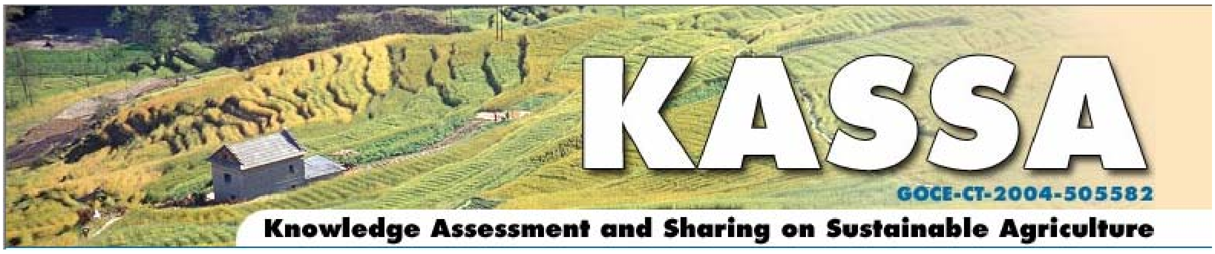

Prospects for sustainable agriculture in the European platform of KASSA

S. de Tourdonnet[1*], P. Barz[2], A. Bolliger[3], R-A. Düring[4], M. Frielinghaus[5], R. Kõlli[6], J. Kubat[7], T. Laktionova[8], J. Magid[3], V. Medvedev[8], A. Michels[4], J. Netland[9], J. Novakova[7], D. Picard[1], T. Simon[7], K. Thinggaard[10], E. Vandeputte[11], J. Werrity[2], M. Willms[5]

[1] *Institut National Agronomique (INRA), BP 01, 78850 Thiverval Grignon, France*
[2] *Environmental Network Limited (ENL), The Hillocks, Tarland Aboyne AB34 4TJ, United Kingdom*
[3] *Den Kongelige Veterinaer - og Landbohojskole (KVL), Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark*
[4] *Justus-Liebig-Universität Giessen (JLU), Heinrich Buff-Ring 26, D-35392 Giessen, Germany*
[5] *Leibniz - Zentrum für Agrarlandschafts - und Landnutzungsforschung e.V. (ZALF-e.V.), Eberswalder Str. 84 , D-15374 Müncheberg, Germany*
[6] *Eesti Põllumajandusülikool (EAU), Kreutzwaldi 64, 51014 Tartu, Estonia*
[7] *Výzkumný Ústav Rostlinné Výroby (VURV), Drnovska 507, 16106 Prague, Czech Republic*
[8] *National Scientific Centre - Institute for Soil Science and Agro-chemistry Research (NSC-ISSAR), Chajkovsky Street, N4, 61024 Kharkiv, Ukraine*
[9] *Norsk Institut for Planteforsking (NCRI), Hogskoleveien 7, N-1432 As, Norway*
[10] *Fropatologisk Institut for Udviklingslandene (FIU), Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark*
[11] *Fondation Nationale pour une Agriculture de Conservation des Sols (FNACS), Le Paradis, 95420 Genainville, France*

[*] *Platform Coordinator*

Centre de coopération internationale en recherche agronomique pour le développement
Avenue Agropolis, 34398 Montpellier, France

www.cirad.fr

ACKNOWLEDGMENTS

The research reported here has been carried out in the context of KASSA project (Knowledge Assessment and Sharing on Sustainable Agriculture) a European Commission – funded project (DG-Research - Contract no. GOCE-CT-2004-505582) under the FP6 programme: "*Integrating and strengthening the European Research Area*"; Thematic priority "Sustainable Development, Global Change and Ecosystems", Sub-priority "Global Change and ecosystems".

<u>Disclaimer</u>

KASSA has been coordinated by CIRAD.
It worked between 1 September 2004 and 28 February 2006.
The KASSA Consortium assembled 28 contractors from 18 countries.
KASSA has been implemented through four regional "platforms": Europe, the Mediterranean, Asia and Latin America.
http://kassa.cirad.fr

Partners of the European platforms:

2- INRA, France;
5- FNACS, France;
6- KVL, Denmark;
7- FIU, Denmark;
9- JLU, Germany;
10- Zalf e.V, Germany;
11- NCRI, Norway;
12- ENL, United Kingdom;
13- EAU, Estonia;
14- VURV, Czech Republic;
15- NSC-ISSAR, Ukraine.

Scientific advice has been provided by:

Michel Griffon (CIRAD, France);
Ren Wang (IRRI, Philippines);
Jaromir Kubat (VURV, Czech Republic);
Roberto Peiretti (AAPRESID, Argentina).

This document is the deliverable D3.1 of the workpackages 1.3 & 2.3

Table of contents

INTRODUCTION

The objective of this document is to refine the European platform findings, according to the description of WP 1.3, in order to identify prospects and concrete proposals related to perspectives for sustainable agriculture including:

- The best situations and conditions where alternative practices, technologies and approaches in support of sustainable agriculture are likely to succeed within the platform
- Alternative technologies and approaches in support of sustainable agriculture and the ways of adopting, implementing, disseminating and improving them
- Socio-economic and environmental impacts and externalities expected
- Research items to be tackled and related approaches

As mentioned in the R2.1 report, the European partners have chosen to refine their findings on the conditions and the strategies which potentially permit farmers to shift from conventional agriculture to conservation agriculture. According to our opinion it is better to treat CA more comprehensive, which enables us to take into account not only so called classical conservation agriculture tools (mostly non-tillage – direct sowing and use of cover crop), but all these arable soils management technologies, which contain certain elements of soil protection and/or nature friendly measures. Not only so called full conservation agriculture is included in our evaluation, but also step-by-step developed conservation agriculture elements, which may be the sole possibility in certain specific pedo-climatic conditions.

The issue of the shifting can be linked to the statement presented in the R1.1 report of the European platform: “I should change what I can change.” Three questions are tackled in this statement:

- **Why should I change?** What are the benefits of conservation agriculture and which problems does it permit to solve?
- **Where should I change?** Where is it suitable to perform conservation agriculture (for which soils, for which crops and in which farming system)?
- **How can I change?** What are the strategies leading to conversion, from farmers’ point of view (economic, agronomic and technical aspects), and from governance’s point of view (level of extension, partnership …).

This document gathers the contributions from all the groups on the 3 items mentioned above (3 first sections) leading to the research proposals of the European platform (Section 4).

1. WHY should I change to CA ?

In the current situation for agriculture in the Europe the socio-economic component is very important. The features of CA as it is or will be practiced must support the elements in the Common Agricultural Policy (CAP). The intention of conservation agriculture (CA) is ecologically sound and equilibrated management of local soil resources, which at the same time ensures the good status of environment. CA should give more attention to each soil type (or contour) optimal status and functioning activity (in concordance with soil properties), which enables soil cover to act as environment protective natural body. CA should be beneficial or of great importance for society, thanks for good environmental status (water quality, rationale and effective use of natural resources, based on scientific research.) If scientific proof can be found that CA offers ecologically sound site specific technologies, the importance of CA will grow in the future. This trend can also be strengthened by cross compliance and subsidy mechanisms in CAP.
It is equally important that farmers society benefit from conversion to CA. For farmers the CA could be beneficial for economic, sociologic, agronomic and technical reasons.

1.1. Profitability

For North European countries, to reduce cost (fuel, labour and machinery) is according to our findings the most important driving force for conservation agriculture/no ploughing. The increase of competition at the global scale as at the European scale leads many farmers to tend to reduce the costs and to increase productivity. CA may be a mean to achieve this requirement, involving the reduction of the input costs which is distributed on different categories: less fuel consumption because of reduced or no soil tillage, less time for labour, less machinery needed. This is a very strong feature for CA/no till practices but scientific evidences of the economical impacts of CA are rare at the European Platform level (Tebrügge & Böhrnsen, 1997 a & b; Tebrügge & During 1999; Sandal, 2004a; Nielsen *et al.* 2004).

In most of the country in the European platform yield increase or stabilisation of yield is not a crucial point in discussion of CA conversion or not. As an average yield on poor and medium fertile agricultural areas doesn't change (+/- 10%), yields on very fertile with a high-intensive level of production are slightly decreased. In Ukraine, however, yield increase on chernozems soils within 5-10% are expected. However also here the cost savings is the most important economic element of CA.

1.2. Biodiversity and biological activity

In Europe increasing biodiversity is often considered by scientists as a result of conservation agriculture, but may have negative as well as positive effects.

Weed infestation is described as to increase under reduced tillage (RT). Diversity and abundance of biennial and perennial species increased (Debaeke, 1987, 1994; Verdier *et al*, 1990; Rameau *et al*, 1992; Torresen and Skuterud, 2002; Sandal, 2004b). The infestation risk can be reduced by means of adequate crop succession.

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, plant residues or crops protect the soil surface and deliver food for soil organisms (Dennis et al., 1994; Friebe & Henke, 1992). As a result, mulch covering the soil surface seemed to favour proliferation

by slugs (Sandal, 2004), but on the other hand, could protect crops from slug consumption. Mulch had generally positive effects on density and diversity of Carabidae, spiders and nematodes (Rougon et al, 2001; Bout, 2004; Andersen, 1999).
Studies also clearly indicated that abundance and fresh biomass of earthworms were higher when tillage intensity was reduced (Friebe, 1992a; Friebe & Henke, 1992; Emmerling, 2001; Hangen et al., 2002; Alletto, 2002; Balabane *et al*, 2005).

However, in UK in particular, the exclusion of CA techniques from the programme of “Environmental Stewardship”, which includes the promotion of biodiversity, would indicate that this potential benefit has not yet been brought to the attention of the policy makers.

1.3. Organic matter, carbon sequestration and soil physics

Reducing soil tillage (RT) affects carbon distribution in the profile layer, quality and dynamics.

In Europe, RT leads to change the distribution of soil organic matter (SOM) in the soil profile: when giving up ploughing, soil organic matter provided by crop residues is not buried and accumulates in topsoil (Balesdent *et al*, 1990; Friebe, 1992a +b; Ahrens et al., 1994; Stockfish et al., 1999; Tebrügge, 2000; Horáček et al., 2001). This organic matter in top layers of the soils plays a major role in:

- accumulation of mobile nutrition elements (Langlet and Remy, 1976; Balland, 2002; Riley, 1998; Friebe, 1992a,b; Ahrens et al., 1994; Stockfish et al., 1999; Tebrügge, 2000; Horacek et al, 2001),
- weed control (Brandsaeter et al., 1998; Breland, 1996a),
- sorption of pesticides and heavy metals (Düring et al., 2002a; Düring et al., 2002b),
- biological activity (Dennis et al., 1994; Friebe & Henke, 1992) and pesticides degradation (Stenrød et al., 2005a-d; Düring et al., 2002a-b),
- topsoil physical properties (Monnier *et al*, 1976; Stengel, 1984; Guérif, 1994; Beisecker, 1994; Hallaire *et al,* 2004; Balabane et al, 2005; Riley et al, 2005) and erosion mitrigation (Puget *et al.* 1995; Balabane *et al.* 2005)

There is little information available on the long-term effect of RT on carbon sequestration in Europe. In a survey by Arrouays *et al.* (2002), the storage of carbon in RT systems was estimated by 0.2 +/- 0.13 tC/ha/year in France. Nevertheless, it is crucial to keep in mind that carbon storage strongly depends on pedo-climatic conditions, the presence or not of cover crops in crop rotations, on reduced tillage techniques and on the duration of the implementation of the cropping systems.

As regards soil physics, the data collected demonstrate that the effects of tillage practices highly vary depending on pedo-climate context, crop, work quality and way of mulching. In some situations, RT leaded to soil compaction which penalized the yields (Caneill *et al.* 1994; Hansen, 1996, Sandal 2004) but in others (especially in over-compacted soils), RT improved soil physical properties (Malienko *et al.* 1992; Lyndina, 1998, 2000; Medvedev 1999, 2001; Čupa, 2000; Horáček et al., 2001; Javůrek et al. 2002, 2003).

1.4. Erosion mitigation

Even if it is commonly accepted that CA is a mean permitting to reduce erosion (this has been demonstrated by the Latin America Platform), there are few studies available on that topic in the European Platform. The process of erosion mitigation results from the increase of topsoil stability and water infiltration rate, closely linked to soil organic carbon content and earthworms activity. (Friebe *et al.* 1992; Puget et al. 1995; Balabane et al. 2005). In some case, modifying the times of tillage is sufficient to reduce the risk of erosion, particularly in Northern Europe: in Norway, spring tillage results in little soil loss, whereas autumn ploughing leads to a higher risk (Njøs and Hove, 1986; Borresen and Njos, 1990; Lundekvam and Skoien, 1998).

Erosion and run off measurements show that, in no-till, erosion is reduced both during the cropping period and the intercrop (Martin, 1999; Packer et al., 1992; van Doren et al., 1984; Radcliffe et al., 1988; Fischer et al., 1995). Cover crops used in CA play a major role in erosion mitigation (Breland, 1995). In an integrated view, off-site damages by erosion and sediment deposition should be taken into account which can be minimized by the application of conservation tillage systems.

1.5. Pollution and contamination

Nitrate and phosphate losses may occur in no-till soils when significant macropore flow relocates the nutrients into subsurface soil (Kohl & Harrach, 1991). However, the results of several studies indicate a significant decrease of nutrient (N, P, K) losses under reduced tillage intensity when compared to conventional plough tillage (Eltun, 1995; Eltun and Fugleberg, 1996; Korsaeth and Eltun, 2000; Tebrügge, 2000) due to several processes :

- The infiltrating water by-passing the soil matrix in macropores and channels without intensive exchange with soil solution (Tebrügge, 2000).
- A peak of mineralization without plant cover is avoided when ploughing is abandoned (Kohl & Harrach, 1991; Harrach & Richter, 1994; Richter, 1995; Riley, 1998).
- Catch crops promoted by CA which are of great interest to decrease leaching risk (Breland, 1995; Javůrek and Vach, 2002; Molteberg et al., 2004).

Very little is known on the fate of pesticides under reduced tillage (RT) situations, though it is broadly accepted, that RT and especially no-tillage (NT) may lead to an increased use of herbicides for weed control. However, this increase is not compulsory in RT: several experiences and studies pronounce the importance of adapted crop rotations and cover crops to control weed in such systems (Brandsaeter et al., 1998; Breland, 1996a; Bräutigam, 1993).

The results obtained in Germany clearly show that transfer of pesticides is related to the distribution of soil organic matter (Düring et al., 2002a,b, Real *et al*, 2005). As SOM is enriched in the upper layer of RT soils, pesticides susceptible to sorption on organic matter accumulate near the surface and show less availability to depth transfer. Pesticides are generally 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 no-till conditions (Tebrügge & Düring, 1999). Higher sorption rates of heavy metals under RT were also detected in German studies (Düring et al., 2002a).

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. Far two little is known yet about the behaviour of these substances in the environment.

1.6. Water balance

As reduced tillage systems tend to decrease soil porosity and increase bulk density near the soil surface, this may reduce hydraulic conductivity in some cases (Rasmussen, 1999; Hallaire *et al*, 2004) but in other cases, higher infiltration and by-pass flow during heavy rains was observed due to the increase in the number of macropores (Friebe & Henke, 1992). Besides, evapotranspiration may be reduced and content of soil water may increase in the upper soil layer (Rasmussen, 1999).

Consequences are different according to rain and temperature conditions: in Northern Europe (Norway, UK), it is an issue because of its short growing season, as wet soils result in later seeding and cooler soils. On the other hand, it is an important beneficial trait of conservation tillage in dry areas, conserving the soil water.

1.7. Sociological aspects

In Europe, there is little information on social impact of CA. Nevertheless, several trends can be drawn up out of this study:

- Farmers can take advantage of the reduction of labour time in RT to enlarge their farm, to diversify farming activities or to invest in non-agricultural occupation, leading to a change in social relationships.
- Relationships that are established between farmers using CA generates new forms of farmers networks which favours social stability but sometimes, may lead to marginalization (with regards to the neighbourhood especially). These networks constitute a meeting place for the farmers interested in the alternative practices and create social animation, which provide new dynamism to rural populations.
- Conservation agriculture and organic farming often lead farmers to develop or assert their proper identity. They are deeply rooted in a specific conception of the relationship existing between farming and nature. This identity affects the way that farmers perceive their profession and their place in the society.
- Conservation agriculture requires personal training and permanent questioning of practices, which contribute to farmers' personal education.

2. WHERE should I change to CA?

2.1. The conditions of technical changes

Non-adequate use of CA technologies, which may be unsuitable in local pedo-ecological and social conditions, decreases opportunities for CA. This is also the case when the pedo-ecological equivalence is not taken into account. Absence of or badly attainable large scale soil maps, or none connection with data bases as base for ecologically sound land use, is detrimental. The same is the case of absence of know-how about suitability of crops to local pedo-ecological conditions and absence of state supported arable soils monitoring network with easily attainable soil data for farmers. Scarce knowledge about cover crops and possibilities of their using in restoration or remediation of soil functioning capacity in certain agro-ecological zones or local conditions can also be lacking.

This means that the where question is linked to the development of new technologies and nex know how: what is impossible today may be possible tomorrow thanks to new machinery, plant material or knowledge.

2.2. Environmental conditions.

In general, when moving from south to north of Europe the focus on climatic factors that should be taken into account, shift as illustrated in fig 1. Moving northward Ca- opportunities will depend on temperature, water logging and short vegetation period and less on drought hazard and water deficiency. But these climatic factors will interact firmly with soil properties and also crop.

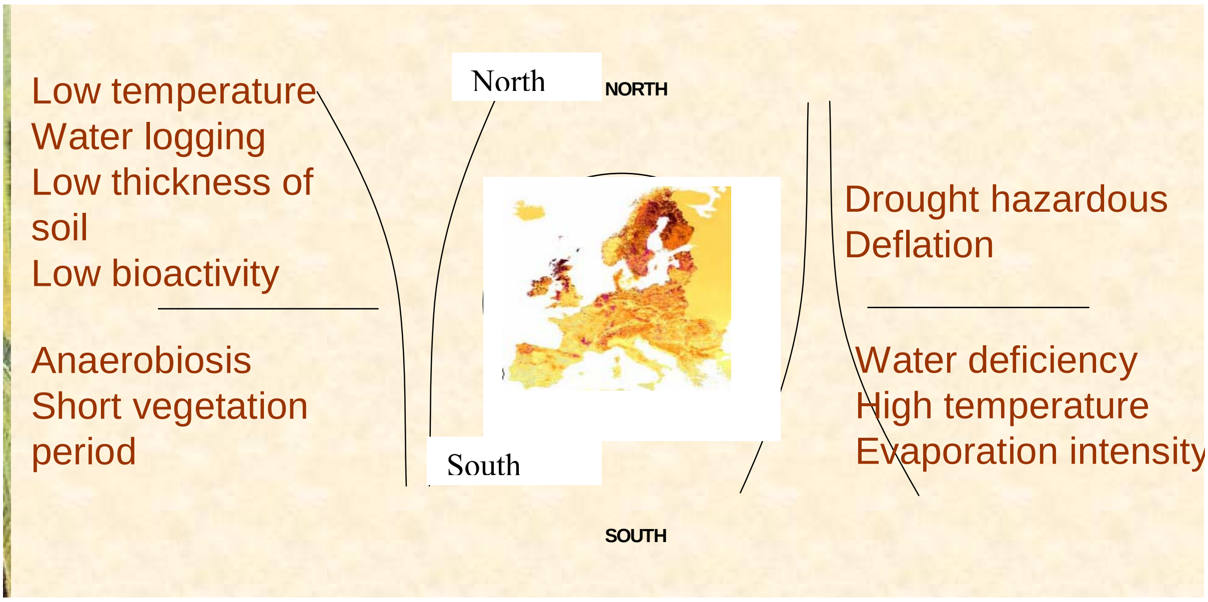

Figure 1.

Amount of precipitation is important to take into account. At high precipitation levels, no ploughing would be difficult in heavy clay and cold sand and silt soil. CA methods are best suited to the drier and warmer regions. These regions are more likely to be susceptible to soil erosion and less likely to be affected by water logging. The latter trait could be considered a regional constraint affecting the possible uptake of CA in future.

In Northern area with slow and late warming in spring the opportunities for CA without suffering on yield quality and size is often limited. Only small geographical distances change length of growing period for instant in Norway. That is due to change in altitude but also distance form coast line. Cold and wet sand and silt soil and heavy clay is difficult to cultivate without ploughing in a short season.

In general reduced tillage methods are best suited to medium textured soil and well drained clay, and clay loam soils. It is more difficult to achieve reduced/none tillage in heavy clay, sandy and silty soils due to compaction and/or poor drainage ability. Organic matter content will modify these relationships. Sandy and silty soil with a satisfying level of organic matter will be easier to grow without ploughing than soil with very low organic matter content. This is an example of the complexity of the “where” question. Chernozems soils in Ukraine are ideal for CA, while solontzetic, overmoistened, gleyed, sandy and stony soils are regarded as not suited. Drainage conditions have to be considered. Under good drainage conditions no ploughing has proved to be favourable most soil types

2.3. Agronomical conditions

Winter crops are often convenient crops for CA. Yields of wheat, oat, rape and barley are generally not strongly affected by RT practices, whereas the RT systems (and especially the direct drilling ones), have often penalized the yields of maize. Yields of maize under RT are closely linked to soil compaction, soil drainage and the sowing machine used. The response of sugar beet yields to tillage practices appears highly variable from case to case and linked to sowing conditions. In general, root crops and potatoes are not the best option for no-till practices.

Fields and areas heavily infestation by weeds difficult to control and high pressure of pests like slugs and mouse, are not suited for CA. In wet area with insufficient crop rotation mycotoxins might also be an obstacle for practises with no ploughing.

2.4. Farm or unit size

The opportunity and capacity of new equipment, makes CA/reduced tillage well designed for big farms or units. This coincides well with growing farm/unit size in all European countries. This is a common finding in all country with large size farms. This is mainly due to that owners of big farms can afford to invest in adequate technology, while small farmers tend to use old and not specialized equipment. It is also worth noting that smaller farms, by their nature, will be less able to benefit from the economies of scale associated with reduced labour costs, will be less able to offset the costs associated with the purchase of specialised CA agricultural machinery and are also less likely to have very large individual fields that are at increased risk of wind and rain induced soil erosion. CA is definitely suited for large-scale agriculture, but is it not applicable for small-scale agriculture? This is close connected with the “how” question. CA can be closely related to OF and growing of high valuable crops. Then use of cover crop and more sophisticated cropping technique known from the LA platform can be introduced. On smaller farms, machine cooperation is often necessary.

2.5. Proposals

Soil monitoring data enable the farmer to control and regulate soil parameters in needed direction. The lack of reliable data should be solved by monitoring of soil humus and nutrient status of agricultural areas by different soil types and agro-ecological zones. Ukraine has elaborated extensive maps showing the opportunities for CA in different crops and geographical areas, which is advisable.

To be able to develop optimal conservation agriculture programme, should all areas influenced by agricultural activity as prerequisite have available large scale computerized soil maps with multisided information about soil properties and a know-how about dominating soil types suitability for crops, crops demands to soil conditions and possibilities for different alternative land use.
CA must (is able to) besides of producing goods (food, feed, products for industry) also to be a tool for amelioration of environmental status. By step-by-step shifting from conventional agriculture to conservation agriculture it is recommended to start as soon as possible on all agricultural areas. By a step-by-step approach we think for example following changes (from…to): deep ploughing -> thin ploughing; bare fields -> covered by crops or by mulch; minimal tillage-> non-tillage; conventional agriculture -> using of different soil remediation methods (liming, hydro-melioration, chemical amelioration)

The shifting to CA should be started in areas and on farms where the conditions for this exists (existing of local know-how, provision of needed machinery, soils suitable for CA). In Nordic areas where the conditions for decomposition of accumulated plant residues on soil surface or in superficial layer is limited due to low temperature, low biological activity and anaerobic conditions, additional manipulation are needed to increase decomposition intensity.

The “where”-question is often a question of combinations of soil properties, climatic conditions and crop.

Criteria for classification of soils into areas with variable benefit of conversion to CA should be developed. In most cases it is not only one condition that should be taken into account. For instant under Nordic condition the soil mineral component is important. As a start this could be expressed by two way tables with soil types on one axis. On the other axis are different conditions like precipitation, temperature, drainage conditions (permeability), crop. The scales should be according to accepted nomenclature. The next step would be to bring in the computer and connect these tables in a more complex “decision support system (DSS)”. In a future project proposal this could be proposed as a tool for farmers and central and regional decision makers. We need however to make an inventory of already existing DSS and modelling approaches to find if there is something to start with.

With a few examples from Norway we will try to demonstrate how the first tables of a “decision support system” in cereals could look like. (red= good opportunity for CA, blue=no opportunity for CA)

Crops

Crop- / Mineral component	Winter wheat	Spring wheat oats	Spring barley
Clay			
Sandy silty clay			
Clay loam			
Sandy silty clay loam			
Sand, silt			

Precipitation

Precipitation / Mineral component	Low	Medium	High
Clay			
Sandy silty clay			
Clay loam			
Sandy silty clay loam			
Sand, silt			

Permeability –drainage condition

Permeability-drainage / Mineral component	Good	Medium	Bad
Clay			
Sandy silty clay			
Clay loam			
Sandy silty clay loam			
Sand, silt			

Farm size

For small farm growing high valuable crops the use of cover crop and more sophisticated cropping technique known from the LA platform can be introduced. Therefore CA possibly can develop in two directions:

- Large scale intensive farming on big farms/units
- CA close related to OF on smaller farms.

Both directions have their specific needs for research and development.

- Large-scale farming need research to develop environmentally friendly and sustainable crop management (reduced use of pesticide, leaching of pesticide and nutrients, resistance development, mycotoxin)
- Enhanced efficiency of CA methods on small scale agriculture. Transferring knowledge from other platforms is important in this connection

2.6. Conclusion

To our opinion one kind or an other of sustainable agriculture must be adopted for most (or all) arable soils. The conservation agriculture with non-tillage and direct sowing is most suitable on biologically active, medium textured and highly productive arable soils. But CA has more instruments applicable for less favourable conditions and for repairing disrupted soil and mitigation of unfavourable environmental and climatic conditions. It is a matter of defining the right CA strategies for the site-specific conditions.

3. HOW can I change to CA?

3.1. Access to technology

In order to reap the maximum benefits of RT/CA in terms of time/labour and vehicle traffic reductions, as well as decreased machine stocking and optimising seeding, weed/pest control and harvesting times, farmers need specialised machines, such as chisels with different tools, special seeders for mulch seeding and direct seeding in residues without seedbed preparation, harvesters with special tools for optimal straw distribution on the soil surface and equipment for weed and pest control. Although such equipment is generally available in most Western European countries (Norway, Denmark, Germany and France), where farmers can afford new equipment and producers are commonly interested in catering to their clientele's needs, continuously adapting, modifying and trialling their equipment, this appears not to be the case in the Eastern European countries (Ukraine, Czech Republic and Estonia), where seeders for direct sowing, for example, are very rare, and what is available is often unsuited for the specific environment. Suitable equipment for working through heavy trash or mulch, however, appears to be relatively scarce in general. The expense of specialised machinery generally also puts it out of reach of small-scale farmers (< 100 ha), while further distinguishing between farmers in Western Europe from those of Eastern Europe, where the cost of new and specialised machinery is frequently considered a constraint to converting to RT /CA. Possible options to alleviate "affordability constraints" for small-scale or resource-poor farmers consist of purchasing equipment in groups or using private contractors to perform operations. Farmers responding to interviews in eastern Germany, however, commonly insisted upon maintaining flexibility for tillage operation, which both indicates that farmers ideally want to maintain access to traditional plough equipment in addition to RT/CA gear, but also that private rather than communal ownership of key equipment is commonly the most preferable option.

3.2. Access to finance

For large-scale (> 100 ha), financially-stable farms in Western Europe, external financial support for conversion to RT/CA is generally not necessary. Danish farmers' decisions to convert form conventional to organic agriculture, for example, are rarely influenced by the availability of conversion funds, and there is reason to believe that the same is the case for conversion to RT/CA. Small farms and/or farmers in Eastern Europe, on the other hand, often require financial support for conversion. In eastern Germany, interviewed small-scale farmers stated that they required support over a period of 3 –10 years of conversion, due mainly to high prices of machines and special herbicides. Such support, on the other hand, can prove problematic. Although different regional support programmes contributing between 60–150 €/ha exist in Germany and are important for the farmers income, these do not exist in the Ukraine, for example, where banks are additionally often unwilling to grant credits for agriculture, as many agricultural enterprises have had a poor record in repaying loans, while leasing agreements have often proved suboptimal, especially given that leased equipment has sometimes been of poor quality. Although state or EU authorities could potentially pay a role in enhancing the development of agricultural innovations, through, for example a system of potentially partially compensating banks if these accrue losses in association with agricultural investments, such schemes do not exist. Financial support should also be available for extension of advisory services, because the future of conservation agriculture/ tillage depends on the quality of such advisory services.

3.3. Access to Knowledge

3.3.1. Use/ adaptation of machinery

The need for special instruction and training on new equipment (key machines) and updates is crucial. In Denmark, the Agricultural Advisory Service, a private farmer-funded organisation at national level, employs 16 RT equipment specialists throughout the country to assist farmers with problems related to their RT/CA equipment, while the 288-member Danish Reduced Tillage Farmers Union, shares advice and experiences of equipment over public media, such as the internet and local radio. In some places, on the other hand, a lobby against RT/CT may in some instances stifle the free exchange of information and advice on appropriate RT/CA options available to willing farmers.

Data from eastern Germany further underscores that the education level on large farms (> 500 ha) is generally higher and there are more training opportunities over conversion period than on small-scale farms. Often in small farms (< 100 ha), especially in part-time farms, the knowledge level is low and there is no time to visit training courses. In many cases the machinery is out of date, but farmers cannot modernise.

3.3.2. Management of soil structure

Problems with soil compaction in light textured and water-logging in very heavy soils is a concern increasingly raised by farmers attempting RT/CA. However, farmers often have insufficient knowledge about the correlation between soil structure and soil functionality and soil fertility, and are relatively unaware of the sensitivity of soil to compaction and structural damages. Although successful management requires time to monitor field, part-time smallholder farmers rarely have enough time or resources for such continuous control. Another problem of small farmers is that, if they resort to using private contractors to seed and harvest, these may not have time to perform operations when soils are sufficiently dry, thereby greatly increasing the risk of damage the soil structure in topsoil and subsoil.

3.3.3. Weed and pest management

Pressure from weeds such as Bromus or creeping thistle (*Cirsium arvense*) are one of the most common concerns voiced by farmers attempting RT/CA and can constrain adoption of RT and increase reversion to conventional ploughing significantly. Although special herbicides, such as glyphosate and other broadband herbicides, - the basis for successful RT/CA -, Danish experiences over a number of seasons under RT indicate that grass weeds become harder and harder to control, sometimes necessitating large glyphosate applications with minimal success. Danish advisory services actually recommend that farmers revert to ploughing from time to time (e.g. every 4-5 years) in order to keep better control of weeds. More long-term experiments are undoubtedly necessary to observe the development of weed species after a longer period without ploughing.

Pests are in theory controllable through appropriate crop rotation, although relatively few European farmers, especially when faced with restricted growing seasons, feel they can afford the luxury of adapting crop rotation to pest pressure rather than market conditions. Also problematic are the increases of snails, especially in sugar beet, and mice in grain crops although farmers do have possibilities (mechanical and chemical) to reduce pressure from these pests. More long-term, on-farm observation are, however, also necessary in this context.

3.3.4. Management of cover crops and residues

Many regional experiences and trials on cover crop management within various crop rotations appear to exist throughout Europe, and include winter and summer catch crops, intercrops, under-sown crops. However, at present, few farmers actually cultivate cover crops within

market crop rotations because of the high relative costs and insufficient machine and labour for synchronised harvest – reseeding operations. For frost resistant crops it is necessary to use a total herbicide before seeding, for frost susceptible crops the farmers use broadband herbicides. Direct seeding is problematical in some regions, because of the yield decreases caused by poor emergence. Often, also, available equipment is not particularly suited for the management of straw. Harvester with special straw distribution tools are a key machine and important for the quantity and quality of followed crop yields, and German experiences indicate that mouse pressure is largely influenced by straw distribution.
The cultivation of cover crops to function in as part of integrated weed and pest management may increase with the new rules of EU (cross compliance). Experiences on energy plant seeding into residues without ploughing and seedbed preparation and the residue management after harvest of energy plants are largely lacking. It remains to be seen how the increase of biogas production (maize plus slurry) in Germany has an impact on RT/CA technology development, especially as biogas production is profit-orientated rather than related to soil fertility concerns. The area under maize cultivation will be increased very much in farms with animal production caused a change of technology.

3.3.5. Management of rotation

Although much knowledge on the effects of preceding and succeeding crops in a rotation exists in scientific literature, and it is arguable that astute crop rotations are the basis of successful sustainable agriculture and CA, market pressures, caused by the changed support system of the EU and the decrease of market prices for many products, in combination with the need to boost short-term profitability, mean that few farmers actually practise agronomically ideal rotations. In some regions, the high proportion of rented farms (short time of contracts) and the large number of abandonded or part-time farms have a negative impact for knowledge about the interesting crop rotation and soil fertility.

3.4. Risks/Benefits assessment

A problem with assessing the full benefits and risks of RT/CA is the lack of methods to evaluate monetarily all impacts, direct and indirect (for example reduce of soil degradation, reduce of pollution, reduction of emission caused by wind erosion, etc). In the case of increased incalculable risks (increase of special weeds like *Bromus*, degradation of soil structure) the farmers favour plough tillage. In crop rotation with a high part of root crops (> 30 %) it is more easy to reduce tillage for a longer period than in crop rotation with a high part of grain (> 60%).
The most important risks for the farmers are the following:

- weed and pest (mouse, snails) pressure is fairly hard to control or predict,
- heavy soils with precipitation about 700 mm are problematical,
- no optimal manure management is possible for mixed or animal farms,
- very high management requirements for the whole system is necessary and often not possible,
- the management of high lot of straw residues after grain harvest is difficult,
- the decrease of the yield level in the conversion period is especially difficult for small farms,
- in crop rotations with grass seed production are no technical solutions for reduced tillage available,
- without the very expensive special machines is the risk very high,
- private contractors cannot realize the optimal deadlines for operations
- incalculable risks increase in some farms and are important for small instable farms

3.5. Step by step process

Many farmers propose a step-by step implementation of RT/CA. Together with efficient advisory services and objective advice in every region and in experimental stations with long-time experiments it will be possible to plan every step and control of the success and the failure. The farmers should be have the possibilities for training and to realise different soil tillage (reduced, ploughing, without) during the conversion time. Consequences are the development of indicator systems and decision support systems to decide the next steps on the way to an optimal conservation system.

3.6. Governance

Important role-players:

- Farmer associations and organisations that can facilitate farmer-to-farmer knowledge-sharing or resource acquisition, as well as voicing concerns and issues and creating awareness at higher levels on the public agenda and among machinery producers and the agrochemical industry
- A good network of official and privately-financed advisory services for independent consultation based on established knowledge in soil science, soil fertility, agriculture, technology, plant development, plant control, managerial economics. These should function as provider of expert advice tailored to the needs of the individual farmers, as well as serving as a link (information in both directions) between machinery producers, the agrochemical industry and agribusiness, where it is difficult for farmers to do so directly
- Experimental farms with long-term investigations of variants with ploughing and reduced tillage and zero tillage variants in every region with different soil and climate conditions, also acting as centres for training and communication (learning by doing)
- Research organisations and universities conducting on-going research in order to fill knowledge gaps, but also functioning to train/educate specialists, consultants and farmers
- Machinery syndicates and private contractors with knowledge about soil functions/soil physics and machine systems for all kinds of CA, as well as the agro-chemical industry (herbicides, pesticides) working towards creating more suitable implements and inputs for a wide range of scenarios, and driven by farmer and research demand.

These various partners (role-players) harmonise their approaches in order to formulate special instructions on new machines, special instruction about straw management, updated information about weed control and pest control have to be communicated.

4. RESEARCH PROPOSALS OF THE EUROPEAN PLATFORM

The European Platform (EP) of the KASSA-Project has had a fruitful discussion at the platform meetings. After assessing and gathering the knowledge from the partner countries, the knowledge gaps to be filled by future research were thoroughly discussed. At the base of these questions the need for future research was refined. Most of the refined research topics are closely linked to each other or have cross-linked impacts. Therefore it was stated, that integrated research approaches should be considered in order to tackle not singular but super-ordinate questions. This led to the development of three main integrated research proposals that will be described here. It also led to a reflection on methodological approaches, combining short- and long-term experiments, on farm research and modelling.

4.1. Agronomic challenges and environmental impacts of Conservation Agriculture

Changing from conventional to conservation agriculture the farmer has to tackle several challenges to maintain or improve his agronomic and economic standards. Abandoning ploughing is not just to be seen as a change of the tillage system. It rather has to go along with an adaptation of the whole farming system. Therefore, some aspects hinder farmer to change and are seen as constraints for the implementation of CA. Among these aspects, the most important challenges are:

- site specific suitability of pedoclimatic conditions for CA
- weed and pest management
- effects on yields and yield stability, particularly in dry regions and during the dry periods
- not necessarily higher yields, but decreased cost per unit production
- management of cover crops and catch crops
- appropriate technology (machinery)
- adapted crop rotations
- soil organic matter maintenance and accumulation
- more efficient water use
- water and air erosion
- plant nutrient availability, management, organic and mineral fertilisation, decreased nutrient losses

Future research is asked to develop strategies in order to support the farmer and to supply practical tools for the implementation of CA.

Most often, these rather agronomic questions have environmental impacts that are inevitably coupled to them. One major problem for instance is the probably increased use of herbicides when abandoning ploughing. The challenge is to develop strategies to reduce herbicide use. From farmers experiences it is known that an adapted crop rotation as well as cover crops help preventing severe weed infestation. This example shows that regarding agronomic challenges, the linked environmental impacts must not be neglected. Furthermore, general knowledge gaps concerning the environmental impacts were identified within the work of the KASSA-Project. Among these, the most important environmental questions to be tackled by future research are:

- *Pollutants*
    - *fate and behaviour of pesticides*
    - *ground water protection*
    - *fate of heavy metals in soils under CA*
    - *fate and behaviour of persistent organic pollutants (POP)*
- *Greenhouse gases and carbon cycle*
    - *greenhouse gas emissions from soils under CA*
    - *methodical questions on the measurement of greenhouse gases*
    - *assessment of benefits and constraints of CA*
    - *climate change and CA*
- *Biodiversity*
    - *impacts of CA on agrobiodiversity*
    - *up-scaling from field scale to regional scale*
    - *biodiversity and agronomic problems (pests like slugs etc.)*

From the knowledge base of the KASSA-Project it is recommended to set up integrated research approaches for the following general topics:

4.1.1. Integrated Weed and Pest Management

As ploughing is the most important means to fight weeds, pests and diseases, new strategies have to be developed without neglecting environmental aspects. The risk of appearance of resistance to the most commonly used pesticides should also be taken into account. Therefore, strategies have to include the use of herbicides and their fate in environmental compartments as well as the reduction of pesticide use with means of appropriate crop rotations and cover crop management. Hazardous additives of pesticides as well as their metabolites and their contamination paths should be topics of closer regard. Similarly, risk of a higher infestation of several pests and diseases may increase in the conservation agriculture taking advantage of the "green bridge" provided by the grain losses at the harvest. Possibilities to mitigate this risk by means of crop rotation and catch crops should be tackled. Possibilities to replace pesticides, mainly fungicides with bio-preparations and development of new resistant varieties (including GMO) must be taken into account. Also the chances of biotechnology have to be considered at that point. Another critical issue is the use of anti-slugs pesticides and there effects on earthworms.

4.1.2. Strategies for Organic Farming and knowledge exchange

Organic Farming is emerging in most European countries. It will be a challenge to find ways of implementing reduced tillage techniques in Organic Farming systems with the total prohibition of chemical pesticides. At that moment, farmers do not have the chance to make use of the benefits of CA, because yield depression and severe weed infestation are inescapable. Both systems, CA and OF, may adopt strategies from each other. Development of joint CA and OF systems that would be suitable for small farms in less favoured soil and climate conditions should be an important research topic.

4.1.3. Management of biodiversity

Biodiversity is one major topic in the future of European agriculture. The CAP has again made one step forward to pronounce the multifunctional role of agriculture in Europe. It seems important to assess the impacts of CA on biodiversity. There are several benefits of CA on biodiversity identified, knowledge is far from complete, though. Different scales should be taken into account, when regarding biodiversity, particularly the landscape level.

Special attention should be paid to soil biodiversity assessment, methodology of which is still far to be satisfactory. Soil biodiversity is closely connected to soil fertility, maintenance of the soil ecological functions and sustainability of the agricultural land use.

4.1.4. Integrated crop rotations and the use of cover plants

Suitable crop rotations are crucial elements in the transition to CA. Besides of the biophysical conditions (soil, climate, biology), the socio-economic factors have to be taken into account (economic viability). As mentioned before, an appropriate crop rotation is a measure to cope with weed, pest and diseases problems, plant nutrition, organic and mineral fertilisation, soil cover and organic matter balance. Nevertheless, the appraisal of crop rotations has to be economically sound. Rotations meeting both demands, decrease of weed problems and maximization of the farmers income have to be developed. The research for and use of adapted crop varieties, biotechnology and seeding technology has to be included into this development. For many decades the plant breeding has been oriented to conventional tillage.

Cover plants enhance soil fertility and protect soil from erosion. On the other hand, cover plants may decrease or increase weed infestation, according to the way they are used. Techniques of CA may also improve soil physical properties, for example through the increase of earthworms' populations, and there is a need to better understand how to implement those cultivation techniques to achieve this improvement.

4.1.5. Integrated nutrient management and conservation of soil fertility

Conservation of soil fertility is a major concern of sustainable agriculture and maintenance of the soil ecological functions. By reducing tillage intensity the nature and distribution of soil organic matter changes as well as superficially applied organic and inorganic fertilizers. For a sustainable soil fertility management and an environmentally sound use of fertilizers profound knowledge of organic matter and nutrient turnover are inevitable. Research of that kind must include techniques for the use of manure and sludge when reducing tillage intensity. Dynamics of the soil organic matter proceeds in the long-term time periods (several decades). The long-term field experiments are therefore invaluable in such studies. Plant nutrient dynamics and availability within soil profile can be altered in the CA, usually, increased demand for mineral nitrogen has been reported. More experimental data are needed to assess the availability of plant nutrients. From an environmental point of view it will be important to assess the risks of nutrient leaching and ground water pollution with the knowledge, that preferential flow might be pronounced in soils under reduced tillage. Pollutants originating from organic wastes (compost and sludge) as well as hazardous substances from mineral fertilizers should be concerned.

4.1.6. indicators of the soil fertility and soil quality in the conservation agriculture

Conservation agriculture remarkably affects soil properties. In order to evaluate its effect a set of indicators is necessary to be reconsidered and suited for the conservation agriculture. They include physical, chemical and biological properties of soils, change of soil structure, detailed studies on erosion of soils, studies of soil compaction, short term and long-term dynamic and balance of C in soils, soil microbiological changes (biodiversity).

4.1.7. development of new machinery

Effective, high performance, lower energy demanding machinery is needed that would be tailored for specific soil and climate conditions and for different farm sizes (small in marginal regions, big in the lowlands, e.g.).

4.2. Implementation and propagation of CA

Implementing CA the farmer is confronted with several challenges. It is of major importance to maintain or improve the farmer's competitiveness and income. Therefore the implementation has to be assessed from a socio-economic point of view as well as from an agronomic and environmental point of view. Main issues for future research were discussed to be the following subjects:

- **Profitability**
  - **market conditions:** under which conditions is CA profitable? What are the boundaries for profitability?
  - **savings:** It is known that shifting to CA is linked to savings in time, costs, labour and natural resources. Research has to focus on the assessment and the quantification of these savings under different conditions. Comparative economic studies between CA and CT should be accomplished in specific soil and climate conditions. Methods for cost-benefit calculation of CA should be further developed.
  - **investment:** A constraint for the farmer to change his system to CA are high investment costs for new machinery. Especially on the EP scale, where there are uncertainties in the transition period, strategies have to be developed here.
  - **transition:** what is needed to facilitate the transition from conventional to conservation agriculture? Training, education and advice for the farmer should be considered.
  - **CA as alternative:** Good experiences are reported for large-scale farms. But is CA a viable alternative for small-scale farming and has it benefits in income for rural areas?

- **Suitability**

  The biophysical conditions are of crucial importance for the success or failure of conservation agriculture. Climate and soil are the major factors. It is recommended to develop databases and decision support system (DSS), where biophysical data, crops and agronomic techniques are merged together and models introduced when necessary in order to facilitate the decision of the farmer. Furthermore, a tool like this could support advisory institutions and politics in the development of suitable land use strategies. The DSS should consider recent market politics to meet the demands of the market and to ensure the income of the farmer.

- **Appropriate local and regional policy**

  Strongly linked to the issue before is to develop an appropriate policy to support and disseminate CA.
  - **support for transition:** As stated above, the transition to CA is critical for the farmer. Training and education is needed and trials should be supported. It has to be proven, if subsidies or financial support in another way are viable means for support of CA in Europe.
  - **machinery is a key issue:** cooperation between farmers and industry is needed to design and experiment new materials, more adapted to CA.
  - **suitable areas:** If suitable areas, where CA may develop good benefits, could be determined, specific regional support could be given.
  - **CA as alternative for rural areas:** It has to be proven, if CA is an alternative for rural areas and if it shows to be economically viable there.

- **land stewardship:** the CA system has beneficial effects for the environment in rural areas. This benefit should be well and reliably assessed and compensated. Objective criteria should be elaborated.

- **Propagation of CA**
  - **knowledge transfer:** CA is not well known among politics and institutions. For the promotion of CA, it will be inevitable to improve the knowledge transfer from science to politics about the benefits and constraints of CA.
  - **support for farmers initiatives:** farmers initiatives are a main driving force for the dissemination of CA. In which ways these initiatives could be supported by a political or institutional framework is a question for future research.
  - **farmers networks:** it was reported that a major driving force for CA were farmers networks. Ways have to be found to strengthen these networks and the knowledge exchange between European farmers.
  - **advisory service:** the agricultural advisory service has to be trained systematically to support farmers in their questions when implementing CA. Appropriate tools have to be developed for practical decision support.

4.3. Food quality and human health

Within the European Union, currently the quantity of crop production is assured. However, the quality of food sometimes is reduced and may develop to a severe problem in the future. The global distribution of organic and inorganic pollutants and their accumulation in certain environmental media result in increasing levels in vegetable and animal food. Inadequate farming practices can raise the incidence of biogenic harmful substances such as mycotoxins. Soil acts as a sink for those pollutants and may be also a source for a burden of plants and animals which feed on the plants cultivated on those soils. The contamination of soil is clearly influenced by the form of cultivation.

The challenge to realize a sustainable production of foods by conservation agriculture (CA), which maintains and improves soil quality and ensures income for farmers and related employees, must consider health and well-being of today's and coming generations. With a "fork-to-farm" approach to protect consumers from health threats, quality of foods should be ensured along the production chain.

As a first stage of the food production chain, research and development in CA should tackle the following human health sensitive themes:

- **Behaviour of pesticides**
  In many cases, CA is attributed to a higher usage of synthetic pesticides such as total herbicides. Until now, there are knowledge gaps considering degradation of those herbicides in soils and on plant surfaces. Further, transport from soil to water bodies (i. e. ground water and surface waters, respectively) of the herbicides and especially their metabolites must be elaborated on different scales. The uptake of plant protection agents and their degradation products into plants should be an additional task with special regard to consumer protection. For this, it is indispensable to develop suitable high-throughput analytical procedures to investigate and monitor the fate of pesticides within the food production chain. Generation of a valid data set then should allow for the assessment of

pesticides and metabolites in soil, water, and plant by existing modelling approaches. With such a tool box, recommendations for an adjusted use of pesticides in CA can be made.

- **Strategies to reduce pesticide input**
  The most important way to reduce pesticide input in CA is the establishment of suitable crop rotation. With a stringent management to cultivate various crops on farm scale, the weed and pest pressure can be reduced significantly and below thresholds of damage. By this, the soil can be prevented from becoming minerally depleted to go on producing healthy crops. An integrated approach regarding the use of cover crops, "green manure", and the inclusion of energy plants and renewable raw materials for industry should be pursued.

- **Mycotoxins in preharvest contamination of agricultural crops**
  Toxic metabolic by-products of fungi, known as mycotoxins, have received considerable attention during the past several years. Some mycotoxins have been associated with human health problems. Certain mycotoxins are suspected carcinogens. Plant protection strategies and extent of nitrogen fertilization can influence the mycotoxin content in plants. To reduce extended use of synthetic pesticides such as fungicides, the use of 'alternative' plant protective agents such as microalgae should be examined under CA conditions with special regard to protect consumers against mycotoxins.

- **Reducing the uptake of pollutants into crops and animals**
  There is increasing concern for the accumulation of organic and inorganic pollutants in crops. Some of them, i. e., cadmium poses threat to consumer health, and diet is the main source of cadmium exposure for non-smoking people. The positive correlation of cadmium concentrations in grain with soil cadmium concentrations justifies a distinct investigation of the behaviour of heavy metals in soils under different cultivation regimes. In CA, the accumulation of pollutants like heavy metals and organic pollutants like PCB can be in parallel to humus accumulation. On the other hand, the availability for any transport of these substances to adjacent ecosystems and plant uptake may be reduced. The long-term behaviour of persistent pollutants should be assessed by modelling which should allow for recommendations to minimize the transfer of pollutants from soil to water and plants. With crop rotations supplemented by hyper accumulating plants (usable as energy plants), soils are to remediate to some extent to ensure sustainable crop production.

5. REFERENCES

Ahrens, E. et al. (1994): Mikrobiologische Beurteilung von Bodenbearbeitungssystemen unter besonderer Berücksichtigung der C- und N-Umsetzungen sowie der Einflüsse von Herbizidanwendungen. In: Tebrügge, F. & M. Dreier (Hrsg.) (1994): Beurteilung von Bodenbearbeitungssystemen hinsichtlich ihrer Arbeitseffekte und deren langfristige Auswirkungen auf den Boden, S. 41-64.

Alletto L., 2002. Travailler le sol sans retournement de surface. Bilan sur la fertilité physique, chimique et biologique d'un sol limoneux de Bretagne après 3 années de travail simplifié. Rapport de stage. Ecole Supérieure d'Agriculture de Purpan. CA Morbihan, Université Rennes, INRA Rennes. 87 pages + annexes

Andersen, A., 1999. Plant protection in spring cereal production with reduced tillage. II. Pests and beneficial insects. Crop-Protection 18:651-657.

Arrouays D, Balesdent J, Germon JC, Jayet PA, Soussana JF, Stengel P., 2002. Stocker du carbone dans les sols agricoles en France? Contribution à la lutte contre l'effet de serre. Expertise scientifique collective rélaisée par l'INRA à la demande du MEDD.

Balabane M, Bureau F., Decaens T., Akpa M., Hedde M., Laval K., Puget P., Pawlak B., Barray S., Cluzeau D., Labreuche J., Bodet JM., Le Bissonnais Y., Saulas P., Bertrand M., Guichard L., Picard D., Houot S., Arrouays D., Brygoo Y., Chenu C., 2005. Restauration de fonctions et propriétés des sols de grande culture intensive : effets de systèmes de culture alternatifs sur les matières organiques et la structure des sols limoneux, et approche du rôle fonctionnel de la diversité biologique des sols. GESSOL/projet Dmostra. Rapport final, 119 pages.

Balesdent, Mariotti, Boisgontier, 1990. Effect of tillage on soil organic carbon mineralization estimated from 13C abundance in maize fields. Journal of soil Science, 41, 587-596

Balland D., 2002. P,K,Mg et la simplification du travail du sol. Perspectives Agricoles N°56, 32-47

Beisecker, R. (1994): Einfluß langjährig unterschiedlicher Bodenbearbeitungssysteme auf das Bodengefüge, die Wasserinfiltration und die Stoffverlagerung eines Löß- und eines Sandbodens. Diss. Uni Giessen, Inst. f. Landeskultur.

Borresen, T. 1999. The effect of straw management and reduced tillage on soil properties and crop yields of spring-sown cereals on two loam soils in Norway. Soil and Tillage Research 1999; 51 (1-2):91-102.

Bout A, 2004. Impact du couvert végétal permanent ou du non travail du sol sur les populations de Carabidae. Rapport d'étude. Université de Tours. CRITT INNOPHYTT. 59 pages + annexes

Brandsaeter, L.O., J. Netland, and R. Meadow. 1998. Yields, weeds, pests and soil nitrogen in a white cabbage-living mulch system. Biological Agriculture and Horticulture 16:291-309.

Bräutigam, V. (1993): Einfluß verschiedener Bodenbearbeitungssysteme auf Halmbasiskrankheiten des Getreides, die Unkrautentwicklung und –bekämpfung. MEG 231. Diss. Uni Giessen, Inst. f. Landtechnik.

Breland, T.A. 1995. Green manuring with clover and ryegrass catch crops undersown in spring wheat: Effects on soil structure. Soil Use and Management 11:163-167.

Breland, T.A. 1996a. Phytotoxic effects of fresh and decomposing cover crop residues.

Breland, T.A. 1996b. Green manuring with clover and ryegrass catch crops undersown in small grains: Effects on soil mineral nitrogen in field and laboratory experiments. Acta Agriculturae Scandinavica Section B-Soil and Plant Science 46:178-185.

Caneill J., Bodet JM, 1994. Simplification du travail du sol et rendement des cultures. Les colloques INRA. n°65 pp 63-82

ČUPA (2000) The effect of previous crop soil cultivation on the yield of grain maize and winter wheat in the drier area of southern Moravia

Debaeke P., 1987. Effet des systèmes de culture sur la flore adventice dicotylédone annuelle. Intérêt de la modélisation pour l'étude de l'évolution à long terme du stock de graines de l'horizon travaillé. Thèse de docteur de l'INAP-G. 342 pages + annexes

Debaeke P., Orlando D., 1994. Simplification du travail du sol et évolution de la flore adventice: conséquences pour le désherbage à l'échelle de la rotation. Les colloques n°65. pp35-62

Dennis, P., M.B. Thomas, and N.W. Sotherton. 1994. Structural Features of Field Boundaries Which Influence the Overwintering Densities of Beneficial Arthropod Predators. Journal of Applied Ecology 31:361-370.

Düring R.A., Gäth S., 2002. Tillage effects on the accumulation of polychlorinated biphenyls in biosolid-amended soils. J. Plant Nutr. Soil Sci., 165, 299-304

Düring R.A., Hoß T., Gäth S., 2002. Depth distribution and bioavailability of pollutants in long-term differently tilled soils. Soil & Tillage Research 66, 183-195

Eltun, R. 1995. Comparisons of Nitrogen Leaching in Ecological and Conventional Cropping Systems. Biological Agriculture & Horticulture 11:103-114.

Eltun, R., and O. Fugleberg. 1996. The Apelsvoll cropping system experiment: VI. Runoff and nitrogen losses. Norwegian Journal of Agricultural Sciences 10:229-248.

Eltun, R., O. Nordheim, and O. Fugleberg. 1996. The Apelsvoll cropping system experiment VII. Runoff losses of soil particles, phosphorus, potassium, magnesium, calcium and sulphur. Norwegian Journal of Agricultural Sciences 10:371-384.

Emmerling, Ch. (2001): Response of earthworm communities to different types of soil tillage. Applied Soil Ecology 17: 91-96.

Fischer, P. et al. (1995): Geringere Herbizideinträge in Oberflächengewässer durch reduzierte Bodenbearbeitung? Mitt. Dtsch. Bodenkundl. Gesellsch. 76: 253-256.

Fischer, P. et al. (1995): Geringere Herbizideinträge in Oberflächengewässer durch reduzierte Bodenbearbeitung? Mitt. Dtsch. Bodenkundl. Gesellsch. 76: 253-256.

Friebe, B. (1992a): Entwicklung der Makro- und Mesofauna unter dem Einfluß langfristig differenzierter Bodenbearbeitung. In: Friebe, B. (1992): Wechselwirkungen von Bodenbearbeitungssystemen auf das Ökosystem Boden. Beiträge zum 3. Symposium vom 12.-13. Mai 1992 in Gießen. Wiss. Fachverlag Dr. Fleck, Giessen, ISBN 3-928563-30-0: 117-130.

Friebe, B. (1992b): Wechselwirkungen von Bodenbearbeitungssystemen auf das Ökosystem Boden. Beiträge zum 3. Symposium vom 12.-13. Mai 1992 in Gießen. Wiss. Fachverlag Dr. Fleck, Giessen, ISBN 3-928563-30-0.

Guérif J, 1994. Effects of reducing soil tillage on structural state of surface layers: consequences on physical properties and soil mechanical behaviour. Les colloques INRA n°65. pp13-33

Hallaire V., Lamandé M., Heddadj D., 2004. Effet de l'activité biologique sur la structure des sols soumis à différentes pratiques culturales. Impacts sur leurs propriétés de transfert. EGS 11, 47-58

Hangen E., Buczko U., Bens O., Brunotte J., Hüttl R. F., 2002. Infiltration patterns into two soils under conventional and conservation tillage: influence of the spatial distribution of plant root structures and soil animal activity. Soil & Tillage Research 63, 181-186

Hansen, B., H. Alrøe, and E. Kristensen. 2001. Approaches to assess the environmental impact of organic farming with particular regard to Denmark. Agriculture, Ecosystems and the Environment 83:11-26.

Hansen, S. 1996. Effects of manure treatment and soil compaction on plant production of a dairy farm system converting to organic farming practice. Agriculture, Ecosystems and Environment 56:173-186.

Harrach, T. & U. Richter (1994): Einfluß langjährig differenzierter Bodenbearbeitungssysteme auf die Durchwurzelbarkeit des Bodens und die Stickstoffverlagerung mit dem Sickerwasser. In: Tebrügge, F. & M. Dreier (Hrsg.) (1994): Beurteilung von Bodenbearbeitungssystemen hinsichtlich ihrer Arbeitseffekte und deren langfristige Auswirkungen auf den Boden. S. 129-176.

Horacek J., Ledvina R., Raus A. (2001) The content of quality of organic matter in cambisol in a long-term no tillage system

Javůrek, M. VACH (2003) The influence of soil protection technology on grain yield of spring barley in year with deficit of precipitation

Javůrek, M. Vach (2002) Production and pedological effect of soil protection stand establishment of field crops

Kohl, R. & T. Harrach (1991): Zeitliche und räumliche Variabilität der Nitratkonzentration in der Bodenlösung in einem langjährigen Bodenbearbeitungsversuch. Z. f. Kulturtechnik und Landentwicklung 32(2), S. 80-87.

Korsaeth, A., and R. Eltun. 2000. Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway. Agriculture Ecosystems and Environment 79:199-214.

Langlet B, Remy JC, 1976. Incidence de la simplification du travail du sol sur la dynamique de l'azote. Colloque ITCF, décembre 1976. pp 189-204

Lundekvam, H., and S. Skoien. 1998. Soil erosion in Norway. An overview of measurements from soil loss plots. Soil Use and Management 14:84-89.

Lyndina T.E., 2000, The field crops roots grow and productivity under of varied systems of soil tillage, J. "Agrochemia and Soil Science", Kiev: Agrarna nauka, Vol.60, P.35-40.

Lyndina T.E., Sendetskaya O.A., 1998, About influence mulching on some agrophysical properties chernozem typical, J. "Agrochemia and Soil Science", Kiev: Agrarna nauka, Vol.59, P.44-49.

Malienko A.M., Majronovski A.E., Kolomiets V.N., 1992, The change of soddy-podzolized soil physical state under tillage methods, J. "News of Agrarian Science", N 4, Moscow, P.90-96.

Martin P., 1999. Reducing flood risk from sediment-laden agricultural runoff using intercrop management technique in northern France. Soil and tillage Research 52 (1999)

Medvedev V.V., Lyndina T.E., 2001, Scientific preconditions of soils primary tillage minimalization and perspectives of its introduction in Ukraine, J. "News of Agrarian Science", N 7, Kiev, P.5-8.

Medvedev V.V., Lyndina T.E., Pashenko V.F., Dorozko I.M., 1999, Agrophysical and economical evaluation of soil zero-tillage use at agricultural crops growing, J. "News of Kharkiv State Agrarian University". Seria "Soil Science, Agrochemistry, Land Farming, Forestry", Is. 2, P. 92-99.

Molteberg, B., M. Henriksen Trond, and J. Tangsveen. 2004. Use of catch crops in cereal production in Norway

Monnier G, Stengel P., Bodet JM, 1976. Conséquences de la répartition des matières organiques sur le comportement du sol. Colloque ITCF, décembre 1976. pp151-165

Nielsen, V., Mortensen, H. and Sørensen K., (2004) Brændstofforbrug, arbejdsforbrug og kapacitet ved reduceret jordbearbejdning og direkte såning. DJF rapport, Landbrug nr. 105. pp 89.

Njøs, A., and P. Hove. 1986. Studies of soil erosion by water. Final Report No. 655. Norwegian Agricultural Research Council.

Packer, J.C. et al. (1992): Infiltration and soil erodibility benefits of conservation tillage. In: Normann, M.J.T.(ed.): Proceedings of the 2nd Australian agronomy conference: 192.

Puget P, Chenu C, Balesdent J, 1995. Total and young organic matter distributions in aggregates of silty cultuvated soils. European Journal of Soil Science, 46, 449-459

Radcliffe, D.E. et al. (1988): Effect of tillage practices on infiltration and soil strength of a typic Hapludult soil after ten years . Soil Sci. Soc. Am. J. 52: 798-804.

Rameau C., Viron H., 1992. Conséquences du travail du sol et de l'intensification du désherbage sur l'évolution de la flore adventice dans une rotation blé, colza, orge. 15° conférence COLUMA, décembre 1992, Versailles

Rasmussen, I., Askegaard, M. and Olesen, J.E. (1999). Weed control in crop rotations for grain production. Paper presented at XI EWRS Symposium, Basel.

Real B., Labreuche J., Heddadj D., 2005. L'impact du travail du sol sur les transferts de produit phytosanitaires. PA, 309, 24-28

Richter, U. (1995): Einfluß langjährig differenzierter Bodenbearbeitungssysteme auf das Bodengefüge und den Stickstoffhaushalt. Diss. Uni Giessen, Inst. f. Bodenkunde.

Riley, H., E. Ekeberg, and T. Boerresen. 1998. Long term trials with reduced tillage. Grønn forskning 1/1998:191-199.

Riley, H.C.F., M.A. Bleken, S. Abrahamsen, A.K. Bergjord, and A.K. Bakken. 2005. Effects of alternative tillage systems on soil quality and yield of spring cereals on silty clay loam and sandy loam soils in the cool, wet climate of central Norway. Soil and Tillage Research 80:79-93.

Rougon D, Briot S, Cadoux F, Drouet J, Pineau X, Rougon C, 2001. Biodiversité des carabidae des grandes cultures en région centre. Symbioses 4, 27-31

Sandal, E. (2004a) Årets forsøg med reduceret jordbearbejdning. Planteproduktion 2004, 5.1 Reduceret jordbearbejdning –Direkte såning –Tilpasset jordbearbejdning Temadag 2 december 2003, Horsens. http://web.agrsci.dk/jtb/nyheder/jordbear/

Sandal, E. (2004b) Reduceret jordbearbejdning. Danish Agricultural Advisory Centre www.lr.dk

Stengel S., Douglas JT, Guérif J., Goss MG., Monnier G., Cannell RQ., 1984. Factors influencing the variation of some properties of soils in relation to their suitability to dierct drilling. Soil and Tillage research, 4 35-53

Stenrød, M., M.-P. Charnay, and O.M. Eklo. 2005a. Variability of soil microbial characteristics through the growing season in three sandy loam soils. (submitted to Biology and fertility of soils).

Stenrød, M., M.-P. Charnay, P. Benoit, and O.M. Eklo. 2005b. Degradation of glyphosate in three sandy loam soils as affected by temperature and soil characteristics. (in prep).

Stenrød, M., M.-P. Charnay, P. Benoit, and O.M. Eklo. 2005d. Spatial variability of soil microbial characteristics in two Norwegian sandy loam soils as affected by surface topographical features. (accepted if revised according to reviewers' comments, Soil biology and biochemistry).

Stenrød, M., O.M. Eklo, M.-P. Charnay, and P. Benoit. 2005c. Effect of freezing and thawing on soil microbial activity and glyphosate degradation in two Norwegian soils. (submitted to Pest management science).

Stockfisch, N. et al. (1999): Ploughing effects on soil organic matter after twenty years of conservation tillage in Lower Saxony, Germany. Soil & Tillage Research 52: 91-101.

Tebrügge F., Düring R. -A., 1999. Reducing tillage intensity - a review of results from a long-term study in Germany. Soil & Tillage Research 1999, 53, 15-28

Tebrügge, F. & A. Böhrnsen (1997a): Crop yields and economic aspects of no-tillage compared to plough tillage: Results of long-term field experiments in Germany. In: Tebrügge, F. & A. Böhrnsen (eds.) Proceedings of the 2nd workshop 15-17 May, Silsoe, UK: Experience with the applicability of no-tillage crop production in the West-European countries. Wissenschaftl. Fachverlag Gießen, p. 25-44.

Tebrügge, F. & A. Böhrnsen (1997b): Results and conclusions of the surveys on No-Tillage. In: Tebrügge, F. & A. Böhrnsen (eds.) Proceedings of the 4th Workshop 12-14 May, Boigneville, France: Experience with the applicability of no-tillage crop production in the West-European countries. Wissenschaftl. Fachverlag Gießen, S. 54-153.

Tebrügge, F. (2000): Comparison of soil machine interactions by intensiv tillage and no-tillage 22 pp.. Poceedings 4th Inten. Conf. on Soil Dynamics, CD-ROM. Adelaide, Australia.

Tebrügge, F. (2000): Visionen für die Direktsaat und ihr Beitrag zum Boden-, Wasser- und Klimaschutz. Vortrag, Zollikofen-Bern, 28.06.2000.

Torresen, K.S., and R. Skuterud. 2002. Plant protection in spring cereal production with reduced tillage. IV. Changes in the weed flora and weed seedbank. Crop Protection 21:179-193.

Torresen, K.S., R. Skuterud, L. Weiseth, H.J. Tandsaether, and S.H. Jonsen. 1999. Plant protection in spring cereal production with reduced tillage. I. Grain yield and weed development. Crop Protection 18:595-603.

van Doren, D.M. et al. (1984) : Influence of long-term tillage and crop rotation on water erosion. Soil Sci. Soc. Am. J. 48: 636-640.

Verdier JL., Drogeat C., Mamarot J., Lopez C., 1990. Evolution du stock semencier dans une rotation triennale. 14° conférence COLUMA, Versailles