Legume Futures

Legume-supported cropping systems for Europe

Legume Futures Report 4.2

Generation and evaluation of legume-supported crop rotations in five case study regions across Europe

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FOREWORD

Legume Futures, "Legume-supported crop rotations for Europe", is an international research project funded under the European FP7 programme. It has 20 partners in 13 countries. The project aims to develop, design and assess legume-supported cropping systems to improve the economic and environmental performance of farming in Europe.

This report is concerned with the socio-economic aspects of legume cultivation. One of the key instruments of modern cropping system design is the development of agronomically and economically highly efficient and environmental sound crop rotations. In our first project meetings we agreed to restrict the project works to conventional farming in order to limit the workload and allow for a high quality level of the research works.

A modelling approach was developed to systematically generate and agronomically evaluate a large set of crop rotation options. The objective of the report is the description of this approach and its capability to facilitate the design of novel cropping systems including legume crops.

The modelled crop rotations with and without legumes that were generated by this work serve as a basis for further socio-economic and environmental assessments of legume-supported cropping systems within the Legume Futures project.

Johann Bachinger

Müncheberg, Germany,

18 December 2013

INTRODUCTION

Legumes grown in crop rotations have positive agronomic and economic impacts that enhance the sustainability of European cropping systems (Jensen et al. 2011; Köpke and Nemecek 2010; Peoples et al. 2009b). However, legume crops play a minor and decreasing role in European crop rotations despite their positive rotational effects. One of the main reasons for farmers do not grow legume crops is due to their perceived low gross margins compared to alternative crops. However, this crop-level perception is thought to neglect many rotational effects.

Quantifying the impacts of legumes in crop rotations is a challenge since crop rotations in general and particular those including legumes are relatively rare or simplified in European farming practice. In order to explore the impacts of legumes beyond the current farming practice, crop management and rotations needed to be derived from other sources. A systematic assessment using a modelling approach for the evaluation of current and novel legume-supported crop rotations was proposed.

The main objective of the research reported here was i) to describe a modelling approach to assess the agronomic and economic impacts of legumes in crop rotations and ii) the application of the developed approach in selected case study regions across Europe. An additional objective was the systematic selection of a limited sub-set of rotations for the application of dynamic bio-physical models (Legume Futures Report 6.2) for a detailed analysis of their environmental impact and the calculation of marginal abatement cost curves (Legume Futures Report 4.4). The approach presented in this report consists of a static and rule-based crop rotation generator and evaluation approach that is able to produce and evaluate the broadest agronomically feasible spectrum of rotations for different regions and sites across Europe.

Five case study regions were selected from the Legume Futures consortium representing different socio-economic and bio-physical conditions and agro-climatic zones. The case study regions were Västra Götaland (Sweden), Eastern Scotland, Brandenburg (Germany), Sud-Muntenia (Romania) and Calabria (Italy). The assessment uses crop management and rotational data from a survey conducted in the selected case study regions in 2012-2013.

First, the overall assessment framework of the approach is described. Second, the methodological approach of the crop rotation generation and the agronomic and economic evaluation is presented. Third, the first application of the approach in the five case study regions is shown and followed by an overall discussion.

METHODS

The assessment framework

The overall assessment framework consisted of a three-step approach:

1. Evaluation of single crop production activities (CPA). Agronomic evaluation consisted of the assessment of nitrogen (N) leaching, N_2-fixation, calculation of the N-balance and pest, disease and weed infestation. As part of the economic evaluation, gross margins and forage costs were calculated. CPA data were derived from a survey among crop production experts across five European regions.

2. Generation of agronomically sound crop rotations based on a rule-based crop rotation generator. Rotational rules were derived from a survey among crop production experts across five European regions.

3. Evaluation of whole crop rotations. Generated rotations were evaluated by aggregating the single evaluation results of CPA for whole rotations and additional rotational assessments including the N efficiency.

Data base of crop production activities (CPA)

CPA data were derived from a survey among crop production experts across five European regions. CPAs differ per region, site class (e.g. soil type), crop, pre-crop and management (sowing, application of fertilizers and pesticides, harvesting method). Beyond the CPA data site data concerning bio-physical characteristics were collated.

Agronomic evaluation of single crop production activities

The agronomic evaluation of single crop production activities includes a nitrogen balance and a phytosanitary risk assessment. The assessments use a static and rule based approach with an annual temporal scale (Bachinger and Zander 2007). The nitrogen balance assessment includes the indicators i) NO_3-leaching, ii) N_2 fixation and iii) calculation of the N-balance. The phytosanitary risk assessment includes the infestation risk of i) pests, ii) diseases and iii) weeds.

Nitrogen balance assessment

A modelling approach was developed for the assessment of nitrogen balances of cropping systems based on ROTOR, a static and rule-based tool for evaluating crop rotations for organic farming systems (Bachinger and Zander 2007). The functions in the nitrogen assessment module of ROTOR have been modified in order to assess conventional legume and non-legume supported farming systems. The algorithms of N-mineralization, N_2 fixation, NO_3-leaching and N-balance have been modified to consider the effect of mineral and organic N-fertiliser applications adequately. The model considers the effects of different soil types and preceding crops on N_2 fixation, N-mineralisation from soil and NO_3-leaching.

Model input

The required input data for the nitrogen assessment are summarized in **Fehler! Verweisquelle konnte nicht gefunden werden.**1. The assessment demands regional- and site-specific average data for soil, precipitation and annual cropping practises. Crop data are regional averages.

Table 1: Input data for the N assessment model

Type of data	Variable
Soil data (per site class)	Texture [%] Organic carbon content of the top soil [% C in DM] C to N ratio of SOM Bulk density of top soil [g/cm³] Stone content [%] Depth of top soil layer [cm] Annual mineralisation rate [%] Total water holding capacity in the root zone [mm] Maximum increase in soil N supply caused by optimum pre-crop [% compared to cereal pre-crop]
Weather data (per site class)	Annual precipitation [mm] Precipitation during winter months [mm]
Annual cropping data (per CPA)	Yield [t/ha FM] (site and preceding crop specific) Legume percentage in legume-grass and legume-cereal mixtures [%] Tillage system [plough/reduced tillage] Harvesting of by-product (straw) [yes/no] Cover crop [yes/no] Amount of mineral N fertiliser applied [kg N ha^{-1}] Amount of organic manure application [kg N ha^{-1}] Time of organic manure application [spring/autumn] Type of organic manure [solid/liquid]
Crop data (per crop and region)	N, P and K content in main and by-product [%] DM content in FM [%] Ratio main product : by-product Crop specific SOM mineralization factor Ndfa max. and Ndfa min [%] N content in crop residues and roots Ratio of N in yield : N in stubble and root residues Ratio of fixed N : total N in legumes

N-balance calculation

The N balance allows for the assessment of N removal, N_2-fixation, and N losses through nitrate leaching, according to site characteristics and preceding crop category. According to Hege (1995), the sum of the atmospheric deposition and the non-symbiotic N_2-fixation can be assumed to equal the denitrification losses and therefore has been excluded here. The annual N balance of each crop production activity (CPA) is calculated as:

(1) $$N_{balance} = (N_{fix} + N_m + N_s + N_{fert}) - (N_{remov} + N_{lea})$$

where $N_{balance}$ is the CPA-specific N balance (kg N ha^{-1}), N_{fix} the N_2-fixation of grain legumes as sole or intercrops and forage crops as sole crop calculated with equation (2) and of legume-grass mixtures calculated with equation (6), N_m the N in manure, N_s the N in seeds, N_{fert} the N in mineral fertiliser, N_{remov} the N removal of harvested products, N_{lea} the NO_3-leaching calculated with equation (7).

N_2-fixation calculation

N_2-fixation is calculated specifically per crop, and varies depending on preceding crop, yield, the soil content of mineralised N from preceding crop residues in spring, and inputs from organic, plant-available N from manure and mineral fertiliser. Equation (2) is applied for sole-cropped grain and forage legumes and cereal-legume mixtures and equation (6) for legume-grass mixtures.

N_2-fixation for sole crops and cereal-legume mixtures is calculated as (adapted from Hülsbergen and Biermann 1997):

(2) $$N_{fix} = Y_{CPA} \, N_C \, R_{NR} \, R_{Nfix} \, R_L$$

where Y_{CPA} is the CPA specific yield (t ha^{-1}), N_C indicates the N content of the harvested grain dry matter (%), R_{NR} the crop specific ratio of N in grain yield to N in crop and root residues, R_{Nfix} the ratio of symbiotically fixed N to total N, and R_L is the legume portion in the dry matter yield (in cereal-legume mixtures). R_{Nfix} depends on the soil content of mineralised N from preceding crop residues in spring, and on inputs from organic, plant-available N in manure and mineral fertiliser. We assumed that R_{Nfix} is a linear function of plant-available N in the soil (N_{soil}) which is defined by two related values:

(3) $$R_{NfixMin} \rightarrow N_{soil} \geq 150 \text{ kg N ha}^{-1}$$
(4) $$R_{NfixMax} \rightarrow N_{soil} < 30 \text{ kg N ha}^{-1}$$

R_{Nfix} for any given N_{soil} value between 30 and 150 kg is calculated by the function equation:

(5) $$R_{Nfix} = R_{NfixMax} \, (a \, N_{soil} + b)$$

Where 'a' is the slope and 'b' the intercept of the linear function.

Table 2: Maximum and minimum Ndfa (R_{Nfix}) values for selected crops (adapted from Peoples et al. 2009a and Palmason et al. 1992) and resulting slopes and intercepts of the linear equation.

Crop	$R_{NfixMax}$	$R_{NfixMin}$	a	b
Faba bean	0.92	0.60	-0.0029	1.0870
Common bean	0.68	0.38	-0.0047	1.1103
Pea	0.99	0.50	-0.0041	1.1237
Lupins	0.98	0.86	-0.0010	1.0306
Soy bean	0.95	0.60	-0.0031	1.0921
Pea/oat mixture	0.99	0.60	-0.0033	1.0985
Vetch/rye mixture	0.99	0.80	-0.0016	1.0480
Clover	0.95	0.70	-0.0022	1.0658
Alfalfa	0.95	0.70	-0.0022	1.0658

N_2-fixation of legume-grass mixtures can be computed for different percentages of legumes in the dry matter of the gross yield according to Schmidt (1997) and Schmitt and Dewes (1997) as follows:

$$(6) \qquad N_{fix} = (Y_{tot}\, R_L\, N_L\, R_{Nres}\, R_{LNfix} + Y_{tot}\, (1 - R_{Lb})\, N_G\, R_{Gnfix})\; 10$$

where Y_{tot} is the total dry matter yield without harvest losses at 5 cm cutting height [t ha^{-1}] (calculated as $Y_{tot} = Y_{CPA}R^{-1}_{Hloss}$ where R_{Hloss} is the ratio of harvest losses set to 0.65 for hay and 0.85 for silage crop). R_L is the legume portion in the dry matter yield, N_L the N content in legume dry matter [%], R_{Nres} the ratio of N in legume yield to N in stubble and root residues, R_{LNfix} the ratio of symbiotically fixed N to total N in legumes, N_G is the N content in grass yield, and R_{GNfix} is the ratio of fixed N transferred to grass ($R_{Gnfix} = 0.25R_L$).

Nitrate leaching calculation

NO_3 leaching is calculated as a function (adopted from Gäth and Wohlrab, 1992) of the soil leaching probability and N surplus (Annex 1):

$$(7) \qquad N_{lea} = N_{surp}\, L_P$$

where N_{surp} is the N surplus [kg ha^{-1}], calculated with equation (8), L_P the leaching probability during the winter months (L_P is mean winter precipitation divided by water holding capacity at rooting depth; L_P values > 1 were set to 1):

$$(8) \qquad N_{surp} = N_m + N_{fert} + N_{min} - N_{remov}$$

where N_{min} is the cropping activity specific N mineralisation [kg ha^{-1}], calculated with equation (9).

As proposed by Bachinger and Zander (2007), mean nitrogen mineralisation was assumed to be a function of the total organic nitrogen content (N_{org}) modified by the pre-crop specific N supply level. The site-specific organic carbon content is assumed to be stable in agronomically suitable crop rotations with a well-balanced N supply:

(9) $N_{min} = N_{org}\, R_{mina}\, R_{minNL}\, R_{minC}$

where N_{org} is the organic N content [kg ha^{-1}] in the ploughing horizon (Ap) calculated with equation (10), R_{mina} the mean annual soil N mineralisation rate of N_{org}, R_{minNL} the coefficient of the preceding crop specific residual N level (coefficients taken from ROTOR), and R_{minC} is a coefficient to modify N_{min} depending on the crop and the associated soil tillage and irrigation intensity (i.e. 1.1 for grain legumes, 1 for all other crops and 1.5 for irrigated crops in Calabria).

(10) $N_{org} = R_{Corg}\, R^{-1}_{CN}\, BD\, D_{Ap}\, 10^5$

where R_{Corg} is the content of organic carbon in topsoil [%], R_{CN} the C/N ratio, BD is the bulk density, D_{Ap} the depth of ploughing horizon [cm].

This static assessment does not distinguish different pools of soil organic matter from which N is mineralized or between organic and inorganic N residues (Bachinger and Zander 2007). However, the coefficient R_{minNL} takes the different N pools indirectly into account for the different residual N levels.

Phytosanitary risk assessment

The infestation risk of pests, disease and weeds is based on an expert ranking of problematic pests, disease and weeds that are influenced by crop rotation.

The evaluation is crop specific with a ranking from -2 to 2, where negative values indicate a reduction potential and positive values indicate an increase of the infestation risk (Annex 2). The rotational infestation risk is calculated by averaging the single values of all crops in a rotation according to Bachinger and Zander (2007).

Across the case study regions, problematic pests, disease and weeds vary. However, some were seen as problematic in several case study regions such as cereal nematodes, take all and couch grass.

From one to several mentioned pests, disease and weeds per case study region, a selection was made for the evaluation at rotational level (**Fehler! Verweisquelle konnte nicht gefunden werden.**), with a focus on cereal pests and diseases, where applicable. In Romania and Italy (for weeds) only groups of pests, disease and weeds were provided in the survey and were therefore used for the evaluation. For Scotland, data were insufficient to perform the analysis on crop rotation level.

Table 3: Problematic pests, disease and weeds selected for evaluation

Case study region	Pests	Diseases	Weeds
Brandenburg (DE)	cereal nematodes	take-all	couch grass
Calabria (IT)	cereal nematodes	*Blumeria graminis*	*Phalaris canariensis* L.; *Avena sterilis* L.; *Cynodon dactylon* Pers.
Västra Götaland (SE)	cereal nematodes	take-all	couch grass
Eastern Scotland (SC)	n.d.	*Sclerotinia sclerotiorum*[1]	couch grass[1]
Sud-Muntenia (RO)	different pests[2]	different fungi[2]	different weeds[2]

[1] data not sufficient available for crop rotation assessment; [2] only data on groups of pests, diseases and weeds were reported; n.d. = no data

Economic evaluation of single crop production activities

Economic evaluation is conducted on the level of single CPAs and aggregated at rotational level. For arable crops, the gross margin is the main indicator for economic evaluation and for forage crops the costs used for producing the forage (cost per MJ metabolisable energy). Subsidies are not included in these calculations.

Equation (11) shows the calculation of the gross margin (calculated for arable crops in rotations only) including labour costs (GM_L) and equation (12) is calculated without labour costs (GM):

(11) $$GM_L = R_{CPA} - (C_{VAR} + C_L)$$
(12) $$GM = R_{CPA} - C_{VAR}$$

where R_{CPA} are the revenues calculated with equation (13), C_{VAR} the total variable costs calculated with equation (14) and C_L the costs of labour calculated with equation (15):

(13) $$R_{CPA} = Y_{MP}P_{MP} + Y_{BP}P_{BP}$$
(14) $$C_{VAR} = C_{seed} + C_{fert} + C_{pest} + C_{irrig} + C_{MA} + C_S$$
(15) $$C_L = L_{Time}L_{Cost}$$

where Y_{CPA} is the fresh matter yield (t ha^{-1}), $P_{Product}$ the product price, C_{seed} the cost of seed, C_{fert} the total cost of fertilizers, C_{pest} the total costs of pesticides, C_{irrig} the costs of irrigation, C_{MA} the variable costs of machinery, C_S costs of other services, L_{Time} the amount of time used for field operations [hours] and L_{Cost} the labour costs [€ hour^{-1}].

The costs to produce forage crops per amount of energy content are calculated as:

(16) $C_{FOR} = C_{VAR}/ME_{CROP}$

where C_{FOR} are the costs of produced energy (calculated for forage crops in rotations only) and ME_{CROP} the content of ME (metabolisable energy content) [MJ ME/t dry matter].

Generation of crop rotations

Since crop rotations in general and those including legumes are rarely found in European farming practice, rotations for evaluation had to be derived elsewhere. The approach described here is a rule-based crop rotation generator that is able to produce a large set of agronomic suitable rotations for single regions and sites across Europe. Generated rotations are of a cyclical nature with a fixed rotation length (Castellazzi et al. 2008).

The generator has been developed in Python (www.python.org, 2013). Input data and output data were stored in a PostgreSQL database as backend and an export to a MS Access database was used to (i) support discussions – e.g. with stakeholders – about input data, rules, results, and restrictions and (ii) as interface to allow further processing of the results. The structure of the input data is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

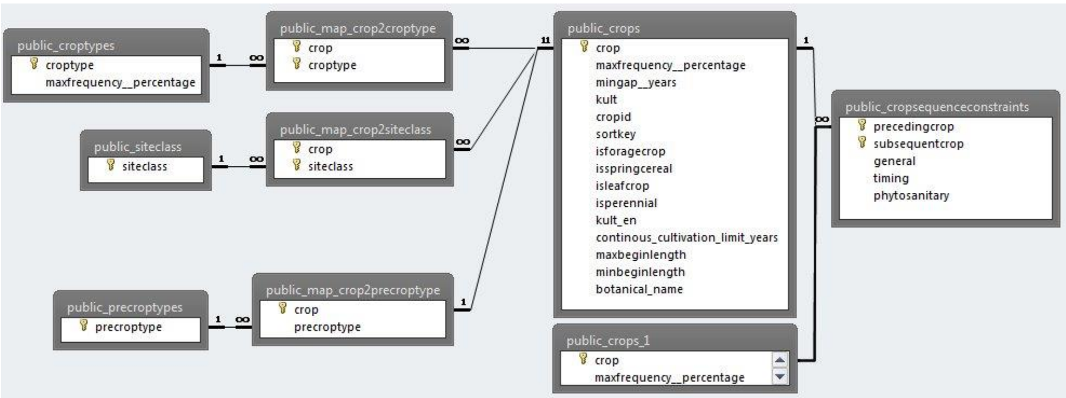


Figure 1: Database of crop rotation generator - entity relationship diagram

Region-specific crop rotation rules were the basis for generating crop rotations of 3 to 6 years for each region and different site classes when indicated. Rules capture characteristics regarding a single crop, crop type, and crop-pairs (crop-crop combination as least sequence) within a crop rotation. Input data were stored in (database) table crops, crop types, and crop sequence constraints (**Fehler! Verweisquelle konnte nicht gefunden werden.**, for details see **Fehler! Verweisquelle konnte nicht gefunden werden.**, **Fehler! Verweisquelle konnte nicht gefunden werden.**, Table 6). Due to the particular type of relationship between these tables some mapping tables (map_*) were added to the database design.

Table 4: Crop characteristics for generating crop rotations (table public crops)

Crop characteristics	Description	Example
Crop [name]	Name of crop	alfalfa
Maxfrequency_crop [%][1]	Maximum frequency of the crop in a rotation	34%
mingap [years]	Minimum gap until the crop can be cultivated again	4 years
cropid [no.]	ID of the crop	11
sortkey [no.]	Position of the crop in a rotation e.g. beginning	1
Isforagecrop [yes/no]	production for green forage, hay or silage	Yes
Isspringcereal [yes/no]	Is the crop a spring crop	No
Isleafcrop [yes/no]	Is the crop a leaf crop	Yes
isperennial [yes/no]	Is the crop a perennial crop	Yes
continous_cultivation_limit [year]	Maximum continuous cultivation time of the crop	2
maxbeginlength	Maximum cultivation length of perennials	2
minbeginlength	Minimum cultivation length of perennials	2
botanical_name	Botanical name of the crop	medicago sativa

[1] The maxfrequency [%] of a non-perennial crop is either smaller or equal to 100/(mingap+1) e.g. for lupin: 100/(4+1) = 0.2

The parameters were used to describe the restrictions and rules. For example to control soil-borne pests and diseases the minimum cultivation break (mingap [years]), the maximum share of crops (maxfrequency_crop [%]) and the crop sequence constraints (phytosanitary sequence score [score]) are relevant. Crop type frequency constraints (maxfrequency_croptype [%]) help to control soil-borne pests and diseases that are relevant for crops of the same type e.g. cereal nematodes.

Table 5: Crop type characteristics for generating crop rotations (table public croptypes)

Crop type characteristics	Description	Example
Croptype [name]	Name of crop type	Forage legumes
Maxfrequency_croptype [%]	Maximum frequency of the crop type in a rotation	34%

Timing restrictions (timing [score]) ensure that the cropping periods of subsequent crops do not overlap and allow sufficient time for seedbed preparation. Phytosanitary restrictions (phytosanitary [score]) ensure that no crop combinations lead to phytosanitary problems e.g. pea after pea. The general crop sequence score (general [score]) is a combined assessment of the timing, phytosanitary and other restrictions.

Table 6: Crop sequence constraints for generating crop rotations (table public cropsequence constraints)

Crop sequence constraints	Description	Example
Preceding crop [name]	Name of crop (foreign key)	Alfalfa
Subsequent crop [name]	Name of crop (foreign key)	Winter wheat
general [score]	General suitability of the crop as a pre-crop for a subsequent-crop	3 (very good)
timing [score]	Timing suitability of the crop as a pre-crop for a subsequent-crop	3 (very good)
phytosanitary [score]	Phytosanitary suitability of the crop as a pre-crop for a subsequent-crop	3 (very good)

For the generation of rotations the general crop sequence score was applied to characterise the suitability of a pre-crop to a subsequent crop. It is a qualitative score between 0 and 3 (Table 7).

Table 7: Scaling of the crop sequence score

Score	Description
0	impossible crop combination
1	possible with limitations
2	possible combination
3	excellent combination using positive rotational effects

In order to produce no rotations that are at risk of failing due to risky combination (e.g. timing constraints), only sequences without limitations (score >1) were considered.

For each case study region a set of site classes were defined and crops were mapped to these site classes.. In conjunction with the allowed crop sequences (crop sequence constraints) the overall set of possible crop rotations could be reduced to a subset of rotations collecting only those crops.

Table 8: Mapping crop to siteclass for generating crop rotations (table public.crop2siteclass)

Crop type characteristics	Description	Example
Crop [name]	Name of crop	Alfalfa
Siteclass [class]	For each region predefined site classes	1[1]

[1] Site classes 2 and 3 were also suitable

Evaluation of whole crop rotations

The evaluation of whole crop rotations considers the long-term effects at the level of full rotations. For this purpose, single CPAs are systematically aggregated for whole crop rotations. The rotational evaluation includes the overall N balance in relation to the N input, the nitrogen efficiency of applied N inputs, potential N fertiliser savings, rotational gross margins and rotational pest, disease and weed infestation risks.

Rotational nitrogen balances

To ensure a sufficient N supply on the level of crop rotations, the contribution of each CPA to the overall N balance of a full rotation was assessed.

The N balance in relation to the total N input (N_{BI}) of full rotations was calculated as:

(17) $$N_{BI} = sumN_{balance} / sum(N_{fix} + N_m + N_s + N_{fert})$$

Rotations with an N_{BI} between -10% and 10% were regarded as 'balanced', rotations below -10% and above 10% were regarded as 'unbalanced' in terms of N supply.

The nitrogen utilisation rate or N efficiency (N_{eff}) of the N output in relation to the N input of organic and mineral N fertiliser and N in seed was calculated as:

(18) $$N_{eff} = sumN_{remov} / sum(N_m + N_s + N_{fert})$$

Aggregation of single evaluation results for whole rotations

Following the key-and-lock principle, single CPAs are linked using the codes for the precrop demand and supply, nurse crop demand and supply, region and site class (Figure 2). In the case where more than one CPA was suitable to be linked, rotations were duplicated to allow all possible options of CPAs in one rotation. This increased the total number of evaluated rotations.

Gross margins, nitrogen balances and pest, diseases and weed infestation risk of individual CPAs were then aggregated for crop rotations (using the key-and-lock principle) by calculating the mean value of all involved CPAs over the rotation. The N balance in relation to the N input (N_{BI}) is calculated by dividing the sum of all single N balances of the rotation and dividing it by the sum of the N inputs. The nitrogen efficiency (N_{eff}) of the N output in relation to the N input from external sources (excluding N_2-fixation) is calculated by the sum of the N removal divided by the sum of N inputs from external sources.

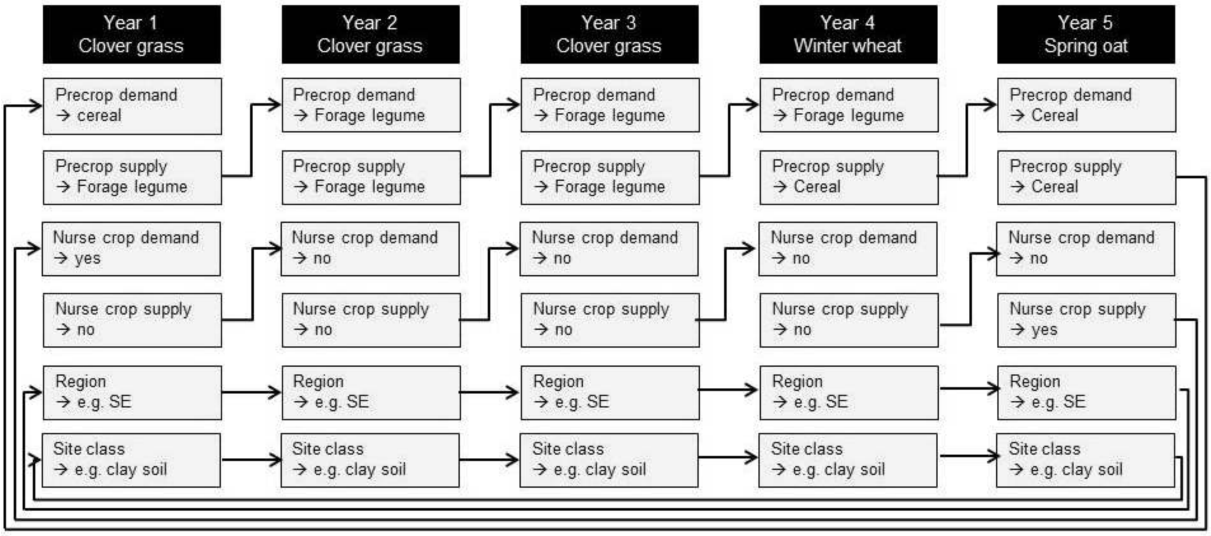


Figure 2: Aggregation of single CPA to whole (generated) crop rotations using specific CPA that are coded with their 'precrop demand', 'precrop supply', 'nurse crop demand', 'nurse crop supply', region and site class.

Description of the case study regions

The assessment approach has been applied in five case study regions across Europe with diverse and contrasting cropping systems covering the major agro-climatic zones from the Nemoral to the Mediterranean zone and from the Atlantic to the Continental South are included (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

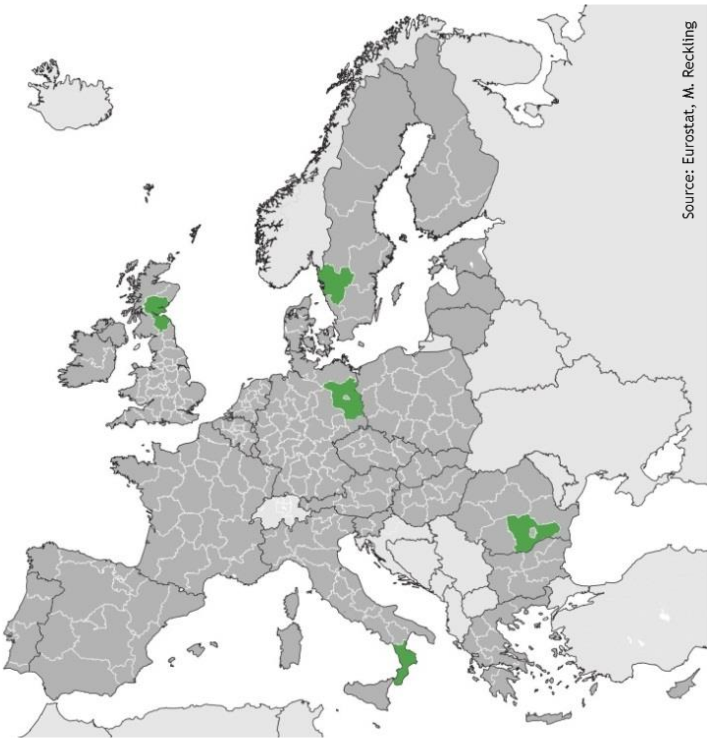


Figure 3: Selected case study regions across Europe

Case study regions were selected because of their contrasting bio-physical and socio-economic conditions and the availability of agronomists with experiences and access to legume and cropping system specific data (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

In Sweden, the clay soil types of Västra Götaland were selected as it represents one of the major cropping areas with both arable and mixed farms. In Eastern Scotland, the soil grades from 1 to 5 were selected. Although, mixed cropping is common across all grades except 4, arable cropping is concentrated on grade 1 to 3 and forage/grassland on grade 3 and 4. In Brandenburg (Germany), five common soil classes were selected. Mixed cropping is common across the classes but a concentration of profitable arable crops is found on class 1 to 3. Class 5 represents very marginal and sandy soils. In Romania, the Chernozem soils of Sud-Muntenia were selected representing one of major cropping areas of medium and large scale farms. Here the application concentrates on pure arable farms and excludes forage production. In Calabria (Italy), three site classes were distinguished (two irrigated and one rainfed). One irrigated and the rainfed site is located in the lowland with arable and forage crops. The other irrigated site is located in the highland that is characterised by potato cultivation in all crop rotations. Annex 3 provides an overview of the crops studied per site class and region.

Table 9: Stratification of selected case study regions across Europe

Agro-climatic zone	Country, NUTS region	NUTS2 code	Researc h institute	No. of site classes	Area covered by site classes
Nemoral	Sweden, Västra Götaland	SE23	SLU	1	50%
Atlantic	Scotland, Eastern	UKM2	SRUC	4	66%
Continental North	Germany, Brandenburg	DE41, DE42	ZALF	5	99%
Continental South	Romania, Sud-Muntenia	RO31	NARDI	1	42%
Mediterranean	Italy, Calabria	ITF6	UDM	3	58%

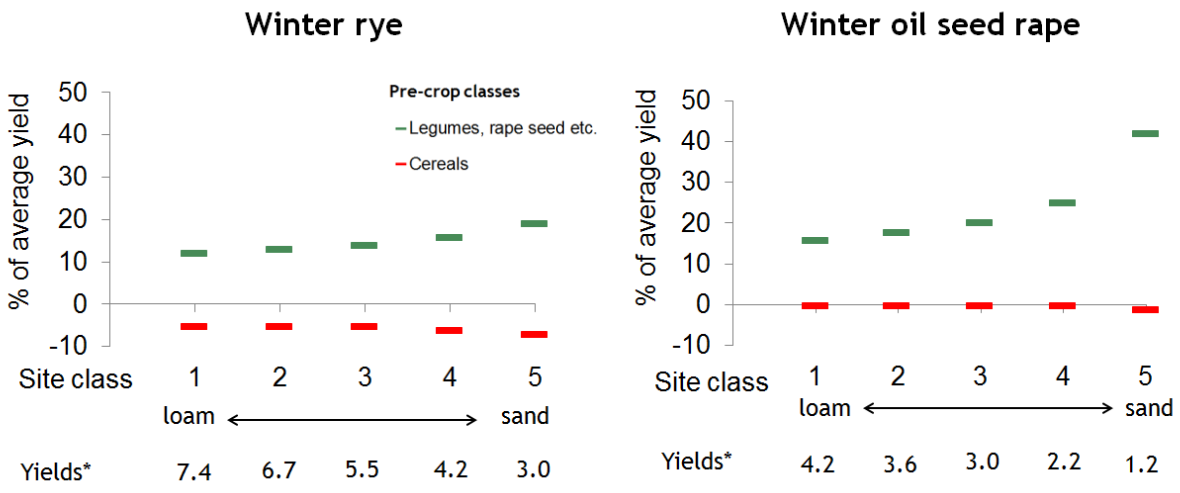
Data source

In each of the five case study regions a structured survey was conducted in the years 2012-2013 to obtain crop production data on pre-crop and site specific crop management and crop rotation rules. Data was collected for all common non-legume crops and agronomical suitable legumes. Statistical data from official statistics was the basis of information and has been complemented by expert knowledge. Two to four experts were consulted in each region and each one had >5 years of experience in applied agronomy with special competence in legume cropping systems and crop rotations.

Crop production activities (CPA)
The crop production data includes crop, pre-crop and site specific production activity (CPA) (Annex 4). Each CPA begins with stubble tillage and ends with the last harvest measure and differs in terms of pre-crop, site, fertilisation, tillage, harvesting method and other differences in crop management. Each CPA is labelled with different codes allowing for the aggregation of single CPAs for whole crop rotations (0).

Pre-crop effects
A special emphasis of the survey was on the pre-crop effects of all crops that affect the management activity of the subsequent crop. Considered pre-crop effects were the effect on yield (e.g. shown in Figure 4), fertilisation and the effect on agro-chemical applications. N fertilizers can potentially be saved in succeeding crops either leading to lower fertiliser applications or higher yields with the same amounts of N fertiliser inputs. The latter was perceived to be more applicable to the farmers' decision making and therefore followed when data was collected in the survey. Such information was not available from official statistics and therefore derived from other sources that included primary data from long-term field experiments (including

unpublished data), scientific literature and expert knowledge.



* Average yields from regional statistics 2003-2009 (LELF 2010)

Figure 4: Preceding crop effect caused by different preceding crop types on winter rye and winter oil seed rape in the case study region Brandenburg (Germany).

Limitations of the data

The limited available information on legume crop management and pre-crop effects was the greatest challenge for the data collection and presents some uncertainty of this data. However, this information is extremely important in assessing the multiple ecological and economic services of legume crops. Therefore, the collected information was checked for plausibility by a group of agronomist and economists and against available scientific literature.

In Romania, no data was collected for animal production systems and forage crops and economic data was difficult to obtain. Therefore, the data includes only a limited number of arable crops. In Italy, the case study region is stratified into three site classes with different bio-physical and socio-economic conditions. The generation of rotations and N-assessment considers these differences. However, the defined CPAs do not capture differences of site conditions.

RESULTS

The results section reports the first application of the assessment approach in the five case study regions across Europe.

Generation of crop rotations

Agronomically feasible crop rotations were generated for all selected case study regions with different proportions of legume crops (**Fehler! Verweisquelle konnte nicht gefunden werden.**). However, on a few site classes no rotations could be generated due to the applied restrictions i.e. not sufficient leaf crops on marginal soils in Brandenburg and the irrigated sites in Calabria to generate rotations without legumes and absence of crops besides grassland on Grade 5 in Scotland. The no. of rotations represent the generated options and do not allow any ranking.

Table 1: Application of the rotation generator in the five case study regions and their different site-classes

Study region	Site-class	No. of generated crop rotations	
		With legumes	Without legumes
Brandenburg (DE)	LBG1	199	28
	LBG2	2370	415
	LBG3	964	242
	LBG4	54	0
	LBG5	11	0
Västra Götaland (SE)	Clay soil	41552	3122
Calabria (IT)	Irrigated-highland	13	1
	Irrigated-lowland	28	0
	Rainfed-lowland	908	10
Sud-Muntenia (RO)	Chernozem	133	4
Eastern Scotland (SC)	Grade 1&2	8802	2212
	Grade 3	8802	2235
	Grade 4	883	225
	Grade 5	0	0

Agronomic and economic evaluation of generated crop rotations

At rotational level, the environmental impacts are compared with the nitrogen output (removal of N in the harvested products) for rotations including legumes and rotations without legumes. The assessment is conducted separately for arable and forage oriented systems. The results in the following sections are shown for selected site classes as examples that are characterised in Table 11.

Table 11: Selected site classes within the case study regions across Europe

Country, region	Site class	Soil type	% of total region
Germany, Brandenburg	LBG2 and LBG3[1]	Loam and sandy clay loam	59
Italy, Calabria	rainfed	Loam	36
Romania, Sud-Muntenia	Chernozem	Chernozem	42
Scotland, Eastern	Grade 3	Cauldside/Whitsome/Darvel/Hobkirk	40
Sweden, Västra Götaland	clay soil	Silty clay loam	50

[1] LBG2 for arable and LBG3 for forage oriented rotations

Nitrate leaching

Comparing the N leaching with the nitrogen output in forage oriented systems, clover-grass compared to pure grass based rotations in Eastern Scotland and Västra Götaland has comparable N outputs (Figure 5), with reduced N leaching in Eastern Scotland (16% across all sites) and a slightly increased N leaching in Västra Götaland. In Brandenburg, silage maize based rotations (the most common forage crop) are compared with forage legume rotations (clover-grass or alfalfa). Rotations with forage legumes increase the N output by on average 50 kg N ha^{-1} a^{-1} and reduced N leaching by 12-18 kg N ha^{-1} a^{-1} for the selected site. Across all sites, the increase in N output is on average 16% with decrease of N leaching of 24%. In the current farming practise in Calabria, most forage crops are legumes (Sulla, clover and alfalfa) and therefore only few rotations without legumes can be used for comparisons. There is a tendency for higher N output in rotations with forage legumes (sulla and clover) but without a reduction of N leaching. In Sud-Muntenia, no forage oriented systems were studied.

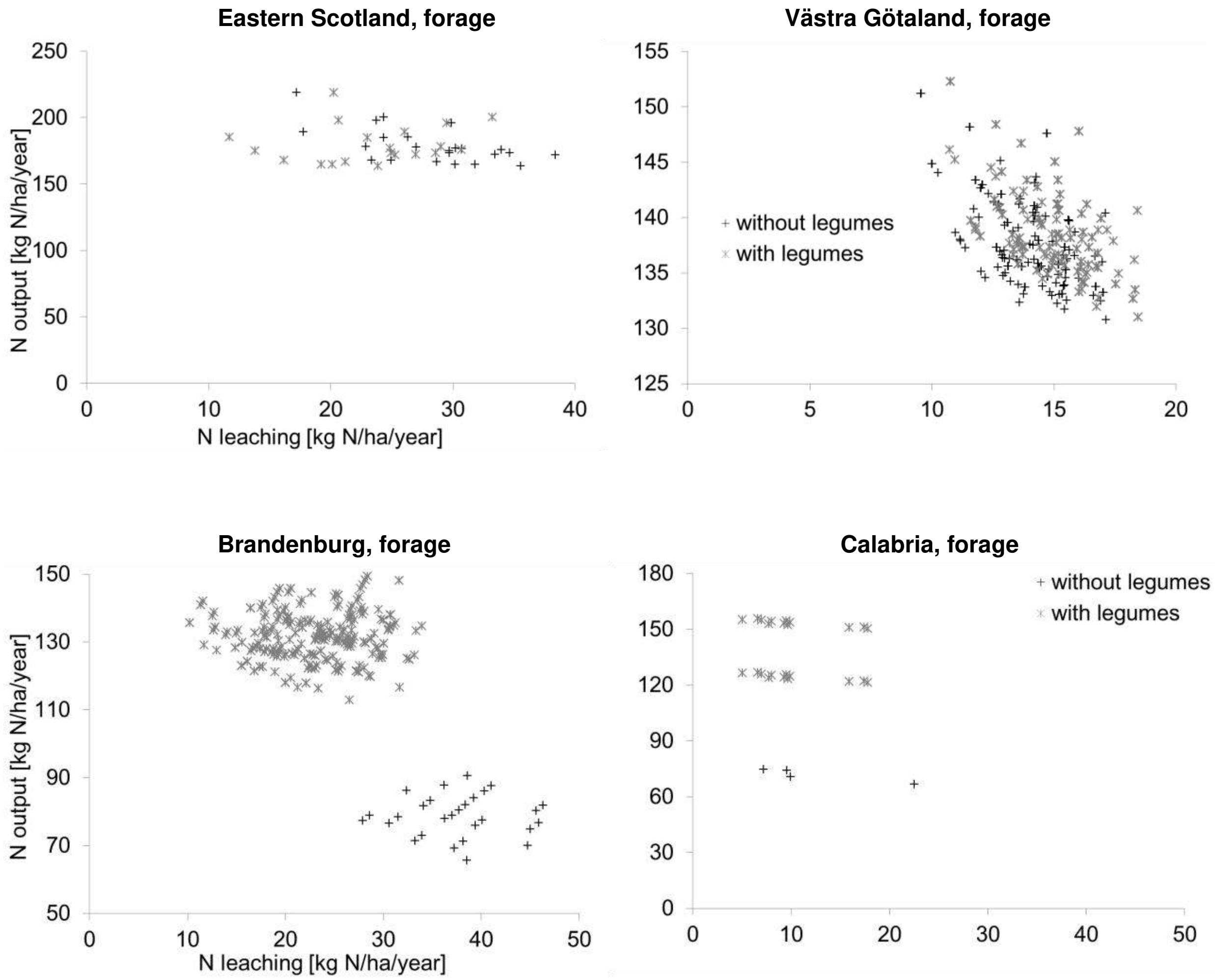


Figure 5: Nitrate leaching plotted against the nitrogen output of generated crop rotations with and without legumes in forage oriented systems in Eastern Scotland, Västra Götaland, Brandenburg and Calabria

In Västra Götaland, Eastern Scotland, Brandenburg and Sud-Muntenia, grain legumes in arable rotations have a higher N output compared to similar rotations without legumes (Figure 6). In Brandenburg legume-supported rotations have the largest N output due to the higher share of leaf crops. Because of the underlying phytosanitary restrictions of the different crop types rotations with legumes allow for a higher portion of leaf crops within the generated rotations and these have a higher N output.

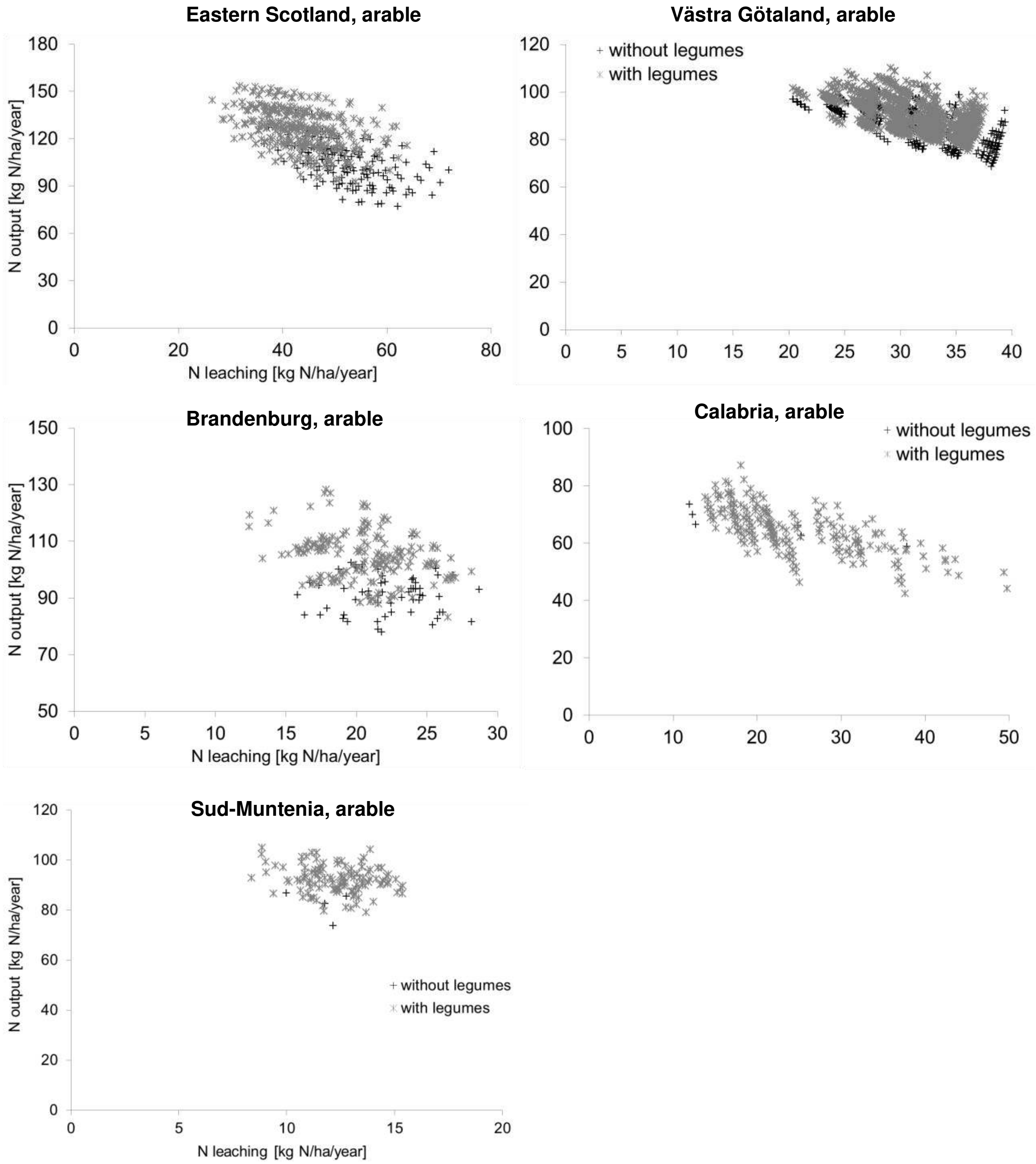


Figure 6: Nitrate leaching plotted against the nitrogen output of generated crop rotations with and without legumes in arable oriented systems in Eastern Scotland, Västra Götaland, Brandenburg, Calabria and Sud-Muntenia.

In Eastern Scotland and Västra Götaland, legume-containing rotations with a comparable or slightly higher N output reduce N leaching. However, this effect is not noticed if the averages of both systems are compared. In Brandenburg, N leaching is slightly reduced in comparable rotations (on average by 10% across all sites). In Calabria where grain legumes are common in current crop rotations, only few rotations without legumes could be generated which limit the comparison. Here on average, most of the legume-containing rotations had a higher N leaching compared to the few rotations without legumes. This can be explained by the relatively large inputs of N_2-fixation in the legume-supported rotations and the generally low application of N fertilizers to non-legume crops. In Sud-Muntenia, the comparison is also limited due to the few rotations without legumes. Legume-supported rotations have a higher N output compared to the few rotations without legumes and some rotations have higher, others a lower N leaching.

Nitrogen balance

Under all management and site conditions, the calculations for forage legumes show the most positive N balances with on average 176 kg N ha^{-1} a^{-1}. For grain legumes, the N balance was neutral or slightly positive. Cereals crops have positive and negative N balances depending on the yield and fertilization. At crop rotation level, positive N balances of forage legumes compensate for negative balances of non-legume crops, leading to neutral or positive rotational N balances.

The rotational N balance as an index (N output/N input) is used to compare the sustainability of rotations with and without legumes. Negative values indicate that the N output from the system exceeds the N input. In that case, the sustainability of the system is at risk and it is an indication for declining yields. In forage oriented rotations in Eastern Scotland, Västra Götaland and Brandenburg the rotational N balance is positive and only negative in Calabria. In all case study regions, rotations with legumes increase the N balance by 37-92% except in Eastern Scotland (here both systems have comparable rotational N balances). In arable oriented rotations, a large share of rotations is negative in Calabria, Eastern Scotland and Sud-Muntenia. Rotations with legumes increase N balances when two similar rotations are compared.

Phytosanitary risks
The assessment of pests, diseases and weeds shows large variations between regions and across rotations and is influenced by the indicators (Table 3) selected by the experts responding to the survey.

Forage oriented rotations in Brandenburg on average increase the infestation risk of pests and weeds and decrease the infestation risk of diseases. However, compared to rotations without legumes, rotations with legumes have a lower infestation risk of pests, diseases and weeds respectively i.e. the infestation risk with the perennial weed couch grass (*Elymus repens* L.) is lower in forage oriented rotations (clover and alfalfa based) with scores between -0.4 and 0.4 (Figure 9) compared to silage maize based rotations (scores between 0.2 and 1.5). Pest infestation with cereal nematodes is also lower in forage oriented rotations. In arable rotations with and without legumes weeds and pests increase for a large share of the generated rotations. However, around 18 rotations with legumes reduce the infestation of cereal nematodes (scores between 0 and -0.4).

In Västra Götaland, clover-grass based rotations reduce on average the infestation risk of pests and diseases compared to pure grass based rotations that increase the infestation risk. The infestation risk with cereal nematodes reduces in forage oriented rotations with scores for grass-clover between 0 and -1 compared to pure grassland based rotations with scores between 0 and 1 (Figure 9). In the arable oriented rotations with grain legumes and without oat, the infestation risk of cereal nematodes also reduces. Rotations that increase cereal nematodes also increase weed infestation with couch grass. There is no difference between rotations with and without legumes concerning weed infestation.

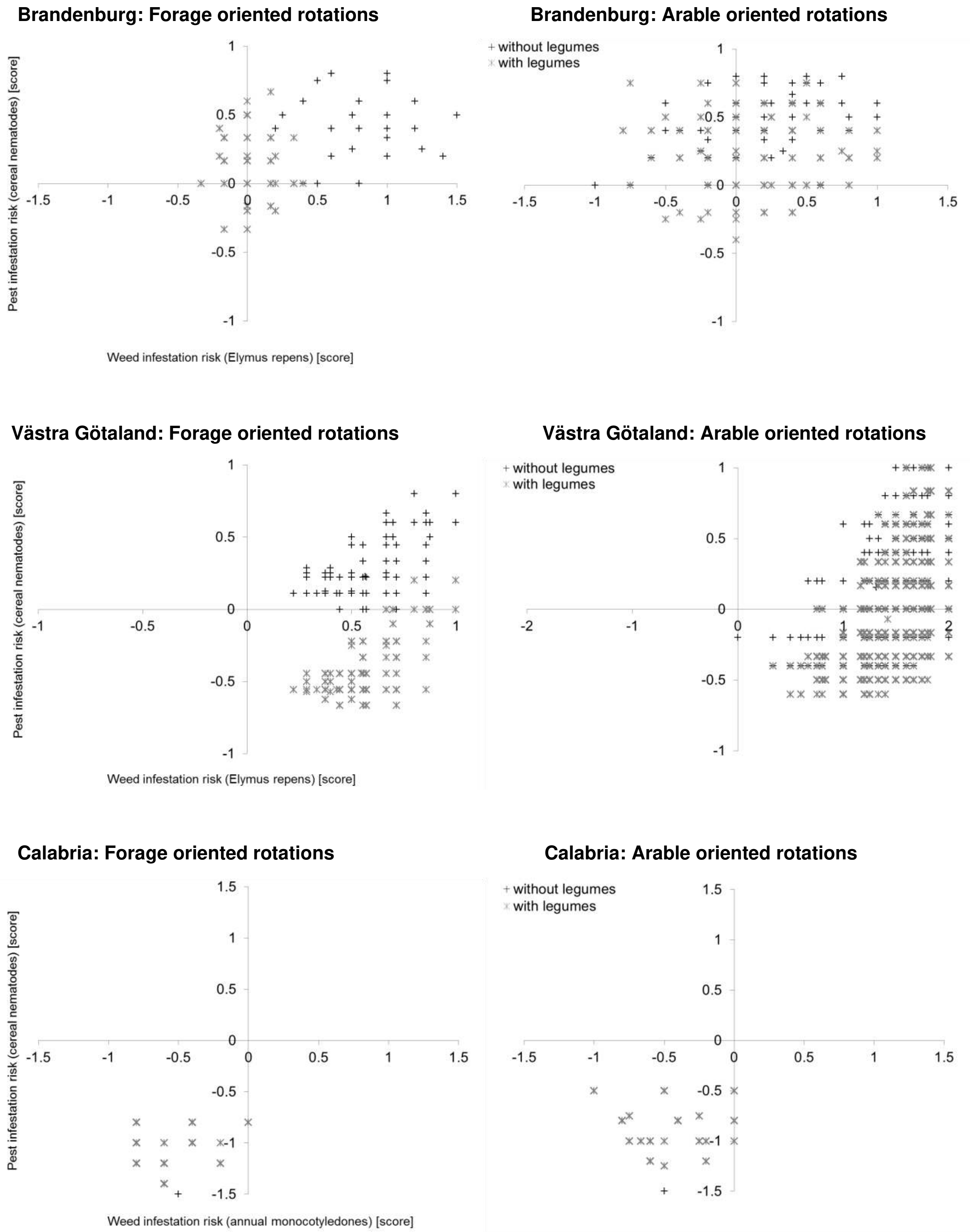


Figure 9: Weed infestation risk (*Elymus repens* L. and annual monocotyledons) plotted against pest infestation risk (cereal nematodes) for forage and arable rotations with and without legumes in Brandenburg, Eastern Scotland and Calabria. Negative scores indicate a reduction and positive values an increase of the

infestation risk with a score from -2 to 2.

In Calabria, all generated rotations reduce the infestation of cereal nematodes and annual monocotyledons (*Phalaris canariensis* L., *Avena sterilis* L., *Cynodon dactylon* Pers.). Seven arable and four forage oriented rotations without legumes had the same scores. A comparison between rotations with and without legumes is not possible due to the limited number of generated rotations.

In arable-oriented rotations in Sud-Muntenia, pest infestation risk increases (group of pests) by all rotations with scores between 1 and 1.5 (Figure 10). Weed infestation risk (group of species) increases by most rotations with scores between -0.3 and 1.2. Few rotations with and without legumes slightly reduce the infestation risk. However, it is unclear what pests and weeds are behind these groups. In Eastern Scotland, data were insufficient for the phytosanitary risk assessment.

Sud-Muntenia: Arable oriented rotations

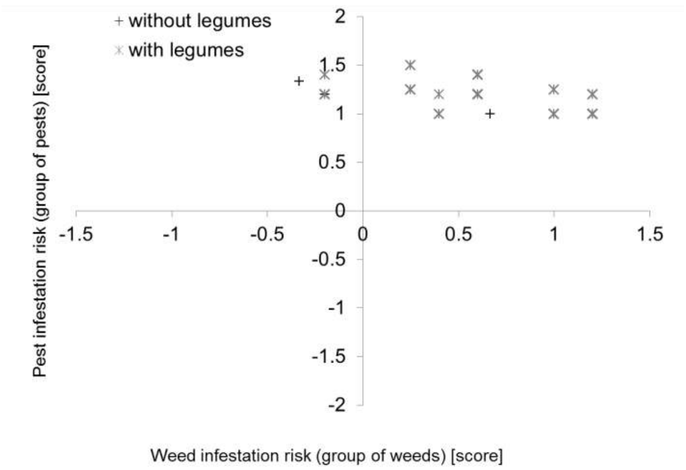


Figure 10: Weed infestation risk (group of weeds) plotted against pest infestation risk (group of pests) for arable rotations in Sud-Muntenia with and without legumes. Negative scores indicate a reduction and positive values an increase of the infestation risk with a score from -2 to 2.

Economic evaluation

Grain legumes have a lower economic performance when compared against other crops such as winter wheat and when not evaluated at the level of whole crop rotations. This is mainly caused by lower yields but comparable production costs, leading to low and often negative gross margins. Prices for grain legumes are comparable or slightly higher but do not compensate for lower yields. Gross margins (without labour costs) range between -366 € ha^{-1} in Germany for lupins and 668 € ha^{-1} in Italy for lupins. In Germany, prices for grain legumes range between 102 € t^{-1} for pea and 182 € t^{-1} for faba bean whereas prices for winter wheat are 165 € t^{-1}. In

Eastern Scotland, Västra Götaland and Sud-Muntenia, grain legumes have higher gross margins compared to Brandenburg and Calabria. In Calabria, the gross margin is negative for faba bean and pea due to very low yields and low prices whereas yields and prices for lupin (grown in another site class) are much higher, resulting in high gross margins. Table 13 shows economic relevant data for selected grain legumes across the regions.

Table 13: Economic evaluation of grain legumes across the case study region

Country	Site class	Crop	Yield (t ha^{-1})	Price (€ t^{-1})	Revenues (€ ha^{-1})	Variable costs (€ ha^{-1})	Gross margin (€ ha^{-1})
Brandenburg	LBG2	faba bean	4.00	102	408	730	-322
Brandenburg	LBG2	lupin	2.50	150	375	679	-304
Brandenburg	LBG2	pea	3.00	182	545	750	-204
Calabria	irrigated_1	lupin	2.50	400	1000	573	427
Calabria	irrigated_2	faba bean	1.60	250	400	560	-160
Calabria	irrigated_2	pea	1.20	260	312	487	-175
Sud-Muntenia	Chernozem	pea	3.50	325	1138	828	310
Eastern SC	Grade 3	faba bean	5.00	197	986	701	285
Eastern SC	Grade 3	pea	4.00	240	960	714	246
Västra Götaland	clay soil	faba bean	3.10	168	521	397	124
Västra Götaland	clay soil	pea	3.00	207	621	455	166

Gross margins of winter wheat grown after cereals, range across all sites from 147 to 763 € ha^{-1}. When the yield benefit of legumes for succeeding cereals is taken into account, the gross margin of cereal crops and the rotational gross margin is higher. Gross margin of winter wheat grown after grain legumes or rapeseed ranges from 322 to 868 € ha^{-1} (selection shown in Table 14). The additional gross margin for winter wheat grown after grain legumes/other break crops compared to a cereal pre-crop ranges from 106 to 188 € ha^{-1} (296 € ha^{-1} in Romania were pre-crop types differ from the other sites and do not allow direct comparisons). Cereals grown after forage legumes profit from the highest pre-crop effect. The additional gross margin of winter wheat grown after forage legumes ranges from 116 to 301 € ha^{-1}.

Table 14: Gross margins of winter wheat grown after cereals and legume pre-crops

Country	Site class	Pre crop type	Yield (t ha-1)	Price (€ t-1)	Revenues (€ ha-1)	Variable costs (€ ha-1)	Gross margin (€ ha-1)	Additional gross margin (€ ha-1)
Brandenburg	LBG2	cereal	5.7	165	942	779	162	0
Brandenburg	LBG2	grain legume	6.8	165	1123	801	322	160
Brandenburg	LBG2	forage legume	6.8	165	1123	801	322	160
Calabria	highland	cereal	3.2	250	800	626	175	0
Calabria	highland	grain legume	3.5	250	875	530	345	171
Calabria	highland	forage legume	3.6	250	900	530	370	196
Eastern SC	Grade 3	cereal	7.5	186	1395	986	409	0
Eastern SC	Grade 3	grain legume	8.0	186	1488	973	515	106
Eastern SC	Grade 3	forage legume	8.0	186	1488	963	525	116
Västra Götaland	clay soil	cereal	6.1	188	1147	645	501	0
Västra Götaland	clay soil	grain legume	7.1	188	1335	645	689	188
Västra Götaland	clay soil	forage legume	7.7	188	1448	645	802	301
Sud-Muntenia	Chernozem	cereal	3.6	232	835	688	147	0
Sud-Muntenia	Chernozem	grain legume	5.0	232	1160	717	443	296

The rotational gross margins of arable rotations with grain legumes in Brandenburg, Västra Götaland and Calabria are lower compared to rotations without legumes. The average gross margin deficit is -27, -36 and -121 € ha^{-1} a^{-1} in Brandenburg, Västra Götaland and Calabria, respectively. In Eastern Scotland, there is no average gross margin deficit across the rotations with and without legumes. In Sud-Muntenia, rotations with grain legumes (especially common bean for food consumption) have higher rotational gross margins compared to comparable rotations without legumes. The economic relevance of crop rotations with and without legumes at the farm level for specific farm types including forage and arable oriented rotations are reported in Legume Futures report 4.3.

Selection of crop rotations

A set of generated crop rotations are selected for the modelling performed with DNDC (DeNitrification-DeComposition, a computer simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems) and MAC (Marginal Abatement Cost). The selection identified agronomically sound and economically best performing rotations (Annex 5). The set include four rotations per site class and study region, one rotation with and without legumes, each forage and arable oriented.

The following selection criteria were applied:

1. The selection is restricted to balanced rotations in terms of N supply and demand (N_{BI}>-10% and <10%), except in Calabria, where no balanced rotations are available.
2. For rotations with forage crops, the selection is restricted to the rotations that produce forage crops at lowest cost (minimum C_{FOR}).
3. The remaining rotations are filtered to the rotations with the highest gross margins (up to 25 € less than the maximum GM).
4. From the remaining, the rotations with the highest N efficiency calculated as N_{eff} are selected.

Table 15 shows an exemplary selection of arable legume-supported crop rotations for Brandenburg (site class: LBG2). From a total number of 249 crop rotations the rotations with the highest gross margin (25 € less than the maximum) are shown. The rotation rapeseed – triticale – faba bean – winter wheat – spring barley (ID 1367) is selected in this example due its high rotational gross margin of 106 € ha^{-1} a^{-1} (<25 € less compatible then the most profitable rotation (ID 1368) with a gross margin of 129 € ha^{-1} a^{-1} and the highest nitrogen efficiency (Neff) of 1.09.

Table 15: Arable oriented rotations with legumes in Brandenburg (site class: LBG2) with the highest gross margins for systematic a selection

ID	Year 1	Year 2	Year 3	Year 4	Year 5	Rotation gross margin (€ ha^{-1})	Rotation efficiency (Neff score)
1368	wrape	tritica	pea	wwheat	sbarley	129	0.95
1216	wrape	wwheat	sbarley	tritica	pea	128	0.94
1169	wrape	wwheat	wrye	sbarley	pea	122	0.96
1212	wrape	wwheat	sbarley	wrye	pea	122	0.96
1225	wrape	wrye	pea	wwheat	sbarley	120	0.97
1159	wrape	wwheat	wrye	wrye	pea	111	1.07
1448	wrape	tritica	sbarley	wrye	pea	108	0.98
1202	wrape	wwheat	sbarley	pea	wbarley	107	0.95
1365	wrape	tritica	pea	wwheat	wbarley	107	1.03
1458	wrape	wbarley	pea	wwheat	sbarley	107	0.95
1248	wrape	wrye	pea	tritica	sbarley	106	1.00
1367	**wrape**	**tritica**	**fababea**	**wwheat**	**sbarley**	**106**	**1.09**
1379	wrape	tritica	pea	wrye	sbarley	106	1.00
1359	wrape	wrye	sbarley	tritica	pea	105	0.99

DISCUSSION

Legume crops have positive rotational effects (e.g. Köpke and Nemecek 2010) that need to be evaluated at rotational level. Crop rotations were therefore generated according to agronomic criteria that resulted in agronomic sound systems with a large diversity of crop rotations. These rotations are currently not used in practice but allow the evaluation of a large set of options not restricted by current land use practices (economic trends, policy interventions etc.). A range of tools for generating crop rotations have been developed (e.g. Schönhart et al. 2011, Bachinger and Zander 2007, Dogliotti et al. 2003), but the generator described here provides more flexibility to deal with a variety of cropping restrictions and transparency of the model functions (allowing interaction with crop science experts).

The reduction in the use of mineral N fertilizers in legume-supported rotations due to biological N_2-fixation is the main resource benefit. This reduces greenhouse gas emissions. The analysis shows that rotations with grain legumes and those with perennial forage legumes save on average 21 and 45 kg N ha^{-1} a^{-1} of mineral N fertilizers, respectively with at the same time higher N outputs and thus higher protein production. The absence of mineral N fertilizer use in the year of the legume crop, the need of N fertilizer were reduced in subsequent crops or yields in subsequent crops were increased at the same amount of N fertilizers highlighting an increased N efficiency caused by nitrogen residues, improved rootability and improved phytosanitary status (break crop effect). Nitrogen efficiency plays a key role from the environmental perspective since it is among the main elements in eutrophication of water bodies. N efficiency and a positive contribution to the rotational N budget are largest in rotations with forage legumes.

Although legumes are generally considered to increase the risk of NO_3-leaching especially in the post-harvest period (Peoples et al. 2009b), the results from the presented assessment at rotational level indicate comparable or lower leaching rates. This can be explained by the lower overall N fertilizer application rates and an optimal cropping sequence resulting from the generation. Intercropping of grain legumes with cereals reduced nitrate leaching. Catch crops were excluded in the present study since they do not play an important role in the case study regions except Brandenburg according to the results from the expert survey. However, legume cultivation in combination with catch crops could further reduce nitrate leaching.

The phytosanitary risk assessment reveals a potential to reduce the infestation risk of problematic pests, disease and weeds as also reported by Kirkegaard et al. (2008). Lower infestation risk can be explained by the break crop effect of legumes that can reduce the infestation with pests, disease and weeds especially in cereal-dominated rotations (Kirkegaard et al. 2008). Thus, rotations evaluated with a reduced infestation risk, indicate agronomically more sustainable systems with a potentially lower pesticide need that is not considered in the current economic evaluation. However, the static approach of averaging the infestation risk across rotations does not allow for dynamic infestation effects of different crop sequences. These effects are partially taken into account through the phytosanitary frequency and sequence restrictions applied in the crop rotation generator.

Although single legume crops have low gross margins across all regions except for common bean in Sud-Muntentia, the economic performance at rotational level shows a different picture. Gross margin deficits of rotations including legumes are indicated only for three out of the five regions. In the other two regions, the farm-level economic performance of rotations with legumes is comparable or higher than rotations without legumes. The main reasons for low gross margins of grain legumes remain the low yields compared to alternative crops combined with prices and costs that are comparable to cereals. The positive pre-crop and break-crop effect increases the economic performance of subsequent crops and at the same time leads to positive agronomic impacts such as resource efficiency and lower infestation risks of problematic pests, disease and weeds.

The analysis shows that the pre-crop yield effect has high implications for the economic and agronomic assessment. A quantification of this effect is difficult due to the lack of available data and the complexity of the underlying processes, and therefore depends on expert judgements and modelling. The yield effects provided by the experts in the survey were comparable to data reported in the literature (e.g. Köpke and Nemecek 2010, Kirkegaard et al. 2008).

Legumes in crop rotations have also positive impacts on environmental indicators that were not studied in this assessment including biodiversity, flowering and reductions of N_2O emissions. N_2O emissions were assessed using this modelling approach for Legume Futures report 1.6. For biodiversity and flowering adequate rules still need to be defined to include these into a rule-based assessment.

The analysis shows that legumes have the potential to produce biomass for food, feed and biofuels in various crop rotations and at the same time to increase the sustainability of the agro-ecosystems. The research makes clear that the agronomic and economic performance of legumes is only adequately evaluated when all rotational effects are taken into account. However, in order to utilize the positive agronomic and environmental benefits, the remaining gross margin deficit of legumes should be compensated or further improved e.g. with the development of new value chains and markets, improvements in agronomy and breeding. To foster legume cultivation, agronomic research needs to focus on increasing yields, yield stability, quantification of the pre-crop effect and the development of novel cropping systems.

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ANNEX 1: Soil and weather characteristics per case study and site-class

Region	site	%sand	%silt	%clay	Corg (% C in DM)	C:N ratio	Bulk density topsoil (g/cm³)	depth of top soil layer (cm)	annual mineralisation rate (%)	precrop yield effect[2]	water holding capacity in the root zone (mm)	annual precipitation (mm)	precipitation in winter (mm)	N_{org}	Leaching probability (L_P)
BB	LBG1	40	35	25	0.90	11.0	1.5	30	1.8	0.45	320	510	220	3682	0.69
BB	LBG2	50	25	25	0.74	11.0	1.5	30	1.8	0.60	180	510	220	3027	1.00
BB	LBG3	70	15	20	0.63	11.0	1.5	30	1.8	0.65	130	510	220	2577	1.00
BB	LBG4	80	10	10	0.56	11.0	1.5	30	1.8	0.75	100	510	220	2291	1.00
BB	LBG5	85	5	10	0.51	11.0	1.5	25	1.8	0.80	56	510	220	1739	1.00
IT	Irrig. highland	60	20	20	0.76	6.8	1.1	50	1.3	0.65	110	1000	750	6193	1.00
IT	Irrig. lowland	61	24	14	0.87	11.0	1.3	30	1.3	0.65	120	800	500	3085	1.00
IT	Rainfed	47	31	23	1.04	11.0	1.2	30	1.3	0.65	150	700	450	3262	1.00
RO	Chernozem	65	17	18	1.04	12.0	1.3	40	1.6	0.60	400	515	96	4507	0.24
SC	Grade 1&2	78	8	14	3.00	12.5	1.5	30	0.5	0.60	88	809	426	10800	1.00
SC	Grade 3	68	15	17	2.54	15.0	1.4	30	0.7	0.60	91	809	426	7061	1.00
SC	Grade 4	65	20	15	4.55	11.3	1.3	30	0.3	0.60	94	809	426	15100	1.00
SC	Grade 5	65	20	15	4.55	11.3	1.3	30	0.3	0.60	94	809	426	15100	1.00
SE	Clay soil	17	50	33	2.30	11.0	1.3	30	1.2	0.45	145	145	224	7339	0.40[1]

[1] L_P could not be calculated for this site adequately with the implemented function; therefore a default value of 0.4 was assumed (Bergkvist personal communication)
[2] precrop yield effect between low (cereals) and high (legumes, leaf crops) in % low e.g. for poor sandy soils +80% and loess +10%

ANNEX 2: Phytosanitary risk assessment for all legume crops and selected non-leguminous crops across case studies

Crop	Germany, Brandenburg			Italy, Calabria			Romania, Sud-Muntenia			Sweden, Västra Götaland		
Legume crop	P	D	W	P	D	W	P	D	W	P	D	W
Faba bean	-1	-1	0	0	0	-1				-1	-2	1
Pea	-1	-1	1	0	0	-1	1	-1	2	-1	-2	2
clover-grass (mixture)	0	0	0							-1	-1	0
Lupin	-1	-1	0	0	0	-1						
Alfalfa (sole)	0	0	0	0	0	-2						
Clover (sole)				0	0	-2						
Common bean							1	-1	2			
Soybean							2	1	2			
Sulla				0	0	-2						
Pea-oat (SE), vetch-oat (IT)				-1	0	-1				2	1	2
Grass										0	0	0
Silage maize	0	-1	2	-1	0	-1				0	-1	2
Winter rapeseed	-1	-1	-1	-2	0	0	1	2	-2	-1	-2	-1
Winter wheat	1	2	2	-1	0	-1	1	2	2	0	2	2

P = pest, D = disease, W = weeds (see region specific characterisation in Table 9)

ANNEX 3: Case study regions and site-classes and the distribution of studied crops

Region	Västra Götaland, Sweden	Eastern Scotland				Brandenburg North-East and South-West, Germany					Sud-Muntenia, Romania	Calabria, Italy		
NUTS2	SE23	UKM2				DE41 and DE42					RO31	ITF6		
Institute	SLU	SRUC				ZALF					NARDI	UDM		
Subtype	Clay soil	Grade1 &2	Grade3	Grade4	Grad e5	LBG5	LBG4	LBG3	LBG2	LBG1	Chernozem[5]	Irrigate highland	Irrigate lowland	Rainfed
Arable non-legume crops	linseed silage maize spring barley spring oat spring wheat spring oil seed rape winter rye winter oil seed rape winter triticale winter wheat grass	spring barley winter barley swedes s/w oat potato spring rape winter rape spring wheat winter wheat	spring barley winter barley swedes potato spring rape winter rape spring wheat winter wheat s/w oat grass	spring barley swedes spring oat spring rape winter rape spring wheat winter wheat winter oat grass	grass	winte r rye	winter rye silage maize	winter wheat winter rye winter rape silage maize oats spring barley	winter wheat winter rye winter barley triticale winter rape silage maize oats spring barley	winter wheat winter rye winter barley triticale winter rape silage maize	winter wheat oil seed rape maize, grain sunflower winter barley	oil seed rape potato soft wheat	barley durum wheat maize oat soft wheat triticale	barley durum wheat oat oil seed rape soft wheat triticale
Grain legumes	faba bean pea pea/oat	pea faba bean	pea faba bean	pea faba bean	-	lupin rye/ vetch	pea lupin	pea lupin	pea lupin faba bean	faba bean	pea comm. bean soy bean	lupin	pea faba bean	faba bean oat/vetch pea
Forage legumes	grass-clover	-	-	grass-clover	grass-clover	serra della	grass-clover	grass-clover alfalfa	grass-clover alfalfa	grass-clover alfalfa	-	alfalfa clover	alfalfa	clover sulla

ANNEX 4: Crop production activities for the case studies Brandenburg (DE), Västra-Götaland (SE), Calabria (IT), Sud-Muntenia (RO) and Eastern Scotland (UK), selection

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
							by-product	main product				no labour	with labour	N	P	K	N	P	K
BB	LBG1	alfalfa	cereal	24.7	39	0.35	0	962	658	9	15	304	167	0	27	233	0	0	0
BB	LBG1	alfalfa	foragelegume	24.7	39	0.35	0	962	523	7	15	439	330	0	27	233	0	0	0
BB	LBG1	barley	cereal	6.7	139	0.86	0	932	855	4	15	77	13	92	24	33	0	0	0
BB	LBG1	barley	foragelegume	8.1	139	0.86	0	1127	898	4	15	229	164	146	29	41	0	0	0
BB	LBG1	barley	leafcrop_grainlegume	8.1	139	0.86	0	1127	898	4	15	229	164	146	29	41	0	0	0
BB	LBG1	faba bean	Cereal	4.5	102	0.86	0	459	751	4	15	-292	-359	0	23	52	0	0	0
BB	LBG1	pea	Cereal	3.5	182	0.86	0	636	770	4	15	-134	-200	0	17	41	0	0	0
BB	LBG1	silage maize	Cereal	34.0	31	0.35	0	1044	892	13	15	151	-41	64	10	0	153	35	26
BB	LBG1	silage maize	cereal	34.0	31	0.35	0	1044	953	12	15	91	-87	93	10	27	114	20	13
BB	LBG1	silage maize	cereal	34.0	31	0.35	0	1044	988	11	15	56	-104	112	20	71	76	13	9
BB	LBG1	silage maize	foragelegume	38.0	31	0.35	0	1167	894	13	15	273	80	65	10	0	153	35	26
BB	LBG1	silage maize	foragelegume	38.0	31	0.35	0	1167	978	12	15	189	10	94	13	45	114	20	13
BB	LBG1	silage maize	foragelegume	38.0	31	0.35	0	1167	1005	11	15	161	1	113	20	89	76	13	9
BB	LBG1	silage maize	leafcrop_grainlegume	38.0	31	0.35	0	1167	894	13	15	273	80	65	10	0	153	35	26
BB	LBG1	silage maize	leafcrop_grainlegume	38.0	31	0.35	0	1167	978	12	15	189	10	94	13	45	114	20	13
BB	LBG1	silage maize	leafcrop_grainlegume	38.0	31	0.35	0	1167	1005	11	15	161	1	113	20	89	76	13	9
BB	LBG1	triticale	cereal	6.7	157	0.86	0	1050	811	4	15	239	173	94	24	33	0	0	0
BB	LBG1	triticale	foragelegume	8.1	157	0.86	0	1269	855	4	15	414	347	105	29	41	0	0	0
BB	LBG1	triticale	leafcrop_grainlegume	8.1	157	0.86	0	1269	855	4	15	414	347	105	29	41	0	0	0
BB	LBG1	winter oil seed rape	cereal	4.2	310	0.89	0	1301	1003	5	15	298	219	208	34	35	0	0	0
BB	LBG1	winter oil seed rape	leafcrop_grainlegume	4.9	310	0.89	0	1518	1045	5	15	473	393	228	39	41	0	0	0
BB	LBG1	winter rye	cereal	7.2	132	0.86	0	950	810	4	15	140	74	87	25	36	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
BB	LBG1	winter rye	foragelegume	8.6	132	0.86	0	1134	838	4	15	296	230	85	30	43	0	0	0
BB	LBG1	winter rye	leafcrop_grainlegume	8.6	132	0.86	0	1134	838	4	15	296	230	85	30	43	0	0	0
BB	LBG1	winter wheat	cereal	6.9	165	0.86	0	1140	834	5	15	306	235	147	24	35	0	0	0
BB	LBG1	winter wheat	foragelegume	8.2	165	0.86	0	1355	865	5	15	490	419	149	29	42	0	0	0
BB	LBG1	winter wheat	leafcrop_grainlegume	8.2	165	0.86	0	1355	865	5	15	490	419	149	29	42	0	0	0
BB	LBG2	alfalfa	cereal	23.4	39	0.35	0	911	643	9	15	268	131	0	25	221	0	0	0
BB	LBG2	alfalfa	foragelegume	23.4	39	0.35	0	911	507	7	15	404	294	0	25	221	0	0	0
BB	LBG2	barley	cereal	5.6	139	0.86	0	779	772	4	15	7	-53	117	20	28	0	0	0
BB	LBG2	barley	foragelegume	6.8	139	0.86	0	946	807	4	15	139	78	90	24	34	0	0	0
BB	LBG2	barley	leafcrop_grainlegume	6.8	139	0.86	0	946	807	4	15	139	78	90	24	34	0	0	0
BB	LBG2	faba bean	cereal	4.0	102	0.86	0	408	730	4	15	-322	-389	0	21	46	0	0	0
BB	LBG2	lupin	cereal	2.5	150	0.86	0	375	679	4	15	-304	-370	0	15	3	0	0	0
BB	LBG2	oat	cereal	3.8	145	0.86	0	551	581	3	15	-30	-82	84	14	19	0	0	0
BB	LBG2	oat	foragelegume	4.9	145	0.86	0	711	615	3	15	96	44	96	18	25	0	0	0
BB	LBG2	oat	leafcrop_grainlegume	4.9	145	0.86	0	711	615	3	15	96	44	96	18	25	0	0	0
BB	LBG2	pea	cereal	3.0	182	0.86	0	545	750	4	15	-204	-270	0	14	35	0	0	0
BB	LBG2	silage maize	cereal	31.1	31	0.35	0	956	890	13	15	66	-125	61	10	0	153	35	26
BB	LBG2	silage maize	cereal	31.1	31	0.35	0	956	938	12	15	18	-159	87	10	13	114	20	13
BB	LBG2	silage maize	cereal	31.1	31	0.35	0	956	972	11	15	-16	-176	106	20	57	76	13	9
BB	LBG2	silage maize	foragelegume	34.9	31	0.35	0	1070	892	13	15	178	-14	64	10	0	153	35	26
BB	LBG2	silage maize	foragelegume	34.9	31	0.35	0	1070	955	12	15	115	-63	89	11	31	114	20	13
BB	LBG2	silage maize	foragelegume	34.9	31	0.35	0	1070	990	11	15	81	-79	108	20	75	76	13	9
BB	LBG2	silage maize	leafcrop_grainlegume	34.9	31	0.35	0	1070	892	13	15	178	-14	64	10	0	153	35	26
BB	LBG2	silage maize	leafcrop_grainlegume	34.9	31	0.35	0	1070	955	12	15	115	-63	89	11	31	114	20	13
BB	LBG2	silage maize	leafcrop_grainlegume	34.9	31	0.35	0	1070	990	11	15	81	-79	108	20	75	76	13	9
BB	LBG2	spring barley	cereal	4.4	163	0.86	0	717	596	3	15	121	69	97	15	22	0	0	0
BB	LBG2	spring barley	leafcrop_grainlegume	5.1	163	0.86	0	831	618	4	15	214	161	104	18	26	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
BB	LBG2	triticale	cereal	5.6	157	0.86	0	877	776	4	15	102	36	84	20	28	0	0	0
BB	LBG2	triticale	foragelegume	6.8	157	0.86	0	1065	812	4	15	254	188	93	24	34	0	0	0
BB	LBG2	triticale	leafcrop_grainlegume	6.8	157	0.86	0	1065	812	4	15	254	188	93	24	34	0	0	0
BB	LBG2	winter oil seed rape	cereal	3.6	310	0.89	0	1115	961	5	15	154	76	184	29	30	0	0	0
BB	LBG2	winter oil seed rape	leafcrop_grainlegume	4.2	310	0.89	0	1301	1000	5	15	300	221	204	34	35	0	0	0
BB	LBG2	winter rye	cereal	6.5	132	0.86	0	857	789	4	15	68	2	82	23	32	0	0	0
BB	LBG2	winter rye	foragelegume	7.7	132	0.86	0	1016	810	4	15	206	140	78	27	38	0	0	0
BB	LBG2	winter rye	leafcrop_grainlegume	7.7	132	0.86	0	1016	810	4	15	206	140	78	27	38	0	0	0
BB	LBG2	winter wheat	cereal	5.7	165	0.86	0	942	779	5	15	162	93	119	20	28	0	0	0
BB	LBG2	winter wheat	foragelegume	6.8	165	0.86	0	1123	801	5	15	322	253	117	24	34	0	0	0
BB	LBG2	winter wheat	leafcrop_grainlegume	6.8	165	0.86	0	1123	801	5	15	322	253	117	24	34	0	0	0
BB	LBG3	alfalfa	cereal	20.8	39	0.35	0	810	570	9	15	240	104	0	22	197	0	0	0
BB	LBG3	alfalfa	foragelegume	20.8	39	0.35	0	810	434	7	15	375	267	0	22	197	0	0	0
BB	LBG3	barley	cereal	4.3	139	0.86	0	598	684	4	15	-85	-145	59	20	22	0	0	0
BB	LBG3	barley	foragelegume	5.4	139	0.86	0	751	714	4	15	38	-23	64	19	27	0	0	0
BB	LBG3	barley	leafcrop_grainlegume	5.4	139	0.86	0	751	714	4	15	38	-23	64	19	27	0	0	0
BB	LBG3	graclov	cereal	21.1	42	0.35	0	888	669	9	15	219	83	0	25	185	0	0	0
BB	LBG3	graclov	cereal	26.0	42	0.35	0	1092	689	9	15	403	262	0	30	227	0	0	0
BB	LBG3	graclov	foragelegume	21.1	42	0.35	0	888	426	7	15	462	360	0	25	185	0	0	0
BB	LBG3	lupin	cereal	2.1	150	0.86	0	315	615	4	15	-300	-366	0	13	24	0	0	0
BB	LBG3	oat	cereal	2.9	145	0.86	0	421	507	3	15	-86	-138	73	10	14	0	0	0
BB	LBG3	oat	foragelegume	3.9	145	0.86	0	566	537	3	15	29	-23	83	14	19	0	0	0
BB	LBG3	oat	leafcrop_grainlegume	3.9	145	0.86	0	566	537	3	15	29	-23	83	14	19	0	0	0
BB	LBG3	pea	cereal	2.5	182	0.86	0	455	686	4	15	-232	-298	0	12	29	0	0	0
BB	LBG3	silage maize	cereal	26.9	31	0.35	0	825	819	13	15	5	-185	50	10	0	153	35	26
BB	LBG3	silage maize	cereal	26.9	31	0.35	0	825	863	12	15	-38	-219	73	10	0	114	20	13
BB	LBG3	silage maize	cereal	26.9	31	0.35	0	825	884	11	15	-59	-217	92	20	38	76	13	9

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
BB	LBG3	silage maize	foragelegume	30.3	31	0.35	0	930	821	13	15	109	-82	52	10	0	153	35	26
BB	LBG3	silage maize	foragelegume	30.3	31	0.35	0	930	875	12	15	55	-129	75	10	8	114	20	13
BB	LBG3	silage maize	foragelegume	30.3	31	0.35	0	930	898	11	15	32	-127	94	20	53	76	13	9
BB	LBG3	silage maize	leafcrop_grainlegume	30.3	31	0.35	0	930	821	13	15	109	-82	52	10	0	153	35	26
BB	LBG3	silage maize	leafcrop_grainlegume	30.3	31	0.35	0	930	875	12	15	55	-129	75	10	8	114	20	13
BB	LBG3	silage maize	leafcrop_grainlegume	30.3	31	0.35	0	930	898	11	15	32	-127	94	20	53	76	13	9
BB	LBG3	spring barley	cereal	3.3	163	0.86	0	538	516	3	15	21	-31	83	11	17	0	0	0
BB	LBG3	spring barley	leafcrop_grainlegume	3.9	163	0.86	0	636	534	3	15	101	49	88	14	20	0	0	0
BB	LBG3	triticale	cereal	4.3	157	0.86	0	674	639	4	15	34	-28	61	15	22	0	0	0
BB	LBG3	triticale	foragelegume	5.4	157	0.86	0	846	671	4	15	175	112	67	19	27	0	0	0
BB	LBG3	triticale	leafcrop_grainlegume	5.4	157	0.86	0	846	671	4	15	175	112	67	19	27	0	0	0
BB	LBG3	winter oil seed rape	cereal	3.0	310	0.89	0	929	803	5	15	126	54	154	24	25	0	0	0
BB	LBG3	winter oil seed rape	leafcrop_grainlegume	3.6	310	0.89	0	1115	842	5	15	273	200	174	29	30	0	0	0
BB	LBG3	winter rye	cereal	5.3	132	0.86	0	699	666	4	15	33	-30	62	22	27	0	0	0
BB	LBG3	winter rye	cereal	16.7	52	0.45	0	867	490	5	15	377	297	73	38	125	0	0	0
BB	LBG3	winter rye	foragelegume	6.4	132	0.86	0	844	675	4	15	169	107	57	22	32	0	0	0
BB	LBG3	winter rye	foragelegume	19.1	52	0.45	0	993	490	5	15	503	424	72	38	125	0	0	0
BB	LBG3	winter rye	leafcrop_grainlegume	6.4	132	0.86	0	844	675	4	15	169	107	57	22	32	0	0	0
BB	LBG3	winter rye	leafcrop_grainlegume	19.1	52	0.45	0	993	490	5	15	503	424	72	38	125	0	0	0
BB	LBG4	graclov	cereal	19.4	42	0.35	0	816	651	9	15	165	30	0	23	170	0	0	0
BB	LBG4	graclov	cereal	23.4	42	0.35	0	984	660	9	15	324	183	0	27	205	0	0	0
BB	LBG4	graclov	foragelegume	19.4	42	0.35	0	816	408	7	15	409	307	0	23	170	0	0	0
BB	LBG4	lupin	cereal	1.8	150	0.86	0	270	603	4	15	-333	-399	0	11	21	0	0	0
BB	LBG4	pea	cereal	2.0	182	0.86	0	364	653	4	15	-290	-356	0	10	23	0	0	0
BB	LBG4	silage maize	cereal	21.4	31	0.35	0	658	817	13	15	-159	-348	32	10	0	153	35	26
BB	LBG4	silage maize	cereal	21.4	31	0.35	0	658	855	10	15	-197	-353	68	20	12	76	13	9
BB	LBG4	silage maize	cereal	21.4	31	0.35	0	658	857	12	15	-199	-379	49	10	0	114	20	13

Country	Sltalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
BB	LBG4	silage maize	foragelegume	24.0	31	0.35	0	737	818	13	15	-81	-271	33	10	0	153	35	26
BB	LBG4	silage maize	foragelegume	24.0	31	0.35	0	737	858	12	15	-121	-301	50	10	0	114	20	13
BB	LBG4	silage maize	foragelegume	24.0	31	0.35	0	737	867	10	15	-130	-287	69	20	24	76	13	9
BB	LBG4	silage maize	leafcrop_grainlegume	24.0	31	0.35	0	737	818	13	15	-81	-271	33	10	0	153	35	26
BB	LBG4	silage maize	leafcrop_grainlegume	24.0	31	0.35	0	737	858	12	15	-121	-301	50	10	0	114	20	13
BB	LBG4	silage maize	leafcrop_grainlegume	24.0	31	0.35	0	737	867	10	15	-130	-287	69	20	24	76	13	9
BB	LBG4	triticale	cereal	3.2	157	0.86	0	501	594	4	15	-93	-154	47	11	16	0	0	0
BB	LBG4	triticale	foragelegume	4.1	157	0.86	0	642	622	4	15	20	-41	52	14	20	0	0	0
BB	LBG4	triticale	leafcrop_grainlegume	4.1	157	0.86	0	642	622	4	15	20	-41	52	14	20	0	0	0
BB	LBG4	winter oil seed rape	cereal	2.2	310	0.89	0	681	724	5	15	-43	-111	112	18	18	0	0	0
BB	LBG4	winter oil seed rape	leafcrop_grainlegume	2.7	310	0.89	0	836	759	5	15	77	8	130	22	23	0	0	0
BB	LBG4	winter rye	cereal	4.1	132	0.86	0	541	614	4	15	-73	-134	49	14	20	0	0	0
BB	LBG4	winter rye	cereal	15.3	52	0.45	0	797	468	5	15	328	250	66	35	115	0	0	0
BB	LBG4	winter rye	foragelegume	5.0	132	0.86	0	660	626	4	15	33	-28	44	18	25	0	0	0
BB	LBG4	winter rye	foragelegume	17.3	52	0.45	0	901	468	5	15	432	354	67	35	115	0	0	0
BB	LBG4	winter rye	leafcrop_grainlegume	5.0	132	0.86	0	660	626	4	15	33	-28	44	18	25	0	0	0
BB	LBG4	winter rye	leafcrop_grainlegume	17.3	52	0.45	0	901	468	5	15	432	354	67	35	115	0	0	0
BB	LBG5	lupin	cereal	1.5	150	0.86	0	225	591	4	15	-366	-431	0	9	17	0	0	0
BB	LBG5	rye vetch	cereal	20.0	36	0.30	0	729	379	5	15	350	272	50	11	15	0	0	0
BB	LBG5	rye vetch	cereal	20.0	36	0.30	0	729	379	5	15	350	272	50	11	15	0	0	0
BB	LBG5	seradella	cereal	17.5	24	0.20	0	417	202	4	15	215	160	0	11	68	0	0	0
BB	LBG5	winter rye	cereal	2.9	132	0.86	0	383	557	4	15	-175	-238	39	10	14	0	0	0
BB	LBG5	winter rye	cereal	14.2	52	0.45	0	739	451	5	15	288	210	64	32	106	0	0	0
BB	LBG5	winter rye	foragelegume	3.7	132	0.86	0	488	565	4	15	-77	-140	33	13	18	0	0	0
BB	LBG5	winter rye	foragelegume	16.0	52	0.45	0	832	451	5	15	381	303	62	32	106	0	0	0
BB	LBG5	winter rye	leafcrop_grainlegume	3.7	132	0.86	0	488	565	4	15	-77	-140	33	13	18	0	0	0
BB	LBG5	winter rye	leafcrop_grainlegume	16.0	52	0.45	0	832	451	5	15	381	303	62	32	106	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
IT	irrigated_1	alfalfa	cereal	11.5		0.87	0	0	1024	25	13	-1024	-1349	0	38	0	40	10	3
IT	irrigated_1	alfalfa	foragelegume	10.3		0.87	0	0	931	22	13	-931	-1217	0	29	0	0	0	0
IT	irrigated_1	alfalfa	leafcrop_grainlegume	10.3		0.87	0	0	931	22	13	-931	-1217	0	29	0	40	10	3
IT	irrigated_1	clover	cereal	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	irrigated_1	clover	foragelegume	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	irrigated_1	clover	leafcrop_grainlegume	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	irrigated_1	lupin	cereal	2.5	400	0.86	0	1000	573	12	13	427	271	28	53	33	0	0	0
IT	irrigated_1	lupin	leafcrop_grainlegume	3.0	400	0.86	0	1200	533	12	13	668	512	28	24	33	0	0	0
IT	irrigated_1	potato	cereal	12.0	250	0.22	0	3000	1581	30	13	1419	1029	33	29	40	120	60	18
IT	irrigated_1	potato	foragelegume	14.0	250	0.22	0	3500	1524	30	13	1976	1586	22	19	27	120	60	18
IT	irrigated_1	potato	leafcrop_grainlegume	12.7	250	0.22	0	3175	1581	30	13	1594	1204	33	29	40	120	60	18
IT	irrigated_1	winter oil seed rape	cereal	2.5	400	0.91	0	1000	811	12	13	189	33	59	29	40	0	0	0
IT	irrigated_1	winter oil seed rape	foragelegume	3.5	400	0.91	0	1400	726	12	13	675	519	43	15	20	0	0	0
IT	irrigated_1	winter oil seed rape	leafcrop_grainlegume	3.0	400	0.91	0	1200	754	12	13	446	290	48	19	27	0	0	0
IT	irrigated_1	winter soft wheat	cereal	3.2	250	0.86	0	800	626	12	13	175	19	43	15	20	0	0	0
IT	irrigated_1	winter soft wheat	foragelegume	3.6	250	0.86	0	900	530	12	13	370	214	52	0	0	0	0	0
IT	irrigated_1	winter soft wheat	leafcrop_grainlegume	3.5	250	0.86	0	875	530	12	13	345	189	52	0	0	0	0	0
IT	irrigated_2	alfalfa	cereal	11.5		0.87	0	0	1024	25	13	-1024	-1349	0	38	0	40	10	3
IT	irrigated_2	alfalfa	foragelegume	10.3		0.87	0	0	931	22	13	-931	-1217	0	29	0	0	0	0
IT	irrigated_2	alfalfa	leafcrop_grainlegume	10.3		0.87	0	0	931	22	13	-931	-1217	0	29	0	40	10	3
IT	irrigated_2	barley	cereal	3.5	220	0.86	255	770	515	12	13	510	354	36	40	0	0	0	0
IT	irrigated_2	barley	foragelegume	3.5	220	0.86	255	770	480	12	13	545	389	27	30	0	0	0	0
IT	irrigated_2	barley	leafcrop_grainlegume	3.3	220	0.86	255	726	501	12	13	480	324	32	36	0	0	0	0
IT	irrigated_2	durum wheat	cereal	3.0	260	0.86	0	780	786	12	13	-6	-162	62	40	0	0	0	0
IT	irrigated_2	durum wheat	foragelegume	4.0	260	0.86	0	1040	786	12	13	254	98	36	40	0	0	0	0
IT	irrigated_2	durum wheat	leafcrop_grainlegume	3.2	260	0.86	0	832	686	12	13	146	-10	52	0	0	0	0	0

Country	Sltalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
IT	irrigated_2	faba bean	cereal	1.6	250	0.86	0	400	560	10	13	-160	-290	0	19	0	0	0	0
IT	irrigated_2	faba bean	leafcrop_grainlegume	1.8	250	0.86	0	450	560	10	13	-110	-240	0	19	0	0	0	0
IT	irrigated_2	pea	cereal	1.2	260	0.86	0	312	487	10	13	-175	-305	0	19	0	0	0	0
IT	irrigated_2	pea	leafcrop_grainlegume	1.5	260	0.86	0	390	487	10	13	-97	-227	0	19	0	0	0	0
IT	irrigated_2	silage maize	cereal	36.0	25	0.35	0	900	904	24	13	-4	-316	58	60	27	0	0	0
IT	irrigated_2	silage maize	foragelegume	38.0	25	0.35	0	950	823	24	13	127	-185	38	38	24	0	0	0
IT	irrigated_2	silage maize	leafcrop_grainlegume	38.0	25	0.35	0	950	710	24	13	240	-72	54	56	27	0	0	0
IT	irrigated_2	triticale	foragelegume	3.5	250	0.86	0	875	605	12	13	270	114	52	0	0	0	0	0
IT	irrigated_2	triticale	leafcrop_grainlegume	3.0	250	0.86	0	750	597	12	13	153	-3	47	0	0	0	0	0
IT	irrigated_2	winter oat	cereal	2.0	270	0.86	180	540	464	12	13	256	100	62	40	0	0	0	0
IT	irrigated_2	winter oat	foragelegume	2.8	270	0.86	250	756	410	12	13	597	441	43	15	20	0	0	0
IT	irrigated_2	winter oat	leafcrop_grainlegume	2.0	270	0.86	180	540	438	12	13	282	126	48	19	27	0	0	0
IT	irrigated_2	winter soft wheat	cereal	3.2	250	0.86	0	800	626	12	13	175	19	43	15	20	0	0	0
IT	irrigated_2	winter soft wheat	foragelegume	3.6	250	0.86	0	900	530	12	13	370	214	52	0	0	0	0	0
IT	irrigated_2	winter soft wheat	leafcrop_grainlegume	3.5	250	0.86	0	875	530	12	13	345	189	52	0	0	0	0	0
IT	rainfed	barley	cereal	3.5	220	0.86	255	770	515	12	13	510	354	36	40	0	0	0	0
IT	rainfed	barley	foragelegume	3.5	220	0.86	255	770	480	12	13	545	389	27	30	0	0	0	0
IT	rainfed	barley	leafcrop_grainlegume	3.3	220	0.86	255	726	501	12	13	480	324	32	36	0	0	0	0
IT	rainfed	clover	cereal	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	rainfed	clover	foragelegume	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	rainfed	clover	leafcrop_grainlegume	8.7		0.86	0	0	657	18	13	-657	-891	0	19	0	40	100	30
IT	rainfed	durum wheat	cereal	3.0	260	0.86	0	780	786	12	13	-6	-162	62	40	0	0	0	0
IT	rainfed	durum wheat	foragelegume	4.0	260	0.86	0	1040	746	12	13	294	138	36	40	0	0	0	0
IT	rainfed	durum wheat	leafcrop_grainlegume	3.2	260	0.86	0	832	686	12	13	146	-10	52	0	0	0	0	0
IT	rainfed	faba bean	cereal	1.6	250	0.86	0	400	560	10	13	-160	-290	0	19	0	0	0	0
IT	rainfed	faba bean	leafcrop_grainlegume	1.8	250	0.86	0	450	560	10	13	-110	-240	0	19	0	0	0	0

Country	Sltalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
IT	rainfed	oat-vetch	cereal	30.0	75	0.28	0	2250	385	15	13	1865	1670	27	30	0	0	0	0
IT	rainfed	oat-vetch	leafcrop_grainlegume	35.0	75	0.28	0	2625	385	15	13	2240	2045	27	30	0	0	0	0
IT	rainfed	pea	cereal	1.2	260	0.86	0	312	487	10	13	-175	-305	0	19	0	0	0	0
IT	rainfed	pea	leafcrop_grainlegume	1.5	260	0.86	0	390	487	10	13	-97	-227	0	19	0	0	0	0
IT	rainfed	sulla	cereal	11.1		0.88	0	0	687	15	13	-687	-882	0	19	0	0	0	0
IT	rainfed	sulla	foragelegume	11.4		0.88	0	0	687	15	13	-687	-882	0	19	0	0	0	0
IT	rainfed	triticale	foragelegume	3.5	250	0.86	0	875	605	12	13	270	114	52	0	0	0	0	0
IT	rainfed	triticale	leafcrop_grainlegume	3.0	250	0.86	0	750	597	12	13	153	-3	47	0	0	0	0	0
IT	rainfed	winter oat	cereal	2.0	270	0.86	180	540	464	12	13	256	100	62	40	0	0	0	0
IT	rainfed	winter oat	foragelegume	2.8	270	0.86	250	756	410	12	13	597	441	43	15	20	0	0	0
IT	rainfed	winter oat	leafcrop_grainlegume	2.0	270	0.86	180	540	438	12	13	282	126	48	19	27	0	0	0
IT	rainfed	winter oil seed rape	cereal	2.5	400	0.91	0	1000	811	12	13	189	33	59	29	40	0	0	0
IT	rainfed	winter oil seed rape	foragelegume	3.5	400	0.91	0	1400	726	12	13	675	519	43	15	20	0	0	0
IT	rainfed	winter oil seed rape	leafcrop_grainlegume	3.0	400	0.91	0	1200	754	12	13	446	290	48	19	27	0	0	0
IT	rainfed	winter soft wheat	cereal	3.2	250	0.86	0	800	626	12	13	175	19	43	15	20	0	0	0
IT	rainfed	winter soft wheat	foragelegume	3.6	250	0.86	0	900	530	12	13	370	214	52	0	0	0	0	0
IT	rainfed	winter soft wheat	leafcrop_grainlegume	3.5	250	0.86	0	875	530	12	13	345	189	52	0	0	0	0	0
RO	Chernozem	common bean	ro_1	1.0	1200	0.89	0	1200	580	39	1	620	596	0	0	0	0	0	0
RO	Chernozem	common bean	ro_2	1.0	1200	0.89	0	1200	580	39	1	620	596	0	0	0	0	0	0
RO	Chernozem	common bean	ro_3	2.5	1200	0.89	0	3000	597	39	1	2403	2379	0	0	0	0	0	0
RO	Chernozem	common bean	ro_4	2.0	1200	0.89	0	2400	588	39	1	1812	1787	0	0	0	0	0	0
RO	Chernozem	maize	ro_1	7.0	212	0.86	0	1484	678	111	1	806	743	140	0	0	0	0	0
RO	Chernozem	maize	ro_2	7.0	212	0.86	0	1484	678	111	1	806	743	140	0	0	0	0	0
RO	Chernozem	maize	ro_3	6.0	212	0.86	0	1272	667	111	1	605	542	130	0	0	0	0	0
RO	Chernozem	maize	ro_4	4.2	212	0.86	0	890	656	111	1	234	171	120	0	0	0	0	0
RO	Chernozem	Pea	ro_3	3.5	325	0.86	0	1138	828	34	0	310	294	0	0	0	0	0	0
RO	Chernozem	Pea	ro_4	2.5	325	0.86	0	813	816	34	0	-3	-19	0	0	0	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
RO	Chernozem	Soybean	ro_2	1.0	440	0.89	0	440	501	39	1	-61	-85	0	0	0	0	0	0
RO	Chernozem	Soybean	ro_3	2.5	440	0.89	0	1100	526	39	1	574	550	0	0	0	0	0	0
RO	Chernozem	Soybean	ro_4	2.0	440	0.89	0	880	521	39	1	359	334	0	0	0	0	0	0
RO	Chernozem	sunflower	ro_2	3.0	390	0.93	0	1170	529	40	2	641	567	120	0	0	0	0	0
RO	Chernozem	sunflower	ro_3	2.4	390	0.93	0	936	501	40	2	435	361	95	0	0	0	0	0
RO	Chernozem	sunflower	ro_4	1.2	390	0.93	0	468	454	40	2	14	-60	60	0	0	0	0	0
RO	Chernozem	winter barley	ro_1	6.0	200	0.86	0	1200	722	26	2	478	437	100	0	0	0	0	0
RO	Chernozem	winter barley	ro_2	6.0	200	0.86	0	1200	715	26	2	485	444	90	0	0	0	0	0
RO	Chernozem	winter barley	ro_3	5.0	200	0.86	0	1000	715	26	2	285	244	95	0	0	0	0	0
RO	Chernozem	winter barley	ro_4	4.2	200	0.86	0	840	700	26	2	140	99	85	0	0	0	0	0
RO	Chernozem	winter oil seed rape	ro_2	3.5	400	0.91	0	1400	651	26	1	749	733	80	0	0	0	0	0
RO	Chernozem	winter oil seed rape	ro_3	3.0	400	0.91	0	1200	656	26	1	544	528	95	0	0	0	0	0
RO	Chernozem	winter oil seed rape	ro_4	3.0	400	0.91	0	1200	656	26	1	544	528	95	0	0	0	0	0
RO	Chernozem	winter wheat	ro_1	5.0	232	0.86	0	1160	717	22	2	443	405	105	0	0	0	0	0
RO	Chernozem	winter wheat	ro_2	5.0	232	0.86	0	1160	709	22	2	451	413	95	0	0	0	0	0
RO	Chernozem	winter wheat	ro_3	4.8	232	0.86	0	1114	745	22	2	369	330	140	0	0	0	0	0
RO	Chernozem	winter wheat	ro_4	3.6	232	0.86	0	835	688	22	2	147	109	90	0	0	0	0	0
SC	Grade 1&2	Barley_spring_Grain	cereal	6.5	174	0.86	0	1131	745	20	13	386	122	100	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Grain	cereal	6.5	174	0.86	0	1131	768	20	13	363	99	110	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Grain	cereal	6.5	174	0.86	0	1131	768	20	13	363	99	110	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Grain	foragelegume	7.5	174	0.86	0	1305	725	20	13	580	316	55	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Grain	foragelegume	7.5	174	0.86	0	1305	755	20	13	550	286	76	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Grain	leafcrop_grainlegume	7.5	174	0.86	0	1305	735	20	13	570	306	73	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Grain	leafcrop_grainlegume	7.5	174	0.86	0	1305	760	20	13	545	281	83	24	46	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 1&2	Barley_spring_Grain	leafcrop_grainlegume	7.5	174	0.86	0	1305	760	20	13	545	281	83	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Seed	cereal	6.5	210	0.86	0	1365	745	20	13	620	356	100	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Seed	cereal	6.5	210	0.86	0	1365	768	20	13	597	333	110	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Seed	foragelegume	7.5	210	0.86	0	1575	725	20	13	850	586	55	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Seed	foragelegume	7.5	210	0.86	0	1575	755	20	13	820	556	76	24	46	0	0	0
SC	Grade 1&2	Barley_spring_Seed	leafcrop_grainlegume	7.5	210	0.86	0	1575	735	20	13	840	576	73	24	46	90	45	12
SC	Grade 1&2	Barley_spring_Seed	leafcrop_grainlegume	7.5	210	0.86	0	1575	760	20	13	815	551	83	24	46	0	0	0
SC	Grade 1&2	Barley_winter_Grain	cereal	8.0	174	0.86	216	1392	924	20	13	684	420	181	30	60	0	0	0
SC	Grade 1&2	Barley_winter_Grain	foragelegume	9.0	174	0.86	240	1566	893	20	13	913	649	155	30	60	0	0	0
SC	Grade 1&2	Barley_winter_Grain	leafcrop_grainlegume	9.0	174	0.86	240	1566	903	20	13	903	639	164	30	60	0	0	0
SC	Grade 1&2	Barley_winter_Seed	cereal	8.0	210	0.86	0	1680	924	20	13	756	492	181	30	60	0	0	0
SC	Grade 1&2	Barley_winter_Seed	foragelegume	9.0	210	0.86	0	1890	893	20	13	997	733	155	30	60	0	0	0
SC	Grade 1&2	Barley_winter_Seed	leafcrop_grainlegume	9.0	210	0.86	326	1890	903	20	13	1313	1049	164	30	60	0	0	0
SC	Grade 1&2	field bean_Grain	cereal	6.0	197	0.86	0	1184	701	10	13	482	350	0	17	41	0	0	0
SC	Grade 1&2	field bean_Grain	leafcrop_grainlegume	6.0	197	0.86	0	1184	701	10	13	482	350	0	17	41	0	0	0
SC	Grade 1&2	Oat _spring_Grain	cereal	6.0	180	0.86	210	1080	720	20	13	570	306	96	22	42	90	45	12
SC	Grade 1&2	Oat _spring_Grain	cereal	6.0	180	0.86	210	1080	743	20	13	547	283	103	22	42	0	0	0
SC	Grade 1&2	Oat _spring_Grain	cereal	6.0	180	0.86	210	1080	743	20	13	547	283	103	22	42	0	0	0
SC	Grade 1&2	Oat _spring_Grain	foragelegume	6.5	180	0.86	234	1170	700	20	13	704	440	51	22	42	60	30	8
SC	Grade 1&2	Oat _spring_Grain	foragelegume	6.5	180	0.86	234	1170	730	20	13	674	410	72	22	42	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 1&2	Oat _spring_Grain	leafcrop_grainlegume	6.5	180	0.86	234	1170	710	20	13	694	430	68	22	42	72	36	10
SC	Grade 1&2	Oat _spring_Grain	leafcrop_grainlegume	6.5	180	0.86	234	1170	735	20	13	669	405	79	22	42	0	0	0
SC	Grade 1&2	Oat _spring_Grain	leafcrop_grainlegume	6.5	180	0.86	234	1170	735	20	13	669	405	79	22	42	0	0	0
SC	Grade 1&2	Oat_winter_grain	cereal	8.5	180	0.86	330	1530	792	20	13	1068	804	121	26	50	0	0	0
SC	Grade 1&2	Oat_winter_grain	foragelegume	9.0	180	0.86	342	1620	770	20	13	1192	928	104	26	50	0	0	0
SC	Grade 1&2	Oat_winter_grain	leafcrop_grainlegume	9.0	180	0.86	342	1620	780	20	13	1182	918	110	26	50	0	0	0
SC	Grade 1&2	Pea _Grain	cereal	5.5	240	0.86	0	1320	727	10	13	593	461	0	22	41	0	0	0
SC	Grade 1&2	Pea _Grain	leafcrop_grainlegume	5.5	240	0.86	0	1320	727	10	13	593	461	0	22	41	0	0	0
SC	Grade 1&2	Potato_Root	cereal	50.0	150	0.22	0	7500	3761	105	13	3739	2353	200	65	208	120	60	16
SC	Grade 1&2	Potato_Root	cereal	50.0	150	0.22	0	7500	3813	105	13	3687	2301	220	65	208	0	0	0
SC	Grade 1&2	Potato_Root	foragelegume	55.0	150	0.22	0	8250	3761	105	13	4489	3103	200	65	208	90	45	12
SC	Grade 1&2	Potato_Root	foragelegume	55.0	150	0.22	0	8250	3813	105	13	4437	3051	207	65	208	0	0	0
SC	Grade 1&2	Potato_Root	leafcrop_grainlegume	55.0	150	0.22	0	8250	3761	105	13	4489	3103	200	65	208	108	54	14
SC	Grade 1&2	Potato_Root	leafcrop_grainlegume	55.0	150	0.22	0	8250	3813	105	13	4437	3051	214	65	208	0	0	0
SC	Grade 1&2	Potato_Seed	cereal	27.0	190	0.22	0	5130	3517	105	13	1613	227	90	86	125	0	0	0
SC	Grade 1&2	Potato_Seed	foragelegume	30.0	190	0.22	0	5700	3517	105	13	2183	797	76	86	125	0	0	0
SC	Grade 1&2	Potato_Seed	leafcrop_grainlegume	30.0	190	0.22	0	5700	3517	105	13	2183	797	83	86	125	0	0	0
SC	Grade 1&2	Rape _spring_Grain	cereal	2.5	420	0.91	0	1050	654	15	13	396	198	101	13	25	90	45	12
SC	Grade 1&2	Rape _spring_Grain	cereal	2.5	420	0.91	0	1050	678	15	13	372	174	101	13	25	0	0	0
SC	Grade 1&2	Rape _spring_Grain	foragelegume	3.0	420	0.91	0	1260	634	15	13	626	428	95	13	25	60	30	8
SC	Grade 1&2	Rape _spring_Grain	foragelegume	3.0	420	0.91	0	1260	664	15	13	596	398	95	13	25	0	0	0
SC	Grade 1&2	Rape _spring_Grain	leafcrop_grainlegume	3.0	420	0.91	0	1260	644	15	13	616	418	98	13	25	72	36	10
SC	Grade 1&2	Rape _spring_Grain	leafcrop_grainlegume	3.0	420	0.91	0	1260	669	15	13	591	393	98	13	25	0	0	0
SC	Grade 1&2	Rape _winter_Grain	cereal	4.5	420	0.91	0	1890	1009	15	13	881	683	204	22	41	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 1&2	Rape _winter_Grain	foragelegume	5.0	420	0.91	0	2100	993	15	13	1107	909	169	22	41	0	0	0
SC	Grade 1&2	Rape _winter_Grain	leafcrop_grainlegume	5.0	420	0.91	0	2100	998	15	13	1102	904	186	22	41	0	0	0
SC	Grade 1&2	Soft wheat_spring	cereal	7.5	210	0.86	0	1575	859	20	13	716	452	173	24	46	90	45	12
SC	Grade 1&2	Soft wheat_spring	cereal	7.5	210	0.86	0	1575	890	20	13	685	421	173	24	46	0	0	0
SC	Grade 1&2	Soft wheat_spring	foragelegume	8.0	210	0.86	0	1680	839	20	13	841	577	150	24	46	60	30	8
SC	Grade 1&2	Soft wheat_spring	foragelegume	8.0	210	0.86	0	1680	874	20	13	806	542	150	24	46	0	0	0
SC	Grade 1&2	Soft wheat_spring	leafcrop_grainlegume	8.0	210	0.86	0	1680	849	20	13	831	567	159	24	46	72	36	10
SC	Grade 1&2	Soft wheat_spring	leafcrop_grainlegume	8.0	210	0.86	0	1680	879	20	13	801	537	159	24	46	0	0	0
SC	Grade 1&2	Soft wheat_winter	cereal	9.5	186	0.86	0	1767	1004	20	13	763	499	203	30	60	0	0	0
SC	Grade 1&2	Soft wheat_winter	foragelegume	10.0	186	0.86	0	1860	982	20	13	878	614	190	30	60	0	0	0
SC	Grade 1&2	Soft wheat_winter	leafcrop_grainlegume	10.0	186	0.86	0	1860	992	20	13	868	604	193	30	60	0	0	0
SC	Grade 1&2	Soft wheat_winter _Seed	cereal	9.5	210	0.86	0	1995	1004	20	13	991	727	203	30	60	0	0	0
SC	Grade 1&2	Soft wheat_winter _Seed	foragelegume	10.0	210	0.86	0	2100	982	20	13	1118	854	190	30	60	0	0	0
SC	Grade 1&2	Soft wheat_winter _Seed	leafcrop_grainlegume	10.0	210	0.86	0	2100	992	20	13	1108	844	193	30	60	0	0	0
SC	Grade 1&2	Swede_Fodder	cereal	90.0	24	0.15	0	2160	634	20	13	1526	1262	75	43	83	90	45	12
SC	Grade 1&2	Swede_Fodder	cereal	90.0	24	0.15	0	2160	666	20	13	1494	1230	75	43	83	0	0	0
SC	Grade 1&2	Swede_Fodder	foragelegume	100.0	24	0.15	0	2400	634	20	13	1766	1502	75	43	83	60	30	8
SC	Grade 1&2	Swede_Fodder	foragelegume	100.0	24	0.15	0	2400	666	20	13	1734	1470	75	43	83	0	0	0
SC	Grade 1&2	Swede_Fodder	leafcrop_grainlegume	100.0	24	0.15	0	2400	634	20	13	1766	1502	75	43	83	72	36	10
SC	Grade 1&2	Swede_Fodder	leafcrop_grainlegume	100.0	24	0.15	0	2400	666	20	13	1734	1470	75	43	83	0	0	0
SC	Grade 3	Barley_spring_Grain	cereal	5.0	174	0.86	0	870	726	20	13	144	-120	100	24	46	90	45	12
SC	Grade 3	Barley_spring_Grain	cereal	5.0	174	0.86	0	870	749	20	13	121	-143	110	24	46	0	0	0
SC	Grade 3	Barley_spring_Grain	cereal	5.0	174	0.86	0	870	749	20	13	121	-143	110	24	46	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 3	Barley_spring_Grain	foragelegume	6.0	174	0.86	0	1044	706	20	13	338	74	55	24	46	90	45	12
SC	Grade 3	Barley_spring_Grain	foragelegume	6.0	174	0.86	0	1044	736	20	13	308	44	76	24	46	0	0	0
SC	Grade 3	Barley_spring_Grain	foragelegume	6.0	174	0.86	0	1044	736	20	13	308	44	76	24	46	0	0	0
SC	Grade 3	Barley_spring_Grain	leafcrop_grainlegume	6.0	174	0.86	0	1044	716	20	13	328	64	73	24	46	90	45	12
SC	Grade 3	Barley_spring_Grain	leafcrop_grainlegume	6.0	174	0.86	0	1044	741	20	13	303	39	83	24	46	0	0	0
SC	Grade 3	Barley_spring_Grain	leafcrop_grainlegume	6.0	174	0.86	0	1044	741	20	13	303	39	83	24	46	0	0	0
SC	Grade 3	Barley_spring_Seed	cereal	5.0	210	0.86	0	1050	726	20	13	324	60	100	24	46	90	45	12
SC	Grade 3	Barley_spring_Seed	cereal	5.0	210	0.86	0	1050	749	20	13	301	37	110	24	46	0	0	0
SC	Grade 3	Barley_spring_Seed	foragelegume	6.0	210	0.86	0	1260	706	20	13	554	290	55	24	46	90	45	12
SC	Grade 3	Barley_spring_Seed	foragelegume	6.0	210	0.86	0	1260	736	20	13	524	260	76	24	46	0	0	0
SC	Grade 3	Barley_spring_Seed	leafcrop_grainlegume	6.0	210	0.86	0	1260	716	20	13	544	280	73	24	46	90	45	12
SC	Grade 3	Barley_spring_Seed	leafcrop_grainlegume	6.0	210	0.86	0	1260	741	20	13	519	255	83	24	46	0	0	0
SC	Grade 3	Barley_winter_Grain	cereal	7.0	174	0.86	182	1218	905	20	13	495	231	181	30	60	0	0	0
SC	Grade 3	Barley_winter_Grain	foragelegume	7.5	174	0.86	197	1305	874	20	13	627	363	155	30	60	0	0	0
SC	Grade 3	Barley_winter_Grain	leafcrop_grainlegume	7.5	174	0.86	197	1305	884	20	13	617	353	164	30	60	0	0	0
SC	Grade 3	Barley_winter_Seed	cereal	7.0	210	0.86	0	1470	905	20	13	565	301	181	30	60	0	0	0
SC	Grade 3	Barley_winter_Seed	foragelegume	7.5	210	0.86	0	1575	874	20	13	701	437	155	30	60	0	0	0
SC	Grade 3	Barley_winter_Seed	leafcrop_grainlegume	7.5	210	0.86	269	1575	884	20	13	959	695	164	30	60	0	0	0

Country	Sltalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 3	field bean_Grain	cereal	5.0	197	0.86	0	986	701	10	13	285	153	0	17	41	0	0	0
SC	Grade 3	field bean_Grain	leafcrop_grainlegume	5.0	197	0.86	0	986	701	10	13	285	153	0	17	41	0	0	0
SC	Grade 3	Oat _spring_Grain	cereal	4.5	180	0.86	168	810	701	20	13	277	13	96	22	42	90	45	12
SC	Grade 3	Oat _spring_Grain	cereal	4.5	180	0.86	168	810	724	20	13	254	-10	103	22	42	0	0	0
SC	Grade 3	Oat _spring_Grain	cereal	4.5	180	0.86	168	810	724	20	13	254	-10	103	22	42	0	0	0
SC	Grade 3	Oat _spring_Grain	foragelegume	5.0	180	0.86	180	900	681	20	13	399	135	51	22	42	60	30	8
SC	Grade 3	Oat _spring_Grain	foragelegume	5.0	180	0.86	180	900	711	20	13	369	105	72	22	42	0	0	0
SC	Grade 3	Oat _spring_Grain	foragelegume	5.0	180	0.86	180	900	711	20	13	369	105	72	22	42	0	0	0
SC	Grade 3	Oat _spring_Grain	leafcrop_grainlegume	5.0	180	0.86	180	900	691	20	13	389	125	68	22	42	72	36	10
SC	Grade 3	Oat _spring_Grain	leafcrop_grainlegume	5.0	180	0.86	180	900	716	20	13	364	100	79	22	42	0	0	0
SC	Grade 3	Oat _spring_Grain	leafcrop_grainlegume	5.0	180	0.86	180	900	716	20	13	364	100	79	22	42	0	0	0
SC	Grade 3	Oat_winter_grain	cereal	7.0	180	0.86	270	1260	773	20	13	757	493	121	26	50	0	0	0
SC	Grade 3	Oat_winter_grain	foragelegume	7.5	180	0.86	282	1350	751	20	13	881	617	104	26	50	0	0	0
SC	Grade 3	Oat_winter_grain	leafcrop_grainlegume	7.5	180	0.86	282	1350	761	20	13	871	607	110	26	50	0	0	0
SC	Grade 3	Pea _Grain	cereal	4.0	240	0.86	0	960	714	10	13	246	114	0	22	41	0	0	0
SC	Grade 3	Pea _Grain	leafcrop_grainlegume	4.0	240	0.86	0	960	714	10	13	246	114	0	22	41	0	0	0
SC	Grade 3	Potato_Root	cereal	38.0	150	0.22	0	5700	3761	105	13	1939	553	200	65	208	120	60	16
SC	Grade 3	Potato_Root	cereal	38.0	150	0.22	0	5700	3813	105	13	1887	501	220	65	208	0	0	0
SC	Grade 3	Potato_Root	foragelegume	42.0	150	0.22	0	6300	3761	105	13	2539	1153	200	65	208	90	45	12
SC	Grade 3	Potato_Root	foragelegume	42.0	150	0.22	0	6300	3813	105	13	2487	1101	207	65	208	0	0	0
SC	Grade 3	Potato_Root	leafcrop_grainlegume	42.0	150	0.22	0	6300	3761	105	13	2539	1153	200	65	208	108	54	14
SC	Grade 3	Potato_Root	leafcrop_grainlegume	42.0	150	0.22	0	6300	3813	105	13	2487	1101	214	65	208	0	0	0
SC	Grade 3	Rape _spring_Grain	cereal	2.0	420	0.91	0	840	635	15	13	205	7	101	13	25	90	45	12
SC	Grade 3	Rape _spring_Grain	cereal	2.0	420	0.91	0	840	659	15	13	181	-17	101	13	25	0	0	0
SC	Grade 3	Rape _spring_Grain	foragelegume	2.5	420	0.91	0	1050	615	15	13	435	237	95	13	25	60	30	8
SC	Grade 3	Rape	foragelegume	2.5	420	0.91	0	1050	645	15	13	405	207	95	13	25	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
		_spring_Grain																	
SC	Grade 3	Rape _spring_Grain	leafcrop_grainlegume	2.5	420	0.91	0	1050	625	15	13	425	227	98	13	25	72	36	10
SC	Grade 3	Rape _spring_Grain	leafcrop_grainlegume	2.5	420	0.91	0	1050	650	15	13	400	202	98	13	25	0	0	0
SC	Grade 3	Rape _winter_Grain	cereal	3.5	420	0.91	0	1470	1009	15	13	461	263	204	22	41	0	0	0
SC	Grade 3	Rape _winter_Grain	foragelegume	4.0	420	0.91	0	1680	993	15	13	687	489	169	22	41	0	0	0
SC	Grade 3	Rape _winter_Grain	leafcrop_grainlegume	4.0	420	0.91	0	1680	998	15	13	682	484	186	22	41	0	0	0
SC	Grade 3	Soft wheat_spring _Grain	cereal	5.5	210	0.86	0	1155	840	20	13	315	51	173	24	46	90	45	12
SC	Grade 3	Soft wheat_spring _Grain	cereal	5.5	210	0.86	0	1155	872	20	13	283	19	173	24	46	0	0	0
SC	Grade 3	Soft wheat_spring _Grain	foragelegume	6.0	210	0.86	0	1260	820	20	13	440	176	150	24	46	60	30	8
SC	Grade 3	Soft wheat_spring _Grain	foragelegume	6.0	210	0.86	0	1260	855	20	13	405	141	150	24	46	0	0	0
SC	Grade 3	Soft wheat_spring _Grain	leafcrop_grainlegume	6.0	210	0.86	0	1260	830	20	13	430	166	159	24	46	72	36	10
SC	Grade 3	Soft wheat_spring _Grain	leafcrop_grainlegume	6.0	210	0.86	0	1260	860	20	13	400	136	159	24	46	0	0	0
SC	Grade 3	Soft wheat_winter _Grain	cereal	7.5	186	0.86	0	1395	986	20	13	409	145	203	30	60	0	0	0
SC	Grade 3	Soft wheat_winter _Grain	foragelegume	8.0	186	0.86	0	1488	963	20	13	525	261	190	30	60	0	0	0
SC	Grade 3	Soft wheat_winter _Grain	leafcrop_grainlegume	8.0	186	0.86	0	1488	973	20	13	515	251	193	30	60	0	0	0
SC	Grade 3	Soft wheat_winter _Seed	cereal	7.5	210	0.86	0	1575	986	20	13	589	325	203	30	60	0	0	0
SC	Grade 3	Soft wheat_winter _Seed	foragelegume	8.0	210	0.86	0	1680	963	20	13	717	453	190	30	60	0	0	0
SC	Grade 3	Soft wheat_winter _Seed	leafcrop_grainlegume	8.0	210	0.86	0	1680	973	20	13	707	443	193	30	60	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 3	Swede_Fodder	cereal	70.0	24	0.15	0	1680	634	20	13	1046	782	75	43	83	90	45	12
SC	Grade 3	Swede_Fodder	cereal	70.0	24	0.15	0	1680	666	20	13	1014	750	75	43	83	0	0	0
SC	Grade 3	Swede_Fodder	foragelegume	75.0	24	0.15	0	1800	634	20	13	1166	902	75	43	83	60	30	8
SC	Grade 3	Swede_Fodder	foragelegume	75.0	24	0.15	0	1800	666	20	13	1134	870	75	43	83	0	0	0
SC	Grade 3	Swede_Fodder	leafcrop_grainlegume	75.0	24	0.15	0	1800	634	20	13	1166	902	75	43	83	72	36	10
SC	Grade 3	Swede_Fodder	leafcrop_grainlegume	75.0	24	0.15	0	1800	666	20	13	1134	870	75	43	83	0	0	0
SC	Grade 4	Barley_spring_Grain	cereal	4.0	174	0.86	0	696	706	20	13	-10	-274	100	24	46	90	45	12
SC	Grade 4	Barley_spring_Grain	cereal	4.0	174	0.86	0	696	729	20	13	-33	-297	110	24	46	0	0	0
SC	Grade 4	Barley_spring_Grain	cereal	4.0	174	0.86	0	696	729	20	13	-33	-297	110	24	46	0	0	0
SC	Grade 4	Barley_spring_Grain	foragelegume	5.0	174	0.86	0	870	686	20	13	184	-80	55	24	46	90	45	12
SC	Grade 4	Barley_spring_Grain	foragelegume	5.0	174	0.86	0	870	716	20	13	154	-110	76	24	46	0	0	0
SC	Grade 4	Barley_spring_Grain	foragelegume	5.0	174	0.86	0	870	716	20	13	154	-110	76	24	46	0	0	0
SC	Grade 4	Barley_spring_Grain	leafcrop_grainlegume	5.0	174	0.86	0	870	696	20	13	174	-90	73	24	46	90	45	12
SC	Grade 4	Barley_spring_Grain	leafcrop_grainlegume	5.0	174	0.86	0	870	721	20	13	149	-115	83	24	46	0	0	0
SC	Grade 4	Barley_spring_Grain	leafcrop_grainlegume	5.0	174	0.86	0	870	721	20	13	149	-115	83	24	46	0	0	0
SC	Grade 4	Barley_spring_Seed	cereal	4.0	210	0.86	0	840	706	20	13	134	-130	100	24	46	90	45	12
SC	Grade 4	Barley_spring_Seed	cereal	4.0	210	0.86	0	840	729	20	13	111	-153	110	24	46	0	0	0
SC	Grade 4	Barley_spring_Seed	foragelegume	5.0	210	0.86	0	1050	686	20	13	364	100	55	24	46	90	45	12
SC	Grade 4	Barley_spring_Seed	foragelegume	5.0	210	0.86	0	1050	716	20	13	334	70	76	24	46	0	0	0
SC	Grade 4	Barley_spring_Seed	leafcrop_grainlegume	5.0	210	0.86	0	1050	696	20	13	354	90	73	24	46	90	45	12

Countr y	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variabl e costs (€/ha)	Labou r (h/ha)	Labou r costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SC	Grade 4	Barley_spring_See d	leafcrop_grainlegume	5.0	210	0.86	0	1050	721	20	13	329	65	83	24	46	0	0	0
SC	Grade 4	Oat _spring_Grain	cereal	3.0	180	0.86	108	540	681	20	13	-33	-297	96	22	42	90	45	12
SC	Grade 4	Oat _spring_Grain	cereal	3.0	180	0.86	108	540	704	20	13	-56	-320	103	22	42	0	0	0
SC	Grade 4	Oat _spring_Grain	cereal	3.0	180	0.86	108	540	704	20	13	-56	-320	103	22	42	0	0	0
SC	Grade 4	Oat _spring_Grain	foragelegume	3.5	180	0.86	126	630	661	20	13	95	-169	51	22	42	60	30	8
SC	Grade 4	Oat _spring_Grain	foragelegume	3.5	180	0.86	126	630	691	20	13	65	-199	72	22	42	0	0	0
SC	Grade 4	Oat _spring_Grain	foragelegume	3.5	180	0.86	126	630	691	20	13	65	-199	72	22	42	0	0	0
SC	Grade 4	Oat _spring_Grain	leafcrop_grainlegume	3.5	180	0.86	126	630	671	20	13	85	-179	68	22	42	72	36	10
SC	Grade 4	Oat _spring_Grain	leafcrop_grainlegume	3.5	180	0.86	126	630	696	20	13	60	-204	79	22	42	0	0	0
SC	Grade 4	Oat _spring_Grain	leafcrop_grainlegume	3.5	180	0.86	126	630	696	20	13	60	-204	79	22	42	0	0	0
SC	Grade 4	Oat_winter_grain	cereal	4.5	180	0.86	180	810	753	20	13	237	-27	121	26	50	0	0	0
SC	Grade 4	Oat_winter_grain	foragelegume	5.0	180	0.86	192	900	731	20	13	361	97	104	26	50	0	0	0
SC	Grade 4	Oat_winter_grain	leafcrop_grainlegume	5.0	180	0.86	192	900	741	20	13	351	87	110	26	50	0	0	0
SC	Grade 4	Swede_Fodder	cereal	55.0	24	0.15	0	1320	634	20	13	686	422	75	43	83	90	45	12
SC	Grade 4	Swede_Fodder	cereal	55.0	24	0.15	0	1320	666	20	13	654	390	75	43	83	0	0	0
SC	Grade 4	Swede_Fodder	foragelegume	60.0	24	0.15	0	1440	634	20	13	806	542	75	43	83	60	30	8
SC	Grade 4	Swede_Fodder	foragelegume	60.0	24	0.15	0	1440	666	20	13	774	510	75	43	83	0	0	0
SC	Grade 4	Swede_Fodder	leafcrop_grainlegume	60.0	24	0.15	0	1440	634	20	13	806	542	75	43	83	72	36	10
SC	Grade 4	Swede_Fodder	leafcrop_grainlegume	60.0	24	0.15	0	1440	666	20	13	774	510	75	43	83	0	0	0
SE	clay soil	faba bean	cereal	3.1	168	0.86	0	521	397	4	22	124	44	0	14	27	0	0	0
SE	clay soil	faba bean	foragelegume	3.1	168	0.86	0	521	397	4	22	124	44	0	14	27	0	0	0
SE	clay soil	faba bean	leafcrop_grainlegume	3.1	168	0.86	0	521	397	4	22	124	44	0	14	27	0	0	0
SE	clay soil	Forage maize	cereal	42.0	32	0.25	0	1330	1032	6	22	298	170	101	0	0	114	21	13
SE	clay soil	Forage maize	foragelegume	42.0	32	0.25	0	1330	1032	6	22	298	170	101	0	0	114	21	13
SE	clay soil	Forage maize	leafcrop_grainlegume	42.0	32	0.25	0	1330	1032	6	22	298	170	101	0	0	114	21	13
SE	clay soil	Grass ley, after grass ley	leafcrop_grainlegume	20.0	48	0.35	0	959	416	6	22	543	406	138	0	0	114	21	13

Countr y	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variabl e costs (€/ha)	Labou r (h/ha)	Labou r costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SE	clay soil	Grass ley, undersown	cereal	20.0	48	0.35	0	959	416	6	22	543	406	138	0	0	114	21	13
SE	clay soil	Grass ley, undersown	cereal	20.0	48	0.35	0	959	671	6	22	287	151	183	45	86	0	0	0
SE	clay soil	Grass/clover after ley	foragelegume	18.9	47	0.35	0	894	327	6	22	567	431	65	0	0	114	21	13
SE	clay soil	Grass/clover, undersown	cereal	18.9	47	0.35	0	894	327	6	22	567	431	65	0	0	114	21	13
SE	clay soil	Grass/clover, undersown	cereal	18.9	47	0.35	0	894	582	6	22	312	175	110	45	86	0	0	0
SE	clay soil	Intercrop, pea/oats	cereal	4.0	33	0.31	0	133	394	7	22	-261	-413	38	10	10	0	0	0
SE	clay soil	Intercrop, pea/oats	foragelegume	4.9	33	0.31	0	162	394	7	22	-231	-383	38	10	10	0	0	0
SE	clay soil	Intercrop, pea/oats	leafcrop_grainlegume	4.4	33	0.31	0	146	394	7	22	-248	-399	38	10	10	0	0	0
SE	clay soil	pea/oats, nurse crop	cereal	4.0	33	0.31	0	133	318	7	22	-185	-337	0	0	0	183	42	31
SE	clay soil	pea/oats, nurse crop	foragelegume	4.9	33	0.31	0	162	318	7	22	-155	-307	0	0	0	183	42	31
SE	clay soil	pea/oats, nurse crop	leafcrop_grainlegume	4.4	33	0.31	0	146	318	7	22	-172	-323	0	0	0	183	42	31
SE	clay soil	linseed	cereal	1.6	466	0.93	0	746	367	5	22	378	272	54	0	0	0	0	0
SE	clay soil	linseed	foragelegume	1.6	466	0.93	0	746	367	5	22	378	272	54	0	0	0	0	0
SE	clay soil	linseed	leafcrop_grainlegume	1.6	466	0.93	0	746	367	5	22	378	272	54	0	0	0	0	0
SE	clay soil	pea	cereal	3.0	207	0.87	0	621	455	4	22	166	70	0	14	27	0	0	0
SE	clay soil	pea	foragelegume	3.0	207	0.87	0	621	455	4	22	166	70	0	14	27	0	0	0
SE	clay soil	pea	leafcrop_grainlegume	3.0	207	0.87	0	621	455	4	22	166	70	0	14	27	0	0	0
SE	clay soil	Spring barley	cereal	4.6	171	0.87	0	787	372	5	22	415	302	87	0	0	0	0	0
SE	clay soil	Spring barley	foragelegume	5.6	171	0.87	0	958	372	5	22	586	473	87	0	0	0	0	0
SE	clay soil	Spring barley	leafcrop_grainlegume	5.1	171	0.87	0	872	372	5	22	500	388	87	0	0	0	0	0
SE	clay soil	Spring barley for malting	cereal	4.6	214	0.87	0	984	376	5	22	608	496	87	0	0	0	0	0
SE	clay soil	Spring barley for malting	foragelegume	5.6	214	0.87	0	1198	376	5	22	822	710	87	0	0	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SE	clay soil	Spring barley for malting	leafcrop_grainlegume	5.1	214	0.87	0	1091	376	5	22	715	603	87	0	0	0	0	0
SE	clay soil	Spring oats	cereal	4.4	143	0.86	92	629	347	5	22	374	261	78	0	0	0	0	0
SE	clay soil	Spring oats	foragelegume	5.4	143	0.87	92	772	347	5	22	517	404	78	0	0	0	0	0
SE	clay soil	Spring oats	leafcrop_grainlegume	4.9	143	0.87	92	701	347	5	22	445	332	78	0	0	0	0	0
SE	clay soil	Spring oats nurse crop	cereal	4.0	143	0.87	0	572	238	5	22	334	222	0	0	0	114	21	13
SE	clay soil	Spring oats nurse crop	foragelegume	4.9	143	0.87	0	701	238	5	22	463	350	0	0	0	114	21	13
SE	clay soil	Spring oats nurse crop	leafcrop_grainlegume	4.4	143	0.87	0	629	238	5	22	392	279	0	0	0	114	21	13
SE	clay soil	Spring oil seed rape	cereal	1.9	432	0.93	0	821	465	5	22	356	257	103	28	28	0	0	0
SE	clay soil	Spring oil seed rape	foragelegume	1.9	432	0.93	0	821	465	5	22	356	257	103	28	28	0	0	0
SE	clay soil	Spring oil seed rape	leafcrop_grainlegume	1.9	432	0.93	0	821	465	5	22	356	257	103	28	28	0	0	0
SE	clay soil	spring wheat	cereal	4.6	196	0.87	0	902	543	6	22	359	237	122	23	23	0	0	0
SE	clay soil	spring wheat	foragelegume	5.6	196	0.87	0	1098	543	6	22	555	433	122	23	23	0	0	0
SE	clay soil	spring wheat	leafcrop_grainlegume	5.1	196	0.87	0	1000	543	6	22	457	335	122	23	23	0	0	0
SE	clay soil	Whole-crop silage	cereal	5.9	43	0.37	0	256	548	7	22	-292	-444	98	19	36	0	0	0
SE	clay soil	Whole-crop silage	foragelegume	8.5	43	0.37	0	369	548	7	22	-180	-331	98	19	36	0	0	0
SE	clay soil	Whole-crop silage	leafcrop_grainlegume	8.0	43	0.37	0	347	548	7	22	-201	-353	98	19	36	0	0	0
SE	clay soil	winter oil seed rape	cereal	3.4	432	0.93	0	1469	437	5	22	1031	917	133	0	0	114	21	13
SE	clay soil	winter oil seed rape	cereal	3.4	432	0.93	0	1469	695	5	22	774	659	168	36	36	0	0	0
SE	clay soil	winter oil seed rape	foragelegume	3.4	432	0.93	0	1469	695	5	22	774	659	133	36	36	0	0	0
SE	clay soil	winter oil seed rape	foragelegume	3.6	432	0.93	0	1555	454	5	22	1101	986	133	0	0	114	21	13
SE	clay soil	winter oil seed rape	leafcrop_grainlegume	3.4	432	0.93	0	1469	437	5	22	1031	917	133	0	0	114	21	13
SE	clay soil	winter oil seed rape	leafcrop_grainlegume	3.6	432	0.93	0	1555	695	5	22	860	745	168	36	36	0	0	0
SE	clay soil	winter rye	cereal	5.5	186	0.87	0	1023	621	7	22	402	259	147	28	28	0	0	0
SE	clay soil	winter rye	foragelegume	7.0	186	0.87	0	1302	621	7	22	681	538	147	28	28	0	0	0

Country	SItalye class	Crop	Pre crop type	Yield (t/ha)	Price (€/t)	DM (%)	Revenues (€/ha)		Variable costs (€/ha)	Labour (h/ha)	Labour costs (€/h)	Gross margin (€/ha)		Mineral fertiliser (kg/ha)			Organic fertiliser (kg/ha)		
SE	clay soil	winter rye	leafcrop_grainlegume	6.5	186	0.87	0	1209	621	7	22	588	445	147	28	28	0	0	0
SE	clay soil	Winter triticale	cereal	5.4	166	0.87	0	896	553	6	22	343	209	118	32	32	0	0	0
SE	clay soil	Winter triticale	foragelegume	6.9	166	0.87	0	1145	553	6	22	592	458	118	32	32	0	0	0
SE	clay soil	Winter triticale	leafcrop_grainlegume	6.4	166	0.87	0	1062	553	6	22	509	375	118	32	32	0	0	0
SE	clay soil	winter wheat, bread	cereal	6.1	184	0.87	0	1122	621	6	22	501	378	147	28	28	0	0	0
SE	clay soil	winter wheat, bread	foragelegume	7.7	184	0.87	0	1417	621	6	22	795	672	147	28	28	0	0	0
SE	clay soil	winter wheat, bread	leafcrop_grainlegume	7.1	184	0.87	0	1306	621	6	22	685	562	147	28	28	0	0	0
SE	clay soil	winter wheat, feed	cereal	6.1	188	0.87	0	1147	645	5	22	501	384	147	40	40	0	0	0
SE	clay soil	winter wheat, feed	foragelegume	7.7	188	0.87	0	1448	645	5	22	802	685	147	40	40	0	0	0
SE	clay soil	winter wheat, feed	leafcrop_grainlegume	7.1	188	0.87	0	1335	645	5	22	689	572	147	40	40	0	0	0

Pre-crop types: cereal=all cereals including maize; leafcrop_grainlegume=grain legumes, rape seed, sunflower; foragelegume=all forage legumes or forage legume-grass mixtures; ro_1=soy bean, common bean; ro_2=pea; ro_3=winter wheat, rape seed; ro_4 maize, sunflower, barley
Site-class: irrigated1 = irrigated_highland; irrigated_2 = irrigated_lowland

ANNEX 5: Selected crop rotations for all case studies and selected sites according to economic and ecological criteria

Region	siteclass	with forage	with legume	year 1	year 2	year 3	year 4	year 5	year 6	avg Costs/ ME [10 cents/ MJ ME]	avg GM [€/ha]	avg N leaching [kg N/ha]	avg N balance [kg N/ha]	Neff[1]	NBI[1]	avg pest[1]	avg disease[1]	avg weeds[1]
BB	LBG1	no	no	wrape	wwheat	wbarley					288	22	-11	0.93	-0.07	0.33	0.33	0.00
BB	LBG1	no	yes	wrape	tritica	fababea	wwheat	wbarley			197	18	-5	1.29	-0.03	0.00	0.00	0.20
BB	LBG1	yes	no	wrape	tritica	maize_s	wwheat	wbarley		7	274	26	-5	0.86	-0.03	0.20	0.00	0.60
BB	LBG1	yes	yes	alfalfa	alfalfa	wwheat	wbarley	wrape	tritica	7	320	13	19	1.91	0.09	0.17	0.17	0.17
BB	LBG2	no	no	wrape	wwheat	wbarley					161	33	-10	0.84	-0.07	0.33	0.33	0.00
BB	LBG2	yes	no	wrape	wwheat	maize_s	sbarley			8	199	51	-8	0.72	-0.05	0.25	0.00	1.00
BB	LBG2	no	yes	wrape	tritica	fababea	wwheat	sbarley			106	34	-8	1.16	-0.06	0.00	0.00	0.60
BB	LBG2	yes	yes	alfalfa	alfalfa	wwheat	sbarley	wrape	wrye	8	201	24	16	1.91	0.08	0.17	0.33	0.33
BB	LBG3	no	no	wrape	wrye	sbarley					105	35	-20	0.85	-0.20	0.00	0.00	0.00
BB	LBG3	yes	no	wrape	wrye	maize_s	sbarley			9	105	42	-9	0.73	-0.08	0.00	-0.25	0.50
BB	LBG3	no	yes	wrape	wrye	wrye	wrye	pea			55	19	-10	1.27	-0.10	-0.40	0.20	0.00
BB	LBG3	yes	yes	graclov	graclov	wrye	sbarley	wrape	wrye	11	205	18	15	2.18	0.09	0.00	0.17	0.00
BB	LBG4	no	yes	pea	wrye	wrye	wrye	wrye			-95	10	-13	1.63	-0.20	-0.20	0.60	0.20
BB	LBG4	yes	yes	graclov	graclov	wrye	lupin	wrye	wrye	12	15	8	14	4.42	0.10	-0.17	0.33	0.00
BB	LBG5	yes	yes	seradel	wrye	ryevetc	wrye	wrye		6	44	5	9	2.23	0.09	-0.40	0.20	-0.20
BB	LBG5	no	yes	lupin	wrye	wrye	wrye	wrye			-194	10	-9	1.58	-0.18	-0.20	0.60	0.00
IT	irrigated_1	yes	yes	alfalfa	alfalfa	wwheat	potato	wwheat			581	31	125	1.37	0.38	-0.50	0.00	-1.50
IT	irrigated_1	no	no	potato	wrape	wwheat	wrape	wwheat			444	48	-71	1.43	-1.31	-1.50	0.00	-0.50
IT	irrigated_1	no	yes	potato	lupin	wwheat	lupin	wwheat			509	69	-39	2.14	-0.31	-0.50	0.00	-1.00
IT	irrigated_2	no	yes	fababea	wwheat	fababea	maize_s			3	71	18	-22	2.51	-0.29	-0.50	0.00	0.00

Region	siteclass	with forage	with legume	year 1	year 2	year 3	year 4	year 5	year 6	avg Costs/ ME [10 cents/ MJ ME]	avg GM [€/ha]	avg N leaching [kg N/ha]	avg N balance [kg N/ha]	Neff[1]	NBI[1]	avg pest[1]	avg disease[1]	avg weeds[1]
IT	irrigated_2	yes	yes	alfalfa	alfalfa	alfalfa	durum	wbarley			582	1	164	2.08	0.45	-0.40	0.00	-1.60
IT	rainfed	yes	yes	wrape	wwheat	oatvetc					514	6	12	2.53	0.10	-1.33	0.00	-0.67
IT	rainfed	no	no	wrape	wwheat	wrape	tritica				358	12	-27	1.26	-0.48	-1.50	0.00	-0.50
IT	rainfed	no	yes	wrape	wwheat	fababea	wwheat				283	18	-20	1.54	-0.29	-1.00	0.00	-0.25
RO	Chernozem	no	yes	soybean	maize_g	wwheat	wrape				497	14	5	1.12	0.04	1.25	1.50	1.00
RO	Chernozem	no	no	wrape	maize_g	wwheat					409	13	9	0.80	0.08	1.00	1.67	0.67
SC	Grade 1&2	no	yes	potato	wwheat	wrape	wwheat	woat	fababea		1578	22	3	1.15	0.01			
SC	Grade 1&2	no	no	potato	wwheat	wwheat	wwheat	wwheat	wrape		1606	25	2	0.86	0.01			
SC	Grade 3	yes	no	grass	grass	grass	wrape	sbarley		10	549	23	109	0.57	0.35			
SC	Grade 3	yes	yes	graclov	graclov	graclov	woat	soat		9	554	29	102	0.84	0.33			
SC	Grade 3	no	yes	potato	wwheat	swedes	swheat	fababea	woat	7	831	41	-5	1.07	-0.03			
SC	Grade 3	no	no	potato	wwheat	wbarley	woat	swedes	swheat	7	850	47	-13	0.79	-0.08			
SC	Grade 4	yes	no	grass	grass	grass	sbarley			12	237	28	130	0.49	0.42			
SC	Grade 4	yes	yes	graclov	graclov	graclov	swedes	sbarley		10	237	25	90	0.80	0.34			
SE	clay soil	yes	no	wrape	tritica	maize_s	linseed	wrye			562	26	12	0.73	0.08	-0.40	-0.60	0.80
SE	clay soil	no	no	wrape	tritica	sbarley	wwheat	sbarley			642	23	11	0.76	0.08	-0.50	-0.50	0.00
SE	clay soil	yes	yes	graclov	graclov	graclov	wrape	wrye	soat		566	16	56	0.91	0.27	-0.33	-0.50	0.33
SE	clay soil	yes	yes	wrape	tritica	sbarley	peaoat	wwheat	sbarley	35	642	21	11	0.95	0.08	0.33	0.00	0.67
SE	clay soil	no	yes	wrape	wrye	pea	tritica	linseed	wrye		501	23	12	0.90	0.09	-0.50	-0.50	0.83