Conservation Agriculture in Europe

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Chapter 15
Conservation Agriculture in Europe

G. Basch, T. Friedrich, A. Kassam and E. Gonzalez-Sanchez

Abstract This chapter provides a description of the past and recent development of conservation agriculture (CA) in Europe. It reviews scientific and technical literature as well as empirical evidence reported by the European Conservation Agriculture Federation (ECAF) and its national member associations.

Starting from the early beginnings of CA in Europe, this chapter reviews the development of CA until its current status. This clearly indicates that Europe lags far behind other regions in the world in terms of the adoption and spread of CA. This chapter presents actual data of adoption in several European countries as far as it is reported by national CA associations. It also reviews the most relevant experiences gained throughout Europe, focussing on crop performance, impact on soil quality, and weed, insects and disease incidence, as well as environmental and economic aspects of CA. Challenges and possible reasons for the relatively low uptake of CA in Europe are discussed, including the influence of national and European agricultural policies and regulations on the past evolution of CA uptake in Europe. Finally, this chapter provides an outlook into future prospects for up-scaling of CA in Europe, and what the likely impact of global changes and constraints may mean for the adoption and spread of CA in Europe.

Keywords Aggregate stability · Biodiversity · Common Agricultural Policy · European Conservation Agriculture Federation · Weed management

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15.1 Introduction

Conservation agriculture (CA) is a relatively recent concept which has its origins in soil and water conservation systems, which were developed in the 1940s and 1950s in response to the dust bowls in the USA that became known as conservation tillage. Since the middle of the twentieth century, both the need for soil and water conservation due to the intensification of agricultural land use and technological advances led to an increased demand and interest in conservation tillage systems and the gradual replacement of conventional plough tillage, which for many centuries, was the most effective way to guarantee satisfactory weed control, nutrient mineralization and seedbed preparation.

This chapter reviews developments in the science and practice of CA in Europe over the last few decades beginning in the late 1960s. It reviews reported information from several European countries, most of which have national associations dedicated to the promotion of CA and are members of the European Conservation Agriculture Federation (ECAF).

Today, compared to other regions, Europe is lagging behind in terms of the adoption of CA. Only the African continent with about 1 million ha under CA—corresponding to 1 % of the global arable land—has a lower relative uptake when compared to Europe's approximately 1.36 million ha (not including Russia) under CA, which corresponds to approximately 2 % of the global arable cropland. These rates of uptake of CA lag far behind other regions in the world. For example, countries and regions such as USA, Canada, Paraguay and western Australia show adoption rates of 15, 30, 79 and 100 %, respectively (Friedrich et al. 2014).

Based on the history of CA in Europe, this chapter provides a sketch of the present state of CA and reviews experiences that may or may not help to explain the reason for the low adoption of CA in Europe in general and why adoption is much higher in some countries than in others. Challenges and opportunities are analysed in the light of both research findings and farmer experiences as well as under the economic and political conditions within the Common Agricultural Policy (CAP) framework.

15.2 History of CA in Europe

The initial adoption of conservation tillage was driven by different motives in different regions of the world where these techniques are widely applied today. In the USA, it was mainly the concern for the degradation of highly erodible prairie soils subject to both wind and water erosion due to intensive mechanical soil disturbance. Soon, the economic benefits of reduced and no-tillage crop production systems became as relevant as the concern for soil conservation, leading to the massive adhesion of farmers to the new technology for crop establishment and grassland renovation. Despite the occurrence of severe soil erosion in many parts of Brazil, it was

Table 15.1 Results of the first experiences with CA in some European countries

Country	Year	Experience	Reference
UK	1955	++	Christian (1994)
The Netherlands	1962	−−	Van Ouwerkerk and Perdok (1994)
Germany	1966	+	Bäumer (1970)
Belgium	1967	+	Cannell and Hawes (1994)
Switzerland	1967	+	Cannell and Hawes (1994)
Italy	1968	+/–	Sartori and Peruzzi (1994)
France	1970	+	Boisgontier et al. (1994)
Spain	1982	++	Fernández-Quintanilla (1997)
Portugal	1984	++	Carvalho and Basch (1994)

+=positive, ++=very positive, −−=not feasible

mainly the economic aspect that led farmers to initially adopt no-tillage, there in the early 1970s (IAPAR 1981).

In Europe, the first step towards CA in the form of no-till was driven by the attempt to reduce plough tillage and thus production costs associated with machinery, fuel, time and labour. The replacement of soil tillage, partly or entirely, both for crop establishment and for pasture renovation, began at the end of the first half of the last century, but only the availability of chemicals such as plant growth regulators and herbicides triggered a wider application of conservation tillage and the consequent research in reduced and no-tillage (Phillips and Phillips 1984). Despite intensive research on the different aspects of conservation tillage after the invention of paraquat in 1955 and its commercial release in 1961, no-tillage and even reduced tillage were applied only at a very small scale until the end of the last century.

Throughout Europe, the history of CA varies considerably from country to country as did the first experiences with the use of no-till (Table 15.1). In the UK, the first, very positive results made the area under no-till grow to almost 300,000 ha in the early 1980s. However, the straw burn ban caused farmers to abandon this technique due to increasing problems of weed control and volunteer cereals (Christian 1994). On the contrary, the first experiences carried out by Bakermans and de Wit in the Netherlands were far from successful, which made Van Ouwerkerk and Perdok (1994) conclude that no-tillage was not feasible in Dutch arable farming. Already in the early 1980s, very positive results were reported from Spain and Portugal, where both water scarcity during spring and summer and severe water erosion potential during winter encouraged the use of soil conservation measures. While in many countries, the reduced adoption of CA was driven initially by research institutions, already in the 1960s and 1970s in Denmark and at the very end of the last century in Finland, the initial adoption was farmer-driven. In Denmark, however, the no-till practice was replaced by reduced or minimum tillage before seeding, whereas the spread of no-till among farmers in Finland was rather fast, reaching 13 % of the total area of cereals and oilseed crops by 2008 (Soane et al. 2012).

At the end of the last century, CA in Europe was mostly characterized by the adoption of different levels of reduced tillage with little correspondence to the full CA system as defined by FAO (FAO 2013a). The establishment of the ECAF in

1999, which, together with the UN Food and Agriculture Organization held the first World Congress on Conservation Agriculture in 2001 in Madrid, contributed to a 'renaissance' not only of conservation tillage practices but also an increased concern regarding the two other main principles of CA: permanent soil cover both in annual and perennial crops and the utilization of balanced but market-oriented crop rotations to reduce the input of agrochemicals and to overcome a potential increase of problem weeds, pests and diseases. Still, Europe lags far behind other regions in the uptake of CA and continues to be a 'developing' continent in the adoption of CA.

15.3 Present State of CA in Europe

Since the end of the last century, not least because of the action of ECAF and its affiliated member associations, some advances in the uptake and spread of CA has occurred in Europe, albeit with large differences between countries. As far as information on the extent of adoption is concerned, difficulties persist because in most European countries there are no official statistics differentiating different crop establishment or soil management systems. In countries or regions where so-called agri-environmental measures support the use of CA, official data are available which, however, may not cover the total area under CA. In addition, the definition of farming practices considered compliant with CA also may differ somewhat from country to country. In some countries, mulch sowing systems and 'temporary' no-till are considered and reported as areas under CA. Therefore, some authors distinguish between area under no-till and under CA (Friedrich et al. 2014). The most reliable information on the area under CA and its percentage of cultivated area, even for European countries, can be retrieved from the FAO Aquastat webpage (FAO 2013b; Fig. 15.1). The data obtained by ECAF from its member associations in Europe are incorporated in this worldwide database.

In 2011, the areas under CA in the countries listed in Fig. 15.1 add up to 1.36 Mha, which corresponds to a share of 1.92 % of the total arable land in these countries. In 2005, although not covering exactly the same countries, an average percentage of adoption for Europe was estimated at 1.1 % (Basch et al. 2008). Spain is by far the leading Western European country in terms of no-till adoption, with around 650,000 ha under CA corresponding to almost 5 % of total arable land. Only Finland presents a higher share of arable land under CA with more than 7 %. Surprisingly, this figure was achieved within a short period of time (since 1998) and can be explained by the farmer-driven process of adoption that only later was supported by extension services and research organizations as well as the agribusiness sector. Within the bigger countries, it is only the UK that surpasses the 2 % of adoption, whereas France and Italy present adoption rates of around 1 %. Despite the existence of an increasing number of successful CA practitioners in Germany, adoption of CA remains low as the main interest of farmers continues to be mulch-tillage systems, not at least due to the growing pressure from ecologists pointing at CA

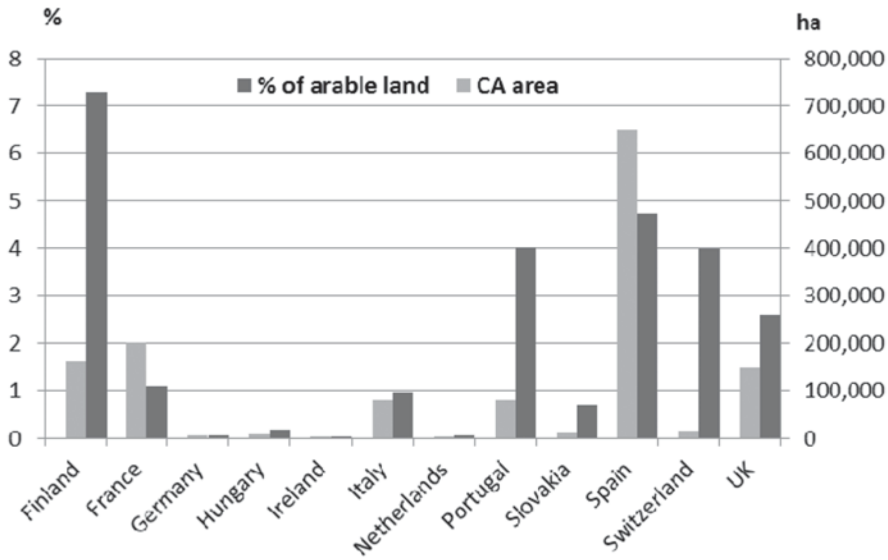

Fig. 15.1 CA adoption in annual crops in some European countries. (Source: FAO (2013b), ECAF (2013, personal communication))

being allegedly a farming system dependent on the use of more herbicides, which in practice is not proven.

Over the last two decades, there has been an increased perception in Europe for the need for effective soil conservation in perennial crops. Considering that nearly 80 % of the 10.4 Mha of perennial crops in the European Union (EU) are covered by olives and grapes (48 and 32 %, respectively), it is evident that a considerable part of this area is under Mediterranean conditions, and often on undulated and even hilly areas (Jones et al. 2006). Although the principles of CA were mainly developed for arable cropping systems, they are considered equally feasible in perennial cropping systems, especially with regard to minimum soil disturbance and permanent soil cover, applied not only for tree crop establishment but also, and more importantly, for growing. It is therefore not astonishing that the adoption of CA principles can be found in Spain and Italy with around 0.9 and 0.5 million ha under CA, respectively (personal communication: AEAC/SV 2013, AIGACoS 2013, the Spanish and Italian CA associations, respectively), which correspond to almost 20 % of the total area under perennial plantations in these two countries. Smaller areas under CA are reported for Portugal (30,000 ha; personal communication: APOSOLO 2013) and Slovakia (10,000 ha; personal communication: SNTC 2013). In Germany, both in vineyards and fruit orchards, the most frequent soil management system is based on cover crop establishment in every second inter-row space. For other countries, at least to our knowledge, there are no data available on the adoption of CA in perennial crops.

15.4 Experiences with CA in Europe

As mentioned above, research work on CA in countries in Europe started soon after the release of paraquat in the early 1960s. Since then—and earlier in western and central Europe than in Southern Europe—many experiments, some long term, have been undertaken to compare the performance of no-till and reduced or min-till crop establishment with the traditional, mainly plough-tillage-based soil management system. This focus on field experiments and research solely comparing pure soil tillage systems rather than concentrating on improving CA-based systems has certainly not contributed to optimizing the performance of CA systems under different pedo-climatic conditions and cropping systems. Therefore, many of the available research results may not reflect the potentially attainable performance of CA cropping systems when compared to conventional systems.

The following sections review the most relevant results obtained in several countries and regions throughout Europe covering the crucial aspects of crop performance, soil quality, weed, disease and pest incidence, environmental aspects including ecosystem services and economic aspects including input use efficiency.

15.4.1 Crop Performance

The comparison of the performance of different agricultural practices is mostly done through the determination of crop yields. In many European countries, data on crop yields with no-till compared to conventional tillage are available. Some of these data covering regions from North to South are summarized in Table 15.2. No clear pattern can be deduced when comparing crops or seeding period. However, in general, it appears that crops under NT perform relatively better in central and southern European countries when compared to northern European countries. For the same country and the same crops, very different results are reported (Känkänen et al. 2011; Alakukku et al. 2009). Other reviews and results on comparative crop yields in different countries are reported for Scandinavia (Arvidsson 2010; Alakukku et al. 2009; Riley et al. 1994), the UK (Christian and Ball 1994), Germany (Tebrügge and Böhrnsen 1997a) and Spain (González et al. 1997; Cantero-Martínez et al. 1994; Hernánz and Sánchez-Girón 1994).

As an overall result of the analysis of crop yields from the manifold experiments under different conditions, most of NT yields range within 10% of those under conventional tillage. The results presented in Table 15.2 show increasing yield levels under drier conditions. Detailed analysis indicates that lower yields under NT are often the result of problems related to soil compaction, poor residue management or weed management (Soane et al. 2012). Especially under high-yielding conditions producing high quantities of crop residues, management poses increasing challenges to crop establishment. Lower temperatures in the topsoil, partially due to crop residues, were also reported to adversely affect both crop and weed seed germination (Morris et al. 2010; Riley et al. 1994).

Table 15.2 Selected examples of crop yields obtained with no-till and ploughing in various locations in Europe. (Adapted from Soane et al. 2012)

Country	Crop	No. of harvests	Ploughed yield (t ha^{-1})	No-till as % of ploughed	References
Norway	Winter wheat/ barley	27	5.17	99	Riley et al. (1994)
Sweden	Winter wheat/ Barley	22	4.89	91	Riley et al. (1994)
Sweden	Winter wheat	n.a.	6.26	95	Arvidsson (2010)
	barley	n.a.	4.25	88	
Finland	Spring barley Spring barley	8 7	4.3 4.3	95 100	Alakukku et al. (2009)
Finland	Spring barley Oats	4 4	5.89 6.38	61 91	Känkänen et al. (2011)
Denmark	Winter	5	2.44	89	Rasmussen (1994)
	Oilseed rape	5	4.13	96	
	Winter wheat	6	5.52	101	
	Spring barley	6	4.36	83	
Denmark	Winter wheat	6	8.57	83	Schjønning et al. (2010)
Scotland	Spring barley	15	4.79	91	Soane and Ball (1998)
	Winter barley	9	8.8	99	
England	Winter wheat Winter wheat	4 4	8.40 7.79	105 92	Cannell et al. (1986)
Germany	Winter wheat	32	6.57	100	Tebrügge and Böhrnsen (1997a)
	Sugar beet	8	67.9	100	
	Oilseed rape	3	3.64	109	
	Silage corn	3	50.7	88	
	Sugar corn	3	10.6	99	
France	Maize	8	8.37	102	Labreuche (pers. communication)[a]
	Wheat	11	8.59	102	
	Barley	12	7.82	101	
Portugal	Wheat	4	2.22	103	Basch et al. (1997)
	Wheat	10	1.73	98	
	Barley	4	1.89	113	
Spain	Barley	n.a.	2.62	103	Lacasta Dutoit et al. (2005)
	Sunflower	n.a.	0.87	108	
Spain	Barley	1	3.50	100	Fernández-Ugalde et al. (2009)
	Barley	n.a.	1.00	200	

[a] Personal communication: J. Labreuche, 2011, Arvalis Institut du Végétal, Boigneville, France

Yields during wetter years are frequently reported to be lower especially on clay soils with poor drainage (Cannell et al. 1986). Interactions between crops, soil type and regional climate conditions with regard to the success of CA have often been observed throughout Europe. Under relatively cold soil conditions in spring, autumn-sown crops seem to perform comparatively better under CA than spring-sown crops, which can be attributed to delayed crop emergence (Anken et al. 2004) or deficient crop establishment, especially on wet clay soils (Carvalho and Basch 1994). In many cases, sandy soils were less suited to no-till than loams or clay loam soils, due to weak soil structure which tend to compact (Ehlers and Claupein 1994; Van Ouwerkerk and Perdok 1994). In other cases, some crops perform better when grown under CA on certain soil types. Under similar climate conditions, Tebrügge and Böhrnsen (1997a) found higher yields of NT sugar beet on loamy soil, but lower yields on a sandy Cambisol. Although rainfed sunflower should benefit from increased water availability under CA due to reduced evaporation losses, yields on Vertisols in South Portugal were lower under CA (Carvalho and Basch 1994). Basch et al. (1998), who found yield differences between tillage systems even under irrigated conditions, explain this through a reduced sunflower root development caused by a higher penetration resistance under NT and weak soil structural conditions.

Despite the wide difference in crop yields under different conditions when grown conventionally compared to CA, any possible initial yield reductions are overcome after the transition phase mainly due to improvements in soil structure and biopores, increased N and water availability in the soil and, not least, the farmer gaining practical experience with the CA system (Soane et al. 2012).

15.4.2 Soil Quality

Soil quality is usually assessed through physical, hydrological, chemical and biological parameters. Unlike other regions in the world, and with the exception of areas in the Mediterranean, most European cropland has been considered reasonable quality, showing low risk of degradation. However, at the very beginning of this century, a European Commission driven initiative called 'Soil Thematic Strategy' drew attention to major threats that 'apparently' European soils are also subject to. Although this initiative did not result in a European Soil Framework Directive, similar to other existing directives on Water, Air, Biodiversity, etc., it triggered action in the form of research, demonstration and support of soil conservation measures through changes in farming practices to combat the identified major soil threats, being erosion, loss of organic matter and loss of soil biodiversity (Van-Camp et al. 2004).

Over the last few decades, considerable research has been undertaken to assess the responses of soils to changes in their management, mainly soil tillage and soil cover, through either crop residues and/or cover crops. The results obtained allow anticipating the most important soil responses after a medium or long-term shift to CA. A more detailed compilation of the soil responses obtained mainly under European conditions is reported by Ball et al. (1998), Tebrügge (2003) and Imaz et al. (2010). Potential benefits and disadvantages of CA are summarized in Table 15.3.

With regard to soil physical properties, the gradual improvement of soil structure under CA and consequent higher aggregate stability was experienced under the most diverse climatic and soil conditions. Initial gains in bulk density and soil strength under NT were often compensated through a more vertically oriented

Table 15.3 Summary of the most frequently reported changes in soil properties after several years of no-till. (Adapted from Soane et al. 2012)

Benefits	Disadvantages
Increased aggregate stability, especially near surface	Increased bulk density at 0–25 cm depth can lead to poor aeration when wet
Increased organic matter content near surface	Increased moisture content near surface in spring in northern regions delaying drilling
Increased vertical and stable pore structure	Reduced soil surface temperature, especially in spring in northern regions delaying drilling
Increased biological activity, especially earthworms	Increased acidity near surface
Increased infiltration rate	Increased accumulation of P near surface with risks of loss in runoff
Increased hydraulic conductivity in subsoil on well structured soils	
Increased soil strength and load bearing capacity with reduced damage from traffic	

macroporosity with root channels and earthworm activity; contributing to soil aeration, water intake and moisture retention (Vogeler et al. 2009). After some years, however, and given that excessive traffic load under wet conditions is avoided, initial higher bulk densities may equal or even be less than those under conventional tillage. Still the benefits in terms of bearing capacity remain, though late harvests of summer crops under wet conditions may pose enormous challenges to soil structure under CA.

Changes in soil hydrology, after the adoption of CA, can be expected through the modification of soil structure, impact on infiltration rate, hydraulic conductivity and evaporation from the soil surface due to a higher rate of soil cover. The increase in infiltration rate over time after CA adoption has been well documented (Vogeler et al. 2009). In general terms, this is explained as the result of the raindrop energy-breaking mulch cover, better aggregate stability and higher topsoil SOC content (Lampurlanés and Cantero-Martínez 2006), as well as the vertically oriented macropore structure along the soil profile (Strudley et al. 2008).

However, changes in the hydraulic behaviour of the soil through CA adoption are not limited to water intake, drainage and evaporation. Carvalho and Basch (1995) observed a profound change in pore size distribution after 6 years of no-till on a vertic Cambisol (Fig. 15.2). The pore volume responsible for the retention of plant available water (50–0.2 µm) increased from 5.1 to 9.4% under no-till in the top 30 cm soil layer. The differences in water availability between no-till and ploughed land were very small resulting in identical crop yields under central European conditions (Vogeler et al. 2009), but in the semiarid northeast of Spain, barley yields doubled under no-till (Fernández-Ugalde et al. 2009).

Regarding chemical soil properties, the stratification of soil organic carbon and nutrients such as available P and K becomes more pronounced in the absence of soil tillage due to decomposition of crop residues and increased microbiological activity. Apparently, this accumulation near the soil surface does not interfere with

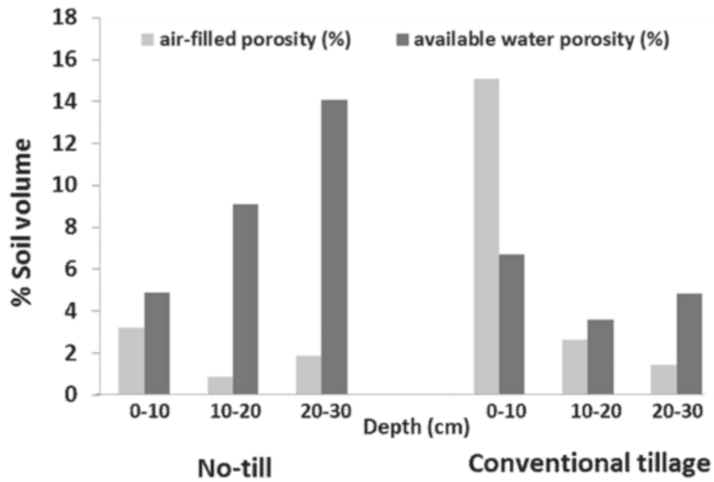

Fig. 15.2 Air-filled and available water porosity in the topsoil layers of a vertic Cambisol under conventional and no-tillage. (Adapted from Carvalho and Basch 1995)

plant nutrient uptake (Peigné et al. 2007). Other likely changes in chemical soil characteristics are increased soil acidity in the surface layer due to residue decomposition (organic acids) and nitrification of ammonium-based fertilizers (Ekeberg and Riley 1997), and increased enzymatic activity such as urease, which recommends avoiding the use of urea fertilizers (Rochette et al. 2009). After long-term application of no-till practices, Piovanelli et al. (2006) observed improved chemical fertility in the form of increased soil organic matter; whereas Mazzoncini et al. (2011) reported higher nitrogen contents, which agrees with the results of Carvalho et al. (2010) and Regina and Alakukku (2010).

The contribution of soil life to soil health and function is indisputable. Numerous European studies underpin the importance of minimal or no soil disturbance, and the food and shelter provided by crops including cover crops and their residues, for both diversity and number of soil organisms, and also above-ground wildlife. Increased numbers of earthworms in the absence of tillage and the presence of residues at the surface is the most frequently reported indicator for enhanced biological activity under CA (Peigné et al. 2009; Pelosi et al. 2009; Boguzas et al. 2006; Anken et al. 2004; Fortune 2003; Kladivko 2001; Ehlers and Claupein 1994). After 5 years of no-till on a Luvisol in South Portugal, the number of earthworms was almost threefold (39 vs. 129) and after 3 years of straw residue (0, 2000 and 4000 kg ha^{-1}), earthworm numbers increased from 100 to 122 and 136 individuals m^{-2} respectively. In addition, microbial activity and population, such as mycorrhizas (Brito et al. 2006), as well as other macro fauna and even ground-nesting birds that find more favourable habitats under CA, all contribute to the enriched biodiversity and food webs/chains below and above the ground surface.

15.4.3 Weeds, Diseases and Insect Pests

From scientific as well as practical experience, it is well known that the adoption of CA may cause changes in the incidence and type of weeds, insect pests and diseases. Some attempts to introduce CA have failed due to the unsuccessful or uneconomic control of these problems. Even the well-established no-till system in the UK was abandoned in the early 1980s after the straw burn ban, due to subsequent problems with weeds and volunteer cereals. The shift to no-till especially favours perennial grass weeds (e.g. *Agropyron repens*) but also some annual grass weeds such as sterile brome (*Bromus sterilis)*, black-grass (*Alopecurus mysuroides)* and annual meadow grass (*Poa annua*), and some broadleaved weeds like cleavers (*Gallium aparine*) and groundsel (*Senecio vulgaris*). Before the effective control by selective weedicides in cereal-based crop rotations, grass weed infestation meant a serious challenge to CA farmers, who in many situations adopted the stale seedbed technique to overcome weed infestation (Schutte et al. 2014). Many other weeds and overall weed numbers declined either due to effective chemical control, missing protection through seed burial or shading by crop residues acting as a physical barrier to weed seed emergence. Yet, volunteer cereals were a severe problem in a following no-till cereal crop in central and northern Europe (Melander 1998).

As a result of long and dry summers, the southern regions of Europe are challenged much less by perennial weeds as most of the weed species present are annual, with the exception of badly drained lowlands or continuously irrigated areas (Basch and Carvalho 1994). In rainfed conditions, the control of annual weeds under CA is facilitated in case the first wave of weeds is successfully controlled before the establishment of autumn-sown crops (Calado et al. 2010, Barros et al. 2008). Under no-till, these researchers observed a reduction in late re-infestation when compared to conventional tillage in which old weed seeds are brought up to soil layer from where they can germinate during the season. Barros et al. (2008) further stressed the importance of the higher soil-bearing capacity under no-till allowing for the correct timing of application of any necessary weed control measure. In general, in the more humid regions of Europe, grasses and some perennial weeds pose greater challenges to CA systems, while annual weeds seem to cause less problems throughout Europe.

The challenge posed by herbicide-resistant weeds has been known in Europe for a long time, but it is not limited to no-till or CA conditions. However, the more frequent use of non-lethal doses of glyphosate-based herbicides may carry a higher risk of developing resistant weeds in no-till systems. Problems with herbicide-resistant weeds could put at risk opportunities for wider adoption of no-till in Europe, calling therefore for complementary and effective integrated weed management measures that include permanent soil cover either through residues or cover crops where possible and, above all, crop rotations under CA conditions (Soane et al. 2012).

Slugs, whether seed hollowing or leaf damaging, present a potential threat to the successful establishment of crops under CA, especially under humid and high residue conditions (Hammond et al. 1999). Several strategies have been proposed to cope with this problem, ranging from the application of mulluscicides or calcium cyanamide that increase production costs and affect other beneficial soil organisms, to deeper seed placement and aggressive residue cultivation. In order to intervene in time, monitoring before and after seeding is recommended (Jordan et al. 1997, Glen et al. 1990). Other proposals to reduce undesirable initial slug incidence include avoidance of anti-slug treatments to favour higher populations of predator beetles and other natural enemies of slugs as shown by Symondson et al. (1996) under direct drilling. While the incidence of some insect pests such as springtails in sugar beet decreases under mulch conditions, others such as the European corn borer (Soane et al. 2012), lesion nematodes (Mota et al. 1997) and mice (Xavier et al. 2005) may increase due to the practice of no-till.

Pathogens contained in crop residues may bear a higher risk of disease infection of subsequent crops, especially in monocropping systems (Mikkola et al. 2005). However, the few studies available in Europe comparing the effects of conventional and CA-based cropping systems on the incidence of disease provide no clear evidence if one or the other practice favours or suppresses the occurrence of crop diseases. Bräutigam and Tebrügge (1997), for example, found no difference between ploughing and no-till in eyespot infestation in wheat after 3 years, but considerably higher infestations after 8 years when ploughing. In the Czech Republic, Matusinsky et al. (2009) found that soil management only had a limited effect on the incidence of stem-based diseases, whereas *Fusarium avenaceum* was more prevalent with tillage in 2007. In Norway, reduced incidence of clubroot (*Plasmodiophora brassicae*) in reduced and no-tilled brassica crops was observed by Ekeberg and Riley (1997), but Fortune et al. (2003) reported higher levels of infection of net blotch (*Pyrenophorateres*) and rhynchosporium (*Rhychosporium secalis*) under reduced tillage. Also, the incidence of barley yellow dwarf virus on no-till winter barley was considerably less when compared to ploughing (Jordan et al. 1997; Kendall et al. 1991).

15.4.4 Environmental Aspects of CA

Concerns about the environmental performance of farming practices rank high in Europe. Legislations and regulations govern the use and amount of many production inputs. It is therefore not astonishing that environmental impacts of CA or no-till have been investigated thoroughly in Europe and that there are many studies on the aspects of environmental behaviors of CA. The main concerns are related to erosion, nutrient and pesticide dispersal and, in the last two decades, emissions of greenhouse gases also (Holland 2004; Davies and Finney 2002).

For a long time in Europe, runoff and soil erosion have been underestimated as being a widespread problem not only with regard to the degradation of agricultural soils but also as an environmental problem affecting off-site ecosystems and water resources. Only in the twenty-first century has erosion been officially recognized as a major threat to agricultural soils and to the environment (Van-Camp et al. 2004). More evident and severe in some regions than in others, erosion is now a concern of almost all national and regional authorities in Europe. The Mediterranean regions, due to the concentration of rainfall in the winter months, are especially prone to severe erosion events (García-Ruiz 2010; Basch and Carvalho 1998), but also other regions in Europe are seriously threatened by soil erosion. Ploey et al. (1991) estimated this area to be around 25 Mha in western and central Europe, with an average annual soil loss of tens of Mg ha^{-1} on several million hectares. Others have estimated that the annual average soil erosion rate within the European Union is in the order of 17 Mg ha^{-1} (Troeh and Thompson 1993), and individual events may cause soil losses between 20 and 40 Mg ha^{-1} (Montanarella 2006).

Much evidence has been collected about the benefits of CA and no-till in effectively reducing soil erosion rates: improved soil structure, vertically oriented macropores and thus greater downward movement of water in the soil as well as the breakdown of the energy of raindrops through residues contributing to much less soil detachment and crust formation (Basch et al. 2012a) which are key processes that decrease soil losses by up to 95 % and surface runoff by up to 60 % under CA when compared to conventional soil management (Márquez et al. 2008; Ordóñez et al. 2001). Although less widespread—such as on sandy soils in the Netherlands (Van Ouwerkerk and Perdok 1994) and in East Germany—wind erosion has been effectively controlled by the adoption of CA (López and Arrúe 2005; IRENA 2005). However, under certain conditions, the absence of soil disturbance alone is not sufficient to keep runoff and erosion well below the rates found under conventional tillage management. In an experiment in olive groves in southern Spain, Gomez et al. (2009) obtained not only higher runoff coefficients in inter-rows kept weed-free but also higher erosion rates. Only the establishment of barley as a cover crop was able to reduce both runoff and erosion effectively.

Besides the impact on degradation of agricultural land, runoff and erosion contribute decisively to the off-site transport of nutrients and pesticides and thus to the environmental impact of farming. Both nutrients and pesticides can be transported in a dissolved form in runoff water, but the strong adsorption of many pesticides and phosphorous to soil particles make off-site transported sediments a major source for contamination and eutrophication of water bodies. Yet, the occurring soil stratification under CA and the consequent enrichment of the uppermost surface layer in SOM and the dissolved fraction of P may lead to higher concentrations of dissolved fractions in the runoff of no-till fields. Despite 70 % reduced off-site transport of particulate P under no-till, Puustinen et al. (2005) found almost four times more dissolved P in the runoff. Some authors attribute the higher availability of dissolved P at the surface of no-till fields also to the decay of weeds or cover crops and to surface-applied fertilizers (Ulén et al. 2010; Muukkonen et al. 2009). Further improvement of water infiltration by integrating the other two principles of CA to no-till farming may minimize the losses of dissolved P in runoff under no-till conditions.

Mechanisms for off-site transport of pesticides are similar to those of nutrients. Strongly soil-bound pesticides, such as glyphosate, the most widely used herbicide in CA systems, would only be a problem if considerable amounts of soil were lost by runoff. Several studies confirm that both the persistence of herbicides in soil and the amounts found in runoff from fields under no-till are reduced (Cuevas et al. 2001; Cox et al. 1999). Basch et al. (1995) attribute the lower persistence of pesticides in the soil under CA to the higher microbiological activity in the surface soil layer and the reduced concentration in the runoff to a stronger adsorption to higher amounts of SOM. With the exception of one first runoff event after application, these researchers found at different sites in southern Portugal that concentrations of atrazine and metolachlor in maize and isoproturon in winter wheat were lower in CA compared to conventional tillage. They also highlighted the importance of avoiding applications just before heavy rains, especially under CA conditions where weeds or crop residues retain considerable parts of the applied herbicide. Borin et al. (1997) confirmed similar results from other experimental sites in Italy and Germany, which also participated in the EU project on 'Effects of tillage systems on herbicide dissipation'.

Although nitrogen compounds may be transported in runoff, the main losses of nitrogen from agricultural fields occur in the form of nitrate leaching. The release of an EU Nitrates Directive and the classification by the EU of areas as 'nitrate vulnerable zones' indicate the severity of this problem in Europe. Farming practices are therefore scrutinized with regard to their impact to nitrate leaching (Hansen et al. 2010). However, as far as the practice of CA is concerned, results from several studies are inconclusive (Hansen et al. 2010; Oorts et al. 2007a). There is general agreement that the absence of tillage in autumn reduces mineralization and thus leaching of nitrate over winter (Hansen et al. 2010; Düring et al. 1998). In addition, Tebrügge (2003) argued that despite a greater percolation of water under no-till, there is no increase in nitrate leaching as most of the downward water movement occurs as bypass flow. He also concluded that the predominant form of nitrogen under no-till is organically bound nitrogen not subjected to vertical displacement as is the case with mineral nitrogen from fertilizer. Crop residues, especially those with higher C/N ratios will further tend to immobilize mineral nitrogen, thus reducing nitrate leaching (Morris et al. 2010).

Over the past 20 years, the analysis of the environmental impact of any economic activity has increasingly included its contribution to greenhouse gas (GHG) emissions. To obtain a full picture on the GHG footprint of any system change introduced, a complete life cycle assessment would be required. In agriculture, and apart from the well-known methane emission sources, which are flooded rice and ruminants, it is all the cultivated land that may contribute to the emission of GHG. According to Eurostat data from 2010 (Fellmann et al. 2012), agriculture in Europe contributed almost 10 % to the total EU‒27 GHG emissions deriving around one-third from enteric fermentation, one-sixth from manure management, and more than 50 % from agricultural soils. Astonishingly, the JRC report (Fellmann et al. 2012) noted that 'emissions (and removals) of carbon dioxide (CO_2) from agricultural soils are not accounted for in the "agriculture" category. Whereas detailed statistics are available for the 27 member states on their agricultural share and evolution of methane and nitrous oxide emissions, no precise data are available on CO_2 emissions from agricultural soils'.

While analyzing the impact of different soil management practices on CO_2 fluxes from agricultural soil, short- and long-term effects must be considered. There is a broad consensus on the strong short-term increase of CO_2 emissions after conventional tillage when compared to CA, but in the longer term, not all researchers have found consistent reductions in CO_2 emissions under CA (Vinten et al. 2002), and under certain conditions some researchers even found higher CO_2 fluxes under no-till (Oorts et al. 2007b). Results from the measurement of CO_2 fluxes at a given moment, even if over a longer period of time, are strongly influenced by total C and N, but also by mineral N, water content, weather conditions and the amount and form of SOM (Regina and Alakukku 2010). Whether there is a long-term negative or positive balance with regard to CO_2 fluxes can be assessed to some extent by the evolution of SOM. Provided organic carbon inputs through biomass residues (above and below ground) are similar, the comparison of the evolution of SOM should provide a clear indication for the performance of different farming practices in terms of their carbon flux balance.

Although not linear over time (Freibauer et al. 2004), carbon sequestration has increased with the adoption of CA, especially under favourable conditions, i.e. under no-till and the retention of crop residues (Corsi et al. 2012; Basch et al. 2012b, 2010; Mazzoncini et al. 2011; Bhogal et al. 2007; Oorts et al. 2007c; Tebrügge 2003). According to the finding that SOM change was negatively correlated with initial SOM content (VandenBygaart et al. 2002), it also appears that the highly SOM-depleted soils in the Mediterranean region respond faster and with higher carbon sequestration rates to carbon-enhancing changes in soil management. However, in order to evaluate the full potential for carbon sequestration through changes in land use and soil management, excluding short-term effects of changes in soil biological processes, time scales of up to 100 years may be necessary under European conditions to reach a new equilibrium (Smith 2004). Several authors have used average carbon sequestration rates to highlight the importance and potential of widespread adoption of CA practices for the mitigation of anthropogenic CO_2 emissions at national and European levels (McConkey et al. 2000; Basch et al. 2002; Tebrügge 2002). Tebrügge (2002) estimated for EU-15, based on the assumption of no-till and conservation tillage adoption on 30 and 40 % of arable land, respectively, that a total emission reduction of CO_2 could be achieved by carbon sequestration in the soil. Together with an additional reduction of 5 $MtCO_2$ $year^{-1}$ through savings in fuel consumption, the total emission reduction could have accounted for around 39 % of the EU-15 commitment in terms of CO_2 emission reduction target within the Kyoto Protocol until 2012. These estimates also show that the mitigation potential of CO_2 emission through fuel savings using CA is far from that of carbon sequestration in the soil.

Concerning other GHGs, especially nitrous oxide, the results obtained for different soil management systems seem to be more controversial. It is well known that soil moisture and compaction, leading to less soil aeration, favour denitrification processes. Reduced aeration due to higher soil moisture under CA, especially on poorly drained soils, are therefore conditions where higher N_2O emissions are reported (Regina and Alakukku 2010; Ball et al. 2008; Oorts et al. 2007b). It seems however that with time, and the build-up of a favourable soil structure and porosity, the conditions under CA become less prone to the release of N_2O when compared to the conventional tillage (Six et al. 2004). Under well-aerated soil conditions similar (Rochette 2008) or even reduced N_2O emissions (Mutegi et al. 2010) were measured

Fig. 15.3 Evidence of increased incidence of above-ground vertebrate species (hares and Little Bustard) under CA. (Fotos: R. Freixial, left; AEAC/SV, right)

under no-till when compared to ploughing, and in the case of incorporation of leguminous crops through tillage, considerably higher N_2O emissions were detected when compared to no-till (Almaraz et al. 2009). The varying results regarding N_2O emissions while comparing soil management systems clearly indicate the need for further and continuous long-term research especially with regard to reduced mineral nitrogen fertilization requirements under improved soil fertility conditions with CA.

Under European conditions, little is known about the impact of soil tillage management on the emission or absorption of methane from soil. Ball et al. (1999) reported some increased methane emission under no-till, yet other authors did not find appreciable levels and differences between soil management systems (Regina and Alakukku 2010).

The decline in biodiversity has been considered by the Soil Thematic Strategy as an important threat to European soils (Van-Camp et al. 2004). Biodiversity as such can be looked at from the functional point of view affecting the productivity of soils but also from an environmental or ecological point of view as it goes much beyond interfering with the natural infrastructure and the soils' functions to provide ecosystem services. Today, it is evident from international scientific studies as well as from observational evidence from farmers' fields and agricultural landscapes that intensive soil tillage adversely affects soil biodiversity and health.

Besides the improvement of functional biodiversity through CA and no-till, already referred to in the section on soil quality, and including microfauna but especially meso- and macrofauna, there are below- and above-ground living vertebrate species such as birds and hares (Fig. 15.3) that benefit from no-till and the shelter that crop residues provide. Holland (2004) provided a comprehensive review on the environmental consequences of the adoption of CA in Europe.

15.4.5 Economic Aspects of CA

Initial uptake of no-tillage in Europe was voluntary and driven by the need to reduce crop establishment costs (Basch et al. 2008). More surprising is the fact that the declining economic viability through continuously increasing costs for inputs in the form of fuel, agrochemicals and labour but also through environmental restrictions did not lead to a breakthrough in terms of widespread adoption of CA systems. Economic returns almost throughout Europe have been highly favourable when applying the CA system. Calculating the profits of several crop rotations since the beginning of different long-term soil management systems at five different sites in Hessian/Germany, Tebrügge and Böhrnsen (1997a) obtained 17.8, 6.9, 15.7, 10.3 and 20.3 % higher profit, respectively, under no-till when compared to conventional ploughing, despite several years of smaller yield benefit at the beginning. Depending on the starting yield level and the market prices for the crops, and considering a 500-ha farm, they calculated 'acceptable' yield reductions (break even with the plough system) for no-till between 12 and 28 %. Under rainfed conditions in southern Portugal and for a 500-ha farm, Marques and Basch (2002) calculated a necessary level of wheat production to obtain a breakeven net margin of 1431 kg ha^{-1} for the plough system, whereas only 1130 kg ha^{-1} for the no-till system. These calculations, however, do not reflect other advantages of the no-till system that might translate into economic benefits, which are more days available for crop establishment and the better trafficability on no-till soil allowing the correct timing for top dressing or herbicide application even in wet winters (Basch et al. 1997), lower wear and tear costs on machinery and equipment as well as environmental and soil health benefits. In Finland, Mikkola et al. (2005) found that yield reductions up to 15 % under no-till were still economically tolerable.

In the final report of the European project on Sustainable Agriculture and Soil Conservation (SoCo 2009), the authors report cost savings with respect to labour in no-till systems of up to 50–75 % and up to 60 % of cost savings with fuel consumption. Although the adoption of CA may require some initial investment in machinery, mainly seeding equipment, the later reduction in overall machinery and respective costs for repair and replacement are significant, especially for larger farms. Freixial and Carvalho (2010) calculated a reduction in variable costs of around 80 % for the maintenance of tractors and seeding or tillage equipment after changing from conventional plough tillage to no-till cereal-based crop rotation on a farm of 350 ha in southern Portugal.

While the adequate timing of the application of agrochemicals may be a source of economic savings, improved soil fertility and better nutrient and water cycling and availability under CA are one of the most important economic benefits of CA. Besides the reduction of phosphorus losses through runoff and erosion (Soane et al. 2012), the possible reduction in mineral nitrogen inputs through higher total nitrogen contents in the SOM content could contribute to an improved nitrogen and water use efficiency and productivity of mineral fertilizer applied. In a nitrogen fertilization response trial, Carvalho et al. (2012) found a significant relationship between SOC content in the top 30 cm of the soil, level of nitrogen applied and wheat yield (Fig. 15.4).

On the same soil but with 2 % SOM content obtained after 11 years of no-till and crop residue retention, instead of 1 % SOM under conventional tillage and straw removal, the wheat crop yielded more with less nitrogen.

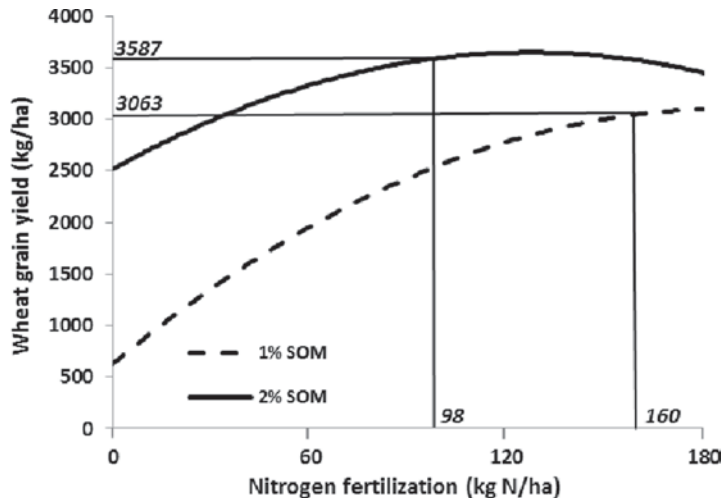

Fig. 15.4 Effect of soil organic carbon (SOC) content (0–30 cm depth) on the wheat response to nitrogen fertilization. The nitrogen level values (160 and 98 in *italic*) are relative to the most economical N level for each SOC value considered. The values for wheat grain yield (3063 and 3587 in *italic*) are relative to the respective predictable yields. (Adapted from Carvalho et al. 2012)

It is evident that the achievable cost savings through the implementation of CA systems far outweigh any potential small yield reductions that may occur in some instances, mainly in the transition phase from conventional tillage system to CA system. Still, the aforementioned examples do not account for the environmental costs or benefits that a change to CA may save or add to the system.

15.5 Challenges for CA in Europe

Bearing in mind the potential benefits that can be delivered through the application of CA as described in the previous sections, it raises the question 'why is Europe lagging so far behind other regions in the adoption of CA?' In an inquiry conducted in several European countries among two stakeholder groups, divided into practitioners (farmers) and experts (advisors, researchers, extensionists), Tebrügge and Böhrnsen (1997b) concluded that farmers who were applying CA had a positive attitude with regard to CA, highlighted the economic more than the ecological benefits, and complained about the lack of advice and applied research results. In contrast, experts were more sceptical, stressing the potential yield depressions as the main disadvantage of CA. In a study carried out in 2007 on behalf of the Spanish Ministry for Agriculture, 135 inquiries by Spanish CA farmers were analysed to find out more about the performance of CA practices (Veroz-González et al. 2008). The general conclusion was that despite a change in weed flora, CA does not increase weed control problems and the referred trends did not indicate any more or less problems with pests and diseases with CA. Production levels were reportedly maintained which together with reduced costs contributed to improved competitiveness of farms. The following sections discuss what makes European farmers reluctant to change.

15.5.1 Cultural and Economic Entrenchment of Tillage Agriculture

Even today, European farmers believe that by mechanically tilling and working the soil, they are doing good by burying any growing weeds and weed seeds, mineralizing nutrients, breaking soil compaction, aerating the soil and creating a 'suitably' loose seedbed for sowing a variety of crops. The perfect inversion of the upper soil layer that effectively controlled perennial grass weeds and provided a clean seedbed for sowing made the mouldboard plough the preferred tillage implement and the symbol of modern agriculture. Therefore, it is not surprising to still find ploughing contests all over Europe. Knowing the history of this implement, it is comprehensible why Europeans are the strongest defenders of the plough.

15.5.2 Favourable Natural Conditions and Yield Levels

In many regions of the world, the adoption of CA has been in response to adverse crop growing conditions caused by severe natural constraints, e.g. severe soil erosion, or the need to reduce costs due to high production risks or farming under marginal economic conditions. Despite the occurrence of less favourable conditions, such as low soil fertility (low soil organic matter), dry conditions and/or erratic rainfall distribution and poor soil structure, in some, mostly southern parts of Europe—the most important agricultural regions of Europe with the biggest influence on the definition of agricultural policies and on technological development—natural conditions for crop production and the financial support provided to farmers under the CAP agreement are favourable. Therefore, in most regions in Europe, the perception of the need to change and the drivers to search for better and sustainable solutions is insufficient.

Due to these favourable conditions, yield levels in many intensively cultivated regions in Europe are very high although difficult to sustain (Lin and Huybers 2012; Brisson et al. 2010; Petersen et al. 2010) and there is concern regarding possible yield losses as the result of a system change. In fact, some researchers have reported yield (not necessarily profit) reductions in the first year after CA adoption due to reasons outlined in Sect. 15.4.1. After the transition phase or under optimal conditions, crop yields are similar to or greater than those under conventional tillage right from the start. Still, in many cases, the performance of CA relative to plough tillage is measured on the basis of a crop yield and not on a profit or production cost per unit of grain basis.

15.5.3 Weed, Insect Pest and Disease Challenges

As referred to in Sect. 15.4.3, weeds, insect pests and diseases may pose serious problems to the prescriptive and ready-to-use application of CA principles. Certain weeds, mainly perennials and some grass weed species may become more abundant while overall weed numbers normally decline under CA. Successful weed control in CA means a change in timing of herbicide application and in the type of herbicides used, not necessarily higher amounts of chemicals applied. More persistent herbicides with residual effects are used less as they will not do their job effectively when retained in crop residues. Advanced CA farmers rely more and more on integrated weed control strategies based on the combination of crop rotation, cover crops and residue management. However, the general perception that no-till requires more herbicide applications to control weeds adequately remains one of the greatest obstacles for the acceptance of CA as a sustainable farming system.

With regard to insect pest and diseases, it is mainly slugs (Sect. 15.4.3.) and the increased incidence of head blight disease (*Fusarium* spp.) recorded in wheat that raised arguments against the uptake of CA. Whereas slugs may increasingly be controlled by higher numbers of predating beetles, under wet conditions, they may cause problems locally that need to be monitored carefully. The higher incidence of mycotoxins producing head blight under CA, reported mainly in Germany, France and Switzerland, may be suppressed by not following wheat after maize, and through adequate residue management and the use of resistant wheat varieties (Vogelgsang et al. 2005). In general terms, the inquiry conducted by Tebrügge and Böhrnsen (1997b) among 101 European farmers revealed that between 76 and 80 % of the participating CA farmers did not experience more problems with insect pests and diseases, respectively, after the change from conventional tillage to CA.

15.5.4 Crop Residues and Management

Within Europe, tremendous differences exist in terms of agro-ecological conditions with extremely high productivity levels and high input farming systems in the central and northern regions (and southern when irrigated) and rather extensive, rainfed agricultural systems in the Mediterranean region. The amount of crop residue the planters have to deal with varies from less than 2 Mg ha^{-1} to more than 10 Mg ha^{-1}. In regions with low productivity, crop residues and stubble (mainly cereals) are frequently used as fodder for livestock, whereas in high productivity regions, retention of crop residues in the field is common. Both situations present big challenges for the uptake and spread of CA, as high amounts of residue cause problems for drilling equipment and seed placement under wet conditions but also for warming and drying in spring, whereas low residue levels prevent the rapid improvement of soil conditions and water conservation under CA. Several solutions are used to deal with high residue levels, including improved chopping and distribution equipment on the combine harvester, high stubble cut, improved no-till drilling equipment, and even seeding by broadcasting small seeds like rape before the cereal harvest. Although the importance of crop residue retention for soil improvement and water availability in Mediterranean regions has been demonstrated (Basch et al. 2012b), it remains a challenge to guarantee adequate soil cover, especially under rainfed conditions, unless, as it happens in some countries or regions, payments for agri-environmental measures compensate for any loss of income.

15.5.5 Availability of Suitable Seeding and Planting Equipment and Inputs

One of the biggest challenges for the European farmer to adopt CA is the lack of adequate no-till drilling equipment. Under low residue conditions, most of the imported drilling machines from North and South America work considerably well, while on wet and clayey soils the management of high residue levels pose increased challenges for crop establishment. The low demand for adapted and specific drilling equipment did not encourage European manufacturers to develop machinery in this specific area compared to other regions where many solutions and options are available to cope with specific local conditions. It is not by chance that Finland has the highest percentage of arable land under CA. Despite about ten different brands of no-till seeders on the market, one Finnish manufacturer has more than a 50 % share of no-till drills sold in Finland. Some improvements have been noticed in the availability of chopping and distribution devices of harvest equipment.

Besides equipment, the availability or even the identification of crop varieties that respond to specific constraints when sown under CA conditions is still a challenge for breeders and seed companies in Europe. Varieties with improved germination under lower soil temperatures, more vigorous initial root development or a better response to different nutrient and water dynamics could make the difference for the success of CA, as well as specific, locally adapted mixtures of cover crops.

15.5.6 Problem-Oriented Research and Training in CA

Despite some intensive and long-term research carried out in several European countries in the field of CA, there seems to be no notable link between research and adoption by farmers. It also appears that the research was mainly driven by academic interest with little focus on practical and solution-oriented research. Only in regions where CA farmers organize farmers' groups, as it happened decades ago in South America, some bottom-up approach occurs, and researchers and extension workers whether public or private are called to provide solutions to further improve CA. In some countries or regions, such as Spain, the role of the national CA association has been decisive for a wider uptake of CA, mainly through training and technology transfer actions, organization of field days and exchange with experts, as well as through their efforts to guarantee support from the private sector and public institutions.

15.5.7 Common Agricultural Policy (CAP) and Economic Pressure

For almost 50 years, farming in Europe has been subjected to the strong influence of the CAP framework. The objectives of these policies changed substantially over this period; nonetheless, there was always and continues to exist strong financial support for the farming sector. Until more or less 10 years ago, subsidies were mostly production oriented favouring high productivity levels, obtained with massive external inputs, instead of promoting competitiveness and sustainability. The constant transfer of welfare from the consumer and taxpayer to the producer in the form of subsidies (named compensatory payments) prevented the necessary adaptation of European agriculture to the changes and new realities of a global agricultural market. Even with the tremendous fluctuations of commodity prices, European farmers do not yet fully perceive the need to lower productions costs and become economically sustainable, as much of the risk in farming is still covered by CAP subsidies. This dependence on subsidies has made most European farmers focus their activities towards maximization of subsidies rather than think and act in the long term and invest in soil fertility and health. It therefore seems that without financial incentives, new production methods will not be widely accepted, especially those referred to as being 'knowledge and management intensive' such as CA. Unless there is a clear change in the support policy for the agricultural sector, i.e. shifting away from unspecific, non-restrictive direct payments (1st Pillar of CAP) towards stronger support of overall sustainable productions systems through either conditioning 1st Pillar payments or agri-environmental measures supported through Rural Development Policy (2nd Pillar), little will change in the attitude of European farmers and EC policy makers regarding the mainstreaming of CA as a basis for sustainable production intensification. Although the new policy instrument of the 1st Pillar, the so-called Greening, is directed to the provision of environmental public goods, the measures proposed (maintenance of permanent grassland, ecological focus areas and crop diversification) are clearly insufficient to achieve the objectives explained in the CAP 2014–2020 reform proposal (Basch et al. 2012c).

15.6 Common and National Policies Affecting CA

In Europe as a whole, CA has received relatively little public support compared to other production methods. This support varies strongly from country to country and even between regions within Europe. In general, it is provided either through incentive for farmers to adopt certain management practices or, to a much smaller extent, through the promotion of mostly fundamental research with some relevance for CA.

15.6.1 Research Support

As mentioned in Sect. 15.2, even with some relevant research into the consequences of change in soil management practices, most research was focussed on conservation tillage and the comparison of the performance of different tillage systems, rather than on enhancing CA or other soil-improving management systems. From the scientific literature, there has been some research support at a national level in response to the increasing awareness of the seriousness of some of the later identified 'threats to European soils'. On a European level, an increasing concern with soil-related issues is noted with the start of the Fifth Framework for Research and Technological Development of the EU in 1998. Several research, technology transfer and knowledge dissemination projects have been put in place since then to close knowledge gaps and to create awareness of the need for soil conservation. In more recent years, several European transnational research projects such as 'Smartsoil', 'Ramsoil' and 'SoCo' have been funded to study ways to mitigate soil threats and to identify best management practices to achieve this mitigation. Similarly, in the next framework named Horizon 2020, calls are open to improve the insight into 'soil quality and functions' and 'sustainable crop production' and the 'assessment of soil-improving cropping systems', initially named 'assessment of CA systems'.

15.6.2 Soil Thematic Strategy Initiative and Rural Development Measures

The increasing awareness that sustainability of agricultural production can only be guaranteed if its most important resources are maintained or improved, gave rise to policy-driven initiatives towards soil protection both nationally and Europe-wide, with the Soil Thematic Strategy Initiative being the most visible attempt. Although the working groups established within this initiative clearly identified the major threats to European soils and proposed action that lead to the proposal of a European Soil Framework Directive, the ratification of this Directive was blocked by five-member states. Despite or most likely as a result of the failure of a European initiative, soil conservation became more and more an issue at national level and was encouraged by the possibility to support soil-protecting farming practices through so-called agri-environmental measures co-financed between the EU and member states through the Rural Development Program Funds (2nd Pillar of CAP). In some member states, this lead to the launch of support schemes for the uptake of CA either nationwide (Portugal) or limited to some regions (Spain, Germany, Italy). In Switzerland, it is in the Canton of Berne where a highly sophisticated support scheme to fight soil erosion started in 1993 (Schwarz et al. 2007). It is in this and three other cantons with similar support schemes where CA was practiced on around 5% of arable land in 2006 (Ledermann and Schneider 2008).

The support schemes introduced and the respective levels of 'compensation' vary from country to country and even between regions. They can range from non-inversion conservation or mulch tillage (Saxony/Germany) to strip tillage on wide-row crops to pure no-till. Additional measures, such as those in place in Portugal during the past few years, should compensate the farmer in case he left high stubble or the entire straw on the field. In Spain, additional subsidies of up to 40% of the costs of new no-till seeders were granted by several regional governments and governmental institutions. However, due to the economic crisis and the obligatory co-financing of the Rural Development measures through the member states or regional authorities, support and further uptake of CA measures have been seriously compromised.

15.7 Prospects for Up-Scaling CA in Europe

15.7.1 Effects of Climate Change

In Europe, climate change is a real concern for society and of major importance to farmers. Whether in Northern regions where winters are supposed to become milder and autumns and springs wetter, or in southern, central or eastern countries with expected increases in drought incidence in spring and summer, climate change will affect agriculture both in regard to adaptation strategies to be adopted and through its potential for mitigation. If winter climate conditions in northern Europe become wetter, possibly with more intense rainfall, widespread application of CA could limit the higher risk of water erosion and associated problems through off-site transport of sediments and agrochemicals. In regions where rainfall becomes less and more erratic, with longer summer droughts, no-till in combination with residue cover would improve soil water use efficiency to maintain or even improve yield levels (Basch et al. 2012b).

As referred to in Sect. 15.3.4, carbon sequestration in agricultural soils could contribute significantly to the mitigation of anthropogenic CO_2 emissions. The reversibility of this process if soils were submitted again to intensive soil tillage after years of SOM accumulation through CA makes very few decision makers believe in the long-term CO_2 emission mitigation potential of CA.

15.7.2 Soil and Crop Management-Related Policies

Probably more than elsewhere, soil and crop management practices in Europe are extremely scrutinized and regulated by the respective authorities with regard to their environmental performance, both at national and European level. Today, CA is recognized as a farming practice which can effectively reduce runoff and erosion, and even enhance SOM content. This is clearly demonstrated through the CA-promoting agri-environmental measures already in place in several European countries. The general acceptance of the conclusions of the Soil Thematic Strategy as a European Soil Framework Directive could have further positive impact on the adoption of CA, as it clearly addresses several of the identified soil threats.

On the other hand, more restrictive regulations for the use of herbicides as well as surface applied but not immediately incorporated slurry may pose increasing challenges to the use of CA systems based on no-till. Although the use of herbicides is not necessarily higher under CA when compared to conventional tillage, the perceived risk of not having the means to eventually handle weed problems may make farmers hesitate to adopt CA.

15.7.3 Evolution of Production Costs and Commodity Prices

At present, a considerable percentage of European farms are economically viable only due to the subsidies received in the form of the so-called Single Farm Payment. There is enormous pressure both from outside and inside the EU to reduce the direct payments and make support to farmers dependent on the verifiable delivery of public goods. More than in the past, the current CAP reform stresses the need for more competitiveness of European agriculture, as CAP expenditure within the EU budget has been maintained over the last 18 years despite the increase from 15 to 28 member states. The prospect of decreasing direct payments and the simultaneous increase of production costs, together with stagnating and extremely volatile agricultural commodity prices, will force farmers, also in Europe, to adopt farming methods that reduce overall production costs while maintaining productivity levels. As demonstrated in Sect. 15.4, CA will immediately reduce fuel costs and working time per unit area, reduce investment in machinery and maintenance costs, and, in the case of irrigation, result in less water and energy consumption. In the medium and long term, benefits from improved soil fertility are expected through lower levels of mineral fertilizer inputs. The concomitant improvement in the environmental and economic performance of farming through the application of 'good' CA has often been described as a win–win situation. The upward evolution of production costs and commodity prices, together with the reduction in subsidies will most probably be the fastest driver to have CA adopted on a much larger area, also in Europe.

15.8 Conclusions

In a few regions of Europe, CA has been well adopted while in others, this farming practice is almost unknown or regarded as exotic. The fact that CA is successfully applied under the most diverse pedo-climatic conditions (from the most southern regions in Spain up to Scandinavia) means that the reasons Europe lag far behind other regions in the world in the uptake of CA cannot be explained by less favourable soil or climate conditions or differences in cropping systems. There are two fundamental conditions that appear to make the difference when comparing with other regions of the world.

The use of agrochemicals in agriculture for weed and pest management in agriculture is a central issue both with regard to food safety and environmental impact. Consumers and society as a whole are receptive to arguments that justify the restriction of pesticides. Europe has probably one of the strongest regulations that control the release of plant protection products on the market (Regulation (EC) No 1107/2009) and the homologation of products must be obtained for each country. It therefore does not seem surprising that the alleged increased input of herbicides and other chemicals for disease and pest control is the main barrier to the full acceptance of CA as a sustainable crop production concept.

Less than a constraint, but more a missing driver for the adoption of CA, is the level of support European farmers still receive. Although subject to today's world market prices of commodities, the enormous transfer of welfare from consumers and taxpayers to the agricultural sector allows farmers to maintain less efficient and thus less competitive production systems.

There is no doubt that the change from conventional to conservation agriculture requires the acquisition of new knowledge, skills and a great deal of observation and learning capacity. However, farmers who wish to change do not find the necessary practical knowledge among extension workers and advisors, whether public or commercial. Despite some already existing farmer-to-farmer exchange, only the institutional promotion of education, capacity development and extension in CA-based sustainable soil management would help bridge the gap between the objectives of sustainable resource management recurrently proclaimed in the CAP and the implementation of real sustainable soil management. Lessons learned from other regions in the world, such as in Canada or Brazil, where the carbon offset potential of CA or its capacity to 'cultivate good water' (*Cultivando Água Boa*) are officially recognized and paid for as ecosystem services (Kassam et al. 2013), may teach European stakeholders and decision makers that the inclusion of the principles of CA in the CAP 'greening' measures of the 1st Pillar direct payments could reach a much larger area under sustainable management.

Regionally, there are other bottlenecks that may act as a deterrent to the wider uptake of CA, such as high crop residue amounts, specific weed problems, soil compaction or lack of adequate machinery. Persistent pioneer farmers, more than results from research, have demonstrated that CA does work in Europe, once it has adapted to the existing conditions. Research can help improve knowledge gaps and available technology, and obtain scientific evidence for the many benefits of CA in order for it to gain acceptance by the public. However, even if farmers were convinced and researchers were willing to help, in a Europe with agriculture driven by CAP and the respective authorities, it appears that it is up to the political decision makers and administrative stakeholders to set or change the course towards the right direction, bearing in mind the words of the former US President Roosevelt: 'A nation that destroys its soils, destroys itself'.

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