2011; Yin, 2008). The optimization model and the creation of the fictitious farms provide in-depth knowledge of the studied problem during real conditions.

This study contributes with new aspects regarding farm-based grain handling facility compared to the grain traders. Edling (2002) stresses opportunities regarding additional compensation of the storage and segregation of different qualities. Moreover, the consideration of segregation and various qualities of crops are not considered to any large extent in earlier studies. This study considers a combination of delivering to the grain trader at harvest and storing the grain by investing in a farm-based grain handling facility. This type of combination has not been taken into account in earlier studies. Edwards (2013) argues that investing in a facility is a flexible strategy to increase the marketing options regarding agricultural commodities. However, this study is based on previous research and similarities can be found regarding the profitability of farm-based grain handling facilities.

The model reveals that solely an investment in farm-based grain handling facility is not the optimal solution for the fictitious farms. The highest profit is achieved when the grain is sold exclusively or partly to the grain trader. The incentive to invest in a facility increases with tillable land. This result is consistent with studies by Westlin *et al.* (2006) and Ugander *et al.* (2012). These studies show the difficulty to increase profit by investing in a farm-based grain handling facility, particularly on smaller farms. Furthermore, the results of their studies show similar results concerning the incentive to invest on larger areas of available land. The reason that the incentives increase is due to the capital cost is evenly distributed to the available hectares of land. This implies greater cost per hectare for smaller farms and lower cost for larger farms.

The result that emerged from this study may be different if the study was using intrinsic values from reality concerning inputs, grain prices and farm-based grain handling facility. Svensson (1988) estimates the mark-up of machinery, sold by retailers, to be approximately 17 percent of market value. It is possible for retailers who supplies farm-based grain handling facility to increase the price of initial investment (list price) due to the mark-up. This study uses investment alternatives from Tornum that are complete buildings with dryer and several storage bins. These alternatives are advanced and more expensive than low cost approaches, such as in-bin drying and basic grain handling facilities. By accounting for low cost approaches, the results that emerged from this study may be different.

Agricultural commodity prices have sharply fluctuated at the global market in recent year, resulting in uncertain earnings and affecting the profitability for the producers (Olsson *et al.,* 2014). Different marketing strategies can be used to reduce fluctuations and thereby risk by using other contracts such as forward contract and future contract. This study does not account for risk and hence contracts reducing risk is not included in this study. Pool 1- and pool 2-prices are used as market strategies since it is a generalizable measure when selling grain at different periods in time. It should be mentioned that it is possible to achieve a higher price for the commodities by using other pricing tools. However, it is strongly dependent on the decision maker and the bargaining power of the farm.

7.1.1. The initial optimization of the case farms

Selling to the grain trader at harvest and accepting a lower price is the most profitable strategy for the 200-hectare farm. The small-sized farm-based grain handling facility, which is most suitable for the smaller farm, generates a substantially lower profit. Quality crops, such as seed production, do not compensate for capital cost per hectare of the small-sized facility. Hence, the grain trader is the most profitable strategy for the 200-hectare farm. Khatchatourian *et al.* (2013) and Radajewski *et al.* (1988) stress the economic benefits of alternative techniques for heating the grain in the dryer. This study uses oil furnace, represented in the variable cost of drying grain, which is expensive per kilogram of grain dried (Jayas & White, 2003). Alternative heating system for smaller farms do not matter to any larger extent since the variable cost is a minor cost in relation to the high capital costs.

The 500-hectare farm shows different results regarding the profitability of farm-based grain handling facilities compared to the 200-hectare farm. Combining the grain trader with a medium-sized facility is the most optimal solution for the 500-hectare farm. The reason for the optimal operation of the 500-hectare farm depends on storage capacity. This facility can only store 470 hectare hence 30 hectare is sold to the grain trader at harvest. The storage capacity of the large-sized facility is enough to store the entire harvest on the 500-hectare farm. However, the capital cost is substantially higher in relation the farm-size, which generates a smaller profit compared to the medium-sized facility. The small-sized facility can only store 320 hectare and is far from the most optimal solution of the farm. There are similar profit level for the optimal solutions pertaining the grain trader and the medium-sized facility. The relationship between the medium-sized facility and the 500-hectare farm is more economically beneficial, which results in a lower capital cost per hectare compared to the situation on the 200-hectare farm. This outcome is consistent with Westman’s (2006) research, which reveals lower capital cost per kilogram of stored grain for larger farms.

The results for the 800-hectare farm reveal incentives for investing in a farm-based grain handling facility, as opposed to the results on the 200- and 500-hectare farms. Similar to the 500-hectare farm, the optimal strategy for the farm is to combine the grain trader with the medium-sized facility. Similarities are found in earlier studies, arguing that farm-based grain handling facilities are more profitable on larger farms (Westlin *et al.*, 2006; Ugander *et al.,* 2012; Westman, 2006). However, it is rare to find an investment in a facility to yield the maximum profit on the farm. Westlin *et al.* (2006) finds an investment in a farm-based grain handling facility to be the solution for the 1000-hectare farm, which is shown on the 800-hectare farm in this study. The storage capacity of medium-sized facility is not suitable for the 800-hectare farm; however, the storage capacity of the large-sized facility is more customized to the 800-hectare farm. The optimal solution of the 800-hectare farm consists of the medium-sized facility in combination with the grain trader, which implies streamlining the profit of the medium-sized-facility. The result occurs due to lower capital cost of the medium-sized facility compared to the large-sized facility. The storage capacity of the medium-sized facility is not enough to store the entire yield of the 800-hectare farm. This implies that the most profitable crops can be stored in the facility and remaining crops (not stored) can be sold at harvest to the grain trader in order to obtain the optimal solution. However, investing solely in the large-sized facility implies storing the entire yield on the farm, generates a slightly lower profit compared to the optimal solution of the 800-hectare farm. This can be explained by the distribution of crops in these two cases. The optimal solution maximizes the storage capacity of the medium-sized facility by growing as much linseed for seed production as possible. The large-sized facility tries to maximize the profit per hectare instead of maximizing the storage capacity, which implies growing as much winter wheat for seed production as possible. The results emerged from the model reveals the importance of distribution of crops, storage capacity and acreage, when defining the most profitable solution for a farm.

The model optimizes the storage capacity of a farm-based grain handling facility differently depending on the available land. The storage capacity is an essential factor regarding crops grown for storage on farm. The model tends to maximize the gross margin per hectare when storage capacity and the available land are binding restrictions. This implies cultivation of crops with the highest gross margin i.e. seed production of winter wheat with high bulk density per hectare (9,4 m^3 per hectare). In the opposite scenario, where land restriction is non-binding, the storage is optimized through highest gross margin per m^3 of storage. Hence, seed production of linseed with low bulk density per hectare (2,9 m^3 per hectare). These results indicate the importance of adjusting the storage capacity of the farm-based grain handling facility to the available land and gross margin per hectare/m^3. Thus, adapting to changes concerning the surroundings of the company in order to maintain competitiveness (Johnson *et al.*, 2011).

The cost of the construction represents a major part of the total cost regarding farm-based grain handling facilities. Ånebrink (1980) states that increasing initial investment affects the capital cost. The cost structure of the initial investment can be reduced by using existing buildings on the farm (*ibid*). Ekström (1972) stresses the consideration of farm-size, geographical area and type of cropping system when investing in a farm-based grain handling facility. Ånebrink (1980) and Ekström (1972) emphasize the use of existing resources for farm operations, which can motivate an investment of a farm-based grain handling facility on smaller areas.

7.1.2. Optimization issues

The results mentioned above originates from the model developed in this study and is based on the *five steps of the optimization process* by Lundgren *et al.* (2001). The real conditions of "pure crop farms" in Östergötland are interpreted and simplified into the model such as crop rotation, quality of crops, segregation etc. The simplification of the actual problem is crucial step in building an optimization model (*ibid*). Misinterpretation of the actual problem, when simplifying, causes disturbing the relevance of the results. There are some crucial steps in the interpretation of the actual problem concerning the assumptions for the fictitious farms. In reality, farms are heterogeneous regarding the initial conditions. This study generalizes the actual problem and assumes homogeneous conditions in order to identify the main problem. Lundgren *et al.* (2001) stresses the importance of verifying previous steps in order to obtain a valid solution and result. This study verifies the steps by comparing to earlier studies and investigates whether the results are reasonable regarding farm-based grain handling facilities. However, the results that emerged from this study are not entirely suited for generalization due to the heterogeneous farms in reality.

Mathematical programming tries to find the most efficient way of using resources to maximize the chosen objectives (Sinha 2006). Turban *et al.* (2005) stresses the normative approach, which attempts to find the best possible outcome of all actions. Hence, this study uses a mathematical programming model to optimize the operation of the fictitious farms regarding their choice of grain handling strategy. The study is based on three assumptions by Turban *et al.* (2005) concerning the decision maker; rational behaviour, knowing the consequences of all actions and has the ability to rank them according to preferences. The model in this study considers these assumptions regarding the decision maker awareness of the outcome and its consequences. There is volatility in parameters concerning grain prices, discount rate, yields and production costs, which are difficult to assess. The study assumes the decision maker has the ability to rank all possible outcomes in order to evaluate the profitability of farm-based grain handling facilities. The rationality of financial and economic behaviour in reality is questionable (Turban *et al.*, 2005). Irrational behaviour occurs in reality and depends on the lack of information, incorrect interpretation and incompetence.

7.2. Sensitivity analysis

The sensitivity analysis reveals how the uncertainty of seed production, discount rate and the marginal value of land affect profits and the optimal organisation of the farm. The model assumes the decision maker is risk-neutral, which implies choosing the activities (quality of crops) generating the highest profit. The outline of this study is based on fundamental microeconomics where profit is generated by subtracting the total cost from total revenues (Gravelle & Rees, 1992).

7.2.1. Seed production

The 200-hectare farm is not affected by seed production since selling to the grain trader at harvest it is the optimal strategy for the farm. Crops grown for seed production generates the highest gross margin e.g. seed production of winter wheat provides an additional 2200 SEK per hectare compared to selling to the grain trader at harvest. However, an investment in farm-based grain handling facility is necessary in order to enable seed production. The small-sized facility is too expensive compared to the additional gross margin of seed production to generate the highest profit of the farm. The profit generated by the optimal solution for the 500-hectare farm differs by 102 SEK per hectare. The elimination of seed production changes the optimal organization of the farm; the grain is sold to the grain trader at harvest. Excluding seed production on the 500-hectare farm implies no investment in a facility and a loss of profits by 102 SEK per hectare. There are similarities between the 200- and 500-hectare farms regarding the elimination of seed production, an investment in farm-based grain handling facility is not the optimal solution for the farm. The elimination of seed production changes the optimal strategy for the 800-hectare farm, which is similar to the 500-hectare farm. Moreover, profits decrease by 309 SEK per hectare when seed production is excluded. When seed production is excluded, the optimal solution of the 800-hectare farm is to sell all the grain to the grain trader at harvest.

In summary, seed production appears to be a vital factor that determines if the optimal organization of the farm includes an investment in a farm-based grain handling facilities. None of the optimal strategies on the fictitious farms includes an investment in a facility without seed production. On the contrary, the profits from the optimal solutions do not differ substantially when seed production is excluded.

The results that emerge from this study reveal that seed production is the most profitable quality of crops. However, seed production entails greater risk exposure compared to other qualities of grain (Pers. Comm., Wildt-Persson, 2015). In order to evaluate the utility of seed production for the farm, the risk needs to be accounted by using other theories. A descriptive technique is appropriate for this type of problem. However, a Turban et al. (2005) state that the descriptive technique does not optimize the performance of the system since it exclusively highlights differences in the scenarios.

7.2.2. Discount rate

The real discount rate affects whether an investment in a farm-based grain handling facilities is an optimal strategy or not. The discount rate is of importance when evaluating an investment (Wålstedt, 1983). An accurate estimation of the discount rate reduces the risk of incorrect assessments regarding an investment (Olve & Samuelson, 2008). The discount rate does not affect the optimal system on the 200-hectare farm unless the real discount rate is 1 percent. The discount rate is not of great importance for the 200-hectare farm since selling to the grain trader at harvest is the optimal solution.

The farmer becomes less sensitive to rate fluctuations when using the grain trader at harvest. The 500-hectare reveals substantial variations in profit and grain handling system when the discount rate range changes from 1 to 9 percent. The optimal system consists of the grain trader and the medium-sized facility until the rate increases to above 5,2 %. At a higher discount rate, the grain trader is the most profitable strategy of the farm. The capital cost of the medium-sized facility becomes too expensive at high discount rates.

The 800-hectare farm clearly reveals the major impact the discount rate has on the optimal solution. The larger facility is the optimal solution at 1 percent discount rate. The medium-sized facility in combination with the grain trader yields the highest profit for discount rates between 3 to 7 percent. The grain trader is the best strategies of the farm at 9 percent discount rate or higher. The results of the sensitivity analysis of discount rate show notable disparities between the profits obtained for different systems on the farms larger than 500-hectare. The discount rate affects the capital cost for the farm-based grain handling facilities much more than the capital cost of selling to the grain trader at harvest. This is due to the low cost of initial investment for the concrete slab necessary to deliver the grain at harvest to the grain trader. On the contrary, the initial investment of the facilities entails a great capital cost. Lagerkvist (1999) discusses the importance of farm-size and orientation of the farm when estimating the discount rate in the agricultural sector. Wålstedt (1983) stresses the importance of estimating an accurate discount rate for investment appraisal, which is notable in this study. The discount rate is an influencing factor in the choice of investment for larger farms.

7.2.3. Marginal value of additional land

The marginal value of land for the fictitious farms differs between the farms. The result emerging from the sensitivity analyse compares the willingness to pay for additional hectare of land. The comparison is made between selling to the grain trader at harvest and investing in a farm-based grain handling facility. There is a clear difference regarding the willingness to pay for an additional hectare, on the 200- and 800-hectare farms. The storage capacities of the facilities are not fully used on the 200- and 800-hectare farms. Hence, the value of an additional hectare is higher when using the grain trader as a grain market strategy. The marginal benefit of selling the grain to the grain trader is substantially higher compared to the medium-sized facility.

The storage capacity of the medium-sized facility on the 500-hectare farm is already fully used, which implies optimum use of the facility. Hence, no profit is generated by an additional hectare of land. Since there are no restrictions regarding the volume sold at harvest to the grain trader, the marginal value of an additional hectare of land will always have a value. A non-fully used storage capacity of a farm-based grain handling facility has a greater willingness to pay for an additional hectare of land compared to selling the grain to the grain trader at harvest. The higher marginal value of land when investing in a facility is explained by the value of seed production. Hence, a farm-based grain handling facility is advantageous for expansive agricultural firms (Edling, 2002).

This study reveals that there are differences regarding the willingness to pay for additional land by 1400-1700 SEK per hectare when investing in a farm-based grain handling facility compared to selling to the grain trader at harvest. Hence, investing in a facility increases the willingness to pay for additional land. This value is substantially higher than the marginal value defined by Ugander *et al.* (2012). They estimate the marginal value of land to increase by 600-1000 SEK per hectare. The difference between this study and Ugander *et al.* (2012) can be explained by the consideration of seed production, which is a major contributor to the higher willingness to pay for an additional hectare. Ugander *et al.* (2012) states that their level of willingness to pay for additional land is substantial in relation to current rental cost for land. 40 percent of Sweden's agricultural land is rented and the average rental cost in Östergötland was approximately 2100 SEK per hectare in 2014 (www, SJV 5, 2015). This means that the added willingness to pay for additional land, when investing in a farm-based grain handling facility, promotes expansion of acreage.

8. Conclusions

The study aims to find the most profitable combination of grain handling strategies for each fictitious farm based on segregation, qualities of crops and the possibility to combine different investment alternatives. Three research questions are developed in order to reach the aim and are answered in this chapter.

It is economically feasible to invest in a farm-based grain handling facility to achieve profitability, given the prevailing conditions on the case farms in this study. However, it is not economically feasible to invest in a large-sized farm-based grain handling facility on the 200-hectare. For the 500-hectare and 800-hectare farms, it is economically feasible to invest in all types of facilities.

The most profitable strategy for the 200-hectare farm is to market all grain produced to the grain trader at harvest. In order to achieve maximum profitability on 500- and 800-hectare farms the optimal strategy is to invest in both a medium-sized grain handling facility and deliver to the grain trader at harvest. Hence, the combination of these two generates highest profitability and is the economically optimal strategy at 500- and 800-hectare. An investment in an exclusively farm-based gain handling facility is difficult to justify economically as these alternatives never generate higher profitability than selling to the grain trader at harvest.

The sensitivity analyses reveals how the results are affected by the uncertainty of seed production, discount rate and the marginal benefit of an additional hectare affects the farm. Farm-based grain handling facilities enables seed production, a crucial factor regarding the profitability of the optimal strategy for the farm. None of the optimal solutions for the case farms includes an investment in a facility without seed production. Selling to the grain trader at harvest is the most optimal strategy for all farms when seed production is excluded. This is of substantial importance for larger farms since seed production contributes with a considerable value when investing in a facility.

The discount rate affects the capital cost for the farm-based grain handling facilities to a greater extent than capital cost of selling to the grain trader at harvest. Changes in discount rate primarily affect the 500- and 800-hectare farms since the optimal investment at these farms includes a storage facility. In summary, low discount rate increases the incentive to invest in farm-based grain handling facilities whereas higher rates encourage selling to the grain trader at harvest. Hence, the level of initial investment determines the effects of changing discount rates. Farm-based grain handling facilities that optimize the storage capacity reveal no willingness to pay for an additional hectare of land. Farms investing in a facility have a greater willingness to pay for an additional hectare when the storage capacity is not fully used, compared to selling the grain to the grain trader at harvest. Hence, expansive agricultural enterprises benefits in the long-term when investing in an over dimensioned facility.

In conclusion, adjusting the storage capacity of the farm-based grain handling facility to the cropping system yields the highest gross margin per hectare. The results that emerge from this study indicate the importance of choosing the most suitable farm-based grain handling facility rather than adjusting the size of the facility to all available land.

8.1. Further research

Further studies within this research area regarding the risk exposure of seed production and farm-based grain handling facilities are necessary. Moreover, interesting combination of grain handling strategies would be interesting when including more investment alternatives such as low cost approaches. By using a descriptive technique, the utility of a farm-based grain handling facility could be explored. However, this would not optimize the solution of a farm but contribute with new aspects, such as risk exposure, regarding farm-based grain handling facilities. Another approach to examine the profitability of investing in a farm-based grain handling facility would be to investigate the bargaining power of smaller farms and larger farms when selling grain to a grain trader.

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Appendix 1: Gross margin calculation

Table 13. A template of income and separable costs per hectare.

Incomes and separable costs per hectare			
	Quantity	Price	SUM
INCOMES			
Sales	Kg	SEK	SUM
EU subsidy	no	SEK	SUM
SUM INCOMES			**SUM**
SEPARABLE COSTS			
Seed	Kg	SEK	SUM
Fertilizer nitrogen (N)	Kg	SEK	SUM
Fertilizer phosphor (P)	Kg	SEK	SUM
Fertilizer potass (K)	Kg	SEK	SUM
Fuel, loader	h	SEK	SUM
Fuel, combine	h	SEK	SUM
Fuel, tractor	h	SEK	SUM
Herbicides	no	SEK	SUM
Insecticides	no	SEK	SUM
Fungicides	no	SEK	SUM
Transport	dt	SEK	SUM
Analysis of grain	no	SEK	SUM
SUM SEPARABLE COSTS 1		SEK	**SUM**
Maintenance, machinery		SEK	SUM
Working capital			SUM
SUM SEPARABLE COSTS 2			**SUM**
Real net user cost of capital and depreciation costs of assets		SEK	SUM
Labour		SEK	SUM
SUM SEPARABLE COSTS 3			**SUM**
GROSS MARGIN			
GM 1 = INCOMES - SEPARABLE COSTS 1			SUM
GM 2 = INCOMES - SEPARABLE COSTS 2			SUM
GM 3 = INCOMES - SEPARABLE COSTS 3			SUM

Appendix 2: Gross margins

Table 14. Gross margin for each crop and quality regarding economies of scale.

	Crop	Quality	Gross margin (*GM 3*) *SEK/hectare* 200-hectare farm	500- and 800-hectare farms
The grain trader	Winter wheat	Mill	4 545	4 913
	Winter wheat	Feed	4 214	4 551
	Spring wheat	Mill	3 093	3 659
	Spring Barley	Malt	3 047	3 568
	Spring Barley	Feed	2 413	2 934
	Winter rapeseed		3 583	3 432
	Linseed	Industry	1 878	2 410
Farm storage	Winter wheat	Mill	5 499	5 877
	Winter wheat	Feed	5 285	5 632
	Winter wheat	Seed	6 789	7 136
	Spring wheat	Mill	3 651	4 231
	Spring wheat	Seed	5 020	5 600
	Spring Barley	Malt	3 519	4 054
	Spring Barley	Feed	2 713	3 248
	Spring Barley	Seed	4 028	4 563
	Winter rapeseed		4 640	4 486
	Linseed	Industry	2 013	2 558
	Linseed	Seed	3 072	3 617

Appendix 3: Farm-based grain handling facility Small-sized

Table 15. Presents the initial investment for the small-sized grain handling facility.

Equipment		Price
Conveyor system		
Tipping pit	27 m^3	
Curved pit conveyor	60 t/h	
Bucket elevator	60 t/h	
Bucket elevator	60 t/h	
3xTop conveyor	3*60 t/h	
Ground conveyor	60 t/h	
Ground conveyor	60 t/h	
Manifolds and pipes		
2x air cleans with pipes and cyclones		**706 138 SEK**
Dryer		
Double batch dryer	2x35 m^3	
Hot-air furnace with flue gas fan	640 kW	
Air exchanger and fan		
Warm and wet air pipes		**622 685 SEK**
Storage		
Self-emptying storage bin	69,4 m^3	
Self-emptying storage bin	71,8 m^3	
Self-emptying storage bin	86,2 m^3	
Self-emptying storage bin	76 m^3	
Self-emptying storage bin	76 m^3	
4x Venting bins	4x120 m^3	
2x Outloading bins	2x80,2 m^3	
2x Cylindrical silos	2x582 m^3	
2x aeration fans		
Air lines		
Venting		**1 547 084 SEK**
Building		
Dryer building		
Boiler room and dust room		
Control room		**731 816 SEK**
Electricity		
Control cabinets double batch dryer		
Lighting and installation		**338 946 SEK**
Construction		
Ground works		
Concrete slab for dryer building		
Concrete slab for cylindrical silos		
Mounting		**2 103 008 SEK**

Total price: 6 049 678 SEK

Appendix 4: Farm-based grain handling facility Medium-sized

Table 16. Presents the initial investment for the medium-sized grain handling facility.

Equipment		Price
Conveyor system		
Tipping pit	27 m^3	
Curved pit conveyor	60 t/h	
Bucket elevator	60 t/h	
Bucket elevator	60 t/h	
Bucket elevator	60 t/h	
Top conveyor	60 t/h	
Top conveyor	60 t/h	
Top conveyor	60 t/h	
Ground conveyor	60 t/h	
Ground conveyor	60 t/h	
Manifolds and pipes		
2x Air cleans with pipes and cyclones		**892 302 SEK**
Dryer		
Continuous dryer	31,5 m^3	
Hot-air furnace with flue gas fan	640 kW	
Warm and wet air pipes		**475 038 SEK**
Storage		
Self-emptying storage bin	69,4 m^3	
2x Self-emptying storage bin	2x86,2 m^3	
4x Self-emptying storage bin	4x76 m^3	
6x Venting bins	6x120 m^3	
2x Outloading bins	2x80,2 m^3	
3x Cylindrical silos	3x723 m^3	
3x Aeration fans		
Air lines		
Venting		**2 272 481 SEK**
Building		
Dryer building		
Boiler room and dust room		
Control room		**753 642 SEK**
Electricity		
Distribution box for continuous drying of moisture regulator		
Lighting and installation		**405 708 SEK**
Construction		
Ground works		
Concrete slab for dryer building		
Concrete slab for cylindrical silos		
Mounting		**2 760 358 SEK**

Total price: 7 559 529 SEK

Appendix 5: Farm-based grain handling facility Large-sized

Table 17. Presents the initial investment for the large-sized grain handling facility.

Equipment		Price
Conveyor system		
Tipping pit	27 m^3	
Curved pit conveyor	80 t/h	
Bucket elevator	80 t/h	
Bucket elevator	80 t/h	
Bucket elevator	80 t/h	
3xTop conveyor	3x80 t/h	
Curved ground conveyor	80 t/h	
Ground conveyor	80 t/h	
Ground conveyor from dryer 80 t/h		
Manifolds and pipes		
2x Air cleans with pipes and cyclones		**1 540 665 SEK**
Dryer		
Continuous dryer	50,4 m^3	
Hot-air furnace with flue gas fan	1300 kW	
2x Fans		
Warm and wet air pipes		**783 171 SEK**
Storage		
Self-emptying storage bin	69,4 m^3	
3x Self-emptying storage bin 3x86,2 m^3		
6xSelf-emptying storage bin 6x76 m^3		
8x Venting bins	8x120 m^3	
2x Outloading bins	2x80,2 m^3	
4x Cylindrical silos	4x1348 m^3	
4x Aeration fans		
Air lines		
Venting		**3 530 690 SEK**
Building		
Dryer building		
Boiler room and dust room		
Control room		**939 806 SEK**
Electricity		
Distribution box for continuous drying of moisture regulator		
Lighting and installation		**509 703 SEK**
Construction		
Ground works		
Concrete slab for dryer building		
Concrete slab for cylindrical silos		
Mounting		**4 743 964 SEK**

Total price: 12 048 000 SEK

Appendix 6: Initial investment adjusted

Appendix 4 illustrates the production price index for farm buildings from 2005 to 2014. The index indicates an increase of 28,4 % since 2005. The initial investments are adjusted upwards by the index of farm buildings.

Table 18. The production price index for farm buildings from 2005-2014 and the initial investments are adjust upwards by the index.

Production price index (PM-index), 2010=100

Years:	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Farm Buildings	82,11	86,62	93	96,3	96,1	100	102,4	104,02	104,64	105,42

Farm-based grain handling facilities:	**Small-sized**	**Small-sized**	**Medium-sized**	**Medium-sized**	**Large-sized**	**Large-sized**
Year:	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**
Conveyor system	550 000	706 138	695 000	892 302	1 200 000	1 540 664
Dryer	485 000	622 685	370 000	475 038	610 000	783 171
Storage	1 205 000	1 547 084	1 770 000	2 272 481	2 750 000	3 530 691
Building	570 000	731 816	587 000	753 642	732 000	939 806
Electricity	264 000	338 946	316 000	405 708	397 000	509 703
Construction	1 638 000	2 103 008	2 150 000	2 760 358	3 695 000	4 743 964
Total price (SEK)	4 712 000	6 049 678	5 888 000	7 559 529	9 384 000	12 048 000

Appendix 7: Electricity price

Appendix 5 shows the average prices on electricity (including network charges, tax and charge for green certificate, VAT is not included) in SEK/kWh paid by industrial consumers (www, SCB, 2015).

Table 19. The average price on electricity.

Year	Period	Electricity prices for industries using 20 - 500 MWh per year	
2007	January - June	0,67	
	July - December	0,7	
2008	January - June	0,75	
	July - December	0,86	
2009	January - June	0,83	
	July - December	0,81	
2010	January - June	0,89	
	July - December	0,88	
2011	January - June	0,9	
	July - December	0,85	
2012	January - June	0,82	
	July - December	0,77	
2013	January - June	0,76	
	July - December	0,76	
2014	January - June	0,73	
	July - December	0,72	
	Average price:	**0,79375**	SEK/kWh

Appendix 8: Oil price

Appendix 6 shows the average price on fuel oil after the restitution in SEK/m^3 and in SEK/liter. The restitution only affects agricultural enterprises and implies that 70% of the energy tax and 70% of the CO_2 taxes will be refunded (www, Swedish Tax Agency 2, 2015).

Table 20. The average price on fuel oil after restitution in SEK/m3and in SEK/liter.

Year	**Initial oil price (SEK/liter)**	**VAT (SEK/liter)**	**Excl. VAT (SEK/liter)**	**Energy tax (SEK/liter)**	**CO2 tax (SEK/liter)**	**Final oil price (SEK/liter)**
2006	10946	2189	8757	740	2620	6405
2007	10822	2164	8657	750	2660	6270
2008	12855	2571	10284	760	2880	7736
2009	10917	2183	8734	800	3010	6067
2010	11906	2381	9525	790	3010	6865
2011	13025	2605	10420	800	3020	7746
2012	13735	2747	10988	820	3100	8244
2013	13277	2655	10621	820	3090	7884
Average (SEK/m3)	12185	2437	9748	785	2924	**7152**
Average (SEK/liter)						**7,15**

*All numbers are based on average value from each period.

Appendix 9: Grain prices

Appendix 7 illustrates the price of grain from 2009 – 2013 (Pers. Comm., Wildt-Persson, 2015). The average price of grain (SEK/ton) for pool 1 & 2 is based on appendix 7.

Table 21. The price of grain from 2009-2013.

Crops	Quality	2009			2010			2011			2012			2013		
		Pool 1	**Pool 2**	Diff	**Pool 1**	**Pool 2**	Diff	**Pool 1**	**Pool 2**	Diff	**Pool 1**	**Pool 2**	Diff	**Pool 1**	**Pool 2**	Diff
Winter Wheat	Mill	1000	1110	110	1600	2000	400	1720	1750	30	1900	2030	130	1650	1750	100
	Feed	900	1080	180	1450	1900	450	1750	1750	0	1850	2020	170	1650	1700	50
Spring wheat	Mill	1130	1130	0	1580	2050	470	1820	1750	-70	1950	2090	140	1700	1750	50
Spring Barley	Malt Tipple	920	1000	80	1430	1900	470	1900	1820	-80	1750	1720	-30	1420	1500	80
	Feed	820	970	150	1450	1650	200	1600	1700	100	1650	1620	-30	1350	1300	-50
Winter Rapeseed		2400	2770	370	3200	4250	1050	4000	4100	100	4000	3950	-50	3250	3300	50
Linseed	Industry	2800	3680	880	4200	4700	500	4300	4100	-200	-	-	-	3950	3300	-650