Effects of the new Swedish strategic Plan for CAP 2023-2027 on proportion of Cultivated Perennial Grasses in Uppsala

Aggregate modelling of farmland allocation in Sweden using Positive Mathematical Programming

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Abstract

Changes in compensations and subsidies in the new proposed Swedish strategic plan for CAP will alter farmers' decisions on the allocation of arable land. This study estimates effects on allocation of cultivated perennial grasses as a result of the proposed abolishment of the current environmental compensation for the named crop. The estimation is based on positive mathematical programming and the study is delimited to Uppsala. Three different calibration approaches for positive mathematical programming are used and the results indicate a decrease in perennial grasses. The results are discussed in regards to environmental goals regarding carbon sequestration and biodiversity established by the EU.

Keywords: Agriculture, Positive Mathematical Programming, Agricultural Policy, CAP

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Abbreviations

CAP	Common Agricultural Policy
EC	Environmental Compensation
EU	European Union
PMP	Positive mathematical programming
LP	Linear programming
NLP	Non-linear programming

1. Introduction

The introduction section provides a background on the problem, objectives, research question and the delimitations chosen for the study.

1.1 Problem formulation

Agricultural policy within the EU is directed and framed by the Common Agricultural Policy (CAP) which is adopted and implemented by all member states. For the period 2023-2027, the Swedish government has proposed a strategic plan for its policies and it comes with several changes that could affect farmer's decisions regarding production practices and land allocation. Modelling using mathematical programming can provide relevant information on such decision processes where economic or econometric methods might be less useful (Hazell & Norton 1986). The policy of interest examined in this paper is the abolishment of the environmental compensation for cultivated grass forages (ley) in areas not entitled for compensation support. The environmental compensation for cultivation of grass forages has previously constituted 500kr/ha in the established support areas of category 13 (SFS 2015:406), in which the majority of Uppsala municipality is included. However, in the strategic plan for CAP 2023-2027, the abolishment of the foregoing subsidy is proposed.

The strategic plan for CAP 2023-2027 includes three general goals, of which one concerns positive environmental externalities from agriculture including carbon sequestration, sustainable production and biodiversity (Regeringen 2021). With this background, decreased nutrient leaching and the stimulation of sustainable farming motivated environmental compensations for cultivated perennial grasses as a policy for achieving this objective. The specific objective (d) in article 6 in *Regulation (EU 2021/2115) of the European Parliament and of the Council* further legitimates this objective.

At least one ex ante evaluation of the proposed strategic plan ordered by the Swedish Board of Agriculture has been presented (Denninger et al. 2021) and the evaluation report briefly covers the abolishment of environmental compensation for cultivated grasslands. The report points out the positive effects of carbon sequestration due to perennial grasses covering the soil and refers to findings from Bolinder et al. (2017) and Brady et al. (2019) and concludes that the strategic plan contains no analysis of the effects on farm-level nor climatic effects. The lack of analysis regarding the effects of the abolishment of environmental compensation for perennial grasses on farm- or regional level motivates and justifies this study.

1.2 Objectives and research question

This study's objective is to examine the research question:
- *What are the effects of the new Swedish strategic plan for CAP 2023-2027 on farmers' crop allocation decisions and proportion of cultivated grass forages in Uppsala?*

Positive mathematical programming (PMP) is used to answer the research question. The objective is not only of environmental character, but also comes with economic implications as the abolishment of the environmental compensation for grass forages affects farmer's profitability. With regards to the specific objectives of the EU regulation (2021/2115) article 6, this paper seeks to make a contribution to the evaluation of the Swedish strategic plan for CAP 2023-2027 on aggregate farm-level crop allocation.

1.3 Delimitations

Uppsala municipality is chosen as a suitable study area as it is one of the regions in Sweden affected by the proposed compensation abolishment. The policy implications, however, may not be limited to Uppsala but can be applied to other regions in Sweden also be affected by the proposed policy change. The proposed strategic plan for CAP includes multiple changes in subsidy- and compensation rates and this study focuses solely on the abolishment on the abolishment of the environmental compensation for grass forages and concluding policy evaluations are not to be considered valid for the new strategic plan altogether.

1.4 Outline

The purpose of the literature review, which forms the next section, is to define the literary context in which this study is intended to fill gaps. The literature review presents prominent works relevant to this study and further clarifies the scope of the study. The third section accounts for the relevant methodology including subsections such as conceptual framework, model specification and data descriptions. The fourth section presents the results obtained from the PMP-model and is followed by the fifth section discussing the results and policy implications from an economic and environmental perspective. Finally, section six presents the concluding remarks and also proposes questions for further research.

2. Literature review

For simplicity, the literature used in this study is categorized into two groups covering works of practical research useful for policy implications and theoretical research with methodological implications.

The first category consists of studies such as Bolinder et al. (2017) and Brady et al. (2019), providing analyses on carbon sequestration and emissions of perennial grass crops. Bolinder et al. (2017) assert that the abruption of intensive crop rotation schemes, cultivating annual highly productive and profitable crops, with cultivated grass forages increases the carbon sequestration in the soil. However, the cultivation of perennial grass crops is generally less profitable than annual crops such as grains and vegetables, which initially motivated the implementation of the environmental compensation for cultivated grass forages.

Brady et al. (2019) simulated, using policy evaluation software AgriPoliS, the introduction of two-year grass crops into the crop rotation schemes in the southern parts of Götaland (comparative to Uppsala region as they are both in the Swedish board of Agriculture established compensation area 13). They discovered that if 25% of the arable land would be used for cultivated grass forages, the carbon sequestration in the soils could increase to 7.8% compared to a conventional crop rotation excluding cultivated grass forages. The results of Bolinder et al. and Brady et. al studies may indicate how the proposed strategic plan alters the prerequisite for achieving its objective of decreasing carbon emissions from agriculture. Thus, these sources are particularly useful for the policy evaluation discussion in this study.

The second category includes works of theoretical character that are necessary to develop a suitable mathematical model. Since a PMP approach is used in this study, prominent publications such as Howitt (1995), Bauer & Kasnakoglu (1990) and Hazell & Norton (1986) are used to provide a theoretical framework for the development of the mathematical model.

Howitt (1995) is regarded as the first article that summarised the procedure of PMP, even though similar programming had been implemented some years prior. Howitt urges limited data requirements, consistency with microeconomic theory and ability to exactly replicate base year observations as advantages of PMP. The article explicates the steps required to develop the PMP-model and is useful for this study as it gives appropriate guidelines for the PMP-model development.

Bauer & Kasnakoglu (1990) propose improvements for farm level and aggregate sector modelling aiming at mitigating problems in modelling farmer behaviour. The authors further justify the introduction of non-linearities into aggregate sector models and explain the advantages with calibrating the model in such a way that empirical observations can be replicated by the model. The disadvantages with linear programming for agriculture are highlighted, such as high sensitivity to commodity price changes, disregarding rotational constraints and leading to overspecialisation of a certain crop. Their work is particularly useful for this study as the advantages of including non-linearities and the relation between farm level behaviour and aggregate sector level is examined.

Hazell & Norton (1986) provide an extensive description of mathematical programming for economic analysis in agriculture and explicate practical methods for model construction as well as policy analysis from mathematical programming. Their book establishes common praxis for the role of mathematical programming in agriculture and in detail elaborates the difference in farm level and sector level models. To develop the model used in this study, inspiration and guidance is derived from their work.

Specific adjustments for smaller scale regional and farm models by Helming and Peerlings (2005), Nakashima (2010) and Borges et al. (2010) provide practical examples of PMP usage in the context of agricultural economics. All these works have similarities to this study and hence provide valuable ideas to this study's model development.

3. Methodology

The methodology section covers a discussion on choice of study objects, relevant concepts and theories. It also presents a detailed description of the PMP calibration method and the data used in the study.

3.1 Conceptual framework

The research question proposed in section 1 can be addressed using different approaches, such as econometric methods including regression and time series analysis. However, Hazell & Norton (1986) highlight disadvantages of econometric approaches, such as difficulties in estimating consequences of changes in economic structure, and propose mathematical programming as a more suitable option in this regard. Mathematical programming can provide an empirical link between observed behaviour and economic theory and reflect behavioural changes of observed actors in the economy (ibid.). Normative linear programming is however problematic due to the need of constraints that have no economic or technological justification (Röhm & Dabbert 2003). Optimization with mathematical programming in agriculture can be motivated as it depicts the economic problem of utilizing limited resources in an optimal way relative to a set objective (Buysse et al. 2007). Normative mathematical programming without calibration has dominated modelling in agricultural economics for decades, but divergence between observed outcome and modelled outcome is nowadays unacceptable in policy analysis (Arata 2017). Aimed at mitigating this divergence, Howitt (1995) proposes PMP in particular as the calibration of a mathematical model against a base year provides the possibility to exactly replicate the empirical values obtained for the base year. This feature is valuable for policy developers as it provides a certain measure of accuracy.

PMP is simply one way to model changes in resource use due to technological development, price changes or policy changes, and the approach has been widely used by policy analysts for the calibration of European and non-European aggregated sector models for animal and crop production since 2000 (Mack et al. 2019). This is especially when functions for farm-level behaviour are difficult to derive (Heckelei 2002). In reality, agricultural production systems use crop rotation schedules to mitigate risk for diseases, weeds and insects even though profitability between the crops differ. A normative linear programming model will, however, maximize profit by only producing the most profitable crop and this issue is called overspecialisation. The PMP approach eliminates the need for rotational constraints aimed at mitigating model overspecialisation and is functional even though limited data is available (Chen & Önal 2012). The advantages of PMP in evaluating policy effects in agriculture motivates the application of PMP in this study. However, PMP also has its disadvantages and these are addressed in sub section 3.6.

3.2 Theoretical framework

The PMP approach is formalised in three steps (Howitt 1995). It builds on a linear profit maximization problem with resource constraints. In this study, the linear programming problem has profit maximization as the objective and available land and labour as the constraints. Land allocated to the five most common crops in Uppsala are used as independent variables in the model and these are winter wheat, barley, oat, rapeseed and perennial grasses. Since the majority of the arable land in Uppsala is allocated to these crops, the sum of the land occupied by these is defined as the total available land restriction used in the programming model. The second restriction introduced in the model is available labour, which is simply defined by the sum product of the required labour per hectare for each crop and the allocated land in the base year.

Once the initial profit maximisation problem and constraints are defined, Howitt´s (1995) three steps can be used. Firstly, particular dual values, or shadow prices, for each crop production activity are obtained by solving the constrained linear programming problem. In this particular case, the dual values reflect the value of producing one more unit (one hectare) of that crop. The dual values are then used in the second step to derive calibrating parameters for a non-linear programming model. In the third step, the PMP-model is derived by using the calibrating parameters together with the observed data from the base year. The abolishment of the environmental compensation for cultivated grasslands will impact the profit function in the linear programming problem and its effect on land allocation can be estimated with the PMP model. Each step is more thoroughly explained in the model specification section.

3.3 Data

Most data required is obtained from the Swedish Board of Agriculture’s statistical database. This includes data on land allocation in Uppsala and average crop yields for the selected base year. The required data for constructing the constraints, such as required labour and crop contribution, is obtained from agricultural contribution calculations presented by the County Administrative Board Västra Götaland and are in this study assumed to be similar to the true values in Uppsala. Contribution calculations for perennial grasses are obtained from Agriwise and are specific for Uppsala.

3.3.1 Economic data for agricultural production in Uppsala

The following table presents data on crop allocation in the base year 2021. The PMP-model is calibrated against these base year data.

Table 1. Base year Economic data

2021	Winter Wheat x_1	Barley x_2	Oat x_3	Rapeseed x_4	Perennial Grass x_5
Revenue (SEK ha^{-1})	9720	5520	6274	11250	7402
Cost (SEK ha^{-1})	7107	5470	5048	8287	5256
Margin (SEK ha^{-1})	2613	50	1226	2963	2146
Land Allocation 2021 (ha)	14148	6943	1618	1198	13122
Required Labour (hours ha^{-1})	5,6	4,4	4,3	5,3	3,9

	Land (ha)	Labour (hours)
Resource Constraints	37029	174260,6

3.4 Model specification

The PMP approach begins with the following LP problem (definitions of variables and parameters are listed in Table 2):

$$
\begin{aligned}
& Max\ Z = p'x - c'x \\
& s.t. \\
& Ax \leq b \qquad [\lambda] \\
& x \geq 0 \qquad\qquad (1)
\end{aligned}
$$

where Z is the profit function and p and c are prices and costs related to specific production activities. X is the land allocated to each production activity, A is a matrix of input/output coefficients and b is set to $b=Ax^o$.

Table 2. Variable and parameter definitions

Variables	
Z	Dependent variable, profit
x	Land allocated to each production activity

λ	Dual values of resource constraints
ρ	Dual values of calibration constraint
Parameters	
p	Revenue per hectare associated with production activity
c	Cost per hectare associated with production activity
A	Matrix of input/output coefficients
b	Vector of resource constraints set to $b = Ax^o$
d	Linear cost coefficients to be calibrated
Q	Matrix of quadratic cost coefficients to be calibrated
Other	
x^o	Observed base year values
ε	Small constant number set to 10^{-6}

Similar optimisation problems are common in agricultural policy modelling on both farm and aggregate level. However, these linear programming models tend to cause problems with overspecialisation in the most profitable crop (Chen & Önal 2012). As these models substantially deviate from observed farm behaviour, they are not appealing for policy developers. This is where calibration of the model with empirical data is necessary. Historically, calibration of mathematical programming models has been done by introducing rotational constraints and upper and lower bounds to the production activities but the empirical justification of this modelling approach is weak. Howitt (1995) proposed the introduction of a calibration constraint where land allocation is restricted to observed values in the base year:

$$\begin{aligned} &Max\ Z = p'x - c'x \\ &s.t. \\ &Ax \leq b \qquad [\lambda] \\ &x \leq x^o + \varepsilon \qquad [\rho] \\ &x \geq 0 \end{aligned} \qquad (2)$$

where the second restriction is called the calibration constraint. Under the assumption that the vector of revenues per unit area is positive, the inclusion of the calibration constraint will force the model to reproduce the observed values from the base year (Nakashima 2010).

By solving the updated linear programming problem, the dual values or shadow prices for the calibration constraint can be obtained and these are defined as ρ. Howitt (1995) proposes the introduction of these dual values into a simple quadratic model such that:

$$\begin{aligned} &Max\ Z = p'x - d'x - 0{,}5x'Qx \\ &s.t. \\ &Ax \leq b \qquad [\lambda] \end{aligned}$$

$$x \geq 0 \qquad (3)$$

where the cost coefficients d and Q are specified using the dual values ρ. This is the third and final non-linear programming model and it too reproduces the activity levels observed in the base year and builds on the assumption of increasing marginal cost. When the PMP model design is established, the abolishment of the environmental compensation in the strategic plan is introduced by lowering the revenue per unit perennial grass. The problem solution then indicates how the land allocation is changed as a consequence of the abolished environmental compensation. In Appendix 1, the linear programming problem (2) is specified, using the aggregate farm-level data from Table 1. The non-linear programming problem assuming quadratic costs (3), is quantitatively specified here with economic data from Table 1.

$$Max\ 9720x_1 + 5520x_2 + 6274x_3 + 11250x_4 + 7402x_5 - \sum_{i=1}^{i=5} d_i x_i - 0{,}5 \sum_{i=1}^{i=5} q_{ii} x_i^2$$

$$s.t.\ x_1 + x_2 + x_3 + x_4 + x_5 \leq 37029,$$
$$5.6x_1 + 4.4x_2 + 4.3x_3 + 5.3x_4 + 3.9x_5 \leq 174260.6,$$
$$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0. \qquad (4)$$

where q_{ii} in the non-linear model is an element of the quadratic cost matrix Q. However, there are different approaches for specifying the parameters d and Q from the calibration constraint's dual values and these are discussed in the next section. The different specification approaches are subject to certain assumptions and ultimately all of them are used separately and evaluated afterwards.

3.4.1 Parameter specification

As with any programming model, the objective is to design a model that satisfactory depicts reality. Hence, the calibration parameters d and Q in the proposed PMP model have to be specified in such a way that the model is able to realistically capture policy changes, price changes and responses in farmers' behaviour. Different approaches for specifying these parameters have been proposed aimed at avoiding arbitrary simulation behaviour (Ejaz Qureshi et al. 2013; Mérel & Howitt 2014). This section presents and discusses three different parameter specification approaches that have been applied historically in PMP modelling.

The approach that was first used widely has later been referred to as the standard approach. The standard approach lets $d = c$ and the q-elements of the Q-matrix to be calculated as:

$$q_{ii} = \frac{\rho_i}{x_i^o} \qquad (5)$$

and this method of specification is motivated by simplicity (Henry de Frahan et al. 2007). The disadvantage of the standard approach is that it tends to produce overreactions to changed economic structures and generally creates a poor response behaviour of the PMP-model (Heckelei 2002). This has been shown with ex post simulations where predicted outcomes have been compared with actual outcomes.

Another approach for specifying the calibration parameters is the average cost approach. It builds on the assumption that observed cost associated with each production activity (c) equals the average cost of the respective variable cost functions for each crop. It can then be shown that the specification:

$$q_{ii} = \frac{2\rho_i}{x_i^o} \qquad (6)$$

is consistent with microeconomic theory. The average cost approach lets $d = c\text{-}\rho$ and this approach is used and further discussed by Nakashima (2010).

The third calibration approach brought up in this study is the Paris approach where the linear cost coefficient, d, is set to zero and:

$$q_{ii} = \frac{c_i + \rho_i}{x_i^o} \qquad (7).$$

An advantage with this specification approach is that it tends to generate more realistic responses to changed economic incentives, even though the quantitative specification is arbitrary (Heckelei 2002).

All these specification approaches have the ability to exactly replicate observed base year data, but respond to external changes differently (Henry de Frahan 2007). There are more approaches that economists have developed to mitigate the parameter specification problem and produce the most realistic models. Worth mentioning is the exogenous elasticities approach and maximum entropy calibration that are further explained and used by Paris & Howitt (1998), Heckelei (2002), Henry de Frahan (2007) and Graveline & Mérel (2014). In this study, all three previously presented approaches are used and the resulting estimations of the PMP models are compared and discussed.

3.5 Choice of study area and parameters

As mentioned in the delimitations-section, Uppsala municipality is chosen as the geographical setting as the majority of its land is affected by the abolishment of the environmental compensation for perennial grasses. Year 2021 is chosen as the base year for the PMP calibration as it gives a suitable depiction of how the land was allocated before the proposed abolishment of the EC.

3.6 Criticism and disadvantages of PMP

The PMP approach has been acknowledged to be useful for modelling agricultural problems, yet it has been met with various criticism (Mérel & Howitt 2014). Borge et al. (2010) and Buysse et al. (2007) underscore the assumption that the land allocation in the base year is optimal which is not necessarily true. This assumption is critical and the choice of base year is hence to be done carefully to determine that it is representative for the farm behaviour. Furthermore, PMP is restricted in its prediction capacity as it is bound to the production activities applied in the base year (Howitt 1995). With technological progress and political changes, the PMP approach is limited to the information contained in the empirical data of the base year and thus cannot take into consideration new technology or new scientific findings.

Heckelei (2002) presents an extensive summary of inconsistencies with the original PMP approach. One of them is the arbitrary specification of the calibration parameters addressed in previous sub sections, which is also underscored by Kanellopoulus et al. (2010). He further asserts that the original PMP approach using one observation only is acceptable as a calibration method used together with additional data on technology or farm behaviour. With only information from one base year, the parameter specification will always result in arbitrary simulation behaviour if no additional exogenous information is provided. This can be mitigated using parameter calibration with exogenous elasticities or the maximum entropy approach with additional information suggested by Paris and Howitt (1998). The implications of these issues on the results and their reliability are further discussed in the discussion section of this paper. Further developments to extend the original PMP model have been made by Röhm & Dabbert (2003), Buysse et al. (2007) and Chen & Önal (2012) among others and include exogenous factors such as risk and competition. Even though the PMP approach is used practically within policy analysis, its acceptance within academics is disputed. However, the role of PMP in academics might become stronger as PMP is developing closer to econometrics (Mérel & Howitt 2014).

4. Results

The three different specification approaches for the calibration parameters generated different estimations of the change in land allocation when the abolishment of the environmental compensation was simulated in the PMP model. When the environmental compensation for perennial grasses was subtracted from the revenue per unit used in the non-linear problem (4), the problem was solved for optimal land allocation with profit maximization as the objective. The base year values as well as the land allocation simulated by the PMP models are summarized in the following table:

Table 3. Estimated land allocation

Land allocation in ha	Winter Wheat x_1	Barley x_2	Oat x_3	Rapeseed x_4	Perennial Grass x_5
Base year	14148	6943	1618	1198	13122
Specification:					
Standard	14148	9710	1618	1198	10000.2
Average Cost	14148	8326	1618	1198	11561.1
Paris	14241.2	7006.5	1630.7	1204.4	12309.3

The standard approach for parameter calibration resulted in a PMP estimation with the largest decrease of perennial grasses due to the abolishment of the EC. Simultaneously, the land allocated to barley was substantially increased. The average cost approach generated somewhat smoother changes in optimal allocation but also with a decrease in cultivation of perennial grasses and increase in barley. The solutions produced by the PMP model using the Paris approach generated the smoothest changes in optimal land allocation with a slight decrease in perennial grasses and increase in all other production activities.

By solving the LP problem in the first phase of the PMP procedure, the following calibration parameters were specified for each approach:

Table 4. Calibration parameters for different specification approaches

	d_1	d_2	d_3	d_4	d_5	q_{11}	q_{22}	q_{33}	q_{44}	q_{55}
Stand. Approach	7107	5470	5048	8287	5256	0.18	0.00	0.73	2.42	0.16

Av. Cost Approach	4557.63	5470	3870.86	5384.23	3154.32	0.36	0.00	1.46	4.85	0.32
Paris Approach	0	0	0	0	0	0.68	0.79	3.85	9.34	0.56

The parameters are specified as shown in equation (5), (6) and (7).

5. Discussion

This study´s objective is to estimate the effects on land allocation in Uppsala due to the proposed abolishment of the environmental compensation for perennial grasses in the new strategic plan for CAP 2023-2027. The PMP approach used in this study forecasts that arable land designated to perennial grasses will decrease when the environmental compensation is abolished for the named crop. All three parameter specification approaches have forecasted this decrease, but with substantially different magnitudes. As shown in Table 3, the PMP model using the standard approach, average cost approach and Paris approach respectively estimate the decrease to 23.8%, 11.9% and 6.2%.

These estimations could be useful for policymakers as the cultivation of perennial grasses have desirable positive externalities such as carbon sequestration, decreased nutrient leaching and increased biodiversity (Bolinder et al. 2017; Brady et al. 2019). These positive externalities are included in the objectives of EU regulation (2021/2115), which may cause concerns in relation to the proposed abolishment of the environmental compensation. However, the compensation has previously only been amenable for productive agricultural land in category 13 established by the Swedish board of Agriculture and the result don´t tell anything about how the production of perennial grasses could switch to less productive soils in other categories of land. If the abolishment of the environmental compensation makes it less profitable to produce perennial grasses in highly productive areas of Sweden, it could consequently make the cultivation of this crop in less productive regions more competitive. This could increase the total area cultivated with perennial grasses, however, the PMP approach used in this study is not able give any indications in this regard.

The results of the PMP approach also have to be interpreted in regards to the limitations inherent to the method. Three different calibration approaches have been used in this study that have been shown to have different disadvantages. As has been presented in section 3.6, the PMP approach has difficulties taking technological progress and political changes into consideration and is also bound to the production activities included in the base year (Howitt 1995). The calibration approaches used, have also been pointed out to be too arbitrary when no additional exogenous information is included (Heckelei 2002). However, the PMP approach was widely used for policy analysis in agricultural economics during the 90s and

00s because it generated smooth predictions, required minimal data sets and produced results in line with empirical observations. PMP is still used within agricultural economics but often with incorporation of other methods simultaneously. One recent example is Laskookalayeh et al. (2022) who incorporated robust programming and PMP simultaneously to estimate effects of irrigation management and water distribution and deemed the combined method suitable and feasible.

In terms of providing an answer the research question: *What are the effects of the new Swedish strategic plan for CAP 2023-2027 on farmers' crop allocation decisions and proportion of cultivated grass forages in Uppsala?*,
the positive mathematical programming method has generated results that are comprehensible and reasonable. I argue that the results are useful not only for Uppsala, but also for other Swedish regions within the category 13 established by Swedish Board of Agriculture. However, the environmental implications of the predicted decrease in cultivated perennial grasses are not trivial as the total change in areas covered by perennial grasses in Sweden is unknown. Locally, findings from Bolinder et al. (2017) and Brady et al. (2019) apply and carbon sequestration and biodiversity is expected to decrease in the effected regions.

6. Concluding remarks

The new Swedish strategic plan for CAP will alter decision behaviour among active farmers and this study's findings provide inputs on the effects of the new proposed policy. Uppsala municipality is one of the regions in Sweden affected by the proposed policy and is in focus in this study but policy implications, however, may not be limited to Uppsala but can be applied to other regions in Sweden also affected by the proposed policy change.

Further research is necessary to fully evaluate the actual effects of the proposed policy. I propose an ex-post evaluation of the abolishment of the environmental compensation based on empirical data focusing on the affected regions. I also propose a more general approach that could simulate changes in land allocation of the total arable land in Sweden and present environmental implications of the policy when taking land allocation changes in other regions of Sweden into account.

In summary, this study provides an analysis on the effects of the proposed abolishment of environmental compensation for cultivated perennial grasses with regards to the established objectives of CAP.

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Appendix 1

Specification of linear programming problem (2) with economic data from Table 1:

$$Max\ 9720x_1 + 5520x_2 + 6274x_3 + 11250x_4 + 7402x_5 - 7107x_1 - 5470x_2 - 5048x_3 - 8287x_4 - 5256x_5$$

$$\begin{aligned}
&s.t.\ \ x_1 + x_2 + x_3 + x_4 + x_5 \leq 37029,\\
&5.6x_1 + 4.4x_2 + 4.3x_3 + 5.3x_4 + 3.9x_5 \leq 174260.6,\\
&x_1 \leq 14148\ (1 + 10^{-6}),\\
&x_2 \leq 6943\ (1 + 10^{-6}),\\
&x_3 \leq 1618\ (1 + 10^{-6}),\\
&x_4 \leq 1198\ (1 + 10^{-6}),\\
&x_5 \leq 13122\ (1 + 10^{-6}),\\
&x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0.
\end{aligned} \tag{8}$$

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