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A farm economic module for tactical decisions on sugar beet area

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Abstract

For decisions at operational level in sugar beet growing (for example on plant density, nitrogen fertilizer rate and harvest date), returns above allocated variable costs can be used as a criterion for comparing the economics of different options. For (tactical) decisions on sugar beet area, the sugar beet grower has to take into account the opportunity costs of labour and equipment. Our calculations are based on the assumption that these can be reflected by the respective allocated fixed costs. In this paper, a method of allocating fixed costs to crops in the cropping plan is described and included in PIEteR, a bio-economic model for sugar beet growing. Seed and ware potato and sugar beet had the highest returns above allocated variable costs, but when allocated fixed costs were also taken into account, sugar beet appeared to be more profitable than seed potato.

When sugar quota were included in our calculations, the returns above allocated variable and fixed costs decreased with sugar yields beyond quota level, because prices of C-beets are lower than those of quota-beets. Growing C-sugar beet was not attractive; wheat growing was more profitable. However, the estimated area required to grow the exact amount of quota-sugar was uncertain with a standard deviation of ± 10%.

Keywords: Beta vulgaris, decision support, gross margin, profit, simulation model, sugar beet

Introduction

The production model PIEteR ('**P**roduction model for sugar beet, including **I**nteractions between **E**nvironment and growing decisions, and their influence on the quantitative, qualitative and financial **R**esult') has been developed as a basis for a field specific decision support system in sugar beet (*Beta vulgaris* L.) growing in The Netherlands. It focuses on grower's decisions at semi-operational and operational level. The main decisions at semi-operational level are those on N-fertilization and plant density, which have to be taken before sowing (Smit *et al.*, 1995a,b). The decisions at operational level which can be supported by PIEteR, are those on resowing, which have to be taken one month after sowing, and on harvest and delivery dates, to be taken from the beginning of August and onwards (Smit *et al.*, 1996b, 1997). The model predicts root and sugar yields, from which sugar content is calculated, (K + Na) and α-amino-N contents, from which the extractability index is calculated, and the operating receipts, defined as the amount of money that the farmer receives after delivering his beets, corrected for internal quality (sugar content and extractability index according to Van Geijn *et al.* (1983); Smit & Struik, 1995; Smit *et al.*, 1995a). The model predicts the parameters listed for every day during the growing season, using historical weather data until the day of simulation and average weather data afterwards (Smit *et al.*, 1997). The simulated rates of crop development until canopy closure and of root and sugar production afterwards are corrected for suboptimal soil moisture contents.

So far, we have focused on decisions at operational and semi-operational level. In this paper, we study the decision on the area of sugar beet at a tactical level. Quota regulations restrict the amount of sugar beet which can be delivered for the full quota price. When the deliveries are smaller than the quota over a number of years, the quota will be reduced. The opposite is not true: when the deliveries are larger than the quota over a number of years, the quota will not be enlarged. The grower will generally try to avoid reduction of the quota, since sugar beet is one of the most profitable crops in Dutch arable farming. Therefore, he will tend to minimize the risk of producing an amount of sugar below his quota; as a result of this, he decides to grow an area of sugar beet that is larger than necessary to produce his quota when average root and sugar yields over a number of years are considered. However, it is questionable whether this is a good decision. A module has been developed and included in PIEteR to compare the marginal returns and the costs of an increase of the area by 1 ha.

For tactical decisions on the area of sugar beet in the cropping plan for the next year, on which we focus in this paper, one must consider total farm area and organisation, including fixed labour and equipment as being fixed. Often, linear programming (l.p.) is used to assess the most profitable cropping plan and, optionally, the required equipment. In our case, PIEteR is used because of its field specific character, so that variation in the output parameters listed and in weather conditions are taken into account. Farms and fields vary to a large extent because of differences in soil type and quality, resulting in differences in susceptibility for drought stress and different optimal sowing and harvest dates and nitrogen fertilization rates. The input of PIEteR and the model itself are field specific, so that computer simulations for different fields lead to different results. Additionally, a series of weather data over 38 years or more can be used to obtain insight in the variation of the output parameters for the fields studied (Smit *et al.*, 1997). Although the l.p. technique has the advantage that many activities and restrictions can be included in the analysis simultaneously and opportunity costs are calculated for limiting production factors as land, labour and equipment, including the variations listed would make the l.p. model too complex to oversee and handle.

Unlike a linear programming model, PIEteR does not calculate opportunity costs for equipment and labour, so that these have to be estimated differently. Therefore, two possibilities are considered: 1) The opportunity costs equal nil; equipment and labour are not limiting and cannot be used differently. When the opportunity costs equal nil, we take the returns above allocated variable costs as a measure for planning; 2) The opportunity costs are positive; labour and equipment are limiting and there are alternative ways to use them. The opportunity costs can be so high that an increase of the capacity, purchase of land (with quota) and equipment, and an increase of the fixed labour force, are profitable. This level of opportunity costs is more or less the upper level of the opportunity costs. In some cases, the upper level of opportunity costs may be even higher since equipment and labour are mostly to be obtained in full units. An alternative would then be to utilize residual capacities on other farms. When an increase of capacity and labour is profitable, the opportunity costs can be reflected by the allocated fixed costs of labour and equipment, based on replacement values. Most farms will have opportunity costs in between nil and the upper level mentioned. In our calculations in this paper both upper and lower limit are taken into account. With increasing sugar beet area, both the operating receipts of an extra ha of sugar beet, mainly with sugar yields beyond the quota level, and the allocated fixed costs decrease. Different options of land use with given total farm area, equipment and (fixed) labour are compared on the basis of returns above allocated variable and/or fixed costs.

In this paper, we present a farm economic module of PIEteR to compare the profitability of sugar beet with other crops, also taking into account the availability of labour and machinery. The new module was applied on 16 different practical situations. Moreover, the optimal sugar beet area and the uncertainty connected with the calculation of this area compared to the sugar quota were discussed.

Materials and methods

Different definitions of returns can be used. In arable farming, the term 'returns above operating costs' is often used; it results when the allocated operating or variable costs are subtracted from the total revenues or operating receipts. The revenues should include all cash and non-cash revenues. The variable costs contain: seed; fertilizers; chemicals; crop insurance; interest; and tare penalties (Kay & Edwards, 1994; Roeterdink & Haaksma, 1993). The variable costs are a good measure for operational decision making, since long-term factors such as costs of machinery and land are not taken into account (Roeterdink & Haaksma, 1993).

The parameter 'returns to management' is calculated by subtracting total costs from total revenues or, which is the same, the total ownership costs from the total returns above operating costs (Kay & Edwards, 1994) and it is suitable for evaluation at strategic level. In our calculations, intended for support of tactical decision making, we applied another term: 'returns above allocated variable and fixed costs', shortly 'returns' (Equation 1), which does not include costs of land. 'Fixed costs' are here defined as the total operation costs or the costs of labour, equipment and contract work, which is different from the normal definition.

$$\text{returns} = \text{oper. rec.} - (\text{var. costs} + \text{calc. fixed costs}) \quad (1)$$

in which:

returns	= returns above allocated variable and fixed costs	(kfl ha^{-1})
oper. rec.	= operating receipts	(kfl ha^{-1})
var. costs	= allocated variable costs	(kfl ha^{-1})
calc. fixed costs	= allocated fixed costs	(kfl ha^{-1})
1 kfl	= 1000 Dutch guilders	

Equation 1 gives the contribution of a crop to the total returns of a farm, taking into account the organisation of the farm (crop rotation, percentage of the crops that is labour intensive, fixed labour force), including farm equipment and cropping plan, since the allocated calculated fixed costs greatly depend on the combined use of the available machinery for the different crops. Contractors' costs are not included in the term 'fixed costs', but because we wanted to discuss costs of labour, equipment and contractors as a group, they are listed under fixed costs in this paper.

A module of PIEteR was developed to include the economic aspects of other crops than sugar beet, to calculate costs of machinery, labour and contractors per crop and in total, and to compare returns above allocated variable and fixed farm costs. The crops included were ware, seed and starch potato, sugar beet, winter and spring wheat, spring barley and pea. The method of cost allocation applied has been described by Van Niejenhuis (1981). Recently, Schoorlemmer *et al.* (1997) have also paid attention to this subject.

We defined a standard equipment for arable farms, not including equipment for storage of products (Table 1). For each machine, except for tractors and transportation, the number of treatments per crop was estimated, multiplied by the areas of the respective crops. The total costs of each machine were divided by the total treated area, resulting into the average costs per ha treated. By multiplying the average costs per machine by the number of treatments for a crop, the allocated costs of the machine for a hectare of the crop were obtained. For tractors and transportation the same procedure was applied, but total costs were not allocated to area treated but to working hours.

The (normative) costs of each machine consisted of two major posts: 1) depreciation, interest, maintenance and insurance; 2) costs of depot. The first post contained a fixed percentage for each machine multiplied by its replacement value. The second post contained the required area in the machine depot per machine, including 40% for walking, etc.

The total costs of machinery per ha of each crop were calculated as the sum of the required treatment costs; contractors' costs (standard tariffs from Roeterdink & Haaksma (1993)) and allocated labour hours (from Roeterdink & Haaksma (1993)) were added to calculate the total fixed treatment costs. The allocated labour hours consisted of the respective use of both tractors and the time for hand labour. We assumed that labour was available for a price of *f* 28.34 per hour (Roeterdink & Haaksma (1993)). General and management activities, like book keeping, delivery

Table 1. Standard equipment for arable farms, not including equipment for storage

Type	Capacity (kW, tonnes, m, l)	Replacement value (kfl)
Tractor 1	35 kW	65
Tractor 2	70 kW	110
Transportation	8 tonnes	23.6
Plough	1.2 m	18.8
Fertilizer spreader	18 m, 1500 l	8.0
Power harrow	3 m	16.7
Potato planter	3 m	25
Row rotary cultivator	3 m	24.2
Chemical sprayer	21 m	27.2
Chemical sprayer for row application	3 m	2.3
Harrow for weed control	3 m	10

of products outside the farm, cleaning, etc., were not included.

The returns of the different crops were calculated as the multiplication of observed yields from the basic data of Wijnands *et al.* (1995) of the main products and their standard prices; for the latter and for additional minor products, standard values from Roeterdink & Haaksma (1993) were applied. By subtracting standard values for allocated variable costs from the same source, the returns above allocated variable costs were obtained. The returns above allocated variable and fixed costs were calculated by subtracting the costs of labour, equipment and contract work from the returns above allocated variable costs. Standard working hours for treatments and hand labour, prices of labour and standard costs of contract work were also derived from Roeterdink & Haaksma (1993).

We ran the model for 16 combinations of farm and year as described in Table 2 (with data on soil type, farm size and cropping plan). The combinations had been randomly selected from the basic data of Wijnands *et al.* (1995). The data covered different regions in The Netherlands during the years 1991–1993. Other crops than listed and set-aside were not included in the module.

To examine the effect of sugar quota, we assumed that 2500 kg (ha total arable land, including set-aside and area of crops which had not been included in the module)$^{-1}$ could be delivered for a price of 0.115 kfl (ton beet)$^{-1}$ with a sugar content of 16% and an extractability index of 85 (Menu, 1993); for beet above quota, a sugar beet price of 0.045 kfl ha^{-1} was assumed. Returns for C-sugar beet growing were calculated by giving the quota of each farm value 0. With given allocated variable and fixed costs of sugar beet growing and simulated root yields, a limit price was calculated for which the returns above allocated variable and fixed costs for sugar beet growing were equal to nil.

Table 2. Size and cropping plan of 16 combinations of farm and year.

Farm nr [1]	Soil type	Total size (ha)	Ware potato (ha)	Seed potato (ha)	Starch potato (ha)	Sugar beet (ha)	Winter wheat (ha)	Spring barley/ wheat (ha)	Pea (ha)	Other [2]
A-1993	Sandy	26.3	0	0	7.9	6.0	7.7	4.7	0	0
A-1992	Sandy	23.4	0	0	7.3	5.9	4.2	3.5	2.6	0
B-1992	Loess	51.2	12.6	0	0	15.3	8.9	0	0	14.4
C-1992	Sandy	90.8	0	1.9	36.4	20.0	0	20.5	4.0	8.0
D-1991	Reclaimed peat	51.5	0	1.2	11.4	13.0	0	9.4	0	16.5
E-1991	Sandy	54.6	0	2.3	15.9	12.3	0	0	0	24.1
F-1991	Sandy	73.0	0	2.0	22.5	18.5	7.3	1.5	0	21.2
G-1991	Reclaimed peat	107.2	0	0	33.9	23.0	0	0	7.5	42.8
H-1991	Sandy	34.6	0	1.0	12.3	6.5	4.0	0	0	10.8
I-1992	Light clay	50.6	3.5	9.1	0	8.0	9.1	0	4.1	16.8
I-1991	Clay	49.4	4.2	8.0	0	8.0	12.5	0	4.0	12.7
J-1992	Light clay	62.1	0	24.9	0	17.7	0	19.5	0	0
J-1991	Light clay	63.6	0	24.5	0	19.5	17.9	1.7	0	0
K-1992	Clay	45.0	0	14.0	0	8.8	5.7	6.3	0	10.2
K-1991	Clay	43.7	0	11.1	0	8.9	15.8	1.4	0	6.5
L-1992	Clay	38.6	10.3	0	0	9.8	15.3	3.3	0	0

[1] Code of a farm (A-L) and the relevant year (1991–1993).
[2] Mainly set-aside.

Results

Table 3 gives the results of calculations for 16 combinations of farm and year. Returns above allocated variable costs, allocated costs of labour, equipment and contractors, and returns above allocated variable costs and allocated costs of labour, equipment and contractors were calculated with PIEteR for the 16 combinations listed. The rules for calculation have been given in 'Materials and methods'. The results per crop were averaged over all combinations with the respective crop in its cropping plan.

The returns per crop above allocated variable costs were very different per combination of farm and year. On average, seed potato had the highest returns, 8 kfl ha^{-1}, and starch potato and pea the lowest, about 1.7 kfl ha^{-1}. The average costs of labour, equipment and contractors varied between 1.1 kfl ha^{-1} and 4.2 kfl ha^{-1} for spring wheat and ware potato, respectively. The average returns above allocated variable and fixed costs were highest for seed potato, 4.3 kfl ha^{-1}, and almost nil or even negative for wheat, spring barley and pea, and starch potato, respectively. The simulated returns for sugar beet were much higher than the observed ones.

When sugar quota of 2500 kg ha^{-1} and a sugar beet price above quota of 0.045 kfl ton^{-1} were assumed, the average returns above allocated variable costs of sugar beet, based on simulated yields for the different combinations of fields and years, decreased from 6.64 kfl ha^{-1} to 6.21 kfl ha^{-1}. The returns above allocated fixed costs for the same yields decreased from 2.87 kfl ha^{-1} tot 2.44 kfl ha^{-1}. The sugar quota of ten farms were not exceeded.

When all sugar quota were set to nil, the returns above allocated variable costs and those above allocated fixed costs were 1.33 kfl ha^{-1} and –2.45 kfl ha^{-1}, respectively (Table 3). Table 4 gives the simulated root yields, the allocated variable and fixed costs and the prices of C-beet for which the returns above allocated variable and

Table 3. Returns above allocated variable costs, fixed costs and returns above allocated fixed costs; average values of 16 farm/year combinations, with observed and simulated yields and prices of sugar beet, respectively.

Crop	Number of farms	Returns [1] (kfl ha^{-1}, kfl)	Fixed costs [2] (kfl ha^{-1}, kfl)	Returns [3] (kfl ha^{-1}, kfl)
Ware potato	4	5.35	4.23	1.12
Seed potato	11	7.96	3.69	4.27
Starch potato	8	1.70	3.18	–1.48
Sugar beet_obs [4]	16	5.11	3.77	1.34
Sugar beet_sim [5]	16	6.64	3.77	2.87
Sugar beet_sim [6]	16	6.21	3.77	2.44
Winter wheat	11	1.81	1.62	0.185
Spring wheat	2	1.27	1.12	0.077
Spring barley	9	2.48	1.21	1.27
Pea	5	1.72	1.58	0.140
Total cropping plan [4,7]	16	163	117	52.5
Total cropping plan [5,7]	16	185	117	71.6
Total cropping plan [6,7]	16	183	117	66.3

[1] Returns above allocated variable costs.
[2] Allocated costs of labour, equipment and contractors.
[3] Returns above allocated variable costs and allocated costs of labour, equipment and contractors.
[4] Observed sugar beet yields and average sugar beet prices were used (the latter from Roeterdink and Haaksma, 1993).
[5] Simulated sugar beet yields and sugar beet prices were used. Sales system: 0.115 kfl (1 kfl = 1000 Dutch guilders) per net ton of sugar beet, corrected with 9% per percent sugar content above or under 16% and with 0.9% per point extractability index above or under 85; penalties for dirt tare were not included in our calculations. This system was used in 1993 by Suiker Unie, one of the sugar beet processing companies in the Netherlands (Menu, 1993).
[6] As [5], but with the following assumptions:
a *a sugar quota of 2500 kg (ha total arable land)$^{-1}$*;
b a sugar beet price above quota of 0.045 kfl ton^{-1}.
Additional results (average values of 16 farm/year combinations):

Estimated sugar quota	=	135 tonnes
Amount of C-sugar	=	11.0 tonnes
Operating receipts quota part	=	7.54 kfl ha^{-1}
Operating receipts non-quota part	=	0.23 kfl ha^{-1}.

Ten farms did not produce C-sugar.
The average returns above allocated variable costs and the returns above allocated variable and fixed costs (not including costs of land) of C-sugar beet growing were 1.33 kfl ha^{-1} and –2.45 kfl ha^{-1}, respectively. When costs of equipment were not taken into account, allocated fixed costs were 2.08 kfl ha^{-1} and the returns above allocated variable and fixed costs –0.75 kfl ha^{-1}.
[7] Average total values per farm.

Table 4. Simulated root yields and operating receipts; standard allocated variable costs; fixed costs (labour, equipment and contractors); returns above allocated variable and fixed costs when sugar quota = 0; and limit price for C-beets when the returns above allocated variable and fixed costs = 0. Values of 16 combinations of farm and year.

Farm nr [1]	Root yield (tonnes ha^{-1})	Operating receipts [2] (kfl ha^{-1})	Variable costs [3] (kfl ha^{-1})	Fixed costs [4] (kfl ha^{-1})	Returns [5] (kfl ha^{-1})	Limit price C-beet [6] (kfl ton^{-1})
A-1993	74.7	9.85	1.65	4.93	−3.21	0.088
A-1992	66.4	8.27	1.65	5.14	−3.81	0.102
B-1992	64.2	7.37	1.65	3.42	−2.18	0.079
C-1992	73.5	9.86	1.65	2.95	−1.29	0.063
D-1991	47.8	6.27	1.73	3.82	−3.40	0.116
E-1991	54.0	6.81	1.73	3.86	−3.16	0.104
F-1991	48.2	6.31	1.73	3.22	−2.77	0.103
G-1991	53.4	7.02	1.73	3.00	−2.32	0.089
H-1991	50.7	6.22	1.73	4.77	−4.22	0.128
I-1992	83.7	11.06	1.36	3.92	−1.51	0.063
I-1991	67.8	8.60	1.36	3.84	−2.15	0.077
J-1992	70.5	9.16	1.36	3.08	−1.27	0.063
J-1991	51.2	5.77	1.36	3.00	−2.05	0.085
K-1992	71.8	9.37	1.36	3.90	−2.02	0.073
K-1991	65.1	8.31	1.36	3.86	−2.28	0.080
L-1992	84.1	10.87	1.61	3.67	−1.49	0.063

[1] Code of a farm (A-L) and the relevant year (1991 – 1993).
[2] Operating receipts, not corrected for tare content.
[3] Allocated variable costs, according to Roeterdink & Haaksma (1993); differences are due to differences in region.
[4] Allocated costs of labour, equipment and contractors.
[5] Returns above allocated variable and fixed costs with a price of C-beet of 0.045 kfl ton^{-1}.
[6] The price of C-beet to make the returns above allocated variable and allocated fixed costs equal to nil.

fixed costs were equal to nil for all farms included. The limit price varied between 0.063 kfl ton^{-1} for farms C, J (in 1992) and L, and 0.128 kfl ha^{-1} for farm H.

Discussion

Five of the farms (D – H in Table 4) were located on North-eastern sandy and reclaimed peat soils and had observed returns above allocated variable costs for sugar beet in 1991 of 2.99 kfl ha^{-1} (value not listed). Cuperus (1989) calculated these in a normative way as 3.28 kfl ha^{-1}. The observed yields for the farms in this area were lower than the simulated ones: 41.4 tonnes ha^{-1} and 50.8 tonnes ha^{-1}, respectively. Yield potential of the fields simulated was probably lower than the average regional one. This problem could be solved by including historical field or farm levels for root and sugar yield (Smit *et al.*, 1996a). However, we did not have the information required. Moreover, the number of observations was too small for detailed conclusions. For demonstration purposes, we based our calculations and the decision making on the simulated yields, costs and returns instead of the observed ones. For the other crops, observed yields were used in the calculations.

The returns above allocated variable costs were highest for seed and ware potato and sugar beet (Table 3). Jager (1995b) mentioned average values of 10.1 kfl ha^{-1}, 6.75 kfl ha^{-1} and 5.94 kfl ha^{-1} for the three crops respectively for all arable farms (on clay soils in the case of seed potato) in 1989–1993. In our calculations, seed potato growing on other than clay soils played a role. Jager's values for sugar beet were in between the observed and simulated results in Table 3.

The returns above allocated fixed costs of sugar beet were higher than those for ware potato (Table 3). In general, Dutch arable farmers try to maximize the area of (seed and/or ware) potato and sugar beet, which is in agreement with the profitability indications given in Table 3. The respective areas are limited by maxima for cropping intensity and/or by sugar quota. The last limitation is not a very rigid one, however. When a farmer delivers more sugar beet than his quota allows, he will have a problem with profitability. When he delivers less than his quota, each year, he will loose part of his quota in the end. Therefore, more insight into the risk that the production exceeds the quota is needed to take balanced decisions on the area of sugar beet to grow.

For the 16 combinations in general, a decrease of the area of sugar beet with 1 ha decreased the total profit by 2.87 kfl, not taking into account costs of land and the (small) increase of allocated fixed costs through the decreased total farm area (Table 3). Likewise, an increase of the area of sugar beet with 1 ha increased the total profit by 2.87 kfl. However, with total farm area fixed, sugar beet had to replace another crop, most likely winter wheat. Therefore, the returns above allocated variable costs and allocated costs of labour, equipment and contractors of 1 ha of winter wheat, 0.185 kfl, had to be subtracted from the extra loss or profit of 1 additional ha of sugar beet, so that an extra net loss or profit of 2.69 kfl remained. This calculation was only valid below the quota limits.

Beyond the quota limits, the situation was totally different. The average returns above allocated variable costs of 1 ha of C-beet were of the same order of magnitude as those of spring wheat, but when fixed costs were also taken into account the returns were negative, even when costs of equipment (1.69 kfl ha^{-1}) were not taken into account (Table 3). Thus, growing 1 ha more than necessary to deliver the grower's quota was not profitable. With very high prices for C-beet, this could be different. The minimal price at which C-beet growing is profitable depended largely on the yield level, but also on the fixed costs (Table 4). With the simulated root yields listed, which were on average higher than the observed ones, the C-price had to be at least 0.063 kfl ton^{-1} to make C-beet growing profitable. This is not often the case (H.C. Antonissen, CSM Sugar, pers. comm., 1995) and even then growing winter wheat or spring barley would often be more profitable in terms of returns above allocated variable and fixed costs (Table 3).

For direct profit, growing of C-beet would not be profitable, according to our calculations, which confirm the simpler calculation of the difference between gross margin and contractors costs. Moreover, this paper has given an impression of the combined effect of farm size and root yield on the minimum price of C-beets for profitable C-beet production. In winter time, when the seed is ordered, it is hard to foresee what the root yield and sugar content will be in the next season. Smit *et al.* (1997) showed that on April 12th (the average sowing date in The Netherlands), there is a probability of 68%, that the sugar yield will be in the range [average – standard deviation, average + standard deviation] and that the standard deviation is 9.2%; we assumed that this value is also valid for other regions than Wageningen. When a sugar beet area of 10 ha with 'average' yields over a series of years is required to deliver an amount of sugar equal to the quota, an area of 9–11 ha would be sufficient in practice, i.e. in 68% of the years, the sugar quota can be produced with an area of 9 – 11 ha. Similarly, in 95% of the years, an area of 8–12 ha is required.

When the grower decides to sow 11 ha of sugar beet, whereas 10 ha appears to be sufficient, then the loss is 4.48 kfl, the difference between the quota and C-beet prices, multiplied by the average simulated root yield (64 tonnes.ha^{-1}; not listed). Assuming that the grower decides to sow 9 ha of sugar beet, whereas 10 ha appears to be required, and this process repeats itself year after year, then the sugar quota will decrease by the sugar yield of 1 ha. In the long run, 1 ha of sugar beet has then to be replaced by winter wheat, most likely, which results in a loss of 2.68 kfl, being the difference between the returns above variable and fixed costs of 1 ha quota beets and 1 ha of winter wheat (Table 3). This is true, when the decision is taken in the autumn before; when the decision is taken near sowing date and there fore operational, spring wheat or spring barley have to be considered as alternative crops. In that case, the loss will be 5.37 kfl and 4.16 kfl, respectively, based on returns above variable costs, only. In the case of winter wheat, the first loss is larger than the second one, but the first is incidental and the second structural.

When the growing season proceeds, PIEteR could help to calculate the (expected) day of exceeding the sugar quota, taking this estimate into account in decisions on delivery and (mainly) harvest dates (Smit *et al.*, 1997). PIEteR was run with weather data of 38 years. The variation in sugar yields was relatively high so that the prediction of the 'expected day' could not be very precise. Nevertheless, when time passes by the predictions can be made more precise, since the uncertainty about future weather conditions is replaced by given weather data and/or short term predictions. Monte Carlo techniqes could be an alternative approach instead of variation analysis (Smit *et al.*, 1997).

Costs of equipment were based on replacement values, being the value that a grower pays when the same machine is re-purchased, including the technical progress that has been made since the old one was bought. These costs represent more or less the upper limit of the opportunity costs. In practice, a lot of growers on smaller farms work with second-hand equipment and/or base their decisions on salvage values, resulting in lower opportunity costs. On the other hand, the equipment listed (Table 1) is a very sober standard equipment; in practice one may expect a larger equipment, for example harvesting equipment, especially on larger farms with a considerable potato area. Moreover, buildings and equipment for storage of (mainly harvested) products had not been taken into account, which would affect mainly the costs of potato growing. We calculated average costs of labour, equipment and contractors of 2.91 kfl ha^{-1} over all farms and all crops, whereas Jager (1995a) calculated 3.63 kfl ha^{-1} on average for larger arable farms (with a size of about 40 dsu (Dutch Size Units) or more) in 1985/86 – 1990/1991. However, he included farms with vegetable and/or bulb flower growing in the open field in his calculations, which require a lot of labour.

The method of cost allocation to crops should be used carefully; the removal of a crop from the cropping plan could theoretically lead to higher returns because of cost saving. However, total costs of labour and equipment do not decrease in that case (Schoorlemmer *et al.*, 1997). Therefore, the calculations that we made for marginal changes, can not easily be extended to more significant changes.

PIEteR can be used for analysis of cropping plans of different farms and for marginal changes of individual cropping plans. In many cases, however, the cropping plan allows only one field to be selected for sugar beet growing in the following year and variation in sugar beet area is relatively small. Still, the conclusion that the planned area should not exceed the calculated area (sugar quota/average sugar yield per ha) by more than 10%, can be used as a rule of thumb by sugar beet growers. Moreover, use of the model delivers more insight in the relative profitability of sugar beet as compared to other crops.

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