Legume Futures

Legume-supported cropping systems for Europe

Legume Futures Report 4.3

Evaluation of legume-supported agriculture and policies at farm level

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Legume Futures

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INTRODUCTION

Despite their environmental benefits the cultivation of legumes in Europe declined and is now less than 2% of the arable land in the EU. The reasons are on the one hand the high import of cheap soya for animal feeding and on the other hand the low profitability of legumes compared to other crops such as rape seed and wheat[1]. Reasons of the low profitability are the insufficient yield level, the lack of yield stability and the low producer price especially for grain legumes. But there are other, often neglected benefits of legumes such as the pre-crop effect, the N-self-sufficiency and the phytosanitary effects on succeeding crops. To capture these positive effects it is necessary from an economic perspective to look at the whole crop rotation instead of the single crop. Therefore, we examine here how legumes could be integrated into crop rotations and if at farm level the profitability could be maintained or increased. Different approaches were taken for pure arable and mixed farms. The focus is on conventional farms (rather than organic farms).

METHODOLOGY

Legumes have a distinct impact on the succeeding crop that may encompass higher yields and savings in N fertilizers and pesticides. Therefore, the economic analysis of the profitability of legumes requires an extended approach compared to other arable crops. This means that the full potential of legumes can only be assessed when taking whole rotations into account. In case of forage or feed crops we additionally have to look at the whole farm, taking the interaction between crop and livestock production into account.

Therefore, two different approaches were chosen. In all of the five study regions the rotations used on farms without livestock were compared with respect to gross margins and the best performing rotations per land type are identified. Additionally, in two regions, mixed farms were simulated with a linear programming farm model to examine the potential of legume supported animal feed production taking farm internal interactions into account (see Table 1). In the following sections the data collection, calculation of gross margins and the farm modelling approach are described.

[1] Backhaus ,G.F. 2009. "Anbau und Züchtung von Leguminosen in Deutschland - Sachstand und Perspektiven - Fachgespräch im Julius Kühn-Institut - 21./22. April 2009 in Braunschweig - Begrüßung und Einleitung." *Journal für Kulturpflanzen* 61(9):301.

Table 1: Overview of the farms and methods used per region defined farm type

Region	**Arable farm**[1]	**Mixed farm**[2]
Brandenburg (Germany)	✔	✔
Calabria (Italy)	✔	
Eastern Scotland	✔	
Västra Götaland (Sweden)	✔	✔
Sud-Muntenia (Romania)	✔	

[1] Ranking of gross margins; [2] Farm model

Data collection

The data collection through both the economic and the rotational surveys is described in Deliverable Report 4.1. This has been carried out in five economic case study regions in order to allow for the generation of crop rotations, to perform gross margin calculations and to establish the farm models.

The cropping activities of the respective crops should be defined taking into account various pre-crop classes with the aim to crystallize the respective pre-crop effect of legumes and other crops. The following table gives an overview of the collected data sets:

Table 2. Overview of the method used, depending on the region and the defined farm type

Region	No. sites	No. crops	No. production practices	No. rotations	Arable farm (ha)	Dairy farm (ha)	No. livestock activities	No. of cows
Brandenburg (Germany)	5	15	112	3042	257	247	1	248
Calabria (Italy)	3	10	58	452	45	0	0	0
Eastern Scotland (United Kingdom)	4	14	253	18514	304	0	0	0
Västra Götaland (Sweden)	1	15	54	50739	300	150	1	100
Sud-Muntenia (Romania)	1	8	54	137	1846	0	0	0

Crop rotation generation

Given the peculiarity of legumes, being profitable also through positive effects in succeeding crops, the farm model should take these benefits into account. The easiest way to do this is to feed the farm model with rotations. The farm model simulates farm level economic decision making by choosing 1 or several rotations per soil type. These rotations together have to provide the farm with the forage required by livestock activities and the same rotations have to process the manure from livestock. To obtain a fit for demand and supply for both matter flows: the share of the different forage producing crops and of manure using crops has to be fine-tuned. This fit can be obtained best if a large number of different combinations of different crops (rotations) are available within the farm model. Another problem is model validation. As every rotation has a fixed share of different crops only these shares will appear in the final solution. If we want to compare model output with reality then we need a larger number of rotations with different shares of different crops in order to allow the reproduction of real crop shares with the model. Finally we can say that the more restrictions a model has, the more rotations are required to fulfil all restrictions and to find a solution. There are thus a few reasons to have a large number of rotations in a farm model in order to be able to find for every possible set of restrictions and objectives the best solution.

Thus a large number of rotations are required in order to

- examine the validity of the farm model
- cover all required combinations of different crops to feed livestock

- process all manure from livestock
- take into account all benefits of legumes

The generation is described in detail in the deliverable 4.2.

Calculation of rotational gross margin

The economic evaluation of rotations at field level is based on gross margins. Contrary to other gross margin definitions we don´t calculate a profit rate but the average profit contribution of each rotation by subtracting variable and labour costs from the total revenues per ha. Gross margins are a good measure for the profitability of one rotation compared to others, but will not show the final profit for a farmer as they still have to cover other land and generic farm costs, that depend on the individual setting of each farm. Here we calculated gross margins for all generated rotations of the five case study regions. The average gross margin per year was calculated for each crop rotation to be able to compare the different gross margins of crop rotations of different length. Within this calculation all mentioned pre-crop effects of legumes were taken into account.

Equation (1) shows the calculation of the rotational gross margin.

$$(1)\ gross\ margin_r \ = (revenues_r - variable\ costs_r - labor\ costs_r)/No_r$$

The gross margin calculation includes revenues, variable costs and total labour costs, which are determined by the following three equations:

$$(2)\ revenues_r \qquad = \sum_{c,p} (X_{r,c,p} P_{c,p} + Y_{r,c,p} P_{c,p})$$

$$(3)\ variable\ costs_r = \sum_{c} (costs\ seeed_{r,c} + costs\ fertilizer_{r,c} + costs\ pesticides_{r,c} + costs\ maschinery_{r,c} + costs\ other_{r,c})$$

$$(4)\ labor\ costs_r \qquad = \sum_{c} (labor\ use_{r,c} + salary_{r,c})$$

Variable list:

$X_{r,c,p}$ =	yield per product, crop and rotation
$Y_{r,c,p}$ =	yield per by-product, crop and rotation
$P_{c,p}$ =	price of a product (p) of a crop (c)
r =	rotation

c = crop
p = product
No = number of years within each crop rotation

Optimized crop production in arable farms

The optimized crop production plan for arable farms can easily be determined by ranking the average rotational gross margin. Thereby other restrictions like the available machinery or labour availability are ignored as the according data are not available and we assume that in the long run farmers will adapt their resources to the most favourable production system. Crop rotations with the highest average gross margin are therefore the most profitable crop rotation in each region.

Optimized crop production in mixed farms

Mixed farms show interactions with livestock feed needs and manure delivery which can best be handled by a linear programming approach. Therefore in the next section the farm model which is applied for the mixed farms in two of the five case study regions were defined (Table 1).

Model description

The individual farm modelling has been implemented in the bio-economic model MODAM (Multi Objective Decision support tool for Agroecosystem Management). The model offers the possibility to determine the impact of different agricultural policy options. For the simulation of the decision behaviour of farmers in the context of increased cultivation of legumes, a new version of the model MODAM was used, developed on the basis of the GAMS model FSSIM[2]. The model has a modular structure and has been extended to livestock.

In linear programming, a farm is described as a linear system of equations. Individual factors such as land or labour are limited, so that the different production activities are competing for these scarce factors. The solution of the equation system is a combination of production activities with the highest total gross margin. The model assumes that the farmer acts as a homo economicus. The actual decision behaviour of individual farmers depends in practice also on other personal or unrecognized internal factors or factors which depend on the location. However, in

[2] Louhichi,K. et al. October 2010. "FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies." *Agricultural Systems* 103(8):585-97.

the long run the development aspires mostly to the identified economic optimum. The model approach is a comparative static.

Model structure

MODAM is a modular constructed farm model which simulates the various branches of production with their production activities. It is based on linear programming and is calculated using GAMS (General Algebraic Modelling System). Input parameters are internal resources, such as land, labour force, number of animals, etc. and production activities depending on the type of farm and the type of agro-environmental sites. These data are stored in a MS-Access database. Using a GAMS module an interface was developed, that reads the required data from the database and makes them available for the farm model.

Each of the modules consists of the definition of the individual elements: sets (indices), parameters and equations as well as the structures for reading the data and the actual model equations. The modules can refer to each other and thus form the internal relationship such as production of forage that can be used for their own livestock or for sale. Outputs are for instance the total gross margin, the cropping pattern or the number of animals. These data are written in a second MS-Access database and prepared for the evaluation of different versions or scenarios.

Livestock

Livestock is mostly characterized by the existence of different sex and age groups within a type of livestock that show different feed and housing demands and a continuous in and outflow between the different groups of animals. The flows are related to the replacement rate, the fertility rate and the mortality rate of each group - each depending on breed and intensity of the production. The more age stages are distinguished the more realistic the feed requirements can be met . We used here the approach of FSSIM to capture these different groups in one so called “dressed animal” (DA) that aggregates the demands (forage and concentrates, housing, labour and other costs) and deliveries (sold animals, milk, meat etc.) of the different age and sex groups in one production activity. Only fattening activities of animal husbandry do not include the rearing of offspring. This approach simplifies the farm model but requires the exact definition of the herd composition in advance. We applied these calculations in a MS-Access database and transferred the results into the GAMS model.

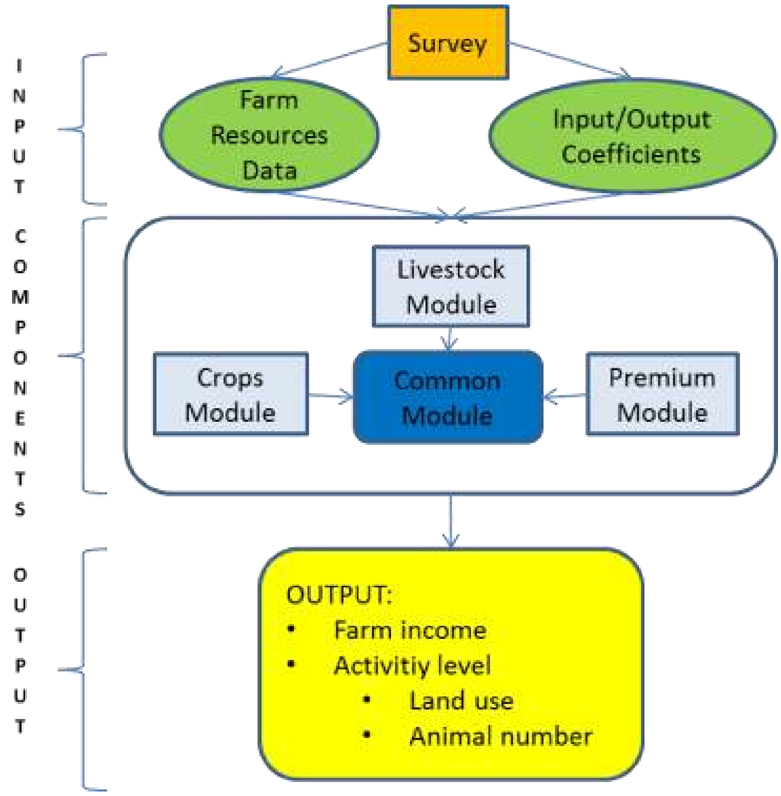

Figure 1: Model structure

The model, we used, consists of the following modules

- Crop
- Animal husbandry
- Premiums.

Scenarios

Scenarios are used to examine possible futures. They are not a direct forecast but show possible development paths. They consist in our view of frame conditions that are analysed with the help of modelling tools. Our scenarios examine the implications of different policy options for the cultivation of legumes in order to investigate the profitability of legumes for farmers. We distinguish here three options:

(I) area payments as paid in 2013[3],

(ii) no payments at all, and

3 this is the final phase of the decoupling process in Germany, where area payments were unified for grass and arable land, while payments for livestock have been terminated

(iii) the new CAP with the greening regulations that include a 5% Ecological Focus Area (EFA) aiming at biodiversity through set aside, but also allows for cultivation of grain legumes.

Table 3: Scenarios

	Reference region specific per ha payment	No Subsidies no payments	Greening 5% ecological focus area (EFA)
Brandenburg	300 €	✔	Area payment 175€ (2019) Greening top-up 85€
Calabria	300 €	✔	✔
Eastern Scotland	130 €	✔	
Västra Götaland	230 €	✔	✔
Sud-Muntenia	120 €	✔	

The reference scenario takes the regional area payments from 2013 which differ between 120 €/ha/a in Romania and 300 €/ha/a in Italy and Brandenburg. The greening scenario shows lower area payments with a top-up if 5% of the arable land is transformed in the so called ecological focus area (EFA). If the greening rules are followed, farmers obtain again a total area payment, which is together with the top up from the greening still about 40 € lower (in the long run in Germany) than the area payments from 2013. However, the relations are such that farmers will not choose to renounce the greening payments except they are able to generate very high gross margins. Brandenburg is the only region where this scenario is taken into account.

REGIONAL PROFITABILITY OF LEGUMES

For the economic analysis, five contrasting NUTS regions where selected (see also Legume Futures Report 1.2. and Deliverable Report 4.1). These regions (Regional Case Studies) delivered the data for the generation and evaluation of crop rotations to capture the variability of cropping systems between regions and farm types across Europe (Figure 2). For each of the regions typical or promising (from the perspective of legumes) farms were selected for the economic analysis.

This section presents the data relevant for the economic analysis that were collected in the context of the economic survey (see Deliverable Report 4.1 and 4.2) between 2012 and 2013. On the one hand, the survey captured data on statistical information and model farms to get an overview in terms of the dominant farm types and the most cultivated crops and on the other hand crop and livestock production data were collected. The economic data of the crop production activities can be found on the website of Legumes Futures. Also In the context of D4.2 rotations were generated based on survey data, and mapped to the collected crop production data in order to obtain economically and ecologically evaluated crop rotations. These rotations are the crop rotation activities within the farm model and have in case of livestock farms to be balanced with forage needs and manure supply of the livestock.

Brandenburg, Germany (ZALF)

Calabria, Italy (UDM)

Eastern Scotland (SAC)

Västra Götaland, Sweden (SLU)

Sud-Muntenia, Romania (NARDI)

Figure 2: Selected case study regions across Europe

Brandenburg (Germany)

Brandenburg is characterized by a variety of rural, mostly sparsely populated areas with small villages and small towns. In many areas, agriculture and forestry with its related industries constitute the major employer, and often the only ones.[4]

In 2010 the agricultural area was 1,416,490 hectares in total, 1,031,910 hectares of arable land and 286,950 hectares of permanent grassland. In 2010, there were 5460 farms in Brandenburg (EUROSTAT, 2014). The average size of the farms was approximately 238 ha.[2] 71% of the farms are individual farms. Of the 3,932 individual farms 1590 were managed as a principal activity on a regular basis.[5] For the remaining 2,342 farmers, agriculture is only a sideline. The predominant form of farms in Brandenburg is still the forage crop farming/ dairy farming with a total share of 40 %.[8]

Around 50% of the arable land was used for cereal production and 26% for forage production (Figure 3). The main cultivated arable crops in 2010 were rye (19%), wheat (16%), forage maize (15%) and oilseed rape (13%). Pulses accounted for about 2% and forage legumes for about 3% in 2010[6] (EUROSTAT, 2014).

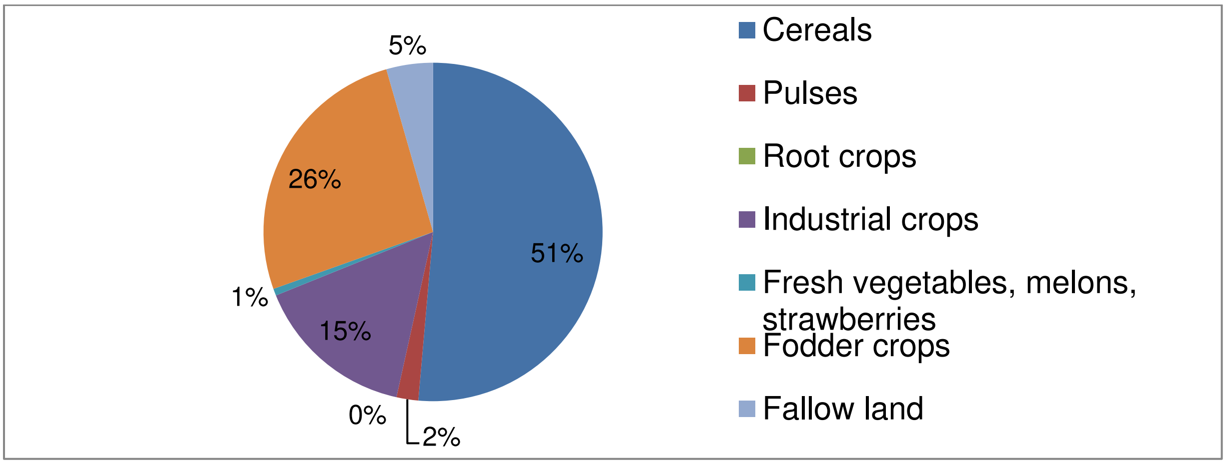

Figure 3: Land use in Brandenburg

The modelled farms

In Brandenburg an arable farm and a mixed farm with dairy production were selected. For both farm types we calculated the average resource endowment, according to the last available statistics (Statistisches Landesamt, 2010; see Table 4). In

4 http://www.brandenburg.de/cms/detail.php/lbm1.c.387376.de

5 http://www.mil.brandenburg.de/sixcms/detail.php/528497

6 EUROSTAT, 2014

Brandenburg the arable land is divided into 5 different types of soil and weather conditions (Landbaugebiete (LBG) / agro environmental zones). The share of these different areas is shown in Table 5. To represent Brandenburg environmental conditions the distribution was applied to the total available area of both farms in Brandenburg (see Table 5).

Table 4: Characteristics of selected farms in Brandenburg

Farm type	**Total land [ha]**	**Arable land [ha]**	**Grassland [ha]**	**Farm labour [h/ha]**	**Stable places**	**Milk yield [kg/a]**
Dairy farm	257	200	57	22	248	8331
Arable farm	247	247		3		

The average arable farm in Brandenburg has a size of 247 hectares[7] with an average manpower of 3h/ha. The average size of a dairy farm is about 257 ha agricultural land, with about 248 stable places and an average manpower capacity of 22 h/ha (statistical report). The average milk yield per cow is 8331 kg/a[8].

Table 5: Distribution of agro-environmental zones in Brandenburg and in selected farms

		Total land	**LBG 1**	**LBG 2**	**LBG 3**	**LBG 4**	**LBG 5**
Distribution in Brandenburg	[%]	100	7.3	22.2	36.4	27.1	6.9
Arable farm	[ha]	247	18	55	90	67	17
Mixed farm	[ha]	257	18.8	57	93.5	70	17.7

Cropping activities

An important and often neglected issue in the analysis of legumes are there positive impacts on succeeding crops. To cover these benefits of legumes, which in a similar way can also occur with other pre-crops, we distinguish in Brandenburg three classes of preceding crops: (i) cereals, (ii) grain legumes, non-cereal crops and grass and (iii) forage legumes. Our crop production experts defined crop production activities for in total 15 cash and forage crops in Brandenburg (Table 6).

7 Amt für Statistik Berlin-Brandenburg. 2011. Betriebswirtschaftliche Ausrichtung der landwirtschaftlichen Betriebe im Land Brandenburg 2010. Statistischer Bericht C IV 9 - 3y / 10.

8 Amt für Statistik Berlin-Brandenburg. 2009. Milcherzeugung und Milchverwendung im Land Brandenburg Jahr 2008. Statistischer Bericht C III 7 - m 12/08.

Table 6: Defined pre-crop classes and crops on arable land in Brandenburg

Cereals (CER)		**Grain legumes, Non-cereal crops, Grass (GL)**			**Forage legumes (FL)**
Winter cereals	**Spring cereals**	**Grain legumes**	**Non-cereal crops**	**grass**	**Forage legumes**
Winter barley	Spring barley	Faba bean	Silage maize	Ley grass	Alfalfa
Winter wheat	Spring oats	Lupin	Rapeseed		Grass/clover
Winter rye		Pea			Rye vetch
					Seradella

For each crop, various cropping activities were defined for the different soil types and the different pre-crop classes. In total 106 cropping activities for Brandenburg were defined.

Cereals show a positive yield effect, when they are grown after legumes or other non-cereal crops (Table 7). No matter whether the previous crop is a forage legume or a grain legume, the effect is the same. This yield increase in cereals has a small effect on variable costs as labour and machinery costs and fertilizer application would slightly rise with the increased yields. However the net effect on gross margins is positive and results in higher gross margins from 80 € in rapeseed up to 300 € on the better soils in Brandenburg.

Table 7: Yield in [t/ha] and the change of yield [%] for the cultivation of the arable crops in Brandenburg depending on the pre-crop class

Pre-crop*	LBG1			LBG2			LBG3			LBG4			LBG5		
	CER	FL	GL	CER	FL	GL	CER	FL	GL	CER	FL	GL	CER	FL	GL
Alfalfa	24.7	0%		23.4	0%		20.8	0%							
Faba bean	4.5			4.0											
Clover grass							21.1	0%		19.4	0%				
Lupin				2.5			2.1			1.8			1.5		
Silage maize	34.0	12%	12%	31.1	12%	12%	26.9	13%	13%	21.4	12%	12%			
Pea	3.5			3.0			2.5			2.0					
Rye, vetch													20.0		
Spring barley				4.4		16%	3.3		18%						
Seradella													17.5		
Spring oat				3.8	29%	29%	2.9	34%	34%						
Triticale	6.7	21%	21%	5.6	21%	21%	4.3	26%	26%	3.2	28%	28%			
Winter barley	6.7	21%	21%	5.6	21%	21%	4.3	26%	26%						
Winter oil Oilseed rape	4.2		17%	3.6		17%	3.0		20%	2.2		23%			
Winter rye	7.2	19%	19%	6.5	19%	19%	5.3	21%	21%	4.1	22%	22%	2.9	28%	28%
Winter wheat	6.9	19%	19%	5.7	19%	19%									

* CER = cereal; FL = forage legume; GL = leafcrop, grainlegume, grass

Table 8: Gross margins [€/ha] of grain legumes and other non-forage crops in Brandenburg depending on the pre-crop class and site

pre-crop* / crop	LBG1			LBG2			LBG3			LBG4			LBG5		
	CER	FL	GL	CER	FL	GL	CER	FL	GL	CER	FL	GL	CER	FL	GL
Faba bean	-359			-389											
Lupin				-370			-366			-399			-431		
Pea	-200			-270			-298			-356					
Spring barley				-138		-178	-282		-118						
Spring oat				-82	44	44	-138	-23	-23						
Triticale	173	347	347	36	188	188	-28	112	112	-154	-41	-41			
Winter barley	94	406	354	-152	252	85	-320	1	-97						
Winter rape	219		393	76		221	54		200	-111		8			
Winter rye	74	230	230	2	140	140	-30	107	107	-134	-28	-28	-238	-140	-140
Winter wheat	235	419	419	93	253	253									

* CER = cereal; FL = forage legume; GL = leafcrop, grain legume, grass

In forage crops like silage maize the effect of legumes as a previous crop is the same as in cereals. The same applies to winter oil seed rape, which cannot be grown after legumes.

Legumes in arable farms in Brandenburg (Germany)

Table 9 shows for different site classes the economically most profitable crop rotations, selected from the total of 404 generated arable crop rotations. Economic costs and benefits of these rotations were calculated for 5 different site classes based on site specific yields and inputs.

Table 9: Most economic rotations for an arable farm in Brandenburg in different situations on different site classes - gross margins in bold represent the optimal crop production plan.

								Gross margins with area payments		
	Site class	**Rot. no.**	**Crop 1**	**Crop 2**	**Crop 3**	**Crop 4**	**Crop 5**	**[€/ha/a]**	**+ 114 €/ha legume***	**+ 499 €/ha legume****
No area payments	LBG1	11	wrape	wwheat	wbarley			**244**	**244**	244
	LBG1	12	wrape	wbarley	Faba bean	wwheat	wbarley	145	168	**245**
	LBG2	21	wrape	wwheat	sbarley			**64**	64	64
	LBG2	22	wrape	wwheat	wrye	wrye	pea	42	**65**	**141**
	LBG3	31	wrape	wrye	wrye	wrye	pea	-10	13	90
	LBG4	41	pea	wrye	wrye	wrye	wrye	-157	-135	-58
	LBG5	51	lupin	wrye	wrye	wrye	wrye	-257	-234	-157
Minimum* **	All							0	0	0
With area payments (300 €/ha/a)	LBG1	11	wrape	wwheat	wbarley			**544**	**544**	544
	LBG1	12	wrape	wbarley	Faba bean	wwheat	wbarley	445	468	**545**
	LBG2	21	wrape	wwheat	sbarley			**364**	364	364
	LBG2	22	wrape	wwheat	wrye	wrye	pea	342	**365**	**441**
	LBG3	31	wrape	wrye	wrye	wrye	pea	**290**	**313**	**390**
	LBG4	41	pea	wrye	wrye	wrye	wrye	143	165	242
	LBG5	51	lupin	wrye	wrye	wrye	wrye	43	66	143
Minimum* **	All		Set aside with mulching once a year					280	280	280
With area payments (260 €/ha/a including greening top up)	LBG1	11	wrape	wwheat	wbarley			**504**	**504**	504
	LBG1	12	wrape	wbarley	Faba bean	wwheat	wbarley	405	428	**505**
	LBG2	21	wrape	wwheat	sbarley			**324**	324	324
	LBG2	22	wrape	wwheat	wrye	wrye	pea	302	**325**	**401**
	LBG3	31	wrape	wrye	wrye	wrye	pea	**250**	**273**	**350**
	LBG4	41	pea	wrye	wrye	wrye	wrye	103	125	202
	LBG5	51	lupin	wrye	wrye	wrye	wrye	3	26	103
Minimum* **	All		Set aside with mulching once a year					240	240	240

* coupled payment for legumes of 114 € /h - obtained from the difference between rot.no. 21 and 22

** coupled payment for legumes of 499 € /h - obtained from the difference between rot.no. 11 and 12

*** minimum gross margin that has to be obtained to enter the optimum solution

Site class LBG1 shows the highest yield potential while LBG5 contains the most sandy and marginal soils. The table shows that crop production without subsidies is only economically feasible on site class LBG1 and LBG2. The site classes 3-5 are not cultivated. Also it is not profitable to grow legumes on one of these site classes. Only the crops winter oil seed rape, winter wheat and barley are grown. Overall, only about 30% of the area is cultivated. In this case the total gross margin of the farm is 7888 €/a (see Table 10) – too little for full time farming. There are no changes in the cropping pattern on LBG1 and LBG2 if area payments are paid or not (Figure 3). Only on LBG3 there is a change because without area payments no crops will be cultivated on this area. For arable farms LBG3 is the most attractive site class in Brandenburg to cultivate legumes especially peas.

With area payments site class LBG3 becomes interesting with a rotation including peas that deliver a gross margin that is only about 10 € higher than set aside including mulching once a year. The total share of legumes in this scenario would be about 7 % of the total area while site classes 4 and 5 with 34 % of the total area would be set aside.

In the new CAP scenario, area payments are reduced. This has no influence on the ranking of rotations, also the rotation on site class LBG3 shows still a 10 € higher gross margin compared to set aside. This results in the same crop shares as before and greening conditions are easily fulfilled through set aside (34%) and cultivation of peas (7%). However, farmers will earn less under the new CAP with a decrease of area payments by 40 €/ha/a (Table 10).

Table 10: Farm results for an arable farm

Area payments	Coupled payment legumes	Total land	Set-aside	LBG 1	LBG 2	LBG 3	LBG 4	LBG 5	Total gross margin	Total premium payments	Area with legumes	Share legumes
[€/ha/a]	[€/ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[€/a]	[€/a]	[ha]	[%]
no	-	73	174	18	55	0	0	0	7888	0	0	0
	+ 114*	73	174	18	55	0	0	0	7943	1252	11	4
	+ 499**	73	174	18	55	0	0	0	12192	7278	29	12
300	-	163	84	18	55	90	0	0	55877	48900	18	7
	+ 114*	163	84	18	55	90	0	0	57980	52201	29	12
	+ 499**	163	84	18	55	90	0	0	69154	65151	33	13
260	-	163	84	18	55	90	0	0	49357	42380	18	7
	+ 114*	163	84	18	55	90	0	0	51460	45681	29	12
	+ 499**	163	84	18	55	90	0	0	62634	58631	33	13

In addition to the area payments we examined the impact of direct coupled support for legumes. For every site that would not have legumes in an optimal solution we looked for the first best rotation including legumes, The gross margin deficit compared to the optimal rotation was taken as a basis for a premium and increased by 1€ to become the economic optimum. We generated thus two levels of premiums with 114 €/ha and 499 €/ha with the impact that legume cultivation would increase to 29% respectively 33% of the area. Therefore in Brandenburg a premium of 116 €/ha would be sufficient to induce a considerable increase in legume area.

It is important to note that the above gross margins include the pre-crop effects of legumes on subsequent crops. Would this not be taken into account, the gross margin of the legume based crop rotation on site class 3 would drop from of 290 €/ha/a to 261 €/ha/a, with the result that barley instead of the legume pea is grown or mulch would be a more profitable alternative. No legumes would then be grown and a subsidy for legumes would be necessary.

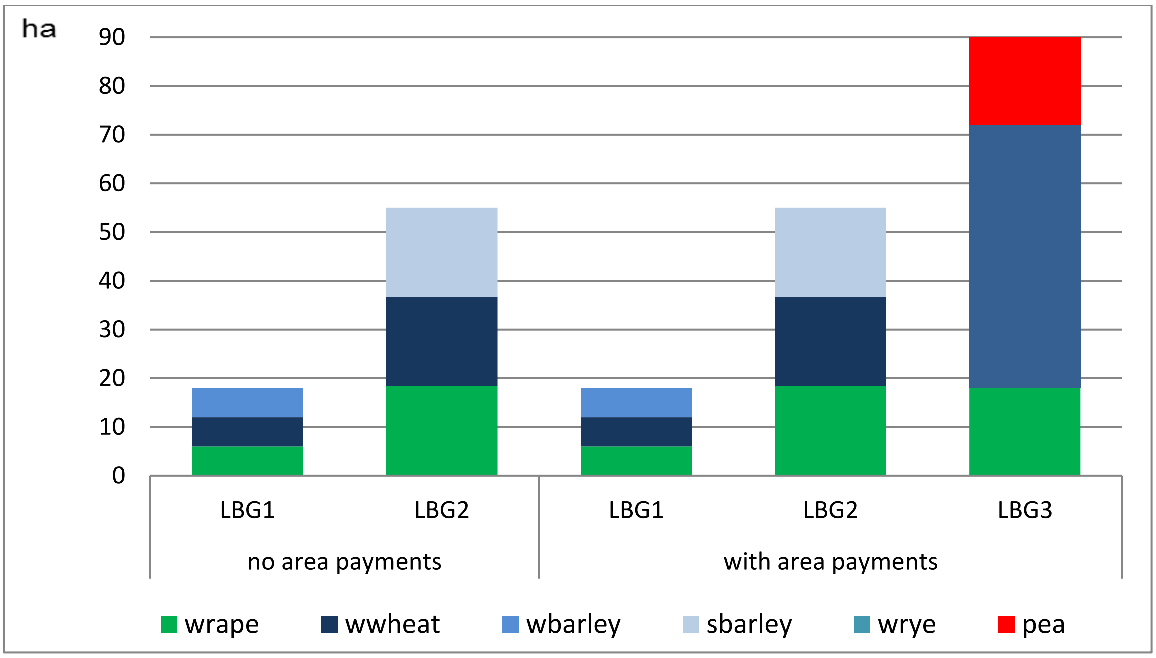

Figure 4: Cropping pattern per site class - with and without area payments for an arable farm in Brandenburg

There are no changes in the cropping pattern on LBG1 and LBG2 if area payments are paid or not (Figure 4). Only on LBG3 there is a change because without area payments no crops will be cultivated on this area. For arable farms LBG3 is the most attractive site class in Brandenburg to cultivate legumes especially peas.

Legumes in dairy farms in Brandenburg (Germany)
The cropping pattern of mixed farms was calculated with the help of the linear programming farm model. In total, 3,042 crop rotations were available in the farm model – showing combinations with and without legumes and with and without different forage crops. The crop rotations selected for the economic optimum for the modelled dairy farm in Brandenburg are shown in Figure 4.

Table 11: Most economic crop rotations per site class for a dairy farm in Brandenburg under different situations

	Site class	Crop1	Crop2	Crop3	Crop4	Crop5	Crop6	Cultivated area [ha]
Without area payments	LBG1	wrape	wwheat	wbarley				19
	LBG2	alfalfa	alfalfa	wbarley	wrape	wwheat	wrye	39
	LBG2	wrape	wwheat	sbarley				18
	LBG3	wrape	wrye	maize_s	wrye	pea		61
	LBG3	wrape	wrye	maize_s	wrye	lupin		31
	LBG3	wrape	wrye	wrye	wrye	pea		2
	LBG4	lupin	wrye	maize_s	maize_s	maize_s		69
Area payments 300 €/ha/a	LBG1	wrape	wwheat	wbarley				19
	LBG2	wrape	wwheat	sbarley				33
	LBG2	alfalfa	alfalfa	wbarley	wrape	wwheat	wrye	24
	LBG3	wrape	wrye	maize_s	maize_s	lupin		38
	LBG3	wrape	wrye	maize_s	wrye	pea		35
	LBG3	wrape	wrye	wrye	wrye	lupin		21
	LBG4	lupin	wrye	maize_s	maize_s	maize_s		70
	LBG5	ryevetc	wrye	wrye				18
Area payments 260 €/ha/a	LBG1	wrape	wwheat	wbarley				19
	LBG2	wrape	wwheat	sbarley				33
	LBG2	alfalfa	alfalfa	wbarley	wrape	wwheat	wrye	24
	LBG3	wrape	wrye	maize_s	wrye	lupin		59
	LBG3	wrape	wrye	maize_s	maize_s	pea		26
	LBG3	wrape	wrye	wrye	wrye	pea		9
	LBG4	lupin	wrye	maize_s	maize_s	maize_s		70
	LBG5	ryevetc	wrye	wrye				18

Without area payments, it is not profitable for the farmer to cultivate crops on the site class 5 (Table 11). With area payments and with area payments according to the new CAP all sites would be cultivated in this mixed farm. The feeding regime calculated in both scenarios with area payments shows that lupines are rather used for feed concentrates than sold at market prices. The share of grain legumes is under area payments with 13% relatively high which shows that grain legumes are undervalued on the market (Table 12). Contrary to the arable farm, the mixed farm uses most of its area – even areas that are under arable conditions not profitable, but which can offer valuable forage.

Table 12: Farm results for a dairy farm in Brandenburg under different situations

	Total land	Set-aside	LBG 1	LBG 2	LBG 3	LBG 4	LBG 5	Dairy cows	Total gross margin	Total premium payments	Area grain leg.	Share grain leg.	Area forage leg.	Share forage leg.
	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[ha]	[head]	[€/a]	[€/a]	[ha]	[%]	[ha]	[%]
No area payments	238	19	19	57	94	69	0	76	34204	0	32	13%	13	5%
Area payments 300 €/ha/a	257	0	19	57	94	70	18	82	110431	77100	33	13%	14	5%
Area payments 260 €/ha/a	257	0	19	57	94	70	18	82	100151	66820	33	13%	14	5%

Alfalfa, lupin, rye-vetch and silage maize are only used as forage whereas peas and all other crops are sold. That means in contrast to arable farms more legumes especially grain legumes would be cultivated because of forage production. Lupins which are for arable farms unprofitable are getting profitable in dairy farms.

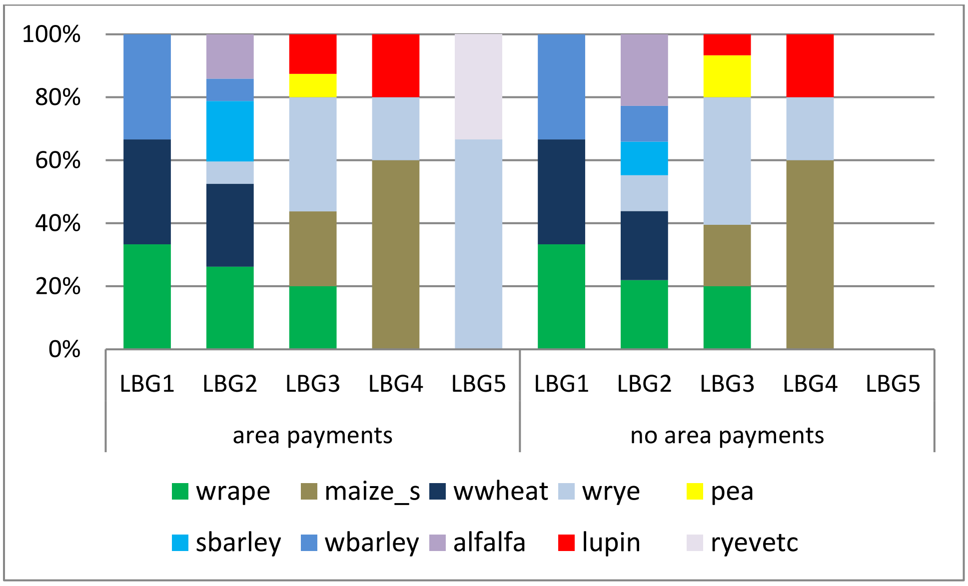

Figure 5: Cropping pattern with area payments per site class in dairy farms in Brandenburg

The cropping pattern does not differ that much if taking area payments into account or not. Because of the possibility of cultivating winter rye and rye-vetch on LBG5 when receiving area payments the shares of other crops changes a bit. Rye-vetch is used as forage which means less forage of other site classes is needed which causes the shift.

Calabria (Italy)

Calabria is a small less-developed region dominated by agriculture.[9] Because of its special geographical and morphological conditions it is unique with respect to agricultural practices.[10] The agricultural area in 2010 was 549,250 ha in total of which 155,980 were arable land, 140,710 ha were permanent grassland and 250,980 were permanent crops. There were 137,790 in 2010. The average farm size was approximately 4 ha (EUROSTAT, 2014). 66% of the farms have a farm size lower than 2 ha, almost all farms are independent. 62% of the farms used more than 50% of the production for self-consumption. Subsistence farming is thus important. About 4,200 farms in Calabria (3%) are considered as having commercial potential covering 10 – 50 ha (pers. comm. Aurelio Pristeri) and about 23% of the area.

The cropping pattern on arable land shows 58% of cereals and 17% of forage crops. The main cultivated arable crops in 2010 were durum wheat (26%), oat (9%) and temporary grassland (9%). 11% of the arable land is fallow land. The cultivation of pulses is approximately 2% and of forage legumes 2% too (EUROSTAT, 2014).

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[9] http://www.lifeinitaly.com/tourism/calabria#sthash.nlBSK8Nd.pdf

[10] http://www.inia.es/gcontrec/pub/034-042-%2811404%29-Effects_1161760151906.pdf

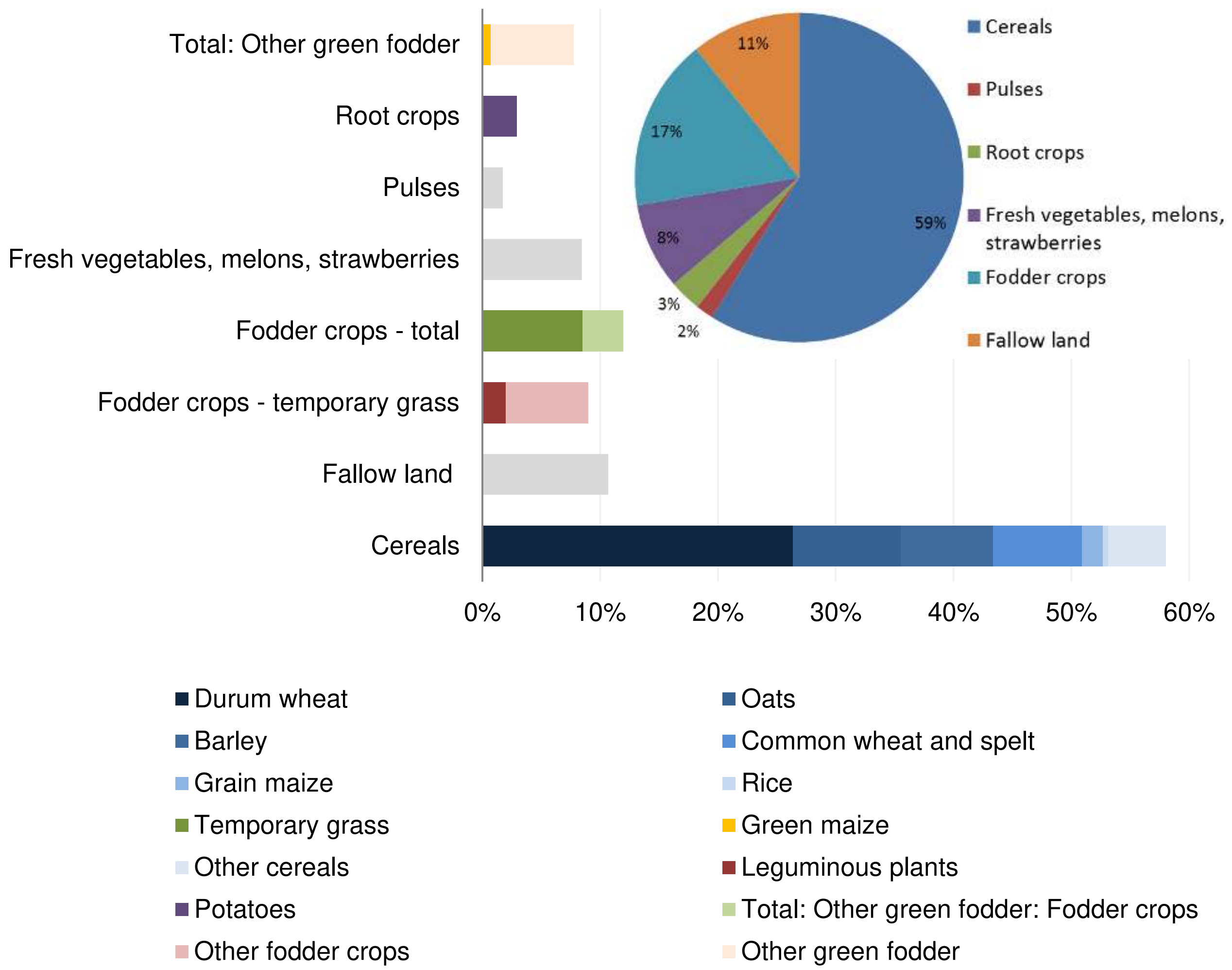

Figure 6: Land use in Calabria in 2010

The modelled farm

Legume Futures aims to assess exemplarily the commercial potential of legumes in distinct regions. We, therefore, concentrated on commercially interesting, efficient farms. For Calabria, our experts devised an arable farm which has a dimension of 45 ha in total and a labour capacity of 20 h/ha (Table 13). The predominant soil type of this farm is loam. The defined farm is a rain-fed farm.

Table 13: Defined farm in Calabria

Farm type	Total land [ha]	Arable land [ha]	Farm labour [h/ha]
Arable farm	45	45	20

Cropping activities

In Calabria a total of 10 cash and forage crops were defined for a rain fed farm by our experts (Table 14). Depending on the pre-crop class and soil type various cropping activities were defined for each crop. In total 25 cropping activities were defined for a rain fed arable farm.

Table 14: Defined pre-crop classes (CER, GL, FL) and crops on rain fed arable land in Calabria

Cereals (CER)	Non-cereal crops, grass (GL)			Forage legumes (FL)
Winter cereals	**Grain legumes**	**Non-cereal crops**	**Grass**	**Forage legumes**
Durum wheat	Faba bean	Rapeseed	Grass	Oat-vetch
Triticale	pea			Sulla
Winter barley				
Winter oat				
Winter wheat				

Pre crop effect

In Calabria we distinguished between the pre-crop effect of forage and grain legumes. Cereals (excluding triticale), rape and sulla show a positive yield effect when grown after a forage legume. Winter oat and winter oil seed rape as subsequent crops show the highest yield effect of a 40% increase in yields. If crops are grown after grain legumes or other non-cereal crops the yield effect is much lower. Above, not only cereals and rape as subsequent crops show a positive yield effect but also legumes grown after other non-cereal crops such as oilseed rape show higher yields compared to cultivation after cereals.

In addition to the increased revenues of succeeding crops through increased yields, the residual N after legumes allows for a reduction of N-fertilizers in subsiding crops, resulting in reduced fertilizer costs (Table 16). The gross margins of Calabria crops increase if they are grown after forage legumes (Table 17). After grain legumes we see for most crops as well an increase in gross margins, except for winter barley where the gross margin decreases and winter oat where the gross margin does not change. Also the gross margins of grain legumes increase when they are grown after leaf crops like rape.

Table 15: Yield in [t/ha] for the cultivation of available crops for a rain fed arable farm in Calabria depending on the pre-crop class

	Pre-crop class			Yield increase	
Crops	CER	FL	GL	FL	GL
Durum	3	4	3.2	33%	7%
Faba bean	1.6		1.8		13%
Oat vetch	30		35		17%
Pea	1.2		1.5		25%
Sulla	11.11	11.41		3%	
Triticale		3.5	3		
Winter barley	3.5	3.5	3.3	0%	-6%
Winter oat	2	2.8	2	40%	0%
Winter rape	2.5	3.5	3	40%	20%
Winter wheat	3.2	3.6	3.5	13%	9%

CER = Cereal; FL = Forage legume; GL = non-cereals, grainlegume, grass

Table 16: Fertilizer costs in [€/ha] of all rain fed crops in Calabria depending on the pre-crop class

	Pre-crop class			**Change of fertilizer costs**	
Crops	**CER**	**FL**	**GL**	**FL**	**GL**
Durum	180	140	80	-22%	-56%
Faba bean	27		27		0%
Oat vetch	105		105		0%
Pea	27		27		0%
Sulla	27	27		0%	
Triticale		80	72		
Winter barley	140	105	126	-25%	-10%
Winter oat	180	126	154	-30%	-14%
Winter rape	211	126	154	-41%	-27%
Winter wheat	126	80	80	-36%	-36%

CER = cereal; FL = forage legume; GL = leafcrop, grainlegume, grass

According to our data, the most economic crop is oat-vetch, with a gross margin of 2,045 €/ha, which is very high probably related to certain conditions we could not clarify in the scope of the project. The most profitable cereal crop is winter barley (GM: 354 €/ha) followed by winter oat (GM: 100 €/ha). The grain legumes faba bean and pea and the forage legume sulla have a negative gross margin.

Table 17: Gross margins [€/ha] of cash crops in Calabria depending on the pre-crop class

Crops	CER	FL	GL
Durum wheat	-162	138	-10
Faba bean	-290		-240
Pea	-305		-227
Triticale		114	-3
Winter barley	354	389	324
Winter oat	100	441	126
Winter rape	33	519	290
Winter wheat	19	214	189

CER = cereal; FL = Forage legume; GL = non-cereal, grain legume, grass

Taking all pre-crop effects into account, the economic ranking of the crops changes. Winter rape followed by winter oat is most profitable when grown after a forage legume. If a grain legume is the previous crop then oat vetch followed by winter barley is more profitable.

Legumes in arable farms in Calabria (Italy)

Actual land use in Calabria is dominated by cereals with a share of almost 60%. Pulses contribute only 0.5% of the total land use or 2% of arable land.

Out of a total of 452 generated crop rotations for a rain fed arable farm in Calabria the most economic crop rotations are shown in Table 18. In all scenarios the rotations are dominated by rapeseed and winter barley. Only under greening conditions faba bean is included. With and without area payments winter rapeseed and winter barley will be cultivated at equal shares.

Table 18: Most economical crop rotations for an arable farm in Calabria

Scenario	Rotation	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Gross margin [€/ha/a]	cultivated area [ha]
No area payments	rot1	wrape	wbarley	wrape	wbarley		179	45
with area payments	rot1	wrape	wbarley	wrape	wbarley		479	45
Greening	rot1	wrape	wbarley	wrape	wbarley		479	33.75
	rot2	wrape	wbarley	wrape	wbarley	Faba beann	436	11.25
Subsidy	rot2	wrape	wbarley	wrape	wbarley	Faba beann	480	45

Table 19 shows the farm results for the defined arable farm. Without any area payment the farmer generates the lowest gross margin of about 8,033 €/a and no legumes would be grown. Getting area payments of 300 €/ha/a of arable land the gross margin of the farm rises to 21,533 €/a, but still no legumes were grown.

With the introduction of the greening area 5% grain legumes were grown. For the farmer the total gross margin increases marginally.

Table 19: Farm results for a rain fed arable farm in Calabria

	Total land	Total gross margin	Total area payments	Area with legumes	Share legumes
	[ha]	[€/a]	[€/a]	[ha]	[%]
No area payments	45	8033	0	0	0
area payments 300 €/ha/a	45	21533	13500	0	0
Greening	45	21057	13500	2.25	5
Subsidy 217 €/ha	45	21578	15449	9	20

Coupled payment for grain legumes

The statistics for Calabria report 11% of the arable area in Calabria as set-aside (Eurostat, 2014). This means that most farmers would easily comply with greening regulations without changes in the cropping plan, as the existing set-aside area can be declared as EFA. If policy nevertheless opts for an increase in the legume cultivation area, an option would be to introduce a coupled payment for legumes. The minimum for a coupled payment for legumes in the Calbrian context would be 217 €/ha to be effective on the cropping pattern In response to such a payment the share of faba bean would go up to 20% of the arable land.

Eastern Scotland

Agricultural production in Eastern Scotland is favoured by the warming influence of the North Atlantic drift. During the growing season, crops benefit from long cool days and no severe stress. This, together with the generally high plant health status, is the reason for relatively high yields especially of cereals. The production itself is not very intensive.

The agricultural area in 2010 was 1,288,230 ha in total over 7,160 farms. The average farm size was approximately 175 ha (EUROSTAT, 2014). Most of the farms have only one owner.

The dominant land use form is permanent grassland with 67% of the agricultural area. Only 33% is used as arable land, of which more than 50% is covered by cereals. The main cultivated crops on arable land are barley (29%), temporary grassland (28%), wheat (20%) and potatoes and rape with 5% of each crop

(EUROSTAT, 2014). The cultivation of grain legumes was in 2010 about 1% of the arable area. Forage legumes were not grown as arable crops.

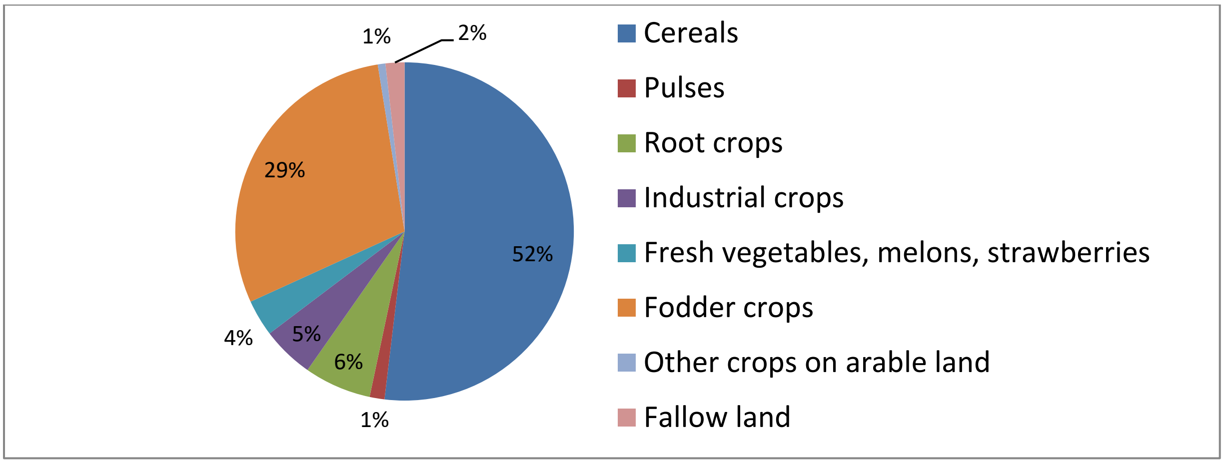

Figure 7: Land use in Eastern Scotland

The modelled farm
The total area of a typical average arable farm is about 304 ha of which 72% is arable land and 18% is grassland. The farm labor capacity is about 23 h/ha (see Table 20).

Table 20: Defined arable farm in Eastern Scotland (Shailesh Shrestha, SCRU)

Farm type	**Total land [ha]**	**Arable land [ha]**	**Grassland [ha]**	**Farm labour [h/ha]**	**Sheep**
General cropping	304	218	86	23	101

The area of the arable farm is divided in four site classes according to their respective shares in this region and for every site class cropping activities are defined (Table 21).

Table 21: Distribution of arable land in Eastern Scotland per site class

	Total land	**Grade1&2**	**Grade 3**	**Grade 4**	**Grade 5***
[%]	100	21	40	5	34
[ha]	304	64	122	15	103

* not suitable for arable crops

Cropping activities

For a total of 14 crops cropping activities were defined depending on the site class and pre-crop class (Table 22). It involves various cereal crops, grain legumes, other leaf crops and different forage crops. In total 128 cropping activities for Scotland were defined of which 30 activities are for forage production.

Table 22: Defined pre-crop classes and crops on arable land in Eastern Scotland

Cereals (CER)		**Grain legumes, non-cereals, grass (GL)**			**Forage legumes (FL)**
Winter cereals	**Spring cereals**	**Grain legumes**	**Non-cereal crops**	**Grass**	
Winter barley	Spring barley	faba bean	Potato	grass	clover grass
Winter oat	Spring oat	pea	Spring rape		
Winter wheat	Spring wheat		Winter rape		
			Swedes		

Various pre-crop effects of legumes were mentioned by our experts. One effect is the positive yield effect of legumes to subsequent crops and the second is the positive effect on fertilization. Depending on the site class the yield of subsequent crops increases between 5% and 25%. It does not matter if the legume is a forage legume or a grain legume the yield effect of both is the same (Table 23).

Table 23: Yield in [t/ha] and the change of yield [%] for arable and forage crops in Eastern Scotland depending on the pre-crop class and site class

	Grade 1&2		**Grade 3**			**Grade 4**		
Crop	**CER**	**GL**	**CER**	**FL**	**GL**	**CER**	**FL**	**GL**
Faba bean	6.0		6.0	5.0		5.0		
Grass clover					97.9			81.2
Grass				38.0			31.0	
Pea	5.5		5.5	4.0		4.0		
Potato	50.0	55.0	55.0	38.0	42.0	42.0		
Spring barley	38.5	44.5	44.5	27.0	33.0	33.0	20.0	25.0
Spring oat	6.0	6.5	6.5	4.5	5.0	5.0	3.0	3.5
Spring rape	2.5	3.0	3.0	2.0	2.5	2.5		
Swedes	90.0	100.0	100.0	70.0	75.0	75.0	55.0	60.0
Spring wheat	7.5	8.0	8.0	5.5	6.0	6.0		
Winter barley	8.0	9.0	9.0	7.0	7.5	7.5		
Winter oat	8.5	9.0	9.0	7.0	7.5	7.5	4.5	5.0
Winter rape	4.5	5.0	5.0	3.5	4.0	4.0		
Winter wheat	9.5	10.0	10.0	7.5	8.0	8.0		

If the subsequent crop is a cereal crop or rapeseed then legumes have a positive effect on fertilization too, because of less nitrogen use. The effect of forage legumes is a little bit higher than the effect of grain legumes (Table 24).

Regardless of the pre-crop class and the site class potatoes followed by winter oat are the most profitable crops in Eastern Scotland. However, spring barley is most unprofitable. In this region grain legumes have a very good gross margin especially on the site class 1 and 2 (Table 25). At each site class, the crop gross margin increases when crops can be grown after legumes. Sometimes they even get positive when they previously had negative gross margins when grown after cereals.

Table 24: Fertilizer costs of non-forage crops depending on the site class and pre-crop class in Eastern Scotland

	Grade 1&2		Grade 3			Grade 4		
	CER	GL	CER	FL	GL	CER	FL	GL
Faba bean	77	77	77		77			
Pea	88	88	88		88			
Potato	582	582	582		582			
Sping barley	223	215	223	210	215	223	210	215
Spring oat	203	195	203	190	195	203	190	195
Spring rape	164	155	164	150	155			
Spring wheat	292	280	292	275	280			
Winter barley	329	308	329	298	308			
Winter oat	242	230	242	220	230	242	220	230
Winter rape	331		331	315	320			
Winter wheat	353	340	353	330	340			

Table 25: Gross margins [€/ha] of non-forage crops in Easter Scotland

	Grade 1&2		Grade 3			Grade 4		
	CER	GL	CER	FL	GL	CER	FL	GL
Faba bean	350	350	153		153			
Pea	461	461	114		114			
Potato	2301	3051	501		1101			
Spring barley	99	281	-143	44	39	-297	-110	-115
Spring oat	283	405	-10	105	100	-320	-199	-204
Spring rape	174	393	-17	207	202			
Spring wheat	421	537	19	141	136			
Winter barley	420	639	231	363	353			
Winter oat	804	918	493	617	607	-27	97	87
Winter rape	683		263	489	484			
Winter wheat	499	604	145	261	251			

Legumes in arable farms in Eastern Scotland

The most economically competitive rotations for the general cropping farm are shown in Table 26. With and without area payments, rotations with potato are always the most profitable rotations because of the high gross margins of potatoes. However, this cropping option is restricted by contracts.

Table 26: Economic best rotations for an arable farm in Eastern Scotland

	site class	rotation	crop 1	crop 2	crop 3	crop 4	crop 5	crop 6	GM
No area payments	Grade 1&2	rot 1	potato	wwheat	woat	pea	wbarley	wrape	1040
		rot2	wrape	wbarley	woat	pea	wbarley		645
	Grade 3	rot3	potato	wwheat	woat	Faba bean	wbarley	wrape	436
		rot4	wrape	wbarley	woat	Faba bean	wbarley		323
Area payments 130 €/ha/a	Grade 1&2	rot2	wrape	wbarley	woat	pea	wbarley		775
	Grade 3	rot4	wrape	wbarley	woat	Faba bean	wbarley		453

With and without mentioning the pre-crop effects of legumes, legume-supported crop rotations always have the highest rotational gross margin. On site class 1 and 2, pea is the most profitable legume and on site class 3 it is faba bean. That means for this farm, grain legumes would be cultivated on12% of the total area.

Site class 4 and 5 are only usable for forage production. Since the defined farm is a general cropping farm also sheep are present. Because of time constraints and data constraints sheep could not be taken into consideration. That's why here no crops are grown on site class 4 and 5.

If the farmer receives an area payment of about 130 €/ha/a[11] nothing changes in the cropping pattern (Figure 8). On both site classes at least four crops are grown of which one is oilseed rape and the second is a grain legume. The other crops are cereals (winter oat, winter barley) which dominate.

[11] Scottish government, 2013, http://www.scotland.gov.uk/Resource/0044/00441902.pdf

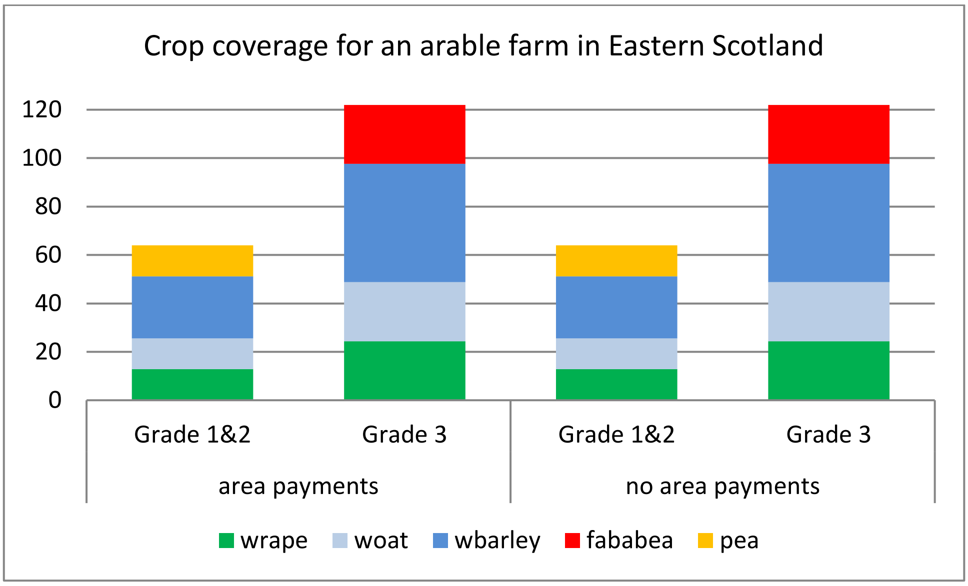

Figure 8: Cropping pattern of an arable farm in Eastern Scotland

The only difference for the farmer when he receives area payments is the higher total gross margin (Table 27).

Table 27: Farm results for the arable farm in Eastern Scotland

	Total land [ha]	Set-aside [ha]	Grade 1&2	Grade 3	Total gross margin [€/a]	Total premium payments [€/a]	Area with legumes [ha]	Share legumes [%]
No area payments	185	119	64	122	80,698	0	37	12
Area payments 130 €/ha/a	185	119	64	122	104,878	24,050	37	12

Västra Götaland (Sweden)

In Västra Götaland, agriculture plays an important role. The predominately agricultural areas are located in the plains that also have abattoirs and dairies as well as other food and feed processing plants.

In 2010 the size of the agricultural area of this region is 655.380 ha (EUROSTAT, 2014) which is about 53% of the total area. 88% of the agricultural area is used as arable land and 12% as grassland.

The cultivation of forage crops (43%) and cereals (41%) are the main usage of the arable land. The main cultivated forage crop is temporary grassland and the main cultivated cereals are winter wheat (14%), oat (12%) and spring barley (10%) (EUROSTAT, 2014). However, the cultivation of peas and field beans is about 2%

(The yearbook of agricultural statistics 2011, SJV). 9% of the arable land is fallow land.

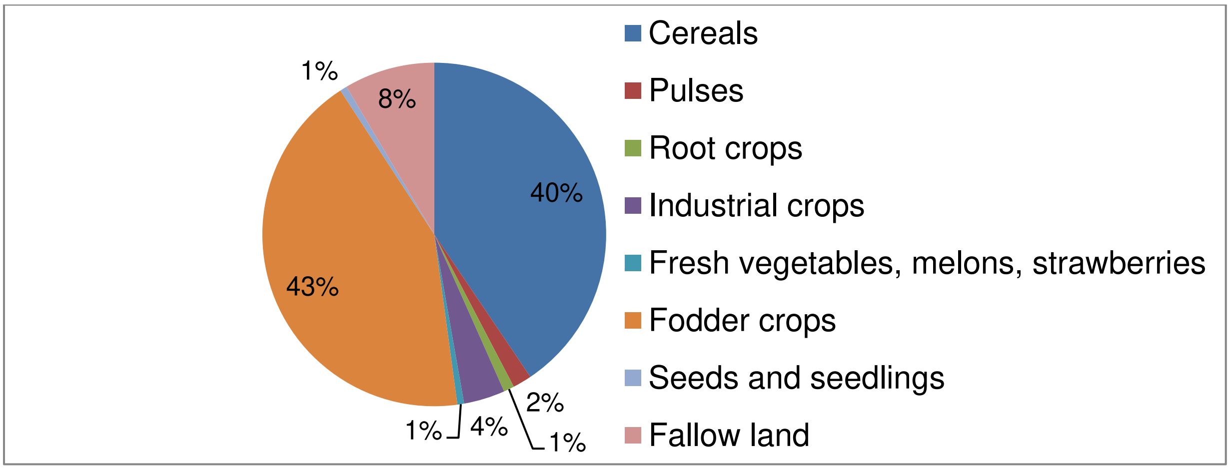

Figure 9: Main arable and forage crops in Västsverige in 2010

Only 6% of the farms are farms with a juridical status. 83% of the agricultural area is managed as independent farm businesses. The majority of both the individual farms as well as the farms with juridical status have a farm size of more than 50 ha (EUROSTAT, 2014).

The modelled farms
Two typical farms were defined for this region (Table 28). The defined arable farm is a specialized on crop husbandry farm with a total land of 300 ha and a working capacity of 6 h/ha. The soil of the farm is a clay soil. 50 % of the area of this region is covered by this soil. The defined mixed farm is a dairy farm with a capacity for 100 dairy cows and a total land of 150 ha of which 87 % is arable land and 13 % is grassland. The total working capacity is 30 h/ha. The soil of the farm is a clay soil.

Table 28: Defined arable and dairy farm in Västra Götaland

Farm type	Total land [ha]	Arable land [ha]	Grassland [ha]	Farm labour [h/ha]	Animal places	Milk yield [kg/a]
Arable farm	300	300		6		
Dairy farm	150	130	20	30	100	10,300

Cropping activities
For a total of 15 crops our experts described crop production practices (Table 29). These crops include cash forage crops.

Table 29: Defined pre-crop classes and crops on arable land in Västra Götaland

Cereals (CER)					Forage legumes (FL)
Winter cereals	Spring cereals	Grain legumes	Non-cereals	Grass	
Winter triticale	Spring barley	Faba bean	Silage maize	ley grass	Grass/clover
Winter rye	Spring oat	Pea	Winter rapeseed		Intercrop, pea-oat
Winter wheat	Spring wheat		Spring rapeseed		
			Linseed		

Crop production activities take the different pre-crop classes into account (Table 29). In total 54 cropping activities were defined. The pre-crop effects here only take the different pre-crop classes and its yield effect on the subsequent crop into account, while no effect on N-fertilization was mentioned. The argument here is that a yield increase implies a need for a somewhat increased N fertilization, thus the N input will be more or less the same.

As it can be seen in Table 30 only cereal crops react with a yield increase when grown after a legume or another non-cereal crop. The yield increase of cereals grown after a forage legume is 10 % higher as if they are grown after a grain legume or another leaf crop. After a forage legume the yield increases of between 22% - 28% and after a grain legume or another leaf crop it increases between 11% - 19%.

Table 30: Yield in [t/ha] and the change of yield [%] for the cultivation of the arable crops in Västra Götaland depending on the pre-crop class

Crops	Pre-crop class			Yield change	
	CER	FL	GL	FL	GL
Faba bean	3.1	3.1	3.1	0%	0%
Linseed	1.6	1.6	1.6	0%	0%
Pea	3.0	3.0	3.0	0%	0%
Spring barley	4.1	5.0	4.6	22%	11%
Spring oats	4.4	5.4	4.9	23%	11%
Spring oil seed rape	1.9	1.9	1.9	0%	0%
Spring wheat	4.6	5.6	5.1	22%	11%
Winter oil seed rape	3.4	3.4	3.4	0%	0%
Winter rye	5.5	7.0	6.5	27%	18%
Winter triticale	5.4	6.9	6.4	28%	19%
Winter wheat	4.3	5.4	5.0	26%	16%

CER = cereal; FL = forage legume; GL = non-cereal, grain legume, grass

The increase of gross margins is much higher when crops are cultivated after forage legumes (Table 31). As it can be seen only cereal crops as subsequent crops are positive effected if they are grown after legumes or other leaf crops.

Table 31: Gross margins of arable crops in Västra Götaland and the change of the gross margin depending on the pre-crop class

	Pre-crop class			Change of GM after:	
Crop	**CER**	**FL**	**GL**	**FL**	**GL**
Faba bean	44	44	44	0%	0%
Linseed	272	272	272	0%	0%
Pea	70	70	70	0%	0%
Spring barley	389	565	477	45%	23%
Spring oats	261	404	332	55%	27%
Spring oil seed rape	257	257	257	0%	0%
Spring wheat	359	555	457	55%	27%
Winter triticale	349	598	515	71%	48%
Winter oil seed rape	659	659	745	0%	13%
Winter rye	431	710	617	65%	43%
Winter wheat	529	852	740	61%	40%

CER = cereal; FL = forage legume; GL = non-cereal, grain legume, grass

The gross margin increases between 45% and 71% if the cereal crops are grown after forage legumes and for cultivation after grain legumes or other leaf crops it increases between 13% and 48%. Triticale and winter wheat are those cereal crops which respond most strongly. Barley and oats are those cereal crops which respond to the slightest.

Legumes in arable farms in Västra Götaland (Sweden)
Table 32 shows the most economic crop rotations under different assumptions from the total of 19544 generated crop rotations for an arable farm in Västra Götaland.

The selected crop rotations differ only slightly. They all contain winter oil seed rape and winter wheat and most of them spring barley, too.

Without any area payments crop rotation 1 has the highest rotational gross margin of 478 €/ha/a, which makes it the economically most excellent crop rotation. The rotation contains linseed which is actually less grown in the region. When adjusting the result to the current situation, crop rotation 2 is the most economical rotation for the farm. This rotation contains 80% cereals and is therefore a strong cereal dominated rotation. The main crop in this rotation is winter wheat (60%).

Table 32: Optimal rotations for an arable farm in Västra Götaland under different scenarios

	Rotation	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	gross margin [€/ha/a]
No area payments	rot1	wrape	wwheat	linseed	wwheat	sbarley	478
	rot2*	wrape	wwheat	wwheat	wwheat	sbarley	463
Area payments 230 €/ha/a	rot1	wrape	wwheat	linseed	wwheat	sbarley	708
	rot2	wrape	wwheat	wwheat	wwheat	sbarley	693
Greening	rot2	wrape	wwheat	wwheat	wwheat	sbarley	693
	rot5	wrape	wwheat	Faba beann	wwheat	sbarley	663
Subsidy	rot5	wrape	wwheat	Faba beann	wwheat	sbarley	694

* this rotation is the basis for the calculation of the gross margin deficit, which is the minimum subsidy required to support legumes

With an introduction of an area payment of 230 €/ha/a for arable land nothing will change in the cropping pattern as it can be seen in Figure 10. Even taking into account all pre-crop effects, the gross margin of crop rotations with legumes is below the gross margin of crop rotations without legumes. Rotation 5 which contains faba bean as legume crop is the most economical rotation with legumes (Table 33). The average gross margin of this crop rotation without any subsidy is 433 €/ha/a. This puts it at 30 €/ha below the crop rotation with the highest gross margin (without taking linseed into account), which contains winter wheat instead of faba bean (rotation 2).

Only with the introduction of an ecological focus area of 5% legumes become attractive for this area. Here faba beans are the most attractive legume.

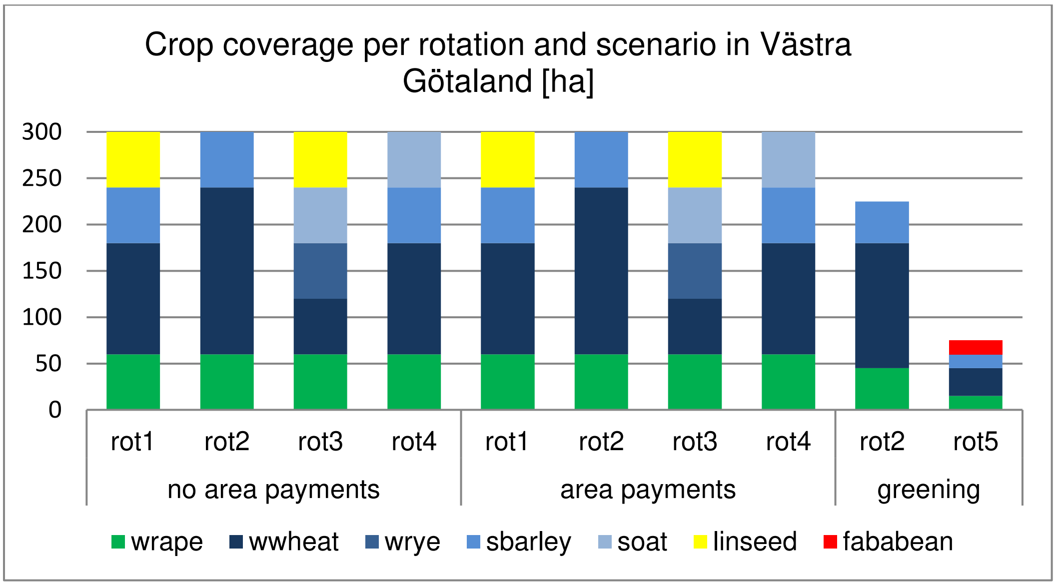

Figure 10: Cropping patterns for an arable farm in Västra Götaland under different situations

Table 33 shows the corresponding farm results. If the farm do not receive any area payments the total gross margin of the farm with 138851 €/a is lowest and no legumes are grown. If the farm receive an area payment for arable land of 230 €/ha/a the total gross margin rises up to 207,851 €/a but still no legumes are grown. With the introduction of the ecological focus area 5% of faba beans would be grown to get the full payments. Under this situation the total gross margin of the farm decreases by 1% compared to the situation without a greening area.

Table 33: Farm results for an arable farm in Västra Götaland under different situations

	Total land [ha]	Total gross margin [€/a]	Total premium payments [€/a]	Area with legumes [ha]	Share legumes [%]
No area payments	300	138,851	0	0	0
area payments 230 €/ha/a	300	207,851	69,000	0	0
Greening	300	205,580	69,000	15	5
Subsidy 156 €/ha	300	208,287	78,387	60	20

To set-aside the greening area is no option for the farmer because then he gets only the area payments of 230 €/ha/a which is the actual payment in this moment. This payment is much lower than the rotational gross margin of the legume-based rotation, so it is more profitable for the farmer to grow legumes on this area.

Finally, crop rotations with two leaf crops are economically the best rotations if the leaf crop is not a legume and if all pre-crop effects are taken into account. Winter rape is the most excellent leaf crop followed by linseed and spring rape. Among the legumes faba bean is most excellent. Before a legume comes in the crop rotation it is still better to prefer to dispense the second leaf crop and cultivate a cereal crop like winter wheat. Only in the case of cultivating legumes on the ecological focus area or with an introduction of a subsidy for legumes of about 156 €/ha they become attractive. The area of cultivated legumes rises from about 5% up to 20% (Table 33).

Legumes in dairy farms in Västra Götaland (Sweden)
The most economic crop rotations for the defined dairy farm in Västra Götaland under different situations are shown in Table 34. Overall a total of 50739 crop rotations were generated. Because of technical constraints regarding the model the amount of rotations were reduced. Of all crops the first hundred best rotations were taken into account. For the arable crops here the rotational gross margin was taken as decision parameter. For the forage crops the average cost per metabolized energy was taken as the decision parameter. At last a total of 9976 rotation were taken into account for the modelling.

Table 34: Most economic crop rotations for a dairy farm in Västra Götaland under different situations

	Crop1	Crop2	Crop3	Crop4	Crop5	Cultivated area [ha]	Average liquid manure used [m³/ha]
Without area payments	graclov	graclov	graclov	F. bean	soat	51	18
	graclov	graclov	graclov	F.bean	soat	42	24
	wrape	wwheat	Faba bean	wwheat	sbarley	37	0
Area payments 230 €/ha/a	graclov	graclov	graclov	F.bean	soat	51	18
	graclov	graclov	graclov	F.bean	soat	42	24
	wrape	wwheat	Faba bean	wwheat	wrye	37	0

If we have a look on the most economic crop rotations for a dairy farm in Västra Götaland it can be seen that two different rotations were used because the first two rotations only differ in the amount of liquid manure needed and not in the cropping pattern (Table 34). The cropping pattern does not change with introduction of an area payment of about 230 €/ha (Figure 11). The only difference is the higher total gross margin of the farm when receiving an area payment (Table 35). In all rotations grain legumes especially faba beans are included which is totally different to arable farms were a regulation is needed to get grain legumes in the rotations. This means it is more profitable for a farmer to grow grain legumes for animal feeding instead of growing them as a cash crop. In total the share of grain legumes is about 14% of the arable land which is already more than required as ecological focus area in the new CAP.

Also forage legumes especially clover grass are cultivated with a share of 45% of the arable area which means it is here the most cultivated crop. Clover grass and faba beans are only used for forage. Spring oat and winter oil seed rape are both used as forage and for sale. Winter wheat and spring barley are only cultivated as cash crops.

Table 35: Farm results for a dairy farm in Västra Götaland under different situations

	Arable land [ha]	Set-aside [ha]	Dairy cows [head]	Total gross margin [€/a]	Total premium payments [€/a]	Area with grain legumes [ha]	Share of grain legumes [%]	Area with forage legumes [ha]	Share of forage legumes [%]
No area payments	130	0	81	162311	0	18	14%	58	45%
Area payments 230 €/ha/a	130	0	81	192211	29900	18	14%	58	45%

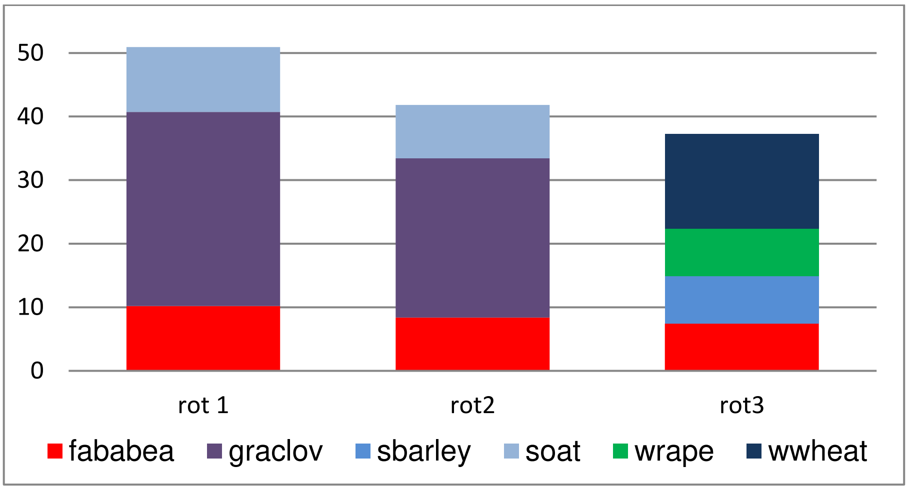

Figure 11: Cropping pattern for a dairy farm in Västra Götaland

Discussion
Actually only 2% of grain legumes are grown in the region of Västra Götaland but it seems that he potential of grain legumes in dairy farms is much higher because of the possibility to use it as protein rich forage.

In the clover grass mixture the share of clover is about 30%.With respect to the nutritional values clover grass differs not much in contrast to grass. The crude fiber content of clover grass is a little bit less with marginally higher protein content. But the variable costs of clover grass are about 90 €/ha lower than of grass because of less nitrogen fertilizer is needed. The yield differs not much but is a little bit lower when growing clover grass. All in all, the dominant positive characteristics make clover grass more attractive as forage than others.

Sud-Muntenia (Romania)

The selected region in Romania is the NUTS 2 region Sud-Muntenia. The region dominated by agricultural production[12]) and still has potential for an intensified agricultural development.[13]

In 2010 the agricultural area of the region is 2.333.680 ha (EUROSTAT, 2014) which is 92% of the total area. 80% of the agricultural area is arable land, 16% is grassland and 3% are permanent crops. The main cultivated crops are wheat (35%), maize (20%), sunflower (13%), rape (12%) and barley (7%). The cultivation of soybeans is about 0.4% and about 0.6% in Romania. No statistics were found for the cultivation of peas in the selected region, but in 2009, the cultivation of peas in Romania was

[12] Radulescu et al., 2010
[13] Lascar 2013

22700 ha, which represents approximately 0.2% of the agricultural area of Romania (EUROSTAT, 2014).

The agriculture structure is generally very heterogeneous and highly fragmented.[14] 99% of agricultural farms are individual farms with one owner which approximately manage 54% of the UAA and 1% of the farms with juridical status which manage 46% of the UAA (Lascar 2013).

The average farm size in Sud-Muntenia is about 3.3 ha. The average size of independent farms is about 1.7 ha. For farms with legal personality is about 242 ha (Ivascu 2012). 19% of the farms are specialised arable farms and these use 69% of agricultural land.

The modelled farm
The small farms in Sud-Muntenia are largely subsistence oriented. However, the potential of legumes, here of grain legumes, can best be explored in commercial farms, which are able to optimize their production with a market orientation. We therefore, selected a large farm although the majority of farms are small farms. Our typical arable farm has 1,846 ha agricultural land with a working capacity of 32 h/ha (Table 36).

Table 36: Typical farm in Sud-Muntenia

Farm type	Total land [ha]	Arable land [ha]	Farm labour [h/ha]
Arable farm	1846	1846	32

The farm has only one site class with a chernozem soil. Chernozem is a very fertile and high productive soil and covers about 42% of the land. On this soil, the farm has the opportunity to grow 8 crops of which 3 are legumes. The non-legume crops are grain maize, sunflower, winter barley, winter rape and winter wheat. The grain legumes are common beans, peas and soybeans.

For each of these crops cropping activities were defined depending on the previous crop type. In total 26 cropping activities were defined. Based on these cropping activities a total of 137 rotations was generated. 133 rotations are rotations with legumes and four of them are rotations without legumes (D 4.2.).

Cropping activities
Actual agricultural land use in Sud-Muntenia is characterised by a high share of 64% of cereals (Figure 12), 25% are industrial crops mainly sunflower and rape and only 1% is actually grown with pulses (Figure 12). Nevertheless until the 1980's and 90's Rumania grew about 500.000 ha soy bean grown, but this declined to about 50.000 ha by 2009. Common beans, which extended over 200,000 ha in 1988, disappeared

[14] Ivascu 2012; Lascar 2013

practically complete. Also the form praxis of intercropping common beans with maize declined in the 1980s due to widespread use of herbicides.

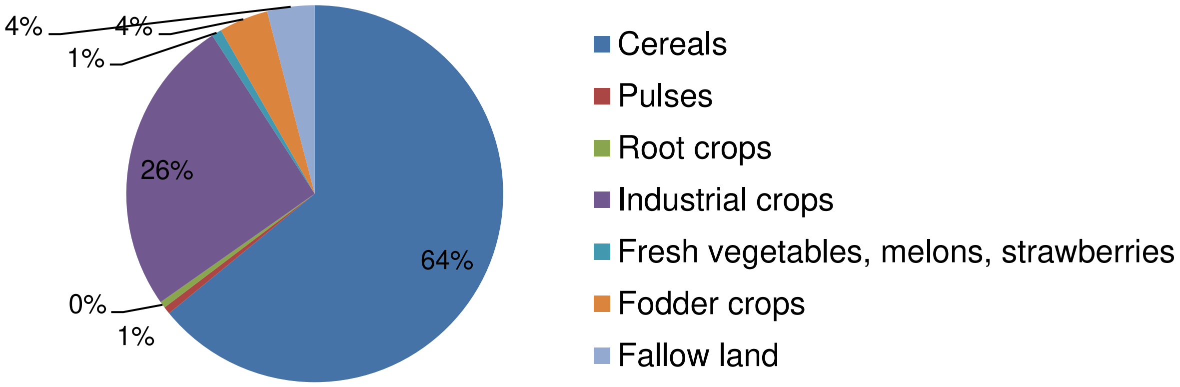

Figure 12: Land use in Sud-Muntenia in 2010 (Source: EUROSTAT, 2014)

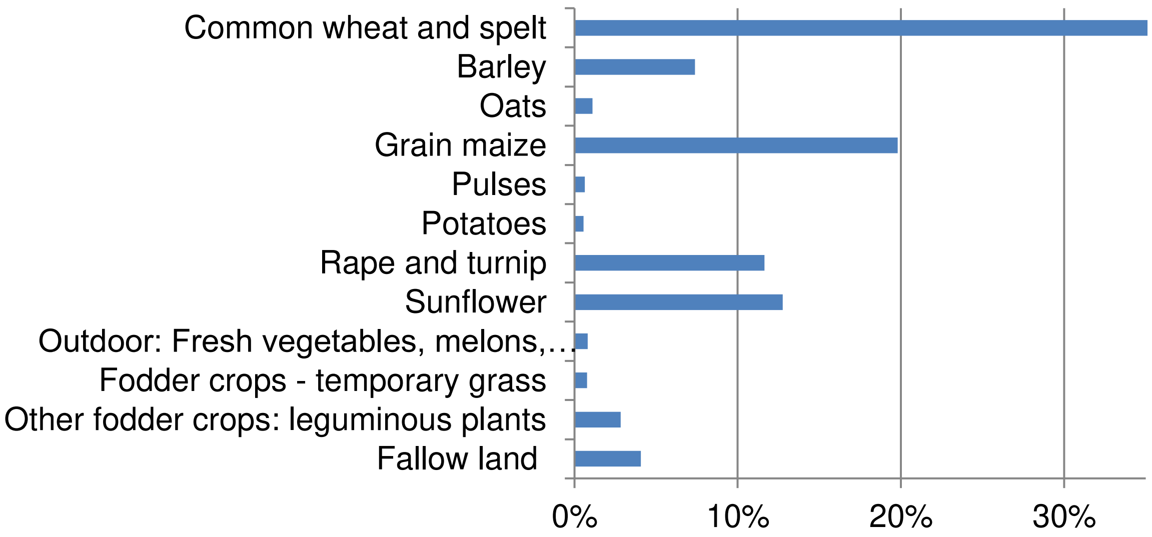

Figure 13: The acreage of cultivated crops in Sud-Muntenia in 2010 in percent (Source: EUROSTAT, 2014)

Table 37: Defined pre-crop classes and crops on arable land in Sud Muntenia

Pre-crop class 1	Pre-crop class 2	Pre-crop class 3	Pre-crop class 4
Common bean	Pea	Winter rape	Grain maize
Soy bean	Lupin	Winter wheat	Sunflower
	Pea		Winter barley

Our experts defined in total 8 crops which can be grown on the farm. In Romania, the crops shown in

Table 37 were divided on the basis of their different pre-crop effect in 4 different pre-crop classes. Grain legumes are distinguished in two pre-crop classes where common bean and soy bean are in pre-crop class 1 and pea is in the pre-crop class 2 (

Table 37).

The main pre-crop effect mentioned by our experts is the positive yield effect to subsequent crops, if this is not a legume too because then the yield decreases. The worst pre-crop class is class 4 with grain maize, sunflower and winter barley. The pre-crop classes 1 and 2 are the classes with legumes. If the fourth pre-crop class is taken as basis Table 38 shows the change in yield of crops if they are grown after legumes (common bean, soy bean or pea) or after other crops like winter oil seed rape and winter wheat. If crops can be cultivated after a grain legume like common bean, soy bean or pea all of them show the same effect to the subsequent crop. The highest effect can be seen if sunflowers are grown after peas. Here the yield increases by 2.5 times (150%). The lowest effect can be seen if winter oil seed rape is grown after peas. Here the yield only increases by 17%.

Table 38: Yield in [t/ha] and change of yield in [%] of defined crops in Sud-Muntenia according to the pre-crop class

	Pre-crop class				Yield change		
Crop	**1**	**2**	**3**	**4**	**1**	**2**	**3**
Common bean	1	1	2.5	2	-50%	-50%	25%
Grain maize	7	7	6	4.2	67%	67%	43%
Pea			3.5	2.5			40%
Soy bean		1	2.5	2		-50%	25%
Sunflower		3	2.4	1.2		150%	100%
Winter barley	6	6	5	4.2	43%	43%	19%
Winter oil seed rape		3.5	3	3		17%	0%
Winter wheat	5	5	4.8	3.6	39%	39%	33%

Table 39 shows the gross margin and the differences of the gross margin compared of all arable crops in Sud-Muntenia depending on the pre-crop class. The basis for the differences is the pre-crop class 4. Apart from the common bean and the soy bean, the gross margins increase if the crops are grown after legumes because of the yield increase. Here the peas (pre-crop class 2) have a greater effect on the gross margin of the subsequent crop than common bean and soy bean.

Table 39: Gross margins and gross margin differences in [€/ha/a] of arable crops in Sud-Muntenia depending on the pre-crop class

	pre-crop class				GM difference in [€/ha/a]		
	1	**2**	**3**	**4**	**1**	**2**	**3**
Comon bean	396	396	**1,879**	**1387**	-992	-992	492
Grain maize	743	743	542	171	572	572	371
Pea			294	-19			313
Soybean		-85	550	334		-419	216
Sun flower		567	361	-60		627	421
Winter barley	437	444	244	99	338	345	145
Winter rape		**733**	528	528		205	0
Winter wheat	405	413	330	109	296	305	222

When considering the economic efficiency of the respective crops on the basis of the gross margin without taking the pre-crop effects of legumes into account the legume common bean is most economical followed by winter oil seed rape, soy bean and grain maize if the previous crop is one of pre-crop class 4. If the previous crop is one of pre-crop class 3 then the order is slightly different (Table 38). The gross margin of the common bean is by far the highest and amounts to 1879 €/ha if it is grown after winter oil seed rape or winter wheat or 1387 €/ha/a if it is grown after sunflower or winter barley as the worst pre-crop class. Because common bean is used for human nutrition we excluded it.

If crops are grown after legumes, which belong to the pre-crop class 2 or 1, it can be seen that grain maize is the most economical crop with a gross margin of 743 €/ha followed by winter oil seed rape and sunflower.

Legumes in arable farms in Sud-Muntenia (Romania)
A total of 137 crop rotations were generated. Approximately 93% of these generated crop rotations are rotations with legumes and only 3% are rotations without legumes. The number of crop rotations with peas is 63 in total and with common beans and soybeans 35 of each.

All the best crop rotations regarding the gross margin include the crops grain maize, winter wheat and winter oil seed rape. The only difference is the legume crop which influences the gross margin (Table 40).

If the farmer receives no area payments apart from common bean, rotations with pea or soy beans have highest gross margins if the pre-crop effects are taken into account. If the pre-crop effects are not taken into account, rotations with soy beans are still most profitable but rotations with peas rank behind rapeseed based rotations. The proportion of legumes is about 25% of the arable land.

Table 40: Average rotational gross margins for the most profitable crop rotations with legumes and all other rotations without legumes

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Gross margin [€/ha/a]
No area payments	common bean	grain maize	wwheat	wrape		815
	*soybean	grain maize	wwheat	wrape		483
	wrape	grain maize	wwheat			393
	wrape	grain maize	wbarley			390
	wrape	wwheat	wwheat	sunfl	wbarley	330
	sunfl	wwheat	wwheat	wrape	wbarley	230
Area payments 120 €/ha/a	soybean	grain maize	wwheat	wrape		603

* this rotation is the basis for the calculation of the total gross margin of the farm

With introduction of an area payment of about 120 €/ha/a (2012) nothing changes in the cropping pattern. The only change for the farmer is the higher gross margin because of getting area payments (Table 41).

An introduction of an ecological focus area of about 5% of the arable area would also lead to no changes.

Table 41: Farm results for an arable farm in Sud-Muntenia

	Total land [ha]	Total gross margin [€/a]	Total premium payments [€/a]	Area with legumes [ha]	Share legumes [%]
No area payments	1846	890737	0	462	25
Area payments 120 €/ha/a	1846	1112257	221520	462	25

Already 97% of the generated crop rotations take legumes into account. All of them generate a positive rotational gross margin which means that they are very high valued from our experts as well as their pre-crop effects to the subsequent crop.

Even if no pre-crop effects are taken into account crop rotations with common bean and soybean are the most profitable. Consequently legumes especially common bean and soy bean have a high potential in Sud-Muntenia (Romania).

Discussion

Our findings are in strong contrast to the actual situation in Sud Muntenia. A look in the history of legume cultivation in Romania shows that legumes have been grown for 4,000 years. Previously, mainly lentils, vetches, peas and faba beans were grown. Later on common beans, soya beans, alfalfa and clover were cultivated. Today most of the legumes are completely unknown. Common beans have practically disappeared and the cultivation of soy beans has been drastically reduced. Alfalfa and clover are still grown. The cultivation is about 3% of the arable land in 2010 (EUROSTAT, 2014). Figure 14 shows the cultivation development of soy beans in Sud-Muntenia from 2003 to 2011. The highest cultivation of soy beans was in 2006 and then the cultivation decreased sharply. In 2011 the cultivation of soy beans was only 10% of the cultivation of 2006.

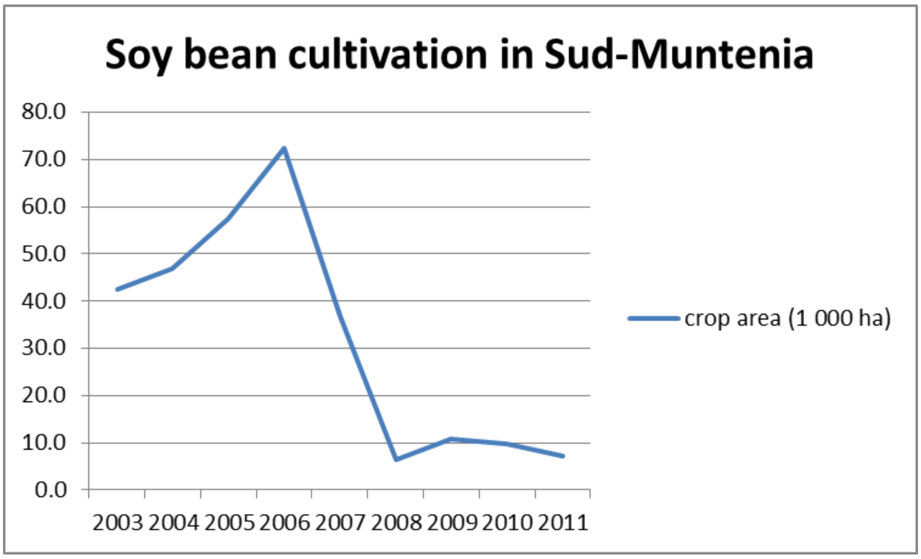

Figure 14: Cultivation development of soy beans in Sud-Muntenia (Source: EUROSTAT, 2014)

This may on one hand be explained by other priorities especially for subsistence farms and on the other hand by problems in marketing of grain legumes.

DISCUSSION

The analysis showed that the inclusion of pre-crop effects and consideration of N-savings changes the economic valuation of legumes at farm level and leads in some regions to different management decisions. The economic performance of individual legume crops is unprofitable or at least unfavorable compared to other crops in most regions, largely due to their low yields and accordingly low gross margins, which is in some cases more than 50% lower than in cereals.

In specialised arable farms the potential of grain legumes differs between the regions. In regions such as Scotland and Romania the potential of grain legumes is highest. Legumes have competitive gross margins only in these regions. Here they would even be profitable without taking into account the positive pre-crop effects. In Scotland especially, peas and faba beans, depending on the site class and in Romania especially soy beans have a high potential. However actual land use patterns don´t reflect this potential, which reflects marketing problems.

On arable farms in Brandenburg, mainly peas have the highest potential. However, their positive effects in crop rotations do not fully compensate the highly negative gross margin, related to low yields. Taking area payments into account brings them into the crop production plan on soil type LBG3 because their gross margin is slightly higher than the area payment minus costs of mulching, which is compulsory in set aside.

In regions such as Calabria or Sweden, despite positive effects of legumes and area payments, these are not sufficient to grow grain legumes in arable farms, as they are the most unprofitable crops here because of their low yields compared to non-legumes. Only by cultivating grain legumes on ecological focus areas or by paying of extra subsidies are they of interest. The most profitable legume in both regions is faba bean.

In Brandenburg and Sweden both grain legumes and forage legumes have more potential for on-farm feeding in dairying. Next to clover grass, lupines in Brandenburg and faba beans in Sweden have highest potential. Here it seems that farmers are not very familiar with the cultivation of legumes which indicates the advisory system may have a role to play. However, the inclusion of some legumes in feed is limited by anti-nutritional factors. The relatively high starch content can also promote acidosis in excessive use and in conjunction with high shares of cereals. They should therefore be given in squashed form and thermally treated, as this has a positive effect on their intake and degradability in the rumen. The costs for the treatment is about 65€/t, which depends also on the scale of these processing entities. Finally, it is recommended to add not more than 4kg per animal and day in the feed ration[15]

In some regions legumes tend to be more risky crops in arable farms than cereals like in Brandenburg and Sweden and in some regions not, like in Scotland and Romania. Yield fluctuations can cause that they will quickly be unprofitable for farmers especially in Brandenburg. This is mainly due to the lack of genetic progress in leguminous plants. In Germany for instance, only one breeder house has a full breeding program for faba beans and peas. For winter wheat, however, there are 16 full breeding programs.[16] Thus, there are marginally varieties of legumes adapted to the requirements.[17] The yield of cereals have therefore increased faster in recent decades

To become marketable for arable farms mainly in Brandenburg, Italy and Sweden breeding on yield stability and higher yields should be improved. In regions like Scotland and Romania better advice should be given to farmers.

Basically it should be paid attention to good harvest and ensilage conditions in roughage such as grass or clover grass silage because considerable fluctuations may occur in the crude protein content depending on the cut and quality of ensilage.[18]

[15] http://www.lfl.bayern.de/mam/cms07/ite/dateien/eiwei__alternativen_milchvieh.pdf
[16] Dahlmann
[17] Quelle: DAFA
[18] http://www.lfl.bayern.de/mam/cms07/ite/dateien/eiwei__alternativen_milchvieh.pdf