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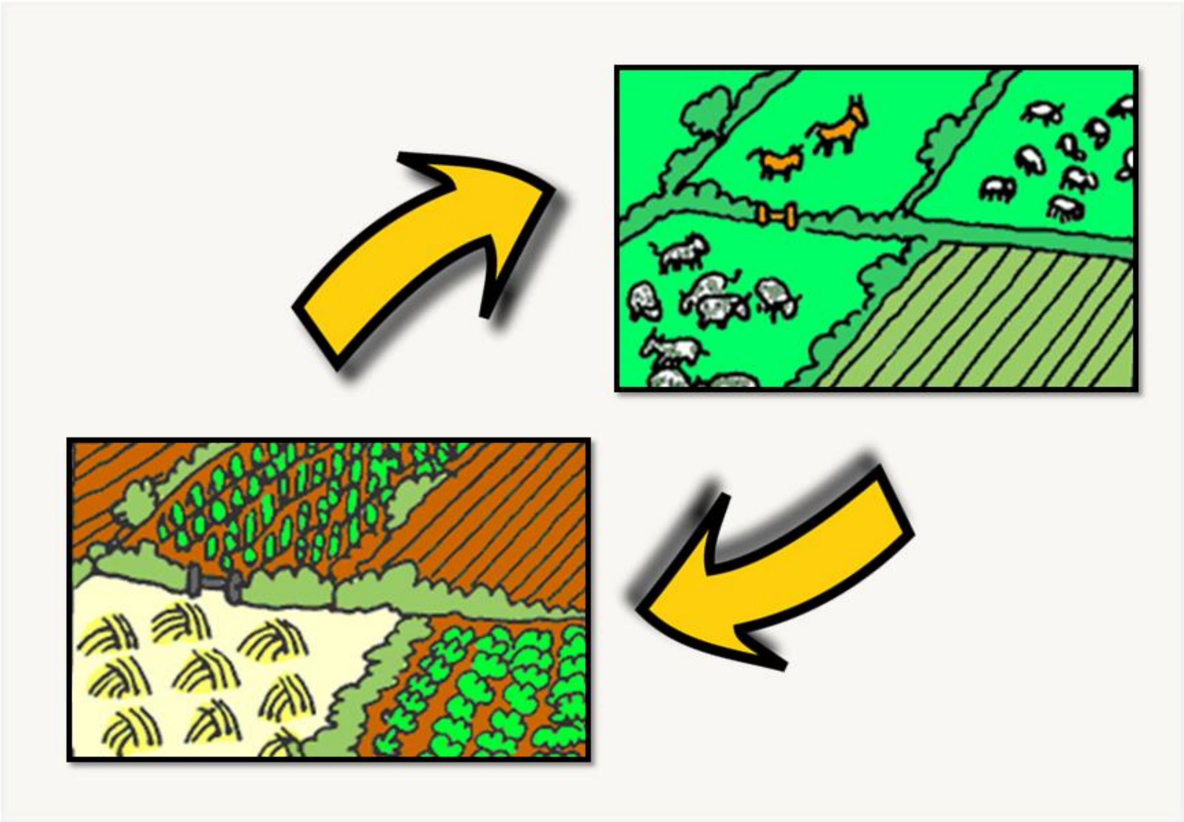

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MSc Thesis Plant Production Systems

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Summary

Bio-economic models (BEMs) have been developed for exploring farm plans and adaptation strategies accounting for constraints in biophysical and socio-economic resources. BEMs enable to link farmers' resource management decisions to alternative production possibilities with sets of input-output relationships of agricultural activities in formulations. BEMs have been widely applied under various agro-ecological conditions and several spatial and time scales. They also have been combined with other models (e.g. crop and market model) and approaches (e.g. participatory approach) in integrated assessment frameworks. However, although individual farms are interdependent in use of available farm resources in a region, the interactions among different farms are not often taken into account in existing BEM studies.

For example, in Flevoland (the Netherlands) it is common to exchange land among arable and dairy farms for more efficient resource use in the region. For arable farms, land exchange improves their economic performance since profitable crops can be grown on rented dairy land without considering crop rotational constraints. Dairy farms also receive benefits from land exchange, since they can apply manure on the rented arable land. Earlier studies revealed that the potential for land rent has a large impact on scenario studies in Flevoland.

The aim of this study is to evaluate the economic and environmental effects of land exchange among farms using a regional model based on linear programming (LP). To this end, first, a mathematical formulation considering the main components, important relationships, and restrictions that should be included in a regional land exchange BEM, was developed. The objective function was set as total gross margin being subject to various constraints. To avoid that some farms gain all benefits while others are going out of business we maximized the minimum gross margin increase (max-min approach). Next, in order to demonstrate the type of analysis that can be conducted and to assess the impact of land exchange, the regional model was applied to arable farming in Flevoland (the Netherlands). According to the data, there were 920 arable farms, which were classified in seven farm types based on the farming orientation, size and intensity. The number of dairy farms was 301, which is 24% of the total number of arable and dairy farms combined. The potato rotation constraint was set at once per three years, 30% of dairy land was allowed to be rented out to arable farms and regional production levels considering demand of crops were taken into account. A sensitivity analysis was conducted to assess the response to a change in the defined parameters and constraints.

Also, a spatial analysis was done to assess the effect of the assumption that the locations of both arable and dairy farms were distributed randomly in the region. Furthermore, the environmental effects of land exchange were assessed based on two indicators, effective organic matter (Eff_OM[1]), and nitrogen use (N use) from fertilizer and manure.

The results showed a small but positive impact of land exchange of +5.4% when total regional gross margin was maximized, and +3.5% for the more likely situation when benefits were distributed equally (max-min approach). Environmental impacts were small but negative: effective organic matter decreased with -1.0%, while nitrogen use increased with 1.3%. A stricter potato rotation constraint (once per four years), which is needed to maintain soil quality, increased the impact of land exchange (in the max-min approach) on gross margin to 10.4%, and at the same time reduced nitrogen use (-5.9%), but also reduced Eff_OM (-7.0%). When relaxing the regional production constraints (as not all crops are constrained by regional demand), the impact of land exchange on gross margin further increased to +18.8%.

The total gross margin maximization model encouraged high intensive farms to take most of the benefits of land exchange, while small scale farms went out of business. This can be explained by the higher yields on high intensive farms, and the assumption that yields depend on the farm type and not on the location. The max-min approach increased relative gross margin in an equal way across farms, but this encouraged small scale farms to grow more profitable crop in order to compensate their low productivity and rent out their land to other farms that can grow low profitable crops in more productive way than the small farms. This resulted in the decrease of average area of the small scale farms and the increase of gross margin per hectare. In this situation, the regional production constrained forced the large farms to produce less profitable crops. Although the farm distance and transportation frequency did not affect the total gross margin that much, the farms tended to exchange land with the close-by farms. This indicated that arable farms in Flevoland have enough access to dairy farms to rent land, improving their economic performance.

This study developed a regional BEM to assess the impacts of land exchange, and partially assessed the environmental and economic impacts of land exchange in terms of arable farmers. The impact on gross margin is relatively small with +3.5%, but may increase to +18.8% with a stricter potato rotation and no constraints regarding regional production. Changes in yields and prices may further affect the impact. Environmental impacts were smaller, but generally

[1] The effective organic matter is defined as the organic matter that is able to be used one year after application in the soil, which contributes to build up soil organic matter in the long term.

negative. The assessment can be extended by also considering the impact on dairy farms. For example, more efficient manure use may imply that nitrogen is used more efficiently at regional level.

Key words: bio-economic model; decision support; land exchange; mathematical programming; max-min; objective function

Abbreviations

AgriAdapt: Assessing the adaptive capacity of agriculture in the Netherlands to the impacts of climate change under different market and policy scenarios

BEMs: Bio Economic Models

CAP: Common Agricultural Policy

CBS: Dutch Agricultural Census

Eff_OM: Effective Organic Matter

FADN: Farm Accounting Data Network

FSSIM: Farm System SIMulator

LP: Linear Programming

N use: Nitrogen use

NGE: the Dutch version of European Size Unit

RHS: Right Hand Side

UAA: The Utilized Agricultural Area

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1. Introduction

1.1. Background

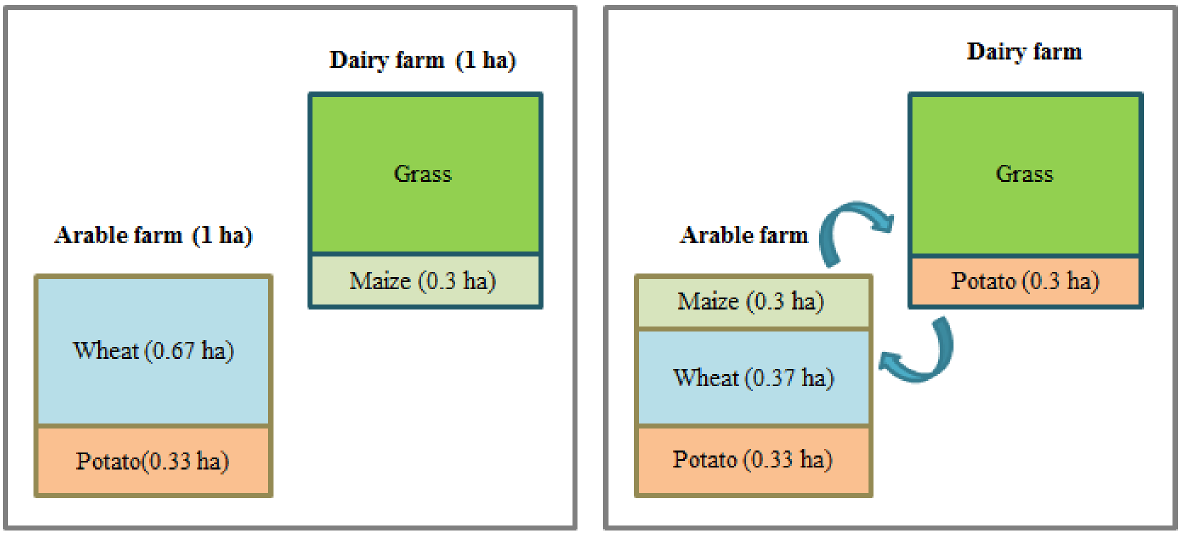
Current agricultural activities are affected by unprecedented changes caused by various exogenous drivers. For example, climate change will change crop yields in most areas (Kang et al. 2013; Challinor et al. 2014). Volatility in market prices has increased because of globalization and the market liberalization (FAO, 2011). Environmental regulation such as nitrogen use in fertilizer has become stricter, especially in developed countries (Lebacq et al., 2015). Furthermore, the demand for food has rapidly increased due to the population growth in the world (FAO, 2012). Nevertheless, an alarm has been raised for consuming a lot of available resources to produce food because of the depletion of the finite resources (Rockström et al., 2009). Hence, decision makers in the agricultural sector, such as farmers, policy makers and managers who are responsible for agricultural developments in private sectors, must explore alternative farming systems to adapt to the agro-ecological and socio-economic changes and enhance the resilience in farming, which can guarantee an adequate food production toward a sustainable future (Layton, 2011).

Bio-economic models (BEMs) have been developed for exploring farm plans and adaptation strategies accounting for constraints in biophysical and socio-economic resources (Fallis, 2013). The definition of a BEM is ``a model that links formulations describing farmers' decisions for resource management to formulations that define current and alternative production possibilities regarding required inputs to achieve certain outputs and associated externalities'' (Janssen and van Ittersum, 2007). The agro-ecological environment, the farm endowments, and the socio-economic environment, such as policies and demand and supply of the region, affect the decision making of the farmers. Therefore, a number of BEMs have been developed to simulate how different farms respond to changes in agricultural and environmental policies before their implementation (ex-ante assessment) under various agro-ecological conditions and several spatial and time scales (Abaza et al. 2004; Janssen & van Ittersum, 2007; Bezlepkina et al. 2011). Also, BEMs have been combined with other models and approaches in integrated assessment frameworks. For instance, climate change impacts and adaptation measures were assessed at crop and farm levels by combining a crop simulation model and a market model with a BEM and a participatory approach (Reidsma et al., 2015). Another example is the study by Wolf et al. (2015), where a BEM was linked with crop, market, and environmental emissions models to compare the relative significance of climate change to technological, management, price and policy changes of arable farming systems in several European countries. However, while interactions among farms regarding available farm resources are influencing farmers decision-making, adaptation strategies and impacts of scenarios (Regan et al., 2016), these are not often taken into account in the existing models (Flichman and Allen, 2013).

1.2. Problem description and available models

A farming system is composed of individual farm systems having their own resources, development strategies and constraints, and interacting among farms with common estate resources (Giller, 2013). Although the available resources can be exchanged in practice, they are often considered to be fixed within a story line of regional scenarios in current bio-economic studies (Berger & Troost, 2014). For example, it is very common to exchange or rent land among farmers. Such land exchange contributes to relaxing crop-rotation constraints and improving resource use efficiency in the region.

Here we describe an example to show that land exchange is able to provide a better farming performance in a region compared to one without land exchange. We assume that there is an arable farm of 1 ha that is growing potato and wheat, and a dairy farm of 1 ha that is growing grass and maize (Figure 1). The gross margins of potato and wheat are €6,000 per ha and €1,000 per ha, respectively. The arable farmer has a constraint of crop rotation. Potato can be grown once per three years to limit soil borne diseases and keep the soil quality. The dairy farm can rent 30% of his grassland to the arable farm. Land exchange enables the arable farmer to have a long potato-based crop rotation. When the arable farm only grows crops on his own land, the gross margin from potato (0.33 ha) and wheat (0.67 ha) is €2,650. Land exchange allows the arable farm to gain €4,150 from potato (0.63 ha) and wheat (0.37 ha), an increase of 57%. The dairy farmer can apply manure on both fields of potato and maize. Besides, he can ask the arable farmer to take care of the maize field, such as ploughing and spraying. Therefore, the land exchange can generate benefits for both farms. Land exchange might also change the farm profitability due to the farm structural change in terms of farm size and intensity.



Arable farm income without land exchange

Crop	Size (ha)	Gross margin (€ /ha)	Profit (€)
Potato	0.33	6000	1980
Wheat	0.67	1000	670
		Total	2650

Arable farm income with land exchange

Crop	Size (ha)	Gross margin (€ /ha)	Profit (€)
Potato	0.63	6000	3780
Wheat	0.37	1000	370
		Total	4150

Figure 1. The example of land exchange between an arable and a dairy farm. Each farm has 1ha of available land and exchange 30% of the land between the farms.

Current bio-economic models do not take into account this interaction between farms, implying that sub-optimal solutions are created at a regional scale. When land rent is included, the amount of rented land is often assumed to be fixed (e.g. Wolf et al., 2015), while knowledge on the potential for land rent is needed to estimate impacts of scenarios, as model results are very sensitive to this (Tsutsumi, 2015).

In order to utilize a BEM for scenario exploration in a certain region, it is important to consider how to aggregate from the individual farm level via a farm representation to regional levels (Hijmans & van Ittersum, 1996). Three main aggregation biases can arise by: i) spatially fixed input and output prices, ii) ignoring labour market inter-dependencies between farm types and iii) no interaction of resource endowments between farm types. According to Jansen & Stoorvogel (1998), if there is good infrastructure and distances between farms and markets in a region are small, the bias of spatially fixed prices is acceptable. Also, labour market inter-dependencies between farm types does not affect results too much. However, the simple sum of individual farm type models without taking into account the interactions of resource endowments between farm types does not represent the situation at regional level well. For instance, if a model can take into account a strategy that promotes local exchange of land and manure between farms, it will generate more efficient and effective solutions to utilize the local resources as shown in the above example.

Although several models that consider interactions between farms (e.g. Lobianco & Esposti, 2010; Happe et al., 2011; Schreinemachers & Berger, 2011), and studies that consider farm structural change due to changes in socio-economic and biophysical conditions exist (e.g. Bakker, et al., 2014; Happe et al., 2006; Mandryk et al., 2012), a BEM that includes resource exchange that can lead to important structural changes (size and intensity) of farms still does not exist (Flichman & Allen, 2013). In this study, we focus on the impact of land exchange among farms on agriculture at regional level.

1.3. The objective and research questions

The objective of this research is to evaluate the economic and environmental impacts of land exchange on arable farms using a regional bio-economic model. The research questions are: 1) What are the main components, important relationships, and restrictions that should be included in a regional BEM to capture land exchange interaction among farms? 2) What is the mathematical formulation of such a model? 3) What is the impact of taking into account land exchange between farms, in the case study Flevoland, in the Netherlands?, and 4) How sensitive are the model's results to the values of important input-output parameters and available resources?

To address the research questions, firstly, the requirements for a regional BEM were figured out through a review. The starting point for the model formulation was a farm optimization model based on linear programming (LP) with an objective function of maximizing total gross margin subject to a set of available resources and policy constraints. The model was programmed and solved in FICO Xpress. The model was applied to arable farming in Flevoland (the Netherland) with the available data of the region to demonstrate the type of analysis that can be conducted and to assess the impact of land exchange. It was also examined how different parameters and constraints would impact the objective value under a given set of assumptions.

The first two research questions are solved in the Material and methods section (see section 2). For the last two research questions, the answers are described in the Results section (see section 3). Finally, the usability and the limitations of the developed model are discussed.

2. Material and methods

2.1. Regional bio-economic model

In order to develop a regional bio-economic model which can take into account the interactions between farms, we formulated a farm optimization model based on linear programming (LP). Here the meaning of indices, parameters and variables used are explained in tables. The equations of the objective function and the required constraints for the regional land exchange are also described.

2.1.1. Sets, parameters and variables

Table 1 shows sets and indices of the model. Crops, arable farms, dairy farms and farm types of arable farms were set in the model.

Table 1. Sets and indices in the land exchange model

Index	Description
c	Index for crops
f, *k*	Index for arable farms
d	Index for dairy farms
t	Index for farm types of arable farms

Table 2 presents descriptions and units of used parameters.

Table 2. The descriptions and units of parameters in the land exchange model.

Parameters	Description	Unit
ADL_d	Available dairy land from dairy farm d that is available for land exchange	ha
$COSTS_{c,t}$	Variable production cost of crop c in farm type t	€/ha
$CRCo_c$	Rotation constraint for a specific crop c	-
$CRROTA_c$	Maximum share of a specific crop c	-
$Dis\_A_{f,f}$	Distance between two arable farms	km
$Dis\_D_{f,d}$	Distance between one arable and one dairy farm	km
$FT_{f,t}$	Mapping farm type f with farm type t i.e. if farm type f belongs to farm type t then $FT_{f,t}$ = 1 else 0	-
FQ	Frequency of visiting rented land	-
H_lab_C	Wage of hired labour	€/h
LAB_A_c	Required labour of crop c	h/ha
LAB_A_f	Available family/unpaid labour of farm f	h
$Manureuse_{c,t}$	Manure use per ha of crop c in farm type t	ton/ha
MP_c	Market price of crop c	€/ton
$Nuse_{c,t}$	Nitrogen use per ha of crop c in farm type c	kg/ha
$FOCUS_c$	Percentage of the focus area of crop c	%
$OLAND_f$	Owned arable farm area of farm f	ha

$PARL$	Rental cost of arable land for other arable farms	€/ha
$PDRLin$	Rental cost of dairy land for arable farms	€/ha
$PDRLot$	Rental cost of arable land for dairy farms	€/ha
Pro_Max_c	Maximum production level of crop c in a region	ton
Pro_Min_c	Minimum production level of crop c in a region	ton
$QUOTA_c$	Quota of crop c	-
$ROTA_c$	Maximum share of crop c in arable land	%
SOM_c	Effective organic matter per ha of crop c	kg/ha
SUB_f	Amount of quota of sugar beet of farm f	ton
TC	Transportation cost per ha of rented land	€/ha/km
TGM_f^o	Maximized individual farm gross margin without land exchange	€
$Yield_{c,t}$	Yield of crop c in farm type t	ton/ha

Variables in the model are shown in Table 3. For capturing land exchange, variables $ARLin_{f,k}$ and $ARLot_{f,k}$ indicate the area of exchanged land among arable farms. Besides, variables $DRLin_{f,d}$ and $DRLot_{f,d}$ show the area of exchanged land among arable and dairy.

Table 3. The descriptions and units of variables in the land exchange model.

Variables	Description	Unit
$ARLin_{f,k}$	Area that is rented in by arable farm f from arable farm k	ha
$ARLot_{f,k}$	Area that is rented out by arable farm f to arable farm k	ha
$DRLin_{f,d}$	Area that is rented in by arable farm f from dairy farm d	ha
$DRLot_{f,d}$	Area that is rented out by arable farm f to dairy farm d	ha
Eff_OM	Total effective organic matter	kg
$GM_{c,t}$	Farm gross margin of crop c in farm type t	€
g_m	Auxiliary variable g-	-
g_p	Auxiliary variable g+	-
H_Lab_f	Total hired labour of farm f	h
RGM	Relative change of gross margin of farm	%
TGM	Total regional gross margin	€
TGM_f	Total gross margin of farm f	€
$TLAND_f$	Total land area of farm f after land exchange	ha
$T\_Manureuse$	Total manure use	ton
T_Nuse	Total nitrogen use	kg
$X\_CR_{c,f}$	Area of crop c in farm type t	ha

2.1.2. Objective functions

In terms of practical decision-making, farmers focus mostly on economic result maximization, although they are concerned about other indicators such as soil organic matter balance as a long-term farm performance as well (Mandryk et al., 2014). In this study we assumed that the main objective of the farmer is maximization of total gross margin (Equation 1).

$$max\left\{\begin{aligned} TGM = & \sum_{c,f,t} GM_{\ c,t} * (\text{X\_CR}_{\ c,f}) + \sum_{f,k} PARL * \left(ARLot_{f,k} - ARLin_{f,k}\right) \\ & - \sum_{f,d} PDRLin * DRLin_{f,d} + \sum_{f,d} PDRLot * DRLot_{f,d} \\ & - \sum_{f} H\_lab\_C * H\_lab_{f} - \sum_{f,k \in AF_f} TC * FQ * Dis\_A_{f,f} * ARLin_{f,k} \\ & - \sum_{f,d \in DF_f} TC * FQ * Dis\_D_{f,d} * DRLin_{f,d} \end{aligned}\right\} \tag{1}$$

where *TGM* is the total gross margin (€) in a region, $GM_{c,t}$ is the gross margin of each crop *c* in farm type *t* (calculated as $GM_{c,t} = yield_{c,t} \cdot MP_c - COST_{c,t}$), $X\_CR_{f,c}$ is the optimal level of crop *c* in farm *f*, *PARL* is price for arable rented land, $ARLotL_{f,k} - ARLinL_{f,k}$ is the area of land exchange between arable farms, *PDRLin* is the cost to rent in dairy land, while *PDRLot* is the gain when arable farms rent out land to dairy farms, $DRLin_{f,d}$ is area of rented in land, $DRLot_{f,d}$ is area of rented out land, *H_lab_C* is the hired labour cost per hour and H_Lab_f is the optimal level of time for hired labour for farm f. *TC* indicates transportation costs per distance (km) between the farms. *FQ* means the frequency that farmers have to go to the rented land far from their original places to do activities such as planting, fertilization and harvesting. The area of rent in land (ha) is multiplied by the transportation cost. The transportation costs are calculated for both land exchange among arable farms and arable and dairy farms. AF_f and DF_f are the sub-set of farms that are close enough to exchange land.

The main reason for land exchange is relaxation of farm specific rotational constraints and improvement of economic performance. In order to avoid a situation that the benefits of land exchange go to part of the farms and the others do not get anything, a max-min approach is introduced, equalizing the relative change in gross margin per arable farm (*RGM*). A new objective function: maximization of minimum relative change in gross margin per arable farm is applied (equation 2)

$$max\ \{RGM\} \tag{2}$$

Where

$$\frac{TGM_f - TGM_f^o}{TGM_f^o} 100 \le \ RGM \qquad \forall f \tag{3}$$

Where TGM_f in equation 3 is the optimized individual gross margin taking into account land exchange. TGM^0_f is the optimized individual gross margin without land exchange. Variable *RGM* is the relative change of gross margin (%) that shows the difference between TGM_f and TGM^0_f. The benefits of land exchange are distributed more equally among farms by maximizing *RGM*. In this case, the *RGM* can not be negative.

In addition to the total gross margin, we calculated the outcomes of effective organic matter and nitrogen use with equations 4 and 5 in order to evaluate some environmental impacts of land exchange:

$$Eff\_OM = \sum_{c,f} X\_CR_{c,f} * SOM_c \tag{4}$$

$$Nuse = \sum_{c,f,t} X\_CR_{c,f} * Nuse_{c,t} \tag{5}$$

2.1.3. Constraints

The objective function is optimized subject to a range of resources and policy constraints. The values of resources and constraints can be uncertain, the sensitivity to these will be evaluated in the model runs.

Available land

The available land constraint is:

$$\sum_{c} X\_CR_{c,f} \le \ TLAND_f \qquad \forall f \tag{6}$$

$$TLAND_f = \ OLAND_f + \sum_k \left(ARLin_{f,k} - ARLot_{f,k}\right) + \sum_d \left(DRLin_{f,d} - DRLot_{f,d}\right) \qquad \forall f \tag{7}$$

where $TLAND_f$ is equal to the currently owned land ($OLAND_f$) plus the area rented from other arable farms and dairy farms ($ARLin_{f,k}$, $DRLin_{f,d}$), minus the area rented to other arable farms and dairy farms ($ARLot_{f,k}$, $DRLot_{f,d}$). The available land constraint makes sure that in each arable farm the total optimal crop level does not exceed the total available land of each farm (Equation 6).

Limit size of exchanged land

The relationship between variables $ARLin_{f,k}$ and $ARLot_{k,f}$ should be equal, since when one arable farm rents in a certain size of land from another arable farm, the other arable farm rents out the land to the arable farm (equation 8, Figure 2).

$$ARLin_{f,k} = ARLot_{k,f} \quad \forall f, k \tag{8}$$

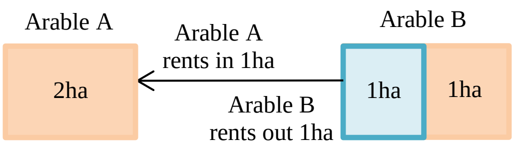


Figure 2. Land exchange among arable farms (equation 8).

For dairy land, the exchange with arable land is more flexible than exchange between arable farms. The equation 9, constraint 'size of exchanged dairy land' indicates that the total size of rented dairy land by arable farms is equal to total size of rented out arable land to dairy farms (Figure 3). The land exchange rate among arable and dairy farms was assumed to be one to one in this study.

$$\sum_f DRLin_{f,d} = \sum_f DRLot_{f,d} \quad \forall d \tag{9}$$

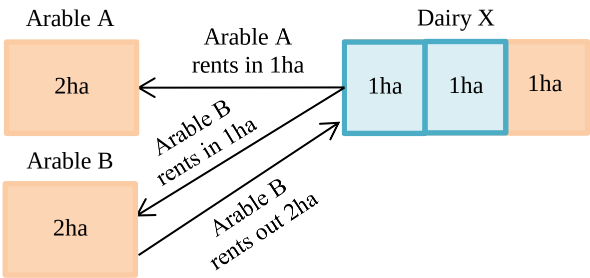


Figure 3. Land exchange among arable and dairy farms (equation 9).

A subletting among farms was not allowed in this model. Therefore, the total size of rented arable land from one farm to another was set to be smaller than the owned arable land of the farm from which the land is rented (equation 10). In the same way, the total size of rented dairy land should not be larger than the original size of the dairy farm in each dairy farm (equation 11, Figure 4)

$$\sum_{f} ARLin_{f,k} \leq OLAND_k \quad \forall k \tag{10}$$

$$\sum_{f} DRLin_{f,d} \leq ADL_d \quad \forall d \tag{11}$$

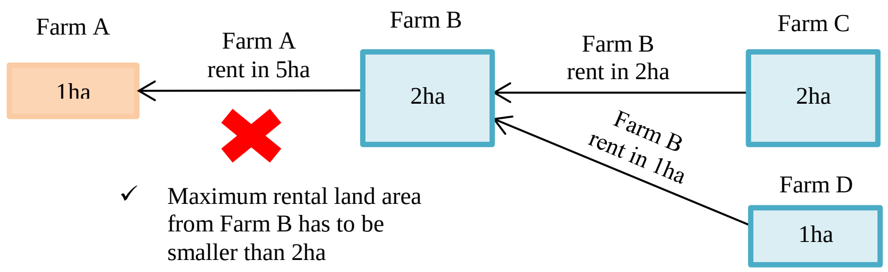


Figure 4. Limit size of exchanged land (equation 10 and 11).

Specific focus area

The model also has a constraint which encourages farms to keep a certain amount of space for a specific reason. For example, the EU has the greening policy. All farms that have over 15 ha have to keep a certain percentage of their land (including the rented land) as ecological focus area. Therefore, the focus area per farm ($X\_CR_{\text{"focus area"},f}$) should be greater than total land size ($Land_f$) multiplied by the certain percentage of crop c ($FOCUS_c$) (equation 12)

$$X\_CR_{\text{"focus area"},f} \geq TLAND_f \cdot FOCUS_c \quad \forall c, f \mid FOCUS_c > 0 \tag{12}$$

Quota system

We set up a constraint for quota systems for a certain crop, with the current production level as an upper bound. For instance, the exceeded amount of sugar beet production has no economic benefit in the Netherlands. Consequently, the constraint describes that the amount of simulated quota crop area on each farm ($\sum_t X\_CR_{quota\ crop,f}$) multiplied by the yield of crop c in farm type t ($YIELD_{quota\ crop,t}$) does not exceed the current production level in each farm (SUB_f) (equation 13).

$$\sum_{t} X\_CR_{"quota\ crop",f} * YIELD_{quota\ crop,t} \leq SUB_f * QUOTA_c \quad \forall f|QUOTA_c = 1 \tag{13}$$

Crop rotation

The crop rotation constraint determines that the amount of a certain crop production cannot exceed the rotation frequency in arable farms including rented in arable land ($ARLot_{f,k}$) and rented out arable land to other arable farm ($ARLinL_{f,k}$). We assumed that any crop can be grown without the rotation constraint in the rented dairy land ($DRLin_{f,d}$) as another field is rented each year (equation 14).

$$X_{CR_{c,f}} \leq \{AREA_f + \sum_{k}(ARLin_{f,k} - ARLot_{f,k}) - \sum_{d} DRLot_{f,d}\} * ROTA_c + \sum_{d} DRLin_{f,d} \ \forall c,f \tag{14}$$

For crops in the same family, an additional rotation constraint is needed (equation 15). For example, when a farm grow seed potato and consumption potato at the same time, the total frequency of potatoes should be within the potato rotation constraint, in addition to the single crop rotation constraint. The simulated area of the specific family crop production per farm ($\sum_c X\_CR_{c,f} * CRCo_c$) should be smaller than the sum of total arable area times the specific family crop rotation ($CRROTA_c$) plus dairy rented area.

$$\sum_{c} X\_CR_{c,f} * CRCo_c \leq \{AREA_f + \sum_{k}(ARLin_{f,k} - ARLot_{f,k}) - \sum_{d} DRLot_{f,d}\} * CRROTA_c + \sum_{d} DRLin_{f,d} \quad \forall f|CRCoc = 1 \tag{15}$$

Available labour

The labour constraint describes that the simulated total labour requirement ($\sum_c X\_CR_{c,f} * LAB_c$) of all crops should be less than farm labour availability (LAB_A_f) plus hired labour (LAB_H_f) (equation 16).

$$\sum_{c} X\_CR_{c,f} * LAB_c \leq LAB\_A_f + LAB\_H_f \quad \forall f \tag{16}$$

Regional production constraint

We set a maximum regional production constraint to avoid surplus production for each crop. It is determined based on the demand in a region. The simulated total production in each crop ($\Sigma_{f,t}$ $X\_CR_{c,f} * YIELD_{c,t}$) should be less than the parameter of maximum production level of the crop (Pro_Max_c) (equation 17).

Also, the minimum production level is determined by the constraint to meet the minimum needs of crops and prevent from monoculture production in a region. The simulated total production in each crop is set to be greater than the parameter of the minimum production level in each crop (Pro_Min_c) (equation 18).

$$\sum_{f,t} X\_CR_{c,f} * YIELD_{c,t} \leq Pro\_Max_c \quad \forall c \mid Pro\_Max_c > 0 \tag{17}$$

$$\sum_{f,t} X\_CR_{c,f} * YIELD_{c,t} \geq Pro\_Min_c \quad \forall c \mid Pro\_Min_c > 0 \tag{18}$$

2.2. Data set for Flevoland case study

The above model was applied for a case study of arable farming in Flevoland (the Netherlands). General information and the background of land exchange in Flevoland is described. Furthermore, used data set is shown in this section.

2.2.1. Case study: Flevoland, the Netherland

Flevoland is located in the center of the Netherlands (Figure 5). It was established in 1986 as the twelfth province. There are favorable conditions for agricultural production due to the high quality soils, good infrastructure, availability of an efficient land use and water availability. There are mainly large arable farms specialized in the production of profitable crops like carrots, onions, potatoes and sugar beet. According to the Dutch Agricultural Census (CBS 2016), the total size of farms specialized in field crops in Flevoland in 2015 was 52,316 ha, and the number of farms was 938 (average size: 55.8 ha). Regarding dairy farms in Flevoland, the total size of dairy farms was 15,112 ha, and the number of farms was 298 (average size: 50.7 ha).

Farm structural change has taken place due to a complex and dynamic process of farms adaptations to external and internal driving factors. The structural change can force some farms to stop farming, and others to expand and/or intensify. In Flevoland several exogenous factors, such as technology developments, and changes in markets, policy and climate, have affected changed land use in the last 30 years (Mandryk et al., 2012). The number of arable farms declined by 30% between 1980 and 2010, while the average size of farms increased by 20% (CBS, 2009). One of the main reasons is that farmers tend to have scale merits through increasing farm size because prices of main crops in Flevoland have been decreasing over time.

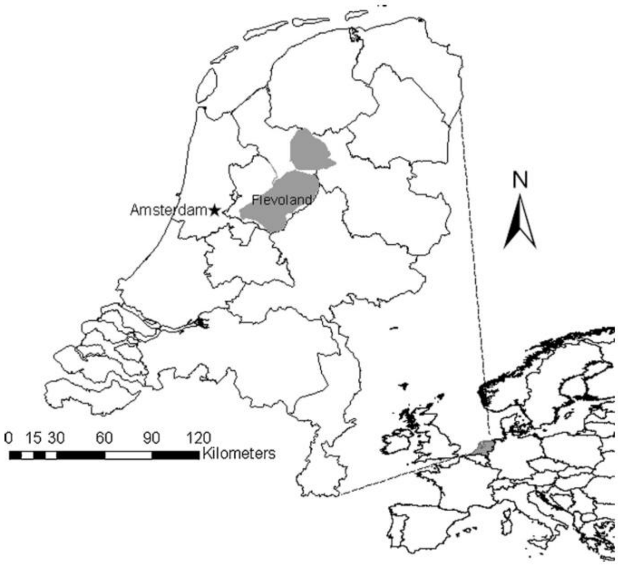


Figure 5. The map of Flevoland in the Netherland.

2.2.2. Land exchange in Flevoland

In Flevoland, it is very common that arable and dairy farmers exchange land. Arable farms have to apply their crop rotation including less profitable crops such as winter wheat to avoid soil borne diseases and maintain the soil quality. However, the profits from these crops hardly pay for the land use cost. Therefore, arable farmers want to exchange their land with land from dairy farms that previously produced grass or maize. This enables them to raise their total gross margin by increasing the production of more profitable crops. Dairy farms have land available, but they have to keep more than 70% of grassland in order to apply 250 kg manure N ha^{-1} due to the nitrogen legislation; otherwise, they can only apply 170 kg manure N ha^{-1} on average (European Commission, 2015). Hence, thirty percent of dairy land is generally exchangeable with arable farms. A land exchange rate is not always one to one, since land is exchanged based on its value; i.e., how much profits can be generated on the land. Consequently, if an arable farmer rents one ha from a dairy farmer to grow potato, the dairy farmer gets from one and a half to two ha of arable land in order to grow maize, although specific arrangements are the results of negotiations. This means that land exchange with arable farms enables the dairy farmer to grow more maize than before. Also, the dairy farmer can have more possibilities to apply manure on both exchanged fields. This is an incentive for the dairy farmer to exchange land, because he can avoid to pay for disposal of manure. In addition, the dairy farmer can get services from the arable farmer. For example, if the dairy farmer grows maize on rented land, the arable farmer can plough the field and spray maize as a service. From this point of view, the cooperation between arable and dairy farms can contribute to optimal farm management regarding more efficient use of available resources at the regional level.

2.2.3. Farm typology

In this study, the farms were grouped into seven farm types (PMM, PMH, PLM, PLH, EMM, ELM and NLM) based on the farm typology of the European Union proposed by Andersen et al. (2007) and Mandryk et al. (2012) (Table 4 and Table 5). The typology is based on three main dimensions i.e. size, intensity and orientation. The size is determined by economic size using the Dutch version of European Size Unit (NGE). One NGE is equivalent to € 1,420. The intensity is based on NGE per ha. Regarding the orientation, farms are classified based on the current activities in (i) production oriented farms that are only focusing on food production (no multifunctional activities or less than 10% output from one multifunctional activity), (ii) entrepreneur oriented farms that have output from multifunctional activities between 10 to 50% or they have different activities except for nature conservation, (iii) nature oriented farms that are participating in nature conservation.

Table 4. Farm typology used in the research based on Mandryk et al., (2012).

Dimension	Division	Threshold
Size (NGE)	Medium	< 70
	Large	≥ 70
Intensity (NGE/ha)	Medium	< 2.0
	High	≥ 2.0
Orientation	Production	No multifunctional activities or less than 10 % outcome from one multifunctional activity
	Entrepreneur	More than 10 % income from alternative societal agricultural activities or minimum two different activities apart from nature conservation
	Nature	Participating nature conservation

*One NGE is equivalent to € 1,420.

The utilized agricultural area (UAA) and farm number were recalculated based on the statistical data used in Mandryk et al. (2012) (Table 5 and Appendix Table A1). 1009 arable farms were classified into twenty-three groups in Mandryk et al. (2012) (see Appendix Table A1). Although for only six farms input-output data were collected in Mandryk et al. (2014), we summarized the twenty-three groups into seven farm types. We chose only arable farms excluding vegetable and flower farms. The small size farms were included to medium size, and very large size farms were added to large size farms. Nature oriented farms were all grouped into a medium intensity farm since there was no input-output data for high intensity farms and the portion of nature oriented farm was only 2 % in total utilized agricultural area in Flevoland. Finally, 920 arable farms were assumed to exist using 50,876 ha of land in Flevoland, which covers 93% of the original farm groups from Mandryk et al. (2012) (see Appendix Table A3). In addition to that, there are 301 dairy farms of which the average size is 45.9ha and 30% of the land is exchangeable with arable land (based on data from 2008, similar to the arable farms) (see Appendix Table A4). The size of individual farms was determined by using a distribution with the average farm size of each farm type and a standard deviation of the average farm size of each farm type times 0.05. The available labour per individual farm was calculated based on the available labour per farm representing the farm type (Mandryk et al., 2014) and a standard deviation of the representing available labour per farm type times 0.05. It should be noted that the available labour is not based on average, but on the data of one farm per farm type only. Regarding the available labour for PMM and PMH that were not investigated in Mandryk et al., (2014), the values were created based on PLM (for PMM) and PLH (for PMH) multiplying the ratio of available labour between medium and large size farms (EMM/ELM = 0.32). For hired labour, €16.5 per hour was used assuming all-around workers that work 7 hours per day for 20 days per month were hired in farms (KWIN-AGV 2015).

Table 5. The land size, number and available labour for seven arable farm types used in this study.

Farm type	Orientation	Size	Intensity	UAA[a] (ha)	Number [b]	average size [c] (ha)	available labour [d] (h/year)
PMM	Production	Medium	Medium	8,678	300	28.9	915
PMH		Medium	High	2,042	85	24.0	1056
PLM		Large	Medium	23,821	295	80.8	2860
PLH		Large	High	10,039	140	71.7	3300
EMM	Entrepreneur	Medium	Medium	1,191	30	39.7	1600
ELM		Large	Medium	3,488	51	68.4	5000
NLM	Nature	Large	Medium	1,616	19	85.1	4080
Total				50,876	920	55.3	

*[a]UAA is utilized agricultural area
* [b]Number and [c]average size are from the AgriAdapt project (Mandryk et al., 2012)
* [d]Available labour is from Mandryk et.al. (2014)

2.2.4. Crop characteristics

Farm and crop characteristics were based on individual farm data which were collected by interviews in spring 2011 (Mandryk et al., 2014, Table 6). Each individual farm represented a different farm type and the yields are determined based on the intensities (practices) and not on the location. The data of Mandryk et al. (2014) did not include farm types that were production oriented with medium size, therefore, the characteristics of these two farm types were determined by referring to the same intensity in the large size class. Regarding the costs of seed potato, the original value was quite high (€ 7,633/ha) compared to other crop costs and the calculated gross margin was not comparable with that of other data sources, the CBS-Statline and LEI between 2008 and 2010 (Schaap et.al., 2013). Hence, the seed potato costs were adjusted to the one (€ 2,043/ha) used in Schaap et al (2013). We added fertilizer N, P and K costs at €0.69, €1.70 and €0.47 per kg to the costs. The commodity price of urea, TSP and potassium chloride were taken from the World Bank, averaged between 2013 and 2015 (World Bank, 2016). The composition of N, P and K was assumed at 46%, 21% and 63%, respectively.

Among the crops, on average seed potato is most profitable, followed by winter carrot, seed onion, consumption potato, chicory, sugar beet, green pea and winter wheat for the farm types that have medium intensity level (Figure 6). In terms of the crop profitability of farm types that have high intensity, seed onion is slightly more profitable than winter carrot. From Mandryk et.al. (2014), we could only get crop data for a farm type if the interviewed farm cultivated that specific crop. However, here all farms were allowed to grow all crops described in Mandryk et al. (2014). When crop data were lacking, we used data from a farm type that had the same orientation or intensity.

All crops have their own effective organic matter (Eff_OM) values, which refer to the contribution of organic matter input from the crop residues. To calculate organic matter balances per crop, more data are needed, but this was beyond the scope of this study. Using the Eff_OM values can provide first insights in environmental impacts of activities. Furthermore, the application of artificial and organic fertilizer per crop were provided per farm representing a farm type. The nitrogen use (kg per ha) per crop per farm type was calculated based on their combination of artificial and organic fertilizers. The nitrogen content of manure was assumed at 4.1kg per ton manure on a fresh weight basis (Rosen & Bierman, 2005).

Table 6. Crop characteristics per arable farm type (Mandryk, 2014).

Farm type	Crops	Price (€/ton)	Yield (ton/ha)	Costs (€/ha)	GM (€/ha)	Labour (h/ha)	Eff. OM (kg/ha)	Artificial fertilizer (kg/ha)			Organic fertilizer (1000kg/ ha)
								N	P	K	
PMM	Seed potato	260	45	2043	9657	70	900	72	42	96	0
	Winter carrot	140	85	2,992	8,908	21	150	54	0	112	0
	Seed onion	130	70	2727	6373	37	150	125	48	93	0
	Consumption potato	140	63	2610	6210	26	900	54	0	180	40
	Sugar beet	40	100	1635	2365	14	1400	120	0	0	0
	Chicory	130	35	2,255	2,295	44	650	0	0	0	20
	Green peas	170	8	170	1,190	11	500	27	69	0	0
	Winter wheat	140	11	786	754	13	2650	81	0	0	30
	Fallow	0	0	0	0	0	0	0	0	0	0
PMH	Seed potato	260	44	2043	9397	70	900	30	0	0	20
	Winter carrot	140	85	2,992	8,908	21	150	54	0	112	0
	Seed onion	130	90	2727	8973	37	150	0	0	0	20
	Consumption potato	140	63	2610	6210	26	900	54	0	180	40
	Sugar beet	40	90	1635	1965	14	1400	54	0	0	20
	Chicory	130	35	2,255	2,295	44	650	0	0	0	20
	Green peas	170	8	170	1,190	11	500	27	69	0	0
	Winter wheat	140	11	786	754	13	2650	81	0	0	30
	Fallow	0	0	0	0	0	0	0	0	0	0
PLM	Seed potato	260	45	2043	9657	70	900	72	42	96	0
	Winter carrot	140	85	2,992	8,908	21	150	54	0	112	0
	Seed onion	130	70	2727	6373	37	150	125	48	93	0
	Consumption potato	140	63	2610	6210	26	900	54	0	180	40
	Sugar beet	40	100	1635	2365	14	1400	120	0	0	0
	Chicory	130	35	2,255	2,295	44	650	0	0	0	20
	Green peas	170	8	170	1,190	11	500	27	69	0	0
	Winter wheat	140	11	786	754	13	2650	81	0	0	30
	Fallow	0	0	0	0	0	0	0	0	0	0
PLH	Seed potato	260	44	2043	9397	70	900	30	0	0	20
	Winter carrot	140	85	2,992	8,908	21	150	54	0	112	0
	Seed onion	130	90	2727	8973	37	150	0	0	0	20
	Consumption potato	140	63	2610	6210	26	900	54	0	180	40
	Sugar beet	40	90	1635	1965	14	1400	54	0	0	20
	Chicory	130	35	2,255	2,295	44	650	0	0	0	20
	Green peas	170	8	170	1,190	11	500	27	69	0	0
	Winter wheat	140	11	786	754	13	2650	81	0	0	30
	Fallow	0	0	0	0	0	0	0	0	0	0
EMM	Seed potato	260	45	2043	9657	70	900	114	136	240	0
	Winter carrot	140	85	2,992	8,908	21	150	115	0	240	25
	Seed onion	130	80	2727	7673	37	150	133	49	240	0
	Consumption potato	140	55	2610	5090	26	900	359	135	366	0
	Sugar beet	40	90	1635	1965	14	1400	122	0	90	0
	Chicory	130	35	2,255	2,295	44	650	24	38	173	0
	Green peas	170	7	170	1,020	11	500	27	0	0	25
	Winter wheat	140	10	786	614	13	2650	213	42	0	0
	Fallow	0	0	0	0	0	0	0	0	0	0
ELM	Seed potato	260	45	2043	9657	70	900	114	136	240	0
	Winter carrot	140	85	2,992	8,908	21	150	115	0	240	25
	Seed onion	130	80	2727	7673	37	150	133	49	240	0
	Consumption potato	140	55	2610	5090	26	900	359	135	366	0
	Sugar beet	40	90	1635	1965	14	1400	128	0	0	0
	Chicory	130	35	2,255	2,295	44	650	24	38	173	0
	Green peas	170	7	170	1,020	11	500	27	0	0	25
	Winter wheat	140	10	786	614	13	2650	213	42	0	0
	Fallow	0	0	0	0	0	0	0	0	0	0

NLM	Seed potato	260	45	2043	9657	70	900	72	42	96	0
	Winter carrot	140	85	2,992	8,908	21	150	115	0	240	25
	Seed onion	130	70	2727	6373	37	150	140	18	155	0
	Consumption potato	140	63	2960	5860	26	900	265	35	150	0
	Sugar beet	40	100	1635	2365	14	1400	122	0	90	0
	Chicory	130	35	2,255	2,295	44	650	24	38	173	0
	Green peas	170	7	170	1,020	11	500	27	0	0	25
	Winter wheat	140	11	786	754	13	2650	199	0	0	0
	Fallow	0	0	0	0	0	0	0	0	0	0

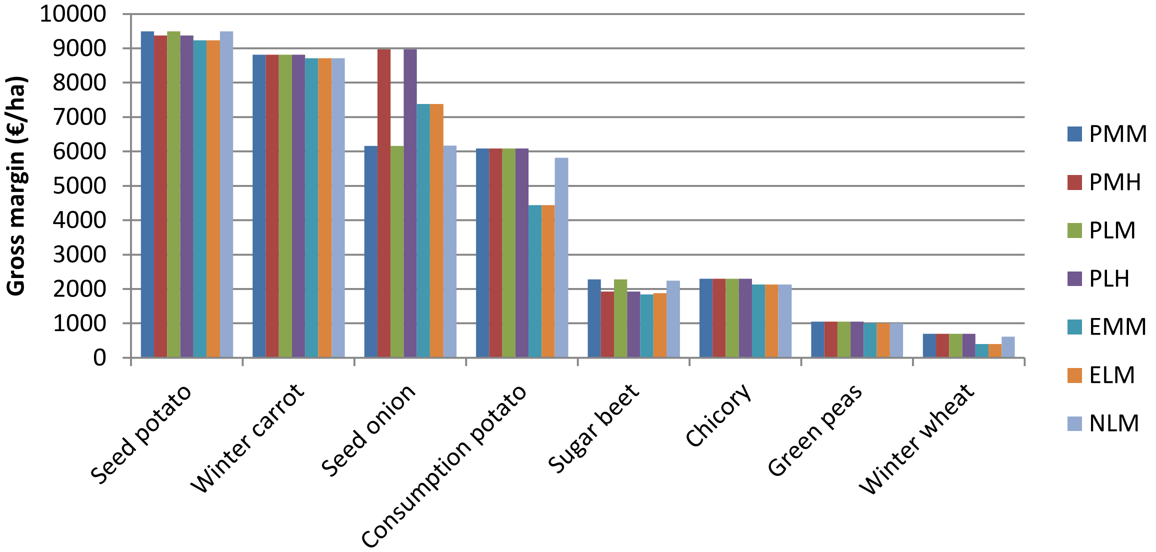


Figure 6. Regional crop production level for each crop per farm type.

2.2.5. Available resources and RHS of constraints

Crop rotation

There is a crop rotation constraint for every crop (Table 7). Potatoes including both consumption and seed potato cannot be cultivated more than once every three years (0.33). For seed potato, the maximum is once every four years (0.25).

Table 7. Crop rotation constraints (based on Mandryk et al., 2014).

	Rotation
Winter carrot	0.17
Seed onion	0.17
Potatoes[a]	0.33
Sugar beet	0.2
Chicory	0.25
Green pea	0.17
Winter wheat	0.5

[a] potatoes 0.33 includes seed potato 0.25

Ecological focus area

We assumed that there has to be fallow land as 'ecologically beneficial elements' according to the greening policy under the 2013 CAP reform in the EU (European Parliament, 2013). The arable farms that have more than 15 ha have to dedicate at least 5% to ecological beneficial elements. Hence, all farms kept 5% of their total land, including the rented land, as fallow area (Melorose, et al., 2015).

Sugar beet quota

Sugar beet production was determined for each farm to be on average less than that of current production level, which was 18.4% of the total farm area. It was calculated by available land per farm multiplied by 0.184 with a standard deviation (the yield times 0.05). Sugar beet quota will be abolished 2017, but as they are still in place in the years simulated, they were included in the model.

Regional production level

We set up the limitation of regional productions since the demand of the agricultural production has to be taken into account in the regional model to avoid surplus production. The limit amounts (ton) of each crop were identified by 130% of the average production levels from 2011 to 2015 in Flevoland (Table 8). The data were taken from CBS and Eurostat. Regarding green pea, there was no data specifically. We assumed the maximum production level of green pea is 1,000 ton.

Farmers in Flevoland grow less profitable crops, such as winter wheat to keep soil quality in the field. There should be an organic matter balance constraint; however, we do not have data for the calculation. Therefore, minimum production level for each crop were applied to ensure a certain level of soil quality and minimum demand in Flevoland. The values were based on 70% of the average production levels between 2011 and 2015 in Flevoland.

Table 8. The crop production level in Flevoland for five years and the average (ton) (CBS, 2016)

	2011	2012	2013	2014	2015	Average
Seed onion	659,875	605,436	542,953	519,841	544,160	574,453
Winter carrot	340,367	309,313	539,897	-	-	396,526
Consumption potato	611,310	555,028	529,149	554,340	460,073	541,980
Seed potato	328,162	343,790	331,531	338,506	350,870	338,572
Sugar beet	852,738	843,858	859,845	1,001,273	768,931	865,329
Chicory	1,252	2,712	2,355	1,655	1,971	1,989
Green peas	-	-	-	-	-	-
Winter wheat	121,423	136,831	141,593	129,146	128,439	131,486

Land exchangeable distance between farms

We assumed that farms are allowed to exchange land between different farms only when the distance between the farms is within 3 km in this study. There is no regulation about the exchange distance in Flevoland; however, this is needed in order to avoid the latency issue of the model run because the model is supposed to calculate about a half million distance combinations for 920 farms.

2.2.6. Costs of land exchange

Land rental price

The rental prices for agricultural land in the Netherlands are quite high compared to other European countries. According to the statistical data from FADN (2011), the rental cost is €895 per ha in 2008 in the Netherland, compared to Denmark and Greece at €599 and €273, respectively. The rental cost in Flevoland is relatively high compared to other provinces in the Netherlands. According to Rijksdienst voor Ondernemend Netherland (2015), the price is €1174 per ha. This rental price was used when arable farms rent in other arable farms and dairy farms. When arable farms rent out their land to dairy farms, the gain from land rental was assumed to be half of cost of land rental since generally profitable crops are grown in the dairy rented land, while less profitable crops are grown in arable rented land.

Transportation cost

We took into account the transportation costs based on the gasoline price in the Netherlands, using the highest price within three months in 2016 (from 18th of July to 17th of October: http://www.globalpetrolprices.com/Netherland/gasoline_prices/) and assuming fuel efficiency is 16 km/L. We also assumed that farmers have to go to the rented land eight times for farming activities: ploughing, planting, fertilization (two times), spraying (two times), irrigation and harvesting in a year. Therefore, the transportation cost is calculated as: X(distance between farms) km * € 1.52 (euros/L) * 8 (activities) * 2 (return) /16 (km/L).

2.3. Setup of calculations and model simulations

Three type of simulations were run in this study in order to figure out the impacts of land exchange. There are shown in this section. Sensitivity and spatial analysis are also explained here.

2.3.1. Land exchange in a regional model

Three simulations were run to evaluate the economic and environmental impacts of land exchange in Flevoland (Table 9). Simulation_1 optimizes total gross margin in a region without land exchange; the simulation just sums up the optimized gross margin of individual farms. Simulation_2 optimizes the regional gross margin with taking into account land exchange. Simulation_3 also optimizes the regional gross margin with taking into account land exchange, but uses the max-min approach. The difference with simulation_2 is that simulation_3 tries to distribute the benefits of land exchange to all farms ensuring the gross margin for each farm before taking into account land exchange. For the simulation_3, first, we run the model without land exchange (simulation_1) and got the optimized gross margin for each farm (TGM_f^0). It was used to calculate the relative change of gross margin of farm. The minimum relative change was maximized in simulation_3.The simulations were programmed and solved in FICO Xpress (see Appendix Model script).

Table 9. The classification of the three simulations.

	Simulation_1	Simulation_2	Simulation_3
Objective function	Maximization of total gross margin	Maximization of total gross margin	Maximization of minimum relative change of gross margin
Land exchange	No	Yes	Yes
Max-min approach	No	No	Yes

The model was defined in a way that arable farms rent out land to dairy farms from which they rent in land, as much as possible, because the land exchange is generally conducted as a one-to-one or one-to-many relationship among farms. Therefore, the auxiliary variables *g_m* and *g_p* were included in the equation $DRLin_{f,d}$ - $DRLot_{f,d}=0$, in order to apply linear goal programming with a two-sided goal (equation 19). The integral of g_m and g_p was minimized to express these mutual relationships (equation 20).

$$DRLin_{f,d} - DRLot_{f,d} + g\_m_{f,d} - g\_p_{f,d} = 0 \tag{19}$$

$$min\left\{\sum_{f,d}(g\_m_{f,d} + g\_p_{f,d})\right\} \tag{20}$$

We also minimized the total amount of rented land to avoid unnecessary land exchange. Unnecessary land exchange occurs when Farm_A rents land to Farm_B, the land is rented out to Farm_C by Farm_B, and eventually, Farm_C rents the land back to Farm_A (equation 21).

$$min\left\{\sum_{k}(ARLin_{f,k} + ARLot_{f,k}) + \sum_{d}(DRLin_{f,d} + DRLot_{f,d})\right\} \tag{21}$$

The equations 19, 20 and 21 were applied in both simulation 2 and 3.

From outcomes generated by the three simulations, we assessed the impacts of land exchange in terms of total gross margin, farm structural change, crop allocation for each farm type and environmental indicators.

2.3.2. Sensitivity analysis

As parameters and constraints are uncertain, it was examined how sensitive the optimal solution is to changes in several parameters and constraints. It is useful for evaluating provided solutions, and also to be able to provide policy relevant insights from the responses of the simulation. For instance, a technological development may result in yield increases and the potato rotation might be stricter in the future to prevent soil problems. A sensitivity analysis was conducted for 1) potato rotation, 2) regional production, 3) exchangeable dairy land rate 4) distance between farms and 5) transportation frequency. We decreased or increased the original values (Table 10).

Table 10. The change of coefficient and constraints value in a sensitivity analysis.

Constraints	Value					
Potato rotation	0.17	0.25	0.33*	0.5	0.7	1.0
Max. regional production (%)	100	120	130*	150	170	200
Min. regional production (%)	0	20	50	70*	100	-
Exchangeable dairy land (%)	0	20	30*	50	70	100
Farm distance	0	1.5	3*	15	-	-
Transportation frequency (times)	0	8*	16	32	-	-

*Default set value

2.3.3. Spatial analysis

The locations of all arable and dairy farms were randomly determined with x coordinates and y coordinates in a square (40km by 40km) since the total area of Flevoland is about 1,418 km^2 (Figure 7). Arable farms occupied 32% and dairy farms occupied 9% in terms of the total area of Flevoland.

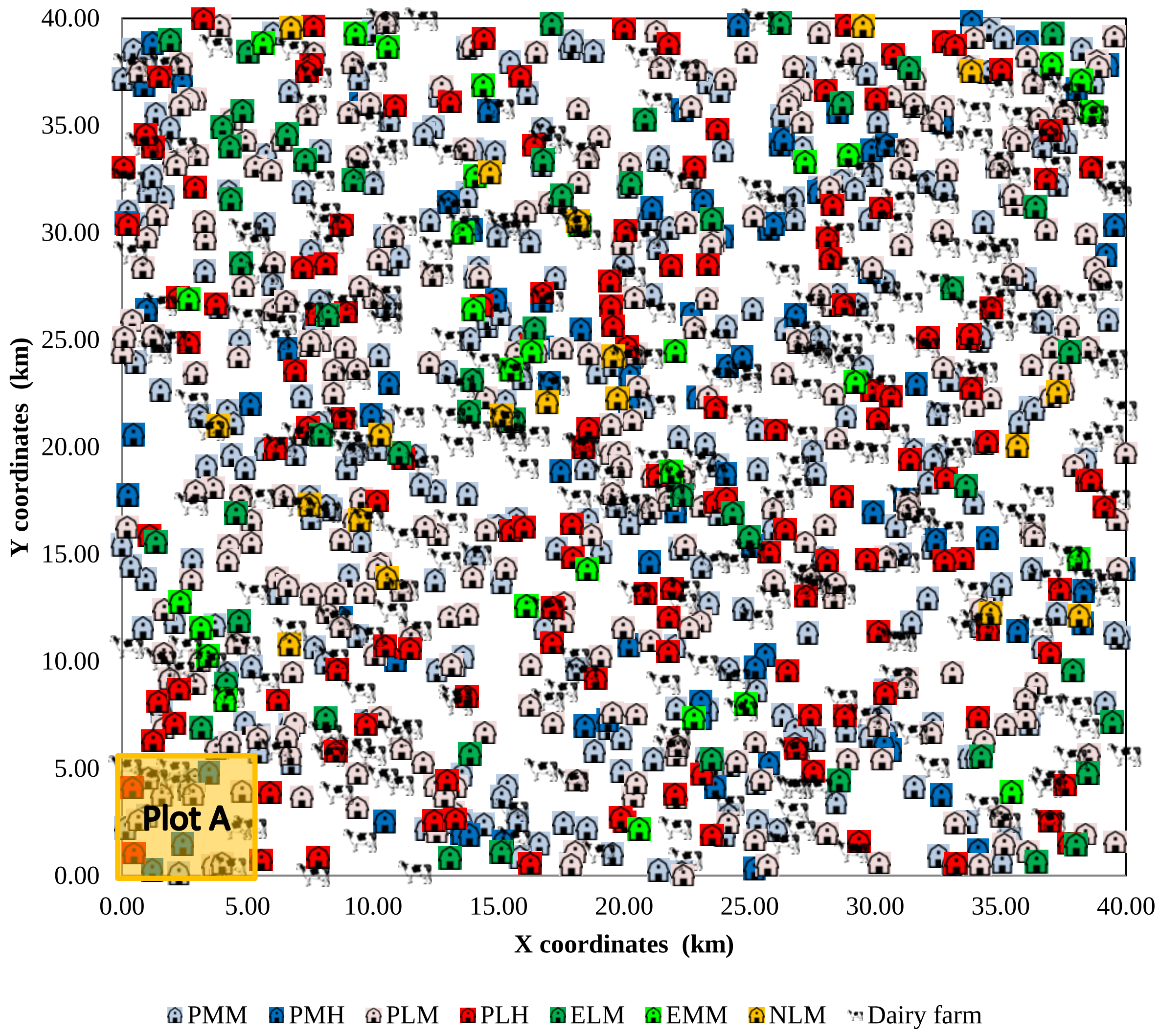
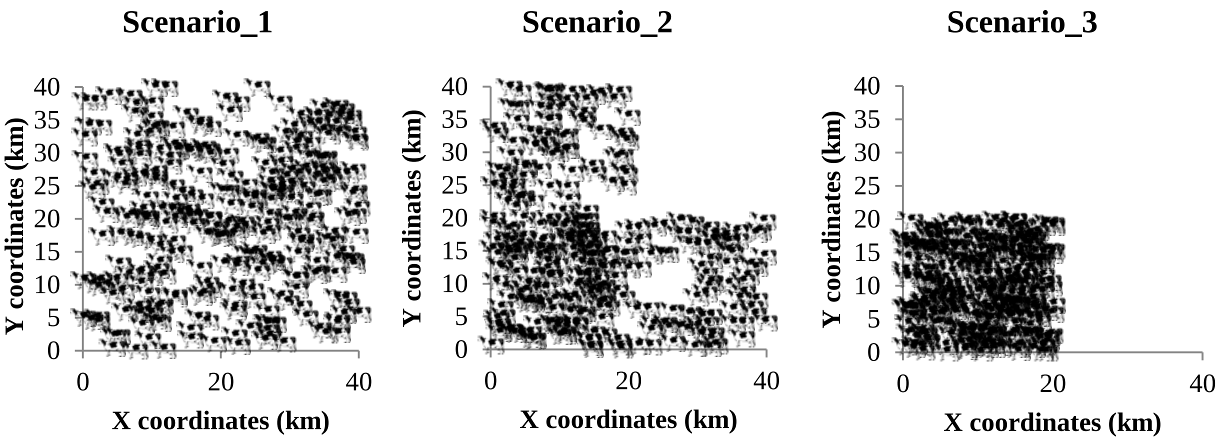


Figure 7. The simulation map of arable and dairy farms in Flevoland.

In order to see the result of land exchange in detail, we focused on a small plot of 5 by 5 km^2 (Figure 7, Plot A). Furthermore, to examine the impacts of spatial aspects, we simulated the simulation with three different distribution patterns of dairy farms with keeping 3km for land exchangeable distance (Figure 8). We did not simulate the real distribution of farms in Flevoland due to a lack of spatial information. Scenario 1 had a random distribution of dairy farms. This was the original distribution in this model. In scenario 2, 50% of dairy farms (151 farms) were distributed in the first quarter, two quarters had 25% of dairy farms (75 farms), and the other quarter had no dairy farm. In scenario 3, all dairy farms (301 farms) were allocated in the first quarter. The distance constraint affects this spatial analysis.



Quarter	X (km)	Y (km)	Scenario_1 Fraction	Scenario_1 Farm number	Scenario_2 Fraction	Scenario_2 Farm number	Scenario_3 Fraction	Scenario_3 Farm number
Quarter 1	0-20	0-20	0.25	76	0.5	151	1	301
Quarter 2	20-40	0-20	0.25	75	0.25	75	0	0
Quarter 3	0-20	20-40	0.25	75	0.25	75	0	0
Quarter 4	20-40	20-40	0.25	75	0	0	0	0
Total			1	301	1	301	1	301

Figure 8. Three scenarios of available dairy farm distribution.

2.3.4. Environmental impacts

To analyse the environmental impact of land exchange, we calculated Eff_OM and N use for simulation 1, 2 and 3, and for the most relevant outcomes of the sensitivity analysis. In addition, in order to explore the trade-off between gross margin and Eff_OM, we added a new objective: maximization of Eff_OM in the model. The provided optimal solution was used for the constraints of minimum Eff_OM, and the model was again run with the objective maximization of minimum increase of gross margin (max-min approach). The provided values of gross margin indicated the maximum gross margin when the Eff_OM was maximized in simulation_3. We gradually reduced the parameter of Eff_OM value until the value became unfeasible. We did a similar analysis for nitrogen use.

3. Results

The impacts of the land exchange on gross margin, farm structure, and optimal crop allocation are described in the following sections. Also, the sensitivity of these impacts of land exchange to changes in the level of constraints is presented. In addition, we show the results of the spatial analysis, and the environmental impacts.

3.1. The economic and farm structural impacts of land exchange

3.1.1. Gross margin change

The results of the model showed that total aggregated gross margin of arable farms in Flevoland was €283.1 million when total gross margin was maximized without taking into account land exchange, whereas the total gross margin increased up to €298.3 million (+5.4%) when land exchange was allowed between farms (simulation_2, Table 11). The benefits were one-sided on farms that have high intensity in their productions (PMH and PLH; +90.3% and +91.0%). On the other hand, production oriented farms which have medium intensities slightly reduced their gross margin with -5.0% and -7.6%. The entrepreneurial and nature oriented farms decreased their gross margin with 84.8%, 84.0% and 78.2%. The main reason for the re-allocation of land and gross margin to specific farm types, is because these farms are able to achieve higher yields (Table 6), and the optimal total gross margin becomes higher when these farm types take the farm land.

The max-min approach (simulation_3) distributed the benefits of the land exchange to all farms in a more "equal" way, and therefore, all farms raised their gross margin up to 3.5%, which made total gross margin €292.9 million.

Table 11. Total gross margin and the difference between simulation_1 per farm type in three simulations (€ million)

Farm type	Simulation_1	Simulation_2	difference	Simulation_3	difference
PMM	46.1	43.7	-5.0%	47.7	3.5%
PMH	10.9	20.6	90.3%	11.2	3.5%
PLM	135.6	125.3	-7.6%	140.3	3.5%
PLH	53.5	102.2	91.0%	55.4	3.5%
EMM	6.9	1.1	-84.8%	7.2	3.5%
ELM	20.5	3.3	-84.0%	21.2	3.5%
NLM	9.6	2.1	-78.2%	9.9	3.5%
Total	283.1	298.3	5.4%	292.9	3.5%

difference: 100*(Gross margin$_{simulation2or3}$ – Gross margin$_{simulation1}$)/ Gross margin$_{simulation1}$

3.1.2. Farm structural change

Table 12 describes farm structural change after optimization in three simulations. The land exchange in simulation_2 occurred both among arable farms and among arable and dairy farms. Entrepreneur oriented farms were completely eliminated when the simulation optimized regional gross margin taking into account land exchange. About half of the land was rented out to other arable farms, and the other half to dairy farms. The farm type nature oriented farms also significantly reduced their land area, renting most to other arable farms (-55%), and also a large part to dairy farms (-45%). On the other hand, production oriented farm types expanded their land areas. While medium intensity farms (PMM and PLM) increased their land area through the land exchange with other arable farms, high-intensity farms (PMH and PLH) significantly raised their land area up to 49% and 44%, respectively, renting large areas from dairy farms. In order to compensate for the rented dairy land by PMH and PLH, the rests of the arable farms rented out a large fraction of their land to dairy farms. The total farm number decreased with 10.2% to 826 farms, and average farm size increased with 11.4% to 61.8 ha.

Table 12. Farm structural change between simulation 1 and 2.

	Simulation 1	Simulation 2					
Farm type	Original land	Exchanged land among arable farms (ha)	The percentage of exchanged arable land (%)	Rented out arable land to dairy farms (ha)	Rented in dairy land to arable farms (ha)	Total land (ha)	Change (%)
PMM	8,721	166	2%	346	68	8,609	-1%
PMH	2,029	383	19%	17	630	3,025	49%
PLM	23,909	1,145	5%	559	264	24,759	4%
PLH	10,093	1,886	19%	66	2,665	14,577	44%
EMM	1,187	-605	-51%	582	0	0	-100%
ELM	3,513	-2,070	-59%	1,443	0	0	-100%
NLM	1,641	-904	-55%	650	34	121	-93%
Total	51,092	0	0%	3,662	3,662	51,092	0%

In simulation_3, entrepreneurial farms lost about 20% of their area through the land exchange with other arable farms (Table 13). The sizes of arable land rented out and dairy land rented in were exactly the same for all farm types, since the land exchanges were done on a one-to-one basis between an arable farm and a dairy farm.

Table 13. Farm structural change between simulation 1 and 3.

	Simulation 1	Simulation 3					
Farm type	Original land	Exchanged land among arable farms (ha)	The percentage of exchanged arable land (%)	Rented out arable land to dairy farms (ha)	Rented in dairy land to arable farms (ha)	Total land (ha)	Change (%)
PMM	8,721	545	6%	311	311	9,266	6%
PMH	2,029	0	0%	381	381	2,029	0%
PLM	23,909	651	3%	1,283	1,283	24,560	3%
PLH	10,093	-2	0%	1,476	1,476	10,090	0%
EMM	1,187	-317	-27%	121	121	870	-27%
ELM	3,513	-877	-25%	340	340	2,636	-25%
NLM	1,641	0	0%	20	20	1,641	0%
Total	51,092	0	0%	3,931	3,931	51,092	0%

When it comes to the farm structural change in the region, simulation_2 resulted in a large change in area occupied per farm type. The area occupied by production oriented farms with high intensity increased from 20% to 29% and from 4% to 6%, for large and medium farms respectively. The ones that have medium intensity (PMM and PLM) increased their relative area with 1%. As a result of these changes, the dominance of production oriented farms increased from 88% to close to 100% (Figure 9).

On the other hand, simulation_3 more or less maintained the relative areas of each farm type compared to simulation_1, when land exchange was not taken into account, but there was still an increase to 90% production oriented farms.

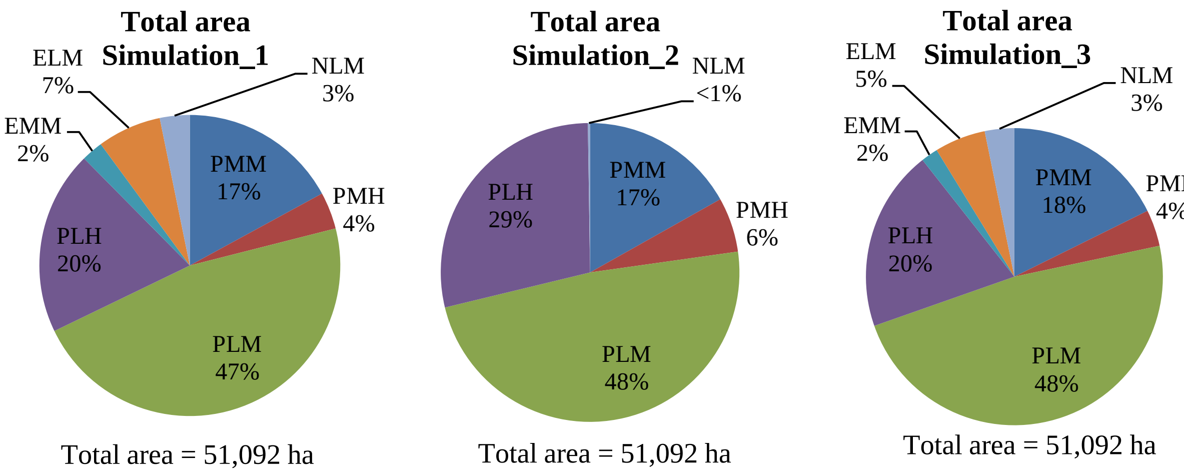


Figure 9. Relative area per farm type in the three simulations.

For the rented dairy land by arable farms, 88% and 95% out of total exchangeable dairy land (4,139 ha) were exchanged in simulation_2 (3,662 ha) and simulation_3 (3,931 ha), respectively (Figure 10). Eighty percent of available dairy land was rented by high-intensity farms in simulation_2. Regarding rented out arable land, high-intensity farms did not exchange their land with dairy farms, even though they rented in large area of dairy farms (Figure 11). The rest of the farms rented out their arable land to dairy farms instead. In simulation_3, all arable farms exchanged their land with dairy farms on a one-to-one basis. The available dairy land was allocated more or less based on the original area of the arable farm types in order to distribute the benefits of the land exchange equally.

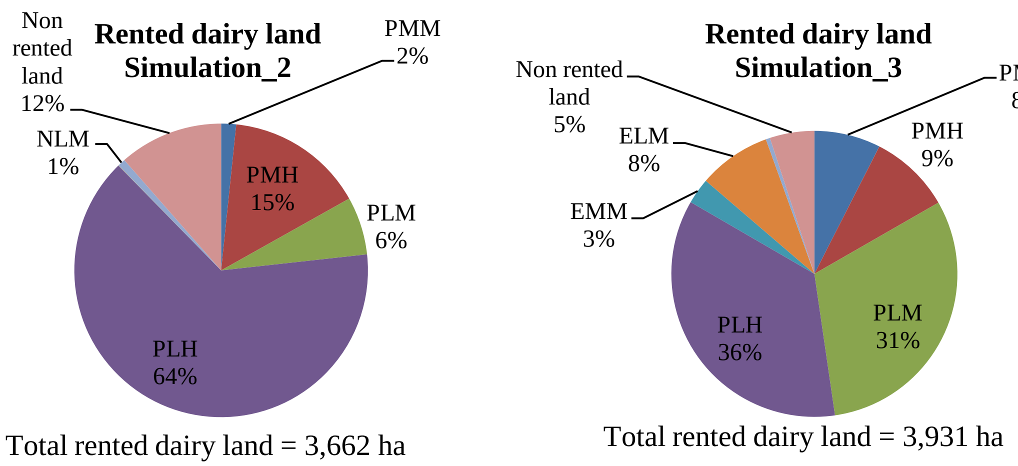


Figure 10. The percentage of rented dairy land area per farm type.

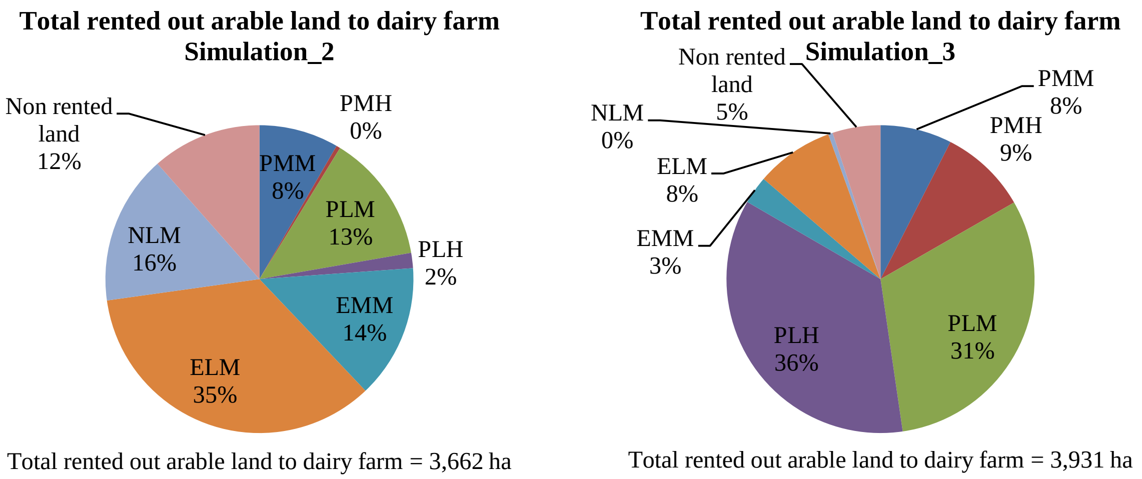


Figure 11. Rented out arable land to dairy farms in simulation_2 and simulation_3.

3.1.3. Crop allocation

According to

Figure 12, in simulation_1 the regional production constraint was binding for seed potato, winter carrot, seed onion and chicory, whereas consumption potato was bound by the potato rotation constraint. Green pea and winter wheat, which are low profitable crop, were produced to meet the minimum production level in the region. The rest of the land was allocated to sugar beet production.

Land exchange increased the area of consumption potato from 14% to 18% and 19%, replacing sugar beet for which the area decreased from 15% to 12% in both land exchange models (simulation_2 and 3). This indicated that land exchange allowed arable farmers to extend the potato rotation using land of dairy farms. For the rest of the crops the relative area of the production remained the same, because of the regional production constraints.

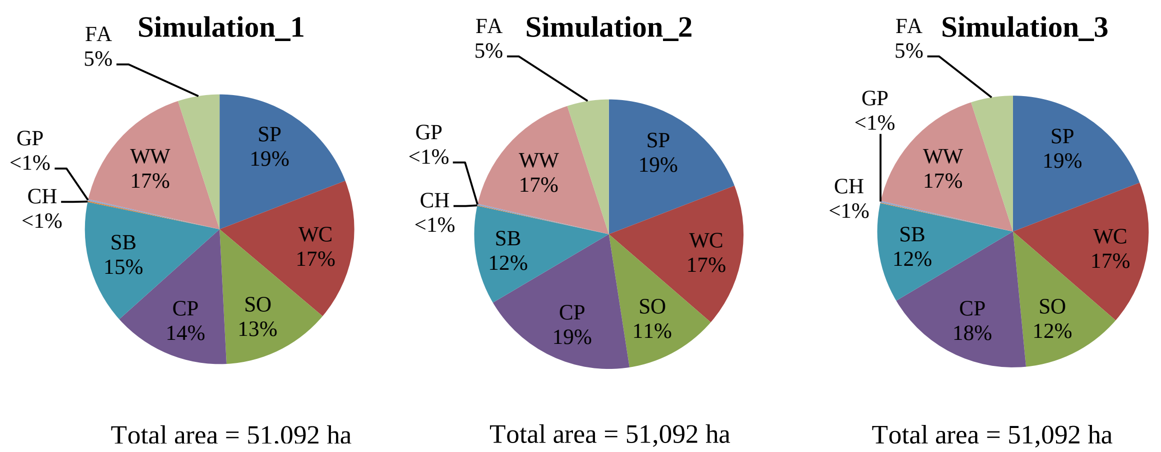


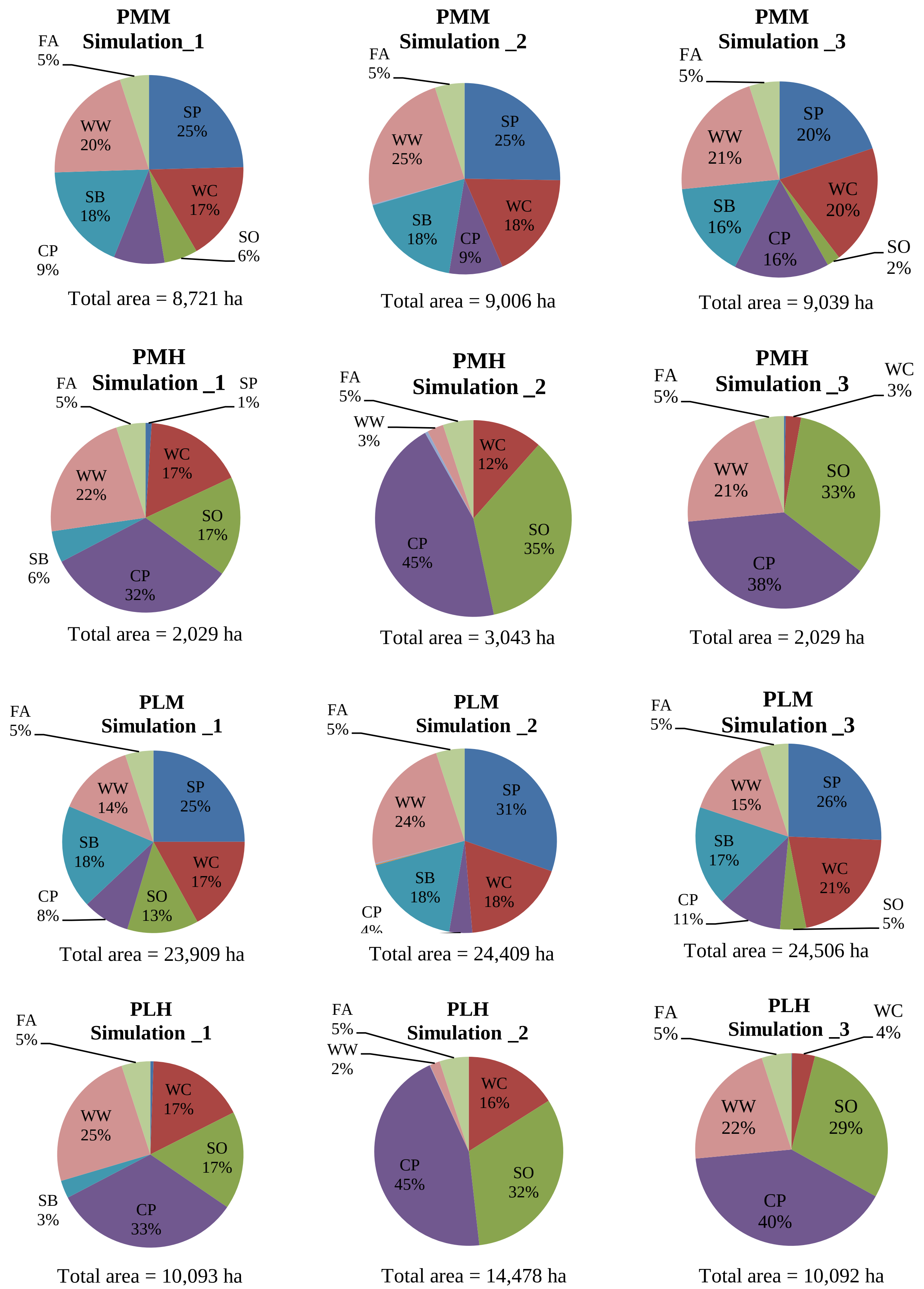
Figure 12. Crop allocation with all simulations in Flevoland.

SP seed potato, WC winter carrot, SO seed onion, CP consumption potato, SB sugar beet, CH chicory, GP green peas, WW winter wheat, FA fallow land.

When zooming into farm type level, both land exchange simulations (simulation_2 and simulation_3) encouraged arable farms to allocate more land to their profitable crops compared to simulation_1 (Figure 13). Although the crop allocation was similar between simulation_1 and simulation_3, the simulation_2 dramatically changed it because of the large farm structural changes.

In simulation_2, the most profitable crop for all farm types, seed potato, was cultivated mostly on farm types that have medium intensity with production orientation and few on NLM. PMM and PLM reduced their seed onion area with -6% and -15%, while increasing winter wheat area +5% and +12%. High intensive farms increased their area of seed onion (PMH:+18%, PLH :15%), which is the second most profitable crop for this farm type. The yield is 28.5% higher than on medium intensive farms. They also increased the consumption potato area (PMH:+13%, PLH :12%), eliminating sugar beet area and reducing winter wheat area (PMH:-19%, PLH :-23%). Land exchange encouraged arable farms to cultivate the most profitable crops, and as yields differed per farm type, this made crop allocation less diversified at farm type level.

In simulation_3, changes in crop allocation were smaller than in simulation_2, but the directions of change for production oriented farms were similar. Entrepreneur and nature oriented farms stopped growing the low profitable crop winter wheat. PMM slightly increased winter carrot (+3%) and consumption potato (+7%) area, while reducing seed potato (-5%) and seed onion (-4%). PLM raised winter carrot and consumption potato area with + 4% and +3%, while seed onion area was reduced with -8%. For the entrepreneurial farm types (EMM and ELM), both increased areas of seed potato (+10%), winter carrot (+11%) and seed onion (+11%), replacing areas of sugar beet (EMM: -18%, ELM: -19%), consumption potato (EMM: -9%, ELM: -8%) and winter wheat (EMM: -4%, ELM: -6%). High intensive farm types (PMH and PLH) enhanced seed onion area with +16% and +12% and consumption potato area with +6% and +7%, respectively. On the other hand, the area of winter carrot dropped down with -14% and -13%, and sugar beet area was eliminated with decreases of -6% and -3%. NLM did not change the crop allocation that much.


PMM Simulation_1
FA 5%
SP 25%
WW 20%
SB 18%
WC 17%
SO 6%
CP 9%
Total area = 8,721 ha
PMM Simulation _2
FA 5%
SP 25%
WW 25%
SB 18%
CP 9%
WC 18%
Total area = 9,006 ha
PMM Simulation _3
FA 5%
SP 20%
WW 21%
WC 20%
SB 16%
CP 16%
SO 2%
Total area = 9,039 ha
PMH Simulation _1
FA 5%
SP 1%
WC 17%
WW 22%
SO 17%
SB 6%
CP 32%
Total area = 2,029 ha
PMH Simulation _2
FA 5%
WW 3%
WC 12%
SO 35%
CP 45%
Total area = 3,043 ha
PMH Simulation _3
FA 5%
WC 3%
WW 21%
SO 33%
CP 38%
Total area = 2,029 ha
PLM Simulation _1
FA 5%
WW 14%
SP 25%
SB 18%
WC 17%
CP 8%
SO 13%
Total area = 23,909 ha
PLM Simulation _2
FA 5%
WW 24%
SP 31%
SB 18%
WC 18%
CP 4%
Total area = 24,409 ha
PLM Simulation _3
FA 5%
WW 15%
SP 26%
SB 17%
WC 21%
CP 11%
SO 5%
Total area = 24,506 ha
PLH Simulation _1
FA 5%
WC 17%
WW 25%
SO 17%
SB 3%
CP 33%
Total area = 10,093 ha
PLH Simulation _2
FA 5%
WW 2%
WC 16%
CP 45%
SO 32%
Total area = 14,478 ha
PLH Simulation _3
FA 5%
WC 4%
WW 22%
SO 29%
CP 40%
Total area = 10,092 ha

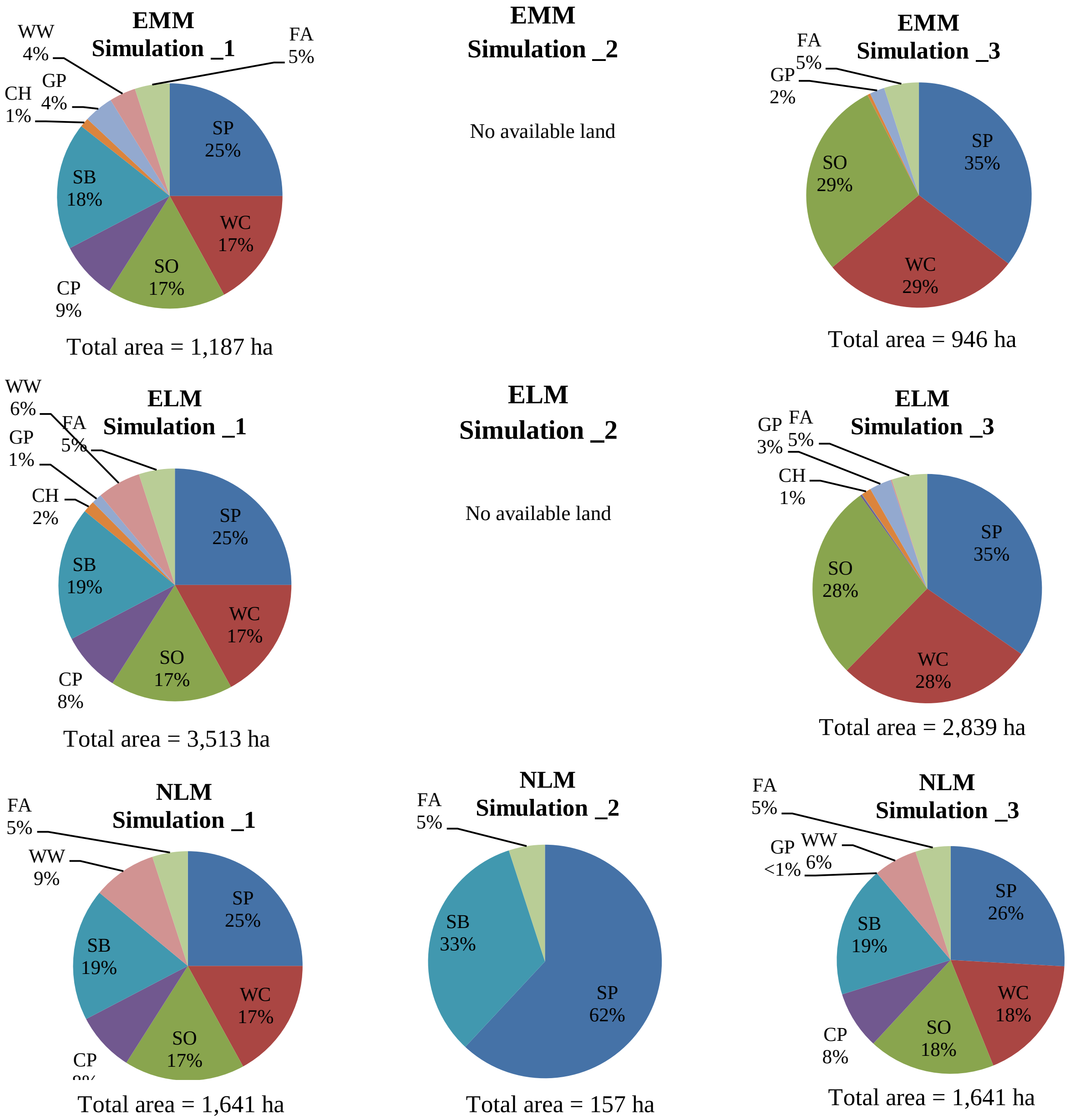


Figure 13. Crop allocation after land exchange per farm type.

SP seed potato, WC winter carrot, SO seed onion, CP consumption potato, SB sugar beet, CH chicory, GP green peas, WW winter wheat, FA fallow land.

3.1.4. Change in gross margin per hectare

Due to the change in total gross margin, available land and crop allocation, the gross margin per hectare, both at regional and farm type level changed. Both land exchange simulations improved the gross margin per hectare at regional level because of the extension of the potato crop rotation, from €5,552/ha (simulation_1) to €5,882/ha (simulation_2) and €5,777/ha (simulation_3) (Figure 14). Simulation_2 enabled four farm types, PMM, PMH, PLH and NLM, to enhance their gross margin per hectare, while for the others gross margin per hectare decreased. Although gross margin per farm increased equally with the max-min approach in simulation_3, the increase in gross margin per hectare was different because of the farm structural change (Figure 14). EMM and ELM increased their gross margin per hectare from €5,838/ha and €5,838/ha to €7,228/ha and €7,581/ha since they rented out their arable land to farms that have production orientation and medium intensity, and reduced the total land area obtaining the same relative increase as other farm type (see Figure 13). By changing to grow three profitable crops instead of growing sugar beet and winter wheat, the two farm types (EMM and ELM) could achieve a large gross margin per hectare increase (see Figure 13). On the other hand, the gross margin per hectare of the farm types that are production oriented were only slightly improved, or even decreased (PMM) as these farm types increased average area. In addition, production oriented farms were in charge of producing winter wheat. From a regional point of view, this is most efficient to maximize the total gross margin because the gross margin of winter wheat provided by production oriented farm types is higher than on the rest of the farm types due to higher yields and lower fertilizer costs.

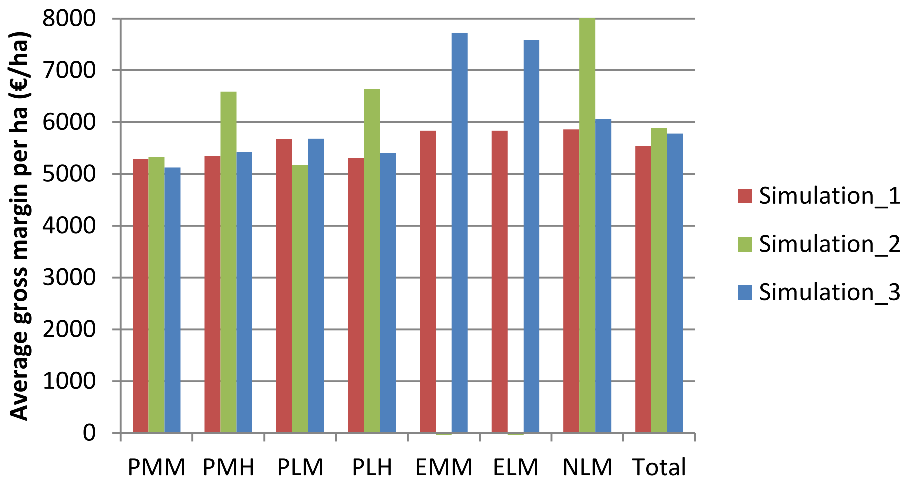


Figure 14. Gross margin per ha from crop sales in available land. The rental cost (€1,174/ha) is subtracted from the profits.

3.2. Sensitivity analysis

As was observed in the previous section, results are very sensitive to the constraints considered. Not all may be needed, and some may be different in reality. In order to examine how sensitive the optimal solution is to changes in the so-called right hand side (RHS) vector (constraints), a sensitivity analysis was conducted for important model parameters; 1) potato rotation, 2) regional production, 3) exchangeable percentage of dairy land, 4) distance between farms and 5) transportation frequency.

In order to understand the impact of land exchange, the outputs from simulation_1 and simulation_3 are compared in Figure 15, 16 and 17. The orange dotted lines show the default constraint values. In the default simulations, total gross margin increased from €283.1 million to €292.9 million, an increase of 3.5%.

Relaxing the potato rotation constraint increased gross margin in both simulation_1 and simulation_3, but reached an equilibrium around 0.5 (i.e. half of the area can be potato) (Figure 15a). The benefits of land exchange also decreased when the potato constraint is relaxed. On the other hand, when the potato rotation constraint got stricter to once per four years (which is needed in the long term to conserve soil quality), the total gross margin would drop down to €252.7 million euro (-10.7%) in simulation 1, while in simulation_3 the drop is relatively minor to €281.3 million (-4.7%). The effect of land exchange thus became much larger from 3.5% to 10.4% compared to the default constraint (once per three years).

Regarding the maximum regional crop production constraints, the total gross margin reached an equilibrium at maximum regional production levels of 130% in simulation_1, while the total gross margin reached an equilibrium at 200% in simulation_3 (Figure 15b). With the maximum regional production constraints at 200%, the gross margin in simulation_1 and 3 became €292.8 and €308.3 million, and the impact of land exchange was 5.3%.

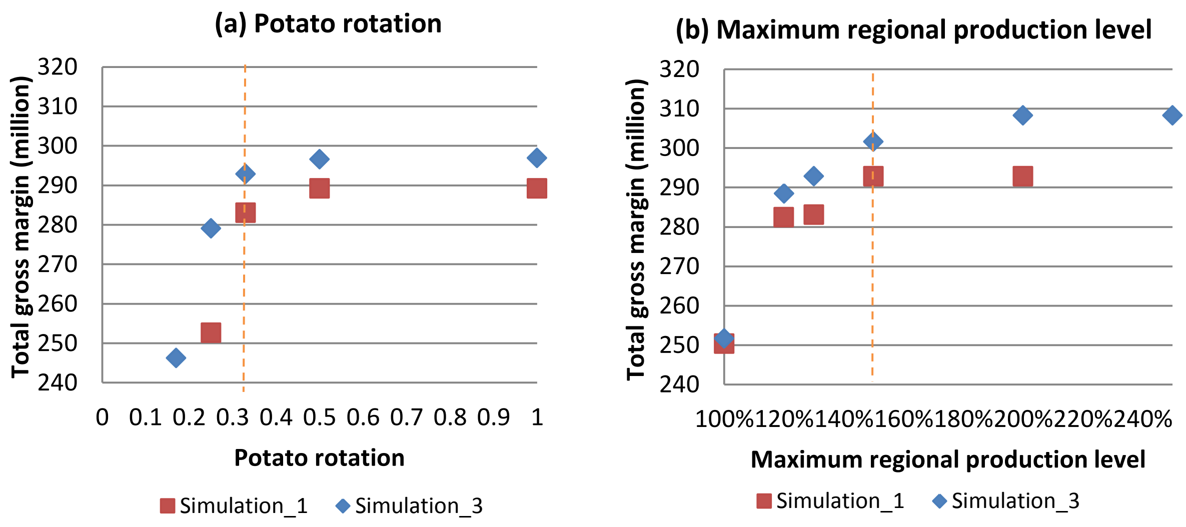


Figure 15. Sensitivity analysis for (a) potato rotation, (b) maximum regional production level in simulation 1 and 3. The orange lines indicate the default value.

When the minimum regional crop production constraints were relaxed from 70% to 20%, the total gross margin reached an equilibrium in both simulations (Figure 16a). With the minimum regional production constraints at 20%, the gross margin in simulation_1 and 3 became €285.4 and €299.9 million, and the impact of land exchange was 5.1%. When the constraints were became stricter to 100%, simulation_1 became infeasible.

Regarding the percentage of dairy farm land that can be rented, the impact of land exchange increased with the increase of available dairy land (Figure 16b). When 100% of dairy farm land is exchangeable with arable farms, the total gross margin in simulation_3 became €299.6 million, and the difference with simulation_1 was 16.0 million (5.6%). When we assume that only 20% of dairy land area was allowed to be rented to arable farms due to the stricter nitrogen legislation, the total gross margin in simulation_3 would decrease with €2.1 million (-0.7%), and the impact of the land exchange also reduced to 3.3%.

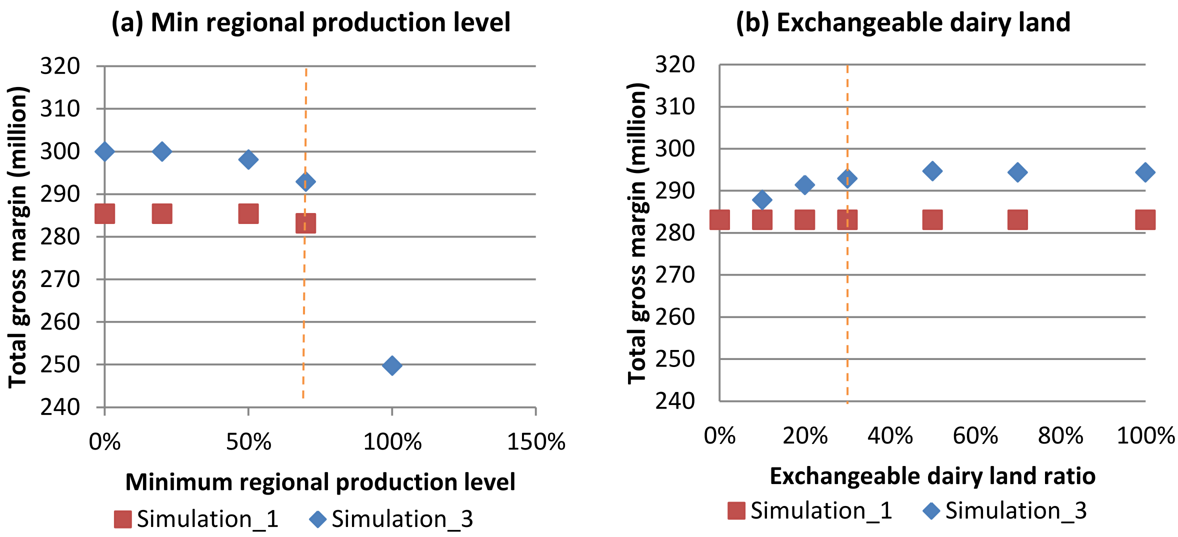


Figure 16. Sensitivity analysis for (a) minimum regional production level, (b) exchangeable dairy land in simulation 1 and 3. The orange lines indicate the default value.

The constraint regarding distance of farms had a small effect (Figure 17a). The total gross margin in simulation_3 decreased to €293.9 (-0.4%) when the distance was reduced from 3 km to 2 km. Allowing exchange at a larger distance than 3 km did not affect total gross margin.

The impact of the transportation frequency on total gross margin was very small (Figure 17b). Even when the frequency was increased from the default value of 8 to 100, the total gross margin decreased only -0.8% in simulation_3 and the effect of land exchange was minor.

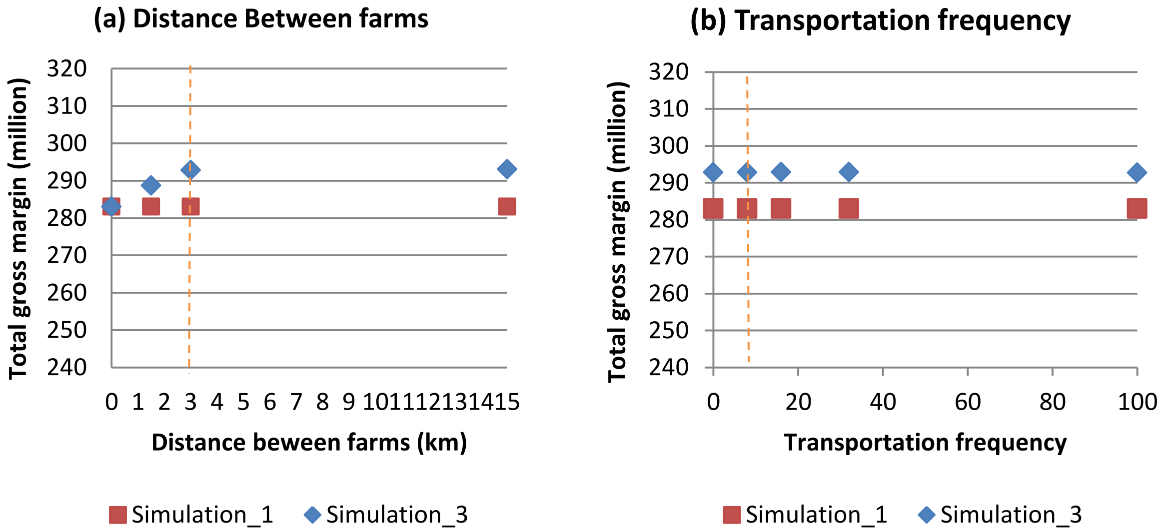


Figure 17. Sensitivity analysis for (a) distance between farms, (b) transportation frequency in simulation 1 and 3. The orange lines indicate the default value.

The conclusion from the sensitivity analysis is thus that the potato rotation constraint has the largest impact on total gross margin, especially if it would be stricter, but that the maximum regional production level also largely restricted the maximum gross margin level of the region.

As the maximum and minimum regional production constraint are uncertain, and limited possible changes when changing other constraints, the sensitivity analysis was also conducted with getting rid of the regional production constraints. The gross margin resulting from simulation_1 with default constraints increased with 10.6% to 313 million, while in simulation_3 it increased with 25.3% to € 367 million, compared to the gross margin with regional production constraint. The effect of land exchange changed from 3.5% to 17.1%.

For all other constraints, removing the regional production constraint increased the effect of land exchange on total gross margin. When the potato rotation constraint was relaxed to once per four years, the effect of land exchange became larger from 10.4% to 18.8% compared to the previous sensitivity analysis (Figure 18a). For the dairy land constraint, the impact of land exchange at 100% of available dairy land increased from 4.0% to 31.6% compared to the previous sensitivity analysis (Figure 18b).

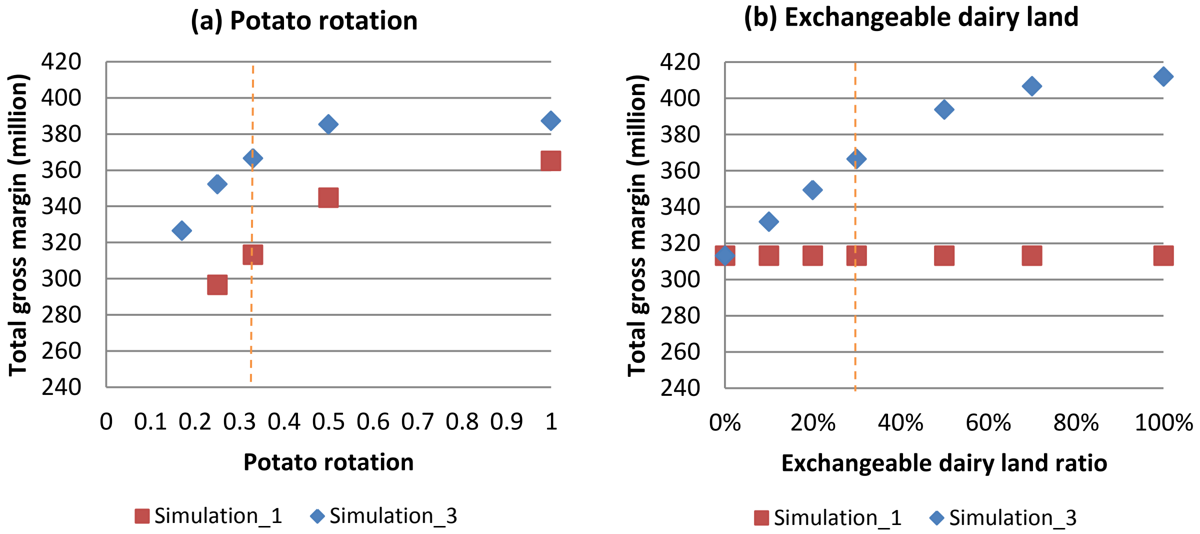


Figure 18. Sensitivity analysis for (a) potato rotation, (b) exchangeable dairy land in simulation 1 and 3. The orange lines indicate the default value.

When production constraints were eliminated, the model could no longer calculate with more than 15km land exchange distance due to memory issues. Transportation frequency still did not affect gross margin even if the regional constraints were removed (Figure 19). The land exchange impact was also stable when the frequency of working on rented land increased.

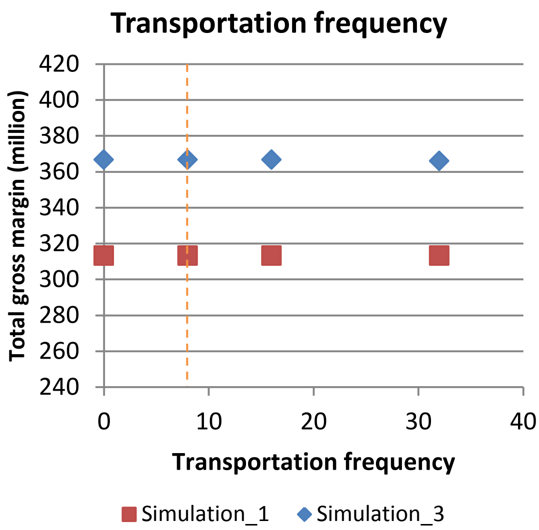


Figure 19. Sensitivity analysis for transportation frequency in simulation 1 and 3. The orange lines indicate the default value.

3.3. Spatial analysis

Table 14 shows the total land area exchanged between arable and dairy farms at different distance levels provided by model_3. It revealed that the land exchanges often occurred among nearby farms. 1,695 ha of land was exchanged at a distance within 1 km, followed by 1,685ha of land with a distance of 1 to 2 km, and 551ha of land with a distance of 2 to 3 km. The model tended to let arable farms exchange their land with the lowest transport costs as possible.

Table 14. The total land size exchanged between arable and dairy farm in different distance levels (ha).

	Distance levels (km)			
Farm Type	0-1	1-2	2-3	Total
PMM	172	117	21	310
PMH	139	153	88	380
PLM	584	603	96	1283
PLH	654	599	223	1476
EMM	40	60	21	121
ELM	96	148	96	340
NLM	10	4	5	19
Total	1695	1685	551	3931

In order to visualize the land exchange in simulation_3, we focused on a 5 by 5 km^2 plot (X coordinate from 0 to 5, Y coordinate from 0 to 5) (Figure 20). There were seventeen arable farms with four farm types (PMM, PLM, PMH and PLH) and five dairy farms (D23, D28, D136, D224 and D297) in the focused area. The arrows show the land exchanges between farms, and the color circles indicate the available range of land exchange for each dairy farm. Two farms, PLH96 and PMH2 were not located in the exchangeable ranges of dairy farms. D224 and D136 had land exchanges with three arable farms, D28 and D23 had land exchanges with two farms, whereas D297 had no interaction with arable farms. There was no land exchange between arable farms in this particular area.

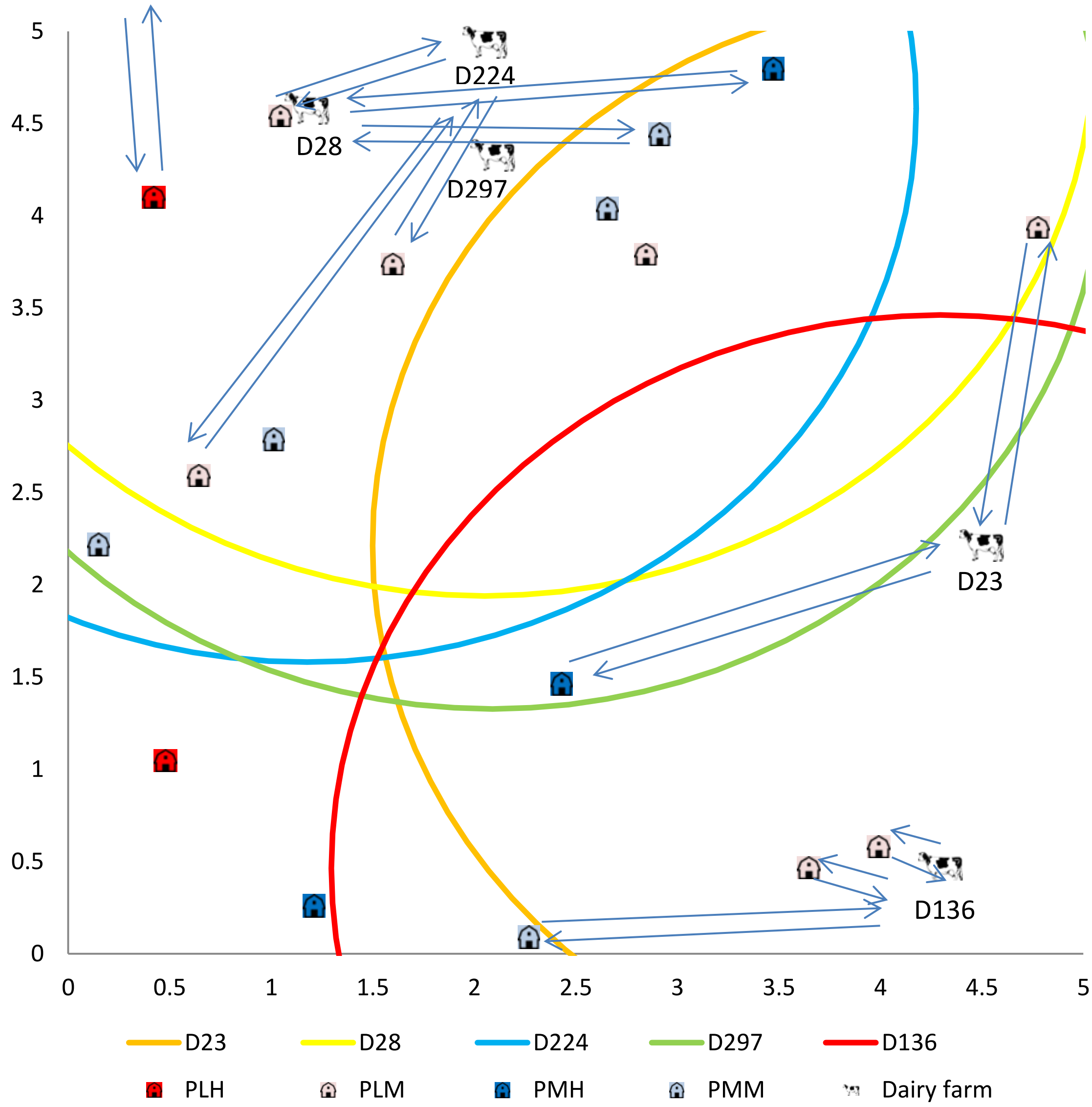


Figure 20. Land exchange description in a focused area (x coordinate: 0 - 5km, y coordinate: 0 - 5 km).

Table 15 shows the total gross margin from simulation_2 and simulation_3 with different scenarios changing dairy farm distribution keeping the exchange distance constraint with 3km. The result identified that dairy farm distribution affected the total gross margin, but very little. When 50% of dairy farms were located in the first quarter and 25% of dairy farms were located in two other quarters, respectively, the total gross margin in simulation_2 was only affected with -0.003%, and in simulation_3 it also slightly decreased with 0.1%, compared to the scenario where dairy farms were homogeneously distributed in the region. When dairy farms were all placed in one quarter, the reduction of the total gross margin was larger than in scenario 2, with 0.5% and 1.0% in simulation_2 and simulation_3, respectively. When the dairy farms are distributed homogenously (scenario 1), 95% of available dairy land was exchanged, but some of arable farms could not rented in dairy land. In scenario 3, the total area of rented in dairy land decreased to 63% out of total available dairy land. The land was exchanged with the arable farms which locate within x coordinate 23 km (20 + 3km) and y coordinator 23km. Most of arable farms which locate in quarter 1 could rented in dairy land. Also, the total area of the exchanged land among arable farms increased from 1,199 ha (scenario 1) to 3,261 ha. Therefore, the difference of the total gross margin between scenario 1 and scenario 3 was only 1.0%.

Table 15. The total gross margin when the distribution of dairy farm was changed. Scenario _1: homogeneous distribution, Scenario _2: one quarter has 50%, two quarters have 25%, and one quarter has no dairy farms, Scenario _3: one quarter has 100% of dairy farms.

	Scenario_1	Scenario_2		Scenario_3	
	Total gross margin (€ million)	Total gross margin (€ million)	Difference	Total gross margin (€ million)	Difference
Simulation_2	298.3	298.2	-0.003%	296.8	-0.5%
Simulation_3	292.9	292.7	-0.1%	289.9	-1.0%

3.4. Environmental impacts

The total impacts of land exchange on the average effective organic matter (Eff_OM) per hectare slightly decreased with -0.3% in simulation 2 and with -1.0% in simulation 3 (Table 16). The high intensive production oriented farms (PMH and PLH) decreased the Eff_OM with -50% and -52%, respectively in simulation 2, while medium intensive production oriented farms (PMM and PLM) and NLM increased with 9%, 29% and 26%, respectively. The rest of the farms (EMM and ELM) largely decreased due to the loss of available land. In simulation 3, both entrepreneurial farms (EMM and ELM) relatively largely decreased the effective organic matter with -43% and -46%. PMH, PLH and NLM also decreased with -4%, -6% and -8%, whereas PMM and PLM increased with +1% and +5%.

Table 16. Effective organic matter (Eff_OM) per hectare and the difference between simulation_1 per farm type with three simulations (kg/ha)

Farm type	Simulation_1	Simulation_2	difference	Simulation_3	difference
PMM	1,135	1,241	9%	1,147	1%
PMH	1,017	508	-50%	968	-4%
PLM	964	1,245	29%	1,008	5%
PLH	1,046	497	-52%	984	-6%
EMM	738	0	-100%	418	-43%
ELM	788	0	-100%	427	-46%
NLM	851	1,069	26%	787	-8%
Total	990	987	-0.3%	980	-1%

difference: $100*(Eff\_OM_{simulation2or3} - Eff\_OM_{simulation1})/Eff\_OM_{simulation1}$

Table 17 shows the total nitrogen use (N use) per hectare and the difference between simulation 1 and simulation 2 or simulation 3. Simulation 2 decreased the average N use per hectare with -3%, whereas in simulation 3 it increased with 1%. In simulation 2 production oriented farms with medium intensity (PMM and PLM) increased the N use per hectare with 1% and 6%, while production oriented with high intensive farms decreased N use per hactare with -8% and -14%. NLM also decreased with -28%, and EMM and ELM completely eliminated due to the loss of available land. For simulation 3, production oriented farms increased or did not change their nitrogen use per hectare (PMM: +1%, PMH: +5%, PLM: 0%, PLH: +5%), while the rests of farms decreased them (EMM: -7%, ELM: -9% and NLM: -1%).

Table 17. Total nitrogen use (N use) per hectare and the difference between simulation_1 per farm type with land exchange simulations (kg N/ha)

Farm type	Simulation_1	Simulation_2	difference	Simulation_3	difference
PMM	117	118	1%	125	7%
PMH	147	135	-8%	155	5%
PLM	111	119	6%	111	0%
PLH	150	128	-14%	158	5%
EMM	154	0	-100%	143	-7%
ELM	157	0	-100%	142	-9%
NLM	142	101	-28%	140	-1%
Total	126	122	-3%	128	1%

difference: $100*(\text{N use}_{simulation2or3} - \text{N use}_{simulation1})/\text{N use}_{simulation1}$

Table 18 shows the average nitrogen use per ha and nitrogen use from manure per ha in simulation_2 and 3. The nitrogen use ratio of nitrogen from manure to total use is also displayed. The farm types that have intensive practices have relatively higher total nitrogen use per ha because they allocate more consumption potato which has a high nitrogen demand (Table 6). In addition, as the nitrogen use percentage from manure is 75% for consumption potato on these farms, the nitrogen use percentage from manure for the two intensive farms is relatively higher compared to the other farm types. The results are based on an assumption that manure application rate for each crop is fixed even when arable farms grow the crops in dairy land. The nitrogen use ratio of nitrogen from manure may increase when arable farms grow crops in dairy land since first manure is applied in dairy land as much as possible within the nitrogen legislation.

Table 18. The total nitrogen use and nitrogen use from manure per ha in each simulation

	Simulation 1		Simulation 2		Simulation 3	
Farm type	N from manure per ha	N use ratio (manure/total)	N from manure per ha	N use ratio (manure/total)	N from manure per ha	N use ratio (manure/total)
PMM	40	34%	47	40%	52	42%
PMH	100	68%	107	79%	116	75%
PLM	30	27%	36	30%	37	33%
PLH	101	67%	102	79%	117	74%
EMM	22	14%	0	0%	31	22%
ELM	19	12%	0	0%	32	22%
NLM	17	12%	0	0%	18	13%
Total	47	37%	61	50%	52	42%

Figure 21 shows a trade-off analysis between total gross margin and the environmental impacts in Flevoland from simulation_1 and simulation_3. Regarding the Eff_OM, the gross margin almost linearly decreased when average Eff_OM per hectare increased, in both simulation_1 and simulation_3. At the same Eff_OM amounts, the total gross margin is always higher in simulation_3. Similar, at the same gross margin level, the total Eff_OM is higher in simulation_3, suggesting positive effects of land exchange. In terms of the relationship between total gross margin and average nitrogen use per hectare (artificial and organic), both simulations showed that the gross margin increased with the increase of nitrogen use. Similar to Eff_OM, the gross margin in simulation_3 was higher at the same N input level.

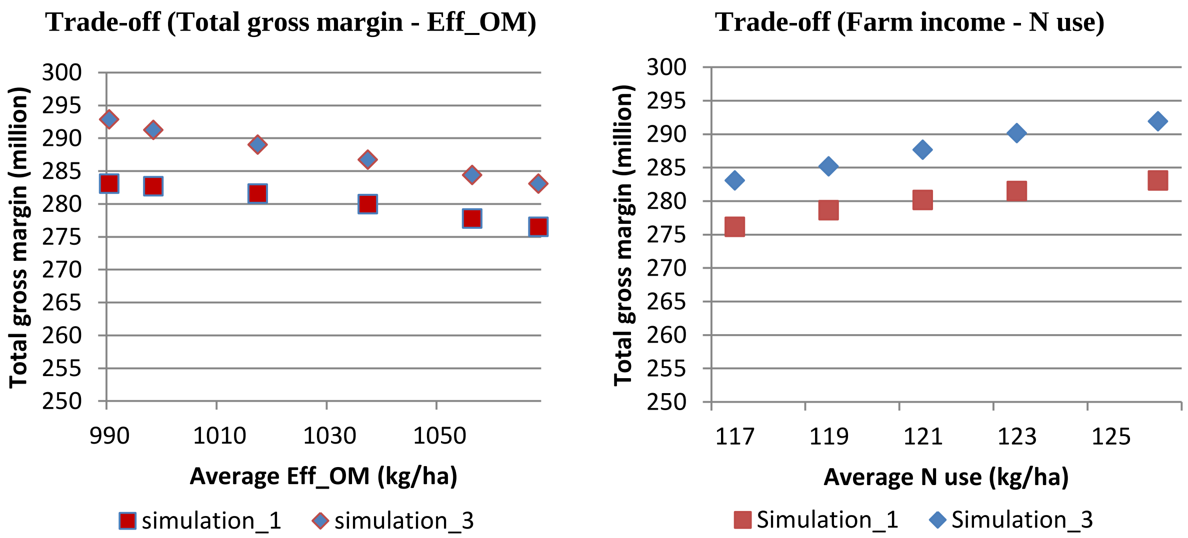


Figure 21. The trade-off between total gross margin and average Eff_OM (left) and trade-off between total gross margin and average N use (right).

Table 19 shows a summary of the economic and environmental impacts of land exchange. In the default situation, the land exchange increased gross margin with 5.4% (simulation 2) and 3.5% for the more likely situation when benefits were distributed equally (simulation 3). The impacts on environmental indicators were relatively smaller. Eff_OM reduced with -0.3% (simulation 2) and -1.0% (simulation 3). Simulation 2 reduced N use with -3.2%, but simulation 3 increased with +1.3%.

A stricter potato rotation constraint (once per four years), which is needed to maintain soil quality, increased the impact of land exchange on gross margin to 11.4% (simulation 2) and 10.4% (simulation 3), and at the same time reduced nitrogen use to -9.7% (simulation 2) and -5.9% (simulation 3), but also reduced Eff_OM to -5.6% (simulation 2) and -7.0% (simulation 3). When relaxing the minimum and maximum regional production constraints, the impact of land exchange on gross margin further increased to 18.7% (simulation 2) and 17.1% (simulation 3). The land exchange impact of Eff_OM was also strongly affected by the constraints. The percentages decreased to -21.9% (simulation_2) and -12.5% (simulation_3). On the other hand, N use was slightly increased with 0.3% (simulation_2) and 0.5% (simulation_3). Finally, stricter potato constraint without regional production constraint increased the impact of land exchange on gross margin 20.9% (simulation_2) and 18.8% (simulation_3), also on N use 1.4% (simulation_2) and 0.7% (simulation_3), and decreased Eff_OM to -20.5% (simulation_2) and -12.9% (simulation_3).

Table 19. The summary of the economic and environmental impacts of land exchange with four constraints set types in three simulations.

Indicator	Constraint change	simulation_1	simulation_2	Change (%)	simulation_3	Change (%)
Economic (€ million)	Default	283	298	5.4%	293	3.5%
	Potato rotation once per 4 years	253	282	11.4%	279	10.4%
	No regional production	313	372	18.7%	367	17.1%
	Potato rotation once per 4 years and no regional production	297	359	20.9%	352	18.8%
Eff_OM (thousand kg)	Default	50,597	50,425	-0.3%	50,070	-1.0%
	Potato rotation once per 4 years	55,599	52,508	-5.6%	51,687	-7.0%
	No regional production	31,854	24,867	-21.9%	27,864	-12.5%
	Potato rotation once per 4 years and no regional production	32,056	25,480	-20.5%	27,935	-12.9%
N use (thousand kg N)	Default	6,451	6,244	-3.2%	6,534	1.3%
	Potato rotation once per 4 years	6,642	5,997	-9.7%	6,251	-5.9%
	No regional production	5,066	5,084	0.3%	5,093	0.5%
	Potato rotation once per 4 years and no regional production	4,498	4,563	1.4%	4,529	0.7%

4. Discussion

In this study, the economic and environmental impacts of land exchange among arable and dairy farms in Flevoland were examined using a regional bio-economic model. Arable farms rent land from dairy farms to be able to grow a larger area of profitable crops that are restricted by rotational constraints, which improves their economic performance. A regional bio-economic model was developed based on linear programming (LP), with variables related to rented land among farms. Total regional gross margin was optimized, subject to constraints like available land including rented land, available labour, crop rotation, certain crops quota, specific focus area and regional production levels. The max-min approach was additionally applied to equalize the increase in gross margin across farms. Both simulations were compared with a model optimizing total gross margin without land exchange.

In this chapter, the results of the model regarding impacts of land exchange are discussed, taking into account the outcomes from the sensitivity and spatial analysis. In addition, we discuss about the impact of this study on future scenario studies, followed by possible improvements of the land exchange model.

4.1. The impacts of land exchange

The results showed that the impacts of land exchange on total gross margin were 5.4% when total gross margin was optimized (simulation_2) and 3.5% when benefits were distributed equally (simulation_3). Both simulations enabled arable farms to extend the potato rotation using the rented dairy land. It is reported that the average gross margin per hectare of farming activities in Flevoland has been increasing over the years and reached to €4,846/ha in 2015 (Vogelzang et al., 2016). Land exchange is commonly done in Flevoland, therefore, the reported gross margin per hectare includes the impacts of land exchange. The model indicated that the gross margin per ha in Flevoland might be able to become from €5,777/ha (simulation_3) up to €5,882/ha (simulation_2) by optimizing land exchange and crop allocation, although these outcomes were generated with some assumptions. For instance, the farms were randomly distributed in the region and all farms were supposed to agree with the proposed land exchange plan.

The optimized crop allocation at regional scale was not changed that much in both land exchange simulations; however, simulation_2 exchanged too much land among arable farms. This solution forced entrepreneurial and nature oriented farmers to go out of the business. The main explanation for that is that production oriented farms reached higher yields, and yields were assumed to be dependent on farm type and not on location. This is a theoretically optimized result to satisfy the objective of maximizing total gross margin, but is not likely to be the aim of decision makers since it is too radical change. Also, this would not fit the direction of The European Common Agricultural Policy (CAP) since the CAP is shifting to support a diversification of agriculture due to the new social demand for activities such as recreational activities, educational activities and care activities (Pfeifer, 2011).

Simulation_3 with the max-min approach ensured a more equal distribution of benefits. This approach enabled small scale arable farms (entrepreneur oriented farms) to exchange 10% of their land with dairy land and grow more profitable crops in the rented in land. This approach also encouraged the small scale farms to rent out their land to production oriented farms which are more productive. In this situation, the regional production constrained forced the large farms to produce less profitable crops. Although this might reduce the profitability (average gross margin per hectare) on production oriented farm types, it is the most efficient way to maximize the minimum relative change of gross margin for each farm, which equally increases gross margin across all farms.

There was 3.5% of economic impacts of land exchange in simulation_3; however, if there was a large gap in terms of productivity among farms, the land exchange impacts would be smaller since more profitable crop would be allocated to smaller scale farms to complement the low productivities under the regional production constraints, which leads to reduce the total economic impacts of land exchange. Such a conflict between objectives of equity ("fairness") and utilitarianism ("total good") in a mathematical programming model used for policy decision makings has been discussed earlier (Hooker & Williams, 2012).

The minimum relative change of gross margin from the optimized gross margin provided by simulation 1 (no land exchange) was maximized in simulation 3 (max-min approach), and therefore, all farms were able to increase their gross margin equally, which did not change the total number of farms in the region in this case. In fact, it was projected that the number of farms would decrease and average farm size would increase toward 2050 in Flevoland (Mandryk et al., 2012). When using the model to assess farm structural change, the max-min approach would not be the most suitable approach.

Environmental impacts in simulation 3 were small but negative: effective organic matter decreased with -1.0%, while nitrogen use increased with 1.3%, mainly because sugar beet production (higher Eff_OM and lower N use) was replaced with consumption potato production (lower Eff_OM and higher N use) by land exchange activity. A previous study with empirical farm data also revealed that the environmental benefits of cooperation between specialized farms were not realized, since the available resources were generally used to intensify the farming activities (Regan et al., 2016).

Regarding the change of total nitrogen use, when the potato constraint became stricter in simulation_1, it increased with +3.0% (6,451 thousand N-kg to 6,642 thousand N-kg; Table 19) despite reducing consumption potato production, which relatively consumes larger amounts of nitrogen. This is because the change of potato rotation constraint reduced both seed potato and consumption potato production with an associated reduction of -221 thousand kg-N and -329 thousand kg-N, respectively, while it increased sugar beet and winter wheat production, with associated increase of +246 thousand kg-N and +484 thousand kg-N. As the N use per hectare of seed potato is smaller than that of sugar beet and winter wheat, over all there was an increase in N use in simulation_1. In simulation_3 farmers mostly reduced consumption potato production with -702 thousand kg-N, while they were able to keep seed potato production (see Appendix Table 2). In this situation, N use decreased with -4.3%.

4.2. Sensitivity and spatial analysis

When the potato rotation constraint became stricter to once per four years, the land exchange effects became higher. This was because when arable farms were not allowed to change their land (simulation 1), the decrease in potato cultivation frequency reduced total gross margin, while land exchange allowed arable farms to compensate this reduction by renting dairy land that allowed to grow potato continuously. While many farmers still cultivate potatoes once every three years, the general rule is that potatoes can only be cultivated once every four years. As farmers also acknowledge the problems with soil quality, the rotation will likely become stricter (Mandryk et al., 2014).

The maximum and minimum regional production level determined the optimized total gross margin in this Flevoland case study (i.e., these were binding constraints). The production levels were assumed to be between 70% and 130%, respectively, of the average production in Flevoland over five years from 2011 to 2015. When we conducted a sensitivity analysis removing the production constraints, more available dairy land in the region was used to increase the profits of arable farms up to €366.6 million (+25.2%). It should be noted however that market prices of the crops were not changed by the supply, and therefore the real impact will be likely lower.

It was assumed that 30% of the dairy land could be rented, because of the derogation requiring 70% of dairy land to be cultivated with grass. If only 20% of dairy land was allowed to be exchanged with arable farms, the land exchange impact would decrease from 3.5% to 2.9% (-0.6%) because of the less available land on which a profitable crop can be grown. On the other hand, when the constraint for exchangeable dairy land was relaxed from 30% to 50%, the impact of land exchange would increase +0.6%. However, the crop rotation on dairy farm land was not taken into account in this study. For instance, if an arable farm rents 50% of the land from a dairy farm, the arable farm can only grow potato on 33% of the land, but the model allowed him to grow up to 50% of potato on the rented land. Therefore, the impact of land exchange would have been smaller if the crop rotational constraint was included for dairy rented land as well.

The spatial analysis indicated that in the total gross margin maximization model, the farms that were located closer to dairy farms were better able to access them due to the lower transportation costs. In addition, the sensitivity analysis showed that an exchangeable distance between farms of more than 3 km did not affect the total gross margin. This indicated that the arable farms in Flevoland have enough available dairy land within 3 km to optimize total gross margin. There is no regulation about the distance to exchange land with other farms in Flevoland and some farms are exchanging their land with others even at more than 35 km distance. Policy makers might be able to encourage farmers to exchange land within 3 km, which can reduce, for instance, environmental impacts such as CO_2 emissions from transportation (this is not captured in this study) with keeping total gross margin in the region.

Even if the frequency of the transportation increased from eight to hundred, the total gross margin was not affected that much. Farmers sometimes spray every week against Phytophthora during the growing season, and therefore the frequency can be up to sixteen times, but it does not affect the total gross margin due to the small costs compared to the gains.

4.3. Influence on future scenarios

This study could be used to improve the previous scenario studies for agriculture (e.g. Kanellopoulos et al., 2014; Reidsma et al., 2015; Wolf et al., 2015) by taking into account land exchange impact. Earlier scenario studies in Flevoland have maintained farm structure and available resources constant, and did not consider land exchange explicitly. Tsutsumi

(2015) compared results from the bio-economic farm model FSSIM as used by Kanellopoulos et al. (2014) and Wolf et al. (2015), and showed that the difference in projected future gross margin was largely due to assumptions regarding rented land, where mono-crop activity is allowed. When the arable farms are allowed to rent land, the model output of gross margin was larger, especially under the future scenario that have larger yield and price change. Impacts of changes in climate, technology, management and prices thus depend on the amount of land exchange. To improve such assessments, knowledge is needed on the amount of land that can be rented, which depends on the amount of dairy farms in the region, the percentage of dairy land that can be rented, and rotation constraints. The land exchange model developed in this study shows the amount of land that can be rented, and can therefore mitigate uncertainty in these future scenario studies.

4.4. Possible improvements of the land exchange model

In the objective function, only maximization of total gross margin in the region was taken into account. However, farmers' objectives are broader because of the increasing awareness of the relevance of multifunctional agriculture in the modern society (Renting et al., 2009). The negative environmental impacts due to agricultural activities with high intensity have been considered problematic in the Netherlands (Bos et al., 2013). When comparing the results of simulation 1, 2 and 3 with the observed farm plans (Mandryk et al. 2014), we can see differences indicating that maximizing total gross margin is not the only objective of farmers. Farmers indicated that soil quality, nutrient balance, labour intensity and risk aversion were important farmers' objectives. Therefore, multi-objective optimization algorithms have been developed in order to consider multiple objectives such as minimizing nitrogen surplus or maximizing soil organic matter (Groot et al., 2012). The single objective of this study can be improved to multiple strategic objectives using the weights of multiple objectives for each farm type in Mandryk et al. (2014) with a more complicated utility function. It should be noted however that the weights based on what farmers say differs from the weights based on what farmers do, implying that there is uncertainty in the weights of multiple objectives.

Crop rotation was taken into account in this study; however, the land exchange model resulted in less crop diversity in some farms under the gross margin optimization objective. For instance, simulation_3 maximized minimum increase of each farm gross margin, therefore, low productive farms such as EMM and ELM got about 90% of root crops in their optimized crop allocation. Farmers usually grow wheat to increase organic matter content and preserve soil quality. Therefore, a maximum share of root crops in a farm should be taken into account in the crop rotational constraint. Crop diversity in a farm is also important to have resilience against weather and price volatility (Lin, 2011). The market price was homogeneous for all farm types. However, nature conservation and entrepreneurial oriented farms might have added value strategies apart from production oriented farms, which might be able to make up for the relatively lower productivity.

In addition, the land exchange rate was assumed to be one to one in this study; however, it should depend on the potential value of the exchanged land for farmers. When an arable farm rents out land for the maize production of a dairy farm, and the dairy farm rents out land for potato production of the arable farm, one to one exchange is not fair for the dairy farm due to the lower profitability of maize compared to potato. In this study, the rental cost for dairy farms from arable farms was assumed to be half price than that of arable farms from dairy farms, but also the land size of rented out from the arable farm could be set up larger than the rented land from the dairy land (e.g. 1 (dairy land) : 2 (arable land)).

The transportation costs were assumed to be proportional to the area of rented land, as technical issues in the model prevented another solution. Even though the transportation cost did not affect that much to the total gross margin, it should be improved to represent a real situation.

This study partially assessed the environmental and economic impacts of land exchange in terms of arable farmers. The assessment of land exchange impact on dairy farms can be done additionally to assess impacts and explore alternative farming systems in the whole region. For dairy farms, manure use management is important to be assessed. Manure application rate has to be less than 250 kg manure N ha^{-1} per year for farms that have more than 70% of grassland, otherwise only 170 kg manure N ha^{-1} can be applied due to the nitrogen legislation. When the dairy farms can exchange land with arable farms, they have more opportunities to apply their manure in the fields. Also, there is another benefit for dairy farms that they can ask farm management such as ploughing and spraying for maize in rented land from arable farms. In addition, the use of crop residues as animal feed and bedding materials and the effect of cropping on subsequent pasture growth are expected. The scenario studies to assess the impacts of climate and socio-economic change on Dutch dairy farms using bio-economic farm model have been performed (van de Ven & van Keulen, 2007; Paas et al., 2015; Van Calker et al., 2004). Mixed cropping-livestock systems have also has been analysed for economic and environmental aspects. Thamo et al. (2017) investigated the economic impacts of mixed cropping-livestock system to climate change with a whole-farm bio-economic optimization model. However, the cooperation between farms at reginal scale is not considered in these studies. Therefore, a further study taking into account the impacts of farms' interactions on dairy farms can be combined with this study for the whole regional assessment.

5. Conclusion

We developed a regional land exchange model using a liner programming with new variables of land renting activities among arable and dairy farms and regional constraints which determine the feasible range of alternative solutions. Two types of objective functions 'maximization of total gross margin' and 'maximization of minimum relative change on gross margin' (max-min approach), were included in the model. The model was applied to Flevoland (the Netherlands), which has 920 arable farms classified into 7 farm types and 301 dairy farms, in order to assess the economic and environmental impacts of land exchange.

It was revealed that the economic impacts of land exchange on arable farms were positive with +5.4% when total regional gross margin was maximized, and +3.5% for the more likely situation when benefits were distributed equally (max-min approach). Effective organic matter reduced with -0.3% when total regional gross margin was maximized, and -1.0% in the max-min approach. Nitrogen use decreased with the objective of maximization of total regional gross margin, while increased with 1.3% in max-min approach. The results of the simulation that total regional gross margin was maximized encouraged high intensity farms to take most of the benefits of land exchange, while small scale farms went out of business. The max-min approach equally increased gross margin for all farms, which resulted that lower productive farms enabled to grow more profitable crops to complement the lower productivity.

When the potato constraint was made stricter (once every four years), which will likely happen in the Netherlands to preserve soil quality, the land exchange impacts with max-min approach increased gross margin with 10.4%, and at the same time reduced nitrogen use with -5.9%, but also decreased effective OM with -7.0%. The economic impact may increase to 18.8% when the regional production constraint was also relaxed in the model. This implied the importance of taking take into account the interactions between farms for the scenario studies using BEMs.

In order to improve the land exchange model, firstly, root crop rotation should be applied to avoid the situation that the arable land is fully occupied by root crops. Secondly, the rotational constraint also should be taken into account in rented dairy land. Multiple-objective functions can be applied for each farm type using different sets of weights for the objectives. The study can be further conducted by taking into account the impacts on dairy farms in order to explore other aspects regarding resource management such as more efficient manure use in a region.

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Appendix

Table A1. Farm typology in Flevoland as developed by Mandryk et al. (2012) and link to farm types in the BEM (column 1) and farm data from Mandryk (2014).

Farm type in the model	No.	Orientation	Size	Intensity	Specialization	% arable UAA	NGE	ha	NGE/ha	Available data Mandryk et al. (2014)
PMM	1	production	small	medium	diverse: arable/specialized: root crops	0.5	11	9	1.1	-
-	2				vegetables	0.04	13	9	1.4	-
PMH	3		medium	high	diverse: mainly root crop/specialized: root crops	2.4	50	22	2.3	-
-	4				flower bulbs	0.06	41	6	7.3	-
PMM	5			medium	diverse: mainly root crops/diverse: arable/specialized: root crops	9.7	46	29	1.6	-
-	6				vegetables	0.4	41	25	1.7	-
-	7		large	high	flower bulbs	0.2	111	16	7.0	-
PLH	8				diverse: mainly root crops/specialized: root crops	5.2	104	44	2.4	P1
-	9			medium	vegetables	0	82	50	1.6	-
PLM	10				diverse: mainly root crops	19.3	104	64	1.6	P2
-	11		very large	high	flower bulbs	4	589	61	9.7	-
PLH	12				diverse: mainly root crops/specialized: root crops	6.6	254	108	2.4	P1
PLM	13			medium	diverse: mainly root crops	8.7	224	130	1.7	P2
EMM	14	entrepreneur	medium	medium	diverse: mainly root crops	1.4	55	36	1.5	E2
-	15				vegetables	0	0	0	0.0	-
ELM	16		large	medium	diverse: mainly root crops	4.1	99	61	1.6	E1
ELM	17		very large	medium	diverse: mainly root crops	0	224	130	1.7	E1
NLM	18	nature	medium	medium	diverse: mainly root crops/diverse: arable/specialized: root crops	0	46	29	1.6	N1
-	19				vegetables	0	0	0	0.0	-
NLM	20		large	high	diverse: mainly root crops	0.1	97	37	2.6	N1
NLM	21			medium	diverse: mainly root crops	0.6	105	61	1.7	N1
NLM	22		very large	high	diverse: mainly root crops	0.8	334	132	2.5	N1
NLM	23			medium	diverse: mainly root crops	0.4	199	114	1.7	N1

Table A2. The crop allocation and nitrogen use when potato constraints became stricter in simulation_1 and simulation_3

	Simulation1							Simulation3						
	Crop allocation			Nitrogen use				Crop allocation			Nitrogen use			
Crop	Default (ha)	Potato constraint:0.25 (ha)	%	Default (thousand kg/ha)	Potato constraint:0.25 (thousand kg/ha)	Difference (thousand kg/ha)	%	Default (ha)	Potato constraint:0.25 (ha)	%	Default (thousand kg/ha)	Potato constraint:0.25 (thousand kg/ha)	Difference (thousand kg/ha)	%
Seed potato	9,782	6,751	-31%	757	535	-221	-29%	9,781	9,699	-1%	756	751	-5	-1%
Winter carrot	8,685	8,685	0%	645	645	0	0%	8,785	8,785	0%	683	678	-4	-1%
Seed onion	6,661	6,661	0%	755	755	0	0%	6,195	6,196	0%	632	631	-1	0%
Consumption potato	7,248	6,022	-17%	1,642	1,313	-329	-20%	9,210	6,022	-35%	2015	1,313	**-702**	-35%
Sugar beet	7,595	9,407	24%	924	1,171	246	27%	6,057	9,286	53%	728	1,154	427	59%
Chicory	73	73	0%	2	2	0	0%	39	73	86%	1	2	1	86%
Green peas	100	185	86%	13	24	11	86%	100	100	0%	13	13	0	0%
Winter wheat	8,390	10,750	28%	1,713	2,197	**484**	28%	8,367	8,374	0%	1,707	1,708	2	0%
Fallow	2,554	2,554	0%	0	0	0	0	2,554	2,554	0%	0	0	0	0
Total	**51,092**	**51,092**	**0%**	6,451	6,642	**191**	**3.0%**	51,092	51,092	0%	6,534	6,251	**-283**	**-4.3%**

Model script in Fico Xpress

```
model Land_Exchange
uses "mmxprs"; !gain access to the Xpress-Optimizer solver
uses "mmsheet";! gain access to excel work sheet

declarations
! SETS
C: set of string ! set for crops including GRASS and Fallow
F: set of string ! set of farmers
D: set of string ! set of dairy farmers
T: set of string ! set of farm types

MP    : array(C) of real    ! MARKET PRICE FOR EACH CROP
COSTS : array(C,T) of real ! COST FOR EACH CROP IN EACH FARM TYPE
AREA : array(F) of real ! AREA FOR EACH FARM
YIELD: array(C,T) of real ! YIELD FOR EACH CROP IN EACH FARM TYPE
ROTA : array(C) of real ! ROTATION OF EACH CROP
LAB   : array(C) of real ! Required labour for each crop
LAB_A : array(F) of real ! AVAILABLE LABOUR OF EACH SEASON
OBLEV : array(C) of real ! obligatoryLevel OF EACH CROP
QUOTA : array(C) of real ! quota of crop
SUB : array(F) of real ! amount of quota of sugar beet
TGM_fo : array(F) of real ! Income constraints for each farm
PARL : real ! Price for arable rente land
PDRLin : real ! Price for dairy rente in land
PDRLot : real ! Price for dairy rente out land
ADL : array(D) of real ! Dairy land (glass land)
H_lab_C : real ! Hired labour cost per hour
Dis_D : array(F,D) of real !distance between arable and dairy
Dis_A : array(F,F) of real !distance between arable farms
locA_x : array(F) of real ! location_X of arable farms
locA_y : array(F) of real ! location_Y of arable farms
locD_x : array(D) of real ! location_X of dairy farms
locD_y : array(D) of real ! location_Y of dairy farms
FT: array (F,T) of real ! farm types for each farm
PoCo: array (C) of real! potato rotation constraints
PoRo: real ! Potato rotation constraint
Product: array (C) of real ! Production constraints in a regional level
MinPro: array(C) of real !Mimimum production level
SOM: array (C) of real ! Effect of organic matter
NuseF: array(C,T) of real ! Nitrogen use from fertilizer
NuseM: array(C,T) of real ! Nitrogen use from manure
Manureuse: array(C,T) of real ! Manure use
TC: real ! transportation cost

! variables
X_CR: array(C,F) of mpvar ! area of crop in arable land
ARLin: array(F,F) of mpvar ! area of rent in arable land
ARLot: array(F,F) of mpvar ! area of rent out arable land
DRLin: array(F,D) of mpvar ! area of rent in dairy land
DRLot: array(F,D) of mpvar ! area of rent out dairy land
Eff_OM_F : array(F) of mpvar ! Eff_OM
H_Lab:array(F) of mpvar ! Hired labour
TGM: mpvar ! total income
TGM_F: array(F) of mpvar
X_Eff_OM : mpvar ! total Eff_OM
X_Nuse : mpvar ! total Nuse
Nuse_F : array(F) of mpvar !  Nuse
X_Manureuse : mpvar ! total Manureuse
Manureuse_F : array(F) of mpvar ! Manureuse
RGM: mpvar ! Relative profit change of the farm
X_V: mpvar ! farm income per ha
X_C: mpvar ! difference of land exchange between arable and dairy
g_m: array(F,D) of mpvar!variable g-
g_p: array(F,D) of mpvar !variable g+
end-declarations
```

```
initializations from "mmsheet.excel:161104WInput_output.xlsx"
!SETS
C as "[In_output$B2:B10]"
F as "[Arealabour$B7:B926]"
D as "[Arealabour$J7:J292]"
T as "[Arealabour$R7:R13]"

!parameters
MP    as "noindex;[MP$B2:B10]"
AREA  as "noindex;[Arealabour$E7:E1015]"
COSTS  as "noindex;[COST$B2:H10]"
YIELD as "noindex;[YIELD$B2:H10]"
LAB as "noindex;[LAB$B2:B10]"
LAB_A as "NOINDEX;[Arealabour$F7:F1015]"
OBLEV as "noindex;[OBLEV$B2:B10]"
QUOTA as "noindex;[QUOTA$B2:B10]"
SUB as "noindex;[Arealabour$H7:H1015]"
H_lab_C as "noindex;[H_lab_C$B1]"
locA_x as "noindex;[Arealabour$C7:C1015]"
locA_y as "noindex;[Arealabour$D7:D1015]"
FT as "noindex;[FT$B2:H1015]"
PoCo as "noindex;[PoCo$B2:B10]"
ROTA  as "noindex;[ROTA$B2:B10]"
SOM as "noindex;[SOM$B2:B10]"
NuseF as "noindex;[NuseF$B2:H10]"
NuseM as "noindex;[NuseM$B2:H10]"
Manureuse as "noindex;[Manureuse$B2:H10]"
PARL as "noindex;[PARL$A2]"
PDRLin as "noindex;[PDRLin$A2]"
PDRLot as "noindex;[PDRLot$A2]"
Product as "noindex;[Product$B2:B10]"
MinPro as "noindex;[MinPro$B2:B10]"
PoRo as "noindex;[ROTA$B12]"
ADL as "noindex;[Arealabour$N7:N307]"
TC as "noindex;[TC$A1]"
locD_x as "noindex;[Arealabour$K7:K307]"
locD_y as "noindex;[Arealabour$L7:L307]"
end-initializations

forall(f in F, k in F)
dist_A(f,k):= sqrt((locA_x(f)-locA_x(k))^2+(locA_y(f)-locA_y(k))^2)
forall(f in F, k in F |dist_A(f,k)<=3) Dis_A(f,k):= 1

forall(f in F, d in D)
dist_D(f,d):= sqrt((locA_x(f)-locD_x(d))^2+(locA_y(f)-locD_y(d))^2)
forall(f in F, d in D |dist_D(f,d)<=3) Dis_D(f,d):= 1

TGM is_free

! Objective:Total gross margin with Exchange
  E_INCOME := TGM = sum(f in F)TGM_F(f)
  forall (f in F)
  E_FarmIncome(f):= TGM_F(f)= SUM(c IN C, t in T| FT(f,t)=1)
MP(c)*X_CR(c,f)*YIELD(c,t)- SUM(c IN C, t in T| FT(f,t)=1) X_CR(c,f)*COSTS(c,t)-
H_Lab(f)*H_lab_C - sum (k in F) PARL*ARLin(f,k)- sum(d in D) PDRLin*DRLin(f,d) + sum
(k in F)PARL*ARLot(f,k)+ sum(d in D)PDRLot*DRLot(f,d) - sum(k in
F|Dis_A(f,k)=1)ARLin(f,k)*TC*dist_A(f,k)- sum(d in
D|Dis_D(f,d)=1)DRLin(f,d)*TC*dist_D(f,d)

!Eff_OM
  E_Eff_OM:= X_Eff_OM = sum(f in F)Eff_OM_F(f)
  forall(f in F)
  E_farmEff_OM(f):= Eff_OM_F(f)= sum(c in C)X_CR(c,f)*SOM(c)

!Nuse
  E_Nuse:= X_Nuse = sum(f in F)Nuse_F(f)
  forall(f in F)
```

```
  E_farmNuse(f):= Nuse_F(f)= sum(c in C, t in T| FT(f,t)=1) X_CR(c,f)*(NuseF(c,t)+
NuseM(c,t))

!Manureuse
  E_Manureuse:= X_Manureuse = sum(f in F)Manureuse_F(f)
  forall(f in F)
  E_Farm_Manureuse(f):= Manureuse_F(f) = SUM(c in C, t in T|
FT(f,t)=1)X_CR(c,f)*Manureuse(c,t)

! Available land
  forall (f in F)
  E_AV_ALAND(f):= sum(c in C)X_CR(c,f) <= AREA(f) + sum(k in F)(ARLin(f,k) -
ARLot(f,k)) + sum(d in D)(DRLin(f,d) - DRLot(f,d))

! Land exchange between arable farms
  forall(f in F, k in F| Dis_A(f,k)=1)
  E_EX_ALAND(f,k):=  ARLin(f,k)  =  ARLot(k,f)

! Land exchange between an arable farm and a dairy farm
  forall(d in D)
  E_EX_Dland(d) :=sum(f in F| Dis_D(f,d)=1) DRLin(f,d) = sum(f in F| Dis_D(f,d)=1)
DRLot(f,d)

! The limits of land exchange
  forall(k in F)
  E_AL(k) := sum(f in F)ARLin(f,k)<= AREA(k)

  forall(d in D)
  E_DL(d) := sum(f in F)DRLin(f,d)<= ADL(d)

! Fallow land
  forall (c in C, f in F| OBLEV(c)>0 )
  E_Setaside(c,f):= X_CR(c,f)>= OBLEV(c)*(AREA(f) + sum(k in F|
Dis_A(f,k)=1)(ARLin(f,k) - ARLot(f,k)) + sum(d in D|Dis_D(f,d)=1)(DRLin(f,d) -
DRLot(f,d)))

! Sugar beet quota
  forall (c in C, f in F| QUOTA(c)>0 )
  E_quota(c,f):= SUM(t in T| FT(f,t)=1)X_CR(c,f)*YIELD(c,t) <= QUOTA(c)*SUB(f)

! CROP ROTATION
  forall(c in C, f in F)
 E_ROTA(c,f) :=  X_CR(c,f) <= (AREA(f) + sum(k in F| Dis_A(f,k)=1)(ARLin(f,k) -
ARLot(f,k)) - sum(d in D| Dis_D(f,d)=1)DRLot(f,d)*Dis_D(f,d))* ROTA(c) + sum(d in
D|Dis_D(f,d)=1)DRLin(f,d)

! Potato rotation constraint
  forall(f in F)
  E_PoCo(f) :=  sum(c in C)X_CR(c,f)*PoCo(c) <= (AREA(f) + sum(k in F|
Dis_A(f,k)=1)(ARLin(f,k) - ARLot(f,k)) - sum(d in D|
Dis_D(f,d)=1)DRLot(f,d)*Dis_D(f,d))* PoRo + sum(d in D|Dis_D(f,d)=1)DRLin(f,d)

! LABOUR CONSTRAINT
  forall (f in F)
  E_LAB(f) := sum(c in C) X_CR(c,f)*LAB(c) <= LAB_A(f)+ H_Lab(f)

! Regional MAX production level
 forall(c in C| Product(c)>0)
 E_Pro(c) := sum(f in F, t in T| FT(f,t)=1) X_CR(c,f)*YIELD(c,t)<=Product(c)

 !Regional MIN production level
forall(c in C| MinPro(c)>0)
E_MinPro(c) := sum(f in F, t in T| FT(f,t)=1) X_CR(c,f)*YIELD(c,t)>=MinPro(c)

! IN YOUR FILE YOU HAD THESE CONSTRAINTS BELOW THE MAXIMIZATION OF INCOME BUT THEN
THEY BECOME VALID ONLY AFTER YOU CALCUATE INCOME
! Distance constraints between arable and dairy farms
```

```
! Not allow land exchange
  E_DisD:= sum(f in F, d in D) (DRLin(f,d)+DRLot(f,d))= 0
  E_DisA:= sum(f in F, k in F) (ARLin(f,k)+ARLot(f,k))= 0

!X_Eff_OM >= X
!X_Nuse <= Y

!For model_2
!allowing land exchange
!E_DisD:=  sum(f in F, d in D| Dis_D(f,d)=0) (DinL(f,d)+DotL(f,d))=0
!E_DisA:=  sum(f in F, k in F| Dis_A(f,k)=0) (RinL(f,k)+RotL(f,k))=0

!SOLVE THE PROBLEM
maximize(TGM)
!maximize(X_Eff_OM)
!minimize(X_Nuse)

writeln("model-no land exchange-clompleted");
forall (f in F) TGM_fo(f) :=getsol(TGM_F(f))
!forall (f in F) OMCONS(f) :=getsol(Eff_OM_F(f))
!forall (f in F) NUCONS(f) :=getsol(Nuse_F(f))

!allowing land exchange
E_DisD:=  sum(f in F, d in D| Dis_D(f,d)=0) (DRLin(f,d)+DRLot(f,d))=0
E_DisA:=  sum(f in F, k in F| Dis_A(f,k)=0) (ARLin(f,k)+ARLot(f,k))=0

!Not allow land exchange
!E_DisD:= sum(f in F, d in D) (DinL(f,d)+DotL(f,d))= 0
!E_DisA:= sum(f in F, k in F) (RinL(f,k)+RotL(f,k))= 0

!Income change proportion
forall(f in F|TGM_fo(f)>0)
E_U(f):= (TGM_F(f) - TGM_fo(f))/TGM_fo(f) >= RGM

!SOLVE THE PROBLEM
maximize(TGM)
!maximize(X_Eff_OM)
!minimize(X_Nuse)

!X_Eff_OM >= (1-0.0000001)*getsol(X_Eff_OM)
!X_Nuse <= (1+0.0000001)*getsol(X_Nuse)

!Constraint for EFFOM (*1000)
!X_Eff_OM >= X

!Constraint for Nuse
!X_Nuse <= Y

maximize(RGM)
!maximize(X_A)
!maximize(X_B)

!GET SOLUTION
!X_income>= getsol(X_income)

RGM >= getsol(RGM)

!minimizing land exchange with other farms
forall(f in F, d in D)
E_FX(f,d):= DRLin(f,d) - DRLot(f,d) + g_m(f,d) - g_p(f,d)=0

minimize(sum(f in F, d in D)(g_m(f,d) + g_p(f,d)))
sum(f in F, d in D)(g_m(f,d) + g_p(f,d))<=getsol(sum(f in F, d in D)(g_m(f,d) +
g_p(f,d)))

!alternative solution for minimizing land exchange
minimize(sum (f in F)(sum(k in F)(ARLin(f,k) + ARLot(f,k)) + sum(d in D)(DRLin(f,d) +
DRLot(f,d))))
```

```
sum(f in F, k in F| Dis_A(f,k)=1)(ARLin(f,k) + ARLot(f,k)) + sum(f in F, d in
D|Dis_D(f,d)=1)(DRLin(f,d) + DRLot(f,d)) <= getsol(sum(f in F, k in F|
Dis_A(f,k)=1)(ARLin(f,k) + ARLot(f,k)) + sum(f in F, d in D|Dis_D(f,d)=1)(DRLin(f,d) +
DRLot(f,d)))

if(getprobstat=XPRS_OPT) then

writeln("INCOME million: ",","," + getsol(TGM/1000000))
writeln("-------------------")
writeln("Land allocation:")
forall(f in F,c in C| getsol(X_CR(c,f))>0) writeln(c,",",f," :",getsol(X_CR(c,f)))
writeln("-------------------")
writeln("Arable rentin:")
forall(f in F, k in F| getsol(ARLin(f,k))>0) writeln(f,",",k," :",getsol(ARLin(f,k)))
writeln("-------------------")
writeln("Arable rentout:")
forall(f in F, k in F| getsol(ARLot(f,k))>0) writeln(f,",",k," :",getsol(ARLot(f,k)))
writeln("-------------------")
writeln("Dairy rentin:")
forall(f in F, d in D| getsol(DRLin(f,d))>0) writeln(f,",",d," :",getsol(DRLin(f,d)))
writeln("-------------------")
writeln("Dairy rentout:")
forall(f in F, d in D| getsol(DRLot(f,d))>0) writeln(f,",",d," :",getsol(DRLot(f,d)))
writeln("-------------------")
writeln("Final land area:")
forall(f in F) writeln(f,",","," :", AREA(f)+ getsol(sum(k in F)(ARLin(f,k) -
ARLot(f,k)) + sum(d in D)(DRLin(f,d) - DRLot(f,d))))
writeln("-------------------")
writeln("Income for each farm:")
forall(f in F) writeln(f,", :",getsol(TGM_F(f)))
writeln("-------------------")
writeln("Income for each farm per ha:")
forall(f in F|(AREA(f)+ getsol(sum(k in F)(ARLin(f,k) - ARLot(f,k)) + sum(d in
D)(DRLin(f,d) - DRLot(f,d))))>0) writeln(f,", :",getsol(TGM_F(f))/(AREA(f)+
getsol(sum(k in F)(ARLin(f,k) - ARLot(f,k)) + sum(d in D)(DRLin(f,d) - DRLot(f,d)))))
writeln("-------------------")
writeln("Income change:")
writeln ("MAXINCOMEPROPORTION :",getsol(RGM))
writeln("-------------------")
writeln("-------------------")
writeln("Total Eff_OM: " + getsol(X_Eff_OM/1000))
writeln("Eff_OM:")
forall(f in F) writeln(f,", :",getsol(Eff_OM_F(f)/1000))
writeln("-------------------")
writeln("Total Nuse :" + getsol(X_Nuse)/1000)
writeln("Nuse:")
forall(f in F) writeln(f,", :",getsol(Nuse_F(f)/1000))
writeln("-------------------")
writeln("-------------------")
writeln("INCOME million: " + getsol(TGM/1000000))
writeln("Total Eff_OM: " + getsol(X_Eff_OM/1000))
writeln("Total Nuse :" + getsol(X_Nuse)/1000)

else
	if (getprobstat=XPRS_UNB) then
		writeln("Problem is UNBOUNDED")
end-if
	if (getprobstat=XPRS_INF) then
		writeln("Problem is INFEASIBLE")
end-if
end-if

end-model
```

Table A3. Arable farms' location (x and y), available land, available labour and sugar beet quota.

No.	Farm	x	y	available land total (ha)	Available labour (h)	Sugar beet quota (ton)
1	PMM1	25.1	26.4	28.3	919.1	514.8
2	PMM2	13.6	4.7	26.9	946.1	500.6
3	PMM3	23.4	12.7	28.1	925.9	541.0
4	PMM4	3.1	21.4	27.1	891.0	465.9
5	PMM5	20.2	16.4	28.9	874.0	484.9
6	PMM6	3.4	19.1	27.2	948.8	555.1
7	PMM7	7.5	16.7	29.3	835.8	518.9
8	PMM8	34.8	33.1	30.0	1017.0	560.2
9	PMM9	31.6	4.1	28.8	962.0	524.8
10	PMM10	3.9	26.5	28.2	967.6	496.5
11	PMM11	15.3	22.1	29.4	915.6	511.5
12	PMM12	7.8	21.1	28.6	860.4	530.5
13	PMM13	11.7	19.6	32.6	937.0	574.6
14	PMM14	4.2	21.7	29.8	862.0	565.4
15	PMM15	15.0	29.8	28.9	900.2	536.7
16	PMM16	39.8	11.1	32.2	881.3	635.2
17	PMM17	32.1	12.9	28.2	864.3	529.0
18	PMM18	0.3	30.6	26.3	894.8	516.3
19	PMM19	19.9	4.9	28.1	901.8	522.0
20	PMM20	3.7	11.7	28.2	947.1	533.9
21	PMM21	34.7	13.1	30.1	951.3	551.3
22	PMM22	24.0	1.9	30.9	898.4	615.9
23	PMM23	1.1	30.4	30.3	929.7	562.6
24	PMM24	33.0	23.1	26.5	874.7	502.6
25	PMM25	30.8	16.3	28.8	935.1	513.1
26	PMM26	25.3	4.3	28.9	922.2	540.9
27	PMM27	29.3	26.6	28.0	902.4	496.7
28	PMM28	30.3	7.4	27.1	974.4	473.6
29	PMM29	25.9	16.2	29.9	965.6	515.6
30	PMM30	29.5	23.7	28.6	1005.6	501.6
31	PMM31	10.7	35.2	25.9	894.7	480.8
32	PMM32	12.1	2.2	27.1	929.3	464.5
33	PMM33	27.6	6.3	28.9	933.9	574.7
34	PMM34	34.2	25.0	30.7	946.7	557.6
35	PMM35	37.1	34.4	28.3	983.5	509.7
36	PMM36	20.2	32.1	33.5	991.2	612.9
37	PMM37	13.7	31.8	26.5	914.1	491.5
38	PMM38	16.2	36.5	30.4	887.8	588.4
39	PMM39	26.1	2.1	29.8	911.5	534.7
40	PMM40	1.4	35.5	29.3	978.3	545.3
41	PMM41	37.7	34.2	29.5	960.1	526.1
42	PMM42	14.1	14.8	28.7	900.6	542.5
43	PMM43	16.3	29.6	26.8	913.1	478.5
44	PMM44	13.6	10.2	29.8	849.4	556.3
45	PMM45	22.3	0.1	27.4	1001.3	517.9
46	PMM46	34.3	20.2	27.9	861.9	507.0
47	PMM47	28.5	3.4	28.8	964.0	506.1
48	PMM48	1.6	24.9	28.4	892.9	558.3
49	PMM49	23.3	5.4	26.6	904.9	485.1
50	PMM50	29.9	32.7	30.1	921.9	577.1
51	PMM51	26.3	35.4	29.6	929.0	571.4
52	PMM52	36.7	37.6	28.6	952.0	567.7
53	PMM53	1.6	33.9	28.5	958.6	575.8
54	PMM54	15.7	16.6	28.7	971.1	552.7
55	PMM55	9.1	14.0	30.4	979.1	607.4
56	PMM56	9.0	19.0	31.3	798.4	573.9
57	PMM57	31.6	19.8	30.5	905.1	559.3
58	PMM58	16.7	34.8	30.8	892.7	531.4
59	PMM59	21.2	5.4	32.1	892.2	571.7
60	PMM60	17.6	2.4	28.1	906.5	506.0
61	PMM61	6.0	27.6	27.8	916.7	458.5
62	PMM62	4.2	9.4	28.0	905.3	531.5
63	PMM63	7.9	26.8	29.1	942.4	550.3
64	PMM64	4.4	19.6	32.0	923.2	607.8
65	PMM65	13.8	31.7	29.9	900.6	541.1
66	PMM66	34.3	25.1	30.3	952.3	591.7
67	PMM67	23.8	16.9	28.0	925.9	546.3
68	PMM68	16.8	11.5	28.4	939.5	533.2
69	PMM69	29.8	30.6	30.7	797.2	568.2
70	PMM70	34.5	37.5	27.5	860.2	454.9
71	PMM71	17.3	15.2	27.8	892.1	524.6
72	PMM72	25.3	2.5	30.4	974.3	570.6
73	PMM73	18.6	16.6	26.6	945.4	474.0
74	PMM74	37.3	25.1	28.0	920.0	544.3
75	PMM75	26.8	31.6	26.7	999.0	476.0
76	PMM76	21.3	29.3	29.1	928.3	593.9
77	PMM77	10.7	28.5	30.6	945.9	571.6
78	PMM78	26.3	7.5	28.9	956.3	549.0
79	PMM79	23.1	14.4	26.7	945.7	507.2
80	PMM80	16.6	1.5	30.5	999.2	603.6
81	PMM81	30.4	27.7	29.4	889.5	572.0
82	PMM82	0.8	11.6	29.6	854.4	532.0
83	PMM83	22.2	20.4	27.3	929.6	548.8
84	PMM84	35.4	1.7	30.0	964.7	590.2
85	PMM85	13.5	2.5	29.8	991.5	597.3
86	PMM86	24.2	5.2	31.4	866.2	647.4
87	PMM87	23.8	19.1	27.7	931.3	469.1
88	PMM88	1.0	2.8	27.6	845.1	503.8
89	PMM89	13.8	38.6	27.0	958.6	507.8
90	PMM90	27.2	7.0	31.9	880.6	608.5
91	PMM91	12.6	9.6	28.6	864.3	528.7
92	PMM92	19.6	1.0	29.1	828.3	514.9
93	PMM93	1.0	13.8	31.4	877.5	574.7
94	PMM94	37.4	34.8	29.9	900.2	509.9
95	PMM95	19.0	23.5	29.1	897.8	573.3
96	PMM96	2.9	4.4	29.6	957.5	565.1
97	PMM97	5.5	6.5	30.3	856.5	573.6
98	PMM98	28.7	32.4	29.3	852.3	560.9
99	PMM99	26.4	25.5	29.6	977.0	539.6
100	PMM100	0.4	14.5	29.1	873.6	504.7
101	PMM101	36.3	14.3	28.9	942.4	513.1
102	PMM102	36.2	21.8	29.0	908.6	584.5
103	PMM103	12.8	2.5	30.4	864.3	575.8
104	PMM104	25.3	18.9	29.9	937.3	553.3
105	PMM105	31.5	35.9	31.5	929.5	572.4
106	PMM106	32.3	7.1	28.7	818.6	557.8
107	PMM107	14.1	27.9	30.6	909.6	533.5
108	PMM108	15.5	38.0	29.2	999.1	535.8
109	PMM109	32.1	32.3	31.2	881.0	562.3
110	PMM110	35.1	0.6	28.9	985.7	546.3
111	PMM111	6.7	7.0	28.8	960.3	542.3
112	PMM112	16.0	23.2	31.2	946.8	687.6
113	PMM113	4.9	7.1	28.9	951.2	496.8
114	PMM114	36.0	27.8	28.3	952.9	517.2
115	PMM115	34.6	39.4	28.7	881.7	562.0
116	PMM116	29.7	37.4	29.5	866.7	515.1
117	PMM117	25.3	8.6	29.3	852.7	593.7
118	PMM118	27.1	33.9	30.1	875.7	574.9
119	PMM119	28.5	27.1	28.9	863.5	577.2
120	PMM120	7.7	10.6	29.1	894.1	567.2
121	PMM121	0.5	38.5	29.3	883.3	533.9
122	PMM122	24.8	12.4	30.4	885.3	538.9
123	PMM123	23.3	37.0	27.0	952.9	512.5
124	PMM124	31.1	8.8	26.4	897.5	475.0
125	PMM125	27.2	6.4	30.7	870.7	544.5
126	PMM126	10.2	24.2	28.5	870.7	509.5
127	PMM127	27.8	25.1	28.5	841.7	490.0
128	PMM128	5.7	19.9	29.1	940.7	539.9
129	PMM129	12.3	30.6	27.2	834.7	522.7
130	PMM130	9.7	7.2	30.1	886.5	572.8
131	PMM131	3.3	28.2	28.5	900.3	605.5
132	PMM132	9.5	15.6	29.8	952.0	561.6
133	PMM133	6.7	36.6	28.4	885.5	531.7
134	PMM134	22.1	10.7	29.3	890.0	498.8
135	PMM135	32.5	0.9	30.2	906.0	550.2
136	PMM136	33.7	2.5	28.3	903.5	474.0
137	PMM137	9.6	39.3	27.6	931.4	525.8
138	PMM138	28.9	6.8	27.5	885.0	529.3
139	PMM139	24.1	25.6	29.2	955.1	519.1
140	PMM140	12.5	17.9	27.7	928.7	547.6
141	PMM141	13.9	25.0	27.6	957.3	553.6
142	PMM142	32.3	15.3	27.9	951.6	425.2
143	PMM143	0.0	37.2	30.4	1005.7	539.9
144	PMM144	37.2	12.2	28.2	906.9	471.2
145	PMM145	30.1	35.2	32.0	816.6	559.8
146	PMM146	10.5	26.6	28.9	999.2	501.5
147	PMM147	18.1	9.6	28.4	966.6	493.1
148	PMM148	21.1	27.1	27.8	917.8	522.9
149	PMM149	18.5	19.0	29.0	918.0	554.7
150	PMM150	5.8	33.6	29.5	898.7	526.4
151	PMM151	33.8	5.5	29.1	990.6	551.8
152	PMM152	35.0	13.6	27.1	919.9	456.7
153	PMM153	39.6	11.3	29.7	924.9	549.2
154	PMM154	17.8	38.6	30.5	889.9	515.6
155	PMM155	27.3	11.3	31.5	840.7	612.7
156	PMM156	18.8	38.4	29.4	850.8	580.9
157	PMM157	3.8	6.0	28.1	921.2	505.7
158	PMM158	34.3	30.5	29.3	937.3	554.1
159	PMM159	12.4	34.9	28.2	923.7	531.9
160	PMM160	17.9	0.5	28.9	886.4	506.1
161	PMM161	18.8	5.8	28.0	955.8	516.0
162	PMM162	14.9	33.7	28.4	931.8	512.1
163	PMM163	38.2	38.6	30.2	951.3	525.5

164	PMM164	23.2	20.1	27.0	885.0	482.8
165	PMM165	15.9	25.1	31.6	1016.6	629.1
166	PMM166	24.2	2.8	27.5	876.4	475.7
167	PMM167	1.6	7.7	28.1	927.2	542.2
168	PMM168	19.7	17.2	26.8	966.2	513.7
169	PMM169	1.9	34.9	29.4	925.0	554.6
170	PMM170	1.7	31.6	26.2	815.2	488.7
171	PMM171	38.4	19.4	29.7	904.5	575.6
172	PMM172	0.2	31.0	28.6	946.5	531.2
173	PMM173	22.1	7.8	30.0	905.9	651.6
174	PMM174	14.2	28.4	29.2	905.1	508.6
175	PMM175	15.0	16.3	28.3	838.4	524.0
176	PMM176	19.6	23.8	27.4	920.0	522.0
177	PMM177	33.1	0.5	27.4	944.8	495.4
178	PMM178	9.4	37.2	32.7	895.6	591.3
179	PMM179	22.3	35.7	25.7	847.1	461.3
180	PMM180	21.3	33.4	28.2	991.4	543.8
181	PMM181	19.4	6.9	28.1	870.8	568.2
182	PMM182	21.4	0.2	29.1	896.5	568.2
183	PMM183	6.0	39.3	29.3	937.0	532.9
184	PMM184	20.9	16.9	30.0	965.3	592.0
185	PMM185	1.0	38.2	27.8	917.5	490.8
186	PMM186	14.6	25.6	28.6	886.6	530.8
187	PMM187	20.8	21.8	28.2	870.8	498.7
188	PMM188	26.8	30.6	28.5	872.3	521.4
189	PMM189	17.3	27.9	28.9	869.9	475.9
190	PMM190	14.4	2.4	30.1	945.7	545.4
191	PMM191	27.9	14.8	30.6	932.2	577.8
192	PMM192	8.4	17.1	27.4	904.1	497.3
193	PMM193	4.7	24.5	26.7	871.7	502.6
194	PMM194	34.0	5.5	29.7	921.4	574.3
195	PMM195	14.5	26.0	28.2	943.5	479.6
196	PMM196	9.4	11.2	29.8	846.4	552.8
197	PMM197	32.8	32.1	27.9	904.0	500.4
198	PMM198	7.2	22.3	28.4	866.1	507.3
199	PMM199	6.2	13.2	28.5	950.9	520.6
200	PMM200	16.7	33.1	27.9	848.6	552.4
201	PMM201	24.0	33.8	31.5	904.1	548.0
202	PMM202	7.9	33.8	31.0	952.9	587.0
203	PMM203	32.1	18.3	28.9	888.4	509.8
204	PMM204	17.9	38.6	30.2	906.2	536.2
205	PMM205	11.0	28.9	30.6	948.4	581.4
206	PMM206	5.7	30.4	27.9	969.1	500.1
207	PMM207	14.0	33.9	28.4	1007.3	522.4
208	PMM208	15.4	4.2	29.7	876.5	481.4
209	PMM209	8.1	9.9	28.7	978.8	541.3
210	PMM210	0.6	37.5	29.9	818.1	562.1
211	PMM211	15.1	13.7	31.8	998.0	630.3
212	PMM212	10.5	29.8	28.4	946.1	501.3
213	PMM213	18.0	38.9	31.2	963.6	594.9
214	PMM214	27.8	32.1	29.8	895.9	491.5
215	PMM215	21.8	30.2	30.6	962.8	558.0
216	PMM216	31.0	15.0	28.6	872.4	533.1
217	PMM217	30.0	14.7	30.4	914.8	568.5
218	PMM218	4.4	21.1	31.4	914.3	549.3
219	PMM219	13.8	17.8	29.1	863.0	565.6
220	PMM220	12.5	13.8	30.6	838.4	537.0
221	PMM221	15.8	2.6	27.2	879.2	510.0
222	PMM222	27.5	19.8	29.7	978.1	597.1
223	PMM223	10.0	32.3	29.5	918.2	514.6
224	PMM224	26.8	6.8	26.4	899.9	497.9
225	PMM225	35.8	21.2	31.3	983.1	591.9
226	PMM226	4.9	19.0	29.4	1001.1	620.7
227	PMM227	36.2	7.1	31.8	964.8	552.8
228	PMM228	35.1	39.1	27.3	932.8	485.5
229	PMM229	5.4	5.8	28.2	893.1	512.5
230	PMM230	0.2	2.2	31.4	875.4	551.1
231	PMM231	25.3	20.8	30.9	911.1	557.0
232	PMM232	1.0	31.9	29.1	914.5	532.4
233	PMM233	20.0	28.5	27.8	880.4	472.2
234	PMM234	21.8	18.9	26.7	906.4	514.6
235	PMM235	23.8	36.6	27.9	915.6	503.6
236	PMM236	7.2	31.9	26.7	940.7	546.5
237	PMM237	27.6	18.7	28.7	858.7	517.6
238	PMM238	23.6	5.1	29.6	941.2	583.6
239	PMM239	22.2	15.3	31.0	852.5	550.5
240	PMM240	32.5	19.6	27.5	868.1	482.0
241	PMM241	30.4	8.6	29.1	925.6	565.1
242	PMM242	23.3	7.7	27.3	906.9	543.3
243	PMM243	36.7	25.9	28.8	975.8	530.4
244	PMM244	38.7	37.0	29.7	898.9	581.5
245	PMM245	4.3	31.9	29.0	951.2	516.1
246	PMM246	19.9	6.4	29.8	882.5	511.4
247	PMM247	36.7	10.7	27.4	912.9	486.6
248	PMM248	31.5	11.8	29.3	977.9	497.8
249	PMM249	12.0	34.6	31.4	892.2	563.1
250	PMM250	24.2	9.6	31.1	908.3	596.7
251	PMM251	2.3	0.1	25.8	948.9	485.5
252	PMM252	10.2	19.9	30.9	877.9	576.4
253	PMM253	15.1	26.2	31.8	853.6	631.5
254	PMM254	9.3	19.7	32.8	928.8	531.4
255	PMM255	37.3	32.2	31.2	959.9	549.1
256	PMM256	7.5	17.7	29.5	857.5	550.2
257	PMM257	11.9	18.2	29.9	929.3	533.7
258	PMM258	2.8	14.7	30.5	894.7	516.7
259	PMM259	12.9	23.5	29.5	960.9	527.9
260	PMM260	33.9	17.4	29.3	887.4	539.6
261	PMM261	6.9	19.7	29.2	988.3	562.0
262	PMM262	13.3	9.8	25.8	907.9	450.0
263	PMM263	32.5	21.5	26.8	890.8	519.4
264	PMM264	7.5	29.1	28.0	900.9	526.7
265	PMM265	0.5	23.9	29.8	955.0	556.5
266	PMM266	36.4	21.8	27.5	829.5	486.5
267	PMM267	18.5	2.2	29.4	911.8	527.1
268	PMM268	6.7	5.2	33.3	920.4	602.6
269	PMM269	29.8	6.5	29.0	897.8	498.1
270	PMM270	12.7	36.4	27.9	991.7	518.0
271	PMM271	30.5	6.7	30.1	860.9	539.1
272	PMM272	21.4	33.5	28.2	923.7	472.3
273	PMM273	37.2	34.3	29.6	880.3	512.9
274	PMM274	8.1	17.2	27.5	895.2	494.0
275	PMM275	21.0	30.6	28.8	986.9	541.8
276	PMM276	19.1	15.1	28.6	880.7	539.4
277	PMM277	1.5	22.6	32.0	926.3	591.9
278	PMM278	2.7	4.0	29.7	877.6	586.1
279	PMM279	32.3	19.4	28.5	977.5	529.5
280	PMM280	34.2	11.6	28.9	947.4	553.3
281	PMM281	15.9	0.8	28.6	978.5	548.5
282	PMM282	10.0	39.4	30.3	961.7	588.3
283	PMM283	26.8	6.1	25.9	1050.3	453.7
284	PMM284	8.7	30.3	31.8	945.2	639.4
285	PMM285	29.2	32.0	29.5	914.3	468.5
286	PMM286	0.0	15.4	29.4	961.2	558.9
287	PMM287	1.2	32.6	31.6	935.7	638.3
288	PMM288	30.8	38.1	28.9	904.1	493.2
289	PMM289	10.4	21.2	28.9	947.9	555.1
290	PMM290	7.6	25.6	28.7	920.8	489.3
291	PMM291	39.3	25.9	29.1	882.8	501.6
292	PMM292	15.1	3.7	28.6	946.0	502.7
293	PMM293	35.4	31.7	27.2	854.6	505.9
294	PMM294	4.7	24.9	28.4	969.8	541.8
295	PMM295	27.2	37.6	28.2	946.7	519.5
296	PMM296	5.2	9.7	29.7	904.7	525.0
297	PMM297	39.2	8.1	30.2	975.0	528.8
298	PMM298	2.1	11.8	30.5	904.0	571.2
299	PMM299	36.7	34.0	27.8	912.0	497.9
300	PMM300	28.9	21.4	27.5	953.6	473.4
301	PMH1	26.2	34.1	24.6	1113.2	429.6
302	PMH2	1.2	0.3	24.2	1057.4	415.5
303	PMH3	1.2	38.8	23.8	1007.7	410.4
304	PMH4	28.5	35.6	24.6	974.8	400.5
305	PMH5	10.6	23.0	25.3	1038.1	403.1
306	PMH6	38.0	36.7	24.8	1069.6	401.1
307	PMH7	26.4	34.3	24.8	1083.8	441.9
308	PMH8	39.3	37.8	22.1	1072.1	392.6
309	PMH9	23.9	29.8	24.9	1046.5	419.4
310	PMH10	25.2	0.3	25.3	1022.1	410.1
311	PMH11	25.6	10.3	21.1	989.4	362.4
312	PMH12	19.4	7.2	24.2	1080.0	418.2
313	PMH13	1.0	26.4	24.4	1104.3	430.2
314	PMH14	32.7	3.7	22.3	950.8	387.3
315	PMH15	39.6	30.3	22.6	1090.4	332.9
316	PMH16	25.8	30.2	22.3	1056.6	364.5
317	PMH17	16.7	26.8	23.7	1055.0	411.2
318	PMH18	23.0	22.3	23.5	1124.8	385.3
319	PMH19	0.9	36.9	23.2	1038.6	391.4
320	PMH20	0.2	30.4	23.5	1124.2	397.3
321	PMH21	17.5	18.9	24.8	1098.5	414.5
322	PMH22	33.9	39.8	23.3	1084.6	386.3
323	PMH23	0.2	17.8	24.3	948.9	390.3
324	PMH24	31.7	22.9	24.1	1048.2	429.1
325	PMH25	10.5	2.5	23.9	1067.3	378.4
326	PMH26	2.4	37.1	24.9	997.9	411.5
327	PMH27	6.7	24.6	25.9	1014.9	406.8
328	PMH28	36.1	38.9	24.2	929.3	380.7
329	PMH29	24.1	18.7	22.6	1035.8	350.4
330	PMH30	27.8	31.9	24.7	1065.0	341.6
331	PMH31	26.0	30.4	23.9	1162.0	369.2
332	PMH32	23.7	4.1	22.5	1035.4	399.6
333	PMH33	35.7	11.4	24.7	1083.1	431.8
334	PMH34	29.9	33.8	24.5	1050.9	379.1
335	PMH35	20.2	23.3	23.6	1048.2	392.4

336	PMH36	17.0	23.0	24.7	980.0	385.2
337	PMH37	20.2	10.7	23.0	1033.7	365.9
338	PMH38	21.1	31.1	21.3	1091.0	361.5
339	PMH39	9.5	36.0	24.5	1005.9	377.7
340	PMH40	8.8	12.0	23.3	995.7	378.2
341	PMH41	22.7	26.2	23.1	984.9	388.6
342	PMH42	38.3	11.7	24.3	991.8	406.9
343	PMH43	18.5	7.0	24.0	1050.6	392.2
344	PMH44	13.5	2.0	25.2	1081.2	413.0
345	PMH45	26.9	26.1	23.8	1148.8	374.2
346	PMH46	18.3	25.5	25.3	1097.2	439.3
347	PMH47	34.5	15.7	24.8	999.7	415.1
348	PMH48	9.9	21.5	24.7	1045.8	429.3
349	PMH49	30.6	5.8	23.0	1035.1	402.0
350	PMH50	2.4	1.5	23.3	1034.5	360.4
351	PMH51	3.5	4.8	23.0	1125.2	362.8
352	PMH52	20.2	22.1	22.2	999.4	348.7
353	PMH53	31.2	17.5	23.8	1147.4	407.6
354	PMH54	24.1	23.8	25.5	1041.2	428.1
355	PMH55	22.4	35.7	23.7	1091.3	377.2
356	PMH56	16.8	24.6	22.1	1104.4	307.0
357	PMH57	22.1	17.0	22.8	1092.6	342.7
358	PMH58	32.7	35.1	22.5	1133.9	392.4
359	PMH59	29.8	28.1	24.0	1031.0	435.8
360	PMH60	24.6	39.7	25.2	1075.5	437.9
361	PMH61	14.9	26.9	21.9	1045.7	372.5
362	PMH62	34.1	1.2	25.0	1088.1	398.1
363	PMH63	25.8	5.2	24.4	1042.8	367.8
364	PMH64	13.8	1.9	24.5	1176.4	412.5
365	PMH65	39.2	28.9	24.6	1095.3	411.1
366	PMH66	39.9	14.3	23.8	967.4	382.5
367	PMH67	21.0	14.6	23.4	1062.2	335.5
368	PMH68	32.4	15.7	23.2	960.2	376.1
369	PMH69	13.9	30.1	23.1	980.5	376.5
370	PMH70	25.2	9.7	26.3	996.5	441.3
371	PMH71	5.1	22.0	22.6	993.3	377.3
372	PMH72	25.1	15.4	22.2	1095.7	377.0
373	PMH73	13.0	31.4	24.1	992.0	410.8
374	PMH74	0.5	20.6	23.1	1020.6	386.2
375	PMH75	23.1	31.5	23.6	1018.4	352.3
376	PMH76	30.4	6.1	24.8	1018.0	404.6
377	PMH77	14.6	35.7	23.9	1093.7	406.3
378	PMH78	15.2	1.6	24.5	1074.8	387.6
379	PMH79	23.1	7.3	22.9	1055.6	397.0
380	PMH80	29.9	16.9	25.1	1115.1	412.7
381	PMH81	30.5	34.1	24.2	965.9	388.6
382	PMH82	10.9	10.1	23.7	1116.2	401.1
383	PMH83	23.1	8.1	22.4	1102.2	410.4
384	PMH84	38.3	13.3	27.0	1099.8	500.0
385	PMH85	24.7	24.2	24.7	1053.1	412.5
386	PLM1	28.4	20.4	85.4	2990.8	1648.0
387	PLM2	36.1	1.1	85.0	2661.3	1592.1
388	PLM3	24.9	38.4	84.2	2889.8	1532.5
389	PLM4	16.1	31.0	79.4	2790.6	1382.5
390	PLM5	22.1	3.6	80.2	3035.1	1564.1
391	PLM6	12.5	4.2	79.4	2925.6	1449.0
392	PLM7	22.1	5.6	78.6	2788.8	1483.3
393	PLM8	21.1	17.1	85.7	2864.7	1727.0
394	PLM9	5.3	33.1	73.6	2869.7	1327.9
395	PLM10	27.0	36.7	81.8	2960.1	1436.8
396	PLM11	22.7	35.9	85.6	2590.3	1540.2
397	PLM12	33.2	2.4	80.1	2874.5	1414.3
398	PLM13	34.1	6.9	82.7	2834.4	1494.4
399	PLM14	37.5	22.7	80.9	2942.0	1448.3
400	PLM15	1.6	3.7	82.2	2908.1	1582.6
401	PLM16	18.2	35.8	76.0	2633.0	1433.1
402	PLM17	16.3	0.6	74.8	3189.5	1284.1
403	PLM18	31.4	17.4	79.5	2793.5	1479.2
404	PLM19	22.9	37.6	75.6	2704.3	1502.1
405	PLM20	36.2	16.0	82.4	2968.9	1553.6
406	PLM21	0.4	25.9	85.3	2867.7	1591.3
407	PLM22	8.2	12.2	82.4	2946.9	1488.5
408	PLM23	32.7	23.7	78.4	2657.4	1459.6
409	PLM24	28.4	13.0	86.2	2881.1	1507.1
410	PLM25	14.3	28.0	85.5	2710.6	1563.3
411	PLM26	35.0	33.0	75.4	2981.4	1566.0
412	PLM27	38.8	38.0	77.8	2638.9	1434.8
413	PLM28	4.3	15.4	84.2	2734.9	1532.2
414	PLM29	10.2	28.8	77.3	2462.8	1449.9
415	PLM30	1.7	10.4	81.7	2958.5	1471.7
416	PLM31	13.7	12.2	82.7	2953.9	1556.7
417	PLM32	32.7	30.1	82.7	2803.1	1555.5
418	PLM33	20.4	27.0	72.1	2888.8	1329.2
419	PLM34	21.7	18.1	79.0	3123.6	1538.6
420	PLM35	19.5	19.7	75.8	3032.3	1374.9
421	PLM36	18.7	15.9	83.0	2741.6	1444.2
422	PLM37	33.7	37.8	81.2	2630.1	1340.7
423	PLM38	14.5	16.1	85.7	2923.1	1611.7
424	PLM39	3.6	0.5	81.3	3103.8	1542.7
425	PLM40	30.3	5.4	79.9	2933.8	1645.0
426	PLM41	32.9	32.9	86.1	2708.2	1535.8
427	PLM42	36.5	9.0	87.7	2978.6	1569.8
428	PLM43	13.2	3.0	86.6	2546.2	1588.4
429	PLM44	1.0	29.8	73.3	2896.2	1337.4
430	PLM45	35.2	1.5	81.0	2954.9	1414.2
431	PLM46	31.1	29.4	80.5	2770.1	1445.6
432	PLM47	25.9	17.1	85.3	2769.4	1581.6
433	PLM48	35.5	28.1	82.4	2972.0	1589.9
434	PLM49	24.0	37.2	87.8	2900.4	1463.0
435	PLM50	25.2	6.2	81.9	2772.0	1491.5
436	PLM51	39.7	14.3	78.2	2674.2	1545.0
437	PLM52	13.7	33.9	84.0	2727.9	1605.8
438	PLM53	19.5	17.8	77.5	2674.0	1430.5
439	PLM54	19.1	10.2	84.9	2889.6	1571.8
440	PLM55	13.3	4.2	79.1	3009.2	1395.2
441	PLM56	2.8	13.8	82.8	2883.8	1458.9
442	PLM57	18.1	1.1	81.4	2430.4	1608.6
443	PLM58	9.4	23.6	77.7	2397.8	1487.1
444	PLM59	7.5	24.7	80.5	2698.9	1507.4
445	PLM60	4.8	3.9	81.6	2886.2	1395.2
446	PLM61	34.0	39.1	87.6	2419.6	1659.6
447	PLM62	35.6	31.3	79.0	2606.7	1522.6
448	PLM63	1.2	25.2	79.1	3109.4	1581.5
449	PLM64	19.8	19.8	80.0	3032.9	1463.9
450	PLM65	4.7	17.7	73.7	2863.7	1382.2
451	PLM66	36.3	37.0	84.2	2946.0	1466.2
452	PLM67	0.6	2.6	76.8	3019.6	1337.4
453	PLM68	0.0	24.4	86.4	2977.2	1637.3
454	PLM69	6.8	9.5	79.8	2814.2	1387.5
455	PLM70	28.1	2.0	83.5	2630.9	1616.0
456	PLM71	3.3	29.7	83.6	2771.3	1489.3
457	PLM72	7.3	20.6	71.3	3200.4	1283.5
458	PLM73	12.0	5.3	76.5	2671.2	1368.7
459	PLM74	6.9	7.1	82.0	2697.2	1427.0
460	PLM75	21.1	18.6	81.3	2668.8	1427.4
461	PLM76	31.3	9.2	83.9	3085.2	1721.5
462	PLM77	3.0	33.6	72.1	2774.6	1407.0
463	PLM78	6.2	13.9	84.6	2862.7	1641.2
464	PLM79	25.2	1.7	78.1	2588.1	1378.5
465	PLM80	6.4	17.7	70.4	2738.9	1295.0
466	PLM81	12.7	36.8	68.5	2866.4	1183.1
467	PLM82	6.7	5.7	83.2	2798.9	1556.4
468	PLM83	10.1	10.3	77.0	2978.9	1278.7
469	PLM84	10.0	27.0	80.9	2654.6	1331.6
470	PLM85	26.0	13.8	79.5	2931.2	1349.4
471	PLM86	38.8	28.4	73.2	2870.0	1318.4
472	PLM87	14.0	38.7	84.2	2951.2	1480.2
473	PLM88	21.4	37.7	79.8	2999.4	1474.0
474	PLM89	2.9	36.2	78.0	3040.3	1501.3
475	PLM90	9.7	13.2	82.1	2807.0	1475.5
476	PLM91	23.6	29.6	88.6	2722.1	1688.0
477	PLM92	31.3	8.8	75.6	2834.6	1408.8
478	PLM93	32.7	35.9	84.2	2636.6	1508.6
479	PLM94	7.5	13.1	81.2	3070.4	1567.7
480	PLM95	23.3	26.9	83.8	2904.4	1558.9
481	PLM96	36.9	27.0	83.9	2560.3	1661.6
482	PLM97	30.6	36.3	84.4	2954.3	1570.6
483	PLM98	28.2	32.1	77.3	2753.4	1413.7
484	PLM99	8.5	13.2	82.7	2956.0	1496.5
485	PLM100	15.7	24.4	83.4	3100.8	1544.9
486	PLM101	2.9	23.4	87.1	2969.2	1468.7
487	PLM102	22.7	32.5	79.7	2953.4	1507.1
488	PLM103	39.0	27.8	73.9	3036.5	1365.6
489	PLM104	36.0	7.4	84.5	2726.1	1603.3
490	PLM105	26.7	36.4	81.3	2907.5	1430.2
491	PLM106	12.6	15.9	82.8	2975.4	1549.6
492	PLM107	26.9	24.9	81.6	2754.2	1576.8
493	PLM108	9.2	16.6	82.4	2675.5	1587.4
494	PLM109	38.9	37.8	88.9	2758.7	1623.4
495	PLM110	1.4	30.8	83.0	2698.6	1478.4
496	PLM111	38.5	5.7	83.9	2861.5	1511.8
497	PLM112	32.3	35.2	77.0	2677.7	1520.0
498	PLM113	22.8	25.6	81.2	3081.8	1493.7
499	PLM114	18.6	24.3	78.4	2634.1	1414.4
500	PLM115	28.9	5.4	78.8	2818.2	1512.0
501	PLM116	3.6	18.1	90.0	2679.2	1641.9
502	PLM117	22.2	6.0	72.9	2874.2	1402.5
503	PLM118	1.7	6.9	81.8	2741.3	1506.8
504	PLM119	4.6	10.8	76.8	2867.4	1388.5
505	PLM120	28.3	26.6	77.1	3100.8	1561.8
506	PLM121	16.5	38.4	86.5	2664.0	1624.1
507	PLM122	9.2	37.9	83.6	2701.4	1569.4

508	PLM123	36.1	38.2	85.8	2832.5	1516.7
509	PLM124	26.6	36.0	78.0	3049.0	1451.2
510	PLM125	11.1	13.3	80.9	3016.9	1423.6
511	PLM126	1.0	4.5	77.6	2633.0	1402.0
512	PLM127	10.5	39.8	78.4	2690.0	1411.4
513	PLM128	20.3	21.3	80.4	2921.6	1397.4
514	PLM129	2.7	36.2	79.1	2955.2	1394.6
515	PLM130	16.3	7.9	87.9	2821.7	1762.3
516	PLM131	31.6	36.0	85.0	2886.4	1476.1
517	PLM132	38.4	1.9	78.5	2904.1	1475.4
518	PLM133	38.4	29.9	85.6	2839.3	1620.8
519	PLM134	33.1	9.5	81.5	2681.8	1338.4
520	PLM135	7.9	24.9	76.7	2852.9	1483.3
521	PLM136	9.5	17.6	85.6	3103.5	1614.7
522	PLM137	28.4	22.4	76.7	2954.9	1544.6
523	PLM138	8.7	11.6	75.7	2805.8	1366.6
524	PLM139	20.6	22.8	86.1	2979.5	1615.4
525	PLM140	6.6	13.5	82.9	2861.9	1408.8
526	PLM141	37.7	25.6	80.3	2584.1	1464.9
527	PLM142	3.9	39.6	83.8	2704.8	1529.1
528	PLM143	37.0	22.3	74.7	3080.2	1384.9
529	PLM144	11.5	11.1	78.0	2606.9	1398.5
530	PLM145	26.8	37.7	76.8	2794.9	1445.3
531	PLM146	15.3	14.3	79.0	2786.6	1423.6
532	PLM147	21.3	39.4	77.4	2807.3	1423.4
533	PLM148	17.9	0.5	82.0	3096.8	1592.6
534	PLM149	21.8	17.5	86.4	2825.0	1596.7
535	PLM150	8.7	15.7	77.1	2720.5	1363.6
536	PLM151	19.0	34.5	86.2	2969.7	1515.6
537	PLM152	9.5	27.5	75.9	2820.0	1266.7
538	PLM153	13.1	9.8	78.9	3186.6	1407.1
539	PLM154	20.2	33.2	78.8	2973.6	1548.4
540	PLM155	30.5	14.9	82.7	2962.5	1533.0
541	PLM156	34.6	22.3	78.5	2856.4	1501.1
542	PLM157	31.3	17.1	84.8	2869.9	1492.6
543	PLM158	34.2	12.4	82.1	3107.0	1553.8
544	PLM159	6.1	28.6	81.1	3037.1	1507.3
545	PLM160	5.2	16.6	83.8	3052.1	1471.1
546	PLM161	27.8	27.1	76.6	2995.6	1475.4
547	PLM162	2.3	35.9	81.9	3214.9	1670.3
548	PLM163	31.3	33.9	88.4	3068.8	1469.8
549	PLM164	5.2	15.5	83.4	2855.1	1510.5
550	PLM165	8.4	22.5	84.9	2701.9	1574.8
551	PLM166	22.5	30.5	74.1	2849.6	1395.6
552	PLM167	6.4	34.3	76.3	2935.0	1386.6
553	PLM168	2.9	18.0	78.7	2857.6	1394.9
554	PLM169	31.6	37.2	81.7	2901.5	1542.4
555	PLM170	12.4	28.0	91.0	2951.9	1638.1
556	PLM171	20.5	24.3	82.4	2926.8	1516.4
557	PLM172	23.8	17.5	71.5	2914.4	1275.6
558	PLM173	0.8	28.4	77.0	2819.4	1277.2
559	PLM174	3.3	30.5	82.9	3087.9	1503.1
560	PLM175	9.4	4.8	78.3	2834.7	1216.6
561	PLM176	2.9	8.9	83.9	2965.1	1669.6
562	PLM177	36.3	23.8	76.8	2668.9	1295.6
563	PLM178	23.1	11.9	72.0	2943.2	1290.3
564	PLM179	30.1	7.0	88.4	2761.8	1635.4
565	PLM180	39.5	39.1	82.6	2987.3	1644.8
566	PLM181	8.5	23.6	77.1	2910.0	1496.6
567	PLM182	6.0	26.4	83.3	2859.2	1504.8
568	PLM183	34.2	0.5	82.8	2807.9	1452.7
569	PLM184	0.2	16.3	83.8	2853.3	1631.2
570	PLM185	23.3	22.3	78.9	3068.7	1595.0
571	PLM186	14.4	6.7	90.0	2853.7	1569.1
572	PLM187	23.5	29.5	80.6	2836.1	1552.1
573	PLM188	9.9	36.0	83.4	2849.0	1535.8
574	PLM189	14.0	13.9	87.2	2965.9	1598.9
575	PLM190	27.8	39.3	77.3	2959.1	1285.6
576	PLM191	26.3	23.4	78.9	2528.6	1401.3
577	PLM192	0.1	25.1	81.4	2912.7	1549.2
578	PLM193	25.7	0.5	80.9	2889.1	1494.6
579	PLM194	16.3	9.8	85.3	2888.3	1435.1
580	PLM195	7.4	35.5	77.6	2912.4	1406.5
581	PLM196	4.9	34.3	87.1	2776.1	1544.6
582	PLM197	29.9	28.4	78.9	2871.6	1451.0
583	PLM198	9.4	33.5	81.8	2610.7	1689.6
584	PLM199	35.5	31.8	83.7	2999.8	1484.6
585	PLM200	2.1	33.3	82.0	2579.8	1573.0
586	PLM201	37.4	23.6	79.2	2977.2	1412.2
587	PLM202	4.2	14.7	84.9	2899.4	1543.5
588	PLM203	32.2	6.7	82.1	2649.6	1485.2
589	PLM204	12.3	23.9	81.3	2716.0	1468.3
590	PLM205	10.8	29.9	85.3	3079.2	1569.4
591	PLM206	25.2	30.8	84.6	3009.1	1552.7
592	PLM207	3.0	23.5	81.8	2832.2	1508.6
593	PLM208	18.6	33.5	77.2	2927.8	1445.6
594	PLM209	22.6	11.6	80.6	2886.9	1553.4
595	PLM210	7.7	38.4	82.4	2883.6	1539.3
596	PLM211	23.1	17.2	78.6	2725.5	1642.2
597	PLM212	2.8	3.8	85.4	2639.5	1625.1
598	PLM213	28.4	13.7	82.3	3061.6	1518.7
599	PLM214	17.0	31.4	78.5	3020.5	1429.1
600	PLM215	35.6	34.4	86.3	2896.9	1437.8
601	PLM216	22.5	15.4	82.9	2735.1	1579.5
602	PLM217	35.2	7.0	81.4	2929.1	1396.7
603	PLM218	35.0	2.8	77.3	2857.1	1371.0
604	PLM219	27.2	15.6	74.0	2955.2	1381.0
605	PLM220	8.9	24.6	83.5	2935.4	1530.4
606	PLM221	11.1	5.9	78.6	2764.9	1488.6
607	PLM222	18.2	32.4	77.9	3058.5	1364.4
608	PLM223	10.3	7.4	76.7	2915.3	1422.0
609	PLM224	4.7	24.2	78.4	3243.0	1423.8
610	PLM225	39.6	1.6	79.9	2416.1	1493.9
611	PLM226	39.6	16.6	77.8	2819.7	1584.7
612	PLM227	36.5	35.3	82.9	2937.7	1600.7
613	PLM228	15.5	21.2	83.7	2754.0	1437.8
614	PLM229	6.6	26.8	92.0	2738.6	1701.9
615	PLM230	4.4	35.3	78.3	2868.6	1393.8
616	PLM231	20.4	3.7	80.2	3002.2	1530.2
617	PLM232	18.1	4.4	76.4	2836.9	1465.7
618	PLM233	12.9	3.7	79.0	3114.5	1420.8
619	PLM234	31.1	33.0	74.3	2878.5	1348.5
620	PLM235	24.2	2.5	75.7	3023.7	1347.4
621	PLM236	33.8	25.2	79.7	2749.1	1537.9
622	PLM237	10.3	14.6	75.4	2613.3	1413.8
623	PLM238	0.7	37.5	87.3	2759.2	1632.6
624	PLM239	10.2	14.3	79.2	2976.3	1452.8
625	PLM240	20.5	4.3	77.0	3025.1	1400.6
626	PLM241	36.8	30.2	82.4	2780.7	1557.0
627	PLM242	24.5	5.3	78.5	2736.0	1452.0
628	PLM243	28.0	16.4	83.4	2964.1	1582.7
629	PLM244	13.0	12.1	79.7	3034.7	1428.5
630	PLM245	27.1	35.1	79.6	2787.5	1523.1
631	PLM246	9.0	35.6	86.2	3242.2	1618.9
632	PLM247	22.3	18.7	85.9	2682.9	1476.4
633	PLM248	17.2	7.1	79.8	2747.2	1455.5
634	PLM249	21.1	10.9	79.9	2853.1	1429.6
635	PLM250	29.1	38.3	84.2	2795.9	1498.4
636	PLM251	27.5	13.9	78.4	3011.6	1388.2
637	PLM252	6.6	6.5	82.9	2749.3	1525.5
638	PLM253	30.2	0.6	81.3	2919.6	1545.9
639	PLM254	5.4	6.4	84.5	3025.7	1459.6
640	PLM255	20.0	11.6	84.0	2622.3	1502.5
641	PLM256	26.9	25.0	78.9	2692.5	1444.2
642	PLM257	38.0	19.1	80.4	2872.9	1562.0
643	PLM258	37.1	24.6	83.6	2699.7	1653.6
644	PLM259	36.0	8.2	85.0	2837.2	1474.2
645	PLM260	36.3	15.9	84.2	2918.8	1464.6
646	PLM261	1.9	9.2	84.7	2728.7	1459.2
647	PLM262	17.5	24.6	83.2	2921.8	1570.1
648	PLM263	7.5	24.9	84.6	2710.2	1629.5
649	PLM264	19.5	7.6	80.8	2668.1	1469.1
650	PLM265	3.8	5.9	79.0	2879.5	1447.9
651	PLM266	17.6	12.7	83.0	2666.6	1352.9
652	PLM267	7.2	3.7	81.2	2792.2	1471.6
653	PLM268	20.0	29.5	84.1	2672.2	1529.4
654	PLM269	4.3	6.2	78.7	2947.0	1523.0
655	PLM270	34.4	6.3	76.4	3031.2	1384.2
656	PLM271	38.5	24.6	79.8	2922.4	1465.6
657	PLM272	25.5	4.5	78.9	2905.0	1406.6
658	PLM273	3.1	10.0	80.9	2871.9	1447.0
659	PLM274	22.4	0.0	77.2	2595.0	1363.0
660	PLM275	34.0	21.9	79.9	3262.6	1566.9
661	PLM276	20.5	7.5	82.3	2595.3	1572.8
662	PLM277	19.5	21.0	79.0	2544.4	1342.2
663	PLM278	2.3	37.9	82.7	3129.4	1623.9
664	PLM279	17.6	11.8	72.9	2894.6	1335.4
665	PLM280	14.5	22.3	87.2	2809.8	1623.0
666	PLM281	4.0	0.6	83.0	2945.6	1473.9
667	PLM282	40.0	19.7	83.7	2852.4	1596.5
668	PLM283	12.6	2.0	85.1	2625.4	1586.8
669	PLM284	1.7	12.4	82.3	2735.1	1519.4
670	PLM285	37.6	35.5	80.3	2575.7	1402.0
671	PLM286	9.4	3.2	82.9	2984.6	1557.3
672	PLM287	5.9	32.9	87.3	2780.4	1492.4
673	PLM288	35.7	34.3	77.3	2788.7	1362.9
674	PLM289	4.8	27.5	84.4	3140.1	1574.8
675	PLM290	8.3	5.9	83.5	2888.6	1476.9
676	PLM291	2.2	33.2	86.2	3016.6	1601.7
677	PLM292	19.9	19.1	83.3	3029.7	1543.2
678	PLM293	12.1	16.3	79.7	2782.5	1542.1
679	PLM294	16.5	24.4	77.4	2868.8	1391.4

680	PLM295	13.8	12.2	77.6	2645.2	1416.0
681	PLH1	2.7	24.9	71.9	3283.7	1192.2
682	PLH2	2.2	27.0	74.8	3281.2	1166.7
683	PLH3	8.5	5.8	70.9	3442.5	1126.1
684	PLH4	11.5	10.6	75.5	3500.7	1371.8
685	PLH5	20.0	2.5	74.6	3204.9	1205.4
686	PLH6	38.5	18.4	71.6	3015.0	1176.7
687	PLH7	13.0	4.4	76.2	3435.0	1252.7
688	PLH8	32.8	18.5	72.6	3412.0	1240.0
689	PLH9	7.2	28.4	66.5	3226.5	1161.1
690	PLH10	28.3	31.3	75.1	3507.8	1223.8
691	PLH11	38.6	18.5	74.5	3240.9	1245.1
692	PLH12	33.5	14.8	75.3	3417.4	1323.5
693	PLH13	2.1	7.1	77.0	3372.6	1317.7
694	PLH14	34.5	20.3	67.5	3236.2	1144.7
695	PLH15	8.1	28.5	72.0	3223.1	1205.7
696	PLH16	23.5	1.9	73.1	3719.2	1219.1
697	PLH17	20.1	24.7	63.8	3226.8	1100.9
698	PLH18	39.2	17.2	67.4	3480.0	1064.8
699	PLH19	19.4	27.7	69.6	3489.1	1237.8
700	PLH20	14.3	26.6	75.2	3587.9	1310.6
701	PLH21	5.9	3.9	70.6	3181.7	1212.8
702	PLH22	3.8	26.7	69.7	3241.6	1112.1
703	PLH23	23.3	28.5	67.2	3276.9	1149.4
704	PLH24	28.9	39.7	66.9	3383.2	1097.9
705	PLH25	30.1	21.3	77.4	3409.8	1225.8
706	PLH26	34.1	7.4	72.1	3183.0	1169.9
707	PLH27	26.4	16.1	75.5	3696.3	1220.1
708	PLH28	28.1	29.7	65.2	3258.7	1022.2
709	PLH29	29.9	22.6	70.7	3467.5	1150.3
710	PLH30	34.5	11.4	73.6	3618.1	1244.0
711	PLH31	30.4	8.5	72.2	3355.7	1097.8
712	PLH32	37.0	10.4	72.2	3357.1	1124.7
713	PLH33	27.4	7.5	68.0	3348.0	1210.9
714	PLH34	29.7	14.8	70.4	3330.5	1177.4
715	PLH35	35.0	37.6	70.0	3285.9	1247.5
716	PLH36	26.5	9.5	75.5	3326.3	1225.1
717	PLH37	1.5	37.3	66.3	3336.3	1092.3
718	PLH38	25.8	15.1	67.9	3442.4	1101.8
719	PLH39	8.8	30.3	77.6	3266.9	1322.4
720	PLH40	10.9	35.9	72.6	3358.1	1150.0
721	PLH41	19.9	2.7	73.4	3234.3	1136.5
722	PLH42	0.2	30.4	76.2	3499.4	1260.0
723	PLH43	17.1	10.9	73.2	3214.9	1168.7
724	PLH44	15.5	16.1	67.5	3062.1	1187.5
725	PLH45	5.6	0.7	74.9	3415.8	1324.0
726	PLH46	2.9	32.1	76.8	3124.8	1357.7
727	PLH47	20.1	30.1	79.9	3389.8	1343.1
728	PLH48	29.4	1.6	66.3	3435.4	1217.8
729	PLH49	33.8	22.7	71.8	3564.1	1271.0
730	PLH50	13.7	8.4	64.4	3348.1	973.9
731	PLH51	8.9	26.3	75.5	3135.2	1203.9
732	PLH52	20.0	39.5	69.0	3096.2	1178.8
733	PLH53	7.8	0.8	74.0	2978.2	1285.3
734	PLH54	7.8	26.2	74.4	3176.0	1193.2
735	PLH55	32.1	25.1	73.7	3196.0	1219.3
736	PLH56	16.0	16.2	71.1	3139.6	1199.6
737	PLH57	22.8	33.1	75.4	3471.5	1302.9
738	PLH58	22.0	3.8	69.0	3280.4	1189.3
739	PLH59	32.8	38.9	72.7	3293.3	1156.8
740	PLH60	1.5	8.1	68.5	3232.3	1106.4
741	PLH61	7.5	37.8	71.8	3219.7	1255.2
742	PLH62	12.4	2.6	65.2	3271.4	1140.2
743	PLH63	1.2	34.0	71.6	3231.7	1133.5
744	PLH64	28.8	7.4	70.8	3303.9	1177.2
745	PLH65	21.8	10.5	69.1	3178.0	1111.5
746	PLH66	19.5	26.6	71.4	3314.6	1148.5
747	PLH67	36.8	32.5	64.5	3430.9	946.7
748	PLH68	21.8	38.8	81.2	3319.5	1318.2
749	PLH69	3.3	40.0	70.8	3252.3	1156.6
750	PLH70	28.0	36.6	75.4	3327.6	1273.0
751	PLH71	21.4	18.7	70.5	3381.6	1162.8
752	PLH72	16.7	27.2	75.9	3117.1	1254.2
753	PLH73	28.8	26.6	68.9	3246.3	1115.0
754	PLH74	27.3	13.0	71.7	3220.4	1158.8
755	PLH75	17.9	16.4	71.6	3456.8	1075.1
756	PLH76	23.7	34.8	69.7	3294.6	1200.7
757	PLH77	6.9	23.5	74.2	3155.8	1171.8
758	PLH78	26.1	20.8	70.6	3387.7	1111.1
759	PLH79	32.8	14.7	66.5	3174.1	1092.1
760	PLH80	20.9	13.1	70.5	3376.8	1143.3
761	PLH81	15.9	37.3	70.5	3049.5	1165.9
762	PLH82	14.4	39.1	68.9	3286.6	1195.9
763	PLH83	8.6	9.6	69.1	3178.7	1163.0
764	PLH84	9.7	7.0	69.6	3226.4	1088.4
765	PLH85	7.4	37.5	70.6	3191.0	1136.8
766	PLH86	8.8	21.3	75.3	3439.4	1301.8
767	PLH87	13.3	2.6	73.5	3546.1	1422.8
768	PLH88	18.9	9.2	69.0	3200.8	1195.0
769	PLH89	23.6	17.4	71.3	3430.5	1236.7
770	PLH90	21.9	13.4	73.4	3534.3	1137.9
771	PLH91	21.8	12.0	69.0	3201.5	1197.2
772	PLH92	10.5	10.7	74.8	3219.8	1186.4
773	PLH93	26.9	5.9	69.8	3439.3	1151.2
774	PLH94	37.0	34.8	74.6	3576.0	1176.4
775	PLH95	18.0	14.8	75.3	3368.8	1204.9
776	PLH96	0.5	1.0	75.3	3257.7	1273.6
777	PLH97	23.7	21.8	72.0	3144.8	1179.9
778	PLH98	38.6	33.0	81.0	3384.9	1278.3
779	PLH99	28.2	28.8	73.4	2808.8	1353.6
780	PLH100	37.4	13.4	79.6	3101.3	1305.9
781	PLH101	10.2	17.5	71.1	3005.0	1153.3
782	PLH102	7.4	20.9	71.2	3380.0	1273.2
783	PLH103	33.3	0.6	70.4	3233.0	1233.3
784	PLH104	16.4	34.1	75.0	3216.7	1196.0
785	PLH105	37.6	4.2	74.6	3205.1	1282.3
786	PLH106	30.2	31.1	74.6	2939.2	1182.4
787	PLH107	16.3	0.6	72.8	3298.0	1252.7
788	PLH108	2.3	8.7	73.9	3422.2	1204.3
789	PLH109	27.6	4.9	69.8	3144.3	1137.1
790	PLH110	6.2	8.2	73.0	3293.7	1215.5
791	PLH111	1.1	15.9	73.6	3301.8	1260.3
792	PLH112	30.6	22.4	75.9	3246.3	1295.6
793	PLH113	0.4	4.1	77.5	3187.7	1258.6
794	PLH114	6.1	19.9	70.1	3305.7	1187.0
795	PLH115	0.9	34.6	73.3	3346.1	1210.6
796	PLH116	33.7	25.0	72.9	3298.3	1267.8
797	PLH117	19.6	25.6	77.9	3435.5	1250.2
798	PLH118	33.2	38.8	72.9	3553.7	1133.6
799	PLH119	28.1	14.7	72.7	3419.3	1190.5
800	PLH120	0.1	33.0	64.4	3163.6	1031.2
801	PLH121	37.7	1.5	75.5	3338.1	1244.1
802	PLH122	1.2	6.3	72.6	3412.7	1140.3
803	PLH123	30.1	36.2	67.5	3150.1	1193.9
804	PLH124	11.2	19.5	66.7	3256.4	1136.3
805	PLH125	28.7	17.7	68.8	3040.4	1154.5
806	PLH126	18.4	20.0	70.9	2971.5	1129.8
807	PLH127	16.3	24.7	73.0	3565.5	1149.6
808	PLH128	23.1	4.7	75.6	3344.7	1296.9
809	PLH129	7.6	39.6	74.3	2936.1	1229.2
810	PLH130	21.9	28.5	73.5	3361.4	1165.1
811	PLH131	30.7	38.3	69.1	3552.9	1161.9
812	PLH132	31.4	19.4	80.1	3221.5	1408.4
813	PLH133	34.7	26.5	67.5	3464.6	1049.5
814	PLH134	18.6	20.9	69.5	3603.7	1150.8
815	PLH135	17.2	12.5	70.3	3191.5	1225.0
816	PLH136	24.1	17.6	74.4	3355.9	1339.7
817	PLH137	30.1	11.4	72.8	3525.3	1213.0
818	PLH138	13.1	36.1	73.0	3435.2	1169.1
819	PLH139	33.8	25.3	72.6	3127.4	1229.5
820	PLH140	37.0	2.5	75.1	3309.8	1174.4
821	EMM1	2.7	26.9	44.4	1597.1	783.5
822	EMM2	38.1	14.8	39.8	1622.3	604.9
823	EMM3	16.1	12.6	38.9	1642.7	605.2
824	EMM4	20.6	2.2	39.3	1564.3	652.6
825	EMM5	16.3	24.4	39.9	1518.4	639.1
826	EMM6	22.8	7.3	38.7	1530.9	625.8
827	EMM7	35.4	3.9	41.3	1590.0	703.8
828	EMM8	14.0	26.4	39.3	1403.8	697.2
829	EMM9	29.2	23.0	36.2	1657.9	575.1
830	EMM10	13.6	30.0	42.5	1613.9	650.3
831	EMM11	15.5	23.6	37.9	1590.7	651.8
832	EMM12	27.2	33.3	37.0	1728.3	624.6
833	EMM13	29.0	33.6	39.5	1521.3	615.2
834	EMM14	18.6	14.3	41.5	1784.5	693.0
835	EMM15	3.4	10.2	41.1	1562.1	669.3
836	EMM16	18.2	30.3	40.9	1619.9	661.2
837	EMM17	3.1	11.6	36.9	1628.0	638.7
838	EMM18	4.1	8.2	38.9	1715.3	666.0
839	EMM19	5.6	38.8	36.0	1726.6	603.7
840	EMM20	14.4	36.9	41.2	1524.2	670.0
841	EMM21	38.2	37.1	37.7	1671.1	672.4
842	EMM22	2.3	12.8	40.1	1547.4	673.5
843	EMM23	14.1	32.6	41.5	1683.8	682.2
844	EMM24	24.9	8.0	42.6	1580.5	731.6
845	EMM25	9.3	39.3	39.4	1572.7	708.6
846	EMM26	21.9	18.8	40.2	1473.4	600.8
847	EMM27	37.1	37.9	36.5	1586.2	614.8
848	EMM28	38.7	35.6	40.6	1588.3	640.4
849	EMM29	10.6	38.7	38.6	1559.5	614.5
850	EMM30	22.1	24.5	38.4	1722.2	579.0
851	ELM1	26.2	39.8	65.5	5032.3	1135.3

852	ELM2	4.0	34.9	71.1	5519.1	1185.7
853	ELM3	28.6	4.4	70.2	4378.5	1234.6
854	ELM4	39.5	7.1	65.4	5519.3	1033.9
855	ELM5	37.8	24.4	74.2	4877.2	1213.1
856	ELM6	5.0	38.4	74.3	5226.6	1209.6
857	ELM7	4.8	28.6	70.3	4374.4	1181.7
858	ELM8	13.9	5.7	71.7	5031.1	1165.7
859	ELM9	37.9	9.6	76.5	4978.6	1359.4
860	ELM10	33.1	27.4	76.0	5059.2	1242.0
861	ELM11	17.5	31.7	67.2	4834.0	1093.1
862	ELM12	4.8	35.7	66.9	4786.0	1113.1
863	ELM13	24.3	16.9	72.7	4783.0	1305.5
864	ELM14	25.0	15.8	68.6	5253.9	1177.0
865	ELM15	4.3	31.5	71.6	5305.0	1218.4
866	ELM16	13.8	21.6	65.4	5004.0	940.7
867	ELM17	22.3	17.7	66.9	4999.9	1087.0
868	ELM18	31.4	37.7	69.0	5187.3	1239.8
869	ELM19	38.0	1.4	67.1	5238.2	1122.9
870	ELM20	8.1	7.3	69.2	4525.8	1150.7
871	ELM21	23.5	30.6	68.2	4680.5	1169.2
872	ELM22	6.6	34.6	67.4	4707.4	1083.3
873	ELM23	13.1	0.8	67.3	4820.3	1095.6
874	ELM24	37.1	39.3	65.6	5545.2	1095.7
875	ELM25	8.2	26.2	68.1	5184.7	1241.0
876	ELM26	15.6	21.3	73.9	5241.9	1289.2
877	ELM27	17.1	39.7	70.3	4966.7	1107.6
878	ELM28	7.3	33.4	66.2	5295.8	1085.6
879	ELM29	15.1	1.1	67.0	4987.0	1115.1
880	ELM30	1.4	15.6	70.0	4751.5	1211.7
881	ELM31	3.2	6.9	67.8	5184.4	1099.2
882	ELM32	16.4	25.5	68.5	4855.6	1103.2
883	ELM33	36.4	31.2	65.8	5328.6	1096.2
884	ELM34	4.3	34.0	68.5	5019.0	1116.7
885	ELM35	38.5	4.8	66.8	4764.0	1153.0
886	ELM36	4.6	16.9	71.3	4936.1	1222.0
887	ELM37	16.8	33.4	67.1	5051.8	1008.9
888	ELM38	7.9	20.6	70.5	5074.3	1240.6
889	ELM39	23.5	5.4	67.0	5155.5	1104.7
890	ELM40	4.2	8.9	68.5	4640.5	1152.5
891	ELM41	20.3	32.3	67.4	4735.8	1123.1
892	ELM42	28.7	36.0	65.9	4688.0	1108.1
893	ELM43	33.6	18.2	68.2	5125.1	1172.8
894	ELM44	34.2	5.5	64.1	5114.6	1061.7
895	ELM45	36.5	0.6	70.3	4650.5	1237.1
896	ELM46	11.0	19.7	68.8	5249.9	1160.2
897	ELM47	14.0	23.1	67.2	5233.9	1104.5
898	ELM48	4.7	11.9	69.3	5370.0	1163.8
899	ELM49	9.2	32.4	72.8	4965.7	1264.9
900	ELM50	1.9	39.0	71.0	5184.1	1218.1
901	ELM51	20.8	35.3	62.4	5183.6	960.7
902	NLM1	37.3	22.6	85.5	3958.3	1606.6
903	NLM2	38.2	12.1	89.6	4356.2	1696.5
904	NLM3	33.8	37.5	93.1	4210.1	1783.0
905	NLM4	17.0	22.1	86.4	4178.5	1675.8
906	NLM5	18.2	30.6	87.2	3914.3	1655.4
907	NLM6	6.7	10.8	86.2	4034.4	1486.2
908	NLM7	3.9	21.0	82.4	4068.6	1583.7
909	NLM8	10.3	20.6	91.2	3750.1	1583.9
910	NLM9	14.7	32.8	81.8	4202.3	1466.9
911	NLM10	35.7	20.1	86.3	3877.8	1511.7
912	NLM11	9.5	16.6	91.6	3692.9	1801.3
913	NLM12	6.7	39.6	86.7	4094.8	1680.8
914	NLM13	34.6	12.2	82.3	4174.8	1544.0
915	NLM14	19.7	22.3	89.3	4046.8	1715.1
916	NLM15	19.6	24.2	87.7	4551.2	1744.7
917	NLM16	29.5	39.6	89.1	3813.9	1615.2
918	NLM17	10.6	13.9	83.4	4154.1	1611.0
919	NLM18	7.5	17.3	78.5	3888.0	1371.6
920	NLM19	15.1	21.5	82.2	4057.9	1504.0

Table A4. Dairy farms' location (x and y), available land and exchangeable land.

Farm	x	y	total land (ha)	Exchangeable land (ha)
D1	13.7	1.0	41.4	12.4
D2	14.8	10.5	46.5	14.0
D3	10.7	17.9	47.4	14.2
D4	13.9	4.9	45.0	13.5
D5	14.7	19.2	46.6	14.0
D6	19.3	5.6	47.4	14.2
D7	3.7	0.2	46.6	14.0
D8	2.8	6.8	45.4	13.6
D9	9.3	17.1	44.6	13.4
D10	14.0	17.0	47.0	14.1
D11	10.3	6.9	41.9	12.6
D12	16.3	15.7	48.6	14.6
D13	12.7	13.2	44.8	13.4
D14	2.2	14.4	46.6	14.0
D15	6.9	13.5	44.4	13.3
D16	5.8	9.2	40.4	12.1
D17	10.4	16.9	41.5	12.5
D18	6.7	8.7	46.6	14.0
D19	10.2	16.8	48.4	14.5
D20	0.1	0.1	44.9	13.5
D21	4.2	17.9	47.6	14.3
D22	13.9	9.3	44.6	13.4
D23	5.6	15.6	43.0	12.9
D24	13.7	4.5	53.0	15.9
D25	18.3	3.8	42.7	12.8
D26	0.2	9.2	43.5	13.1
D27	14.0	2.8	48.0	14.4
D28	5.3	14.8	43.0	12.9
D29	13.6	12.5	48.1	14.4
D30	15.7	4.2	45.3	13.6
D31	12.4	2.3	43.5	13.0
D32	2.8	11.2	45.6	13.7
D33	11.0	12.8	42.9	12.9
D34	3.0	11.2	46.5	14.0
D35	17.7	9.6	44.9	13.5
D36	15.0	15.5	45.5	13.6
D37	5.7	12.2	44.9	13.5
D38	17.2	3.0	46.8	14.0
D39	4.8	4.2	45.9	13.8
D40	12.7	17.8	46.0	13.8
D41	10.8	11.6	44.8	13.4
D42	8.6	16.3	46.8	14.0
D43	4.7	13.5	47.2	14.2
D44	12.8	3.3	42.0	12.6
D45	15.7	14.6	47.3	14.2
D46	7.0	10.0	46.6	14.0
D47	12.6	1.0	47.0	14.1
D48	1.7	18.9	44.3	13.3
D49	15.6	13.2	46.0	13.8
D50	11.6	15.8	42.3	12.7
D51	3.9	8.9	45.4	13.6
D52	1.2	18.2	43.9	13.2
D53	12.1	19.2	47.4	14.2
D54	16.7	8.8	44.0	13.2
D55	7.0	3.9	45.9	13.8
D56	15.9	6.9	44.0	13.2
D57	10.9	4.1	50.0	15.0
D58	5.3	18.1	44.6	13.4
D59	3.4	3.0	41.7	12.5
D60	0.1	19.6	49.4	14.8
D61	4.4	5.7	52.0	15.6
D62	15.6	14.4	46.8	14.0
D63	13.9	19.1	40.9	12.3
D64	9.4	6.8	42.0	12.6
D65	8.4	13.7	50.2	15.1
D66	12.3	6.8	42.7	12.8
D67	19.5	11.4	47.3	14.2
D68	5.0	13.5	48.5	14.6
D69	8.7	14.8	48.2	14.5
D70	7.4	16.3	45.3	13.6
D71	9.6	17.9	44.9	13.5
D72	12.0	5.1	42.3	12.7
D73	7.8	7.6	40.2	12.1
D74	7.9	4.6	44.8	13.4
D75	7.8	8.2	48.8	14.6
D76	6.0	17.0	48.1	14.4
D77	15.6	7.9	49.4	14.8
D78	8.2	12.2	46.0	13.8
D79	12.1	2.5	47.8	14.3
D80	4.9	13.6	48.9	14.7
D81	17.0	16.8	44.2	13.3
D82	16.6	13.5	44.2	13.2
D83	18.0	10.6	47.0	14.1
D84	16.4	4.1	46.5	13.9
D85	18.6	10.9	46.6	14.0
D86	13.8	16.6	49.0	14.7
D87	11.6	19.6	40.1	12.0
D88	11.9	12.1	46.6	14.0
D89	11.8	17.6	47.5	14.3
D90	2.9	8.4	45.6	13.7
D91	12.6	12.8	42.5	12.8
D92	3.4	13.2	45.2	13.6
D93	8.2	13.6	46.5	14.0
D94	18.2	5.0	46.6	14.0
D95	7.4	5.8	45.1	13.5
D96	10.2	7.8	50.9	15.3
D97	6.5	12.7	46.8	14.0
D98	6.6	4.1	46.7	14.0
D99	5.9	9.1	45.3	13.6
D100	6.8	0.3	47.1	14.1
D101	15.3	17.6	42.8	12.8
D102	12.0	18.1	53.0	15.9
D103	13.9	4.7	48.9	14.7
D104	12.4	15.1	45.6	13.7
D105	14.5	11.7	43.6	13.1
D106	9.6	0.7	47.0	14.1
D107	11.8	18.2	45.7	13.7
D108	4.3	1.2	43.5	13.1
D109	15.0	11.9	47.4	14.2
D110	10.5	9.1	48.1	14.4
D111	6.5	19.4	44.7	13.4
D112	8.8	19.8	44.2	13.3
D113	5.7	19.8	42.8	12.8
D114	13.8	1.0	45.6	13.7
D115	12.5	6.5	47.1	14.1
D116	2.5	15.2	45.7	13.7
D117	17.4	0.2	46.1	13.8
D118	20.0	18.8	48.1	14.4
D119	18.6	5.7	47.1	14.1
D120	14.8	5.1	48.8	14.6
D121	19.5	18.1	44.3	13.3
D122	3.7	11.1	44.8	13.4
D123	10.5	8.9	48.0	14.4
D124	16.3	1.3	43.7	13.1
D125	18.6	12.2	43.8	13.1
D126	0.1	14.7	47.2	14.2
D127	2.5	4.5	42.8	12.9
D128	5.7	18.9	42.8	12.8
D129	10.3	18.1	46.8	14.0
D130	5.6	3.1	48.8	14.6
D131	17.1	15.0	45.9	13.8
D132	12.5	6.2	45.0	13.5
D133	10.4	7.4	49.3	14.8
D134	12.5	2.9	52.8	15.8
D135	4.2	18.0	44.0	13.2
D136	16.0	1.2	49.6	14.9
D137	20.0	14.8	47.4	14.2
D138	0.7	8.6	41.0	12.3
D139	19.0	2.7	46.1	13.8
D140	6.8	10.9	47.2	14.2
D141	15.8	1.9	46.1	13.8
D142	14.0	3.0	47.7	14.3
D143	13.9	2.3	47.1	14.1
D144	7.5	6.7	46.4	13.9
D145	5.1	19.1	45.1	13.5
D146	20.0	20.0	45.8	13.7
D147	4.4	6.2	49.7	14.9
D148	9.0	16.5	44.4	13.3
D149	10.1	2.5	48.7	14.6
D150	15.5	0.0	44.0	13.2
D151	8.8	18.5	45.1	13.5
D152	15.9	31.2	45.8	13.7
D153	18.8	21.7	43.7	13.1
D154	14.8	32.3	46.6	14.0
D155	4.2	24.1	43.3	13.0
D156	2.6	21.1	47.0	14.1
D157	9.7	29.1	46.6	14.0
D158	13.0	36.4	48.2	14.5
D159	2.4	30.8	45.7	13.7
D160	0.7	24.1	39.3	11.8
D161	18.4	31.6	47.4	14.2
D162	19.8	24.5	47.5	14.3
D163	9.8	32.3	46.8	14.0
D164	7.0	23.7	43.6	13.1
D165	12.4	21.8	47.0	14.1

D166	7.3	33.6	46.3	13.9
D167	12.5	27.5	45.8	13.7
D168	3.4	36.2	47.9	14.4
D169	16.9	22.9	46.4	13.9
D170	19.8	34.3	45.9	13.8
D171	12.0	28.4	42.4	12.7
D172	2.7	25.7	49.3	14.8
D173	11.8	35.5	45.6	13.7
D174	19.9	29.6	47.9	14.4
D175	2.6	38.4	47.6	14.3
D176	2.8	22.7	46.7	14.0
D177	19.4	33.8	46.7	14.0
D178	17.4	28.6	48.4	14.5
D179	12.0	30.8	50.0	15.0
D180	0.5	26.2	47.4	14.2
D181	10.3	30.5	47.8	14.3
D182	14.0	20.0	43.2	13.0
D183	3.8	24.9	46.1	13.8
D184	9.7	23.4	43.8	13.1
D185	19.4	28.3	47.5	14.3
D186	0.5	27.1	42.6	12.8
D187	14.7	28.9	48.0	14.4
D188	11.1	26.2	46.8	14.0
D189	9.3	28.4	43.7	13.1
D190	4.5	25.0	47.8	14.4
D191	11.9	24.6	53.5	16.0
D192	18.3	32.5	48.3	14.5
D193	10.6	20.4	47.8	14.3
D194	11.1	37.5	44.8	13.5
D195	16.2	35.2	49.4	14.8
D196	4.1	27.0	47.6	14.3
D197	16.3	20.8	45.1	13.5
D198	2.1	36.6	48.2	14.5
D199	7.7	33.2	43.5	13.1
D200	1.6	35.5	41.1	12.3
D201	0.9	33.5	45.2	13.5
D202	0.3	35.1	49.5	14.9
D203	5.2	33.4	44.8	13.4
D204	16.0	28.9	45.3	13.6
D205	17.3	27.3	44.7	13.4
D206	5.8	32.5	47.4	14.2
D207	2.6	26.6	50.0	15.0
D208	7.5	22.7	48.2	14.5
D209	17.0	30.8	46.8	14.1
D210	17.0	26.9	44.2	13.3
D211	5.7	33.6	43.5	13.1
D212	18.1	26.0	49.2	14.8
D213	16.6	31.5	45.0	13.5
D214	18.8	23.1	43.1	12.9
D215	20.0	36.8	44.8	13.4
D216	13.7	38.8	45.6	13.7
D217	11.0	25.2	44.8	13.4
D218	12.0	26.8	48.1	14.4
D219	19.3	20.1	46.5	14.0
D220	9.6	35.9	47.1	14.1
D221	15.2	39.4	46.4	13.9
D222	8.9	26.6	45.8	13.7
D223	18.5	33.6	41.5	12.5
D224	2.3	35.4	46.4	13.9
D225	17.7	33.7	49.1	14.7
D226	5.7	36.9	45.7	13.7
D227	24.0	15.1	45.8	13.7
D228	29.2	16.3	45.9	13.8
D229	31.4	11.2	47.2	14.1
D230	38.5	17.2	49.5	14.9
D231	22.9	9.9	42.7	12.8
D232	30.8	9.8	40.9	12.3
D233	36.5	7.0	43.5	13.1
D234	34.2	12.0	45.8	13.8
D235	32.4	7.5	44.7	13.4
D236	23.9	7.4	46.2	13.9
D237	28.0	15.1	47.1	14.1
D238	21.7	12.2	42.2	12.7
D239	23.6	14.6	46.8	14.0
D240	28.6	10.3	44.9	13.5
D241	27.3	16.9	45.5	13.6
D242	24.9	10.6	45.7	13.7
D243	39.6	11.2	42.9	12.9
D244	21.2	6.2	45.9	13.8
D245	38.7	18.3	44.6	13.4
D246	26.9	18.1	42.5	12.8
D247	31.9	18.0	46.6	14.0
D248	33.3	9.1	47.6	14.3
D249	33.3	10.5	47.1	14.1
D250	35.2	3.4	47.6	14.3
D251	31.3	11.3	50.4	15.1
D252	32.4	4.7	44.1	13.2
D253	21.0	4.2	49.0	14.7
D254	31.7	11.1	44.9	13.5
D255	27.0	17.0	43.8	13.1
D256	23.0	11.1	47.6	14.3
D257	20.9	0.5	43.4	13.0
D258	28.3	15.4	42.1	12.6
D259	23.8	11.5	46.3	13.9
D260	35.0	10.4	42.7	12.8
D261	28.5	9.7	45.3	13.6
D262	23.4	13.6	43.6	13.1
D263	25.3	13.6	44.8	13.4
D264	28.0	17.5	44.0	13.2
D265	35.8	19.1	43.3	13.0
D266	30.9	14.7	45.5	13.6
D267	25.2	10.2	44.3	13.3
D268	35.6	0.9	46.0	13.8
D269	23.8	7.4	44.2	13.3
D270	24.3	15.2	41.8	12.6
D271	35.5	7.8	47.8	14.3
D272	30.9	14.4	46.0	13.8
D273	24.8	17.7	43.4	13.0
D274	37.1	17.3	46.2	13.8
D275	24.3	2.9	46.2	13.8
D276	22.2	13.1	39.5	11.8
D277	34.1	10.9	43.5	13.0
D278	30.0	13.3	43.4	13.0
D279	21.0	11.4	44.7	13.4
D280	20.9	16.8	46.7	14.0
D281	33.2	2.1	44.5	13.3
D282	30.2	12.6	45.9	13.8
D283	20.3	7.2	43.0	12.9
D284	34.5	17.9	49.1	14.7
D285	23.8	9.5	44.3	13.3
D286	28.1	15.9	42.5	12.7
D287	26.9	9.3	44.8	13.4
D288	34.7	4.2	43.9	13.2
D289	34.2	12.2	46.0	13.8
D290	25.0	12.3	46.5	13.9
D291	33.8	17.3	50.6	15.2
D292	20.3	7.2	41.9	12.6
D293	22.9	3.1	46.7	14.0
D294	28.2	19.5	44.7	13.4
D295	30.0	7.9	46.1	13.8
D296	30.6	17.9	46.9	14.1
D297	39.1	1.7	45.8	13.7
D298	30.9	5.2	46.8	14.0
D299	21.4	10.7	50.0	15.0
D300	37.7	20.0	46.9	14.1
D301	37.3	3.0	47.0	14.1