Impacts of cross compliance measures on environmental indicators

An assessment tool to evaluate environmental impacts at the European scale

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An assessment tool to evaluate environmental impacts at the European scale

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Abstract

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The EU cross-compliance (CC) instrument implies that farmers receive payments subject to meeting Statutory Management Requirements (SMRs) related to environment, food safety, animal and plant health and animal welfare, as well as standards of good agricultural and environmental conditions (GAECs). This report describes the approach and application methodology of an environmental impact tool to evaluate cross compliance measures on environmental effect indicators. It consists of a selection of the effect indicators to be applied and assessment tools to be used with a review of the CC measures to be evaluated in assessing the environmental impacts. Furthermore, it includes an evaluation of CC measures related to the Nitrates Directive and selected GAECs with the coupled CAPRI-MITERRA model for the prototype of the environmental impact tool.

Keywords: cross-compliance, environmental effect, Nitrates Directive, Ammonia, greenhouse gases, gross balance, nitrogen, phosphate.

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Preface

This report is based on a progress report for the CCAT project carried out in the period 2006-2010. The main objective of this project was to develop an analytical tool that enables the integrated assessment of the impact of Cross Compliance (CC) at regional level. Impacts assessed by the tool include effects on agricultural markets, producer's income, consumer's welfare, land use, soil, water, air, climate, biodiversity and landscapes, as well as food safety, animal welfare and health. The project included an evaluation of the impact of cross-compliance since 2005. The analytical tool enables the assessment of impacts of CC given different implementation pathways and specific national and regional conditions. This report describes the approach and application methodology of the environmental impact tool to evaluate cross compliance measures on environmental effect indicators.

Summary

The EU cross-compliance (CC) instrument implies that farmers receive payments subject to meeting Statutory Management Requirements (SMRs) related to environment, food safety, animal and plant health and animal welfare, as well as standards of good agricultural and environmental conditions (GAECs). This report describes the approach and application methodology of an environmental impact tool to evaluate cross compliance measures on environmental effect indicators. It consists of a selection of the effect indicators to be applied and assessment tools to be used with a review of the CC measures to be evaluated in assessing the environmental impacts. More specifically, the report presents:

- A characterization of selected environmental effect indicators for soil-, air- and water quality and climate, including (Chapter 2).
- An overview of the overall modelling approach and the use of different models to calculated the selected environmental effect indicators, i.e. MITERRA Europe, EPIC and DNDC, coupled to the economic CAPRI model (Chapter 3).
- An overview of the selected cross compliance measures in the various SMRs and GAECs, to be analyzed with the modelling tools (Chapter 4).
- An evaluation of CC measures related to the Nitrates Directive and selected GAECs with the coupled CAPRI-MITERRA model for the prototype of the environmental impact tool (Chapter 5).

The model results include:

- Air: Emissions of (i) ammonia in kg NH3-N/ha/yr and (ii) greenhouse gases N2O and CH4 in kg N2O-N/ha/yr and kg CH4/ha/yr
- Soil: gross balance of: (i) C allowing to calculate the change in soil organic carbon content in the topsoil in g/kg (ii) the nutrients N in kg N/ha/yr and P in kg P/ha/yr and (iii) the metals Cd, Cu and Zn in g/ha/yr, including inputs of these metals to soil by fertilizer, manure and sewage sludge and the output by crop removal.
- Water: Nitrates in water, including leaching in kg N/ha/yr and concentrations in mg NO3/l.

The potential environmental impacts of all measures in SMRs and GAECs and the selected measures in SMRs and GAECs, including the way in which effect indicators will be calculated with one or more models in the CCAT tool, are presented in annexes.

1 Introduction

The 2003 Mid-Term Review (MTR) of the Common Agricultural Policy (CAP) introduced a number of adjustments to agricultural support. One of the most substantive changes was the introduction of a system of decoupled payments per farm (Single Farm Payment). Moreover a cross-compliance (CC) instrument was to accompany this system making the payments conditional on meeting Statutory Management Requirements (SMRs) related to environment, food safety, animal and plant health and animal welfare, as well as standards of good agricultural and environmental condition (GAECs). The CC instrument has been implemented from 2005 onwards in the EU-15. It specifies that all farmers receiving direct payments are subject to compulsory cross-compliance (Council Regulation No 1782/2003 and Commission Regulation No. 796/2004).

The primary objective of the whole policy reform of 2003 was to promote a more market-oriented and sustainable agriculture. However, it remains largely unknown how the introduction of cross-compliance affects producers' income, consumers' welfare and environmental aspects. Overall, little knowledge is available until now on the effects of CC on sustainability, because it has only recently been implemented in a selection of the EU Member States (MS) and also because of the variation across MS, with respect to minimum standards for GAECs. In addition, the impacts of CC may largely vary as a result of a combination of practical implementation within a specific national and regional context and farmers' decisions. Although some estimates are available about the costs of CC, information on their benefits is hardly available. The CCAT project aims to clarify this latter aspect, thus contributing to a more balanced picture of both benefits and costs of CC.

The work in task 4.2 of the project focuses on the development of an environmental impact tool to evaluate cross compliance measures. It is divided into four major activities (1) selection of the effect indicators and assessment tools with a review of the CC measures to be evaluated in assessing environmental impacts; (2) implementation of particular CC measures into the models; (3) evaluation of the environmental impacts of particular CC measures at the regional scale and (4) derivation of simplified measure-impact relationships to be implemented in the analytical tool. In this text, we focus on the first task by presenting:

- A characterization of selected environmental effect indicators for soil-, air- and water quality and climate (Chapter 2).
- An overview of the overall modelling approach and the use of different models to calculated the selected environmental effect indicators (Chapter 3).
- An overview of the selected cross compliance measures, related to the SMRs and GAECs mentioned, to be analyzed with the modelling tools (Chapter 4).
- An elaborated approach to evaluate CC measures related to the Nitrates Directive and selected GAECs for the prototype of the environmental impact tool, being part of the overall impact assessment tool (Chapter 5).

2 Selected environmental effect indicators

2.1 Relevant indicators for soil-, air- and water quality and climate

EU agriculture has experienced important changes which has generally lead to both intensification, extensification and land abandonment. In most European countries, agriculture is also one of the most important land use activities and can be considered as a sector with important impacts on the quality of water, air and soil and on climate.

The IRENA operation on agri-environmental indicators (EEA, 2005) but also several other studies (e.g. Boatman et al., 1999; EEA, 1999; Jørgensen and Schelde, 2001; Agra CEAS Consulting Ltd., 2003; EEA, 2004; Petit et al., 2004; Carey, 2007 etc.) show that the following indicators are most relevant with respect to the environmental impacts of agriculture:

- Greenhouse gas and ammonia emissions from agriculture caused by high concentrations of livestock, mineral fertiliser consumption and intensive farming practices (tillage and frequent ploughing), affecting both air quality and climate change. Relevant IRENA indictors are atmospheric emissions of ammonia (IRENA 18.2) and greenhouse gases (IRENA 19 and 34.1).
- Diffuse pollution from agriculture affecting the (chemical) quality of soil, ground and surface waters. It contributes significantly to pollution of soil and water through leaching and runoff of nitrogen, phosphorous, heavy metals and pesticides. Key drivers for nutrient losses from agriculture are use of fertilisers, pesticides, concentrate feeding, high livestock densities and farm management practices. Actual losses are further influenced by environmental factors, including soil type and related soil properties, such as organic matter and clay content, hydrological status, temperature climate and precipitation. Relevant IRENA indicators are the gross balance of the nutrients N and P (IRENA 18), nitrates in water (IRENA 30 and 34.2), soil organic carbon content in the topsoil (IRENA 29), inputs of heavy metals (Cd, Pb, Cu Zn, Ni, Cr, Hg) to soil by sewage sludge (IRENA 21), the consumption of pesticides (IRENA 9) and the occurrence of pesticides in soils (IRENA 20) and in water (IRENA 30).
- Soil degradation, caused by soil compaction (IRENA 29) and soil erosion (IRENA 23) affecting the physical quality of the soil. Areas degraded by soil compaction are increasing because wheel loads in agriculture are still increasing (JRC, 2005). Soil compaction of the topsoil or subsoil involves an increase in the density of soil particles and pores. Compaction can reduce water infiltration capacity and, increase erosion risk by accelerating run-off. Soil compaction to ever-greater depth has adverse effects on the soil biodiversity and soil structure and may lead to problems, such as disturbed root growth. At this moment we see that European soils are more threatened by soil compaction than ever before. It is now the first in the ranking of soil damages just before soil erosion (EEA, 2005). Soil erosion in Europe is especially a problem in the Mediterranean region, which is characterised by long dry periods followed by heavy bursts of rainfall, falling on steep slopes with unstable soils (EEA, 2005). Because of the dry summers in these areas, soil cover is also limited in summer which increases the risk for erosion in autumn when the rainfall starts. In the Northern parts of Europe erosion by water is not such a problem as rainfall is spread out more evenly over the year and there are fewer regions with steep slopes and shallow soils. Nevertheless, less crop rotations and increase of maize acreage in the last decades contributed to soil erosion. Beside water erosion, there is also erosion caused by wind. This is a problem in more open, flat or undulating terrain with sandy soils where soil cover is limited over the year and wind-breaking landscape elements are missing.

2.2 Indicators to be evaluated by the environmental impact tool

The objective of Task 4.2 is the assessment of impacts of cross compliance measures on air-, soil-, and water quality. In this context, a choice has to be made which environmental indicators we aim to address. In the analytical tool, we include all aspects that can be quantified in a reasonable way on a European wide scale. The inadequacy of information on pesticide use on a European wide scale and the complexity of modelling pesticide behaviour makes it difficult to make adequate predictions of pesticide accumulation and leaching in response to measures. Furthermore, pesticides are not under cross compliance measures. Consequently, the impact of cross-compliance measures on pesticides is not included in the integrated environmental modelling framework.

Considering the information given above, the overall objective of the modelling framework is to assess the impact of cross-compliance measures on air-, soil-, and water quality in terms of:

- Atmospheric emission of ammonia and greenhouse gases (air quality and climate).
- Soil accumulation or release of carbon (organic matter), phosphorous and heavy metals (chemical soil quality).
- Soil erosion (physical soil quality).
- Leaching and runoff of nitrogen and possibly phosphorus and heavy metals (water quality).

The word possibly for phosphorus and heavy metals is because it is not yet sure whether predictions are feasible in view of the data demand. In Table 1 a more detailed selection of indicators is given in view of the IRENA and OECD indicator frameworks discussed above. Most of the possible indicators are in the pressure category. More specifically the model results will include:

Air

- Emissions of ammonia in kg NH3-N/ha/yr (IRENA 18.2 and 34.1).
- Emissions of the greenhouse gases N2O and CH4 in kg N2O-N/ha/yr and kg CH4/ha/yr (IRENA 19),

Soil.

- Soil erosion in m3 soil/ha/yr (IRENA 23).
- Gross balance of C allowing to calculate the change in soil organic carbon content in the topsoil in g/kg (IRENA 29).
- Gross balance of the nutrients N in kg N/ha/yr and P in kg P/ha/yr (IRENA 18).
- Gross balance of metals, including inputs of heavy metals to soil by sewage sludge in g/ha/yr (IRENA 21) but also by other sources and the output by crop removal.

Water

- Nitrates in water: leaching in kg N/ha/yr and concentrations in mg NO3/l (IRENA 30 and 34.2).
- Possibly concentrations of metals and phosphate in water (not in IRENA).

Table 1
Main environmental impacts fields and selected indicators for assessing impacts of cross compliance measures.

Environmental field of impact	Selected indicator	Source (indicator framework)	Type of indicator DPSIR
Air quality	Total atmospheric emissions of ammonia (NH_3) form agriculture[1]	IRENA, OECD agri-environmental Indicators	P
Climate	Emissions of nitrous oxide by agriculture	IRENA	P
	Emissions of methane by agriculture	IRENA	P
	Gross total GHG emission from agriculture in CO_2 equivalents	IRENA, OECD agri-environmental Indicators	P
Physical soil quality	Soil erosion by water[2]	IRENA	P
Chemical soil quality	Top soil organic carbon content	IRENA	P
	Gross phosphorus balance	IRENA, OECD agri-environmental Indicators	P
	Use of sewage sludge (metal input)	IRENA	S
Ground and surface water quality	Gross nitrogen balance	IRENA, OECD agri-environmental Indicators, Eurostat	P
	Nitrate leaching to ground water and runoff to surface water from agriculture[3]	IRENA, OECD agri-environmental Indicators	S

[1] The IRENA indicator gives 'Contribution of agriculture to atmospheric emissions of ammonia (NH_3).
[2] The IRENA indicator gives 'Annual soil erosion risk by water' and 'Area and share of agricultural land affected by water erosion"'.
[3] The IRENA indicator gives 'Share of nitrates in ground and surface water derived from agriculture'.

Pesticide accumulation (occurrence in soil) and leaching (occurrence in water) is not included as an indicator because: (i) pesticides are not under cross compliance measures, (ii) the information on pesticide use on a European wide scale is inadequate and (iii) the complexity of modelling pesticide behaviour makes it difficult to make adequate predictions of pesticide accumulation and leaching in response to measures at a large scale. Regarding the mentioned indicators, environmental targets relevant to agriculture have been set at country or regional level for atmospheric emissions of ammonia and green house gases, nitrates in water and the consumption of pesticides (IRENA 03).

3 Modelling approach, modelling tools and input data

3.1 General approach

An integrated approach focusing on all the impacts mentioned above depends on the availability of models and data at the European scale. For the environmental assessment, existing models will be further adapted and integrated into the framework or modelling outputs will be translated into knowledge rules and integrated into the analytical tool (WP5). The existing and tested models to be used are: (i) MITERRA-Europe in combination with parts of CAPRI, being a set of integrated and relatively simple models for use at the continental (EU) level and (ii) DNDC and EPIC, being detailed biogeochemical and hydrological soil models, for use at the plot level and simplified meta-models based on these models at the continental (EU) level.

The main idea is to extend the MITERRA Europe model with at least the balance of carbon and metals and possibly phosphorous and metal leaching (see below), to assess the impacts on all air, soil and water quality indicators on a European wide scale with the exception of soil erosion. Regarding soil erosion, a separate meta-model in terms of e.g. simplified regression functions will be derived from the EPIC model. The main idea of using DNDC and EPIC is further to derive meta models for N_2O emission (DNDC), N balance (DNDC), N leaching (DNDC and EPIC) and N runoff (EPIC) to assess impacts of specific CC measures on these air and water quality indicators that cannot be evaluated by MITERRA Europe. Results of measures that can only be evaluated with EPIC or DNDC can be transferred to MITERRA Europe, e.g. in terms of percentage reduction in emission of N_2O leaching of nitrate or runoff of nitrogen for specific combinations of land use and soil, for including application on a European scale. Furthermore, a comparison will be made between MITERRA Europe and DNDC and EPIC meta-model predictions on a European wide scale for both the present situation and after the inclusion of the same sets of CC measures as one way to evaluate the uncertainty in the MITERRA Europe predictions. The indicators that are predicted by the extended MITERRA Europe model and the meta models of DNDC and EPIC, being relevant in the CCAT project, are given in Table 2.

Table 2
Indicators predicted by the extended MITERRA Europe, and the meta models of DNDC and EPIC used in CCAT.

Compartment	Indicator	Unit	MITERRA Europe extended	DNDC	EPIC
Air/	NH_3 emission	kg NH_3-N/ha/yr	X	-[1]	-
Climate	N_2O emission	kg N_2O-N/ha/yr	X	X	-
	CH_4 emission	kg CH_4/ha/yr	X	-[1]	-
Soil	Erosion	m^3 soil/ha/yr	-	-	X
	Carbon balance	kg C/ha/yr	X	-[1]	-[2]
	Phosphorous balance	kg P/ha/yr	X	-	-[2]
	Metal balance	g/ha/yr	X	-	-
Water	Nitrogen balance	kg N/ha/yr	X	X	X
	Nitrogen leaching[3]	kg N/ha/yr	X	X	X
	Nitrogen runoff	kg N/ha/yr	X	-	X

[1] DNDC includes modules to assess these fluxes but they are not included in the DNDC meta models used in CCAT since (i) NH_3 and CH_4 emissions are limited to the agricultural soils and do not include the housing and manure storage systems and (ii) the carbon balance calculated by DNDC is still not thoroughly validated.
[2] EPIC includes modules to assess these fluxes but they are not included in the EPIC meta models used in CCAT because EPIC is not validated for carbon and phosphorous balance in Europe.

For phosphorous and metal leaching, the prediction by MITERRA Europe is put in brackets, since application on a European scale is doubtful in view of available soil data. The specific approach to predict air, soil and water quality indicators with the aid of extended MITERRA Europe model, making use of the detailed models DNDC and EPIC, is further illustrated in Figure 1. The approach will be to:

- *Further develop the MITERRA Europe model as* an integrated tool for the assessment of the specific impacts of CC on air (ammonia and greenhouse gas emissions) soil (organic matter, nutrients, metals) and water quality indicators (nutrients and metal loads) by including the carbon and metal balance and possibly phosphorous and metal leaching.
- Further develop, parameterize and apply the *mechanistic models* DNDC and EPIC for the assessment of the impacts of CC measures on air, soil and water quality indicators and perform a sensitivity analysis for the most influential parameters.
- *Develop* meta models for soil erosion and N leaching/runoff based on EPIC results (See Figure 5) and meta models for N2O emissions, N balance (N input minus net N removal) and N leaching based on DNDC results (See Figure 6) to be used the final CCAT tool.
- *Assess impacts* of identified CC measures on air, soil and water quality indicators by quantifying the effects of these measures on parameters affecting N and GHG fluxes and erosion, as calculated with MITERRA Europe and the DNDC and EPIC meta models against the baseline of the year 2005.
- *Provide the models* to be incorporated in the final CCAT tool (WP5). This will be the combination of the extended MITERRA Europe model, the meta model for erosion and the other mentioned meta models in terms regression functions between inputs and outputs.

A compilation of the cost of the measures is also needed. With the CAPRI model (see also Chapter 5) an estimation of the costs could be made related to regional specific changes in farming practices and from this the most likely changes in animal numbers and crop areas can be derived that influence the environmental effects. The baseline against which the effects of CC measures are evaluated is the year 2005 CC measures are only related to the implementation of GAECs while the effects of SMRs are not part of CC as they are based on already existing Directives (no additional compliance since 2005). This aspect is further discussed in Chapter 5.

3.2 Modelling tools

MITERRA Europe
The modelling tool that we intend to expand and use at the continental (EU) level is an integrated simple model entitled MITERRA Europe. Where needed, information of CAPRI will be included. Furthermore, the scale of application may in the future change from NUTS2 level (resolution used in MITERRA) to so-called Homogeneous Soil mapping Units (HSMUs), as used in an overall modelling framework entitled INTEGRATOR, in which MITERRA Europe is the agricultural sub-model. This framework also includes the interaction between agriculture and nature by emission-deposition relationships.

Model description: MITERRA-Europe is a simple, integrated model (including parameters and data) developed by Alterra in 2006 under a contract from EU Directorate-General Environment and available and operational since March 2007 (Velthof et al., 2007). It is a transparent and simple model to estimate quantitatively the effectiveness of mitigation options and strategies for NH_3 and non-CO_2 greenhouse gas emissions (N_2O and CH_4) and N (specifically NO_3) leaching in agriculture. The model is builds upon data and calculation rules of existing models. The scope and range is EU25 plus Romania and Bulgaria. As with the CAPRI model, MITERRA Europe is programmed in GAMS. This contributes to the flexibility of the tool to be used in CCAT in co-operation with CAPRI. It consists of an input module with activity data and emission factors, a set of (packages of) measures to mitigate NH_3 emission and NO_3 leaching, a calculation module, and an output module presenting results in tables and maps.

Model extension: The fluxes to be considered with the extended MITERRA Europe tool are summarized in Figure 2 and Table 3. The expansions are inclusion of the carbon balance, metal balance, including metal leaching and phosphorous leaching. The idea is to include these aspects in MITERRA Europe on the basis of formulations in the INITIATOR2 model developed for the Netherlands. More information on INITIATOR2 is given below.

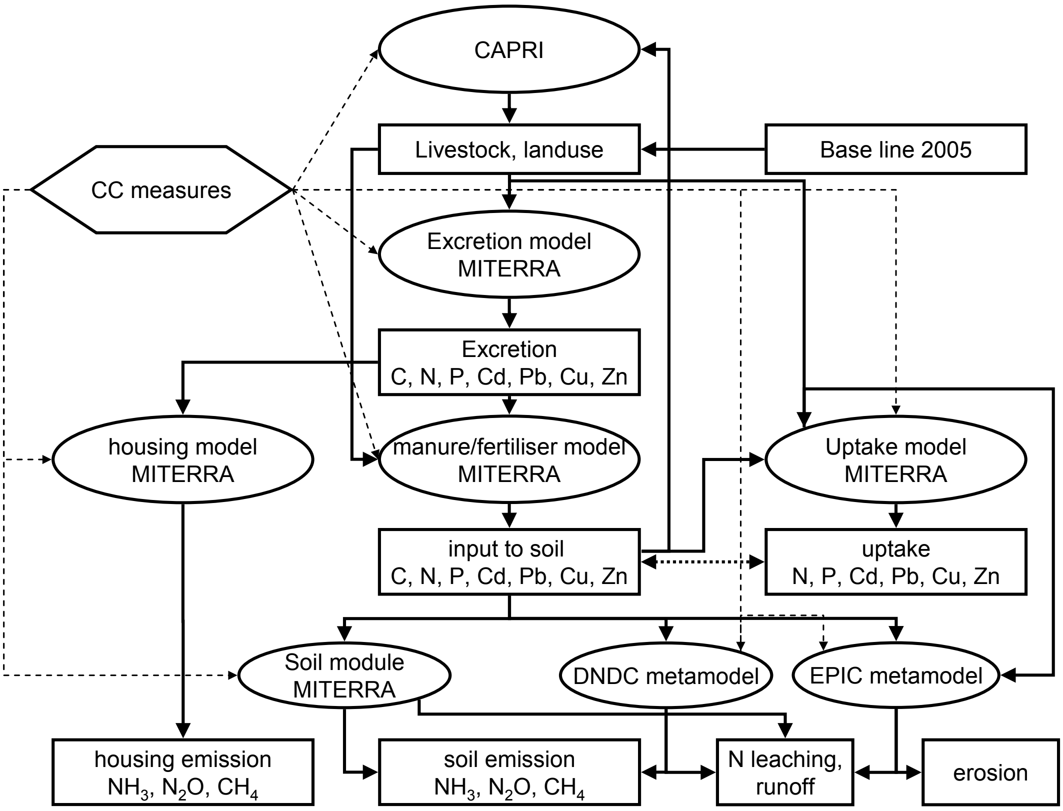

Figure 1
Approach to predict air, soil and water quality indicators with the aid of extended MITERRA Europe model and the meta models of DNDC and EPIC (the DNDC meta model will only predict N_2O emissions but not NH_3 and CH_4).

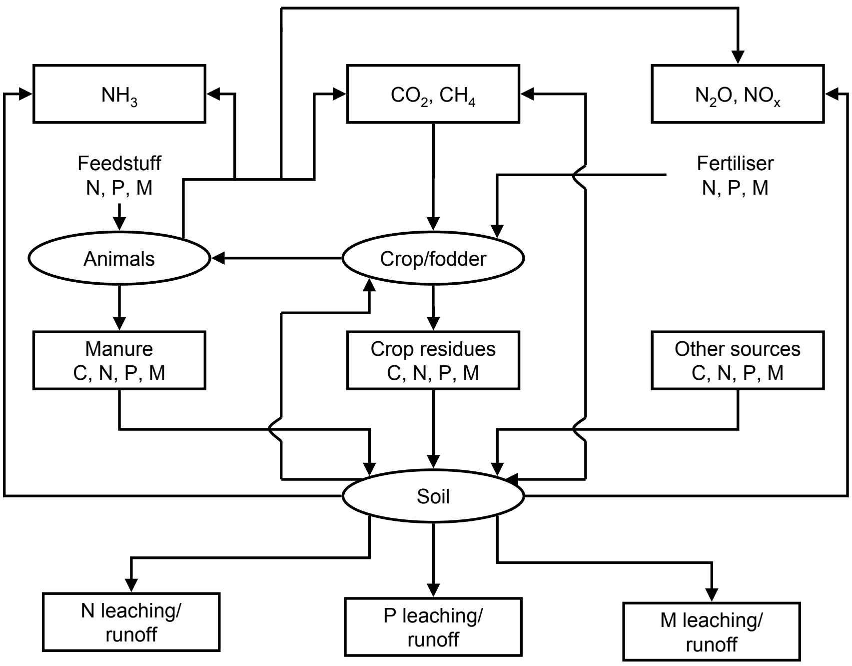

Figure 2
Fluxes considered with the extended MITERRA Europe tool.

The expansions are inclusion of the carbon balance, metal balance, including metal leaching and phosphorous leaching. The idea is to include these aspects in MITERRA Europe on the basis of formulations in the INITIATOR2 model developed for the Netherlands. More information on INITIATOR2 is given below.

Table 3
A summary of the fluxes considered in MITERRA Europe in its original and extended form.

Compartment	Indicator	MITERRA Europe Original	MITERRA Europe extended
Air	NH_3 emission	X	X
	N_2O emission	X	X
	CH_4 emission	X	X
Soil	Carbon balance	-	X[1]
	Phosphorous balance	X	X
	Metal balance	-	X
Water	Nitrogen balance	X	X
	Nitrogen leaching	X	X
	Nitrogen runoff	X	X
	Phosphorous leaching	-	(X)[2]
	Metal leaching	-	(X)[2]

[1] The focus will be on a change in C input due to changes in use of animal manure and in crop residues, assuming no change in C release.
[2] The X in brackets for phosphorous and metals implies that it is not yet sure whether this will be predicted, since the data availability for doing this is limited.

The INITIATOR2 model**,** which stands for Integrated Nutrient ImpacT Assessment Tool On a Regional scale (De Vries et al., 2005b) is developed as an integrated model to gain insight in all environmental impacts of excessive manure application simultaneously. INITIATOR2 is an extension of the model INITIATOR (Integrated NITrogen Impact Assessment Tool On a Regional scale) that was developed to: (i) gain insight in the fate of all major nitrogen flows in the Netherlands (De Vries et al., 2003), (ii) calculate 'regional specific nitrogen ceilings' (maximum amounts of reactive nitrogen that does not lead to exceedance of critical limits or targets) (De Vries et al., 2001b) and (iii) assess the impacts of improved farming practices and technical measures such as changes in animal housing on nitrogen fluxes in the Netherlands (De Vries et al., 2001a).

Apart from all N fluxes, INITIATOR2 also includes the emissions of all CO_2 and non-CO_2 greenhouse gases, fine particles and odour and the accumulation, runoff and leaching of phosphate, base cations and heavy metals (De Vries et al., 2005b). For carbon a modelling approach comparable to the CESAR model is used (Vleeshouwers and Verhagen, 2002). This is a carbon balance model that considers C flows at field level and allows evaluation of changes in farm management and differences in effects at regional level for the whole EU. The policy aim of INITIATOR2 is to provide information on the effectiveness of specific (single target oriented) policies on the simultaneous reduction of relevant element fluxes (greenhouse gases, nutrients and heavy metals) to atmosphere, ground water and surface water. INITIATOR2 has been applied in the Netherlands to demonstrate: (i) the evaluation of mitigation measures and policies on ammonia and greenhouse gas emissions and on phosphorous and metal leaching (De Vries et al., 2005b, 2006) and (ii) the use of the model to improve the national IPCC based assessments of soil emissions of nitrous oxide (De Vries et al., 2005a). Furthermore, INITIATOR2 was applied at a landscape scale to make an integrated assessment of present farm management on atmospheric emissions, leaching and runoff of ammonia, greenhouse gases and nutrients (De Vries et al., 2007). The model formulations to be used in MITERRA Europe should be such that it can evaluate the changes in farming measures coming from implementation of CC as these measures may be different from the measures related to management changes already evaluated with the INITIATOR2 model.

The DNDC model

Model description: The Denitrification-Decomposition (DNDC) model (Li et al., 1992; Li, 2000; Li et al., 2004; Li et al., 2006) is a process-oriented mechanistic detailed simulation model of soil carbon and nitrogen biogeochemistry. It is originally developed for use at the field level and further developed for the use at regional scale. DNDC is a multi-ecosystem model designed for assessing the emissions of N_2O, CH_4, and NH_3 from the soil into the atmosphere and the stock changes of organic carbon in the soil profile on the basis of mechanistic process-understanding. The model consists of two components. The first component, consisting of the soil climate, crop growth and decomposition sub-models, predicts soil temperature, moisture, pH, redox potential and substrate concentration profiles driven by ecological drivers (e.g., climate, soil, vegetation and farm management). The second component uses the information on the soil environment to calculate the major processes involved in the exchange of greenhouse gases with the atmosphere, i.e., nitrification, denitrification and fermentation. It consists of the nitrification, denitrification and fermentation sub-models and predicts greenhouse gas emissions from the soil (CO_2, N_2O, CH_4), the dynamics in soil carbon pools and NH_3 fluxes based on the modelled soil environmental factors. The model thus is able to track production, consumption and emission of carbon and nitrogen oxides, ammonia, and methane. The model has been tested against numerous field data sets of nitrous oxide (N_2O) emissions and soil carbon dynamics (Li et al., 2005). DNDC has also been widely used also for regional modelling studies, under other in the United States of America (e. g., Tonitto et al., 2007), China (Xu-Ri et al., 2003; Li et al., 2006), India (Pathak et al., 2005), and Europe (e. g., Brown et al., 2002; Butterbach-Bahl et al., 2004; Neufeldt et al., 2006; Sleutel et al., 2006).

Model extension: DNDC will be further developed within the integrated project NitroEurope (started in February 2006) and the data base for application for EU will be compiled. The linkage with the livestock sector will be done using the CAPRI model, within which the representation of NH_3, N_2O and CH_4 emissions have been updated / implemented in the EU CAPRI-*DynaSpat* project. In the CAPRI-*DynaSpat* project a link was further established between DNDC and CAPRI in order to better assess the environmental impact of agriculture considering both socio-economic and environmental factors. The modelling framework of the combined CAPRI-DNDC modelling framework is schematically shown in Figure 3.

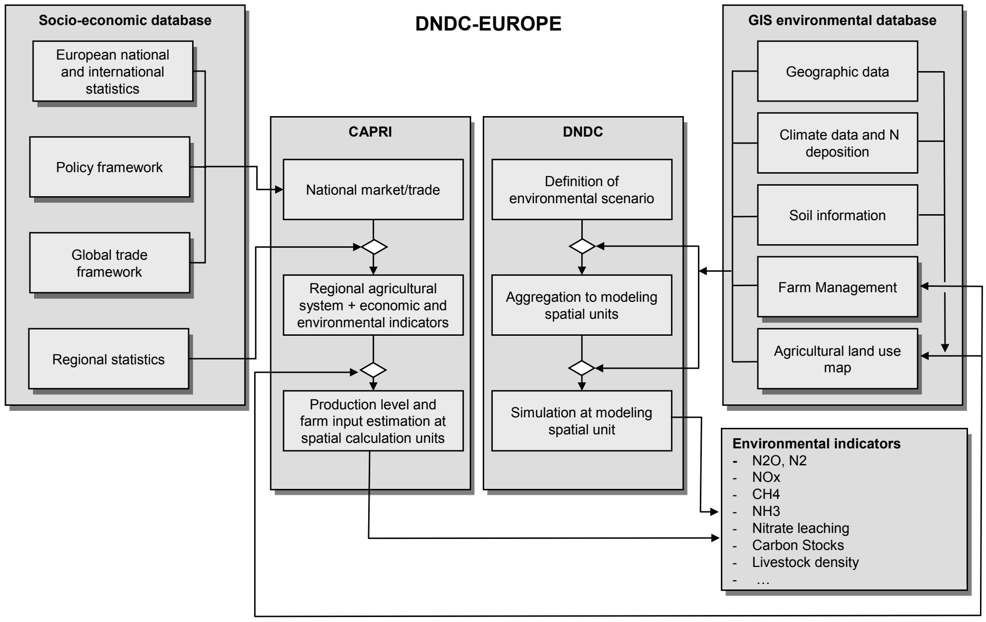

Figure 3
Modelling framework of the combined CAPRI-DNDC modelling approach on a European scale.

It includes the generation of (i) agricultural land use maps at the level of so-called homogeneous soil mapping units (HSMUs) for 29 different crops for CAPRI *ex post* or *ex ante* calculations; (ii) the estimation of farm management (in terms of nitrogen application rates) at the HSMU-level; (iii) the definition of environmental scenarios and the set-up of DNDC model runs; and (iv) finally the integration of the results into a common database.

Further improvements are needed regarding the parameterization of measures in DNDC. Improvements will also be necessary for example in the representation of different nitrogen application techniques or tillage systems. If required, the combined CAPRI-DNDC model will be further improved to better represent farm type specific fluxes of pollutants and farm-internal flows of material (leading to pollutant-swapping effects).

The EPIC model

Model description: The EPIC model was originally focused on the effect of soil erosion on productivity and EPIC was originally named as the Erosion Productivity-Impact Calculator. However, since the model expanded, it is nowadays also known as the Environmental Policy Integrated Climate model (see EPIC website: http://www.brc.tamus.edu/epic/). EPIC is now an integrated field scale crop-soil model especially well-suited to evaluate crop growth, irrigation requirements (including an option for auto-irrigation), nutrient uptake and cycling and erosion. It is composed of several simulation components for weather, hydrology, nutrient cycling, pesticide fate, tillage, crop growth, soil erosion, crop and soil management and economics (Williams, 1995). It predicts the effects of management decisions on soil, water, nutrient and pesticide movements and their combined impact on soil loss, water quality and crop yields for areas with homogeneous soils and management. EPIC has been thoroughly evaluated and applied from local to continental scale (Gassman et al., 2005). Typical applications including the effect of N and P losses as affected by different tillage systems, crop rotation and fertiliser application, etc. The model had been used to assess crop yield as affected by various farming practices and climate change scenarios.

As with DNDC, EPIC is a mechanistic detailed model, specifically developed for use at the field level. However, much efforts have been made to apply the model also on a regional scale. At the RWER unit of JRC the EPIC-EAGLE interface has been developed, an integrated ARC-GIS front-end to run EPIC (see Bouraoui and Aloe, 2007). EAGLE is short for the European Agrochemicals Geospatial Loss Estimator with most of the parameters required to run EPIC readily available at EU level (Mulligan et al., 2006). A graphic presentation of the GIS link between EPIC and needed databases on climate, land use, land management and soil is given in Figure 4.

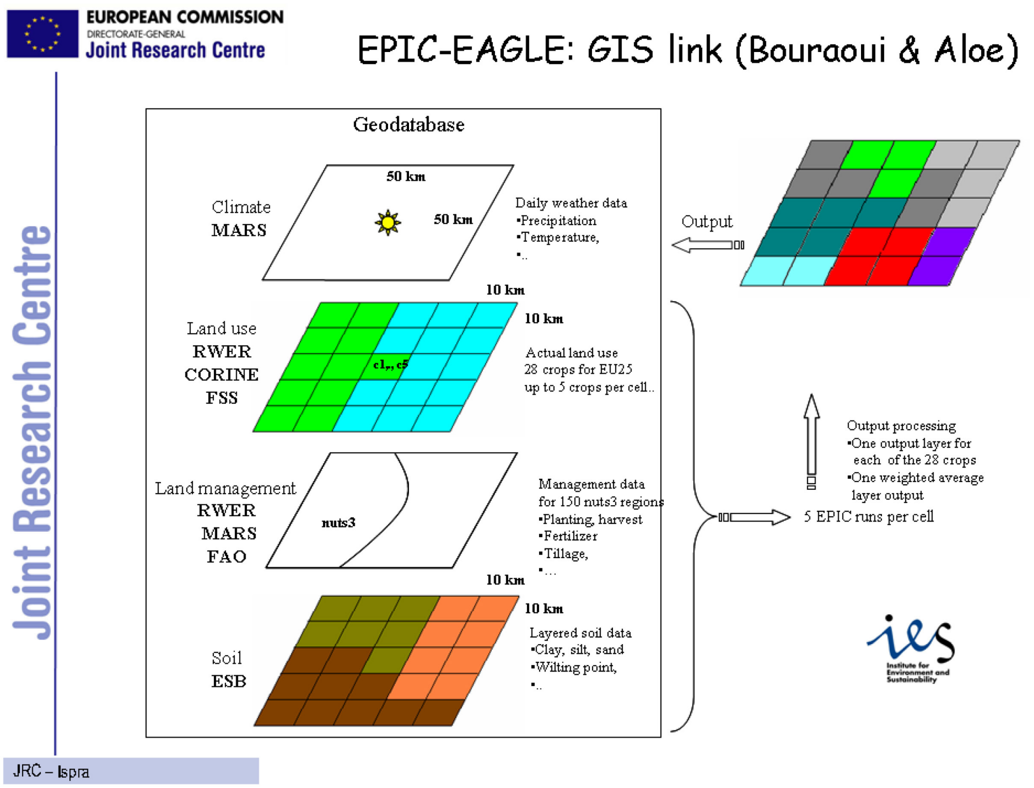

Figure 4
Graphic presentation of the EPIC-EAGLE GIS link.

Model use: The approach chosen here consists of the translating the EPIC modelling results in a metamodelling framework for the specific indicators required. The metamodel approach will provide flexibility to perform repeated policy scenarios without having to rerun the complete model. Metamodels can be thought of as statistical summary functions of generated model output. The metamodeling approach in combination with EPIC has been used before to address agricultural policy issues (see Lakshminarayan et al., 1996). However, the current implementation of EPIC-EAGLE will need also to be calibrated for different parameters. As a first step, the EPIC model will be calibrated on, for example, measured crop yields. Modelled erosion will be harder to 'validate' and here the number of previous studies indicating a good capacity of the model to present erosion and crop yields at the field scale provides a certain degree of confidence in the model output (Wang et al., 2006). After calibration or 'verification' of certain model outputs, the EPIC model will be executed using the EPIC-EAGLE interface at pan-European scale using the current 10 by 10 km grid-cell setup.

The EPIC output may then be aggregated to the desired regional (NUTS 2) or HSMU level and regression functions will be used to define metamodel relations. For example, if we are interested in erosion, based on the simulation data, we can specify erosion as a function of a selection of management factors; soil; and topographic properties and climate properties. The metamodel will allow us to get a reasonable confidence in the response of crop yields or erosion to management, landscape and meteorological variables without having to rerun the EPIC model.

3.3 Use of meta models of EPIC and DNDC in CCAT

Meta-modelling involves selecting a statistical approximation of detailed model results to reduce the running time and memory consumption of detailed models, often considered as a black-box by no expert users.

The approach used for the meta-models of EPIC
EPIC predicts N leaching, N runoff and Erosion, using regression meta-models or look up tables as described in Van der Velde et al. (2009). The focus of the EPIC model is on: (i) erosion, because EPIC is the only model that can predict this physical soil quality indicator, and (ii) N leaching/runoff, since the model is also best suited for the calculation of crop uptake and thus for the prediction of N balances and leaching. Actually, EPIC also predicts long-term soil compaction due to natural processes, but not the compaction in response to heavy machinery, being the relevant aspect with respect to cross compliance. Furthermore, it predicts pesticide leaching, but only at a plot scale and application of this model on a European scale is not possible (see before).

The approach to predict these outputs is to apply the EPIC model for many combinations of land use, soil type and climate and derive a meta model from the results for inclusion in the CCAT tool as illustrated in Figure 5. With respect to erosion, crop-specific meta-model functions for erosion with and without cross compliance are derived. The evaluations focus on the GAEC issue 'minimal level of maintenance' in particular 'green cover', and the GAEC issue 'soil erosion' specifically the 'depth of ploughing'. In particular, the following steps are carried out to apply the detailed EPIC model for erosion:

- We derive response functions that describe erosion under different crops.
- For CC measures that affect EPIC (related GAEC Minimal level of maintenance: green cover, GAEC Soil erosion: depth of ploughing) we derived two functions for erosion under a certain crop, one with and one without the CC measures.
- Dependent on the crop shares projected by MITERRA/CAPRI, and the implementation of GAECs these meta models will then be used to quantify erosion.

The following steps were carried out to apply the detailed EPIC model for the N balance, N leaching and N runoff:

- EPIC currently determines fertilizer use from plant nutrient requirements and not from actual national fertilizer rates. It EPIC is run with the so-called automatic fertilizer option; in other words plant nutrient stress is not occurring. This will be adapted in view of actual fertilizer rate estimates; alternatively N leaching (the nutrient focus of EPIC) can only be assessed relatively. EPIC will use independent (CAPRI MITERRA based) fertilizer amounts to derive the N leaching and runoff meta-models
- From the pool of model results a meta-model (statistical model) is derived that includes the major driving factors explaining the majority of the variability of the model results. The information of this meta-model will be included in the analytical tool. The meta model for N leaching/runoff will be derived including the measures.

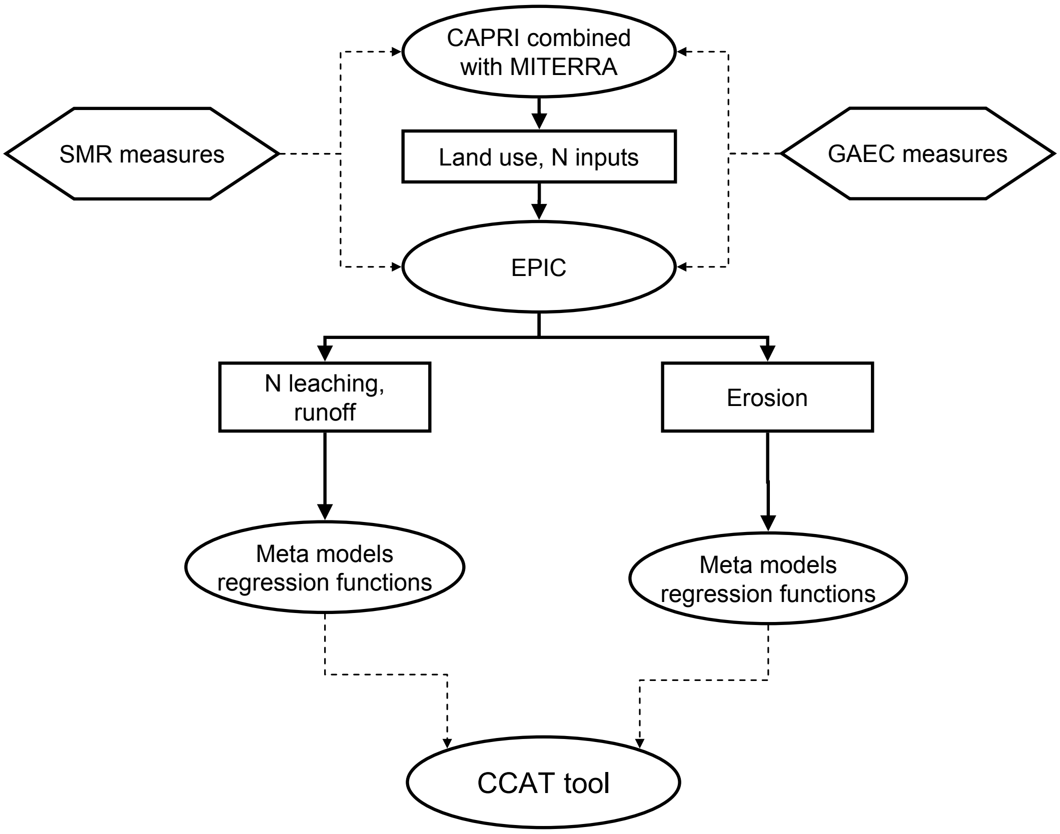

Figure 5
Approach to assess impacts of CC measures on soil erosion and N leaching/runoff by applying EPIC and deriving meta models for inclusion in the CCAT tool.

The measures affecting N leaching/runoff are mainly related to the N directive and these measures are first evaluated by CAPRI (in combination with MITERRA: see Chapter 5) to give changes in land use and N inputs which then will be used in the meta models to assess N leaching/runoff. For the GAECS, related to both N runoff/leaching and soil erosion, we assume that a measure is directly an input for the model without intervention of CAPRI (see Figure 5). The predictors used in the various regression models are given in Table 4. With respect to the type of meta-models that have been derived from EPIC model simulations, a distinction is made between EPIC model outputs that can be simulated using CAPRI-MITERRA outputs as predictor values and those that cannot be evaluated based on such outputs.

Table 4
Predictors used in the EPIC meta-models for N leaching, N runoff and erosion.

Predictor	N leaching	N runoff	Erosion
Fertiliser N use (kg ha^{-1})	x	x	
Slope (degrees)		x	x
Organic matter content of the topsoil (0-30 cm) (%)	x		
annual precipitation (mm yr^{-1})	x	x	x
annual percolation (mm yr^{-1})	x		
Mean maximum temperature (°C)	x		
Maximum soil moisture content of the topsoil(-)	x		
Soil hydraulic conductivity of the top soil (mm hr^{-1})	x	x	x

For EPIC outputs that are dependent on N fertiliser use rates, CAPRI-MITERRA estimates of these rates can subsequently be used as input in EPIC meta-models. This holds for nitrate leaching and organic nitrogen in solid particles transported with runoff for which regression relations have been derived using fertiliser use and other environmental characteristics, such as slope and average rainfall as input (see Table 4). Regression models for these outputs are applied for all SMRs involving a change in N input.

Erosion, however, is not related to N input and can thus not be related to CAPRI-MITERRA outputs, while it is an important EPIC result in relation to cover cropping and no-till practices (GAEC issues). For these practices specific look-up tables have been derived from EPIC simulations for selected crops. More specifically look-up tables operating at NUTS2 level have been derived for all measures that cannot be evaluated with CAPRI-MITERRA, i.e. for (i) Erosion for all GAEC measures (no till and cover crop) and (ii) N runoff and N leaching for the GAEC measure no-till (although no till is evaluated by CAPRI-MITERRA, it does not lead to a change in N input). The EPIC runs included a comparison of:
Cover crop or no cover crop:
- E1 Baseline run with no cover crop for irrigated and non-irrigated maize.
- E2 As E1 with clover as a cover/N fixing crop.

Tillage or no tillage:
- E3 Baseline run with conventional till practices in barley.
- E4 As E3 but with no-till practices.

From the model calculations with the runs E1-E4, the percentage change associated with a change in agricultural practices (tillage versus no tillage and cover crop versus no cover crop) at NUTS2 level was averaged for the three main model outputs, i.e. erosion, N runoff and N leaching. These numbers can than directly be implemented to generate output in the CAPRI-MITERRA platform.
In summary, the approach for the use of EPIC meta-models is such that (see Van der Velde et al., 2009):
- SMRs in the Nitrate Directive that imply a change in the N input by N fertilizer + N manure, as simulated by CAPRI-MITERRA, will directly be evaluated by Multiple linear regressions based on EPIC simulations for N leaching and N runoff. Results of MITERRA for these outputs can be compared to those by EPIC, but the latter results are limited to maize and barley.
- GAEC measures in terms of inclusion of a cover crop or zero tillage is implemented through the use of the look-tables in terms of a percentage change compared to base line, and these results are superimposed on the MITERRA output (in case of N leaching and N runoff) or directly as a change independent of MITERRA output (erosion).

The approach used for the meta-models of DNDC-EU
Among the large number of DNDC outputs, we derived meta-model for selected CCAT environmental indicators, i.e. N surplus (defined as soil N input - net N removal), N_2O emission and N leaching (Figure 6). We run the meta-models to estimate the indicators according to a random forest approach, being a certain statistical approximation. More details on this approach are given in Follador and Leip (2009).

At the beginning the simulations through Europe-DNDC have been carried out at HSMU level. Afterward we had to upscale to CCAT-NUTS level to integrate our meta-model into the final platform. The aggregation of HSMU values have been carried out by means of a weighted area algorithm taking into account both the input and output data on the whole NUTS agricultural land covered by the studied crops.

In this contribution we only present the results for corn and barley crops. To reduce the time and memory consumption, also considering the number of scenarios (7) and the length of the period (1990-99) to simulate, we decided to select a representative sample subset among the entire EU25 agricultural lands. More details about the DNDC-EU meta-model to be included in the CAPRI-MITERRA simulation platform is provided in Follador and Leip (2009). The DNDC meta-models predict N surplus, N leaching and N_2O emissions using a range of predictors as shown in Table 5. A description of SMRs and GAECs evaluated by the DNDC metamodels is given in Table 6.

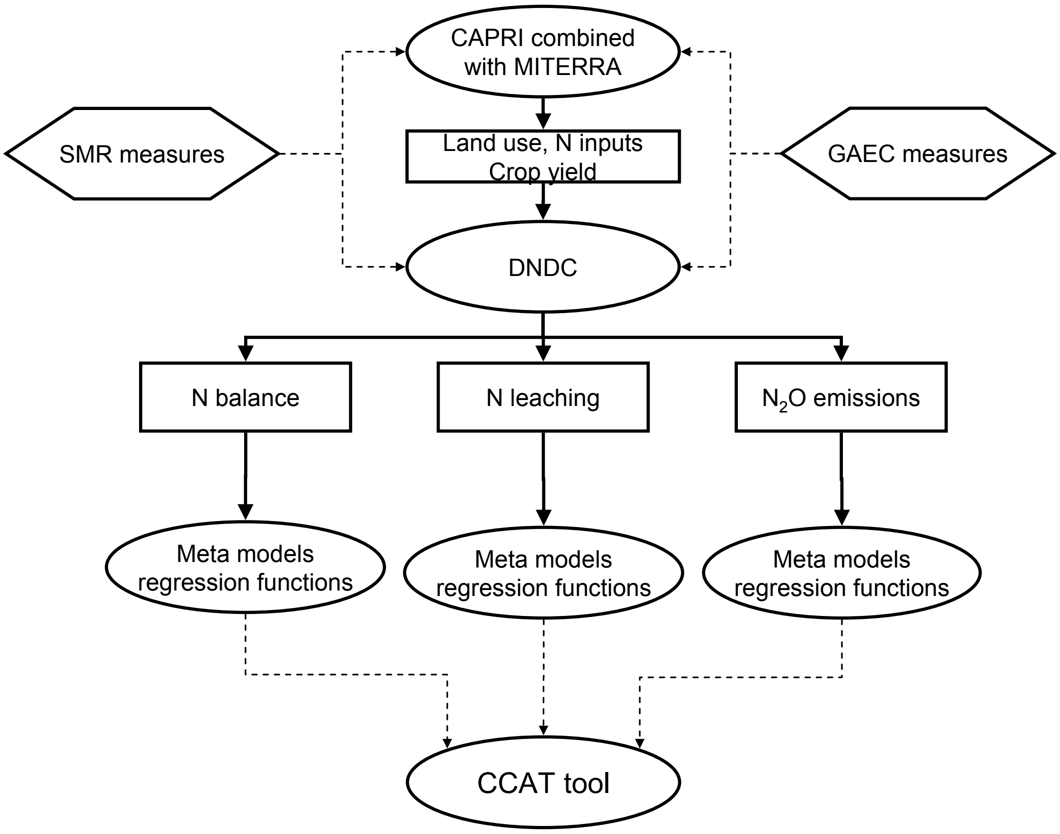

Figure 6

Approach to assess impacts of CC measures on N_2O emissions, N balance and N leaching by applying DNDC and deriving a meta models for inclusion in the CCAT tool.

Table 5

Predictors used in the DNDC meta-models for N surplus, N leaching, and N_2O emissions.

Predictor	N surplus	N leaching	N_2O emissions
Annual N Fertilizer rate (kg ha^{-1} yr^{1})	x	x	x
N manure application rate (kg ha^{-1} yr^{1})	x	x	x
N deposition (kg ha^{-1} yr^{1})	x	x	x
N fixation (kg ha^{-1} yr^{1})	x	x	x
N in residue (kg ha^{-1} yr^{1})	x	x	x
Soil Bulk density		x	x
Soil Organic Carbon in topsoil (-)		x	x
Soil pH (-)	x	x	x
Soil clay content (-)	x	x	x
Annual precipitation (mm yr^{1})	x	x	x
Mean maximum temperature (°C)	x	x	x
Mean minimum temperature (°C)	x	x	x

Table 6
Description of scenarios and measures related to SMRs and GAECs evaluated by the DNDC metamodels.

SMR	Name	Description	DNDC scenario and parameterisation
SMR2	Maximum manure N application standard	The amount of applied N in manure and excreted during grazing may not exceed 170 kg N per ha in a region. Excess manure is transported or processed.	Comparison of S1: Corn Reference Scenario1 with S3: Corn Max Manure scenario[2] Comparison of S5: Barley reference scenario[1] with S7: Barley max manure scenario[2]
SMR8	Growing winter crops	Growing catch crops will result in i) less N leaching below rooting zone, ii) less surface runoff, and iii) less requirement of fertilizer N in the following year.	Comparison of S1: Corn Reference Scenario with S4: Corn Catch crop scenario[3]
GAEC	Name	Standards	DNDC scenario and parameterisation
GM3	Minimum coverage-arable land	Vegetative cover between agricultural crops, which is then ploughed into the soil, also termed as catch crops, green manure and winter crops.	Comparison of S1: Corn Reference Scenario with S4: Corn Catch crop scenario[3] Actually equal to SMR8.
GM4	Tillage method	Zero tillage.	Comparison of S1: Corn Reference Scenario with S2: Corn No tillage Scenario[4] Comparison of S5: Barley reference scenario with S6: Barley No tillage scenario[4].

[1] The baseline scenario includes only a corn or barley monoculture, with one tillage application and a tillage depth of 20cm
[2] This scenario limits the N in manure spreading to 170 kg N/ha yr^{-1} (with few exceptions), compared to the reference scenario.
[3] Catch crops scenario includes two cycles of corn-catch crop system which lasts five years (two years of corn + three years of alfalfa). Corn like baseline, alfalfa without tillage and fertilizer application.
4 The no tillage scenario differs from the reference scenario because of the absence of tillage.

3.4 Model input data

The environmental effect indicators calculated with MITERRA Europe, EPIC and/or DNDC focus on balances (inputs, net uptake by crops and leaching) of C, N, P and metals, including atmospheric emissions of N compounds (NH_3 and N_2O) and of CH_4. An overview of major input data in relation to the use of the various models is given in Table 7. In view of these calculations, all models require at least the annual inputs of one or more of these elements by fertilizers, animal manure and biosolids (sewage sludge, compost etc.). It thus implies that we always need to know the application rates and types of fertilizers (nitrogen, phosphate, potassium etc.), animal manure (cows, pig, poultry etc.) and biosolids (sewage sludge, compost etc.) to assess the annual inputs of C, N, P and metals.

Furthermore, information is needed on inputs by atmospheric deposition and N_2 fixation in case of N. Element outputs always include net crop removal, being the product of harvested crop yield and element contents in the harvested crop, and leaching from the root zone being the product of water flux and element concentration in the water.

Table 7
Major input data needed by MITERRA Europe (extended), and the meta models of DNDC and EPIC.

Indicator	Needed inputs	Unit	Models involved
General for all balances	Application rates and types of - fertilizers - animal manure - biosolids Yields of harvested crops	 kg /ha/yr ton/ha/yr ton/ha/yr ton/ha/yr	 MITERRA Europe DNDC EPIC
Nitrogen balance	N2 fixation Atmospheric N deposition N contents in fertilizers, animal manure, biosolids and crops	kg N/ha/yr kg N/ha/yr mg N/kg	MITERRA Europe DNDC EPIC
NH_3 emission	NH_3 emission factors/parameters	Depends on model (e.g. % of N excreted)	MITERRA Europe
N_2O emission	N_2O emission factors/parameters	Depends on model (e.g. % of N excreted)	MITERRA Europe DNDC
Nitrogen leaching[1]	N leaching fraction	Depends on model (e.g. % of N applied)	MITERRA Europe DNDC EPIC
Nitrogen runoff[2]	N runoff fraction	Depends on model (e.g. % of N applied)	MITERRA Europe EPIC
Carbon balance	C/N ratios in animal manure and biosolids (sewage sludge, compost etc)	-	MITERRA Europe
CH_4 emission	CH_4 emission factors per animal category	kg CH_4/ha/yr	MITERRA Europe
Phosphorous balance	Atmospheric P deposition P contents in fertilizers, animal manure, biosolids and crops	kg P/ha/yr mg P/kg	MITERRA Europe
Phosphorous leaching[1]	P adsorption parameters	Depends on model	MITERRA Europe (possibly)
Metal balance	Atmospheric Cd, Cu, Pb and Zn deposition Cd, Cu, Pb and Zn contents in fertilizers, animal manure, biosolids and crops	g/ha/yr mg/kg	MITERRA Europe
Metal leaching	Metal adsorption parameters	Depends on model	MITERRA Europe (possibly)
Erosion	Erosion parameters	Depends on model	EPIC

4 Cross compliance measures to be analysed with the environmental modelling tools

4.1 Relevant Statutory Management Requirements and Good Agricultural and Environmental Conditions

Statutory Management Requirements (SMRs)
In total nineteen legislative acts, called Statutory Management Requirements (SMRs), have been established that apply directly at the farm level in the fields of environment, public, animal and plant health and animal welfare and farmers are sanctioned in case of non-compliance. In principle the SMRs are uniform for all Member States and should be implemented in national and regional legislation in a similar way. However, in practice there is still a large difference in the way these are translated in national and regional requirements and standards. An overview of the SMR requirements is given in Annex III of the CCAT report on the Deliverables 2.1 and 2.2 (Jongeneel et al., 2007a). In this context, the following directives are relevant for environment (see also Annex 1 of Jongeneel et al., 2007a):
- Nitrate Directive: Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31.12.1991, p. 1).
- Sewage Sludge Directive: Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (OJ L 181, 4.7.1986, p. 6).
- Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (OJ L 20, 26.1.1980, p. 43). Articles 4 and 5.
- Habitat directive: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna (OJ L 206, 22.7.1992 p. 7) Articles 6, 13, 15 and 22(b).

Measures in the Habitat directive cannot be evaluated with the set of available models, since thy all focus on agricultural soils. A summarized overview of the Cross Compliance requirements to be met by the farmer in the other three directives are given Table 8. Details of all the measures defined in these three directives and the possibility to evaluate them with the set of available models is further elaborated in Chapter 4.2 and related annexes.

Good Agricultural and Environmental Conditions (GAECs)
In the context of cross compliance, there is specifically the need for compliance with the requirements to maintain land in Good Agricultural and Environmental Condition (GAEC). A summarized overview of the GAECs to be met by the farmer, to warrant appropriate soil protection (prevent soil erosion, avoid loss of soil organic matter and protect soil structure), ensure a minimum level of maintenance of land and avoid the deterioration of habitats, that will be evaluated by the CCAT environmental impact tool (specifically EPIC and DNDC) is given in Table 9. In the context of CCAT, the effects of SMRs will thus not be evaluated as effects of CC. Using the baseline year 2005, we will assume that SMRs are already complied with. It will only be done as an evaluation of the impacts of complying versus not complying with the environmental directives implied in the SMRs.

Table 8
The Cross Compliance requirements according to the Statutory Management Requirements (SMRs) in EC directives included in the CCAT tool for environmental impacts.

EC Directive / Regulation	What will be the Cross Compliance requirements to be met by the farmer and included in the CCAT tool?
Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by **nitrates** from agricultural sources (OJ L 375, 31.12.1991, p. 1) Articles 4 and 5.	Farmers with land in NVZs should comply with the mandatory measures contained in the Nitrate Directive, i.e. limits to the application of Nitrogen in animal manure, special measures for the storage, application methods and timing of fertilizer and animal manure.
Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when **sewage sludge** is used in agriculture (OJ L 181, 4.7.1986, p. 6), Article 3.	Use only of sludge treated in accordance with the Directive. Observation of specified harvesting intervals and other requirements to prevent contaminants (e.g. heavy metals) reaching the human food chain. Farmers in NVZs will be expected to record the use of sludge in their Fertilizer and Manure Plan and to observe the relevant closed period, as necessary.
Council Directive 80/68/EEC of 17 December 1979 on the **protection of groundwater** against pollution caused by certain dangerous substances (OJ L 20, 26.1.1980, p. 43). Articles 4 and 5.	The major consequence of this Directive is that farmers require authorization for disposal of spent sheep dip and pesticide washings to land. Where List I and List II substances are otherwise used, manufactured, stored or handled, farmers will be expected to comply with relevant legislation, codes of practice or other relevant good practice.

Table 9
The Cross Compliance requirements according to the Good Agricultural and Environmental Conditions (GAECs) included in the CCAT tool for environmental impacts.

GAEC	What will be the Cross Compliance requirements to be met by the farmer and included in the CCAT tool?
Minimum level of maintenance	Minimum livestock stocking rates or/and appropriate regimes Protection of permanent pasture
Soil erosion	Protect soil through appropriate measures Minimum soil cover Minimum land management reflecting site-specific conditions
Soil organic matter	Maintain soil organic matter levels through appropriate practices Standards for crop rotations where applicable Arable stubble management

Since there is a large range in agricultural farming systems operating in very different climatic circumstances, a great deal of freedom has been left to Member States and regions to implement GAECs. Unlike the SMRs, Member States are allowed a great level of freedom in selecting the number of GAEC standards and determining how they should be implemented. As with the SMRs, not all measures defined in the GAECs can be evaluated with the set of available models. This aspect is further elaborated in Chapter 4.3.

Cross compliance and SMRS and GAECs
According to the commission, effects of CC can only be related to implementation of GAECs and of the obligation to maintain permanent grassland. SMR implementation cannot be related to CC, however, as these

are laws (Directives) that already existed before CC was implemented. CC policy only aims at increasing the compliance with these Directives.

4.2 Selected environmental effect indicators for the Statutory Management Requirements and their modelling approach

The list of Statutory Management Requirements (SMRs) from the CIFAS database was used as presented in the excel sheet 'abf_smr_overview.xls'. Regarding environmental impacts we first evaluated the expected environmental impacts of SMRs in the groundwater protection directive, sewage sludge directive and nitrate directive, while distinguishing in the likelihood of an impact (yes, no or possible). The results are given in Annex 1. Based on this results, an overview was made of:
- selected measures in SMRs;
- the effect indicators that will be calculated in view of the measures;
- the models included in doing such a calculation;
- the way in which the measures will be evaluated by the MITERRA Europe model.

The result is presented in Annex 2. It are measures that can be parameterized and evaluated with MITERRA Europe, DNDC and/or EPIC. The number of measures was reduced by the following procedure:
- Remove all measures that are basically the same, but e.g. differs in technique (e.g. appropriate fertilization on sloping sites in Austria: Slot sowing, Cross ditches with plant cover; Cross-strip sowing and Slot sowing is considered as one measure).
- Indicate whether a measure can potentially be evaluated with the models MITERRA Europe, EPIC or DNDC.
- Select all measures that are potentially suitable for implementation and briefly describe who this can be achieved.

4.3 Selected environmental effect indicators for the Good Agricultural and Environmental Conditions and their modelling approach

The list of Good Agricultural and Environmental Conditions (GAECs) from the CIFAS database was used as presented in the excel sheet 'abf_gaec_overview.xls'. Regarding environmental impacts we evaluated the expected environmental impacts of the GAECs for minimum level of maintenance, soil erosion, soil organic matter and soil structure and while distinguishing in the likelihood of an impact (yes, no or possible). The results are given in Annex 3. Based on this review, an overview was made of:
- selected measures in GAECs;
- the effect of the indicators that will be calculated in view of the measures;
- the models included in doing such a calculation;
- the way in which the measures will be evaluated by these models.

The results are presented in Annex 4. These are measures that in principle can be parameterized and evaluated with MITERRA Europe, DNDC and/or EPIC. The number of measures were grouped by the following procedure:
- Measures that potentially can be evaluated with the models MITERRA Europe, EPIC or DNDC were indicated.
- All measures that are potentially suitable for implementation and that are similar in their intended effect were grouped.

4.4 Selected environmental effect indicators

Differences in the first prototype and the final CCAT tool are related to the spatial resolution in the EU wide assessments and the impacts fields considered in relation to the various SMRs and GAECs considered. Regarding the spatial resolution, the model is applied at NUTS2 level. Other impacts, such as market & producer income (M), calculated by CAPRI or impacts on land use, landscape and biodiversity are presented in Deliverable 2.3 (Jongeneel et al., 2007b). Insight in the models used in the CCAT tool (in the prototype, MITERRA Europe is used only) and the results that they will give in view of measures in SMRs and GAECs is given in Table 10. Finally, information on the type of results predicted by each model in the prototype and the final CCAT tool is presented in Table 11 . The explanation of the letters A, S and W is given in Table 10. In general: (i) A or air quality stands for NH_3, N_2O and CH_4 emission in case of MITERRA and for N_2O emission in case of DNDC, (ii) S or soil quality stands for C, P or metal balances in case of MITERRA and for erosion in case of EPIC and (iii) W stands for N balances and N leaching/runoff for all models.

Table 10
Environmental impacts fields in relation to SMRs and GAECs as evaluated by MITERRA, EPIC and DNDC in final CCAT tool.

SMRs and GAECs	Assessments by models in final CCAT tool			
	MITERRA	EPIC	DNDC	All models
Nitrates Directive	ASW	W	AW	ASW
Sewage Sludge Directive	S(W) [1]	-	-	S(W)[1]
Groundwater Directive	S(W) [1]	-	-	S(W) [1]
Soil erosion-minimum coverage	-	S	-	S
Soil erosion-minimum land management	-	S	-	S
Soil erosion-retain terraces	-	S	-	S
Soil organic matter-standards for crop rotation	SW[2]	S[2]	W[2]	SW[2]
Soil organic matter- stubble management	SW[2]	S[2]	W[2]	SW[2]
Minimum level of maintenance-minimum livestock stocking density and appropriate regimes	SW[2]	S[2]	W[2]	SW[2]
Minimum level of maintenance-Protection of permanent grassland	SW[2]	S[2]	W[2]	SW[2]

A=air and climate (atmospheric emissions); S=soil quality (carbon, phosphorous and metal balances, erosion); W=water quality (nitrogen balance, leaching and runoff).
[1] S stands for phosphorous and metal balances and W for their leaching when this will be predicted.
[2] S stands for carbon balance (MITERRA) or erosion (EPIC) and W for N balances (all models).

Table 11
Indicators predicted by the extended MITERRA Europe, DNDC and EPIC meta models used in CCAT.

Compart-ment	Indicator	Unit	Prototype 1	Relevant for SMRs/ Directives	Relevant for GAECs
Air/ climate (A)	NH_3 emission	kg NH_3-N/ ha/yr	MITERRA Europe	Nitrates	-
	N_2O emission	kg N_2O-N/ ha/yr	MITERRA Europe	Nitrates	-
	CH_4 emission	kg CH_4/ ha/yr	MITERRA Europe	Nitrates	-
Soil (S)	Erosion	m^3 soil/ ha/yr	-	-	Minimum level of maintenance Soil erosion
	Carbon balance	kg C/ha/yr	MITERRA Europe	Nitrates, Sewage Sludge	Minimum level of maintenance Soil organic matter
	Phosphorous balance	kg P/ha/yr	MITERRA Europe	Nitrates, Sewage Sludge	-
	Metal balance	g/ha/yr	-	Nitrates, Sewage Sludge Ground water	-
Water (W)	Nitrogen balance	kg N/ha/yr	MITERRA Europe	Nitrates, Sewage Sludge	Minimum level of maintenance Soil organic matter
	Nitrogen leaching	kg N/ha/yr	MITERRA Europe	Nitrates	-[2]
	Nitrogen runoff	kg N/ha/yr	MITERRA Europe	Nitrates	-[2]
	Phosphorous leaching	kg P/ha/yr	-	Nitrates	-
	Metal leaching	g/ha/yr	-	Nitrates Sewage Sludge Ground water	-

[1] The brackets for phosphorous and metals implies that it is not yet sure whether this will be predicted.
[2] In principle, changes in runoff and leaching can be predicted with EPIC but are expected very small.

5 Integrated evaluation of measures in the nitrate directive with CAPRI-MITERRA

5.1 Introduction

In the prototype, the included SMRs are limited to the Nitrate Directive (ND), that are only evaluated with the MITERRA Europe model in interaction with the CAPRI model. Furthermore, the evaluation will take place at NUTS2 level. This limitation allows a quick start for the first prototype, specifically because the measures are already intensively discussed with the Commission in the context of the EU service contract related to the development and application of MITERRA Europe. In the final version, the impact of measures in the 'Sewage Sludge Directive' and the 'Groundwater Directive' will also be included. Furthermore, several additional measures in the GAECS will be evaluated and again at a much higher spatial detail (HSMUs instead of NUTS2 level), as discussed in the previous section.

Below, we first describe the approach of the evaluation of measures in the Nitrate Directive with a combination of CAPRI and MITERRA Europe (Chapter 5.2) and we then describe how we will assign the selected measures in the 'Nitrates Directive' to one of the eight implemented measures within MITERRA Europe (Chapter 5.3).

5.2 Interactive approach between MITERRA Europe and CAPRI within the prototype

General approach
A schematic overview of the interaction between MITERRA Europe and CAPRI within the CCAT prototype is presented in Figure 7. The CAPRI model in combination with MITERRA predicts: (i) cost of the measures, (ii) the likely changes in animal numbers and (iii) the change in crop shares, whereas MITERRA in combination with CAPRI predicts the emissions of NH_3 and N_2O and the leaching of N. The interaction between the models is explained below, with the numbers refer to those occurring in the figure.

1. Measures and their parameterization
A set of measures related to the Nitrate Directive (ND) is defined, i.e. which measures are implemented and at which degree of implementation (see number 1 in Figure 7). These measures need to be parameterized by both MITERRA Europe and CAPRI.

The implementation implies that measures are assigned to the NUTS2 regions for which they are applicable and they are parameterized in terms of changes of model parameters and/or model inputs. The degree of implementation implies the fraction of the area of a NUTS2 region for which the measure is applicable.

Parameterization of measures. Measures must be parameterized in MITERRA-Europe in terms of changes in N excretion rates, emission fractions from housing systems and land applications etc. The selected measures in the 'Nitrate directive' with MITERRA Europe and their clustering to eight predefined overall measures is given in Annex 2. In the Annex, the almost final column relates to the MITERRA Europe measure, numbered from 1 - 8. These measures are given in

Table 13. By the combination of Annex 2 and Table 12, the various measures in the 'Nitrate directive' are evaluated. For their parameterization, we refer to Velthof et al. (2007).

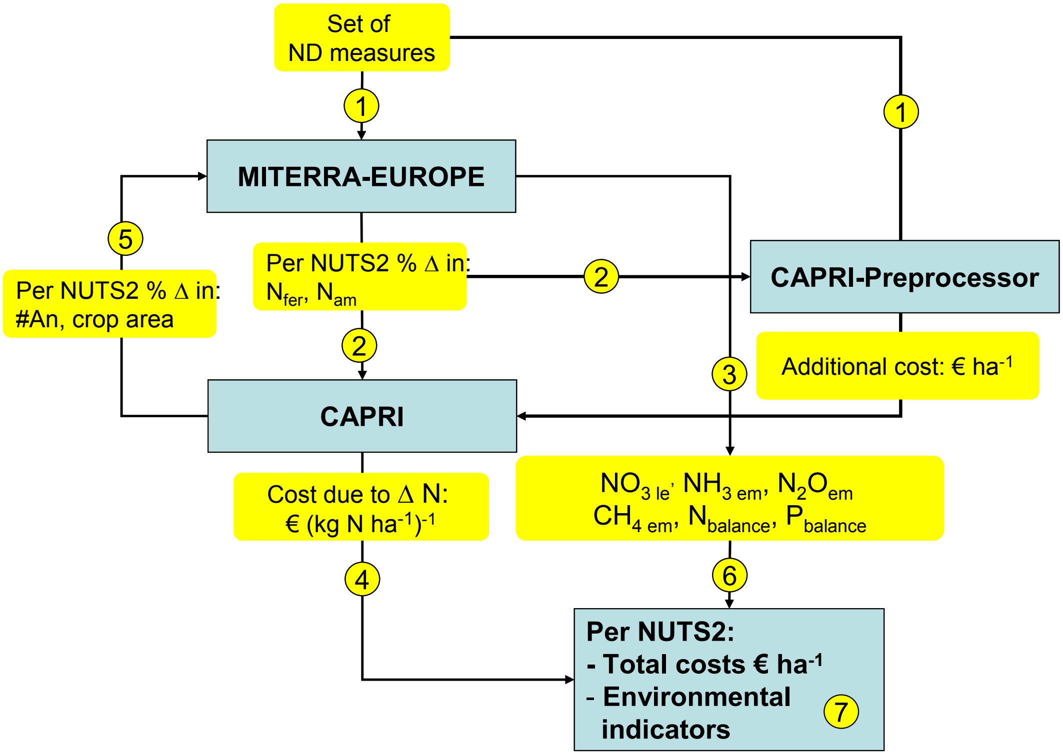

Figure 7
Schematic presentation of the interaction between MITERRA Europe and CAPRI.

Furthermore measures must be parameterized in CAPRI terms of cost. Here a distinction will be made in fixed costs (e.g. the investment for a manure storage) and variable costs (e.g. cost related with the grown of cover crops). For the fixed costs the yearly burden will be calculated (taking into account costs of capital, depreciation, etc.). Estimates will also be made for the costs of the measures that are not included in the CAPRI model (e.g. the costs for building new manure storage). These will be further determined in the CAPRI-Pre-Processor to be developed (see point 3 *CAPRI-Pre-processor calculations*).

Base years. The measures are mainly based on the current parameterization in MITERRA Europe for the years 2000, 2010, and 2020. In the test case the year 2000 will be used as the reference year, because this is already present in MITERRA Europe and the year 2020 as object year. CAPRI actually uses 2002 as base year and 2013 as projection year. For the test case this inconsistency will be neglected. In the future we envisage moving the base year to 2005. The projection year can be any year between base year and 2020. The projection tool incorporated in CAPRI is quite demanding and hence 'harmonized' projection years will be part of Prototype1.

2. MITERRA Europe calculations on changes in fertilizer and manure use
Based on the selected scenario and degree of implementation, the changes in fertilizer use and manure use in %-change as compared to the reference year will be derived for all NUTS 2 regions and disaggregated at specific activity levels (see

Table 13). These results will be used in the CAPRI-Pre-processor, as they influence additional cost, and in the core CAPRI simulation tool, as they affect the changes in animal numbers and land use (crop areas). Furthermore, it will be used in the CAPRI model to predict changes in N fertilizer use and N manure use according to this model, which is used by DNDC and EPIC in the final CCAT tool (but not in the prototype) to assess impacts on N balances, N leaching and N runoff with these models (see numbers 2 in Figure 7). In the final CCAT tool the potential impact of CC-related measures on yields will also be taken into account, where CAPRI will use the yield corrections as provided by MITERRA Europe (and background models like DNDC and EPIC).

Table 12
Description of the nitrate directive measures in MITERRA-Europe.

ND	Name	Description	Parameterisation
1	Balanced N fertilizer application	The amounts of applied N fertilizer and manure applied are tuned to the crop N demand, while taking into account the contributions from atmospheric deposition, mineralisation and biological N fixation.	N fertilizer is decreased with the difference between total supply of plant-available N (fertilizer + manure + grazing + N-fixation + N deposition + mineralisation) and N-demand ((N in harvested crop + N in crop residues) * uptake factor) until a minimum fertilizer application rate. When balanced N fertilization is still not accomplished the application rate of manure N is reduced and excess manure is processed and removed from agriculture.
2	Maximum manure N application standard	The amount of applied N in manure and excreted during grazing may not exceed 170 kg N per ha in a region. Excess manure is transported or processed.	When manure N exceeds 170 kg N per ha, excess manure is divided over NUTS2 regions in the specific country. When there is still an excess the remaining manure is processed and removed from agriculture. However, some derogation to the limit of 170 kg N per ha apply (see Velthof et al., 2007).
3	Limitation to N application in winter and wet periods	If manure is applied during the growing season in stead of the winter, the availability and effectiveness of manure N for crops increases.	Reduction of N fertilizer with the amount of N from winter manure, assuming that 25% of the manure is applied in winter and that 50% of the N from this manure is plant-available when applied in spring.
4	Limitation to N application on sloping grounds	The amounts of applied fertilizer and manure N are decreased on sloping land.	N fertilizer and manure is reduced by 50% for steep slopes, 25% for intermediate slopes, 5% for slight slopes, and no reduction for flat areas.
5	Manure storage with minimum risk on leaching	Manure and slurry storages without concrete floor and cover are converted into storages with concrete floor and with cover.	All liquid manure storages are assumed to have concrete floors, 50% of solid manure storages without concrete floor are converted to storages with concrete floor and 50% of solid manure storages without cover are converted into storages with cover.
6	Appropriate application techniques	This measure leads to a higher efficiency of applied N and less leaching.	The leaching fraction is reduced by 10%.
7	Buffer zones	Buffer zones are unfertilized zones near water courses, which decrease leaching and surface runoff of N to surface water.	In buffer zones (assumed width of 100 m) the leaching and surface runoff fractions are reduced by 50%.
8	Growing winter crops	Growing catch crops will result in i) less N leaching below rooting zone, ii) less surface runoff, and iii) less requirement of fertilizer N in the following year.	Measure can be applied in 15-25% of the agricultural area, leaching and surface runoff fractions are reduced by 25%, and fertilizer N application is reduced with 10-25 kg N for regions where N surplus > 100 kg N per ha.

Table 13
Changes calculated by MITERRA Europe

NUTS 2 region	Change in N fertilizer use (%)	Change in manure N use (%)
A1….		
A2……		
B1…..		
Etc.		

3. CAPRI-Pre-processor calculations on additional cost
The CAPRI-Pre-processor calculates all the additional costs related to the applied Nitrate Directive measures and the changes in N input, as calculated by MITERRA Europe. More specifically, the CAPRI-Pre-Processor will calculate total additional cost per activity and region, taking into account the degree of implementation and compliance of all relevant measures. The CAPRI scenario is specified only by this additional cost per activity and region. Input/output coefficients and behavioural parameters remain unchanged in the prototype focusing on the nitrate directive. Elements that are included in the calculations are:

– variable costs: e.g. costs associated with manure transportation and spreading.
– fixed costs: e.g. the amortized costs associated with investment in additional storage capacity and manure handling, treatment or spreading equipment.

The effective percentage cost increases will depend on the degree of compliance assumed in the specific scenario evaluated. As describe before, both MITERRA Europe and the CAPRI-Pre-processor will use the same (consistent) assumptions with respect to base year or reference level of compliance and scenario specific (finally achieved) level of compliance.

4 and 5. CAPRI calculations on changes in animal numbers land cover and variable costs
The change (decrease) in manure application as derived with MITERRA Europe will be translated (scaled) to CAPRI to assess the N fertilizer and N manure use in this model. The details of this linkage are given below. This will influence the manure distribution and the relation of mineral fertilizer and manure for all crops in CAPRI and will be used to assess the need for manure treatment[1]. Given the percentage additional cost increases as estimated in the CAPRI pre-processor, CAPRI calculates the economic effects and changes in agricultural structure, i.e. (see number 4 and 5 in Figure 7, respectively):

– Change in animal numbers, distributed over the various animal categories.
– Change in land cover, both in crop type and crop areas.

In addition CAPRI also calculates the corresponding variable costs (see number 5 in Figure 7). The changes in animal numbers and crop areas in % compared to the reference year are given to MITERRA Europe, as shown in Table 14.

[1] The amount of N fertilizer and the N availability from manure in CAPRI are influenced by behavioural parameters in the model which will not be adjusted for the prototype. More work on this field, i.e. translating e.g. manure treatment in shifts of behavioural parameters, will be done for the final CCAT tool.

Table 14
Example of table presenting the changes in animal numbers and crop areas in % compared to the reference year calculated by CAPRI and given to MITERRA Europe.

NUTS 2 region	Change in animal number per animal type, in %					Change in crop area per crop type, in %					
	1	2	3	4	5	1	2	3	4	5	6
A1…. A2…… A3……. B1….. Etc.											

6 and 7 MITERRA-Europe calculations on changes in N fluxes and final results
Using the updated changes in animal numbers and land cover as calculated by CAPRI, MITERRA-Europe calculates the various outputs, including N fluxes (NH_3 and N_2O emissions and nitrate leaching/runoff in kg N per ha agricultural land, CH_4 emissions, N and P balances (see number 6 in Figure 7). The final result of the scenario is for each NUTS 2 region these model outputs and the additional costs in Euro per ha or head (see number 7 in Figure 7).

Linkage between MITERRA and CAPRI
The interaction between MITERRA and CAPRI within the CCAT prototype is driven by: (i the relative changes in amount of animal manure as calculated by MITERRA: N_{am} (M) and (ii) the relative changes in amount of fertilizer as calculated by MITERRA: N_{fe} (M). Rather than absolute values, relative changes as calculated by MITERRA are used to establish the linkage between the two models. This procedure is chosen because of its simplicity and to avoid difficulties due to different parameterization of both models which may lead to differences in absolute values. Within CCAT we will use the economic results from CAPRI and the environmental results from MITERRA. Consequently, this inconsistency will not be visible by the results. Nevertheless, the extent of this inconsistency and the effect of this on the presented outputs must be quantified.

The CAPRI method
In CAPRI the amount of available N for nutrient uptake for a NUTS2 region, $N_{av}(C)$, is calculated as:

$$N_{av}(C) = \sum_{ac} \left(f_{Nex}(C,ac) \cdot n(ac)\right) \cdot f_{Nav}(C) + (N_{fe}(C) + N_{fix}(C) + N_{dep}(C)) \cdot A \quad (1)$$

where:
$N_{av}(C)$ = CAPRI N availability for crop production (kg N $Nuts^{-1}$)
f_{Nex} (C,ac) = CAPRI N excretion per animal per animal category ac (kg N $head^{-1}$)
$n_{(ac)}$ = CAPRI number of animals per animal category ac (head $Nuts^{-1}$)
$f_{Nav}(C)$ = CAPRI N availability factor for crop uptake (-)
$N_{fe}(C)$ = CAPRI N fertilizer gift (kg N ha^{-1})
$N_{fix}(C)$ = CAPRI N fixation (kg N ha^{-1})
$N_{dep}(C)$ = CAPRI N deposition (kg N ha^{-1})
A = Area of a NUTS2 region (ha $Nuts^{-1}$)

The demand by crops for a NUTS2 region, $N_{dem}(C)$, is calculated as:

$$N_{dem}(C) = \sum_{ct} \left(N_{up}(C,ct) \cdot A(ct)\right) \cdot f_{of}(C) \quad (2)$$

where:
$N_{dem}(C)$ = CAPRI N demand for crop production (kg N $Nuts^{-1}$)
$N_{up}(C,ct)$ = CAPRI N uptake of crop per crop type ct (kg N ha^{-1})
A(ct) = Area of crop ct within a NUTS (ha)
$f_{oc}(C)$ = Over fertilization factor (-)

Within CAPRI the amount of fertilizer ($N_{fe}(C)$) is solved by stating:

$$N_{dem}(C) = N_{av}(C) \quad (3)$$

This may lead to different fertilizer amounts compared to MITERRA.

The linkage with MITERRA
Within the CCAT analytical tool we will use the relative changes in animal manure application (N_{am} (M)) and fertilizer use (N_{fe} (M)) from MITERRA as input for the optimization and the cost calculations in CAPRI. The amount of excretion in CAPRI for a NUTS region is adjusted as:

$$N^{M}_{am,scen}(C) = N^{M}_{am,ref}(C) \cdot \frac{N_{am,scen}(M)}{N_{am,ref}(M)} \quad (4)$$

With

$$N^{M}_{am,ref}(C) = \sum_{ac}\left(f_{Nex}(C) \cdot n(ac)\right) - N_{em,h}(C) \quad (5)$$

where:
$N^{M}_{ex}(C)$ = MITERRA results adjusted excreted amount in CAPRI (kg N $Nuts^{-1}$)
$N_{am,scen}(M)$ = the amount of animal manure applied in a NUTS region as calculated by MITERRA for a specific scenario (set of measures) (kg N $Nuts^{-1}$)
$N_{am,ref}(M)$ = Amount of animal manure applied in a NUTS region as calculated by MITERRA for the base year (kg N $Nuts^{-1}$)

An important reason for using the relative changes from MITERRA in CAPRI is that CAPRI is using slaughtered number of animals, whereas MITERRA is using real animal numbers. Furthermore, CAPRI is using its own excretions rates which may differ from those of MITERRA. Both aspects may cause serious differences and thus the pragmatic solution of transferring relative changes was chosen for the prototype. For the final version the transfers of absolute numbers might be considered.

The amount of fertilizer use in CAPRI in a NUTS region is adjusted as:

$$N^{M}_{fe}(C) = N_{fe}(C) \cdot \frac{N_{fe,scen}(M)}{N_{fe,ref}(M)} \quad (6)$$

where:
$N_{fe,scen}(M)$ = N fertilizer gift applied in a NUTS region as calculated by MITERRA for a specific scenario (set of measures) (kg N $Nuts^{-1}$)
$N_{fe,ref}(M)$ = N fertilizer gift applied in a NUTS region as calculated by MITERRA for the base year (kg N $Nuts^{-1}$)

Next Eq. (4) is substituted in Eq. (1) and Eq. 5 in Eq. (2). Subsequently, Eq. (3) is solved while keeping $N_{fe}(C)$ fixed to the reference value and f_{of} (C) variable. This guarantees that CAPRI does alter the ratio animal manure to fertilizer in the same way as it was calculated by MITERRA.

5.3 Summary of main results

In this prototype of the CCAT tool the impacts of the Nitrate Directive on the environmental indicators were assessed. There were six compliance scenarios included in the CCAT tool for which the environmental indicators were calculated:
– Baseline compliance in 2005 (differs per Nuts 2 region)
– 50% gap closure (halve way between 2005 baseline and 100% compliance)
– 0% compliance
– 50% compliance
– 75% compliance
– 100% compliance

In the figures below some first results of the impact assessment for the Nitrate Directive are shown. Figure 8 presents the change in NH_3 emission, N_2O emission, N surplus and N leaching for the EU27 for the different compliance scenarios compared to zero compliance. The largest decrease occurs for N leaching, for which the Nitrate Directive is intended. However, the figure also shows that the Nitrate Directive has positive influences on other emissions and the N surplus, mainly because of a decrease of the N input. For the 2005 baseline compliance the N leaching is about 3.2% lower, but with full compliance it could be up to 5%.

In Figure 9 the spatial distribution of the nitrate concentration in groundwater is given for the 2005 baseline. In several regions with intensive livestock, e.g. The Netherlands, the health limit of 50 mg NO_3/l, as set by the WHO, is exceeded. Also some regions in southern Europe with low precipitation surpluses have NO_3 concentrations that are too high. The other map of Figure 9 shows the relative decrease in NO_3 concentration compared to zero compliance.

Besides the NO_3 concentration in groundwater also the spatial distribution of the other environmental indicators is included in the CCAT tool. In Figure 10 the NH_3 emission and the N lost by surface runoff are shown as example. Livestock intensive regions (the Netherlands, Bretagne, Northern Italy) have the highest NH_3 emission, while N lost by surface runoff is more related with the environmental conditions.

Besides the complete package of measures for the Nitrate Directive (except balanced fertilization), we also assessed the impact of individual measures on the environmental indicators.

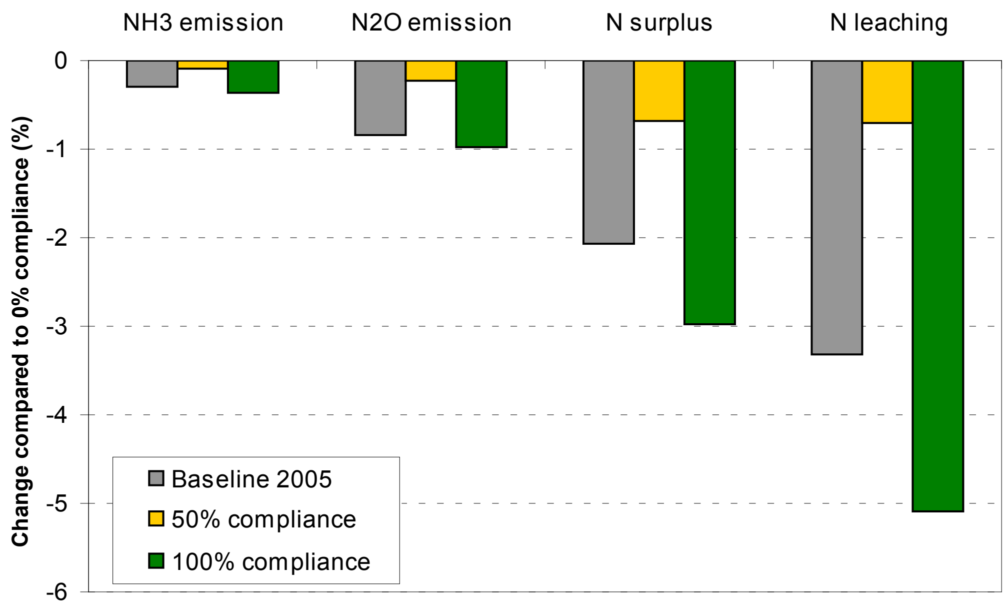

Figure 8
Change in NH_3 emission, N_2O emission, N surplus and N leaching compared to zero compliance for the EU27.

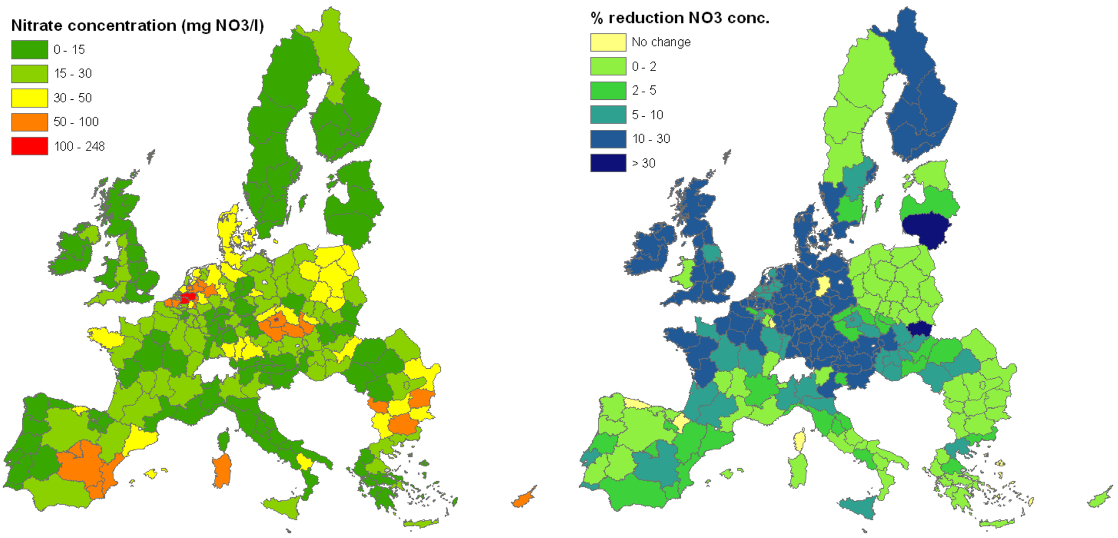

Figure 9
Nitrate concentration in groundwater for the NUTS2 regions in Europe (left) and the reduction of the NO_3 concentration due to the Nitrate Directive compared to zero compliance (right).

Figure 11 shows the results of the individual measures assuming full compliance for the EU27. Balanced fertilization, i.e. tuning the amounts of applied N fertilizer and manure to the crop N demand, is by far the measure with the highest reduction in emissions, N surplus and N leaching. Appropriate application techniques, e.g. split applications, and limitation of fertilizer application in winter and wet periods are also effective measures to decrease N leaching.

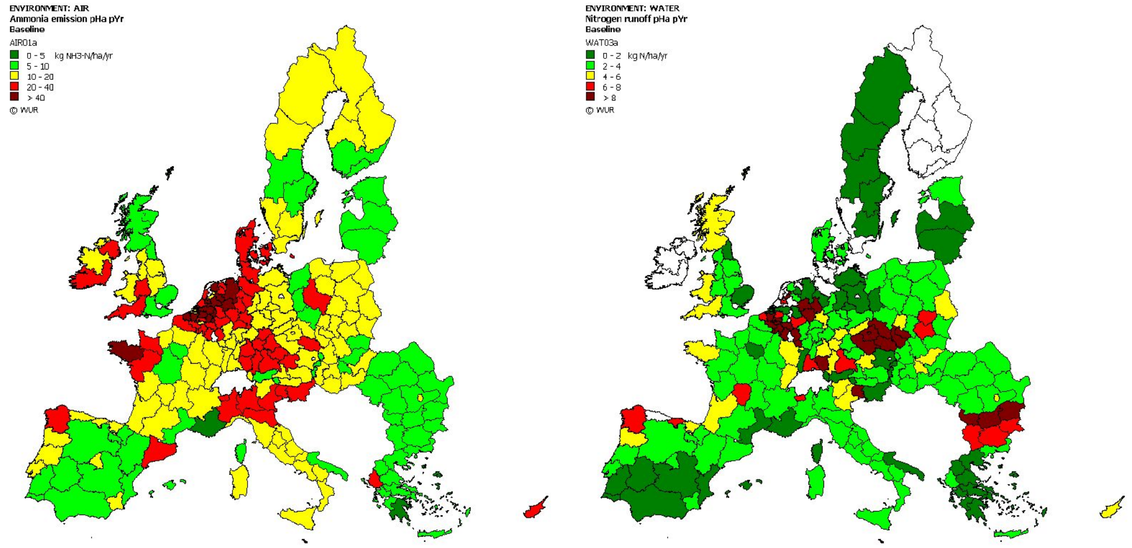

Figure 10
NH_3 emission (left) and N lost by surface runoff (right) per NUTS2 region.

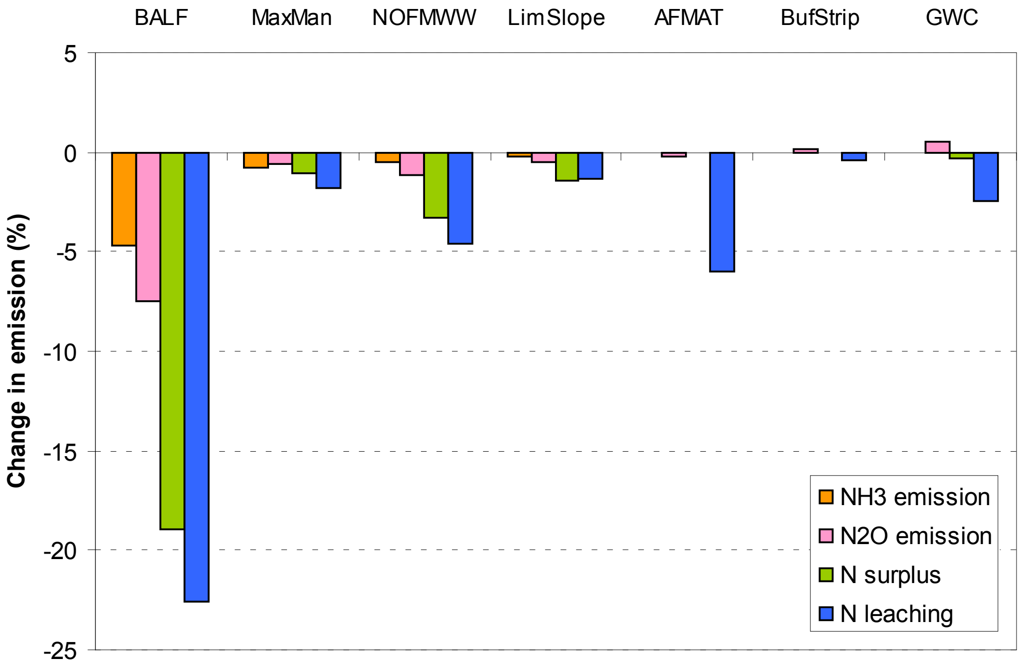

Figure 11
Impact of individual measures for full compliance on the environmental indicators (BALF=Balanced N fertilization, MaxMan=Maximum manure application, NOFMWW=Limitation of fertilizer application in winter and wet periods, LimSlope=Limitation of fertilizer application on sloping grounds, AFMAT= Appropriate application techniques, BufStrip=Buffer zones, GWC=Growing winter crops).

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Appendix 1 Expected environmental impacts of Statutory Management Requirements (SMRs) in the groundwater protection directive, sewage sludge directive and nitrate directive

Directive	SMR Short name SMR	Environmental impacts						
		Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
Groundwater protection: Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (OJ L 20, 26.1.1980, p. 43).	Groundwater - Authorisation - discharge of listed substances	X	0					X
	Groundwater - Authorisation - sheep dip, pesticides	X	0					X
	Groundwater - Codes of practice	X	0					X
	Groundwater - Codes of practice - mineral oil	X	0					X
	Groundwater - codes of practice overflow pipes	X	0					X
	Groundwater - codes of practice seepage drain	X	0					X
	Groundwater - Discharge of listed substances							
	Groundwater - Discharge of waste water							
	Groundwater - Installations maintenance							
	Groundwater - Mechanical cleaning of irrigation and drainage networks	X	X					X
	Groundwater - Plant protection	X	0					X
	Groundwater - Prohibited direct discharge	X	0					X
	Groundwater - Prohibited direct discharge - on ground and top of subsoil	X						X

Directive	SMR Short name SMR	Environmental impacts: Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Groundwater - Prohibited direct discharge - ovine baths and pesticides waste wash	X	0					X
	Groundwater - Prohibited direct discharge phytosanitaries waste	X	0					X
	Groundwater - Spraying instruments washing	X	0					X
Nitrates Directive: Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31.12.1991, p. 1)	Nitrates - application time	X	X		0	0		
	Nitrates - fertilization distance to waters	X	X		0	0		
	Nitrates - organic manure application rates	X	X		X	X	0	
	Nitrates - Application requirements	X	X		X	0		
	Nitrates - Application restrictions	X	X		0	0		
	Nitrates - Application restrictions - after harvesting	X	X		0	0		
	Nitrates - Application time	X	X		0	0		
	Nitrates - Application time - farms in specific action programme	X	X		0	0		
	Nitrates - Application time - liquid manure	X	X		0	0		
	Nitrates - Application time - vulnerable zone	X	X		0	0		
	Nitrates - Application to frozen, snow-covered, water-saturated soil -	X	X		0	0		
	Nitrates - Application to steep slopes -	X	X		0	0		
	Nitrates - Application to steep slopes - liquid manure	X	X		X	X		
	Nitrates - Application to steep slopes, frozen, snow-covered, water-saturated soil	X	X		X	X		
	Nitrates - cleaning water -	X	0		0	0		
	Nitrates - direct application of slurry -	X	0		X	X		
	Nitrates - Farm records -							
	Nitrates - Farming - distance to waters	X	X		0	0		
	Nitrates - Fertilization (mineral) in NSA	X	X		0	0		
	Nitrates - Fertilization by inclination	X	X		0	0		
	Nitrates - Fertilization distance to waters -	X	X		0	0		

Directive	SMR Short name SMR	Environmental impacts						
		Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Nitrates - Fertilization distance to waters - liquid manure	X	X		X	X		
	Nitrates - Fertilization distance to waters - mineral fertilizers	X	X		0	0		
	Nitrates - Fertilization in NSA	X	X		0	0		
	Nitrates - Field record							
	Nitrates - Field record							
	Nitrates - land-use/cultivation requirements	X	0		0	0		
	Nitrates - Maintenance of machinery -	0	0		0	0		
	Nitrates - Manure application time -	X	X		X	X		
	Nitrates - Manure application time - limits in autumn	X	X		X	X		
	Nitrates - Manure stacks, shelters, outdoor yards -	X	X		X	X		
	Nitrates - Manure storage facilities	X	X		X	X		
	Nitrates - Manure trading							
	Nitrates - maximum number of animals	X	X		X	X	0	
	Nitrates - Mineral P and N	X	X		0	0		X
	Nitrates - N amount 170	X	X		0	0		
	Nitrates - N limits per hectare	X	X		X	X		
	Nitrates - N limits per hectare - crop and soil specific	X	X		0	0		
	Nitrates - N limits per hectare - crop rotation	X	X		0	0		
	Nitrates - N limits per hectare - crop specific	X	X		0	0		
	Nitrates - N limits per hectare - manure	X	X		0	0		
	Nitrates - N limits per hectare - manure without grazing	X	X		X	X	0	
	Nitrates - N limits per hectare - organic fertilisers	X	X		X	X		
	Nitrates - N limits per hectare - vulnerable zone	X	X		0	0		
	Nitrates - New vulnerable zone - action plan							
	Nitrates - outdoor areas -	X	X		X	X		
	Nitrates - outflows to water courses -	X	X		0	0		
	Nitrates - Planning and farm records -							

Directive	SMR Short name SMR	Environmental impacts Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Nitrates - Planning and farm records - high N production							
	Nitrates - Planning and farm records - manure							
	Nitrates - Planning and farm records - N fertilisers							
	Nitrates - Planning and farm records - pig breeding							
	Nitrates - pluvial waters -	X	X					
	Nitrates - Preservation of flooded meadows -	X	X					
	Nitrates - Preservation of humid zones	X	X					
	Nitrates - Reversal of the meadows	X	X					
	Nitrates - Spreading authorisation - slurry							
	Nitrates - Spreading notification							
	Nitrates - Storage issues	X	X		X	X		
	Nitrates - Storage issues - avoiding leakage	X	X		X	X		
	Nitrates - Storage issues - capacity	X	X		X	X		
	Nitrates - Storage issues - compost	X	X		X	X		
	Nitrates - Storage issues - effluent storing	X	X		X	X		
	Nitrates - Storage issues - ensilage facilities, dung yards	X	X		X	X		
	Nitrates - Storage issues - liquid manure	X	X		X	X		
	Nitrates - Storage issues - livestock holdings	X	X		X	X		
	Nitrates - Storage issues - notification							
	Nitrates - Storage issues - on field	X	X		X	X		
	Nitrates - Storage issues - silage	X	X					
	Nitrates - Storage issues - solid manure	X	X		X	X		
	Nitrates - Vulnerable zone - action plan							
	Nitrates - Vulnerable zone - fertilization distance to waters	X	X		0	0		
	Nitrates - Vulnerable zone - fertilization distance to waters - liquid livestock waste	X	X		X	X		

Directive	SMR Short name SMR	Environmental impacts Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Nitrates - Vulnerable zone - min vegetation cover	X	X		0	0		
	Nitrates - Vulnerable zone - N limits	X	X		0	0		
	Nitrates - Vulnerable zone - surplus N	X	X		0	0		
	Nitrates - Vulnerable zone - management requirements	X	X		0	0		
	Nitrates - Vulnerable zone - new action plan							
	Nitrates - Vulnerable zone - steep slopes	X	X		0	0		
	Nitrates - Water protection strips with perennial vegetation -	X	X		0	0		
	Nitrates - water protection zones	X	X		0	0		
	Nitrates - Winter coverage	X	0					
	Nitrates - Winter coverage - termination 10. Oct	X	0					
	Nitrates - Winter coverage - termination 20. Oct	X	0					
	Nitrates - Winter coverage - > 5 ha arable land	X	0					
	Nitrates - Winter coverage - sowing 15. Oct.	X	0					
	Nitrates - Winter coverage - sowing 5. Oct.	X	0					
	Nitrates - Zones of complementary action							
	Nitrates - Zones of reinforced action							
Sewage Sludge Directive: Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (OJ L 181, 4.7.1986, p. 6)	Sewage - application authorisation							
	Sewage - application notification							
	Sewage - application restrictions	X	0					X
	Sewage - application restrictions - arable land	X	X		0	0		X
	Sewage - application restrictions - before sowing	X	X		0	0		X
	Sewage - application restrictions - forest	X	X		0	0		X
	Sewage - application restrictions - frozen, snow-covered, water saturated soil	X	X		0	0		X
	Sewage - application restrictions - grasslands	X	X		0	0		X
	Sewage - application restrictions - moorland	X	X		0	0		X
	Sewage - application restrictions - organic persistent pollutants	X	X		0	0		X

Directive	SMR Short name SMR	Environmental impacts						
		Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Sewage - application restrictions - soil classification	X	X		0	0		X
	Sewage - application restrictions - soil erosion	X	X					X
	Sewage - application restrictions - time	X	X		0	0		X
	Sewage - application restrictions - vegetable	0	0					0
	Sewage - application restrictions - vegetable and fruits	0	0					0
	Sewage - application restrictions - Veneto							
	Sewage - application restrictions - water pollution	X	X					0
	Sewage - application restrictions - water protection zones	X	X					0
	Sewage - application technique	X	X		0	0		X
	Sewage - documentation							
	Sewage - grazing and forage crops restrictions	0	0		0	0		0
	Sewage - harvest restrictions	0	0		0	0		0
	Sewage - harvest restrictions - grazing, forage	0	0		0	0		0
	Sewage - heavy metal limits	X	X					X
	Sewage - heavy metal limits - content of the field	X	X					X
	Sewage - Heavy metals	X	X					X
	Sewage - manager's certification							
	Sewage - max application rate	X	X		0	0		X
	Sewage - max. application rate_10t	X	X		0	0		X
	Sewage - max. application rate_2,5t	X	X		0	0		X
	Sewage - max. application rate_2LU	X	X		0	0		X
	Sewage - max. application rate_50cbm	X	X		0	0		X
	Sewage - max. application rate P-soil-content	X	X		0	0		X
	Sewage - N limits per hectare	X	X		0	0		X
	Sewage - record keeping							
	Sewage - sludge treatment	X	X					X
	Sewage - soil analysis							
	Sewage - soil analysis - phosphorus							

Directive	SMR Short name SMR	Environmental impacts						
		Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
	Sewage - soil pH limits	X	X		0	0		X
	Sewage - storage	X	X		0	0		
	Sewage - use of codes of practice	X	X		0	0		X

Appendix 2 Selected measures in the Nitrate Directive, Sewage Sludge Directive and Groundwater Directive (SMRs) and the models in the CCAT tool that will evaluate the measures

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
116	No application of mineral fertilizer, slurry, muck and sludge on areas without GREEN COVER between 15 October and 15 February.	N fertilizer input = 0 for landuse X	Austria	X		X	3	
117	No application of mineral fertilizer, slurry, muck and sludge on areas with GREEN COVER between 15 November and 15 February.	N fertilizer input = 0 for landuse X	Austria			X	3	
118	Regulations for manure storage on fields: Minimum distance to surface water is 25 m.	Reduce N leaching from manure storage	Austria				7	
119	Restriction of organic manure application: 170 kg N/ha and year	Set N in by animal manure to a maximum	Austria	X		X	2	
483	Methods for spreading of manure on non-cultivated areas - Liquid and solid manure that is spread on non-cultivated areas must be ploughed down as fast as possible and within 6 hours.	Reduce NH_3 emission during application	Denmark			X	6	
962	Requirement for the ploughing in of farmyard manure: If you spread farmyard manure or other organic fertilizers in the counties of Halland, Skåne or Blekinge, you must plough it within four hours. This applies throughout the year.	Reduce NH_3 emission during application	Sweden			X	6	
1038	Farmers must spread N fertiliser and organic manures evenly and accurately.	Higher N efficiency	United Kingdom	X		X	6	
963	Requirement for the ploughing in of farmyard manure: If you spread farmyard manure or	Reduce NH_3 emission during application	Sweden	X		X	6	Only a slight effect because of

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	other organic fertilizers during the period from 1 December to 28 February, it must be ploughed in on the same day.							low temperature
628	Fertilization after harvesting is only permitted to field grass, underseeds, autumn sowings including intercropping and for straw fertilization.	Higher N efficiency of fertilizer	Germany	X		X	6	
120	No application of organic manure, compost and sewage compost between 30 November and 15 February (for certain crops: 1 February).	Higher N efficiency of organic manure	Austria	X		X	3	
472	Periods for manure spreading - In the period from harvest to 1 February, no liquid manure must be spread. The exception is spreading from harvest to 1 October on areas with fodder grass that stands throughout the winter, and for areas where winter rape.	Higher N efficiency of organic manure	Denmark	X		X	3	
610	General prohibition of applying liquid manure, poultry excrements or nitrogenous-liquid secondary raw material fertilizer between 15 November and 15 January. The competent authority may permit exemptions with regard to the special characteristics of the f	Higher N efficiency of organic manure	Germany	X		X	3	
756	Spreading is prohibited during the fall-winter season, from 1 November through the end of February as a general rule. With reference to specific local pedoclimatic conditions regional authorities may define different prohibition starting dates.	Higher N efficiency of organic manure	Italy	X		X	3	
964	From 1 November to 15 February you may not spread commercial fertilizer. From 1 January to 15 February you may not spread farmyard manure or other organic fertilizer.	Higher N efficiency of organic manure and inorganic fertilizers	Sweden	X		X	3	
1047	Farmers must not apply N during the following periods: For sandy or shallow soil types - organic manures with high available N (slury, poultry	Higher N efficiency of organic manure	United Kingdom	X		X	3	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	manure or liquid digested sewage sludge): - no spreading between 1 Sept - 1 Nov for autumn sown arable crop.							
814	It is not allowed to apply liquid manure on agricultural land without a green plant cover in the period between 15 November and 15 February.	Higher N efficiency of organic manure	Slovenia	X		X	3	
1048	Farmers must not apply nitrogen fertilizers during the following periods: Nitrogen fertiliser: - no spreading between 1 Sept - 1 Feb for arable crops - no spreading between 15 Sept - 1 Feb for grassland Organic manures: - no spreading between 1 Aug	Higher N efficiency of inorganic fertilizer	United Kingdom	X		X	3	
1030	Closed periods when NO application should be made: Inorganic nitrogen fertilisers - all soils (depends on NVZ): 15 Sept - 20 Feb on grassland, 1 Sept - 20 Feb on other land (exceptions are possible after justification, 3 day notice should be made).	Higher N efficiency of inorganic fertilizer/ lower rates limited to NVZ	United Kingdom	X			3	
899	In holdings located in areas vulnerable to water pollution by nitrates, the periods during which the application of certain types of fertilizers is forbidden as fixed by the Administration, must be respected.	Higher N efficiency of inorganic fertilizer/ lower rates limited to NVZ	Spain	X			3	
121	No application of nitrogenous fertilizer when soil is frozen or covered with snow.	Higher N efficiency of inorganic fertilizer	Austria	X		X	3	
575	Fertilizers must not be applied to frozen, water-saturated, flooded and snow-covered soils.	Higher N efficiency of inorganic fertilizer	France	X		X	3	
965	You may not spread fertilizer on waterlogged or flooded land, or on snow-covered or deep-frozen land.	Higher N efficiency of inorganic fertilizer	Sweden	X		X	3	
122	Appropriate fertilization on sloping sites (measures for sugar-beets and maize): Slot sowing.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Austria	X		no slopes	4	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
574	Fertilization is not allowed to steeply sloping ground of 7%.	Higher N efficiency of inorganic fertilizer and less fertilizer use	France	X		no slopes	4	
746	Regional authorities, due to particular local conditions detect, identify and establish the various slope/incline limits beyond which it is prohibited to use manure, nitrogenous fertilizers and similar materials. They regulate and enforce the agronomic pr	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	Italy	X		no slopes	4	
1031	Inorganic nitrogen fertilisers and organic manure must not be applied: To steeply sloping fields	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	United Kingdom	X		no slopes	4	
747	It is prohibited to spread animal slurry on lands with an inclination greater than 15%;	No manure application	Italy	X		no slopes	4	
815	Application of liquid manure is forbidden on steeply sloping areas. There is a high risk that the liquid manure is drained off due to its inappropriate application.	No manure application	Slovenia	X		no slopes	4	
749	It is prohibited to spread animal slurry and manure on flooded, frozen or snow-covered lands, and near watercourses.	Higher N efficiency of organic manure and less manure use	Italy	X		X	3 and 7	
816	Application of liquid manure is not allowed on agricultural land, where: - the soil is saturated with water or flooded; - the soil is frozen or snow cover is above 10 cm; - the area has the status of a water protection zone.	Higher N efficiency of organic manure and less manure use	Slovenia	X		X	3 and 7	
1032	Inorganic nitrogen fertilisers and organic manure must not be applied: when the soil is waterlogged, flooded, frozen hard (for last 12 hours or longer in the preceding 24 hours) or snow covered.	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	United Kingdom	X		X	3	
614	Nitrogenous fertilizers may only be applied, if the soil is	Higher N efficiency of	Germany	X		X	3	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	absorptive. That means that fertilizers are not to be applied on soil that is saturated with water and deeply frozen or strongly covered soils with snow.	inorganic fertilizer and less fertilizer use						
883	In livestock holdings located in areas vulnerable to water pollution by nitrates, cleaning water shall circulate through moisture proof routes and shall be collected in effluent storing facilities.	Lower leaching form manure storage	Spain	X			5	
576	Fertilization closer than 35 m to waters is not allowed in the case of fertilizers of categories I and II. In the case of fertilizers of category III, fertilization closer than 2 m to waters is not allowed.	Higher N efficiency of inorganic fertilizer and less fertilizer use	France	X			7	
618	In the case of the application of nitrogenous fertilizers a sufficient distance must be kept to waters in order to avoid direct entry of fertilizers in surface waters.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Germany	X			7	
750	It is prohibited to spread livestock manure, nitrogenous fertilizers and similar materials within 5 metres of distance from the bank of water courses; within 10 metres from the riverside of water courses that have been identified by the regional administration.	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	Italy	X			7	
881	Fertilizers' application in the vicinity of water courses or of water supplying points in vulnerable areas to water pollution by nitrates shall respect minimum distances depending on fertilizer kind	Higher N efficiency of inorganic fertilizer and less fertilizer use	Spain	X			7	
1034	Farmers must not apply N fertiliser in a way that contaminates watercourses, or apply organic manures within 10 metres of watercourses.	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	United Kingdom	X			7	
619	The application of liquid manure at a distance of 10 meters or less to the edge of bodies of water is inadmissible.	Higher N efficiency of liquid manure and less liquid manure use	Germany	X			7	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
620	The application of mineral fertilizer at a distance of 5 meters or less, measured from the edge, is inadmissible.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Germany	X			7	
1035	Chemical fertiliser shall not be applied to any land in a location or manner that makes it likely that the chemical fertiliser will directly enter any inland or coastal waters.	Higher N efficiency of liquid manure and less liquid manure use	United Kingdom	X			7	
621	In Thuringia, in case of fertilization a minimum distance of 10 meters to bodies of water (bodies of water of the 1st order) or/and 5 meters (bodies of water of the 2nd order, constantly having water) is to be kept.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Germany	X			7	
581	In the Centre region, the winter cover of all soils is obligatory in case of remainder post-harvest.(?)	Include catch crop	France	X			8	
1039	On land on farm which was used in any year to produce a leafy vegetable crop not comm	Include catch crop	United Kingdom	X			8	
128	No application of nitrogenous fertilizer on soggy or flooded soils.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Austria	X			3	
745	It is prohibited to spread animal slurry and manure during the period ranging from 15 December to 28 February.	Higher N efficiency of animal manure and less animal manure use	Italy	X			3	
966	In the period from 1 August to 30 November you may only spread farmyard manure and other organic fertilizers on growing crops or on land which you are going to sow during the period. However, there is an exception to the ban on spreading on uncovered land	Higher N efficiency of animal manure and less animal manure use	Sweden	X			3	
584	The amount of livestock manure applied to the land each year, including by the animals themselves, shall not exceed 170 kg N per hectare	Maximum amount of animal manure use	France	X			2	
752	In the vulnerable areas,	Maximum	Italy	X			2	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	maximum limits of N hectare/year must be observed for all kinds of fertilizers or manure containing N. Action programme promoted by the region provides for different and more strict limits than the standard of 170 kg/ha/year.	amount of animal manure and fertilizer use						
1043	Farmers must adhere to the following nitrogen limits: (i) whole farm within NVZ (including grazing deposition) - arable crop requirement 210kg/ha total N (note 1) - grassland crop requirement 250kg/ha total N (ii) field limit (excluding grazing)	Maximum amount of animal manure and fertilizer use	United Kingdom	X			2	
969	You must not spread more nitrogen than the crop may be expected to need. When you calculate the dose of fertilizer, you must take into account the nitrogen that the crop obtains from other sources, such as from the preceding crop.	N balanced fertilization	Sweden	X			1	
129	Appropriate fertilization (same regulations as 'basic premium' of ÖPUL - Austrian Agri-Environmental Programme): Water act permission is necessary when total amount of N-fertilizer exceeds 210 kg N/ha on areas with GREEN COVER or nitrogen consuming crops.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Austria	X			6	
895	Farmers shall respect statutory terms and maximum allowed quantities of nitrogenous fertilizers applied to crops.	Maximum amount of fertilizer use	Spain	X			2	
1050	Farmers must not apply more N fertiliser than a crop requires, taking account of crop uptake, soil N supply, excess winter rainfall, and plant or crop available N from organic manures.	N balanced fertilization	United Kingdom	X			1	
486	Limits for manure spreading (harmony rules) - The amount of manure used on a farm must not exceed	Maximum amount of animal manure use	Denmark	X			2	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	1.4 livestock units per ha per planning period (1 August to 31 July).							
626	Maximum limits for the application of fertilizers containing N: 170 kg N/ha per year from livestock manure on arable land and up to 210 kg N/ha per year on grassland or on areas with a crop rotation with high N-demand.	Maximum amount of fertilizer use	Germany	X			2	
753	Maximum limits for the application is 170 kg /ha/year of N coming from slurry and livestock manure. This limit includes contribution given by animals during grazing and by the agronomic utilization of process water.	Maximum amount of animal manure and fertilizer use	Italy	X			2	
820	Yearly application of N-fertilizers of livestock origin must not exceed 170 kg/ha.	Maximum amount of animal manure and fertilizer use	Slovenia	X			2	
896	The maximum amounts of organic fertilizers applied to the soil per year shall not exceed the equivalent to 210 kg of nitrogen per hectare.	Maximum amount of animal manure and fertilizer use	Spain	X			2	
1044	Farmers must limit the organic manure loading averaged over the whole farmed area each year (beginning on 19 December) to: - 250kg total N per ha for grassland in any NVZ; - 170kg total N per ha for non-grass crops in a NVZ that was designated in 1996	Maximum amount of animal manure use	United Kingdom	X			2	
1045	Applications of organic manure to individual fields must not exceed 250 kg per ha of total N in any 12-month period. This limit does NOT include manures deposited by grazing animals.	Maximum amount of animal manure use	United Kingdom	X			2	
897	Maximum allowed quantities of mineral nitrogenous fertilizers are fixed.	Maximum amount of fertilizer use	Spain	X			2	
611	After harvesting of the main fruit only 40 kg NH4-N/ha (ammonium nitrogen) or 80 kg total N/ha (total nitrogen) are to be applied on arable land	Maximum amount of fertilizer use	Germany	X			2	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	with liquid manure, poultry excrements or nitrogenous-liquid secondary raw material fertilizer.							
1066	Limit applications of organic manure to 250 kg/ha of total nitrogen NOT including manure deposited by animals.	Maximum amount of animal manure use	United Kingdom	X			2	
700	In areas established as nitrate vulnerable zones: The quantity of manure that is added each year in the soil, either by the farmers or directly by animals, should not contain nitrogen above 170 kg/hectare	Maximum amount of animal manure use	Greece	X			2	
898	In agricultural holdings located in areas vulnerable to water pollution by nitrates, the maximum allowed quantity of dung per ha fixed by the administration must be respected.	Maximum amount of animal manure use	Spain	X			2	
1046	Organic manure use within the NVZ must not exceed the farm-based limits (including grazing deposition): 250 kg organic N/ha averaged over all of the grassland in an NVZ, 170 kg organic N/ha, averaged over all the non-grassland in an NVZ.	Maximum amount of animal manure use	United Kingdom	X			2	
884	Livestock holdings located in areas vulnerable to water pollution by nitrates shall keep those outdoor areas used by waiting livestock waterproof and with a slope sufficient to ensure the evacuation of effluents.	Lower leaching form manure storage	Spain	X			5	
473	Restrictions on where and how to spread manure - Animal manure, silage juice and waste water must not be spread in such a way or on such areas, that there is a risk of runoff to lakes, water courses and drains (in the course of thaws or heavy showers).	Higher N efficiency of animal manure and less animal manure use	Denmark	X			7	
885	Outflows, especially those of livestock origin, to any body of water, i.e. standing or flowing bodies of water or dry river beds, shall be avoided.	Higher N efficiency of animal manure and less animal manure use	Spain	X			7	
494	Balance between nitrogen	N balance	Denmark	X			1	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	supply and demand - In the planning period, the use of nitrogen for manure purposes must not exceed the farm's nitrogen quota.	fertilization						
578	no N spreading in flooded grassland	Higher N efficiency of animal manure and less animal manure use	France	X			3	
707	In areas established as nitrate vulnerable zones, farmers should apply the quantities of nitrogenous fertilizers and observe the directions with regard to frequency, time and quantity of applied nitrogen per dose, as determined per crop and soil class	Maximum amount of fertilizer use	Greece	X			6	
882	In agricultural holdings located in areas vulnerable to water pollution by nitrates, fertilizers shall not be applied to a band of soil near water courses according to the width prescribed by the administration.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Spain	X			7	
703	In areas established as nitrate vulnerable zones: Dispose of liquid livestock waste in area of at least 20 metres distance from surface waters and 50 metres from sources, wells or water drillings that are used for human consumption.	Higher N efficiency of animal manure and less animal manure use	Greece	X			7	
582	All farms in NVZ should keep a minimum of vegetation during rainy periods:- Intermediary cultures traps for the nitrates (CIPAN);- Management of the residues ;- Management of the regrowths.	Include catch crop	France	X			8	
755	For the vulnerable areas, a limit of 170 kg/hectare applies. The limit is guaranteed by the observance of the maximum value of the animal live weight that can be raised per hectare. These limits correspond to: 1) 8 quintals/ha for birds and rabbits 2) 12	Maximum amount of animal manure and fertilizer use	Italy	X			2	
704	In areas established as nitrate vulnerable zones: Avoid the	Higher N efficiency of	Greece	X			4	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
	disposal of liquid waste as well as the application of organic manure in areas with a slope bigger than 8%	animal manure and less animal manure use						
577	Along the waterways, there should be permanent vegetation like field margin, hedge etc. introduced or maintained	Higher N efficiency of inorganic fertilizer and less fertilizer use	France	X			7	
484	Plant cover - The farm must either sow spring crops or create areas with catch crops in autumn in order to ensure effective nitrogen uptake during autumn. - The area used for catch crops must make up at least 6% of the catch crop area.	Include catch crop	Denmark	X			8	
972	50% of arable land must be covered by vegetation during autumn or winter (green fields). The demand only applies to farmers with more than five hectares of arable land.	Include catch crop	Sweden	X			8	
973	If multiannual crops, ley and catch crops are intended to be sown before 1 August or stubble from harvested crops to be recognized as green fields, tilling or the termination of growth by chemical means are not allowed before 10 October.	Include catch crop	Sweden	X			8	
974	If multiannual crops, ley and catch crops sown before 1 August or stubble from harvested crops are intended to be recognized as green fields, tilling or termination of growth by chemical means are not allowed before 20 October.	Include catch crop	Sweden	X			8	
975	60% of arable land must be covered by vegetation during autumn or winter (green fields). The demand only applies to farmers with more than five hectares of arable land.	Include catch crop	Sweden	X			8	
976	Autumn crops and catch crops must sown no later than 15 October.	Include catch crop	Sweden	X			8	

The nitrate directive								
Number	SMR	Which effect indicator to include and how	State Name	MITERRA-EUROPE	EPIC	DNDC	MITERRA measure	Remark
977	Autumn crops and catch crops must sown no later than 5 October.	Include catch crop	Sweden	X			8	
617	Nitrogenous fertilizers should only be applied if the soil is absorptive. That means that fertilizers are not to be applied on soil that is saturated with water or deeply frozen or on soils strongly covered with snow.	Higher N efficiency of inorganic fertilizer and less fertilizer use	Germany	X			3	
1033	Farmers must not apply any materials containing N when the ground is waterlogged, flooded, frozen hard or snow covered.	Higher N efficiency of inorganic fertilizer/manure and less fertilizer/manure use	United Kingdom	X			3	

Sewage Sludge Directive								
Number	SMR	How to include	State Name	MITERRA	EPIC	DNDC	MITERRA measure	Remark
653	Application of sewage sludge on agriculturally or gardening used soils is prohibited if examinations of soil in line with § 3 paragraph 2 or 3 indicate that the contents of the heavy metals specified in § 4 paragraph 8 exceed at least one of the values.	No sewage sludge in particular areas	Germany					
762	Sewage sludge utilization is allowed only if the sewage sludge, when it is used, does not exceed the limit values of concentration of heavy metals and other parameters established by the law.	Maximum contents of X in sewage sludge	Italy	X				Use the minimum value of estimated present metal concentrations and maximum concentrations in sewage sludge in sewage sludge
979	The sludge used must not contain more metals than the values listed below. Maximum metal content in sludge, mg/kg dry matter: Lead 100, Cadmium 2, Copper 600, Chromium 100, Mercury 2.5, Nickel 50, Zinc 800.	Maximum contents of X in sewage sludge	Sweden	X				Use the minimum value of estimated present metal concentrations and mentioned maximum concentrations in sewage sludge
1089	The application of sewage sludge must not increase the metal concentrations in the soil above the limits as set in the sludge table in the Regulations.	Maximum contents of X in sewage sludge	United Kingdom	X				In principle this is a simplification since this requires a dynamic model including information on present levels and adsorption characteristics of the soil
980	Sewage sludge may only be spread on arable land if the metal contents of the soil are lower than the values listed below. Maximum metal content in the soil, mg/kg dry matter: Lead 40, Cadmium 0.4, Copper 40, Chromium 60, Mercury 0.3, Nickel 30, Zinc 10.	Maximum contents of X in sewage sludge	Sweden	X				In principle this is a simplification since it actually should be: No sewage sludge in particular areas, i.e. where soil concentrations exceed limit values, but this information is not available on a general European wide level.
981	When you spread sewage sludge on arable land you must not introduce more metal per hectare per year than listed below. There are also limits on how much phosphorus and nitrogen you may spread over a seven-year period.	Maximum contents of X in sewage sludge	Sweden	X				In principle this is a simplification since it actually should be a limit to the application rate (product of amount of seage and maximum

Sewage Sludge Directive								
Number	SMR	How to include	State Name	MITERRA	EPIC	DNDC	MITERRA measure	Remark
								concentration)
1112	The producers of the sludge are responsible for keeping to the legal requirements on concentrations of metal contaminants in the sludge itself and the soil to which it is applied.	Maximum contents of X in sewage sludge	United Kingdom	X				
711	Comply with the provisions of articles 3 and 4 of the Joint Ministerial Decision (JMD) 80568/4225/91 (B 641). (Directive 86/278/EEC).	Maximum contents of X in sewage sludge	Greece	X				
771	The utilization of sewage sludge in agriculture is allowed only if it is treated beforehand; if it is fit to be used as fertilizer or to have a corrective effect on the land; if its content of toxic or noxious substances is not dangerous for land, crop an	Maximum contents of X in sewage sludge	Italy	X				Again a simplification of reality

Groundwater Directive								
Number	SMR	How to include	State Name	MITERRA	EPIC	DNDC	MITERRA measure	Remark
720	Land spreading of organic matter containing List II substances should be done in accordance with good farming practice. All silage and slurry pits should be structurally sound. Clean water run-off should be channelled away from dirty water collection point.	Set all contaminants that exceeds threshold values at that threshold. MITERRA: only list II	Ireland	X				
723	It is not allowed to spread slurry close to wells or in excess amounts for soil absorption. Land spreading of organic matter materials containing List II substances is done according to good farming practice.	Set all contaminants that exceeds threshold values at that threshold. MITERRA: only list II	Ireland	X				
1020	Farmers must not make any discharges of List I substances to groundwater or cause pollution of groundwater by List II substances (see Appendix 2d for lists).	Set all contaminants that exceeds threshold values at that threshold. MITERRA: only list II	United Kingdom	X				

Appendix 3 Expected environmental impacts of measures related to Good Agricultural and Environmental Conditions (GAECs) for soil erosion, soil organic matter and minimum level of maintenance

			Environment						
		Short name	Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
Soil erosion	Minimum coverage	Field greening	0	0				X	0
		Maintenance - grazing and outdoor feeding sites						X	
		Maintenance - minimum maintenance	0	0				X	0
		Maintenance - minimum maintenance - non cultivated land	0	0				X	0
		Maintenance - set-aside - catch crops	0	0				X	0
		Maintenance - set-aside - establishment of plant cover	0	0				X	0
		Maintenance - set-aside - must of plant cover	0	0				X	0
		Maintenance - set-aside - oil plants rules	0	0				X	0
		Maintenance - set-aside - re-establishment of plant cover	0	0				X	0
		Maintenance - set-aside - species	0	0				X	0
		Maintenance - set-aside - tillage Sept 1						X	
		Maintenance - set-aside - tillage Oct 10						X	
		Prohibition of ploughing up permanent grassland - change by 10%	X	0		0	0	X	
		Soil erosion - minimum coverage	0	0				X	0
		Soil erosion - minimum coverage - arable land	0	0				X	0
		Soil erosion - minimum coverage - fallow and set-aside land	0	0				X	0
		Soil erosion - minimum coverage - fallow and set-aside land herbicide use	0	0				X	0
		Soil erosion - minimum coverage - non-cropped land - ANDA	0	0				X	0
		Soil erosion - minimum coverage - olives - NAVA	0	0				X	0
		Soil erosion - minimum coverage -	0	0				X	0

			Environment						
		Short name	Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
		permanent crops							
		Soil erosion - minimum coverage - post-harvest management - W	0	0				X	0
		Soil erosion - minimum coverage - temporary cover crop	0	0				X	0
	Minimum land management reflecting site-specific conditions	Maintenance - appropriate livestock density - upland overgrazing		0				X	
		Maintenance - supplementary feeding sites - rotation		0				X	
		Prohibition of ploughing up permanent grassland - slopes and protection zones		0		0	0	X	
		Soil erosion - collection of rainwater		0				X	
		Soil erosion - cultivation distance to waters		X				X	
		Soil erosion - drainage		0				X	
		Soil erosion - grass margins		0				X	
		Soil erosion - grazing and poaching		0				X	
		Soil erosion - livestock access to watercourses		0				X	
		Soil erosion - minimum coverage - wind erosion						X	
		Soil erosion - modification of plots						X	
		Soil erosion - no row crops on slopes		0				X	
		Soil erosion - steep slopes		0				X	
		Soil erosion - supplementary feeding sites		0				X	
		Soil erosion - tillage on slope - arable land - NAVA		0				X	
		Soil erosion - tillage on slope - permanent crops - ANDA		0				X	
		Soil erosion - uncultivated margins		0				X	
	Retain terraces	Maintenance - landscape features		0				X	
		Maintenance - landscape features - terraces		0				X	
		Soil erosion - maintenance of landscape and other features		0				X	
	Other standards?								
Soil organic matter	Standards for crop rotations where applicable	Soil organic matter - break crops	0					X	X
		Soil organic matter - crop rotation	0					X	X
		Soil organic matter - crop rotation - humus balance	0					0	
		Soil organic matter - crop rotation - three crops						X	
	Arable stubble management	Field greening	0	0				X	0
		Soil organic matter - arable stubble management						X	
		Soil organic matter - manure management	0			0	0	X	
		Soil organic matter - stubble burning management				0	0	0	
		Soil organic matter - stubble				0	0	0	

			Environment						
		Short name	Ground water quality	Surface water quality	Water quantity	Air quality	Climate	Physical soil quality	Chemical soil quality
		burning prohibition							
	Other standards?								
Minimum Level of Maintenance	Others refering to Minimum level of maintenance	Field greening	0	0				X	0
		Maintenance - minimum maintenance - abandoned land		0				X	
		Maintenance - permanent grassland	0	0				X	0
	Avoiding the encroachment of unwanted vegetation on agricultural land	Field greening	0	0				X	0
		Maintenance - permanent grassland	0	0				X	0
		Maintenance - minimum livestock density	0	0				X	0
		Maintenance - appropriate livestock density - undergrazing	0	0				X	0
	Protection of groundwater	Field greening	0	0				X	0
		Prohibition of ploughing up permanent grassland - slopes and protection zones	0	0		0	0	X	0
		Maintenance - set-aside - fertilization restrictions	X	X				0	0
		Maintenance - set-aside - management	0	0				0	0
		Maintenance - set-aside - oil plants rules	0	0				X	0
	Protection of permanent pasture	Field greening	0	0				X	0
		Prohibition of ploughing up permanent grassland - slopes and protection zones	0	0		0	0	X	0
		Maintenance - permanent grassland	0	0				X	0
		Maintenance - appropriate livestock density	0	0				X	0
		Maintenance - minimum maintenance - mowing, grazing	0	0				0	0
	Protection of suface	Maintenance - set-aside - catch crops	0	0				X	0
		Prohibition of ploughing up permanent grassland - slopes and protection zones	0	0		0	0	X	0
		Maintenance - set-aside - must of plant cover	0	0				X	0
	Retention of landscape features	Field greening	0	0				X	0
		Maintenance - permanent grassland	0	0				X	0
	Minimum livestock stocking rates or/and appropriate regimes	Maintenance - minimum livestock density	0	0				X	0
		Maintenance - appropriate livestock density - overgrazing - SC	0	0				X	0
		Maintenance - permanent grassland	0	0				X	0
	Other standards?								

Appendix 4 Selected measures in GAECs and the way in which effect indicators will be calculated with one or more models in the CCAT tool

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
1	Austria	Minimum level of maintenance	Avoiding the encroachment of unwanted vegetation on agricultural land	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2, 3	Introduce a cover crop in winter to maintain crop area, this needs to be implemented in the EPIC model, but should be possible theoretically. We could in principle do the same with DNDC	We will be able to model something that is in the 'spirit' of this measure. I am thinking of cover crops during winter for example. So, although not specifically, we can address issues that are similar to this measure. I think that we should be flexible with the interpretation here.
3	Austria	Minimum level of maintenance	Others referring to Minimum level of maintenance	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
175	Netherlands	Minimum level of maintenance	Others referring to Minimum level of maintenance	Maintenance - minimum maintenance - abandoned land	It is generally prohibited to have bare fallow. It means farmers have to seed a crop on all plots taken out of production (can be green crop, non-food/non-feed crop or forage legumes, in case of organic farming on all land).	1, 2	see 1	Maintenance of crop cover, cover crop

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
4	Austria	Minimum level of maintenance	Protection of groundwater	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
8	Austria	Minimum level of maintenance	Protection of permanent pasture	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
302	Sweden	Minimum level of maintenance	Protection of surface	Maintenance - set-aside - catch crops	For multiannual set aside you are required to sow a catch crop. If the set aside is to be annual, you may in certain cases leave the land unworked after harvest the year before the set aside year. If you sow the catch crop into the main crop which precedes the set aide it is possible to choose annual or multiannual set aside. The following plants are approved as catch crops: grasses (but not cereals), clover, alfalfa, vetch, goat's rue, birdsfoot trefoil, California bluebell and white mustard. You can sow the plants as single crops or mixed. The proportion of legumes in the seed for sowing may not exceed 30% of the seed mixture by weight. You can also allow an existing ley to become the catch crop on set aside land. If you have used a ley for harvesting or grazing in the preceding growing season and are now allowing it to be the catch crop under set aside, the limit of 30% of legumes in the seed for sowing does not apply.	1,2,3		Catch crop, set-aside specific though
11	Austria	Minimum level of maintenance	Retention of landscape features	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
15	Austria	Soil erosion	Minimum coverage	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
113	Greece	Soil erosion	Minimum coverage	Field greening	Ensure that in parcels in areas with an inclination greater than 10%, there is plant cover during periods of rainfall, until the preparation of the soil for the next seeding, depending on the crop.	1, 2	see 1	Maintenance of crop cover, cover crop
125	Hungary	Soil erosion	Minimum coverage	Soil erosion - minimum coverage	ensure a minimum soil cover before spring sown crops in areas exposed to erosion.	1, 2	see 1	Maintenance of crop cover, cover crop
139	Ireland	Soil erosion	Minimum coverage	Maintenance - minimum maintenance	Ensure that soil is covered by vegetation (crop cover, crop residue, stupple cover) or else ploughed. Finely tiled bare (unsown) seedbeds are not permitted over the winter.	1, 2	see 1	Maintenance of crop cover, cover crop
178	Netherlands	Soil erosion	Minimum coverage	Maintenance - minimum maintenance	You are obliged to seed a crop on all plots taken out of production.	1, 2	see 1	Maintenance of crop cover, cover crop
179	Netherlands	Soil erosion	Minimum coverage	Soil erosion - minimum coverage	On land threatened by erosion: Crops should be sown directly after the harvest or, cover crop should be mulched, or the soil should be covered by straw and the measures breaking water run-off should be installed (didges, canals, hedges or soil protective crops).	1, 2	see 1	Maintenance of crop cover, cover crop
235	Spain	Soil erosion	Minimum coverage	Maintenance - minimum maintenance - non cultivated land	Exactable conditions to avoid erosion. Minimum coverage of soil. Non-cropped land. Those lands not cultivated, not intended for pastures, nor used to activate rights for set-aside, shall meet the same maintenance conditions required for fallow land (optionally: traditional cropping practises, minimal tillage practices or practices to maintain an adequate vegetation cover, either spontaneous or through the sowing of enhancing species), even though, in this case,	1, 2	see 1	Maintenance of crop cover, cover crop

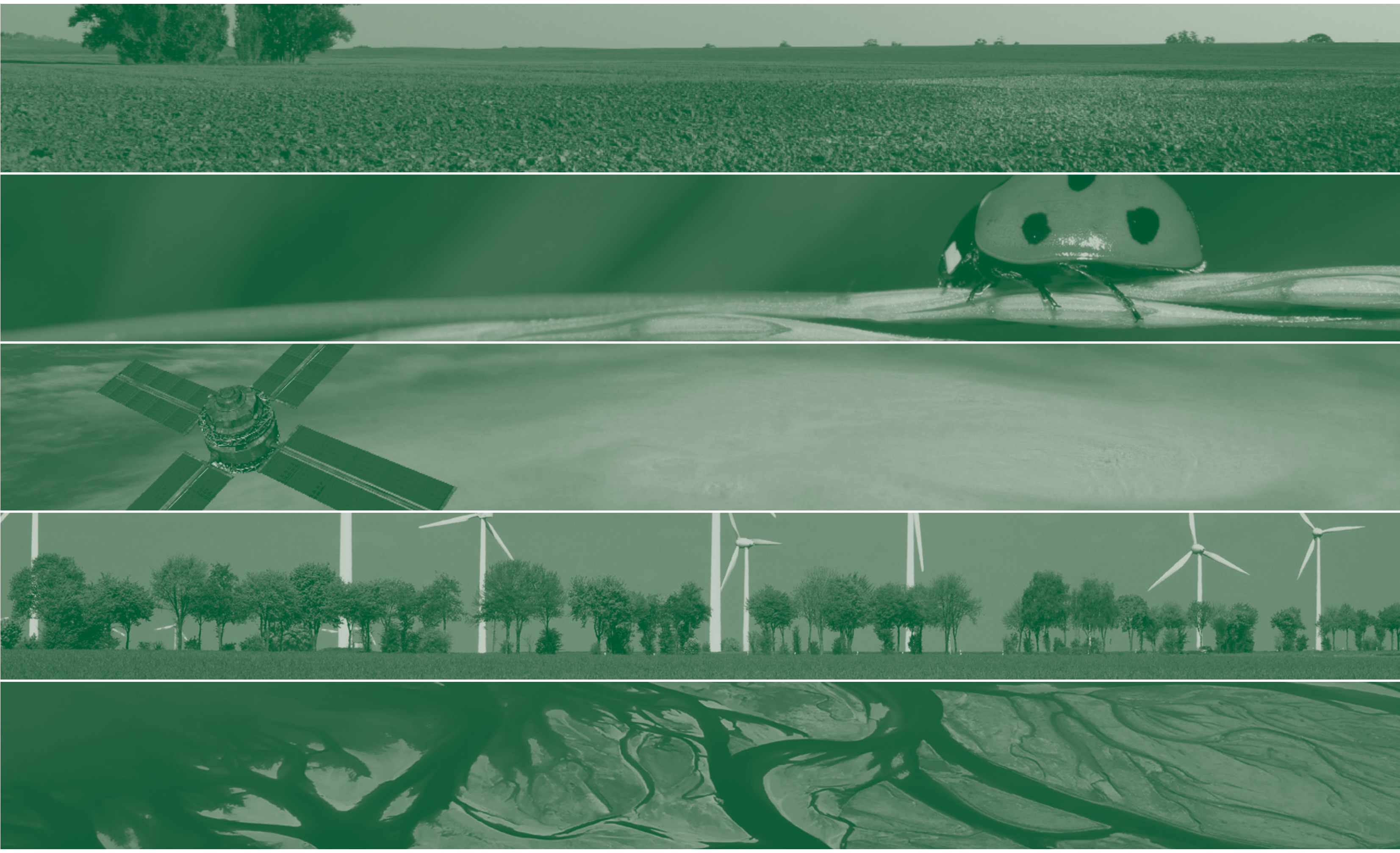
	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
					weed killers shall not be applied. On the contrary, those necessary maintenance works could be made for the elimination of weeds and invading vegetation, bush and tree. Alternatively to the previously indicated practices and with purposes of fertilization, a total maximum amount of 20 tons per hectare (t/ha) of dung or 40cu m/ha of slurry in a period of three years could be incorporated, provided that the soil has a vegetable cover or its immediate introduction is foreseen, complying in any case with what is set out in Royal Decree 261/1996 of 16 February on the protection of waters against pollution by nitrates from agricultural sources. The control of weeds shall be made in accordance with the criteria previously set out.			
395	United Kingdom	Soil erosion	Minimum coverage	Soil erosion - minimum coverage	All cultivated land must have either crop cover, stubble cover, grass cover or be ploughed or disced over the following winter. Finely tilled bare seedbeds are not permitted over the winter.	1, 2	see 1	Maintenance of crop cover, cover crop
396	United Kingdom	Soil erosion	Minimum coverage	Soil erosion - minimum coverage - arable land	All cropped land over the following winter must where soil conditions allow: - crop cover, grass cover, stubble cover, ploughed surface or roughly cultivated surface. Fine seedbeds must be created very close to sowing.	1, 2	see 1	Maintenance of crop cover, cover crop
16	Austria	Soil erosion	Minimum land management reflecting site-specific conditions	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
36	Belgium	Soil erosion	Minimum land management reflecting site-specific conditions		At least one anti-erosion measure must be taken on sites which are highly vulnerable to erosion: 1° maintain the land under permanent cover: 2° cultivation of winter cereals: the land should be left without cover for no more than three months and should	1, 2	see 1	Maintenance of crop cover, cover crop, winter crop

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
					be sown as far as possible following the contours of the land if the plot of land is longer than 100 metres in that direction; 3° cultivation of summer cereals or flax: provide cover crops to be worked in no more than two weeks before the sowing date and sow the plot as far as possible following the contours of the land if it is longer than 100 metres in that direction; 4° cultivation of crops which are susceptible to erosion: land should be left without cover for no more than two months before the sowing of the main crop and one of the following measures should be taken: a) do not work the soil; b) work the soil only in such a way as not to turn it before sowing the cover or catch crop and immediately sow the main crop; c) provide a buffer zone of 10 m³ or a dyke half a metre high with a length of at least a quarter of the circumference of the plot, at the bottom of the plot; d) do not work the soil or work it only superficially in such a way as not to turn it before sowing the cover or catch crop and additionally work the soil very superficially (no more than 5 cm deep leaving a rough seed bed behind) before sowing the main crop.			
180	Netherlands	Soil erosion	Minimum land management reflecting site-specific conditions	Soil erosion - minimum coverage - arable land	In areas with soil erosion: directly after the harvest and before 1 October for cereals and 1 December for other crops the soil is cultivated. The cover crop must be sown.	1, 2	see 1	Maintenance of crop cover, cover crop
405	United Kingdom	Soil erosion	Minimum land management reflecting site-specific conditions	Soil erosion - minimum coverage - wind erosion	In areas prone to wind erosion the steps reducing risk of soil loss in spring by maintaining crop cover, using coarse seedbeds, shelter belts or nurse crops or other measures. Where capping is a problem coarse seedbed should be formed or cap should be broken.	1, 2	see 1	Maintenance of crop cover, cover crop

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
199	Slovenia	Soil erosion	Others referring to Soil Erosion	Soil erosion - tillage method	Agricultural land shall be cultivated in a manner minimizing soil erosion, applying agrotechnical measures to reduce erosion effects.	2		To vague though
270	Spain	Soil erosion	Others referring to Soil Erosion	Soil erosion - coverage and management	Exactable conditions to avoid erosion. Minimum coverage of soil. Areas with a high risk of erosion. In areas with a high risk of erosion, the restrictions, guidelines for rotation of crops, including the organic amendments, as well as the types of vegetal cover that are established by the competent administration to avoid the decline and the loss of soil and natural habitat, must be respected.	2	Possibly, one specific crop rotation could be evaluated across the whole of Europe to evaluate the effect on, for example, nutrient leaching	Crop cover and rotation
19	Austria	Soil erosion	Retain terraces	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
21	Austria	Soil organic matter	Arable stubble management	Field greening	GAEC- GREEN COVER: On arable land which is out of cultivation GREEN COVER is obligatory, and these areas have to be maintained during growing season (usually between April and September).	1, 2	see 1	Maintenance of crop cover, cover crop
200	Slovenia	Soil organic matter	Others referring to Soil organic matter	Soil organic matter - crop rotation	3-year crop rotation is obligatory on at least 50 % of arable land of individual farms. Grass, clover and their mixtures on arable land are part of crop rotation and can remain on the same part of land for more than three years. Fallow land, additional and supplementary crops are treated as part of crop rotation. Maize on all arable land of individual farms is allowed in monoculture for not more than three years. Burning of harvesting residues is prohibited.	2,3	see 270	Crop rotation

	State	GAEC Issue	GAEC Sub Issue	Short name GAEC	GAEC	Which model [1]	How to include the measure	Remarks
132	Hungary	Soil organic matter	Standards for crop rotations where applicable	Soil organic matter - crop rotation	using crop rotation with regard to the agro-ecological features of the region	2,3	see 270	Crop rotation
142	Ireland	Soil organic matter	Standards for crop rotations where applicable	Soil organic matter - crop rotation	Maintain an adequate level of soil organic matter by means of appropriate cropping rotations or cropping practices where necessary. In case of low level of organic matter farmer will be required to change this system by growing a suitable break crop or by incorporating organic materials.	2,3	see 270	Crop rotation
414	United Kingdom	Soil organic matter	Standards for crop rotations where applicable	Soil organic matter - break crops	On arable land: use suitable break crops in an arable rotation or optimise the use of organic materials by basing rates of application on soil and crop needs. Where break crops are not used, a record should be kept for five years of organic materials and quantities applied to arable land.	2,3	see 270	Crop rotation

[1] 1= MITERRA Europe, 2 = EPIC, 3 = DNDC



Alterra is part of the international expertise organisation Wageningen UR (University & Research centre). Our mission is 'To explore the potential of nature to improve the quality of life'. Within Wageningen UR, nine research institutes – both specialised and applied – have joined forces with Wageningen University and Van Hall Larenstein University of Applied Sciences to help answer the most important questions in the domain of healthy food and living environment. With approximately 40 locations (in the Netherlands, Brazil and China), 6,500 members of staff and 10,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the exact sciences and the technological and social disciplines are at the heart of the Wageningen Approach.

Alterra is the research institute for our green living environment. We offer a combination of practical and scientific research in a multitude of disciplines related to the green world around us and the sustainable use of our living environment, such as flora and fauna, soil, water, the environment, geo-information and remote sensing, landscape and spatial planning, man and society.

More information: www.alterra.wur.nl/uk