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Adoption of cover crops for climate change mitigation in the EU

Smit, B., Janssens, B., Haagsma, W., Hennen, W., Adrados, J.L., Kathage, J.

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Contact information
Name: Jonas Kathage
Address: European Commission, Joint Research Centre,
Email: Jonas.Kathage@ec.europa.eu
Tel.: +34 9544-88212

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Executive Summary

In order to contribute to the EU's ambitions to reduce its greenhouse gas emissions by 2030, different technological and management options are being analysed. Within the agricultural sector, catch and cover crops (CCC) are considered a viable option to mitigate greenhouse gas emissions. CCC are crops grown for the protection of the agricultural land which would otherwise be bare against erosion and nutrient losses. They immobilise nitrogen such that it remains available in the soil after the harvest of the main crop for the next main crop. If managed correctly, catch and cover crops can enhance climate change mitigation through soil carbon sequestration (building up the soil organic carbon content of the soil) and reducing emissions from fertiliser production.

In this report, we conduct a survey for different case study regions in Europe (Castilla y León in Spain; Sud – Muntenia in Romania; Centre in France; and Overijssel in the Netherlands) focusing on the mitigation and adoption potential. From the survey results we observe that CCC are mainly grown after wheat, barley, silage maize or sunflower, the most popular species being ryegrasses, mustards, clovers, vetch, oats, phacelia and rye. In most cases CCC are sown after the harvest of the main crop, after a seedbed preparation, and adopters generally do not apply irrigation, N-fertilisation (mineral or organic) or crop protection. The termination of these crops is in most cases by ploughing or by using herbicides (glyphosate).

In Spain, the concept of CCC is not very well known. Common vetch was the most applied species, mostly after cereals but in some cases after sugar beet or potato. Part of the CCC was undersown. Irrigation and N-manure were often applied, but seedbed preparation, N-fertiliser and crop protection were not frequently mentioned. Half of the Spanish adopters did not harvest this crop and the other half harvested it for selling, for own use or for fodder. The majority of adopters used ploughing for termination of CCC.

In France, unlike the other regions in the survey, a wide variety of CCC species was applied. Black oat (Avena strigosa), white mustard (Sinapis alba), common vetch (Vicia sativa) and Phacelia were most frequently mentioned, which were mostly sown after wheat and barley harvest. French farmers are in general well informed about catch and cover crops. While most farmers apply seedbed preparation, irrigation, N-fertilization and crop protection are not often applied. The large majority of French adopters did not harvest the CCC and terminated the crop through ploughing.

Dutch respondents knew the CCC-concept, since most of them grew green maize on sandy soils as a part of their fodder production for their dairy herd. Thus, they had to comply with the Nitrates Directive to grow a CCC after the maize and they did that mostly after harvest. Half of them grew Italian or English ryegrass and the other half (cutting) rye. This practice led to a relatively long CCC-period on the field compared to the three other regions in the survey. Irrigation, N-fertilisation, N-manure and crop protection were not often applied, but all adopters applied seedbed preparation. Half of the CCC-growers terminated the crop through ploughing, a quarter through a different mechanical form and the others through herbicides.

In Romania, not all farmers knew the concept of CCC-growing, although quite a share of the adopters did so as an obligation by the Romanian Agency for Payments and Intervention for Agriculture. Rapeseed and green peas were the most frequently applied CCC-species, after wheat or sunflower harvest and after a seedbed preparation. Like in the other regions, irrigation, N-fertilisation, N-manure and crop protection were not often applied. The majority of adopters did not harvest the crop and more than 80% of the adopters in Romania ploughed the CCC for termination.

Farming activities related to the use of CCC take on average 3.4 hours per ha. The total cost of all inputs (seeds, fertiliser/manure, pesticides, water) and all operations (seedbed preparation, sowing, application of fertiliser/manure and plant protection, irrigation, fuel, harvest and termination, including contractors hired) is on average 144 €/ha. Adopters estimated that growing CCC reduces the fertiliser need of the following main crops by 6.6%, and increases yields of the following main crops by 4.2%.

Most adopters grow CCC because of existing policies and most consider cultivation mandatory. Overall, agronomic reasons play a smaller role, and environmental motives are of little relevance to the adoption decision. The reasons why non-adopters do not grow CCC include a lack of benefits, high cost and labour requirements, lack of awareness, and unsuitable weather and crop rotations, among others. A majority of non-adopters indicate that they would start growing CCC if additional subsidies were provided.

Estimated CCC adoption rates based on the share of farmers using CCC range from 12% in Castilla y León, 46% in Sud – Muntenia, 84% in Centre to 99% in Overijssel. However, most adopters grow CCC on only a small share of their arable land, with the exception of Overijssel. The estimated adoption rate based on the regional area potentially available for CCC cultivation (after cereals, protein and industrial crops) is well below

20% in the Spanish, Romanian and French regions and 90% in Overijssel. The adoption potential is combined with regionally differentiated estimates of carbon sequestration from CCC per hectare to calculate the total potential climate change mitigation from CCC in each of the case study regions.

1 Introduction

The EU has the goal of reducing its greenhouse gas (GHG) emissions in order to contribute to global climate change mitigation. In 2014, the EU decided to reduce its emissions by 40% in 2030 compared to 1990.[1] Agriculture is among the sectors under the non-Emissions Trading System (NETS), with an EU-wide goal of 30% reduction compared to 2005. The 30% reduction NETS goal is to be distributed unequally among Member States (MS) according to the Effort Sharing Regulation (ESR).[2] The MS then have to decide how and in which NETS sectors their distributed domestic emission reduction goal should be achieved, and to which degree agriculture and agricultural sub-sectors should be involved.

At the JRC the study 'Economic Assessment of GHG mitigation policy options for EU agriculture (EcAMPA)' is designed to assess some aspects of a potential inclusion of the agricultural sector into the EU 2030 climate policy framework. In the context of possible reductions of non-CO_2 emissions from EU agriculture, EcAMPA estimates production effects of various policy scenarios using the CAPRI modelling framework. The EcAMPA study examines the adoption of different technical mitigation options in agriculture under different policy scenarios and their economic impacts. Successful modelling of mitigation options requires information on various parameters including the behaviour of farmers towards adoption of new technologies and management practices. So far, various mitigation options for reducing non-CO2 emissions were analysed in the studies EcAMPA I and EcAMPA II. Options to reduce direct and indirect CO2 emissions are included in the study EcAMPA III (EC, forthcoming in 2019). Winter cover crops are one of the mitigation options included in EcAMPA III.

Cover crops are crops grown for the protection of the surface which would otherwise be bare against erosion and nutrient losses. Catch crops are meant to 'catch' and immobilise available nitrogen remaining in the soil after the harvest of the main crop. They store the nitrogen in the plant tissue and thus prevent leaching into the groundwater. When a cover or catch crop is terminated (e.g. ploughed), the nitrogen becomes available again for the next main crop ("green manure"). A common typology also used by Eurostat distinguishes between three different types of soil cover: cover crops (to reduce soil erosion), green manure crops (which is any crop ploughed under to maintain soil organic matter and fertility) and catch crops (to prevent leaching; since statutory catch crops can be undersown just before harvest of the preceding main crop).

Catch and cover crops (CCC), if managed right, can enhance mitigation of climate change through two main mechanisms: soil carbon sequestration (slowly building up the soil organic carbon content of the soil, a process that takes decades to reach equilibrium) and reducing emissions from fertiliser production (if CCC as green manure reduces fertiliser use in the following main crop). Albedo change is another potential mechanism by which CCC could enhance mitigation (Kaye and Quemada, 2017). While large uncertainties regarding the extent of the potential mitigation by CCC remain, reducing these uncertainties is not the focus of this study. This study focuses on the considerable lack of information on how CCC are being implemented at the farm level and on the reasons why farmers are not growing CCC more. Many farmers do not adopt CCC and, therefore, there is a potential to improve climate change mitigation by increasing CCC adoption. An understanding of the reasons why farmers do not adopt more CCC is thus essential. If farmers are using CCC, it is important to understand not only why they are doing so but also the details of CCC management practices (which may or may not support mitigation) and reasons for the chosen management practices. By improving the understanding of these issues, the study can contribute to better modelling of mitigation options in agriculture, policy design and evaluation.

Apart from climate change mitigation, CCC can also have other environmental and agronomic benefits. These include reducing leaching, erosion, and improving soil health, some of which may also improve adaptation to climate change (Kaye and Quemada, 2017). In addition, cover crops have a role in pest management as they can break pest cycles and control weeds. A green manure effect can come from mineralisation of CCC residues, and even more from legume CCC. Alternatively, CCC can be harvested and used or sold as livestock feed. Different species are suitable to be used as CCC and often farmers grow a mix of several species to enhance various benefits.

However, CCC can also have negative agronomic and economic effects, some of which may help explain low adoption. CCC may increase pests and diseases or become weeds themselves in the future. Labour requirements may increase and there is a cost associated with buying seed and establishing and incorporating CCC. In dry weather, establishment may be challenging. CCC may have a yield effect on the following main crop. Whether they have an effect seems to depend on the CCC and main crop, and on the use

[1] http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

[2] http://europa.eu/rapid/press-release_MEMO-16-2499_en.htm

of fertiliser. For example, according to one review of the evidence, no effects on soybean yield have been found, but maize yield increased significantly when legumes were used as CCC and decreased significantly when non-legumes were used as CCC (Alvarez et al., 2017). Apart from yield effects, the sowing of CCC can increase farmers cost (purchase of seeds, cost of cultivation) and work. Water depletion could also become a problem as a result of growing CCC in low rainfall areas. As with yield, the effects of CCC on leaching are also ambiguous (Miguez and Bollero, 2005, Tonitto et al., 2006, Valkama et al., 2015, Alvarez et al., 2017).

These various costs and benefits influence the decision of farmers to grow or not grow CCC. Apart from these costs and benefits, political incentives have been put in place in many cases that exert an influence on that decision as well, for example greening, the Nitrate Directive, or Rural Development Programs. Finally, there may be other economic, sociological and psychological factors at play, too (Pe'er et al., 2017).

The goal of this study is to find out why farmers decide to grow or not grow CCC, and, when they grow them, which management practices are used (species, labour requirements, seed cost, harvesting/ploughing and other agronomic and economic details). The study was conducted using farm surveys in a number of case studies in different farming systems and regions of the EU. Particular attention was given to the selection of case studies, to make sure they include cases of CCC that are most relevant for mitigation.

After this introductory chapter, Chapter 2 describes the process of the selection of case studies and the design of a survey of farmers in the selected regions. This selection is based on detailed assessments of current adoption, adoption potential and climate change mitigation potential of CCC in the EU (Annex 1). Chapter 3 contains an analysis of the results of the survey. Chapter 4 draws conclusions.

2 Design of an EU-wide farm survey for assessing the use of catch and cover crops by farmers

This chapter contains three parts: the selection of the case studies, based on the assessments of the mitigation and adoption potential (Annex 1); the design of the questionnaire (final questionnaire attached in Annex 2); and the procedure followed in the survey.

2.1 Selection of case studies

2.1.1 Requirements

The survey contains a number of different case studies of CCC in the EU. A case study is defined by a particular country or region within a country and a farming system which is comparable across farmers within the case study. The case studies are selected on the basis of the current adoption and mitigation as well as the future adoption and mitigation potential they offer. Adoption potential is understood as the extent of the area where CCC are not yet adopted but adoption is feasible. Mitigation potential is understood as the amount of greenhouse gases that are sequestered and avoided by using CCC compared to not using CCC. Table 1 shows how the case studies are prioritised.

Table 1. Priorities of case studies with different combinations of mitigation and adoption potential

	High adoption	**Low adoption but high adoption potential**	**Low adoption and low adoption potential**
High mitigation or high mitigation potential	**Medium priority**	**High priority**	**Low priority**
Low mitigation or low mitigation potential	**Low priority**	**Low priority**	**Low priority**

Case studies where adoption of CCC is and can be expected to remain very large have a medium priority. Higher priority was assigned to cases where there is a higher potential for adoption and for mitigation. Cases of crops or regions where the adoption of CCC does not have a large potential for mitigation (for example because of the crop species or the specific climatic conditions), have low priority. The aspect of feasibility of adoption is also to be considered: if adoption is less likely to increase in response to potential changes in policy, a case has lower priority. The study was intended to be composed mainly of high priority case studies (55-65% of total number of case studies), followed by medium priority case studies (25-35%) and low priority case studies (5-15%).

After compiling a shortlist of 10-15 high, medium and low priority cases, additional factors were taken into account to further narrow down the selection. These factors include geographic diversity, in the sense that some of the selected case studies should come from northern, humid and rainfed regions and others from the Mediterranean, semi-arid and/or irrigated regions. Different countries have also been included to allow for some diversity of political and regulatory environments (including some regions with a political/regulatory environment more conducive to CCC adoption, and some with a less-conducive environment).

The number of different case studies and the number of interviews per case study was decided with a view to the objective of the study to obtain representative data. The number of case studies was determined to be 4 at a minimum and the number of interviews per case study between 100 and 200. The total number of interviews (case studies x interviews per case study) was 600 at a minimum.

It was taken as important to obtain a sufficient number of interviews with adopters and a sufficient number of non-adopters of CCC to allow for valid statistical analysis of both groups. One of the goals of the survey was also to obtain data on the adoption rate of CCC and, for this purpose, farmers were initially contacted independently of their adoption status and no full interview was conducted above a maximum quota assigned to the group (adopters or non-adopters). The number of adopters and non-adopters encountered (even if not fully interviewed), was to be recorded to allow for an estimation of the adoption rate.

2.1.2 Mitigation and adoption potentials

For the creation of the shortlist of case studies, the mitigation potential and the adoption potential were estimated for each crop group (for details see Annex 1). The total mitigation potential per NUTS2 region (in kg CO_2e per year) was calculated as the sum of the mitigation potential from C and the mitigation potential from N.[3] Two important processes make up for the total climate change mitigation potential, (1) carbon sequestration, resulting in higher soil organic matter content, and (2) reduction of nitrogen losses, including a reduced need of N-fertiliser production:

$$C_r = a_{cr} * f * m * b_r$$

where C_r is the mitigation potential from carbon sequestration (in kg CO_2e), a_{cr} is the number of hectares of a specific main crop c in region r, potentially adopted for growing a CCC after or under, f a conversion factor of biomass into soil organic matte (in kg SOM/kg biomass), m a conversion factor of soil organic matter into climate change mitigation (in kg CO_2e/kg SOM/year) and b_r is the biomass production of the CCC in region r (in kg per ha).

$$N_r = a_{cr} * s * n_c * r_r$$

where N_r is the mitigation potential from the reduction of nitrogen losses (in kg CO_2e), a_{cr} is the number of hectares of a specific main crop c in region r, potentially suitable for growing a CCC after or under, s is a conversion factor from N-surplus into N-savings, including the influence of precipitation surplus, n_c is the surplus in crop residues and soil after harvest of main crop c (in kg/ha) and r_r is the precipitation surplus in region r during a fallow period after a specific main crop (in mm).

The mitigation potential concerning carbon sequestration by CCC in a region can be calculated as the biomass production in the region on potentially adopted land for growing a CCC and the conversion of that biomass into soil organic matter, leading to climate change mitigation. The mitigation potential concerning the reduction of nitrogen losses for growing CCC in a region can be calculated as the amount of N surplus of the main crop on potentially adopted land for growing a CCC and the conversion of that surplus in N-savings taking into account the precipitation surplus after the main crop, leading to climate change mitigation.

The mitigation potential is derived from Poeplau and Don (2015). They conducted a meta-analysis on the potential of cultivating cover crops for carbon sequestration in agricultural soils. Using data from 37 different sites they calculated an annual change rate of 320 ± 8 kg C/ha/year. The meta-analytical estimate of a global C sequestration by using cover crops from Poeplau and Don (2015) is comparable to values tabulated by several other references mentioned by Kaye and Quemada (2017). The C sequestration rate of 320 ± 8 kg C/ha/year is equal to a mitigation rate of 1,170 ± 290 kg CO_2e/ha/year. The data underlying these figures comes largely from moderate climate regions; only a small number was located in tropical areas. Therefore, the value of 1,170 kg CO_2e/ha/year was assumed to give an average figure for the EU as a whole. However, within the EU, there are big differences in growing conditions, not only leading to differences in main crop yields but also in CCC yields and, consequently, in mitigation potential per ha. These differences were taken into account through weighting the value of 1,170 kg CO_2e/ha/year according to region on the basis of the average grain yield from cereals per ha per region, being 5.53 t per ha (weighted average; source: Eurostat). We assumed that:[4]

1) the mitigation potential is linearly correlated with the biomass produced by the CCC;
2) the amount of biomass of a CCC in a specific NUTS2 region is linearly correlated with the grain yield of cereals in that region, including similar growing conditions like level of moisture supply, nitrogen supply, etc.;
3) the average value of 1,170 kg CO_2e/ha/year correlates with an average grain yield of cereals in the EU.

These assumptions were integrated in the estimation method in such a way, that the mitigation potential (in kg CO_2e) is linearly higher in regions with higher than average grain yields (due to favourable growing conditions) and linearly lower in regions with lower yields. The regional grain yields express the growing

[3] As explained in Annex 1, this calculation has been applied for the C-sequestration, being the major of source of mitigation compared to the contribution of reducing N-losses and N-fertiliser input. This results in an underestimation of the mitigation potential, but that does not have much influence on ranking case study regions with a high potential.

[4] Meta data on EU-level are not available to prove these assumptions. The agronomic reasoning applied can be found in different handbooks on crop production and in Smit (1996).

conditions in that region. These conditions are assumed to have the same effect on both grain yields and CCC biomass yields. Estimations of the CCC biomass yields lead to estimations on the amount of C which can be sequestered in the soil, assuming a more or less constant C-content of CCC.

The starting point for estimation of the adoption potential is that a cover crop can be grown under or after every cereal and industrial crop and under or after green maize. The adoption potential is calculated as the total number of hectares of cereals, industrial crops [5] and green maize (as the most feasible crop for a CCC among the group of green harvested plants [6]) per NUTS2-region, but corrected for the area on which cover crops were already grown in 2010. In regions with a high share of cereals and a low current adoption rate of cover crops (Eurostat, 2010), the potential to adopt (more) CCC is high. Besides these three 'big' crops, attention was paid to permanent crops, mainly olive and vineyards. Other crops could be important in certain regions or MS, but their acreage is small compared to the three big crops and the two permanent crops listed. Since acreage of a crop is dominant in the calculation of the adoption potential, others than these five crops have not been paid attention to in the selection of case study regions.[7] For the estimation of the climate change mitigation potential, data were derived from Rodríguez-Entrena et al . (2012), as explained in Annex 1. The average climate change potential in olive growing in the largest olive growing area in the EU, Andalucía in Spain, was estimated at 1.470 kg CO_2/ha/year, which was used to estimate a total figure for this permanent crop in that region as well.[8]

Subsequently, the mitigation potential (expressed in kg CO_2e per ha per year) and the adoption potential (expressed in ha) were individually ranked and scored. Moreover, the product of both variables was calculated, indicating the total mitigation potential in a region (in kg CO_2e per year). This final figure gives the best criterion for the case study selection. It presents an estimation of the total (extra) climate change mitigation in a region which is reached when on all land where growing a CCC is feasible but not yet applied, a CCC is successfully cultivated. A high value for this combined variable complies with the criteria for selection of high priority case study regions, being a low adoption but high adoption potential and a high mitigation or mitigation potential (Table 1). Besides, one region was selected where the adoption was already high, representing a medium priority case. Annex 1 contains details on the estimated mitigation and adoption potentials. The selection from the shortlist is summarised below.

2.1.3 Case study shortlist

The basis for the case study selection is given in Table 2 (also see Annex 1). Andalucía in Spain scores high, because of a high estimated climate change mitigation of olives in that region: 2.3 Mt CO_2e, which directly follows the first region that was ranked for the three big perennial crop groups (cereals, industrial crops and green maize), the region Centre in France, with an estimated mitigation potential of 2.4 Mt CO_2e per year.

5 For some industrial crops, undersowing of a CCC is difficult. Winter rape fully covers the land in spring time which hinders undersowing. In soya and sunflower, (harvest time in France mid-September) undersowing in spring is an option. For these industrial crops, summer sowing of a CCC (after harvest) is also a possibility but sufficient moisture during the summer period is a basic condition for a successful germination and start of the CCC. Also post-harvest crop residues can adversely affect the development of a CCC but it is possible to grow a cover crop when the straw is well-chopped and well-spread (in some cases improved by a low N-fertiliser rate after harvest).

6 In the group of green harvested plants, green maize gives the best option to grow a CCC (undersown or after harvest if harvested in time). Most other green harvested plants offer very limited or no possibility for undersowing. An interesting option for green plants is to grow an extra crop cut (biomass) which is then not harvested but destroyed.

7 However, when other crops appear in the regions selected, most likely in the same cropping plan as the 'big' crops, they are included in the survey, to give a complete picture.

8 The olive area in Spain is 2,572,7931 ha, of which 1,860,458 ha are non-irrigated and 712,335 ha are irrigated. Andalucía is the main producing region with 1,549,663 ha, followed by Castile-La Mancha with 405,883 ha and Extremadura with 264,934 ha, and other regions such as Cataluña and Valencia (Rodríguez-Entrena et al., 2012).

Table 2. Shortlist of case studies

Order ([1])	Region	NUTS2 number	Farming system/crop	Priority level ([2])	Remarks
1	Centre, France	FR24	Mainly cereals	High	
2	Andalucía, Spain	ES61	Olive	High	Option of mulching, dry summers, also high score in ranking of 3 big crop groups
3	Castilla y León, Spain	ES41	Mainly cereals	High	
4	Mecklenburg-Vorpommern, Germany	DE80	Green maize – cereals – industrial crops	High	
5	Poitou-Charentes, France	FR53	Cereals – industrial crops	High	
6	Sud – Muntenia, Romania	RO31	Cereals – industrial crops	High	
7	Sachsen-Anhalt, Germany	DEE0	Green maize – cereals – industrial crops	High	
8	Picardie, France	FR22	Cereals – industrial crops	High	
9	Champagne-Ardenne, France	FR21	Cereals – industrial crops	High	
10	Midi-Pyrénées	FR62	Cereals – industrial crops	High	
11	Pays de la Loire, France	FR51	Green maize – cereals – industrial crops	High	
12	Lithuania	LT00	Cereals	High	
13	Niederösterreich, Austria	AT12	Cereals	Medium	High adoption rate
14	Overijssel, Netherlands	NL21	Sugar beet – potato – onion - cereals	Medium	High adoption rate

([1]) Based on ranking of total mitigation potential per region (see Annex 1)
([2]) Priority level according to Table 1

In Table 2, French, Spanish, Romanian, German and Lithuanian regions dominate the ranking order. Many of these regions have rotations with mainly cereals and industrial crops. The two German regions include also green maize, which is interesting from the point of view of the nitrate leaching aspect. The French region Champagne also has considerable acreages of vineyards, a permanent crop with opportunities and a necessity to grow CCC, since they are often located at slopes.

The order of case studies in Table 2 is in the first place dominated by the fact that big crops have large acreages and a high mitigation potential. A second criterion for the selection in the shortlist was to include a diversity of farming systems: crop rotations with cereals and industrial crops, crop rotations with green maize (probably including mixed farms) and farming systems with permanent crops. In different farming systems, farmers may make different choices, e.g. depending on costs of using CCC, expected effects on the profitability of the farming system as a whole, etc. Different climate zones were included to investigate whether that factor makes a difference for adoption and whether nevertheless successful ways of growing a CCC can be identified. A third criterion was to include geographical diversity, which is represented in the shortlist with MS from Southern and Northern, and Eastern and Western Europe. These MS also represent different political/regulatory environments, a fourth criterion. In north-western MS relatively high N-fertilisation rates are applied in combination with relatively high precipitation levels. In these regions, the authorities are more focused on adoption of leaching avoiding measures (e.g. growing CCC) than in Eastern European MS with drier conditions.

The shortlist had to contain also some cases with medium priority. Those could be:

- Vineyards in Champagne-Ardenne, France. The adoption rate seems to be low there. It could be that wine-farmers are afraid of diseases like fungi from plants growing between the rows, so the space between the rows is often left bare;
- Austria, with high adoption rates (risk of erosion could be a factor, though);
- A crop rotation with potato, sugar beet, cereals and/or onion and/or carrot, as found in North-West European MS, like Belgium, the Netherlands, Denmark and parts of Germany, UK and Northern France. The adoption rates and mitigation potentials are relatively high in these regions, especially in the Netherlands.

An option for the case studies is to cluster neighbouring NUTS regions in a Member State into one combined case study region. This could e.g. be useful for number 14, the province of Overijssel, which is a relatively small region with a relatively small area of arable land. It could be combined with e.g. the province of Flevoland, a province with much more arable land but with lower shares of cereals in the cropping plan.

2.1.4 Final selection of case studies

The selection of case studies was refined by taking into account estimates of current adoption rates and farm system characteristics in the shortlisted regions. This information was also used to decide on the number of interviews per regions and minimum farm sizes to be included. For more details, see Annex 1.

The final selection of case studies is shown in Table 3. The first three regions (FR24, ES41 and RO31) are a selection from the top-six regions with high priority in the shortlist for different MS and including Andalucía as an important olive growing region. The fourth region (NL21) is a medium priority case. Regions 1 and 2 are comparable in cropping plan (mainly cereals), but region 1 (Centre) has a higher adoption rate and more rainfall than region 2 (Castilla y León). Sud-Muntenia, Romania (region 3) had comparable adoption rates as Lithuania, but the variability in Romania was bigger, both in cropping plan (more industrial crops) and farm size. The climate in Romania is to some extent comparable to Castilla y León, but the entrepreneurial and political context is different, probably resulting in differences in decision making in both MS. The adoption rates of Niederösterreich, Austria, and Overijssel (the Netherlands) were comparable. The Netherlands (Overijssel, region 4) were selected because of a wider range of crops including green maize and a smaller urgency to avoid erosion.

Table 3. Final selection of case study regions

Nr.	NUTS2 code	Region	Sample size	Minimum farm size for participation (ha)	Maximum number of adopters in sample
1	FR24	Centre, France	150	5.7	50%/100% (2)
2	ES41	Castilla y León, Spain	150	6.3	50%
3	RO31	Sud – Muntenia, Romania	150	7.4	50%
4	NL21	Overijssel, the Netherlands (1)	150	3.1	70%/100% (2)

(1) Due to a lack of non-adopters in Overijssel, a few farmers in the province of Flevoland were also contacted
(2) Relaxed to 100% after difficulties of finding non-adopters

Two interesting potential case studies, olive growing in Andalucía and arable farming in Sachsen-Anhalt, were not included in the final selection for the following reasons:

- CCC appeared only feasible in irrigated olive growing, reducing the potential climate mitigation to a third of the potential (500,000 ha versus 1 million ha non-irrigated; (Rodríguez, 2018)). It also appeared that in olive growing, natural vegetation is considered as a CCC, whereas the concept of intentional sowing of CCC is unknown there;
- The only way to make the survey feasible within the available budget was to reduce the number of case studies. The cropping plans and climate of the German regions in the shortlist were to some extent comparable to the ones in the Netherlands, so that selection of the Netherlands covered more or less the situation in Germany.

Besides the selection of the case study regions, decisions were taken on the number of interviews per region, the ratios between adopters and non-adopters in the samples and the crops covered by farmers:

- It was decided to divide the 600 minimum interviews equally over the four case studies selected, i.e. 150 per region. This gave a statistically sound number of interviews per region, enabling statistical analysis of at least the main group per region (which should at least contain 60 respondents);
- For the first three regions, it was decided to try finding as many adopters as possible, with an initial maximum share of 50% in the sample. For the Netherlands, since the likelihood of finding non-adopters was lower, the number of adopters was limited to 70%. In all cases, there was no minimum quota;
- However, during the test of the questionnaire in the four regions, the interviewers observed that non-adopters were very hard to find in France and the Netherlands. For that reason, the maximum quotas in those two MS were relaxed to 100%.
- All four regions are arable regions[9], but in most cases they grow more crops than only cereals and/or industrial crops of, in the case of the Netherlands, sugar beet – potato – onion – cereals (Table 2). Therefore, it was important not to limit the approach of farmers to the main crops in the different regions selected, but also to include farmers who grow crops like sunflower, oilseed rape, soybean and green maize.

2.2 Questionnaire design

The questionnaire had to be designed with the goal of gaining unbiased, unambiguous and precise information on the reasons why farmers use or do not use CCC and, if CCC are used, details on how they are managed. Additional farm and farmer characteristics which might be relevant to explain differences in

9 Overijssel in the Netherlands has also quite a number of dairy farms, many of them growing grass and green maize.

farmers' behaviour regarding CCC were collected. Each question had to be phrased and designed with a view of getting the most unbiased answer possible. Different case studies may require different questions, but the questionnaire had to be kept as comparable as possible across case studies. The minimum number of questions in the questionnaire had to be 30.

The questionnaire had to be composed of three blocks of questions: First, for all farmers, questions related to (economic, sociological, political, etc.) reasons for or against the adoption of CCC. Questions could be different for adopters of CCC and non-adopters, but the aspects covered are the same. Second, for those farmers adopting CCC, questions related to the CCC practices implemented in detail (which species, rotation, planting dates, agronomic practices, use of CCC after termination). Third, for all farmers, questions about general farm and farmer characteristics (e.g. age, education, economic size, types of operations, etc.). The conceptual framework (overview of external factors affecting the adoption decision by farmers) is included in Annex 1 and the final questionnaire in Annex 2.

2.3 Survey procedure

Within the selected case study regions there is a lot of variability in farm size. Therefore, a stratified sampling by adoption status and farm size would have been preferable. However, farmers were approached to participate in the survey mainly through meeting points and discerning between farm sizes beforehand was difficult. Moreover, no information on adoption rates was available for the different farm size categories.

The quality of the survey depends on the quality of the interviewers and on the availability and cooperation of farmers. To reach a high level of quality of questionnaire results, it was decided to only carry out face-to-face interviews by professional interviewers. This approach was thought to work better than telephone calls. The farmer was more concentrated on the interview, took more time to reply to the interviewer and felt more comfortable due to the 'live contact' with the interviewer.

The first step in the survey was to train the interviewers to carry out this specific survey with its specific final questionnaire and contents. The interviewers needed to understand what the survey was about, especially what CCC were, which crop species were suitable as a CCC, when and why they were grown and how decisions on a farm were taken in general.

The second step was to approach (arable) farmers in the regions selected and to invite them to participate in the survey. The main entry point to farmers was the meeting points of cooperatives and agricultural suppliers of seeds of e.g. cereals, fertilisers, pesticides, etc. If there was no sufficient number of participants (especially adopters), other entry points were used, such as meeting points for other arable crops than cereals, networks of advisors, extension services and applied researchers. The population of farmers included those who grew cereals (wheat, barley, grain maize, triticale, rye, oats, spelt), oilseed rape, sunflower, soybeans or green maize/silage maize, the so-called 'target crops', as stated in the questionnaire.

When the interviewer came in contact with a potential participant, two questions were asked in order to assess whether this person would be suitable and acceptable for the survey:

1. Is this person the farmer, i.e. is he or she the person who takes the decisions on the farm?
2. Is the farm large enough, i.e. is the size larger than the threshold values in Table 3?

When both questions received 'yes' as an answer, then the interviewer proceeded with the interview. But when the person was not the one who took decisions or when the farm was not large enough, the interviewer would ask the person in front of him if (s)he knew a person in the room or in his/her network who complied with both conditions and the interviewer would try to approach that person. The answers to these questions were part of the questionnaire.

The third step was to explain what would be done with the results of the interview and that there was a guarantee that no personal details would be published. The interviewer told the participant that the survey would take about half an hour of his time and that the information would only be used for research objectives. The interviewer asked the name and the telephone number of the farmer, so that he could contact the farmer in case he would observe unanswered questions or unclear answers after the interview. Then the interviewer would ask whether the farmer knew what a CCC was (also included in the questionnaire). After the answer of the farmer, the interviewer would give the definition of a CCC, stressing that a CCC is a crop that is intentionally sown in-between main crops in a rotation. After checking if the farmer understood the concept of CCC, the next question was if (s)he was an adopter or a non-adopter.

The fourth step was to collect the interview results from each interviewer, checking that each question was filled in correctly and completely. The survey coordinator (Kantar TNS) collected all data and provided them to the research team of Wageningen University, who performed the analysis presented in the next chapter. Kantar TNS did a final check on the data accuracy.

3 Analysis of survey results

This chapter is divided into adoption rates, description of the interviewed farmers and farms, analysis of main survey questions, and the implications for adoption and mitigation potential. The total number of respondents in tables is 623 unless stated otherwise.

3.1 Adoption rates

3.1.1 Castilla y León, Spain

In Spain, the interviewers contacted 174 farmers in total (Table 4) and conducted full interviews with 155. Approximately 90 of the 155 full interviews comprised farms with some irrigated crops, and the adopters were usually in this group of farms. The adoption rate among these 90 farmers was 26 persons or 28.9%. In order to calculate the adoption rate for the full group of arable farmers, a correction was made for the ratio of farmers with (some) irrigated crops. Table 5 shows that in 2016, there were 70,000 arable farmers in the region with a total of 3.5 million ha of land. Of the total acreage of 3.5 million ha, 3.0 million ha were not irrigated. This acreage was spread over 63,000 farms. 0.4 million ha were irrigated, spread over 30,000 farms. Thus, most arable farmers had non-irrigated land and 30,000 out of 70,000 farms irrigated (all or part of) their land.

Of the total sample of 155 farmers in Spain, 90 had farms with some irrigated crops. These 90 belonged to the group of 23,000 (arable) farmers with more than 5 ha of land and some irrigation. These 23,000 farmers made up 40.0% of the total group of arable farmers with more than 5 ha of land. As a consequence, the adoption rate among all arable farmers in Spain was calculated as 11.6% (40% of 28.9%).

Table 4. Sampling results in Castilla y León, Spain

Number of adopters	26
Number of adopters interviewed	26
Number of adopters who did not answer or were not interviewed	0
Number of non-adopters	140
Number of non-adopters interviewed	129
Number of non-adopters who did not answer or were not interviewed	11
Total number of contacts	174

Table 5. Numbers of farms and their acreages with and without irrigation in Castilla y León

Group of farms	Number of farms	Acreage (ha)
All arable farms	70,501	3,470,903
Of which with land without irrigation	63,221	3,049,632
Of which with land with irrigation	30,369	421,176
Farms with Usable Agricultural Area (UAA =SAU) smaller than 5 ha (1)	12,664	25,906
Of which with land without irrigation	7,982	18,534
Of which with land with irrigation	7,129	7,273
Farms with Usable Agricultural Area (UAA =SAU) more than 5 ha	57,837	3,444,997
Of which with land without irrigation	55,239	3,031,098
Of which with land with irrigation	23,240	413,903

(1) This division relates to the minimum farm size that was included in the survey (see Table 3).

Source: INE (2016).

3.1.2 Centre, France

Table 6 shows that in France 397 farmers in total were contacted. 332 of these were adopters and 120 of them were interviewed. 65 were non-adopters, from whom 42 were interviewed. That means that the adoption rate in the full group of farmers approached was 332 out of 397 or 83.6%. In total, 163 farmers were interviewed and the ratio between adopters and non-adopters in the interview sample was approximately 3:1.

Table 6. Sampling results in France

Number of adopters	332
Number of adopters interviewed	120
Number of adopters who did not answer or were not interviewed	211
Number of non-adopters	65
Number of non-adopters interviewed	42
Number of non-adopters who did not answer or were not interviewed	23
Total number of contacts	397

3.1.3 Overijssel, The Netherlands

In the Netherlands, it appeared difficult to find a farm without CCC. All farmers that were approached were included in the final sample, and as a consequence, the adoption rate in the Netherlands is similar to the adoption rate in the final sample obtained. In total, 151 farmers were interviewed, from whom 124 in the province of Overijssel and 27 in the province of Flevoland. Of these 151, only two were non-adopter, i.e. an adoption rate of 98.7%.

3.1.4 Sud – Muntenia, Romania

Table 7 shows that in Romania 243 farmers in total were contacted. 112 of these were adopters and 78 of them were interviewed. 131 were non-adopters, from whom 77 were interviewed. That means that the adoption rate in the full group of farmers approached was 112 out of 243 or 46.1%. In total, 155 farmers were interviewed and the ratio between adopters and non-adopters in the interview sample was approximately 1:1 (which was perfect from our initial sampling design).

Table 7. Sampling results in Romania

Number of adopters	112
Number of adopters interviewed	78
Number of adopters who did not answer or were not interviewed	34
Number of non-adopters	131
Number of non-adopters interviewed	77
Number of non-adopters who did not answer or were not interviewed	54
Total number of contacts	243

3.1.5 Summary of adoption rates

Table 8 summarizes the numbers of farmers approached and interviewed and the adoption rates in the four MS. In total, 965 farmers were approached over the four MS. All of them were classified as either ‘adopter’ or ‘non-adopter’. Out of this group of 965 farmers, 623 farmers or 64.6% participated in the interviews, fulfilling the requirements of at least 150 interviews and the maximum shares of adopters per MS (Table 3). The adoption rate calculated from the samples of farmers approached varied between 12% in Spain and 99% in the Netherlands. On average, 60% of the farmers were adopters, but that figure is of little relevance since it has not been weighted for total numbers of farmers in the four regions. These numbers are significantly different between the four regions involved.

Table 8. Estimated adoption rates

Member State	Number of farmers			Adoption rate (%)
	Approached	Interviewed	Adopters	
Spain	174	155	26	11.6
France	397	162	120	83.6
The Netherlands	151	151	149	98.7
Romania	243	155	78	46.1
Total	965	623	373	60.0

3.2 Description of the interviewed farmers and farms

All of the 623 farms in the sample grew cereals or other target crops (like rapeseed, sunflower or green maize). The farms were on average largest in Romania (over 400 ha, of which 92% target crops) with a maximum farm acreage of 5,000 ha (Table 9). The Dutch farms were smallest on average, counting 72 ha with only less than 20% of target crops. This is due to the fact that the province of Overijssel has many dairy farmers, who in general grow at least 80% of their land with grass. This has to do with a so-called derogation deal between the EC and the Dutch dairy farmers. This deal gives the Dutch farmers the opportunity to apply 230 (in case of sandy soils) or 250 kg (on other soils) of N in manure per ha instead of the normal maximum rate of 170 kg N per ha, when at least 80% of the farm acreage is grassland. The second crop on such farms is green or silage maize, which, as a consequence cannot be higher than 20%. Derogation is not compulsory, but the majority of dairy farms apply for this regulation. The regulation gives them more space to get rid of their manure on their own farmland, keeping transportation costs towards other farms (accepting this manure) low. Remarkably, adopters had larger farms than non-adopters, which may indicate a difference in management qualities between the two groups.

Table 9. Farm size and acreage of target crops

MS	Farm size (ha)					Acreage of target crops (ha) (1)	Share of target crops (%) (1)
	Average	Minimum	Maximum	Adopters	Non-adopters		
Spain	110	7	700	136	105	94	85
France	167	21	897	182	124	132	79
Netherlands	72	8	400	72.4	36.5	14	19
Romania	426	7.4	5,000	773	73.8	390	92
Total	194	7	5,000	259	97.9	158	81

(1) On the farms of adopters.

Of the 623 respondents, 514 or 83% indicated that they knew what CCC were (Table 10). That share was highest in the Netherlands and France (with 100% or almost 100%) and lowest in Spain (63%). 71% of the Romanian respondents indicated that they knew about CCC. 373 respondents indicated that they grew CCC, i.e. 60% of the total survey population. Again, the Netherlands had the highest score (99%) and Spain the lowest (17%). In Romania and France, half and three quarters of the respondents grew CCC, respectively. Table 10 also lists the average acreage of CCC grown on the farms of the respondents. Besides the absolute acreages, which were largest in Romania (with about 100 ha per farm on average), also the share of the CCC-acreage related to the share of the target crops (listed in Table 9) were calculated. Adoption of CCC does not only deal with the share of farmers that grow such crops; also the share of the land that could theoretically be used to grow a CCC, i.e. the total acreage of target crops, is of importance. The highest mitigation effect will be reached when 100% of the acreage of target crops is also used for growing a CCC. This share appeared to be less than a quarter of the potential acreage or, stated differently, three quarters of the potential acreage was not used for growing a CCC. The share was highest in the Netherlands (above 90%, but to be understood from a cropping plan with 80% grassland) and lowest in Spain (18%). However, the shares in France (24%) and Romania (26%) were not much higher and there should be much room for increase.

Table 10. Knowledge of CCC, sample adoption shares and CCC acreage

MS	**Knowledge of CCC**		**Growing CCC**		**Acreage of CCC**	
	Number	**Share (%)**	**Number**	**Share (%)**	**(ha)**	**Share of acreage of target crops (%)**
Spain	98	63	26	17	17.0	18.1
France	155	96	120	74	31.4	23.8
Netherlands	151	100	149	99	12.5	91.2
Romania	110	71	78	50	101.3	26.0
Total	514	83	373	60	37.4	23.7

Table 11 shows that 80% or more of the farmers interviewed grew arable crops. In Spain and Romania this was true for (almost) all farms. The farmers in the survey were selected because they grew one or more of the target crops, which were all arable crops; indeed, all respondents indicated that they grew one or more of the target crops. In total, 37 respondents indicated that they did not grow arable crops, of whom 26 were French farmers. Most of these farmers had livestock and (mostly) grassland. Thus, this is clearly a definition problem. Specifically, dairy farmers with a cropping plan with mainly grassland and green maize tend to see green maize as a fodder crop, not as an arable crop. Because they are not arable farmers, they think they do not grow arable crops (at least, that could be the explanation for this observation).

Table 11. Agricultural activities on the farm (% of farmers) ([1])

	Spain	France	Netherlands	Romania	Average
Arable crops	99	84	93	100	94
Permanent crops	11	46	10	14	21
Livestock	14	35	99	28	43
Grassland	14	27	95	1	34
Forests	10	3	2	0	4
Other	0	6	5	1	3

([1]) The numbers per MS sum up to more than 100%, since more than one answer could be given.

Most farmers indicated a total household income below € 50,000 (Table 12).

Table 12. Household income (farm and non-farm)

	Spain	France	Netherlands	Romania	Total
0 - 25,000 €	77	100	22	66	265
25,000 -- 50,000 €	38	45	59	27	169
50,000 -- 75,000 €	17	9	30	5	61
75,000 -- 100,000 €	10	2	19	7	38
100,000 -- 125,000 €	6	2	11	6	25
125,000 -- 150,000 €	2	0	4	9	15
150,000 -- 175,000 €	2	0	2	5	9
175,000 -- 200,000 €	1	0	1	3	5
More than 200,000 €	2	4	3	27	36
Total	155	162	151	155	623

The farmers in the survey had on average 82% from their income from agriculture (Table 13). For the farmers in Spain and Romania 90% of their farm income came from arable farming. In France 17% and 13% came from livestock and permanent crops, respectively, and the farmers in the Netherlands were mostly dairy farmers with more than 80% of their income from livestock and only 5% from arable farming.

Table 13. Farm share of household income and farm activities share of farm income

	Spain	France	Netherlands	Romania	Average
Farm income (% of household income)	85.3	67.4	88.1	87.9	82.2
Arable farming (% of farm income)	90.5	66.8	5.1	88.2	63.1
Livestock (% of farm income)	7.3	17.3	84.2	7.7	28.6
Permanent crops (% of farm income)	1.4	12.8	1.1	2.6	4.6
Other farm activities (% of farm income)	0.8	3.1	9.5	1.5	3.7

The average age of the respondents was almost 49 years (Table 14). 50 of them (8%), mostly from Romania, were female.

Table 14. Age (average) and gender (number)

	Age	Gender	
		Male	Female
Spain	51.6	152	3
France	49.5	151	11
Netherlands	48.3	147	4
Romania	46.2	123	32
Average	48.9	573	50

On average, 60% of the respondents had a high school or university degree (Table 15). These numbers were especially high in France and Romania. The share of farmers interviewed with a specific agricultural education was almost 77% on average. Almost 90% of the French and Dutch farmers had such an education.

Table 15. Education level and agricultural education (% of farmers)

	Spain	France	Netherlands	Romania	Average
Primary school or lower	48.4	0.0	2.0	0.0	12.6
Secondary school	20.0	7.4	68.2	11.0	26.6
High school	20.6	59.9	28.5	51.6	40.2
University	11.0	32.7	1.3	37.4	20.6
Agricultural education	49.7	88.9	88.7	78.7	76.6

The average scores on willingness to take risks were higher in the Netherlands and Romania than in France and Spain (Table 16). In general, Dutch farmers are known to have a relatively high level of entrepreneurship, including a willingness to take risks. The farms in Romania were relatively large. The farmer on a large farm is either a person who succeeded in acquiring such a large farm through taking risks or he is a director of such a farm, more a manager with a different risk attitude than a traditional family farmer. The French and Spanish respondents were mostly cereal growers, aiming for high yields and low costs in order to earn a reasonable income. The profile of such farms relates to a relatively low willingness to take risks. More risk seeking farmers would probably hold livestock or grow vegetables or permanent crops.

Table 16. Willingness to take risks

	Average score ([1])
Spain	4.7
France	5.5
Netherlands	6.3
Romania	6.5
Average	5.7

([1]) scale from 1 (not at all willing to take risks) to 10 (very willing to take risks).

About 60% of the farms involved in the survey (372) were an individual or family farm or natural person (Table 17). Besides, 20% was a private company and 20% had another juridical status, e.g. cooperation between husband and wife, a very popular form in the Netherlands.

Concluding, the survey was carried out among very different farmers in terms of e.g. education level and risk attitude, and with very different farm characteristics like farm size, structure and system.

Table 17. Juridical status (number)

	Spain	**France**	**Netherlands**	**Romania**	**Total**
Natural person/Individual farm/family farm	125	88 ([1])	127 ([2])	101	441
Private company	26	67 ([3])	23 ([4])	54	170
Cooperative	3	0	0	0	3
Other ([1])	1	7	1	0	9

([1]) In this group, 11 farms had a GAEC-status ('Groupements d'Exploitation en Commun').
([2]) This group contains 58 farms with a partnership-status ('maatschap') between the farmer and his partner and/or their child(ren).
([3]) This group contains 32 farms with an EARL-status (Exploitation Agricole à Responsabilité Limitée).
([4]) In this group, 19 farms with a VoF-status ('Vennootschap onder firma') and 2 with a BV-status ('Besloten Vennootschap') were included.

3.3 Analysis of the main survey results

3.3.1 Management practices by adopters

This section focuses on CCC-species, N-fertilisation rates, termination methods etc., combining this information into a kind (or a number) of growing system(s) of CCC per MS. The tables in this section (mostly) count up to 373 observations, being the total number of adopters in the survey. Averages were calculated over all respondents in the sample population, in this case the adopters.

Overall, Italian/Annual ryegrass, white mustard, common vetch/garden vetch/tare/vetch and black/lopsided/bristle oat were the most frequently mentioned CCC-species by the respondents (Table 18). However, there were big differences between the MS in species selection, probably due to e.g. agronomic reasons: which species grow well under the different agro-ecological conditions (climate, soil type, crop rotation)? Remarkably, the French CCC-growers used a wider range of CCC-species than their colleagues in the other three MS. A possible reason could be a more frequent use of mixtures of species in France, but the dataset does not provide information on the use of mixtures.

Table 18. CCC-species (number of farmers) ([1])

	Spain	France	Netherlands	Romania	All
Black/lopsided/bristle oat (Avena strigosa)	1	42	6	3	52
English ryegrass (Lolium perenne)	0	4	16	0	20
Italian/Annual ryegrass (Lolium multiflorum)	0	7	71	0	78
Pearl Millet (Pennisetum glaucum)	0	1	0	0	1
Oil radish (Raphunus sativus)	0	24	5	0	29
White mustard (Sinapis alba)	0	55	5	9	69
Brown mustard (Brassica juncea)	0	13	0	3	16
Egyptian clover/Berseem clover (Trifolium Alexandrinum)	0	32	1	0	33
Blue lupin/narrowleaf lupin (Lupinus angustifolius)	0	0	0	0	0
Red clover (Trifolium pratense)	0	9	3	1	13
Common vetch/Garden vetch/Tare/Vetch (Vicia sativa)	25	34	0	3	62
Serradella (Ornithopus sativa)	0	1	0	0	1
White clover/Dutch clover/ Ladino clover (Trifolium repens)	0	11	1	1	13
Lupin/Lupine (Lupinus species)	0	2	0	0	2
Phacelia (Phacelia tanacetifolia)	0	44	0	0	44
Tartary buckwheat/Green buckwheat/Ku qiao/Bitter buckwheat (Fagopyrum tataricum)	0	16	0	0	16
Tagetes (Tagetes Patula)	0	0	1	0	1
Vila-vila/Sticky nightshade/Red buffalo-bur/Fire-and-ice plant/Litchi tomato/Morelle de Balbis (Solanum sisymbriifolium)	0	0	0	0	0
Corn spurry (Spergula arvensis)	0	0	0	1	1
Other (specify):	6	49	79	69	203
Total	32	344	188	90	654

([1]) No data was collected on the application of mixtures of CCC-species and on the composition of such mixtures.

Some adopters indicated that they grew different species of CCC on their farm, but the data did not show whether they used a mixture of different CCC-species or separate species after e.g. different crops or on different fields with perhaps different characteristics (like soil type). Another reason for the large number of species in France could be a relative high variation in the French study region concerning soil type, water availability or other conditions, requiring different species for optimal performance in terms of dry matter production (above and underground). However, this hypothesis was not tested.

In different MS, there was a large number of respondents who indicated that they grew other species than given in the list (Table 19). This was specifically the case in Romania (88%) and the Netherlands (53%), but also in Spain (23%) and France (41%) quite a share of adopters selected this option during the interview.

Table 19. Number of respondents who indicated that they grew 'other' CCC-species.

	Spain	France	Netherlands	Romania
Number of respondents	6	49	79	69
Share of respondents (%) per MS	23	41	53	88

In the group of 'other species', rapeseed was frequently mentioned as a CCC. In some cases (mainly in Romania), this species was mentioned in combination with mustard or triticale, indicating that a mixture was applied. In most (9) cases of purely grown rapeseed (n=13), the crop was not harvested or too soon to be regarded as a normal main crop. Some adopters mentioned 'cutting rye', which could serve as a fodder crop afterwards.

In Spain, other CCC-species mentioned were alfalfa, rape seed, peas, yero (leguminous) and Carobs (Prosopis juliflora, bean). None of these adopters used CCC-mixtures, at least not from the group of 'other species'. 20% of the French 'other'-respondents indicated that they used more than one CCC-species, but it is not clear whether these were mixtures or not. At least 45 % of the French 'other' respondents used a leguminous crop (e.g. field beans, peas, clover, alfalfa) and 14% used rapeseed as a CCC. Two respondents mentioned that they used mustard as an anti-nematode CCC. Other crops mentioned were radish (Asian, Japanese, daikon, forage), moha, linen, sorghum, soy, buckwheat, febrile and sunflower, millet, white oats and severole.

In the Netherlands, silage maize is harvested during the period September-October. 75% of the respondents 'other' indicated to sow rye (e.g. mentioned rye, winter rye, cutting rye, feed rye, leaf rye) after silage maize. At least 16% of the respondents indicated to sow grass (Italian ryegrass, Tall fescue, Timothy) or a combination (perhaps but not necessarily a mixture) of grass species (mainly English and Italian ryegrass). Mixtures of clover and timothy, of English ryegrass, red clover and timothy and of English and Italian ryegrass were explicitly mentioned.

The cropping plans of the selected Romanian farms mostly contained cereals, rapeseed and protein crops. Almost half of the Romanian 'other'-respondents indicated to grow rapeseed or a combination of rapeseed and another CCC-species. 25% of the adopters grew peas (green peas, fodder peas, yellow pea) as a CCC. Some other adopters mentioned wheat, triticale, oats, mustard, barley and alfalfa (the latter mostly being a main crop, but in this case either not harvested or harvested for selling, which is not necessarily limited to a main crop).

Most CCC-crops were grown after wheat (Spain, France, Romania), barley (France), green maize (The Netherlands) or sunflower (Romania) (Table 20). Other crops that were frequently mentioned as a preceding main crop were potato (12 times), flower bulbs, mostly tulips (6 times, all in the Netherlands), different types of pea (6 times), onions (4 times, all in the Netherlands), sugar beet (3 times, in Spain and France).

Table 20. Main crops under or after which CCC were grown (numbers of farmers)

	Spain	France	Netherlands	Romania	All
Wheat	15	100	4	62	181
Barley	12	57	2	12	83
Green maize / Silage maize	1	5	138	0	144
Grain maize	0	8	0	19	27
Triticale	2	7	0	2	11
Rye	3	3	5	1	12
Oats	2	6	0	2	10
Spelt	0	3	0	0	3
Oilseed rape	1	9	0	12	22
Sunflower	0	3	0	15	17
Soybeans	0	2	0	0	2
Other crop	10	10	17	1	38

CCC were mostly sown after the harvest of the main crop and not undersown (Table 21). Reasons not to apply undersowing were:

- CCC do not fit in certain crops like flower bulbs or potatoes and even green maize can be too high for a CCC;
- Undersowing gives competition between crops;
- Sowing of CCC in an existing crop is not always feasible and/or the farmer needs to have special machinery;
- Starting with a clean soil after the main crop;
- Potential damage of the CCC during harvest of the main crop or when a herbicide is used.

An important reason for undersowing was a lower risk and a higher profitability.

Table 21. Timing of CCC sowing (number of farmers)

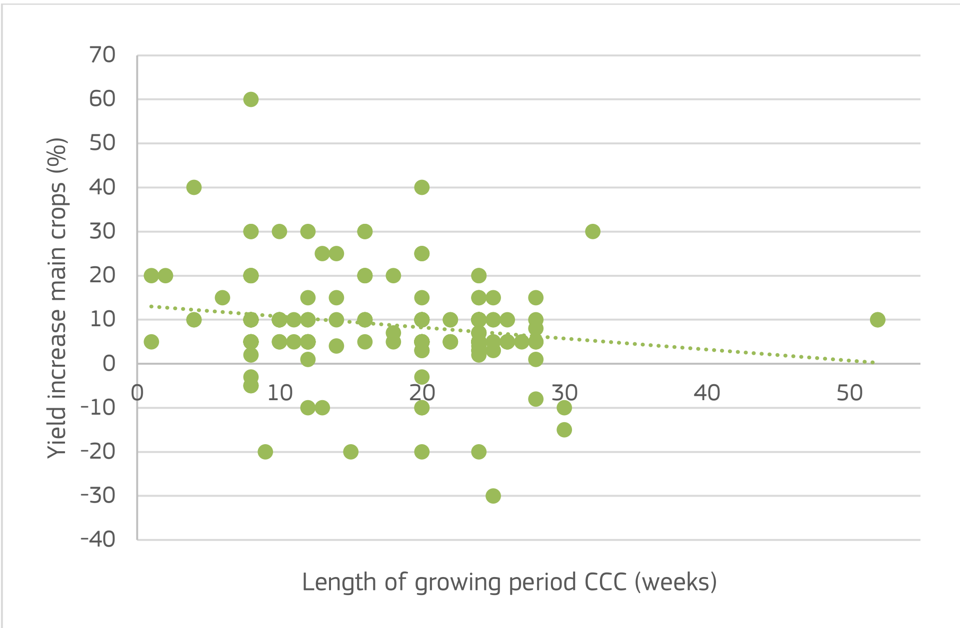
	Spain	France	Netherlands	Romania	Total
After harvest of main crop (aftersowing)	18	112	140	69	339
Into main crop while still growing (undersowing)	3	1	2	0	6
Some after harvest, some into main crop	5	7	7	9	28

On average, the CCC was terminated or harvested after 16 weeks, counted from the sowing date of the CCC (Table 22). In France and Romania this period was shortest, with on average 13 weeks, and in the Netherlands longest, with 21 weeks or almost 5 months. Most of the respondents in the Netherlands grew CCC after silage maize on sandy soils. On such (dairy) farms, silage maize is often grown on the same field for several years. Because the soil is light, ploughing is mostly carried out in March/April, shortly before the next maize crop is sown. As a consequence, the CCC is sown at the end of October or the beginning of November and terminated next March/April, which explains this long growing period. In most other cases, in Spain, France and Romania, the main crop is a winter crop, so that the CCC is sown in July/August and terminated in October/November just before sowing the next winter crop, limiting the growing period to about three months. Under favourable weather conditions, a longer growing period would lead to a higher biomass production of the CCC. However, the relatively long growing period in the Netherlands coincides with the winter period, with relatively low temperatures and radiation intensities. A shorter growing period in the three other MS under generally higher temperatures and radiation intensities could on average lead to a similar or even higher biomass production as in the Netherlands, at least when sufficient water is available. However, it could not be derived from the dataset, that longer growing periods led to higher climate mitigation effects, since no questions were included on the (estimated) biomass production by the CCC. There was even a slightly negative correlation between the length of the growing period of the CCC and its estimated effect on yield increase of the crops in the cropping plan (Table 34, Figure 1), but could be due to a more realistic estimation of such effects by Dutch adopters compared to some adopters in the other MS.

Table 22. Growing period of CCC before termination (or harvest)

	Spain	France	Netherlands	Romania	Average
Weeks after sowing	14.9	13.0	21.5	13.0	16.5

Figure 1. Yield increase of the main crop due to CCC-growing as estimated by adopters and length of the CCC growing period (n=172).



Out of the total group of 373 adopters, 303 applied seedbed preparation (Table 23). When the numbers per MS are compared with the total number of adopters that sow the CCC partly or fully after the harvest of the main crop, then on average 83% of the farmers applied seed preparation. It will be hard (though not impossible) to prepare a seedbed when the main crop is already on the field. 95% of the Dutch adopters applied seedbed preparation after the harvest of the main crop and only 35% of the Spanish colleagues.

Table 23. Application of seedbed preparation for CCC

	Spain	France	Netherlands	Romania	All
Number of farmers	8	87	140	68	303
% of adopters who aftersow (1)	34.8	73.1	95.2	87.2	82.6

(1) Calculated from the sum of respondents who sow the CCC completely or partly after harvest (as presented in Table 21).

On average, 50 kg of CCC-seeds were used per ha (Table 24). The quantity was relatively high in Spain (more than 100 kg/ha) and relatively low in France (27 kg/ha). These amounts highly depend on the species used (Table 18), which have different weights per 1,000 seeds. The price per kg was on average 4.11 euro. The seed cost per ha varied between 50 euro in Romania and 190 euro in the Netherlands. According to the Dutch handbook KWIN, green manures seeds cost between 100 and 250 euro/ha.[10]

Table 24. CCC seed quantity and cost (n=370) (1)

	Spain	France	Netherlands	Romania	Average
Quantity (kg/ha)	101.0	27.5	50.2	66.7	50.0
Price (euro/kg)	4.51	5.72	3.48	2.77	4.11
Costs (euro/ha)	147	85.3	188	49.0	123

(1) Data not entirely reliable and to be interpreted with caution.

On average, not many farmers applied irrigation, N-fertiliser or N from manure or crop protection to CCC (Table 25). Farmers in Spain were an exception, with almost 40% applying irrigation or manure to the crop. This percentage refers to a number of ten respondents for each of the activities, but only three of them applied both irrigation and manure. Four of the ten Spanish farmers that applied manure, had also livestock.

Table 25. Use of irrigation, fertiliser, manure and crop protection in CCC (% of farmers)

	Spain	France	Netherlands	Romania	Average
Irrigation	38	5	2	1	5
N-fertiliser	4	6	8	8	7
N-manure	38	14	13	1	13
Crop protection	4	2	5	14	6

N-fertilisation was only applied by some of the respondents. The estimated N-rate was about 20 kg N/ha, with a relatively high rate in France (more than 40 kg/ha) (Table 26).

10 The data on seed quantity, price and (calculated) cost are not fully reliable because of potential misunderstandings that occurred during the interviews and resulting outliers that could not be entirely resolved by re-contacting farmers and data cleaning.

Table 26. N-rates applied in CCC (1)

	Spain	France	Netherlands	Romania	Average
Amount of fertiliser (kg/ha)	50.0	62.5	44.1	90.0	49.8
Amount of N applied (kg/ha) (2)	2.0	43.3	15.7	16.2	22.6

(1) n=1 for Spain, 4 for France, 9 for the Netherlands, 1 for Romania; 12 other adopters also applied N-fertilisation, but did not know how much and/or with which N-content.
(2) The Nitrogen-contents listed seemed not to be very accurate, which makes these N-rates not very reliable. The amounts for Spain and Romania are based on only one respondent.

Most adopters (almost 80% of the interviewed group) did not harvest CCC (Table 27). More than half of the Spanish adopters indicated that they harvested CCC to sell it, for own use or for fodder. There may be a link with the figures in Table 25, indicating that 38% of the Spanish adopters used manure on the CCC. They had either livestock themselves (4 out of 10 respondents) or a close relationship with a livestock farmer. This could explain for both the application of manure and the harvest of fodder among the Spanish adopters. In Romania, a third of the farmers did this. In France and the Netherlands about 10% harvested CCC for fodder.

Table 27. Shares of farmers that do not harvest CCC or do harvest it for certain purposes (%) (1)

	Spain	France	Netherlands	Romania	All
No harvest	54	80	88	69	79
Harvest for selling	15	6	0	19	7
Harvest for own use	15	4	3	10	6
Harvest for fodder	31	12	9	3	10
Harvest for bioenergy	0	2	0	1	1
Other	0	3	1	1	2

(1) The total percentages per MS can exceed 100 because multiple answers were possible.

When a farmer does not harvest CCC, there must be another way of termination of this crop, since after a while a new main crop needs to be planted. Ploughing was the most common way for termination (62%), especially in Spain and Romania (Table 28). 43 out of 45 farmers that applied a herbicide for CCC termination, indicated that they used glyphosate for that. The category 'other' contained mostly mechanical methods in addition to plough and roller/crimper. The method applied has an effect of the net C-sequestration rate and probably needs more attention (see Annex 1).

Table 28. Termination method (% of farmers) (1)

	Spain	France	Netherlands	Romania	Average
Plough	79	63	50	83	62
Herbicide	14	8	27	0	15
Roller/crimper	0	8	4	0	4
Frost	0	13	3	0	5
Mowing	7	1	3	0	2
Mulching	0	2	0	0	1
Other (2)	7	25	37	30	31

(1) The total percentages per MS can exceed 100, because multiple answers were possible.
(2) The most frequently mentioned other methods were cultivator, disc harrow and grinding.

Most farmers carried out the activities related to CCC out by themselves or by other family members or employees on the farm (Table 29). In the Netherlands, relatively many farmers made use of contract work, mainly because a large number of them were dairy farmers without specialized machinery for crop growing. On average, 3.4 labour hours per ha were spent to CCC, varying between 2.4 hours per ha in the Netherlands and 6.3 hours per ha in Spain. The overall cost per ha varied between less than 100 and more than 175 euro/ha in France and Spain, respectively, with an average of 144 euro/ha.

Table 29. Total labour input, contract work and total cost of all inputs related to CCC

	Spain	France	Netherlands	Romania	Average
Labour input (hours/ha) (1)	6.3	2.7	2.4	5.6	3.4
Contract worker hired (% of farmers) (2)	4	6	38	3	18
Cost of all inputs (euro/ha) (3)	177	94	173	153	144

(1) Overall number of person labour hours of hired workers and unpaid workers (farmers and family members), including all operations (seedbed preparation, sowing, application of fertiliser/manure, plant protection, irrigation, fuel, harvest and termination).
(2) Share of farmers that hired a contract worker for one or more activities.
(3) The cost for all the inputs (seeds, fertiliser/manure, pesticides, water) and all the operations related to CCC per ha (seedbed preparation, sowing, application of fertiliser/manure and plant protection, irrigation, fuel, harvest and termination, including contractors).

The overall picture of farming systems with CCC is that a CCC is grown after wheat, barley, silage maize or sunflower. The most popular species are Italian/Annual ryegrass, white mustard, common vetch/garden vetch/tare/vetch and black/lopsided/bristle oat. In most cases the CCC is sown after the harvest of the main crop, after a seedbed preparation. The adopters mostly do not apply irrigation, N-fertilisation or N from manure nor crop protection. The CCC is in most cases not harvested but ploughed or terminated with glyphosate. Most farmers carry out the activities related to CCC by themselves or by other family members or employees on the farm. Those activities took about 3.5 hours and the total costs of labour, contract work and inputs amounted to about 150 euro/ha.

An overall view of the data showed that farmers within a region applied more or less the same ways to grow and handle CCC:

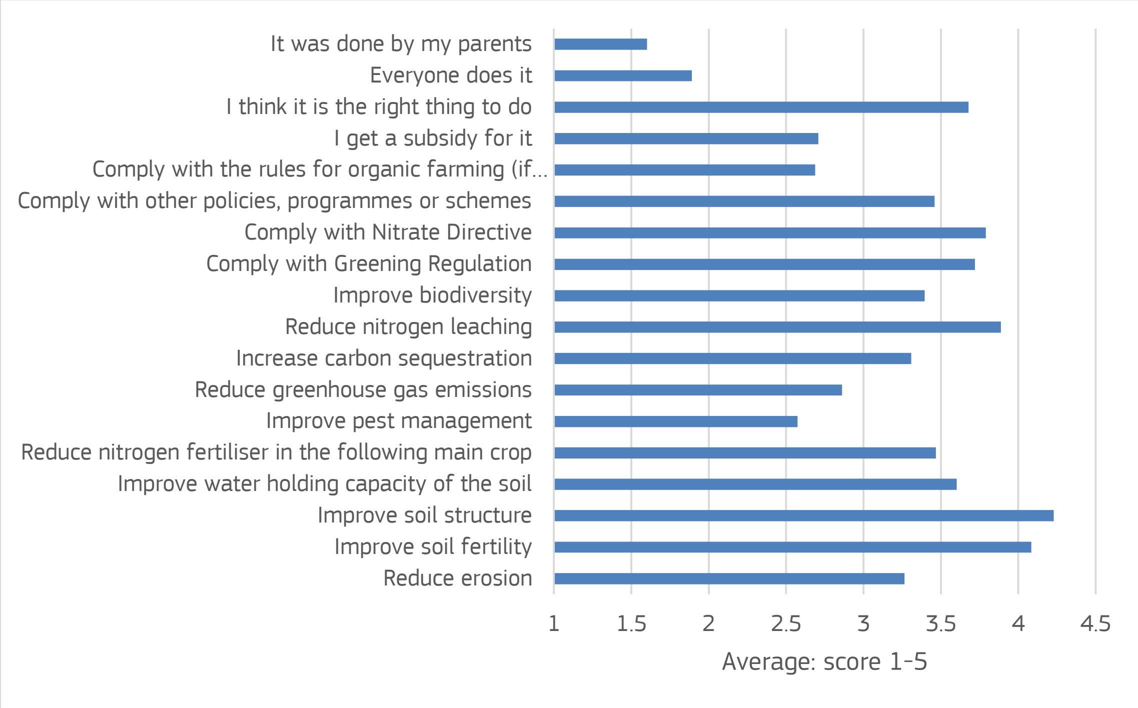
- In Spain, the CCC-concept was not very well known. Common vetch was the most applied CCC-species, mostly after cereals but in some cases after sugar beet or potato. Part of the CCC was undersown. Irrigation and N-manure were often applied, but seedbed preparation, N-fertiliser or crop protection were not frequently mentioned. Half of the Spanish adopters did not harvest the CCC and the other half harvested it for selling, for own use or for fodder. The majority of adopters ploughed the CCC;

- In France, unlike the other regions in the survey, a wide variety of CCC-species was applied. Black oat (Avena strigosa), white mustard (Sinapis alba), common vetch (Vicia sativa) and Phacelia were most frequently mentioned, which were mostly sown after (the harvest of) wheat and barley. The French farmers were in general well informed about the CCC-concept. Most farmers applied seed bed preparation, but irrigation, N-fertilisation, N-manure and crop protection were not often applied. Contrary to the other three regions in the survey, the few French adopters who applied N-fertilisation, did that in a relatively high rate (40 kg/ha). The large majority of French adopters did not harvest the CCC, although some harvested the crop for fodder. 60% of the CCC-growers terminated the crop through ploughing, a quarter through a different mechanical form and the others through a herbicide or frost.
- All Dutch respondents knew the CCC-concept, probably (also) because most of them grew green maize on sandy soils as a part of their fodder production for their dairy herd. Thus, they had to comply with the Nitrate Directive to grow a CCC after the maize and they did that mostly after harvest. Half of them grew Italian or English ryegrass and the other half (cutting) rye, providing them (however only 10% really did that) the opportunity to harvest fresh green fodder in early spring, just before the next green maize crop would be sown. This practice led to a relatively long CCC-period on the field compared to the three other regions in the survey. Irrigation, N-fertilisation, N-manure and crop protection were not often applied, but all adopters applied seedbed preparation, which was logical after a harvest with relatively heavy harvester machinery in a relatively wet season (at least in the Netherlands). Half of the CCC-growers terminated the crop through ploughing, a quarter through a different mechanical form and the others through a herbicide.
- Finally, in Romania, not all farmers knew the concept of CCC-growing, although quite a share of the adopters did so as an obligation by the Romanian Agency for Payments and Intervention for Agriculture (APIA). Rapeseed and green peas were the most frequently applied CCC-species, after (the harvest of) wheat or (sometimes) sunflower and after a seedbed preparation. Like in the other regions, irrigation, N-fertilisation, N-manure and crop protection were not often applied. The majority of adopters did not harvest the crop, but almost 30% harvested the crop for selling or own use. More than 80% of the adopters in Romania ploughed the CCC afterwards and the others applied a different form of mechanical termination.

3.3.2 Opinions of adopters on CCC

Besides management practices and inputs, the opinions of the (373) adopters were asked for in the questionnaire. Figure 2 shows the importance of different possible reasons for growing a CCC. 'Improve soil structure', 'improve soil fertility' and 'reducing nitrogen leaching' received the highest scores. 'It was done by my parents' and 'Everyone does it' were the least popular reasons. 'Increase carbon sequestration' and 'Reduce nitrogen leaching' did not receive high scores. Compliance with the Nitrate Directive and the Greening obligations were relatively important reasons.

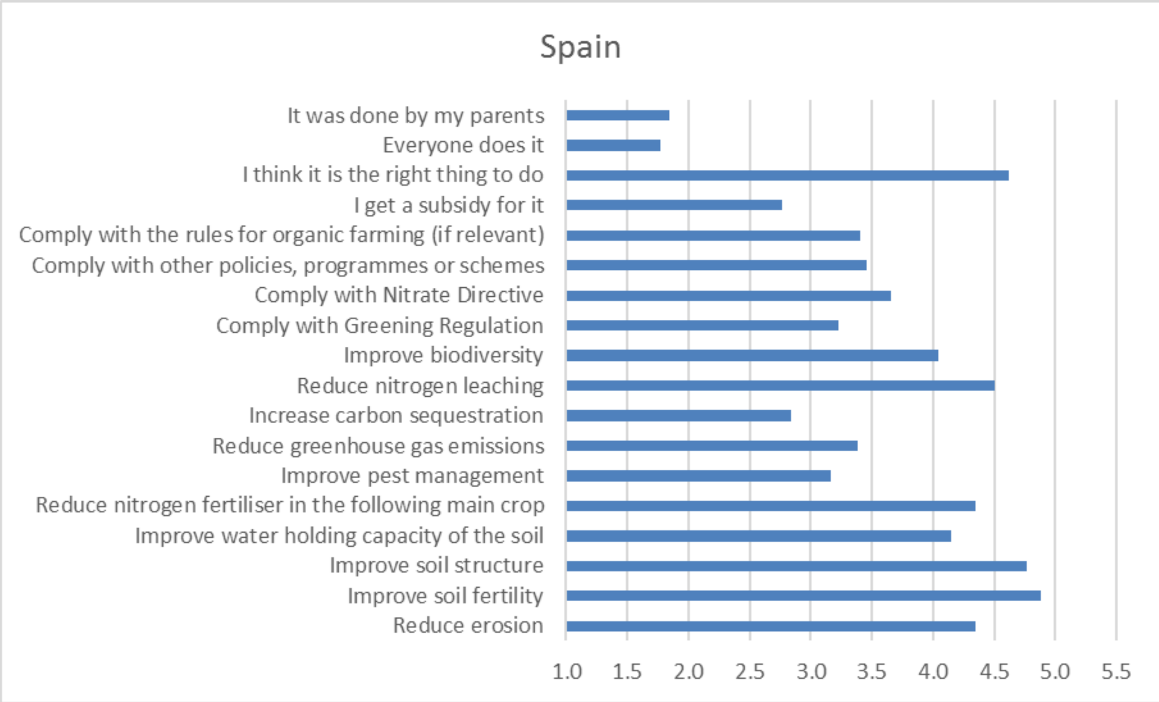
Figure 2. Importance of different possible reasons for growing CCC (all MS)



Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

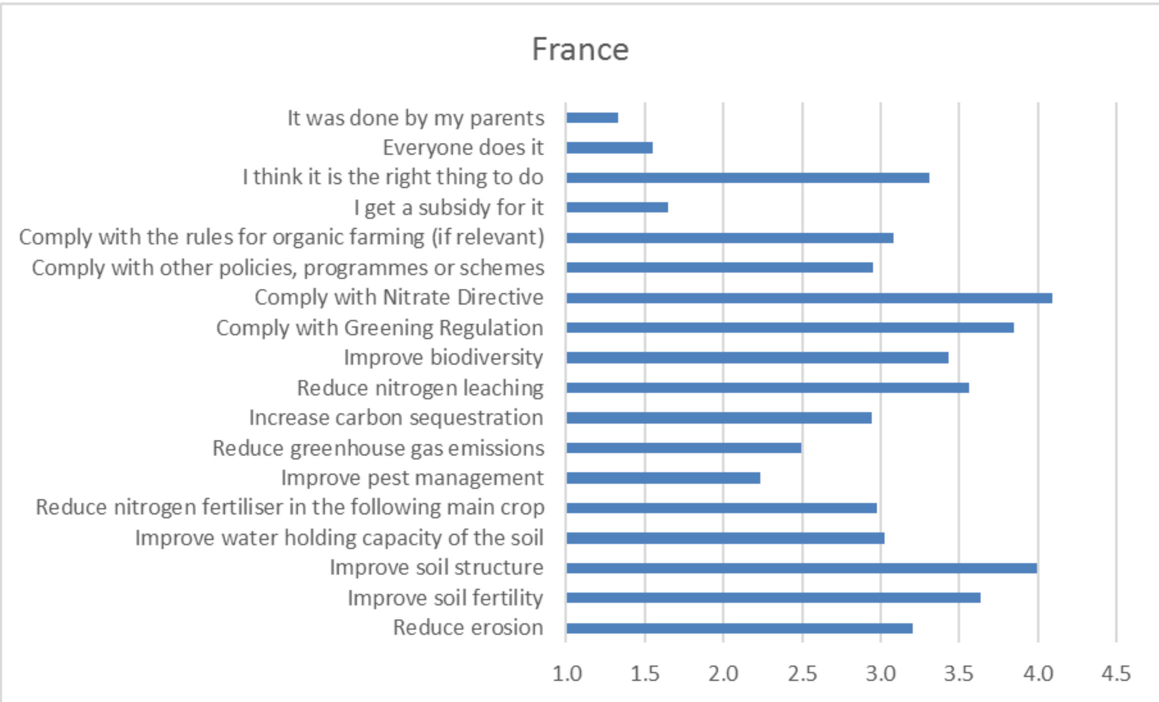
In Figure 3 – Figure 6, the reasons for growing a CCC are presented for the four MS. In Spain, the highest scores were similar to those for the survey as a whole. Also 'I think it is the right thing to do' received a high score (Figure 3). Subsidies, carbon sequestration, pest management and greenhouse emissions were not important as a reason to grow a CCC. In France, again soil structure and soil fertility scored high values, but also compliance with the Nitrate Directive and with the Greening Regulation were important reasons (Figure 4). Also for the French adopters, subsidies, carbon sequestration, pest management and greenhouse emissions were not important. The adopters in the Netherlands mostly responded 'Improve soil structure', 'improve soil fertility', 'reducing nitrogen leaching' and 'I think it is the right thing to do' (Figure 5). Compared to the other MS, 'Increase of carbon sequestration' received a relatively high score. In Romania, receiving a subsidy was indicated as the most important reason to grow a CCC (Figure 6). All other reasons scored relatively high as well, except 'Everyone does it' and 'I think it is the right thing to do'.

Figure 3. Importance of different possible reasons for growing CCC (Spain)



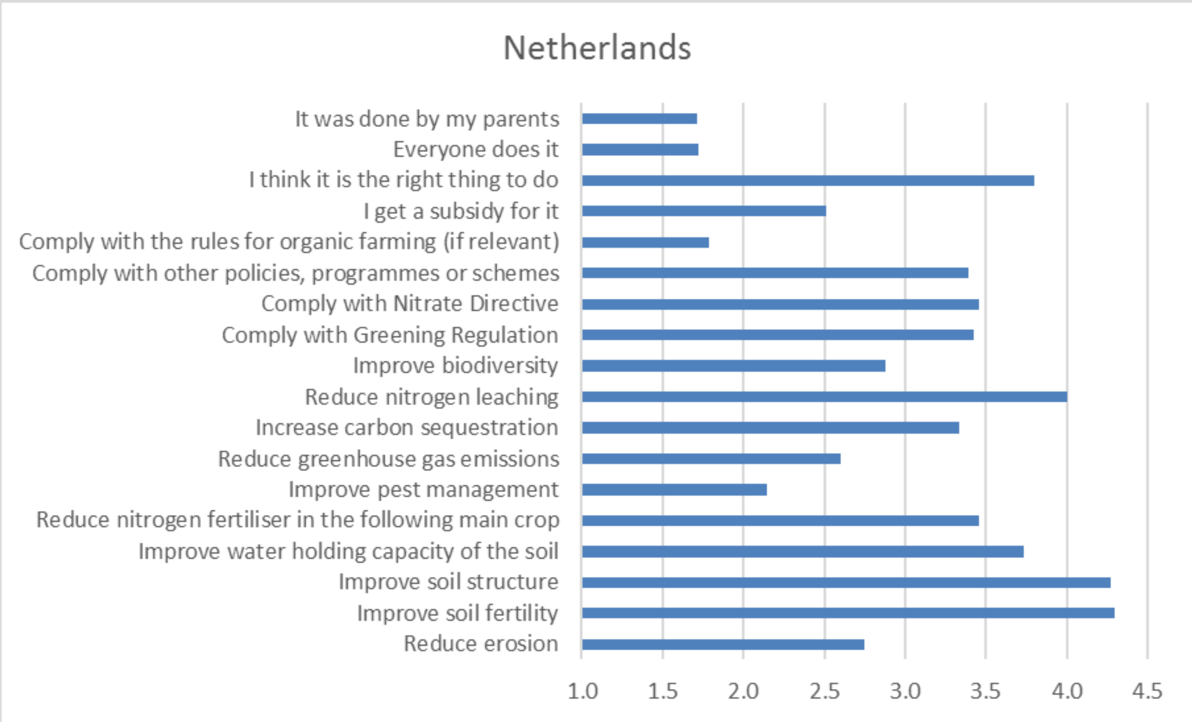
Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 4. Importance of different possible reasons for growing CCC (France)



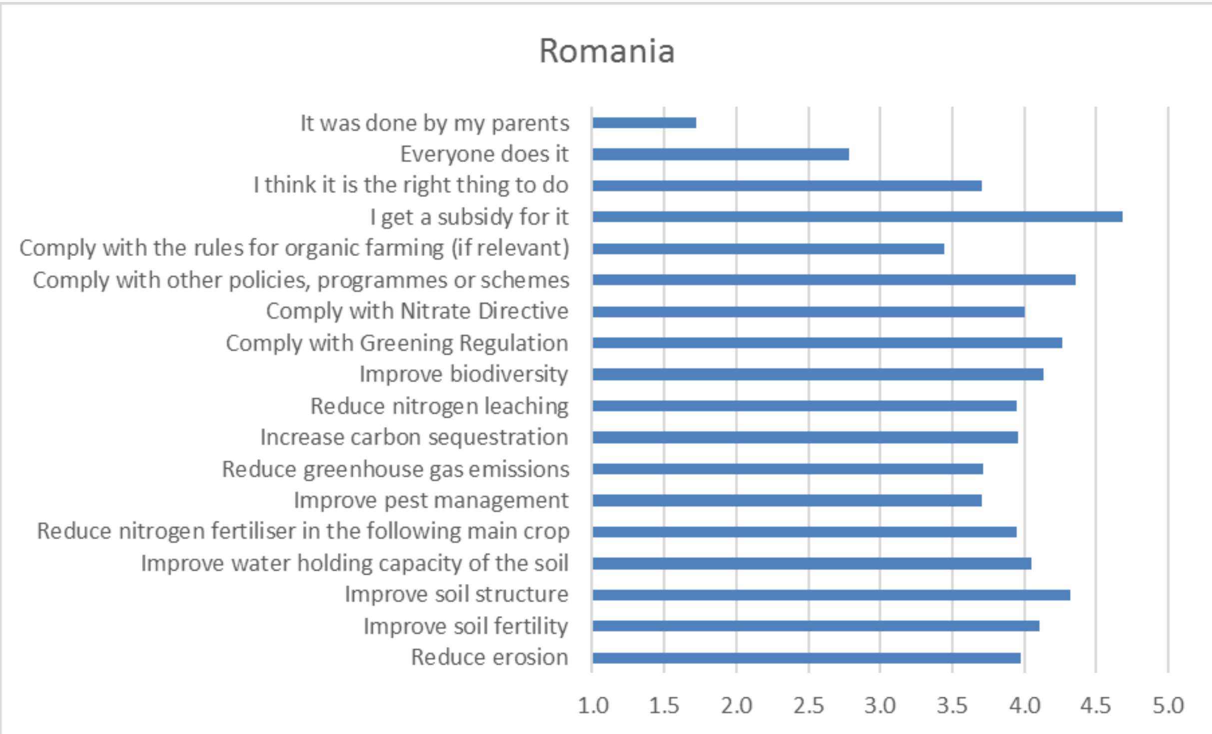
Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 5. Importance of different possible reasons for growing CCC (Netherlands)



Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

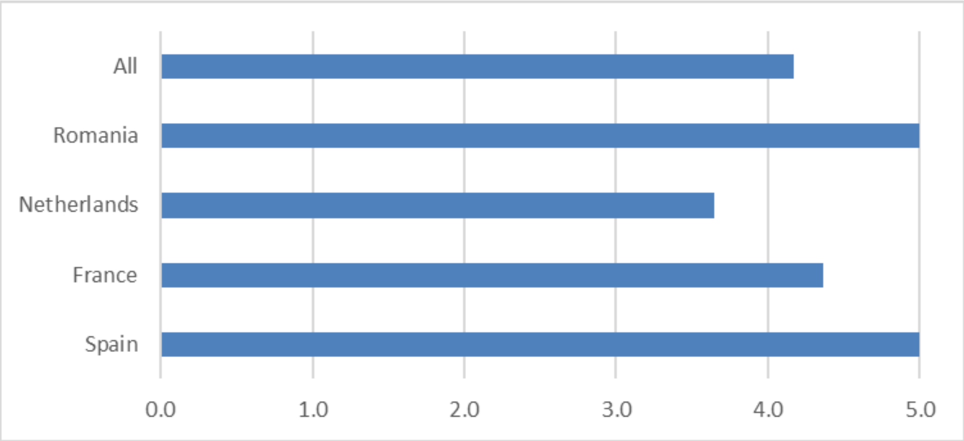
Figure 6. Importance of different possible reasons for growing CCC (Romania)



Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Besides the reasons in Figure 2 – Figure 6, 47 adopters mentioned other reasons. Quite a number of these reasons were more or less the same as in the figures (but were not included in Figure 2 – Figure 6). Other reasons were harvest of fodder for livestock, improvement of the landscape (also for tourism) and biodiversity, the latter for stimulating beekeeping, wildlife and hunting. The Romanian and Spanish adopters evaluated these other reasons as extremely important (Figure 7).

Figure 7. Importance of other reasons to grow CCC



Although there seem to be sufficient reasons to grow CCC, about 44% of the adopters indicated that there are problems or risks that limit them from growing CCC on a larger area (Table 30) and even 58% in France. Problems and risks that are mentioned were: lack of water after sowing the CCC or, on the contrary, that it can be too wet to sow after the harvest of the main crop or terminate it in spring, lack of time, a low benefit compared to the costs of the seeds and of the cultivation, a low yield of the CCC after a late harvest of the main crop, late sowing of the next main crop, rotation problems, a possible ban on glyphosate and lack of water for the next main crop.

Table 30. Adopters facing problems or risks that prevent CCC cultivation on a larger area

	Spain	France	Netherlands	Romania	Average
% of adopters	30.8	57.5	48.3	19.2	44.0

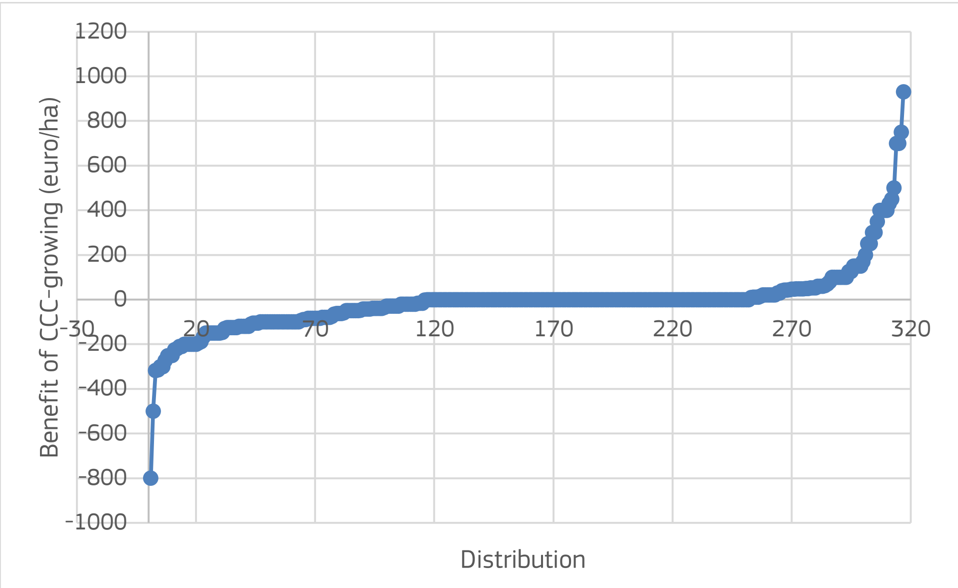
The respondents were asked whether they made or lost money through growing CCC. A third of the adopters interviewed did not estimate a benefit or a loss, another third estimated a benefit and the remaining third estimated a loss (Table 31). Only 15% of the French adopters estimated a benefit, whereas more than 40% of the Dutch and Spanish adopters in this group estimated a benefit. More than 46% of both the French and Romanian adopters estimated a monetary loss. The average benefit (154 euro/ha) was lower than the average loss (194 euro/ha). Especially the Spanish (234 euro/ha) and Dutch farmers (269 euro/ha) estimated high monetary benefits. Weighted totals over shares of farmers with an estimated plus or loss and the respective amounts led to net positive benefits per ha in Spain and the Netherlands and to net losses per ha in France and Romania. The net loss over all adopters involved was 16 euro/ha. Figure 8 shows that the variation in estimation is high. The large majority of adopters estimated no effect or a benefit or loss below 200 euro/ha, but some adopters estimated even benefits or losses of more than 800 euro/ha. More research would be required to find out the adopters' ideas behind such different (and sometimes extreme) values and to present more realistic data for a more fact-based evaluation of the CCC-concept by farmers.

Table 31. Estimated monetary benefit or loss from CCC cultivation (adopters)

	Spain	France	Netherlands	Romania	Average
Monetary benefit (% of farmers)	46.2	15.8	41.6	32.1	31.6
Monetary loss (% of farmers)	30.8	46.7	16.1	46.2	33.2
No monetary benefit or loss (% of farmers)	23.1	37.5	42.3	21.8	35.1
Amount of benefit or loss ([1])					
Money made (euro/ha)	234	101	269	40	154
Money lost (euro/ha)	133	91	185	356	194
Weighted total average (euro/ha) ([2])	67	-26	82	-152	-16

([1]) When relevant, i.e. the average benefit per MS is given from the adopters that indeed estimated a monetary benefit and similarly for the ones who estimated a loss.
([2]) Calculated as the product of the share of adopters estimating a benefit and the estimated benefit minus the product of the share of adopters estimating a loss and the estimated loss. Differences in CCC-acreages between farmers were not taken into account in this calculation.

Figure 8. Distribution of estimated monetary benefits (adopters)



Note: n=317, 56 adopters did not know an answer.

The adopters with a positive estimation of monetary effects, mentioned as reasons:

- Saving nitrogen in the next crop;
- A higher productivity of the next main crop;
- A higher organic matter content in the long term;
- A healthier soil, better soil quality and a better start for the next crop;
- Receiving a subsidy or avoiding a fine;
- Providing or sales of fodder;
- Soil coverage instead of a bare soil;

- Crop diversification in a monoculture.

The adopters with a negative estimation of monetary effects, mentioned as reasons:

- There is no harvest;
- The costs of seeds, tillage, sowing and/or spraying are higher than the yield gain next year and the saving of nitrogen;
- The money spent is lost when the sowing season is too dry;
- There is too little time and hard to carry it out in the right period;
- No subsidies (in particular cases probably);
- A CCC could benefit wildlife and stimulate swine fever.

Both groups mentioned that the estimated benefit or loss greatly depends on the weather.

Besides monetary effects, non-monetary advantages and disadvantages were asked for. About half of the farmers estimated that these advantages and disadvantages would be more or less the same (Table 32). The majority of the other half estimated the non-monetary disadvantages to be greater than the advantages. This share was especially high in Spain. Non-monetary advantages mentioned were mainly the same as the monetary benefits, but there were some additional answers like 'good for the atmosphere', 'biodiversity/wildlife', 'good for the environment', 'more colourful landscape', 'lower weed and disease pressure', 'soil life' and 'less leaching'. The non-monetary disadvantages were similar to those mentioned under the monetary losses, with weather conditions making it hard to fulfil the obligation as a major remark.

Table 32. Non-monetary advantages of CCC-growing greater or smaller than non-monetary disadvantages (adopters)

	Spain	**France**	**Netherlands**	**Romania**	**All**
Greater (% of farmers)	0	3.3	2.7	10.3	4.3
Smaller (% of farmers)	65.4	32.5	52.3	39.7	44.2
More or less the same (% of farmers)	34.6	64.2	45.0	50.0	51.5

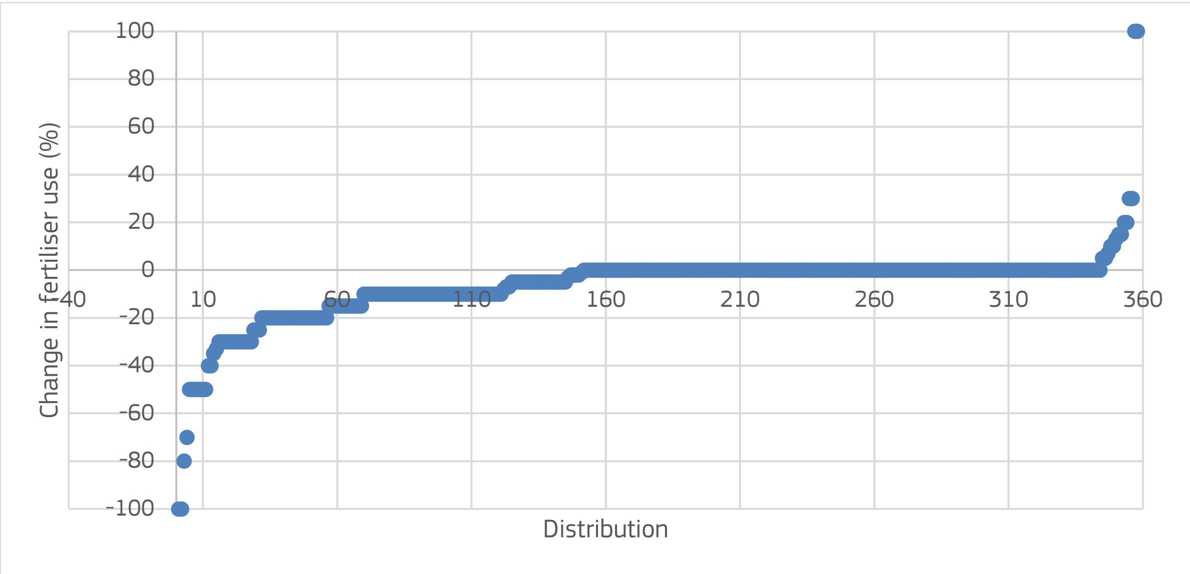
On average, only 4% (10% in Romania) estimated a higher fertiliser need across all CCC and main crops due to CCC-growing (Table 33). Half of the adopters did not estimate any effect and 40% estimated a lower amount of fertiliser. Especially the Spanish adopters (almost two thirds) estimated a lower N-rate. The farmers who estimated an increase of nitrogen fertiliser use estimated an increase of 27%. The other group estimated a decrease of 17%. Weighted totals over shares of adopters with an estimated increase or decrease and the respective amounts led to a net decrease of N-fertiliser use by almost 7% over all adopters. Such a decrease was estimated for all four MS, with the highest decrease in Spain (almost 15%). The large majority of adopters estimated an unchanged fertiliser use or a decrease up to 10%, but some adopters estimated that either the fertiliser use could be decreased by 100% (no fertiliser use anymore) or, on the contrary, doubled (Figure 9). Here again, additional research and dissemination is required to give farmers a more fact-based idea of what effects CCC-growing could have.

Table 33. Estimated CCC effect on fertiliser need of following main crop (adopters)

	Spain	France	Netherlands	Romania	Average
Higher (% of farmers)	0	3.3	2.7	10.3	4.3
Lower (% of farmers)	65.4	32.5	52.3	39.7	44.2
More or less the same (% of farmers)	34.6	64.2	45.0	50.0	51.5
Estimated effect (%)					
More fertiliser	N.A.	22.5	11.3	36.3	27.1
Less fertiliser	22.1	20.5	12.3	24.8	17.5
Weighted total average ([1])	-14.5	-5.9	-6.1	-6.1	-6.6

([1]) Calculated as the product of the share of adopters estimating a higher fertilisation rate and the estimated rate increase minus the product of the share of adopters estimating a lower fertilisation rate and the estimated rate decrease. Differences in CCC-acreages between farmers were not taken into account in these calculations.

Figure 9. Distribution of estimated change in fertiliser need of main crop (adopters)



Note: n=358; 15 adopters indicated they did not know an answer.

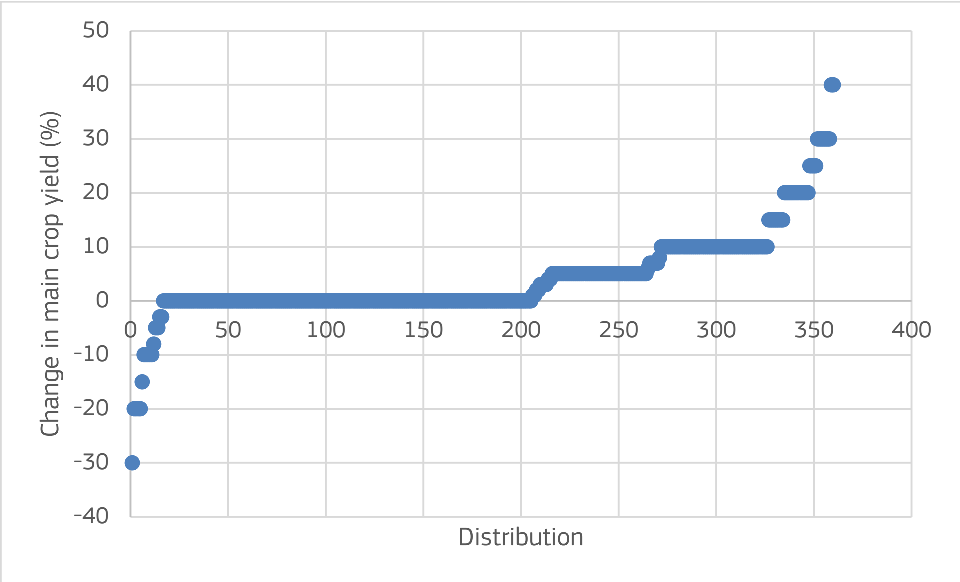
About half of the adopters interviewed estimated a more or less similar crop yield due to CCC-growing (Table 34). In France, this share was even 80%. Only few adopters estimated a lower yield and 45% estimated a higher yield. Especially the Spanish (almost 90%) and the Dutch farmers (two thirds) were in that category. It is remarkable that relatively high shares of Spanish and Dutch adopters estimated both a higher crop yield and a lower fertiliser need (Table 33). The Spanish growers mainly grew N-fixing CCC-species: Common vetch/garden vetch/tare/vetch (Vicia sativa), peas and alfalfa, which explains for their indication of a lower (N-)fertiliser need (Table 18). Those who estimated a higher yield, estimated a yield increase of about 10%. However, this estimation is too optimistic; 2-5% is more common (at least in the Netherlands; D. van Balen, WUR, pers. comm., 2012). The farmers with a negative estimation on crop yield indicated on average a decrease by 12%. Taking all these effects into account the total weighted yield increase could be 4%, varying between 1% in France and more than 15% in Spain. Such estimations could be translated into gross margin increases and in most MS such a calculation would show that the monetary benefits of growing a CCC are higher than the costs. The distribution in yield effects estimated is shown in Figure 10. The large majority of adopters estimated an unchanged yield or an increase or decrease up to 10%, but some adopters estimated an increase of 30% or more or, on the contrary, a yield decrease up to 30%.

Table 34. Estimated CCC effect on yield of following main crop (adopters)

	Spain	**France**	**Netherlands**	**Romania**	**Average**
Higher yield (% of farmers)	88.5	13.3	67.8	35.9	45.0
Lower yield (% of farmers)	0	6.7	2.7	5.1	4.3
More or less the same (% of farmers)	11.5	80.0	29.5	59.0	50.7
Estimated effect (%)					
Higher yield	17.8	11.5	8.5	11.4	10.6
Lower yield	N.A.	11.0	12.0	15.8	12.4
Weighted total average effect ([1])	15.7	0.8	5.4	3.3	4.2

([1]) Calculated as the product of the share of adopters estimating a higher yield and the estimated yield increase minus the product of the share of adopters estimating a lower yield and the estimated yield decrease. Differences in CCC-acreages between farmers were not taken into account in this calculation.

Figure 10. Distribution of estimated yield effect on following main crop (adopters)



Note: n=360; 13 adopters did not have an answer to this question.

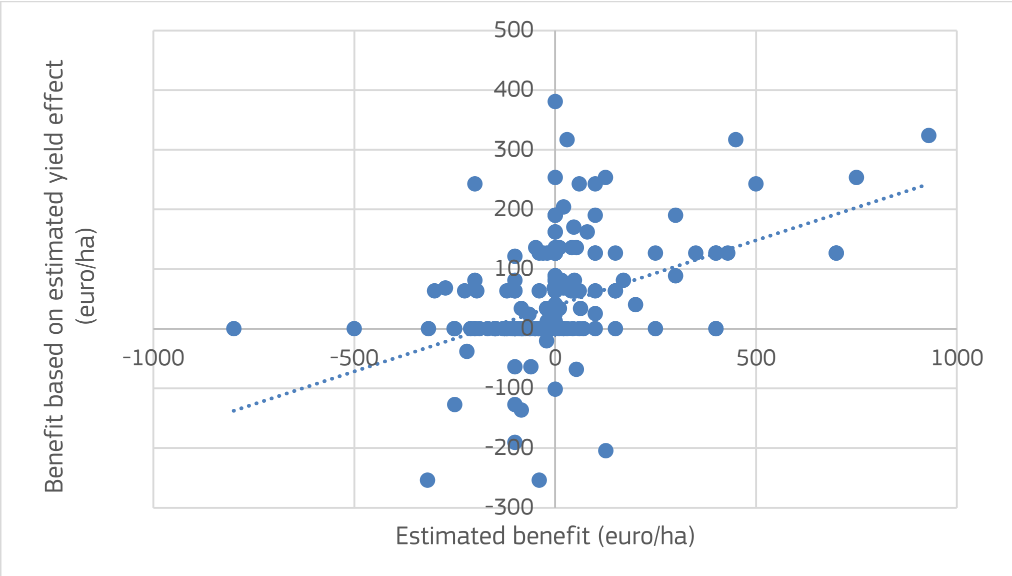
The estimations of yield change due to CCC-growing were cross-checked with the estimations of benefits or losses. To make this possible, the yield changes (in %) were multiplied with the average cereal yield in the specific region and the wheat bread price in the specific MS. The average cereal yields for each NUTS2-region in the EU were collected and the wheat prices were calculated as the average of 12 monthly values in 2018 as published by the EU (EC, 2018). These assumptions are presented in Table 35 and the results of this comparison are given in Figure 11. Overall, a positive correlation was found between the estimation of the benefit or loss on the one hand and the estimation of the yield (i.c. the crop revenues) on the other. However, there were quite a number of adopters who did not estimate a benefit or loss but at the same time estimated a yield increase (mostly) or a decrease (dots on the Y-axis). Further research could be carried out to assess whether these farmers estimated an increase of cost of the same size as the increase in revenues from higher crop yields. There were also quite a number of adopters who did estimate a benefit or loss but no yield effect (dots on the X-axis). Although yield effects could be dominant in the consequences of CCC-growing, other variables like costs and subsidies must have played a role in their benefit or loss estimation.

Table 35. Cereal yields and bread wheat prices in the case study regions

Region	Regional cereal yield (t/ha)	National bread wheat price (€/t)
Castile and León, Spain	4.29	189
Centre, France	7.04	180
Overijssel, the Netherlands	7.67	182
Sud – Muntenia, Romania	4.28	159

Source: Annex 1 and EC (2018). For the Netherlands, price was not available; instead, the price for Germany was used.

Figure 11. Relation of estimated yield effect benefit to estimated benefit (adopters)



Note: n=306; 67 adopters did not give an answer to one or both questions. R^2=0.43.

Overall, 70% of the adopters estimated an increase in soil organic matter or soil carbon due to CCC-growing (Table 36). The percentage was especially high in the Netherlands (almost 80%) and Spain (almost 90%) and relatively low in Romania (less than 50%). Only few farmers estimated a decrease and the remaining group did not estimate a clear effect. Perhaps management of soil organic matter receives less attention in the agricultural knowledge system in Romania than in the other three MS, as a possible explanation for the relatively low percentage in that MS. The overall estimated increase was on average 6.1 % per year. The Romanian and Spanish adopters with a positive estimation of soil organic matter content due to CCC-growing estimated an increase of 14%. The French and Dutch adopters in this group only estimated an increase of about 4%. Assuming a current soil organic matter content of 2.5%, according to the French and Dutch adopters, it would take 10 years of CCC-growing to increase that percentage to 3.5%. In the view of the Romanian and Spanish adopters, such an increase would take only 3 years.

Table 36. Estimated CCC effect on soil organic matter / soil carbon (adopters)

	Spain	France	Netherlands	Romania	Average
Increase (% of farmers)	88.5	70.0	78.5	48.7	70.2
Reduce (% of farmers)	3.8	2.5	2.0	0.0	1.9
More or less the same (% of farmers)	7.7	27.5	19.5	51.3	27.9
Estimated effect (% per year) (1)					
Increase	13.9	3.5	4.4	13.9	6.1
Decrease	N.A.	N.A.	5.0 (2)	N.A.	N.A.

(1) Increase and decrease could also be answered in t/ha/year, but few adopters made use of that option. Many adopters did not have any idea which increase or decrease to estimate: 147 out of 262 of those who estimated an increase, and 6 out of 7 who estimated a decrease;
(2) There was only one adopter who answered this question. As a consequence, total weighted averages could not be calculated.

Most CCC-adopters in the survey (almost 75%) indicated that CCC was mandatory for them and for 20% it was voluntary (Table 37). Only in Spain, the share of voluntary CCC-growing was much higher than elsewhere.

Table 37. CCC mandatory or voluntary under policies/schemes (number of adopters) (1)

	Spain	France	Netherlands	Romania	Average
Mandatory	9	83	128	68	288
Voluntary	16	38	12	9	75
Neither mandatory nor voluntary	1	10	9	4	24

(1) Mandatory and voluntary in this table have to be understood as 'according to some schemes and/or policies'. The third answer option refers to adopters who grow CCC without an obligation or stimulus from a scheme or policy.

The schemes and policies mentioned under this item were:

- CAP (Common Agricultural Policy), specifically the Greening requirement (90 times) and agro-environmental measures (10 times);
- Derogation (86 times), often combined with the Nitrate Directive (12 times), a typically Dutch policy (see explanation below);
- APIA (56 times), who are e.g. involved in application of agro-environmental measures (cross-compliance and good agricultural practice including measures against soil degradation, part of the second CAP pillar).

Almost 80% of the adopters indicated that they grew CCC to comply with the Greening obligation (Table 38). Half of them also had other reasons besides this obligation. Almost all Romanian adopters saw CCC as such and the great majority of them (86%) had no other reason than compliance with this obligation.

Table 38. CCC cultivation in relation to the Greening (Ecological Focus Area) obligation (% of farmers)

	Spain	France	Netherlands	Romania	All
Yes, I grow CCC to fulfil the Ecological Focus Area obligation in order to receive subsidies and only for that reason	50.0	42.5	13.4	85.9	40.5
Yes, I grow CCC to fulfil the Ecological Focus Area obligation, but also for other reasons	30.8	37.5	52.3	12.8	37.8
No, I grow CCC not to fulfil the Ecological Focus Area obligation. I fulfil the Ecological Focus Area obligation with other Ecological Focus Area measures	3.8	6.7	4.0	0.0	4.0
No, I grow CCC not to fulfil the Ecological Focus Area obligation, and also I do not fulfil the Ecological Focus Area obligation (with any other measure)	3.8	1.7	0.0	0.0	0.8
No, I grow CCC but Ecological Focus Area is not an obligation for my farm	11.5	8.3	21.5	1.3	12.3
No, I grow CCC because of other subsidies or obligations unrelated to Greening	0.0	3.3	8.7	0.0	4.6

In the Netherlands, half of the farmers had other reasons for CCC besides the Greening obligation. Apart from that, 149 out of the 151 Dutch adopters held livestock (mainly dairy cows), meaning that in most cases they had at least 80% of their land used as grassland; the remaining 20% was arable land, mainly used for green maize growing. At least 100 of them had less than 15 ha of arable land and did not have the Greening obligation; however, they had to deal with the Nitrate Directive. According to this Directive, farmers have to grow a CCC after green maize on sandy or loess soils. In the total group of adopters in the four MS, only 15% of the farmers interviewed did not have this Greening obligation.

In the case that the Greening (Ecological Focus Area) obligation would no longer include CCC as an option, more than half of the adopters said they would grow the same amount of CCC (Table 39). This share was highest in the Netherlands (almost three quarters) and lowest in Romania (almost a quarter). One third of the farmers in France and Romania would grow less CCC and overall, 20% would stop growing CCC fully. This share was highest in Romania (more than 40%), which is in agreement with their attitude according to Table 38. The high rate of willingness among the Spanish adopters is remarkable, since half of the adopters had indicated, that they only grew CCC to comply with the regulation and to receive subsidy. These answers seem contradictory. It is not clear whether the Spanish adopters fully understood the question and/or the consequences of the scenario without Greening obligations, i.e. that the Greening payments would also stop (or linked to other (obligatory) measures).

Table 39. Area of CCC cultivation without CCC as EFA option

	Spain	France	Netherlands	Romania	Average
Same amount	73.1	48.3	73.8	24.4	55.2
Less	7.7	33.3	16.8	34.6	25.2
None	19.2	18.3	9.4	41.0	19.6

Only a small minority of adopters (4%) received additional subsidies for growing CCC, in most cases as a subsidy per ha of CCC (Table 40). The amount paid was on average 154 euro/ha, but varied between 55 euro in France and almost 250 euro in Spain. In this group of 16 adopters, 13 persons indicated that this subsidy was CAP-related, partly from greening, but also from agro-environmental measures or the young farmers policy. Other policies mentioned were APIA's agro-environmental measures/payments (see above) and 'water basins'. 10 out of the 16 adopters for which this subsidy applied, indicated that they would grow the same amount of CCC without this additional subsidy.

Table 40. Additional subsidies for growing CCC

	Spain	France	Netherlands	Romania	Average
Additional subsidy (% of adopters)	7.7	3.3	5.4	2.6	4.3
Subsidy per ha of CCC (% of adopters)	100	50.0	87.5	100	81.3
Amount (€/ha)	244	55.0	110	169	154

The adopters were also asked whether they estimated a positive effect on the environment and climate change mitigation. Overall, almost 70% estimated a positive effect of CCC on environment but only 40% on climate change mitigation (Table 41). 30 and 60% did not estimate any effect on environment and climate change mitigation, respectively. Almost no adopter estimated a negative effect. Remarkably, 85% and 69% of the Spanish adopters estimated benefits of CCC on the environment and the climate, respectively. These percentages were higher than in the other three MS.

The reasons listed for their opinions were similar to those given as reasons to grow or not to grow a CCC. In answering the question on climate impact, a number of farmers indicated that their contribution to climate change would be small compared to those of planes.

Table 41. Opinions about the effect of CCC on the environment and climate change mitigation (% of adopters)

	Spain	France	Netherlands	Romania	Average
Environmental effect ([1])					
Benefits environment	84.6	60.8	73.8	65.4	68.6
Not affects environment significantly	15.4	35.0	24.2	34.6	29.2
Harms environment	0.0	4.2	2.0	0.0	2.1
Climate change mitigation effect ([1])					
Benefits climate change mitigation	69.2	35.0	39.6	38.5	39.9
Not affects climate change mitigation significantly	30.8	61.7	57.0	60.3	57.4
Harms climate change mitigation	0.0	3.3	3.4	1.3	2.7

([1]) Each of the shares of opinions on the two items sum up to 100%.

In the group of 43 adopters who applied glyphosate to terminate the CCC, 60% estimated to grow the same amount of CCC if glyphosate were no longer available (Table 42). A quarter of this group would grow less and

16% would fully stop growing CCC. Most farmers in this group (33 adopters, applying glyphosate) came from the Netherlands and 73% of them would grow the same amount of CCC without glyphosate.

Table 42. CCC cultivation if glyphosate was no longer available

	% of glyphosate users
Same amount	60
Less	23
None	16

93% of the adopters indicated that there were other farmers in their vicinity that grew CCC in a similar way (Table 43). The differences between the MS were not big. In Spain 11% did not have such a farmer around or did not know such a colleague.

Table 43. Presence of neighbouring farmers growing CCC in a similar way (% of adopters)

Presence	Spain	France	Netherlands	Romania	Average
Yes	88.5	91.7	95.3	92.3	93.0
No	7.7	3.3	3.4	1.3	3.2
Do not know	3.8	5.0	1.3	6.4	3.8

Most adopters gave a score of 5 or more out of 10 when they were asked if they would recommend growing a CCC in a similar way as themselves (Table 44). On average, 18% of the adopters would score a 9 or a 10, i.e. would strongly recommend CCC-growing to colleagues. This percentage was remarkably high (almost 40%) in Spain. On the other hand, half of the adopters would not recommend CCC-growing, specifically two thirds of this group in France. The average score in Spain was 7.1, which is remarkable because of the low adoption rate in that MS. Apparently, the adopters in Spain were enthusiastic about this practice. Adopters with low scores indicated that in their view there were no economic advantages of CCC-growing, it took labour time and made farming complicated. Some of them indicated that they did not want to influence other farmers. The adopters with scores of 7 and higher repeated the advantages that had been mentioned before, like economic benefits, less nitrogen losses and improved soil quality.

Table 44. Recommendation to other farmers to grow CCC in a similar way (% of farmers with each score)

Score [1]	Spain	France	Netherlands	Romania	Average
1	7.7	22.5	12.1	3.8	13.4
2	3.8	3.3	0.0	10.3	3.5
3	0	4.2	1.3	5.1	2.9
4	0	3.3	0.7	10.3	3.5
5	30.8	25.8	12.1	15.4	18.5
6	0	7.5	8.1	5.1	6.7
7	3.8	6.7	20.1	16.7	13.9
8	15.4	14.2	26.8	14.1	19.3
9	0	3.3	5.4	2.6	3.8
10	38.5	9.2	13.4	16.7	14.5
1-6	42.3	66.7	34.2	50.0	48.5
9-10	38.5	12.5	18.8	19.2	18.2
Average	7.0	5.1	6.7	6.1	6.1

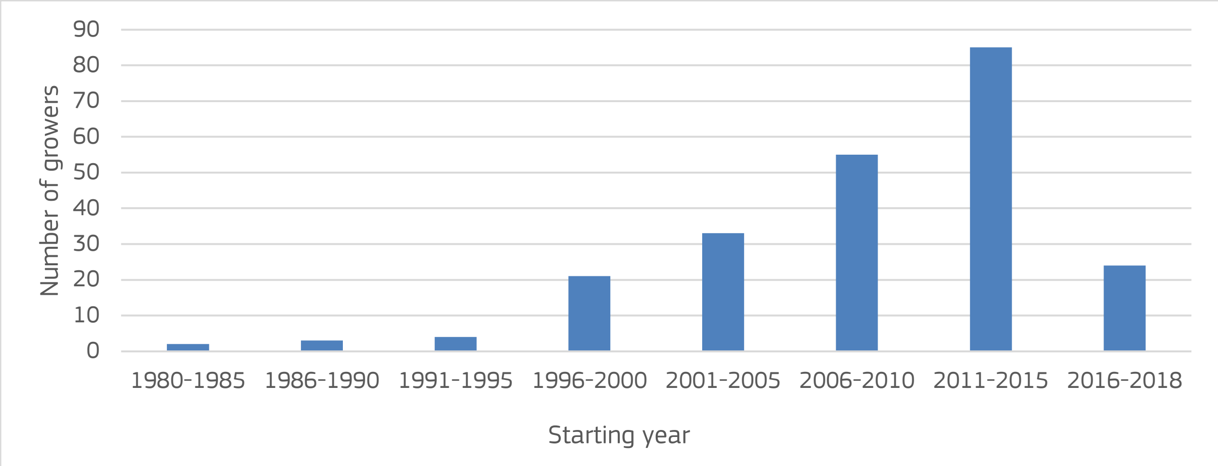
([1]) Scale of 1-10, where 1 is 'I would not recommend it at all' and 10 'I would totally recommend it.'

Important sources of information on CCC were:

- Advisors, partly from agricultural firms and cooperatives;
- Agricultural magazines;
- Internet;
- Contractors;
- APIA (Romania) and chambers of agriculture;
- Study clubs and colleagues;
- Education.

Almost 40% of the adopters had always grown CCC (27% in Spain, 33% in France, 61% in the Netherlands and 10% in Romania). The other adopters started not immediately after taking over the farm. Most members of the latter group started growing CCC after 1996 (Figure 12). Since then an increasing number of farmers have started growing CCC, although they had done so from the beginning of their farming period. This is a sign that CCC-growing has become more common in the last decades. Reasons to start with this practice were mainly similar to the advantages mentioned earlier, like obligation/subsidy, soil improvement, also to avoid erosion, nitrogen fixation and extra fodder for the livestock. There were also some organic farmers who mentioned that they needed to work without chemical pesticides.

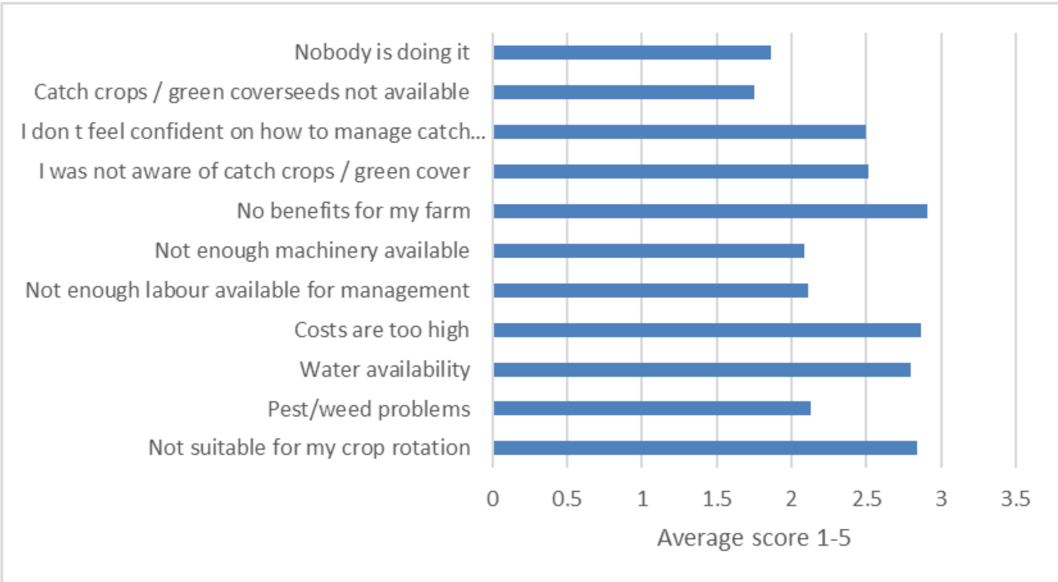
Figure 12. Starting year of CCC cultivation (number of adopters)



3.3.3 Opinions of non-adopters on CCC

Besides 373 adopters, 250 non-adopters were interviewed. It appeared that four issues were mentioned as the major reasons for non-adopting (Figure 13): a) No benefits for my farm; b) Costs are too high; c) Not suitable for my crop rotation; and d) Water availability. Reasons like CCC-seeds not being available, lack of labour or machinery and pest/weed problems were of less importance.

Figure 13. Importance of different possible reasons for not growing CCC (all MS)

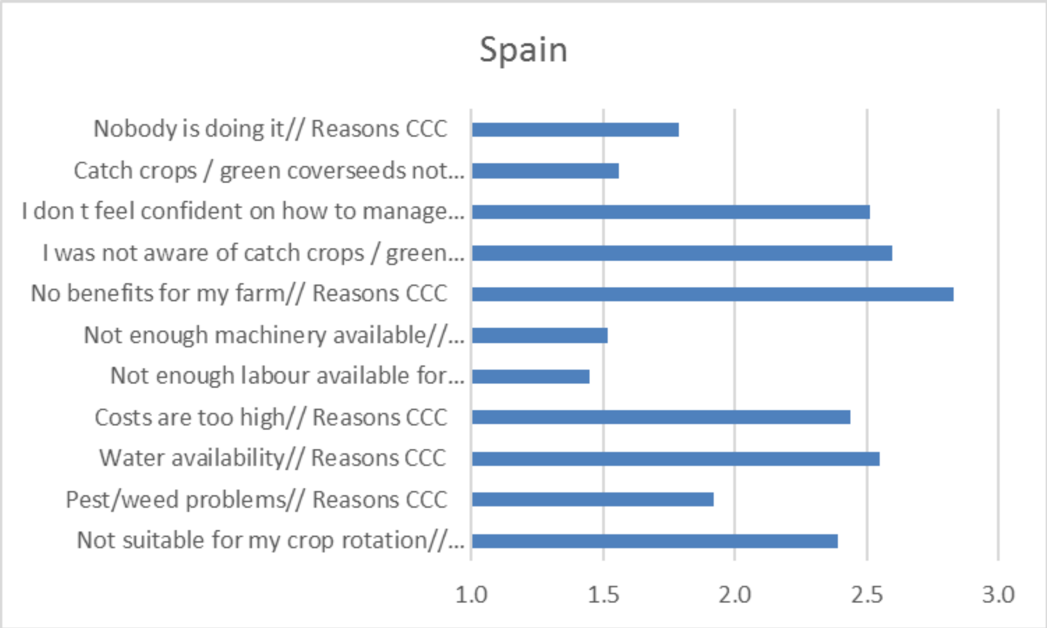


Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 14 – Figure 17 give the reasons for the four MS. In Spain the lack of benefits scored highest (Figure 14). An important reason was also that a lot of non-adopters were not aware of this practice and, as a consequence, did not feel confident on how to manage a CCC. Water availability and high costs also score highly. In France, the major reasons were 'no benefits 'and 'high costs', but growing a CCC was also not considered 'suitable' for the crop rotation (Figure 15). This latter reason was the only reason of importance for the 2 non-adopters in the Netherlands (Figure 16). In Romania, many more reasons received a high score, in

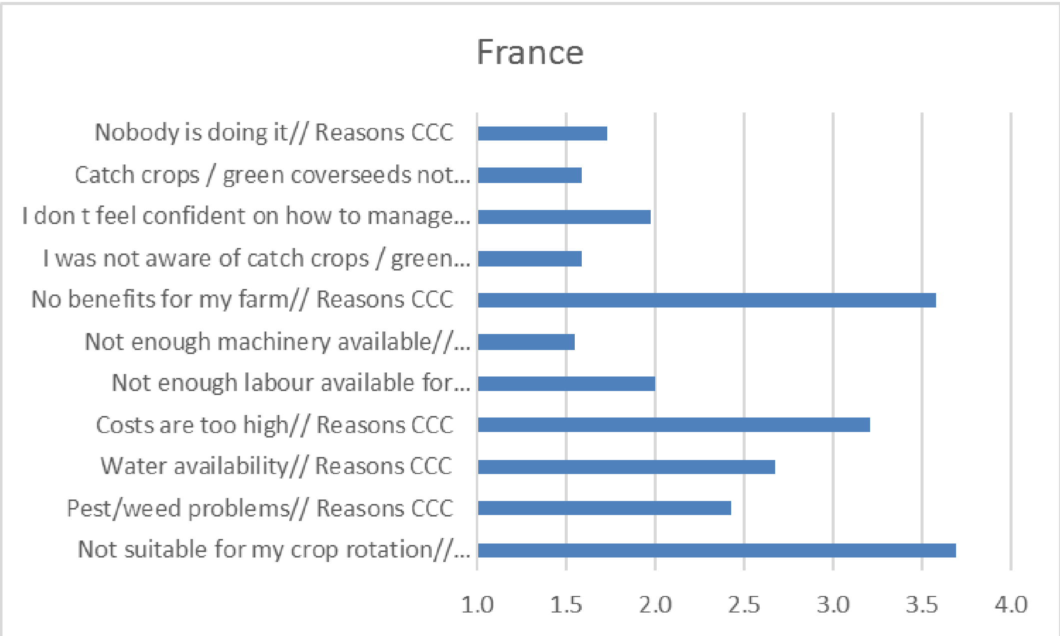
the first place high costs, but closely followed by 'not enough machinery', 'not enough labour available', 'water availability' and 'not suitable in crop rotation' (Figure 17). Some non-adopters in Romania had large farms and dry conditions, which may explain these reasons.

Figure 14. Importance of different possible reasons for not growing CCC (Spain)



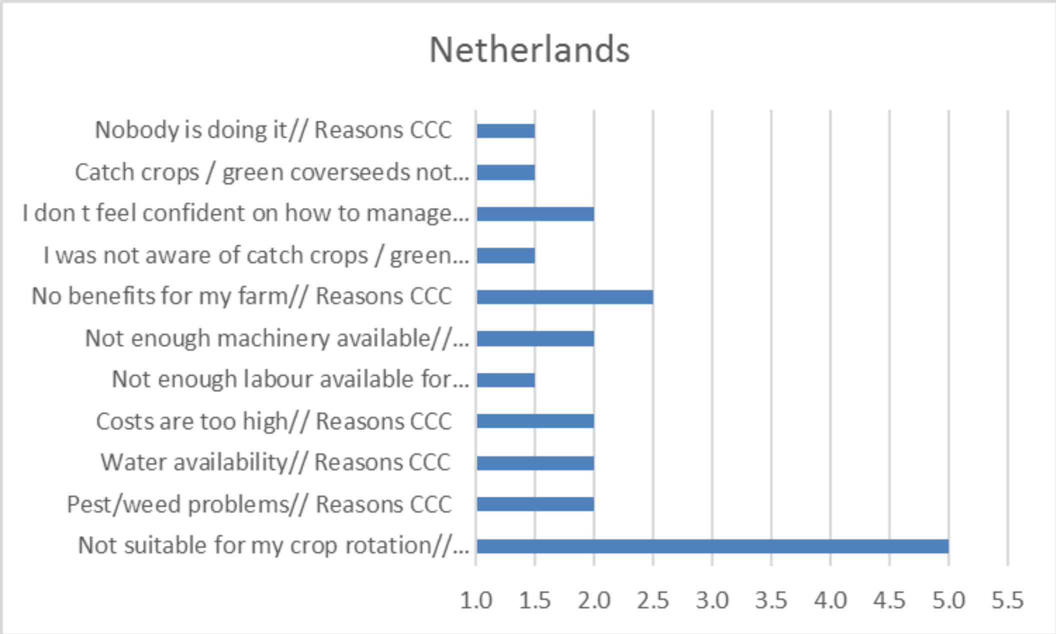
Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 15. Importance of different possible reasons for not growing CCC (France)



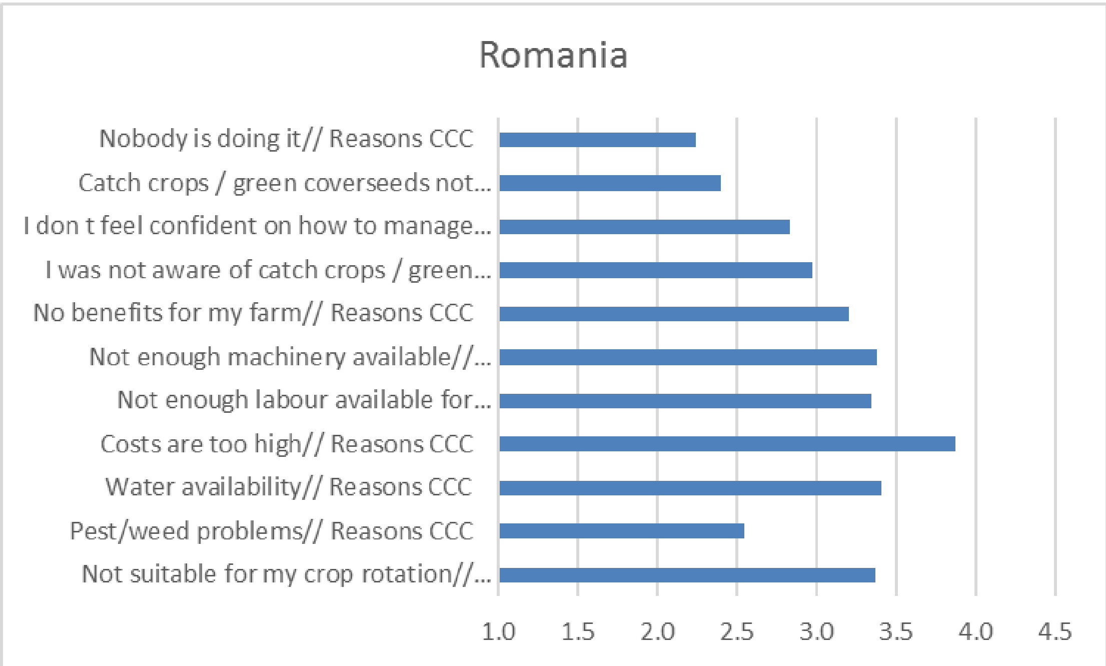
Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 16. Importance of different possible reasons for not growing CCC (Netherlands)



Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

Figure 17. Importance of different possible reasons for not growing CCC (Romania)

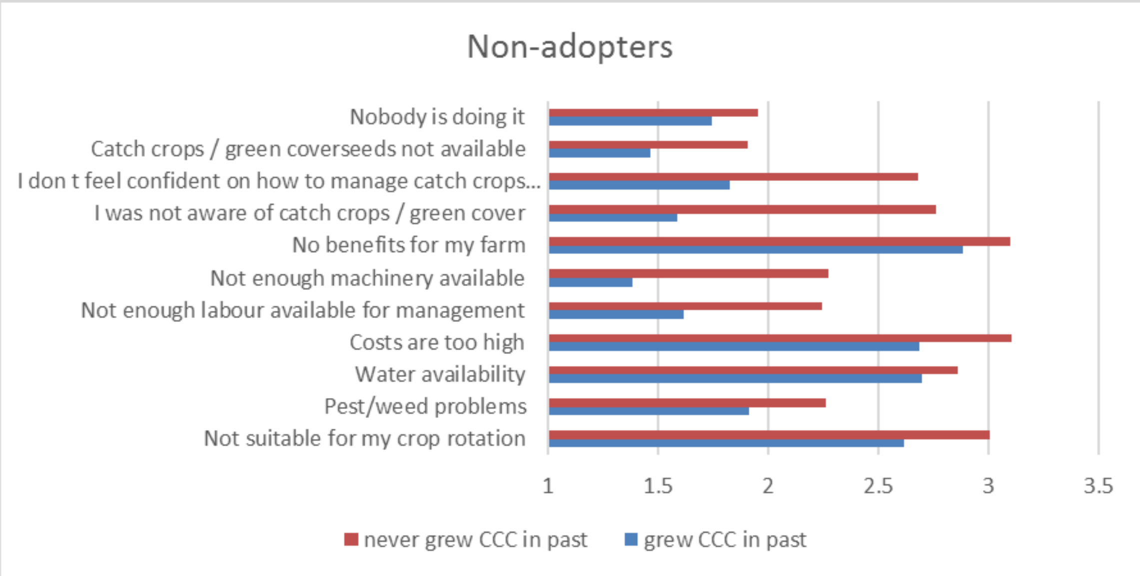


Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

46 non-adopters mentioned other reasons than those in the preceding figures. Most of these reasons could have been categorised under the pre-defined reasons (but have not been included in the figures presented). Important reasons were that growing a CCC can be hard in a dry climate and that a CCC does not fit in every crop rotation.

In the group of 250 non-adopters, there were 47 (or 19%) who had grown CCC in the past but abandoned this practice. Figure 18 provides insight into the differences within the group of non-adopters: the non-adopters who had grown CCC in the past and those who had never grown CCC. Experienced CCC-growers scored lower on all reasons in the list (less important). Apparently, they had a less negative view on CCC-growing due to their experience with this practice. Lack of experience usually leads to a stronger feeling of uncertainty, which shows in this figure. Both experienced and unexperienced non-adopters indicated absence of farm benefits, high costs and that CCC is not suitable for the crop rotation as important reasons for not adopting CCC. The most striking difference is that most growers who had never cultivated CCC, indicated they were not aware of catch crops and green cover and that they did not feel confident on how to manage these crops. Unexperienced non-adopters indicated the availability of machineries and labour as a bigger problem than experienced non-adopters. The availability of water is a problem but there is hardly any difference between experienced and unexperienced non-adopters. When non-adopters were asked why they had stopped CCC-growing, lack of water for irrigation was the most frequent answer. High costs and a relatively high risk of failure because of drought and sometimes a change in cropping plan dominated these reasons.

Figure 18. Importance of different possible reasons for not growing CCC (non-adopters with and without previous adoption)



Note: scale from 1 (not important reason at all) to 5 (extremely important reason).

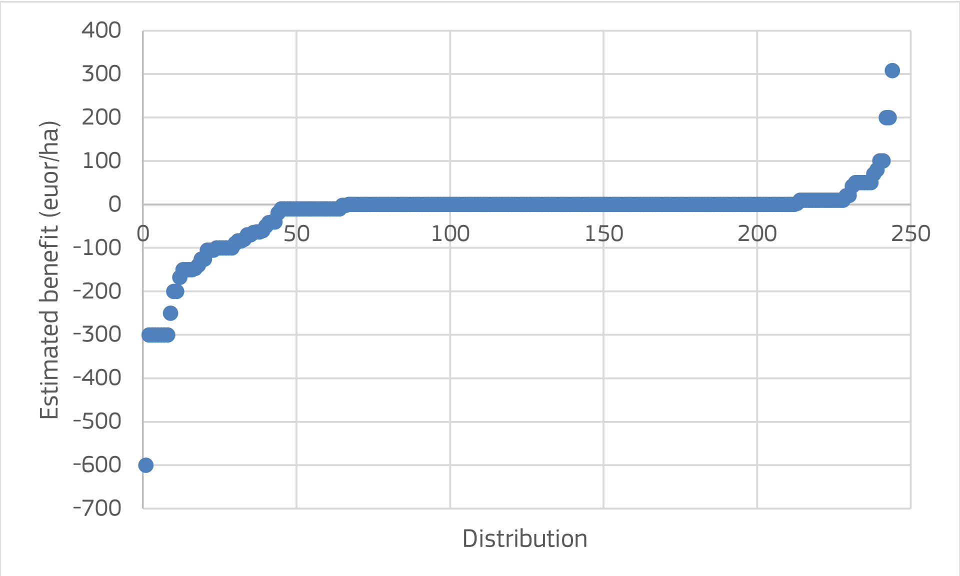
The non-adopters were asked whether they would estimate a monetary benefit or loss if they grew CCC. A quarter of them had no idea and also a quarter estimated a monetary loss (Table 45). Only 15% of the non-adopters estimated a monetary benefit, varying between 4% in Romania and 24% in France. Those who estimated to make a benefit, estimated the amount at 42 euro/ha on average, varying between 21-22 euro/ha in France and Romania and 53 euro/ha in Spain. The ones who estimated a loss, estimated the loss on average at 101 euro/ha, varying between 65 euro/ha in the Netherlands and 133 euro/ha in France. As shown in Table 31, a higher share of the adopters (32%) estimated a monetary benefit than of the non-adopters and the estimated amount was also higher (154 euro/ha). For the non-adopters, the weighted average over all MS was a loss, varying between 13 and 52 euro/ha in Spain and France, respectively. The overall estimated loss was 20 euro/ha, whereas the adopters estimated a similar overall loss (16 euro/ha). Figure 19 shows the distribution in estimations among the non-adopters. The large majority of non-adopters estimated no effect or a benefit or loss below 10 euro/ha, but some adopters estimated even benefits or losses of more than 300 euro/ha.

Table 45. Estimated monetary benefit or loss from CCC cultivation (non-adopters)

	Spain	France	Netherlands	Romania	Average
Monetary benefit (% of farmers)	20.2	23.8	0	3.9	15.6
Monetary loss (% of farmers)	25.6	42.9	50.0	18.2	26.4
No monetary benefit or loss (% of non-adopters)	24.8	23.8	50.0	45.5	31.2
No idea	29.5	9.5	0	32.5	26.8
Amount of benefit or loss ([1])					
Money made (euro/ha)	53.00	21.00	N.A.	21.70	42.39
Money lost (euro/ha)	91.21	133	65.00	87.30	101
Weighted total average (euro/ha) ([2])	-12.64	-52.06	-32.50	-15.04	-20.05

([1]) When relevant, i.e. the average benefit per MS is given from the non-adopters that estimated a monetary benefit and similarly for the ones who estimated a loss.
([2]) Calculated as the product of the share of non-adopters estimating a benefit and the estimated benefit minus the product of the share of non-adopters estimating a loss and the estimated loss. Differences in CCC-acreages between farmers were not taken into account in this calculation.

Figure 19. Distribution of estimated monetary benefits (non-adopters)



Note: n=244, 6 non-adopters did not know an answer.

Besides monetary effects, non-monetary advantages and disadvantages were asked for. More than half of the farmers estimated that the advantages would be greater than the disadvantages, with a relatively high share in Romania (above 70%; Table 46). Only 12% estimated the disadvantages to be greater than the advantages, with a relatively high share of 20% in France. It is remarkable that relatively more non-adopters than adopters (4%, Table 32) estimated greater advantages than disadvantages. This is an opposite result from the monetary estimations. Advantages mentioned by these non-adopters are soil fertility improvement, a beautiful landscape with more wildlife, improved environment, oxygen production and less nitrogen loss. Those who found the disadvantages greater mostly mentioned a monetary reason, i.e. absence of profit. The third category stressed the dependence of the weather.

Table 46. Non-monetary advantages of CCC-growing greater or smaller than non-monetary disadvantages (non-adopters)

	Spain	France	Netherlands	Romania	All
Greater (% of farmers)	42.6	35.7	100	71.4	50.8
Smaller (% of farmers)	10.1	21.4	0	10.4	12.0
More or less the same (% of farmers)	47.3	42.9	0	18.2	37.2

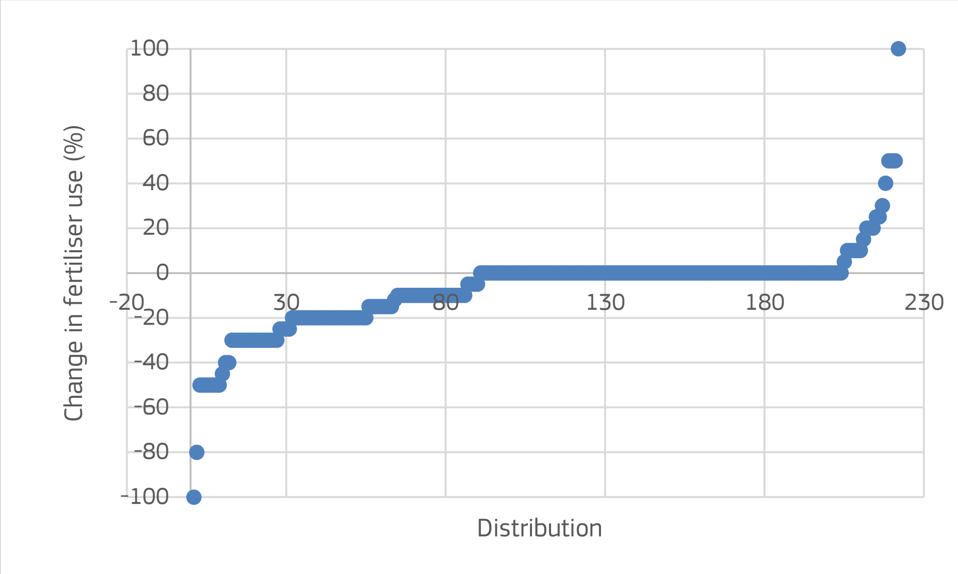
On average, 45% of the non-adopters estimated a decrease of nitrogen fertiliser use in the main crop after the CCC, similarly as with the adopters (Table 33), by more than 50% on average (Table 47), which is much higher than with the adopters (17%). Especially the Spanish non-adopters (60%) estimated a lower fertiliser amount and also the highest decrease (66%). A similar group size was found to estimate a similar fertiliser use. Almost 10% estimated a higher rate, on average by 28%. In the group of adopters this was lower (4%) but with a similar estimated effect (27%). Weighted totals over shares of non-adopters with an estimated increase or decrease and the respective amounts led to a net decrease of N-fertiliser use by almost 22% over all adopters, varying between 3% in Romania and 38% in Spain. This decrease was higher than among adopters. That was true for each of the MS except for Romania, where the adopters overall estimated a decrease by 6% and the non-adopters by 3%. This difference between adopters and non-adopters is remarkable. Overall, the adopters estimated a net benefit from CCC-growing compared to an estimated loss among non-adopters. At the same time, the adopters overall estimated a lower decrease of fertiliser use, which would lead to a lower decrease of fertilisation costs, one of the potential sources of benefit from CCC-growing. Figure 20 shows the distribution in estimations among the non-adopters. The large majority of adopters estimated an unchanged fertiliser use. A limited number of non-adopters estimated an increase, even up to 100% (i.e. a double rate) and quite a number of non-adopters estimated a decrease up to 20%, but some adopters estimated that the fertiliser use could be decreased by 100% (no fertiliser use anymore). Such differences were also observed among the adopters (Figure 9).

Table 47. Estimated CCC effect on fertiliser need of following main crop (non-adopters)

	Spain	France	Netherlands	Romania	Average
Higher (% of farmers)	7.8	16.7	0	9.1	9.6
Lower (% of farmers)	59.7	33.3	50.0	26.0	44.8
More or less the same (% of farmers)	32.6	50.0	50.0	64.9	45.6
Estimated effect (%)					
More fertiliser	25.0	12.5	N.A.	39.3	27.8
Less fertiliser	66.5	25.6	15.0	24.7	54.3
Weighted total average (1)	-37.8	-6.4	-7.5	-2.8	-21.7

(1) Calculated as the product of the share of non-adopters estimating a higher fertilisation rate and the estimated rate increase minus the product of the share of non-adopters estimating a lower fertilisation rate and the estimated rate decrease. Differences in CCC-acreages between farmers were not taken into account.

Figure 20. Distribution of estimated change in fertiliser need of main crop (non-adopters)



Note: n=222; 28 non-adopters indicated they did not know an answer.

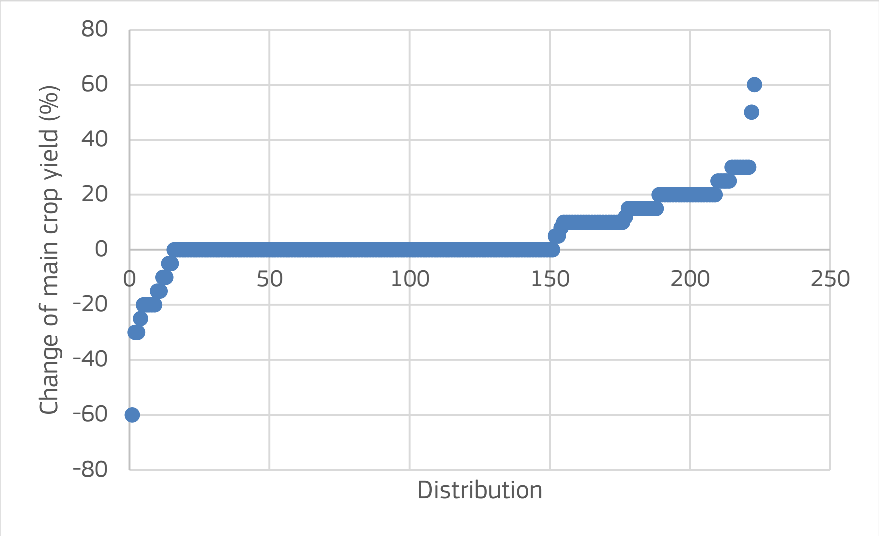
Like the adopters (Table 34), about half of the non-adopters interviewed estimated a more or less similar crop yield due to CCC-growing (Table 48). Only few non-adopters (7%) estimated a lower yield, with almost a quarter in France as highest score; 38% estimated a higher yield, varying between 10% in France and 55% in Spain (there were only two non-adopters in the Netherlands). Among the adopters, the shares of respondents who estimated a higher yield were somewhat higher, specifically in Spain (89 versus 55%). Those who estimated a higher yield, estimated a yield increase of 18%, somewhat higher than among the adopters (11%). The farmers with a negative estimation on crop yield estimated and average decrease of 20%, somewhat higher than in the adopter group (12%). The positive effect was estimated somewhat lower and the negative effect somewhat higher than among the adopters. The total weighted yield increase was estimated at 5%, varying between -5% in France and 9% in Spain. The estimations were lower in all MS compared to the estimations by the adopters; only for Romania the estimations were almost similar, like with the fertilisation rate. This result is in agreement with a lower estimation of benefits by non-adopters compared to adopters, since a higher yield increase by e.g. 5% leads to increased revenues by 5% (ceteris paribus). Such an effect also has a greater impact on gross margin than a decreased fertilisation rate by e.g. 20 kg/ha. The distribution in yield effects estimated is shown in Figure 21. The large majority of non-adopters estimated an unchanged yield or an increase or decrease up to 20%, but some adopters estimated an increase of 30% or more or, on the contrary, a yield decrease up to 60%.

Table 48. Estimated CCC effect on yield of following main crop (non-adopters)

	Spain	**France**	**Netherlands**	**Romania**	**Average**
Higher yield (% of farmers)	55.0	9.5	100.0	23.4	38.0
Lower yield (% of farmers)	6.2	23.8	0.0	1.3	7.6
More or less the same (% of farmers)	38.8	66.7	0.0	75.3	54.4
Estimated effect (%)					
Higher yield (%)	18.3	6.5	7.5	18.8	17.8
Lower yield (%)	17.0	22.0	N.A.	N.A.	20.3
Weighted total average effect ([1])	9.0	-4.6	7.5	4.4	5.2

([1]) Calculated as the product of the share of non-adopters estimating a higher yield and the estimated yield increase minus the product of the share of non-adopters estimating a lower yield and the estimated yield decrease. Differences in CCC-acreages between farmers were not taken into account in this calculation.

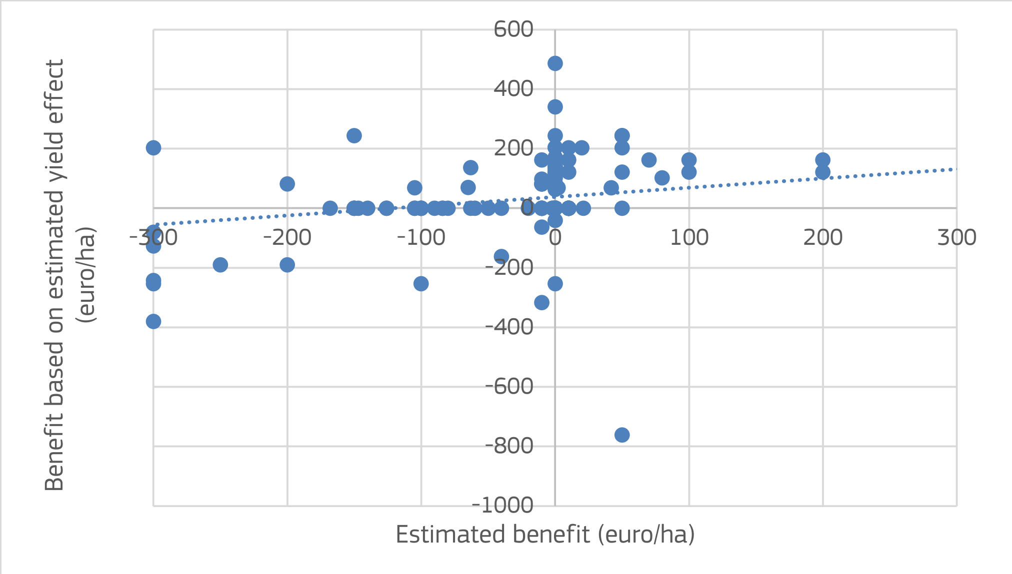
Figure 21. Distribution of estimated yield effect on following main crop (non-adopters)



Note: n=223; 27 non-adopters did not have an answer to this question.

As for the adopters, the estimations of yield change due to CCC-growing were cross-checked for the non-adopters with their estimations of benefits or losses, in the same way as in section 3.3.2 and with the same assumptions as in Table 35. The results are presented in Figure 22. Overall, a positive (but weaker than for the adopters) correlation was found between the estimation of the benefit or loss on the one hand and the estimation of the yield (and the crop revenue) on the other. Like with the adopters, quite a number of non-adopters did not estimate a benefit or loss but at the same time estimated a yield increase or decrease (dots on the Y-axis). There were also quite a number of non-adopters who did estimate a benefit or loss but no yield effect (dots on the X-axis).

Figure 22. Relation of estimated yield effect benefit to estimated benefit (non-adopters)



Note: n=220; 30 non-adopters did not give an answer to one or both questions; R^2=0.26.

Overall, 62% of the non-adopters estimated an increase in soil organic matter or soil carbon due to CCC-growing, varying between 25% in Romania and 84% in Spain (Table 49). This was somewhat lower than among the adopters (70%, Table 36). Only few farmers (2%) estimated a decrease and the remaining group (36%) did not estimate a clear effect. This is more or less similar with the results among the adopters. The same was true for the size of the effect, which non-adopters on average estimated at 7% and adopters at 6%.

Table 49. Estimated CCC effect on soil organic matter / soil carbon (non-adopters)

	Spain	France	Netherlands	Romania	Average
Increase (% of farmers)	83.7	61.9	100	24.7	62.0
Reduce (% of farmers)	0.0	7.1	0	2.6	2.0
More or less the same (% of farmers)	16.3	31.0	0	72.7	36.0
Estimated effect (% per year) ([1])					
Increase	9.9	9.6	1.0	18.3	6.9
Decrease	N.A.	20.0	N.A.	47.5	38.3

([1]) Increase and decrease could also be answered in t/ha/year, but too few non-adopters made use of that option to include them in this table.

Overall, large groups of both adopters and non-adopters did not estimate much effect of CCC-growing on monetary and non-monetary benefits, fertilisation rate, yield level of main crops and soil carbon content. Apparently, dissemination and demonstration projects so far (if any) have not been successful in convincing them of the advantages of CCC-growing. On the other hand, there were also groups of adopters who had different views and estimations on the costs, benefits, advantages and disadvantages than groups of non-adopters. It could be worthwhile to further investigate the differences between both groups. Those differences may be explained by different reasons, as categorised in the two following groups:

- 'Technical' reasons like soil quality including water holding capacity, climatic conditions, cropping plans, labour availability, possibly combined with unfavourable experiences in the past by the non-adopters themselves or by farmers in their neighbourhood;
- More 'personal' reasons, like risk attitude, openness to changes, entrepreneurial skills, attitude towards and involvement in discussions on environmental and climatic issues, sources of information (and its 'colour'), etc.

To obtain more insight in these factors, a cluster analysis could be carried out, evaluating whether groups of indicators from the survey had significantly different values for non-adopters than for adopters, especially for the more extreme groups. A hypothesis could be e.g. that risk-avoiding farmers in dry, sandy regions would estimate the benefits of CCC-growing for the following crop lower and the costs of CCC-cultivation higher than risk-neutral farmers in a fertile soil with good water holding capacity under more temperate climatic conditions. Perhaps also farmers' magazines play a role in the visions and estimations that are being spread among the readers. Those visions and estimations are not always supported by scientific evidence, but they could influence the public opinion.

The non-adopters were also asked what kind of facilities/supports/services/assistance/advise/ incentives/etc. would make them start growing CCC. The non-adopters gave very different answers:

- Advice/assistance;
- Machinery, especially sowing machinery;
- Profit/subsidies (most frequent answer);
- (Cheaper) water/irrigation.

Most non-adopters (almost three quarters) in the survey indicated that they would start growing CCC if they received subsidies (Table 50). The required subsidy was on average estimated at 161 euro/ha. Both the shares of non-adopters and the amounts to be paid were relatively similar in Spain, France and Romania.

Table 50. Willingness to start growing CCC with a subsidy and amount required

	Spain	**France**	**Netherlands**	**Romania**	**Average**
Would grow CCC with a subsidy (% of farmers)	69.0	73.8	0	80.5	72.8
Amount (euro/ha)	156	176	N.A.	154	161

The non-adopters were also asked whether they estimated a positive effect of CCC-growing on the environment and on climate change mitigation. Overall, two thirds of them estimated a positive effect of CCC on environment, but only 42% on climate change mitigation (Table 51). The estimations in both issues were highest among the Spanish non-adopters and lowest among the French. In all MS the estimations among adopters were higher on both issues except for climate change mitigation in Romania (Table 41). Among the non-adopters, 32 and 55% did not estimate any effect on environment and climate change mitigation, respectively. Almost no non-adopter estimated a negative effect. These figures are similar to those in the adopter group.

Table 51. Opinions about the effect of CCC on the environment and climate change mitigation (% of non-adopters)

	Spain	**France**	**Netherlands**	**Romania**	**Average**
Environmental effect (1)					
Benefits environment	74.4	52.4	50.0	58.4	65.6
Not affects environment significantly	24.0	42.9	50.0	37.7	31.6
Harms environment	1.6	4.8	0.0	3.9	2.8
Climate change mitigation effect (1)					
Benefits climate change mitigation	47.3	23.8	50.0	42.9	42.0
Not affects climate change mitigation significantly	50.4	69.0	50.0	55.8	55.2
Harms climate change mitigation	2.3	7.1	0.0	1.3	2.8

(1) Each of the shares of opinions on the two items sum up to 100%.

Reasons that were mentioned by those who estimated a benefit for the environment:

- Improved soil quality including soil fertility;
- Reduced leaching and input of fertiliser;
- Reduced herbicide use;
- Less erosion;
- More biodiversity including wildlife and bees;
- Oxygen production.

Those who estimated a negative effect on environment mentioned mainly extra fuel use. The reasons mentioned by those who estimated a benefit or harm for the climate were quite similar to those for the environment.

Almost 20% of the non-adopters received information on CCC management: 13% in Spain, 38% in France, 100% in the Netherlands (only two non-adopters) and 16% in Romania. Information sources mentioned were the same as listed in 3.3.2 for adopters (below Table 44).

3.3.4 Opinions of all respondents towards climate change

A number of questions were asked for both the adopters and non-adopters in the sample. The first one dealt with the feeling of farmers about the effects of climate change on their farm business (Table 52). On average 40% of the respondents felt that there would be a minor effect, but more than half of the population thought they were losing. The share of farmers in the latter category was especially high in Romania (73%) and France (64%). Divided over adopters and non-adopters, the shares of respondents that felt that their farm business was not much affected from climate change, were almost similar (about 40%). Only a few non-adopters mentioned a positive effect, which was much higher for adopters, being almost 10%.

Table 52. Effect of climate change on farm business (% of farmers)

	Benefiting	Losing	Not much affected
Spain	3.9	49.0	47.1
France	2.5	64.2	33.3
Netherlands	14.6	28.5	57.0
Romania	4.5	72.9	22.6
Average (n=623)	6.4	53.7	40.0
Adopters (n=373)	9.1	50.4	40.5
Non-adopters (n=250)	2.0	59.2	38.8

More than half of the respondents (53%) thought that farmers in general could make a significant difference to climate change mitigation (Table 53). When the same question was focused on their own impact, still 48% agreed. 60% of the farmers thought that farmers in general had a responsibility to mitigate (stop or slow) climate change, even if it came at a cost to their business. This share was even two thirds when it focused on individual responsibility. However, the two responsibility questions were not answered by all respondents, so that the answers may not be fully comparable with those to the impact questions. When divided over adopters and non-adopters, higher shares of adopters (4-7%) agreed with the four statements compared to non-adopters.

Table 53. General and individual farm impact on and responsibility for climate change mitigation (% of farmers agreeing)

	General impact ([1])	**Individual impact** ([2])	**General responsibility** ([3])	**Individual responsibility** ([4])
Spain	54.8	50.3	75.3	80.8
France	51.2	38.9	74.7	87.3
Netherlands	50.3	53.0	57.9	62.5
Romania	55.5	50.3	33.7	35.9
Average (n=623)	53.0	48.1	60.4	66.6
Adopters (n=373)	54.4	50.4	62.1	68.1
Non-adopters (n=250)	50.8	44.4	57.5	61.3

([1]) Full question: 'Do you think that farmers in general could make a significant difference to climate change mitigation, i.e. have an impact on how much climate change is occurring?'
([2]) Full question: 'Do you think that your farm in particular could make a significant difference to climate change mitigation, i.e. have an impact on how much climate change is occurring?'
([3]) Full question: 'Do you think that farmers in general have a responsibility to mitigate (stop or slow) climate change, even if it comes at a cost to their business?' (n= 330)
([4]) Full question: 'Do you think that you personally, as a farmer, have a responsibility to mitigate climate change, even if it comes at a cost to your business?' (n=229)

3.3.5 Driving factors of CCC adoption and non-adoption

The driving forces were partially of an external nature, mainly in the form of obligations from the CAP and the Nitrates Directive, in many cases combined with a subsidy. But many respondents also mentioned internal forces, i.e. motives to a) improve the productivity of the soils, e.g. expressed in soil quality including soil fertility and soil organic matter content, avoidance of erosion; b) have additional fodder for livestock; c) improve the environment through less nitrogen leaching; d) improve the landscape and biodiversity including wildlife; and e) contributing to climate change mitigation.

The external forces differed per MS. Most adopters in the Netherlands grew silage maize on sandy soils, after which growing a CCC was simply obligatory (based on the Nitrate Directive). However, most Dutch farmers understood the reasons for this obligation and seemed to support that obligation, although it was not always easy to comply with this obligation. Most adopters in Romania also grew CCC to comply with an obligation, either from the Greening obligation or from agro-ecological obligations (second pillar of CAP). Unlike the Dutch adopters, the Romanian adopters in general had little understanding for these obligations, found them not easy to comply with and felt unhappy with the costs involved. The French adopters were somewhere in between the Dutch and the Romanian adopters. The Spanish adopters did not feel a pressure from outside to grow CCC and their internal drives were important, although more for environmental than for climatic mitigation purposes.

Many adopters would not grow CCC if there was no legal obligation for it. Their motivation not to adopt CCC-growing was partly based on unfavourable cost-benefit estimations, which could be evaluated as a more or less 'neutral' rational and economic decision. However, it could be argued whether their estimations were correct (fact-based) and complete, e.g. did they include the effect of a CCC on the following main crop? Besides that, non-adopters show in general less interest to undertake measures for the improvement of the environment/climate and/or they had in mind that their contribution to solving environmental or climatic problems would be small or even negligible compared to the proportions of the problems referred to.

3.4 Implications for adoption and mitigation potential

3.4.1 Adoption rates

The potential C-sequestration per region was estimated based on regionalised potential C-sequestration per ha (based on regional cereal yields per ha). In that calculation, the acreage of cereals was multiplied with the adoption rate based on SAPM data (Eurostat, 2010). The 2018 survey provides insight into the current adoption of CCC per region. Table 54 shows adoption rates based on the survey and based on the 2010 SAPM.

Table 54 shows the adoption rates (weighted over acreage) for adopters (first row) and for adopters plus non-adopters (second row). Regions with farms that grow a relatively small acreage of target crops, have a low adoption rate at farm level and a high adoption rate compared to the target crop acreage (Netherlands), the major crop after which CCC is usually grown. In Spain the adoption rates are low because non-adopters have a large area share.

The adoption rate in the SAPM was based on the total arable acreage and the CCC-acreage in a certain region. This corresponds most closely to the adoption rate of adopters plus non adopters at farm acreage level from the survey in 2018 (fourth row in Table 54). A comparison between the two studies is difficult because of differences in representativeness. However, adoption rates of the Netherlands and Spain both fit fairly well for both studies. But in France and Romania, the adoption rates on farm acreage level in the survey (13.9% and 12.0%, respectively) were considerably higher than in the SAPM.

The adoption rate in Spain (2.6%) was low because there were several options to comply with the Greening obligation, whereas in France and the Netherlands there were fewer options, among which CCC-growing. In France (13.9%), the CCC acreage has increased since 2010. The adoption rate in Romania (12%) was high compared to the SAPM because of an obligation by APIA (see section 3.3.2). The adoption rate in the Netherlands in terms of CCC-acreage as a share of target crop acreage was high (90%), but compared to farm acreage comparable to the other survey regions (3-17%). Most of the Dutch farms in the survey were dairy farms, which had a different cropping plan than the (mainly arable) farms in the three other MS, i.e. a large share of grassland (in most cases more than 80%) in their cropping plan, which offered limited possibilities (and advantages) to grow CCC.

Table 54. Adoption rates (%)

	Spain	France	Netherlands	Romania	Average
ha CCC/ha target crops, adopters	15.3	21.8	90.2	14.3	18.0
ha CCC/ha target crops, all farmers	3.0	17.7	89.8	13.1	14.2
ha CCC/ha farm, adopters	12.5	17.2	17.2	13.1	14.5
ha CCC/ha farm, all farmers	2.6	13.9	17.1	12.0	11.6
Adoption rate (SAPM, 2010)	3.1	6.8	20.6	1.0	N.A.

3.4.2 Climate change mitigation potentials

Based on the adoption rates at acreage level (Table 54) and the differences in cropping plans between the farms in the Netherlands compared to the three other MS, an estimation was made for the current and potential C-sequestration. Table 55 summarises the assumptions in these calculations.

Table 55. Assumptions to calculate current and potential C-sequestration.

Region	**C-sequestration (kg CO_2e/ha)** (1)	**Adoption potential (ha)** (2)	**Potential C-sequestration (1,000 t CO_2e)** (3)	**Adoption rate survey (%)**
Spain (Castile and León)	942	2,399,490	2,260.4	3.0
France (Centre (FR))	1,544	1,679,540	2,592.7	17.7
Netherlands (Overijssel)	1,682	47,170	79.3	89.8
Romania (Sud–Muntenia)	938	1,644,718	1,543.5	13.1

(1) Calculated from the average cereal yields in the specific regions as compared to the average cereal yield in the EU. This ratio was used to calculate the average C-sequestration per ha, assuming that this value is linearly correlated with the biomass production of the CCC and that the biomass production of CCC is linearly correlated with the yield of wheat in that region. In practice, there is of course much variation, caused by differences in soil quality, water availability and specific weather conditions, the CCC-species selected, the growing period of the CCC, under- or aftersowing of the CCC and the type of tillage and the amounts of fertiliser and/or irrigation applied. Thus, there can be much variation between farmers, fields and subregions within a region. The survey contained a lot of such data, but it was not possible to correct the theoretical data into more practical data at field or regional level.
(2) The adoption potential on acreage level was calculated as the total acreage of cereals and protein and industrial crops.
(3) Total C-sequestration potential, when CCC is applied on the total acreage of cereals and protein and industrial crops.

Source: own calculations

To assess both the total climate change mitigation potential and the C-sequestration per ha, the total acreages of cereals and protein and industrial crops were included and multiplied with the adoption rate on CCC-acreage level (second row in Table 54). Because of the overestimation of that adoption rate the current C-sequestration will be somewhat lower and the potential C-sequestration in some regions slightly higher in practice, because CCC were also grown (to a certain extent) after other crops than cereals.

The climate change mitigation potential was estimated as the difference between the current regional mitigation (based on CCC adoption area) and the maximum regional mitigation (based on regional cereal areas). Figure 23 (absolute amounts) and Figure 24 (per hectare amounts) show that there is still room to increase the cultivation of CCC after cereal growing, and as a consequence, the amount of C-sequestration, especially in cereal producing regions. In the Netherlands, there was little potential (about 8 kt CO_2e), since both the cereal acreage was low and the adoption rate on cereal acreage level was high. For Spain and

France, the climate change mitigation potential for the regions studied were estimated at 2.2 and 2.1 Mt CO_2e, respectively, and for Romania at 1.3 Mt CO_2e. When these figures are harmonized to ha-level of cereals (i.e. total mitigation potential/total cereal acreage), it appears that in Spain there is still a potential of 900 kg CO_2e or 97%. For France and Romania, these shares were 82 and 87%, respectively, and for the Netherlands 10%.

There are several practical obstacles that make the maximum potential adoption difficult to reach or even unachievable (availability of water, lack of machinery and/or labour, organisational obstacles, the presence of winter rape in the cropping plan). On the other hand, there are more crops than the target crops defined for this study, after which a CCC could be grown, e.g. potatoes and vegetables. However, on EU-level, the acreages of these crops are relatively small compared to the target crops. But potatoes play an important role in the cropping plans of e.g. the Netherlands and Belgium. Besides, permanent crops were left out of the survey and in MS like Spain and France the acreages of olives and vines are so large, that growing a CCC under such crops could be further explored.

In general, more research on the potential yields of different CCC-species under different (weather and climate) conditions would be useful to acquire more insight in the climate change mitigation effects of such crops in different regions. Besides, research and demonstration projects about optimisation of CCC-growing could narrow the gap between potential and current yields and mitigation effects per ha and increase the interest and adoption rate among farmers (number of farmers and the adopted acreage per farm), which could both contribute to a higher mitigation effect. More insight among farmers in the monetary and non-monetary effects of CCC-growing is also required, since unrealistic views were presented in the survey about e.g. increases of soil carbon content and yields of the crops in the cropping plan.

Adopters indicated that subsidies were a driver for growing CCC but the survey also shows a lacking knowledge about CCC under farmers. In this connection the role of advisors, suppliers and even customers has not been investigated but can be important. They could contribute to dissemination of knowledge of the concept and the practical aspects of CCC-growing or even, in the case of traders, processors or customers, make CCC-growing obligatory.

Figure 23. Current and potential C-sequestration in the survey regions

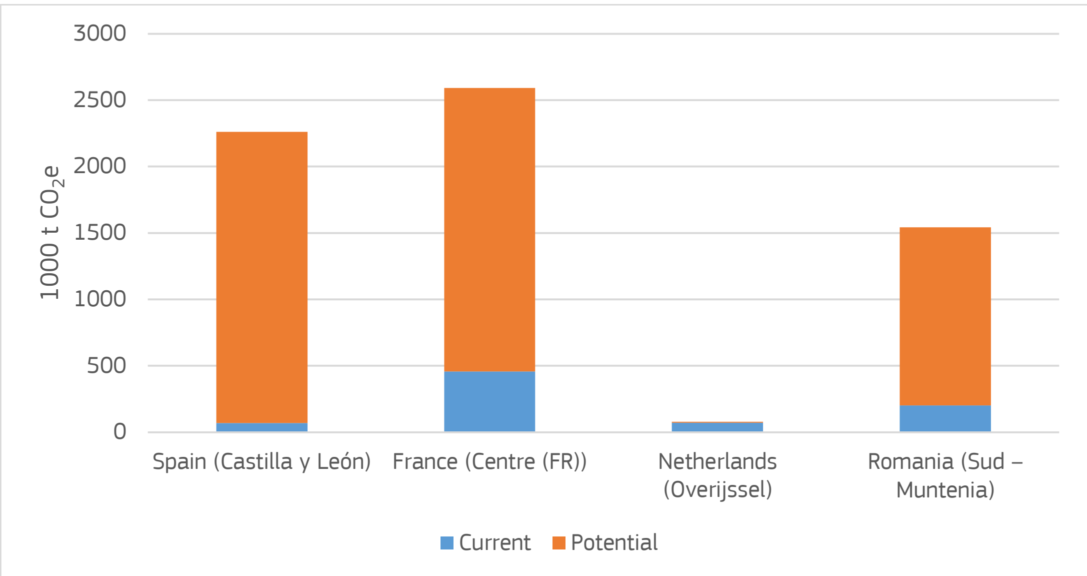
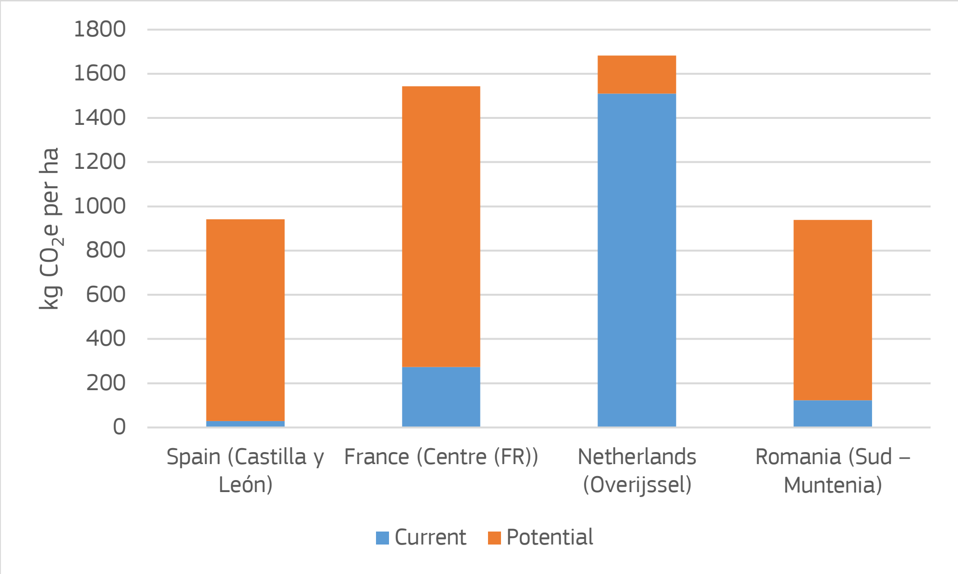


Figure 24. Current and potential C-sequestration per ha of cereals in the survey regions



4 Concluding remarks

A survey was held among 623 farmers in selected regions in four MS, Spain, France, the Netherlands and Romania, with about 150 farmers in each MS included. They were interviewed whether they grew catch and cover crops (CCC) and if yes, questions were raised about the practical ways how they carried out CCC-growing, about the costs and benefits, advantages and disadvantages of a CCC and about their motives to grow CCC. Non-adopters were asked why they did not grow CCC and how they estimated costs and benefits, advantages and disadvantages of a CCC. Both adopters and non-adopters were also interviewed about their attitude towards environmental and climatic issues and their own responsibility towards those issues at their own farms.

From the sample of more than 600 farmers, it appeared that the adoption rate differed greatly among MS: 12% in Spain, 84% in France, 99% in the Netherlands and 46% in Romania. CCC were mainly grown after wheat, barley and green maize. The most popular CCC-species were Italian ryegrass, white mustard, common vetch and black oats. In most cases, CCC were sown after the harvest of the main crop and after some form of seedbed preparation. Undersowing was relatively little known and applied. Other cultivation measures like fertilisation, irrigation, crop protection and harvest were generally not applied to the CCC. It appeared that the length of the growing period of CCC differed greatly among MS. Especially in the Netherlands, long periods were observed, keeping the CCC on the field until the early spring.

Most interviewed farmers (both adopters and non-adopters) estimated that CCC-growing provided or could provide them a financial benefit, mainly due to a lower N-fertilisation rate and a higher yield of the next main crop. But also some disadvantages were mentioned, like seed and operational costs and competition with the main crop for water.

The most important external driving factors to adopt CCC mentioned were legislation (Greening, as a part of the CAP), the Nitrate Directive and subsidies. The prevention of nitrate leaching and the improvement of the soil quality, specifically organic matter content, were mentioned as the most important internal drives for adoption.

It was remarkable, that not all farmers knew what CCC were, especially in Spain. Besides, the awareness among the respondents about the environment was in general higher than about the climate. This is not strange, since EU and national policies have so far not focused on climatic effects, contrary to the environmental effects. Even Greening in the CAP was mainly focused on restoring biodiversity and not on climate change mitigation. Maybe both issues are partly a matter of time (and extension).

For the future, a number of issues need attention:

1 Farmers need more information on the advantages of CCC-growing including fact-based data on costs and benefits of different practices under different conditions. For that, research and dissemination are required.

CCC-growing can be considered as a positive measure towards sustainability in terms of higher soil organic matter contents and reduced risks of erosion and nitrate leaching. Assuming that CCC-growing also contributes to climate change mitigation due to C-sequestration and reduced N-fertiliser use (as shown in Annex 1), research institutes, extension officers, agricultural advisors and policy makers could decide to promote this measure among farmers in the different MS of the EU. It was observed that the concept of CCC-growing was not yet clear to all farmers in all four MS in the survey and this is probably true for more farmers inside and outside the regions and MS that were selected for the interviews. Besides, there was a lot of variation in the estimations that farmers gave, either from (sometimes historical) experience or from intuition, of the costs and benefits and advantages and disadvantages of CCC-growing, not only in terms of seed and operational costs and reduced N-fertilisation rates, which are relatively easy to monitor, but specifically in terms of soil improvement and its consequence in terms of improved fertility levels and increased yield levels of main crops. Let alone whether farmers had any idea how much farming contributes to greenhouse gas effects and to what extent CCC-growing could compensate for that. In other words, more research is needed to be able to inform farmers in a fact-based way how much a CCC could contribute to different sustainability indicators including their crop margins. This information would strengthen the concept of CCC-growing, additionally to other, more common ways of dissemination like demonstration fields and sharing farmers' experiences in farmers' magazines;

2 Farmers need more information under which conditions CCC-growing is not feasible and on alternative practices for climate change mitigation instead.

The research proposed under 1 should also give information under which conditions CCC-growing is not feasible, too risky or not profitable, e.g. due to lack of water for germination or low levels of biomass production, and, as a consequence, too little contribution to the improvement of the soil and the yield of the next main crop. As an alternative, systems with mulching and/or reduced tillage could contribute to the goal of climate change mitigation in such conditions and that information could then also be disseminated;

3 Adoption of CCC-growing is a key factor in utilising the climate change mitigation potential of such practices, for which different instruments can be developed and implemented.

Making farmers aware of climate change issues and providing knowledge about measures like CCC-growing, as proposed above, is one way of stimulating CCC-growing. Another way is to simply turn it into a legal obligation, e.g. as already is the case in or after silage maize growing on sandy and loess soils in the Netherlands (and from 2021 onwards also after potato growing), based on the Nitrate Directive. Also the Greening obligation stimulates CCC-growing, as one of the alternatives to comply with the need to implement ecological focus areas on the farm. Non-compliance will be reduced when some kind of subsidy is coupled to such an obligation. On the other hand, such a subsidy is in many cases not required to make CCC-growing profitable, but, as mentioned above, that should be clearly assessed and disseminated. In general, an increased awareness of the environmental and climatic issues on one hand and the opportunities to contribute to a decrease of such problems on the other could influence farmers' attitude towards CCC specifically and their view in general on how to implement a socially responsible way of farming that is still (or even more) profitable. A study on how farmer magazines discuss such issues could further improve the insights on how to approach farmers, discovering more of the factors, ideas or estimations that are decisive for adopting or non-adopting CCC. This could also increase the insight on the potential of CCC-growing in different regions and MS, willingness to adopt being one of the major factors determining the climate change mitigation potential of CCC-growing, together with optimisation of cultivation measures.

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List of abbreviations and definitions

APIA	Agency for Payments and Intervention for Agriculture (Romania)
CAP	Common Agricultural Policy (of the EU)
CCC	Catch and Cover Crops
CO_2e	Carbon dioxide equivalent
EC	European Commission
EcAMPA	Economic Assessment of GHG mitigation policy options for EU agriculture
EFA	Ecological Focus Area
GHG	Greenhouse gas
ha	Hectares
MS	(EU) Member State
NUTS	Nomenclature of Territorial Units for Statistics (EU regions)
SAPM	Survey on Agricultural Production Methods

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Annexes

Annex 1. Assessment of adoption and mitigation potentials

The annex can be downloaded at https://ec.europa.eu/jrc/en/publication/report-current-adoption.

Annex 2. Questionnaire[11]

Introductory questions

1. Are you the main decision-maker of the farm?

2. Do you grow cereals (wheat, barley, grain maize, triticale, rye, oats, spelt), oilseed rape, sunflower, soybeans or green maize/silage maize every or almost every year?

3. How many hectares do you farm?

4. Out of these total farmed hectares, how many do you grow with cereals (wheat, barley, grain maize, triticale, rye, oats, spelt), oilseed rape, sunflower, soybeans or green maize/silage maize on average each year?

5. Do you know what cover crops or catch crops are?

6. Can you tell us what you think they are?

7. We define CCC as follows. Cover and catch crops are grown primarily to fulfil certain functions such as to reduce leaching, to provide nitrogen to the next crop, to reduce soil erosion, to improve soil structure, soil fertility and soil water properties, to reduce pest pressure on crops, to prevent weed growth, and/or to increase the biodiversity of the farming landscape and environment. CCC are living plants intentionally sown by the farmer. Finished CCC are usually not sold, but terminated and left on the field or ploughed in, although they might also be harvested and used as animal feed or for bioenergy production. CCC are often grown in between main / cash and feed crops, but can also be undersown. Many species can be grown as CCC, for example annual or perennial grasses, brassicas and mustards, legumes or others like linen and buckwheat; and often, mixes of different species are grown. Do you grow any such defined CCC in your farm? (Spontaneous vegetation, crop volunteers, crop residues, straw and mulches are not CCC).

Questions for adopters

8. On how many hectares do you grow CCC each year on average?

9. Which species do you grow as CCC?

10. After which main crop(s) do you grow CCC?

11. Do you sow CCC after the harvest of the main crop, or do you sow CCC into the main crop while the main crop is still growing (undersowing)?

12. After how many weeks of growth do you terminate (or harvest) CCC?

13. Do you prepare a seedbed for CCC with a machine?

14. How much CCC seed (in kg) do you use per ha and what is the price of the seeds per kg?

15. Do you irrigate CCC after sowing?

16. Do you supply extra fertiliser to CCC?

17. How many kg/ha of fertiliser do you use for CCC?

18. What proportion of the fertiliser content is nitrogen?

19. What are the total units in the NPK fertiliser?

20. Do you also supply extra manure to CCC?

21. Do you carry out any plant protection in CCC?

22. Do you harvest CCC, if yes for which purpose?

23. If you do not harvest them, how do you terminate CCC at the end?

[11] The complete version of the questionnaire (including all answer options and filters) is available upon request (JRC-D4-SECRETARIAT@ec.europa.eu).

24. Overall, how many person labour hours of hired workers and unpaid workers (farmers and family members) are required for CCC per ha, including all operations related to CCC (seedbed preparation, seeds, sowing, fertilizer/manure, plant protection, irrigation, fuel, harvest and termination)?

25. Do you contract a specific company or service for operations related to growing CCC?

26. Overall, what is the cost for all the operations related to growing CCC per ha (seedbed preparation, seeds, sowing, fertilizer/manure, plant protection, irrigation, fuel, harvest and termination)? (Including contractors)

27. What is the main reason why you cultivate these CCC?

28. We would like to understand better why you grow CCC. Could you rate the importance of the following possible reasons for growing CCC, and also rate the importance of any other reasons you may have in mind? From 1 (not important reason at all) to 5 (extremely important reason).

Reduce erosion - Improve soil fertility - Improve soil structure - Improve water holding capacity of the soil - Reduce nitrogen fertiliser in the following main crop - Improve pest management - Reduce greenhouse gas emissions - Increase carbon sequestration - Reduce nitrogen leaching – Improve biodiversity - Comply with Greening Regulation - Comply with Nitrate Directive - Comply with other policies, programmes or schemes - Comply with the rules for organic farming (if relevant) - I get a subsidy for it - I think it is the right thing to do - Everyone does it - It was done by my parents - For benefitting the environment - Other

29. Are there any other reasons you have in mind why you grow catch crops / green cover?

30. Which are those other reasons?

31. Could you rate the importance to you of these reasons for growing catch crops / green cover? From 1 (not important reason at all) to 5 (extremely important reason).

32. Is there any problem or risk that limits you from growing CCC on a larger area?

33. Why?

34. Do you make a direct monetary benefit (i.e. make money) or loss (i.e. lose money) from growing CCC? (including any subsidies, you might receive)

35. Why?

36. How much money do you make (approximately) from growing CCC in €/ha?

37. How much money do you lose (approximately) from growing CCC in €/ha?

38. Consider that apart from a direct monetary benefit or loss, growing CCC can have advantages and disadvantages for you that are not monetary. Do you think that overall, the non-monetary advantages are greater or smaller than the disadvantages?

39. Why?

40. On average across all CCC and main crops you grow on your farm, do you think you need more or less fertiliser for the main crop when you grow a CCC before it, or not?

41. How much more fertilizer do you need for the main crops compared to a situation without growing catch crops /green cover before the main crop (in %)?

42. How much less fertilizer do you need for the main crops compared to a situation without growing catch crops /green cover before the main crop (in %)?

43. On average across all CCC and main crops you grow on your farm, do you think you realise a higher or lower yield of the main crop when you grow a CCC before it, or not?

44. How much higher (in %)?

45. How much lower (in %)?

46. On average across all CCC you grow on your farm, do you think growing CCC increases or reduces soil organic matter / soil carbon, or not?

47. If yes, do you have an idea of how much more? (in % per year OR tons of carbon per hectare/year)

48. If yes, do you have an idea of how much less? (in % per year OR tons of carbon per hectare/year)

49. Is growing CCC mandatory for you or voluntary according to some schemes and/or policies?

50. Please name the schemes or policies.

51. Do you grow CCC to comply with the Greening (Ecological Focus Area) obligation in order to receive subsidies for your farm?

52. Imagine the Greening (Ecological Focus Area) obligation did not include CCC as an option, would you grow the same amount of CCC, less or none?

53. Apart from Greening, do you receive any additional subsidies for growing CCC?

54. And from what policy, scheme or programme?

55. Do you receive the subsidy as a payment per hectare of CCC?

56. How much per ha?

57. Imagine you did not receive these additional subsidies, would you grow the same amount of CCC, less or none?

58. All things considered, do you think growing CCC on your farm benefits or harms the environment, or does not affect it significantly?

59. Why?

60. All things considered, do you think growing CCC on your farm benefits or harms efforts to mitigate (stop or slow) - climate change, or does not affect it significantly?

61. Why?

62. If glyphosate were no longer available, would you grow the same amount of CCC, less or none?

63. Are there other farmers around you (or in your area) who grow CCC in a similar way to you?

64. All things considered, how much would you recommend other farmers to grow CCC in a similar way to you, on a scale of 1-10, where 1 is "I would not recommend it at all" and 10 "I would totally recommend it"?

65. Why?

66. What are your main information sources on CCC management?

67. Have you always grown CCC?

68. Which year did you start growing CCC and why?

69. Why do you sow CCC after the harvest of the previous main crop instead of undersowing?

70. Why do you undersow CCC instead of sowing after the harvest of the previous main crop?

<u>Questions for non-adopters</u>

71. We would like to better understand why you do not grow CCC. Could you rate the importance of the following possible reasons for not growing CCC, and also rate the importance of any other reasons you may have in mind? From 1 (not important reason at all) to 5 (extremely important reason).

Not suitable for my crop rotation - Pest/weed problems - Water availability - Costs are too high - Not enough labour available for management - Not enough machinery available - No benefits for my farm - I was not aware of CCC - I don't feel confident on how to manage CCC - CCC seeds not available - Nobody is doing it - Other

72. Are there any other reasons you have in mind why you don´t grow catch crops / green cover?

73. Which are those other reasons?

74. Could you rate the importance to you of these reasons for not growing catch crops / green cover? From 1 (not important reason at all) to 5 (extremely important reason).

75. Have you ever grown CCC?

76. Why did you stop?

77. Imagine you were growing CCC. Do you think you would make a monetary benefit (i.e. make money) or loss (i.e. lose money) from growing CCC?

78. Why?

79. How much money would you make (approximately) from growing CCC in €/ha?

80. How much money would you lose (approximately) from growing CCC in €/ha?

81. Consider that apart from a direct monetary benefit or loss, growing CCC can have advantages and disadvantages for you that are not monetary. Do you think that overall, the non-monetary advantages are greater or smaller than the disadvantages?

82. Why?

83. If you grew CCC, do you think you would need more or less fertiliser for the main crop grown after the CCC?

84. How much more fertiliser? (Please, specify answer in xx%)

85. How much less fertiliser? (Please, specify answer in xx%)

86. If you grew CCC, do you think you would realise a higher or lower yield of the main crop grown after the CCC?

87. How much higher? (Please, specify answer in xx%)

88. How much lower? (Please, specify answer in xx%)

89. If you grew CCC, do you think it would increase or reduce soil organic matter / soil carbon, or not?

90. How much do you think growing catch crops / green cover would increase soil organic matter / soil carbon?

91. How much do you think growing catch crops / green cover would reduce soil organic matter / soil carbon?

92. What kind of facilities/supports/services/assistance/advise/incentives/etc. would make you start growing CCC?

93. If you received subsidies for growing CCC, would you start growing them?

94. How much subsidies (in €/ha) would be necessary for you to start growing CCC?

95. All things considered, do you think growing CCC on your farm would benefit or harm the environment, or not affect if significantly?

96. Why?

97. All things considered, do you think growing CCC on your farm would benefit or harm efforts to mitigate (stop or slow) climate change, or not affect them significantly?

98. Why?

99. Do you receive any information on CCC management?

100. What are your main information sources?

<u>General questions for all respondents</u>

101. Do you feel your farm business is benefiting or losing from climate change, or not being much affected by it?

102. Do you think farmers in general could make a significant difference to climate change mitigation, i.e. have an impact on how much climate change is occurring?

103. Do you think your farm in particular could make a significant difference to climate change mitigation; i.e. have an impact on how much climate change is occurring?

104. Do you think farmers in general have a responsibility to mitigate (stop or slow) climate change, even if it comes at a cost to their business?

105. Do you think you personally, as a farmer, have a responsibility to mitigate climate change, even if it comes at a cost to your business?

106. Which of the following activities do you have on your farm?

Arable crops - Permanent crops – Livestock – Grassland – Forests - Other (specify)

107. Do you farm entirely or partly in a certified organic manner?

108. In which income bracket is your household, including all income from all sources (farming and non-farming) of all household members?

109. What is the share of your total household income derived from farming? (%)

110. What is the share of your farm income derived from arable farming, livestock, permanent crops and other farming sources? Please provide % in numbers (xx)

111. Are you generally a person who is willing to take risks or do you try to avoid taking risks? On a scale from 1 (not at all willing to take risks) to 10 (very willing to take risks).

112. What is your gender?

113. What is your age?

114. What is your education level?

115. Do you have a special agricultural education?

116. Which is the farm's juridical status?

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