Improvement of calculation methods for net grassland production under different grassland utilization systems

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Improvement of calculation methods for net grassland production under different grassland utilization systems

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Foreword

This thesis is organized with an abstract of the thesis, a general introduction, the manuscript with a summary and conclusions. The second part holds a literature review. The title of the manuscript is:
Calculation of net energy intake under different grassland utilization systems

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Abstract

Throughout Europe, grass is major source of nutrition for ruminants. Grass can be grazed, fed fresh, as silage or as hay or in a preserved form as silage or hay. Over the past years summerfeeding has increased at the cost of grazing in dairy herds. One important reason for farmers to house their animals is optimization of grassland utilization. Investigations show than summerfeeding has higher yields than grazing, but is this also the case with net production. This study researched energetic calculation methods for the determination of net grassland production. The energy systems evaluated are the methods of Lantinga, Leisen and the KringloopWijzer (KW). The objective of this paper is to analyse, compare and check the reliability of these energy calculation methods for the determination of the net energy yield of grassland. The next step is to optimize and formulate a new model, based on the models investigated. With this new model European countries can use one calculation method for determining the net energy production from grass. It would be interesting to investigate the influence of grass management type on energy productivity.
Instead of measuring the production of grass in the field, the net energy production of grassland is calculated, based on energetic requirements of the herd for maintenance, production and other additional requirements. These requirements are equal to energy consumed as concentrate, roughages and other feeds. The energy consumed from concentrate and other feeds is subtracted; the remaining energy is from roughages. The difficulty lies in calculating the energy consumed from grazing.

For Lantinga, Leisen and the NEW model the net energy from grass- and maize silage are subtracted as well. The energy remaining originates from fresh grass, in the case of summerfeeding the gap is filled with energy from grass- and maize silage depending on their ratio. The KW uses the VEM-gap calculation; here the energy originating from roughages is divided based on their ratios as calculated in the VEM-gap. In the end when all net energy flows provided are known, the fresh grass and own grass silage or hay form the net energy production of grassland.

All models are compared on three farms Goor, Pool and Spruit. Goor applies summerfeeding, Pool and Spruit apply grazing. For the farm of Goor the energy produced from grass is quite clear. All energy comes from grass silage. For the farm of Pool and Spruit however the energy consumed through fresh grass has to be calculated.
The problem with the model of Leisen is that calculations for energy requirements are only for the grazing season and not for the entire year. In Lantinga and the KW a separation is made for energy requirements during grazing and during the housing period. For Lantinga only cows were taken into account, requirements of other grazers were unavailable. To complete these models adaptations were required based on the KW. The KW is the most complete model. It collects data of an entire year, corrects for requirements of other grazers present and calculates additional energy for replacement, gestation and NEB. A shortcoming of the KW is that it does not include all milk flows, possibly underestimating energy requirements and thus net energy production per ha.
This new model is based on the best parts of the former described models. First, milk flows are included, not underestimating energy required for milk production. The standard energy requirements are derived from the KW, being the most accurate. Additional requirements as used by the KW were adapted to

the farm data. Energy required for replacement and gestation and NEB were corrected for each farm. All these modifications increase the net energy production per ha.
Lastly in the new model the amount of energy consumed through grass has to be determined. Gross amounts fed to the herd for concentrate, roughages and other feeds are known through analysis. However during storage and conservation losses occur. For the models of Leisen and Lantinga these losses are fixed. This is practical but not very trustworthy as between farms and forages large deviations occur for losses. The KW corrects for these losses using the VEM-gap calculations. For summerfeeding this calculation works but in the case of grazing it does not work properly, energy consumed from either grass- or maize silage is overestimated, being higher than the gross amount provided. Thus underestimating the energy provided from fresh grass. Therefore the new model also assumes fixed losses specific for feed type.

The use of the VEM-gap in the KW overestimates energy provided through silages. Energy provided based on silages is higher than gross energy available based on silage analysis. The calculations of the VEM-gap should be modified for farms that apply grazing. Currently energy provided from fresh grass is underestimated, lowering the net energy production per ha. Even so the KW calculates a higher net energy production per ha, due to higher requirements in cows for bonuses of replacement, inefficiency, gestation and NEB. For all models counts the larger the gap between requirements and energy fed the more energy must have been provided through roughages, increasing grass production.

The new model must be further optimized, requirements should be better quantified. Additional energy for growth of other grazers present is not included, the same holds for energy due to walking and grazing activity of other grazers and heifers. For improvement a bonus should be calculated for days spend in grazing. Losses during storage and conservation deviate, currently these losses are fixed. Correcting for these losses as done by the KW is a good thing however their corrections should be adapted for farms that apply grazing. If kept fixed a deviation for losses could be used based on dry matter of silages. Also average weight should be added. As last a comparative study for farms that apply grazing or summerfeeding could prove that, production under grazing is similar to energy from summerfeeding.

1. Introduction

Throughout Europe, grass has always been a major source of nutrition for ruminants. When produced in intensively managed systems, grass has a high nutritional value. This is seen in high concentrations of energy and protein and low levels of fibre. As for the type of feeding there are many options, grass can be fed fresh, predominantly through grazing or in a preserved form as silage or hay. In many western countries, grass is a relative inexpensive feed source for the production of milk by dairy cattle. In calculations from Dillon et al. (2005) every 10% increase in grazed grass in a dairy ration reduced milk production costs with 0.025 €/litre. The cost price of grazing is almost €0.10 per kg DM lower than for silage grass (Galama, 2013). The difference is explained by less cost for machinery, external labour and concentrates.

Secondly, grazing systems provide an environmental and animal welfare friendly image of the dairy sector. When looking at environmental effects of ruminants calculations from Bruggen and Faqiri (2015) have shown that a cow in pasture produces less ammonia than a cow housed indoors. For gasses methane and nitrous oxide expressed in CO_2-equivalents the effect is negligible. The lower levels of nitrous oxide in storage are compensated for by higher levels of methane emission (Bruggen and Faqiri, 2015). With the intensification of the dairy sector in the Netherlands and the growing distance between farmers and consumers, the image of the agricultural sector has deteriorated. The general public appreciates grazing animals in the landscape. The society associate grazing with animal welfare allowing dairy cattle to express their natural behaviour. To improve the sector's image and to stop further drop in grazing cattle several milk factories provide bonuses to farms that have their cattle graze. For instance ongoing the 1st of January 2015 FrieslandCampina has raised the bonus from 0.50 to 1.00 euro per 100 kg milk if cows graze during 120 days, for at least 6 hours a day.

Despite these advantages there is a trend towards less grazing in most European countries. The past decades a lot of dairy farmers stopped grazing their cows. From the period 1997 to 2013 the level of Dutch cattle grazing decreased from 92% to 70% (CBS, 2013). Additional the hours of grazing among grazers is declining as well. In 1998 cows grazed for 13 hours per day, whilst in 2006 cows grazed 8 hours per day (Aarts et al., 2005).

There are several reasons for farmers to feed their cows indoor. For instance, modern, large-scale farms with high yielding dairy cattle, such as those increasingly occurring around Europe, may reduce grazing in order to control the diet and optimise grassland utilization. A grazing system requires short-term and long-term management decisions for adequate herd feeding and pasture budgeting over the grazing season. Also the use of milk robots increases, which is more difficult to manage in combination with grazing (KOM, 2011). Aarts et al. (2008) investigated the yield of grasslands, farms that houses cows permanently indoors have 15% higher dry matter yields than farms that apply grazing.

In grass-based systems, low grass dry matter intake (DMI) of pasture has been identified as the major factor responsible for limiting milk production by high producing dairy cattle (Kolver and Muller, 1998). Cows with high milk production capacity require additional feeding to meet nutrient requirements. Reported DMI levels of early lactating dairy cows grazing high quality grass or fed on freshly cut grass rarely exceeds 19kg/d (Bargo et al., 2003) and corresponding milk production levels are some 28kg/d at maximum (Dijkstra et al., 2008). In research from Kolver and Muller (1998) high producing cows received either a pasture-only diet or a TMR. The pasture-only diet had lower intakes for total DM (19.0 vs 23.4 kg/d) and net energy for lactations. Consequently cows consuming pasture gave less milk (29.6 vs 44.1 kg/d). Cows lacked energy to produce higher levels of milk (Kolver et al., 1998).

Efficient use of grasslands is becoming growingly important, especially in the EU with the disappearance of the milk quota in April 2015, the milk price is no longer guaranteed. The expectation is that the coming years farmers have to deal with larger price fluctuations in milk and feed. The prognosis until 2023 is that the average milk price will be €33.50 per 100 kg milk, with 4.4% fat and 3.5% protein (Livestock and Vermeij, 2013).

In expectation to the milk quota abolition, farmers anticipated to a restriction of herd size based on animal rights or phosphate production of a reference year. Farmers whom otherwise would have waited invest in large stables and expand their herd size to increase milk production. Over the past decades herd size has increased severely. The average dairy farm had 42 cows in 1984 to 85 cows in 2014. Secondly in 2000, 45 dairy farms had 250 cows or more, this number has increased tremendous to 295 in 2014 (CBS, 2014). In most cases an increased milk production and herd size is not paired with an increased farm area. From the period 2003 to 2013 the average farm intensity increased from less than 15.000 to 18.000 kg/ha. The expectation is that farmers will continue to expand their herd, but not grow accordingly in hectares increasing the farm intensity to 22.000 kilogram in 2018. Increasing herd sizes makes grazing more difficult, the amount of available pasture may be inadequate, putting too much pressure on the crop and soil (Koopman, 2014). This leads to an increase in grazing pressure through higher stocking rate (SR). An increased SR limits DMI as less herbage is available per cow. In Bargo et al. (2002) pasture DMI of unsupplemented dairy cows increased from 17.7 kg/d to 20.5 kg/d as pasture allowance increased from 25 to 40 kg DM/cow per day (Bargo et al., 2002). Also milk production increased respectively with 19.1 vs 22.2 kg/d. Herbage intake can be increased by offering larger allowances, but with higher residuals in subsequent grazing (Taweel, 2006). Supplementation of concentrates lowered pasture dry matter intake (Bargo et al., 2002), thus lowering the efficiency of grassland productivity, but increase efficiency on a cow level.
In research from Lantinga et al. (1999) animal performance of cows was compared under different nitrogen fertilizer levels, however when looking at increasing days in grazing milk production in kg FPCM per cow per day decreased but milk production in kg FPCM per hectare increased. High prices for milk and low concentrate prices are economical drivers for farmers to change toward a high milk production per cow in other words summerfeeding.
From the reasons outlined above it is clear that current trends in livestock farming in Europe cause a decline in the popularity of grazing for dairy cows. Eventually each farmer has its own reasons for choosing a management system suited to their farm and wishes.

The aim of any feeding system is to provide sufficient nutrients to the animals depending on breed, age and the level of production using available feeds. Plenty of studies have been carried out on energy requirements, energy value of the diet, digestibility and utilization of energy by lactating cows. Especially around Europe new energy feeding systems were developed. Every European country has its own method for calculating energy production of grassland (Vermorel and Coulon, 1998). Current evaluation systems are based on the NE_L system (France, Germany, Netherlands and US), however some are based on the metabolizable energy (ME) content of feeds (United Kingdom, and Sweden). Differences between energy calculation systems have several origins. Possibly due to an over- or underestimation of the NE content of forages and others or because of lower efficiency of ME utilization for milk than estimated. Dijkstra et al. (2008) studied several energy evaluation systems, including the Dutch NE system (Es, 1978). In their study the estimate of the feed value of grass for milk production by dairy cattle was inaccurate. Lower energy requirements were predicted based on observed milk production than energy supply based on intake. To design optimal grass-based systems, accurate estimates of the feed value of grass are required. Current energy evaluation systems often let expect higher milk production on grass-based diets than observed (Bruinenberg et al., 2002).
Reasons for such discrepancies may include higher requirements of cows fed fresh grass than assumed in various energy evaluation systems and an unbalanced supply of nutrients. As well as adjustments for metabolic and digestive interaction between feeds as for energy requirements of animals for maintenance, lactation, BW changes, gestation and grazing. The maintenance energy requirements for modern, high yielding dairy cows exceed those of traditional, moderate yielding dairy cows that were used to develop most current energy evaluation systems (Agnew, 2005). From investigations done in “Koeien & Kansen” it appeared that in practice, 4% more feed is used than theoretically required by cows (Galama et al., 2001). For a part these feeding losses are due to spoilage and rest feed in the stable. This amount is estimated to be 2% of the feed which is never eaten by the animals. It disappears to the manure storage and has no role for calculating the excretion (as is done in the KW). The other 2% is possibly explained due to inefficient digestion of feed, for instance by sick

animals or a sub-optimal feeding, a higher maintenance requirements for high producing cows or a to high estimation of the feeding value of some products. Several authors claim that the VEM value awarded to roughages is overestimated (Agnew et al., 1998; Bruinenberg et al., 2002). Therefore in composing calculations for excretion energy is covered at 102%. This assumption is in line with a fixed excretion in dairy cattle (Tamminga et al., 2004).

The amount harvested can be measured and analysed for nutrients fresh or ensiled. Although this may be accurate losses still occur in the stable and during conservation. All these losses from the moment of harvest until the moment of consumption deviate, large differences are found between and within farms. This makes it hard to accurately estimate the amount of energy lost in the process.
Feeding of grazing ruminants is difficult to manage in practice due to inability of the farmers to accurately estimate nutrient intake from grazed pasture. It is unclear how much grass delivers in terms of DM and energy and utilized by their cows to be transformed into milk. To accurately determine the net energy production of grassland this paper uses a different approach. In this study energy production of grass is determined from animal performance in terms of milk production and growth to calculate back how much energy has been produced out of grass. Instead of calculating herbage accumulation and taking in account field losses and digestibility losses.

The present study involves research on energetic calculation methods for determination of net grassland production. The objective of this paper is to analyse, compare and check the reliability of three energy calculation methods for the determination of the net energy yield of grassland. It would be interesting to discover what distinguishes the energy calculation methods from one another. The next step is to optimize and formulate a new model, based on the three models investigated.
The hypothesis is: The net energy intake is influenced by energy calculation method.
The energy systems evaluated are the methods of Lantinga, the KringloopWijzer (KW) and the method as developed by Thomet and adapted by Leisen which is designed for grazing cattle. The underlying meaning is that eventually European countries can agree on one calculation method for determining the net energy production from grass.
Additional we would like to know if the net energy produced from grasslands in grazing is similar to summerfeeding. The influence of grass management type is evaluated on energy productivity and the relationship between intake and milk yield of cows per ha. The models will be tested on three farms, (1) an intensive farm that applies summerfeeding, (2) a intensive farm with grazing during the day and (3) an extensive organic farm with grazing day and night. Secondly the idea is that the variety between farms will expose differences between models.

2. Materials and Methods

To calculate the energy production of grasslands, several data is required. In the following chapter the first part is about the required data needed to fill in the models. The second part the models of Leisen, the KW and Lantinga are amplified. Also a new model was designed, referred to as `NEW model` from now on, by extending the calculations used in the KW. This was done by taking the best of the three models and by including more specific farm data in the model.

2.1. Data collection

Data from the farms of Pool and Van de Goor that was used for the analysis came from bookkeeping documents and personal communication. Data was used of the year 2014, 1st January to 31th December. The three calculations methods were tested on both farms to see differences between and within methods.
The farm of Pool is an organic farm on a mostly peaty soil. For a breed Pool chose "Blaarkop", as they are a strong breed with a good fertility. As much grazing as possible is applied, if conditions allow for grazing cows start to graze half March to half November. Cows graze for 20 hours. Also heifers graze from 1st of March to the 1st of December. Calves graze from start of July to the end of November. Short grazing is used. Next to grass the ration exists of little concentrate and maize silage.
The other farm is a conventional farm managed by Van de Goor which houses Holstein Friesian (HF) cows. Cows receive summerfeeding year round. Grass produced is harvested and ensiled to be fed in a TMR to the cows. Next to grass cows receive a large proportion of maize silage and concentrate, with a bit of distillers' grain or beet pulp.

A cow needs energy for physiological processes. Depending on the state of the animal (lactation/gestation) extra energy is needed. The driving force behind milk production is energy, for dairy cattle in the Netherlands expressed in VEM since 1977. For this normative requirements have been set for cows housed in respiration chambers, which have been verified with feeding trails with cows in tie stalls. Next to VEM for maintenance and the production of milk, cows require energy for movement, gestation, growth and mobilisation of body reserves (NEB) and the regain of weight later in lactation (Tamminga et al., 2004).

2.2. Calculations methods

In current practice a lot of data is available for each individual cow. If you ask a farmer how much milk a cow produces he can tell you exactly, however when asked how much grass is produced per ha, they can't give a clear answer. It is unclear how much grass delivers in terms of milk. In practice the herbage yield of grass is not measured directly, whilst grass is the main source of nutrition for the dairy cow.

To achieve insights in the energy flows, the energy requirements have to be determined.

When calculating the energetic requirements of free grazing cattle additional energy for grazing and walking to the pasture have to be accounted for. Movement may increase the energy requirements of grazing cattle by 10% or more compared to stall fed animals (Havstad and Malechek, 1982). Grazing animals spend more time and energy on walking, eating and rumination. Whilst stall fed animal take up their nutrients in a shorter period.

Maybe even more important is the energy required for milk production, depending on percentages of fat and protein. Also per kg of body weight an energy correction has to be calculated. Furthermore cows require energy for gestation, negative energy balance and replacement of cows. To calculate these energetic requirements the following chapter will elaborate on three energy calculations systems. Starting with energy calculations of Lantinga and colleagues then the method used by the KW and lastly the method of Leisen which is focused on grazing cattle.

2.2.1. Lantinga

For the third method, energy calculation methods of Lantinga were reviewed for their purpose of calculation of net energy production of grassland. Lantinga his calculation were derived from Meijs (1981) and Es (1978). Energy calculation methods used by Lantinga use the VEM system. Below these will be discussed for their use to determine net energy production of grasslands. One Dutch feeding unit for lactating animals (VEM) contains 1.650 kcal or 6.9kJ Net Energy for Lactation. In general it is more common to use 1 kVEM equal to 6.9 MJ NE_L. VEM is a relative energy measure: barley is used as a reference material. In investigations of Lantinga several calculations were used.

In the following paragraph, the most suited method for determination of net energy production of grasslands is used for comparison. Other studies of Latinga used body weight changes over time could not be used for determination of energy requirements (Schlepers and Lantinga, 1985; Deenen and Lantinga, 1993; Lantinga et al., 1999). This data was unavailable. More explanation about these methods can found in appendix 2.

To test the net energy production of grassland was calculated according to the method of (Lantinga, 1985). For the energy requirements a combination of methods was used (Es, 1978; Meijs, 1981; Deenen and Lantinga, 1993).

The amount of energy consumed through grazing is calculated back from animal performance data (FPCM). A flock within the calculation method of Lantinga is that requirements for the rest of the herd (calves, heifers, dry cows and bulls are untreated, but these can be derived from (Es, 1978). Also energy required for replacement of cows, NEB are not incorporated.

Energy requirements of growing cattle and heifers at different live weights and growth rates are estimated as well (Es, 1978). Therefore energy requirements are averaged for heifers younger and older than 1 year. The same is done for bulls and other cattle present on the farm. Once the VEM requirements of the herd are determined, energy received from concentrate and other feed products can be subtracted (Lantinga, 1985). The remaining energy must come from grass either consumed as forage or silage, together these form the net pasture yield of grass.

Lantinga (1985) calculated the net pasture yield as the difference between daily requirements for maintenance and production of the grazing animals minus the daily energy consumption of the supplemented concentrate, table 1. This method is similar to the KW and the method of Leisen. However for calculation of energy requirements a different formula has to be used. This model however only calculates the VEM utilized from grazing, it does not take into account silage grass or hay, which have to be added.

Table 1: Calculation of the net pasture yield in kVEM ha^{-1}

	Conversion factor	kVEM ha^{-1}
Maintenance (715 cow d ha^{-1})	5.78 kVEM cow^{-1} d^{-1}	4133
Milk yield (15647 kg FCM ha^{-1})	0.46 kVEM kg^{-1} FCM^{-1}	7198
Requirements		11331
Concentrates (1430 kg/ ha^{-1})l	0.94 kVEM kg^{-1}	1344
(Other feeds)		
Net pasture yield		9987

5780 VEM per cow per day is for maintenance
1 kg of milk with 4% FCM contains 460 VEM
Concentrate = 940 VEM kg^{-1} DM

For calculations of energy requirements formulas were based on the original formulas, equation 1. (Es, 1978) with adaptations for extra requirements due to grazing, equation 2 (Meijs, 1981).

$$NE_L = (442\ FPCM + 42.4\ w^{0.75})\ (0.9752 + 0.00165\ FPCM) \qquad (1)$$

$$NE_L = (442\ FPCM + 50.9\ w^{0.75})\ (0.9752 + 0.00165\ FPCM) \qquad (2)$$

It is difficult to assess the energy requirements associated with grazing. The requirements at maintenance are estimated to be 20% higher for grazing animals (Meijs, 1981). The average lactation cow weighed 550 kg with a production of 15 kg milk with 4% fat. Energy requirements of growing cattle and heifers at different live weights and growth rates are estimated as well (Es, 1978). For calculations the weight of herd was estimated based on breed and age. For stall fed animals one kg 4% FCM was found to contain 730 kcal (3054kJ), so its production requires 730/1.65 = 442 VEM. To determine FCM (4%) the following equation is used: FPCM = M(0.4 + 0.15p)
Where: P = fat% and M = Milk production, standard is 4% fat.

The maintenance requirements for housed cattle (Em) is 42.4 VEM per kg of metabolic body weight (MBW = BW$^{0.75}$) (Es, 1978). This number originates from balance trails with dairy cattle wearing harnesses for collection of excreta. Es (1978) considers that the activity of these cows do not differ from cows housed in a free stall barn. Expressed in VEM the maintenance requirement is 42.4 $W^{0.75}$ VEM. The requirement has to be corrected by 300 VEM for every 50 kg below or above 550 kg.

For growth extra energy is needed, one kg of body weight is estimated to contain 5000kcal, to gain one kg of BW during lactation and have a 1.65 energetic efficiency. The value of 1.65 was chosen arbitrarily. The requirements for growth are 5000/1.65 = 3000 VEM kg^{-1} BW gain. The dry period is less efficient (+10%) leading to 3300 VEM. For calculating the VEM of feedstuff the ME contents at the maintenance feeding level is used, using a feeding level of 2.38. For higher or lower feeding levels the requirements deviate + or – 1.8% per level respectively. (Es, 1978).

Some notes regarding the model are; the model only calculates the VEM utilized during the grazing season, it does not take into account silage grass or hay consumed during the rest of the year. Something all calculations methods of Lantinga do not take into account is the energy required for the rest of the herd (calves, heifers, dry cows and bull). Additional energy required for replacement of cows are not incorporated. Therefore these were set equal to those used by the KW which is the most recent. Lastly these formulas are outdated cows have increased in weight and improved production, changing animal requirements, the CVB has adapted their calculations in more recent editions (CVB, 2010).

2.2.2. Leisen and Thomet

The energy calculation model of Leisen is a redesigned model of Thomet. Leisen is a grassland advisor; he collects data from farms across Europe (mostly the Netherlands and Germany) and compares these farms based on region and climate to see what causes the difference between farmers and within the farm itself. The model is designed for cattle grazing in different types of pasture. Instead of using the VEM system the model uses MJ NE_L energetic value.

The model calculates how much herbage is available, by measuring the height of the crop that has been grazed recently. Milk production and the amount of animals grazing on the area are known, making is possible to determine the energetic requirements. From products such as wheat the energy content can be measured accurately. When subtracting the net energy provided through concentrate and other additional feeding the remaining energy is the net energy production of grassland. This calculation is done on a weekly basis. Therefore a more extended model is used for a whole year. To determine the net energy production of grassland, expressed per ha.

The following need to be filled in for calculation of the model:

1) Animal data, for energetic requirements of the herd
    a. Cows, milk production, fat and protein level. For determination of the milk production all milk has to be given, milk to the factory, calves and for personal use.
    b. Heifers, older or younger than 1 year;
    c. Calves;
    d. Bulls;
    e. Horses or other grazing animals. Which have to be separated from the rest of the herd.

For cows it is also important to know the calving interval, with this the amount of calves born can be calculated. Also the average age of the cows is needed, to know how much animals are needed each year for replacement.

2) Milk production: kg of milk and percentages of fat and protein. Also milk produced and given to the calves or used for own consumption. For milk production ECM is used. The formula for ECM can be found in Appendix 7.
3) Supplementary feeds such as concentrate, potatoes, etc fed to the cows are subtracted of the energy requirements to determine the amount of energy from roughages. Energy production of forage area is calculated as kg ECM per hectare from roughages. If available energetic values are used from analysis else assumption are made based on average values. The model also calculates the hectares required to completely feed the herd.

2.2.3. Kringloopwijzer

The calculation method used by KW originates from the Dutch BEX system (RVO, 2015). BEX stands for farm specific excretion. The BEX system is designed to calculate the real excretion of nitrogen (N) and phosphate (P) on a farm level. Farmers have the possibility to reduce their phosphate production. With the BEX systems farmers proof they operate more efficient than fixed governmental values and qualify for "Derogation" which allows them to apply more minerals on their own land. Over the past years the dairy sector has grown tremendously, jeopardizing its maximum phosphate level, 172.9 kiloton phosphate. If the dairy sector is not restraint the dispensation for "derogation" may be withdrawn. To prevent further increase of phosphate production, 2014 is used as a reference year for phosphate rights. With the use of the KW farmers can earn room to develop if they carefully manage their phosphate flow.
The calculation method used in the KW calculates the total energy production of the farm, including heifers and beef cattle. Other types of grazing animals are excluded. The KW is a program in which all nutrients flows of the dairy farm are monitored. This part exists out of data required to fill in the KW, based on the version of 2014.06 d.d. 9 July 2014. The model consists of several tabs which must be filled in completely before going to the next one. Data required to fill in the KW is;

- General data (such as personnel data, year of input, and whether you wish to fill in BEX or BEX + cycles;
- Animal data, how much of each animal category is present. In case other grazers are present, the number of animals: present, bought and sold needs to be filled in. For each animal category need to be indicated whether feed flow is separated or not;
- Milk production and composition;
- Animal manure and fertilizer, type of manure, type of manure application, storage etc;
- The amount of hectares specific for each crop;
- The consumed amount of feed, of each feed the amount and nutritional value need to be recorded. To fill in the data feed is separated for feed at the start of the year, end of the year produced during that year, and the amount sold and bought to calculate the amount of feed consumed.

For more elaborate explanation of the data required to fill in the data, see appendix 1. For this study the focus lies on energy flows on the farm. In the KW the netto grass production is calculated to seal the feeding balance (Aarts et al., 2005). The KW focusses on the N and P cycle, using energy to calculate N and P values. For our study the focus lies on energy flows in the herd. In the calculation process of the KW data on energy requirements and intake is used to calculate the N and P values. Also the VEM production per hectare of grass is calculated on a farm level. In appendix 1 calculation rules used by the KW are further explained. To calculate the VEM-production of grass forage several steps need to be taken. The calculation method exists out of several steps which are explained below, for more details see appendix 1. The following steps originate from RVO (2015) and can be used to determine the kVEM production of grasslands:

1. Calculate the total energy requirements of the herd, minus energy consumed by other grazers. The KW uses weight of cows to determine the amount of energy needed.

Firstly the amount of energy (VEM) needed for the herd is calculated, based on the number of cattle and the nutritional need per animal. The energy requirements are calculated according to custom calculation rules of the CVB (2010) (Schroder et al., 2014). The complete requirements of the farm dairy herd are calculated, including additional requirements for breed, weight, movement, lactation, gestation, replacement heifers, compensation of the Negative Energy Balance (NEB) in the beginning of the lactation and beef cattle if present. Other types of grazing animals are excluded. From the VEM-requirements the VEM-intake is calculated. VEM requirements of the total herd (kVEM/year) is the sum of the VEM requirements of cows, heifers and calves (Schroder et al., 2014). Formulas for calculation of the energetic requirements can be found in appendix 1.

2. Correct for energy consumed through purchased feed.

For the second step fed purchased feeds are subtracted of the total energy requirements of the herd. The rest of the energy requirements should be grown on the farm.

3. Calculate the herd VEM intake from roughages.

Of the remaining energy from roughages ratio's between maize silage, grass silage and fresh grass are determined. The ratio between grass silage and maize silages is determined from fed amounts of silages. The ratio between fresh grass and silage grass is calculated on the type and amount of grazing applied (RVO, 2015). Important are the hours and months of grazing. Situations can occur in which the calculations deviate to much from the real grass intake. That is why a control calculations are executed, to check whether the assumed grass intake according to the standard calculation is realistic.

4. Determine the amount of energy utilized.

The amount of grass ensiled is different from the amount of grass consumed, due to conservation- feeding losses. For the calculation of grass silage these losses are corrected for to determine the yield per ha. Correcting for losses is done using standards (Remmelink et al., 2014). The total net VEM produces is the sum of pasture grass and grass silage consumed. The total VEM production is divided Divide this by the hectares of grass or by the number of cows to determine the net energy production of grassland, expressed in either energy or milk (Remmelink et al., 2014).

A remark that should be made for all three calculation methods is that there is no data for weight on either farm; it is therefore estimated on breed, so 600 kg for an adult cow. Additional weight change for NEB is estimated at 100 kg (Tamminga et al., 2004). It would have been more accurate if animals would have been weighed. For instance if the herd average weight of a cow is higher energy requirements are underestimated as heavier animals require more energy for maintenance.

2.2.4. New Model

The fourth model is the new model, which implements the good of the three models previously explained. The model is a combination of the three models with some minor adaptations, discussed below.

- Inclusion of all milk flows (as applied by Lantinga and Leisen). All energy flows on the farm are included; next to milk provided to the factory milk fed to calves, used for personal consumption and otherwise is summed. If not energy requirements for milk are underestimated.
- For calculations of energy in milk FPCM (KW and Lantinga) is chosen above ECM (Leisen). FPCM is already used in the Netherlands and the farms investigated. Both FPCM and ECM correct for energy in milk and fat, differences are small. Additionally the model of Leisen is different for energy using NE for lactation compared to VEM used by the KW and Lantinga. For comparison VEM is used as it originates in Netherlands and farms investigated use the VEM system.
- In calculations for energy requirements of cows the KW is chosen, being the most specific. Leisen is only focused on the grazing season of cows. Lantinga does separate for cows in the grazing season and cows housed indoors. Both Leisen and Lantinga do not take into account additional requirements for replacement, gestation and NEB. In the KW these bonuses are fixed for the new model corrections were made.
- When calculating the basic requirements of a cow, weight is important. In the KW weight depends on race; a separation is made for Jersey, other breeds and crossbreeds (50% Jersey). However among other breeds and between Holsteins herd's different weight occur. Leisen uses a different approach correcting for every 50 kg weight difference to the standard 600kg Leisen corrects with 116 kVEM. Also Lantinga his calculations have corrections for weight change overtime, unfortunately weight data is unavailable. Therefore in all the models weight is set at 600kg.
- In the KW energy requirements for replacement of cows are fixed at 36.3% with 131 kVEM per cow. In reality replacement is different for each farm. In the new model energy requirements for replacement is thus corrected based on true replacement. Using the data on heifers kept, energy for replacement is recalculated. For the farm of Pool this led to a replacement of 22% and 78 kVEM per cow.
- Second bonus used in the KW is for gestation and NEB. Cows require additional energy for gestation and for a loss and recovery of 100kg due to NEB (Tamminga et al., 2004). Again this bonus is fixed. In the new model the energy required for gestation and NEB is recalculated based on calving interval. In the KW it is assumed that 16% of the cows are in gestation that comes down to 307 days in lactation and 58 days in gestation per calendar year. As the allowance for gestation is based on this number, the energy expenditure for gestation and NEB is overestimated, for instance on the farm of Goor calving interval was 405 days. This would mean that instead of 191 kVEM per cow per year cows require 172 kVEM for gestation and NEB.
- Requirements for heifers and other grazers were drawn from values used in the KW. Reason for this is that the KW has more accurate and animal specific data available. Also Leisen has fixed requirements for other grazers but less detailed as the KW. In Lantinga requirements for heifers are unavailable.
- Lastly in the new model the amount of energy consumed through grass has to be determined. Gross amounts fed to the herd for concentrate, roughages and other feeds are known through analysis. However during storage and conservation losses occur. For the models of Leisen and Lantinga these losses are fixed. This is practical but not very trustworthy as between farms and forages large deviations occur for losses. The KW corrects for these losses using the VEM-gap calculations. For summerfeeding this calculation works but in the case of grazing it does not work in a correct manner, overestimating the energy consumes from either grass- or maize silage, being higher than the gross amount provided. Thus underestimating the energy provided from fresh grass. Therefore the new model also assumes fixed losses specific for feed type.

2.3. Comparison

For comparison the calculations are compared for each of the three farms, there will be no comparison done between the tree farms as they are completely different types of farms with their own herd, history and management. These three farms are chosen to reveal differences between the models for calculation of the net energy production of grassland. Table 2-4 show farm characteristics of all farms containing information about the herd composition, crop management, milk production and amount of grazing. Data is taken from the period of 1.1.2014 until 31.12.2014. Farm characteristics were used to calculate the models and provide background information on the farms.

For the farms of Spruit and Goor feed analysis were available, unfortunately there were no feed analysis performed on the farm of Pool for both purchased as produced roughages. The missing of these data greatly undermines the reliability of the outcome. However for comparison it will make no differences as the error is the same for all models. For farm of Pool values were estimated based on average values of roughages as used by BLGG in the Netherlands (AgroXpertus, 2015d; a; b).

Table 2: Dairy herd composition

Dairy herd composition			
	Goor	Pool	Spruit
Cows	111	74	76
Heifers < 1 year	47	16	37
Heifers > 1 year	35	16	29
Bulls	0	1	0
Fattening bulls	0	0	32
Type of feeding	Summerfeeding	Unlimited grazing	Unlimited grazing
Breed	Holstein Frisian	Blister Head	Mixture of milk breeds
Available for replacement	*37%*	*22%*	*43%*
Needed for Replacement	*35%*	*11%*	*25%*
Deviation	2	8	14
Heifers per 10 cows[1]	7.39	4.32	8.68
Age 1st calf (months)	24	24	25.5
Calving interval (days)	405	365	420

[1.] Relative high number for the farm of Spruit due to large amount of male calves kept for meat.

Table 3: Soil and crops

Soil and crops (expressed in hectares)	Goor	Pool	Spruit
Crop area	44.8	41.2	38.1
Forage area	37.9	35.7	38.1
Maize area	6.9	0.0	0.0
Conservation grassland	0	5.5	0
Other arable land	0	0	0
Part of soil type (%)			
Grassland - Peat / clay / sand	0/100/0	80/0/20	100/0/0

Table 4: Stocking management

Grazing		Goor		Pool		Spruit	
Animal category		days	hours	days	hours	days	hours
Cow	Limited	0	0	14	8	0	0
	Unlimited	0	0	229	20	200	10
Heifers		0		275		180	
Calves		0		153		120	

3. Literature review

3.1. Introduction

The following literature review provides background for understanding and calculation of the net energy production of grass land. Starting with a general view on differences in grazing and cutting on management, grass production, milk yield, animal welfare, environment and energetic requirements. The third chapter elaborates on different types of grazing systems, such as rotational stocking, continuous stocking and short grazing. In the fourth chapter energy losses from harvest until consumption of fresh and conserved grass are reviewed, such as losses in the field, during storage and during feeding. In the last chapter different calculations methods are further explained.

3.2. Grazing versus Cutting

Grazing is an important issue within the dairy sector. In many western countries, grass is a relative inexpensive feed source for the production of milk by dairy cattle. Grazing provide an environmental and animal welfare friendly image of the dairy sector. This chapter compares grazing with cutting on several levels: economics, ruminant physiology, environment, society, management, labour, threat towards grazing, production and energetic requirements.
For the provision of grass several systems are used. With grazing, cows graze on pasture for several hours per day during the growing season either unlimited, or limited (2-8 hours a day) with additional feeding in the stable. There are several type of grazing, rotational and continuous stocking are the two most common types of grazing. Grass can also be provided as grass silage, grass is then mown, wilted and tedded to be stored airtight as silage. Thirdly grass can also be mown and fed as fresh grass in the barn during the summer; this is called 'summer barn feeding'.

For the past decades there is a trend towards less grazing in most European countries. A lot of dairy farmers stopped grazing their cows. From the period 1997 to 2013 the amount of Dutch cattle grazing decreased from 92% to 70% (CBS, 2013). Additional the hours of grazing among grazers is declining as well. In 1998 cows grazed for 13 hours per day, whilst in 2006 cows grazed 8 hours per day (Aarts et al., 2005). This decline is caused by several changes in dairy farming. This decline is caused by economic, practical, social and personal motives. Most important reasons are; higher farm intensification (cows/ha), management, labour input, DM yield, high producing cows, and an increased use of milking robots.

3.2.1. Economics

Efficient use of grasslands is becoming growingly important, especially in the EU with the disappearance of the milk quota in April 2015, the milk price is no longer guaranteed. The expectation is that the coming years farmers have to deal with larger price fluctuations in milk and feed. The prognosis until 2023 is that the average milk price will be €33.50 per 100 kg milk, with 4.4% fat and 3.5% protein (Livestock and Vermeij, 2013). Ensuring low feeding cost is a method to deal with low prices. Conventional farms are on average larger with more cows per farm and per hectare with a higher milk production per cows. Average milk production on organic farms was 6.270 kg compared to 7.700 kg for conventional farms (Ruis and Pinxterhuis, 2007).
In many cases grazing proves to be financially interesting even under difficult circumstances such as: automatic milking system (AMS), small grazing surface, a high milk production per cow and a large herd. In calculations from Dillon et al. (2005) every 10% increase in grazed grass in a dairy ration reduced milk production costs with 0.025 €/litre. Also in Dillon et al. (2008) increased levels of milk production originating from grass lower the cost of production. Countries with high intake from grazing have lower feed costs. The cost price of grazing is almost €0.10 per kg DM lower than for silage grass (Galama, 2013). Evers et al. (2008) investigated the effect of grazing instead of stalling. If conditions were normal the income of farms that apply grazing with 15.000 kg of milk ha^{-1} is € 0.50 to € 2.00 per 100 kg of milk higher than when cows were stalled. When farm intensity is increased, profit remains higher or equal for grazing. Cows harvest the grass themselves and at the same time bring manure and urine to the field. The economic benefit of grazing is largely determined by lower costs for contract work, concentrates, labour and manure disposal (Pol et al., 2013). If cows are milked by an AMS, grazing remains more profitable than stalling. Also at a high milk yield cow^{-1}, income is higher with grazing than with stalling.
The biggest problem for grazing economically appears to be a small area for grazing. If stocking rate is more than 10 cow ha^{-1} stalling is more profitable than grazing. The income at stalling is then € 0.75 100 kg^{-1} milk higher. If a lot of work has to be done by contract work and concentrate is expensive this drops € 0.25 100 kg^{-1} of milk advantage for stalling (Evers et al., 2008). When stocking rate is lower than 10 cows ha^{-1} grazing becomes interesting again. For a large herd

income is determined by several factors, normally grazing leads to the highest income. However when prices for concentrate are low and the amount of contract work is low, stalling becomes interesting again. Grazing a large herd is more difficult as cows need to be able to consume sufficient amounts of fresh pasture grass. In the case 13.4 cows ha^{-1} have to graze summerfeeding becomes cheaper than grazing (13 cows per ha is an extreme value, impractical for grazing). The extra cost for grazing outweighs its benefits. Also intake from grazing is low, 4kg DM d^{-1}. To achieve this cows need sufficient grass and days of grazing. Evers et al. (2008) also found that the income with grazing is € 1.50 to € 3.00 per 100 kg higher than with stalling and summer barn feeding. They also found a positive relationship between uptake of pasture grass and income.
In general, grazing generates more income than stalling, even on large and automated farms (Pol et al., 2013), unless stocking density is too high and a lot of additional feed is required.

3.2.2. Effect of stocking on ruminant physiology

Grazing cows is a management practice that has a large influence on animal health and welfare. The following part will shortly discuss some of the aspects of grazing versus summerfeeding on animal health and behaviour. Quality of these systems depends on management, housing and climate.

Expressing natural behaviour is an important aspect of animal welfare. The ability to express natural behaviour is remarkably better in grazing compared to indoors. In nature cows are used to spend a larger part of the day grazing, foraging from dawn to sunset (Fraser, 1983). Whereas indoors cow intake is mostly after feeding, time spend is relative short and depends on the energetic needs of the cow based on stage of gestation and milk production (Dürst et al., 1993). Grazing positively contributes to animal behaviour and welfare. In cubicle barns cows have the possibility to move around. In pasture cows have more space, being able to avoid dominant animals and move around freely and lie down comfortable. It is unclear however to what extend grazing affects animal welfare (Pol et al., 2002).
The effect of grazing on udder health are conflicting (Pol et al., 2002). Grazing reduces mastitis due to lower infection levels and less environmental bacteria (Washburn et al., 2002) lowering the risk for teat injuries. The combination of these factors lead to increased chance of high cell counts (Goldberg et al., 1992). Grazing is not all positive, head flies which occur only outside can cause summer mastitis. In general however grazing improves udder health. Another disadvantage of cows grazing is they are more likely to get infected with parasites, such as worms and liver fluke (Borgsteede and Burg, 1982). Secondly cows are exposed to the elements of nature like sun and rain, temperatures above 25°C can cause heat stress.

In stables floors are wet and hard increasing the mechanical load of the claw. Relative soft, clean floors that provide sufficient grip for cows to express heat are preferred for a good health of claws and legs. Hard floorings can cause cracks which can be entered by urine and faeces (Belie and Rombaut, 2003). Where wet floors wear off the horn (Bonser et al., 2003). Products of urea multiply this effect by four times (Gregory, 2004). In pastures infectious pressure is much lower due to dry soft flooring and less faeces and urine.
Infectious claw disorders like interdigital dermatitis and dermatitis digitalis are significantly higher in stables than in grazing (Somers et al., 2005) due to a high infection pressure in stables (Somers et al., 2003). Somers et al. (2005) studies the effect of pasture and cubicle housing on animal hoof health. Of the animals observed 23% showed serious lesions of interdigital dermatitis heel erosion (IDHE) at the end of the pasture season and 46% for cows in cubicle housing. Grazing cows have lower amount of clinical lameness. Cows housed in cubicle barns have impaired locomotion due to poor grip and due to floor related infectious claw disorders on one or more legs (Somers, 2004). This has large consequence for the animals welfare and daily performance, milk production is

reduced by 360 kg milk per lame cow (Green et al., 2002). Grazing improves claw health of dairy cattle. Claw disorders and leg injuries that occur in the stable gradually become more severe over time, during the grazing season cows can recover.
Cows prefer to lie on dry soft flooring. In pasture or soft bedding cows lie down faster and smoother.
In cubicles cows are limited in their movement when lying down or standing. In pasture space, lying comfort and grip are not an issue (Tucker et al., 2004). Also in cubicles cows are more reluctant to get heel skin damages, especially when rubber mats are placed. Rubber has a sanding effect on the heel skin. In the worst case the heel burst allowing bacteria to enter and cause inflammations. Deep litter with straw or sand prevents sanding, with rubber 90% of the cows have damages to the heels, while sand beddings are clearly better with just 24% (Weary and Taszkun, 2000).

Grazing brings animal welfare to a higher level and is preferred over cubicle housing, as it reduces the chance on hoof- and leg disorders and udder inflammations. However the gap between grazing and non-grazing deteriorates. Grazing cows, graze less hours during the day, possibly limiting advantages of grazing. New stables provide better conditions such as; deep litter, better flooring, more m^2 per cow and a better climate.

3.2.3. Environmental pressure grazing vs cutting

When looking at environmental effects of ruminants calculations from Bruggen and Faqiri (2015) has shown that a cow in pasture produces less ammoniac than a stabled cow. When urine and manure mix chemical processes are set in motion emitting a lot of ammoniac. Indoors slurry manure and urine are stored together and mixed before manure application in the field, increasing the ammoniac deposition. Also during storage and later when fertilizing ammoniac is released. Total ammoniac produced is therefore much larger. Cows kept indoors year round produce 8 kg of ammoniac more than cows grazing day and night during summertime. If grazing would increase to 80% ammoniac emission would decrease with 0.5 million kg compared to the year 2013.
For gasses methane and nitrous oxide expressed in CO_2-equivalents the effect is negligible. Nitrous oxide needs oxygen to be formed. The lower levels of nitrous oxide in storage are compensated for by higher levels of methane emission (Bruggen and Faqiri, 2015).

3.3. Society

With the intensification of the dairy sector in the Netherlands and the growing distance between farmers and consumers, the image of the agricultural sector has deteriorated. The general public appreciates grazing animals in the landscape. The society associate grazing with animal welfare allowing dairy cattle to express their natural behaviour. To improve the sector's image and to stop further drop in grazing cattle several milk factories provide bonuses to farms that have their cattle graze. For instance ongoing the 1st of January 2015 FrieslandCampina has raised the bonus from 0.50 to 1.00 euro per 100 kg milk if cows graze during 120 days, for at least 6 hours a day.

3.4. Threats towards less grazing

There are several reasons for farmers to feed their cows indoors. For instance, modern, large-scale farms with high yielding dairy cattle, such as those increasingly occurring around Europe, may reduce grazing in order to control the diet and optimise grassland utilization.
Unlimited stocking becomes harder as nutritional demands increase. Cows with high milk production capacity require additional feeding to meet nutrient requirements. The nutritional composition of ration in grazing fluctuates, leading to different levels of nitrogen in the rumen. As milk production increases, these fluctuations negatively affect animal performance. Cutting grass is more ideal for feeding a properly balanced diet and reach a high milk production. Restricted grazing provides cows with a more constant flow of nutrients due to additional feeding indoors, however this does limit feed intake from grazing.

Reported DMI levels of early lactating dairy cows grazing high quality grass or fed on freshly cut grass rarely exceeds 19kg/d (Bargo et al., 2003) and corresponding milk production levels are some 28kg/d at maximum (Dijkstra et al., 2008). With grazing there are relative large fluctuations in the composition of the diet, especially with unlimited stocking energy can limit milk yield. Cows that graze mainly receive perennial ryegrass pasture in their diet, although good in terms of milk composition, milk production does not increase accordingly. In research from Kolver (2003) high producing cows received either a pasture-only diet or a TMR. The pasture-only diet had lower intakes for DM (19.0 vs 23.4 kg/d) and NE_L; however intake of CP and NDF did not differ between the pasture-only diet and TMR. Consequently cows consuming pasture gave less milk (29.6 vs 44.1 kg/d). Supply of metabolisable energy was the first-limiting factor for milk production. In grass-based systems, low grass dry matter intake (DMI) of pasture has been identified as the major factor responsible for limiting milk production by high producing dairy cattle (Kolver and Muller, 1998). Grazing cows were lower in live weight and body condition score (2.0 vs 2.5) Kolver and Muller (1998). The mobilization of energy reserves indicates that extra energy should be provided to support milk production.
The biggest problem in pasture based systems is low DMI. To achieve a high milk production a high DMI is needed. Johansen and Höglind (2007) showed that herbage DMI is positively influenced by herbage allowance if 12 to 24 kg of DM was offered, DMI increased with 0.24 kg for every extra kg DM of herbage allowance. However an increased herbage allowance decreases herbage utilization.
An increased SR limits DMI as less herbage is available per cow. In Bargo et al. (2002) pasture DMI of unsupplemented dairy cows increased from 17.7 kg/d to 20.5 kg/d as pasture allowance increased from 25 to 40 kg DM/cow per day (Bargo et al., 2002). Also milk production increased respectively with 19.1 vs 22.2 kg/d. Herbage intake can be increased by offering larger allowances, but with higher residuals in subsequent grazing (Taweel, 2006). Supplementation of concentrates lowered pasture dry matter intake (Bargo et al., 2002), thus lowering the efficiency of grassland productivity (milk production per ha), but increase efficiency on a cow level (milk production per cow). Production costs per ha increase due to extensification.

In New Zealand, Australia and many parts of Western Europe, pasture can be the sole feed of cows. However to make optimum use of the grass available one should apply seasonal calving to match the growth pattern of the pasture (Dillon et al., 1995). With summerfeeding the nutritional composition is kept similar during the whole year and average date of calving (CD) is irrelevant. In grazing systems however feed composition changes during the season. In seasonal calving the effect of days in lactation becomes more relevant. In research from Dillon et al. (1995) spring-calving in dairy cows was investigated. Comparing calving dates of 23 January and 15 March. Cows calving in March, with the beginning of grass growth showed a reduced milk yield per cow but higher concentrations of fat and protein. Resulting in equal kg of fat and protein (Dillon et al., 1995). In McCarthy et al. (2013) milk production and herbage production remained unaffected by CD. Even if matched grass as a sole feed limits production.

In expectation to the milk quota abolition, farmers anticipated to a restriction of herd size based on animal rights or phosphate production of a reference year. Farmers whom otherwise would have waited invested in large stables and expanded their herd size to increase milk production. Over the past decades herd size has increased severely. The average dairy farm had 42 cows in 1984 to 85 cows in 2014. Secondly in 2000, 45 dairy farms had 250 cows or more, this number has increased tremendous to 295 in 2014 (CBS, 2014). Increasing herd sizes makes grazing more difficult, the amount of available pasture may be inadequate, putting too much pressure on the crop and soil (Koopman, 2014). This leads to an increase in grazing pressure through higher stocking rate (SR).
In most cases an increased milk production and herd size is not paired with an increased farm area. From the period 2003 to 2013 the farm intensity increased from less than 15.000 to 18.000 kg/ha. The expectation is that farmers will continue to expand their herd, but not grow accordingly in hectares increasing the average farm intensity to 22.000 kilogram in 2018.

To make efficient use of pasture (SR) is an important variable. Stocking rate (cows/ha) is defined as the number of animals per unit of land (Allen et al., 2011). Increased SR is associated with a decrease in sward height leading to an increase in tiller population density. Lower stocking rate gave greater live individual tiller weights throughout the experiment and a longer interval between defoliation of individual tillers (Baker and Leaver, 1986).
The effect of increasing SR on grass production within the literature is inconsistent. In Stockdale and King (1980) increasing SR led to a reduction in total grass production. They declared this reduction was due to a reduction in the photosynthetic ability of plants with high SR. Also Sollenberger and Vanzant (2011) found in literature that increasing grazing intensity decreased forage mass production and increased the nutritional value of the forage. However the increasing grazing intensity or SR was related with a reduced individual animal performance. In contrast, Macdonald et al. (2008) observed an increase in grass production at higher SR. Additional nutritional value of the pasture increased, reducing the impact of more cows per hectare. Higher SR reduced milk production per cow, but increased milk production per hectare. Increasing SR negatively affects the amount of pasture available to each animal, but increases the amount of pasture harvested per hectare. There was only a 3% decline in the efficiency of converting feed energy into milk energy as SR increased (McDonald et al., 2008). In McCarthy et al. (2013) cows grazed paddocks on three different SR; low, medium and high, respectively 2.5, 2.9 and 3.3 cows ha^{-1}. Increased SR was related to more intensive grazing, resulting in sward of increased leaf content and nutritive value, associated with increased grass utilization and milk production per ha.

In research from Lantinga et al. (1999) animal performance of cows was compared under different nitrogen fertilizer levels, however when looking at increasing days in grazing milk production in kg FPCM per cow per day decreased but milk production in kg FPCM per hectare increased (table 1).
High prices for milk and low concentrate prices are economical drivers for farmers to change toward a high milk production per cow in other words summerfeeding.

Table 1: Experiment 1. Effect of Fertilizer N on animal performance of dairy cows under rotational grazing. FPCM is fat (4.0 %) and protein (3.3 %) corrected milk.

Fertilizer N (kg ha^{-1})	250	550	250	550
Cow grazing days ha^{-1}	791	908	580	938
Milk production (kg FPCM $cow^{-1}d^{-1}$)	21.5	19.7	22.1	21.8
Milk production (kg FPCM ha^{-1})	17,054	17,882	12,814	20,441

A grazing system requires short-term and long-term management decisions for adequate herd feeding and pasture budgeting over the grazing season. Grazing is more difficult to manage in combination with a milk robots (KOM, 2011). Grazing causes the diet composition to change which is undesired in grazing, furthermore the cow has to walk longer distances to the AMS increases the milk interval, making the robot less efficient. Research from Dooren et al. (2002) shows that only half of the farmers apply grazing in combination with AMS. Which is low compared to the 70% for farmers in the rest of the Netherlands. With a high milk production a farmer is more likely to stall his cattle permanently to keep the ration on a constant level ensuring a high yield.
From the reasons outlined above it is clear that current trends in livestock farming in Europe cause a decline in the popularity of grazing for dairy cows. Whether a farm continuous to graze or stock his cows depends on the economics, possibilities within the farm and personal wishes of the farmer.

3.5. Energy and DM production

In the following part VEM and DM losses under grazing and cutting are discussed. When comparing both VEM values of fresh grass and ensiled material over the years 2010-2014 average VEM varied from 877 to 893 in grass silage and 925 to 947 VEM in fresh grass. Over the years 2010-2014 VEM values were 45 VEM higher in fresh grass. Also the DVE level was higher for fresh grass. The higher amount of VEM is due to more sugars in the fresh grass and secondly through loss of nutrients from ensiling, storage and feeding.
Aarts et al. (2008) investigated the dry matter yield on farms and found that farms that cut their grass have 15% higher DM yields that those farms that apply grazing. However the lower production is compensated by a higher nutritional value in VEM per kg of DM. (Remmelink et al., 2014)

The advantage of grazing is that the net energy production is equal to the net energy intake. For summerfeeding or feeding fresh grass in the stable feeding losses occur, feeding ensiled grass gives on top of that conservation losses. There is a clear effect of the weight of the cut on the VEM value of grass. Compared to cutting for conservation the VEM-value is 4% higher than for cutting for ensiling and 9% higher than for grazing (Remmelink et al., 2014).

In grazing losses of the bruto energy production are estimated on 20% with unlimited stocking, 14% for limited stocking. Harvesting losses related to ensiling are unknown, losses for harvest and conservation of conserved grass are estimated to be 25%. Of whom 5% is lost in the field and 20% energy is due to conservation**.** These large losses are due to relative weak bonds that break protein and energy down. Summerbarnfeeding has the least amount of losses, 7% for harvesting and 5% for feeding (Remmelink et al., 2014).

Remmelink et al. (2014) investigated several products for conservation, energy losses in the field, during conservation and feeding have a large deviation. Several aspects such as; quality of the material amount of dry matter harvested, working procedure, climate, storage have their effect, causing a large spread in grassland production. This makes it difficult to predict losses from harvest to intake by the cow. When calculating the energetic requirements of the herd these losses are irrelevant.
The NH_3 fraction of 5 to 15 in the silage can drop VEM-value by 5 to 11%. A remark should be made that this drop in VEM is not just the drop NH_3, but also due to low DM levels of the analysed material (20-35%) (Schooten and Philipsen, 2011). They make a subdivision for conserved well wet silages (<35% DM), assuming 3-5% VEM drop, and 5-13% for average to poor conserved silages. For dry silage (>35% DM) VEM decrease is estimated at 2-3%.
Also over time silage degrade, for every months ensiled (Schooten and Philipsen, 2011) calculate 0.2-0.3% drop in VEM value.

According to Van der Pol et al. (2002) the highest return from grassland is achieved with summerbarnfeeding (fresh grass in the stable), achieving both a high production of grass and utilization by cattle. High losses for grazing combined with a low production led to the lowest return for unlimited stocking. Summerfeeding achieve a high production, but had to accept relative high conservation losses, leading to similar utilization as for limited stocking (Pol et al., 2002).
The individual animal intake at grazing and efficient milk production is affected by multiple factors including, genotype (Horan et al., 2005), grazing SR and grazing intensity (McCarthy et al., 2013) the mean calving date (CD) and calving rate (Dillon et al., 1995).

The production of grassland and intake by ruminants depends on several factors. It is difficult to estimate the amount herbage due to heterogeneity of the sward. Herbage production is affected by several factors:

- Supply of nutrients and water, if unequal distributed variation within the sward will increase;
- Soil structure and composition, the ground close to water bins may produce less herbage due to intensive treading;
- Botanical composition, high yielding species and varieties are better under similar circumstances.

As the grazing season progresses, variation in herbage mass will increase even more (Lantinga et al., 2004). Due to animal treading and selection, cows select for herbage species or plant parts (topping) and for areas free of manure and urine. Also faeces and urine are not evenly distributed in the field increasing herbage variation.
Herbage intake of dairy cattle can be determined by (Lantinga et al., 2004);

- Factors of sward origin: digestibility, herbage mass and species, chemical composition and plant maturity;
- Factors of animal origin such as: age, weight, stage of lactation and/or gestation, milk production and body condition score;
- Management factors: grazing system, fertilization, SR, supplemented feed and herbage contamination. High SR forces animals to graze the grass short, leaving less residual herbage but with risk of milk production.
- Or external factors such as season and climate.

3.6. Energy requirements for a dairy cow

In current practice a lot of data is available for each individual cow. If you ask a farmer how much milk a cow produces he can tell you exactly, however when asked how much grass is produced per ha, they can't give a clear answer. It is unclear how much grass delivers in terms of milk. In practice the herbage yield of grass is not measured directly, whilst grass is the main source of nutrition for the dairy cow.

A cow needs energy for physiological processes. Depending on the state of the animal (lactation/gestation) extra energy is needed. The driving force behind milk production is energy, for dairy cattle in the Netherlands expressed in VEM since 1977. For this normative requirements have been set for cows housed in respiration chambers, which have been verified with feeding trails with cows in tie stalls.

In most European systems, NE_L is calculated from the ME content of feeds predicted at maintenance intake and the kl (efficiency of ME utilization for lactation). Kl is predicted from energy metabolizability (q = (ME/GE)). Maintenance requirements for lactating cows were derived from calorimetric studies (36). Maintenance requirements amount to 72 kcal of NE_L/kg of BW (The Netherlands). The NE_L is related to the energy contained in the milk produced, which varies according to milk composition, and is set at 748 kcal of NE_L/kg FCM in the Dutch system. (Vermorel and Coulon, 1998)

To achieve insights in the energy flows, the energy requirements have to be determined.

When calculating the energetic requirements of free grazing cattle additional energy for grazing and walking to the pasture have to be accounted for. Next to VEM for maintenance and the production of milk, cows require energy for movement, gestation, growth and mobilisation of body reserves (NEB) and to regain weight later in lactation (Tamminga et al., 2004) see figure 1. Movement can cause energy requirements to increase. According to Es (1978) cows housed in groups have 5% higher maintenance requirements than cows housed in tie stall. Additional requirements for grazing are 30% more than for maintenance (Es, 1974). In grazing the energy requirements of the cattle are higher than for stall fed cows. Grazing animals spend more time and energy on walking, eating and rumination. Whilst stall fed animal take up their nutrients in a shorter period.

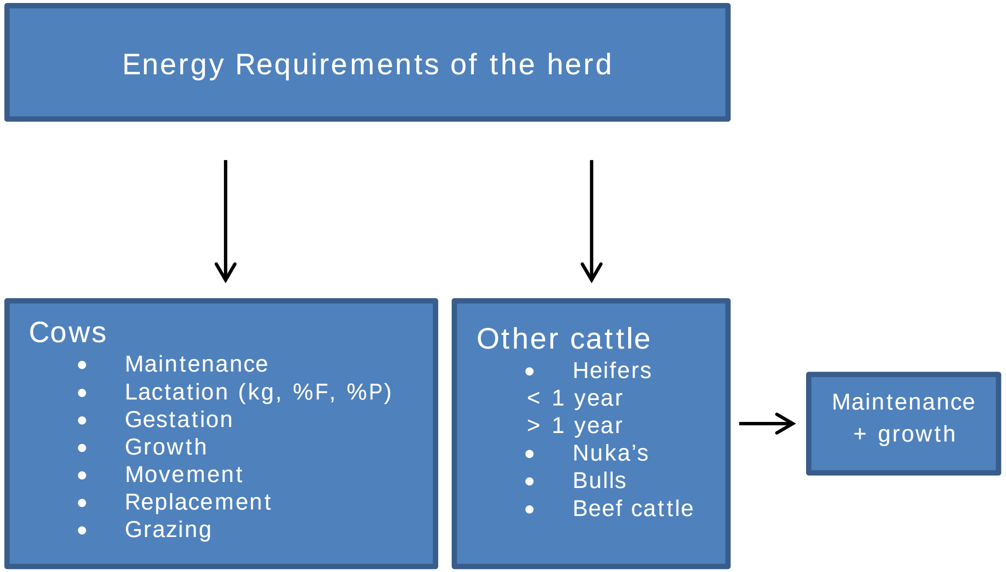

Figure 1: Energy requirements

In later research of Meijs (1981) requirements of cows grazing are 20% higher than stall fed cows. Whilst in Remmelink et al. (2014) grazing cows burn more energy, 6% for limited stocking and 7% for unlimited stocking than cows that roam in the stable. Movement may increase the energy requirements of grazing cattle by 10% or more compared to stall fed animals (Havstad and Malechek, 1982). Although this does not affect grass production, efficiency decreases.
In research from Pol et al. (2002) unlimited stocking was compared with other grass management systems. Limited stocking led to an 9% higher netto kVEM efficiency, summerfeeding is 21% higher and cutting for conservation gives a 8% higher netto kVEM production (Pol et al., 2002). There is thus a large variation in calculating energy requirements related to grazing.
In RVO (2015) 10% extra is calculated for cattle in free stall compared to tie-stall. For grazing an additional energy is calculated at 7.5% and 10% for respectively limited and unlimited grazing for every month spend grazing.
Further maintenance requirements are higher if cows have to walk long distances to the milk parlour or when they graze on steep terrain. When walking 2.5 km per day extra maintenance requirements add up to 250 VEM per day for a 550 kg cow (Meijs, 1981).
Maybe even more important is the energy required for milk production, depending on percentages of fat and protein. Also per kg of body weight an energy correction has to be calculated. Furthermore cows require energy for gestation, negative energy balance and replacement of cows.
During pregnancy a lot of energy goes to the foetus and membranes, energy for pregnancy is less efficient than for milk production. During pregnancy requirements increase from 700 to about 2500 VEM per day (Es, 1978). After parturition, cows require a lot of energy for milk. Lactating animals have bigger organs, heart, lungs and gastrointestinal tract, causing their maintenance requirements to be higher than for non-lactating animals. And of course milk itself contains energy which must be produced.

Feed intake is limited and often not enough to support this high milk production in early lactation. Body reserves are mobilized to supply nutrients for its production. Lastly diets rich in nitrogen such as fresh grass can reach an excess of nitrogen which has to be removed, costing energy in the process.
By determination of the total energy requirement of the herd (cows, heifers, bulls, calves, etcetera other animals receiving feed of the herd) the amount energy needed can be determined. As one Dutch feeding unit for lactating animals (VEM) contains 1.650 kcal or 6.9kJ Net Energy for Lactation it can be calculated how much VEM is needed on the farm to feed all livestock. In general it is more common to use 1 kVEM equal to 6.9 MJ NE_L. VEM is a relative energy measure: barley is used as a reference material.
Next to the many advantages of grazing, applying grazing makes it harder to supply a constant diet of optimal quality. To support grazing many farmers provide supplementary feed in the stable.
A disadvantage of full grazing is an excess of microbial protein which can negatively affect fertility. The microbial protein is released as ammonia at an excessive level, unable to be utilized at a sufficient amount by the rumen microbes. Thus the liver has to metabolise the urea. This step is energy consuming and is a loss of nitrogen in urine (O'Grady et al., 2008).

In many western countries, grass is a relative inexpensive feed source for the production of milk by dairy cattle, grazing is even cheaper due to lower costs for concentrate, contract work, labour and manure disposal. Secondly grazing reduced the environmental impact and improves animal welfare. Further grazing positively contributes to the image of the dairy sector. Various changes such as a larger herd size, higher nutritional demand for production, automatic milking and available pasture make farmers choose to keep their cows indoors.

3.7. Grazing systems

Grazing is the most important method of utilization of grassland in the Netherlands. Grazing can be performed in several ways. The most common methods used are types of continuous and rotational stocking. As cows receive a new pasture they start by selecting leaf from the top layers of the sward. As less herbage becomes available, animals take smaller bites, increase grazing time, biting rate and the number of bites. In later stage of defoliation, eating bites and grazing time decreased and bite size reduced leading to a low intake of herbage. (Chacon and Stobbs, 1976)

3.7.1. Continuous stocking

Continuous stocking is when cattle graze a pasture for an extended period with no rest to the plants from grazing. Under continuous stocking herbage production and consumption occur at the same time changing the physiology of the plant. Under rotational stocking these two are separated.
Continuous stocking is known for, low stocking rate, long grazing periods and no or little fertilization. Grass production levels are low and grazing losses high. Owing to low and variable herbage production rates and poor quality, a high herbage allowance is required. Losses by death and decay, and by maintenance respiration in these physiologically old crops, are therefore high. Some advantages of continuous stocking are low fencing cost, low daily management and when SR is correct acceptable animal gains. Continuous stocking is effective when forage is available in large amounts. If lactating dairy cattle are used the quality offered is limiting milk production. Therefore continuous stocking is even better when implemented with dry cows, or bred heifers. A difficulty of continuous stocking is to control the timing and intensity of grazing. Additional during slow growing periods animals require additional feeding or needs more pasture. Increased area per animal is required as the season advances into the hot summer months, when pasture re-growth slows down. If pasture is too intensively grazed over a longer period of time, forage availability and animal growth will be reduced. A continuous grazed pasture will take longer to recover because plants have been more stressed. There are not many grasses that can withstand the high grazing pressure.

Little is known about the level of herbage production during the grazing season. In a study of (Lantinga, 1985) a model was developed to predict herbage production under grazing. The model can be used to predict herbage intake in rotational stocking and to estimate the additional herbage production during the grazing period and for management of the continuous stocking system. Continuously grazed grass causes cows to increase their bites per day but with a lower bite size when compared to strip grazing. The sward is shorter in continuous stocking costing the cow more effort to graze, biting rate increased as bite size was smaller. (Arriaga-Jordan and Holmes, 1986)

3.7.2. Rotational stocking

Rotational stocking is a system where a large pasture is divided into smaller paddocks allowing livestock to be moved from one paddock to the next. Cattle are concentrated to a small area and remain there for only a few days. Pasture has more time to rest, allowing the plant to initiate re-growth and improve yield and persistence. When applied correctly rotational stocking can improve productivity. Rotational stocking allows for better manure distribution, as has the potential to reduce supplemental feeding and the amount of forage wasted. However it requires more fences and time to move the cattle and supply water and shade for the animals. Use of temporary fences can lower the field cost and be easily moved to supply plenty of fresh material. Rotational stocking can help extend the grazing season, allowing a producer to rely less on stored feed and supplement. Rotational stocking allows the producer to be more in control of the timing and intensity of grazing by cattle. Whatever system is applied the key to making a grazing system work is managing the balance between production and use of forage throughout the year.

3.7.3. Short grazing

A variant of continuous stocking is short grazing (SG). In SG grass is harvested more often at a much younger stage and grazed to a shorter height. The nutritive value of grass can be positively influenced by grazing the grass short. In the case of short-grazing the grass is grazed to a shorter length, this raises the proportion of green leaf and lowers the proportion of grass stem and dead material. The young shoots are rich in protein and energy. As grass gets older the ratio of stem increases lowering the digestibility and nutritional value of the crop *(AgroXpertus, 2015d; a; b)*. Secondly cattle is more willing to eat a diversity of grass species when they are in a young and vegetative state. According to Leisen this is seen in the field as cows eat grasses they would not in a more mature stage of the crop. This improves tillering and provides a dense surface.

Every harvest the plant needs time to regenerate, causing a delay in regrowth. The severity of delay depends on the weight of the current cut and the previous cut. The heavier the longer the delay (Blanken et al., 2006). For grazing the return period is shorter, as well as the weight of the cut leading to more days needed to regenerate.

3.8. Energy losses

Grazing affects both grass production and grass utilization. Losses are due to trampling, manure spots and other field losses. Cutting grass gives losses for harvesting, conservation and feeding. Grazing and cutting both have their own positive and negative effects on pasture production. Where grazing has mostly negative influences from cattle affecting productivity in the field, cutting grass does not hamper productivity, but losses occur in the field, during harvest, storage and feeding. With good management these losses can be limited. In the following chapters important factors will be clarified. The amount of grass ensiled is different from the amount of grass consumed, due to conservation and feeding losses. For the calculation these losses are corrected for to determine the yield per ha. Losses can be corrected using standards (Remmelink et al., 2014).
To gain insight on how much energy a hectare of pasture really produces losses have to be characterised. When looking at the total energy production of grassland net grass production is split in two part, grass grazed and grass cut. Cut grass can be fed fresh to the cows, or stored as silage or hay to be fed during the winter season. In grazing grass is harvested at a much younger stage. More regeneration periods are needed (Taweel, 2006). Losses from harvest to consumption consist out of field losses (grazing losses, cutting losses, harvesting losses) and conservation losses and feeding losses.
As seen in the figure 2 losses during grazing come from trampling and deposition of urine and faeces. For conserved grass harvest losses, preservation losses and feeding losses occur. During forage conservation losses occur in the field. Losses can be divided into respiration loss, leaching loss and mechanical loss.
To get a picture of how much VEM a hectare of pasture really produces in field losses have to be characterised. For the production of pasture a distinction is made for gross and net production. Gross production is the total amount of grass that can be harvested above 5 cm (cutting height). Net production is the amount of grass truly harvested or grazed. For grazing these losses are caused by treading/trampling, manure and urine patches, and lying. When conserving grass as silage, herbage can be removed directly from the field in the case of summerfeeding. This limits losses on the field after cutting due to decay over time and wilting. Whereas in a cutting management losses occur after harvest, due to cutting, wilting, lying in the field. When all losses are characterized net VEM intake remains. In cutting additional losses occur during the ensiling, storage and feeding. As herbage is consumed energy is still lost digestive and metabolic processes.

Instead of calculating herbage production by taking in account field losses and digestibility losses as seen in figure 2, methods we will be using look into animal performance in terms of milk production to calculate back how much energy has been produced out of grass.

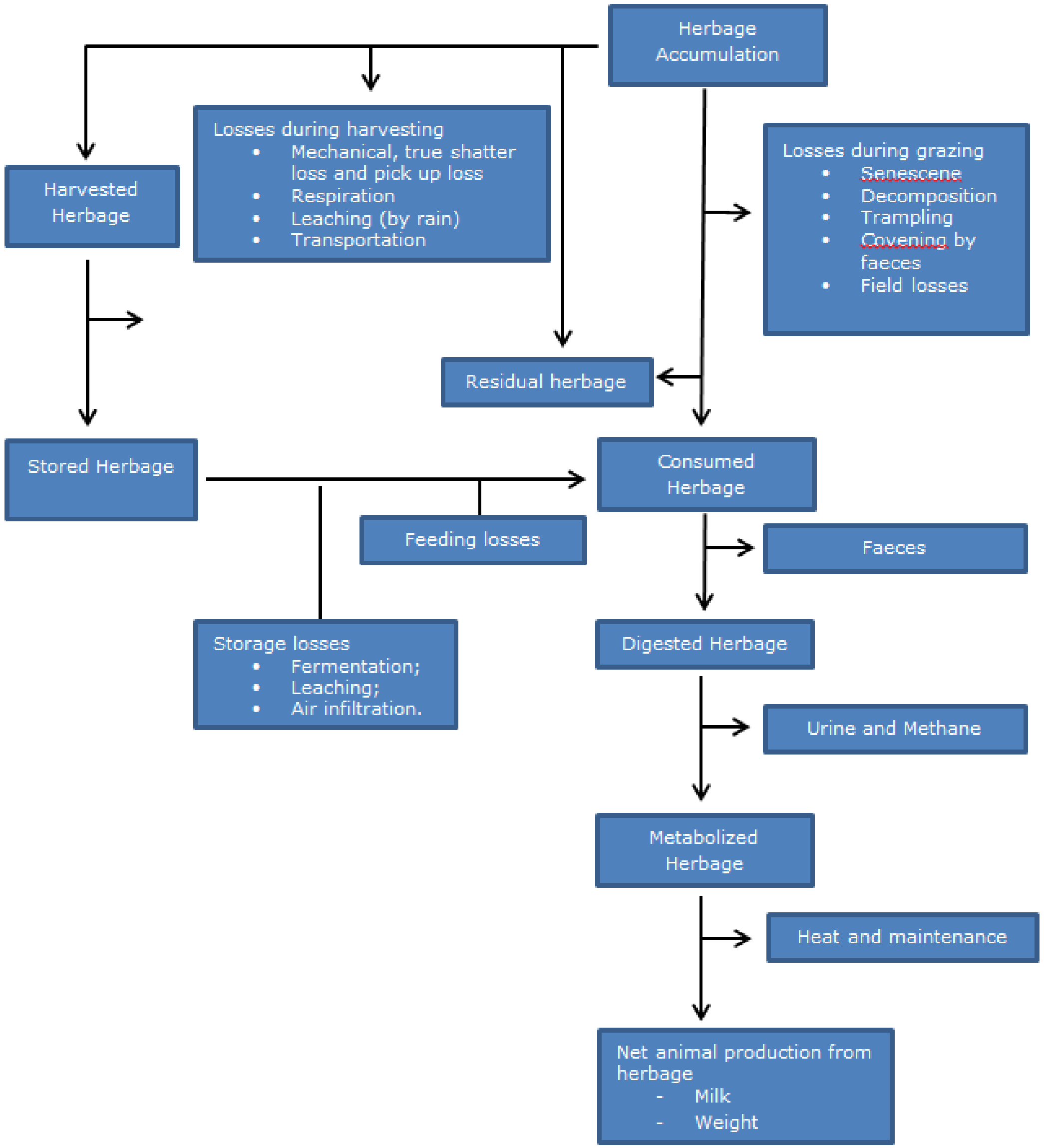

Figure 2: Losses from herbage to milk and growth

3.8.1. Field losses

After cutting herbage are left on the field exposed to the air prior to lifting. During this period physiological and biochemical changes occur which can result in nutrient losses or gains. Field losses for pasture grass are 15% for limited stocking and 20% for unlimited stocking, see table 2. For zero grazing and summerfeeding field losses are 5%. For maize silage feed losses are 2%. (Schroder et al., 2014). Additional leaving cut herbage in the field before lifting increases the risk for mechanical, as well as weather damage and nutrient losses, since wilting and herbage removal are required for this system. For making silage or hay wilting has to be done several times to achieve a low dry matter. Making hay requires more labour, fuel and a longer field period.
Field losses occur in the field due to mechanical losses, respiration, microbiological and leaching losses (by rain), loading and transportation. From harvest to being ensiled grass undergoes several mechanical steps. Fields losses occur during all mechanical operations, i.e. mowing, tedding, windrowing, baling and harvesting. Mechanical operations causes fragmentation of the crop material, parts of the plant are detached and blown away or drop into the stubble (McGechan, 1989). As grass dries, leaves become more brittle, parts of the crop are released and drop into the stubble unable to be picked up when harvested. Losses varied in the range of 0.2 to 0.5 t DM ha^{-1} (McGechan, 1989).

Table 2: Losses as applied in the KringloopWijzer: field losses (grazing losses for grazing, harvesting losses for silages), conservation- and feed losses.

	Field losses	Conservation losses		Feeding losses
	DM/VEM	DM	VEM	DM/VEM
Pasture grass, limited stocking	15	0	0	0
Pasture grass, unlimited stocking	20	0	0	0
Pasture grass, fresh feeding	5	0	0	0
Grass silage	5	10	15	5
Maize silage	2	4	4	5
Wet feeds	0	4	6	2
Additional roughage	0	10	9.5	5
Concentrate and milk powder	0	0	0	2
Minerals	0	0	0	2

(Schroder et al., 2014)

These losses are used for calculations in the KW. These data differentiate between and within product. In reality these losses have no set value and have a large variation. Especially management is very important in this. As is stated by Schroder et al. (2014) it is impossible to specify these losses on a simple and reliable way for each farm.

When grass is cut respiration continues until it is inhibited by either a low moisture content such as in hay or by anaerobic conditions in a silage clamp (McGechan, 1989). The main respiratory substrates are water soluble carbohydrates (WSC). Sugars are oxidized and broken down to H_2O and CO_2. Also proteins are degraded to AA by respiration. The AA are more soluble and likely to leach. Under favourable weather conditions leaching does not occur. Respiration and leaching losses are mainly losses of the WSC component of the forage. The rate of respiratory loss depends on temperature, moisture and WSC content of the forage material.

There is a big difference between placement of urine and faeces between grazing and SF. In grazing manure and urine are excreted on a relative small surface, which makes it impossible to take up the nutrients in short term and increase the chance of losses. Also the grass covered by faeces suffocates, dying. Faeces and urine deposed indoors can be used as a fertilizer. The manure can reach better efficiency, producing higher yields. Additional also the grass around especially the manure spots is not eaten by cows (Wal et al., 2000).

When cutting different types of mowers can be used, without bruising losses are minimal. However with bruising the products is cut shorter. In the Netherlands losses for cutting with a bruiser are limited to 1-2% (Dijk, 1995). He also found 1.2% wilting losses per day to a maximum of three days, when wilting once a day. When wilting a dry silage loses can add up to 1.4% due to crumbling (Schooten and Philipsen, 2011). Losses for tedding and loading are estimated to be 1.7% (Dijk, 1995). During the field period the cut grass continuous to respire. Losses due to breathing in the field are 2% of DM (Wilkinson, 1981). When breathing especially the soluble carbohydrates dissolve, VEM value is estimated to drop during a field period.

Wilting grass has long been adopted throughout Europe, mostly as a management strategy to reduce the water content in the silage. Wilting however causes DM losses (Henderson et al., 1972). Gordon et al. (2000) investigated if wilting perennial ryegrass prior to ensiling would affect milk production and the energy utilization by cattle. Wilting increased DM intake but reduces milk production per unit area of land. Wilting reduced the efficiency of ME conversion to milk energy output, this effect appears to increase with the degree of wilting. This could arise through either effects on maintenance energy requirements, or efficiency of energy utilisation for milk production, or greater partitioning of ME intake towards body tissue gain.
Nutrient losses during wilting of herbage represent the sum of respiration loss, leaching loss and loss through microbial degradation. During wilting losses occur from continuing plant respiration, the activity of aerobic microorganisms. The amount lost due to wilting depends on the temperature, original DM content. Mechanical losses depend on plant properties, the number of turning treatments and DM content. Especially legumes are vulnerable to wilting as their thin leaves dry out faster than the stems they become brittle and are separated from the stem during wilting resulting in high nutritional losses (McGechan, 1989). In Mayne and Gordon (1986a) grass was harvested directly with a flail harvester or pre-cut with a rotary drum mower with or without wilting. Wilting pre-cut grass led to greater herbage losses due to mechanical losses. Additional wilting of a wet material increased nutrient losses, possibly due to greater respiration losses. Also pre-cutting herbage with a rotary drum mower lowered the total herbage ensiled over the season than for a flail harvester. Mayne and Gordon (1986a) conclude that even under good weather conditions, both pre-cutting and wilting can lead to nutrients losses in the field. Their suggestion is thus that harvesting should be based on a one-stage system, avoiding losses of nutrients associated with pre-cutting and pick up operations. However one should always look at the greater picture as wilting results in silages lower in dry matter, reducing losses due to effluent.

3.8.2. Ensiling (storage and conservation)

To conserve grass ensiling is by far the most popular method. The ensiling process includes several steps starting with harvesting the forage and wilting to ensure an adequate dry matter for fermentation, followed by; chopping, loading the silo, compaction to exclude air, storing and finally unloading for feeding. Ensiling forages reduces weather risks and harvest losses. Ensiling is done to exclude air from the silage and minimize losses through plant respiration and activity of microorganisms. It is considered a good method for conservation of nutrients. Preserved silage ensures continuous and consistent forage supply throughout the year. However during the process of ensiling grass is degraded. Conservation losses occur; part of the DM and VEM is lost due to breathing of the grass and through microbial turnover. Protein and cell walls (NDF) are broken down during anaerobic fermentation by bacteria. This process is similar to ruminant fermentation. Silage fermentation thus predigests silage material, making the silage faster fermentable.

Before being conserved the process of ensiling needs to undergo several steps. The ensiling process starts with the aerobic stage where air is still present between plant particles, the pH is high, respiration and proteolysis still continues. When the silage is air-tight lactic acid bacteria convert sugar to lactic acid which causes a drop in pH preserving the silage. Meanwhile oxygen levels drop through oxidative processes. The quick decline in pH is necessary to stabilise the silage and prevent further decay of protein and growth of detrimental bacteria. A part of the lactic acid produced is reformed to acetic acid which reduces the risk for fungi and yeast. The fermentation stage is done and silage becomes stable. When silages are opened and fed they are exposed. Air infiltrated the silage enabling plant respiration and the activity of micro-organisms such as yeast and moulds. Aerobic deterioration causes loss of nutrients, decreased feed intake and risk for mycotoxins in the silage.

If the crop is very moist (less than 30% DM) effluent losses can occur which is to loss of nutrients and to environmental pollution. The loss of effluent depends on the degree of consolidation, chopping length and bruising of the plants and acidic additives.

To prevent leaching losses grass is wilted in the field to increase DM content. If the product is to dry and the buffering capacity is high (high ash content), secondary fermentation can emerge clostridia are formed. Lactic acid and amino acids are further converted to butyric acid, amines and ammonia which is toxic, the pH rises and silage becomes unstable. Butyric acid has an offensive smell and decreases the palatability. Another reason why the DM content should not be too high is poor compaction. Compaction of roughages is determined by height, cover, DM, chopping length and the level of compaction by machinery. A higher density reduced losses during storage and whilst emptying the silage. Providing the silage with a ground layer increased the density considerably. To seal the silage plastic is used. The thicker the plastic the less it is oxygen permeable.

Next to ensiling losses occur when unloading the silage, important factors are the duration of the silage to air exposure, ambient temperature and on the aerobic stability of the silage. Air penetration depends on the density of the silage and the loading method. When loading a smooth surface is preferred, if the surface is porous the surface area is larger being more susceptible to air penetration and increased DM loss.

Following ensiling the plant continuous to respire, firstly due to microbial activity during fermentation and secondly the release of silage effluent from low DM crops. There is a large variation in the results of different studies. (Mayne and Gordon, 1986b; Schooten and Philipsen, 2011)

In Table 3 you can see the main analysis of the different products of grass. It should be mentioned that levels of all components are largely affected by stage of growth, cultivar weight of the cut and fertilization. Crude Protein (CP) and VEM are highest in fresh grass and lower for grass silage and lowest for hay. This is to be expected as losses of protein and energy occur during field processes and conservation. Grass hay contains considerable more fibre than fresh or ensiled material. In general hay is cut in a later stage of the plant, the plant is more mature, which leads to higher levels of NDF and ADF and lower levels of energy, nitrogen and ash. The feeding value of grass increases when harvested in a younger stage. Grazed grass is harvested in a younger stage in which it contains relative less structure increasing the VEM content. Pasture grass thus has better nutritional value than grass- silage and hay.

In table 3 silages and hays were cut at the same time from the same field, even there hay had lower protein and higher NDF and ADF contents. These differences can be attributed due to leaf losses in the field (McGechan, 1989).

Silage storage losses can be subdivided into fermentation loss, air infiltration loss and effluent loss (McGechan, 1990). Fermentation losses occur during the process of fermentation until the silage is stable. Air infiltration losses derive during ensiling, storage and while feeding out. When feeding out air can access the silage once again and microorganisms oxidize nutrients during the feeding out period. Air infiltration has partly invisible losses through oxidation of nutrients and partly visible deterioration due to oxidation of nutrients. To prevent air infiltration chopping length and density are very important. Important factors for silage losses are degree of wilt, chop length, stage of maturity and the use of additive. Unlike expected McGechan (1990) conclude that shorter chopped silage offers less resistance to gas movement than long material. Losses during storage depend upon DM content, grass maturity chop length, density and the use of an additive.

For cut grass conservation losses are 15% energy is lost. For maize silage 4% conservation losses and for wet feeds conservation losses are 6% (Schroder et al., 2014). In Blanken et al. (2006)conservation losses for silage grass depend on dry matter on average 20% VEM is lost if DM is 35% or more. If DM is lower 25-40% of VEM is lost. For maize silage the average VEM lost for conservation is 4% and 5% for feeding.

Table 3: Long term average values from the years 2010 to 2014 of different types of grass products for ruminant nutrition

		Grass		
main analysis	**Unit**	**Fresh**	**Silage**	**Hay**
Dry matter	g/kg	175	455	837
VEM	g/kg DM	933	888	711
Crude protein	g/kg DM	189	157	107
Crude fat	g/kg DM	38	39	21
NDF	g/kg DM	509	482	600
ADF	g/kg DM	264	270	327
ADL	g/kg DM	22	22	36
Ash	g/kg DM	103	114	85
NDF*dig*.	%	72.1	71.6	50.8
Sugars		115	85	103

(AgroXpertus, 2015d; a; b)

3.8.3. Feeding losses

During feeding additional losses occur during taking out roughage from the silage, during transport and as feed rest in the stable. The feeding losses depend on the type and nature of the product. To reduce these losses quality is very important. The quality also determines the amount of feed needed to fulfil the nutritional need of the animal expressed in VEM per kg DM. The yield of grassland is best expressed in kVEM per ha per year. Feeding losses during feeding are 5% for roughages, 3% for wet concentrates and 2% for dry concentrates (Blanken et al., 2006; Remmelink et al., 2014; Schroder et al., 2014).
From investigations done in “Koeien & Kansen” it appeared that in practice, 4% more feed is used than theoretically required by cows (Galama et al., 2001). For a part these feeding losses are due to spillage and rest feed in the stable. This amount is estimated to be 2% of the feed which is never eaten by the animals. It disappears to the manure storage. The other 2% is possibly explained due to inefficient digestion of feed, for instance by sick animals or a sub-optimal feeding, a higher maintenance requirements for high producing cows or a to high estimation of the feeding value of some products.

The problem with losses is the large deviation. It is very difficult to accurately determine the amount energy lost in the process from grass in the field to milk production. Especially since losses have a large variation depending on a multitude of factors (Blanken et al., 2006; Schooten and Philipsen, 2011). In our study we therefore use calculations method that do not estimate losses on field and such but calculate from energetic requirements how much came from grass.

3.9. Knowledge gap

High net energy production per ha is increasingly important, especially in the EU with the disappearance of the milk quota in 2015, the milk price is no longer guaranteed. The expectation is that the coming years farmers have to deal with larger price fluctuations in milk and feed. Feeding of grazing ruminants is difficult to manage in practice due to inability of the farmers to accurately estimate nutrient intake from grazed pasture. It is unclear how much grass delivers in terms of DM and energy and utilized by their cows to be transformed into milk.

Current energy evaluation systems often let expect higher milk production on grass-based diets than observed (Bruinenberg et al., 2002; Dijkstra et al., 2008). Reasons for such discrepancies may include higher requirements of cows fed fresh grass than assumed in various energy evaluation systems due to unbalanced supply of nutrients and rest feed. As well as adjustments for metabolic and digestive interaction between feeds as for differences for energy requirements of animals for maintenance, lactation, BW changes, gestation and grazing. Or overestimating the VEM value of roughages (Dijkstra et al., 2008). Current energy evaluation systems often let expect higher milk production on grass-based diets than observed. According to Leisen the net energy production of grassland in grazing is underestimated Based on his experience in the field energy production from grazing animals is much higher than based on theoretical losses in the field.

There is need for a method that is practical for the farmer, accurate and reliable. Throughout Europe several methods have been developed to calculate the net energy production of grassland (Vermorel and Coulon, 1998). Plenty of studies have been carried out on energy requirements, energy value of the diet, digestibility and utilization of energy by lactating cows.

To accurately determine the net energy production of grassland in this study energy production of grass is determined from animal performance in terms of milk production and growth to calculate back how much energy has been produced out of grass. Instead of calculating herbage accumulation and taking in account field losses and digestibility losses. Three calculation methods for determination of the NE production of grasslands are used, the method of Lantinga, E Leisen and the KW. The objective of this paper is to analyze, compare and check the reliability of these three energy calculation methods to accurately determine of the net energy yield of grassland. Underlying thought is that European countries can agree on one calculation method for determining the net energy production of grassland. A second objective is to create a better understanding of the fate of intensive grassland management systems, to increase VEM use efficiency and to reduce losses to the environment. And lastly check grass management has effect on energy productivity.

Research questions

- What factors are relevant for determination of NE production of grasslands?
- What is the effect of grass management type (grazing vs summerfeeding) on energy productivity?
- What are the differences and comparisons between energy calculation methods for energy requirements?
- Which calculation method is most accurate in determination of the net energy production of grass land?

Hypothesis: The net energy production of grassland is influenced by energy calculation method

4. Results

This chapter presents the results of the three farms: Goor, Pool and Spruit. The calculation methods are compared for each of the farms. Data for the period of 1.1.2014 until 31.12.2014 is used. Section one presents energy requirements based on the animals present (table 2) and fixed values used for the animals. Energy provided through nutrition is presented in section two. Section three compares the net energy production of grassland for the calculation methods. The last part includes the ratio of different feed products within the diet together with the level of self-subsidence of the farm for animal nutrition.

4.1. Energy requirements

The following part encompasses the energy requirements as used by the different calculation methods described earlier plus the NEW model. The NEW model is an optimization, combining the good of the three models to design an accurate, reliable model for calculation of the net energy production of grass land.

4.1.1. Cows

For cows energetic requirements include basic requirements plus energy for milk production, gestation and NEB, movement and replacement (growth of heifers). All three models, calculate energy for physiological processes, milk production and movement. When looking into more detail however differences appear. For milk production Leisen, Lantinga and NEW include all milk flows produced, including milk consumed by the farmers and more importantly by calves, whereas the KW only includes milk that is provided to the factory, table 5. The KW thus underestimates milk production and energy requirements per cow. For the farm of Goor and Pool milk production is underestimated by 3% and on the farm of Spruit it is 16%, due to 30 fattening calves which receive a large amount of milk. The difference between Lantinga and Leisen is due to formulas for calculating the energy amount in milk. The KW and Lantinga use FPCM, whilst Leisen uses ECM. Both FPCM and ECM correct for energy in milk and fat. In table 5 the difference between Lantinga (FPCM) and Leisen (ECM) increase as levels of fat and protein are higher. Additionally the model of Leisen is different for energy using NE for lactation compared to VEM used by the KW and Lantinga. For comparison VEM is used as it originates in Netherlands and farms investigated use the VEM system.

Table 5: Milk production

	Goor			Pool			Spruit		
	KW[1]	Lantinga[2]	Leisen[3]	KW[1]	Lantinga[2]	Leisen[3]	KW[1]	Lantinga[2]	Leisen[3]
Milk production									
To factory (kg)	878000	878000	878000	381700	381700	381700	493000	493000	493000
Personal use (kg)		400	400		0	0		3650	3650
Nuka's (kg)		25100	25100		10800	10800		87600	87600
Total milk yield (kg)	878000	903500	903500	381700	392500	392500	493000	584200	584200
Milk yield cow-1 (kg)	7910	8140	8140	5160	5300	5300	6490	7690	7690
Fat (%)		4,28			4,10			5,09	

Protein (%)		3,44			3,58			3,91	
Total FPCM (kg)	913000	939500	940300	392100	403200	404100	572900	678900	686300
FPCM cow-1 (kg)	8230	8470	8470	5300	5450	5460	7540	8930	9030
FPCM cow-1 day-1 (kg)	26,8	27,6	27,6	17,3	17,7	17,8	24,6	29,1	29,4
FPCM ha-1 (kg)	20400	21000	21000	9500	9800	9820	15000	17800	18000

1. In the KW only the delivered amount of milk to the factory is noted and used in later calculations.

2. The NEW model calculates the same milk production as Lantinga.

3. The model of Leisen makes use of ECM (energy corrected milk) instead of FPCM.

In table 6 the requirements for cows specific for each model are given. The extended version of the energy requirements for cows can be found in appendix 6. In table 6, the KW has higher requirements compared to Leisen and Lantinga, due to bonuses for replacement, gestation and NEB. Energy is calculated for replacements as cows overtime have to be replaced by heifers that require energy to grow. In the KW replacement is fixed, whilst in reality this number can deviate quite largely. In the new model energy for replacement was modified on heifers truly kept for replacement. Especially for the farm of Pool and Spruit replacement was lower than assumed.

Although these bonuses can be lower than assumed in the KW. In the new model true replacement is implemented, for the farm replacement was lower requiring less energy for replacement. The same could occur for energy required for gestation and NEB, as calving interval increases less energy is required. Vice versa calving interval could decrease leading to higher energy bonus of gestation and NEB. Leisen and Lantinga do not correct for gestation and NEB. Furthermore the outcome could have been different with a change in liveweight of cows. In current calculations no data was available on weight; therefore it was assumed that an adult cow weighs 600kg. If corrected for weight, as done in Leisen and Lantinga basic requirements of these two would increase whereas the KW would not.

On the farm of Spruit however a large amount of milk is required for milk fed to calves. The new model is highest, due to inclusion of all milk flows and correcting for the bonuses used in the KW. Lastly Leisen has higher requirements than Lantinga because of higher energy in milk.

Table 6: Energy requirements for dairy cows (expressed in kVEM)

Method	Goor	Pool	Spruit
Leisen	668000	343000	476900
Lantinga	648000	340000	469800
KW	679300	360200	448300
New	689900	361400	499200

4.1.2. Heifers and other grazers

In the KW requirements for heifers and other grazers are fixed. Both the KW and Leisen use their own standardized values per animal category, see table 7. Lantinga has no mention of energetic requirements in his research as his trail was focussed on grazing cows only. In the KW it is assumed that heifers, calves

and other grazing animals do not graze. Leisen only calculates energy for heifers kept for breeding on a yearly basis and calculated the amount of energy needed for this group of animals from nuka until calving. Using the age of first calving (in months) as a correction factor. As the number of heifers can deviate from the previous year, it is not reliable to use the amount of calves kept for breeding.
In table 8, energetic requirements for heifers and other grazers are given for each farm. On the farm of Goor there are no other grazers present. For Pool a bull is kept for breeding. The farm of Spruit energy required for other grazers is considerable due to two sheep and around 30 fattening calves. Leisen calculates lower requirements for heifers, but this can vary depending on age of first calving. However if heifers are present older than 2 years the KW will also calculate energy for this group. For other grazers Leisen uses higher fixed requirements than the KW. In the KW it is assumed that calves <1 year graze 95 days and heifers > 1 year graze 160 days. In reality this is quite different, on the farm of Spruit both calves and heifers graze more days, respectively 120 and 180 days. Also on the farm of Pool the additional energy required due to grazing is underestimated as calves and heifers graze, 150 and 270 days. It is unclear in the KW how much of the energy required for grazers is due to grazing therefore in the new model requirements for calves and heifers are kept similar.

Table 7: Standardized values for energy requirements of heifers and other grazers

	KringloopWijzer	Leisen	Lantinga**	New
Heifers < 1 year (kVEM year-1)	1412	3642*	1412	1412
Heifers < 1 year (kVEM year-1)	2600		2600	2600
Breeding bulls (kVEM year-1)	2623	3623	2623	2623
Fattening bull (kVEM year-1)	1465	2754	1465	1465

* Energetic requirements of heifers from birth till 24 months. Calculations of Leisen do not use fixed energetic requirements of heifers per age category instead.
** Lantinga calculations require additional data on growth rate, therefore ER were assumed to be similar to those of the KW as both system use similar formulas for calculation of the energetic requirements of cows and originate from Es (1978).

Table 8: Energy requirements of heifers and other grazers

	Goor		Pool		Spruit	
	Other models	Leisen	Other models	Leisen	Other models	Leisen
Requirements heifers (kVEM)	157400	149300	64200	58300	127600	126400
Requirements other grazers (kVEM)	0	0	3000	3600	79800	82900

4.1.3. Total energy requirements

In table 9 energetic requirements of all groups are summed together. On top the KW adds a bonus of 2% due to inefficiency in animal digestion and to ensure enough energy is provided to cover energy requirements (Tamminga et al., 2004). As we see in table 9, the KW calculates higher energy requirements than the other two models on the farms of Goor and Pool, but not for the farm of Spruit cause of exclusion of milk to calves. Leisen model has higher requirements than Lantinga and the KW due to higher requirements for heifers and energy content in milk. Not one model is always the highest it depends on several factors; composition of the herd, milk flows and composition, additional requirements for grazing, growth, gestation and NEB. The new model has the highest requirements due to inclusion of other milk flows produces and additional calculated requirements used for inefficiency, replacement, growth, gestation and NEB.

Table 9: Energy requirements of the herd (expressed in kVEM)

Method	Goor	Pool	Spruit

KW	853400	435900	668900
Leisen	817300	404900	686100
Lantinga	804100	406800	677200
New	864200	437200	720800

4.2. Energy fed

The energy fed should match the energy requirements of the herd. In essence all tree calculations methods operate similar. First energy consumed through concentrate and other grazers is subtracted from the total energy VEM-requirements. The remaining energy comes from roughages; maize silage, grass silage and fresh grass. All feed flows on the farm are included to assess the amount of energy fed for each feed product.
The KW accurately collects all feed data on a yearly basis. For grass- and maize silage it is known how much is fed. Before being consumed losses due to storage and conservation occur. The KW uses standardized losses for different types of feed. For instance for grass silage this is 20%, whereas for concentrate it is estimated at 2%. The models of Lantinga and Leisen are designed for cows in the grazing season and do not correct for these losses. These losses are minor during the grazing season as cows receive only a small amount of concentrate, having low storage and feeding losses. But in this study the stable period is included thus causing a large error if not corrected for these losses. Therefore losses used in the KW were adopted in the model of Lantinga, Leisen and the NEW model. When all feed are subtracted the remaining energy should originate from fresh grass in these models. If cows did not graze the error was corrected based on the ratio of grass- and maize silage.
Also in the model of Leisen energy is split between roughages and concentrates. After which the energy from roughages is divided by the number of hectares. The problem is that the number of hectares is based on an estimated yield per hectare, which is very inaccurate. Especially since the energy provided is already known this method is devious.
The KW calculates the net energy from grass using the “VEM-gap”, doing so a correction is done energy consumed through, maize- and grass silage and fresh grass. Losses are adapted according the ratio in which they are consumed. Using the ratio of roughages in the diet, the energy provided by each of these groups is recalculated. The ratio of fresh grass is estimated based on the months and hours of grazing, to see whether the calculated DMI is plausible. The estimated net energy is replaced by the energy provided according to the VEM-gap.
In table 10a the amounts of energy fed through concentrate and other feeds are given for the three farms. These amounts are fixed and do not vary among the models. Energy provides as milk to calves is not taken up in the KW, the KW only includes milk delivered to the factory, as other flows can not be checked and therefore harm the reliability of nutrient efficiency on the farm. This milk flow however is truly produced and therefore taken up in the new model. In table 10b roughages fed are expressed.
When investigating the VEM-gap of Pool the recalculated energy from maize is higher than the bruto energy provided. The same error occurs for grass silage on the farm of Spruit. Even if zero losses are assumed the energy provided from silage is insufficient. It is well possible that the energy lost during conservation and feeding is overestimated. But it is impossible that the energy calculated from the VEM-gap is higher than the energy provided through the diet. On the farm of Goor the herd consumed no fresh grass. Energy requirements unexplained by calculated feed must be corrected in grass- and maize silage, based on their mutual proportion. The losses during storage and conservation thus deviate from estimated losses.
Table 10b shows the highest VEM-intake from fresh grass for the new model: firstly due to higher requirements in total, secondly due to correcting the missing energy completely by fresh grass, whereas the KW also increases energy consumed as silage, leaving less energy to be consumed from grazing.

Table 10a: Net energy provided through concentrate

	Goor	Pool	Spruit
Concentrate (kVEM)	185900	61300	214500
Other feeds (kVEM)	41600	0	20900
Milk to Calves*	11200	4800	44800

* Not performed in the KringloopWijzer

Table 10b: Net energy provided through roughages

	Goor			
	KW	Lantinga	Leisen	NEW
Roughages total (kVEM)	623100	578500	592000	622500
Maize silage (kVEM)	166200	154300	157900	166000
Grass silage (kVEM)	456900	424200	434100	456400
Fresh grass (kVEM)	0	0	0	0

	Pool			
	KW	Lantinga	Leisen	NEW
Roughages total (kVEM)	372300	348600	346700	370900
Maize silage (kVEM)	23500	21500	21500	21500
Grass silage (kVEM)	109100	99600	99600	99600
Fresh grass (kVEM)	239700	227600	225700	249900

	Spruit			
	KW	Lantinga	Leisen	NEW
Roughages total (kVEM)	432100	408400	417400	438400
Maize silage (kVEM)	0	0	0	0
Grass silage (kVEM)	240000	217200	217200	217200
Fresh grass (kVEM)	192000	191100	200200	221200

4.3. Net energy production per ha

The net energy production is the sum of energy consumed through silage and as fresh grass. The energy consumed through silage is accurately measured. The net energy production of grass deviates between models, depending on the amount of fresh grass consumed and the energy requirements estimated in section 3.1. The larger the gap between requirements and energy fed the more energy must have been provided through roughages, increasing grass productivity.
For the farm of Goor the energy produced from grass is quite clear. All energy comes from grass silage. For the farm of Pool and Spruit however the energy consumed through fresh grass has to be calculated. Biggest flaw in the estimation of the net energy of grass silage consumed is the assumed losses during feeding. It is understandable that to make the model practical, fixed values are used. The KW corrects for these losses although not always in a correct manner, overestimating the energy consumes from either grass- or maize silage.
In table 11 the net energy production per hectare is given. The net energy production of grass deviates between models, depending on the amount of fresh grass consumed and the estimated energy requirements. Although the NEW model is consistently higher, especially when fresh grass is consumed in the diet. The KW adapts energy consumed from grass silage and maize silage, which are fixed in the other model. When using the VEM-gap energy from maize silage is increased, lowering the remaining energy originating from grass silage and fresh grass. For the rest differences are related to energy requirements awarded to basic needs for heifers, (different for Leisen) cows, milk production, growth, gestation and NEB.

Table 11: Net energy production per ha (kVEM)

Model	Goor	Pool	Spruit
KringloopWijzer	12044	6445	11029
Lantinga	11180	6097	10436
Leisen	11441	6050	10673
NEW model	12030	6639	11224

4.4. Ratio´s of different feed products according to NEW model

In the following sections ratio´s for different feed products are presented. Table 12a. gives an overview of the different ratios between each individual feed product for the KW and the new model. The energy ratios for the other two models are left out as they are similar to the ratios in the NEW model. Table 12a. clearly shows that the farm of Goor applies summerfeeding, as no fresh grass is consumed. Secondly the farm of Goor feeds a considerable amount of maize silage, where Pool applies very little and Spruit applies none. For concentrate this is different Spruit feeds a high amount of concentrate to the herd, however a large part is fed to fattening bulls. These same bulls also receive a relative high level of energy through milk. The low level of concentrate on the farm of Pool is understandable being an organic farm with lower yielding cows. For organic farms especially concentrate is expensive to feed. When comparing the models for energy ratio’s differences are minimal, except for the ratio of fresh grass and grass silage on the farms of Pool and Spruit. Were the new models fills in the unexplained energy completely with fresh grass the KW also adjusts the net energy fed through silage. In table 12b. a differentiation is made for internal and external feed, to express intensity and self sufficiency of the farm. The farm Goor provides in 62% of their energy requirements, large amounts of concentrate and maize are bought. For the farm of Spruit this amount is 66%, roughages are provided by the farm itself. High levels of concentrate in the diet lower self sufficiency. The farm of Pool provides a large part of the diet by own produced feed. Here also grass silage is bought in considerable, feeding a large amount of roughages to the herd. Increasing the net energy production of grass per ha can increase the self sufficiency of the farm and lower feed cost as less concentrate has to be bought. Feeding ratio's of different feed products provide insight to nutrition and grass productivity on a farm level.

Tabel 12a: Energy ratio of feed products for the new model (1)

	Goor		Pool		Spruit	
Feed product	KW	NEW	KW	NEW	KW	NEW
Concentrate	21,5	21,5	14,1	14,0	32,1	29,8
Other feeds	5,1	5,1	0	0	3,3	3,1
Maize silage	19,2	19,2	5,4	4,9	0	0
Grass silage	52,9	52,8	25,2	22,8	35,9	30,1
Fresh grass	0	0	55,3	57,2	28,7	30,7
Milk	0	1,3	0	1,1	0	6,3

Table 12b: Energy ratio's of feed products for the new model (2)

	Goor		Pool		Spruit	
Own feed / purchased feed (%)	62%	38%	69%	31%	66%	34%
Own grass / purchased grass (%)	100%	0%	78%	22%	98%	2%
Roughages / concentrate and other feed products (%)	72%	28%	85%	15%	61%	39%

5. Discussion

In the following chapter the practical use and reliability of the models is reviewed, to see what their potential is. For starters calculations for energy requirements are discussed, followed by the calculations of the energy fed to the herd. Later limitations of this research are reviewed. In the last part recommendations for future research are given.

5.1. Energy requirements

In essence all tree calculations methods operate similar. They start by determining the amount of energy needed. For calculation of basic requirements of a cow, the KW makes a separation for Jersey, other breeds and crossbreeds (half Jersey). Jersey cows are considerable lighter than Holstein Friesian cows. In the models weight of Holstein Friesian cows is set at 600kg. Also for other breeds weight is set at 600 kg. However among other breeds and between Holsteins herd's different weights occur. For instance on the Farm of Spruit there are also Friesian Dutch cows which are considerable lighter, 500 to 550 kg. To improve the estimation of the energetic requirements of the cows, it would be more accurate to include average weights breed specific with their standardized energetic requirements. Ultimately basic requirements should be based on average weight of an adult cow. Leisen corrects with 116 kVEM for every 50 kg weight difference to the standard 600kg. Also Lantinga calculations have corrections for weight change overtime, unfortunately weight data is unavailable. If in the future the average weight of the herd is available (for instance weighing platform in robotic milking systems), corrections can be made.
When calculating basic requirements for heifers and other grazers kept on a yearly basis the KW uses standardized values. Also the model of Leisen uses fixed requirements for other grazers. In Leisen it is calculated, based on the number of heifers kept for breeding per year and the age of first calving. Thus calculating energy requirements from birth until calving of the calves kept for breeding of that year. Only mistake here is that heifers kept for breeding this year, can deviate from previous year. The model of Lantinga is designed only for cows, having no calculations for energy requirements of heifers and other grazers.

When calculating the energy required for milk production Leisen uses different calculations, leading to slightly higher energy content than for FPCM. To give farmers less space to manipulate the outcome of the KW only milk delivered to the factory is taken into account. Therefore milk fed to calves, used for consumption or otherwise is therefore not included. On all three farms milk is fed to calves. If not corrected for this milk production and energy requirements of cows are underestimated. On farm level however milk fed to calves has no net effect as it is subtracted from energy requirements of heifers. This does not count for other milk flows that do leave the farm, thus increasing energy requirements.

The KW is a very sophisticated model taking into account many flows on a farm level. It is the most accurate model of the three analyzed, collecting a lot of data. To acquire data easily a lot of values are standardized. This is understandable as it reduces the amount work and data to be collected. For farms with summerfeeding it is quite accurate, as we see in table 11. However farms can deviate from standardized values. Only the KW calculates additional energy requirements; replacement, inefficiency in digestion and gestation and NEB.
The KW takes into account additional energy requirements for gestation and replacement which are fixed corrections. In the KW replacement is estimated at 36.3% with 131 kVEM per cow, whilst in reality there is a large variation in replacement. Therefore an adjustment is required for heifers truly kept and not just those required for replacement. All heifers require energy for growth. For improvement the new model includes energy for growth but calculates the true replacement. Replacement can be much lower, on the farm of Pool, just 11% is required, in reality 22% of heifers are available for replacement and thus require energy for growth, 78 kVEM per cow. Alternatively replacement can be a lot higher when a farm is growing. For instance on the farm of Spruit there are

a lot of animals present on the farm which are meant for beef production, which leads to a replacement of 43% and coherently 157 kVEM per cow. If thus not corrected for real growth in heifers energy requirements can be over- or underestimated. Just as heifers other grazers require energy for growth. This part may be small on most farms that sell male calves at 14 days. However in some cases such as on the farm of Spruit 30 male calves are kept for fattening. Not including energy for growth of these calves would mean an underestimation of the energy requirements. For future calculations it would be easier and more accurate to add a standard bonus of energy per animal category than to calculate energy for growth based on a fixed value of replacement.
Furthermore in the KW it is assumed that cows spend 16% per year in gestation. In days per year this means, 307 days in lactation and 58 days in gestation. As the allowance for gestation is based on this number, the energy expenditure for gestation and NEB is overestimated, for instance on the farm of Goor calving interval was 405 days. This leads to fewer cows in gestation on a yearly basis thus lowering energy required for gestation. However it is unclear in the KW which part of the 191 kVEM per cow year is for gestation and which is for NEB. In the new model energy required for replacement is corrected for calving interval. This would mean that instead of 191 kVEM per cow per year cows require 172 kVEM for gestation and NEB.

One of the difficulties in calculating the energetic requirements of the herd is estimating the extra energy required for movement. The model of Leisen is only designed for grazing animals having no separation for energy requirements of animals due to grazing or movement. Data on energy requirements of cows originate from research trails in respiration chambers. There animals are housed in a tie-stall. Therefore first extra energy is required for movement in a free-stall barn and on top of that energy for grazing. For free housing compared to tie stall, the KW estimates energy requirements at 189 kVEM per year which is around 10% (RVO, 2015). For grazing additional energy is calculated at 7.5% and 10% for respectively limited and unlimited grazing for every month spend grazing (RVO, 2015). Lantinga corrects for energetic requirements due to movement compared to cows housed in a tie stall, with 7% in free stall and 20% for grazing cows. The energy bonuses used in the KW, confounds with literature, which also estimate between 6-10% additional energy requirements for grazing (Havstad and Malechek, 1982; Remmelink et al., 2014). Therefore in the new model energy bonuses due to movement were used as in the KW. The use of future technology, such as pedometers or activity meters can give new insight in the true movement and energy requirements related to stable and grazing systems. None of the models calculates any additional requirements due to movement for heifers and calves, thus underestimating energy requirements and energy consumed through fresh grass on Farm of Pool and Spruit where, cows, heifers and calves graze. In the KW it is assumed that dry cows graze and heifers do not, and if heifers graze it is assumed that dry cows do not.
When the complete requirements are calculated the KW adds a bonus of 2%, due to inefficiency in animal digestion and to be sure enough energy is provided to support energy requirements (Tamminga et al., 2004).

5.2. Energy fed

After the energy from concentrate and additional feed is subtracted, energy that remains comes from roughages. Differences between models occur when determining the energy provided from individual roughages.
For all feed product losses occur during storage and feeding. In roughages there is a large variation for these losses. Biggest flaw in the estimation of the net energy of grass silage consumed is the assumed losses during storage and feeding. In the models of Leisen and Lantinga these losses are not mentioned as both models are focused on the grazing season. There cows receive only a small portion of concentrate, making these losses negligible. But as data is used of the entire year silages are fed as well, having considerable losses. The fixed losses used in the KW were also used in the model of Leisen and Lantinga. When all energy flows fed netto are subtracted, rest energy is explained as the net energy consumed through fresh grass. It is not possible to do this for the farm of

Goor, as summerfeeding is applied. Therefore the energy rest or shortage is corrected for energy provided by grass silage and maize silage, based on their mutual proportion. Losses during storage and conservation thus deviate from estimated losses.
In the KW the standardized losses are used to determine the net energy fed of the different roughages. With the use of the VEM-gap losses in roughages are recalculated, based on ratios in the diet, although not always in a correct manner. When investigating the VEM-gap of Pool the recalculated energy from maize is higher than the bruto energy provided. The same error occurs for grass silage on the farm of Spruit. Even if zero losses are assumed the energy provided from silage is insufficient. It is well possible that the energy lost during conservation and feeding is overestimated. But it is impossible that the energy calculated in the VEM-gap is higher than the energy provided through the diet. The ratio of fresh grass is underestimated, consequently lowering the net energy production per hectare. This is to be expected as the KW underestimated previously mentioned energy intake from fresh grass through heifers and calves.
In the KW the VEM-gap corrects for energy consumed by other grazers, as these animals are not included for the BEX. However for our research there is no point in separating the energetic requirements of other grazers from those of cows and heifers.
To calculate the amount of energy fed to the herd Leisen uses a detour. The yield per ha has to be estimated to determine the amount of hectares required. The number of hectares is then used to calculate the net energy production per ha. For calculations used by Leisen see appendix 7. This is rather odd considering the fact that the yield per ha is unknown for products bought such as concentrate. Also for roughages bought it is difficult to determine how much was produced per ha. This is very inaccurate and circumstantial. A second remark is that Leisen separates feed for concentrate and roughages, mixing internal and external feeds. This makes it unclear which part of the energy originates from own produced grass silage. In Leisen all other energy flows fed to the herd are subtracted from energy requirements, leaving energy from fresh grass. This together with own produced grass silage form the net energy production per ha. The model of Leisen was adapted by simply subtracting all other energy fed to the herd.
To acquire a more reliable estimation of the energy production of grassland it is most important to know more specific losses during conservation and feeding. It is very difficult to accurately determine the amount of energy lost. There is a large variation for energy losses in roughages, especially since VEM losses have a large variation depending on a multitude of factors (Blanken et al., 2006; Schooten and Philipsen, 2011), causing a large deviation between cuts and farms. Assuming a fixed amount of losses can over- or underestimate the true losses of energy. Misleading the amount of energy truly consumed as grass. The estimation for losses should be better qualified. For example high moisture content in silage can increase VEM losses (Blanken et al., 2006; Schooten and Philipsen, 2011). Also the NH_3 fraction can cause VEM-value in silage to drop (Schooten and Philipsen, 2011).Or vice versa the use of silage additives can reduce silage losses. Both DM content and NH_3 fraction are standard analysis for silages. For a better estimation in future models it would better to have a distinction for losses, between levels of DM and NH_3, instead of assuming the same level of losses for all silages.

A problem of the KW is that it is based on BEX, being used as proof for farmers they work more efficient than normative values. This allows them to apply more animal manure on their own soil. Farmers thus try to fill in the KW as beneficial as possible, to achieve higher efficiency on paper. In the process the reliability of the KW for calculating energy production from grass is hampered. For instance freights of silage or hay can be left out of the BEX to achieve better results for nutrient efficiency. This underestimates the energy provided in the diet, increasing the net energy production of grassland.
Positive about the KW is that it is still in development; in the old design the goal was to keep the model basic, by taking the relevant data. Later on the model expanded. An updated version is launched on a regular basis collecting more specific data to achieve a more reliable outcome.
The net energy production of grass deviates between models, depending on the amount of fresh grass calculated and the estimated energy requirements. The larger the gap between requirements and energy fed the more energy must have been provided through roughages, increasing grass productivity. The model that calculates the highest energy requirements depends on several factors, such as; composition of the herd, milk flows and composition, additional

requirements for grazing, growth, gestation and NEB and inefficiency. For farms with summerfeeding the KW is a reliable method. However farms that apply grazing calculations of energy intake deviate from what is possible, overestimating the energy consumes from either grass- or maize silage. Also the method of Leisen and Lantinga underestimate energy requirements. This is not directly seen in table 9, they do include all milk flows, but milk fed to calves is subtracted again later, causing no net change in net energy production per hectare. For the rest differences are related to energy requirements awarded to basic needs for heifers, (different for Leisen) cows, milk production, growth, gestation and NEB, being only included in the models KW and NEW.
The comparison between farms is difficult to make. If more farms would have been investigated, the effect of grazing and summerfeeding on the net energy production could be investigated. The problem with comparing data is that farms have their own diet, herd, history and management, exerting their effects on grass production. Therefore to calculate whether grassland production is different for grazing or summerfeeding a large number of farms need to be recorded. Dividing them into groups, based on soil type, farm intensity (cows/ha) and other relevant factors will also provide a reference group to which the farm can reflect.

5.3. Reccommendations

To increase future accuracy of calculating the net energy production of grass land several adjustments need to be done. To improve the estimation of the energetic requirements of the cows, it would be more accurate to include additional data required for;

- Weight of an adult cow, basic requirements based on average weight of an adult cow. If in the future the average weight of the herd is available (for instance weighing platform in robotic milking systems), corrections can be made. A second option would be to include more breeds with their average weights and standardized energetic requirements;
- Calving interval, to correct for energy requirements for gestation and NEB;
- Milk flows, include all milk flows fed to the cows;
- Growth, all heifers and other grazers present require additional energy for growth. Adding a standard bonus of energy per animal category For future calculations it would be easier and more accurate to add a standard bonus of energy per animal category than to calculate energy for growth based on a fixed value of replacement;
- Movement, The use of future technology, such as pedometers or activity meters can give new insight in the true movement and energy requirements related to stable and grazing systems.

The energy fed to the herd can be improved. It is unclear how much energy is truly lost from silage until utilization by the herd. Currently these losses are fixed in Lantinga and Leisen. The KW does recalculate the energy provided by grass- and maize silage but overestimated these values. Energy losses during storage and feeding should be better qualified. To better estimate these losses in future models it would better to have a distinction for losses, between levels of DM and NH_3, instead of assuming the same level of losses for all silages. Secondly for future models all energy provided to the herd is included in the diet, as leaving flows out will overestimate the net energy production of grass.
Grazing has decreased over the past years. One of the reasons pleading for summerfeeding is a higher yield per hectare. Doing a comparative study for farms that apply grazing and farms that apply summerfeeding could prove that, production under grazing is equal or larger to energy from summerfeeding. As the energy not explained by other feed products should thus originate from fresh grass. When doing this farms used for comparison should have the same type of soil and farm intensity. To see a better contrast, grazing farms must apply as much grazing as possible.

6. Conclusion

Between calculation methods there are differences for the net energy production of grassland. These differences originate from the estimation of energetic requirements, the calculation of net energy intake through roughages. Underestimating the energy requirements of the herd, will cause an underestimation of the net energy production of grassland. This was the case in the models of Leisen and Lantinga. Only the KW corrected for additional requirements such as; growth, gestation, replacement and inefficiency. The KW is the most complete model. It collects data of an entire year, corrects for requirements of other grazers present and calculates additional energy for replacement, gestation and NEB. A shortcoming of the KW is that it does not include all milk flows, possibly underestimating energy requirements and thus net energy production per ha. Secondly the calculations of the VEM-gap should be modified for farms that apply grazing. Currently energy provided from fresh grass is underestimated, lowering the net energy production per ha.
The problem with the models of Leisen and Lantinga is that they are focused on cows in the grazing season. Therefore a lot of data such as field losses are untreated. To complete these models adaptations were required based on the KW. Only the KW was developed to be used for calculation of energy production on a yearly basis.

The other big difference is that the KW uses the VEM-gap to calculate energy from fresh grass, grass silage and maize silage, whereas the other two models just subtract all other energy fed. The unexplained energy in KW is divided over the roughages available, depending on their mutual ratio. The calculation of the ratio fresh grass should be revised as it is underestimated. For the models of Lantinga and Leisen this gap is explained by energy provided through fresh grass, if unavailable depending on the ratio maize- and grass silage.
In the new model additional energy requirements as used in the KW were calculated. But for calculation of the amount energy from fresh grass and grass silage, the method of Lantinga and Leisen were followed. Despite the fact there is no correction for losses during storage and feeding in roughages. More deviation for these losses is required, based on analysis of DM and NH_3. Furthermore the models should take into account energy for growth in other grazers and extra energy for movement for heifers and calves. Secondly in the new model additional energy for gestation and replacement were corrected based on farm specific data.

One of the reasons pleading for summerfeeding is a higher yield per hectare. The farm of Goor showed a slightly higher net energy production than Spruit. The farm of Pool is organic and therefore should not be compared to conventional farms. This difference is small when considering the large variation of factors that play a role in the outcome. Doing a comparative study for farms that apply grazing and farms that apply summerfeeding could prove that, production under grazing is equal or larger to energy from summerfeeding.

Word of Appreciation

My thanks goes out to Lantinga for his guidance and feedback throughout the project. I wish to thank Leisen for giving up his free time to bring me his enthusiasm and different mentality towards grazing. Also Jouke Oenema has my graditute for clarifying the KringloopWijzer. As last but not least my thanks goes to the farmers Pool, Spruit and Goor for their hospitality and cooperation.

Appendix 1. Handreiking BEX 1 mei 2015

The following calculation method originates from the BEX system (RVO, 2015). The BEX system is the basic system a farmer can use to calculate the real excretion of nitrogen and phosphate of his farm. All nutrient flows on the farm are measured and analysed for N and P. With this data the farm can proof if it is more efficient than fixed governmental values. If so more manure is available to apply on the field and money can be saved on export. The required data is taken up in the 'handreiking bedrijfsspecifieke excretie' can be used to substantiate (RVO, 2015). The net grass yield is used to seal the feeding balance for the N- and P-production of the dairy herd.

For the KW data regarding the number of animals, animals sold and bought for each animal categories are recorded in 'Uitvoeringsbesluit van de Uitvoeringsregeling Meststoffenwet' (EZ, 2012). The Rijksdienst voor Ondernemend Nederland (RVO) executes the legal I&R regulation. The data is collected from the I&R system, which records, cows, sheep and goats present on the farm. The farmer reports any changes in the herd within 3 days. A distinction is made for breed, because there are large differences in VEM requirements for maintenance due to different body weight. Normally the effect of BW is limited as the majority of the VEM-requirements are based on milk production. However when comparing Jersey cows and cross-breeds weights differ so much that a different level of energy requirements for maintenance is used. In case other grazers are present, the number of animals present, bought and sold need to be filled in. For each animal category need to be indicated whether feed flow is separated or not.

The amount of milk (kg), percentages of fat and protein and level of urea are determined by the dairy industry, per calendar year. In case dairy products are processed and sold on the farm, these amounts need to be recorded.

For animal manure several data is required. Starting with the type of manure for each animal category, expressed in percentages of liquid manure. Secondly the amount of liquid and solid manure that has been imported or exported. Every transportation is sampled, weighted and registered in RVO. An accredited laboratory analyses the manure. In the case of farmer to farmer transportation standardized values are used based on weight and volume. Thirdly start- and end supply of manure are estimated by the farmer. Also the amount of fertilizer and manure application to the crops and the type of manure application used need to be mentioned (expressed in %). Furthermore the type of stable and manure storage capacity need to be registered. For soil and crop it is important to mention the hectares of grass, maize and other arable land with their phosphate condition and soil type. Land is registered in the 'Gecombineerde opgave'. For grass the amount ha that are renewed need to be registered. In the case of crop rotation hectare of grass and arable land need to be given. Also the use of catch crop for arable land is required. Lastly the use of clover needs to be estimated for hectares and occupation (%).

However for energy the far most important part for calculating the net energy production of grassland is feed. The produced feed, the start- and end supply need to be registered and analysed by a certified company. Feed is separated for grass silage, hay, maize silage, other roughages, concentrates and minerals and milk powder. Also feed purchased and sold need to be given per batch. The KW makes a separation between own produced roughages and purchased roughages.

In the case of grazing the days in grazing need to be given per animal category. For cows also the hours per day are required. In the case of summerbarnfeeding the amount of cuts need to be registered.

Lastly the usage of non- BEX products needs to be established. These are products that are not used for feed, but for other purposes such as bedding, straw or saw dust.

The calculation method exists out of several steps which are explained below.

1. Calculate the total energy requirements of the herd, minus energy consumed by other grazers;
2. Correct for energy consumed through purchased feed;
3. Calculate the herd VEM intake from roughages;
4. Determine the amount of energy utilized per hectare.

The calculation method used in for the KW calculates the total energy production of the farm, including heifers and beef cattle. But other types of grazing animals are excluded.

Step 1: Calculating the VEM-requirements of the herd

For calculating the VEM requirements several data is required, the first step starts by calculating the energetic requirements of the present animals and the normative need per animal. Energy requirements are determined using Tamminga et al. (2004) according to custom calculation rules of the CVB (2010). The general formula for the usage of a feed components by the herd is calculated as followed:

VEM intake of each feed component (excluding fresh grass) by the herd = VEM used – VEM used by other grazers.

Furthermore it is important to know if grazing is applied, the production of the cows and breed for weight of the cows and heifers.

Number of animals

- Number of dairy cows, including dry cows;
- Number of heifers (>1year) and calves (<1 year)

For each animal category the total number of day counts is calculated and divided by 365. If needed a subdivision is made for Jersey's and other breeds or cross breeds. A Jersey must have 87,5% of Jersey blood. A cross-breed has between 50 and 87,5% Jersey blood.

Milk production

- Total milk produced (kg per year), as determined by Productschap Zuivel (PZ);
- Fat percentage: averaged per year as determined by dairy company;
- Protein percentage: averaged per year as determined by dairy company.

Average weight of the dairy cows and VEM-requirements of heifers are determined using table 4.

Table 4: Average weight adult dairy cows and VEM-requirements of heifers

	Adult weight dairy cow (kg)	VEM-requirements heifers < 1 jr (kVEM/dier/jaar)	VEM-requirements heifers > 1jr (kVEM/dier/jaar)
Jersey	400	988	1.820
Other breed	600	1.412	2.600
Cross-breed of Jersey and other breed	500	1.200	2.210

The VEM requirements of cows are calculated as the sum of VEM requirements for milk production and for maintenance. For maintenance a difference is made for lactation period and for dry period. The calculation assumes a lactation of 307 day of lactation in a year and 58 dry days. Depending on calving interval this can be corrected. Basic VEM-requirements are based on cows housed in a tie stall. Extra energy requirements are calculated for movement and digestion of feed (grazing), growth (youth), gestation and for mobilisation of body reserves during lactation (NEB allowance) see table 4).
We speak of grazing when cows graze during the grazing season a part of their daily ration. A differentiation is made between unlimited and limited stocking. The number of months in grazing and the average grazing hours per day need to be recorded. In the case of feeding fresh grass indoors the number of months and times fed fresh grass per day the cows must be recorded (see table 5).

Table 5: Additional energy requirements per dairy cow in kVEM (RVO, 2015)

Additional		kVEM/year	kVEM/month
Movement*	No grazing	189	
	Limited stocking		12
	Unlimited stocking		16
Heifers**	Jersey	92	
	Other breeds	131	
	Cross breeds	111	
Gestation and NEB***	Jersey	136	
	Other breeds	194	
	Cross breeds	165	

* Additional energy requirements for movement is 10% of maintenance requirements (1893 kVEM/year) for animals not housed in a tie stall (Tamminga et al., 2004).Compared to no grazing 7.5 and 10% extra energy required for respectively limited and unlimited stocking.
** The additional energy for youth is based on a replacement of 36.25%.
*** NEB = Negative Energy Balance

VEM requirements of the total herd (kVEM/year) is the sum of the VEM requirements of cows, heifers and calves (Schroder et al., 2014).

Formulas for determination of the VEM-requirements of the herd

kVEM requirements heifers

VEM-requirements heifers younger than 1 year: see table 4

VEM-requirements heifers older than 1 year: see table 4

kVEM requirements dairy cows

Milk production

Milk yield/cow	= total milk produced (kg) / number of cows
FPCM/day	= (milk yield/cow (kg) x (0.337 + 0.116 x %fat + 0.06 x %protein))/ 307 (days).
VEM milk yield	= (442 x FPCM/day x (1 + (FPCM/day -15) x 0.00165)) x 307 (days).
kVEM milk yield	= VEM milk yield/1000.

Maintenance
GEW (kg) = live weight dependant on type of cow (see table ..).
VEMmtc during lactation = (42.4 x $GEW^{0.75}$ x (1 + (FPCM/day -15) x 0.00165)) x 307 (days).
VEMmtc during gestation = 42.4 x $GEW^{0.75}$ x (1 + (-15 x 0.00165)) x 58 (days)
VEM maintenance dairy cow = VEM mtc during lactation + VEM mtc durin gestation.
kVEM = VEM maintenance dairy cow/1000.

Additional requirements
kVEM extra per cow = (extra for movement 'no grazing' from table 5 + (months of grazing x extra movement for limited or unlimited stocking)) + extra for heifers from table 5 + gestation and NEB from table 5).

In the calculation method it is assumed that the eventual VEM intake is 2% higher, than the calculated VEM requirements to ensure VEM requirements are covered (Tamminga et al., 2004).
VEM intake = VEM-requirements x 102%.

KVEM requirements of the herd = 1.02 x (((VEM milk production + VEM maintenance + VEM extra) x number of cows) + (VEM heifers < 1 year x number of heifers < 1 year) + (VEM heifers > 1 year x number of heifers > 1 year)).

Step 2: Correct for energy consumed through purchased feed

Of all feed on the farm both produced and sold feed need to be registered for both quality and quantity. For specific data regarding re-ensiling or ensiling two cuts together see RVO (2015). The total VEM-intake is determined as the result of the VEM-intake from all the feed products summed together. If other grazers are present on the farm, corrections have to be made. In the case feed is not separated clearly from feed of the herd, fixed amounts per animal are subtracted. All feed of other grazers are taken up in the calculations. With this the total feed use on the farm can be calculated.
For most feed components (purchased feed) feed intake by the herd can be easily calculated as: supply start of the year + bought – sold – supply end of the year. In practice VEM analysis are not always present, especially for fresh grass it is difficult to determine the feeding value and intake during the grazing season. Therefore a detour is used to calculate the intake from VEM intake of the herd and the VEM intake of purchased feed. (RVO, 2015). In practice the feed intake of the herd can best be estimated by the total intake of maize silage, grass silage and fresh grass as a rest post. For calculation of the amount energy from maize silage, grass silage and fresh grass, VEM-intake from purchased feeds have to be subtracted. The calculation used:
VEM intake from maize silage, grass silage and fresh grass = VEM requirements of the herd – VEM intake of purchased feed = VEM-gap (RVO, 2015).

For the nutrition of the herd, feed components can be separated into two categories:
1. Roughages, maize silage, grass silage and fresh grass;
2. Other feeds: concentrate and all other roughages possible.

In general of group 2 it is known how much is taken up as these feeds are bought on a weight base. The remainder thus must come from the roughages.

Step 3: Calculate the herd VEM intake from roughages

The energy amount fed from roughages is separated to determine net energy production of grassland. The fed amount of maize silage, grass silage and fresh grass fed can be calculated. Before this can be done corrections have to be made for each feed consumed by other grazers, except for pasture the VEM fed can be calculated. For other grazers fixed values are used (Schroder et al., 2014). VEM intake of every feed by the herd = VEM intake – VEM intake by other grazers

The amount eventually really fed can be calculated:
Fed amount = total grown feed + bought feed – sold feed + supply start of the year – supply end of the year
Bear in mind that with re-ensiling silage VEM is lost:
VEM amount after re-ensiling = VEM amount before x 0.98

VEM gap dairy herd = VEM intake herd from fresh grass (FG), grass silage (GS) and maize silage (MS) = VEM requirements herd – VEM intake other feeds – VEM intake other grazers

Calculation of the ratio between GS and MS fed (in kVEM): VEM intake herd from GS / VEM intake herd from MS = (VEM fed on farm from GS – VEM intake other grazers from GS) / (VEM fed on farm from MS – VEM intake other grazers from MS)

Originating from the project 'Koeien en Kansen' fixed ratio's for intake between grass silage and fresh grass are calculated using the following formula:

A. VEM-intake from fresh grass (FG), grass silage (GS) and maize silage (MS) (in kVEM):

- a. VEM-gap herd = VEM-intake from a combination of FG, GS and MS = kVEM_FG + kVEM_GS + kVEM_MS
- b. Division of the VEM intake on farm level calculated amount of fed GS (KVEM total_GS) and MS (kVEM-total_MS):
  - i. Part GS (1) = kVEM total_GS / (kVEM total_GS + kVEM total_MS)
  - ii. Part MS (1) = 1 – part GS (1)
- c. Division of VEM intake from GS and FG:
  - i. Part GS (2) = part FG (grasprod) x a
    In which FG (grasprod) = 1 and:
    - For zero grazing: a = 1,0 (100% grass intake form grass silage)
    - For limited stocking (80% of the grass intake from grass silage): a = 0,8 + (1 – 0,8) x (6 –N of grazing months) / 6
    - For unlimited stocking (60% of the grass intake from grass silage): a = 0,6 + (1 – 0,6) x (6 –N of grazing months) / 6
    - For limited fresh grass stable (82.5% of the grass intake from grass silage): a = 0,825 + (1 – 0,8) x (6 –N of grazing months) / 6
    - For unlimited fresh grass stable (65% of the grass intake from grass silage): a = 0,65 + (1 – 0,8) x (6 –N of grazing months) / 6
  - ii. Part FG (grasprod) = 1 – part GS (2)

These calculations determine how much percent of the total grass intake exists out of grass silages. For fresh grass intake and chemical composition are unknown. For a part of the formulas above a factor is used. If a percentage is given than it needs to be multiplied with 100.

B. Control calculations intake amount from pasture grass and grass silage

Situations can occur in which the calculations deviate to much from the real grass intake. That is why a control calculation is executed, to check whether the assumed grass intake according to the standard calculation is realistic. Assumptions are:

- The variation in limited stocking is 10 to 20 hours per day. For limited stocking it is 2 to 9 hours per day.
- In practice grazing cows have at least two hours of grazing. At 2 hours of grazing a dairy cow consumes 2 kg of dry matter fresh grass (type other breeds table 4 and 5 - for a milk production of 9.500 kg FPCM/year). For each hour grazing 0.75 kg of dry matter is added to a maximum of 20 hours grazing per day (so 18 extra). For each 500kg FPCM more or less dry matter intake (DMI) must be adapted by 2%.
  VEM intake herd from FG grazing = kVEM_FG(control) = (number of grazing months of cows x 30,5) x ((2 + 0,75 x (grazing hours/day – 2)) x (1 + (milk production - 9.500) / 500 x 0,02)) x number cows x VEM-value pasture grass / 1.000 (kVEM)
- For summer feeding it is assumed that DMI of a cow receiving unlimited fresh grass indoors is 87% of the intake of cows in unlimited stocking during 20 hours a day. For a cow with limited fresh grass indoors the DMI of fresh grass is equal to 87% of the intake with 9 hours of grazing per day.
  The formula for summerbarnfeeding is:
  VEM intake dairy herd from fresh grass from summerbarnfeeding =kVEM_FG (control) = number (number of months summerbarnfeeding from dairy cows x 30.5) x ((2 + 0.75 x (grazing hours/day -2)) x (1 + MP/cow/year-9.500) 500 x 0.02) x 0.87) x number of dairy cows x VEM values pasture grass/ 1000 (kVEM)
- The dry matter intake of Jersey and of cross breed is respectively 70 and 85% compared to cows of other breeds. The same percentages also account for the reference level of the milk production to calculate the DMI (respectively 6650 and 8075 kg FPCM/year.
- In the calculations it is assumed dry cows receive fresh grass and heifers do not. The amount taken up by dry cows is assumed to be similar to the DMI of fresh grass by heifers. If both dry cows and heifers graze intake through grazing is underestimated.

For summerbarnfeeding:

- Amount of grazing hours/day = 20 for ‘unlimited’ FG on stable
- Amount of grazing hours/day = 9 for ‘limited’ FG on stable

For both formulas above applies:

- For Jersey and cross breeds, respectively 70% and 85% DMI compared to other breeds. Also the reference for milk production to calculate the DMI (respectively 6650 and 8075).
- VEM value of pasture grass = 960 VEM/kg (Tamminga et al., 2004)

The rest of the calculation goes as follows:

a) VEM-gap herd = VEM intake from a combination of FG, GS and MS = kVEM_FG + kVEM_GS + kVEM_MS
b) Division of the VEM intake on farm level for calculated amount of fed GS (kVEM total_GS) and MS (kVEM total_MS)
   Part GS (1) = kVEM total_GS / (kVEM total_GS + kVEM total_MS)
   Part MS (1) = 1 – part GS (1)
c) Part of VEM intake from GS and FG:

GS (2) = kVEM total_GS / (kVEM total_GS + (kVEM total_FG (control))
Part FG (grasprod) = 1- part GS (2)

d) Rules for calculation of part FG, GS and MS in VEM-gap:
   Part FG_VEM-gap = part FG / (part FG + part GS + part MS)
   Part GS_VEM-gap = part GS / (part FG + part GS + part MS)
   Part MS_VEM-gap = part MS / (part FG + part GS + part MS)
   In these formulas:
   a. part FG = 1
   b. part GS = (part FG / part FG(grasprod)) x part GS(2)
   c. part MS = (part GS / part GS(1)) x part MS(1)
e) Calculation fed amount of FG, GS and MS by herd (in kVEM):
   - kVEM_FG = part FG_VEM-gat x VEM-gat
   - kVEM_gk = part GS_VEM-gat x VEM-gat
   - kVEM_sk = part MS_VEM-gat x VEM-gat

C. If kVEM_FG according to A is smaller than kVEM_FG according to B, the VEM intake of FG, gS and MS of B is used. If not the results according to A are used.

It would also be interesting to separate feed flows as followed:

1. Concentrate;
2. Purchased (roughages) feed;
3. Own produced roughages versus external feeds (1,2) , the higher 3 is the more self-sufficient the farm is in terms of food supply.

Of each feed products is determined how much VEM is consumed. Of bought feed levels are recorded on the label. For VEM levels in silages samples have to be taken and analysed. For fresh grass it is difficult to get a representative image of the average composition. The amount of VEM in fresh grass is determined from analysis performed on silages.

Step 4: Determine the amount of energy utilized

Sum the amount of energy consumed from fresh grass and from conserved that has been utilized by the herd. Divide this by the hectares of grass or by the number of cows to determine the net energy production of grassland.

Appendix 2. Lantinga

The study of Lantinga (1985) involves research on animal production using continuous and rotational stocking systems. With these data, predictive models for herbage production under grazing were developed, correcting for grass accumulation during grazing and animal performance. The net pasture yield over the whole grazing season is estimated from data about animal production using standards for nutrient requirements of grazing cows (Lantinga, 1985). Expressed in VEM the total energy
requirements per ha for the measured animal can be estimated with equation 3:

$$3000\ G + 460\ FCM + 50.9\ w^{0.75}\ n \qquad (3)$$

In which: G = change in liveweight (kg/ha)
FCM = fat-corrected milk production (kg/ha)
W = Average liveweight (kg/cow)
N = number of cow grazing days (cow days/ha)

Unfortunately this method uses body weight change over time, as we do not have this data it is hard to use this calculation method to calculate the energy requirements of the herd. One of the difficulties in determining the energy requirements of cows is the change in body weight during lactation. To accurately assess energy requirements for body weight cows need to be weighted several times throughout the grazing season. In practice it is not very applicable to farmers, as it is very labour intensive. However farms that milk with AMS could have easy access to this data. In a milk robot cows are weighted every time they enter the robot. Therefore in general the weight of the herd is estimated based on breed, as is done in both the method of Leisen and the KW. Furthermore it is difficult to assess the energy requirements associated with grazing.

Deenen and Lantinga (1993) investigated the response curve of fertilizer nitrogen in continuous stocking of dairy cattle or cutting on herbage intake or energy output. Herbage accumulation and herbage intake are expressed in VEM (Es, 1978). During the growing season, herbage DM accumulated in growth periods of up to one month contains about 1000 VEM kg^{-1} DM (Meijs, 1981). Under cutting herbage accumulation was calculated from harvested DM and the energy content. The energy content of the herbage was calculated according to equation 4 (Van Es, 1978);

$$E_h = (0.6 + 0.0024*(ME/44-57))*0.975*ME/1.65 \qquad (4)$$

Where:
E_h = Energy content of the herbage (VEM kg^{-1} DM);
ME = Metabolizable Energy (kcal kg^{-1} DM) = 3.4*DOM+1.4*CP;
DOM = Digestible Organic Matter (g kg^{-1} DM);

CP = Crude protein (g kg^{-1} DM).

Even so this method does not calculate the energy production per unit of land. Performing analysis for protein, ME and DOM could just as easily be done for VEM content per kg DM.
Another method to calculate the herbage intake is measuring the herbage accumulation using cages in the grazed sward. Herbage accumulation is determined as the difference between herbage mass per unit area above a certain height at the start of grazing and at the end of the growing period. The average herbage height is used to estimate the herbage mass consumed in the paddock. However this method is expensive, impractical and very labour intensive.

In Deenen and Lantinga (1993) the maintenance requirements for housed cattle (E_m) is 42.4 VEM per kg of metabolic body weight (MBW = $BW^{0.75}$). A difference of 50 kg more or less in BW is equal to 135 kVEM (Es, 1978). This maintenance estimate was more accurate than a 10% higher estimate for movement in the stable. The requirements at maintenance level are 20% extra for grazing animals than for animals housed in a tie-stall (Meijs, 1981):

$$E_m = 42.4*W^{0.75} * 1.2 \quad (5)$$

Where:
E_m = energy requirements for maintenance (VEM/d);
$W^{0.75}$ = metabolic liveweight (kg).

Daily energy requirements for milk production and weight gain (E_p) was calculated according to and Es (1978):

$$E_p = 442*FPCM*(0.9752 + 0.00165*FPCM) + 3000*G \quad (6)$$

Where:
E_p = energy requirements for production (VEM d^{-1});
FPCM = 4% fat- and 3.3% protein corrected milk (kg d^{-1});
G = live weight gain (kg d^{-1}).

For stall fed animals one kg 4% FCM was found to contain 730 kcal (3054kJ), so its production requires 730/1.65 = 442 VEM (Es, 1978). Energy content of 3000 VEM per kg of body weight change (G) (Es, 1978). Also the method of Deenen and Lantinga (1993) uses live weight changes over time. We do not have weight data, making this method an unreliable option.
The following equation is used to predict the net energy lactation (kcal/kg) (Es, 1978):

$$NE_L\ kg^{-1}\ DM = 0.60\ (1 + 0.004\ (q-57)\ ME\ kg^{-1}\ DM \quad (7)$$

$q = 100\ (ME\ kg^{-1}\ DM)/(GE\ kg^{-1}\ DM)$

The feeding level influences the ME content and the NE_L kg^{-1} DM values. For practical reasons one net energy lactation value for each feedstuff is used. The average feeding level of lactation cows in the Netherlands is 2.38 times maintenance. The average lactation cow weighs 550 kg with a production of 15 kg milk with 4% fat. The requirements for maintenance in lactation are only correct for a feeding level of 2.38. For higher and lower feeding levels the requirements deviate + or – 1.8% per level respectively. The result of equation 7 has to be multiplied by 1-(2.38-1) 0.018 = 0.9752, if the value of ME kg^{-1} DM used in equation 7 applies to the maintenance feeding level. For practical understanding by farmers, VEM was developed rather than to work with Joules or net energy calories. The value of 1.650 was chosen arbitrarily. For calculating the VEM of feedstuff the ME contents at the maintenance feeding level is used, using a feeding level of 2.38. (Es, 1978)

$$VEM/kg = 0.6\ (1+ 0.004\ (q - 57))\ 0.9752 * 1/1.65 * ME\ kg^{-1}\ DM \qquad (8)$$

The paper from Lantinga et al. (1999) is the sequel of Deenen and Lantinga (1993), however this article investigated the response to nitrogen fertilization in rotational stocking of dairy cattle or cutting on herbage intake or energy production. To do this different fertilizer N rates are used on a sand and on a loam soil. Two experiments were carried out. The first experiment calculated herbage production under rotational stocking was assessed as the sum of herbage intake over the entire grazing period. It is not possible to use this method as there are no records, herbage mass or herbage height available. In their second experiment, grassland output at system level was derived from animal performance using standards for; net energy requirements for maintenance and growth and yield and energy value of ensiled herbage. Net energy requirement for maintenance and growth was calculated from the standard equation 9 for housed young male animals adapted for grazing steers (Es, 1978; Meijs, 1981) (Lantinga et al., 1999)

$$NE = \frac{\frac{(500 + 6*LW)*G}{1-(G * 0.3)} * a + (78.87 * LW^{0.75} * b)}{1.65} * c * d \qquad (9)$$

In which:

NE = net energy requirements expressed in Dutch Feed Units for beef Cattle (VEVI);
LW = Live weight (kg/cow^{-1});
G = growth rate (kg/cow^{-1});
a = correction factor for fat deposition (1.15 for steers);
b = correction factor for maintenance due to grazing activity (1.20 for steers);
c = correction factor for the energy requirements at different growth rates ($0.8365 + 0.222*G - 0.04*G^2$);
d = correction factor for the energy requirements at different live weights (0.933 + LW/3000);

This method can't be used for several reasons. The use of live weight changes over time. Secondly this method is designed for beef cattle and not for dairy cattle, lacking corrections for milk production (Lantinga et al., 1999). The second approach used is the calculation of herbage intake approach herbage intake is calculated from the amount herbage present at the start and at the end of grazing. As we have no such data and are impossible to acquire these, this method can't be used.

Similar to the method of the KW, Schlepers and Lantinga (1985) calculate the net pasture yield of grass from animal production data and the yield of harvested silage grass. Standards are used for nutrient requirements of grazing cows and for the yields of silage cuts. With the help of the FCM correction (CVB, 1979). Expressed in VEM the daily energy requirements for grazing dairy cows is found in equation 10 (Es, 1978; CVB, 1979; Meijs, 1981):

$$(4700 + 6(W-550))*1.2+460\ FCM +3000\ G \qquad (10)$$

Where W is live weight (kg cow^{-1})
FPCM is fat-corrected milk production (kg cow^{-1} d^{-1})
G is live weight gain (kg cow^{-1} d^{-1})

Equation 10 was used to estimate the total energy requirements per ha over the grazing season, taking an average live weight of 570kg (Schlepers and Lantinga, 1985). It was assumed that silage grass had an average VEM of 830 VEM kg. Which is quite low as more recently Tamminga et al. (2004) suggested an average VEM content of 875 per kg DM for silage grass. Furthermore equation 10 suggest 20% higher requirements for grazing cows the energy requirements according to equation 9**.** The energy provided from supplements is subtracted. (Meijs, 1981). The remainder plus VEM yield from silage grass is the net pasture yield. Again weight change is used to estimate energy requirements. Also an assumption was made for the amount of energy for grass silage, which is lower than the VEM content nowadays. This formula is outdated cows have increased in weight, increasing their requirements, the CVB has adapted their calculations in more recent editions (CVB, 2010).

Appendix 3. Start Supplies and end supplies

Start supplies

Goor

	kg DM	VEM kg ds-1
Grass silage		
Grass silage 1 2013	31600	937
Grass silage 2 2013	102700	863
Grass silage 3 2013	21250	863
Grass sls voor 2013	30000	760
Total	185550	859
Maize silage		
Maize gr sls 2013	183000	993
Other feeds		
GPS wheat 2013	4350	817
Concentrate		
Geurts	12000	951

Spruit

	kg DM	VEM kg ds-1
Grass silage		
Grass silage 1 2013	78000	863
Autumn silage	50000	866
Total	128000	864

End supplies

Goor

	kg DM	VEM kg ds-1
Grass silage		
Grass silage 1 2014	46950	942
Grass silage 3 2014	49000	895
Grass silage 4 2014	85500	961
Total	181450	938
Maize silage		
Maize kl sls 2014	65580	992
Maize gr sls 2014	219700	985
Total	285280	987
Other feeds		
Brewers grain	4140	947
Concentrate		
Geurts 2014	10000	943

Spruit

Grass silage	kg DM	VEM/kg ds
Grass silage 1 2014	124100	950
Grass silage 2	16000	870
Grass late summer	14000	868
Total	154100	934

Concentrate		
Pulp	30000	925
Muiswinkel	1000	975
Total	31000	927

Appendix 4. Feed mutations

Supply mutations								
Goor			**Pool**			**Spruit**		
	kg DM	VEM kg DM^{-1}		kg DM	VEM kg DM^{-1}	*Grass silage*	kg DM	VEM kg DM^{-1}
Grass silage			*Grass silage*			Grass silage 1 2014	124100	950
Grass silage 1 2014	93900	942	Grass silage	28000	893	Grass silage 2	82600	870
Grass silage 2 2014	84300	883	Grass silage (1)	56000	893	Grass late summer	70600	868
Grass silage 3 2014	49000	895	Hay (2)	38837	704	Hay	15600	704
Grass silage 4 2014	85500	961	16 Bales (3)	4376	839	Total	292900	895
Total (kVEM)	312700	924	Total	127213	833			
		288911	Total (kVEM)		106025	*Other feeds*		
Maize silage						Brewers grain	23998	945
mais kl sls 2014	78700	992	Bought gras	99213	817			
mais gr sls 2014*	219700	985	Own gras	28000	893	*Concentrate*		
Total (kVEM)	298400	987				Van der Bijl	101504	971
			Snijmais			Rose	26984	965
Other feeds			mais gr sls 2013	18900	1195	Muiswinkel	25767	975
Brewers grain 1	26710	947	Total (kVEM)		22586	Pulp	105800	925
Brewers grain 2	21060	965				Total	260055	952
Total (kVEM)	47770	955	*Concentrate*					
			A-brok	47700	940			
Concentrate			Concentrate Prot.	3070	960			
Geurts 2014*	199073	943	Conc. Heifers	6720	940			
Total (kVEM)		187726	Grains (stock)	9000	942			
			Total	66490	941			
			Total (kVEM)		62580			

* The farm of Pool is an extensive organic dairy farm and is therefore not obligated to use the KringloopWijzer. Consequently there were no analysis available for grass silage, hay and bales and corn scrap. Therefore levels of DM and VEM were based on average values of 2014 as determined by (AgroXpertus, 2015d; a; c) . Furthermore it was estimated that grassland would yield 8 tons of dry matter.

Appendix 5. Feed fed to the herd

Goor

Grass silage	kg ds	VEM kg DM^{-1}
Grass silage 1 2013	31600	937
Grass silage 2 2013	102700	863
Grass silage 3 2013	21250	863
Grass autumn	109200	777
Gras sls voor 2013	30000	760
Grass silage 1 2014	46950	942
Grass silage2 2014	84300	883
Grass silage4	85500	961
Grass autumn	100000	863
Total (kVEM)		531356
Maize silage		
mais gr sls 2013	168000	993
mais kl sls 2014	65580	992
Total (kVEM)		231879
Other feeds		
Brewers grain 1	22570	947
Brewers grain 2	21060	965
Total (kVEM)		41697
Concentrate		
GPS wheat 2013	4350	817
Geurts	12000	951
Geurts 2014	189073	943
Total (kVEM)		193262

Spruit

Grass silage	kg ds	VEM kg DM^{-1}
Grass silage 1 2013	78000	863
Grass autumn	50000	866
Grass silage 1 2014	0	950
Grass silage 2 2014	66600	870
Silage late summer	56600	868
Hay	15600	704
Extern (kVEM)		10982
Intern (kVEM)		217685
Other feeds		
Brewers grain	23998	945
Total (kVEM)		22678
Concentrate		
Van der Bijl	101504	971
Rose	26984	965
Muiswinkel	24767	975
Pulp	75800	925
Total (kVEM)		218863
Bruto amount fed (kVEM)		470208

Pool

Grass silage	kg ds	VEM kg DM^{-1}
Grass silage	28000	893
Purchased grass	56000	893
Hay	38837	704
Bales	4376	839
Total (kVEM)		106025
Extern (kVEM)		81021
Own (kVEM)		172528
Snijmais		
Corn pulp 2013	18900	1195
Total (kVEM)		22586
Concentrate		
A-brok	47700	940
Protein conc.	3070	960
Conc. Heifers	6720	940
Grain	9000	942
Total (kVEM)		62580
Bruto amount fed (kVEM)		191190

Bruto amount fed (kVEM)	998194

Appendix 6. Expanded data for energy requirements of cows

Leisen			
ECM per cow (kg)	8471	5461	9030
NEL-requirements/cow for 600 kg	41524	31980	43295
weight per cow *50 kg is 800 MJ*	600	600	600
NEL-requirements per cow real weight	41524	31980	43295
NEL-requirements cows (VEM)	667987	342970	476869
Lantinga			
FPCM per koedag (307)	27,6	17,7	29,1
Lactatiedagen per jaar	307	307	307
Gestation days	58	58	58
stall days	365	122	165
grazing days	0	243	200
Stall fed animal per day (VEM)	5500	5500	5500
Grazing anima per day (VEM)	6168	6168	6168
ER for maintenance (VEM year-1)	2007502	671001	907501
ER for grazing per year	0	1498879,83	1233645,9
ER for productions per day	12438	7880	13159
ER for milk per year (VEM)	3818619	2419115	4039917
Total per cow (kVEM year-1)	5826	4589	6181
Total for all cows (kVEM year-1)	646699	339586	469761
KringloopWijzer			
FPCM per koedag (307)	26,8	17,3	24,6
VEMmtc during lactation	1608745	1583924	1602911
VEMmtc during gestation	290752	290752	290752

kVEM mtc dairy cow	1899	1875	1894
kVEM mtc dairy cows	210844		
kVEM milk yield per cow	3706	2351	3384
kVEM milk yield cows	411412	173965	257192
Additional Requirements per cow			
Gestation and NEB (kVEM/year)	194	194	194
Movement (kVEM/year)	189	189	189
grazing (kVEM/year)	0	128	*107*
Replacement (growth)	131	131	131
kVEM extra per cow	514	642	621
KVEM total additional	57054	38036	47171
Energy requirements per cow (kVEM)	6120	4867	5898
For all cows (kVEM)	679310	360179	448281
Adaptad Model			
FPCM per koedag (307)	27,6	17,7	29,1
VEMmtc during lactation	1610770	1585194	1614744
VEMmtc during gestation	290752	290752	290752
kVEM mtc dairy cow	1902	1876	1905
kVEM mtc dairy cows	211069	138820	144818
kVEM milk yield per cow	3819	2419	4040
kVEM milk yield cows	423887	179023	307049
Additional Requirements per cow			
Gestation and NEB (kVEM/year)	172	194	170
Movement (kVEM/year)	189	189	189
Grazing (kVEM/year)	0	128	107
Replacement (growth)	133	78	157

kVEM extra per cow	516	589	647
KVEM total additional	57330	43596	49166
Energy requirements per cow (kVEM)	6215	4884	6569
For all cows (kVEM)	689859	361440	499211

Appendix 7. Formulas Leisen

Milk production total (kg) = milk delivered to factory + milk for own consumption + milk fed to calves

Milk production per cow (kg) = milk production total / number of cows

Energy corrected milk (ECM) (kg) = (0.38 * % fat + 0.24 * % protein +0.816) * milk production total / 3.14

ECM per cow (kg) = ECM / number of cows

Concentrate per cow (kg) = dry ton concentrate consumed by cattle / number of cows * 100

Concentrate fed to cows = concentrate per cow * number of cows

Milk production from concentrate (kg) = concentrate fed to cows * 2.1

Milk production from roughages (kg) = Milk production total - milk production from concentrate

ECM from roughages (kg) = (0.38 * % fat + 0.24 * % protein + 0.816) * Milk yield from roughages / 3.14

ECM per cow from roughages (kg) = ECM from roughages * number of cows

NEL-requirements per cow (600 kg) = 11504 + 3165 + 3.17 * ECM per cow

NEL-requirements per cow real weight = NEL-requirements per cow + 800 * (real weight - 600) / 50 (.)

NEL-requirements cows = NEL-requirements per cow actual weight * number of cows

NEL-requirements cows from roughages = NEL-requirements cows – concentrate fed to cows (MJ NEL)

NEL-requirements heifers = breeding calves per year * (26850 + (age of first calving-26) * 860)

NEL-requirements heifers from roughages = total NEL-requirements heifers – concentrate fed to heifers (MJ NEL)

NEL- requirements other animals = NEL- requirements bulls + NEL- requirements fattening bulls + NEL- requirements fattening heifers + NEL- requirements other animals

Total NEL- requirements roughages = NEL-requirements cows roughages + NEL-requirements heifers roughages + NEL- requirements other animals

NEL-requirements roughage cow relative = NEL-requirements cows roughages / Total NEL- requirements roughages * 100%

Forage area roughages = sum of hectares of roughages

Forage area for bought roughages = Forage area + Forage area for bought roughages - Forage area for sold roughages

Corrected forage area roughages = NEL-requirements roughage cow relative * Forage area roughages / 100

Concentrate area = sum of hectares of concentrate

Corrected forage area cows with concentrate = Corrected forage area roughages + Concentrate area

NEL-requirements heifers roughages = NEL-requirements heifers roughages *(number of breeding heifers – sold as breeding heifers) / number of breeding heifers

Corrected forage area cows and breeding heifers = forage area cows + forage area breeding heifers + forage area bought

Corrected forage area cows and breeding heifers = forage area cows with concentrate + forage area breeding heifers + forage area bought

Corrected forage area cows and breeding heifers with concentrate = forage area cows with concentrate + forage area breeding heifers + forage area bought

NEL yield/corr. Forage area without concentrate = Total NEL-requirements from roughage / forage area without concentrate

kg ECM per ha from roughages (1) = ECM from roughages / corrected forage area cows

kg ECM per ha from roughages und concentrate (1) = ECM totaal / corrected forage area with concentrate

kg ECM per ha from roughages (2) = ECM from roughages / corrected forage area cows + heifers

kg ECM per ha from roughages und concentrate (2) = ECM total / corrected forage area cows + heifers with concentrate

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