Representation of the Scanian regions GMB and GSS in AgriPoliS and recent model extensions

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List of abbreviations

AgriPoliS – Agricultural Policy Simulator
AL – Arable land
AWU – Annual working unit
c – Continues activity
C – Soil Organic Carbon
CAP – Common Agricultural Policy
CAPRI – Common Agricultural Policy Regionalized Impact model
EC – Equity capital
ED – Excess regional demand
EFAs – Ecological focus areas
EU – European Union
FADN – Farm Accountancy Data Network
GAEC – Good Agricultural and Environmental Condition
GMB – Götalands mellanbygder
GSS – Götalands södra slättbygder
h – Hours
ha – Hectares
HH – Household income
i – Integer activity
K – Potassium
kg – Kilograms
L – Liquidity
LS – Livestock capacities
LSU – Livestock density index
M – Machinery
MIP – Mixed Integer Programming
MTR – Mid Term Review
N – Nitrogen
P – Phosphorus
RHS – Right hand side
S – Total supply of regional calves
SCB – Statistics Sweden
SEK – Swedish crowns
SJV – Swedish Board of Agriculture
SN – Semi-natural pasture
SPS – Single Payment Scheme
UAA – Utilized agricultural area
Y – Yield

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1 Introduction

The Common Agricultural Policy (CAP) has a pervasive influence on agriculture in the EU and is subject to frequent reform to reduce undesirable impacts, adjust to new conditions and meet changing goals (Brady et al., 2009a). Most recently the so-called “greening” reform was implemented in 2015, with the principle aims of achieving a more equitable distribution of payments among farmers and regions, and to improve the CAP’s environmental performance, particularly its contribution to conservation of biodiversity and ecosystem services which are negatively affected by intensive agricultural practices. The mandatory greening measures are maintenance of permanent grassland at existing levels, crop diversification, and allocation of a certain proportion of a farm’s arable land as Ecological Focus Areas (EFAs), where the latter two target more intensively farmed arable cropping regions.

The Agricultural Policy Simulator known as AgriPoliS is an agent-based model comprising a population of heterogeneous farms, or farm-agents, assuming profit maximizing behaviour which compete for agricultural land in a spatial and dynamic environment (Balmann, 1997, Happe et al., 2006). The model is used for policy analysis by evaluating the effects of policy changes on agricultural development and land use in a defined region. A detailed description of AgriPoliS is available in Kellermann et al. (2008). Previously, the model has been used to study for example the impacts of the decoupling of agricultural support in 2005 on production and structural change (Happe et al., 2008, Sahrbacher et al., 2007) and associated environmental impacts (Brady et al., 2009b, Brady et al., 2012) which was primarily expected to influence agriculture in marginal regions. Given that the greening reform is expected to influence intensive arable cropping regions, two new Swedish regions have been incorporated in the AgriPoliS model.

The aim of this paper is to describe and document the development, adaptation and calibration of the AgriPoliS model to two new intensive agricultural production regions in Scania (Skåne), the Götalands mellanbygder (GMB) and Götalands södra slättbygder (GSS). Before the addition of the new regions, the model consists of the Swedish counties of Jönköping, called Skogsbygd (dominated by forest), and Västerbotten, called Norrland (sub-arctic agriculture), both marginal regions. Thus, by adapting AgriPoliS to these two new regions, we now have a model that provides a representative gradient of the predominant agricultural conditions in Sweden and hence are able to provide broader impact assessment of CAP reform.

In this report we focus on the development steps, *i.e.* how the new regions are created (calibration), which data we use to describe the regions and represent the production activities and model validation (Figure 1). In addition, the extensions needed to evaluate the implementation of the EFAs and the new young farmer support, are documented. We also document the extension for modelling the choice of passive farming used in (Brady et al., 2017). No simulation results are, however, presented in this paper.

The report is structured as follows. In section 2 we provide a detailed description of each region and the information that is used as a benchmark during the calibration procedure. In section 3 we explain how we choose the typical farms so that they are representative of the region (Steps 1 and 2, Figure 1). Section 4 describes farm behaviour in AgriPoliS, the model extensions and the policy framework (Step 3). We conclude in Section 5 by evaluating how well the model develops dynamically and corresponds to reality, using the defined policy framework (Step 4).

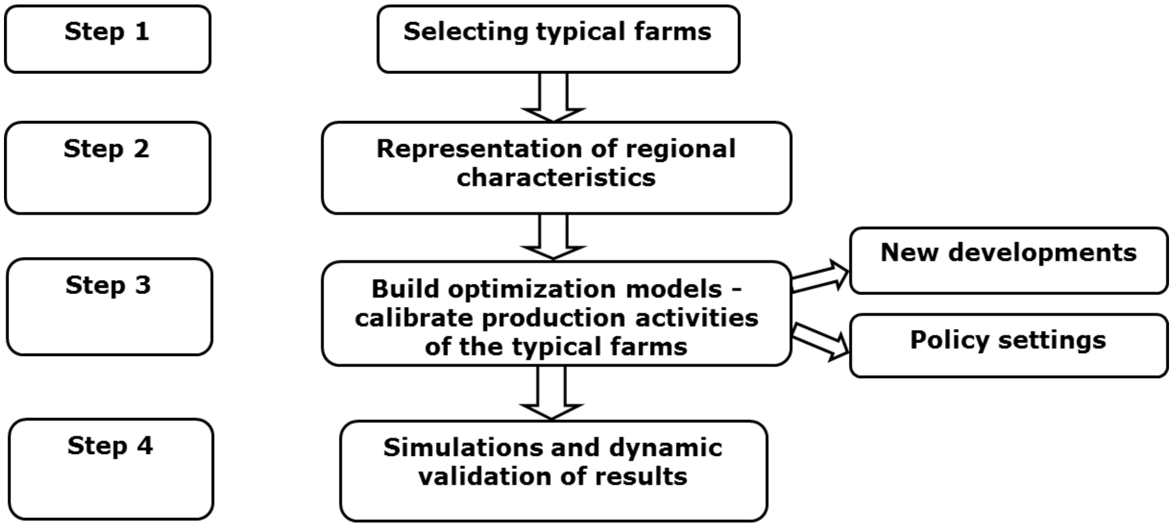

Figure 1. Development steps

2 The new regions

This section describes the regional characteristics of the two new regions and typical forms of agricultural production (types of farming) and land-use. The information presented in this section is used as the basis for calibrating the new regions.

2.1 Contrasting regions

The GMB region is a mixed farming region where around 45% of the utilized agricultural area (UAA) is arable grassland and semi-natural pastures (naturbetesmark), which is used for feeding livestock. In GSS high-value crop production is the dominating activity, where cereals, oilseed crops and sugar beet occupy most of the arable area. Some descriptive statistics of the regions are given in Table 1.

Table 1: Important structural characteristics of the modelled regions

	GMB	GSS
Utilised agricultural area – UAA (ha)	**158,546**	**201,577**
Arable land (ha)	**135,496**	**186,954**
Cereals (ha)	55,472	114,650
Protein crops (ha)	2,044	4,594
Oilseed crops (ha)	8,772	13,588
Sugar beet (ha)	6,945	24,587
Potatoes (ha)	6,410	2,668
Grassland (ha)	48,113	14,704
Fallow land (ha)	1,614	3,900
Other crops (ha)[a)]	6,125	8,262
Semi-natural pasture (ha)	**23,050**	**7,495**
Livestock numbers		
Cattle	**99,091**	**22,833**
Beef cattle	29,810	7,088
Dairy cows	19,885	3,376
Suckler cows	15,447	4,843
Calves under 1 year	33,949	7,526
Sheep	**11,731**	**3,027**
Sows	**18,364**	**14,920**
Fattening pigs	**108,979**	**73,675**

Note: a) The category Other crops includes horticultural and unspecified crops.
Source: (SJV, 2009).

The GMB region is calibrated to 2011 data, whereas GSS is calibrated to 2008 data. The calibration years are different depending on which year the region was incorporated in the model, and using the most recent data available at the time. The data was obtained from the Swedish Board of Agriculture (SJV). To make sure the model follows the real statistics over the years we conduct a dynamic validation of the simulation results (see Section 5). For practical reasons, we model and calibrate subregions of the GSS and GMB regions (Figure 2). The advantage of calibrating a subregion is that we are able to model a contiguous agricultural landscape and avoid the geographical fragmentation of the greater regions. In terms of agricultural and environmental conditions, the subregions are representative of the larger regions.

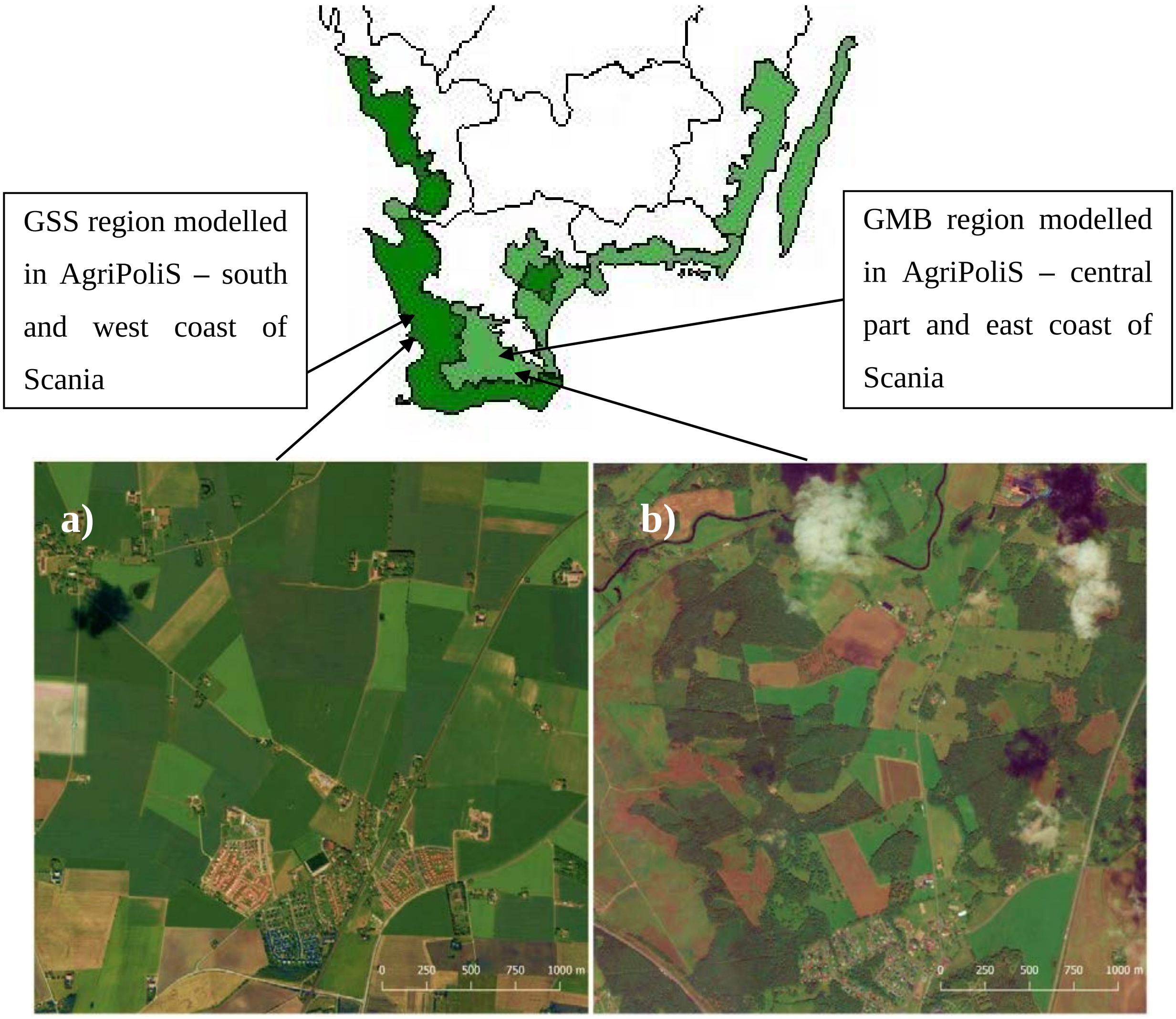

Figure 2: Locations and landscape characteristics of the modelled subregions. Picture a) Typical homogeneous landscape in GSS; and b) Typical heterogeneous landscape in GMB. Source: Statistics Sweden (2012), Google Maps (2017).

2.2 The GMB subregion (Götalands mellanbygder)

The GMB subregion is located in the central and easterly coastal areas of Scania (Figure 2). The UAA in the subregion comprises around 85% arable land and 15% semi-natural *pasture*. The agriculture is characterised by specialized crop or livestock farms, and mixed farms. Fields are generally fragmented and separated by forest or other natural impediments. One third of the total arable area is used for grass production for livestock fodder. Cereals, especially winter wheat and spring barley, are the most important annual crops, comprising 41% of the arable area. The region is relatively productive, having normal yields slightly above the national average (standard winter wheat and spring barley yields are 6.4 t/ha and 4.4 t/ha respectively, compared to the national averages of 6.2 t/ha and 4.3 t/ha) (Statistics Sweden, 2012).

In Sweden, average farm size is based on arable land area and not UAA. Farm size in GMB ranges from very small (less than 2 ha) to very large (over 500 ha) with an average size of 63.5 ha (Table 2), which is 42% larger than the national average (Statistics Sweden, 2012). Most of the farms in GMB (67%) are family owned and have less than 50 ha arable land, whereas most of the arable land (64%) is managed by farms larger than 50 ha (Table 2).

Table 2: Size structure of farms in GMB by area of arable land

	Farms		**Arable land**		**Average size**
Size class	*Nr.*	*%*	*ha*	*%*	*ha*
< 20 ha	882	41	13,713	10	15.6
20-50 ha	588	28	19,242	14	32.7
50-100 ha	333	16	23,296	17	67.0
100-300 ha	273	13	44,065	33	161.4
300-500 ha	35	2	13,727	10	392.2
> 500 ha	25	1	21,452	16	858.1
Total	*2,136*	*100*	*135,496*	*100*	*63.5*

Source: (SJV, 2009).

The natural conditions in GMB favour livestock production, particularly grass-based beef, dairy and lamb. In view of the `type of farming`[1] (or typical farms to be selected in Step 1), the region is characterized by a strong mix of specialized crop and livestock farms, as well as mixed farms (Table 3), with roughly even use of arable land. The majority of livestock farms are beef producers with herds generally larger than 50 head (Table 4). Although the number of specialized dairy farms is relatively small, they contribute to almost 25% of total farm revenues in the region. Similarly, specialized granivore farms bring in a relatively high proportion of revenues. Livestock density is relatively high in GMB (1.06 LSU/ha) compared to the national average (0.56 LSU/ha), which indicates the importance of animal production in the region[2].

[1] The `type of farming` is based on the Swedish typology of farms, rather than the EU-typology because it better covers the variety of different lines of production in the region.

[2] Regional livestock density index is obtained from the modelled typical farms whereas national average from Eurostat database (Eurostat, 2016).

Table 3: Types of farming in GMB by number of farms and arable area

	Farms		Arable land	
Type of farming	*Nr.*	*%*	*ha*	*%*
Field crop	**767**	**36**	**50,099**	**37**
Livestock management	**545**	**26**	**60,996**	**45**
- dairy	114	5	21,564	16
- beef	270	13	23,130	17
- sheep	59	3	2,914	2
- pig	102	5	13,388	10
Mixed	**220**	**10**	**17,007**	**13**
Small farms (< 20 ha)	**603**	**28**	**7,474**	**6**
Total	*2,136*	*100*	*135,496*	*100*

Source: (SJV, 2009).

Table 4: Numbers of livestock in GMB by herd size

Dairy cows		**Beef cattle**		**Ewes and rams**		**Sows**		**Fattening pigs**	
Size of herd	Nr.	Size of herd	Nr.	Size of herd	Nr.	Size of herd	Nr.	Size of herd	Nr.
<= 49	2,342	<= 9	2,087	<= 49	4,165	<= 49	610	<= 99	1,656
50-99	3,629	10-50	7,751	> 50	7,566	50-99	882	100-249	2,321
100-199	6,905	>= 50	19,973			100-199	1,462	250-499	3,869
>= 200	7,009					>= 200	15,410	500-749	6,795
								>= 750	94,338
	19,885		**29,810**		**11,731**		**18,364**		**108,979**

Source: (SJV, 2009).

2.3 The GSS subregion (Götalands södra slättbygder)

The GSS subregion occupies the southern plains of the south and west coasts of Scania (the L shaped area in Figure 2). The landscape is characterized by large open fields on interconnected plains, where crop production is the dominant agricultural activity. Due to the favourable climate and fertile soils, the region is the most productive in Sweden; having the highest standard yields in the country (8 t/ha and 6 t/ha for winter wheat and spring barley respectively) (Statistics Sweden, 2009). The UAA of the GSS subregion is 96 % arable land, which is mainly used for growing annual crops. The dominance of specialized crop farms in GSS is also apparent from the farm structure presented in Table 5. Semi-natural pasture is a minor land use in GSS which is also reflected by the small number of grazing livestock farms (Table 5).

Although the number of pig farms is small, granivore production is an important activity in terms of number of pigs. Since most feed is purchased and manure-spreading contracts are generally signed with neighbouring crop farms, pig producers are not dependent on having their own land for production. The average livestock density per hectare is 0.95 LSU/ha and hence above the national average, which is due to the large number of granivores (Table 6).

Table 5: Type of farming in GSS by number of farms and arable area

	Farms		Arable land	
Type of farming	*Nr.*	*%*	*ha*	*%*
Field crop	**1,735**	**65**	**175,146**	**90**
Livestock management	**238**	**9**	**14,051**	**8**
- dairy	34	1	2,406	1
- beef	135	5	3,291	2
- sheep	23	1	2,868	2
- pig	46	2	5,486	3
Mixed	**196**	**7**	**2,351**	**1**
Small farms (< 20 ha)	**521**	**19**	**2,534**	**1**
Total	*2,690*	*100*	*194,082*	*100*

Source: (SJV, 2009).

Table 6: Numbers of livestock in GSS by herd size

Dairy cows		Ewes and rams		Sows		Fattening pigs	
Size of herd	Nr.	Size of herd	Nr.	Size of herd	Nr.	Size of herd	Nr.
<= 49	319	<= 49	572	<= 49	1,122	<= 99	1,107
50-99	693	> 50	2,455	50-99	1,728	100-249	3,501
100-199	743			100-199	2,483	250-499	6,713
>= 200	1,622			>= 200	9,586	500-749	6,481
						>= 750	55,873
	3,376		**3,027**		**14,920**		**73,675**

Note: specialized beef and suckler cow production are minor activities in the region and thus structural data is not shown.
Source: (SJV, 2009).

An important regional feature is the high share of small farms which might be considered more as hobby farms. The land area managed by this type of farm though is small (Table 7). Instead, the majority of the arable area is farmed by medium to large farms, i.e., > 50 ha, resulting in an average farm size of 72.2 ha, which is almost double the average farm size in Sweden (Statistics Sweden, 2009).

Table 7: Size structure of farms in GSS by area of arable land

	Farms		Arable land		Average size
Size class	*Nr.*	*%*	*ha*	*%*	*ha*
< 20 ha	1,113	41	9,611	5	8.64
20-50 ha	530	20	14,552	7	27.46
50-100 ha	491	18	46,121	24	93.93
100-200 ha	336	13	40,283	21	119.89
200-300 ha	114	4	25,871	13	226.94
300-500 ha	58	2	22,456	12	387.17
> 500 ha	48	2	35,188	18	733.09
Total	*2,690*	*100*	*194,082*	*100*	*72.15*

Source: (SJV, 2009).

3 Calibration of the new regional models

Development of a new region in AgriPoliS requires calibration to the specific agricultural characteristics of the region. Calibration is a procedure in which numerical values are chosen in such a way so that the model reflects observed data. A region is represented in the model by selected typical farms. By typical we mean individual types of farms that are representative of the population of real farms in the region. During the selection procedure (Figure 2, step 1) each selected farm's production characteristics are "upscaled" to represent the structure of agriculture in the region (Table 3 and Table 5). In the next three subsections we describe how we select the typical farms and show how closely the upscaled regional characteristics in the model represent the observed structure.

3.1 Selection of typical farms

The choice of and how many typical farms a region should be represented by, is made using an automated selection procedure developed by Sahrbacher and Happe (2008). The approach is to minimize the sum of squared deviations between structural characteristics of a "real" region and the corresponding "virtual" region. The virtual representation of the region is made by selecting typical farms from a sample of real farms available in the Farm Accountancy Data Network (FADN) survey. The definitions of farm types follow from the FADN definition (European Union, 2008). According to the FADN-definition all farms in the Swedish regions are categorized as family farms, where the economic result is interpreted as compensation for unpaid labour input and own capital of the owner/farmer and his or her family (European Commission, 2002).

The number of farms needed to represent a region depends very much on regional characteristics of farming. If there is small variation in farm size and specialization, a smaller set of farms is needed to represent the regional characteristics.

The selection technique iteratively reduces the number of individual farms from the FADN sample until the squared deviation between the virtual farm structure and the observed structure according to regional statistics is minimal (Table 8). With such a technique, the selection process becomes objective rather than subjective. Traditionally, selection is based on expert knowledge but now when the farm data source is large, an automated selection is preferable. To illustrate how the selection and upscaling procedure are done, we show an example of how four farms (two specialized crop and two dairy farms) are upscaled to their observed characteristics in Table 8. The general characteristics (overall number of farms, production area and livestock capacities) and structural characteristics (distribution of farms in size and herd classes) by which we evaluate the quality of the upscaling are listed in the columns. The sum-product of each farm’s characteristics with the column “nr. of typical farms” provides the “virtual” indicators with which we compare to the data listed in the row “real characteristics”. Obtaining as small a sum of the deviations shown in the row “quadratic relative deviations” as possible is the objective of the optimization. In addition, to strengthen the decision criteria each characteristic relative to the overall quality of the upscaling is assigned an importance factor “weight” – between 0 as not relevant and 2 as very relevant. The importance factors are determined relative to the observed statistics and production activities in the base year. Thus, in this example because we have both crop and dairy farms it was a priority to represent both arable and pasture land but also the number of livestock well. When the most important characteristics are upscaled with an acceptable minimum sum of relative deviations (in this case 5%) and the number of typical farms has been reduced to a number that is practical (usually < 30), we stop the selection of typical farms as the upscaling is considered completed. The example in Table 8 shows that the general characteristics are well represented; the minimized quadratic deviation is within a 10% range of relative deviation. One of the structural characteristic (number of farms in different size classes) deviates by approximately 20% but this large deviation is weighted as less important when it comes to the overall representation and can be accepted as such.

Table 8. Example of upscaling procedure

Objective Function 5%

	General characteristics							**Structural characteristics**													
								Number of farms in farm size classes				**Arable area in farm size classes (ha)**				**Number of dairy cows by herd size**			**Number of beef places**		
Farm number	Farm type	Nr.of typical farms	Total UAA	Arable land	Semi-natural pasture	Beef cattle	Dairy cows	<= 20 ha	21-50 ha	50-100 ha	100-300 ha	<= 20 ha	21-50 ha	50-100 ha	100-300 ha	<= 49	50-99	100-199	< 10	< 50	>= 50
1	CROP1	206	20	20	0	0	0	1	0	0	0	20	0	0	0	0	0	0	0	0	0
2	CROP2	185	29	29	0	0	0	0	1	0	0	0	29	0	0	0	0	0	0	0	0
8	DAIRY2	61	125	88	37	50	75	0	0	0	1	0	0	88	0	0	75	0	0	0	50
9	DAIRY3	35	272	224	48	126	190	0	0	0	1	0	0	0	224	0	0	190	0	0	126
Sum product of upscaled characteristics		487	26630	22693	3937	7460	11225	206	185	0	96	4120	5365	5368	7840	0	4575	6650	0	0	7460
Real characteristics		534	27983	24056	3927	7285	10945	206	232	0	96	4120	5365	5368	7840	0	4575	6370	0	0	7285
Quadratic relative deviation		**0,0077**	**0,0047**	**0,0064**	**0,0000**	**0,0012**	**0,0013**	**0,0000**	**0,0410**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0000**	**0,0019**	**0,0000**	**0,0000**	**0,0006**
Weighting of the different characteristics		1	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Absolute deviation		**-47**	**-1353**	**-1363**	**10**	**175**	**280**	**0**	**-47**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**280**	**0**	**0**	**175**
Relative deviation		**-9%**	**-5%**	**-6%**	**0%**	**2%**	**3%**	**0%**	**-20%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**4%**	**0%**	**0%**	**2%**

Given that the structure of agriculture in the new regions is relatively diverse, the selection procedure resulted in 25 typical farm types for GMB (Table 9) and 27 for GSS (Table 10). The tables show the typical farms selected for each region and the general categories of indicators used in the "upscaling" procedure. The farm-type structure presented in the tables corresponds to the type of farming presented in Table 3 and Table 5. That is, we obtain a similar distribution and importance of both crop and livestock farms in GMB and dominance by crop farms in GSS. With respect to size classes in terms of land and livestock, we are also able to convey and capture almost all ranges (listed in the tables from the smallest to largest capacities). In Table 9 there are two additional farm types (hobby and passive farms) which are defined to reflect farm types relevant for the new agricultural policy framework that are not likely to appear in the FADN sample (which is biased towards larger commercial farms). **Hobby farms** are defined as agricultural holdings with 1-10 ha arable land, less than 5 head of livestock and more than 5% arable crops. **Passive farms** are defined as farms with no livestock and more than 95% grassland (i.e., fallow), where the farmer principally manages their agricultural land to keep it in good condition, but without production, to meet the minimum requirement for collecting direct payments in the form of the Single Payment Scheme.

Table 9: Selected typical farms for GMB

Farm ID No.	Farm type[a)]	Number of farms	Total UAA	Arable land	Semi-natural pasture	Beef cattle[1)]	Suckler cows	Dairy cows	Sheep	Fattening pigs[2)]	Sows[3)]
1	FC	206	20	20	0	0	0	0	0	0	0
2	FC	232	29	29	0	0	0	0	0	0	0
3	FC	185	29	29	0	0	0	0	0	0	0
4	FC	228	55	51	4	0	0	0	19	0	0
5	FC	148	100	100	0	0	0	0	0	0	0
6	FC	43	348	348	0	0	0	0	0	0	0
7	M	30	86	67	19	24	0	49	0	73	10
8	D	61	125	88	37	50	0	75	0	0	0
9	D	35	272	224	48	50	0	190	0	0	0
10	D	12	404	284	120	163	0	245	0	0	0
11	D	13	718	568	150	200	0	300	0	0	0
12	GL	47	159	90	69	158	0	0	0	0	0
13	GL	103	49	24	25	17	19	0	0	0	0
14	GL	76	93	72	21	38	43	0	0	0	0
15	GL	75	145	105	40	43	48	0	0	0	0
16	M	15	214	147	67	54	62	0	0	1141	0
17	GL	17	702	574	128	249	300	0	0	0	0
18	G	59	59	59	0	0	0	0	0	986	0
19	G	11	120	120	0	0	0	0	0	170	96
20	G	11	159	159	0	0	0	0	0	310	156
21	G	10	252	252	0	0	0	0	0	701	383
22	G	17	256	256	0	0	0	0	0	1271	665
23	GL	62	66	47	19	0	0	0	120	0	0
24	Hobby	194	7	7	0	0	0	0	0	0	0
25	Passive	497	9	9	0	0	0	0	0	0	0
Sum product		**2 387**	**161 376**	**137 794**	**23 582**	**30 409**	**14 855**	**19 535**	**11 772**	**111 376**	**18 207**

Notes: [a]) **FC**: Field crop farms; **D**: Dairy farms; **GL**: Grazing livestock farms; **G**: Granivore farms, **M**: Mixed farms. [1]) Beef cattle older than one year. [2]) Fattened pigs of 20 kg or more. [3]) Breeding sows of 50 kg or more.
Source: derived from FADN-data

Table 10: Selected typical farms for GSS

Farm ID No.	Farm type[a)]	Number of farms	Total UAA	Arable land	Semi-natural pasture	Beef cattle[1)]	Suckler cows	Dairy cows	Sheep	Fattening pigs[2)]	Sows[3)]
3	FC	286	9	9	0	0	0	0	0	0	0
4	FC	332	102	102	0	0	0	0	0	0	0
9	FC	110	213	213	0	0	0	0	0	0	0
10	FC	50	603	603	0	0	0	0	0	0	0
12	FC	173	60	60	0	0	0	0	0	0	0
13	FC	60	357	357	0	0	0	0	0	0	0
20	FC	514	24	24	0	0	0	0	0	0	0
27	FC	307	99	99	0	0	0	0	0	0	0
1	D	18	57	54	3	19	0	38	0	0	0
8	D	6	384	375	9	131	0	259	0	0	0
25	D	29	19	16	3	4	0	11	0	0	0
26	D	11	111	102	9	37	0	69	0	0	0
2	GL	26	48	24	24	18	20	0	0	0	0
7	GL	228	21	12	9	6	7	0	0	0	0
11	GL	35	105	102	3	0	0	0	15	0	0
16	GL	13	267	90	177	108	112	0	35	0	0
18	GL	358	11	6	5	3	4	0	0	0	0
19	GL	52	38	33	5	0	0	0	38	0	0
5	G	5	165	165	0	0	0	0	0	1500	170
6	M	17	75	72	3	0	0	0	7	391	104
14	G	9	3	3	0	0	0	0	0	727	0
17	G	5	3	3	0	0	0	0	0	3614	860
21	G	18	12	12	0	0	0	0	0	0	42
22	G	21	81	81	0	0	0	0	0	137	317
23	G	15	3	3	0	0	0	0	0	2043	0
24	G	31	3	3	0	0	0	0	0	0	56
15	M	92	12	12	0	3	0	0	0	12	4
Sum product		**2 821**	**194 046**	**186 569**	**7 477**	**6 241**	**5 004**	**3 316**	**3 075**	**73 386**	**16 435**

Notes: [a]) **FC**: Field crop farms; **D**: Dairy farms; **GL**: Grazing livestock farms; **G**: Granivore farms, **M**: Mixed farms.[1]) Beef cattle older than one year. [2]) Fattened pigs of 20 kg or more. [3]) Breeding sows of 50 kg or more.
Source: derived from FADN-data

3.2 Validation of representation of regional characteristics

In this subsection we evaluate how well the regional characteristics are represented by the chosen typical farms. The accuracy of the upscaling procedure is measured by the deviations of the upscaled farm characteristics from the real structural characteristics of the regions, see Table 11 and Table 12. For clarity, we present the general and structural characteristics separately. The Regional data column shows the official statistic for each characteristic, obtained from the Swedish Board of Agriculture. The column "Upscaling results" presents the sum-product of the characteristics of the selected farms after which follow the Relative and Absolute deviations between the real and calibrated data.

3.2.1 Upscaling results

Examining the deviations relative to the general characteristics of the two regions, it can be seen that the regions are well represented; the deviations are mostly less than 5%. There are some exceptions though, such as the number of farms in GMB and the number of beef cattle and breeding sows in GSS that are over or under-represented. In GMB, although the deviation between the number of farms in the real and virtual region is 12%, given the moderate weight of this characteristic we accept such deviation as we are able to obtain a high equivalence for the areas of arable land and semi-natural pasture. For GSS, we have to accept under-representation of beef cattle by 12% because if their numbers were to be increased, we would have a disturbance in the area of semi-natural pasture, for which we are able to get a perfect fit and has a high priority level (from an environmental perspective). Given that the number of farms with sows and pigs are small it is difficult to get a good representation. Hence, the over-representation of this type of farms by 25% also resulted in a larger deviation of 10% in the total number of sows. But we had to accept this deviation as we do not want to disturb the production of fattening pigs as it is an important general characteristic for the region, for which we obtained a perfect fit.

The specific characteristics display higher deviations than the general ones, but only when these are of less importance. The higher deviation for the specific characteristics also depends on the representativeness of the farms in the samples derived from the FADN data. Since GMB is a mixed farming region we included additional structural characteristics in Table 11 compared to GSS in Table 12. These structural characteristics are important and are given high weights in the upscaling procedure. Since GSS compared to GMB is a more specialized region with smaller variability in farm size and minor livestock production, we used less structural characteristics during the upscaling steps.

Table 11: Upscaling results GMB

General characteristics	Regional Data	Upscaling results	Relative deviation	Absolute deviation
Number of farms	2,136	2,387	12%	251
Utilized agricultural area (UAA; ha)	158,546	161,376	2%	2,830
Number of beef cattle older than 1 year	29,810	30,409	2%	599
Number of dairy cows	19,885	19,535	-2%	- 350
Number of suckler cows	15,447	14,855	-4%	- 592
Number of eves and rams	11,731	11,772	0%	41
Breeding sows with more than 50 kg	18,364	18,207	-1%	- 157
Fattening pigs with more than 20 kg	108,979	111,376	2%	2,397
Structural characteristics				
Area (ha)				
Arable land	135,496	137,794	2%	2,298
Semi-natural pasture	23,050	23,582	2%	532
Total	158,546	161,376		
Number of farms in different size classes				
<= 100 ha	1,803	2,066	15%	246
> 100 ha	333	259	-22%	- 74
Total	2,136	2,387		
Arable area in farm size classes (ha)				
<= 20 ha	13,713	12,280	-10%	- 1,433
20-50 ha	19,242	19,510	1%	268
50-300 ha	67,361	78,258	16%	10,897
300-500 ha	13,727	14,960	9%	1,233
> 500 ha	21,452	16,807	-22%	- 4,645
Total	135,496	137,794		
Area of semi-natural pasture in different size classes				
<=100 ha	17,342	18,016	4%	674
> 100 ha	5,708	5,566	-2%	- 142
Total	23,050	23,582		
Number of farms with livestock				
Cattle	909	484	- 47%	- 425
Dairy cow	208	151	- 21%	- 57
Sheep	338	290	- 14%	- 48
Pig	171	153	- 11%	- 18
Number of dairy cows in different livestock units				
< 200	12,876	12,695	- 1%	- 181
>= 200	7,009	6,840	-2%	- 169
Total	19,885	19,535		
Number of suckler cows by herd size				
<= 19	2,947	1,957	-34%	- 990
<= 99	7,812	7,798	0%	- 14
>= 100	4,688	5,100	9%	412
Total	15,447	14,855		
Number of beef places				
< 50	9,837	8,584	- 13%	- 1,253
>= 50	19,973	21,825	9%	1,852
Total	29,810	30,409		

Number of ewes and rams by herd size				
<= 49	4,165	4,332	4%	167
> 50	7,566	7,440	-2%	- 126
Total	11,731	11,772		
Number of breeding sows with more than 50 kg				
<= 99	1,492	1,356	-9%	- 136
100-199	1,462	1,716	17%	254
>= 200	15,410	15,135	-2%	- 275
Total	18,364	18,207		
Number of fattened pigs with more than 20 kg				
<= 249	3,977	4,060	2%	83
250-499	3,869	3,410	-12%	- 459
500-749	6,795	7,010	3%	215
>= 750	94,338	96,920	3%	2 582
Total	108,979	111,376		

Source: Regional data (SJV, 2009) and Statistics Sweden (2012).

Comparing the structural characteristics in both regions, in GSS we were able to obtain a slightly better representation compared to GMB with smaller deviations in terms of farm size classes and herd sizes. This is a result of the fewer characteristics we adjusted during the upscaling procedure for GSS. For GMB we had to adjust for more structural characteristics and as the number of controls increases, it is difficult to represent all of them accurately with only 25 farm types. On the other hand increasing the number of farm types represents a trade-off between accuracy and practicality for building the model and later evaluating results at a general level. However, the end result shows a good fit to the major structural characteristics, and hence a reasonable trade-off between the number of typical farms and representation of the region.

Table 12: Upscaling results GSS

General characteristics	Regional Data	Upscaling results	Relative deviation	Absolute deviation
Number of farms	2,690	2,821	5%	131
Utilized agricultural area (UAA; ha)	201,577	194,046	-4%	- 7,531
Number of beef cattle older than 1 year	7,088	6,241	-12%	- 847
Number of dairy cows	3,376	3,316	-2%	- 60
Number of suckler cows	4,843	5,004	3%	161
Number of eves and rams	3,027	3,075	2%	48
Breeding sows with more than 50 kg	14,920	16,435	10%	1,515
Fattening pigs with more than 20 kg	73,675	73,386	0%	289
Structural characteristics				
Area (ha)				
Arable land	194,082	186,569	-4%	- 7,513
Semi-natural pasture	7,495	7,477	0%	- 18
Total	201,577	194,046		
Number of farms in different size classes				
<= 20 ha	1,113	1,102	-1%	- 11
20-50 ha	530	592	12%	62
50-300 ha	941	1,042	11%	101
300-500 ha	58	60	3%	2
> 500 ha	48	50	4%	2
Total	2,690	2,821		
Number of farms with livestock				
Cattle	680	781	15%	101
Dairy cow	60	64	7%	4
Sheep	116	117	1%	1
Pig	171	213	25%	42
Number of dairy cows in different livestock units				
< 200	1,754	1,762	0%	8
>= 200	1,622	1,554	-4%	- 68
Total	3,376	3,316		
Number of breeding sows with more than 50 kg				
<= 49	1,122	1,124	0%	2
50-99	1,728	1,736	0%	8
100-199	2,483	2,618	5%	135
>= 200	9,586	10,957	14%	1,371
Total	14,920	16,435		
Number of fattened pigs with more than 20 kg				
<= 99	1,107	1,104	0%	- 3
100-249	3,501	2,877	-18%	- 624
250-499	6,713	6,647	-1%	- 66
500-749	6,481	6,543	1%	62
>= 750	55,873	56,215	1%	342
Total	73,675	73,386		

Source: Regional data (SJV, 2009).

4 Modelling the production possibilities of the typical farms

Once the typical farms are selected and the agricultural structure of the region is well represented by them, the third step in the calibration process is to develop an optimization model of each farm's production possibilities based on their characteristics from Table 9 and

Table 10, including machinery and stable capacities. This is done using Mixed Integer Programming (MIP) to find optimal combinations of their production activities and investments (Hazell and Norton, 1986). The MIP model is used to represent farm-agent behaviour and assumes profit maximization of farm household income, while simultaneously considering factor endowments (land, capital, labour, machinery, stable capacities), production and financing activities, investment possibilities as well as restrictions on farming activities (crop rotation, quotas, livestock density, etc.) (Kellermann et al., 2008). The information regarding which production activities we modelled and which data we used are provided in the next subsection.

4.1 Mixed Integer Programming (MIP) tableau

All the farm activities and restrictions are set up in a MIP tableau that specifies relevant production activities and technological and market relationships (Table 13), which is then used for the static base period calibration of regional production. The columns in the matrix represent the production activities, either continuous or integer, for which the farm-agent attempts to find optimal values (row “activity levels”) that will maximize the household income (HH), while considering the resource, marketing and balance constraints listed in the rows. The *x* symbol shows where interactions between columns and rows occur. For example, the resource constraint row Labour (h) ensures that the used quantity of labour can never exceed the available capacity represented by annual working units (AWU) in hours, listed on the right hand side (RHS). For each possible production activity there is a specific labour input requirement depending on the activity level. The marketing and balance constraints ensure that activity levels are logical.

Table 13. Stylized mixed-integer programme (MIP) tableau

Mixed-integer programme		**Short term loans/saving**	**Buy/sell variable labour**	**Hire contractor**	**Plant production**	**Livestock production**	**Keep/sell heifers**	**Buy/sell manure**	**Sell crop products**	**Decoupled payment**	***Investment activities***	***Buy/sell fixed labour***		
Continuous/integer activity		**c**	**c**	**c**	**c**	**c**	**c**	**c**	**c**	**c**	***i***	***i***		***RHS***
	Objective function	***Gross margin***												
Resource constraints	Liquidity (SEK)	x		x	x	x	x				x	x	≤	L
	Min. equity capital reserve (SEK)				x	x	x				x	x	≤	EC
	Labour (h)		x		x	x		x			x	x	≤	AWU
	Arable land - AL (ha)				x			x					≤	AL
	Semi-natural pasture - SN (ha)					x							≤	SN
	Livestock capacities (places)					x					x		≤	LS
	Machinery (ha)			x	x						x		≤	M
Marketing and balance constraints	Organic N-balance (kg N/ha)				x	x							≤	0
	Winter wheat max. (% of AL)				x								≤	0
	Sugar beet max. (% of AL)				x								≤	0
	Yield crop products (kg/ha)				x				x				≤	0
	Recruitment heifer (head/year)					x	x						≤	0
	Direct payments (SEK)				x	x				x			≤	0
	Stocking density (LU/ha)				x	x							≤	0
	Activity levels	a	b	c	d	e	f	g	h	i	j	k		HH

Notes: c = continuous activities; i = integer activities; RHS = right-hand side (farm capacity limit or balance of activities); HH = household income; L, EC, AWU, AL, SN, LS, M = farm capacities; a to k: activity levels as a result of the optimization problem.
Source: adapted from (Happe, 2004).

The alternative farm organization options available for each typical farm are represented by the activities: i) investments in stable and machinery, ii) buying and selling of labour and iii) financing (borrowing and saving), and listed as columns in the MIP tableau. Besides the advantage of modelling and representing different production activities, it also allows optimization of investments and hence for farms to optimize their production over time (change dynamically).

During the representation and calibration of the MIP model for each typical farm, the following considerations are made:

- New investments cannot occur in the first period, because this will affect the overall upscaled activity levels and won’t reflect the observed production activities in the base period.

- Factor endowments have to be fully used.
- Financial losses have to remain limited. Hence, land rents should be set to average regional rents, farm wages equivalent to off-farm wages and appropriate interest rates for the liquid capital. Otherwise farms would exit too quickly in AgriPoliS due to illiquidity (Sahrbacher, 2011).

4.2 Production activities

This section provides information on the production activities included and data used to represent them in the MIP tableau. The production activities reflect the most common crop and livestock activities observed in the two study regions. The data used for specifying the farm activities are from Agriwise (2015) enterprise budgets for the respective base years for which the regions are calibrated.

4.2.1 Crop production

The enterprise budgets contain information on revenues, variable costs, policy payments, labour input, capital depreciation, machinery input per activity and other technical data on factor use. Table 14 lists the input data for both regions. We divide the information for each production activity into revenues and costs, using the respective quantity and price for them. To make it possible to optimize particular inputs given changes in prices and evaluate changes in the use of these inputs (e.g., for environmental evaluation) the variable costs are disaggregated into specific costs for i) energy, ii) fertilizers (nitrogen, phosphorous and potassium) and pesticides. Capital depreciation and labour input are also separated because these are optimized at the farm level and not by activity per se. In the model, nitrogen fertilizer input is optimized, while inputs of phosphate and potassium are assumed to be applied at a fixed rate of the nitrogen input. Variable costs that are to some extent fixed per hectare of each activity (insurance, consulting, veterinary medicine, etc.) are lumped together in the category “Other costs” (Table 14). Costs for own machinery are modelled based on the cost of farming one hectare of winter wheat, as indicated by one in the machinery input row. Fixed costs for owned machinery are modelled at the farm level (see Section 4.2).

We further distinguish between crop production activities for different soil classes, indicated by the suffix high or low, see Table 14. In order of declining productivity, we have the following land classes in the virtual landscape: three classes of arable land; arable-high, arable-low and arable-permanent grass; and one class of land only suitable for grazing, semi-natural *pasture*. Cros yields depend on the class of land they are grown on. High quality land is mainly used for cultivating winter wheat, rape seed and sugar beet, while low quality land is devoted to temporary rotational grass and fodder production such as feed-quality barley. Other grain and oil seed crops can be grown on both high and low land but the costs on high quality land are higher due to more intensive production. The same holds for grass silage production. However, for protein crops we model two distinctive crops; peas and clover, to account for soil heterogeneity where it is assumed that peas are grown on high and clover on low quality land. Potato and vegetable production are not included in the model because these are not significant crops in the regions. The land type arable-permanent grass is for ruminant fodder, particularly as pasture for dairy cows during the obligatory outside season (i.e., according to Swedish law). Also, farms that have arable grassland and pastures but no ruminants, in order to meet the cross compliance requirements, may use grazing services from farms that have heifers and sheep which is modelled in a regional market. To reflect crop rotations in the regions we implement limits on the maximum percentage of a specific crop that can be grown on individual farms. Another restriction is an upper limit of maximum nitrogen application from animal manure which is set to 204.8 kg N/ha. This is an environmental constraint which reflects the maximum allowed livestock density (1.6 LU per ha).

Table 14. Crop production activities input data

Region	Type	Crop specific inputs	Price SEK/unit	Winter wheat high	Other grain high[1)]	Other grain low	Rape seed high	Rape seed low	Sugar beet high	Protein crop high[2)]	Protein crop low[3)]	Grass silage high	Grass silage low	Arable pasture low	Arable grass permanent	Semi-natural pasture	Fallow land high	Fallow land low	Fallow land per-manent
GMB	Income	Standard yield (kg)		6,600	5,500	4,600	4,100	3,400	494	3,600	274	4,400	4,100	4,200	4,200	1,600	-	-	-
		Price of output (SEK/kg)		1.54	1.24	1.25	3.25	3.25	27.54	1.77	20	-	-	-	-	-	900	900	900
	Costs	Nitrogen (kg/ha)	10.51	139	88	72	182	168	120	0	0	125	103	180	0	0	0	0	0
		Phosphorous (kg/ha)	19.49	17	17	14	28	25	27	15	0	11	7	0	0	0	0	0	0
		Potassium (kg/ha)	10.26	18	13	8	31	19	39	21	15	88	66	0	0	0	0	0	0
		Pesticides (dose/ha)	674	0.93	0.33	0.33	1.59	1.59	3.73	1.27	1.67	0	0	0	0	0	0.4	0.4	0.4
		Energy variable (liter/ha)	9.80	121	98	82	68	56	0	91	38	0	0	0	0	0	0	0	0
		Energy fixed (liter/ha)	9.80	66	61	59	49	46	140	52	89	50	45	40	11	11	0	0	0
		Labour (h/ha)	192	11.3	10.3	10.3	7.5	7.5	32.1	9	10.1	11.6	8	9.8	2	3	2.4	2.4	2.4
		Machinery (unit/ha)		1	0.9	0.9	0.66	0.66	2.27	0.80	0.89	1.07	1.07	0.5	0-	0.05	0.2	0.2	0.2
		Other costs (SEK/ha)		728	521	518	1,645	1,556	4,005	1,279	465	1,663	1,594	120	120	102	220	220	220
		Crop rotation limit (% of arable land)		66	66	66	20	20	18.5	0	0	75	75	0	0	0	0	0	0
GSS	Income	Standard yield (kg)		7,900	5,700	4,600	3,600	3,400	515	4,100	238	6,000	5,000	4,800	-	1,800	0	0	-
		Price of output (SEK/kg)		1.54	1.19	1.19	3.25	3.25	27.54	1.84	18.95	0	0	0	-	0	900	900	-
	Costs	Nitrogen (kg/ha)	10.51	158.5	90.5	72	172	168	120	0	0	183	183	180	-	0	0	0	-
		Phosphorous (kg/ha)	19.49	20.7	17.1	14	25.5	25	28.25	16.8	15	10	10	0	-	0	0	0	-
		Potassium (kg/ha)	10.26	24.5	13.5	8	21	19	43	46	35	86	86	0	-	0	0	0	-
		Pesticides (dose/ha)	674	0.99	0.43	0.43	1.59	1.59	3.73	0.98	2.11	0	0	0	-	0	0.4	0.4	-
		Energy variable (liter/ha)	9.80	145	101	82	59	59	0	96	42	59	59	40	-	0	0	0	-
		Energy fixed (liter/ha)	9.80	68	61	59	47	47	140	78	122	0	0	0	-	11	26	26	-
		Labour (h/ha)	192	11.3	10.3	10.3	7.5	7.5	32.1	10.9	14.5	10	8	7	-	2	2.4	2.4	-
		Machinery (unit/ha)		1	0.9	0.9	0.66	0.66	2.27	0.52	0.69	1.07	1.07	0.5	-	0.05	0.2	0.2	-
		Other costs (SEK/ha)		699	522	522	1,582	1,500	4,032	979	481	1,912	1,402	120	-	0	220	220	-
		Crop rotation limit (% of arable land)		66	66	66	20	20	18.5	0	0	75	75	0	-	0	0	0	-

Note: “-“, means activity is not modelled in that region. 1) Course grains such as: barley, oats, triticale, maize. 2) Mainly peas and beans. 3) Clover.
Source: Agriwise (2015). Data is based on actual levels for 2011.

Labour needs are represented by a labour input for each production activity. Besides the family (unpaid) labour input, farms have the possibility to hire additional farm labour or work off-farm themselves if not all family labour is used on the farm. A standard labour input for field operations for each crop is presented for a farm size of 70 ha. It is assumed to decrease with increasing farm size since farmers can use larger and more efficient machinery the larger the farm. The relevant adjustments to the standard labour input hours to reflect different stable and machinery capacities are presented in Table 16 in the next section. GMB has higher standard labour input for grass fodder activities than GMB reflecting the smaller average field size in this region.

We present the revenues that the farm agents generate from the crop production activities based on average yields, output prices and decoupled payments from the Single Payment Scheme (SPS). Note that GSS farmers receive higher direct payments (3,000 SEK/ha) than GMB farmers (1,827 SEK/ha), since historically these payments were intended to compensate for reduced price support. The support for semi-natural pasture is the same for all land in Sweden. Crop yields are modelled endogenously (see section 4.4.1, “Yield function”) and farmers can either sell the produced quantity on the market or in the case of coarse grain, use it as feed. Grass fodder is used on the farm where it is produced. Protein crops are the only ones that are not modelled through a marketing activity because the yield is not modelled endogenously.

4.2.2 Livestock production

Similar to crop production activities, for the livestock production activities we group the specific input data in revenue and cost components. In Table 15 the columns list the specific livestock activities and the rows show the specific costs and revenues we use in the MIP, which are identical for the regions because fodder and labour requirements are identical for identical livestock types and stable capacities. The variable costs for fodder input are modelled as a fixed ration for grain and grass silage or pasture for each animal type. . The only difference is in the other costs which are used for calibration purposes. It includes the costs that are not explicitly represented in the MIP matrix (veterinary fees, electricity, insurance and other costs) and unobservable opportunity costs such as risk.

Table 15. Livestock production activities input data

	Livestock specific inputs	Price SEK/unit	Bullock dairy cow	Beef cattle	Bull suckler cow	Heifer suckler cow	Heifer dairy cow	Suckler cow	Dairy cow	Sheep	Fattening pigs	Sows
Income GMB/GSS	Animals per year (number)		0.5	0.75	1	1	1	1	1	2	3.25	23
	Slaughter weight (kg)		280	300	350	-	-	-	-	19.5	85.8	
	- price (SEK/kg or place)		24,05	24,71	27	7,990	9,870	754	-	43.36	13.14	484
	Milk yield (l/head)	3.35	-	-	-	-	-	-	9,000	-	-	-
	Coupled payment (SEK/head) [1)]		942	1,327	1,327	-	-	-	-	-	-	-
Costs GMB/GSS	Grass silage requirement (kg)		815	955	1,289	1320	696	1,581	1,644	280	-	-
	Grass pasture requirement (kg)[2)]		1,492	943	-	1,200	786	2,297	1,040	250	-	-
	Grain requirement (kg)		311	1,184	1,037	-	315	114	1,554	309	955	4,977
	Labour (h/head)	192	13.5	11	8.5	13.5	8	15	38	3.8	0.98	15
	- standard capacity		55	55	55	55	55	38	120	200	800	60
GMB	Other calibration costs (SEK/head)		869	1,085	313	171	1,169	203	11,236	337	2,005	2,227
GSS	Other calibration costs (SEK/head)		434	1,646	782	531	1,868	676	11,086	787	2,004	2,479
	Nitrogen excretion (kg/year)		40	36	36	34	34	22	128	14	14	36
	Nitrogen available for crops (kg/ha) [2)]	10.51	8	7.2	7.2	6.8	6.8	4.4	25.6	2.8	2.8	7.2
	Phosphate available for crops (kg/ha)	19.48	6	6	6	6	6	5	17	2	3	10
	Potassium available for crops (kg/ha)	10.26	46	33	33	40	40	28	102	19	5	13

Note: "-" indicates no input data is considered for this activities. 1) Decoupled after 2012. 2) Only 20% of the nitrogen from manure is available immediately for plant growth. 2) Grass can come from pasture on arable land or semi-natural pasture.
Source: Agriwise (2015); (SJV, 2010). Data is based on actual levels for 2011.

The labour input for a stable unit is based on the input for the standard observed capacity for which the enterprise budget is calculated and the larger the stable the less labour required per unit. Regarding the nitrogen content of manure, it is assumed that 20% is available for plant growth when applied to crops.

Revenues can come from several sources for livestock production, for example dairy cows are slaughtered at the end of their milking life. As beef fattening technologies vary in Sweden, the activity is differentiated into the fattening of bullocks and bulls from dairy calves, and calves from suckler cows. Bullocks are raised on pasture until they reach 280 kg, whereas suckler bulls are raised on pasture and then fattened in a stable to a weight of 350 kg. To ensure balance between production of calves and numbers of beef cattle, a regional calf market is active in the model (see Regional calf market 4.4.2), where dairy farms can sell calves to farms specialised in beef production. It is assumed that 20% of dairy calves and 10% of suckler calves are kept for recruitment.

Since we model on a yearly basis, all costs, revenues and feed rations from Agriwise (where they are calculated over the entire production period), are annualised in AgriPoliS. For example, bullocks are kept for 24 months but we convert the activity to average annual production levels, thus 0.5 animals are produced per place and year in AgriPoliS. Additionally, the economic data for sheep and sows includes 2 lambs and 23 piglets respectively, and a unit for fattening pigs' has a turnover of 3.25 pigs per year.

4.3 Investment options

In AgriPoliS, all modelled farms are initialised with stable sizes (places) and machinery capacities (ha) corresponding to the number of livestock and machinery units observed for the typical farm. During simulations, farm-agents can re-invest to maintain their initial endowment or expand their production capacities through new investments. The potential investment options for each region are listed in Table 16. To represent the investment options we used data from SJV and Agriwise. The data from SJV was extracted from the Investment Support Database, which is based on applications for investment support and farmers estimated costs of planned investments. This data was used to validate the investment cost and labour savings for different stable and machinery capacities taken from AgriWise. It should be realised though that investment cost data is the most uncertain data used in the model because these are likely to vary from farm to farm, due to say the owners valuation of their own labour, and local conditions on the building market. Thus the investment costs derived from AgriWise and the SJV database were used to obtain preliminary investment costs. During calibration of each region these costs were then adjusted to ensure the model reproduced observed investment rates in the regions, i.e. reflect revealed investment behaviour. Consequently the investment costs for some capacities vary between GSS and GMB, but generally by ±10% of the preliminary investment cost.

Since data on asset vintages is not available in the FADN, AgriPoliS assigns a random age during the initialisation stage so that residual values and depreciation can be calculated in each simulation period. The maximum useful life of each investment varies depending on type (Table 16). For the investments, economies of scale are considered through the labour demand[3]. Meaning, labour input per unit is lower for larger investments and decreases as stable or machinery size increases (Additional labour column in Table 16). Similarly, the economies of scale are considered through the investment cost per unit or ha. Consequently the average cost is diminishing for larger investments.

If it is not profitable to invest in any of the given investment options, the farms have the possibility to contract machinery services. In addition, farms have the option to disinvest if they do not use all stable places (Kellermann et al., 2008).

[3] To present better the economies of scale aspect, in Table 16 the normal labour input is set to the highest capacity and not the standard observed as displayed in Table 15.

Table 16. Investment options

No.	Investment type	Unit	Capacities	Useful life	GMB Investment cost SEK/place	GMB Additional labour	GSS Investment cost SEK/place	GSS Additional labour[1]
1	Beef stable 1	Places	20	25	24,341	6.4	31,350	4.5
2	Beef stable 2	Places	55	25	21,420	4.5	28,050	4.5
3	Beef stable 3	Places	110	25	19,699	2.0	26,250	2.0
4	Beef stable 4	Places	220	25	17,463	1.0	22,890	1.0
5	Beef stable 5	Places	330	25	16,153	0.5	20,362	0.5
6	Beef stable 6	Places	440	25	15,090	0.0	18,934	0.0
7	Suckler cows 1	Places	20	25	30,959	8.2	28,000	6.5
8	Suckler cows 2	Places	38	25	24,400	7.1	24,300	6.5
9	Suckler cows 3	Places	75	25	18,734	2.2	19,200	1.6
10	Suckler cows 4	Places	150	25	15,330	0.4	16,000	0.5
11	Suckler cows 5	Places	300	25	14,027	0.0	14,875	0.0
12	Dairy stable 1	Places	60	22	126,940	23.0	85,000[2]	12.0
13	Dairy stable 2	Places	120	22	86,790	16.0	80,000[3]	11.0
14	Dairy stable 3	Places	180	22	74,415	8.0	70,500	6.0
15	Dairy stable 4	Places	300	22	65,824	1.0	57,500	1.0
16	Dairy stable 5	Places	600	22	61,907	0.0	51,500	0.0
17	Ewe 1	Places	50	25	6,812	3.8	7,000	1.4
18	Ewe 2	Places	100	25	6,219	2.0	6,400	1.2
19	Ewe 3	Places	200	25	5,100	0.8	5,300	1.0
20	Ewe 4	Places	400	25	4,550	0.1	4,500	0.3
21	Ewe 5	Places	800	25	3,600	0.0	4,300	0.0
22	Fattening pigs 1	Places	100	25	58,962	0.8	65,882	0.7
23	Fattening pigs 2	Places	400	25	25,059	0.6	28,000	0.6
24	Fattening pigs 3	Places	800	25	21,300	0.4	21,300	0.4
25	Fattening pigs 4	Places	1,200	25	20,400	0.3	20,400	0.3
26	Fattening pigs 5	Places	1,600	25	19,800	0.3	19,800	0.3
27	Fattening pigs 6	Places	3,200	25	16,830	0.1	16,830	0.1
28	Fattening pigs 7	Places	6,400	25	14,306	0.0	14,306	0.0
29	Sows 1	Places	44	25	55,208	14.6	60,128	7.0
30	Sows 2	Places	60	25	51,248	13.2	54,333	6.0
31	Sows 3	Places	140	25	39,137	6.1	50,307	4.5
32	Sows 4	Places	200	25	39,562	4.6	48,500	3.0
33	Sows 5	Places	330	25	34,846	2.7	45,270	2.0
34	Sows 6	Places	660	25	26,278	0.8	41,829	1.0
35	Sows 7	Places	1,320	25	24,281	0.0	39,655	0.0
36	Machinery 1	ha	30	20	22,013	9.0	22,000	4.3
37	Machinery 2	ha	60	20	20,000	6.3	19,500	3.3
38	Machinery 3	ha	100	15	17,600	4.2	16,000	2.7
39	Machinery 4	ha	150	15	15,000	2.1	15,500	2.0
40	Machinery 5	ha	200	12	12,784	1.5	12,800	1.4
41	Machinery 6	ha	300	12	10,287	1.0	10,100	1.0
42	Machinery 7	ha	500	12	8,900	0.5	9,400	0.5
43	Machinery 8	ha	800	12	8,878	0.0	8,750	0.0

Note: 1) Additional labour demand per unit relative to the labour demand of the largest investment option. 2) Cost per 45 stable places. 3) Cost per 90 stable places.
Source: (Agriwise, 2015, SJV, 2012).

4.4 Model parameters and key assumptions

Regional parameters and assumptions are necessary to be defined for each new developed region (Table 17). Plot size is set to reflect the scale of production in the region and to adequately capture the size and spatial distributions of fields. To reflect heterogeneity in the managerial capabilities of farm agents, we can influence production costs for farms of identical type through random variability in the managerial ability parameter; i.e., the economic performance is improved (operate at lower unit production cost relative to standard costs) for farms with better management skills.

Interest rates are set according to the source of financing, short or long term. However, agents can only borrow up to the level of 70% of their land assets, and 30% of the equity share of other assets (buildings and machinery). Beside the higher interest rate for short-term borrowed capital to set a natural limit on the amount borrowed, this restriction is another limitation to reflect normal conditions from banks. A maximum of 75% borrowed capital can be used to finance investments.

Table 17. Default values of specific regional parameters in AgriPoliS

No.	Description	GMB	GSS
1	Plot size	2 ha	3 ha
2	Managerial ability (% of standard variable cost)	±10%	
3	Interest rate level		
	long-term barrowed capital	3.5%	
	short-term barrowed capital	4.5%	
	interest on savings	3%	
4	Funding share land	70%	
5	Funding share buildings	30%	
6	Equity finance share	25%	
7	Farm handed over to next generation	every 25 years	
8	Opportunity cost increase when generation change	25%	
9	Length of land rental contracts	9-18 years	
10	Labour hours of annual working unit (AWU)	1,800 hours	
11	Average annual milk yield	9,000 kg	
12	Maximum milk output	35,226,000 kg	5,530,500 kg

When a generational change occurs, the opportunity costs of labour are increased to reflect the higher opportunity cost of the new generation’s labour. Land rental contracts vary in length and once the contract expires the land is returned to the land rental market where it goes to the highest bidder or is abandoned. The land rental market is modelled using an auctioneer-agent that coordinates biddings from farm-agents (Kellermann et al., 2008). Output and input prices are exogenous but can be updated in any particular simulation year in response to policy changes and market developments. For example, expected effects of a policy change on prices can be taken from a sector model such as CAPRI (2011) and be fed into AgriPoliS at relevant points in time. It is also possible to introduce price trends if relevant for the analysis, e.g., for particular factor prices such as labour, energy, fertilizers and pesticides. Generally, we assume that prices are constant and set at the base year level, unless information is available to the contrary. As both regions are small relative to global or EU markets, changes in regional production are assumed not to affect market prices.

Farm agents are assumed to behave rationally and have adaptive expectations, meaning that they are myopic and unaware of future policy or price changes, but rely on expectations based on historical levels. Farms may hire labour on an hourly or fixed contract basis in intervals of 0.5 AWU or 900 hours per year. Last but not least, to ensure that dairy production does not exceed reasonable limits, we have introduced a quasi-regional milk market where the price for new producers is reduced if total production exceeds a realistic level which is based on some factor of the maximum historical production level through expert judgement. Hence, it is assumed to be costly for new producers to secure a delivery contract with the local dairy if their production would result in the assumed maximum level being exceeded.

4.5 New developments

This section describes the developments introduced in AgriPoliS necessary to analyse the new CAP policy changes. It also provides a description of the yield function which is new feature in AgriPoliS developed during the development of the GSS region.

4.5.1 *Yield function*

Through the introduction of the yield function in AgriPoliS, it is now possible to model farm-agents optimal reactions to changes in prices and soil productivity, specifically the interaction between soil fertility, via soil organic carbon content and nutrient input (Brady et al., 2015) . The yield function Y (kg/ha) is calibrated to a specific crop and region for given crop and fertilizer prices, assuming normal yield and nitrogen fertilizer dose, and is expressed as (Brady et al., 2015):

$$Y_j = \hat{a} + \hat{b}N_j + \theta_j \hat{c}N_j^2 + \hat{d}C + \delta_j \hat{e}C \; + \hat{f}NC. \tag{1}$$

where ^ denote estimated parameters of the yield function from experimental data, N is total nitrogen input (kg/ha) from both chemical and organic sources, and C is the soil organic carbon content (% SOC). The calibration parameter θ_j adjusts the curvature of the nitrogen response to reflect farmers' observed fertilizer input decisions, which are assumed to be profit maximizing levels, and δ_j adjusts the curvature of carbon response to maintain the observed level of carbon that results in a plateau yield. In AgriPoliS there is also a parameter γ associated with each crop production activity that can be used to adjust soil carbon content annually as affected by soil management practices.

4.5.2 *Regional calf market*

The price of dairy calves in the region is modelled by adapting the following function developed by Samanidou et al. (2007):

$$p_t = p_{t-1}(1+\beta\frac{ED_t}{S_t}) \tag{2}$$

where ED_t is excess regional demand for calves and S_t is the total supply of dairy calves in period *t*. The parameter β, which takes on a value between 0 and 1, reflects the speed of price adjustment. In our case we found that setting it to 0.5 allows the calf price to adjust fairly smoothly over time. In cases when there is excess demand for calves, the price will increase proportionally to the ratio of excess demand and the price adjustment speed, and when there is excess supply, the price will fall accordingly. While some imbalances may occur over periods, the price function adjust the supply of calves by dairy farms and demand by specialist beef producers within the region towards balance over time.

4.5.3 *Passive farming*

A phenomenon where an agricultural land-owner maintains most of their land to collect CAP support without producing any commodities is defined as *passive farming*. An extended version of AgriPoliS has been used to evaluate whether the emergence of passive farming is hindering agricultural development in the EU, and to what extent it is affected by agricultural policies in particular the Single Payment Scheme (SPS) (Brady et al., 2017). Here we describe the resulting extensions to AgriPoliS.

In Table 18 we illustrate the principles for modelling the possibility to choose passive farming in the MIP for a farm with a limited area of arable land. The choice between passive and active farms is modelled as an integer problem (0 or 1). The columns of the matrix represent the choices available to the farm-agent whereas the rows are constraints, or the boundaries, of their decision space. Row 1 ensures that the farmer cannot allocate more land to the available production activities (indicated by ones) than their arable area (i.e., 100 ha). Row 2 forces the farmer to choose either active or passive farming but not both simultaneously, since the RHS constraint cannot be greater than 1. If a farmer chooses to be active, Row 3 indicates which production activities (by ones) are considered as relevant for active farming. A large negative value (i.e., -∞) ensures that the active farming activities are not restricted and are optimally allocated given the area constraint in Row 1. Note also that active farm-agents are permitted to manage some of their land as fallow if they find it optimal, which is activity "Fallow land active", whereas a passive farm can only manage their arable area as fallow, which is ensured by Row 4. Whether a farmer chooses passive farming or not will depend on its profitability, i.e., revenues and costs compared to active farming which are not shown here, but are attached to each cropping activity column (e.g., values of CAP direct payment).

We modelled this extension only in GMB since the presence of passive farms is significant there (AgriFood Economics Centre, 2015) which is reflected through the typical farm type "passive" in Table 9.

Table 18. Modelling passive farming in MIP tableau

	Production activity I	**Production activity II**	**Production activity III**	**Fallow land active**	**Fallow land passive**	**Farm type active**	**Farm type passive**		**RHS**
	Cont.	Cont.	Cont.	Cont.	Cont.	Int.	Int.		
Arable land (ha)	1	1	1	1	1			<=	100
Farm type choice						1	1	<=	1
Active farming	1	1	1	1		-∞		<=	0
Passive farming					1		-∞	<=	0

Note: Instead of -∞ use a large value, e.g. 5,000; Cont. = continuous values; Int. = integer values; RHS = right hand side constraints.

4.5.4 *Ecological Focus Areas (EFA)*

AgriPoliS is extended to enable evaluation of the greening reform which aims to improve agriculture's environmental performance. To cater for the new policy we introduced new production activities to be considered as EFA's such as: cereals or oilseed crops under-sown with grass of some kind, nitrogen fixing crops (protein crops), willow, fallow land and uncultivated field edges on arable land (SJV, 2015).

Undersown crops are sown simultaneously with the main crop and their growth comes after the main crop is harvested. Grasses and grass clover mixes are often chosen as undersown crops. Sowing the crops together allows cost savings (labour, machinery and energy) compared to sowing the grass separately; sowing separately is an alternative that is allowed but the usual practice in Sweden is to sow together with the main crop (Aronsson, 2017). The main crop in the undersown crops has to be sown before November 1st (SJV, 2015). The winter coverage of fields enhances soil fertility and prevents nutrient leaching. Note that the area of ley that farms receive environmental payments for reducing nitrogen leaching cannot be counted as EFA.

An uncultivated field edge on arable land is a strip along the edge of the field where there is no production. To be counted as EFA it should be kept fallow at least until the last harvest of the adjoining crop and at least the period June to July. Both mechanical and chemical weed control are allowed.

Table 19 provides an example of how the 5% EFA obligation is modelled for a farm with 100 ha arable land with three non-EFA crop production activities (winter wheat, barley and rape seed) and 30 ha grassland. The payment scheme is set to the expected 2019 level when payments will be equalized across Sweden (around 1,758 SEK/ha) of which 30% (527 SEK/ha) is contingent on adopting greening measures and the remaining (1,231 SEK/ha) as a basic payment.

Rows and columns “greening_yes>15ha” and “greening no<15ha” capture the EU exemption from EFA obligations for farms smaller than 15 ha arable land. The next three rows implement the exemption for farms with more than 75% grassland and fodder crops (i.e., rows “greening_yes<75% GL” and “greening no>75% GL”) and a remaining arable area less than 30 ha (row “greening_yes>30ha AL”). Similar to passive farming, the EFA exemptions for arable land and grassland are modelled as integer problems (either 1 or 0) indicated by the rows “greening no<15ha” and “greening no>75% GL”.

The rows “undersown in fall/spring” indicates which crops are considered as the main crop that is undersown with grass. Since these two activities only provide an indication of how much acreage is undersown and take up the same area as the main crop, they do not reduce the area available for production, i.e., excluded from “arable land” row, greening exemption row “greening_yes>15ha” or are allocated any basic or greening support. All conditions are indirectly captured and satisfied by the main crop.

The row “EFA requirement” is used to model the distribution of EFA as a proportion of the crop production activities as well as to weight the different EFA-options that are possible according to the Swedish Board of Agriculture (SJV, 2015). The weights are defined depending on how much each EFA is believed to enhance biodiversity (Matthews, 2015). Fallow land, especially if managed for biodiversity enhancement, is valued the most. Hence, if the “greening_yes>15ha” and “greening_yes<75% GL” rows indicate that the farm must provide EFAs then 5% (0.05) of each ha winter wheat, barley or rapeseed, should be allocated as fallow (0.95). The other EFA activities are weighted relative to fallow land. For example, 1 ha of protein crops or willow/catch crops is counted as 0.7 ha or 0.3 ha EFA respectively.

Field margins are counted differently compared to the others, *i.e.*, a 1 m long margin is counted as 9 m^2 EFA, but must be at least 1 m but no more than 20 m wide (SJV, 2015). Therefore, in Table 19 a farm with 100 ha arable land will be able to meet the 5% EFA requirement, through having either 5 ha fallow land, 7.14 ha (5/0.7) protein plants, 16.7 ha (5/0.3) main crop undersown with grasses or planted willow, or 0.55 ha (5/9) field margins that are assumed to be 1m wide.

Table 19. Implementation of EFA in MIP tableau

	Winter wheat	**Barley**	**Rape seed**	**Semi-nat. pasture**	**Protein crops**	**Fallow land**	**Willow**	**Undersown in fall**	**Undersown in spring**	**Field margins**	**Basic payment**	**Greening payment**	**Greening yes>15ha**	**Greening no<15ha**	**Greening yes<75% GL**	**Greening no>75% GL**		
	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Int.	Int.	Int.	Int.		RHS
Arable land (AL)	1	1	1		1	1	1			1							<=	100
Semi-nat. pasture (GL)				1													<=	30
Basic payment	-1,231	-1, 231	-1,231	-1,231	-1,231	-1,231	-1,231				1						<=	0
Greening payment	-527	-527	-527	-527	-527	-527	-527					1					<=	0
Greening_yes>15ha	1	1	1		1	1	1			1			-∞				<=	15
Greening_no<15ha													1	1			<=	1
Greening_yes<75% GL	0.75	0.75	0.75	-0.25	0.75	0.75	0.75			0.75					-∞		<=	0
Greening_no>75% GL															1	1	<=	1
Greening_yes>30ha AL	1	1	1		1	1	1			1					-∞	-30	<=	0
Undersown in fall	-1		-1					1									<=	0
Undersown in spring		-1							1								<=	0
EFA requirement[1)]	0.05	0.05	0.05		-0.7	-0.95	-0.3	-0.3	-0.3	-9				-∞		-∞	<=	0
Max. area field margin	-0.04	-0.04	-0.04		-0.04					0.96							<=	0
EFAs activity level (ha)					7.14	5	16.7	16.7	16.7	0.55								

Note: 1) The weighting factors are set relative to fallow land. Thus, 1 ha protein crops and catch crop or willow are considered as 0.7 ha and 0.3 ha fallow land, respectively. Field margins are considered to be 1 m wide even though they might be wider in practice (SJV, 2015) and the resulting area is multiplied by 9 to obtain the EFA equivalent area.

Instead of -∞ use a large value, e.g. 5,000; Cont. = continuous values; Int. = integer values; RHS = right hand side constraints.

Note that the modelling of field margins has required some additional assumptions since the width is not definite and the potential length depends on field characteristics (i.e., size and shape). If the parcel is assumed to be square, 1 ha can have a 400 m long field margin (row "Max. area field margin") if each side has a 1 m wide strip this counts as 9 m^2 towards the EFA obligation. Hence, a 400 m long strip counts as 3600 m^2 or 0.36 ha EFA thanks to the weighting factor. Also note that farmers can choose a mix of different EFA types to achieve the obligation depending on what is optimal.

Table 20 displays the economic data used to represent the EFAs. We already introduced details of two EFA measures (fallow land and protein crops) in section 4.1. These two production activities already exist, thus from 2015 they were simply assigned weighting factors and can now be considered part of a farm's EFA area (row "Greening yes>15ha" in Table 19). Since there is not yet economic data available on costs of having a field margin, we assumed that the costs are similar to fallow land. We assume these are somewhat more costly than fallow land due to their smaller contiguous area which makes mechanical and chemical weed control more costly. Protein crops, willow and uncultivated field margins can be allocated to both high and low productive arable land types. Thus, similar to protein crops where we selected two distinctive crops to reflect the soil heterogeneity (Table 14), we applied the same approach for willow where we define two separate activities for willow production depending on soil fertility and consequently expected yield. Hence, willow that is cut every fifth year, yields 23 tons wood for energy and is grown on high productive land. On the contrary, willow that is grown on low productive land yields 16 tons/ha. Since field margins are not used in production there is no need to define separate activities based on soil type and hence use the same economic data. The major cost for this EFA type, like fallow, is the opportunity cost of lost production which is indirectly captured in the optimization.

Table 20. Economic data for additional EFA types

	EFA specific inputs	Price SEK/unit	Willow high	Willow low	Undersown in fall	Undersown in spring	Field margins
Costs	Nitrogen (kg/ha)	10.51	747				
	Phosphate (kg/ha)	19.49	724				
	Potassium (kg/ha)	10.26	424				
	Pesticide (dose/ha)	674		0.33			0.4
	Energy fixed (liter/ha)	9.80	11.8	33.2	13.6	13.6	26
	Labour (h/ha)	192	1.85	1.16	2.5	2	2.4
	Machinery (unit/ha)		0.16	0.10	0.12	0.1	0.2
	Other costs (SEK/ha)		5,504	5,050	720	547	226
Income	Yield (kg)	0.465	23,000	16,000			

Source: Agriwise (2015).

We assume that farm-agents are free to place their selected EFA types where they like on the farm as in reality. Depending on the environmental benefits we analyse with AgriPoliS, in some cases it might be important to consider fallowing land within a particular rotation rather than assuming it is land taken permanently out of production. For example, for biodiversity having rotational fallow land might be more beneficial (nesting habitat, winter food for seed eating birds) where as permanent fallow land is more beneficial for carbon sequestration, reducing nitrogen leaching, reducing sediment runoff, etc. (Hart, 2015). This is an assumption that can be changed depending on the circumstances of a particular simulation.

4.5.5 *Young farmer support*

Besides modelling the new greening measures, another feature of the 2015 CAP reform which we included in the model is the special support for young farmers. The reform hopes in this way to support rejuvenation of the agricultural sector by complementing the existing start-up support to newly established young farmers from the Rural Development Programme (Pillar II). As a result farmers who are 40 years old or younger in the year of application, can be given an additional payment of 55-60 € per ha for a maximum of 90 ha over 5 years (SJV, 2016; Ds, 2014). Support for young farmers is set in Euros but it is paid in SEK depending on the exchange rate, here we assume 9.15 SEK/€ (SJV, 2016). Since Sweden chose the maximum payable amount we set the support to 60 €/ha or 549 SEK/ha, meaning that young farmers can receive a maximum of 49,410 SEK per year over the allowable 5 year period, which is the constraint row “time span” in Table 21. AgriPoliS allocates farm-agents’ ages randomly between 25-65 years on initialization. Thus row “farmer age” indicates if the farmer is younger than 40 and eligible to apply for young farmer support. Similar to the passive farming tableau, young farmers’ support is modelled as an integer constraint (“payment condition” row). This row controls if a farmer is categorized as an older and hence ineligible farmer or is eligible for the young-farmer payment which then is limited by the maximum allowable support that is paid per ha for each production activity.

Table 21. Young farmer support, simplified MIP tableau

	Production activity I	Production activity II	Production activity III	Young farmer payment	Maximum payment	Older farmer	Young farmer		RHS
	Cont.	Cont.	Cont.	Cont.	Int.	Int.	Int.		
Maximum payment				1	-49,410			<=	0
Payment/ha	-549	-549	-549	1				<=	0
Farmer age (FA)						-20	-1	<=	(FA)
Payment condition					1	1		<=	1
Time span							1	<=	5

Note: Cont. = continuous values; Int. = integer values; RHS = right hand side constraints.

4.6 Policy framework

Since both regions are calibrated to years before the new CAP the baseline scenario policy framework in the model is divided in two parts: old CAP until 2014 and new CAP 2015-2020.

The old CAP is related to the *Mid Term Review* (MTR) reform when decoupling of support was introduced in 2005. As a result of this reform the majority of direct support that was linked to production was converted into a single (decoupled) payment, the SPS which farmers receive per ha of land independent of the production of food. Up until 2014 a farm's SPS payment comprised a regionalised basic payment and potentially a farm specific payment or top-up based on the farms previous livestock payments. Additionally Cross-Compliance was introduced, which linked eligibility for payments to following regulations concerning use of plant protection and environmental care, as well as human and animal health. These regulations or Statutory Management Requirements must be followed by the farmer in order to obtain the full SPS payment. Further farmers are required to maintain their agricultural land in Good Agricultural and Environmental Condition (GAEC) if it is not used in production to be eligible for payments. For example, pastures must be grazed by animals each year while arable land can be managed mechanically with mowers to keep the vegetation down. Consequently, instead of focusing on production support, the CAP now aims to more directly support farmers' incomes through decoupled SPS payments and guarantee minimum environmental quality.

The second period of the policy framework from 2015 and onwards (or the future), is related to the “greening” reform”, which entails national convergence or equalization of payments, introduction of a coupled cattle payment and greater focus on the environment via greening measures.

Sweden has chosen to equalize farm subsidies within the country and fully exploit the possibility of special animal premiums (13% of the country's payment budget). As consequence of equalization, which will be phased in over the period 2015-19, all farms will receive the same payment per hectare of arable and pasture land after the four-year phase-in (€ 193 or 1,527 SEK per ha in 2019) and for cattle over one year old a payment of € 91 (800 SEK) per year (Table 22). According to the Swedish Government (Ds, 2014), the cattle payment is a transitional measure to alleviate the negative effects of equalization on the dairy and beef sectors.

After being equalized the payments are divided into a basic and a greening payment. As stated 30% of the SPS payment is conditional on farms fulfilling the EFA obligation. Thus, the payments are modelled as detailed in Table 22.

Table 22. CAP direct payments in the different regions

Year	GMB basic payment (SEK/ha)	GSS basic payment (SEK/ha)	Greening payment (SEK/ha)	Cattle payment (SEK/head)	Young farmer payment (SEK/ha)
2008	1,827	3,000	-	942/1,327**	-
2009	1,827	3,000	-	942/1,327	-
2010	1,827	3,000	-	942/1,327	-
2011	1,827	3,000	-	942/1,327	-
2012	1,827	3,000	-	-	-
2013	1,827	3,000	-	-	-
*2014	1,717	2,820	-	-	-
2015	1,198	1,198	527	800	549
2016	1,206	1,206	527	800	549
2017	1,214	1,214	527	800	549
2018	1,222	1,222	527	800	549
2019	1,231	1,231	527	800	549

Note: *New payment level after completion of modulation of 6% of the support to Pillar 2. ** 942 SEK is coupled payment to bullock from dairy cow whereas 1,327 SEK is coupled payment to beef cattle and bull from suckler cow.
Source: Ds (2014).

5 Validation of dynamic simulation results

Validating the dynamic simulation results is less straightforward than validating the representation of the region as done above (Section 3.2). To begin with, the purpose of the AgriPoliS model—and prescriptive policy analysis in general—is to determine the possible effects of alternative policy options on variables relevant to decision makers, e.g. economic welfare (Nagel, 1999). In other words, our aim is to evaluate the potential or ex ante effects of an anticipated policy change on agricultural structure and landscape variables all other things equal. Accordingly it is not our goal to predict the future with AgriPoliS but to identify the potential impacts of possible policy options, given current socio-economic conditions. In this context simulation experiments have the advantage that one can simulate a situation with and without a policy change and compare the results; such experiments are obviously not plausible in reality. In this way alternative policy options can be tested in policy evaluation models and the results fed to policymakers to provide decision support.

Naturally there will always be uncertainty surrounding the simulated results of the model because of unexpected events, as for example the food price spikes of 2007−08. Such events might indeed outweigh policy effects in the long-run. However foreseeing such events is not the goal of policy modeling. Rather it is to determine the likely implications of a change in the status-quo brought about by a political decision. It is however possible to test the consequences of alternative assumptions about the future in conjunction with a policy change but this is more likely to confound the results, as well as being of secondary, if any importance, to policymakers. For example, if politicians tried to market cuts in the CAP budget today on the pretext that they expected food prices to increase in the future—for reasons unrelated to CAP—they would clearly face a difficult battle. As such our primary goal is to isolate the impacts of the policy change *ceteris paribus*.

Validation of the simulation results can be done in two stages. First, by comparing simulated land use for the baseline policy framework to observed historical trends. Secondly, after the passage of time one can compare simulated results with those revealed by unfolding events. In practice this step implies the possibility for continual model improvement as more data becomes available. Given small changes in socio-economic conditions we would hope to find close agreement between simulated developments in the virtual region and observed developments in reality. On the other hand if significant changes eventuated in socio-economic conditions since initial model calibration we could not expect close agreement between simulated and actual developments. Nonetheless, if the assumptions of the model are subsequently changed to match these changes in conditions we would once again hope to find close agreement between simulated and actual developments.

We have validated the simulations in both ways. In Table 23 we compare the proportional decline in farms over the period 2008–14 according to official statistics with the simulated decline in farms under the baseline scenario in AgriPoliS. First note that we exclude small farms (< 20 ha) from the validation because even though these are large in number they manage a small proportion of the total arable area in both GMB and GSS (Table 2 and Table 7). These farms are also often quasi-commercial (e.g., hobby farms) and therefore problematic to model with precision because of the greater uncertainty about economic parameters such as owners' opportunity costs of labour and investment costs than commercial farms. This implies that simulated changes in the number of these farms will be very sensitive to specific assumptions. Consequently we exclude small farms in the validation of structural change, so as to obtain a better indicator of the rate of agricultural development as indicated by the rate of change in farms important for production (i.e., commercial farms).. Bearing this in mind it can be seen that the rate of change in commercial farms simulated by AgriPoliS until 2014 is similar to reality (Table 23).

Table 23. Comparison of real versus simulated declines in farms 2008−14

	GSS				**GMB**			
	Real		AgriPoliS		Real		AgriPoliS	
	Nr.	*%*	*Nr.*	*%*	*Nr.*	*%*	*Nr.*	*%*
2008	2,992		395					
2011	2,860	- 4	388	- 2	3,354		338	
2014	2,684	- 10	372	- 6	3,121	- 7	303	- 10

Source: (Statistics Sweden, 2009, 2012, 2015).

The simulated changes in land use and livestock production also capture very closely the real structural development in the regions, because it is farms larger than 20 ha that are most important for the structure of production. In Figure 4 and Figure 5 (upper diagrams) it can be seen that the change in the area of arable crops in AgriPoliS has been consistent and following the same trend as in the data for the real regions from Statistics Sweden (SCB), over the evaluation period. For example the area of cereal production in both regions as well as grassland (including semi-natural pasture) in GMB account for the largest proportions in the simulations (similar as Table 1), and are in line with the real development. Of course, the scale is different between the real data and AgriPoliS but this is because we modelled at the subregional level. There is an exception in GMB for fallow land where the simulated area increases faster than the real data. The area of fallow land is though very small relative to the total arable area, thus making it difficult to obtain more exact calibration unless it comes at the cost of other (more important) land use categories and indirectly livestock production.

Regarding the different livestock production activities, the lower diagrams of the figures convey that AgriPoliS also performs well and is able to capture the development visible in the real data. For example granivore production in GSS (Table 1) follows the same trend in both the simulated and real data, it is declining.

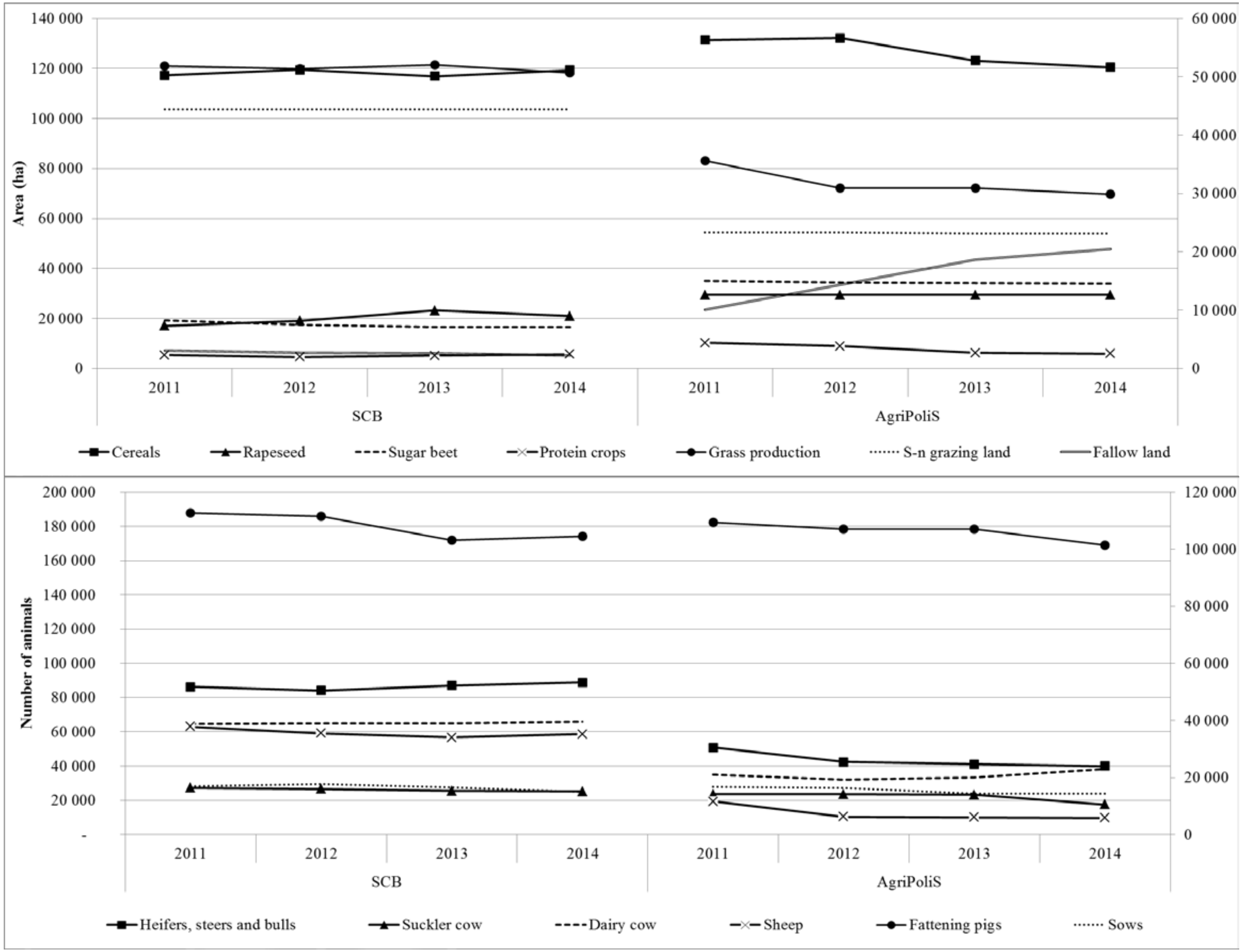

Figure 3. Comparison of real and simulated land use changes (upper diagram) and livestock production (lower diagram) in GMB
Source: (Statistics Sweden, 2009, 2012, 2015).

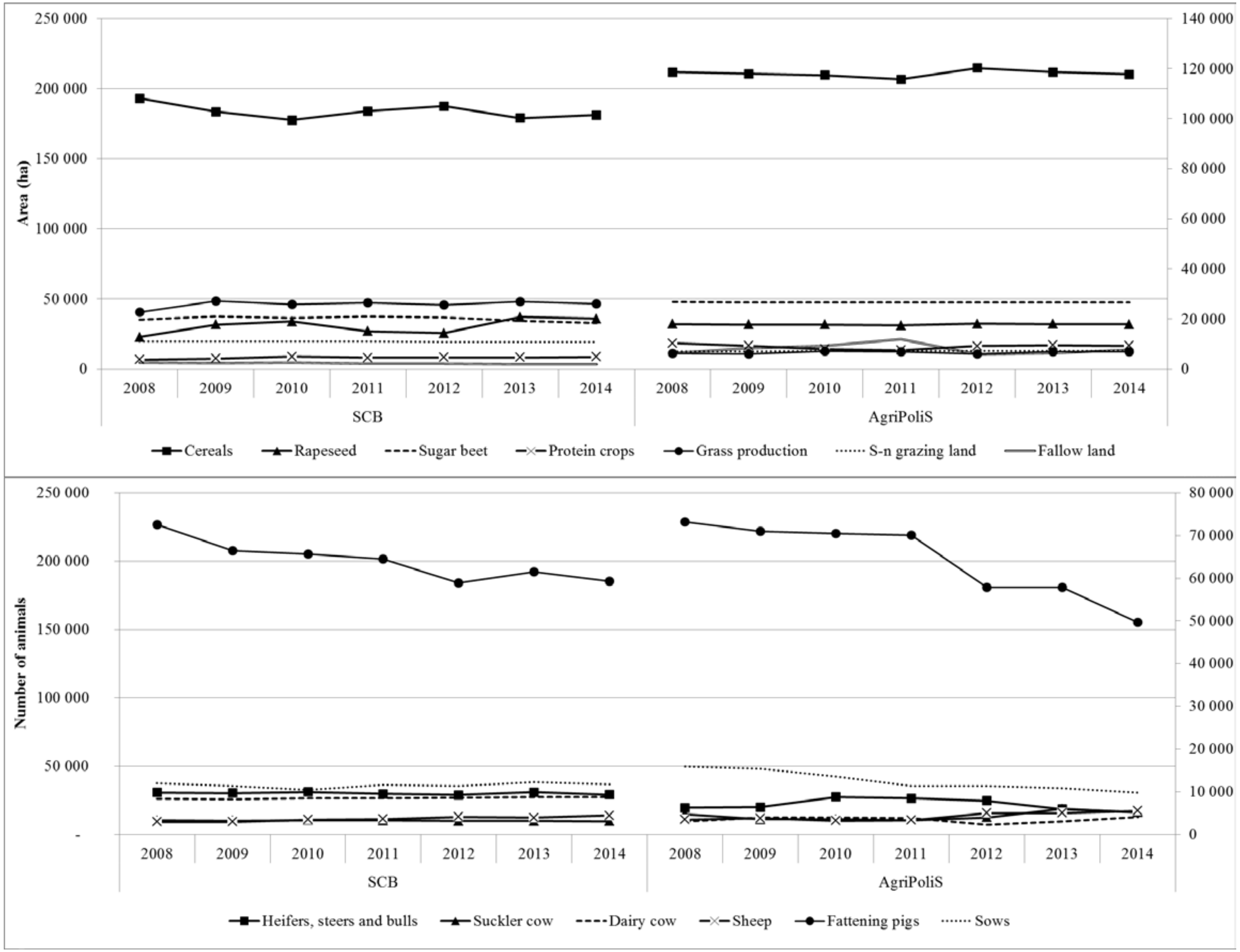

Figure 4. Comparison of real and simulated land use changes (upper diagram) and livestock production (lower diagram) in GSS
Source: (Statistics Sweden, 2009, 2012, 2015).

We also analyzed changes in the total area of arable land in the real regions over the period 2008–14 (Table 24). In both regions the total arable area by 2014 has declined marginally and hence is consistent with our simulation results that the total arable area has remained largely unchanged. In our reference scenario the SPS support per ha arable area is relatively high in both regions compared to the national average which is beneficial for the profit maximizing agents to maintain all land.

Table 24. Actual and simulated developments in the areas of arable crops in GMB and GSS

	GSS				**GMB**			
	Real		AgriPoliS		Real		AgriPoliS	
	ha	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*
2008	329,789		192,768					
2011	328,449	- 0.4	192,878	0.1	312,118		157,273	
2014	327,390	- 0.7	192,881	0.1	310,940	- 0.4	154,749	- 1.6

Source: (Statistics Sweden, 2009, 2012, 2015).

Consequently it can be concluded that the simulated structural development, land use changes and livestock numbers are consistent with the observed developments over the period 2008–14.

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