PROSPECT FOR CONSERVATION AGRICULTURE IN NORTHERN AND EASTERN EUROPEAN COUNTRIES, LESSONS OF KASSA

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SYNOPSIS. In Europe, Conservation agriculture (CA) is less adopted than in the other world adopting regions and, reduced tillage is more used than no-tillage. Use of cover crop is not common. It is currently less researched than it was before the 1990s. One of the main features of CA is the reduction of the production costs which acts as a powerful driving force for the dissemination of CA technologies. In Europe, conversion from conventional agriculture to CA leads to a minor change in yields: ± 10% depending on the countries; and, this is not decisive for farmers as far as CA meets their main expectation: i.e. reduction in costs of fuel, machinery and labour saving. The adoption process responds to a step-by-step strategy and, large sized farms are the main adopters. The increase in competitiveness at the global and at European level brings the general trend of the increase of CA coverage world-wide and the current level of fuel costs together with the trend of the enlargement of the farm size in Europe will probably contribute to the adoption of CA in Europe. The process is likely already ongoing in some European countries; it has to be sustained.
Key words: conservation agriculture, reduced tillage, no-tillage, impacts, Europe.

INTRODUCTION

Conservation agriculture (CA) refers to the simultaneous use of three practices: (i)- reduced tillage or no-tillage and direct seeding for less disturbance of the soil and proper crop establishment; (ii)- cover crops to mitigate soil erosion and to improve soil fertility and soil functions and; (iii)- crop rotation to control weeds, pests and diseases (Derpsch, 2001). Terms such as conservation tillage, zero-tillage and direct drilling also apply to CA. Despite the very early interest of the European research community in CA practices, there still are few synthetic reviews of the research findings (Cannel, 1985; Soane and Ball, 1998; Rasmussen, 1999; Tebrügge and Düring, 1999; Holland, 2004, Deumlich *et al.*, 2006) and, the adoption of conservation agriculture by European farmers is still very weak compared to other regions of the world (Derpsch, 2005).

The rise of environmental concerns along with the questioning of the sustainability of agriculture in Europe in the past decade led the European Commission (EC) to support many research initiatives one of which was an appraisal of the applicability of no-till technology in the western European countries (Tebrügge and Böhrensen, 1997a-b). More recently, the EC has funded a specific support action called KASSA –Knowledge Assessment and Sharing on Sustainable Agriculture, which aimed at tacking stock of past research results on sustainable agriculture (http://kassa.cirad.fr).KASSA focussed on conservation agriculture; this paper deals with the main findings and lessons of KASSA related to Northern and Eastern European countries. It presents the diverse practices of CA in Europe and the current extension of these practices in some European countries. Then, the main drivers likely to boost the expansion of CA in Europe will be presented and discussed. This may help to appreciate the future of agro-ecology in Europe.

METHODS

KASSA is a worldwide initiative. It worked simultaneously within four regional "platforms": Europe, the Mediterranean, Latin America and Asia. The project was implemented through a step-by-step and iterative process. This process began with the development of comprehensive inventories and assessments of existing and validated knowledge on sustainable agriculture in the four different regional "platforms". It continued with a comparative critical analysis across "platforms", the refinement of findings, and concluded with a final synthesis. Reports released at each step were submitted to the critical review of a panel of experts that validated KASSA results before its final delivery. The prospects for sustainable agriculture in Europe took an important part of the agenda of the KASSA closing conference.

The European "platform" of KASSA gathered 11 partners from 8 countries: Czech Republic, Denmark, Estonia, France, Germany, Norway, Ukraine, and United Kingdom. This team has worked on about 353 publications.

RESULTS

Conservation Agriculture practices in Europe

In the diverse European agricultural contexts, the concept of CA gave a wide variety of farming practices, ranging from non-inverting plough to reducing the depth of tillage and/or the number of passes, to the direct sowing within covered soil. Different practices may follow one another in time and may coexist within the same farmland. More attention has been given to the tillage component than to cover crop or to crop rotation (Rasmussen, 1999).The total absence of ploughing and the total absence of tillage may serve as limits to define the practical extent of conservation agriculture in Europe (fig. 1). Within these limits and whatever the type of soil cover management employed, reduced tillage (RT) encompasses all those practices by which soil is not ploughed and, no-tillage (NT) represents all practices without any soil disturbance. The nature and presence or absence of soil cover may be used to identify CA sub-domains.

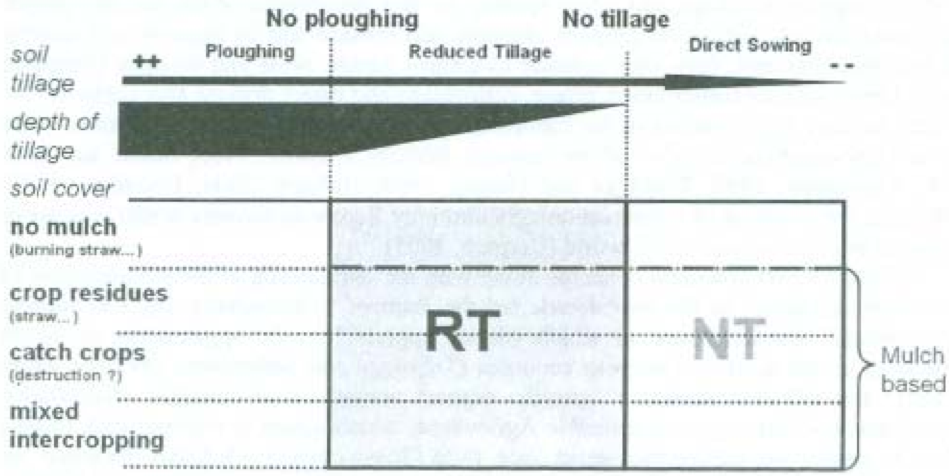

Figure 1. Description of the variety of practices of soil management in Europe. RT: reduced tillage; NT: no-tillage.

Fig. 1 illustrates faithfully the situation in Europe. Indeed, European farmers adapt their practices to the market opportunities and to the practical constraints they face. By 1978, 8-10% of the winter cereals in the UK were performed under NT or RT; however, by 1990, there was a strong move of farmers back to mouldboard ploughing because of a number of unforeseen problems of weed and crop residue management (Soane and Ball, 1998). The same scenario occurred in the Scandinavian countries between the 1970s and the late 1990s (Rasmussen, 1999); whereby the reasons given were residue management problems; grassy weeds infestations and excessive topsoil compaction (Munkholm *et al.*, 2003). Håkansson (1994) mentioned that in Scandinavian areas where CA practices have been advocated without having previously carefully investigated all consequences, farmers who had started using these methods sometimes returned to traditional methods. In erosion risk area in Norway there is a clear tendency to go from RT with no ploughing to apply spring ploughing. According to the Mediterranean "platform" findings, similar results have been observed in Spain following weed or pest infestations.

Table 1: Current extension of CA in the European "platform" participating countries

Country	Farming patterns		RT		NT	
	Number of farms	ha/farm	area (ha) (year)	% of the agricultural used area	Area (ha) (date)	% of the agricultural used area
Czech Republic	54639	68	750 000 (2005)	18%	150 000 (2005)	3.5%
Denmark	48 750	53	150 000 (2004)	6.8%	~0 (2004)	
Estonia	36 859	22	160 000	16%	10 000	1%
France	600 000	70	1 373 800 (2001)	4.6%	50 000 (2001)	0.2%
Germany	420 697	44	3 400 000 (2004)	20%	510 000 (2004)	3.0%
Norway	55 697	19	158 000 * (2004)	15%	6 000 (2004)	0.6%
Ukraine	53 000	800	9 400 000 (2005)	24%	50 000 (2005)	0.1%
United Kingdom	304 800	69	1 416 000** (2000)	7.7%	24 000 (2000)	0.1%

* In Norway, acreage in RT also comprises the area ploughed in spring. ** The area under conservation tillage given for the UK appears implausible as this farming technique is only now entering recognition amongst farmers in this country. It is thought that this figure includes the grazing areas that traditionally represent a very large segment of UK farming and which either are never tilled at all or only ploughed to renew the grazing or "ley", i.e. once every 4-10 years.

Currently, there is no survey at EU or country level of CA coverage in Europe. Data available are scarce and may not apply to the whole cropping system (Table 1). For instance, most of the areas listed as "no-tillage" may correspond to fields managed in NT only for a part of a rotation, whereas the other crops of the rotation are managed using RT or ploughing. Indeed, cereals can be grown under RT or NT while root crops are difficult to manage under these systems. The figures in Table (1) show that CA practices are less adopted in Europe and that RT is more common than NT. Also, there is a large diversity of situations between the countries which entails diversity in the practices used. This diversity results from driving forces and constraints, which are different from country to country.

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Profitability of CA

CA provides a short-term benefit through the reduction of the costs of production; a medium to long-term benefit, via increase in yields, which is supposed to come from soil fertility improvement, erosion reduction and better efficiency of the use of nutrients and water. The economic impact of CA may be assessed through direct margins which result from the difference between gross production directly linked to yield, and input costs. In Europe CA does not necessarily generate increase in yields; and, in most of the countries of the European "platform" the increase or the stabilisation of yield does not appear critical in the decision of farmers whether to adopt CA or not. On average, yield on poor and medium fertile agricultural lands does not change dramatically (+/- 10%); yields slightly decrease on very fertile lands with a high-intensive level of production. In the Ukraine, however, yields are expected to increase by 5-10% on the chernozem and even in this case, the cost savings remains the most important economic element of CA. Hence, in Europe, the economic interest of CA for farmers comes mainly from it influence on the reduction of fuel, labour and machinery costs.

Table 2: Fuel and labour costs in ploughing, RT, NT in Denmark, France and Germany (Sandal, 2004b; Le Garrec, 2003; Tebrügge, 2000)

		Ploughing	RT	NT
Fuel consumption (Litter/ha)	Denmark	40/50	18 to 35	
	France	*Clayey soil*: 75-105 *Clay/loam soil*: 26-38	*Clayey soil*: 18-29 *Clay/loam soil*: 12-25	12-24
	Germany	35	14-25	6
Labour (hour/ha)	Denmark	2/3	1.1-1.7	0.8-1
	France	2	1.5	0.5-1
	Germany	2	0.8-1	0.4

Results (Table 2) show that RT and especially NT greatly reduce the cost of labour and fuel. However, this reduction depends on many factors i.e. the type of soil, crop and machinery. This is illustrated with examples on a loess region (Table 3) and on a loamy soil in northern Germany (Table 4). For winter cereals, on loess soil in Saxony, Germany the reduction of cost amounts to 100 – 120 €/ha and is higher than on loamy soils in northern Germany with about 40 to 50 €/ha.

Data on socio-economic aspects of CA at European level remain scarce and do not allow drawing a comprehensive picture and a realistic comparison between the countries and the farming conditions. Labour saving in particular may allow developing other agricultural or non-agricultural activities generating additional benefits as it has been mentioned in the Mediterranean and Latin American "platforms" of KASSA. Also, the savings may be offset by additional costs induced by plant control (Table 3); and it is reasonably arguable that the rise of the cost of pesticides and/or heavy infestations of weeds, pests and diseases may lead farmers to favour specific crops or to go back to conventional practices.

Table 3: Reduction of costs EUR/ha for conservation tillage and additional expenses for plant control compared with conventional plant production in different farms of the federal state of Saxony, Germany with loess soils. Average 1994 – 2003 (Agrarian report Saxony, 2003).

Crop	Reduction of costs at soil tillage	Additional expenses at plant control (EUR/ha)		
		Herbicides	Fungicides	Slugs/mice
Winter wheat	100-120	+25	No	+20
Winter barley	100-120	+50 - +70	Nop	No
Winter rye	110	No	No	No
Tritical	110	+70	No	No
Spring barley	110	+70	No	No
Winter rape	100-120	+50 - +70	No	No
Sugar beet	100	+50	No	No
Potatoes	250	No	No	No
Corn	100-150	+50	No	Bno
Grass for food	120	No	No	No
Grass for seeds	120	No	No	no

Table 4: Cost reduction for specific crops on large scale experiment on loamy soils in Mecklenburg-Western Pomerania, Northern Germany (Neubauer, 2003).

Crop	Crop specific cost reduction €/ha incl. wages	Labour reduction hour/ha
Winter wheat	53	1.1
Winter barley	41	0.7
Sugar beet	41	0.5

Hence, scientific evidence of the long-term economic impacts of CA is rare at the European platform level (Tebrügge and Böhrnsen, 1997b; Kächele *et al.* 2001; Nielsen *et al.* 2004a-b). Except for Germany and Norway where reduced tillage is subsidised in erosion risk area (Lundekvam *et al.* 2003; Schmidt *et al.*, 2003), the reduction of production costs is the main driving force for CA adoption in European countries as it works in the other countries participating in KASSA. And, the increased competition at the global and European scale will urge farmers to seek for reduction of costs and increase productivity. CA may be a mean to achieve these goals, through the reduction of the input costs which are distributed on different categories: less fuel consumption because of reduced or no-tillage, less time for labour and less machinery needed.

Impact of CA on biodiversity and biological activity

Biodiversity is a critical issue in Europe. Increasing biodiversity in Europe is often considered by scientists as a result of CA (Holland, 2004); and, this increase may have negative as well as positive effects on crop production and farmers attitude towards CA.Weed infestation is described as to increase under RT. Diversity and abundance of biennial and perennial species increase (Torresen and Skuterud, 2002). In long-term Swiss trials, Vullioud *et al.* (2006) observed that the soil seed bank increases more under RT treatments. The infestation risk can be reduced by means of adequate crop succession, but generally farmers' solution is to use herbicide. In the UK and Scandinavian past experiences, weed infestation have forced farmers to go back to plough (Soane and Ball, 1998; Munkholm et al., 2003).

The benefits of RT on soil fauna seem obvious: ploughing may be regarded as an elementary catastrophe for soil fauna because of the destruction of the habitat. Mulch, crop

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residues or crops protect the soil surface and deliver food for soil organisms (Friebe and Henke, 1991; Dennis *et al.*, 1994). The mulch favours proliferation of slugs, snails and mice (Tebrügge, 2001); it has generally positive effects on density and diversity of Carabidae, spiders and nematodes (Andersen, 1999; Rougon *et al.*, 2001). Studies also clearly indicate that abundance and fresh biomass of earthworms is higher when tillage intensity is reduced (Friebe & Henke, 1991; Emmerling, 2001; Hangen *et al.*, 2002; Balabane *et al.*, 2005).

Soil organic matter and carbon sequestration

CA introduces change in the distribution of soil organic matter (SOM) within the soil profile. SOM provided by crop residues accumulates in the topsoil (Stockfish et al., 1999; Tebrügge and Düring, 1999; Horáček et al., 2001). SOM plays a major role in: (i)- accumulation of mobile nutrition elements (Stockfish et al., 1999; Tebrügge and Düring, 1999; Horáček et al., 2001; Lauringson et al., 2004); (ii)- weed control (Brandsaeter et al., 1998); (iii)- sorption of pesticides and heavy metals (Düring and Gäth, 2002; Düring et al., 2002); (iv)- biological activity (Friebe & Henke, 1991; Dennis et al., 1994) and pesticides degradation; (Düring and Gäth, 2002; Düring et al., 2002; Stenrød et al., 2005 and 2006); (v)- topsoil physical properties (Hallaire et al., 2004; Balabane et al., 2005; Riley et al., 2005) and erosion mitrigation (Puget et al., 1995; Balabane et al., 2005).

The long-term effect of CA on carbon sequestration in Europe is less documented. A recent survey (Arrouays *et al.*, 2002) estimates the storage of carbon in RT systems in France to 0.2 +/- 0.13 ton C/ha/year. Nevertheless, diverse factors interfere in the carbon storage i.e. pedo-climatic conditions, cover crops, CA techniques and the length of the implementation of the cropping systems.

Soil physics and related water properties

Regarding soil physics and related water properties, data available tend to demonstrate that CA practices affect soil structure and porosity. The magnitude and the significance of the effects vary depending on soil properties, the climate, crops, the work quality and the way of mulching. In some situations, CA practices lead to soil compaction which reduces yields (Hansen, 1996; Munkohlm *et al.* 2003). The decrease of soil porosity and the increase of bulk density in the topsoil may reduce hydraulic conductivity (Rasmussen, 1999; Hallaire *et al.*, 2004); besides, evapotranspiration may be reduced and the content of soil water may increases in the upper soil layer (Rasmussen, 1999). In others situations, especially in the case of over-compacted or eroded soils, CA practices seems to improve soil physical properties (Čupa, 2000; Horáček *et al.*, 2001; Javůrek and Vach, 2002; Medvedev *et al.*, 2004).

Erosion mitigation

It is commonly accepted that CA is a desirable mean to reduce soil erosion; evidence has been provided by the Mediterranean and the Latin America "platforms" of KASSA. There are few studies available on that topic in Europe though in Germany and Norway, CA practices have been encouraged to face soil erosion (Lundekvam and Skoien, 1998; Tebrügge and Düring, 1999; Borresen and Riley, 2003; Lundekvam *et al.*, 2003). The erosion mitigation results from the increase of the topsoil aggregates stability and the water infiltration rate which are closely linked to SOM, carbon content and earthworms' activity (Friebe and Henke 1991; Puget *et al.*, 1995; Balabane *et al.*, 2005). In some cases, modifying the time of tillage is sufficient to reduce the erosion risk, particularly in Northern Europe. Indeed, spring tillage in Norway results in little soil losses whereas autumn ploughing leads to higher erosion risk (Borresen and Njøs, 1990; Lundekvam and Skoien, 1998).

Erosion and run-off measurements show that in NT erosion is reduced both during the cropping and the intercrop periods (Martin, 1999). Cover crops or catch crops play a major role in erosion mitigation and pesticide translocation control (Breland, 1995; Frielinghaus, 2002). In an integrated view, off-site damages caused by erosion and sediment deposition can be minimized by the application of CA systems.

Pollution and contamination

Nitrate and phosphate losses may occur in NT soils when significant macro-pore flow relocates the nutrients into subsurface layers (Kohl and Harrach, 1994). However, the results of several studies indicate a significant decrease of nutrient (N, P, and K) losses in RT soils compared to conventionally ploughed soils (Eltun et al., 1996; Tebrügge and Düring, 1999; Korsaeth and Eltun, 2000). The loss preventing processes invoked are: (i)- water infiltration occurs in macro-pores and channels, bypassing the soil matrix, which avoid intensive exchange with soil and prevent nutrients from leaching (Tebrügge, 2000) and, (ii)- the peak of mineralization is avoided when ploughing is abandoned (Kohl and Harrach, 1991). Also, catch crops promoted by CA are of great interest in decreasing leaching risk (Breland, 1995; Javůrek and Vach, 2002; Molteberg et al., 2004).

Globally, very few is known on the fate of pesticides under CA practices, though it is broadly accepted, that RT and mainly NT may lead to an increased use of molecules for weed, pests and diseases control. However, this increase is not compulsory in CA: several experiences and studies assert the importance of adapted crop rotations and cover crops to control weed in such systems (Brandsaeter *et al.*, 1998). The results obtained in Germany clearly show that the transfer of pesticides is linked to the distribution of SOM (Düring and Gäth, 2002; Düring *et al.*, 2002). As SOM is enriched in the upper layer of RT soils, pesticides susceptible to sorption on organic matter accumulate near the soil surface and are less prone to depth transfer. Pesticides may be faster broken down in RT soils due to the higher microbial activity. Moreover, losses of agrochemicals via the lateral path may be clearly reduced under NT conditions (Tebrügge and Düring, 1999). Higher sorption rates of heavy metals under RT were also detected in German studies by different extractabilities, especially of Zn and Cd (Düring *et al.*, 2002). Persistent organic pollutants (POP) are rarely mentioned. They are strongly absorbed to the soil matrix and are not suspected to be transported freely dissolved with the water flow. Enhanced accumulation of ubiquitous and persistent polychlorinated biphenyls (PCB) was observed in RT and NT soils which showed a long-term increase in organic matter (Düring and Gäth, 2002).

DISCUSSION

Intensive research on components of CA took place in Europe between the 1960s and the 1990s (Soane and Ball, 1997); but researches were more thematic than systemic. Results available have been generally obtained through long-term stationary field experiments. According to KASSA findings, CA as a concept is less adopted in Europe compared to the main regions in the world practicing this farming system; RT is more used than NT and there is less knowledge on the use of cover crops and crop rotations. In most countries of the European "platform" of KASSA the adoption process is mainly farmer driven and the major driving force is the cost reduction and labour saving: two main farmers' expectations. The only exception is governmental subsidies put on RT in erosion risk area in Norway and Germany. Time saving and the improved timeliness of field operations allow farmers in Spain, as well as in Brazil, to develop other agricultural or non-agricultural activities generating additional benefits. The environmental concerns do not appear decisive in the decision of European farmers whether to shift to CA or not, but these concerns are likely to contribute more in the shifting towards CA when farmers get involved in innovation and learning processes. After years of CA practice, farmers perceive the effectiveness of CA systems in increasing SOM and earthworms' activity, reducing soil erosion, and improving water infiltration and productivity in dry areas which reinforce their choice.

CA is not equally suitable for the whole European agro-ecosystems; this confirms the Scandinavian viewpoint (Håkansson, 1994). The development of CA systems and their socio-economic and ecological sustainability are highly site specific. The fine tuning of CA systems require a continual adjustment which calls for continual knowledge generation and sharing among the stakeholders. In Europe, the use of cover crop and diversified crop rotations is still hardly practiced due to climate and soil limitations, short length of growing period in northern latitudes, lack of adapted crop varieties, difficult management of crop residue in wet conditions and, general market conditions. Thus, the mechanical control of weed provided by plough in conventional systems is replaced by a chemical control in CA systems, which is made easier by the availability of affordable and effective chemicals. As a result, in CA systems the number of herbicides treatments increases on average. The lack of knowledge and technical references on biological control of weed using the competition and allelopathy properties of intercrops and associated crops in CA systems makes the integrated management approach more risky.

The lack of scientific evidence on long term socio-economic and ecological impact of CA systems, the scatter of the available results, the diversity of CA practices used and the wide range of European contexts do not allow to draw a comprehensive picture on CA within Europe, or to anticipate its future development. Nevertheless, the conversion of European farmers to CA is being achieved through a step-by-step strategy; and large sized farms are the most adopters, probably due to their ability to absorb the risk and also to the lack of labour. The short term socio-economic benefits that CA provides through the reduction of costs of production, the need to improve farms' competitiveness, market globalization and the steady increase of fuel cost are likely sufficient to boost CA systems within Europe and to overcome the farmers' and societal possible reluctance due to socio-cultural barriers or environmental considerations. This conversion process is likely already ongoing.

CONCLUSION

A wide range of facts tends to evidence a shifting of European agriculture, at least in the countries participating in KASSA, from plough based systems to RT and NT based systems. The process is mainly farmer driven and the major driving force is the short-term benefits provided by CA systems through the reduction of the production costs. And, there is no scientific documentation of the long-term socio-economic and ecological impact of these systems.

Lessons of past and ongoing experiences lead to suggest that EU and country members' stakeholders, mainly policy and research, have to anticipate the conversion process in order to improve the long-term socio-economic and ecological sustainability of CA in Europe i.e. to reach a win/win situation between farmers' needs and societal expectations. Priorities would be: (i)- to research and develop low input CA systems i.e. with low reliance on pesticides and nitrogen use through integrated weed and pests management strategies, using cover crops and crop rotations; (ii)- to assess the actual ability of CA systems in conserving and improving soil, biodiversity and water quality in the diverse European contexts; (iii)- to carry out studies on the implementation and the propagation of CA systems i.e. profitability; biophysical and sociological conditions for suitability and; appropriate accompanying local and global policies. The aim of these studies should be precise recommendation domains for conservation agriculture within Europe taking into account biophysical, sociological, economical and political conditions; appropriate tools and indicators for monitoring and; reliable decision support systems- DSS for farmers, engineers, extortionists and practitioners.

This calls for an efficient research strategy on CA systems, able: (i)- to twin technology development with impact assessment because impacts depend on the technology development and, the development of appropriate and efficient CA systems rely on impact assessment. (ii)- to study the functioning of CA systems because it is the only mean to succeed in this twining, and; (iii)- to adopt integrative and multi-disciplinary approaches based on global / local researches since the functioning is very sensitive to local conditions, and short / long term researches. The success of the whole process need a strong partnership between the stakeholders, which may call for a governance framework favouring the emergence of innovation systems and shaped strategies for generating and sharing knowledge.

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