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7.5 credit assignment

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Validation of Calibration Equations Developed for the C-Dax Pasture Meter under Danish Conditions

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Abstract

The average dairy cow herd size in Denmark is increasing and with it the consequences of erroneous decisions in the production. Precision farming can help control costs and maximize the revenue and is of increasing interest in modern agricultural business. Feeding is one of the major costs in dairy production and the subject of development of precision methods and tools.

In this report is the precision of a newly introduced method for prediction of pasture yield evaluated. The measurement equipment, called C-Dax Pasture Meter®, estimates dry matter (DM) yield from sward height and has, in a previous study, been calibrated under Danish conditions. The aim of this report is to validate the calibration equations found in that study.

Validation was undertaken with independent data collected in a separate field trial in the same grazing project as the calibration trial. Sward height measurements were paired with harvested DM yield. The difference between yield predicted, by the previously developed calibration equations, and the actual DM yield harvested was evaluated. Three calibration equations were validated: 1) one for early season predictions (i.e. before mid July), 2) one for late season predictions (i.e. after mid July) and 3) one without inclusion of seasonal effects. Between 7-27% of the predictions were within ±10% of the actual yield, which indicates a low precision of the calibration equations and the need for further calibration of the prediction equations. Precision was, however, positively influenced if yield was predicted from sward heights that are within the same interval as the calibration observations were made within. The results further indicate that the precision is positively influence by the use of seasonal calibration equations. The calibration equations are not recommended for practical implementation due to this unsatisfactory precision of the predicted pasture yield.

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1 Introduction

Feed is one of the major costs in dairy production. It constitutes as much as 84% of the variable costs in conventional farming in Denmark and 88% of the variable costs in organic farming (Andersen & Due 2010). Optimization of the feed plans is one way to keep the costs down and incomes up. Optimization requires knowledge about the dairy cows' nutritive needs and the nutritive content of the feeds. Grazing is by many suggested as a cheap source of roughage but it imposes several challenges. The herbage mass at the pasture can not be weighed before or after feeding, as other feeds can, which makes optimization of the feed plan difficult. Utilization of grazing as part of the feeding regime requires estimates of the herbage mass at the pasture and estimates of amount herbage mass ingested by the dairy cows in order to optimize the supplement feeding. These estimates can be obtained by a number of different prediction methods which all require calibration of the prediction equations, for a review see Lopez Diaz & Gonzalez-Rodriguez (2003). Sanderson *et al.* (2001) reported that the precision of the estimates of pasture yield should be minimum ±10% of the actual yield in order for forage budgeting to increase net returns. A lower precision would not justify the investments required by the farmer.

Measures of sward height are used in many prediction methods to estimate pasture yield. Sward measurements can also be used to control the sward state and thereby the quality of the herbage mass. The relationship between sward height and yield is established since long (Robel *et al.* 1970; Davies *et al.* 1989) and the measurement equipment is diverse. A relatively new method is the C-Dax Pasture Meter® (CPM) which has a measuring system based on infrared light beams. The measurement equipment is of such size that is needs to be towed by a vehicle, e.g. an all terrain vehicle (ATV).

1.1 Problem statement

In the master thesis "Herbage Dry Matter Mass of Pastures Estimated through Measures of Sward Height" (Hansson 2011) was the C-Dax Pasture Meter® (CPM) calibrated under Danish conditions. New calibration equations were developed and the coefficient of determination (r^2) was between 0.63 and 0.89. The r^2 reported indicated that over half of the variation in the data is accounted for in the model and the confidence intervals indicated that the model was determined with low uncertainty. In spite of these results the prediction intervals of the equations, and example predictions made with the equations, indicated that there could be great uncertainty about the future predictions (Hansson 2011). The aim of this report is to validate the calibration equations developed in the master thesis by Hansson (2011). In relation to the aim the following question is addressed: How precise are the predictions made by the calibration equations found in the Master's thesis by Hansson (2011)?

Precision is in this report used to describe how close the predicted yield is to the actual yield and is expressed through: 1) the mean distance between predicted and actual yield in the statistical data analysis and 2) the percentage of predictions that are within ±10% of the actual yield.

2 Materials and methods

The data used for validation of the calibration equations were collected in a field trial at the research facilities of the Faculty of Agricultural Sciences at Aarhus University, Denmark. The trial was conducted in 2009 as a part of the grazing project "Grazing – also a part of the future cattle production[1]". The data was used by Hansson (2011) but not in the development of the calibration equations.

2.1 Equipment

The herbage samples cuts, made to determine the pasture yield in kilo dry matter per hectare (kg DM/ha), was cut with either a Haldrup harvester or a modified sheep shearing machine. The Haldrup harvester is a green mass harvester for experimental use, with a cutting width of 150cm. The height samples in millimetres (mm) were made with a CPM which measures height by infrared light. The tunnel shaped machine has rails with 18 sensors mounted on the inside. The sensors are placed 20mm apart staring from ground level and send/receive infrared light; as a light beam is obstructed is additional height registered. For more detailed information see manufacturer's webpage: http://www.c-dax.co.nz.

[1] Danish title on the project: Afgræsning – også en del af fremtidens kvægbrug

2.2 Sampling

The sampling was made on a pasture sown with a seed-mixture consisting of perennial ryegrass cultivars (name within brackets): 30% intermediate diploid (Stefani), 40% intermediate tetraploid (Kentaur) and 30% late diploid (Foxtrot). As part of the sampling procedure was the sward content determined; clover was present and the content varied between 2 and 24%. The pasture was divided into 4 paddocks which were grazed by dairy cows during the study, see Figure 2.1. Within each of these four paddocks were 3 parcels fenced and cows excluded, these parcels were not grazed during the study.

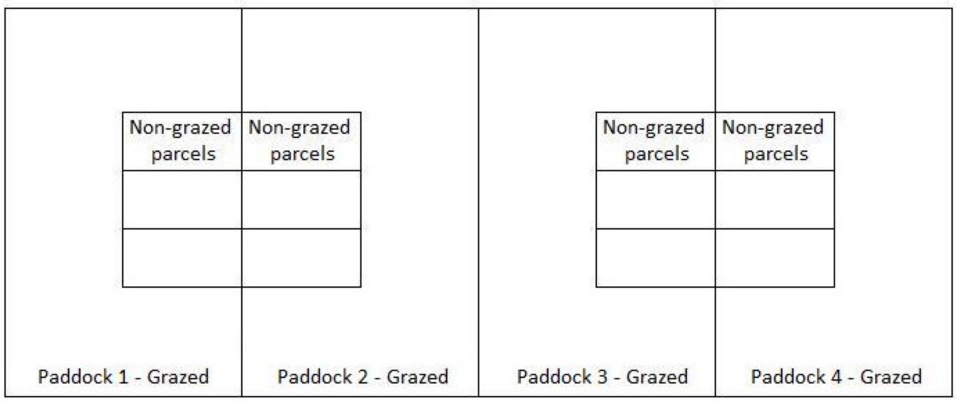

Figure 2.1 - Overview of the study design in the grazing trial from which data material was adopted (mod.e. Kristensen 2011, Appendix 1)

A total of 48 paired observations (CPM height measures and herbage cut samples) were made on 6 dates in September, earliest the 2nd and latest the 18th (see Table 2.1). In the grazed parts of the pasture, i.e. paddock 1-4, was the sward height measured with the CPM along predetermined transects (see Figure 2.2).

Table 2.1 - Number of observations per sample date and treatment

Date	Treatment	# Observations
2 September	Grazed	4
	Non-grazed	8
8 September	Grazed	4
9 September	Grazed	4
	Non-grazed	8
15 September	Grazed	4
16 September	Grazed	4
18 September	Non-grazed	12
Total number of observations in trial		48

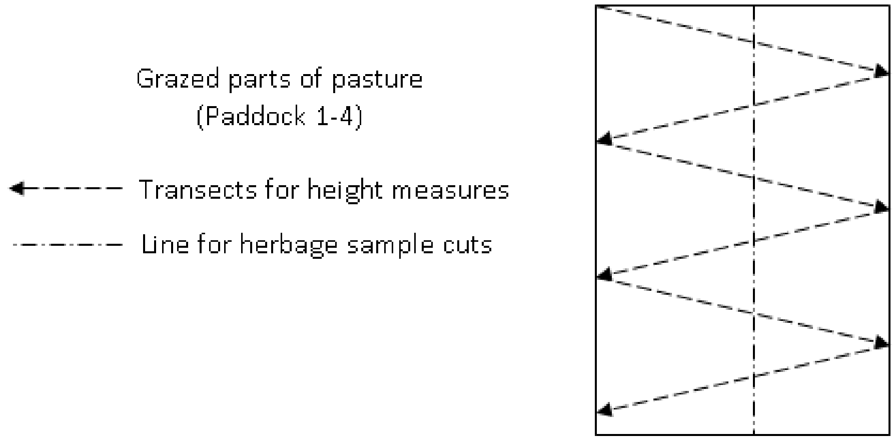

Figure 2.2 - Outline for measurement routes in the grazed parts of the pasture (mod.e. Kristensen 2011, Appendix 1)

The herbage sample cuts were made with a modified sheep shearing machine in 5 squares á 0.25m^2 along a line in the middle of the paddocks (see Figure 2.2). For each paddock was an average yield calculated from the 5 herbage sample cuts, which was paired with the average sward height reported by the CPM software. The non-grazed parcels had the measures 10×1.5m and were harvested with the Haldrup harvester after the sward height was measured with the CPM. The stubble height was 50 mm for all herbage sample cuts.

2.3 Data management and analysis

In the initial plots of the data the observations made in the grazed paddocks showed a negative linear relationship, see Figure 2.3. The linear relationship between sward height and yield is known to be positive (Michell & Large 1983; Douglas & Crawford 1994; Gallegos *et al.* 2009) and it was therefore decided that the observations made in the grazed paddocks were not to be used for validation of the calibration equations. The number of observations in the validation dataset was reduced to 28.

The data were analysed with the statistical computer program R, using the package for statistical linear modelling (R Development Core Team 2009). A test for outliers indentified a deviating observation which was excluded from the dataset before further analysis. The late season calibration equation, i.e. the equation for observations made after mid July, would preferably be used for prediction of pasture yield since the validation dataset observations were all made in September. However, the predictions of pasture yield are, for comparison,

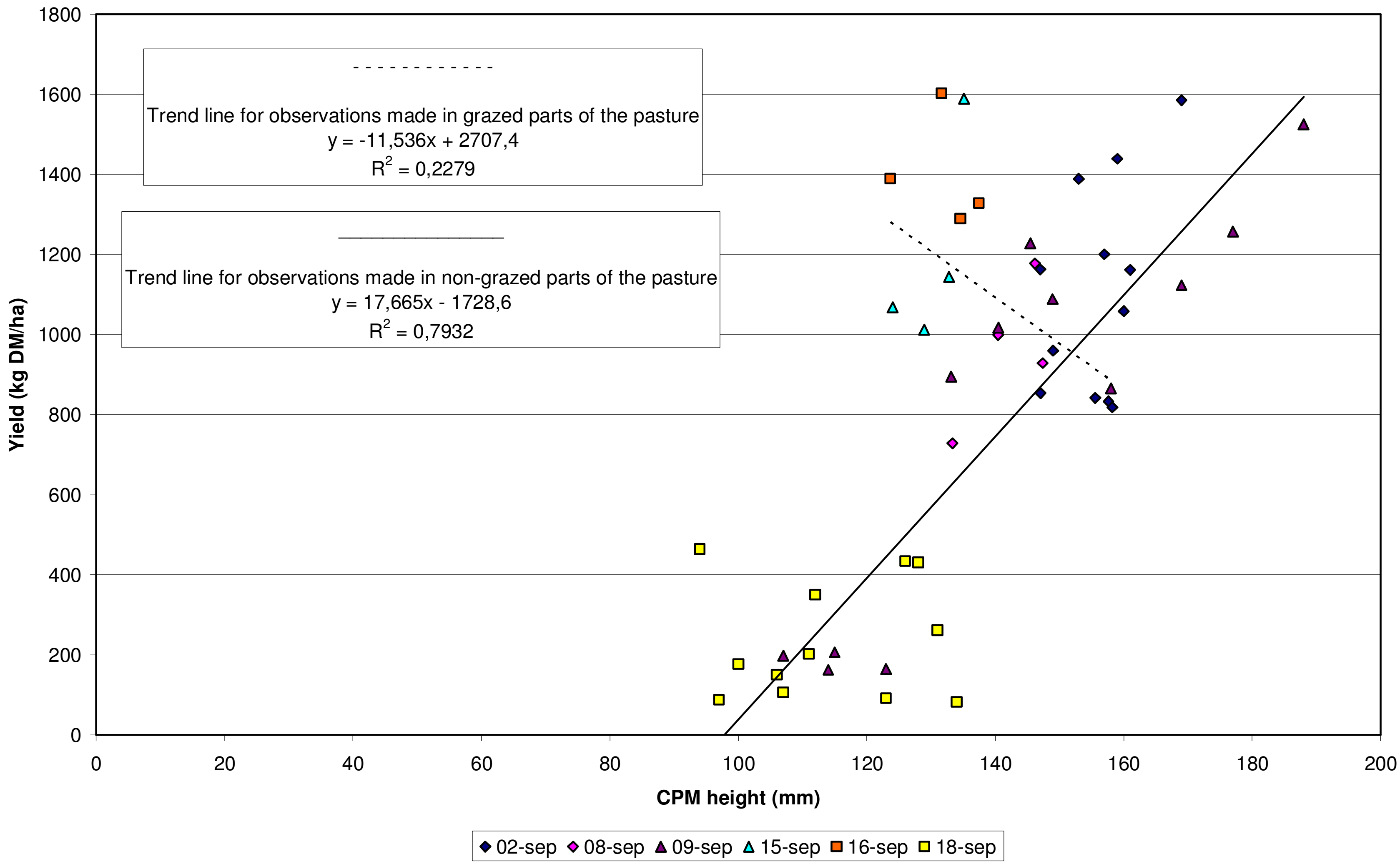

Figure 2.3 - Trend lines for observations made in grazed and non-grazed parts of the pasture respectively

made with both early and late season calibration equation and with calibration equation without seasonal effects. These calibration equations found by Hansson (2011) is presented below:

$$Log(Yield) = 1.8615 \times Log(Height) - 0.9431 \qquad \text{(Early season)}$$

$$Log(Yield) = 2.8498 \times Log(Height) - 3.2233 \qquad \text{(Late season)}$$

$$Log(Yield) = 2.2993 \times Log(Height) - 1.9731 \qquad \text{(Seasonal effects omitted)}$$

The analysis was done with a dataset of 27 observations. The calibration equations are only valid within the sward height range 128-263mm in which the calibration trial observations were made. The analysis was therefore repeated with a subset of data, including only height observations within this range.

3 Results

There was significant difference between the predicted and actual pasture yield for all calibration equations, see details in Table 3.1. The late season calibration equation predicted yields that were closer to the actual yield, compared to predictions made by the other equations. The early season calibration equation predicted yields with the greatest deviation from the actual yield.

Table 3.1 - Results from t-test on all height observations

Calibration equation	*p*-value	Significance level	Mean difference[1] (kg DM/ha)	95% confidence intervals (kg DM/ha)
Early	7×10^{-10}	***	443	±96
Late	0.007	**	133	±94
Season omitted	2×10^{-5}	***	247	±96

[1] The predicted yield being greater than the actual

The calibration equations are only valid within the sward height range 128-263mm in which the calibration trial observations were made. The analysis was therefore repeated with a reduced dataset, including only height observations within this range. The difference between the predicted and actual yield was not significantly different for the late season equation, see Table 3.2 for details. The difference between predicted and actual yield was significant for the other two calibration equations. The mean difference between predicted and actual yield was greatest for the early season calibration equation, as also seen in the previous analysis.

Table 3.2 - Results from t-test on height observation with the range 128-263mm

Calibration equation	*p*-value	Significance level	Mean difference[1] (kg DM/ha)	95% confidence intervals (kg DM/ha)
Early	0.0003	***	357	±158
Late	0.4	NS[2]	60	±159
Season omitted	0.05	*	159	±158

[1] The predicted yield being greater than the actual [2] Not significant

The predicted values were evaluated in relation to the ±10% range of the actual yield that is suggested as a threshold precision level. 15% of the predictions made by early and late season equation were within the range, whereas only 7% of the predictions made by the equation without seasonal effects reached this level of precision. If the subset of data is considered the percentage of predicted values within ±10% of the actual yield is 27% for the early and late season equation respectively and 13% for the equation without seasonal effects.

4 Discussion

The data used for validation was collected in September and therefore the precision of the early season calibration equation can not be fully evaluated. The early season equation precision is most accurately evaluated with observations made before mid July since it was from and for these observations the equation was developed. Predictions were, in spite of height observations being made after mid July, made with all 3 equations (early season, late season and without seasonal effects). The results can be used to evaluate the effect of applying a less suitable prediction equation, e.g. an early season calibration equation in late season. The results should not be used for evaluating the relative precision achieved by the 3 calibration equations.

According to the results reported by Hansson (2011) the early season calibration equation was expected to give the most precise predictions of pasture yield and the late season calibration equation the least precise, see summary of results in Appendix 2. If results of coefficient of determination (r^2), confidence intervals and width of prediction intervals in percentage of the predicted yield (Appendix 2) are considered, the equation without seasonal effects is expected to be more precise than the late season equation. If the prediction intervals for sward heights of approximately 180mm or less are considered (Figure 4.1) are the two equations expected to achieve similar prediction precision. Only one of the sward height observations in the validation dataset was above 180mm and similar precision can therefore be expected.

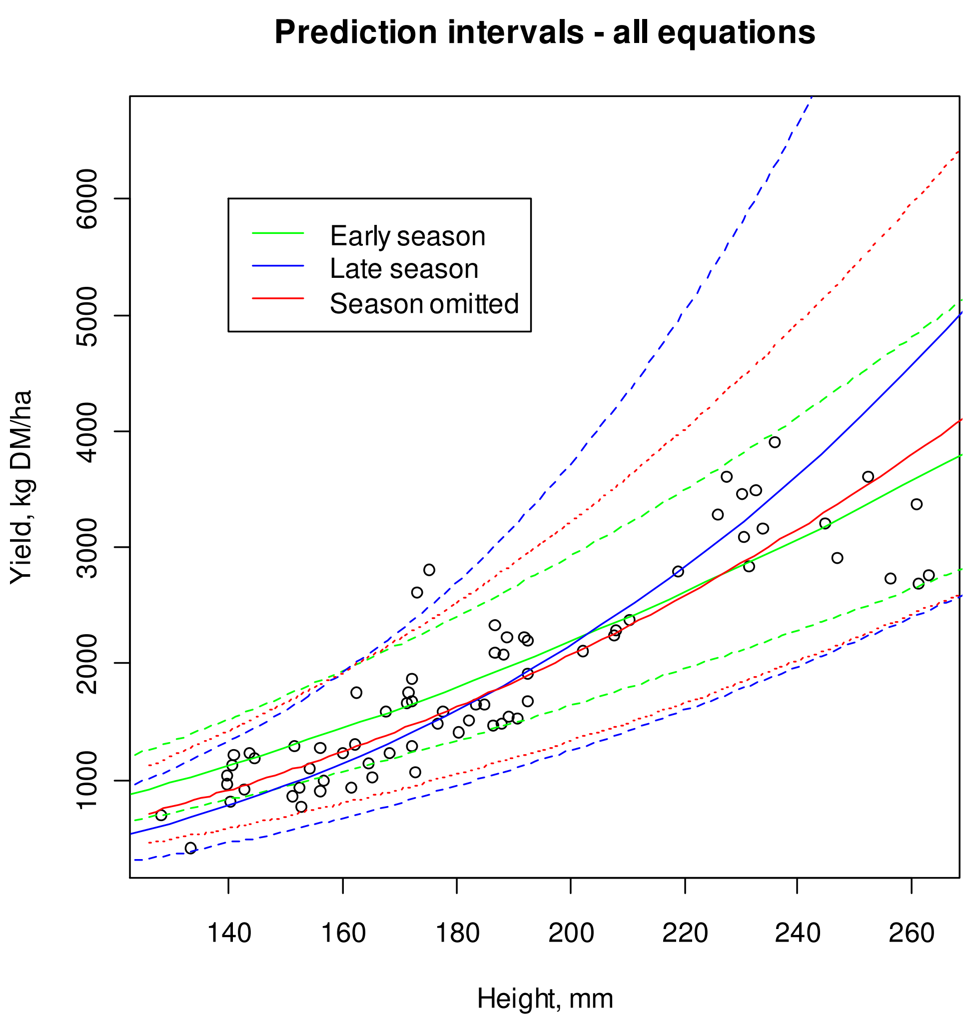

Figure 4.1 - Calibration equations with height before harvest as predictor plotted with 95% prediction intervals (Hansson 2011)

The early season equation predicted yield with low precision, which is expected for sward height observations made after mid July. The early season equation is, according to results reported by Hansson (2011) (Figure 4.1), also expected to overestimate the yield for sward heights below approximately 200mm compared to yields predicted with the late season equation at same height. This expectation was confirmed by the mean difference between the predicted and actual yield reported in Table 3.1 and 3.2.

For sward heights below approximately 180mm the calibration equation without seasonal effects is expected to overestimate the predicted yield in relation to the late season equation (Figure 4.1). Table 3.1 and 3.2 confirms that the yield predicted by the equation without seasonal effects is, on average, higher than the yield predicted by the late season equation. The overestimation by the equation without seasonal effects was further expected to be less than the overestimation by early season equation (Figure 4.1), which again was confirmed by mean differences reported in Table 3.1 and 3.2.

The sward height range in which the calibration observations are made is of importance for future predictions. The results from the analysis of the whole dataset were compared to the results from the analysis of the subset which only included observations of heights that were within the same range of sward heights observed in the calibration trial. This comparison shows that predictions made from height observations within this range only were closer to the actual yield than if the predictions were made from all observed heights, outside or within the range (c.f. Table 3.1 and 3.2).

The percentage of predictions that is within ±10% of the actual yield, calculated for each calibration equation, is not in concurrence with the results reported in Table 3.1 and 3.2. In Table 3.1 and 3.2 the early season calibration equation predictions, on average, deviates the most from the actual yield. The percentage of predictions by early season equation that are within ±10% is, however, the same as the corresponding percentage for late season equation and higher than the corresponding percentage for equation without seasonal effects. This is seen both in the analysis of the whole dataset and the subset of data. The contradictory results are most likely caused by a few greatly deviating observations influencing the mean difference between predicted and actual yield. These observations are, however, not outliers in a mathematical sense and were therefore not identified in the statistical test for outliers.

The results in all suggest that the use of seasonal equations is beneficial. The early season equation is expected to give the most precise prediction of yield when sward height is measured before mid July, but further validation is needed for confirmation. For such a validation is an independent dataset with observations done before mid July and within the height range of approximately 130-260mm required.

5 Conclusion

- The calibration equation without seasonal effects overestimates the actual yield compared to the late season calibration equation. The early season calibration equation overestimates the yield more than the equation without seasonal effects, if used for predictions from sward heights observed after mid July.
- Data used for calibration of prediction equations must be collected in the interval in which the future predictions are to be made, since the predictions will be most precise in this interval.
- The results indicate that the seasonal equations are beneficial to use, but for a more certain conclusion further validation with observations of sward height made before mid July is required. The calibration equations found by Hansson (2011) are not recommended for practical implementation since only 7-27% of the predictions done were ±10% of the actual yield.

6 Implications

Low precision estimates are disadvantageous to work with, especially when calculating a feed plan for a large dairy herd. The results in this report may also indicate that there will be consequences of using a less suitable calibration equation, e.g. an early season equation for predictions in late season, for predictions that ultimately effect the production and economy. The results also indicate that it is of great importance that the predictions are made from sward height observations that are within the same range of heights as in the calibration dataset. The CPM method has several advantages and can perhaps, with a precise prediction equation, be a useful tool for Danish farmers. Future collection of data for calibration purposes should be conducted on pastures that are as close as possible to dairy pastures in practice, as was done in the proceeding calibration trial. The importance of observing sward heights within the whole range of interest, e.g. 0-200mm, should be emphasized. Having numerous observations, evenly distributed, within this range can be advantageous since possible trend changes in the dry matter to height relationship could be detected.

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Appendix 1 – Study design of the field trial from which validation data was adopted (Kristensen 2011)

Græsforsøg – Foulum 2009 (forår og efterår)

20. Juli 2009
Troels

Græsmarken – registreringer
Registreringerne skal anvendes til at beskrive de grundlæggende betingelser for forsøget og indgå som del af de eksperimentelle målinger af køerne optag og i modellerne for optag.

Optaget af tørstof under afgræsning er en funktion af græsningtid (min), antal bid pr min og bidstørrelsen (g tørstof), hvor de to første moniteres via sensorer, mens bidstørrelsen ikke registreres direkte. Bidstørrelsen er tæt korreleret til afgrødetilgængeligheden som kan udtrykkes ved afgrødehøjde og -tæthed. Græshøjden kan måles direkte, mens tætheden kan udtrykkes via afgrødemængden, enten pr ko, pr ha eller pr cm græshøjde.

Kendskab til kvaliteten af græsoptaget er afgørende ved estimering af optaget ved diverse markørmetoder, idet fordøjeligheden af foderoptaget er en afgørende parameter.

Græsvæksten kan bruges dels som en del beskrivelsen af betingelserne for forsøget dels i kombination med udviklingen i afgrødemængden til sammenligning med optagelsen registreret via dyrene.

Registreringerne, se tabel 1, er planlagt således at oplysninger om kvalitet og tilgængelighed kan fås med en høj sikkerhed som gennemsnit af de 2 forsøgsuger, og desuden kan beskrives for de underliggende to forsøgsuger med rimelig sikkerhed. Græsvæksten kan vanskeligt fastlægges for de to forsøgsuger separat pga. en lille afgrøde mængde, men det forsøges i maj/juni. Generelt vil estimatet for tilvækst blive noget usikkert da det må laves udenfor det afgræssede areal og det er kendt at græsvæksten i betydeligt omfang er påvirkeligt af udnyttelse metode og andre vækst forhold.

Tabel 1. Tidsplan for registreringerne i forårsrunde 2009

Date	Dag		Græsvækst	Græshøjde & Buske	Græskvalitet	Græstilbud
25-05	Man					
26-05	Tirs		X 8			
27-05	Ons			Data til 1. uge x	X 4	X 4
28	Tors					
29	Fre			x	X 4	X 4
30	Lør					
31	Søn					
01-06	Man					
02	Tirs			x	X 4	X 4
03	Ons		X 8	Data til 2. uge x	X 4	X 4
04	Tors					
05	Fre			x	X 4	X 4
06	Lør					
07	Søn					
08	Man					
09	Tirs			x	X 4	X 4
10	Ons			x	X 4	X 4
11	Tors		X 12			

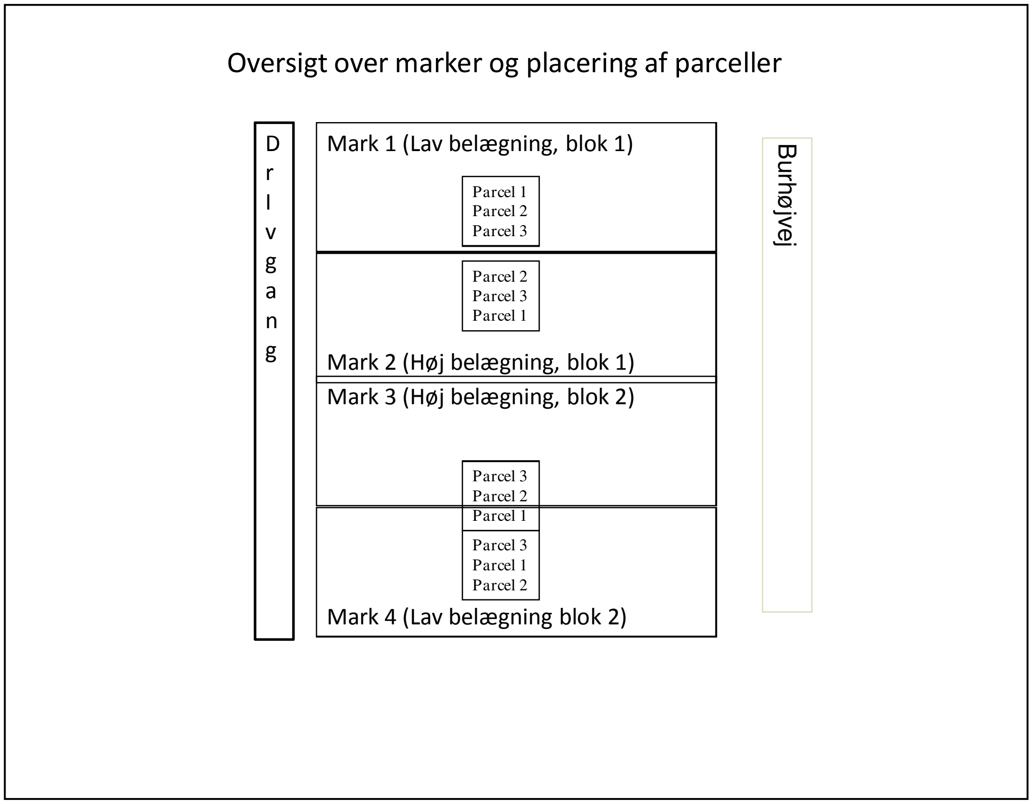
Markering af: Weekend og pinse, periode 1, periode 2.

Tabel 2. Tidsplan for registreringerne i efterårsrunde 2009

Date	Dag		Græsvækst	Græshøjde & Buske	Græskvalitet	Græstilbud
31-08	Man					
01-09	Tirs		X 8			
02-09	Ons			Data til 1. uge x	X 4	X 4
03-09	Tors					
04-09	Fre			x	X 4	X 4
05-09	Lør					
06-09	Søn					
07-09	Man					
08-09	Tirs			x	X 4	X 4
09-09	Ons		X 8	Data til 2. uge x	X 4	X 4
10-09	Tors					
11-09	Fre			x	X 4	X 4
12-09	Lør					
13-09	Søn					
14-09	Man					
15-09	Tirs			x	X 4	X 4
16-09	Ons			x	X 4	X 4
17-09	Tors		X 12			

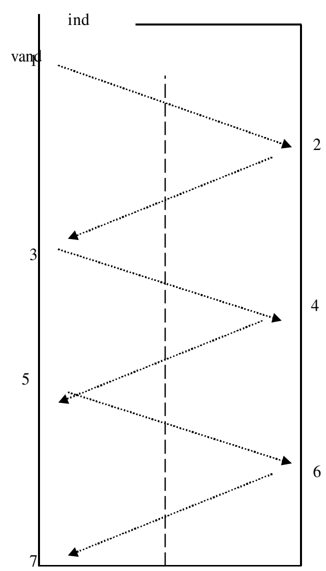
Markering af: Weekend , periode 1, periode 2.

Figur 1. Oversigt over placering af marker og parceller og ID herfor.

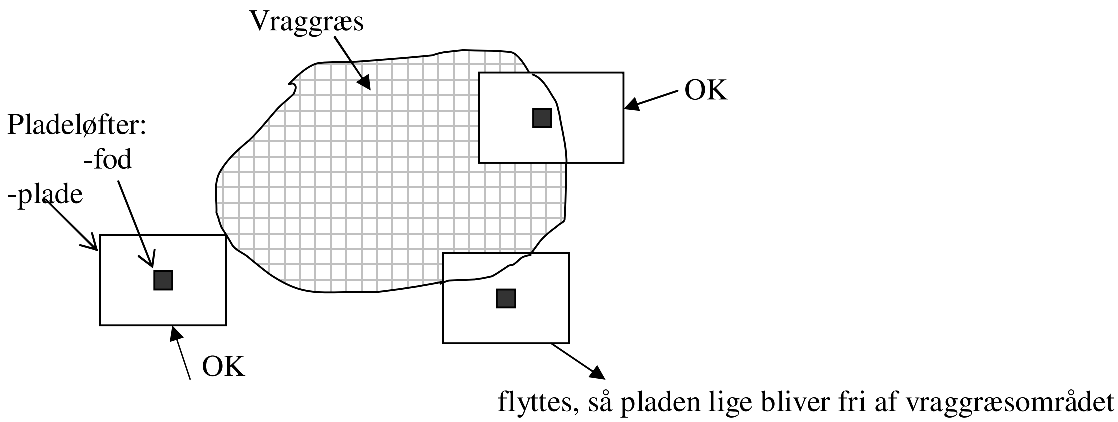


Græshøjde, kvalitet og tilbud.
Disse registreringer gennemføres i afgræsningsfoldene, på de viste datoer. Der startes i de marker som køerne græssede dagen før registrering, mens registreringerne i de andre først kan laves når køerne den pågældende dag har forladt foldene.

Før registreringerne startes opmåles foldene og en "gangrute" mærkes ved at sætte hvide pinde op langs hegnene. Græshøjde og afrivning af græs til kvalitetsbestemmelse skal ske på den W- formede rute, mens afklip til bestemmelse af tilbud laves på en rute midt i folden på langs.



Græshøjde
Udstyr: Plademåler, Notering Skema 1138
Græshøjde måles ved 100 stik på en på forhånd fastlagt rute i hver fold. Ved alle registreringer i hver periode følges samme rute. Højderne klassificeres i afgræsset, topgræsset eller buske. Højdemålingerne skal repræsentere den type vegetation, som højdemålerens fod er placeret i. Dvs. bliver foden placeret lige ved siden af et vraget område og pladen kommer til at hvile på det høje græs flyttes måleren væk fra det vragede område, så pladen lige netop er udenfor. Se nedenstående skitse. Da målingerne bl.a. skal bruges til at beregne areal-andelen af vraggræs, ville denne blive for stor, hvis ikke ovennævnte procedure bliver fulgt.



Højden noteres i mm og hvis målingen foretaget i et ugræsset/vraget område (en egentlig busk) angives 9 i første kolonne, mens der angives 8 hvis målingen foretaget i et vraget område som er topgræsset (dyrene æder eller er begyndt at æde den øverste del).

Græskvalitet
Udstyr: Spand, plasticposer.
Græsprøve til bestemmelse af afgrødekvalitet af det græs som køerne optager, udtages ved at afrive græsset til simulering af koens bid. For at sikre det bedst muligt afrives græs i en halvcirkel svarende til en armslængde. Vraggræs undgås. Afrivningshøjde og intensitet afstemmes efter områdets generelle udnyttelse. Græsset samles i en spand. Der plukkes i 25 punkter langs den faste W-formede rute. Prøven blandes ved at udlægge den i et bånd af tre gange på et bord, og en prøve af mindst 200 g udtages. Prøven sættes til tørstofbestemmelse. Herudover udtages en prøve, som nedfryses til senere foderværdibestemmelse. Det er vigtigt, at prøven holdes køligt fra udtagning og til den senere nedfrysning/køling, og **ikke** i en lukket plastikpose.
ID: Marknr, dato og metode=afriv

Græstilbuddet
Udstyr: Jernramme, græsklipper, plastikposer, Skema "Afgræsning 2009-1".
Bestemmes ved 5 klip langs en rute midt i folden på langs, som vist i figuren. Dog forskydes ruten ca 5 meter for hver registreringsdag for at undgå at få afklip i områder der tidligere er afklippet. Der udvælges tilfældigt 5 repræsentative steder på 1x1 m - det er vigtigt at arealet udvælges som repræsentativt for den del af folden. Husk at det er tilbuddet der skal fastlægges, hvorfor der godt må være buskgræs i området. På hver sted laves en afgrøde bestemmelse (volumen andel af græs, kløver, ukrudt og ubevokset) og der måles græshøjde 5 steder før afklipning. Der afklippes et område på 0,25m^2 midt i det udpegede område til en stubhøjde på 5 cm. Til afmærkning bruges en U-formet jernramme som stikkes ind under afgrøden. Det afklippede græs kommes i en plasticpose som **ikke** må lukkes. Mængden af afklippet afgrøde bestemmes ved vejning efterfølgende på kontoret. Umiddelbart efter vejning udlægges materialet i et bånd af tre gange på et bord, og en prøve af mindst 200 g udtages. Prøven sættes til tørstofbestemmelse. Herudover laves en samleprøve pr fold som nedfryses til senere foderværdibestemmelse.

ID: Marknr, dato og metode=klip.

Græsvækst.
Udstyr: Haldruphøster, Notering Skema 3-2009
Græsvæksten bestemmes ved afklipning i parceller udenfor græsningsfoldene. Der afsættes 3 parceller på 10 m med bredde på 1,5 m svarende til Haldruphøster ved hver forsøgsfold, dvs. i alt 12 parceller.

Før hver afhøstning vurderes afgrødesammensætning og græshøjden bestemmes med pladeløfter ved 5 stik pr parcel og desuden registreres afgrødehøjden med NZ-Grassmeter (hvis den er klar!!!).

Umiddelbart før forsøgsstart "nulstilles" væksten ved afklipning til 5 cm (tilsvarende højde som forudgående slæt) i to af parceller (1 og 2). Efter første forsøgsuge (3.06) afhøstes tilvæksten i en af disse parceller (1) samt i den parcel (3) som står uhøstet siden slæt 14.05. Alle tre parceller afhøstes efter forsøget slutning. Ved hver høst bestemmes afgrødemængden og der udtages en repræsentativ prøve som mærkes med mark nr og parcel nr samt dato. Tørstofbestemmelse laves umiddelbart herefter og der udtages en prøve på mindst 200 g som nedfryses til senere foderværdibestemmelse.

Tabel 2. Plan for Haldrup høst – der er 4 gentagelser

Dato	Parcel			Slætmetode	Højdemålinger	Afgrødevolumen
	1	2	3			
Forårsrunde						
12. maj	x	x	x	Ensilering		
26. maj	x	x		Haldrup	x	x
3. juni	x		x	Haldrup	x	x
11. juni	x	x	x	Haldrup	x	x
Efterårsrunde						
6. august	x	x	x	Ensilering		
1 Sept.	x	x		Haldrup	x	x
9. Sept	x		x	Haldrup	x	x
17. Sept.	x	x	x	Haldrup	x	x

Klima
Vi har adgang til alle typisk klimatiske oplysninger som nedbør, temperatur, vind mv. fra måle stationen på Foulumgaard, hvorfor der ikke skal laves yderlige registreringer.

Markens historie
Der opsamles oplysninger omkring typen af græs udsået og alle handlinger (gødning, slæt, vanding mv.) i løbet af vækstsæsonen. I forbindelse med slæt på arealet vejes den høstede grøntmasse og der udtages prøve til bestemmelse af tørstofindholdet.

Skema Afgræsning 2009-1 Græsvurderinger, målinger og vejninger i afgræsningsmarkerne
Troels

Dato_______

obs	Mark	Volumen, %				Græshøjde, mm					Græs		
		græs	kløver	ukrudt	ubevok	1	2	3	4	5	Afklip g	Frisk g	Tørret g
1	1												
2	1												
3	1												
4	1												
5	1												
1	2												
2	2												
3	2												
4	2												
5	2												
1	3												
2	3												
3	3												
4	3												
5	3												
1	4												
2	4												
3	4												
4	4												
5	4												
Afrivning													
	1												
	2												
	3												
	4												

Skema Afgræsning 2009-2   Græsvurdering, målinger og vejninger i parcellerne
Troels

Dato_______

M ark	par cel	Volumen, %				Græshøjde, mm					Græs		
		græs	kløv er	ukru dt	ubev ok	1	2	3	4	5	Afklip kg	Frisk g prøve	Tørret g prøve
1	1												
1	2												
1	3												
2	1												
2	2												
2	3												
3	1												
3	2												
3	3												
4	1												
4	2												
4	3												

Husk parcel rækkefølge er anderledes i marken

Appendix 2 – Summary of analysis results in calibration study (Hansson 2011)

Table 1 - Summary of coefficients of determination (r^2) and residual standard error ($\hat{\sigma}$) reported for calibration equations with height before harvest as predictor

	Early season	Late season	Without seasonal effects
r^2	0.87	0.63	0.80
$\hat{\sigma}$	0.06	0.11	0.09

Table 2 - Width of prediction intervals in percentage of the predicted yield

	Width of prediction intervals, ± % of predicted yield		
Sward height, mm	Early season	Late season	Season omitted
128	31	59	45
141	30	55	46
231	30	62	45
263	30	-	46

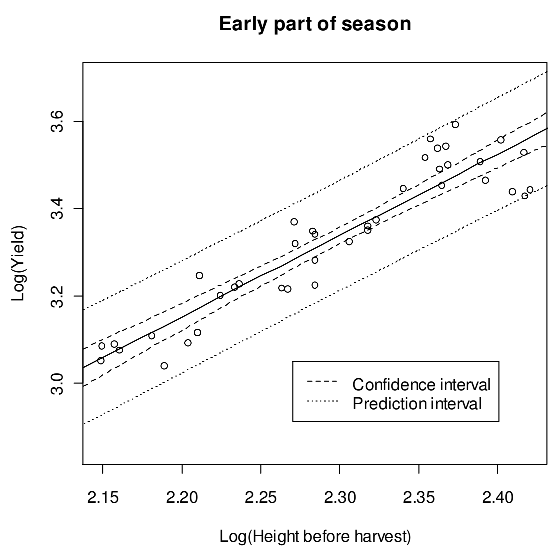


Figure 1 - Calibration equation for early season with Height as the predictor plotted with 95% confidence and prediction intervals

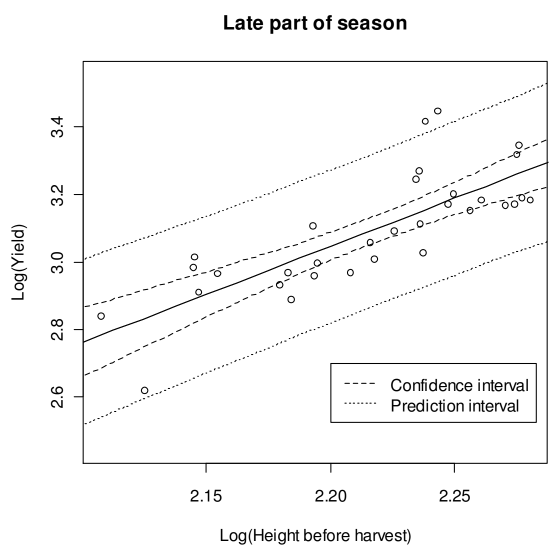


Figure 2 - Calibration equation for late season with Height as the predictor plotted with 95% confidence and prediction intervals

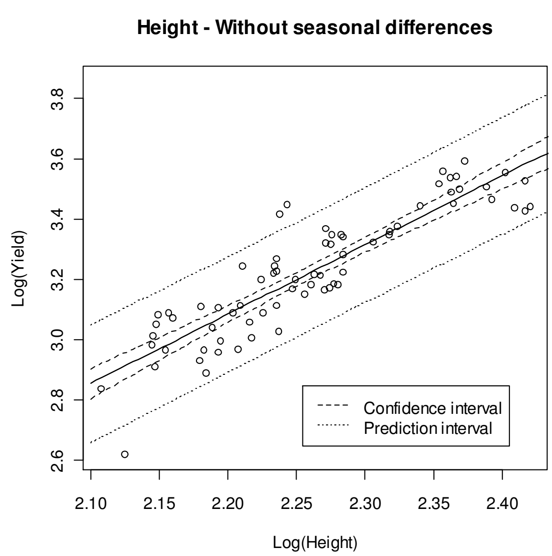


Figure 3 - Calibration equation without seasonal effects with Height as the predictor plotted with 95% confidence and prediction intervals

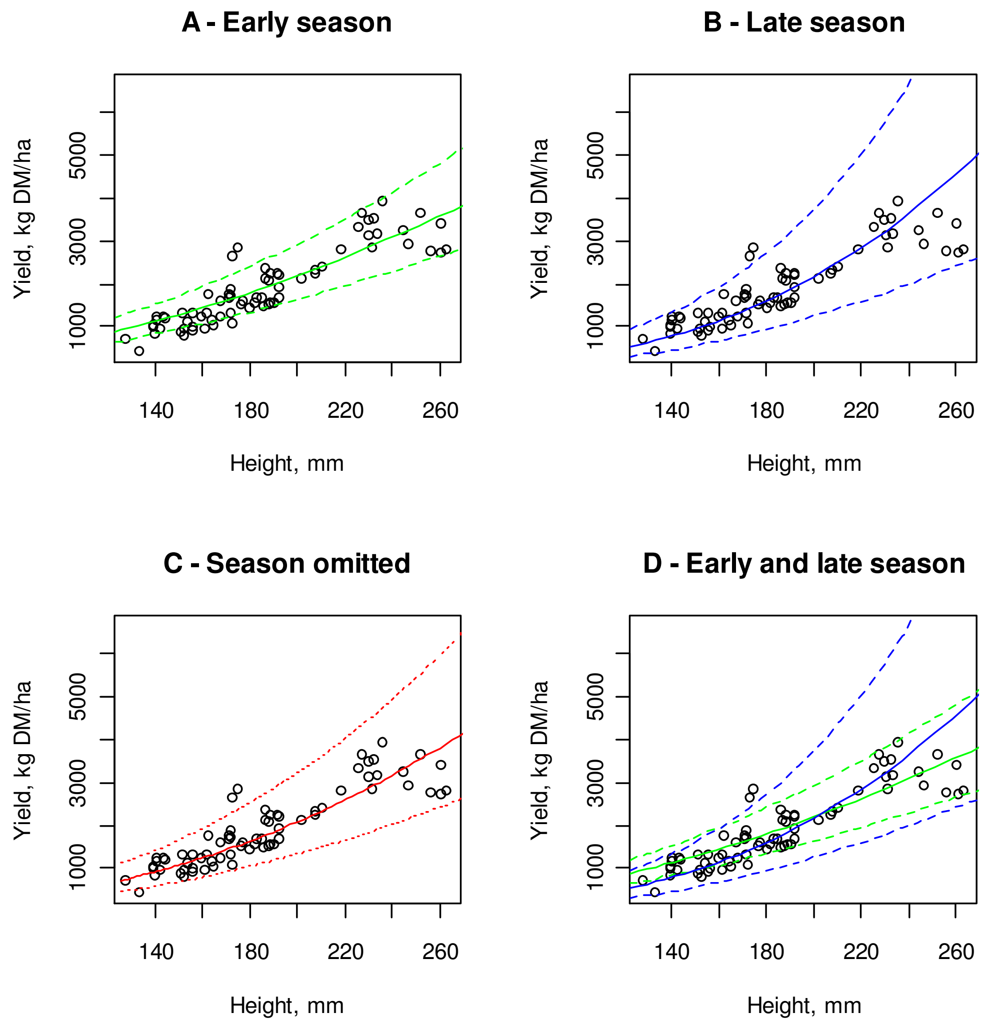


Figure 4 - Anti-logged calibration equations with Height as predictor plotted with 95% prediction intervals: A – Equation 1, B – Equation 2, C – Equation 5, D – Equation 1 and 2 together