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Compatibility of Agricultural Management Practices and
Types of Farming in the EU
to enhance Climate Change Mitigation and Soil Health

Informe

Información del proyecto

CATCH-C

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Final Report Summary - CATCH-C (Compatibility of Agricultural Management Practices and
Types of Farming in the EU
to enhance Climate Change Mitigation and Soil Health)

Executive Summary:
Soil degradation caused by agricultural activity is considered a serious problem in parts of Europe. Current soil management contributes to several soil threats, including erosion, compaction, nutrient imbalances, and declining soil organic matter (SOM). In the long term, loss of soil quality and SOM compromises soil functioning and the ecosystem services provided by soil. Besides, soil management practices can also jeopardize public interests directly - such as climate, environment, biodiversity, and hydrology - even if the soil itself remains largely unaffected. Both types of threats call for counteracting soil management practices on farm. For brevity these are referred to as ‘Best Management Practices’ (BMPs), although no practice is ‘best’ to serve all goals simultaneously.

CATCH-C assessed the merits of selected BMPs, notably their contributions to soil quality, to crop productivity and nitrogen use efficiency (NUE), and to the mitigation of climate change through carbon (C) sequestration and reduction of greenhouse gas (GHG) emissions. The assessment is based on 350 long term experiments (LTEs) from all over Europe that provided experimental evidence; and on surveys among thousands of farmers in the partner countries (Austria, Belgium, France, Germany, Italy, Poland, Spain, and The Netherlands). The surveys provided views from over 2,500 farmers on the compatibility of selected BMPs, chosen to match their respective farm types.

Both for the analysis of LTEs and the design of surveys, CATCH-C developed a farm typology to ensure sufficient coverage of the wide variety of agro-ecological conditions (climate, soil, topography) and farming systems that exists in Europe. A total of 24 major farm types were defined, three in each partner country, and our surveys addressed all of these.

Evaluated BMPs include options for cropping scheme, tillage, crop residue management, and nutrient and water management. They were evaluated against ‘reference practices’: monoculture, bare fallow, ploughing, removal of residues, and the use of mineral fertilisers and flood irrigation. BMPs include crop rotation, reduced or no tillage, incorporation of crop residues, organic manures, and water saving practices. The LTEs showed that these BMPs indeed generally do improve soil quality (biological, physical and/or chemical). For example, all studied BMPs promote biological soil quality, and more so when they increase C input (which is more effective than reducing soil disturbance). However, BMPs often come with trade-offs such as lower yield, lower NUE, and higher GHG emissions, notably N2O. Local conditions strongly affect impacts, both their magnitude and direction. Climate, crop type or soil texture could sometimes help explain the large contrasts found between LTEs. For example, impacts in permanent crops were very different from arable crops, and Mediterranean systems differed largely from those in Central or Northern Europe. The web-based support tool ‘KnowSoil’ summarizes these outcomes for practitioners, and is available in English, French, German, Polish, Italian, Spanish and Dutch. live from late June 2015.

Farmer views were analysed by a uniform protocol that enables to quantify drivers and barriers to the adoption of BMPs. Drivers and barriers reflect perceived impacts from BMPs on yield and produce quality, required inputs and equipment, work organisation, pest and disease pressure, and sometimes on biodiversity and environment. Drivers and barriers may depend on policy measures, but natural processes and financial constraints came forward more frequently. Weather and soil conditions play a dominant role in controlling – year by year - the suitability of BMPs in local practice. Improvement of soil quality was found to be a strong driver for many BMPs in many farm types: farmers are well aware of these benefits. However, increased weed pressure and disease risk, higher use of herbicides, fungicides and fertilizers, yield loss, and the need for specific equipment were generally identified as strong barriers for many BMPs and farm types. We produced a compilation of innovations that aim to overcome such barriers, but many challenges remain.

EU and national policies were analysed to assess how well soil protection and sustainable soil management are embedded in four 'policy packages': CAP-I, RDP, Environment, and national initiatives. With some exceptions, it appears that the current policy framework is insufficient to provide general protection against gradual decline of soil properties and associated services.
CATCH-C proposes avenues and requirements to address this situation.
http://www.catch-c.eu/

Project Context and Objectives:
Soil degradation caused by agricultural activity is considered a serious problem in parts of Europe. Current soil management contributes to several soil threats, including erosion, compaction, nutrient imbalances, and declining soil organic matter (SOM). In the long term, loss of soil quality and SOM compromise soil functioning and the ecosystem services provided by soil. Besides, soil management practices can also jeopardize public interests directly - such as climate, environment, biodiversity, and hydrology - even if the soil itself remains largely unaffected. Both types of threats call for counteracting soil management practices on farm. For brevity these are referred to as 'Best Management Practices' (BMPs), although no practice is 'best' to serve all goals simultaneously.

Several comprehensive studies (Freibauer et al., 2004; Smith et al., 2007; Smith et al.,2008; Schils et al., 2008) have listed options for carbon sequestration in soil, have estimated their effects in terms of the amount of soil carbon captured, and have estimated costs and benefits for farmers. Whereas such model calculations could be refined, this is not what is needed most to achieve real-world improvements, in terms of productivity, climate change (CC) mitigation, and soil quality. What is needed most, is to ensure that 'Best Management Practices' (BMPs) to improve soils and reduce unwanted impacts can indeed be implemented within the biophysical and socio-economic constraints that currently define farming in Europe.

BMPs are often not adopted in real farming practice. Barriers may be that farmers are not aware of the potential long-term benefits (e.g. on yield or soil health), not aware of technologies available, or lack skills to use them. Most likely, however, farmers are aware of BMPs but real barriers exist for them to incorporate BMPs in their system. Barriers may be of agro-environmental, agro-technical, or socio-economic nature. In short, BMPs are often not farm-compatible, or so they are viewed by farmers.

Sustainable soil management in CATCH-C also covers innovative technologies that minimise unwanted impacts and maximise input efficiency. Such innovations include, for example, precision fertilisation, low-dosage spraying (herbicides), energy-efficient mechanisation, controlled traffic, and automated weed detection. These innovative approaches can help overcome practical barriers against adoption of BMP's, as well as resolve conflicts that may arise between the different aspects of sustainability.

Diversity of farming in Europe

Characterizing farming diversity requires the organization and attribution of data on biophysical variables (climate, soils, land use, topography) and on socio-economic aspects (specialization, crops and livestock, farm size, income, etc.). Important sources are the European soil map, climate data from the MARS (Monitoring Agriculture with Remote Sensing) database, the Farm Accountancy Data Network (FADN), and Eurostat. The project also makes use of the integrated pan-European database on agricultural systems (Janssen et al., 2009), compiled by SEAMLESS. Farm type information – based on the Farm Accountancy Data Network (FADN) - is spatially allocated to agri-environmental zones. The resulting units are referred to as FTZs (Farm Types per agro-environmental Zone). Such spatial frameworks were earlier discussed by Van Ittersum et al. (2008), Andersen et al. (2007), and Hazeu et al. (2010).
Sustainable soil management

CATCH-C attributes three principal goals to sustainable soil management:

(1) to enhance the production of food and feed;
(2) to mitigate climate change through carbon sequestration and reduction of GHGs;
(3) to improve and conserve soil quality.

The first of these aims are generalised into 'high productivity', because the efficient use of all resources is key to sustainability, both for economic and environmental reasons. Productivity then refers to product output per unit of land area, labour, water, fossil fuels, manures and fertilisers, and biocides. (It must be recognised that the maximisation of one factor's productivity, e.g. of land area, is often at the expense of another factor's productivity.)

The three aims are interrelated (Fig. 1) and can reinforce one another. We define soil quality itself as the whole array of soil properties that support high productivity. These correspond to three dimensions: biological soil health, chemical soil fertility, and physical quality (structure; density; aggregate stability) and conservation. The simultaneous optimisation of these three integral soil properties is required to secure high productivity of all factors. This may often coincide with enhanced carbon sequestration and reduced emission of GHGs.

Figure 1. Sustainable soil management, its three principle aims, and their relations.

Assessing Best Management Practices (BMPs)

Soil management consists of choices and activities by farmers. These can be grouped into categories:
• composition of the crop rotation (e.g. intensive with tuber crops, extensive with cereals; inclusion of catch crops (nitrate interception), cover crops (erosion; interception), and green manures;
• soil tillage (e.g. no tillage, reduced or conservation tillage, non-inversion tillage);
• nutrient management and manure application (e.g. slurries, farm yard manures, fertilisers, manure separation products, composts; single or split applications; injection or surface spreading);

• crop residue management (removal or incorporation)
• water management (e.g. flooding or water saving methods; drainage);
• crop protection, notably weed management and control of fungi

Within each of these categories, different options can be compared for their impact on productivity, CC-mitigation and soil quality. This requires the selection of suitable indicators to express performance in terms of these three goals. It also requires that Current Management Practices (CMPs) are formalised as a reference, for the main farm types (FTZ units) in the participant countries. Where relevant, these must be linked with existing degradation issues. The options best suited to achieve simultaneous progress on productivity, CC-mitigation, and soil quality are derived from LTE's held by the project partners, and from literature sources. Such well-defined sets of BMPs have, for example, been documented for the UK by Cuttle et al. (2007) to contain diffuse water pollution from agriculture, and by Bhogal et al. (2009) for managing soil organic matter in agriculture. Our process includes the assessment of conflicts and synergies between the respective goals (productivity, CC-mitigation, and soil quality).

Compatibility of Best Management Practices with farming systems
Analyses of the effectiveness of a wide range of management practices for reducing diffuse pollution and for attaining environment-friendly agriculture have been carried out in, for example, Germany and the UK. These cover issues as diffuse pollution by nutrients (nitrate and phosphorus), erosion, GHGs and ammonia emissions, etc. The mitigation effects of individual and combined management practices for a range of different farming systems have been assessed in studies as:
• Inventory of methods to control diffuse water pollution from agriculture' (Cuttle et al., 2007)
• Criteria for environment-friendly agriculture (Hege and Brenner, 2004)
• Best practice for managing soil organic matter in agriculture' (Bhogal et al., 2009).
• Environment insurance system for Agriculture (Eckert et al., 2002).

This type of work shows the applicability of a wide range of management practices at the farm level, their costs to the farmer, the effectiveness, and the likely uptake across a wide range of farm types. CATCH-C aims to take this one step further by collecting farmer views on drivers and barriers for specific BMPs in each particular farming context.

Policies to promote soil protection and better soil management
Relationships between agriculture, climate change and policies have been reviewed in Brouwer and McCarl (2006). Methodologies to study interactions between EU policies and farm management have been extensively studied within the FP6 SEAMLESS project. CATCH-C builds upon such expertise as presented, for example, in Brouwer & van Ittersum (2010). Other examples are Belhouchette et al (2010) (on Nitrates Directive) and Louhichi et al. (2010) (responses of arable and livestock farming to CAP reforms). These studies and approaches show how current policies and proposed changes may affect future farm management in different farming environments and farm types. Theesfeld et al. (2010) developed a procedure to assess institutional compatibility of policies. CATCH-C identifies institutional factors for different types of policies (e.g. financial, regulatory or voluntary) relevant to soil management, and combines these with econometrics to find relations between policies, management practices, and the protection of soil stakes.

CATCH-C Main objectives

The overall aim of the project is to assess and improve the farm compatibility of sustainable soil management practices for productivity, CC-mitigation, and soil quality.

CATCH-C (WP2) develops a typology of the main farm types and agro-ecological zones across Europe. This frame, coupled to a pan-European database of socio-economic and biophysical data, serves to spatially organise the information collected on current management and on the impacts expected from changes in management.

Secondly, biophysical impacts of management practices are assessed (WP3) primarily from a large set of current field experiments, executed by the participants. BMPs are formulated, along with their trade-offs and synergies between productivity, climate change mitigation, and soil quality. Outcomes are compiled in end-user format to raise awareness of BMPs benefits.

Thirdly, the project identifies the barriers against adoption, and formulates ways to remove these (WP4). Farmer views on BMPs are surveyed in all participant countries, costs and benefits of implementation are assessed, and technical and ecological bottlenecks preventing adoption are identified; a scan of available innovations is made to point at ways to overcome barriers.

Policy measures can promote adoption of BMPs in various ways, such as voluntary measures, regulation, and economic incentives. In interaction with policy makers, Catch-C develops (WP5) guidelines for policies to promote the adoption of BMPs, that are consistent with regional agro-environmental and farming contexts.

Dissemination (WP6) includes dissemination to the farmers and policy communities, and scientific publication. The project results on BMPs, their adoption and feasibility in different farm types and environments raise awareness about the pros and cons of respective management and policy options. Farmers and policy communities are reached via workshops, brochures, farmers press and web-based tools.

Specific Objectives

• To identify the major farm types and agro-environmental zones in partner countries
• To assess Current Management Practices (CMPs)
• To assess Best Management Practices (BMPs) for sustainable soil management
• To consolidate proof of the benefits that BMPs can bring by analysing long term experiments (LTEs), and compile outcomes in end-user format (web-tool) to help farmers select BMPs for their specific case
• To identify barriers that prevent adoption of BMPs in the various major farm types by conducting extensive farm surveys
• To document field innovations enabling to overcome barriers against adopting BMPs
• To provide guidelines for soil-oriented policies, compatible with policy instruments already effective at regional, national and EU level.

Project Results:
SECTION I. Typology of farming systems and agri-environmental zones (WP2)

Summary WP2

WP2 has developed an “agri-environment*farm type” typology, by combining soil and climate data (agri-environmental zones, AEZs) with farm specialisation data. The typology was used to select - within each of the eight partner countries - important combinations of farm type and biophysical setting. These are referred to as ‘major FTZs’ or ‘major farm types’, and provided the infrastructure for collecting (also in WP2) specific information on Current Management Practices (CMPs) and soil degradation. The latter two aspects were recorded through interviews with extension officers. Major soil degradation issues were compiled for each of the partner countries. Besides the work in WP2, the typology provided the infrastructure for other work in CATCH-C: (a) to connect results from long term experiments (WP3) with geographical target areas; and (b) to carry out surveys of farmer perceptions on soil management in the major farm types (WP4).

The resulting typology covers almost the entire EU27 and can serve beyond the CATCH-C project in studies that require a farm typology coupled to the biophysical context (climate, soil texture, slope).

Development and application of the typology (Task 2.2)

The typology was developed with specific attention to the participant countries of the CATCH-C project, but covers almost the complete EU27. Limited data were available for Romania, Kroatia and Slovenia. It combines the typical farming systems (FT) and the agri-environmental zones (AEZ) per participant country. The resulting units (intersections of AEZ and FT) are referred to as FTZ units. The agri-environmental zones are aggregations of homogenous spatial mapping units (HSMUs) on the basis of slope, soil texture and climate (Fig. 2.1). The farm typology over Europe (Table 2.1) has been compiled from FADN, by overlaying information on farm specialisation and land use over Europe. Information about farm sizes and farm intensities is also available for all units. Next, the main farm types were spatially allocated to the HSMUs by a procedure adopted from Kempen et al. (2011). See Table 2.2 for an example (Austria). This work resulted in maps of the main agri-environmental zones in the EU27 (Fig. 2.2) and in each of the eight participant countries, and in tables and maps of the major farm types in each of the major agri-environmental zones in each of the eight countries. (Fig. 2.3).

Choosing ‘major farm types’ representative of the partner countries

Based on compiled information (Task 2.2) and national expertise, a selection of the major FTZs in each of the eight participant countries was made. This was required because the labour-intensive inventories on CMPs and the farm surveys could be carried out for a limited number of FTZs only. We are confident that the three selected FTZs per country represent the main agri-environmental zones, main agricultural areas, and the main farming systems in the eight CATCH-C countries. They provide the backbone to carry out inventories on farm management and soil degradation problems in these eight countries. The typology is the same for all participant countries, thus allowing comparisons of compiled outcomes between countries;

it is based on the classes from FADN, the standard used in EU policy making.
Some countries aggregated AEZ classes into larger units, to accommodate to their specific conditions. For example, three slope classes were merged in one particular FTZ in Spain. Such compromises were sometimes necessary to arrive at consolidated major FTZs representative for the country.

Inventory of current management practices (CMPs) (Task 2.3)

Current management practices were recorded for the major FTZs in each of the eight participant countries. First a questionnaire on current management practices (CMPs) and related main soil degradation problems was compiled and tested. Next, it was used by the CATCH-C colleagues to conduct interviews with local experts (i.e. agricultural extension officers) for the selected FTZs in their country. For this inventory, three interviews with Agricultural Extension Officers (AEOs) were conducted for each of the selected FTZs.

For arable systems, the inventory revealed that, according to AEO's, (a) green manures are applied on average on 20% of the total area, (b) conventional tillage is practised on average on 70% of the total area, non-inversion tillage on 30% of the total area, and minimum tillage is hardly applied, (c) animal slurry is applied on the main part (60 to 90%) of the total area in Belgium, Germany and the Netherlands and on a limited part of the total area (<20%) on FTZs in the other CATCH-C countries, and (d) crop residues are incorporated on average in half of the total area.

Outcomes for livestock farming are: (a) green manures are applied on a small part (i.e. 0 to 20%) of the total area, (b) conventional tillage is practised on average on 85% of the total area, non-inversion tillage on 15% of the total area, and minimum tillage is practically not applied, (c) animal slurry is applied on the main part (>80%) of the total area on FTZs in all CATCH-C countries except for Poland where slurry is applied on less than 20% of the total area, (d) on FTZs in Belgium and Netherlands mainly animal slurry is applied, on FTZs in Austria, France and Italy both animal slurry and farm yard manure are applied, and in Poland mainly farm yard manure is applied.

Differences in CMPs between FTZs can partly be explained from differences in farm type and biophysical conditions (e.g. minimum tillage is only applied in Spain and probably mainly in the dry and erosion-sensitive areas in southern Spain). However, regional and national differences in farm structure and land ownership play a role, too, as do historic development of agricultural sectors, protection of the environment and landscape, and intervention by agricultural extension services.

Inventory of the main degradation problems (Task 2.4)

Two approaches were applied to obtain an overview of the main soil degradation problems in the participant countries: CATCH-C colleagues prepared reports on the main soil degradation problems in their countries, based on documented sources available at national level (Set A; see Appendix D of D2.242); and Interviews were held with extension officers, focussing on the selected FTZ units per country (Set B). Three interviews were conducted for each of the three to four FTZs selected in per country. From Sets A and B we compiled (a) a list of the main soil degradation problems, (b) a description of each of the main soil degradation problems and if available, (c) maps of the spatial distribution of the main soil degradation problems (Appendix D to Deliverable D2.242).

The overview (Set A) shows that water erosion, soil contamination (covering both excessive amounts of nutrients, heavy metals and biocides), sub-soil compaction and decrease in soil organic matter are viewed as problems in most countries. Salinization and desertification are mainly of importance in southern Europe (i.e. Spain, Italy). Low soil fertility is a problem in extensively managed areas in Spain. Floods and landslides do occur in the mountainous areas of France and Italy. Soil acidification can be problematic in France and Poland and mainly so with soils overlying acidic parent material. The views by AEOs (Set B) is largely consistent with the country reports (Set A). AEOs mention largely the same soil degradation problems, but focus more on the field level and hence, mention more often problems, such as soil borne diseases, loss of biodiversity and wind erosion, whereas the country reports focus more on the wider (i.e. regional) scale and hence, mention more often contamination as a problem.

Degradation problems can partly be explained from current soil management. Often, however, factors beyond farmers' direct control play an important role like climate (e.g. salinization and desertification in southern Europe), topography (e.g. floods and landslides in hilly and mountainous areas), origin of parent materials (e.g. soil acidification and salinization) and location (e.g. salinization in coastal plains). This type of problems require government action at the regional and/or national scale, such as improved water management, forest protection, and infrastructural / construction works. On the other hand, many issues can indeed be addressed through improved management by farmers, see below.

Linking degradation problems to current practices (CMPs) and possible remedies

Current management practices responsible for the different soil degradation problems have been derived from the interviews with AEOs for each of the FTZs (Table 2.3). Contamination occurs on most farms in Belgium, the Netherlands and Germany which can be explained from the animal slurry application on most farms in these countries. Mainly conventional tillage is applied in all CATCH-C countries, and both on arable and livestock farms, which partly (in addition to resp. topography and heavy machinery and wrong timing of farm operations) explains the water erosion and soil compaction problems on most farms. These practices appear to be the dominant practices in intensive and conventional farming with limited applications of organic matter and crop residues to the soil, monoculture, insufficient coverage of the soil, intensive tillage, use of heavy machinery with high wheel loads, high application levels of fertilisers and biocides, short rotations with intensive cultivation of tuber and root crops, high animal densities which often result in too high animal manure applications, and the replacement of farm yard manure by slurry or fertilizers.

Remedies suggested by AEOs largely coincide with the BMPs evaluated in WP3 and WP4, and the innovations proposed in WP4 (Task 4.5). They are extensively documented in the corresponding sections below.

SECTION II. Evaluation of 'Best Management Practices' (BMPs) based on long term experiments (WP3)

Summary WP3

CATCH-C assessed the merits of selected BMPs, notably their contributions to soil quality, to crop productivity and nitrogen use efficiency (NUE), and to the mitigation of climate change through carbon (C) sequestration and reduction of greenhouse gas (GHG) emissions. The assessment was based on 350 long term experiments (LTEs) from all over Europe (Fig. 3.1).

Evaluated BMPs include options for cropping scheme, tillage, crop residue management, and nutrient and water management. They were evaluated against 'reference practices': monoculture, bare fallow, ploughing, removal of residues, and the use of mineral fertilisers and flood irrigation. BMPs include crop rotation, reduced or no tillage, incorporation of crop residues, organic manures, and water saving practices (Fig. 3.2). The LTEs showed that these BMPs indeed generally do improve soil quality (biological, physical and/or chemical). For example, all studied BMPs promote biological soil quality, and more so when they increase carbon input (which is more effective than reducing disturbance). However, BMPs often come with trade-offs such as lower yield, lower NUE, and higher GHG emissions, notably N2O. Local conditions strongly affect impacts, both their magnitude and direction. Climate, crop type or soil texture could sometimes help explain the large contrasts found between LTEs. For example, impacts in permanent crops were very different from arable crops, and Mediterranean systems differed largely from those in Central or Northern Europe.

Outcomes were summarized in the web-based support tool 'KnowSoil' for practitioners. The tool is available in English, French, German, Polish, Italian, Spanish and Dutch and will be accessible via the EIP Service Platform (web resources). The tool will be live from late June 2015 (http://www.catch-c.eu/KnowSoil/).

Overall evaluation of BMPs

WP3 analyzed the effects of BMPs on crop productivity, climate change and soil quality indicators, based on available European data sets and associated literature, mainly from long term experiments (LTEs). It was carried out by five task groups, each studying the effects of practices on a particular goal - expressed in a set of indicators: crop productivity (Task 3.2) mitigation of climate change (Carbon sequestration, reduction of greenhouse gases (GHG)) (Task 3.3) biological soil quality (Task 3.4) chemical soil quality (Task 3.5) and physical soil quality and conservation (Task 3.6). This 'overall' section shows the combined outcomes from the various task groups, highlights overriding patterns and discusses potential conflicts and synergies between the separate goals distinguished (Task 3.7).

Each task group identified suitable indicators, contributed to a comprehensive literature review and data transfer into the database, and carried out meta-analyses. Data were taken both from literature and from LTEs run by project partners, including unpublished data. All data analysed were first transferred to a shared on-line database. Before the statistical analyses, contrasts between a BMP and a 'reference practice' were computed, expressed either as relative response ratios (RR), or as absolute or relative differences (depending on indicator). Reference practices were monoculture, bare fallow, ploughing, removal of residues, and the use of mineral fertilisers and flood irrigation. Next, a multiple linear model using climate, soil texture/clay content, the duration of practice, the type of crop (for productivity indicators) and the investigated soil depth (for soil quality indicators) as nominal factors was performed to evaluate which conditions (co-variates) affected the impact of the BMP. The quantified outcomes are given in Table 3.1 and a qualitative summary in Table 3.2 showing outcomes from all task groups. Fig. 3.3 shows summarized outcomes from the Task Group on productivity. Similar results were produced by all Task Groups. Details are given in Deliverables

Overall (mean outcome across all data) none of the investigated practices could favourably contribute to all objectives, i.e. maintaining high yields and reducing cultivation costs, mitigating climate change and improving chemical, physical and biological soil quality.
Our analyses confirmed accepted wisdom (from practice and literature) that suitable crop rotations are a precondition for good agricultural management, and rotation turned out generally favourable as compared to monoculture. The inclusion of catch crops, cover crops, and/or green manures in the crop rotation showed generally positive or neutral effects on the investigated indicators.

The application of organic amendments was rated to be beneficial (sometimes neutral) for chemical, physical and, especially, biological soil quality indicators. However, most organic inputs gave drastic increases in N_2O emission, which has to be weighed against gains in soil organic carbon (SOC) brought by these amendments in order to assess net benefits for CC-mitigation. Moreover, depending on the boundaries chosen for the system evaluated, it can be argued that SOC gained from organic inputs had been sequestered already prior to its application to soil, and thus brings no mitigation benefit. Similarly, such gains in SOC could be compared versus CO_2 emissions avoided, had the organic amendment been used for energy replacing fossil fuels.

While organic amendment are often viewed as beneficial for raising soil fertility and yield, their mean effect on crop yields was negative in our analysis. This is due to our chosen boundary condition of ‘equal nitrogen (N) input’. In other words, organic manures were evaluated against mineral fertiliser at the same total N input rate. Part of N from organic manures goes lost as ammonia, and part is organically bound and not directly available for uptake. All organic amendments were positive for soil biology, and were found to be more important for soil life than reducing soil disturbance (tillage).

Practices that cause less soil disturbance compared to conventional ploughing were appreciated differently by the respective task groups. In general, a total omission of tillage enhanced biological and chemical soil quality. Shallow non-inversion tillage was also beneficial for CC-mitigation indicators, and for physical quality criteria. However, effects of no-tillage on soil physical indicators depended much on the farming system. Our analysis of no-tillage data covered both arable and permanent crops. A comparison between these two groups could only be made for Mediterranean conditions. Here, no-tillage (direct drilling) in arable crops showed relevant advantages compared to conventional tillage. For tree crops, however, effects on physical soil quality were rated very unfavorable.

On average, all productivity indicators were adversely affected by reduced tillage (small but significant effects), whereas they showed non-significant negative effects with no tillage. However, the variability of responses was high for both practices (reduced and no-till) and we registered both positive and negative effects depending on local conditions.

The most important single factor to influence the effect of any BMP was the environmental zone (climate).

For soil quality indicators, responses obviously depend on the investigated soil depth, too.

The main conflicts between goals, in our view, relate to management practices that promote soil quality and C sequestration but may result in higher GHG emissions, especially of nitrous oxide. Examples are the incorporation of crop residues, the application of compost and slurry, and the omission of tillage. More extensive assessments are still needed, which were not possible within the frame of this study. Entire life cycles of practices and farm inputs need to be considered, also beyond field and farm boundaries. Further, effects would have to be scaled per unit input to enable more precise comparisons among practices. Finally, the summation of beneficial and adverse effects that a practice may have on different indicators – as needed for an overall evaluation - remains a normative exercise if effects cannot be expressed in the same units.

Productivity (Task 3.2)

• BMP effects are not easily predictable: local conditions play a major role: there is no «one size fits all» solutions
• Yield maintenance is compatible with BMPs, but increase in yield is not: soil quality vs productivity
• Some tradeoffs can be resolved by innovation; others seem to be inherent
• Favorable MPs to enhance SOC & Soil quality: Non-inversion tillage, Organic fertilization, Incorporation of crop residues, Catch & cover crops, green manures
• In more than 80% of the cases, a crop grown in a rotation out-yielded the crop grown in a monoculture. Mean increase was 5%. Best performances were obtained in Western European climate, sand or loam soils, wheat or grain maize, and in long-lasting experiments (10-20 years). Crop N uptake was also generally increased and N surplus was reduced in rotation compared to monoculture
• In 60% of the cases, the use of a harvested leguminous or non-leguminous catch crop resulted in a yield increase of the main crop. Best results were obtained in Eastern Europe, soils other than silt, barley, maize or minor cereals, and in long-lasting experiments. Nitrogen uptake was also increased in 80% of cases, and consequently N surplus was reduced
• Little or no overall effect of incorporated green manure on yield and N uptake was observed, in all pedo-climatic conditions explored.
• Under no-tillage we observed a yield reduction of only 4% in no-tillage compared to conventional tillage, ranging from -32% to +31%. Silt soils performed best. Nitrogen uptake was also lower in 73% of cases, resulting in an average non-significant reduction by 5%.
• Yields were 3% lower when minimum tillage was applied (+52 - -46%). Nitrogen uptake and efficiency were reduced by 9% on average, thus evidencing that N availability was reduced in minimum tillage. Nitrogen surplus was consequently increased by 13 kg N ha-1 on average.
• When compared to a similar N fertilization level supplied using mineral fertilizers, compost additions showed a good supplying capacity of nutrients, Best results with compost were obtained when vegetables (leeks, Brussels sprouts) and peas were cropped, while maize for grain and barley yield were notably depressed
• The application of farmyard manure led to a reduction in yield by 6%, with a notable variability around the mean. Coarse-textured soils, where mineralization is enhanced, created more favourable condition for manured treatments.
• Bovine slurry in coarse-textured released mineral N as rapidly as mineral fertilizers with which slurry was

compared. Therefore, bovine slurry performed even better than solid manure.
• In some of the experiments, crop residues acted as a source of nutrients or of stable organic matter. However, in other cases straw immobilized N or caused technical difficulties at sowing. Residue incorporation was detrimental to crop yield especially in badly structured soils, in all crops.
• See also Fig. 3.3.

Carbon sequestration and GHG reduction for Climate Change Mitigation (Task 3.3)

• Among all practices, the application of external C-sources, such as compost, farm yard manure (FYM) and slurry resulted in the highest overall increases of SOC concentrations. Increments due to these external C inputs ranged between factor 1.37 and 1.21 compared to similar mineral N fertilisation rates.
• Catch crops and cover crops also led to increased SOC contents (on average by a factor +1.16).
• Reduced tillage (reduction of the number of tillage operations or of the depth of disturbance), and the incorporation of crop residues led to SOC increases by factor 1.07 to 1.08 compared to the respective baseline management practices (i.e. mineral fertiliser). High rates of mineral N fertilization gave the same level of increments in SOC, relative to zero N input.
However,
• Incorporating crop residues led to an average 5-fold increase of CO_2 emissions, and a 12-fold increase of N_2O emissions
• Lower increments of N_2O emission occurred with the application of the following BMPs (ranked in order of increasing emission): compost > slurry > (high) mineral N fertilization > No-Till (NT) > catch crops/cover crops.
• Non-inversion tillage (NIT) did not change N_2O emissions compared with conventional ploughing (CT), in the long run
• With FYM the N_2O emissions tended to be lower than with N fertilisation (similar total N rate). It must be noted, however, that large N_2O emissions from FYM may have occured before land application.
• We used the field boundary as system boundary in evaluating these practices. While externally acquired C inputs do enhance SOC, the use of such inputs represents no net C-sequestration (depending on alternative destinations of those materials).

Soil Quality – Soil Health (Task 3.4)

• After a thorough literature survey on the effect of different agricultural management practices on biological soil quality, key indicators were identified (Activity 3.4.1; MS341): earthworm and nematode abundance, microbial biomass carbon and bacterial and fungal communities.
• Experimental data on those indicators from more than 65 European long-term field experiments (LTEs) were extracted from peer reviewed scientific literature and national reports and entered into the WP3-database (Activity 3.4.2; MS342).
• In cooperation with Wim van den Berg (DLO), a statistical analysis on the data was performed which allowed us to quantify the effects of the management practices on the selected biological indicators (Activity 3.4.3; MS343). Further, through a subset regression it was evaluated whether climatic zone, soil texture and duration of practice influence these effects.
• The agricultural management practices that were considered in our study were the use of crop rotations (vs. monoculture), application of no- and non-inversion tillage (vs. ploughing), organic fertilization with

farmyard manure, animal slurry or compost (vs. mineral fertilizer) and crop residue incorporation (vs. removal).
• Only for tillage and organic fertilization a sufficient amount of data was collected which allowed a thorough statistical analysis.
• Overall, farmyard manure and compost amendment emerged as the best management practices for increasing both earthworm abundance and MBC content.
• Apparently, soil biota benefit more from organic materials added to the soil, which serve as a food source, than from reduced soil disturbance (more stable habitat) (Fig. 3.4)
• For the other 'management practice x biological indicator' combinations, findings from literature were used and reported. Finally, considering both the overall quantitative and qualitative evaluation of the effect of management practices on biological soil quality, a short-list of 'Best Management Practices' was compiled (Activity 3.4.4; D3.344) based on information such as provided in Table 3.3.
• All findings were reported in the task report 'Impacts of soil management on biological soil quality' (D3.344). Finally, the qualitative scores and an explanation for the observed effects were entered in the decision tool (Task 4.4; D4.443).
• In general, it can be noted that soil biology, although known for its role in soil quality, is not often taken into account in soil research and data from long-term field experiments are rather scarce. There is a strong segmentation between physical, chemical and biological disciplines and most research is mainly focusing on one part of the puzzle. To make progress in understanding and steering soil quality, a multidisciplinary approach taking into account all soil disciplines, physics, chemistry and biology, is required.

Soil Quality – Chemical Soil Fertility (Task 3.5)

• The response ratio's (RR) show the relative impact of the respective practices (BMPs) on indicator groups. An RR value of 1 means that on average there was no response of the indicator to the management practice, relative to the reference practice.
• Fertilization with FYM, non-inversion tillage, compost and slurry application and crop rotation were effective for total N indicators, besides the increase of available forms of nutrients.
• Compost was the only practice which significantly improved soil pH. It was effective also for total nitrogen (Nt) content.
• Fertilization with FYM and residue incorporation increased C/N ratio.
• The high values of Nmin, Kavail and Pavail RRs indicate the strong responses to mineral fertilization. However, in this specific case (of mineral fertilisers), the reference treatment was zero input (of the respective nutrients nitrogen, phosphorus, potassium). The high scores are, therefore, somewhat misleading as for other inputs (organic manures) the reference treatment was an equal rate (N, P, or K) given as mineral fertiliser.

Soil Quality-Physical quality and conservation (Task 3.6)

• A qualitative evaluation of impacts of BMPs on soil physical quality was carried out based on the results obtained by a meta-analysis of different physical soil indicators: bulk density (BD), penetration resistance (PR), permeability (PE), aggregates stability (AS), runoff yield (RY) and sediment yield (SY).
• These results confirm that some management practices (MPs) such as minimum tillage, cover crops or the organic fertilization of soils improve the physical characteristics of soils. In permanent tree crops

(olives), ‘cover crops’ occupy the space in between tree rows, and are seen as a form of ‘tillage’. No-tillage in the mediterranean is positive for arable crops (especially in drought years), but is detrimental in permanent cropping, unless combined with cover cropping.
• The number of data sets for specific physical indicators is listed in Table 3.4 a qualitative evaluation is shown in Table 3.5. Underlying quantification is included in Deliverable D3.364.

SECTION III. Compatibility of Soil management options at farm level (WP4)

Summary WP4

Following a series of 171 farmer interviews across partner countries in period P1, a large scale questionnaire-based survey was held, reaching out to about 10,000 farmers in 24 FTZ units, representing the major farming systems in the partner countries (three FTZs in each of eight countries). About 2,500 farmers sent back their responses. The central purpose was to collect farmers’ views on (selected) BMPs, relevant to their farm type and agro-ecological conditions. This provided the basis for our assessment of BMPs, in particular for the identification of drivers and barriers for adoption, and their relative strength. Activities included staff training, collecting farmer addresses, developing and testing questionnaires, organizing response data, and statistical analysis and interpretation of outcomes.

The survey (Task 4.2) was reported first in eight country reports (not deliverables) which were then compiled and reduced into deliverable D4.422. Next, a concise list of drivers and barriers was derived and documented (D4.434). Our survey outcomes reflect opinions and beliefs, rather than measured fact, but many aspects of soil management discussed here are hardly covered by the scientific literature. Moreover, while farmer views may provide no substitute for proven fact, they are perhaps more relevant to the design of effective policies to make soil management more sustainable. Finally, our outcomes refer to a very diverse set of farming conditions across Europe, which is hard to cover by long term experiments.

Next, an inventory was made of costs associated with the application of BMPs (relative to reference practice). This information was collected from advisors, national experts and literature (Task 4.3). The same type of sources served as input for our inventory of innovations (Task 4.5) that aim to support better soil management. A total of 81 innovations were described in the form of fact sheets, collated into deliverable D4.451. Here, innovations (number in brackets) were grouped into categories supporting crop rotation (23), grassland management (1), tillage (21), nutrient management (19), crop protection (8), water management (6) and others (3).

Based on the outcomes from the typology work (WP2), analysis of long term experiments (WP3), the farmer survey (WP4) and the inventory of innovations for soil management (WP4), we compiled the web-based decisions support tool for farmers named ‘KnowSoil’ (Task 4.4; D4.443). The tool explains in concise diagrams in six languages (English, German, French, Italian, Spanish, Polish and Dutch) which practices are favorable to promote sets of indicators (to be chosen by the end-user), and explains the working principles behind practices and processes. It also illustrates selected best practices (tailored to countries) in the form of fact sheets.

Farmer survey – interviews and questionnaires (Task 4.2)

To identify drivers and barriers for adopting BMPs, we applied a behavioral approach, based on the theory of planned behavior. This approach has been proven successful and offers a repeatable methodology which is very valuable for performing attitudinal research in an wide European context. According to this theory, the greater the intention is to behave, the more likely one is to actually perform the behavior. The intention of a farmer to implement a certain BMP is determined by individual beliefs on a set of outcomes (expected effects) associated with the practice, on a set of referents who think the farmer should perform the behavior, and on a set of control factors that might facilitate or obstruct the behavior. All these beliefs influence a farmers' intention to adopt a certain BMP, and are acting as cognitive drivers or barriers which encourage or discourage the farmer to adopt a specific BMP.

We described the main drivers and barriers on BMPs perceived by the farmers in 24 Farm Type Zones (FTZ) spread over 8 European countries (Poland, The Netherlands, Spain, Italy, Belgium, France, Austria, Germany). See Fig. 2.3. These FTZs are regions within a country and are characterized by land use, farm specialization and by slope, soil texture and climate (Table 4.1). The criteria to select FTZs for the study were 1) representation of a large agricultural area, 2) large economic value of the FTZ and/or 3) occurrence of soil degradation problems. The BMPs studied in each FTZ were determined based on expert judgment for their potential contribution to improve soil sustainability in that specific FTZ. A total (all countries) of 21 different BMPs were studied in the survey (Table 4.2).
To identify the outcomes, referents and control factors for each unique BMP in each of the 24 FTZs, 174 semi-structured interviews were first conducted, with an average of about 8 interviews per FTZ. Based on these lists of control factors, outcomes and referents, a large scale survey was constructed for each FTZ separately to reveal which of these outcomes, referents and control factors are perceived as hampering the adoption of a single BMP by the larger population of farmers. Each FTZ was addressed by a corresponding (tailor-made) questionnaire, reflecting the specific farming conditions of the FTZ. This large-scale survey reached out to several hundreds – in some cases up to 2,000 – farmers per FTZ. In total, about 10,000 farmers were reached. Answers were received from a total 2,520 farmers across all FTZs. Farmers were also asked for their opinion on their own current soil quality (Fig. 4.1).

Some of the BMPs were only studied in one or a few FTZs (eg. direct drilling, row application of manure, permanent grazing). For these practices, the main drivers and barriers were summarized per FTZ. Other BMPs were studied across multiple FTZs across countries, such as non-inversion tillage (NIT), cover crops and incorporation of straw. Large differences in adoption rate were found for these BMPs between the FTZs. Adoption rate of NIT varies from 6% to 86% between these different FTZs. However, between FTZs within a country, this adoption rate seems to differ less. In Germany, Austria and Spain, most of the farmers apply NIT. In the Netherlands, Italy and France, moderate adoption rates are seen, whereas in Belgium and Poland, only a small part of the farmers indicate to apply NIT on at least one field parcel (i.e. our definition of adoption). In the Netherlands, adoption rate is remarkably lower on dairy farms than on arable farms. Adoption rates of sowing cover crops varied from 0% to 100% among the different FTZs in which cover crops were included in the questionnaires. As for NIT, the country seems to be an important factor in explaining variation in adoption rate among different regions. In the Netherlands, Belgium, Austria and Germany, cover crops are implemented by most of the farmers on at least one parcel on their farm. In France, Poland and Spain, adoption rates are moderate or vary a lot among regions in the country. Only in

Italy, adoption rate is very low and varies from 1% to 10% of the farmers adopting the practice.

To gain better insight into these differences in adoption rate for NIT, cover crops and incorporation of straw, a comparative analysis of main drivers and barriers across FTZs was established and described. For each of these practices, some widely recognized drivers and barriers could be identified, which means that they are recognized by farmers in different FTZs across different countries. Some examples might illustrate this.The beneficial effects of straw incorporation and cover crops on soil characteristics have been recognized by all regions. Farmers believe that straw incorporation is a good investment for soil quality in the long-term. The scientifically shown advantages of cover crops on preventing erosion and nitrogen leaching have been widely accepted across the FTZs. However, the beneficial effect of NIT on soil characteristics is less recognised and varies among regions and countries. Although research has proven that NIT is an excellent strategy to reduce soil erosion on-site, only farmers in some regions perceive this really as a benefit of this BMP. These regions are located in Belgium, Germany, Austria and France. Farmers do widely agree that NIT has a beneficial effect on cultivation costs and labour compared to conventional tillage. However, not having the appropriate machinery for NIT application is regarded to be an important barrier. With respect to cover crops, farmers expect an increase of total costs and an increase in labour efforts, labour peaks and modified work organisation. In the Netherlands, it was stressed that especially small farms will perceive this as a problem. Farmers do generally agree that NIT leads to more weeds which might increase the use of herbicides.

With respect to productivity, farmers are convinced that crop yields might improve when sowing cover crops while for NIT, survey results show that in several regions, farmers fear lower yields. However, beliefs with respect to the effect of NIT on crop yields are variable and depend on conditions of NIT. This illustrates that for a good understanding of the main drivers and barriers for adoption, taking into account the very specific context of the FTZ is very important. Soil texture, slope, legislation, the nature of the cultivated crops, etc. play a role in a farmers' decision making on whether or not to implement a specific practice. Farmers in almost all FTZs do believe that an additional dose of nitrogen is needed to digest the straw. This should not be a barrier, as believed by the Polish farmers. However, some farmers in Belgium and the Netherlands do believe that legislation does not allow to provide enough N for straw digestion. In Italy, NIT is perceived as less attractive on clay soils and in Belgium, NIT is considered to be less attractive for vegetable crops and crops with small seeds.

On dairy farms in Belgium and the Netherlands, maize is often preceded by Italian rye grass and farmers prefer to incorporate the grass instead of destroying it with chemicals. They think applying NIT is not compatible with incorporating grass. Moreover, in several regions, the legislation with respect to NIT is perceived as very restrictive. Farmers ask for more flexible norms based on the activities of the farms and the regions. Regulations should allow ploughing in some crops that are unsuitable for NIT, e.g. as horticultural crops or when weather conditions are not optimal, e.g. due to Mediterranean climate (dry long summers but high intensity rainfall events). Also for cover crops, some FTZ related barriers were identified. In Germany, the availability of fields that can be irrigated cost efficiently is a precondition for sowing cover crops because subsequently those fields can be used for maize production without fear that cover crops have consumed too much of the soil water. In the Netherlands, the length of growing season is sometimes perceived as too short to sow a green manure.

Other less widely accepted barriers are more of a legal nature. In the Netherlands, two nitrogen standards exist for green manures: a low standard for legumes with nitrogen fixation and a higher standard for all others. The standards do not always allow a farmer to choose the green manure with the largest biomass, or the one that matches best with the soil fauna of his fields.

These findings are of substantial interest to research, extension services, local and national governmental institutions. These actors - in their efforts to improve the adoption of given practices - should be aware of widely recognised drivers/barriers but also of the context related drivers/barriers. Our results also show a very broad picture of barriers as has been suggested by previous work.
Besides obtaining insight into the general belief structure of the respondents in an FTZ, we investigated also differences between adopters and non-adopters. Some barriers and drivers are shared between both groups, whereas others are only a barrier to the group of non-adopters, or are only perceived as a driver by the group of adopters. As an illustration, in Belgium, adopters of NIT seem to have better experience than non-adopters with positive effects on erosion. In Spain, some barriers are believed to be an outcome only for the no- adopters since the management practices are not performed properly. It is a challenge to extension services to understand these differences in belief structure and reverse misconceptions that negatively influence a farmers' intention to adopt a specific behaviour. On the other hand, if some outcomes, referents and control factors are hampering both adopters and non-adopters, there is likely a true need for solutions to overcome such barriers (e.g. further research, trainings, subsidies).

Our results show that adopters, compared to the non-adopters, feel more stimulated by their social environment, which indicates the importance of social environment in increasing adoption. Specialized press and advisors are often consulted among all farmers. Also fellow farmers are a source of information and farmers believe their opinion is valuable. Therefore, it might be worthwhile to include adopters when training non adopters in how to deal with specific barriers, or when aiming to reverse misconceptions among non-adopters.

Our survey outcomes reflect opinions and beliefs, rather than measured fact, but many aspects of soil management discussed here are hardly covered by the scientific literature. Moreover, while farmer views may provide no substitute for proven fact, they are perhaps more relevant to the design of effective policies to make soil management more sustainable. Finally, our outcomes refer to a very diverse set of farming conditions across Europe, which is hard to cover by long term experiments.

Compatibility frame: Drivers and Barriers by categories (Task 4.3)

It was originally planned that a set of rules or conditions be developed on theoretical grounds, to assist us in the search for barriers. This was referred to as a 'compatibility frame', and covered five categories of barriers: Social (e.g. legal/regulatory system, land tenure, social organization), Human (e.g. age, skill, health, work calendar and labor availability), Financial (e.g. costs, investments, access to loans, subsidies, benefits), Technological (e.g. farm machinery, infrastructure, assets), and Natural (e.g. soil, water, crops and cropping calendar, landscape, land quality). Correspondingly, examples of mechanisms to lift barriers are: adjusting legal procedures (social barrier), training to acquire needed skills and knowledge (human barrier), providing access to funding (financial barrier).
However, once the planning of the farmer survey became much more ambitious than originally planned, it

became clear that it would yield a massive amount of information meriting thorough analysis. As a result, we decided to take those outcomes as basis rather than contructing a theoretical frame. Yet we retained the above classification and reported all outcomes in these terms. The work in this task consisted of two components: (i) a structured overview of drivers and barriers for the adoption of so-called ‘Best Management Practices’ (BMPs), seen through the eyes of farmers; and (ii) an inventory of cost associated with the implementation of certain BMPs at the farm. The overview of drivers and barriers was based on a survey (Task 4.2) the inventory of costs was based on empirical information collected by the research team in the project partner countries, through various channels.

Following the above ‘Theory of Planned Behaviour’ (Ajzen, 1988; Ajzen, 1991), combining attitude (A), subjective norm (SN) and perceived behavioural control (PBC), results in a positive or negative intention to actually perform the behaviour. We qualified a driver / barrier as ‘strong’ if it meets two criteria simultaneously. For variables of attitude: both the absolute value for Attitude AND for its underlying ‘belief strength’ are 3 or more. For variables of subjective norm: both the absolute value for Subjective Norm AND its underlying ‘motivation to comply’ are 3 or more. For variables of Perceived Behavioural Control: both the absolute value for Perceived Behavioural Control AND its underlying ‘control belief’ are 3 or more. These criteria were applied to the mean scores over all respondents (to a particular question on a particular BMP in a particular farm type), adopters and non-adopters merged.

In our study, strongest expressions among categories (A, SN and PBC) were usually in category A. This holds both for drivers and barriers. Moreover, drivers were often stronger than barriers. Nevertheless, many cases were found where they appeared equally strong. Strong barriers were often found in categories A and PBC. Generally, variables of SN category were weak, relative to A or PBC. An overview of the main drivers and barriers classified into categories is shown in Appendix-I (document uploaded separately; to be printed as A3).

The first group of indicators relates to soil quality. Within this batch, all BMPs show (many) more drivers than barriers. Expected beneficial impacts on soil indicators are drivers for adopting the proposed BMPs. Farmers appear well aware of the benefits for soil quality. (Here we can say ‘aware’ because views on expected beneficial impacts are endorsed by scientific documentation, see WP3 and Deliverables D3.324 D3.334 D3.344 D3.354 D3.364 D3.371). Their evaluations of soil benefits often rank highest among driver scores, and refer to the whole spectrum of commonly cited soil quality aspects (humus content, structure, workability, rooting, fertility (nutrient supply), soil life, soil borne diseases control, erosion control). In spite of overall benefits of most BMPs to a broad set of soil quality indicators, strong barriers against certain BMPs exist, also within the set of soil quality indicators. Here, the proposed BMPs deteriorate specific aspects of soil quality. Where this occurs, it often relates to physical damage (structure, compaction) and related water dynamics (infiltration, waterlogging, erosion).

The second batch of indicators relates to crop growth, produce quality and – in farms with livestock – feeding. One set of BMPs shows predominantly drivers (beneficial effect on production indicators). These BMPs are in the groups crop rotation, catch and cover crops and green manures (CCCGM), legumes in the rotation, controlled traffic, nutrient management, and water management. In contrast, the overall pattern for reduced tillage and no-tillage is that they reduce yield and produce quality.

The third indicator group relates to crop protection. Crop rotation and CCCGM show predominantly drivers, implying expected benefits in terms of reduced pest, diseases and/or weed pressure. In contrast, these unwanted pressures are believed to increase by the cultivation of legumes, reduced tillage, no-tillage, incorporation of crop residues, the use of compost and digestates.

The next group represent impacts on farm inputs (water, fertilisers, biocides, labour, fuel) but also equipment/machinery and storage capacity (for manures). These indicators, obviously, play a central role in farm economy and organisation, but are sometimes judged in their own right. For example, farmers often dislike an increased use of biocides irrespective of cost or net benefits. This group as a whole shows a rather balanced pattern of drivers and barriers. A BMP with predominantly drivers is crop rotation. A BMP dominated by barriers is the cultivation of CCCGM. For reduced tillage and no-tillage, our results reflect the well known trade-off between time and fuel saving on the one hand (drivers), and increased biocide use and need for adapted machinery on the other (barriers).

In the group of financial indicators, reduced tillage and no-till are dominated by drivers. All other BMPs show largely financial barriers, except in the special case of the Netherlands where economic benefits are associated with the acceptance of organic manures by arable farmers. (Note that – within this group - the lack of subsidies has been quoted in some countries/farm types as a barrier, too.)
The next group contains a large and highly diverse set of indicators or (control) factors, that farmers find themselves faced with. Virtually all outcomes here reflect barriers, rather than drivers.

The next group consists of only two stakes: biodiversity and environment. Here we find practically only drivers, but in very restricted numbers: only few FTZ units have expressed these drivers clearly (we cannot exclude that this is in part due to the formulation of questionnaires). 'Environment' was found relatively important in Belgium, France and The Netherlands, while 'biodiversity' was important in Germany and Austria.

Finally, there is another set of mixed aspects, including legislation. This set is again filled with both drivers and barriers. Some BMPs are drivers because they enable other practices preferred by farmers. Legislation is sometimes a driver, sometimes a barrier. See details in following chapters.
D4.434 includes an assessment of costs related to the implementation of specific BMPs, collected from five CATCH-C partner countries. The key question is related to how costs for a farmer change when changing to the BMP. A common methodology to assess these costs was applied to a range of farming systems in Europe. Because of structural differences in farms and differences in how the BMP is implemented, a direct comparison between countries remained difficult. The BMPs investigated for cost were non-inversion / reduced tillage, and cover / catch crops / green manures.

Decision grid for farmers : the web-tool 'KnowSoil' (Task 4.4)

Based on the outcomes from the typology work (WP2), analysis of long term experiments (WP3), the farmer survey (WP4) and the inventory of innovations for soil management (WP4), we compiled the web-based decisions support tool for farmers named 'KnowSoil' (D4.443). The tool explains in concise diagrams in six languages (English, German, French, Italian, Spanish, Polish and Dutch) which practices are favorable to promote sets of indicators (to be chosen by the end-user), and explains the working principles behind practices and processes. It also illustrates selected best practices (tailored to countries) in the form of fact sheets (Fig. 4.2).

In a first step, the findings of WP3 were gathered in a matrix which summarizes the qualitative effect (i.e. ++/+/0/-/--) of various agricultural management practices (MPs) on a list of soil quality/climate change mitigation/crop productivity indicators (Activity 4.4.1 and 4.4.2). Based on this matrix, a user-friendly webtool was developed, including fact sheets describing mechanisms. The user (e.g. (advanced) farmers, advisers) of the tool has two options: (a) to check the effect of a particular management practice (MP) on a certain indicator. While doing so, the user receives the qualitative score and a short explanation for the observed effect (i.e. mechanism of action). Based on the WP3-reports, the mechanism of action was composed for each MP x indicator combination and includes the effect of influencing factors such as sampling depth, climate, soil texture, crop type, duration of an experiment, etc.; (b) to indicate a desired effect on one or more (chosen) indicators. Based on these preferences, the user receives the most suitable MP to promote the chosen indicators. Further, each MP is accompanied by a fact sheet which gathers the effect (and trade-offs) of the given MP on all indicators. Appendix III shows the Italian set fact sheets, as an example.

The web-based tool will be live in the second half of June 2015, in the above national languages of all project partners. (http://www.catch-c.eu/KnowSoil/)

Promising technological innovations to overcome barriers (Task 4.5)

An inventory was made of practices that we expect contribute to improving soil quality. Commonly recognized examples are reduced tillage, the application of organic inputs (manures, composts), crop rotation, the cultivation of green manures and catch and cover crops, the retention of crop residues on the field, and the use of low-impact machinery. Besides assessing the biophysical merits of these practices, CATCH-C identified barriers against the adoption of better practices (Tasks 4.2 and 4.3). These can relate to practical (technical or agro-ecological) difficulties associated with the introduction of better practices. It is this latter category that was addressed by Task 4.5: innovation to help resolve practical barriers against the adoption of BMPs.

The adoption of sustainable practices on a given farm requires specific tinkering to make them fit within the current context. It is this process of resolving local difficulties or barriers that we refer to as ‘innovation’. Innovations, then, are assemblies - of ideas, instruments, procedures, tips and tricks, etc. - that enable the adoption of better soil management practices. We documented 81 examples of such innovations (D4.451). Given the geographical spread of their origins, they cover a wide variety of European farming systems. Some practices may be well established in one region, but still innovative in another. The format of ‘collected fact sheets’ was chosen to encourage the use of this information by projects or organizations dedicated to disseminating innovations in European agriculture.
Each innovation was described by a separate, illustrated fact sheet, following a standard structure that summarizes the principle of operation, the main advantages, and the type of practice that the innovation aims to support (e.g. reduced tillage, or incorporation of crop residues). The fact sheets also specify to which goals the innovation contributes, and gives key references for more information. The fact sheets were grouped by categories of soil management practices (crop rotation, tillage, nutrient management,

etc.). An overview describing the innovations by category, and their contributions to sustainability goals is included in Appendix-II to this report.

SECTION IV. Soils policies at EU and lower levels (WP5)

CATCH-C assessed soils-related policies using the frame of 'intervention logic' that we combined with institutional analysis and econometrics. The approach breaks down policy packages at European, national and regional levels into strategic objectives, operational objectives, policy measures and expected impacts and assesses the interrelationships between these elements and soil stakes. We have analyzed four major policy packages at EU and national levels (CAP-I, RDP, Environment, national initiatives) on how soil stakes are addressed in policy design and implementation, and developed a numerical scale to express 'embeddedness' of soil stakes in these packages. Next, relations were assessed between this property and respective country characteristics extracted from EUROSTAT.

The main results we have obtained are the following observations:
- The current top-down (from the European to local levels) design of soil-related policy packages ends-up in most countries in a poor embeddedness of soil stakes in policy objectives, policy measures and impact assessment.
- As a consequence, the current policy framework is not sufficient to have a general protective effect against gradual decline of soil properties and the ecosystem services that soils can supply, even at local level.
- Dealing with soil stakes shows spillover effects (indirect effects that policy options have on other regions than those they directly target). While those effects are evident for stakes related to climate change and carbon storage, they exist also for local soil stakes. The competition between regions, in a context of food security challenges, has potential consequences in terms of resource depletion in regions. This effect is clear when policies are designed at the regional level without (supra)national harmonisation: some regions do more efforts towards soil protection than others. In a more positive way, these spillovers also create opportunities to take advantages of local endowments to serve global goals towards climate change mitigation.
- The extend of 'embeddedness' of soil stakes in national policies, and the variety of policy measures that Member States propose to deal with soil stakes, are linked to the MS perception of soil stakes, but also to their strategies regarding eco-innovation and renewable energy, to their trust level in European institutions, and to the bargaining power of their farmers.
- The policy makers we have met all require more flexibility in policy design to address the specific combinations of soil stakes they face at local level, allowing better tailoring to match local farm systems (even if they are aware this should not impede competitiveness).
- Besides the need of independent advisors (in some countries) and increase of knowledge on soil functions at local level (in all of them), we found a need for better interconnection of knowledge gathering across the local, national and European levels.

A coherent policy framework, with clear and shared objectives and precise reporting of outcomes, seems essential to establish a comprehensive strategy for sustainable soil management in agriculture. There are many features that argue for a European level for this framework. These include (i) the obvious underprovision of soil ecosystem services at regional and national levels, (ii) the existence of spillovers for many (even local) soil stakes, (iii) competition between regions in a context of food security challenges and its potential consequences in terms of resource depletion, (iv) opportunities to take advantages of local endowments to serve global goals (climate change mitigation; biodiversity) which require to implement redistribution mechanisms between Member States.

The European level should help to harmonize the monitoring of soil parameters and ecosystems services supplied throughout Europe, encourage Member States to use scientifically sound indicators to assess the impact of the policy measures they chose, and implement redistribution mechanisms between Member States to optimise the supply of public ecosystem services from soils.

However, a top-down design of such a policy framework will not be enough for a better protection of soils against gradual decline. From our point of view, the best example that such a top-down framework can fail is the withdrawal of the GAEC “protection of wetland and carbon rich soil including a ban of first ploughing”. Clearly, the amount of carbon lost from such soils when ploughed will require centuries to be restored again at other agricultural sites, and so at untold financial expense. This is an evident case where the EU level should have been legitimate to play its regulating role, but appeared not so due to reasons beyond soil stakes.

We believe that the European policy effort will greatly gain in efficiency if it concentrates on the coordination with lower levels rather than imposing measures and policy frameworks:
- From the very local to the European level, a better embeddedness of soil stakes into policy packages, up to implementation and impact analysis, would be improved by the possibility offered to local policy makers to include very local and specific soil related stakes into their policies, especially those that are linked to European ones. It is often argued that local stakes can be dealt with by local measures, but including them in EU framework can improve their efficiency because policy makers tend to invest more in environmental issues when they share the cost with other regions (which is due possible by the EU-led feature of a policy). Coordination with the EU level is needed to avoid soil depletion due to regional competition.
- If information about the effects of management practices on soil functions is spread only by international equipment groups or agri-food lobbies, it has lower chances to convince farmers to adopt innovations that aim to improve public goods. Moreover, the independence of monitoring is a key for successful impact assessments. At the interface of the local and national levels, the national level can support independent advisors and knowledge gathering, even at local level. Most of the soil management practices that have been analysed in Catch-C project have effects on soil ecosystem services that differ (and sometimes strongly) depending on local conditions. Policy makers are aware of this differentiation, but they can’t promote measures without a clear idea of their local effects. Moreover, in some countries, the absence of independent advisors impedes knowledge spreading across farmers.
- The third and last element is at the interface of national and EU levels. In a context of crisis, where it is well known that individuals and states tend to favour short term strategies, the effort of the Soil Thematic Strategy towards awareness raising about soil stakes can be perceived by Member States as an attempt to orientate their efforts towards environmental requirements that are considered as important by the EU level only, or as a move towards raising more funds from national levels. We believe that concentrating on the positive effects, i.e. the provision of soil ecosystem services, is more likely to be accepted at all levels than pointing at negative threats to soils.

SECTION V. Dissemination (WP6)

Besides the dissemination activities reported in other sections of this final report, WP6 produced a stand-alone report on dissemination structures in the project's partner countries (D6.625).

Potential Impact:

DISSEMINATION (WP6)

Summary of work in WP6

At the closure of the first period P1, a review on current dissemination structures at regional, national and EU level was produced (D6.625) and the dissemination plan was finalised. Efforts in the second period P2 were entirely devoted to disseminating Catch-C outcomes according to this plan. Apart from following the agreed plan, dissemination itself was mostly a decentralised activity, where partners promoted project outcomes in their own country languages. Often, dissemination activities were intertwined with activities in WP4 (farmer survey and farmer focus groups) and WP5 (policy makers).
A full report on dissemination activities was completed in December 2014, looking back at experiences and lessons learned in the project (D6.641 due 31.12.14). That report includes a full list of all dissemination activities, which is attached to this final project report as Appendix IV.

Dissemination in the Catch-C project followed the outline that was given in the document of work. Due to the diverse nature of these activities, some activities could better fit to the due dates than others. Some dissemination actions such as interaction with farmers, advisors and also editors of farmers magazines demand to respect the time frame of the people involved. So, outcomes that mainly base on the willingness to participate of these external actors, might mismatch the ex-ante schedule in some cases. So, some activities, such as articles in farmers and scientific journals were not yet completely finished at closure of the P2 period. However, papers are negotiated for forthcoming publications and project participants continue work into 2015 to deliver them.

Coordinating of dissemination (Task 6.1)

6.1.1. Internal coordination of tasks and 6.1.2. timing of relevant activities
In October 2012 an overview was elaborated, summarizing planned interactions of the Catch-C partners with target groups in their countries during the next year. The overview on planned interactions was used as a reference base in coordination with the sister project “SmartSOIL”.
For better documentation of interactions a template was provided and sent to all partners in order to systematically collect information on interactions with target groups. During the project duration this list was continuously filled out by partners and updated to the WP6 team on a regular basis. Altogether 342 interactions with target groups were recorded.

6.1.3 Consolidate and refine the ex-ante dissemination plan

The dissemination plan (MS613) was established in three steps:
a) The first draft version of the ex-ante dissemination plan was elaborated in January 2012 and presented to all Catch-C partners during the kick-off meeting. It was discussed during the WP6 session and the feedback was used to improve the first draft.
b) The second draft was discussed at the executive board meeting in Vienna in June 2012. After this the feedback of the executive board members was used to improve the second draft.
c) The ex-ante dissemination plan was circulated to all Catch-C partners the 31.10.2012 via email. Feedback or approval was collected until 1.12.2012.
The dissemination plan had been revised in month 24 (December 2013) according to the remarks in the response to the 1st periodic report. Thus it was extended by incorporating more detailed outputs for specific target groups. The plan was presented to the partners and the advisory board at the annual meeting in Cordoba in February 2014.

6.1.4. Make all web-based dissemination materials available on external section of project website
The project website was established in spring 2012 and is updated in regular intervals. It contains information on the project, the project partners ongoing activities and results. WP6 established a regular newsletter that was sent out to members and interested public. Publications, conference papers, reports and deliverables produced during the project phase were put on the download section of the website soon after their accomplishment.

Dissemination towards farming community (Task 6.2)

6.2.1. Develop format and contents for meetings with advisors, farmers and farmers groups
As a first step a literature analysis on farmer to farmer exchange and social learning was conducted. Based on the insights gained a preliminary outline for a workshop guideline for conduction, reporting and evaluation was developed in October 2013 together with WP4 responsibles and sent out for discussion. The idea was to effectively link farmers, farm advisors and farmers' organisations to the Catch-C project. Therefore one focus group meeting per FTZ should be organised by the partners in order to (1) assess the findings of the farmer surveys (WP4) and generate feedback on barriers and possible solutions and (2) disseminate results towards farmers, farm advisors and farmers representatives. The 14th January 2014 a meeting with WP4 members was held in Wageningen and the final format and content for meetings with advisors, farmers and farmers groups was set up. During the Catch-C meeting in Cordoba the guideline for the workshops was explained to all partners.

6.2.2. Organize meetings with farmers and farmer groups at the level of major FTZ
Based on the Activity 6.2.1. all partners in all eight partner countries organized meetings with farmers and farmer groups and conducted workshops at the level of major FTZ. Between February 2014 and November 2014 all together 23 workshops were conducted within the frame of the developed workshop structure. Preliminary project results were presented and discussed with the farmers. The farmers gave valuable input to the final results and also to the interpretation of the findings. Additionally about 180 further meetings with advisors, farmers and farmers groups have been conducted on various topics of the catch-c focus themes. These activities are included in annex 6.3.

6.2.3. Produce web-content, information brochures and articles in applied journals, about BMPs for

farmers
In order to achieve D6.623: publication of two articles in applied farmers journals per partner country, the partners were provided with guidelines for publication in month 21 (October 2013). So far 19 articles (Dec 2014) have been published. Outlines have been developed for 9 more articles already. Appendix II lists brochures and articles that were produced for applied journals.

6.2.4. Make the decision tool for farmers available as web-applications in language of partner countries
The decision support tool 'KnowSoil' was developed by the ILVO team and in first draft presented the 9th December 2014 in Haarlem. The tool is now available in seven languages (English, French, German, Italian, Dutch, Polish, Spanish). The dissemination tool will be available online from late June 2015 and the link (http://www.catch-c.eu/KnowSoil/) will be circulated to relevant institutions in partner and non-partner countries. The EIP-AGRI Service Point (http://ec.europa.eu/eip/agriculture/) will incorporate the tool in their portal as on-line resource (Pers. Communication Koen Desimpelaere). They will also host the collected fact sheets on innovations for sustainable soil management (D4.453).

6.2.5. Review current dissemination structures at regional, national and EU level
An analysis of literature and documents was conducted to get an overview on current dissemination structures in the EU member countries. Besides scientific publications also grey literature like reports and information material from the advisory bodies, webpages etc. were included in the analysis.
In May 2013 a written expert survey was conducted among all farmer associations that are member in the COPA-COGECA network. It was decided to conduct the expert inquiry via written questionnaires with both tick boxes and open questions, sent out per email to the experts. The inquiry was kindly supported by Antonia Andugar (Senior Policy Advisor at COPA-COGECA head-office).
For the Catch-C project, this report offers an extensive baseline for designing targeted activities of dissemination. It became clear that each partner has to address to those partners that might give best results and broadest scope. Also, instruments that promise high dissemination efficiency without being part of historical regional structures, such as farmers groups can be seen as a fruitful instrument. It is worthwhile to develop and to study these instruments in more detail.

6.2.6. An interview for the National Farmers' union was given on the project and its outcomes, on February 6, 2015, at the NFU premises in Brussels.

Dissemination towards extension and farmer organisations, policy makers (I, P) and science community (Task 6.3)

6.3.1. Produce articles in scientific journals, about BMPs for the major FTZ in partner countries
In month 36 three scientific publications have been published in peer reviewed journals. The 9th and 10th December a meeting with all Catch-C partners took place (Haarlem, the Netherlands) where ideas for future publications were collected, responsible authors were identified and timings were set. At least one publication per WP and WP3 task are planned to be written and submitted between January and December 2015. Scientific papers that were recently published / submitted are given in Appendix II and III. Oral contributions and conference papers were produced for a couple of international and national conferences and workshops. Amongst others, the annual EGU conferences of 2014 and (more so) 2015 (European Geosciences Union, http://www.egu2015.eu/) turned into a platform for many Catch-C

scientists to provide results and discussion inputs.

6.3.1. Brochure summarizing main results from WP3, WP4 and WP5

Based on the discussions and presentations during the final project workshop in Brussels key results and recommendations for policy makers were edited for publication in a brochure. The brochure was presented and commented during the final internal meeting on 9th December 2014. Based on the obtained feedback it was revised. The result is a general brochure in English which can be translated and tailored to their needs by all partners. Additionally the same content will be prepared to be printed as a poster.

6.3.3. One workshop on BMPs per partner country for farm advisors, farmer representatives and policy makers

Especially for policy makers workshops were conducted per partner country. Begin 2014 policy workshops were organized where policy measures concerning soils and their interactions with BMPs were discussed. Additionally in the end 2014 and January 2015 some workshops have been repeated. In the second meeting key results from WP3-5 were presented and critically reflected and interpreted in their relevance for soil policies together with policy makers.

6.3.4. Make project results available to relevant institutions in non-partner countries within EU for dissemination

The brochure 6.3.1. is sent to relevant institutions identified in activity 6.2.5. in the English version as pdf file ready for printing if they wish to do so.

Further distribution will be achieved by including Catch-C outcomes into EIP agri. As negotiated during the Catch-C workshop hold at Brussels, the EIP platform will offer webspace for Catch-C and weblinks to the decision tool, and to the fact sheets on innovation for sustainable soil management (D4.451). EIP-AGRI is an activity raising awareness in farmers and advisors communities throughout Europe.

6.3.5. Final project workshop for policy makers, extension organisations and farmer representatives from partner countries

Concluding workshop “Soil management for our future” was conducted on 19th November 2014 in Brussels. We had 64 participants from 9 countries, representing extension organisations, policy makers, farmer organisations and interested public. Participants came from partner and non-partner countries. Results from workpackages 3-5 as well as overall information on Catch-C were presented by Hein ten Berge, Heide Spiegel, Carlo Grignani, Jo Bijttebier and Nadine Turpin. Additional guest speakers were Jacques Delsalle (DG Environment) and Andreas Gumbert (DG Agriculture). The final open forum discussion was lively with Patrick Barrett (DG Environment), Andreas Gumbert (DG Agriculture), Gail Soutar (National Farmers Union), Koen Desimpelaere (EIP-Agri) and Antonio Frattarelli (Ministry of Agriculture, Food and Forestry, Italy). Main statements that were discussed were:

- There is no „Best“ management practice that works everywhere and for all objectives (productivity, soil quality and climate change mitigation). There are always trade-offs
- Farmers perceive their soil would have good quality. This may be a reason for not applying soil conservation measures
- Policies should focus on specific solutions in specific regions; prioritize goals then encourage practices
- How can ambitions for sustainable soil management be raised?

All communications of the workshop are provided for public download via Catch-C website. A list of participants is given in annex 6.5.

However, during the months after the final project workshop at Brussels, outcomes from WP5 were further elaborated and they came to completion – with new insights gained – only in May 2015. The relevant document (D5.542) was sent to the above speakers representing DG-Agriculture and DG-Environment) and feedback from Mr Gumbert was received and incorporated.

Ex-post synthesis of dissemination experience (Task 6.4)

A full report on dissemination activities was completed in December 2014, looking back at experiences and lessons learned in the project (D6.641 due 31.12.14). That report includes a full list of all dissemination activities, which is attached to this current final project report as Appendix IV.

Further dissemination activities

Catch-C members developed contacts to public and policy beyond the mentioned information channels. Occasionally, Catch-C scientists were asked to act as expert, such as
• Presentation at Netherlands Technical Committee on Soils, 3rd December 2014
• Presentation at JRC, Ispra, January 2015
• Presentation for NFU (National Farmers Union, UK), Brussels video, December 2014
Involvement of partners in national research activities and programs on soil related topic are detailed listed in Appendix V. These involvements were developed during progress of Catch-C and underline the stimulating effect of the activities into national research structures.

Database photographs
In the work area of the website a database of photographs for dissemination was created in August 2013 and regularly updated. Main topics are working procedures or details on BMPs. The photographs were used by partners in their dissemination activites.

Coordination with SmartSOIL
Cooperation with SmartSoil was set up in many ways. Meetings with Catch-C WP6 coordinators and SmartSOIL members took place in October 2013 and occasionally during conferences. Information on time schedules and planned activities was mutually exchanged. For each project respectively the focus was outlined, so that unnecessary redundancy could be avoided. Collaboration at the level of each workpackage was adjusted. Project Coordinators joined the annual meetings annex advisory board meetings of their sister project, and presented progress updates to the ‘other’ consortium.
A joint session was established during the 4th IFSA conference in Berlin, April 2014. Here, members from Catch-C and Smart Soil provided conference talks in the session “Soil management: facilitating on-farm mitigation and adaptation” convened by Julie Ingram (Smart Soil), Sandra Nauman (Smart Soil) and Jan Verhagen (Catch-C). An opinion paper on sustainable soil management is being prepared between Catch-C and SmartSOIL scientists (lead with the respective coordinators) to collate insights from both projects.

Deliverables WP6 Dissemination

D6.623 Two (per partner country) articles on BMPs in farmer's magazines (due 28.11.2014). Several partners have produced more than two articles. Others are still finalising the planned set, or are elaborating additional articles.

D6.625 Report describing by country and at EU level the current structures for dissemination of BMPs (due 28.06.2013; actual delivery 02.07.2013)

D6.631 One article in a scientific journal per WP (for WP2-5) (due 28.11.2014).
Several partners have produced more than two articles. Others are still finalising the planned set, or are elaborating additional articles.

D6.632 Brochure summarizing interactions BMPs-policies. (Due 30.11.2014; actual delivery 03.06.2015)

D6.641 Report on Catch-C experiences on information exchange (due 31.12.2014; actual delivery 02.02.2015).

DISSEMINATION OVERVIEW BY PARTNER

AGES was mainly involved in dissemination activities concerning WP3. Already in the beginning of the project an info webpage about the project in local language was established (http://www.ages.at/ages/landwirtschaftliche-sachgebiete/boden/forschung/projekt-catch-c/). In the first half of 2013 there was a focus on direct interactions with farmers and advisors. 23 interviews with farmers in Tyrol and with 9 advisors in three regions were conducted. In 2014 an interview with 2 agricultural policy experts followed. 13 presentations at scientific conferences were held and two scientific articles were submitted to scientific journals, one of them has already been published. Further, 4 articles were published in applied farmers journals.

IGZ established contact by email and telephone with scientists and data holders of LTEs in various European countries and informed them about the project using the webpage and the project's leaflet. The same means of communication were used to inform regional farmers associations, extension services and administration. IGZ participated in four field days, were 145 farmers, farmers associations and scientists were informed about the project. Further, IGZ participated at a farmers workshop and presented the project. One article for an applied farmers journal has already been drafted. At four scientific conferences and workshops project outcomes were presented in talks and with posters to the science community.

ILVO used the institute's own newsletter and webpage as dissemination tools. Seven articles about Catch-C were published in this newsletter. The long-term experiment BOPACT was shown to relevant stakeholders for example during the Nutrihorst Conference 2013 and the CriNglooP Symposium 2014. 12 interviews and discussions with experts were conducted about the selection of FTZs. 22 farmers were interviewed individually in three major FTZs about drivers and barriers of BMPs and two focus group meetings with 17 farmers and one representative from extension and policy each were conducted about the same topic.

IRSTEA focused on discussions with advisors and other experts about WP4. Nine meetings with 16 participants in total were organized. Three focus group meetings in three major FTZs with 22 farmers and advisors were conducted to discuss drivers and barriers of non-inversion tillage. In addition to the project's webpage a national webpage was established (http://catch-c.irstea.fr/).

IUNG collaborated closely with Agricultural Extension Services (LODR). IUNG contributed with presentations and posters to 6 workshops and conferences of LODR with in total 524 participants, consisting of farmers and advisors. In addition to three focus group meetings with 33 farmers and advisors, six lectures and group discussions about BMPs and WP4 questionnaire results were held for in total 115 farmers. IUNG contributed to nine scientific workshops and conferences with posters and presentations about Catch-C. Additionally, project leaflets were distributed there. Two peer-reviewed scientific articles were published and two articles were published in applied farmers journals.

UGOE joined existing networks for dissemination. The issue of BMPs was explained via an invited talk in a farmer's union conference (about 800 farmers). Furthermore a network of arable farmers and advisors was exploited for presentations via a field day and a strategic 2 day-workshop. 25 farmers were interviewed and a focus group discussion was organized with 9 participants from the farming community, extension and administration to elaborate on drivers and barriers of BMPs. Two articles for an applied farmers journal about drivers and barriers and about trade-offs of BMPs are already drafted. UGOE presented project results on two scientific conferences. As responsible for the project's dissemination UGOE organized the project's concluding workshop for relevant stakeholders in Brussels with 64 participants from all over Europe.

UCO and IFAPA established close contact with the LIFE project BioDEHESA. At four scientific conferences, project results were presented and abstracts for 2 more conferences have already been submitted. The two Spanish partner institutions had four meetings with 22 national policy makers to discuss WP5 and inform about the project. They met with 33 farmers and technicians in three focus group discussions about the results of the WP4 farm surveys. The second annual project meeting was held in Cordoba. On this occasion a radio interview was broadcasted and several online articles were published in local language to inform the public about Catch-C.

UNITO and UMIL collaborated strongly with each other. Both took the opportunity to directly interact with farmers and advisors in interviews and small group discussions. That way about 110 stakeholders from the farming community were reached. Three focus group meetings were organized to discuss drivers and barriers for selected BMPs with farmers, public functionaries and advisors. A field day and a technical congress was used to disseminate results of WP3 to about 200 participants. National extension service was integrated in the outreach of the farm survey. 286 farmers were directly informed about the project with a presentation by the advisory service. Scientists were also reached by direct personal contact and small group discussions. There was intensive exchange with related FP7 and national projects. However, participation at three scientific conferences with several posters and talks permitted dissemination to a wider professional audience. Direct contact with policy makers and national administration was established in seven group discussions with 41 participants. UNITO and UMIL staff were invited to present the Catch-C project at JRC on February 3, 2015 (mini-symposium on soil management).

WUR was very active concerning the direct interaction with farmers by organizing field days, farmers meetings and workshops, mainly focusing on organic matter and soil quality. In total more than 670 farmers and advisors were reached. In addition, two focus group meetings with farmers were held in order to discuss the results of the survey conducted in WP4. One article in an applied journal for bulb growers has already been published, three more articles will be published soon. Policy makers on national and European level were addressed with meetings and articles.

STRATEGIC IMPACT

The CATCH-C project address the following issues listed in the KBBE FP7 work programme:

• Better understanding the complex and dynamic nature of agricultural soil ecosystems, including soil and plant health related aspects,

• Improving farming practices and farm land uses for increasing crop productivity,

• Enhance carbon sequestration capacity, thus limiting the environmental impact of agriculture in terms of GHG emissions.

The overall objective of the CATCH-C project was to establish Best Management Practices for the major farm types (FT) and agri-ecological zones (Z) over Europe, to determine the main barriers for their implementation in the actual farming systems and under the current EC policies, and to determine the main possibilities to foster their implementation through economical, policy and other drivers.

The CATCH-C projects provided the following information to fulfill that overall objective:

a) Inventory of the main degradation problems in major FTZ Units

b) Inventory of the Current Management Practices in the major FTZ Units

c) Inventory of the Best Management Practices to increase factor productivity and resource use efficiency for FTZs

d) Inventory of the Best Management Practices to reduce GHG emissions and to enhance carbon sequestration for FTZs

e) Inventory of the Best Management Practices to maintain soil quality (biological, chemical, physical) and soil conservation

f) Integration of the information from the four groups (i.e. c, d, e) of Best Management Practices including their trade-offs and synergies, to specify for the major FTZ Units the options to increase productivity, to enhance carbon sequestration and reduce GHGs, and to preserve and improve soil quality.

g) Review of the compatibility of Best Management Practices with the major FTZ Units, using a new compatibility frameworkdeveloped by the project.

h) Review of the compatibility of Best Management Practices with EU policies.

i) Decision grid for farmers to implement Best Management Practices.

j) Guidelines for policy makers on the interactions between Best Management Practices and policies at regional, national and EU levels.

This information and these tools from the CATCH-C project allow to assess the current degradation problems and to establish the possibilities and barriers for the implementation of the Best Management Practices.

The participating institutes in the project have a strong focus on experimental work with respect to analyzing the effectiveness and consequences of management practices. These institutes cover and work for a large number of Agro-environmental zones and farm types over Europe. Hence, a strong information

exchange was achieved about actual farming and farm management at a large range of environmental conditions over Europe.
Impact in the scientific domain
Information about degradation problems over Europe, such as, for example, the soil erosion map for un-vegetated surfaces in Europe, is already available (Selvaradjou et al., 2007), being derived from the MARS climate database, the European soil database, the CORINE land cover 2000, and the GTOPO30 (topography) database. However, this project has a different focus, being the identification of Best Management Practices to reduce or prevent such problems, assessing the compatibility of such practices with the major farming systems, and the compatibility of such practices with the current and possibly future EU policies. Besides, Best Management Practices and their effectiveness, costs and benefits and other consequences were analyzed in detail for the major farm types (FT) and agro-environmental zones (Z) over Europe.
The project intends to play a strong role in setting the future agenda by establishing (a) the possibilities and barriers for implementing Best Management Practices over Europe and (b) a series of guidelines for policies to promote the adoption of Best Management Practices.
Impact in the farming community
WP4 assessed the compatibility of Best Management Practices with the major farm types and agro-environmental zones over Europe. This was done first by interviewing farmers about their ideas for implementing such management practices. This yielded more insight in the major barriers (being related to e.g. main crop rotations, economic reasons or current EU policies) for such implementation. The next step was to identify strategies to overcome such barriers for implementation of Best Management Practices. Finally, outcomes were summarized into a tool, i.e. a decision grid, for farmers to show the effectiveness, costs and benefits, and other consequences of the implementation of Best Management Practices; this tool was tailored to different major farm types and agro-environmental zones over Europe; and presented in the languages of the project partners. This work was done in interaction with advisors and farming communities. The tool will be live from late June 2015 on http://www.catch-c.eu/KnowSoil/
Work package WP6 focuses entirely on dissemination of information on Best Management Practices to farmers and policy makers. The responsible institute, UGOE, utilised its wide extensive experience in knowledge dissemination, farm economics and policy support, also in the European context, and with emphasis on sustainable soil management techniques and agri-environmntal programmes.

The consortium partners have extensive working contacts with a wide range of farmer and advisory organisations which were accessed by the project in WP4 and WP6, both for generating project inputs as well as for obtaining feedback from the farming world on project results and views.
Impact on the policy domain
One Work package (WP5) of the CATCH-C project will focus on the assessment of regional, national and EU policies affecting soil management, with the aim to determine how well Best Management Practices are promoted or enabled by policies. The project organized workshops with policy makers to obtain feedback on our assessments, and collect their ideas on how policies cam more effectively promote sustainable soil management practices. Guidelines for soils oriented policies were discussed and summarised as a deliverable (D5.542).

The project also delivers scientifically validated guidelines for policy makers, based on explicit points of interaction between Best Management Practices and regulations and policies at the various levels. This

shows for the major farm types (FT) and agro-environmental zones (Z) inEurope the most suitable agronomic practices and techniques, to strike an optimal balance in terms of productivity, carbon sequestration and GHG reduction for CC-mitigation, and soil quality. Thus, for each of the main FTZ Units and for its main degradation problems, Best Management Practices to handle these degradation problems were derived. We expect that these results from the project will be strongly supportive to the Soil Thematic Strategy (COM(2006)231, 22.9.2006).
The participating institutes achieve a good coverage of large parts of Europe. We expect that the project will so be a vehicle for exchanging views between policy makers from the respective partner countries. This will significantly contribute to the sharing of a scientific basis for soils policies in Europe.
Dissemination and/or exploitation of project results, and management of intellectual property

Dissemination of the project results is an important aspect in the project, both in relation to the development of policies and in relation to the information transfer about sustainability problems and Best Management Practices to reduce and/or prevent such problems.

The project includes three specific work packages which focus to a different extent on dissemination of project information. WP4 collected information about barriers to implement Best Management Practices and developed (based on WP3) a tool to document the interactions between Best Management Practices and barriers (e.g. costs, main crop rotation, policies) for their implementation at major farm types. WP6 organized numerous information exchange meetings with farmers (Appendix 4 to this final report) and used these for demonstrating the pros and cons of Best Management Practices and for selecting suited Best Management Practices for different farm types.

WP5 established the interrelations between Best Management Practices and policies. It organized workshops with policy makers to discuss the options for stimulating the adoption of Best Management Practices; and used these to develop guidelines for optimising policies towards a more sustainable soil use.

Dissemination strategy;
Any dissemination activities and publications in the project shall acknowledge the European Community's Seventh Framework Programme funding.

Management of intellectual property rights
Management of intellectual property were specified in the Consortium Agreement to be signed by all participants before the start of the project. The agreement included specifications on
• pre-existing know-how
• access rights regarding pre-existing know-how for the execution of the project
• access rights for use of project results by partners beyond the duration or outside the project

All project deliverables were / will be made publicly available to optimize the impact of project.

List of Websites:

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