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zur Erlangung des akademischen Grades

Master of Science

# Cost Calculation for Forage Harvesting in Selected Beef Farms and Countries

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# 1 Introduction

## 1.1 Problem Statement

Throughout the last century and more recently in the last decade agriculture changed from a way of life to a profession with a stronger need for holistic education and economic skills (Hoffmann 2009, p.7). Advanced plant breeding and genetic engineering of crops increased yields and required the development of correspondingly sized machinery. At the same time the global livestock sector changed rapidly given the growing demand for animal-source foods that came with population growth and increasing wealth in a more than ever globalized world (Robinson et al. 2011, p. IX). With globalization and increasing productivity and competition, thorough knowledge in management became more and more necessary farmer’s daily work to keep up with workloads and increasing complexity in production. With more livestock and land to farm workloads increased, putting farmers under pressure for economically sound choices with regard to allocation of human and financial resources. At the same time globalization opened markets to competitors from around the world. Where farmers’ major competition for resources and clients used to be their immediate neighbors they find more complex dynamics today. These are major challenges of the contemporary European livestock farmer. Beside state of the art technology and management skills, he requires plentiful information on the feasibility of his activities, i.e. costs and benefits.

In beef cattle production, feed-related costs represent a proportion of 25 and 50 percent of total costs (Deblitz et al. 2013). Hence, feed costs belong to the most important cost components. That is global price increases in prices for soybean and grains affected farmers livelihoods directly in the recent years. (Zinke 2012). As a result, beef finishers and other ruminant livestock producers have commenced to re-assess their amount of purchase feed. Their competitive advantage however, is that bovines unlike pork and poultry can process a variety of forages by their sophisticated gastric system making production of own forages a vital alternative to purchase feed.

Although data on forage production costs at farm level is readily available through regional consultancies or federal institutions (for Germany through the chambers for agriculture) it usually stems from financial accounting. That is, it provides a detailed overview of the types of costs but does not contain information on the composition of these costs and their underlying quantities of inputs, labor and operations. They cannot be linked to production systems and equipment, consequently farmers and other decision makers are well-able to compare forage costs per hectare or kilogram meat but can only guess the crucial differences that lead to advantages of their competitors.

To seize the potential advantage of producing own forages however, farmers need to be able to compare on farm production of forages to prices of purchase feed and other possible outsourcing mechanisms for costs e.g. contractors. Still to this day there have been little studies into the costs for owned machinery in fodder production for beef finishing, let alone an analysis of the individual costs per production step. The latest comprehensive study in this field was published by Gunnarsson et al. (2009) on the costs for timeliness in harvesting schemes. However it focusses on timely harvest and losses in terms of yield, but does not compare systems in terms of total costs. Consequently, decision makers in the agricultural field have to opt for production systems without knowing the immediate costs of their machinery and alternatives in forage production.

## 1.2 Aims and Objectives

The central aim of this thesis is to make a contribution to close the information gap both farmers and manufacturers of farming machinery face when it comes to the production of forages: the actual operation costs. Therefore it shall provide an insight into forage production systems with regard to their operations, machinery and costs.

The following set of research objectives was determined to achieve the aforementioned aims:

a) to identify typical production systems for forage production,
b) to determine the costs for each production system and their individual production steps,
c) to identify driving forces, decision making processes and issues in forage production, and
d) to compare these systems on a European scale in order to reflect the competitive situation in the common market.

The scope of the study does not allow to cover all European countries. As a consequence, a subset of important beef producing countries with different natural conditions, production systems and markets were selected: Germany, France and the UK.

When comparing the production systems the target is to obtain an overview of possible solutions in forage production from an economic point of view at the given conditions of the typical farm settings. The aim is not to rate these systems or identify a ‘best choice’ system but rather to give an overview of forage productions in different environmental and regional conditions in Europe.

At the end of this thesis the reader will be familiar with typical European production systems for forages and the costs involved in these activities. They will be able to foresee the economic implications of producing own forages and make informed decisions on purchasing machinery for that purpose and when to outsource these activities to third parties. Furthermore, it will provide an insight into the reasons for farmers’ decisions based on the typical farm cases provided.

## 1.3 Approach

A literature review provided insights into common production systems of beef cattle and its fodder as well as background information to design research adequately. The *agri benchmark* network (details in chapter 3) was identified as key source to obtain economic data from a set of beef finishing farms with comparable production systems and detailed recordings of machinery costs. Together with the network partners from the countries analyzed, suitable farms from the *agri benchmark* database were selected to provide data. Expert panels of farmers and advisors validated the data so that changes could be made where necessary to reflect regional realities to the maximum. The validated data was then compared and evaluated against the background of the literature review and statements from experts and farmers. Furthermore the expert panels were used to assess the driving forces of farmers' decisions and their driving-forces.

To put the research in a broader context, background information on the importance of fodder costs will be presented in chapter 2. The methodology with required calculations and databases used for the purpose of this thesis will provide the reader with necessary information for understanding the methodology of the research in chapter 3. Before presenting the detailed results obtained by the methodology in chapter 5, an overview of the farms identified and their characteristics will familiarize the reader with the specifications of the typical cases in chapter 4. A discussion of the results in chapter 6 elucidates the context of these results and examines limitations and benefits of the applied methodology. Finally, conclusions are drawn from the discussions and future fields of research are outlined.

# 2 Literature Review

Cost of forages are not very well researched. Though it is simple to find sound statements by consultants for cattle on the economic implications of feed production (c.f. Kunz and Neve 2012, Häberli 2006), the majority of researchers does not address this issue. That said, the literature review will be short and try to give an overview of the most important aspects of forage production.

Forages are of high importance in beef finishing and cattle nutrition: Through their distinct digestive system, ruminants like cattle can make efficient use of forages while other animals cannot (Horrocks and Vallentine 1999, p. 59). Through bacteria in their rumen, beef can break down plant fiber into carbohydrates. Weight-gain from forages in beef cattle is a function of the quality and quantity consumed by the bull (Horrocks and Vallentine 1999, p. 64). To achieve optimum results in finishing cattle has to fatten quickly with high daily weight-gain. In order for cattle to do so, forage has to be provided not only in high quantity but also in sufficient quality (Kunz und Neve 2012, p. 50). This is a central issues of feeding both, cattle and and dairy cows.

Quality of forages is assessed through protein and energy content as well as coefficients like the rNB (ruminal nitrogen balance) to evaluate the amount of nitrogen (that is energy) that will actually be available the bovine after digestion. Weather and overall climate is one of the most important influence on the nutritive value. As part of agricultural production, forage harvest is variable with the regional conditions and the recent weather events (c.f. Gunnarsson et al. 2009, p. 276). The factors influencing forage yield and quality are:

- „Type of plant,
- „Maturity at harvest,
- „Temperature
- „Water Stress ,and
- „Soil fertility. (Petty and Cecava 1995, pp. 93)

A timely harvest therefore is crucial for satisfactory nutritional value of the forage. Forages are usually cut more than once per year, which is why the timing of the first cut is decisive for all following operations as well (Gunnarsson et al. 2009, p. 276).

A ration of forages with high nutritive (i.e. energy-) content will lower production costs (Häberli 2006, p. 3). In all forms of livestock farming the costs for feed and especially forage are of major importance (Bogner et al. 1978, p.18).

With rising costs for grain and energy feed, costs for forages will still be important in the future (Deblitz et al. 2009, p.12).

Calculating these costs is difficult, though, even on farm level (Bogner et al. 1978, p.18) since different factors are contributing: equipment of the farm, availability of labour and costs for existing or new buildings to name but a few.

In 1978 Bogner stated that the costs for labour and buildings influence forage costs strongly (Bogner et al. 1978, p.19). In contemporary literature however, costs for machinery are more important than storage costs (c.f. Häberli 2006, Over 2009).

Total costs for forages are strongly related to the operating costs (Kunz and Neve 2012, p.49). They make the biggest share of the total costs. Therefore cutting costs means cutting operating time or expenses (Kunz and Neve 2012, p. 49) or the yield needs to increase. One way to reduce working time and costs for machinery is by contracting labour (Gunnarsson et al 2009, p. 289). If the forage area is small this is even more efficient than in bigger production systems (Gunnarsson 2009, p. 289).

Another efficient mean for cost reduction is reducing machinery costs by using the full potential of the machines for work (Häberli 2006, p. 1). This can be achieved either by working more own land with these machines or by providing services to other farms.

# 3 Material, methods and calculations

This chapter will outline how research was conducted, what were the steps performed to reach the results presented in the following chapters and how figures have been calculated.

## 3.1 Material

For the purpose of obtaining an overview of the relevant issues in forage production and costs involved literature review was conducted. The results have been presented in the previous chapter (chapter 2 literature review) and will be used where applicable to discuss the results in chapter 6.

For the purpose of empirical research, a database with sufficient homogenously collected data was required. Criteria for the data to match the requirements of the calculations are listed below. Data sets shall …

1. reflect an important part of forage production in the countries analyzed.
2. not be adjusted by statistical means.
3. be consistent, homogeneous and comparable. Thus, the data should origin from one source.
4. include financial as well as physical data (quantities and qualities).
5. collect whole farm data.
6. be available in one language to reduce risk of translation mistakes.
7. stem from farms with cattle husbandry, either fattening or cow-calf.
8. contain operating and overhead costs in sufficient detail (no black box for overhead costs).
9. be validated and discussed with farmers on a regular basis.
10. encompass samples from Germany, France and United Kingdom.

A popular source for data on all types of costs is the Farm Accountancy Data Network (FADN) by the European Commission (EC). It does not fully meet the requirements listed above, especially when it comes to discussion and validation with farmers. The reason for making this point a priority was the idea to run validation groups with farmers to verify the data calculated and obtain their input. For a system that is already established and where farmers are familiar with the personnel this was assumed to be easier than in systems that work similar to FADN where data is sourced from consultants or accountants without immediate contact to the farmers.

After evaluation of the possible sources the database of the *agri benchmark* Beef and Sheep Network was chosen as the most suitable source of empirical information about beef finishers in an international context (c.f. Deblitz, 2010). Given its' standardized approach through which farms are identified and data is collected it is appropriate for scientific comparison of machinery costs (c.f. Deblitz and Zimmer 2005). Additionally, the 14 years experience in the field and a multitude of member countries within *agri benchmark* promised the best possible result range (c.f. Deblitz et al., 2013).

For the exploratory character of this thesis France, Germany and the United Kingdom were selected to represent a major share in the European beef production and comparable farming conditions with respect to legislation (EU) and economic development.

With the help of experts from the network two so-called 'typical farms' (see typical farm approach below) were identified in each country to represent different natural environments and conditions for production. The farms selected and their location are described in more detail in chapter 4 farms.

**The 'typical farm' approach by *agri benchmark***

Data for these farms is collected or modeled following the standard operating procedure of the *agri benchmark* for typical farms. Typical farms are defined as

- existing farms or datasets that describe farms
- in a specific region representing a major share of output for the product considered
- running the prevailing production system for the product considered (i.e. beef meat)
- reflect the prevailing combination of enterprises as well as land and capital resources
- represent the prevailing type of labour organization (Deblitz et al. 2013, p.144).

To produce the data sets for typical farms the network has two approaches:

- so called 'focus groups' or 'panels', consisting of 4-6 farmers, one advisor plus the local research partner who are familiar with the local conditions for beef finishing in order to obtain a well-informed consensus or
- single farms that are 'typified' by replacing farm particularities in production systems specifications, technology, performance, production factors, inputs and prices by prevailing figures of the majority of farms in the region considered (Deblitz et al. 2013, p. 144).

Typical farms are identified in a standard operating procedure with four steps together with the country's or region's research partners (see also Deblitz and Zimmer 2005, p. 2):

1. Regions and locations with importance for the relevant production are identified with the help of maps.

2. The prevailing production systems of the regional ‘hot spots’ are determined and differentiated using a checklist. By integrating typical production systems with the regional hot spots the relevant group of farms can be identified.
3. The farm sizes in terms of annual animal sales and the management level of the farm are evaluated to identify two farms, one average size and one large size to reflect a large proportion of farms and a large proportion of production in the region. If time and/or resources are scarce, focus is given to the reflection of a major proportion of production rather than farms. The management level should be average.
4. After identifying the relevant farms the data is collected and cross-checked in panels of farmers and consultants before validating through economic analysis against other data.

The farm data is updated annually by projecting prices with price indices for all inputs and outputs. It is not necessary to change the herd structure, animal number or performances as they do typically not change much from one year to the other. Exceptions are structural droughts or other dramatic changes in the framework conditions, which have a significant (and typical) impact on animal numbers and productivity. Every 3-5 years the farm data are undertaken a major revision. Updates are produced on annual basis.

The existing data sets of the typical farms were used as the foundation of the following calculations. Data gaps were then filled with technical data from different national sources:

For German farms the databases of Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) and Bayrische Landesanstalt für Landwirtschaft (LfL) were used for that purpose. Details of these sources are described in chapter  given the fact that they were also used in later stages of validating the French and British data.

For France missing data was obtained from the yearly journal of the association of machinery cooperatives (Coopératives d'Utilisation de Matériel Agricole = CUMA) given the lack of a national engineering database.

For the United Kingdom practical values were obtained in expert consultations and compared to the technical data from machine producers.

In a group discussion during the beef and sheep conference of *agri benchmark* in Torino, Italy, on 10$^{th}$ July 2014 all partners met to discuss the further procedure. All partners agreed to use engineering data from the German KTBL to close remaining gaps before validation.

Using existing data from the typical farms on acreage planted with the respective forage crops (grass / grasslands and maize) typical forages of the regions were identified. To model production systems comprehensively single production steps have been determined with the help of engineering databases (KTBL, LfL), literature and experts from the *agri benchmark* network. Next with the existing data from agri benchmark farms and MaKost, the program for machinery costs by KTBL, lists of machinery for each farm based on the individual production systems were compiled.

**KTBL Sources**

To obtain an overview of capacities, fuel consumption, depreciation, repairs and interest KTBL Verfahrensrechner Pflanze proved most useful. It provides information on the operations within the selected production system, machinery used (with specifications), capacity (h/ha), operating costs, fuel use and depreciation for the individual operation by drawing on the database of KTBL.

Calculations are based on the assumption that

- the terrain is even or slightly inclined
- the soil type does not obstruct soil cultivation
- transport of goods is conducted on roads in good or very good condition
- average speed on the road is 40 km/h for the tractor with towed machinery and 20 km/ h for self-propelled machines
- operation speed on the field is limited by the maximum output of machinery
- harvesting-transport-storage-chains are designed so that the harvester does not have to wait. (KTBL 2011, p.1-2).

Subchapter 3.2.3 on page 12 will compare the figures from KTBL for depreciation, repairs and interest to own calculations and explain the differences. For the final results presented in chapter 4 only capacities and fuel consumption values from KTBL Verfahrensrechner Pflanze were used where necessary.

Next, suitable ways to calculate depreciation, interest and repairs were identified. Those values all relate to the annual utilization.

## 3.2 Calculations

### 3.2.1 Operating costs

**Annual utilization**

To calculate the operation costs and unit costs (per ha and ton DM) for each operation step the annual depreciation is divided by the actual utilization of the machinery (compare KTBL 2012, p. 4). The underlying data from *agri benchmark* however does not provide the total utilization for each machine on farm level but for the single production systems. That is there are no indications of the total annual utilization of machinery. The *agri benchmark* data does provide a detailed list of machines, their utilization periods as well as purchase and repurchase prices but not the total annual use of the machines (operating hours). Therefore engineering data from KTBL was used for annual utilization to reduce variations between farms with different number of forage production systems.

The machinery have different utilization units, namely m³, t, ha and hours. Except for the machines that have utilization in hectare, there was a need for intermediate steps to break down the annual utilization to the hectare. All machines with utilization unit m³ could be related to the input in m³ per hectare. Tractors and other machinery that had their utilization in hours were multiplied by the capacity in hours per ha. There were only trailers with utilization unit tons. From the production systems one can easily see that the only activity that trailers are engaged in is the transportation of harvest from the field to the storage. Therefore the transportation trailers were related to the total harvesting volume in tons e.g. tons of maize silage.

**Depreciation Method**

Straight-line depreciation was chosen for all machines because it is common in German farm practice and it was impossible to determine the total utilization at farm level for all farms within this project. Also for performance related depreciation to be feasible it takes high utilization/performance per year that we unlikely find in finishing farms but rather in only-crop farms.

The general equation to calculate straight-line depreciation is

$$\frac{P-S}{UL} = \ annual\ straight\ line\ depreciation$$

With

$$P = Purchase\ price$$

$$S = Salvage\ Value$$

$$UL = Useful\ Life\ of\ Asset$$

(Dabbert and Braun 2012, p. 91).

The latter varies between then farms given the year of purchase and individual preferences of the farmer, that is farmers who resell equipment after a short period (e.g. SP=4) were considered to pay higher depreciation than farmers who own their tractor for 30 years (SP=30). Where no values for the useful life of the equipment (UL) were available from empirical data, technical data from MaKost (KTBL) have been used. In *agri benchmark* only repurchase prices are recorded. Therefore purchase price was assumed to be equal to the repurchase price.

To provide depreciation per hectare the following equation was applied:

$$\frac{annual\ straight\ line\ depreciation}{uitilzation\ units\ \ per\ year}*\frac{utilization\ units}{ha}*number\ of\ \ operations\ per\ ha =\ \ depreciation\ per\ hectare.$$

For tractors however the utilization is commonly given per hour, therefore depreciation per ha was calculated using

$$\frac{annual\ straight\ line\ \ depreciation}{uitilzation\ hours\ \ per\ year}*capacity\ \frac{h}{ha}*number\ of\ \ operations\ per\ ha = depreciation\ per\ hectare.$$

The detailed calculations for depreciation are provided in the excel spreadsheet for each farm in the data disc attached (see data disc Folder 1 – Spreadsheets).

**Interest rate**

Interest charges are generally estimated through the equation

$$(\frac{P-S}{2}+S)*i$$

i.e. simplified

$$(\frac{P+S}{2})*i$$

with

$$P = Purchase\ Price$$

$$S = Salvage\ Value$$

$$i = Interest\ Rate$$

(Dabbert and Braun 2012, p. 94).

For machinery and storage buildings this equation was applied without exceptions. In most cases the salvage value was not provided and hence considered to be zero, since second-hand markets and thus salvage values vary regionally and statistics are not available. Thereby international variations in the interest charges have been minimized.

Interest rate was set at 4% following the example of KTBL to ensure comparability of the data. However 4% is also the nominal interest rate commonly assumed in agricultural economics (compare Mußhoff & Hirschauer 2011, p. 271)

For storage facilities and buildings entering the storage costs (fixed costs) the interest rate was assumed to be 4.25% (compare LfL).

**Repairs**

Unlike maintenance costs or depreciation, repairs do not occur on a regular basis but rather randomly throughout the lifetime of machines. It was not possible to survey the full lifetime of machinery within the framework of this master thesis. Hence, research was conducted for suitable data that was empirically obtained in farms. In KTBL MaKost such data is available. The respective values for repairs and their costs have been compiled by KTBL empirically on partner farms (oral communication with Dr.Fröba, KTBL) and adapted to the machinery in the database where necessary. Such extensive data was not available on national level for France and the United Kingdom. Given the nature of agricultural operations and machinery it was assumed that the way of utilization and therefore the amount of repairs is comparable. Hence, German data for repairs and costs were applied to the UK and France and related to the extent of utilization.

The repairs for each operation were calculated by applying the formula:

$$\frac{Repair\ costs\ (€)}{utilization\ unit} * \frac{utilization\ units}{hectare} = repair\ costs\ per\ hectare.$$

Detailed results for these calculations are depicted in the results chapter. Furthermore, the full excel file of each farm is attached to this thesis on compact disc.

**Irrigation**

Only British farms had costs for irrigation. They were provided by the British partners.

**Costs for fuel**

Costs for fuel were calculated by multiplying the fuel use from the respective national source by the fuel price given in the input sheet (c.f. data disc Folder 1-Spreadsheets).

**Costs for inputs**

Similar to fuel the costs for inputs were calculated by multiplying price and quantity per hectare that were provided in the input sheets.

**Costs for labour**

Labour costs were calculated by multiplying the capacity (h) per hectare with the number of operations per hectare and the hourly salary for family labour.

**Costs for contractors**

Contractor costs have not been calculated  but taken either from data provided in the typical farm for the respective operations or added from national technical databases.

### 3.2.2 Overhead costs

When operating costs (fuel, labour, depreciation, interest and repairs) had been estimated overhead costs were identified. Comparing existing calculator for cost by KTBL, DLG and reviewing literature on the subject three major overhead components were identified: costs for land, storage costs and other costs, a mixture of insurances, costs for accountants and office work.

**Costs for Land**

Data on the costs for land as rented and owned were recorded in the *agri benchmark* network. A weighted average was calculated from these figures using the old rent price in its original purpose and the new rent price to model opportunity costs for owned land that is used in the farm but could be rented. The weighted average formula is:

$$\frac{area\ owned\ (ha) * new\ rent\ price(€) + area\ rented(ha) * old\ rent\ price(€)}{area\ owned\ (ha) + area\ rented\ (ha)}$$

**Costs for Storage**

For the identification of storage costs the list of existing buildings for each farm was reviewed and suitable buildings for each forage selected unless the purpose was designated clearly in the recordings.

- A basic assumption for that purpose was that clamp silages are always stored in a bunker or clamp facility.
- For hay sheds and older storage buildings with low annual depreciation were selected.
- Finally for grass silage in bales the procedure proofed most difficult. Such silages can be stored in many ways: in the open field, on farm on gravel beds, in vacated buildings or old bunker plates. Since storage in the open field is cost effective but can lead to damages in the foil through birds and rodents this form of storage was excluded for all cases. Gravel beds could not be identified through the data and were excluded as well. For the remaining choices (old bunker plates and vacated buildings) availability was checked and costs were compared. The most cost effective version was selected given the fact that cheaper ways of storage were likely.

Storage was calculated imitating the model of LfL (c.f. fixed costs for grass silage in https://www.stmelf.bayern.de/idb/grassilage.html). Since LfL calculations simulate building a storage for the existing harvest rather than using existing buildings, the calculation was modified: Costs of existing buildings were distributed over depreciation time (straight-line depreciation). Interest and maintenance costs were calculated based on the value for annual depreciation. Interest rate was adopted from LfL (4.25%). Imputed interest was estimated (1.25%).

A list with the costs of the buildings selected is included in the appendix on page 23.

**Other overhead costs**

*agri benchmark* records costs very precisely so that the following overhead costs could be included in the category of 'other costs':

- Farm insurances,
- Disability and accident insurance,
- Farm taxes and duties,
- Advisor costs,
- Accountant and legal fees,
- Phone and utility costs, and
- Other input.

These costs were allocated for forages by the following calculation:

$$\textit{Allocation factor beef finishing} = All_{BF} = 0{,}5,$$

as inherent in the agri benchmark model,

$$\textit{Approximation for share of feed costs in full costs} = All_{FC} = 0{,}2$$

$$All_{BF} * All_{FC} = \textit{Allocation factor overhead costs for forage} = 0{,}5 * 0{,}2 = 0{,}1.$$

Consequently, all costs were multiplied by 0,1 and then divided by the area planted per forage in ha.

### 3.2.3 Methods

**Depreciation method and results**

Table 1 (page 14) compares the results for the hay production system from KTBL (grey) to the calculations made for the project. KTBL operations relate to one operation, while own calculations already consider how often the operation is conducted (e.g. mowing three times). The detailed calculations are included in DE 260 (data disc Folder 1 – Spreadsheets). Despite the fact that KTBL figures refer to a single operations, they are significantly higher for most operations.

It is not entirely understandable how that is, because KTBL is an intransparent system that does not show the calculations and databases it generates values from. One possible reason is the field distance that is factored into KTBL with models for average speed that could not be generated within this project. Another possible reason is that depreciation periods in KTBL were lower than in the machinery list used, therefore investment into machines was distributed over lesser years.

However there is no obvious trend of KTBL values being related the calculations performed. Given the fact that it is not possible to understand the KTBL values thoroughly and the need for a comprehensive and uniform approach through all systems considered, the calculations were conducted despite the discrepancies with KTBL, thereby producing data sets that with fully comprehensible and comparable calculations of depreciation interest and repairs.

**Table 1: Depreciation Comparison (Hay DE 260)**

| Operation | Depreciation | Repairs | Interest | Depreciation | Repairs | Interest |
|---|---|---|---|---|---|---|
| **Slurry application** | 12,4 | 13,94 | 2,75 | 3,34 | 13,99 | 1,15 |
| **Rolling (Walzen)** | 6,2 | 5,16 | 1,82 | 4,20 | 6,48 | 1,02 |
| **Slurry application** | 12,4 | 13,94 | 2,75 | 3,34 | 13,99 | 1,15 |
| **Levelling** | 7,65 | 4,2 | 1,84 | 3,01 | 5,60 | 0,73 |
| **Seeding** | s.a. | s.a. | s.a. | 5,47 | 2,50 | 1,64 |
| **Slurry application** | 12,4 | 13,94 | 2,75 | 4,47 | 17,98 | 1,79 |
| **Mowing** | 4,96 | 4,15 | 1,09 | 6,69 | 12,45 | 1,85 |
| **Tedding (Zetten)** | 3,01 | 4,81 | 0,68 | 6,25 | 15,39 | 1,06 |
| **Turning** | 2,55 | 4,09 | 0,57 | 14,56 | 38,61 | 2,50 |
| **Swathing** | 3,29 | 4,56 | 0,72 | 11,14 | 28,92 | 2,00 |
| **Transport** | 6 | 5,61 | 1,52 | 7,37 | 13,32 | 1,18 |

*Sources: KTBL Verfahrensrechner Pflanze, own calculations*

**Validation**

After performance of all calculations and compiling production steps for the all systems with operating costs, working hours and lists on the required machinery, the data was subjected to validation by focus groups with farmers for each typical farm. As in the standard operating procedure focus groups consisted of local beef finishers and an advisor who was familiar with the regional conditions and typical production systems. This approach was adopted from the *agri benchmark* procedure for validation of the typical farm. In preparation of the meetings a guideline for a semi-structured interview was developed jointly with the commercial partner of this project. The English version is attached in the appendix together with minutes of the French and German focus groups (appendix pp. 2-25).

After validation data was revised and changes were made where necessary. The validated data is described in detail in chapter 4.

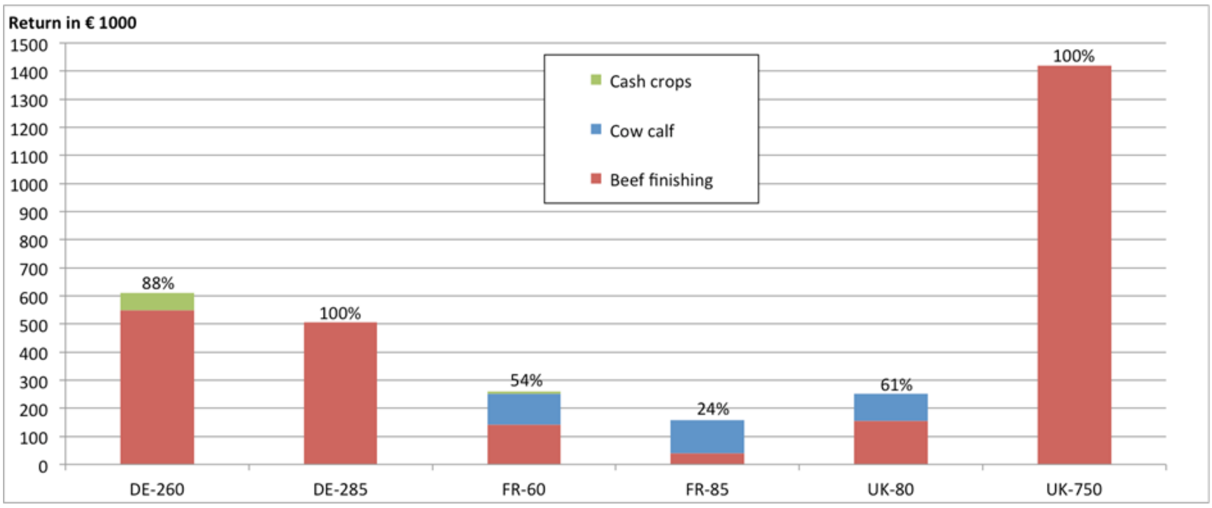
# 4 Farms

This chapter shall make the reader familiar with the typical farms and the production systems that were evaluated within this project. The source of these data are typical farm data from the agri benchmark Beef and Sheep network. They are listed in the spreadsheets provided on the data disc attached (Folder 1-Spreadsheets). The locations and characteristics of the farms will be introduced and summarized in a table at the end of this chapter. Two figures will show farm locations and return structures.

**DE 260**

The farm is located in the region of Landshut (Bavaria) in southern Germany. It finishes bulls of Fleckvieh (Simmental) - breed which are purchased as calves and sold at a life-weight about 720 kg after a fattening period of 494 days. Besides beef finishing, the family farm DE 260 also generates profit through forestry and cash crops. Work is conducted by 2,34 labour units (with 2200 h per year) family labour with a calculated wage (opportunity cost) of € 15,92 per hour. Agriculture contributes 100% of the farm income. Figure 1 below shows the absolute return shares of beef finishing, cow-calf and cash crops in DE 260 and all other farms under investigation. Relative values were included at the top of each column for comparison of the farms.

**Figure 1: Total and relative return shares of typical farms**




The farm operates a total of 86 ha of land. It owns 45 ha of arable land and 5 ha of pastures while renting another 36 ha of arable land. The climate at DE 260 is wet all seasons at an average temperature of 8 °C and an average annual precipitation of 700 mm. Precipitation peaks slightly between June and July but is otherwise distributed evenly over the year. DE 260 is located on sandy loam soils with a yield of 54 t FM/ha (18,9 t DM/ha) for maize silage at 8,2% protein and 11,1 MJ ME/t DM. The yields for grass silage and hay are 8,4 t FM/ha (6,7 t DM/ha) and 22,3 t

FM/ha (7,1 t DM/ha) respectively. Hay has an energy content of 9,5 MJ ME/kg DM and 12,5 % of protein while grass silages have 9,9 MJ ME/t DM at 16,5 % protein.

**DE 285**

The beef finisher DE 285 is located in the federal state of Schleswig-Holstein in the very North of Germany. This family farm fattens Holstein-Frisian calves that are purchased at the age of two weeks for 593 days before selling them at a live weight of 660 kg. Figure X shows that 100% of the farming income is generated in beef finishing.

Most of the total 83 ha of land in DE 285, namely 23 ha of pastures and 42 ha of arable land, is rented to supplement 18 ha of own arable land. Soils are silty loams or clay structures that benefit from even distribution of the average annual precipitation of 840 mm with slight peaks in the growing season between April and October and in January. The annual average temperature in the location of DE 285 is 10 °C. DE 285 produces maize silage and grass silage with yields of 44,8 t FM/ha (13,4 t DM/ha) and 23,6 t FM/ha (8,0 t DM/ha) respectively. Gras silage has an energy content of 9,8 MJ ME/t DM at 15 % protein content while maize silage has only 7% protein but 11,0 MJ ME/t DM.

The farm employs 1 family labour with a calculated wage of € 17,5per hour and 0,04 casual labour for 8 h per year at 10,75per hour.

**FR 60**

FR 60 is a mixed and has beside beef finishing FR 60 a cow-calf herd. Charolais weaners are transferred from the cow-calf enterprise to the finishing unit at the age of 262 days and a live weight of 345 kg. The finishing period takes 243 days and cattle is sold at 720 kg after 243 days. With 54%, beef finishing has the bigger share in revenues, while cow-calf contributes 42% and a small section of cash crops yields the remaining percentage (compare figure 1 page 15). Work on the farm is conducted by 1.1 family labour with a calculated wage of € 13.3 per hour.

The farm rents all its land, 22 ha of arable land and 63 ha of pastures on sandy clay loam. The climate is marine for the location in the Pays de la Loire with annual average precipitation of 750 mm mainly from November to February outside the growing season. Consequently, water supply is a limiting factor for growth at the average annual temperature of 12 °C. Forages in production are grass silage (clamp), hay and maize silage. Hay has a yield of 5,5 t FM/ha and 4,7 t DM/ha at this location. Maize silage yields 32,3 t FM/ha and 10,5 t DM/ha with energy content of 10,8 MJ ME/kg DM and 9% protein content. Grass silage yields are higher in terms of fresh matter (33,3 t FM/ha => 4,5 t DM/ha) but have higher energy content (11,8 MJ ME/kg DM) and more protein (18%).

**FR 85**

With only 24% of its revenues coming from beef finishing, FR 85 is mainly a cow-calf farm (75% of revenues, (compare figure 1 page 15). Limousin cows are kept to produce weaners for sale and limited fattening activities. The farm is run on 1,3 family labour (calculated wage of € 13,30 per hour) in the Limousin region of France. In this location climate is wet all season with regular rainfall that peaks between September and November. The main growing season however is from April until June. The annual precipitation is 1000 mm at an average temperature of 11 °C.

The total farm area of 95 ha includes 36 ha of pastures and 2 ha of arable land of sandy loam qualities. Additionally, 55 ha of pastures and 2 ha of arable land are rented. Two forages are relevant for FR 85: hay and haylage. Yields for hay in this location are 5 t FM/ha (4,2 t DM/ha) at 9% protein content and 8,0 MJ ME/ kg DM. Haylage yields 7,3 t FM/ha (4,1 t DM/ha) with an energy content of 8,6 MJ ME/kg DM and 10,4 % protein.

**UK 80**

UK 80 is a mixed farm located in Yorkshire, United Kingdom. Beef finishing makes up 61% of its revenue share while 39% of the revenues are from its cow-calf enterprise (compare figure 1 page 15). The farm finishes weaners of continental crossbreeds from own production. When they are transferred to the finishing unit, the weaners and are 210 days old and weigh 285 kg. The finishing period is 550 days and animals are sold for slaughtering at 760 kg live weight. Farm labour is conducted by 2.4 family labour with a calculated wage of € 9.41 per hour (GBP 11.07 ; conversion rate is 1.1761 GBP : 1 € for all UK figures).

All pastures (82 ha) are owned. No arable land is farmed in UK 80. Hay yields are 6 t FM/ha and 4.7 t DM/ha with 9.5 MJ ME/ kg DM energy content and 9% protein. For baled grass silage the harvest provides for 61 t FM/ha (5.5 t DM/ha) at 17% protein and 11.2 MJ ME/kg DM. The regional climate is wet in all seasons with even distribution of 575 mm average annual rainfall, despite slight peaks between September and November. The average annual temperature is 13°C.

**UK 750**

In its location in Oxfordshire UK 750 has an average annual precipitation of 600 mm which is evenly distributed throughout the year while the annual average temperature is 10 °C. Growing season lasts from April to September with yields of 42 t FM/ha (11.7 t DM/ha) for maize silage and 23 t FM/ha (5 t DM/ha) for grass silage. The further has a protein content of 9% and an energy content of 11.2 MJ ME/ kg DM. The latter has the same energy content at higher protein content (15%). UK 750 operates on a total of 170 ha which include 35 ha arable land and 50 ha of pastures. The same amount and share of land is also rented. Soils are composed of clay loam.

The farm finishes purchase backgrounders of continental crossbreeds with a starting age of 540 days and live weight of 475 kg. Cattle are fattened for 210 days to be sold at a live weight of 750 kg. All revenues are from beef finishing (compare figure 1 page15). The farm is run by 1,4 family labour (wage: € 12.75 per hour) and 1,1 permanently hired workers (wage: € 9.17 per hour).

Tables 1 and 2 display the key facts about the typical farms with regards to forage production.

**Table 2: Geographical characteristics of typical farms**

| Farm Nr | Type | Location | Climate | Average annual precipitation | Average annual temperature | Soil type |
|---|---|---|---|---|---|---|
| **DE 260** | Beef finisher | Bavaria, Germany | Df - wet all season | 700 | 8 | Sandy loam |
| **DE 285** | Beef finisher | Schleswig-Holstein, Germany | Df - wet all season | 839 | 10 | Silty loam / clay |
| **FR 60** | Mixed | Pays de la Loire, France | Cbf - Marine | 750 | 12 | Sandy loam |
| **FR 85** | Cow-calf | Limousin, France | Df - wet all season | 1000 | 11 | Sandy loam |
| **UK 80** | Mixed | Yorkshire, United Kingdom | Df - wet all season | 574 | 13 | Clay loam |
| **UK 750** | Beef finisher | Oxfordshire, United Kingdom | Df - wet all season | 600 | 10 | Clay loam |

**Table 3: Forages and yields in the typical farms**

| Farm Nr | Hay | Yield in t per ha FM/DM | Grass Silage Roundbales | Yield in t per ha FM/DM | Grass Silage Clamp | Yield in t per ha FM/DM | Maize Silage Clamp | Yield in t per ha FM/DM |
|---|---|---|---|---|---|---|---|---|
| **DE 260** | x | 8.4/6.7 | x | 22.3/7.1 | x | 22.3/7.1 | x | 54.0/18.9 |
| **DE 285** | | | | | x | 23.6/8.0 | x | 44.8/13.4 |
| **FR 60** | x | 5.5/4.7 | | | x | 33.3/4.5 | x | 32.3/10.5 |
| **FR 85** | x | 5.0/4.2 | x | 7.3/4.1 | | | | |
| **UK 80** | x | 6.0/4.7 | x | 11.0/3.54 | | | | |
| **UK 750** | | | | | x | 23.0/5.0 | x | 42.0/11.7 |

# 5 Results

The following subchapters focus on the results in written form and through diagrams. Firstly, national results will be displayed at single farm-level. Therefore, annual overviews of the operations for each production system give an insight into the operations system as a whole and reveal which operations are outsourced to contractors. Then, diagrams of labor input (h/ha) and the costs per operation (€/ha) will help the reader understand which operations are the most time consuming and costly as well as potential links between the two. Duration and costs of operation are displayed per hectare because it is the most comprehensive and suitable unit to measure capacity and operating costs should be easily comparable to the duration of the single operations. Secondly, costs will be compared internationally per forage to reveal the major differences and their causes. For that purpose the costs were related to the dry matter content of the forages to relate the costs to the actual output. The same diagrams were also produced on per hectare basis and can be found in the data disc attached in Folder 4 - diagrams.

Detailed calculations of the results are provided in the data disc Folder 1-Spreadsheets under Production Systems. Therein are contained all the data and calculations used to provide these results. Additionally, in the appendix p. 35-52 each production system and its result sheet is attached.

The sources of the calculations are indicated at the beginning of each country-section.

Manure and slurry stemming from the same farm were not considered in input costs.

## 5.1 Results: German farms

For Germany two farms were considered and their productions systems calculated: DE-260 and DE-285. Their locations and characteristics are described in chapter 4. (P. 15 f.). Sources for the calculations were the typical farm data for both farms as well as the KTBL database. For DE 260 additionally the Bavarian database of LfL was considered for modeling production systems and yields accordingly. For DE 285 a local consultant provided original data from the farm for most contracting work. For the swathing operation in DE 285 neither original data nor database content could be found. Therefore a price list from a regional contractor (Maschinenring Stade) was used to model the contractor fees. Overhead costs have been calculated based on *agri benchmark* data as provided in the appendix page 28.

## 5.1.1 DE 260

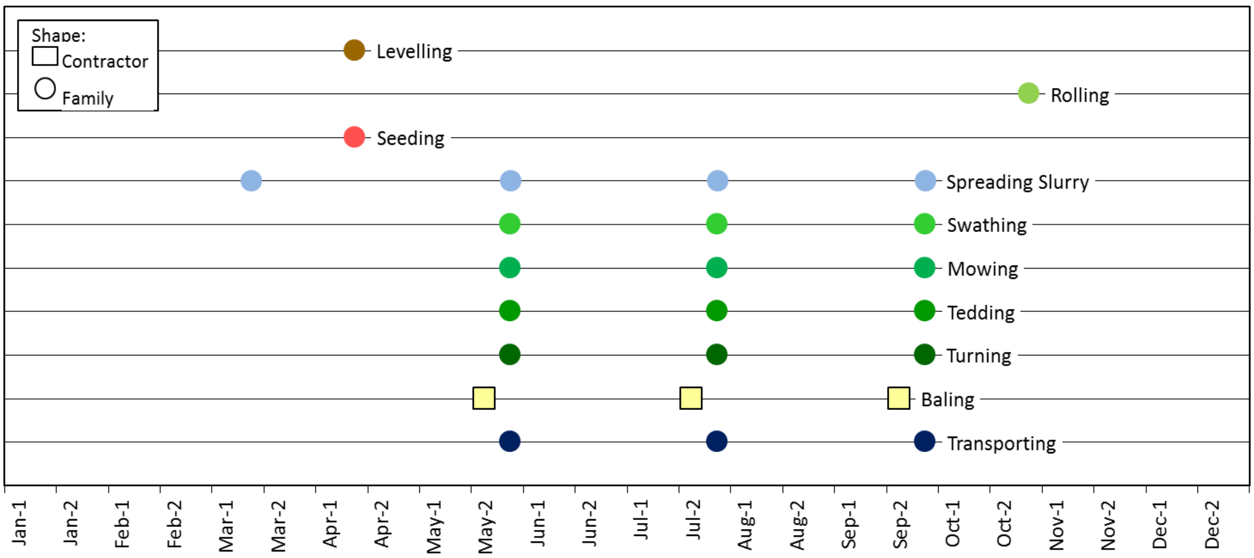
### 5.1.1.1 Operations

In the location of DE 260 four types of forages are produced: hay, maize silage, grass silage in round bales and grass silage in a clamp. They could all be validated in the focus group and are therefore described in detail in the following paragraphs. The typical farm used for this exercise owns only 5 ha of pastures, which are suitable for the production of hay and/or grass silage. To include both production systems it was assumed that they were both grown on the same land. The spreadsheet containing all information on the production systems is included in the appendix on pp. 41.

**Hay**

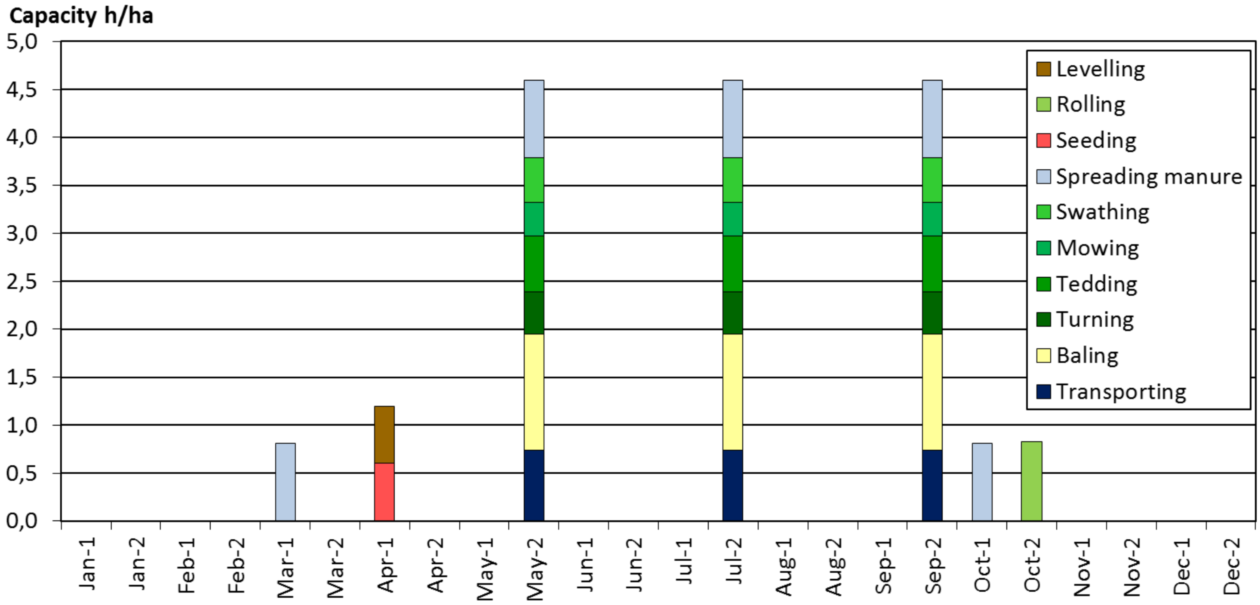
On 5 ha of pasture grass is produced for hay and grass silage. Figures 2, 4 and 6 depict the production steps throughout the year showing that these are no-tillage systems on existing permanent pasture and that no plant protection is applied. All operations are based on family labour except for baling or shredding in clamped grass silage. According to the focus group, it can be considered as typical that hay and grass silage production in the region takes place on permanent grassland because arable land would be used for the production of crops and maize silage which is more profitable than temporary grassland due to the high crop prices and the use of maize silage in livestock and biogas plants.

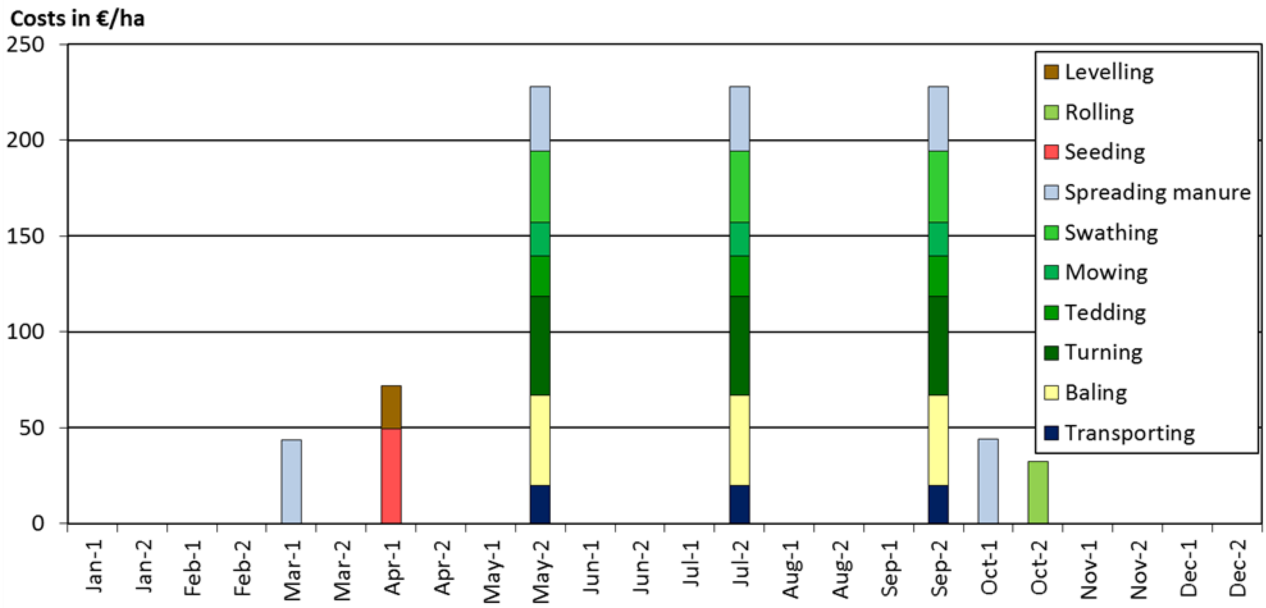
**Figure 2:** Hay - Annual overview (DE 260)




The land is prepared in October by 20 m³ slurry application and rolling, then rests during the winter months. In the beginning of March, slurry (20 m³) is applied again. Thereafter, harrowing and reseeding are performed. Hay is harvested three times at the beginning of its blossom stage in late May, July and September and is then baled in round bales by a contractor without additional drying. The yield is 8,4 t/ha for fresh matter and 6,73 t/ha in dry matter. After each harvest slurry is applied to nurture further growth. Inputs per ha include the 100 m3/ha slurry already mentioned and 6,7 kg/ha of grass seed. Typically no pesticides and no mineral fertilizer are applied in this system. Work peaks in this production system are obviously in late May, July and September (4.6 h/ha) and tied to the harvest (compare figure 3 below). Similarly costs peak in that time (€ 216/ha). Costs and working time are linearly related except for turning: Here capacities from KTBL (0.44 h/ha) for turning were matched with the machinery list, where the equipment for turning would likely be the rotary tedder. For tedding the capacities are lower (0.58 h/ha), that is more time per hectare is required.

**Figure 3:** Hay – Labour input and costs of operations (DE 260)

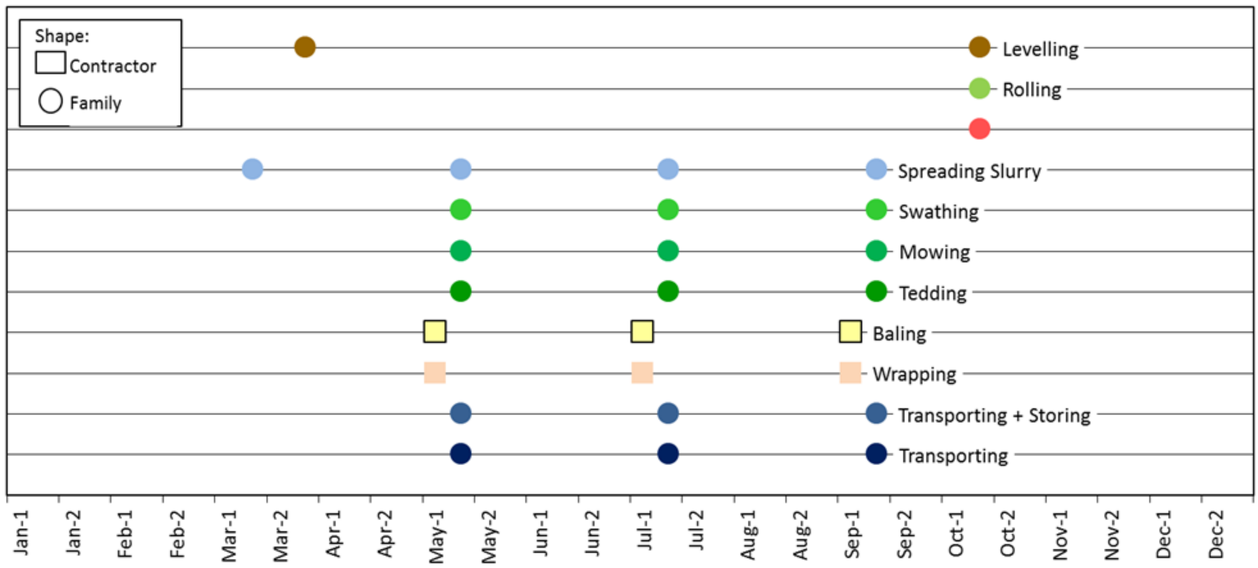


**Grass silage baled**

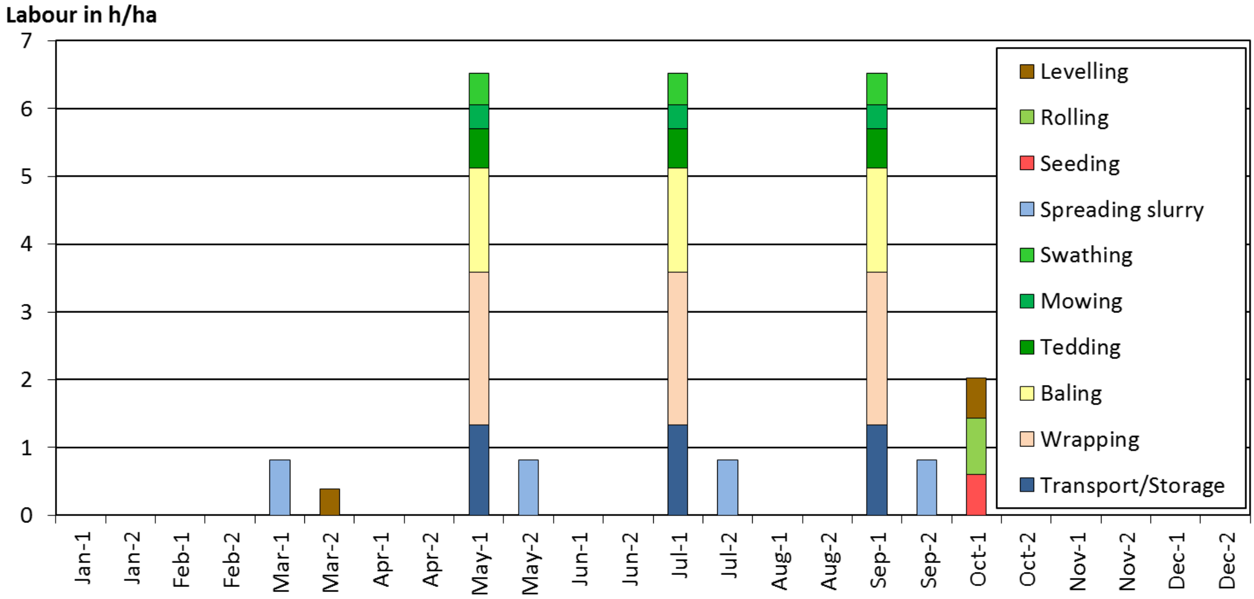
As for hay, the land is prepared by applying 20m³ of slurry and rolling in October for grass silage, but additionally the plot is reseeded with 10 kg of grass seed per hectare and harrowed (see figure 4 below). In early March, 20 m³ slurry is applied before harrowing in the second half of March. With full emergence of the ears the grass is harvested and baled without additional drying or application of silage additives in early May, July and September. A contractor conducts baling and wrapping with foil, all other operations are family labour. Again, 20 m³ of slurry is applied post-harvest, adding to a total of 100 m³ slurry for the whole production system. No pesticides are applied. Figure 5 (p. 24) shows that similar to the hay system grass silages have their working peaks at harvesting time in early May, July and September. Additionally, the first half of October also holds an increased work load for preparatory measures and seeding.

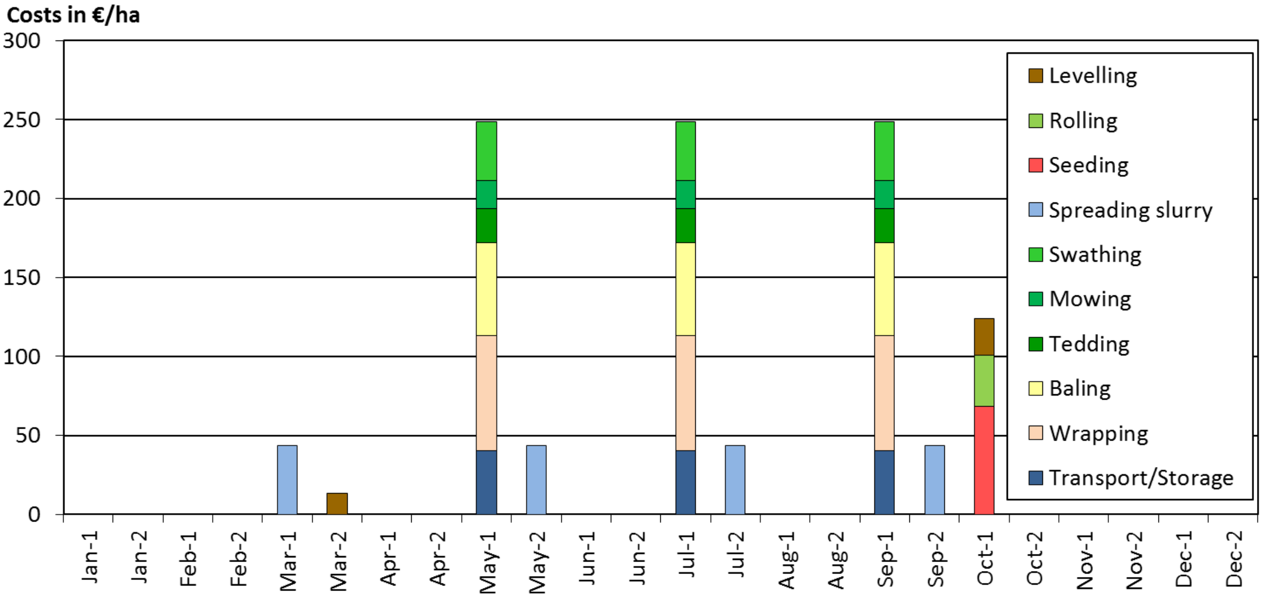
**Figure 4:** Grass Silage (RB)- Annual overview (DE 260)




Workload peaks during harvesting time (6.43h/ha) as illustrated by figure 5 on page 24. More than 50% of the harvesting time is spent on baling and wrapping (combined 3.79h/ha). This relation is also reflected in the costs of these operations (€ 132 /ha), which make more than half of the costs for the harvest (€ 239/ha). Mostly, costs are closely related to the working time, except for seeding. Though it has the same labour requirements (0.6 h/ha) the costs (€ 68/ha) are twice as high (€ 23/ha for leveling). This is due to the input costs of seeds (€ 45/ha) that make two thirds of the operating costs.

**Figure 5:** Grass silage (RB)-Labour input and costs of operations (DE 260)

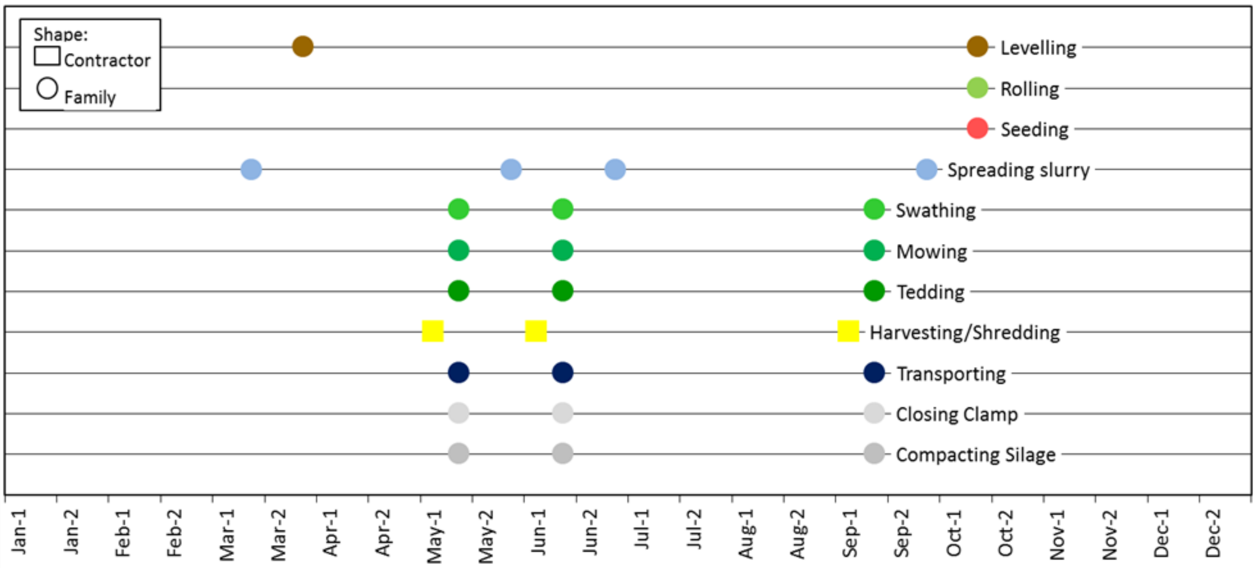



## Grass silage clamped

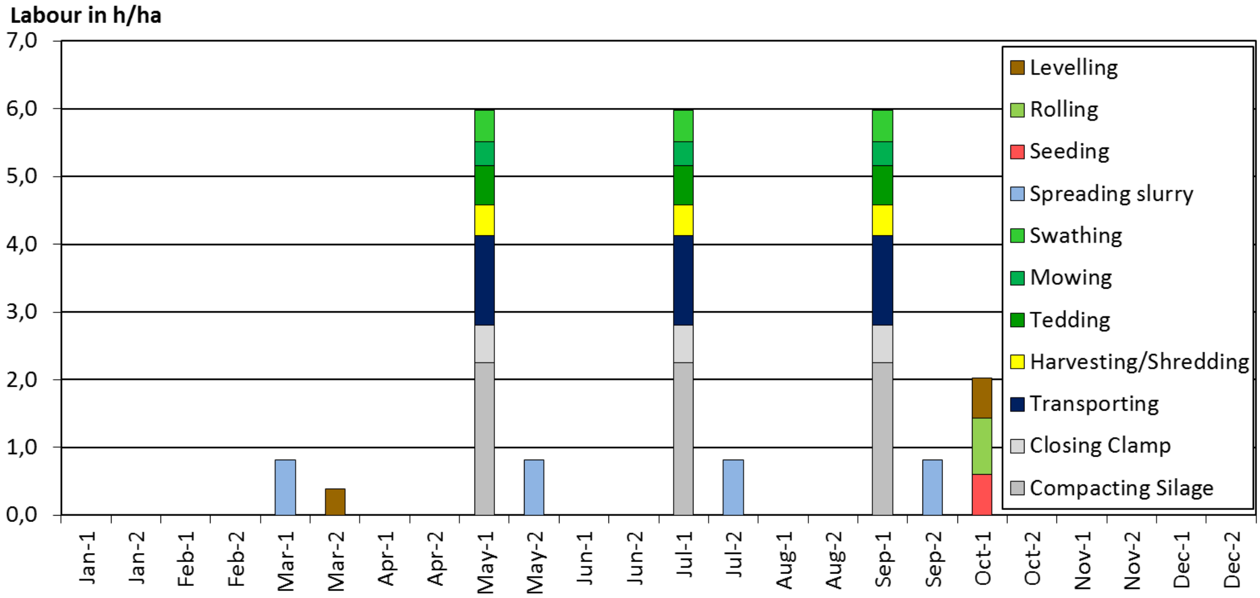
Grass silage for the clamp is produced in exactly the same way as grass silage in round bales (see above) except that after harvesting the silage (mowing, tedding, swathing) a contractor chops the grass for storage in the clamp. After chopping in early May, July and September the silage is transported to the clamp and compacted with a tractor. Figure 6 below provides an overview of the operation steps through the year.

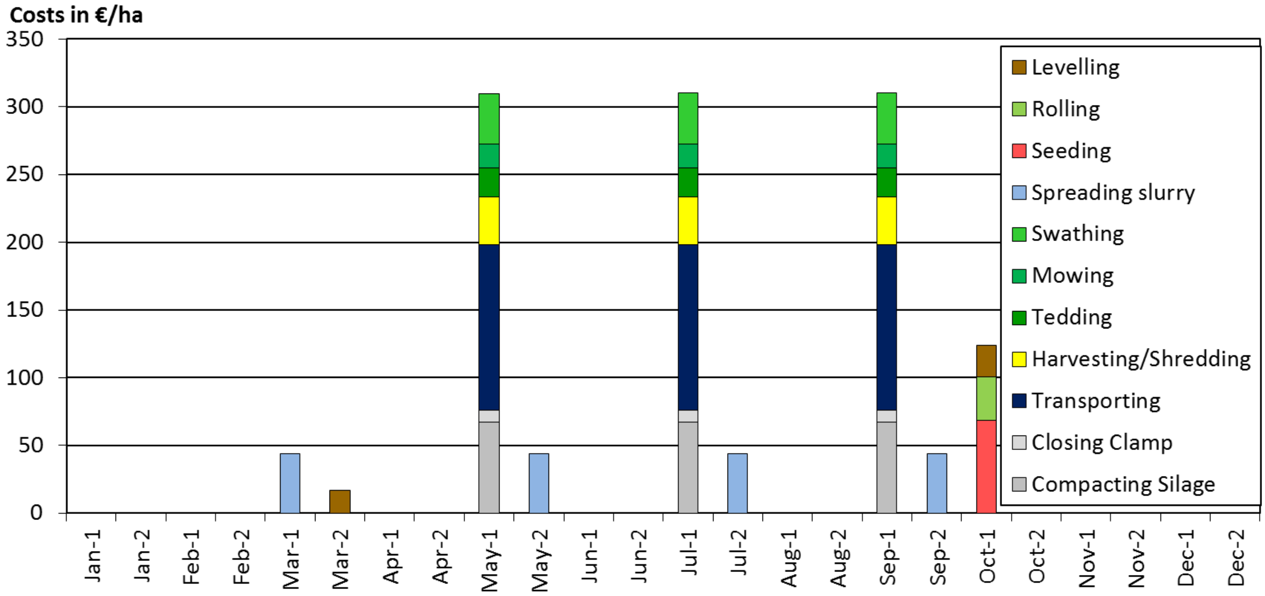
**Figure 6:** Grass silage clamp – Annual overview of operations (DE 260)




The workload diagram (figure 7 page 26) reveals that the working peaks are during the harvesting periods of grass silage in the clamp, like in hay and grass silage for round bales. Workload during those peaks (6.0 h/ha) is similar to grass silage round bales (6.5 h/ha) but slightly lower, saving 1.5 h/ha per year. Compacting silage has the biggest share in the duration of harvesting operations (2.25 h/ha). In the discussions with the focus group for DE 260 and DE 285 compaction played a crucial role and was named as the limiting factor for the speed of the entire harvesting chain. Weight and capacity of the farm tractor is often not compatible with the high capacity of the harvesting equipment provided by the contractor. This issue will be addressed in more detail in the discussion in chapter 6.

**Figure 7:** Grass Silage Clamp – Labour input and costs of operations (DE 260)



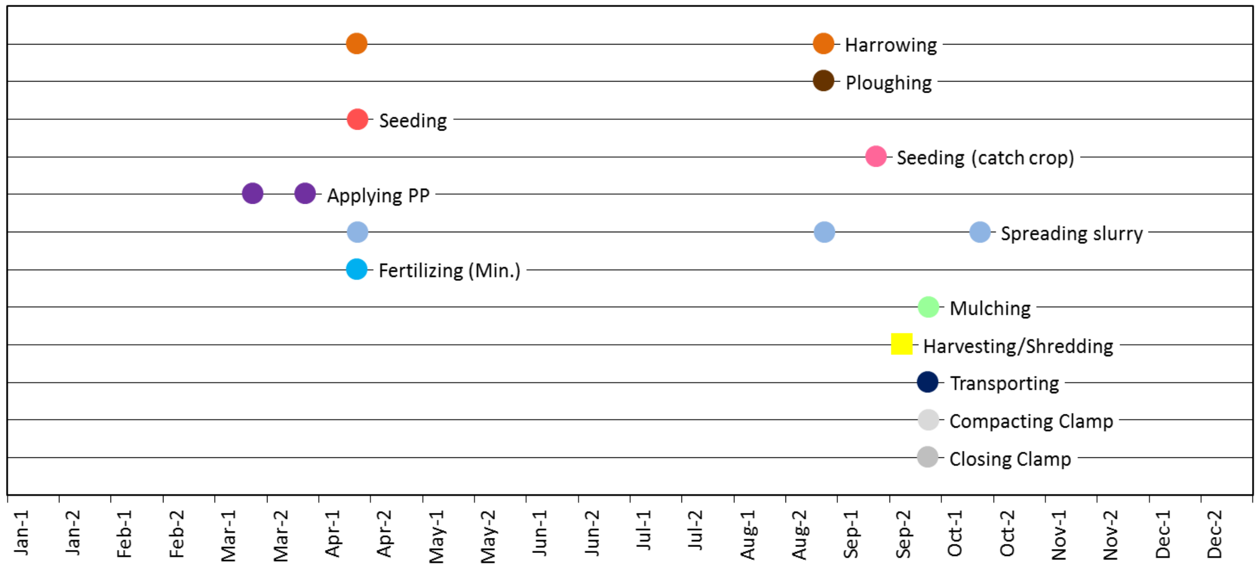




## Maize silage

The major forage in DE 260 in terms of area planted and energy yield is maize silage (compare chapter farms on p. 14). Other than grass-based systems, maize can only be produced on arable land. In August, land is cultivated and fertilized with 20 m³ slurry before ploughing. In early September, mustard is established as catch crop with 10 kg of seed per hectare and fertilized with 20 m³ slurry in early October. After freezing of the catch crop during winter, glyphosate is applied for plant protection in the second half of March. In the first half of April, the field is harrowed and maize is sowed (2kg per ha) with a precision drill. Subsequently, 20 m³ slurry and 400 kg mineral fertilizer (108 kg) are applied. In total of 60 m³ of slurry are spread in this system.

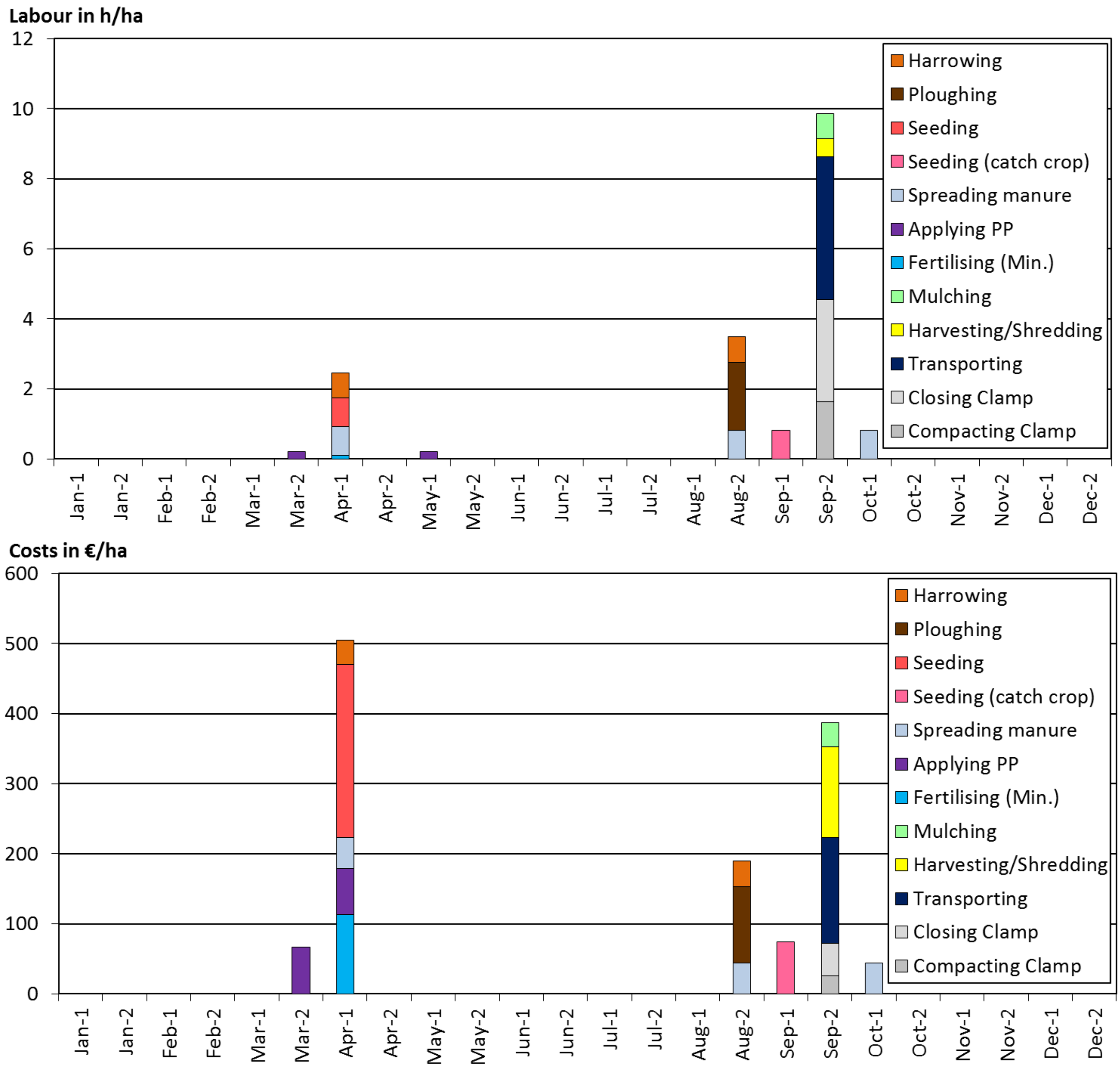
Another plant protection measure is applied in the beginning of May. In late September, the maize is harvested by a contractor and transported by the family before storing it in the clamp and closing the clamp with foil. The remaining straw on the field is mulched post-harvest to reduce the risk of pests. The highest workload for maize silage in DE 260 is in September during the harvest. The second half of April and the first half of August also show an increase in operation on the field.

**Figure 8:** Maize Silage - Annual Overview (DE 260)




Maize silage production in DE 260 clearly has one labour peak, which occurs during harvesting time in the second half of September (compare figure 9 on the next page). Harvesting operations in total occupy labour with 9.8 hours per hectare. Transportation contributes almost half of these costs (4.1 h/ha) due to the high yield in maize. Harvesting costs reflect the high capacity and supposedly related size of the contractor’s machinery (€ 130/ha). Obviously in the first half of April the input costs for fertilizer, seeds and plant protection (€ 108/201/114 per ha respectively are the cause for the disproportionately high operating costs. In harrowing, spreading manure and ploughing costs and labour input are clearly related.

**Figure 9:** Maize Silage – Labour input and costs of operations (DE 260)




## 5.1.1.2 Comparison of forage costs (farm-level)

In the following, costs are differentiated in operating and overhead costs. They are defined as follows (for detailed description of costs see also chapter 3 material, methods and calculations on pp. 5):

**Operating costs**: seeds, fertilizer, plant protection agents, variable machinery costs (namely fuel, depreciation, interest and repairs), costs for labour by family and contractors.

**Overhead costs**: Storage costs of forages in existing buildings, land (rented and owned), share in other overhead costs (includes farm insurance, disability and accident assurance, farm taxes and duties, advisor costs, fees for accountants and legal advice, phone and utilities, other input).

The cheapest forage for DE 260 is maize silage. With total costs of € 100 per t DM, it is only two thirds of the costs of all other forages produced (compare figure page X). Bearing in mind that maize silage also has the highest energy content (11.1 MJ ME / kg DM) makes it even more attractive. Costs for producing both grass silages are similar with round bales costing €239 per t DM and clamped silage € 242 per t DM. Hay is the most expensive forage at € 245 per t DM.

**Figure 10:** Cost comparison for forages analyzed (€/t DM) - DE 260

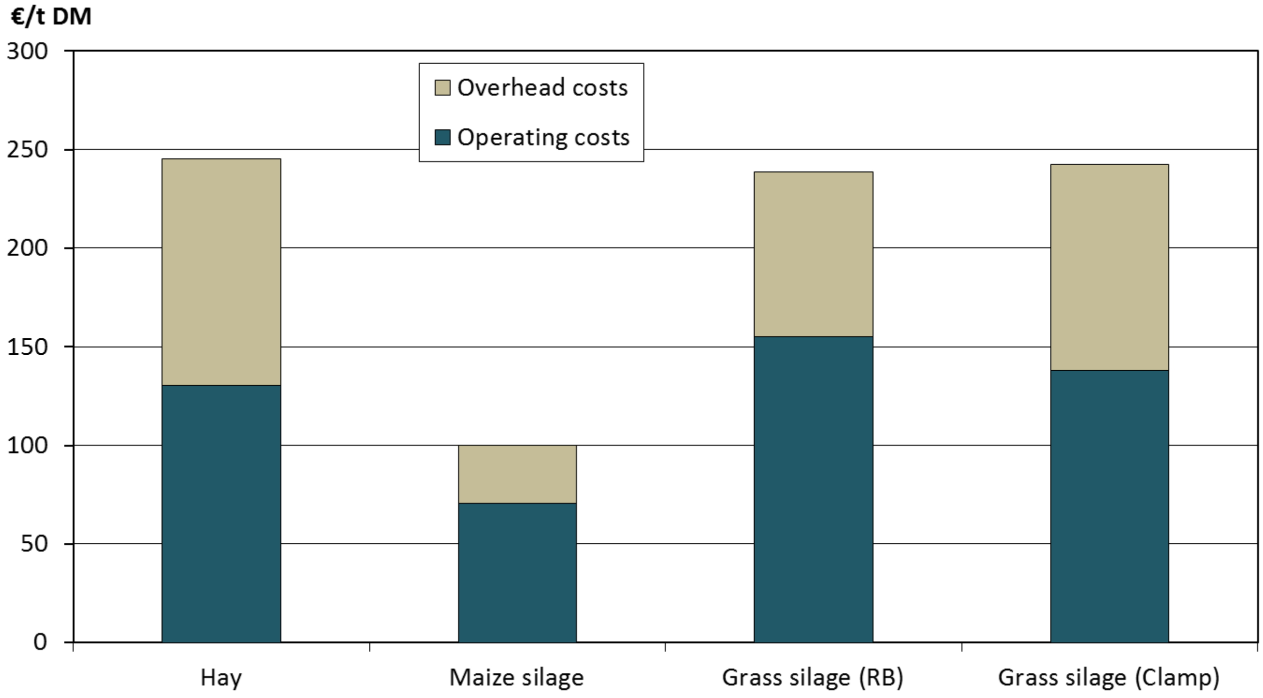
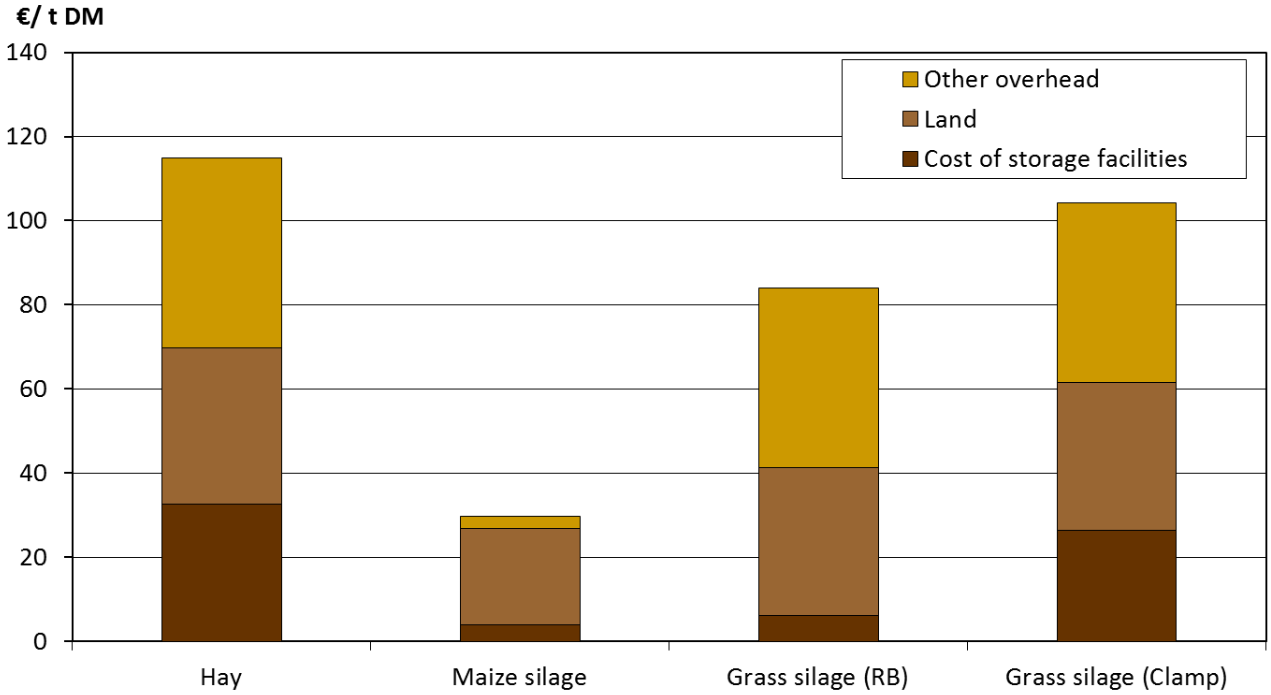



Figure 10 also shows that the proportion of operating costs varies with the type of product. Producing baled grass silage has higher operating costs than the production of clamped silage of the same type. The major reason for this difference in operating costs is the type harvesting operations and quantity. Maize silage is harvested once per year with high capacity equipment that is rented from a contractor and the forage can be stored immediately after cutting. Grass based systems on the other hand require drying or at least wilting of the fresh matter before the actual forage production (baling or storage in clamp) can take place. To facilitate drying grass cut is moved many times e.g. tedded which leads to increased use of machinery and labour (compare figures 5 and 7). After mowing hay is moved in six single operations (1 x tedding, 3 x turning, 2x swathing) before it is baled, that is labour input is very high when compared to the dry matter output. Besides, grass silages and hay are harvested three times per year in DE 260 while maize silage is harvested only once.

Hay has the highest proportion of overhead costs of almost 40 %. The overhead costs displayed in figure 11 show that the greatest proportion is the high cost for storage facilities (€ 33 per t DM).

**Figure 11:** Overhead costs comparison of forages analyzed (€/t DM) - DE 260



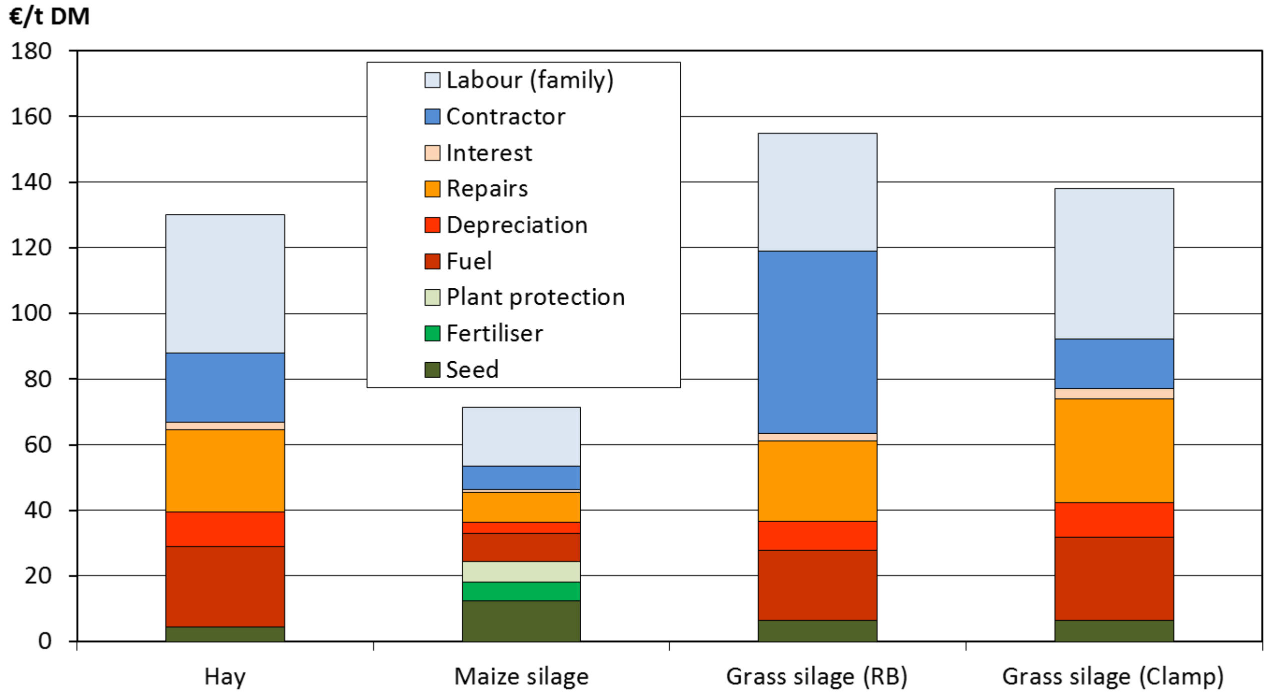

For detailed explanation of the composition and calculation of overhead costs is included in chapter 3 Methodology on pp. 4

The advantage pastures have in terms of land costs (compare data sheet "land costs",appendix p. 27 vanishes when the yield is considered. Through higher dry matter yields of maize silage the land costs are even lower than in the grass systems despite the fact that rental prices for arable land (€ 432 per ha) are € 182 higher than for permanent grassland (€ 250). Additionally, other overhead costs are 90% lower in maize silage because yields and planted area are bigger. Consequently, maize silage has the lowest overhead costs accounting for only half of the grass silage costs.

Furthermore, operating costs for maize silage are the lowest in DE 260 as figure 13 on the next page shows, although its' seed costs are three times as high as in the grass-based systems and fertilizer and plant protection add further costs in maize production. This raises the question why operating costs be that much lower? Maize silage benefits from the quick harvesting operations that are only conducted once per year and within short time, causing relatively low costs for labour and machinery, while grass is cut three times in silages and hay and moved many times through swathing and tedding before the final storage can take place. When comparing the grass-based forages, machinery costs are roughly equal despite the different storage systems that are applied (see figure 12, next page).

The main difference between hay, grass silage in the clamp and in round bales is the amount of labour required by family staff and contractors. While hay and grass silage (clamp) have similar costs for labour (€ 63 per t DM and € 71 per t DM, respectively) as well as proportions of contracted labour and family labour, baled grass silage is the most labour-intensive system. Baling grass silage involves ten times the work time of contractors than storing it in the clamp and causes 50% higher total labour costs per ton (compare spread sheet 260 Results work time).

**Figure 12:** Operating costs comparison of forages analyzed (€/t DM) - DE 260




### 5.1.2 DE 285

Two types of forages are produced at the farm: grass silage in the clamp and maize silage in the clamp. The further has a total planted area of 23 ha on permanent existing pasture which is predominant in this area. Costs and operations were also modeled for the same farm producing grass silage including tilling operations on arable land and are included in the spreadsheet for DE 285 on the data disc attached (Folder 1- Spreadsheets). The major share of forages in terms of area planted in DE 285 is made up by maize silage, which is grown on 60 ha of arable land.

#### 5.1.2.1 Operations

**Grass Silage (Clamp)**

The production begins in the first half of October, when the pasture is leveled with spring tine harrows and re-seeded with 4 kg/ha of grass seed (compare figure on page 32). In the second half of March another leveling operation is performed and the plot is rolled. All these cultivating operations are performed by family labor. Still in late March a contractor spreads slurry (20 m³). Additionally the plot is fertilized twice beginning April with 580 kg of NPK fertilizer (15:9:20) and

240 kg of NP fertilizer (20:20) by family labor. In the second half of May the silage is mowed at full ear emergence and tedded, before a contractor swathes the harvest and shreds it with a chopper. Subsequently the harvest is transported by family labor, compacted and the clamp is being closed. In the second half of June slurry (20 $m^3$) is spread again before harvesting operations are repeated in the second half of July. Post-harvest 10$m^3$ more of slurry are applied and 220 kg of mineral fertilizer (NPK 15:9:20) supplement the organic fertilizer. In the second half of August, the last harvesting operations are performed. Total fertilizer input amounts to 50 $m^3$ of slurry, 800kg of NPK (15:9:20) as well as 240 kg NP fertilizer. No plant protection is applied in this system.

**Figure 13:** Grass Silage (Clamp) – Annual Overview (DE 285)

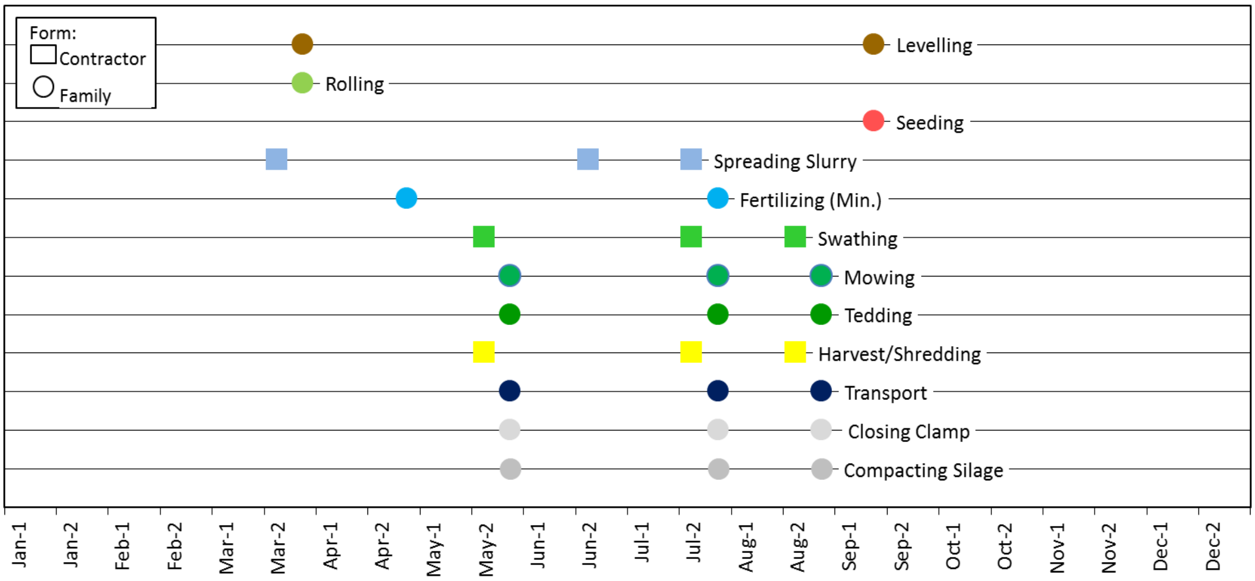
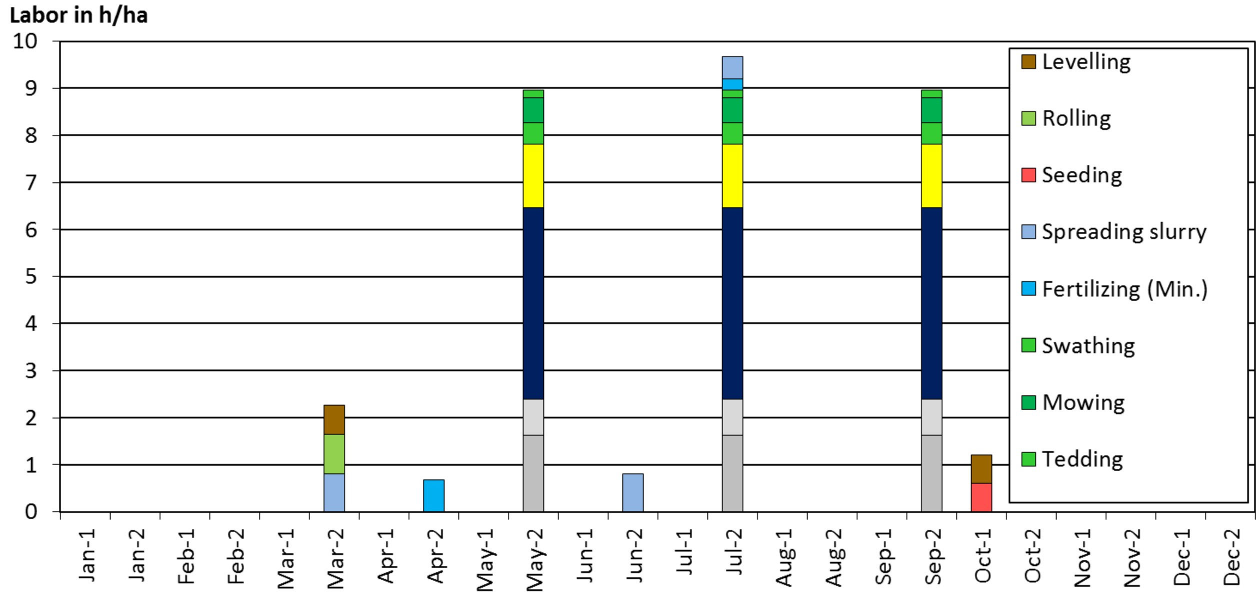
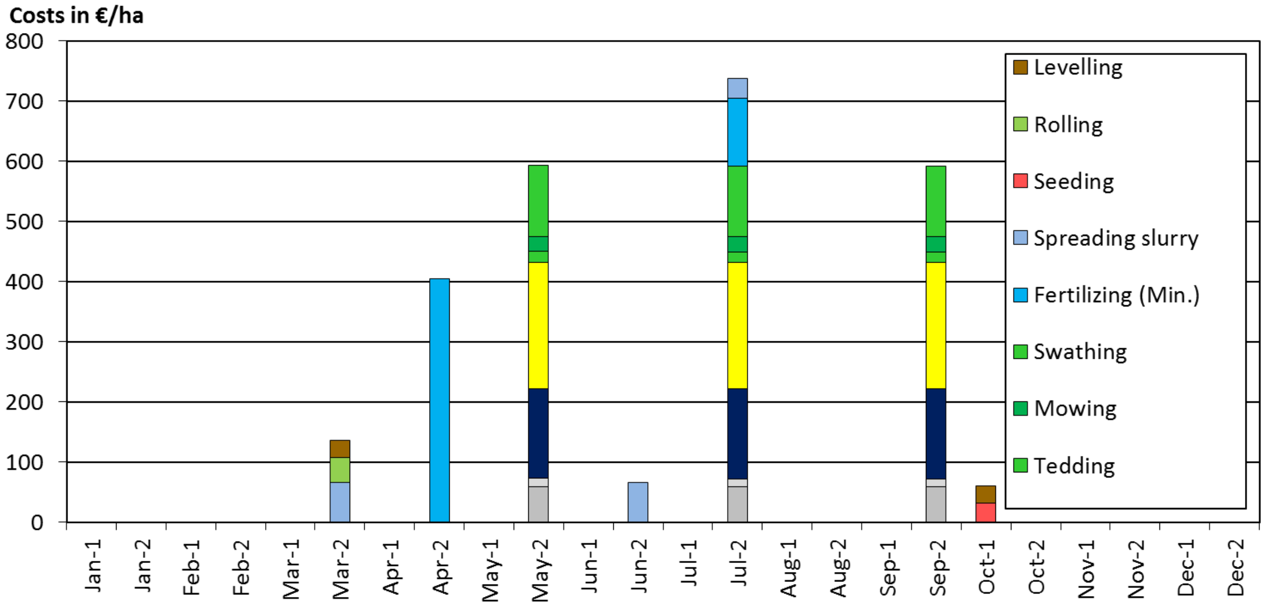



Figure 14 on the next page shows the working peaks and costs for the operations in clamped grass silage in DE 285. It is obvious that harvesting operations are the most time-intense periods of the production. In the second half of July, when the field is fertilized post-harvest the highest workload occurs (9.7 h/ha). Transporting is the most time-consuming single operation with 4.1 h/ha and makes more than 50% of the working time together with compaction of the silage (5.7 h/ha transport & compaction). In this calculation harvesting (1.35 h/ha) and compacting (1.63 h/ha) have about equal shares in time. When comparing workload and costs it is evident that inputs influence the operating costs significantly: Mineral fertilization in April has a total operating time of 0.67 h/ha but amount to operating costs of € 404/ha. Input costs (€ 371/ha), that is, fertilizer costs amount to 92%. Comparing transport and harvesting in terms of duration (0.82 h/ha) reveals that for each minute of the harvester about 5 minutes of transport (4.07 h/ha) are required. In the same time for every Euro per hectare spent on harvesting only € 0.70 /ha are spent on transportation. Another operation that is disproportionately expensive with regard to the working time (0.18 h/ha) is swathing. This could be related to the fuel use in swathing and the factor for external work used in the contracting price.

**Figure 14:** Grass Silage (Clamp) – Labor input and costs required for operations (DE 285)

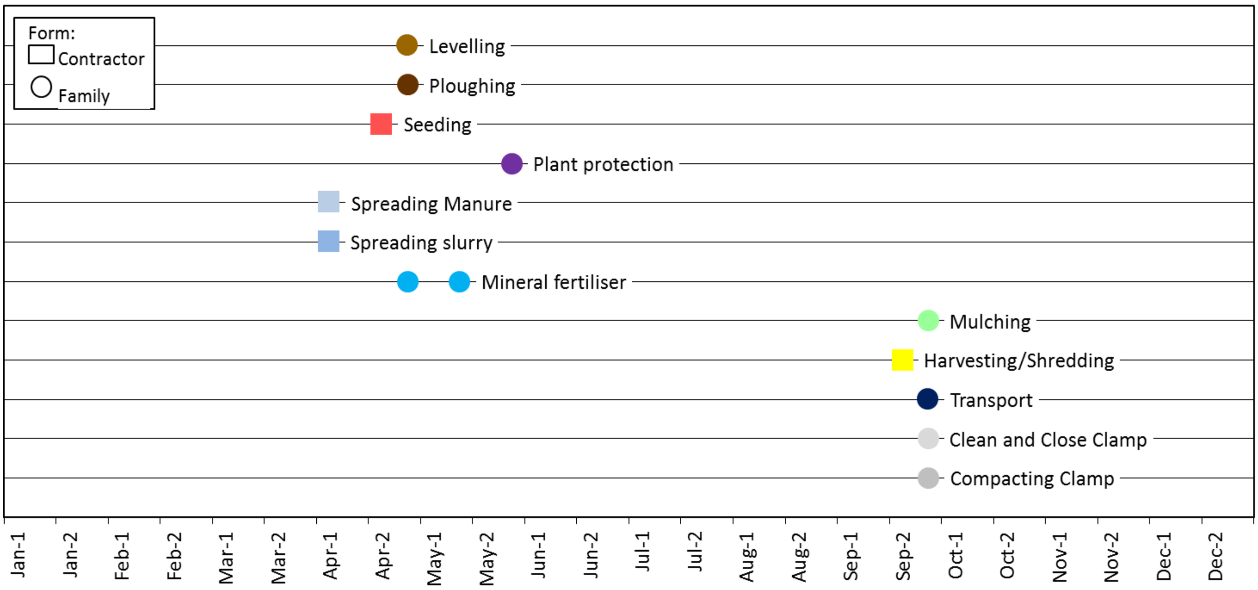



## Maize Silage (Clamp)

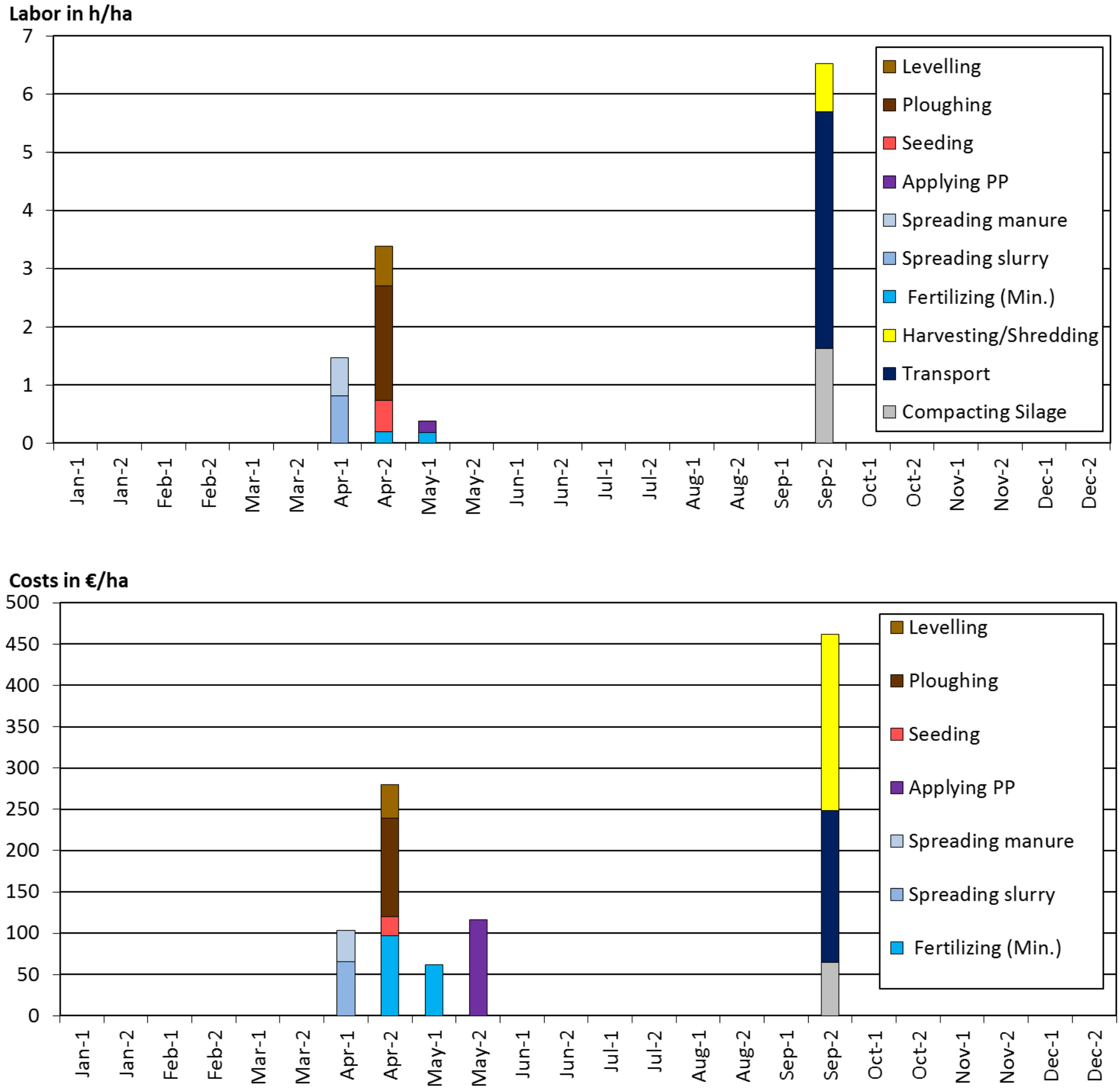
Beginning April a contractor applies 20m³ of slurry and 10 t of manure before family labor ploughs and levels the field with rotary harrows in the second half of April. The contractor also seeds maize (1.3 kg/ha) in late April. Around the same point in time, the field is fertilized with 190 kg of NP fertilizer (20:20). In May family labor applies 110 kg of nitrogen fertilizer (40%) and plant protection (herbicide). End of September the harvest is conducted: A contractor chops maize and family labor transports it to the clamp, where the shreds are compacted and then ensilaged.

**Figure 15:** Maize Silage (Clamp) – Annual Overview (DE 285)




Even though the annual overview for maize silage suggests that the peak workload would be in the second half of April, figure 16 illustrates that the biggest share of working time is allocated to the harvest in the second half of September (6.5 h/ha). As in grass silage, transport is the most time-consuming operation with 4.1 h/ha and takes almost two thirds of the time for harvesting. Besides, ploughing is time intense with 1.97 h/ha. The maize production has two working hot spots: late spring and the second half of September. Though harvesting costs (€ 214/ha) and time have a similar relation to transporting (€ 189/ha) as in grass silage. Within the costs for plant protection (€ 116/ha) only € 4/ha are labor costs, which explains the asymmetry of duration and costs for that operation.

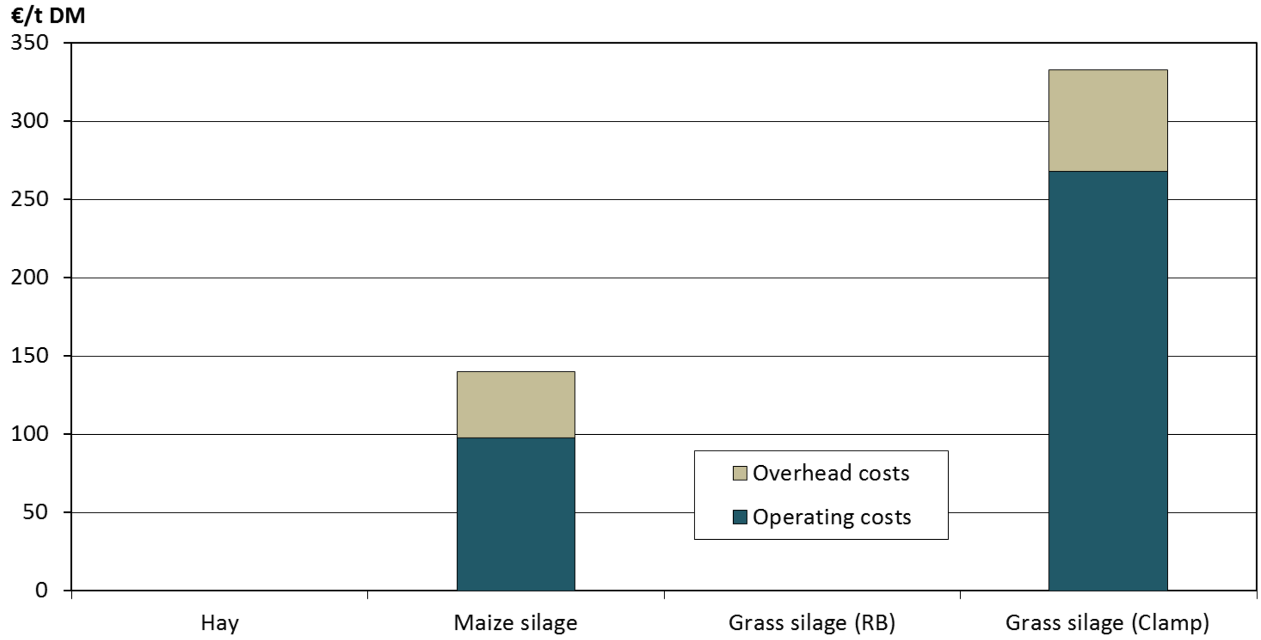
**Figure 16:** Maize Silage (Clamp) – Labor input and costs required for operations (DE 285)




## 5.1.2.2 Comparison of forage costs (farm-level)

Based on dry matter maize silage is the cheapest forage for DE 285 at € 140/t DM as figure 17 on page 36 will show. Also based on the hectare (€ 1874/ ha) maize silage is cheaper than grass silage (€ 2671/ha, compare appendix p. 36). Operating costs make € 98/t DM in maize and € 268/t DM in grass silage. In total grass silage (€ 333/t DM) is more than twice the price of maize silage.

**Figure 17:** Costs comparison for forages analyzed (€/t DM) (DE 285)




The major reason is the operating costs of grass silage, which are roughly three times as high as in maize silage. The distribution of operating costs in figure 19 on the next page will show, whether this relates to the fact that grass is cut three times while maize is only cut once. Overhead costs for maize in DE 285 are a little less than 30% (€ 42 out of 140/t DM) while they make € 65/t DM out of € 333/ t DM (20%) in grass silage. Figure 18 below displays the distribution of overhead costs.

Although land costs are cheaper per hectare in grass silage (€ 325/ha) than in maize silage (€ 400/ha) the dry matter yield in maize (13.1 t DM/ha), which is 50% higher than grass (8,0 t DM/ha), gives maize an advantage over grass of € 11/t DM. The same holds true for costs of storage: the yield makes hem cheaper in maize despite the fact that per hectare the costs are almost the same (€ 142/ha GS, € 145/ha MS).

**Figure 18:** Overhead costs comparison for forages analyzed (€/t DM) - DE 285

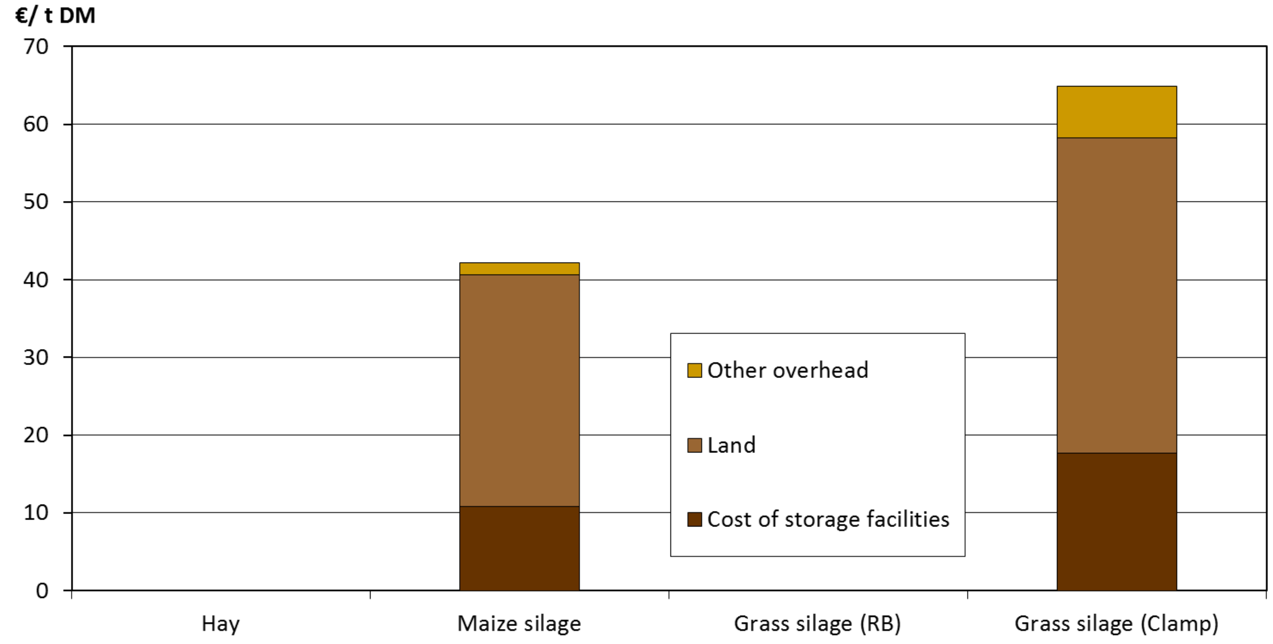



**Figure 19:** Operating costs comparison for forages analyzed (€/t DM) - DE 285

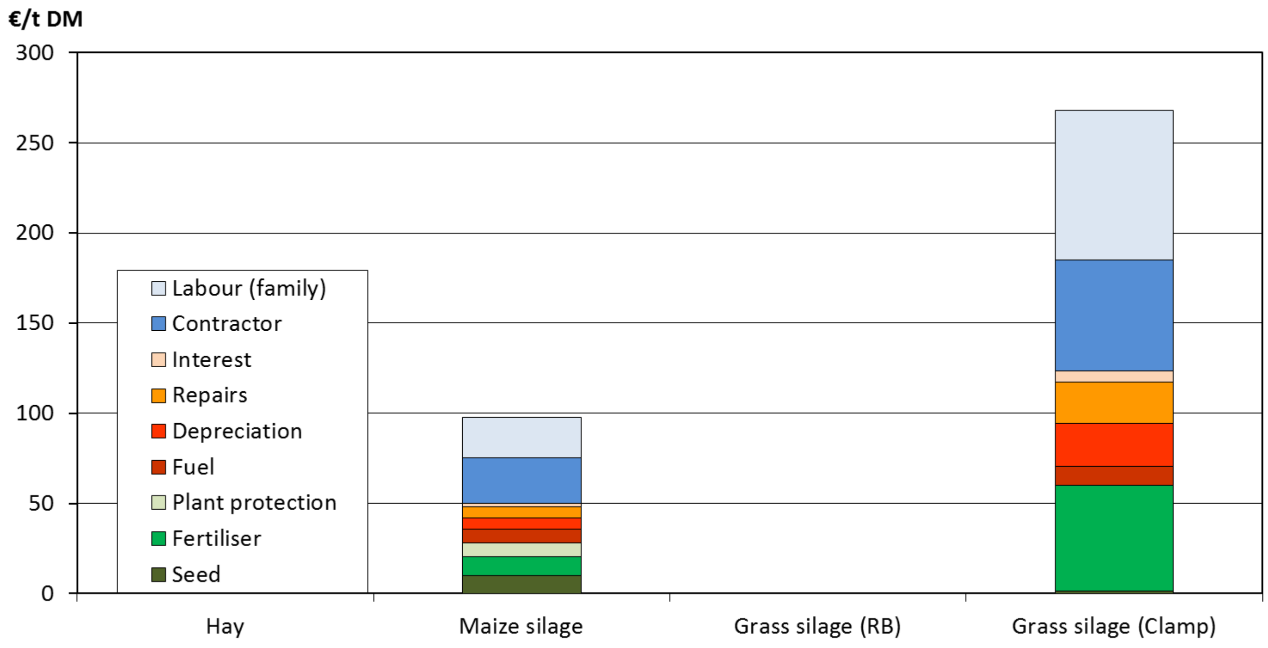



Figure 19 above next page shows that costs for contractor and family labor (€ 144/t DM combined) amount to over 50% of the operating costs (€ 268/t DM) of grass silage. In Maize silage the proportion is almost the same (€ 47 out of € 98/t DM). Since total working time in grass silage is 5,6h/ha while maize only needs 1,5h/ha it makes perfect sense that operating costs are simply three times higher with similar distribution of labor, contractor, variable machinery costs and input costs.

## 5.2 Results: French Farms

For France two farms were considered and their production systems calculated: FR-60 and FR-85. Their locations and characteristics were described in chapter 4. (pp. 15.). Sources for the calculations were the typical farm data for both farms that were already very detailed. Missing data like capacities of machinery and fuel use were added from engineering data provided by CUMA (Coopératives d'Utilisation du Matériel Agricole, French for: Cooperatives Using Agricultural Materials, by our French partners. Where no French data was available German engineering data from KTBL was used to provide datasets of repairs, utilization and depreciation periods for the machines used.

In France cooperatives for machinery between farms or in regional clusters are established and used frequently. In the result sheet (appendix p. 37) total working hours are shown for both, contractor and cooperatives. For graphic representation this distinction did not proof feasible though. Besides, the major aim was to show which operations are outsourced by farmers and for that matter there was no need to differentiate between the two options.

Both farms use aftermath grazing in their grass systems (silage). Since this operation cannot be factored into the costs, it is not displayed.

### 5.2.1 FR 60

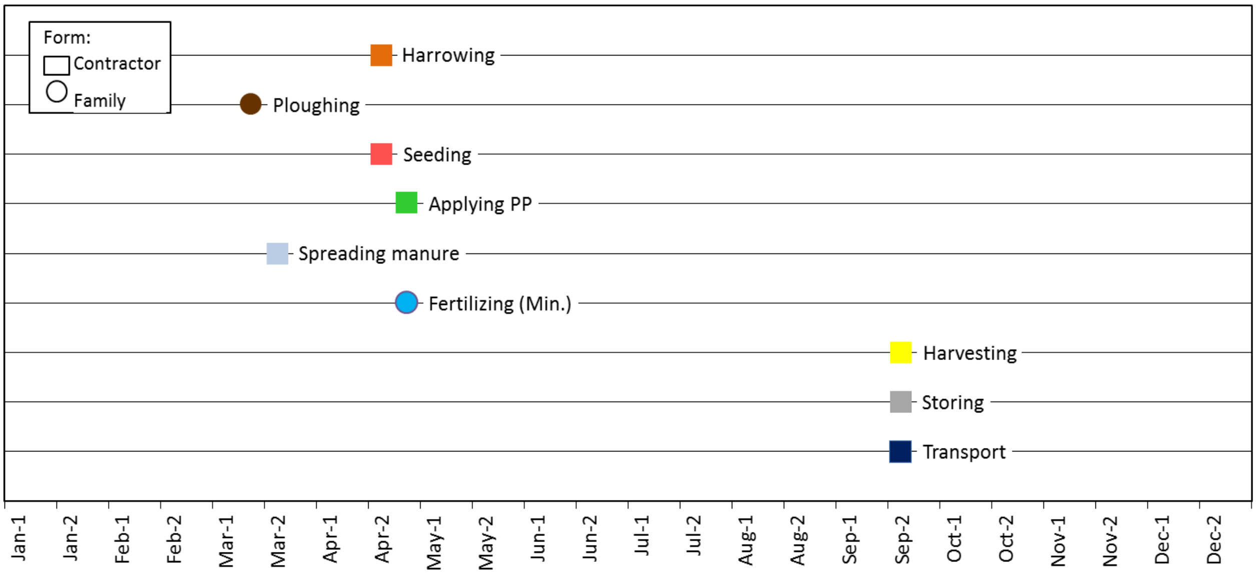
FR 60 produces three types of forages: maize silage, hay and grass silage for the clamp.

#### 5.2.1.1 Operations

**Maize Silage**

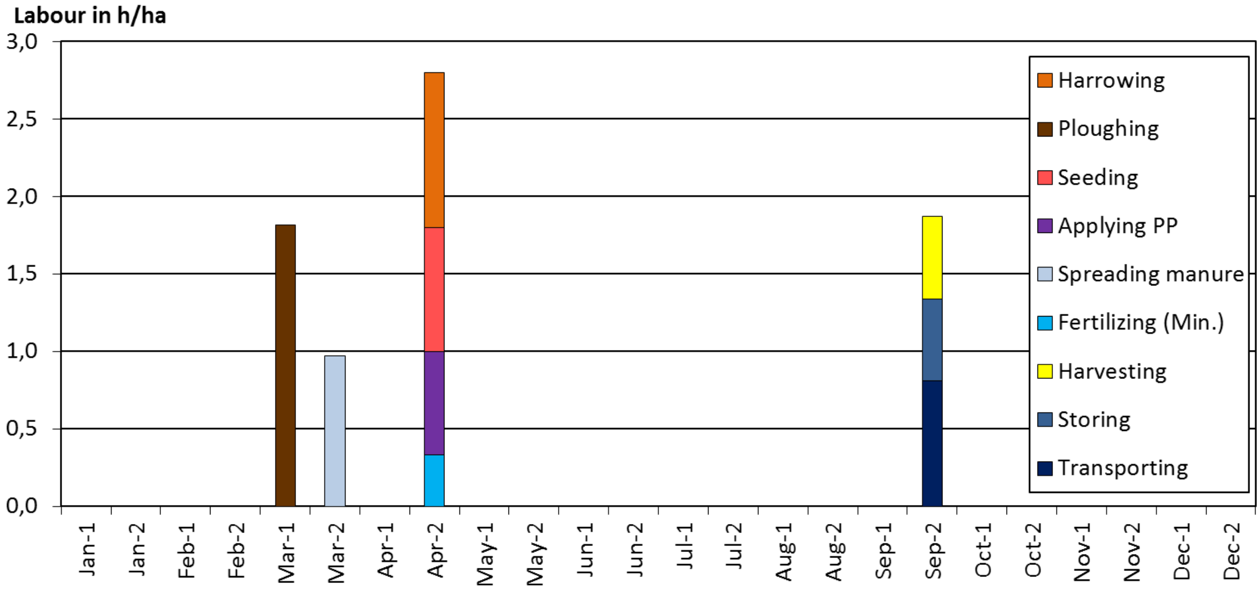
Maize silage is planted on 11 ha of arable land and harvested wax-ripe. The production starts with ploughing in the first half of March conducted by family labour (see figure 20). Shortly after, in the second half of March a cooperative spreads 30 t of manure per hectare. In the second half of April the field is harrowed and sowed with 1.8 kg/ ha of maize seed. Additionally, 100 kg/ ha of NP-fertilizer are applied (18% N, 46 % P) and the field is sprayed with herbicides. The harvest with a chopper is conducted in the second half of September. The harvesting-transport-storage chain is run by a contractor.

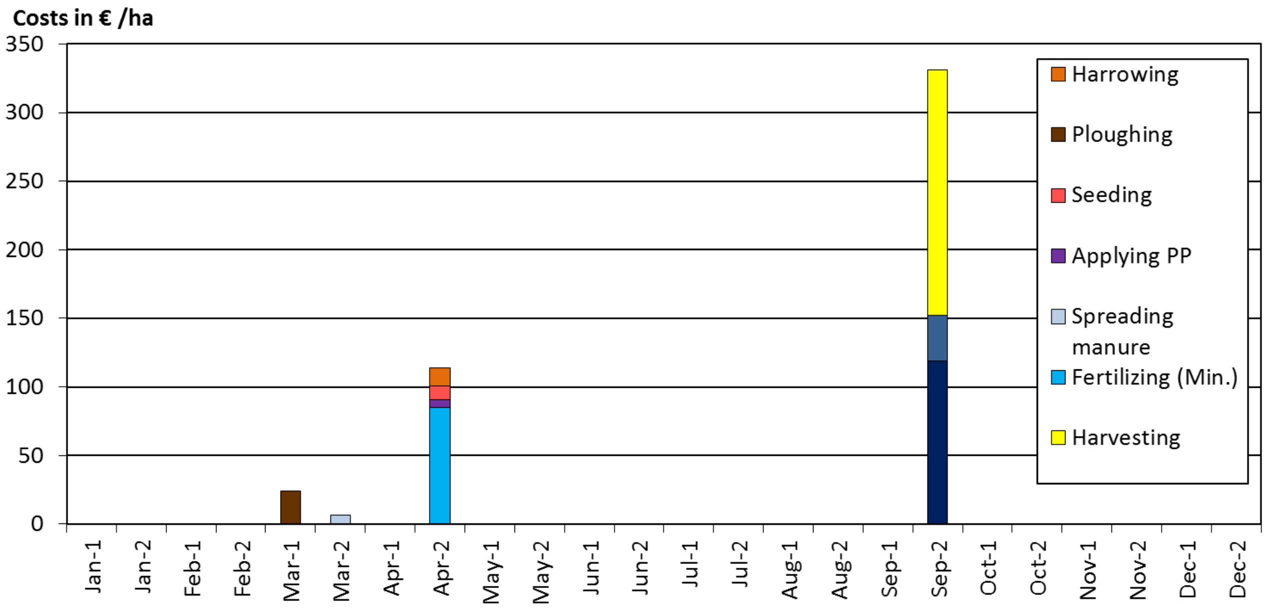
**Figure 20:** Maize Silage - Annual Overview of operations (FR 60)




As the annual overview above suggests there are two labour-peaks in the production of maize silage: the establishment in spring and the harvest in autumn. This is reflected in the cost and labour diagram on page 40 (figure 21). Labour peaks in the first half of March, the second half of April and in harvesting season in September. The single operation requiring most labour is ploughing. The most labour-intense period is the second half of April (2.8 h/ha), when the seed is being established. In terms of costs however, ploughing is rather insignificant (€ 24.18/ha), which can be attributed to the rather low purchase price (2475 €) and high utilization (105 ha/year). By fertilizing the role of input costs is illustrated once again (€ 75 out of € 94/ha). Harvesting operations make the biggest share of the costs (€ 179 /ha). The harvesting season is the most expensive time of the year I this system with € 330 per hectare. The high capacity of the machinery for harvesting of about 30 min per hectare comes at a high price. Neither ploughing nor seed establishment are as costly as the harvesting chain. Especially the harvesting (chopping) itself is costly with € 179/ha. On the other hand ploughing, which is conducted by family labour, costs only € 24/ha. The cheapest operation is the application of plant protection with € 6/ha.

**Figure 21:** Maize Silage – Labour input and costs required for operations (FR 60)

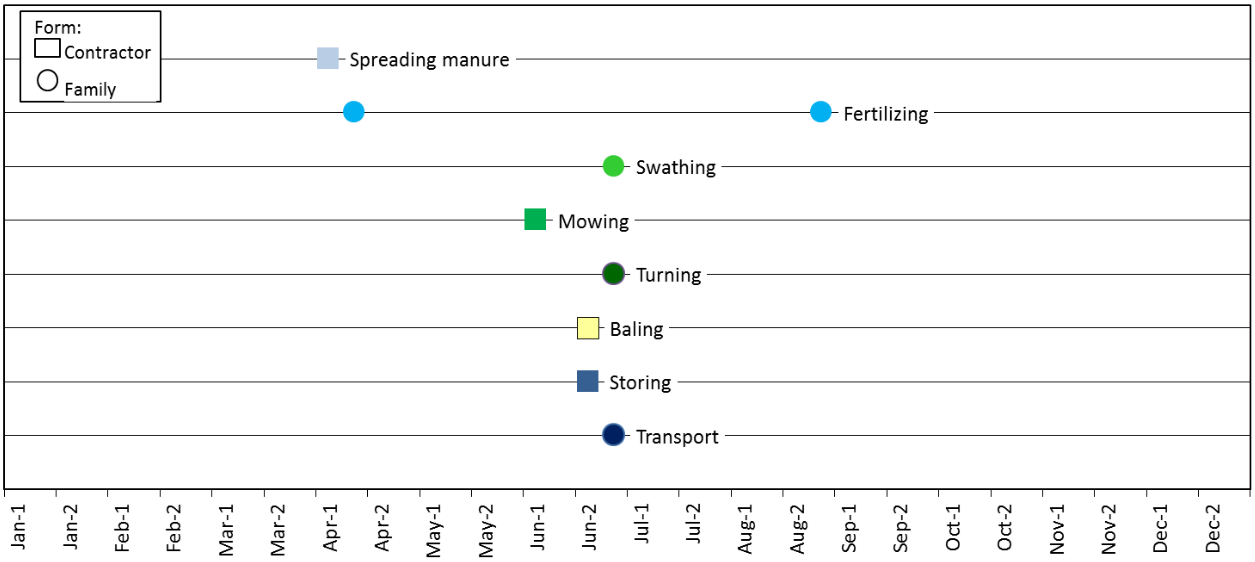



## Hay

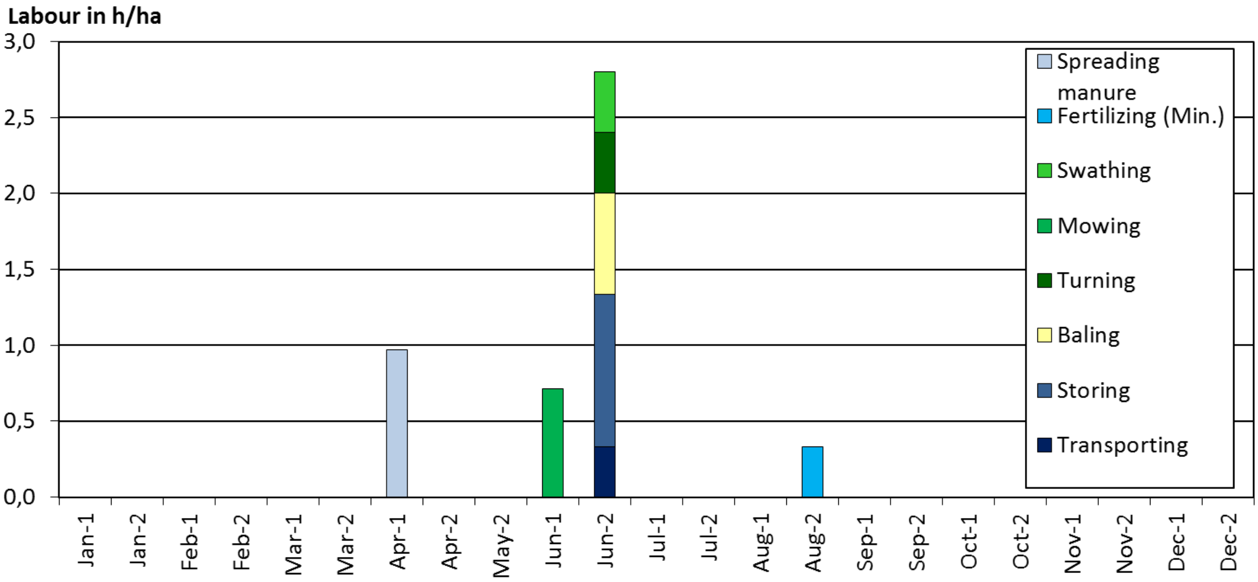
In FR 60 hay is an extensive system with little labour input and operations because no tilling is performed (compare figure 22 below). The allocated pastures (15 ha) are and fertilized with 10 t/ha of manure by the cooperative in early April. In the first half of June the cooperative mows the grass in blossom-stage. No additional drying takes place and after turning and swathing once in the second half of June hay is pressed into round bales, transported and stored at the farm. Post-harvest 150 kg of NP (18% N, 46% P) fertilizer are applied. There is no input of plant protection. Only one harvest is conducted.

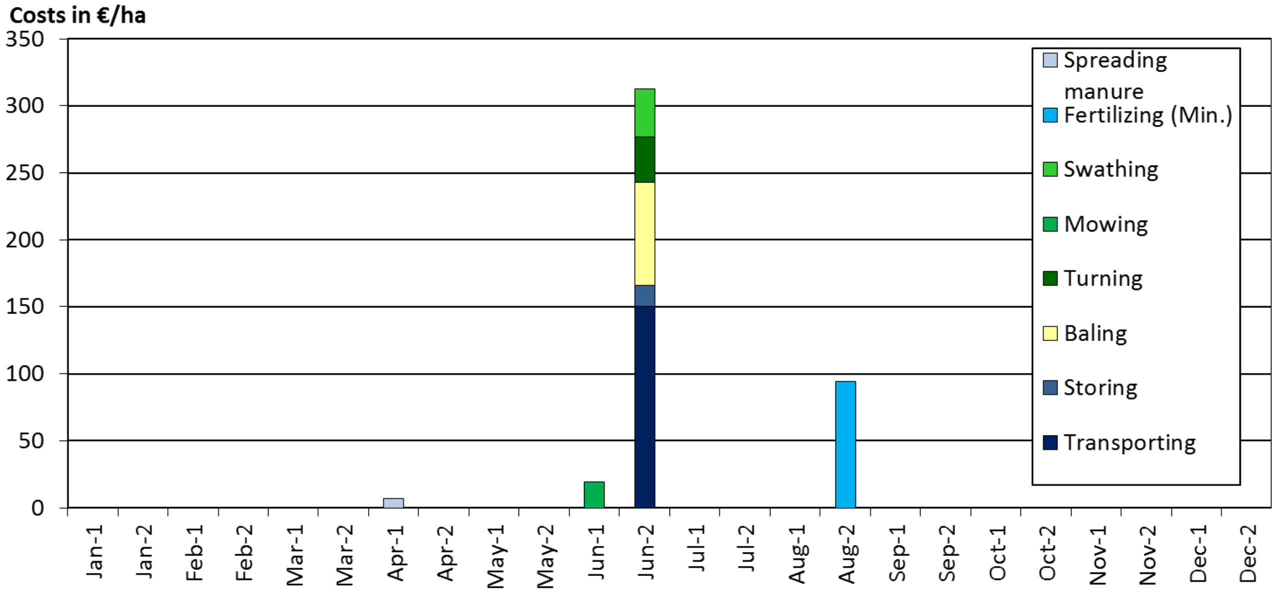
**Figure 22:** Hay – Annual Overview of Operations (FR 60)




Harvesting operations cause the workload to peak in the second half of June as figure 23 below verifies: 3.8h/ha out of the total working time (5.7 h/ha) are required in this period. Storing activities make one fourth of the harvesting time (1.0 h/ha) due to the complex operations of grabbing each bale with a shear grab and stapling bales. Also spreading manure takes more than 15% of the total working time (0.97 h /ha). Overall this production system is rather time extensive though when compared to grass silage (7.8 h/ha) and maize silage (7.4 h/ha). Still the dry matter yield would not justify more labour input.

**Figure 23:** Hay – Labour input and costs for operations (FR 60)

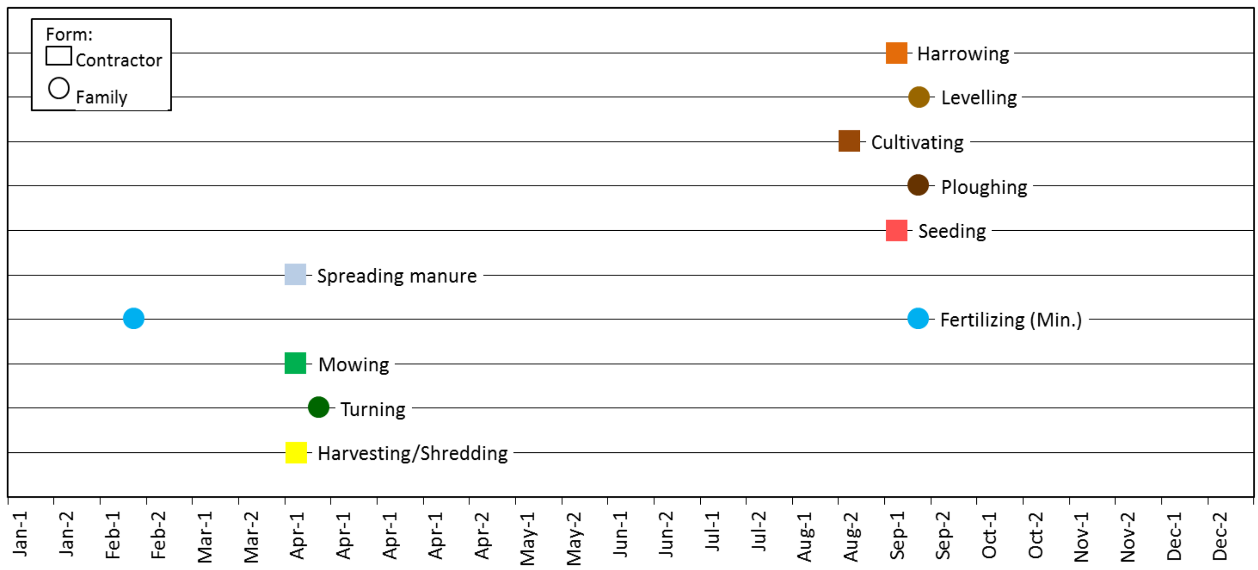





**Grass Silage (Clamp)**

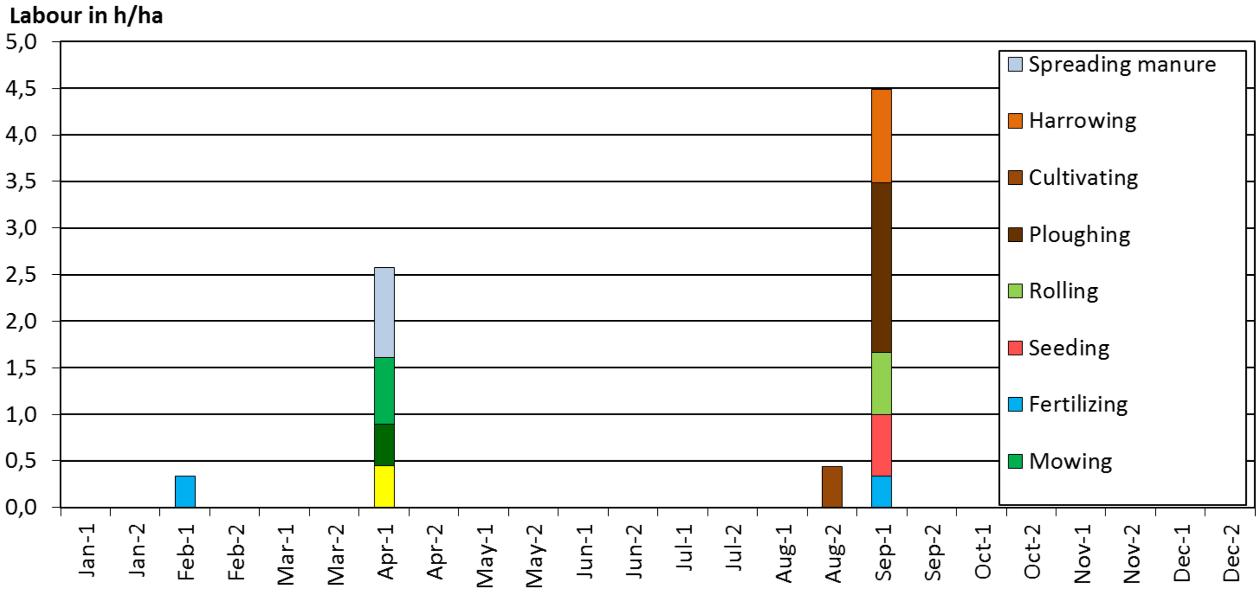
Grass Silage is produced on 12 ha of arable land and harvested at ear emergence one per year. Establishment of the seeds takes place in autumn: end of August the pasture is cultivated before ploughing and leveling it for seeding (30 kg/ha) by a packer and harrowing. The plot is also fertilized with 100 kg of NP fertilizer (18 % N, 46% P) at this time. After winter in late February another 100 kg of NP fertilizer are applied. Plant protection is not typical in this system. In the beginning of April the grass is mowed and turned once before chopping it with a harvester for the clamp.

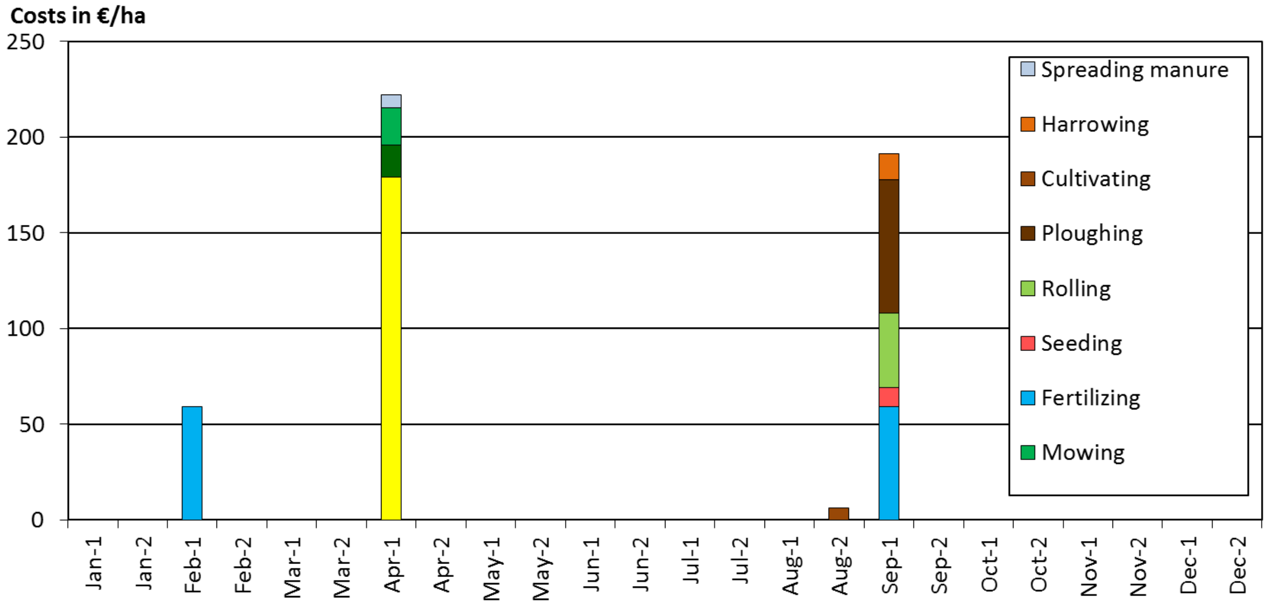
**Figure 24:** Grass Silage (Clamp) – Annual Overview of Operations (FR 60)




As the annual overview (figure 24 above) of the operations suggests the peak-workload (4,5 h/ha) in grass silage is in the first half of September, when more than half of the total operations (6/11) are performed. As for maize, ploughing is the most time-intense operation with 1.82 h/ha. In harvesting time there is another focus of labour input (2.6h/ha). In terms of costs, the harvesting period is more intense (€ 215/ha) than the establishment of the seeds in autumn (€ 191/ha), which is mainly due to the high costs for the harvester (€ 179/ha). Fertilizing costs show a similar relation to input costs as for maize.

**Figure 25:** Grass Silage Clamp – Labour and Costs required for Operations (FR 60)

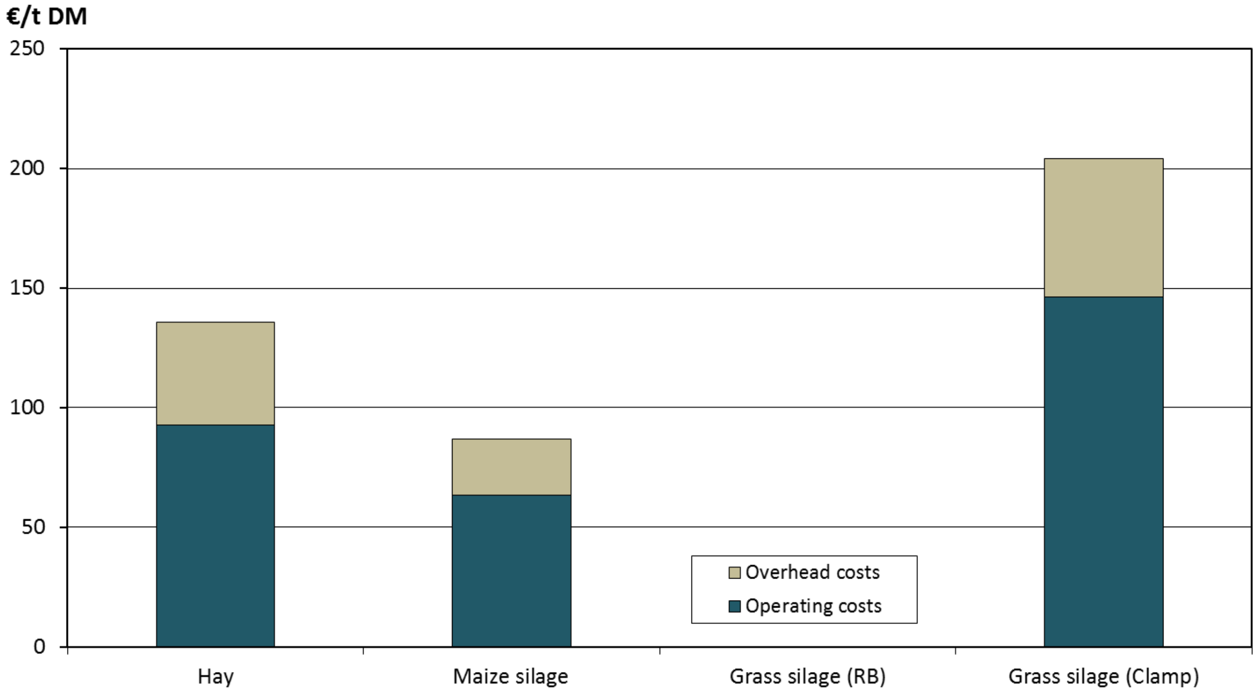



### 5.2.1.2 Comparison of Forage Costs (farm-level)

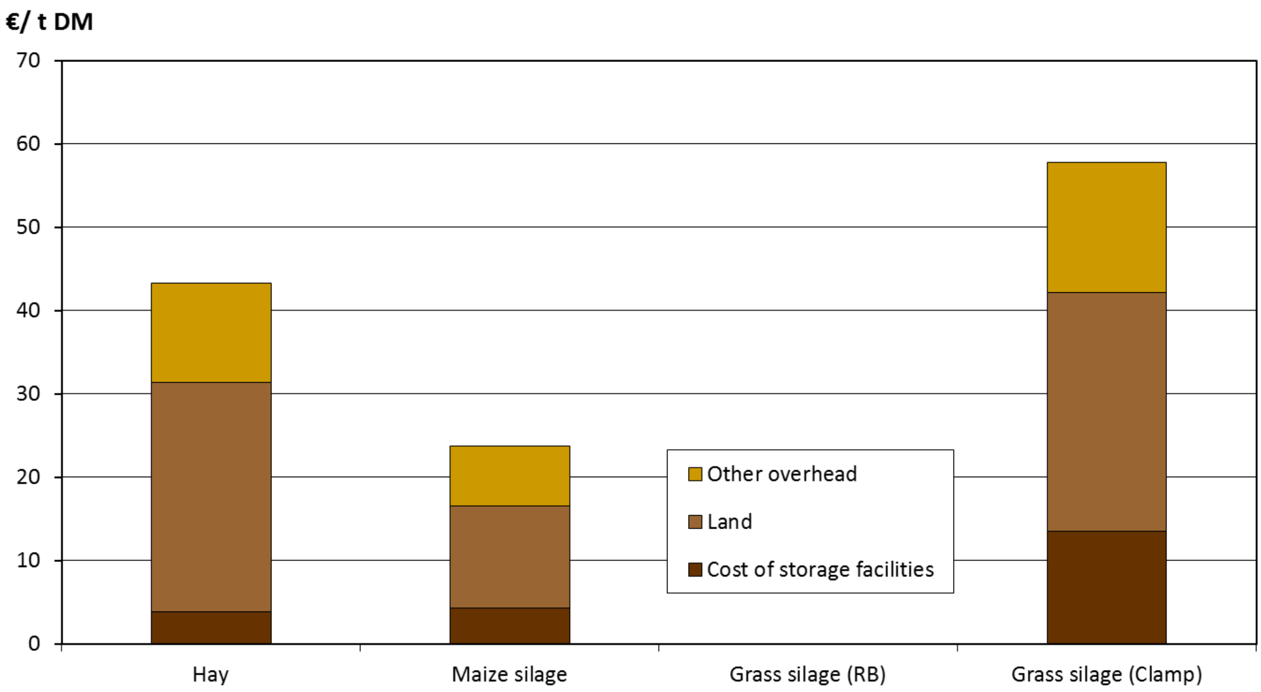
Figure 26 shows the total costs at farm-level for all forages produced in FR 60. Grass silage for the clamp is the most expensive forage in this system with € 204/ha. Hay is € 136/ ha and maize silage is the cheapest forage with € 87/ha. One third of the total costs for maize silage stems from overhead costs (€ 24/ha). Likewise hay has overhead costs of € 43 /ha that is about half its operating costs (€ 93/ ha). Only in clamp silage operating costs (€ 146 / ha) are little less than three times the amount of the overhead costs (€ 58/ha). The main reason for this difference is the high operating costs in clamped grass silage for the intensive tilling operations on the arable land. Besides, overhead costs are much higher in grass silage than in the other systems.

**Figure 26:** Costs comparison of forages analyzed (€/t DM) - FR 60



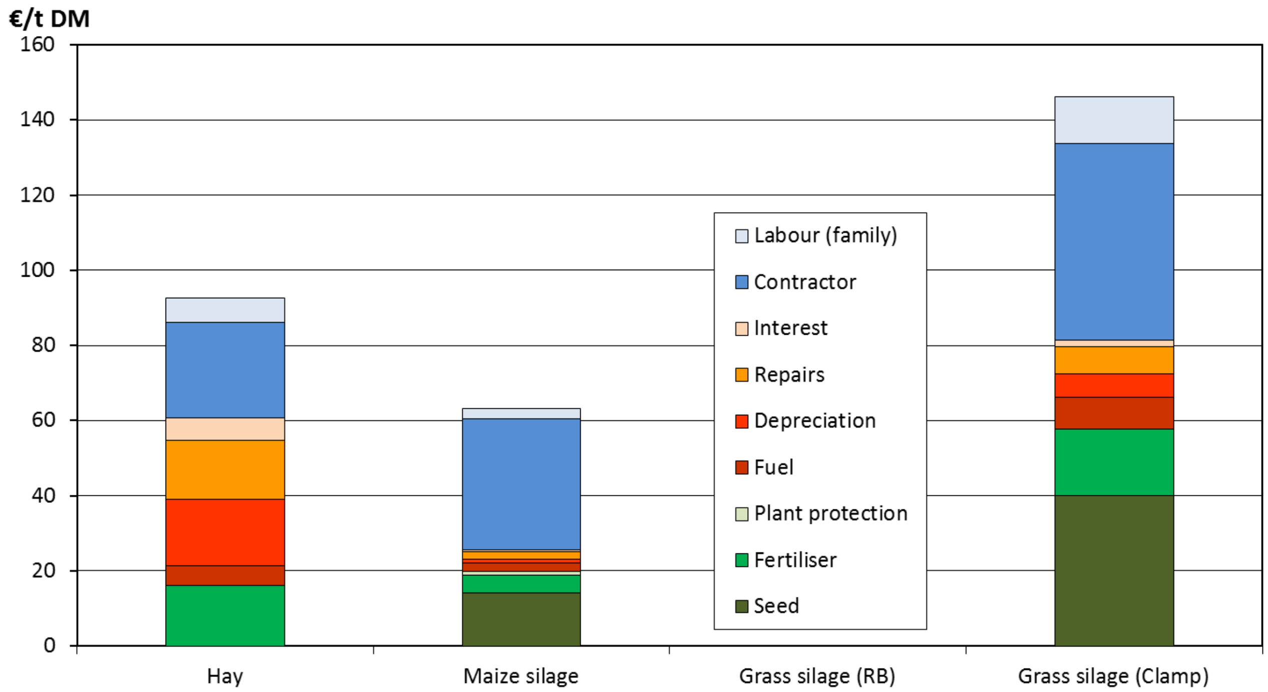

On the next page figure 27 will show the distribution of overhead costs in all systems. Though maize silage has the same storage costs per ton DM as hay (€ 4/ha for both) the high dry matter yield in maize silage creates an advantage when it comes to the costs for land: The land price is the same per hectare in all systems, however in relation to dry matter maize silage has an advantage of € 16/ha lesser land costs through its high DM yield (10.5 t DM/ ha). At the same time grass based forages are 'double-disadvantaged' because of their relatively low dry matter yield (4.5 t DM/ha for grass silage and 4.7 t DM/ha for hay): they have high land costs and high overhead costs. Consequently, the proportions of total costs are mirrored in the overhead costs.

**Figure 27:** Overhead costs comparison of forages analyzed (€/ t DM) – FR 60




Operating costs (see figure 28, next page) reflect the high importance of outsourcing operations in all production systems. In hay (€ 53 out of a total of € 146/t DM) and grass silage (€ 25 out of € 93/t DM) contractor costs have a share of about 30% of the operating costs whilst in maize it is more than 50% (€ 35 out of € 63/t DM). Grass silage has the highest overall labour costs (€ 65/ha combined) due to the variety of operations performed and the time-intensive operations of swathing and turning. Given the high share of contracted labour, variable machinery costs are lower (€ 24/t DM) than in hay production (€ 45 /t DM) though. Input prices for fertilizer are almost the same in grass silage and hay, but the price for sowing (€ 40 / t DM) makes another major difference between the grass based systems. Without seeding, operating costs of grass silage would be only € 16/ t DM more expensive or likely even less because ploughing and packing would also not be necessary anymore and reduce variable machinery costs even further. In the current system, maize remains the cheapest forage in terms of operating, overhead and in conclusion total costs.

**Figure 28:** Operating costs comparison of forages analyzed (€/t DM) – FR 60




## 5.2.2 FR 85

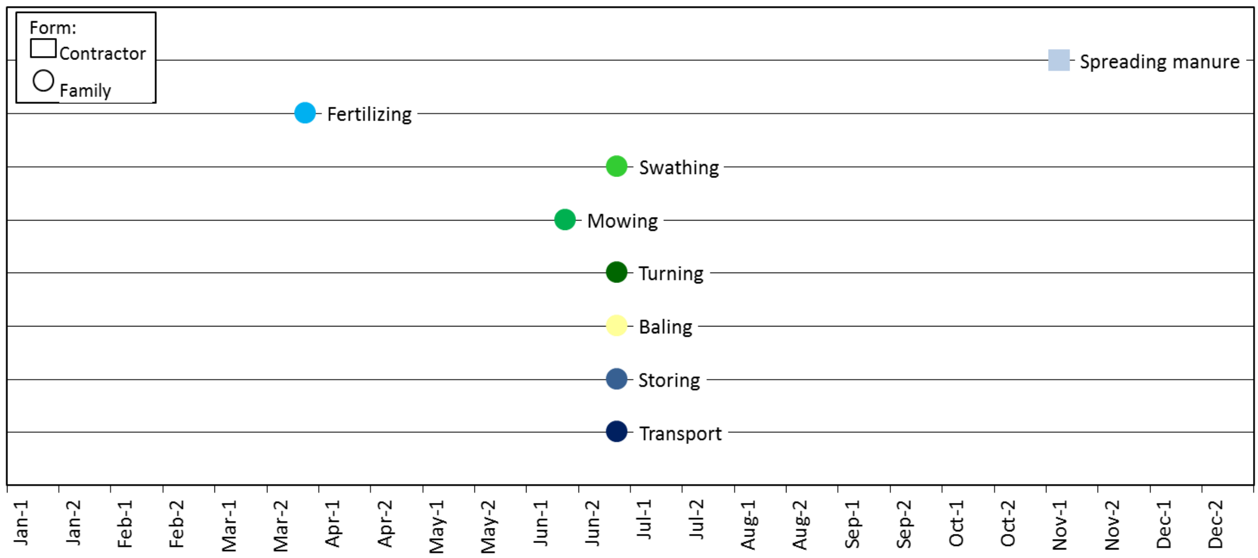
### 5.2.2.1 Operations

Typically for the pasture-rich Limousin region, FR 85 produces only grass-based forages. Three types of forages are relevant on this farm: two types of hay and haylage in round bales. Hay is produced with pre-harvest grazing (dual-use) and without grazing. Since the yield of topped (that is grazed) and non-topped hay does not differ and all other countries produce hay without topping this type of hay was chosen for comparison in this chapter. Detailed calculations were conducted for hay with topping and are included on the disc attached (Folder1 – Spreadsheets). Even though haylage has lower energy content, protein content and FM yield than grass silages, the way it is produced resembles grass silage in bales in both labour intensity and operations. Therefore, haylage will be compared to grass silages in round bales in the international comparison. Both forages are only harvested once per year and operations are mainly conducted by family labour.

**Hay**

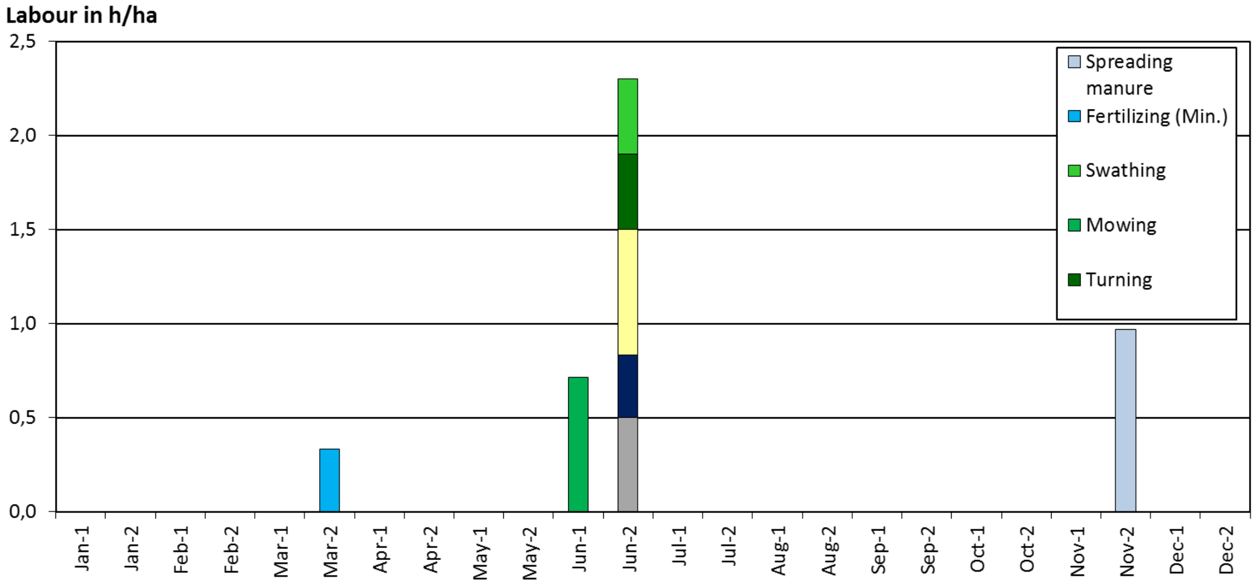
The total acreage used for hay production in FR 85 equals 35 ha of which 22 ha are used for hay without topping. Figure 29 shows the operations conducted throughout the year for hay without topping.

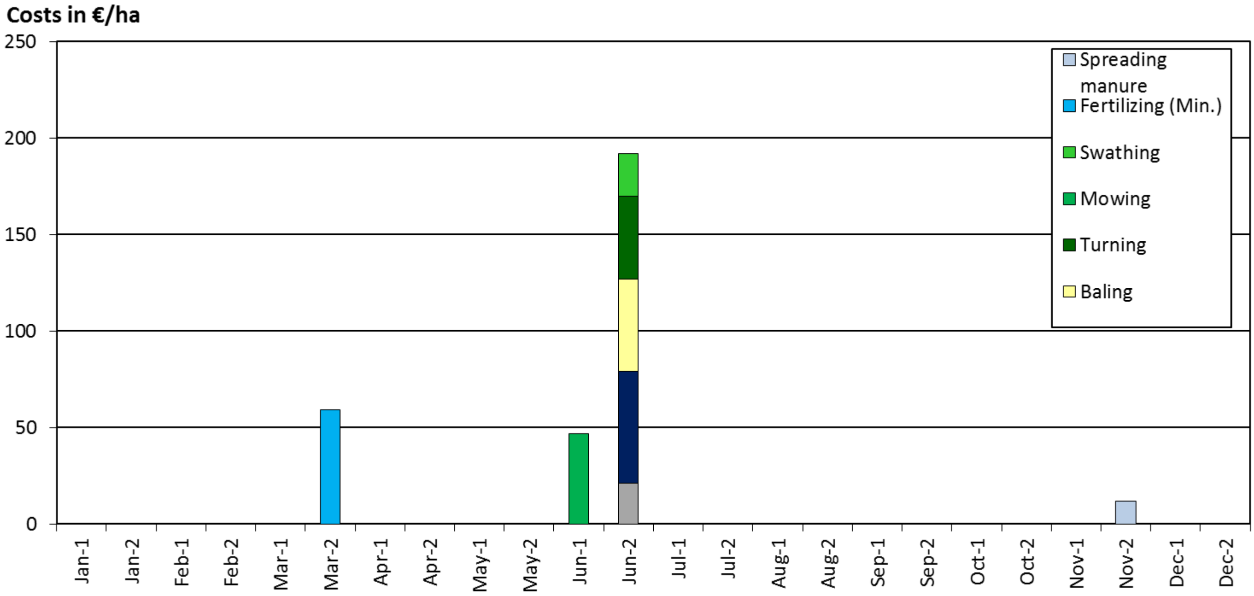
**Figure 29:** Hay – Annual Overview of Operations (FR 85)




The production system has little inputs: no seeds and plant protection is required. In November 10 t/ha of manure are spread. With the beginning of the vegetation period in March 73 kg/ha of nitrogen fertilizer (33.5%) are applied to foster growth. This is the only operation conducted by a contractor. Early June the grass is cut and subsequently turned and swathed to encourage drying before baling, storage and transport in the second half of June. No pesticides are applied in this system and the plot is not re-seeded. This system produces 13 round bales per ha. Figure 30 below shows intensity of the operations in terms of labour and costs. Clearly the peak in workload for the family is during the harvesting period in the second half of June (compare also figure 29 above). This is also the most costly month in production. Furthermore, costs and duration of operations are not always proportional.

**Figure 30:** Hay – Labour input and costs required for operations (FR 85)



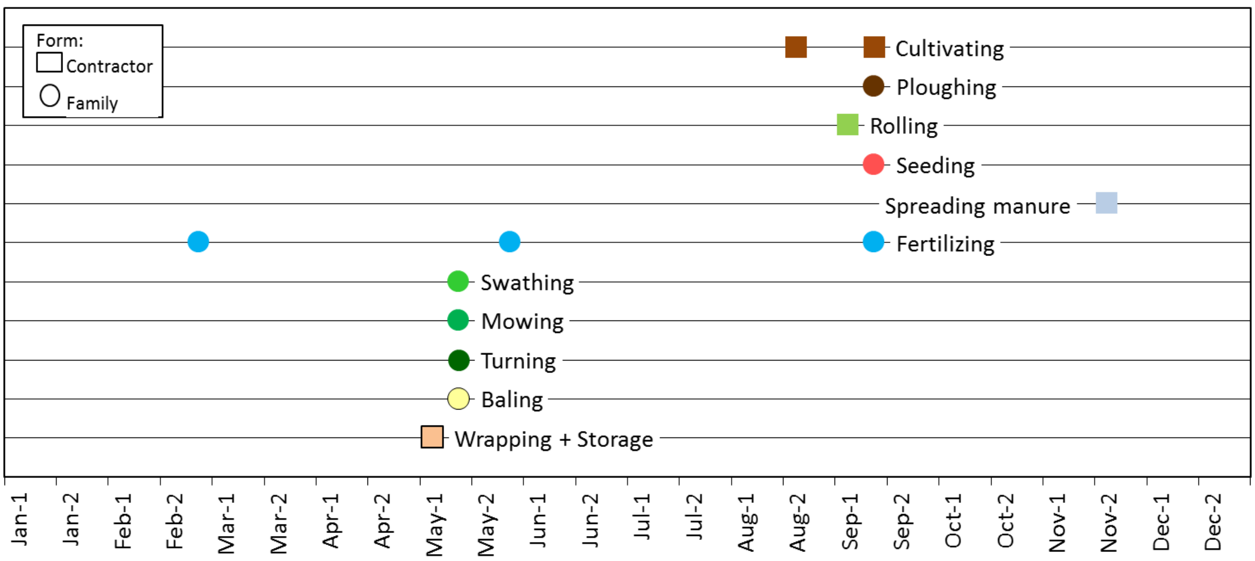

For example, transporting operations require two thirds of the time compared with storing of hay bales but the costs for transporting operations (€ 58/ ha) are about three times those of storing (€ 21/ha). The reason lies in the variable machinery costs: Transporting involves a tractor plus a trailer that is depreciated per year while storage requires equipment that is depreciated by the hour of actual use. Moreover, spreading manure is relatively cheap (€ 12/ha) when related to the labour required. A cooperative spreads manure in all (three) production systems for forages in FR 85 and on other farms. Consequently, the used machinery has high utilization (44 ha in FR 85) and depreciation is low for the cooperative so that the labour involved becomes the biggest component of the price.

Additionally, costs for repairs in manure spreaders are low for they are not prone to collision and damages like equipment for tilling. Another interesting point are labour intensity of swathing and hay turning and their associated costs . Capacity of the machinery is the same (0.4 h/ha) but turning (€ 43/ha) is twice as expensive as swathing (€ 22/ha). The reason for this difference are the purchase prices of the machinery: The hay turner (€ 6.100) was 150% the price of the swather when purchased in 2006. Depreciating both machines over the same period of time with similar utilization (swather: 129 ha/a and hay turner: 113 ha/a) makes a difference of € 314 in annual depreciation and € 12 per hectare of hay in FR 85.

**Haylage**

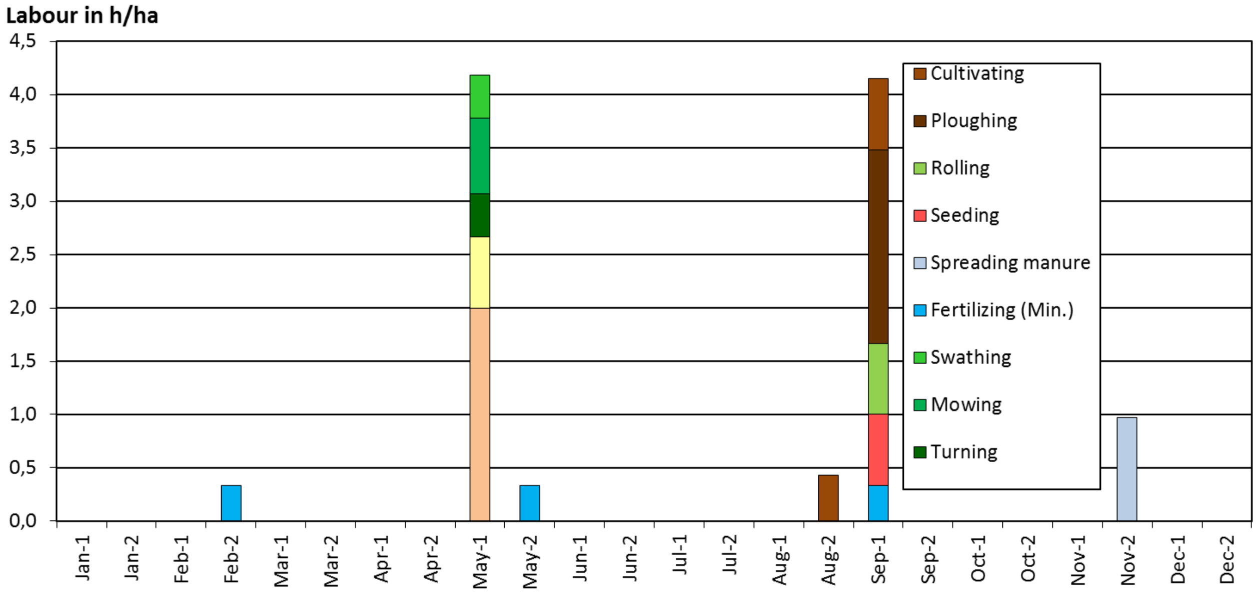
The land is prepared for haylage production by cultivating in August before it is ploughed, sowed (30 kg/ha), cultivated and rolled in the first half of September. Additionally, 160 kg of potassium are applied for fertilization at the end of September. Like hay, haylage is fertilized with 10 t of manure per hectare during winter. In the second half of February and May 200 kg/ha and 100 kg/ha of nitrogen fertilizer (33,5%) is applied, leading to a total fertilizer input of 300 kg N min., 160 kg P and 10 t N org. per hectare. Harvest takes place in the first half of May. Cultivating, rolling, spreading of manure and baling with wrapping are performed by a cooperative. This system produces 19 round bales per hectare.

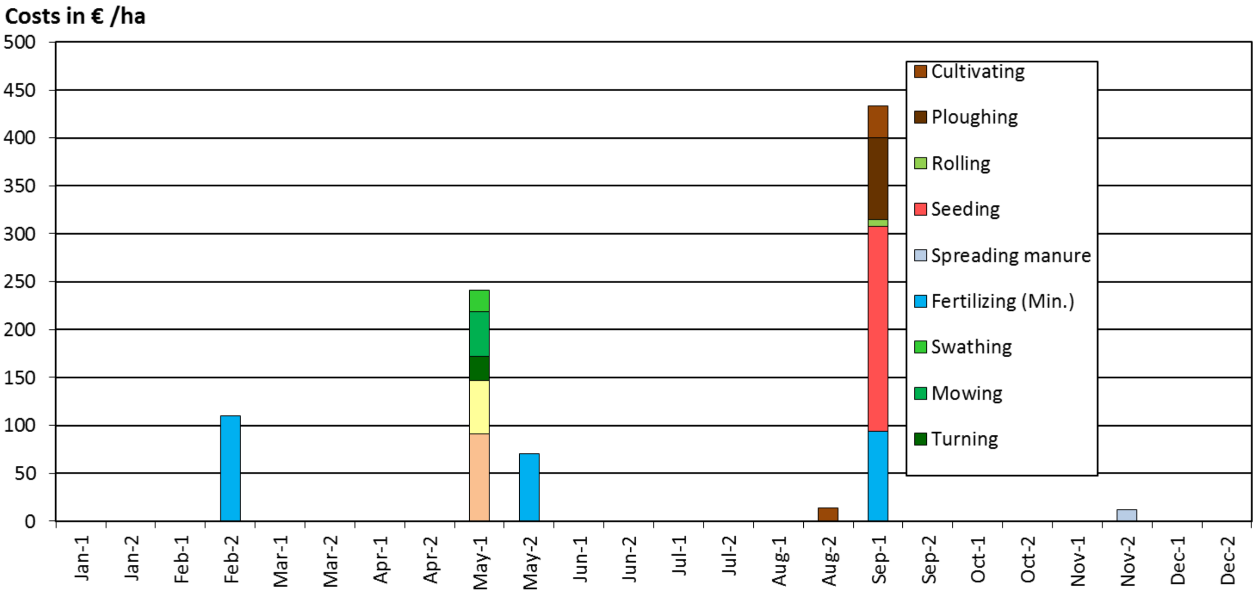
**Figure 31:** Haylage – Annual Overview of Operations (FR 85)




The workload and cost of the operations in haylage production for FR 85 are depicted in figure 32 on page 50. Workload peaks are in the first half of September, when the seed is established and in the first half of May when haylage is harvested and stored. As in hay, the price for manure spreading is relatively low compared with the workload of outsourcing the activity to the cooperative. Though the workload is almost the same when spreading mineral fertilizer, the costs vary obviously with the amount of fertilizer. That is, operating costs for spreading of mineral fertilizer in FR 85 are strongly related to the costs of the input. Labour intensive operations like wrapping & storage and ploughing are not necessarily the most costly though. For ploughing and seeding the proportions are even inversed: ploughing (1.82 h/ha) takes roughly three times as long as seeding (0,67 h/ha) but the costs for sowing (€ 214/ha) and ploughing (€ 85/ ha) have the opposite relation even though variable machinery costs in ploughing are twice the costs for sowing (€ 60/ha > 25 €/ha). The reason are the input prices for the seeds (€ 180 /ha). Clearly, input prices play a critical role in the operating costs of FR 85.

**Figure 32:** Haylage – Labour and Costs required for Operations (FR 85)

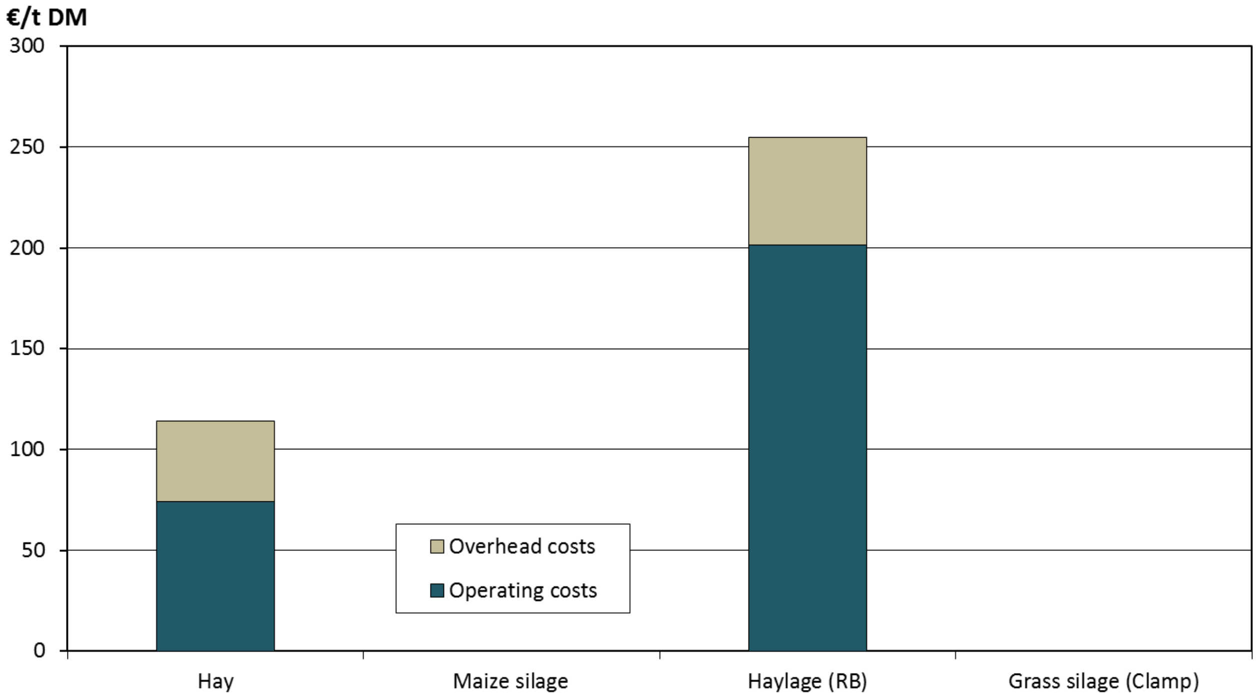


### 5.2.2.2 Comparison of Forage Costs (farm-level)

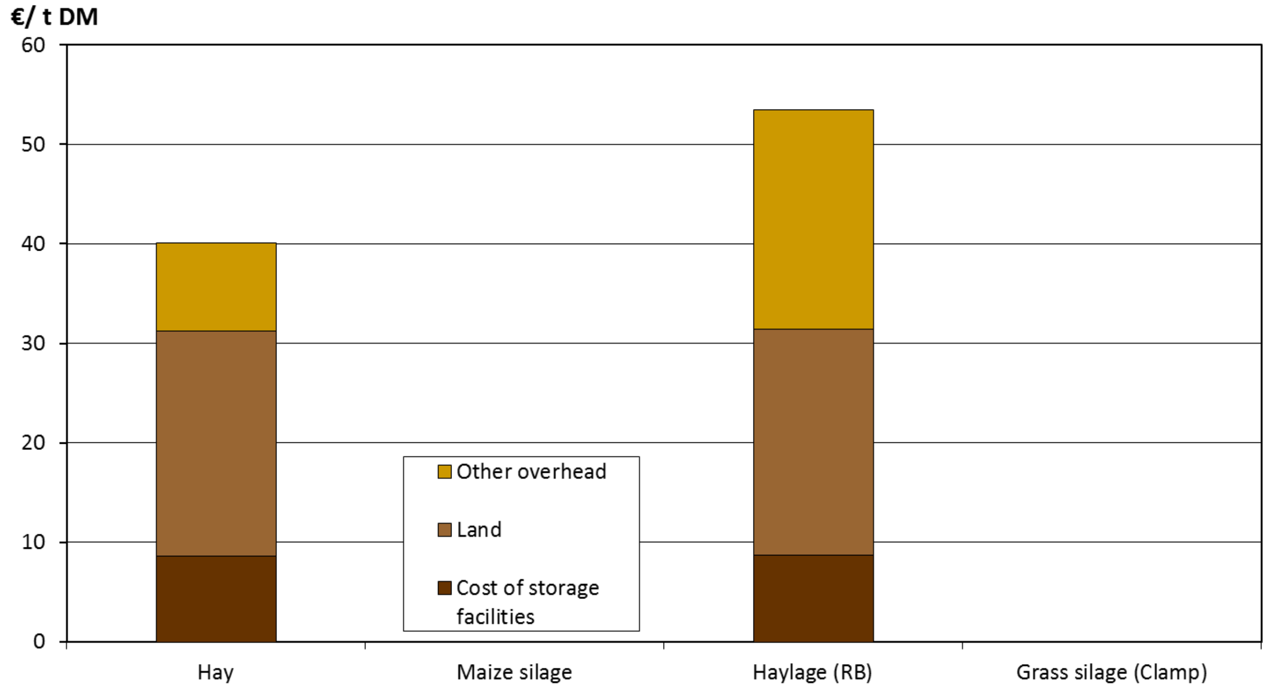
In figure 33 below costs of both forage systems are being compared on farm level per t DM (comparison per ha on data disc in spreadsheets folder 1). Hay (€ 114 / t DM) is produced at half the price of Haylage (€ 255/ t DM) due to high operating costs of the haylage production (€ 202/t DM). In hay round bale production the share of operating costs is about 2/3 of the total costs (€ 74/ha) while operating costs represent 80 percent (€ 202/ t DM out of € 255/ha) of the total costs in haylage. Hay is much cheaper to produce in terms of overhead and operating costs.

**Figure 33:** Costs comparison for analyzed forages (€/t DM) - FR 85



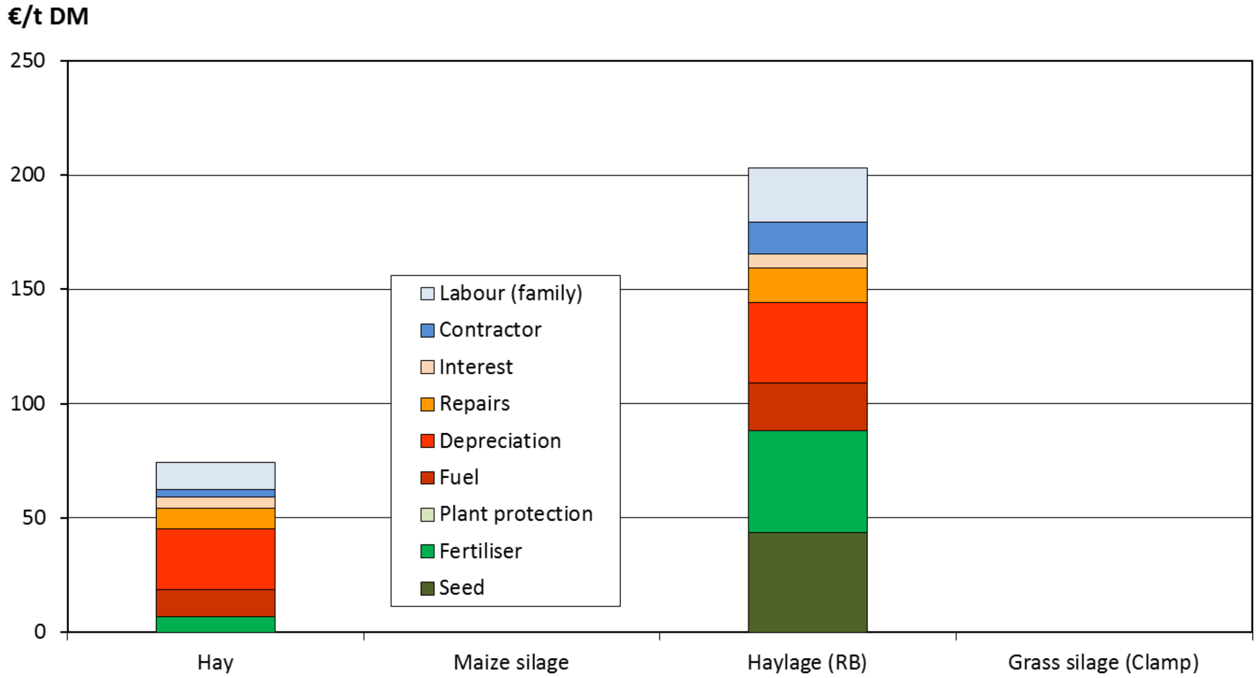

When comparing overhead costs shown in figure 34 (p.52) we see that the costs for land are the same in haylage and hay (€ 23/t DM) because per hectare prices are the same and the dry matter yields only vary by 0.04 t DM/ha. Likewise the storage costs are the same because FR 85 stores both bales in the same hangar (compare data sheet storage costs in the appendix page 26). The variation in overhead costs therefore stems solely from the allocation of other overhead costs and is higher in haylage for the little amount of acreage that is used (9 ha).

**Figure 34:** Overhead costs comparison for analyzed forages (€/t DM)) - FR 85




At first glance figure 35 on page 53 illustrates that hay is produced in a more extensive way than haylage at FR 85. Variable machinery costs are € 25/ha higher for haylage production (€ 77/ha) than for hay (€ 52/ha). However, more essential for the disparity in operating costs are the inputs of fertilizer (€ 45 /ha) and seeds (€ 44/ha) used in haylage accounting for almost half of the operating costs.

**Figure 35:** Operating costs comparison (€/t DM) - FR 85




## 5.3 Results: British Farms

UK 80 and UK 750 are the farms that were used for this study in the United Kingdom. More detailed information on their characteristics is provided in chapter 4 - Farms (p. 15). Input data for calculations was derived from the typical farm data sheets (c.f. data disc folder 1). The project partners at the English Beef and Lamb Executive EBLEX (part of the British Agriculture and Horticulture Development Board AHDB) added missing data from empirical and engineering data of British origin. Remaining data gaps, mainly utilization and repairs for machinery were adjoined from German engineering data of the KTBL database.

In the typical farms of the United Kingdom production of grass silages is a two-year process with interim grazing of the land (compare calculations sheets on data disc in Folder 1). In the spring of the first year existing permanent pasture is subject to light cultivation operations like rolling or disc harrowing. In the summer of that year, cattle are grazing on the pastures. After winter limited cultivation is conducted (leveling or rolling) and only in the summer of the second year silage is harvested. That is the land is used dually but not in the classical way of post-harvest grazing. The operations of grazing and harvest are rather in two different years. The total costs for all operations have therefore been calculated as if they took place in one year and grazing was a separate activity so that overhead costs would not have to be doubled and distort the comparison between farms.

To ensure uniformity in graphic representation of single farm results, grass silage production was modeled for the time span of one year by removing two cultivating operations performed in spring of the second year based on the assumption that after seed establishment in the first year no additional cultivation will be necessary, because harvesting operations will be conducted before renewed cultivation (in spring) is necessary. Additionally grazing activities were ignored for they could not be factored into the workload. Thereby the establishment of the seed and the harvesting activities could be modeled over one year without artificial sheathing of cultivation operations that do not reflect agricultural practice. However in the total costs and operating costs are sums of all operations within the original production system.

### 5.3.1 UK 80

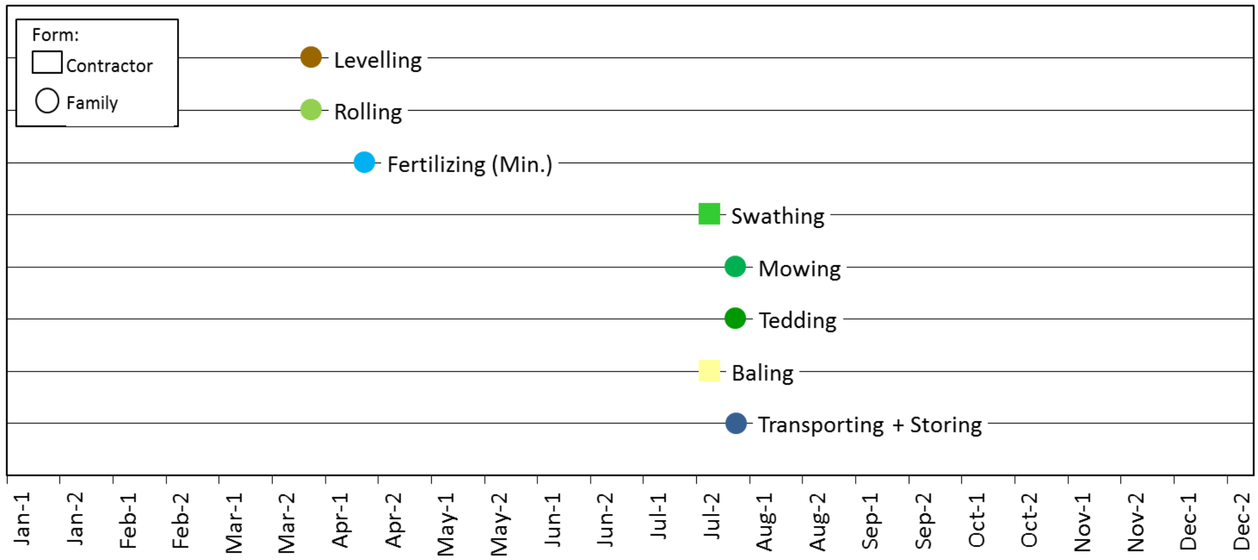
UK 80 produces hay (10 ha) and grass silage in round bales (95 ha) on existing permanent pastures. Additionally the farm has 59 ha of pastures for grazing. Hay and grass silage bales are harvested with a single cut.

#### 5.3.1.1 Operations

**Hay**

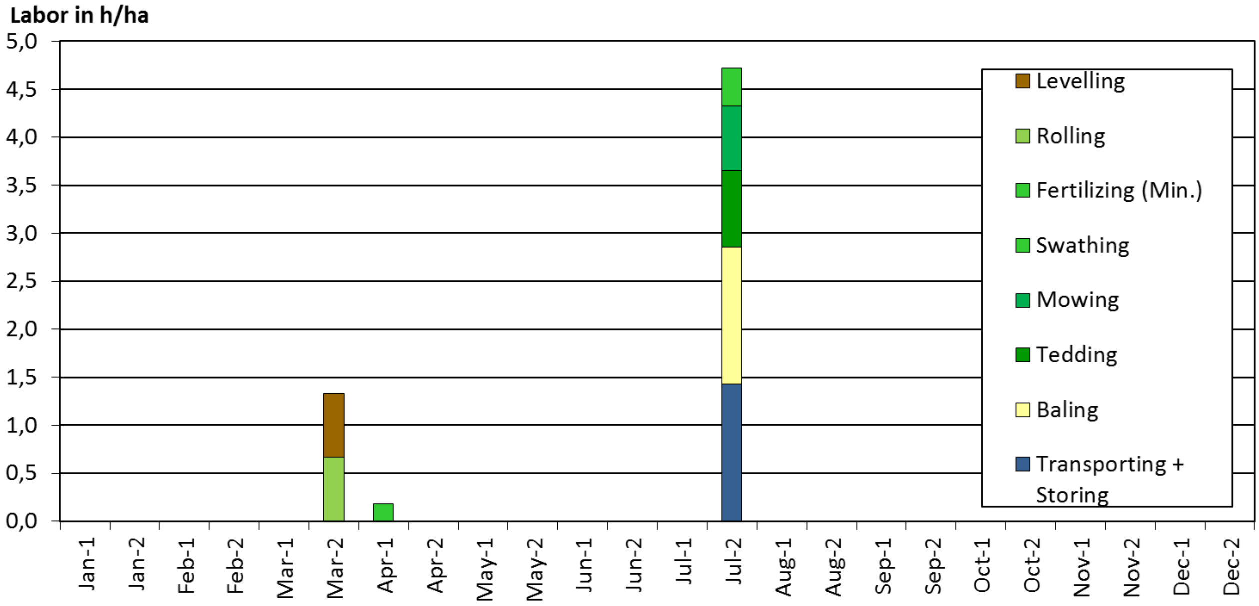
The distribution of annual operations for hay is illustrated in figure36 below. In the second half of March pasture is leveled with spring tine harrows and rolled before applying NPK fertilizer (25 kg of 20:10:10 NPK) in early April. Harvesting takes place in late July when the grass is mowed and turned by family labour. Afterwards a contractor swathes and bales the hay into small square bales of 35 kg. Transport and storage is conducted by family labour at the end of July. Except for baling and swathing, all operations are performed by family labour. Besides fertilizer there are no other inputs to the system. Only one cut is harvested. Consequently, UK 80 can be declared a low input production system.

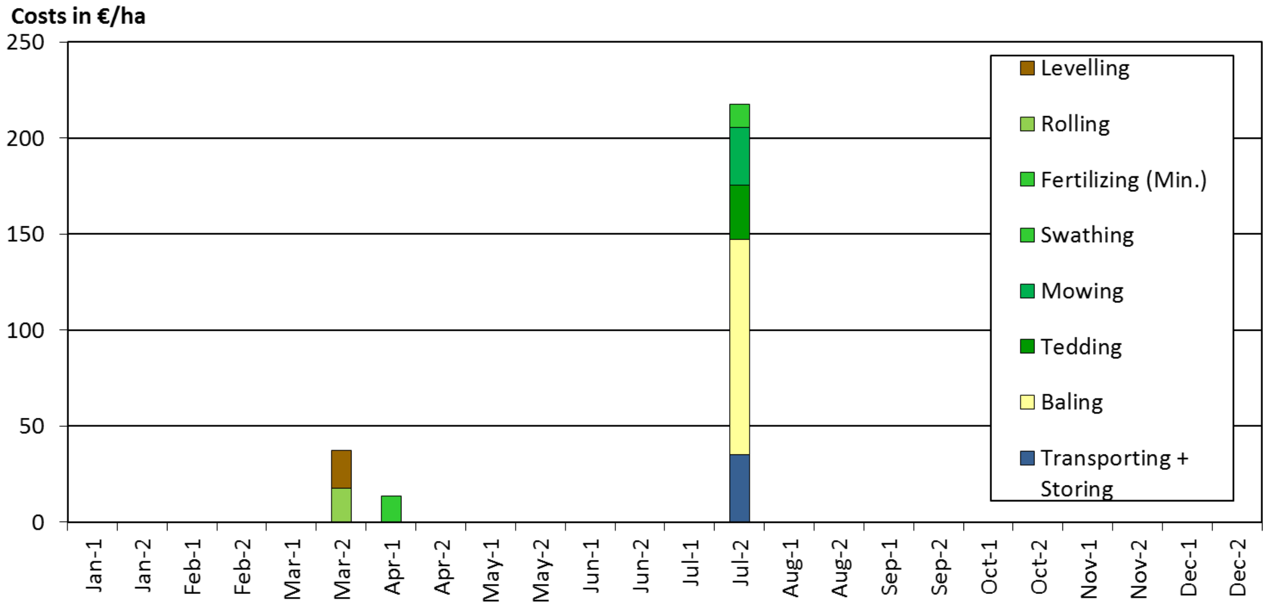
**Figure 36:** Hay – Annual Overview (UK 80)




Hay production in UK 80 requires little labour and financial input as we can see in figure 37 page 56. There is one labour peak (4.7 h/ha) during the harvest in late July, which is 75% of the working time required for this system. Despite the fact that baling and transporting operations require the same amount of time, baling is about three times the price (€ 112/ ha) of transporting (€ 35/ha) because variable machinery costs for tractor and trailer are low (€ 22/ha) while equipment for baling usually has high purchase and repair costs. Baling equipment is sophisticated machinery with multiple mechanical and hydraulic parts that are not overly prone to repairs, but expensive to replace when damaged. Additionally, balers have limited utilization potential within the farm, while trailers and tractors are multi-use equipment. Though contracted work makes about a third of the operational time (1.8 h/ha out of (6.3 h/ha) it contributes almost 50% of the costs (€ 124 / ha out of € 269/ ha).

**Figure 37:** Hay – Labour Input and Costs required for Operations (UK 80)

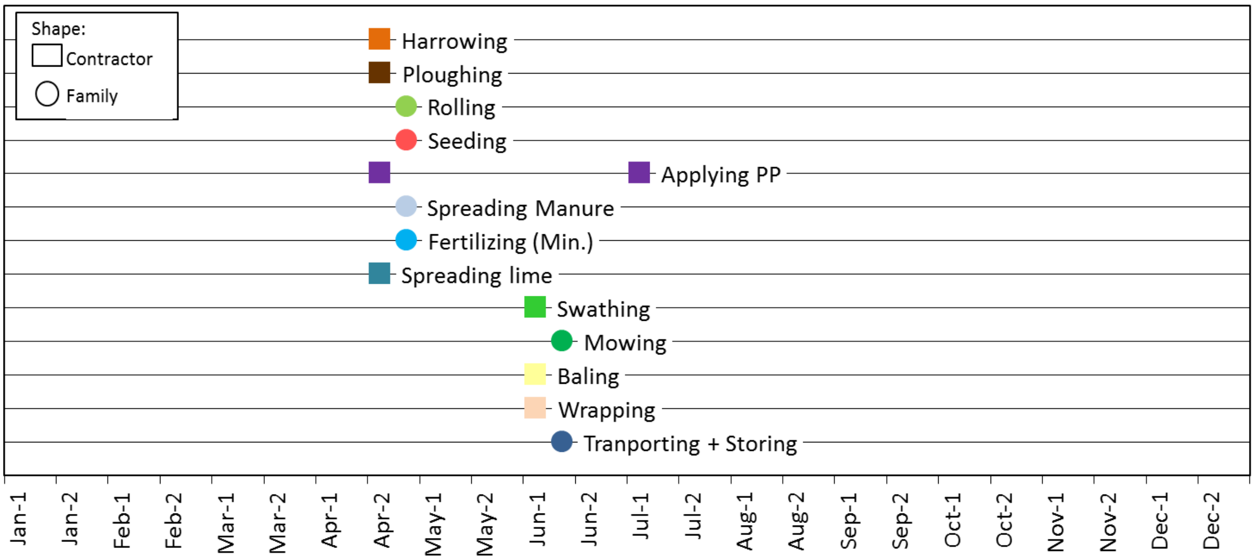



### Grass Silage (RB)

Production of grass silage starts in late April with application of glyphosate for plant protection by a contractor (figure 38 p. 57). Subsequently, 20 t of cattle manure are spread by family labour before a contractor ploughs the pasture, spreads lime (5t/ha) and harrows. Afterwards, family labour spreads 247 kg of establishment fertilizer (15% N, 15 % P, 15% K) and rolls once before seeding the land with 32,5 kg of grass seed per hectare. Another set of rolling is performed and the grass is left to grow until harvesting. In early June the grass is mowed in the state of ear emergence by family labour. A contractor swathes, bales and wraps the silage after cutting and the bales are transported and stored by family. Post-harvest and in the first half of July, Pastor, a broad-spectrum weed controlling agent, is applied by a contractor. Grass is cut only once in this system. No silage additives or additional drying are used.

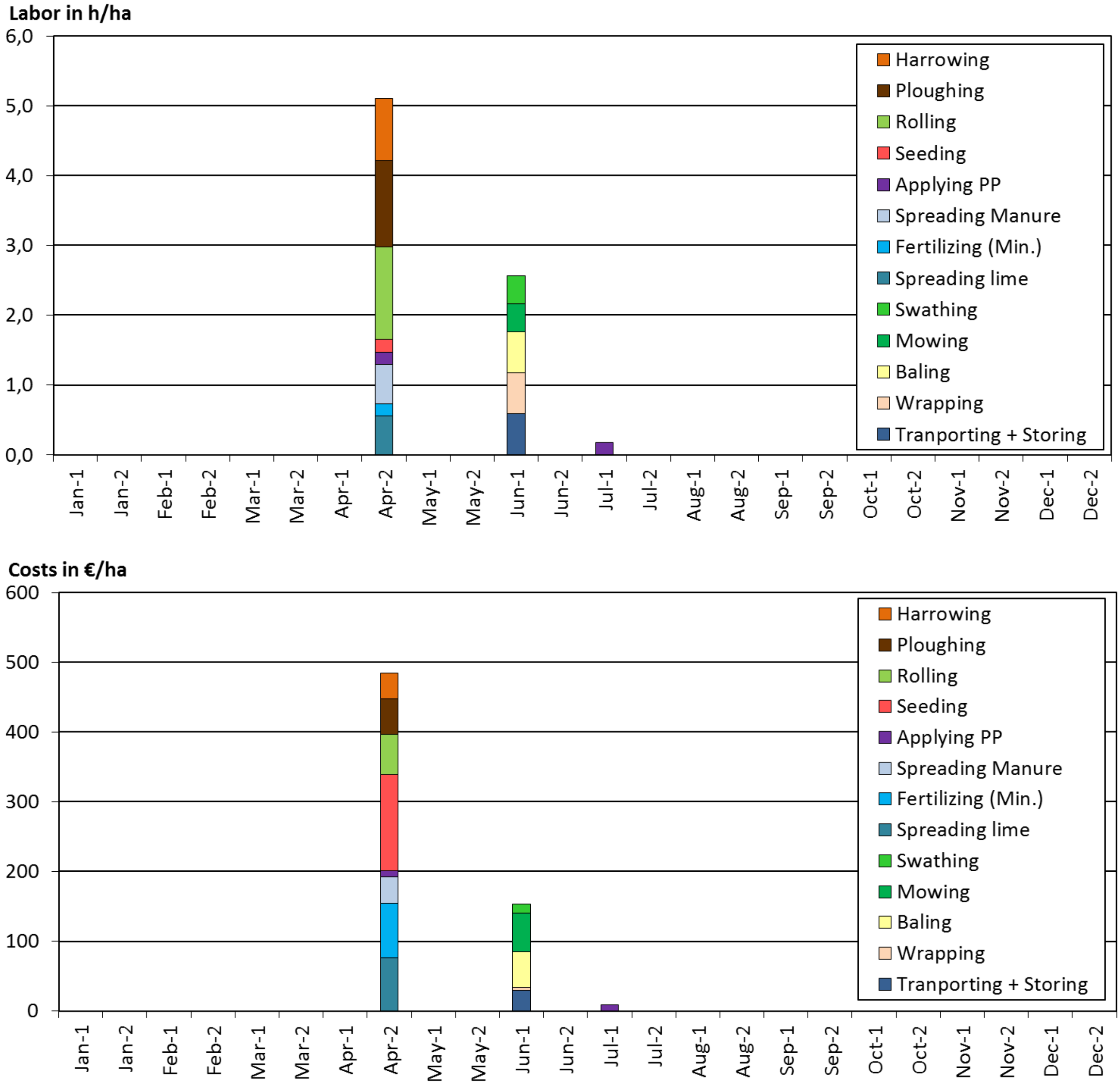
**Figure 38:** Grass Silage (RB) – Annual Overview (UK 80)




Baled grass silage in UK 80 shows has two working peaks in late April and early June but does not require additional labour during the rest of the year (less than 1 h / ha which were neglected). In April there is the highest workload of 5.3 h/ha while harvesting operations in early June contribute 2.6 h/ha to the total working time (8.1 h/ha). When comparing the labour-intensity to the costs of the operations it is evident that for operations requiring input like seeding and fertilizing with purchase fertilizer the input price is the determining factor. For example, seeding costs are € 78/ ha out of which € 66/ha input (seed) costs.

Rolling and ploughing do not only have similar shares in working time (1.2 h/ha ploughing, 1.3h/ha for total rolling operations) but also the costs are similar (€ 50/ha and € 58/ha) although different operators conduct them. However, for drawing conclusions on this relation one would have to know more about the contractor’s equipment. Despite the fact that the diagram for costs does not make wrapping costs visible to the human eye, the operation does have costs. Yet they are € 4/ha which is why they do not appear clearly in the column. The reason for the low price is supposedly that wrapping is matched with the baling operation and therefore the contractor only charges for foil costs in this position.

**Figure 39:** Grass Silage (RB) – Labour and Costs required for Operations (UK 80)




## 5.3.1.2 Comparison of Forage Costs (farm-level)

Figure 40 on the next page illustrates the total costs of the two forages: Hay (€ 115/t DM) is slightly cheaper than grass silage (€ 253/t DM) in UK 80, because the production system for hay is much more extensive. Therefore operating costs are lower (€ 58/ t DM) than for grass silage (€ 211/t DM). When costs per hectare are compared, hay (€ 537/ha) is significantly cheaper than grass silage (€ 960/ha), as page 39 in the appendix shows. What strikes the eye is the high share of overhead costs in hay of € 56/t DM that is one third of the total costs. In figure 41 on page 59 provides more detail on these costs.

**Figure 40:** Cost comparison of forages analyzed (€/ t DM) - UK 80

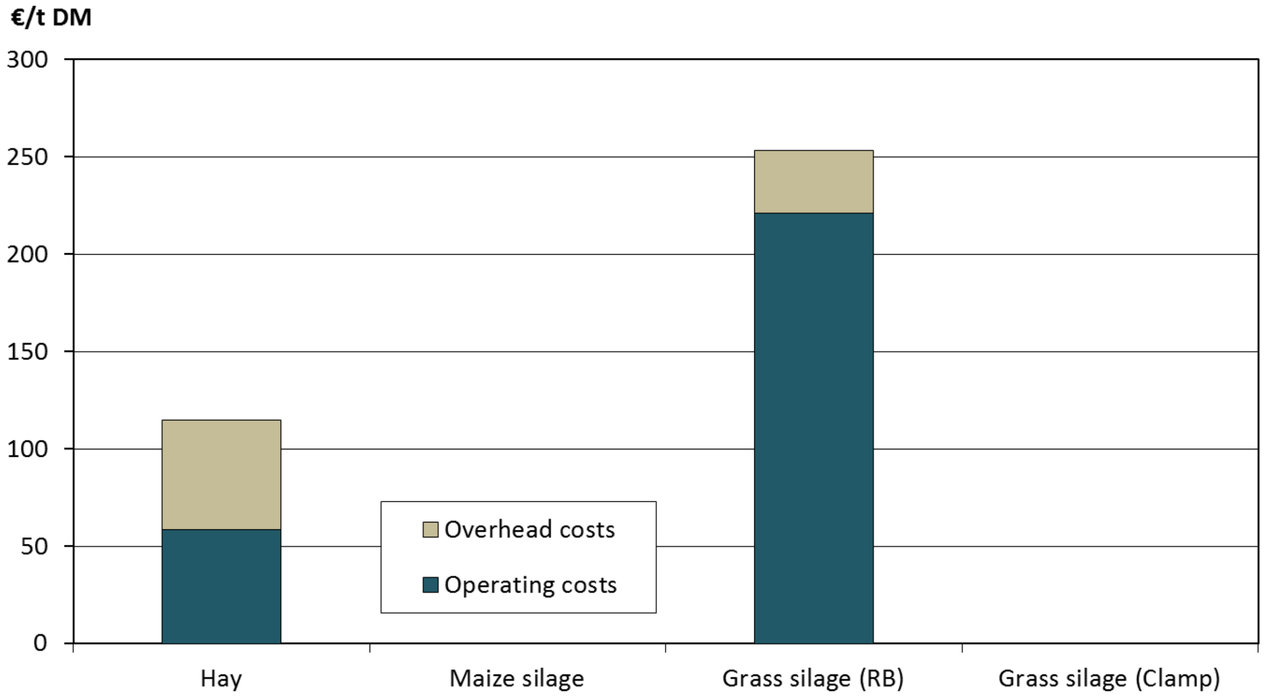
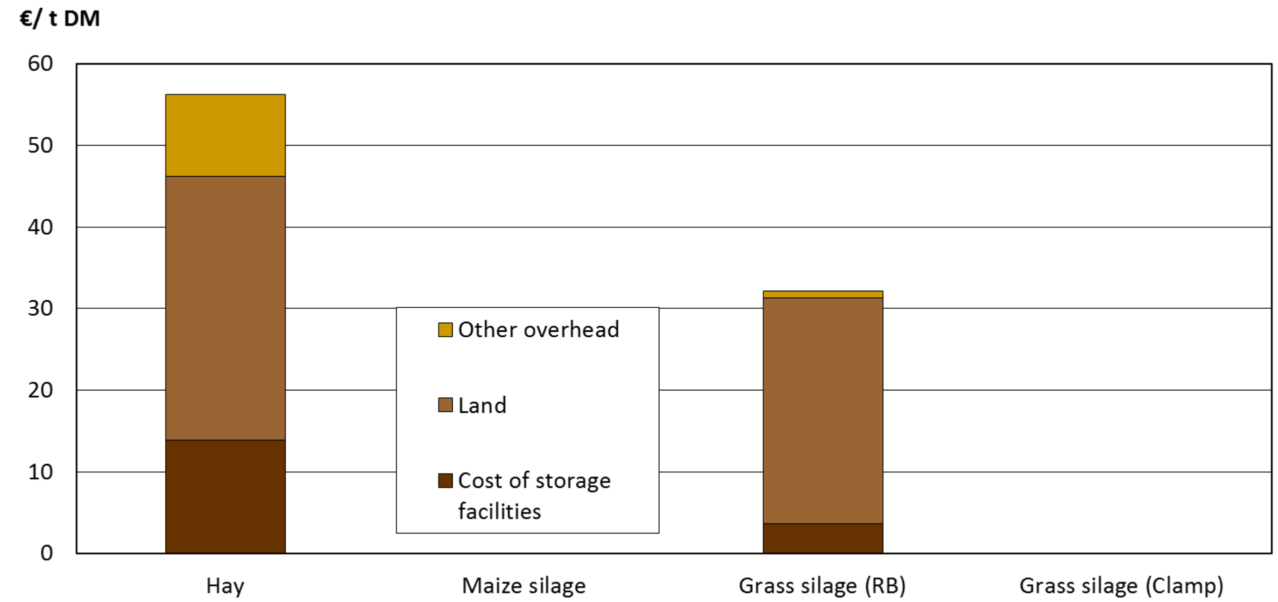



**Figure 41:** Overhead costs comparison of forages analyzed (€/t DM) - UK 80

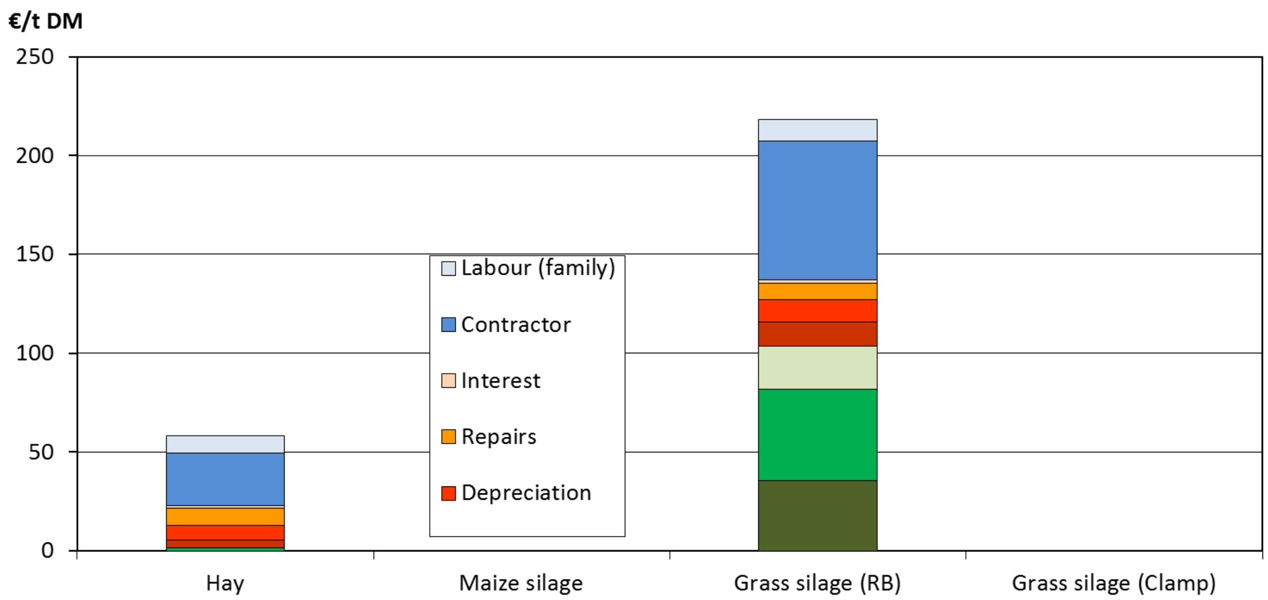



Land costs are the same for hay and grass silage when related to the hectare (€ 152/ha, compare appendix page 39) and also when related to the dry matter yield the difference between hay (€ 32/t DM) and grass silage (€ 28/ha) is rather negligible. Costs for other overhead are ten times as high in hay (€ 10/ t DM) as for grass silage (€ 1/t DM). The reason is that the calculation other overhead costs are distributed on the acreage per crop and hay has only half the planted area (10 ha) as grass silage (95 ha). Costs for storage facilities are lower in grass silage (€ 4/t DM < € 14/t

DM), given that the bales are already wrapped in foil and have lower storage requirements than hay.

When considering the operating costs the relations are inversed again: hay (€ 58/t DM) is cheaper than grass silage (€ 221/ t DM). Though contractor costs for baling and swathing in hay (€ 27/ t DM) are almost half of the operating costs, application of fertilizer, plant protection and seed input make grass silage more expensive and contribute € 35/t DM. Yet the costs for family labour are similar in both systems (€ 11/t DM GS, € 9/t DM Hay) despite the fact that grass silage has much higher labour-input. Again, the reason is the low dry matter yield of hay and the contracting of cost-intense operations i.e. ploughing.

**Figure 42:** Operating costs comparison of forages analyzed (€/t DM) -UK 80




## 5.3.2 UK 750

Two forages have been calculated for UK 750: maize silage and grass silage, both in the clamp. Maize silage has a total planted area of 40 hectares while grass silage is produced from 30 hectares of permanent pasture. Both silages are harvested in only one cut. The farm employs permanently hired staff at a lower wage than the family labour (compare chapter 4 farms p.15). This staff was, however, calculated with the family labour wage rate of € 9.41 per hour to make it comparable with the other farms. Operating machinery by this employee would lead to lower costs for labour in operations that are not outsourced.

### 5.3.2.1 Operations

**Grass Silage (Clamp)**

Grass silage for the clamp is established in the spring of the previous year (compare production systems in the appendix p. 49). For that purpose a contractor applies Glyphosate for plant protection in the first half of March. Then manure (20 t/ha) is spread by family labour before leveling the field with disc harrows in the second half of March. Additionally, a contractor spreads 5 t/ha of ground limestone and 247 kg/ha of establishment fertilizer (NPK 15:15:15) are spread by family labour before drilling out the seeds (32,5 kg/ha) with a tine drill. The plot is rolled twice by family labour. In the first year, the area is then used for grazing. In the following year, the grass is mowed in the second half of April and then swathed by a contractor before harvesting it with a chopper. The transportation chain is operated jointly by family and contracted labour. Finally the clamp is compacted and production finished.

**Figure 43:** Grass Silage (Clamp) – Annual Overview (UK 750)

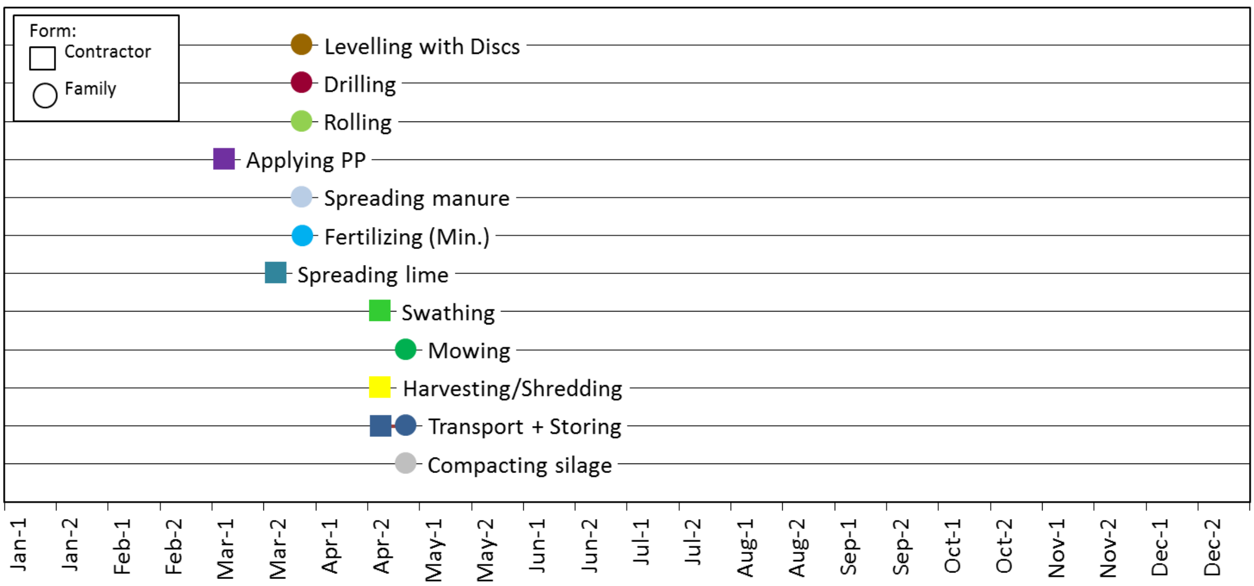
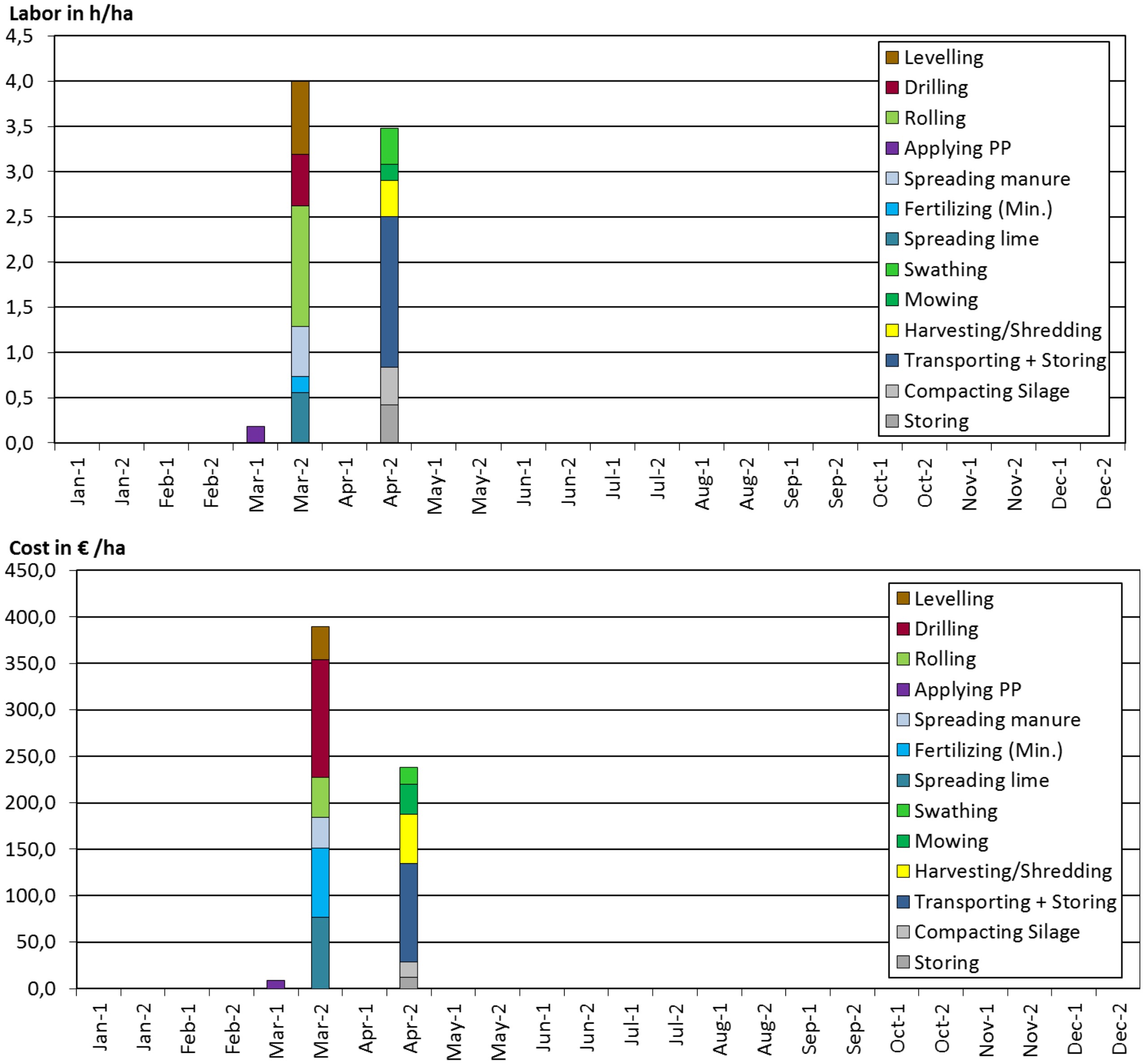


**Figure 44:** Grass Silage (Clamp) – Labour input and costs required for operations (UK 750)

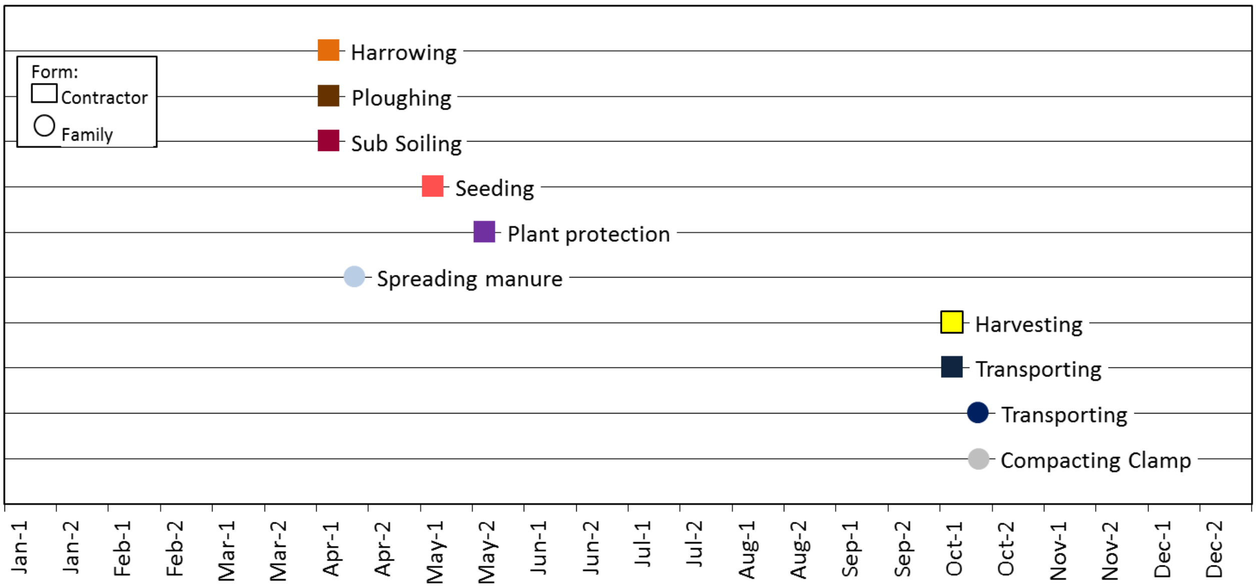



All operations in clamped grass silage all take part within two months in the first half of the year, namely in March and April (see figure 44 above). The biggest proportion of the working time is in the second half of March (4 h/ha) while the harvest in the second half of April requires labour to the extent of 3,5 h/ha. The operation with the longest duration is the transporting and storing chain (1,68 h/ha) in harvesting season. Another time-consuming activity is rolling (1.34 h/ha). Money-wise, rolling is less significant (€ 44/ha) given the cheap equipment with little costs for repairs (compare machinery list UK 750 in appendix page 34). Drilling is disproportionately costly (€ 126/ha) with regard to the time required (0.57 h/ha). This is because of the input costs for seeds (€ 124/ha), which make about 98% of the whole operation. Also fertilizing and lime spreading show the effect of input costs on the total operating costs per production step: Together they take less than an eighth (0.47 h/ha) of the workload in late March but their combined costs (€ 152/ha) contribute 38% of the total cost per ha for that period (€ 392/ha) while their share of input costs is € 143/ha.

**Maize Silage (Clamp)**

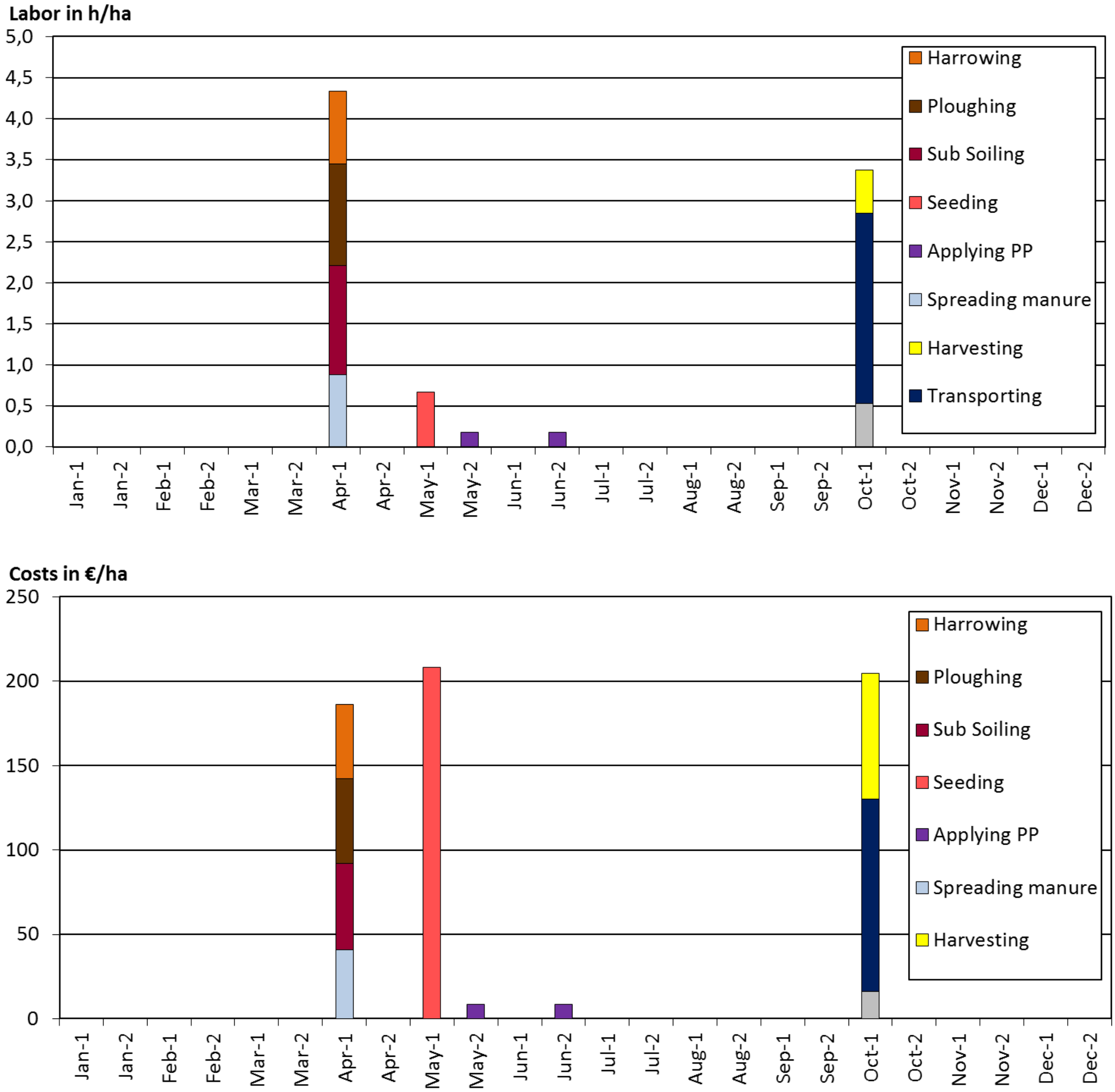
In UK 750 maize silage production starts in the first half of May, when family labour spreads 20t/ha of cattle manure (compare figure 43 below). A contractor works the manure subsoil, then ploughs and harrows the land for seeding (32 kg/ha) in early May. Together with the seeds mineral fertilizer is spread in one operation (N 10%, P 21%). In the second half of the month a contractor applies plant protection (Bromoxynil and Nicosulfuron). Finally, in the first half of October a contractor harvests the maize with a chopper and a transport chain run by family labour and contractor takes the chopped material to the clamp. The clamp is then compacted by family labour.

**Figure 45:** Maize Silage (Clamp) – Annual Overview (UK 750)




The annual overview above suggests that there are two peaks in workload for maize silage in UK 750, which is reflected in the labour diagram in figure 46 on the next page. In the first half of April the preparation of the field for establishment of the seed is most labour-demanding (4.4 h/ha). Tilling operations require 3.4 h/ha. At the beginning of October harvesting operations occupy 3.4 h/ha of labour capacities. Running the transport chain for maize is the most time-consuming operation in in the production system (2.12 h/ha) and accounts for two thirds of the working time in harvesting as well as 50% of the costs (€ 114/ha out of € 212/ha). The discussion will address this part of the production chain adequately, yet one can say that the transportation and storage capacities are more relevant for the duration of the whole harvest than the capacity of the harvesting equipment. For the combination of the seeding and fertilizing activities and the related input costs of seed and fertilizer (€ 170/ha), seeding is the most expensive operation for maize silage (€ 208/ha). The costs of the contractor in this operation are only € 38 /ha despite including machinery and labour.

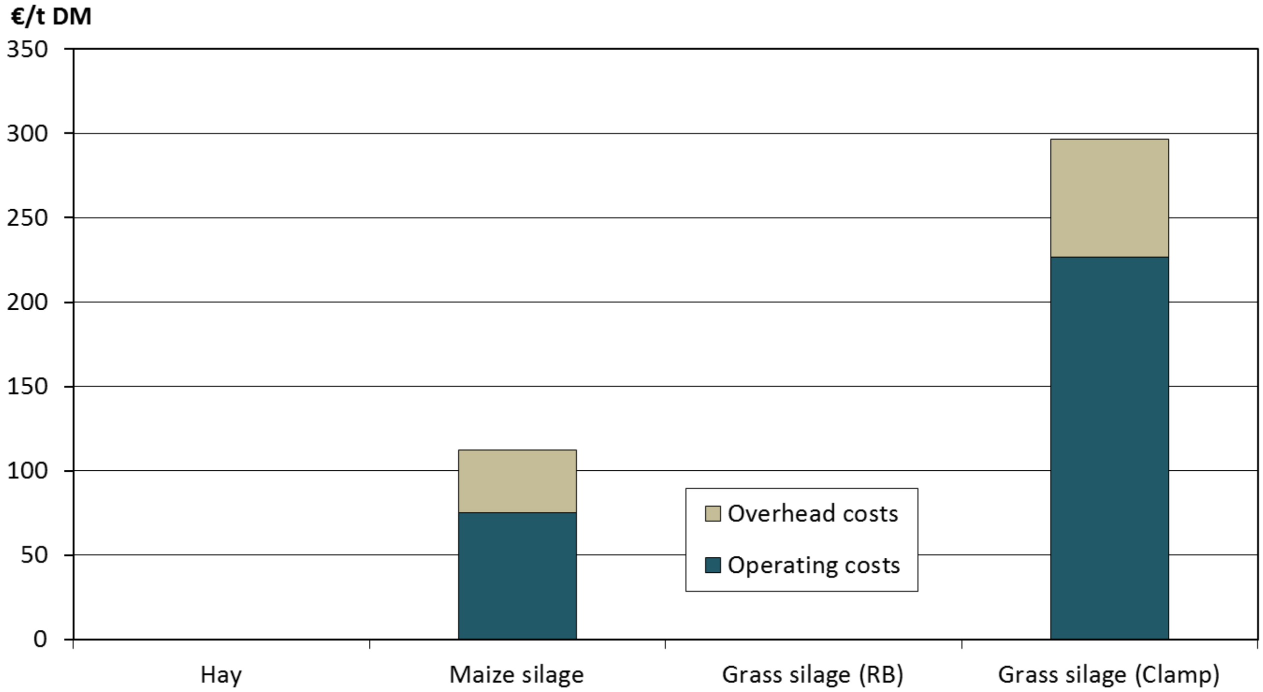
**Figure 46:** Maize Silage (Clamp) – Labour and Costs required for Operations (UK 750)




## 5.3.2.2 Comparison of Forage Costs (farm-level)

Similar to the German and French Farms, producing maize silage (€ 112/ t DM) is also the cheapest forage in UK 750 as a result of the high dry matter yield (11.7 t DM/ha) which is displayed in figure 47 (page 65) . Compared with grass silage (5 t DM/ha), it has a lower cost of € 184/t DM. Grass silage in the clamp is twice the costs at € 296/t DM even though the number of harvesting operations is the same in both systems. Although working time is higher in maize silage (9.0 h/ha vs. 8.18 h/ha for grass silage) its operating costs are only one third (€ 75/t DM) of the operating costs in grass silage (€ 227/t DM). Overhead costs are almost half (€ 37/ t DM) those of grass silage (€ 70/t DM) but amount to 30% of the total costs (€ 75/ t DM). In grass silage the share of overhead costs are responsible for one fourth (€ 70/t DM) of the total costs.

**Figure 47:** Costs comparison of forages analyzed (€/t DM) - UK 750




The detailed distribution of overhead costs is shown in figure 48 (next page). It shows that land costs in both systems are similar at € 17/ t DM for maize and € 22/t DM for grass silage even though per hectare prices for land are cheaper for pasture (€ 108/ t DM vs. € 194/ t DM in MS). Storage costs for maize silage are half those of grass silage on a dry matter basis while on a per hectare basis storage costs for both silages are the same (€ 125/ha, compare results sheet in the appendix page 34). This underlines once again the effect of the dry matter yield.

In the total costs, however, operating costs play a more important role than overhead payments. Their allocation is represented in figure 49. For grass silage, costs for contract work are slightly less than 50% of the operating costs (€ 102/t DM). Remarkably, the proportion of fertilizer costs in the final product is higher in grass silage than in maize silage (€ 33/227 per t DM (10%) vs. € 4/75 per t DM). Generally one would expect the opposite because pasture systems are typically run more with lower inputs than systems on arable land.

Proportions in the operating costs are similar for maize and grass though and reflect the ratio between the total costs of both production systems.

**Figure 48:** Overhead costs comparison of forages analyzed (€/t DM) - UK 750

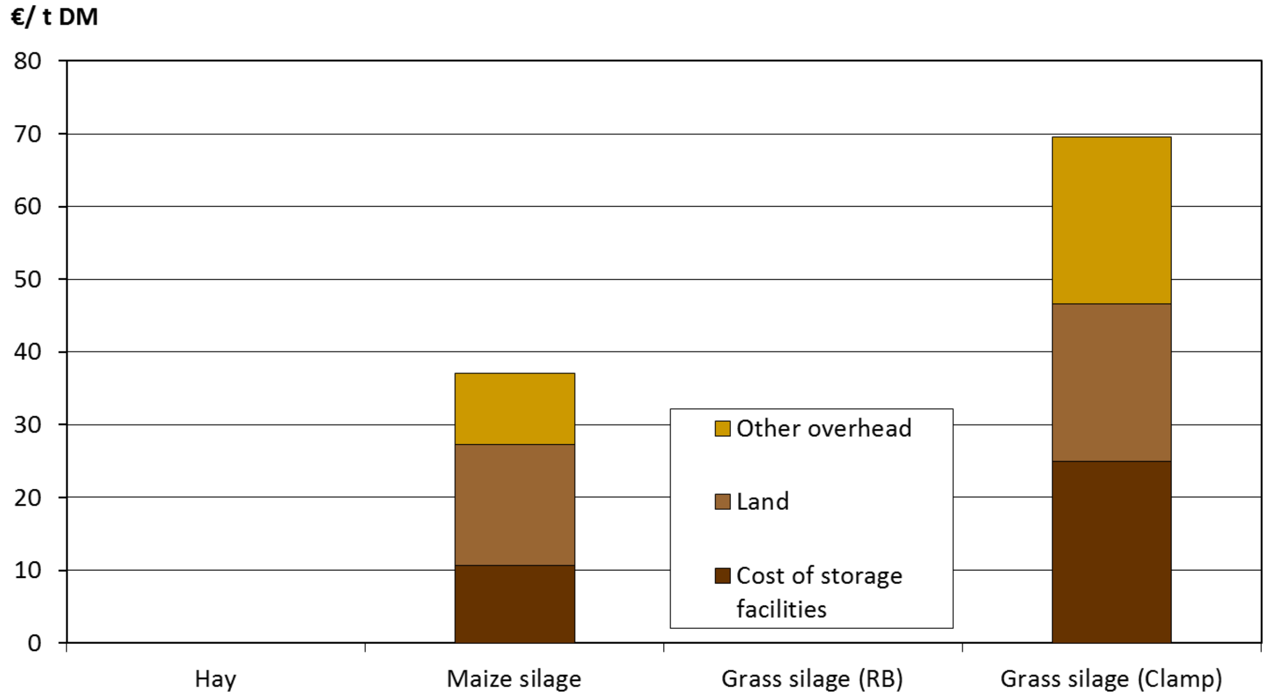
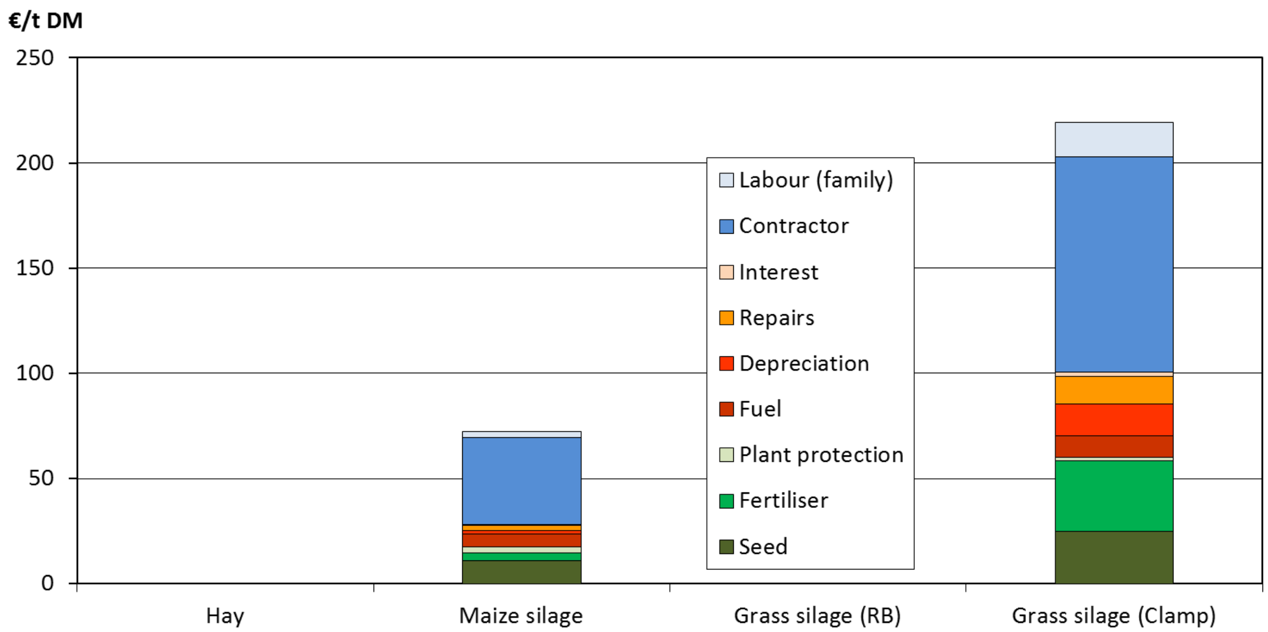



**Figure 49:** Operating costs comparison of forages analyzed (€/t DM) - UK 750



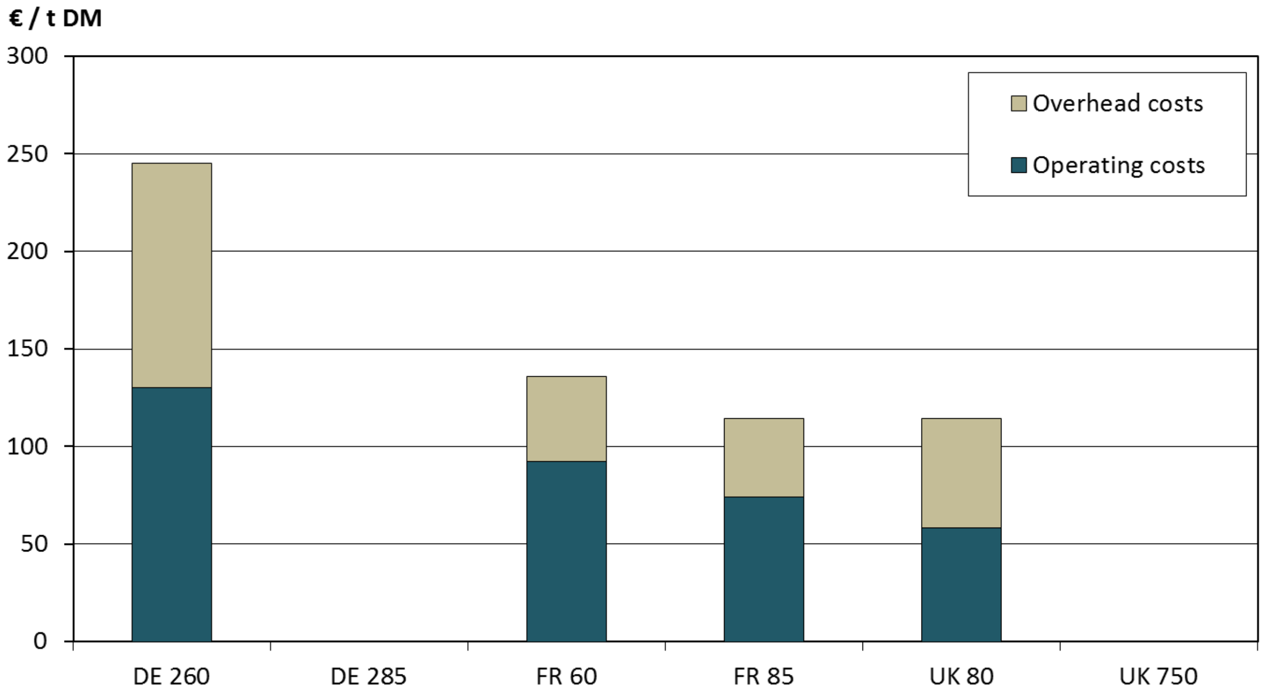
## 5.4 Results: Comparison of Production Systems

Forage production was analyzed by type of forage to compare the costs of productions systems between farms and countries. Comparisons are made based on dry matter yield. Diagrams with comparisons per hectare can be found in the data disc Folder 4- Diagrams.

### 5.4.1 Hay

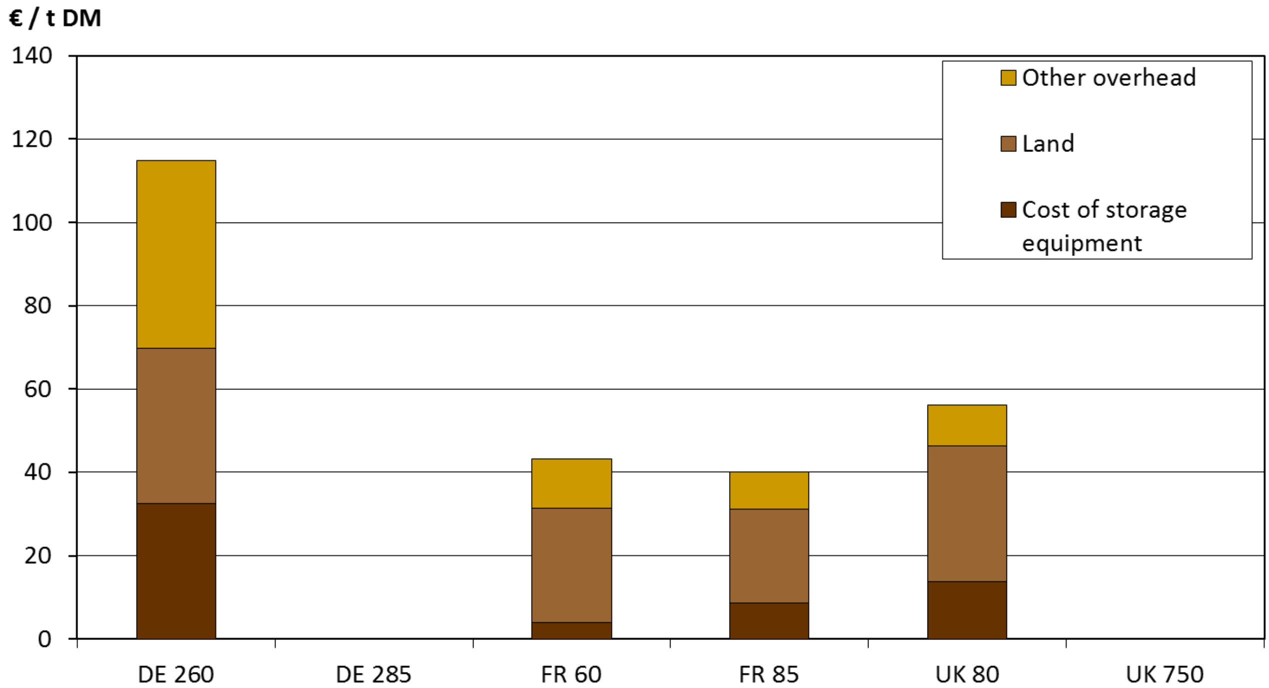
Figure 50 below illustrates that costs for hay production are comparable in France and the United Kingdom, where grass is cut only once but they are significantly higher in Germany where grass is cut three times. FR 85 and UK 80 have the lowest costs with € 114/ t DM, followed by FR 60 with € 136/t DM. The most expensive system is located in DE 260 where the ton DM costs € 245. What is remarkable about the German result is the high percentage of overhead costs (€ 114/t DM), which make almost 50% of the production costs. Land costs in DE 260 are about € 100/ ha higher than in the most expensive competing system (UK 80 € 152/ha); c.f. data sheet land costs in the appendix page x.

**Figure 50:** Hay – Comparison of total production costs per t DM




When related to the dry matter yield however this disadvantage shrinks as figure 51 on the next page will show: land is € 10/ t DM more expensive than the most expensive competitor (€ 27/t DM in FR 60). Costs for storage are also much higher in DE 260 (€ 33/t DM) even twice the price of the second most expensive farm (UK 80 € 14/ t DM). The reason is the little acreage used for hay in DE 260 (5 ha) that influence the storage costs calculation and the fact that existing old buildings are used to store the hay rather than a hangar or a simple shelter.

**Figure 51:** Hay – Comparison of overhead costs per t DM




When operating costs are considered disadvantage of DE 260 still exists, but also differences between the French and British farms become visible, even though the amount of cuts is the same. UK 80 has the lowest operating costs (€ 58/t DM) given the low inputs: no seeds and no plant protection are used and costs for mineral fertilizer are negligible (€ 1.3/ t DM). Another important aspect is variable machinery costs which are displayed in figure 52 below. The British (UK 80) pay € 21/t DM for that cost center while their European neighbors pay at least double (FR 60: € 44/t DM) or even triple the amount (DE 260: € 62/t DM). FR 85 conducts the same amount of operations as UK 80 (8 operations) and outsources half of them to a contractor, which reduces family labour and variable machinery costs usually. But in comparison to UK 80 (€ 21.5/t DM), which contracts 2 operations variable machinery costs are more than twice as high (€ 52.4/t DM). This can be attributed to the fact that depreciation periods in the French farms are much shorter, because the lifetime of the machinery is estimated to be shorter. For instance, a fertilizer spreader in FR 85 has a depreciation time of 5 years at an annual utilization of 77 ha, while the fertilizer spreader in UK 80 is estimated to last 10 years at an annual utilization of 150 h per year at a capacity of 0.7 h/ha, that is 214 ha per year (c.f. spreadsheets for both farms on the data disc). The machine is a rotating disc spreader for FR 85 and a pendulum spreader for UK 80, that is, they are not 100% identical. Still they are comparable equipment for the same purpose with similar technology, which is why it is unlikely for one to last 6 times less long than the other (FR 85 5 x 77 ha = 385 ha and UK 80 10 x 214 ha = 2140 ha).

**Figure 52:** Hay – Comparison of operating costs per t DM

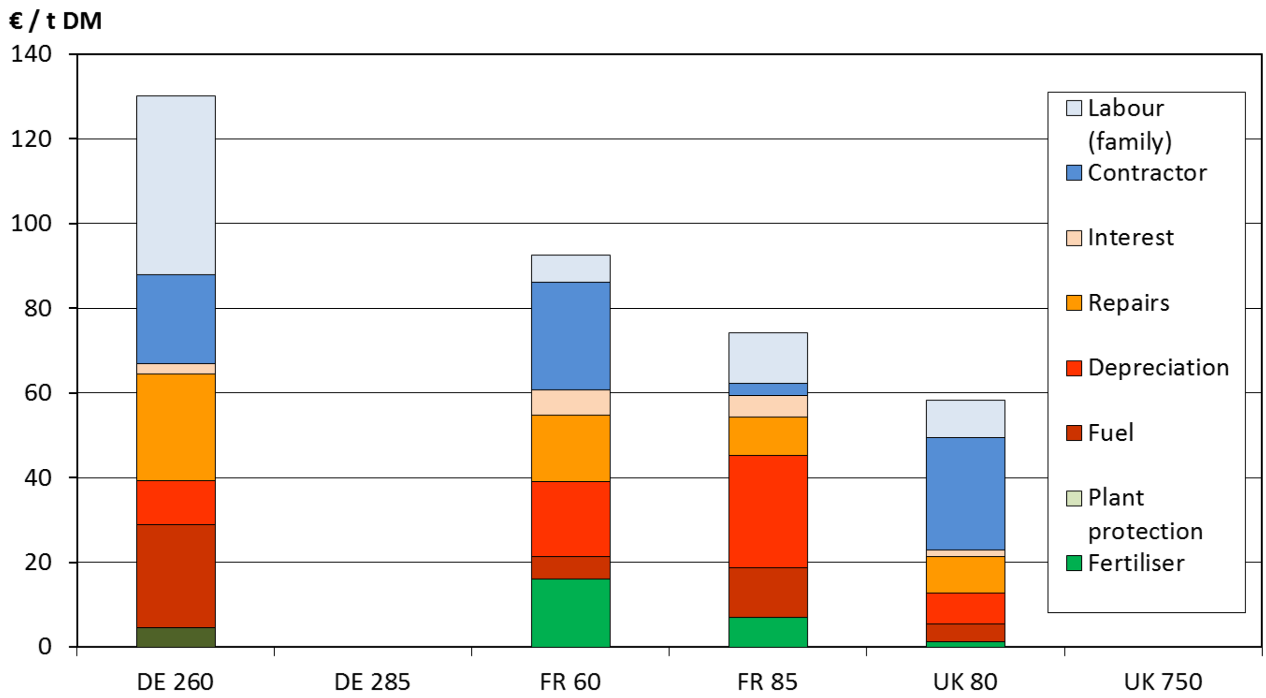
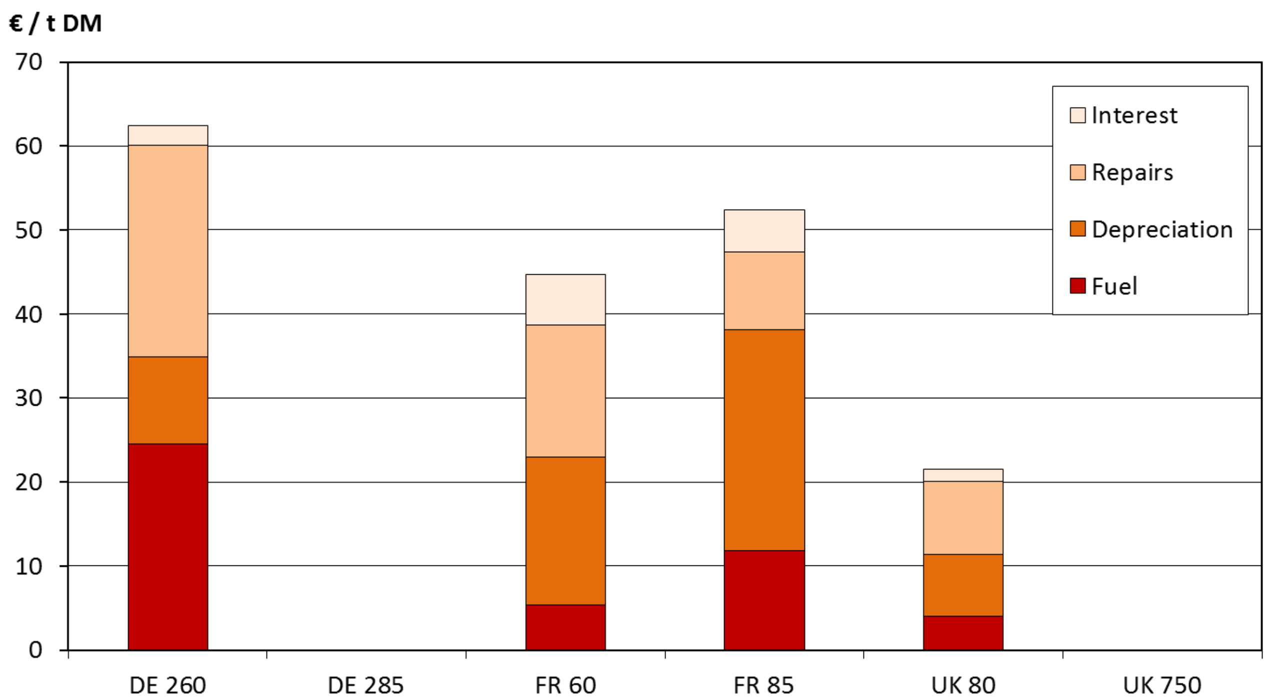



**Figure 53:** Hay – Comparison of variable machinery costs per t DM

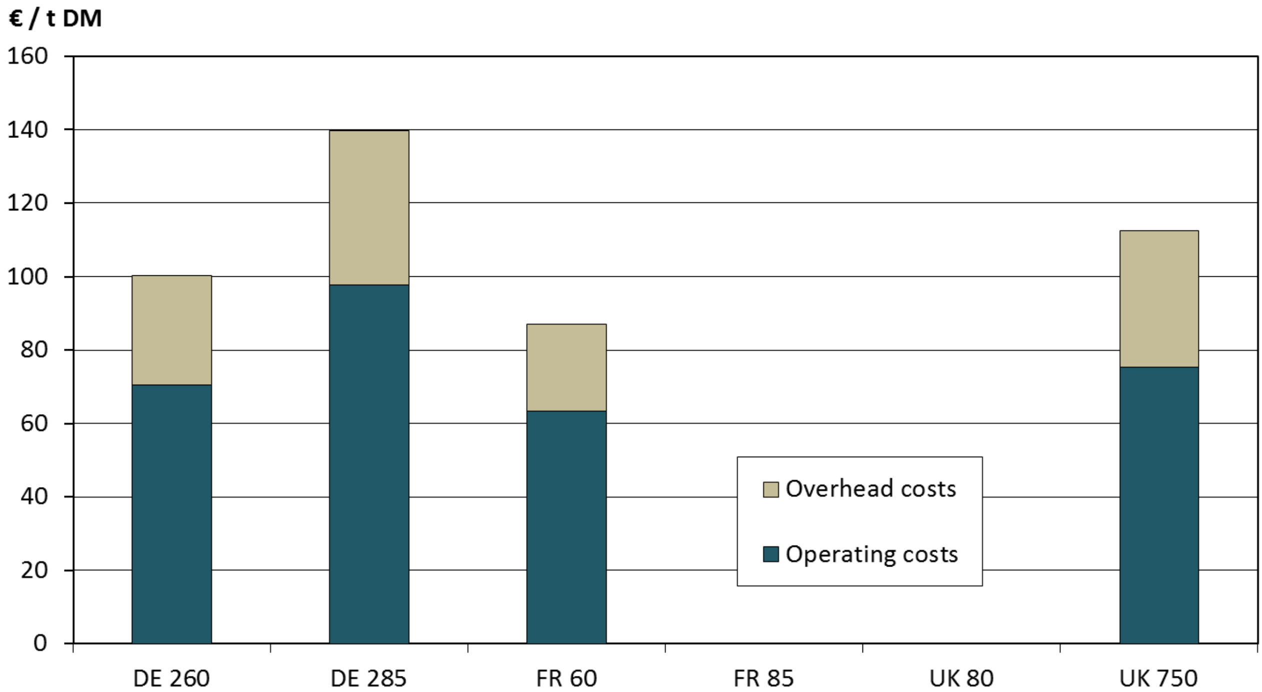



Such differences that affect costs of depreciation and repairs have an influence on the total result: In terms of total costs both farms are equal at € 114/t DM, so the difference in depreciation sums of € 18/t DM would actually make a notable difference with regard to the total result and might even make FR 85 more cost-efficient than UK 80. The discussion will pick up on this topic again.

### 5.4.2 Maize Silage

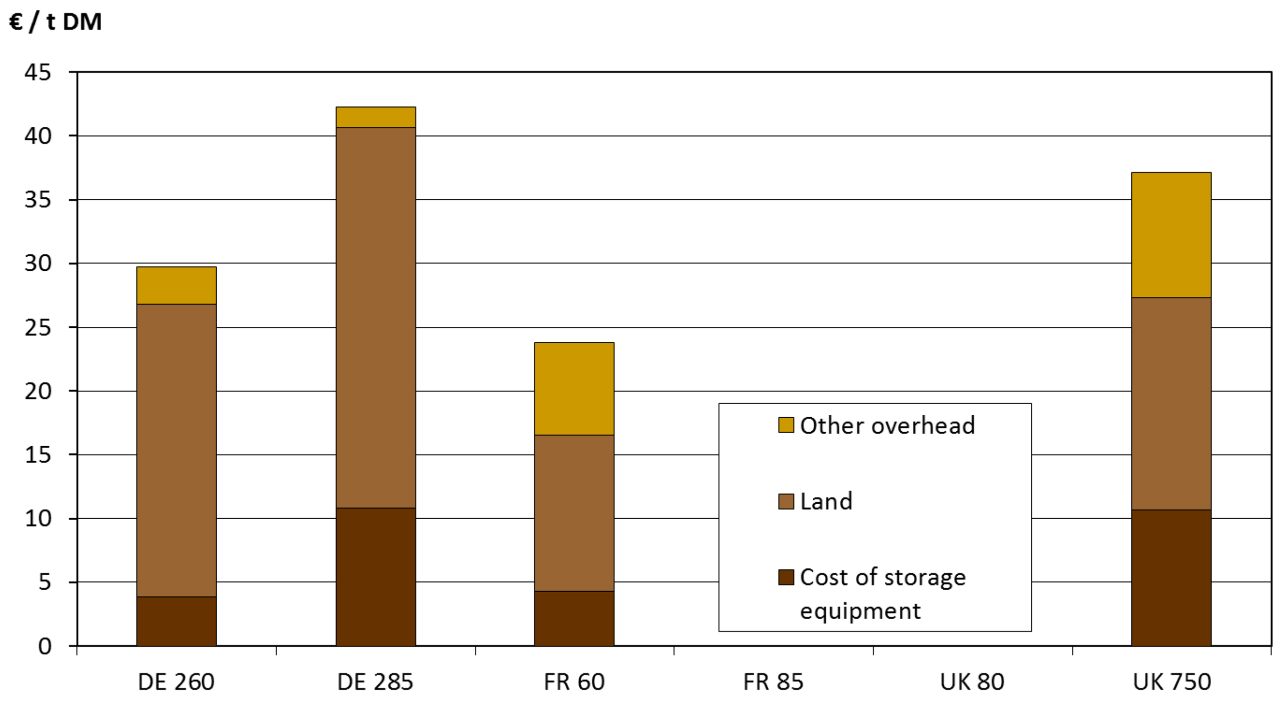
Maize silage is produced in four out of six farms as shown in figure 54 below. FR 60 has the lowest total costs at € 87/t DM while costs are highest in DE 285 (€ 139/t DM). DE 260 pays € 100/t DM and UK 750 € 112/t DM. Except for DE 285 (€ 97/t DM) the operating costs are very similar (€ 63/70/75 per t DM). Figure 55 and 56 will elucidate how overhead and operating costs are distributed and influence the total costs.

**Figure 54:** Maize Silage – Costs Comparison (per t DM)




Overhead costs make about 30% of the total costs in all farms (left to right 29 %, 30%, 27%, 33%). Land costs make the biggest share of overhead costs as figure x will verify. In DE 285 they amount to € 29/ t DM, twice the costs of the cheapest competitor (€ 12/t DM). It reveals the tremendous differences in land prices across Europe, where a common agricultural policy is enforced in countries with very heterogeneous conditions. Costs for storage equipment are the same in DE 285 and UK 750 (€ 100/ t DM) and cheapest in DE 260 (below € 4/t DM). Additionally, one can see that farms with lower dry matter yield (FR 60: 10,5 t DM/ha and UK 750: 11.7 t DM/ha) have significantly higher other overhead costs (both € 10/t DM) than the higher yielding farms (DE 260: 18.9 t DM/ha and DE 285: 13.4 t DM/ha).

**Figure 55:** Maize – Overhead costs comparison (per t DM)




The distribution of operating costs as displayed in figure 56 on (p.72) is slightly more complex to explain and assess:

Costs for seeds are similar and range between €10/t DM in DE 285 and € 14/t DM in FR 60. Costs for further inputs (fertilizer and plant protection) are highest in the most expensive production system (€ 18/t DM) and higher in the German farms (>€ 10/ t DM while <€ 7/t DM in FR60 and UK 750). Since the amount of plant protection applied in the systems is only measured in Euro for all systems it is hard to judge whether this stems from higher costs for plant protecting agents in Germany or whether the amount applied is simply higher in Germany. When considering the labour input both for contracted labour and for family labour and relating it to the variable machinery costs there seems to be a connection between the farms that use more family labour and their variable machinery costs: FR 60 and UK 750 both pay less than € 3/t DM for family labour and spend more than 90% of their expenses for working hours on contractors (€ 34 out of € 37/ t DM for FR 60 and € 41/t DM for UK 750). In the German farms 47% (DE 285 € 22 out of € 47/t DM) or more of these expenses are paid to family labour, therefore the use of owned machinery is higher and the variable machinery costs are higher in absolute terms and also in proportion to the sum of operating costs. In example, in FR 60 and UK 750 variable machinery costs make 15 % or less of the operating costs, while in the typical farms in Germany they make at least 22 %. In figure 57 on the next page the total amount of machinery costs is compared and underlines this statement.

**Figure 56:** Maize Silage – Operating costs comparison (per t DM)

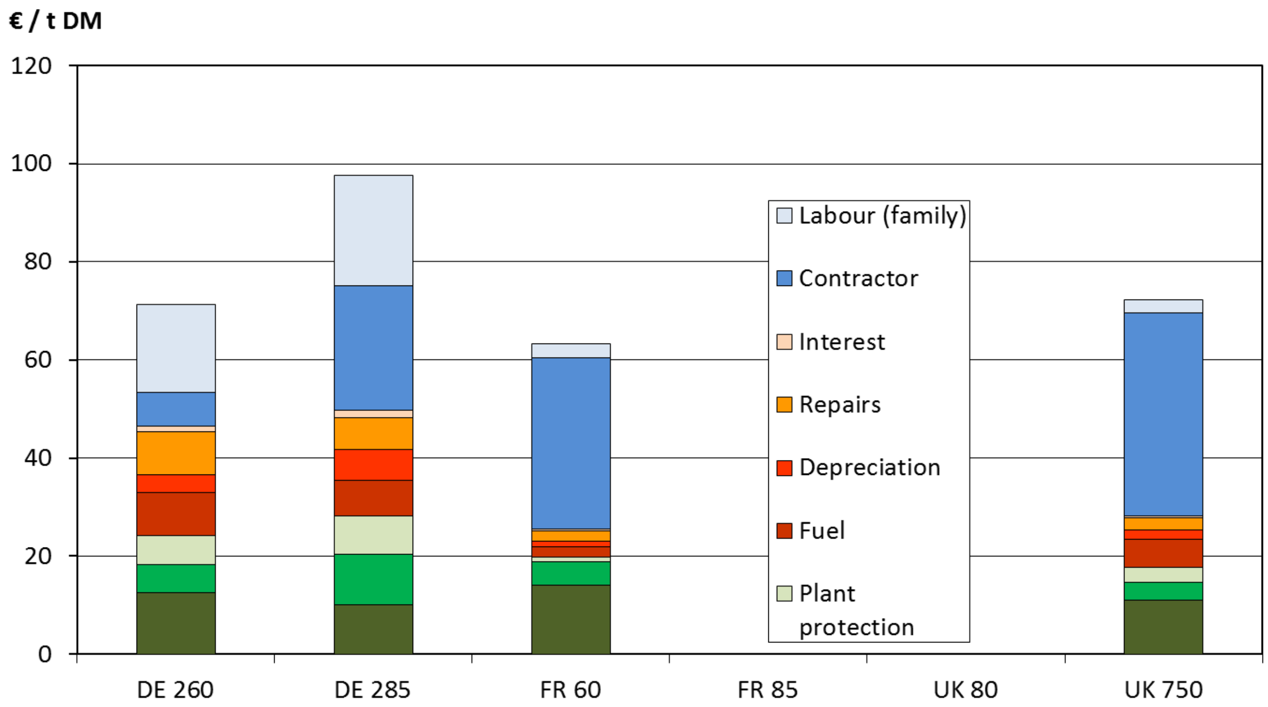
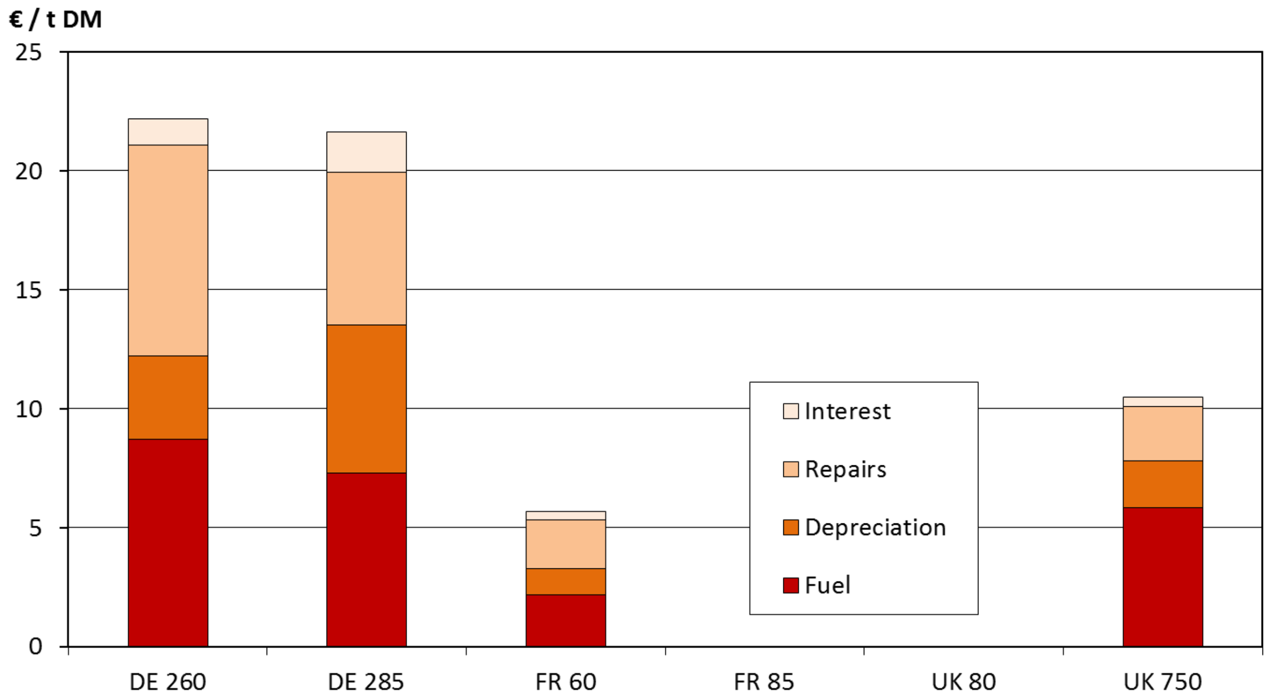


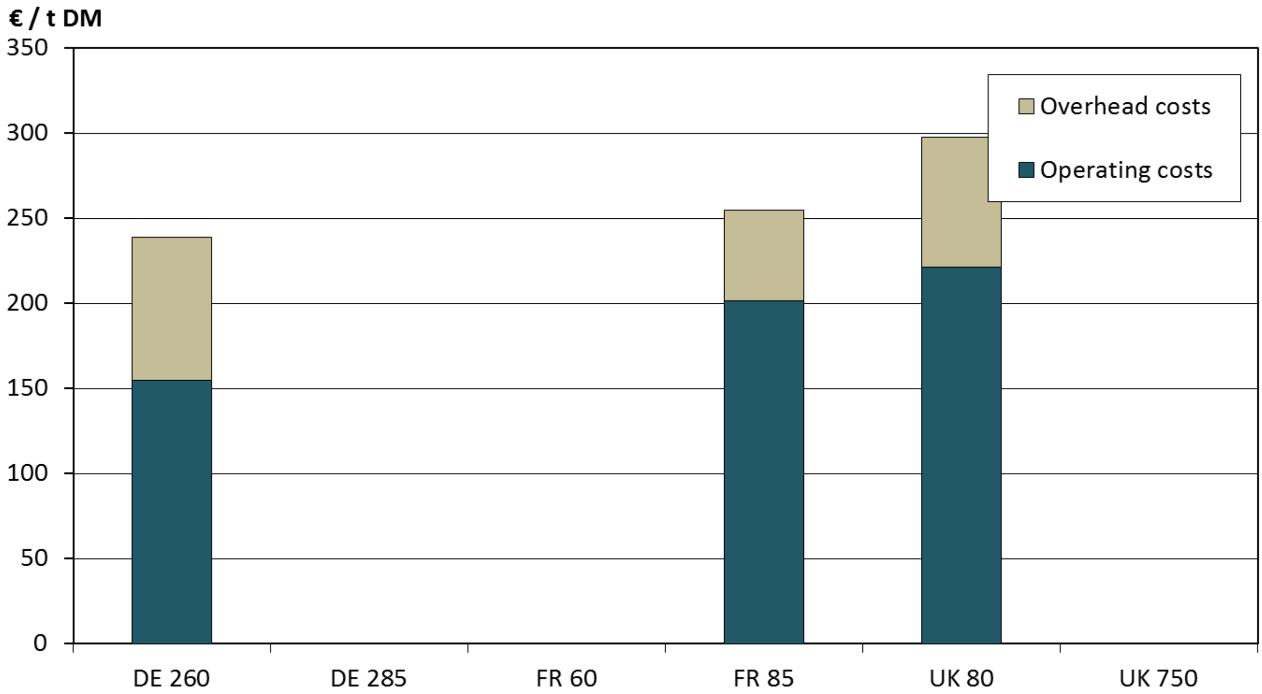

**Figure 57:** Maize Silage – Variable machinery costs comparison (per t DM)



### 5.4.3 Grass Silage (RB)

Round bales from grass silage are produced in three farms: DE 260, FR 85 (haylage) and UK 80. Figure 58 below shows that the German farm has the cheapest overall costs (€ 239/t DM) while the British farm has the highest (€ 297/t DM). Overhead costs are lowest in FR 85 (€ 53/ t DM) and operating costs are lowest in DE 260 (€ 154/t DM). This is unexpected because DE 260 is the only system that cuts three times (others: 1 cut). Comparing with table 3 in chapter 4 farms however the reason is obvious: DE 260 has the highest dry matter yield (7.12 t DM/ha) while FR 85 and UK 80 harvest less than 60% of that amount (4.1 t DM/ ha and 3.54 t DM/ha respectively). Thereby DE 260 can outcompete the other farms even though operating and total costs are highest in this farm per hectare (€ 1102/ha and € 1699/ha respectively). Also overhead costs are highest in DE 260 with € 89 per ton dry matter as figure 59 page 73 points out.

**Figure 58:** Grass silage round bales – Costs Comparison (per t DM)




Next to the expensive costs for land in DE 260 (€ 250/ha = € 35/t DM) the driver of overhead costs in that system are other overhead costs which make 50% of the overhead costs (€ 42/t DM). The reason lies in the way other overhead was calculated: the little acreage in DE 260 of 5ha.

**Figure 59:** Grass silage (RB) – Overhead costs comparison (per t DM)

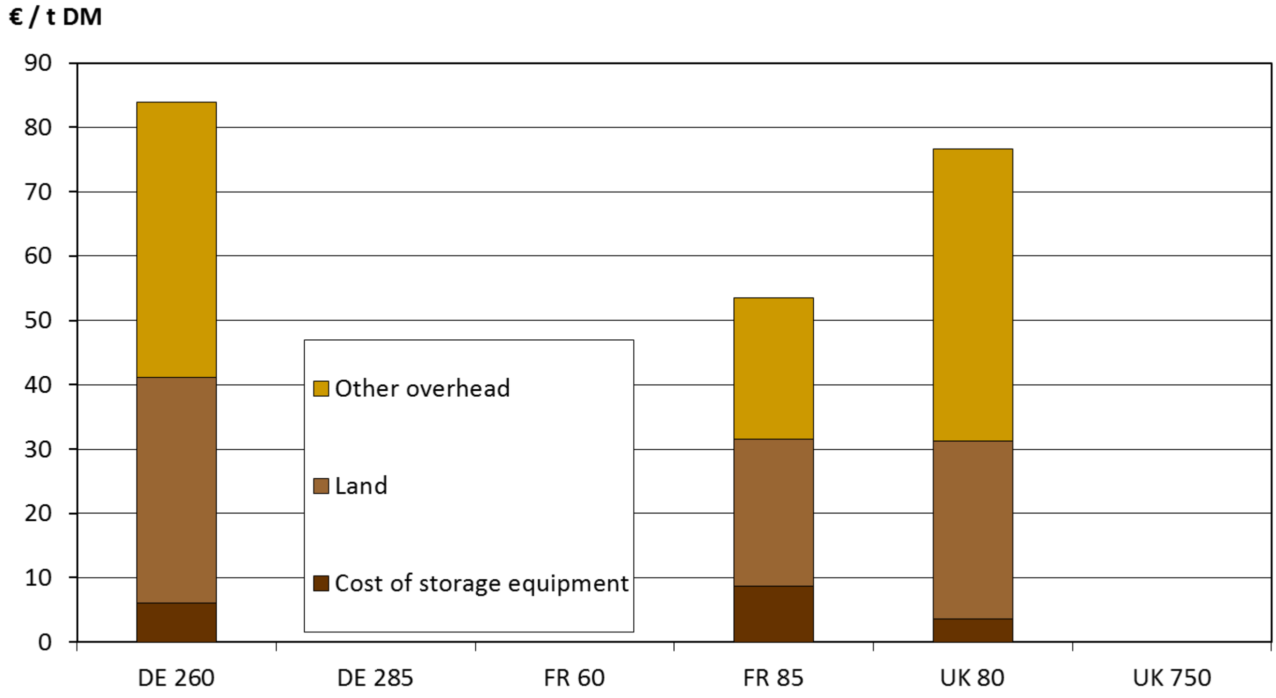



Figure 60 in the next page illustrates how operating costs are composed. Most eye-catching are the fertilizer and seed costs, which hardly exist in DE 260 (€ 6/t DM combined) and make more than a third of the operating costs in FR 85 (43%) and UK 80 (37%). In DE 260 no mineral fertilizer is applied and the plot is reseeded with only 10 kg/ha of seed while UK 80 and FR 85 reseed with 30 kg/ha of seed or more. This figure for Germany stems from the LfL database and was confirmed in the farmers meeting for DE 260. The systems we are looking at operate on established pastures, so that unless there is intensive aftermath with trampling damage, reseeding with 30 kg/ha is rather unlikely at least in German farms.

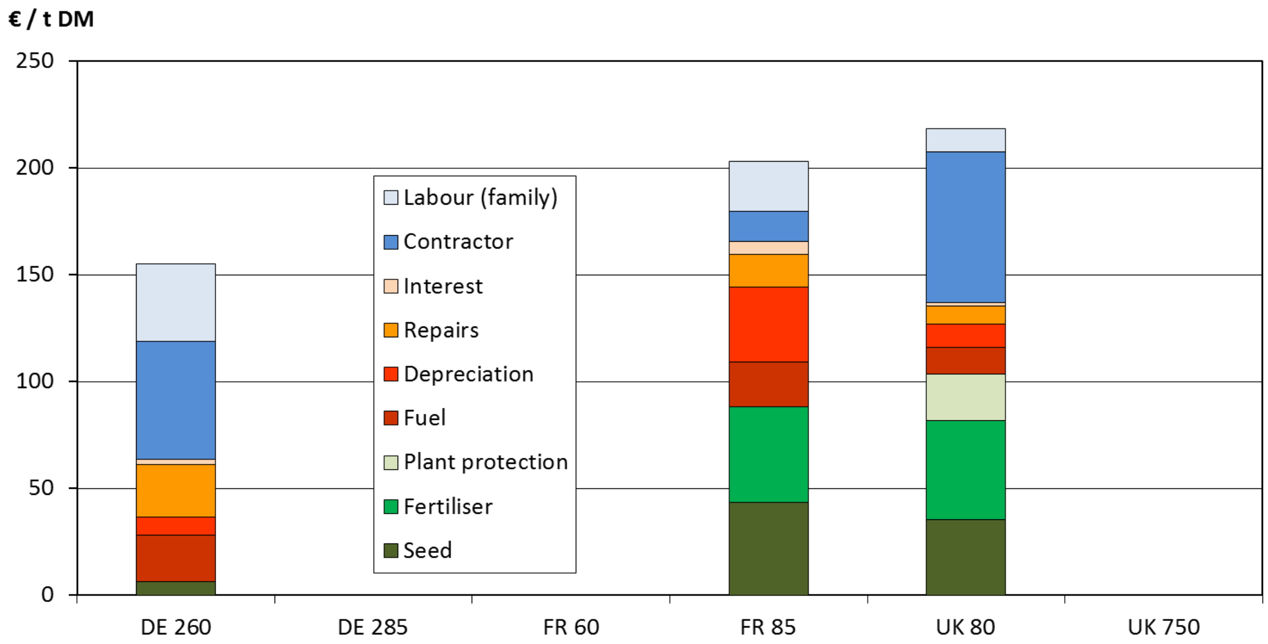
Furthermore the costs for labour input (family and contractor) are more than twice as high in DE 260 (€ 81/t DM) and UK 80 (€ 91/t DM) than in FR 85 (€ 38/t DM). This is surprising for different reasons:

1. The least working steps are in the production system of UK 80 (8), so one would expect labour costs to be lowest for that farm.
2. The ratio of contracted work in FR 85 is 5 out of 14 (ca. 1/3) while it is lower in the other systems, which creates the expectation for the share of contractor costs in labour costs to be higher than in the other systems. Yet it is the lowest share with 37% (€ 14/t DM). Since the yield is not high enough to be the cause for that advantage, the reason must be in the contractor prices. In France many operations are organized in cooperatives of farms that purchase machinery together. Costs for wrapping provide an insight into the advantage of such arrangements: In DE 260 wrapping costs € 177/ha but in FR 85 the price is € 25/ha for the cooperative.

3. DE makes two cuts more than the other farms and therefore should have significantly higher labour costs, which is the case, but UK 80 has the highest labour costs per ton dry matter even though it has the least production steps.

The average cost of a contracted operation in FR 85 is € 15/ha, while in UK 80 it is  and in DE 260 even € 197 /ha. The French solution may be an interesting solution that will be addressed further in the discussion (chapter 6).

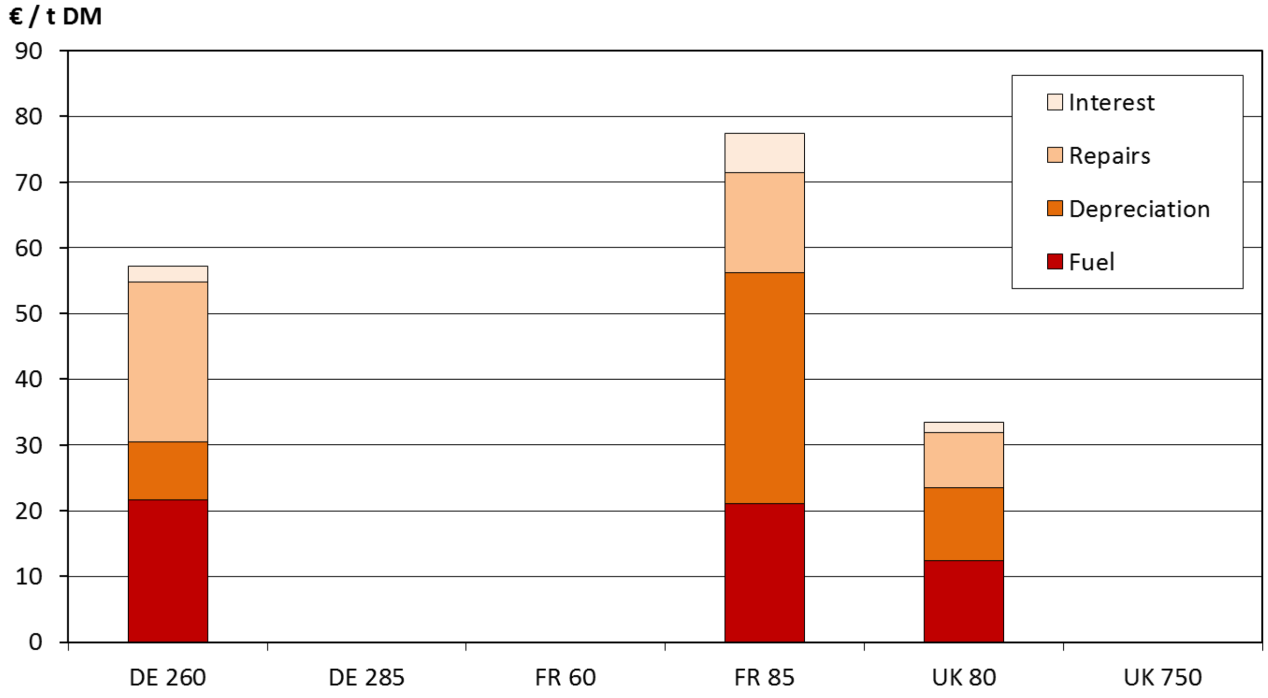
**Figure 60:** Grass silage round bales – Operating costs comparison (per t DM)




Costs for variable machinery are highest in FR 85 though (c.f. Figure 61 page 76) as in maize silage the different duration of depreciation and utilization potentials are reflected when matching UK 80 with FR 85.

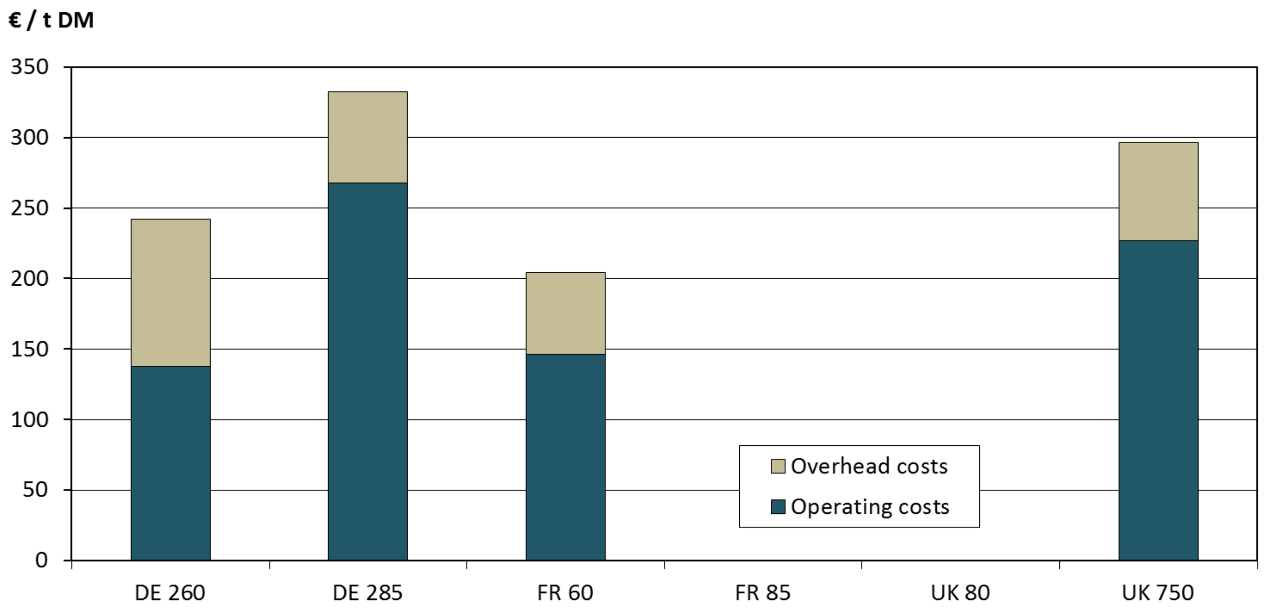
Despite the fact that fuel prices are highest in Germany (DE 260 € 1.4/l > FR 85 € 0.9/l > UK 80 € 0.57/l) this is likely not the explanation for DE 260 having the highest fuel costs. Rather the high amount of operating steps involving the tractor and little contractor use make the difference here. Costs for depreciation are highest in FR 85 given that the depreciation parameters used stem from French engineering data and use lower annual utilization than the data from KTBL that was used for DE 260 and UK 80 (e.g. mower in DE 260 615ha/year for 15 years = 9225 ha and FR 85 94 ha/year for 7 years = 658). The highest variable machinery costs are in FR 85 (€ 77/t DM) where utilization potential is lowest.

**Figure 61:** Grass silage round bales – Variable machinery costs comparison (per t DM)



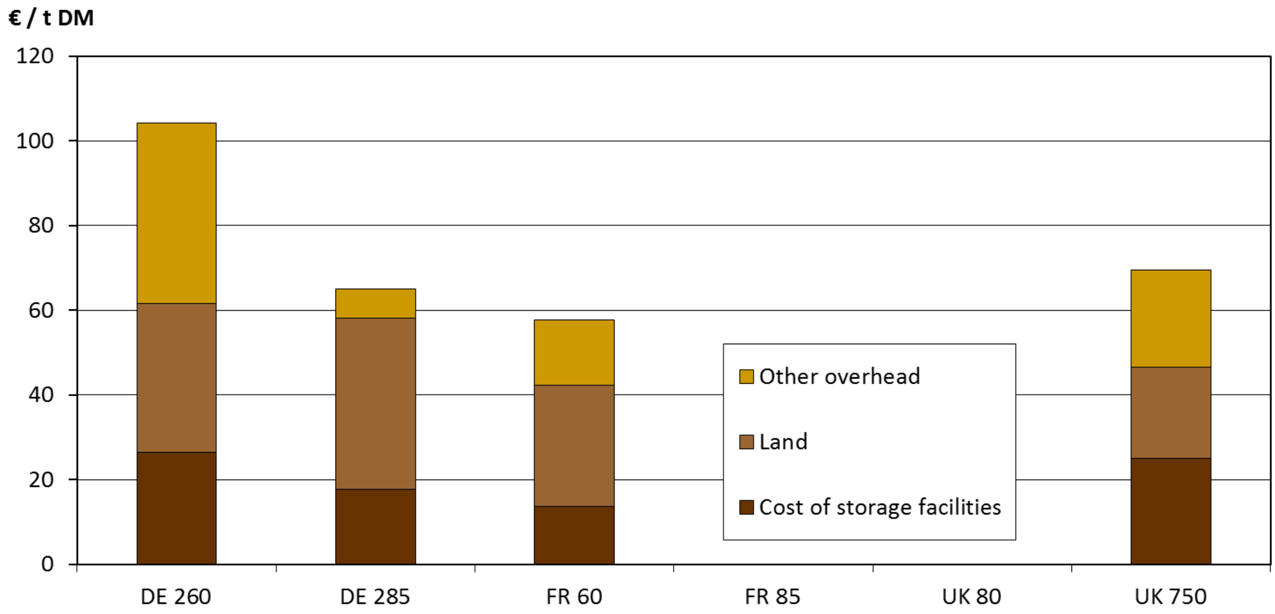

## 5.4.4 Grass Silage (Clamp)

**Figure 62:** Grass silage (Clamp) – Costs comparison (per t DM)




Four farms produce grass silage for the clamp: both German farms, FR 60 and UK 750. The most expensive grass silage production system is DE 285 with three cuts and total costs of € 333/t DM and the cheapest grass silage (clamp) produced in FR 60 (€ 203/t DM) (see figure x page x). DE 260 cultivates at similar operating costs (€ 137/t DM) as FR 60 (€ 146/t DM) but overhead costs are much higher (€ 104/t DM > € 57/t DM). Much higher overhead costs (€ 43/t DM > € 16/t DM) and double the costs for storage (€ 26/t DM > € 14/t DM) are the cause for this difference (c.f. figure 63). For all farms except DE 260 the overhead costs are in a range of 12 Euro (€ 57/t DM to € 69/t DM). That is overhead costs do not make the essential difference in the total costs of the systems (except DE 260). Other overhead costs increase the costs for DE 260 significantly because of the small acreage (5 ha) the system was modelled on (c.f. sheets for the production system on the data disc attached.

**Figure 63:** Grass silage (Clamp) – Overhead costs comparison (per t DM)




The amount and distribution of operating costs is more heterogeneous as figure 64 page 78 shows. Like in total costs DE 285 is most expensive (€ 267/ t DM) followed by UK 750 (€ 227/t DM). FR 60 (€ 146/ t DM) and DE 260 (€ 137/t DM) are on a different level. This is very interesting since DE 260 and DE 285 cut three times but they are not similar in terms of operating costs, rather the opposite. Yields in DE 260 are slightly lower (7.1 t DM/ha < 8.0 t DM/ha), which would be a reason for DE 260 to be more expensive than DE 285 not vice versa. What strikes the eye are the fertilizer costs in DE 285 (€ 58/ t DM) that make about one fifth of the costs. Total input costs (seed, fertilizer, plant protection) make about € 60/t DM in all systems except DE 260 which relies on slurry for fertilization and uses no plant protection. This explains how operating costs are kept low in that systems and how it is still competitive with the cheapest production system in spite of the high overhead costs. Total labour input and distribution between the operators vary strongly between the farms from € 15/t DM (DE 260) to € 102/t DM (UK 750). In FR 60 the input of family labour is the lowest in terms of costs (€ 12/t DM) but makes about half of the total working time 3.5 h/ha (of 7.8 h/ha) within the system. That is mostly expensive activities (e.g. harvesting) have been outsourced. The farms with higher costs for family labour (DE 260 and DE 285) also have higher variable machinery costs as shown in figure x.

**Figure 64:** Grass silage (Clamp) – Operating costs comparison (per t DM)

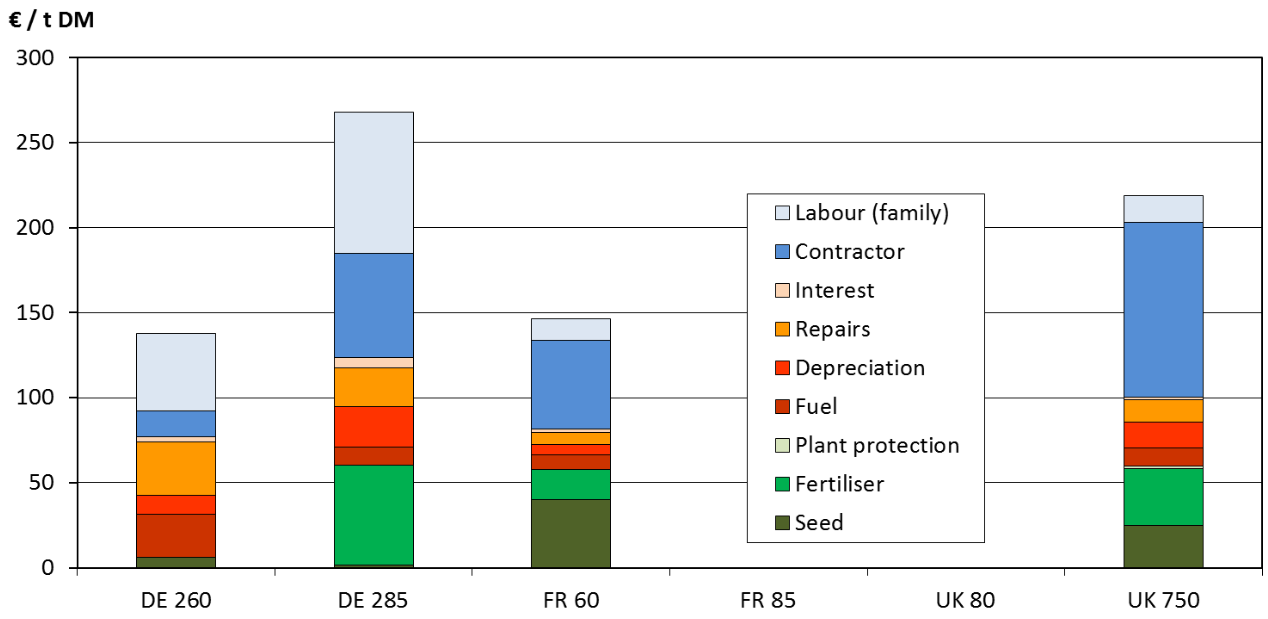
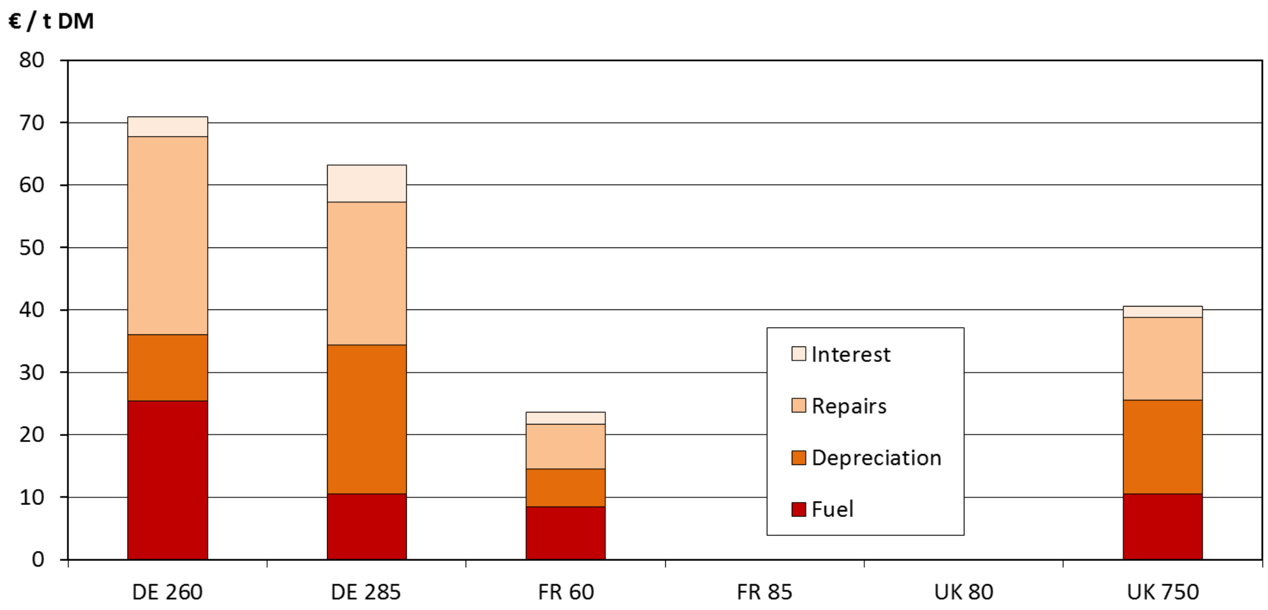



**Figure 65:** Grass silage (Clamp) – Variable Machinery costs comparison (per t DM)




Matching its low cost for family labour FR 60 also has the lowest variable machinery costs because most machines are rented from and operated by a contractor. Fuel costs are disproportionately higher in DE 260 than in DE 285 given that the tractors needed for towing the equipment are bigger with most of the machinery in DE 260 (e.g. mowing in DE 260 with 83 kW in 0.35h/ha and in DE 285 with 45 kW in 0.53 h/ha) that us they consume more fuel. Another reason is that slurry application is not contracted in DE 260 and performed with 102 kW tractor five times per year.

## 5.5 Results: Summary

The results of this project can be summed up into the following bullet points:

- Where maize silage is produced it is the cheapest forage option.
- Input costs (fertilizer, seeds, plant protection) play a bigger role for the costs of the individual operation than labour input when operations are conducted by family labour. Therefore labour input and costs for the individual operation are not always proportionate. In most family operated activities working time and costs are closely related though.
- Grass silage in round bales is the most time-consuming forage option given the required working time and consequently the costs
- Overhead costs vary strongly between the investigated farms and countries. Especially the German farms have a competitive disadvantage from land costs.
- Certain production steps could be outsourced to reduce production costs more effectively. Especially steps that are performed once a year and require specialized equipment that cannot be transferred to other crops or uses (e.g. harvesting of maize silage) show high potential for outsourcing, which is reflected in all production systems.

# 6 Discussion

Chapters 3, 4 and 5 provided a comprehensive insight into the generation of data and the financial results. In the following chapter the qualitative results will be presented. What are the reasons for farmers to outsource, what are their criteria for contractors and which other issues arise in forage production? Firstly, the results will be discussed against the background of the findings in focus groups and relevant literature. One focus will be on research objective c) of identifying driving forces, decision making processes and issues in forage production (see chapter 1 Introduction). Secondly, a reflection on the selected methods will identify needs for revision and reconsideration.

The minutes from the British meetings were not available at the deadline of submission.

## 6.1 Discussion: Results

### 6.1.1 Driving forces for outsourcing machinery operations

There are two forces driving farmers to outsource their operations: workload and costs for machinery. With the increasing investment needs for machinery farmers have to consider purchasing decisions more carefully (compare minutes of focus group DE 285 in appendix p. 19-25). Additionally the increased workload in beef finishing requires farmers to consider the allocation of their working time. The same labour cannot be in the shed and at the field at the same time, so tasks have to be delegated or workers that need to be hired.

### 6.1.2 Decision-making

Farmers consider the following criteria when making decisions about contracting work:

**Availability of operator and machinery**

Given the need for timeliness in agricultural operations and the dependency on the weather there are limitations in the planning of contracted activities. Additionally, harvesting season comes at the same time for multiple farms in one region. If farmers rely on contractors who are not available at short notice, they have no other option to perform the operation. Consequently, they are dependent on the availability of the contractor, which is not necessarily known to them in advance.

**(Expected) quality of contractor work**

The focus groups showed that trust and reliable performance of the contractor on the field are more important to the farmer than the economic benefit. Given the sensitive nature of the agricultural production system all staff working the acreage must be focused on the outcome, i.e., harvest. Since farmers have to bear the consequences of irresponsible or technically wrong operation of machinery on their field with their livelihood or a lost / bad harvest they will only work with reliable contractors who perform services satisfactory. Unfortunately it is in the nature of agricultural activities that success of a production step can oftentimes be seen only after some time has passed. Consequently, contractors cannot be evaluated immediately after performing their task, which puts farmers at risk when choosing contractors. Only time and experience can show whether contractors are reliable and work satisfactory. This may affect the farmers' reluctance to outsource with the possible consequence of occurring higher costs when using own machinery.

**Individual technical skills and experience**

Farmers benefit from experience in their daily work. In their opinion they know their fields and animals best (compare minutes of DE 260 appendix p. 13-18) based on expertise acquired over time. Having a contractor conduct their operations they cannot be sure it was done correctly.

They have to rely on previous experience with contractors (compare minutes of DE 285 p.) or vigorously control the contractor during and after operation. However dedicating more time to controlling is “just as good as doing it yourself” (Farmer’s statement in focus group DE 260).

Another aspect relating to experience and skills is repairing machinery and tinkering for tailor-made solutions. For instance, in focus group DE 260 one farmer had combined parts of an old and a new machine into a precision drill with seeder, thereby saving tilling operations in spring and the investment into a seeder (or contracting seeding). In focus group FR 60 another farmer stated that he contracts operations because repairs for own equipment are expensive and he lacks the technical skill for repairs.

**Existing machinery / opportunity costs**

In the discussion with German focus group south an interesting aspect of the farm tractor utilization arose: Some farmers admitted that some operations are only performed in order to cover the tractors utilization potential. That is, even if the operations are conducted at economic disadvantage today the loss in depreciation is potentially bigger by outsourcing them.

**Social implications**

In the rural settings of most farms one should not underestimate the power of social factors influencing decisions by the farmer. Purchasing a new, bigger tractor is not only a matter of economic necessity and possibilities but also a message to the outside world, especially other farms, that the enterprise can afford such machinery and is economically successful. In consequence it can be undesirable to share machines with colleagues even if that entails economic advantages. Firstly that would display that the farmer is short of money and secondly the cooperation will be advantageous as well for the cooperation partners. The relevance of envy being one factor in such basic economic considerations has been confirmed by both, farmers and advisors, in the German focus group south. To conclude this thought a suitable hypothesis in need of proof would be “As long as farmers can afford to perform all production steps / machinery himself he will do it instead of sharing machines with colleagues or buying contractors in”.

In France, where cooperatives are the rule, the image appears to be different. Sharing labour with the neighbors is perceived as beneficial and important for the farmers (c.f. minutes of focus group FR 60). In this case the advantage of being part of a social and economic structure (entailing solidarity) matters more to the farmers.

### 6.1.3 Issues in forage production

**Clamp: Compacting and Closing**

KTBL assumes that harvesting-transport-storage chains are designed to ensure minimal working hours for the harvester. In LfL compacting of maize silage is considered to take the same time as the harvesting operation. That is, the capacity for the compacting tractor is considered to be equal to the capacity of the harvesting machine.

From our focus group in northern Germany we learned that the capacity of the tractor on the clamp is the limiting factor in the silage harvesting chain. Consequently the harvester has to wait for the compaction on occasions. Therefore the causality is actually vice-versa: the capacity of the tractor determines the capacity of the harvester. In other words, the harvester cannot work at full capacity if the tractor on the clamp does not match its capacity.

The focus groups conducted in Germany however suggested that the central concern of farmers in such chains is optimum compacting of silage in the clamp (for maize silage). In the worst case the harvester has to stop midfield and transport has to wait until the desired degree of compacting is achieved by the tractor or truck on the clamp pile. Only then can the chain deliver further silage. The technical suggestion to solve this issue could be the adaptation of the tractor size on the clamp to the capacity of the harvest chain. However, these vehicles are already available through contractors and could be contracted with the rest of the harvesting chain. It rather seems to be the conviction of farmers that they know best how to compact the silage in the limited area available on the clamp as well as molding it to the desired shape for ensilaging. After all, the compaction plays an important role for the quality of the silage and therefore impacts the finishing result.

The closing of the clamp with foil is scarcely covered in literature. Farmers claim that this process takes much longer than actually anticipated: When asked for the duration of the closing operation alone, they answered that closing the clamp with the entire harvest (60 ha at 44 t FM/ha in DE 285) will take 5 hours with 4 workers (appendix page 23). That is 20 hours are needed for 60 ha or 0.33 h/ha for one worker. In KTBL both maize silage (4,17 h/ha at 50 t FM/ha) and grass silage (0,77 h/ha at 11,9 t FM/ha) have longer closing operations for the clamp, which reveals that the farmers did not link the operation to the acreage of the yield in this case, but only considered the total duration. They are actually much faster than the technical values.

**Field sizes and shapes**

A general remark that resurfaced within focus groups but also during discussions with experts and colleagues on the project is the fact that engineering data only reflects the technical figures for well–rounded and regularly shaped fields i.e. rectangles. In more mountainous and densely settled regions however such fields are nearly inexistent and odd shapes of all sizes are the rule. In such regions forage costs must be higher than reflected in this thesis and cost efficiency becomes more challenging. Machinery with GPS support could be a helpful tool for such regions to identify the shortest and most time efficient way to work such fields. The price of such technology nowadays can hardly be afforded by a typical farm though, due to the limited utilization of the machinery in such small structures. However this problem was not mentioned by the French and British farmers but similar situations in these countries appear to be likely.

**Design of production systems**

In some areas like the south of Germany or grass lands with marginal soils, grass based systems of hay, grass silage and grazing take place on the same plots, that is, a high quality first cut is made into hay for calves while the next cuts are ensilaged to seize the energy content even despite the loss in quality. Double-use on the same plot of land is also common in France and the UK. To model such systems was not the aim of this thesis but can easily be achieved by combining the steps from productions systems for hay and grass silage of the desired kind since both will be grown in established grass lands where plowing and further tilling activities are not necessary. Beside the modalities for the harvest both systems are similar if not the same. Such examples however show that farmers are already aware of the most feasible ways to make use of their land. More research into such combined systems may identify opportunities for machinery that is more adept to the farmer’s needs.

**Self-Sufficiency**

Particularly the French farmers interviewed are keen on getting more independent of purchase feed (compare minutes for focus group FR 60 appendix p.4-12 ). To ensure it, they aim to harvest and store more fodder than required for winter. That is, their costs for fodder costs are higher since they produce more than the cattle would consume in a system which is tightly balanced between own production and purchase feed. For the results of this study this has no implications, since figures were calculated on a per hectare base and costs were not aggregated to the whole-farm level and related to the stocking rate or number of cattle. Similar to their French neighbours, priority of German farmers is to produce a sufficient quantity of forages. This becomes particularly evident in the production of maize. Beef finishers will try to harvest maize grains where possible for the high-energy content to avoid purchasing concentrate (c.f. minutes of focus group DE 260 appendix p.13-18). At the same time maize silage is vital for the ration to ensure digestibility and provide energy. To provide for sufficient fodder throughout the year farmers will therefore prefer to harvest maize silage and only threshing excess maize when the bunkers are filled (c.f. minutes of focus group DE 260 p.14 f.).

**Grass silage in round bales: Do advantages outweigh costs?**

Even though grass silage in bales is the most expensive of the forages analyzed it has advantages that other systems do not have:

- temporal decoupling of harvesting and storage,
- small fodder units that are available independently,

- little to no storage requirements.

These points make grass silage in bales an interesting option for production systems with little acreage (that is small quantities of harvest) where grass silage has a small share in the ration so that feed rate in an average clamp is too low.

At the same time round bales need to be stored and handled with extra care to secure intactness of the foil. This disadvantage will impact the working time with increasing amount of bales.

## 6.2 Discussion: Methods

Different methods and databases have been used to produce results for this thesis. Some of them are discussed hereafter with respect to their usefulness, accuracy and limitations.

**Engineering databases**

French and German engineering databases have been evaluated for results. The methods by which they generated their results are not 100% transparent and the overall validity is hard to assess. Comparing e.g. depreciation data from the French CUMA and KTBL as done in chapter 4 Results suggests that there is no final validity in this data. In a oral conversation with KTBL personnel responsible for the MaKost calculator (Dr. Fröba, minutes of conversation on data disc Folder 2 - minutes) for machinery it was stated that some values have been interpolated between empirical data. For instance a swather in KTBL will have the same maintenance cost per ha irrespective of its size. This is supposedly balanced by the fact that utilization of the equipment increases with size.

**Depreciation, repairs, interest**

The basic calculations used for depreciation, repairs and interest are standard operations in (agricultural) economics. They produced logical results that are related to time and initial purchasing prices. The interest rates of 4% (4.25% in storage calculations) are commonplace (c.f. LfL, KTBL, DLG). Depreciating towed implement per utilization unit is also practiced by KTBL. For depreciation per ha and h this practice is simple because units are given in the capacity of machinery and can be converted easily. For $m^3$, the relation is also simple because the input is usually given in $m^{3,}$ e.g. for slurry trailers or plant protection capacity. Other input-related equipment like manure spreaders (per t manure) are also easy to calculate.

On the other end of the spectrum, calculation of trailers proves difficult and certainly needs optimization. In France trailers are depreciated per year. This way of distribution is not fit for agricultural reality though. On farms, trailers are used for many different operations like transport of produce or purchases. It would be more appropriate to know for how many hours or how many tons the trailer is used. This was the case for the KTBL based data in the German and British systems. One problem remained though: which yield to relate the trailers to? After considering the different options the t DM produce yield was chosen to exclude losses in the process of the harvesting chain since the focus of this project was the final product of forage as it is fed in the shed. This makes sense for baled produce since it is already in the terminal shape and losses are low after baling. For a more realistic (bit also much more complex) model assessments would have to be made on the points in the harvesting transport chain of chopped silages - grass silage (clamp) and maize silage - where most losses occur to produce a pre transportation yield that could be used for depreciation by tons.

**Fuel costs**

In a meeting with all project partners in July 2014 factors for fuel use were determined:

- distance to field
- field size and shape
- soil type and condition (dry, wet), and
- slope of the field. (Davis 2014)

In the scope of this thesis these factors were impossible to evaluate. That shows that the data at hand does not provide a realistic image of the fuel costs but rather pretends that the conditions in all six locations are the same. It is obvious that this is not the case as climate data and soil types show (compare chapter 4 Farms). In engineering data we typically find average values that assume ground is even and soil resistivity does not complicate operations (c.f. KTBL 2011, p. 1). To model soil resistivity and incline sufficiently however, more detailed climate and geographic data is needed. This could not be accomplished within the scope of this thesis or the project but would be an interesting combined project for GIS models combined with GPS machinery.

**Comparison per t DM**

To quantify the yield of forages t DM is a frequently used measure that farmers are familiar with. It provides an impression of the actual output, which is also a measure for efficiency of output per input. Economically this makes sense, which is why this unit was chosen for the comparison of costs. Physiologically however, hay and grass silage have a very important role in cattle feeding though. Typical farms all produce at least one type of grass-based feed and four of them even use their pastures for grazing. In the other two either hay is produced for the calves or grass silage supplements the diet. In the focus group DE 260 one of the farmers reported very good results with diets that contained 30% grass silage or more. The fiber content of the forage is very important in ruminant feed (Horrocks and Vallentine 1999, 67 f.). Therefore it would be more beneficial to compare a more qualitative unit like nXP (ruminal nitrogen balance; unit used in German dairy feeding for nitrogen available in the rumen) availability of data and evaluating silages sufficiently could however, constitute a challenge.

**Farm selection and sample size**

The sample of farms is not sufficient to produce results that are representative for the whole of the countries. Neither can they be considered single case studies though. They were selected in a standardized process to reflect their region in the best possible manner and represent more than one farm and individual farming practices. This was confirmed in the focus groups. For better comparability of the machinery and consequently variable machinery costs within production systems the size of the farms should be a selection criterion.

# 7 Conclusions

The results at hand show that forage production systems and their costs vary between the typical farms and their forages. Main causes for these variations are

- Division of labour (contractor / family labour)
- Costs for land
- Costs for other overhead items
- Costs for inputs
- Yield in DM

Farmers are aware of the linkage between division of labour and machinery costs and base their decisions for or against outsourcing on the following criteria:

- Availability and reliability of a contractor
- Quality of the contractor's work
- Own assets (machinery, network, technical skills).

The price for contracted operations is a secondary criterion for farmers. Instead of outsourcing to contractors the option of establishing cooperatives between farms is a suitable option to reduce costs for machinery by maximum utilization.

# 8 Abstract

Forages are frequently used in the feeding of cattle in Western Europe. Hay, grass silage and maize are home-grown alternatives to purchase feed and grain fodders. But what are the true costs of producing them? Farms in Germany, France and England have been investigated for their forage production and costs with special attention to the distribution of labour between family and contractor workforce. Major difference could be identified and evaluated to improve understanding of farmer's decision-making. As a result detailed insights into forage production were obtained and a detailed set of homogenously calculated data on forage production costs was created.

Grünfutter werden in der Rinderhaltung und –mast Westeuropas viel genutzt. Heu, Grassilage und Maissilage sind attraktive Alternativen zum Futtereinkauf und Körnerfuttern. Doch was sind die wahren Kosten der Grundfutterproduktion? Betriebe in Deutschland, Frankreich und England wurden auf ihre Grundfutterproduktion hin untersucht und der Arbeitsverteilung zwischen Lohnunternehmer und Familien-Arbeitskräften eine besondere Beachtung geschenkt. Wesentliche Unterschiede konnten identifiziert und evaluiert werden, um in Zukunft ein besseres Verständnis für die Entscheidungsfindung der Landwirte entwickeln zu können. Schlussendlich konnte neben einem Einblick in die Beweggründe der Landwirte auch ein detailliertes und einheitlich berechnetes Set an Praxiswerten generiert werden.

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## Eidesstattliche Erklärung

Ich erkläre hiermit an Eides statt, dass ich die vorliegende Arbeit eigenständig und ohne unerlaubte Hilfe Dritter angefertigt habe. Ich habe ausschließlich die angegebenen Quellen benutzt und alle Zitate und Gedankengut anderer als solche kenntlich gemacht. Diese Arbeit wurde noch nicht bei einem Prüfungsamt als Leistungsnachweis vorgelegt

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Friederike Rösner Braunschweig, den 20.09.2014