

Conservation agriculture

Notwithstanding the fact that the history of agriculture invariably centres on ploughing the soil—symbolically and in a very real sense—, a number of stakeholders are pushing for less or no tilling, as an interesting lever to improve farming system performance. Tilling less, or not at all, is one of the prominent features in “conservation agriculture” systems, but this generic term encompasses a variety of practices. What do they entail in terms of cropping system operations? How are these practices actually impacting economic, social and environmental performances? And what are the chances of mainstreaming these systems in France?

A The FAO (UN Food and Agriculture Organization) defines Conservation Agriculture (meaning soil-conservation agriculture) in terms of minimum or no tilling, permanent soil cover, and diversified crop rotation. In 2010, the FAO estimated that conservation agriculture had stretched to 100 million hectares, from only 45 million shortly after the turn of the millennium. Farmers around the world, in other words, are increasingly shifting towards these systems, and indeed doing so in a wide variety of climate zones (tropical, temperate and arid). There are nevertheless considerable disparities from one country to another: conservation agriculture is thriving in the Americas (on over 25 million hectares in the United States, Brazil and Argentina—where these practices span over three-quarters of the arable land)¹. In Brazil, conservation agriculture is most prevalent in large (several-thousand-hectare) farms, but much less so in family farming, which have less machinery. In Europe, conservation agriculture has developed much more modestly, but the trend is nevertheless heading upward, from 400,000 hectares in 2001 to 630,000 hectares in 2006 in France, for example². The proportion of arable areas cultivated without tillage grew from 21% in 2001 to 34% in 2006 (respectively 58%, 47% and 44% for durum wheat, rape and bread

wheat in 2006)³. Based on *Pratiques Culturales* surveys in 2011, the no-tilling areas spanned 53% in the case of durum wheat, 49% in the case of rape, and 40% in the case of bread wheat. There are also differences between French regions: no-tilling is fairly widespread in the Southwest, due to erosion-related issues, and less so in the wetter regions. In Midi-Pyrénées in 2011, for example, the no-tilling areas growing bread wheat, durum wheat and rape added up to 69%, 77% and 85% of the total in that order. Generally speaking, no-tilling is less common on spring crops than winter crops: only 27% of the areas cultivated with sunflower and less than 20% of the areas cultivated with corn were not tilled in 2011.

Cropping systems that apply conservation agriculture principles vary considerably around the world⁴. They can be associated with different notions, for example including “simplified cultivation techniques”, “no-tillage”, “direct seeding mulch-based cropping systems”, and others. These systems have attracted considerable interest, in the form of research and other projects, among NGOs, national and international organizations, and large food-industry companies. In France, the BASE (*biodiversité, agriculture, sol et environnement*) network, *Institut d'agriculture durable, groupe coopératif*

and other organisations are currently conducting experiments with farmers.

This report mainly focuses on France. It presents the main features of the systems that fit the notion of conservation agriculture, and then attempts to qualify their performances and potential for expansion. It is based on CEP (Centre for studies and strategic foresight) research carried out for the French Minister of Agriculture's commission to identify new agricultural models combining economic and environmental

1. See <http://www.fao.org/ag/ca/6c.html>.

2. Scopel E. et al., 2013, “Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A review”, *Agronomy for Sustainable Development*, Volume 33, Issue 1, p 113-130. <http://link.springer.com/article/10.1007%2Fs13593-012-0106-9>.

3. Chapelle-Barry C., 2008, *Dans le sillon du non labour*, Agreste Primeur n° 207, February, Statistics and Forecasts Office:

<http://agreste.agriculture.gouv.fr/IMG/pdf/primeur207.pdf>.

4. See report on the PEPITES (*Processus écologiques et processus d'innovation technique et sociale en agriculture de conservation*) research project comparing French, Brazilian and Madagascan fields: http://www.projet-pepites.org/taches/coordination/actus_coord/seminaire_de_restitution_du_projet.

performance, led by for Marion Guillou⁵. This analysis draws extensively on consolidation work for ADEME (the French Environment and Energy Management Agency) in 2007⁶ and on Scopel *et al.* (*ibid.*).

1 - The principal characteristics of cropping systems in conservation agriculture

Conservation agriculture is based on **three large principles, which need to be applied simultaneously**⁷:

Reducing or eliminating tilling

The “ideal” goal is to eliminate tilling altogether. Farmers, however, often simplify or reduce tilling, in particular during transition phases. The various practices that can replace systematic ploughing include occasional tilling (skipping certain plots, or tilling only before planting crops that need porous soil or shallow seedbeds); pseudo-ploughing (digging without upturning the soil: loosening or subsoiling); shallow tilling with a disk or tooth tool (stubble ploughing or strip-tilling, for example); or direct seeding, under a plant canopy or not, without tilling (only disturbing the soil on the sowing furrow). These different practices can follow each other in turn over time, on a path to zero-tilling, or coexist on the same farm, depending on the plots and crops.

Covering the soil

The soil needs to be permanently covered, either with residue from past crops (mulch), which are returned rather than removed from the farm, or with cover crops planted during the inter-crop period to protect the soil’s surface, keep the soil moist, compete with weeds, etc. These cover crops are rarely commercial plants in France, but can nevertheless play an important role in the system’s operations (recycling water and nitrogen, improving soil structure, producing biomass, etc.). In semi-arid environments, where biomass production is limited and livestock breeding preponderant, there may be competition between using residue to cover the soil and using it as fodder⁸.

Diversifying and lengthening crop rotations

Replacing tilling invariably requires longer crop rotations to keep weeds under control, since weeds are no longer buried when the soil is upturned. Alternating between winter and spring crops is one way

of disrupting weed cycles and curtailing their development, and diversifying and lengthening crop rotations curbs weed flora specialisation. Furthermore, plant residue on the soil’s surface is scarcely compatible with single-crop farming because it helps fungal disease to spread (to wheat, for example) or certain pests to develop (corn borers, for instance).

These three principles converge towards one central and stated goal: to reduce soil degradation and improve soil fertility, by preserving its organic matter, flora and fauna. The benefits that this ‘tritych’ provides have been extensively documented and seem to have garnered widespread consensus among the scientific community. One of the levers—no tilling—has become the most emblematic feature in these systems. But the three levers are equally important and need to be pulled simultaneously. Otherwise, performance can suffer. “System” is the operative word here: it is not merely a question of adding practices, but of combining dynamic interactions between the system’s components. And it requires farmers to acquire new skills and expertise compared to conventional systems. In other words, removing tilling will not improve performance alone, but combining the three levers—tilling, covering the soil and rotating crops—can.

2 - The performances of cropping systems that fit conservation agriculture principles

Performances in reduced-tilling arable cropping systems are less documented than the descriptions of how they work. The available studies highlight the lack of usable data and sufficiently long timescales, the fact that knowledge often hinges heavily on the context and is therefore difficult to compare with knowledge acquired in other contexts, and the need to push ahead with research into the multi-criterion assessment of obtained performance. Scopel *et al.* (*ibid.*) explain that it is particularly difficult to assess conservation agriculture systems because they apply the three principles very flexibly, entailing a huge diversity of actual practices. Moreover, farmers often adopt these principles to a partial extent, meaning that the associated performances vary even more widely. For example, a zero-tilling system without soil cover or crop rotation will be unable to ward off weed flora, and therefore requires a greater deal of chemical control (herbicides).

There is consensus around certain performances, but others are still yielding contradictory results pending a larger corpus of objectivised and statistically significant data.

The main performances that enjoy consensus follow.

- **Working hours are generally shorter**, simply because work does not include tilling. The otherwise heavy workloads to prepare seedbeds are usually lighter. Moreover, no-tilling practices are typically more popular in large (over 400-hectare) farms⁹. So, whereas the shorter working hours are a plus for certain farmers, communities to the contrary may begrudge them because conservation agriculture systems create fewer local jobs.

- **Zero tilling reduces fossil fuel consumption**, instantly saving an estimated 20 to 40 litres of fuel-oil per hectare⁹. CASDAR TTSI¹⁰ project results showed that conservation agriculture operations—all crops combined—consumed 53 LFOE/ha (litres of fuel-oil equivalent) on average, compared to 100 LFOE/ha on conventional arable crops (farms in the Solagro PLANETE 2010 benchmark¹¹). Total energy consumption stood at 390 LFOE/ha in the farms under review, against 470 LFOE/ha

5. See

http://agriculture.gouv.fr/IMG/pdf/Agroecologie_-_Rapport_double_performance_pour_le_MAAF_-_note_principale_et_annexes_-_VF_cle899e18.pdf.

6. Labreuche J. *et al.*, (coordinators), 2007, *Évaluation des impacts environnementaux des Techniques Culturales Sans Labour en France*, ADEME-ARVALIS Institut du Végétal-INRA-APCA-AREAS-ITB-CETIO-MIFVV, 400 p.

<http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=51256&p1=00&p2=11&ref=17597>.

7. See Scopel E. *et al.*, *ibid.*

8. Corbeels M. *et al.*, 2010, *Tailoring conservation agriculture to local contexts and conditions of smallholder farmers in Africa*, Proceedings of ‘Agro 2010 the XIth ESA Congress’, Montpellier, p. 37-38. <http://www.agropolis.fr/agro2010/paper/lundi/corbeels.pdf>.

9. Chapelle-Barry C., *ibid.*

10. CASDAR (*Compte d’affectation spéciale pour le développement agricole et rural*) projects aim to involve agricultural development stakeholders in applied research and innovative drives. The project on “substantially simplified plantation techniques” was coordinated by the Midi-Pyrénées regional chamber of agriculture, from 2008 to 2012; see <http://www.mp.chambagri.fr/-Techniques-tres-simplifiees-d-.html>.

11. PLANETE is an energy and greenhouse-gas assessment method developed by Solagro. The PLANETE 2010 benchmark is based on 3,500 PLANETE assessments from 1999 to 2010. See <http://www.solagro.org/site/286.html>.

on average in the same benchmark group. This can cut overall production costs provided the greater use of pesticides does not send operating expenses through the ceiling.

- **Conservation agriculture improves biological life and biodiversity in soil**, including both macrofauna (gastropods, micro-mammals, beetles, spiders, nematodes, earthworms, etc.) and soil microfauna (more microbial biomass).

- **These systems on average reduce erosion**, by factors ranging from 2 to 10, based on reports in literature¹². This improves water infiltration and soil structure¹³ (leading to greater porosity over the long run), provided there is enough plant residue covering the soil's surface and that rotation includes crops with large root systems (alfalfa and ryegrass, for example). The risk of slaking is therefore lower.

- Conservation agriculture systems help to **increase soil organic matter content**, especially at the surface, and **carbon storage in the soil**. Storage capacity is estimated at 0.1 to 0.4 metric tonnes of carbon per hectare per year in the plough layer (down to 20 cm deep). Plant residue on the surface plays a major role in this process. Carbon accumulation, however, varies according to soil layers, and is very sensitive to soil clay content, which has an effect on organic matter stabilisation.

- Lastly, **soil evaporation is 10% to 50% lower**, depending on the quantity of plant residue. This, in light of climate change, can be an interesting option to improve water availability for crops.

Conservation agriculture systems therefore jointly improve a number of economic and environmental performances. But other performances can be more variable, and in some cases controversial.

- **Yields can increase or decrease, depending on the crop and context**. *Pratiques culturales* surveys in 2006 and 2011 suggested that plots that had not been tilled for the previous five campaigns yielded slightly less than the ones where the soil was upturned every year. Differences in yields however vary from one crop and year to another, and differ according to whether they are compared against systematic, occasional or no tilling. The CASDAR TTSI project results showed that the 18 farms monitored in Southwest France

reported slightly higher yields than the region's average yields with bread wheat, durum wheat, colza, irrigated soybean and irrigated corn, and lower yields with sorghum, sunflower and peas. Several authors highlight issues with sunflower in conservation agriculture, claiming that yields are particularly low.

- **Mechanisation costs** may be lower due to the fact that less tilling entails less equipment wear, but conservation agriculture can also require investment in specific equipment (direct seed drills, precision spaced planters, etc.).

- **As regards Greenhouse Gas (GHG) emissions, results are generally positive in the case of carbon (storage in the soil, at least near the surface), but possibly negative for nitrous oxide (N₂O)** due to the steeper denitrification process, in particular if organic fertiliser is added. N₂O emissions are in fact higher (+0 to 5 kg N-N₂O per hectare and per year) as a result of the higher soil humidity and organic matter content. CASDAR TTSI project results showed GHG emissions averaging out at 1.9 TEQ (Tonnes of Equivalent) CO₂/ha (63% of N₂O and 37% of CO₂), versus 2.16 TEQ of CO₂/ha in the Solagro PLANETE 2010 benchmark (58% of N₂O and 42% de CO₂). In other words, the net GHG balance is unclear on the basis of current knowledge.

- Generally speaking, **the mineralisation rates in the soil's organic matter and the nitrogen available for crop uptake tend to increase** because the temperature and humidity spur organic matter and crop residue rotting. This can entail contrasting consequences: the following crop can require less nitrogen fertilisation (improving the nitrogen balance) or cause nitrogen loss through leaching (lowering environmental performance) when nitrogen mineralisation and the following crop's nitrogen requirements do not match. This depends on the type of crop residue (i.e. whether crops are leguminous or not), their C/N ratio, the weather conditions, the crop cycle, etc. Many studies show that, when covers are managed properly as inter-crops, conservation agriculture systems limit the losses of mineral elements (N, P, K). There is, however, considerable uncertainty about the impact of these systems on phosphorus or pesticide transfer to water.

- The use of pesticides (in particular herbicides) warrants an accurate and objec-

tive assessment (encompassing dosages, products, frequency of use, etc.), because there is considerable controversy over this issue. **No-tilling cropping systems generally see more weed infestation than conventional ones**. Surveys by *Pratiques culturales* in 2006 concluded that non-tilled crops require a 0.3 additional measure of herbicide on average, all crops combined, than tilled ones. The figures in 2011 point in the same direction: a 0.2 additional measure of herbicide for bread wheat and sunflower, and respectively 0.3 for durum wheat and corn, 0.6 for barley, 0.7 for protein peas, 0.8 for rape and 1.3 for sugar beet. That said, situations vary from one cropping system to another, in particular according to whether cover destruction mechanisms are chemical, mechanical or both: cover crops and long crop rotations play a preponderant role staving off weeds, and indeed aggressive bio-agents in general. In the CASDAR TTSI project, for instance, farmers who ran long crop rotations (6 years or longer) used less herbicide than the others.

Conservation agriculture system performance in terms of pesticide use, in other words, needs to be considered on a case-by-case basis. It is important to note that these performances can be considered from an environmental standpoint (the risk of diffuse pollution) and a social viewpoint (the health hazards for users).

- Lastly, **in terms of water requirements**, conservation agriculture can be positive because it curbs soil evaporation (hence preserves water resources) or negative when inter-crop plant cover competes with the following crop.

3 - The potential for mainstreaming conservation agriculture systems

Conservation agriculture cropping systems have been developing considerably around the world for several decades. These systems span more modest areas in France, but the trend is also on the rise. This development nevertheless warrants some perspective because farmers usually adopt

12. See Scopel E. *et al.*, *ibid.*

13. Structuration issues and perhaps compacting may however occur in hydromorphic soil or when clay content is too low.

conservation agriculture principles to a limited extent and/or on a non-permanent basis. In France in 2006, for instance, 34% of the areas were not tilled but only 11% had not been upturned at any point during the previous 5 years. And only 0.2% of the corn and sunflower, 0.4% of the rape, 0.8% of the bread wheat and 3% of the durum wheat had been planted without tilling¹⁴. In 2011, those figures were even lower: 0.5% for corn, 0.5% for rape, 1% for barley and sunflower, and 4% for bread wheat and durum wheat.

Scopel *et al.* (*ibid.*) report that conservation agriculture principles are often adopted to a limited extent: farmers till less or not at all to shorten working hours and cut fuel bills over the short term, but do not necessarily add plant covers or extend crop rotations. Not covering the soil undermines the advantages of not tilling, and the downsides (weed infestation, for example) can outweigh the upsides. This requires additional tilling, labour and inputs, and hence downgrades economic and/or environmental performances and may prompt farmers to revert to their original system.

The reasons for only partially adopting conservation agriculture vary according to the situation. In very large (several-thousand-hectare) farming operations in the Americas, the development of genetically modified crops that resist total herbicides—sidestepping the need to develop crops that resist selective herbicides and providing an alternative to tilling as a weed-control method—has undeniably encouraged the development of direct sowing. These systems, however, are not always diversified (biannual corn and soybean rotation for instance), and require very large amounts of phytosanitary products. In Africa, where farms are typically small and family-run, the hurdles to adopting conservation agriculture are linked to fierce competition for crop residue (*see above*), especially in arid areas; limited access to markets where farmers can purchase equipment (direct seeders, for instance) and/or inputs—which may entail heavier workloads (handling plant covers or removing weeds manually if herbicides are unavailable), most often for women—; and, often, insufficient knowledge of complex ecological processes.

In France, the main obstacle to conservation agriculture development seems to be the economic risk associated with the transition period between two systems, which can lead farmers to revert if the shift

fails. Performances stabilise after several years (the benefits of long crop rotations do not materialise immediately), but farmers generally acknowledge that the transition is difficult to negotiate and requires a steep learning curve. The fact that farmers are attached to tilling, which has been enshrined in farming traditions for centuries, can increase reluctance to abandon tilling. Finally, Corbeels *et al.* (*ibid.*) sum up the factors that smooth the transition to conservation agriculture as follows: sloping and loamy soil (where erosion is an issue), high biomass production potential, limited livestock (no competition for crop residue), the farm's ability to invest, land tenure security, access to agricultural markets, and a favourable institutional environment (group dynamics and suitable advice, for example).

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To conclude, conservation agriculture systems based on the above 'tritych'—no tilling, soil cover and long crop rotation—improve a number of economic and environmental performances. The most significant advantages include lower fossil-fuel consumption, lower soil erosion and evaporation, preservation of soil fertility and greater biodiversity. These upsides notwithstanding, conservation agriculture is not an ideal (certain performances, as we have seen, are controversial) or a one-size-fits-all single model. Considerable research is still required to understand the interactions between agricultural practices and the cycles of the various natural resources.

Support for farmers embarking on a transition to conservation agriculture also appears essential, because these systems are more complex to manage and entail entirely redesigning cropping systems (considerably reducing tilling without rearranging the entire system in depth is one of the causes of failure that are mentioned most often). Farmers who wish to opt for these systems need expert technical advice (on covers and specific equipment, for instance), and more solid education or training in agronomics—focusing on ecosystem operations, water and nitrogen cycles, cover interactions, etc.—to understand these

increasingly complex systems more easily. Economic and environmental performances will only improve concurrently if the reduction in tilling does not become equivalent to a "simplified cropping system". In other words, farmers will need technical reference materials, assessment tools and agronomic rationale to adapt conservation agriculture principles to their particular situation (soil and weather conditions, machinery and labour availability, etc.). Lastly, involving stakeholders from across the entire agricultural sector is essential to accommodate crop diversification, which often requires new outlets.

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14. Chapelle-Barry C., *ibid.*