

Implications of Zero Tillage Based Cropping Systems on Socio-Economy and Policy in the Agricultural Mechanization Subsector*

The role of agricultural engineering in Conservation Agriculture

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Abstract

Zero tillage based cropping systems, also called Conservation Agriculture, are becoming increasingly popular in many different parts of the world. They are considered to be win-win situations providing direct benefits for the farmer as well as the indirect benefits for the general population and the environment.

Nevertheless, the widespread adoption of Conservation Agriculture is, with exception of some South American countries, so far limited and the initial rate of adoption in a new region is slow. There are a wide ranging number of reasons for this, and those related to agricultural engineering and the mechanization aspects of Conservation Agriculture will be shortly described in this paper and solutions proposed.

Conservation Agriculture is changing most, if not all, of the paradigms we used to know about agriculture, such as the bulk density requirements of soil for plants to grow, the optimum layout of a seed bed, the dynamics of soil nutrients and fertilizers and in the same way the objectives of farming practices and mechanization. Accordingly the most important changes in technologies will be required in the methods of planting and in residue management. Weed control, harvesting practices and other farm operations might also have to be revised.

Responses to these new approaches demand a multidisciplinary approach, in which engineers, agronomists and soil scientists work closely together. From the very beginning the development of new equipment should be put into the hands of the commercial manufacturing sector in close collaboration with the farmers and the research and extension sector. It is to be expected, however, that within the commercial sectors there will be both supportive as well as opposing forces for the introduction of Conservation Agriculture.

With the introduction of Conservation Agricultural practices generally, a positive socio economic impact is anticipated. This will also apply to cropping systems having a high percentage of hired manual farm labour. On the other hand contractor services that have specialized on tillage operations will have to change in order to respond to the new markets.

In general, positive impacts from the adoption of Conservation Agriculture are expected, not only for the farming sector, but also for the general population, the national economy and the environment. Government support for the introduction of this type of agriculture can therefore justified as a reimbursement for services which the farmers would provide to the general public. However, direct subsidies on inputs distorting the microeconomics of the farming operation should be avoided.

Summary

Cropping systems, based on zero tillage, also called Conservation Agriculture, are becoming increasingly popular in many different parts of the world. They are considered to be win-win situations providing direct benefits for the farmer as well as the indirect benefits for the general population and the environment.

Nevertheless, the adoption of Conservation Agriculture is, with exception of some South American countries, so far limited and the initial acceptance and rate of adoption in a new region is always slow. There are a number of reasons for this and those related to agricultural engineering and the mechanization aspects of Conservation Agriculture will be shortly described in this paper and solutions proposed.

Keywords: Conservation Agriculture, Zero-tillage, Agricultural Mechanization

1 Implications of Conservation Agriculture on the Choice of Equipment

Conservation Agriculture is changing most if not all of the accepted paradigms we used to know about agriculture, such as the bulk density requirements of soil for plants to grow, the optimum layout of a seed bed, the dynamics of soil nutrients and fertilizers and in the same way the objectives of farming practices in general and mechanization in particular.

1.1 Planting

The most obvious changes in equipment are to be found in planting techniques. Conventional techniques were based on a clean and loose seedbed with a well-defined granular structure. The main challenge for the engineers was to ensure an accurate depth placement and a defined distribution of the seed (and fertilizer if combined) along and across the row.

With Conservation Agriculture all these requirements still remain, but are further complicated by the need to penetrate through organic residues of varying amount and physical characteristics and into soil of very different structure. New equipment has not only to cope with these additional requirements, but it still has to be affordable.

Two of the most common problems are the penetration to accurate planting depths in hardsetting dry clay soils, and the cutting of half-moist residues which tend to be very tough. On top of this the flow of residues through the seed-drill may also create problems. There is no general answer to solve these technical problems; the solution depends very much on local conditions and might even depend on time. For example, difficulty in penetrating hard setting soils might be overcome by heavy seed-drills applying the weight of the equipment onto the coulters. This solution, however, is not possible for animal draft equipment, which has severe weight restrictions. Therefore most animal drawn zero-till planters use chisel coulters which create a penetrating force. However, the problem might disappear after some years, because under Conservation Agriculture, the soil structure and moisture regime at the surface might

change due to the increase of soil organic matter in that horizon, drastically reducing the problem of penetration.

For this reason it is important that engineers developing equipment collaborate closely with farmers and with agronomists because solutions to engineering problems might be found in non-engineering areas! A number of engineering solutions have been sought to overcome the problem of hairpinning¹ of moist straw into the seedslot. Non-engineering solutions to that problem might be the design of the cropping system in a way to ensure that planting is either done into green or dry residues, or the rolling (aligning) of residues in the direction of planting thus avoiding the necessity to cut through the straw, or a stripper harvest to leave the straw anchored, rolling it down only at planting.

1.2 Fertilizer distribution

Fertilizer application techniques also changes under Conservation Agriculture. Obviously the incorporation of fertilizer, considered particularly important for lime in conventional agriculture, is not practically possible. Normally some base fertilization is applied at the time of planting by incorporating with a tine into, or close to the seed furrow. Again, the requirements from the agronomic point of view change. As the general dynamics of soil life and therefor nutrients, change, fertilizer is not strictly applied to one particular crop but to the soil-life system, which then releases the nutrients to the plants. For example, late N-applications can eventually be controlled by covercrops and their decomposition throughout the main cropping season. For the particular case of the application of lime, it has been discovered that a topical application into a cover crop is incorporated into the soil profile through the organic acids on the soil surface as if it had been incorporated mechanically.

However, special consideration, has to be given to the use of slurries and manures. Unless they are properly treated prior to application, a surface application without incorporation might not only lead to high nutrient losses but also conflict with existing legislation regulating the application of these waste products. Because of the high power required to incorporate slurry without a tillage operation its application in this manner is restricted to mechanized farming having the availability of high-powered tractors and high capital for machinery investment.

1.3 Weed control - Spraying

Conventional mechanical weed control (hoeing) under residue is a particular challenge for the equipment designers and faces certain limitations regarding the permissible coverage of residues. In a zero-tillage cropping system this form of mechanical weed control should be avoided as it still intervenes with the soil, accelerating mineralization of soil organic matter, provoking the emergence of weed seedlings and interrupting the surface openings of the macropores. For weed control, different approaches and therefore different implements are required. Some suggested mechanical approaches to weed control could be, depending on the type of weed problem, cutting and mulching, or the rolling and breaking or the chopping off of the flower to avoid seeding. The main approach to weed control would, however, be through agronomic management of the crop rotation and cover crops.

A very important tool for weed control within Conservation Agriculture is the correct selection and application of herbicides. Suitable designs of sprayers for specific cropping situations can help reduce wastage of expensive products. Examples of these are hooded row

¹ Straw is not cut but pushed by the coulter into the seed slot. The seed then falls on top of the straw resulting in germination problems as the seed has no proper soil contact.

crop sprayers and shielded sprayers to reduce drift. In any case the correct calibration of the sprayer, adequate pressure settings to avoid drift, a defined position of the boom parallel to the surface and an absolutely even horizontal distribution of the spray must be assured in the interest of the farmer as well as of the environment. Ineffective herbicide application can eventually lead to a failure of the entire zero-tillage cropping system.

The technique of pre-planting incorporated soil herbicides cannot be utilized in zero-tillage systems for obvious reasons.

1.4 Residue management

"Seedbed" preparation in zero-tillage cropping systems actually starts with the harvest of the main crop or with the management of the cover crop residues. Carelessness at harvest time leads to additional costs or problems during planting. The most important aspect is an absolute even distribution of the residues over the field. Accumulation of residues in swaths or in the turning areas must be avoided. With expanding cutting width and capacity of combine harvesters, or the application of a two step harvest operation with threshing of two windrows at a time in a second operation, the design of residue spreaders that cover the entire working width becomes a real challenge. Problems might also occur in manual systems with centralized threshing.

Where the straw is not needed for other purposes and a zero-tillage planting operation is following a grain harvest, the use of stripper harvesters might be technically the most elegant solution.

In conventional agriculture the generally accepted wisdom is that residues are incorporated. A fast decomposition is considered beneficial in order to make use of the nutrients contained in the residues and to avoid soil structure problems in those crop rotations relying on high cereal content. Therefore chopping of straw has become popular. For Conservation Agriculture the contrary is the case: residues should remain on the soil surface for as long as possible to maintain the soil cover. One problem is that the hairpinning of straw into the seed slot is more difficult to solve with short straw than with long. Therefore in zero-tillage systems it is preferable to spread long straw instead of chopping it. This has the additional benefit of reducing overall energy inputs, thus reducing fuel costs at harvest and threshing time and also increasing the throughput of combines in case of mechanized harvesting.

One completely new feature of zero-tillage cropping systems compared to conventional farming is the management of cover crop residues where applicable. Whereas in conventional farming those would be both shredded and incorporated with a plough or incorporated in one operation with a rotary cultivator as green manure, in Conservation Agriculture they serve for a different purpose. Shredding is not to be recommended because it increases decomposition and cutting and mulching might induce undesirable regrowth. New implements like the knife roller occupy a prominent position in the management of covercrops. It flattens the cover facilitating the access to the field and the planting operation. The covercrop is ideally not cut but only broken into pieces leading to desiccation or even killing the plants limiting the need for herbicides to a minimum.

1.5 Other operations

Depending on cropping and irrigation systems, land formation and layout can be different from the level surface normally required. There are some new developments in this, for example bed planting of cereal crops. Other crops such as potatoes which are conventionally cultivated in ridges might be grown on flat surfaces under artificial (organic or non-organic)

mulch covers. All these changes in growing techniques will have implications for the type and design of equipment used.

One technique which is very beneficial to zero tillage and which is particularly interesting for row or bed crops, is that of controlled traffic. This technique demands the standardization of working widths of the different implements used as well as matching tyre sizes to fit into the rows.

Once a zero-tillage cropping system is in place, any further interference with the soil must be considered very carefully in order to avoid damage to the soil-ecosystem. If for some reason soil tillage is inevitable equipment having the least possible impact should be used. For example, in the case that extreme soil compaction cannot be broken up by rootcrops, a plough will not be adequate or suitable and in this case a paraplow would be much more appropriate.

2 Responses to the New Demand

2.1 Finding engineering solutions

As a consequence of the introduction of Conservation Agriculture, new farm operations with different objectives emerge and, for which new mechanization solutions are required. Prior to setting out to solve the new challenges, engineers should familiarize themselves with the new concepts and then work closely together with agronomists and farmers in the development of the required equipment.

From the very beginning the involvement of the commercial manufacturing sector as well as the farmers in co-ordination with the agronomic and engineering concepts of the research sector in the development of new equipment has proven beneficial. For most new tasks, equipment solutions are generally already available somewhere on the world making a reinvention unnecessary. However, straight importation or copying of equipment existing elsewhere might not fit in well with the local situation in terms of applicability but also in terms of manufacturing capacities, available production technologies and locally available materials. For the development of new equipment, inspiration from other regions, and perhaps even technical exchange or licensing agreements with manufacturers is suggested. Aside from that, the objective of the specific operation and the expected working conditions must be well understood, and specific new features of the new equipment identified. For the development of a zero-tillage seed-drill, for example, it might be necessary to change only the coulter, while the rest of the machine might be taken from existing local designs.

2.2 Commercial interests - Pro and Contra

Conservation Agriculture is by no means a low input/low output system. Apart from environmental considerations it will in most cases also improve the economics of farming, increasing the purchasing power of the farming population. However, the derived economic benefits will depend on the selection of inputs, equipment being one of them.

The development of Conservation Agriculture will therefore be of special interest, not only to the farming community, but also to the commercial service and input supply sector. These interests can be used to form strategic alliances for the promotion and widespread adoption of Conservation Agriculture.

However, in the current farming situation, the business of selling agricultural machinery and equipment and the provision of support services are not particularly attractive and margins are

very tight. It is therefore unlikely that the manufacturing and machinery dealer sector will invest spontaneously in the development and promotion of zero-tillage technology, if it does not receive clear signals that the future market will pick it up. Conversely, agricultural extension workers and progressive farmers will not be able to take zero-tillage up, if the commercial market does not supply them with at least the basic hardware. This conflict usually requires some external intervention or a close collaboration between extension, promotion and commercial input supply sector.

However, there are also distinct interests which will work against widespread and long-term introduction of zero-tillage based cropping systems. Obviously manufacturers of tillage implements like ploughs and disk harrows will not welcome that development, because it displaces the equipment they build and sell from its place of being the primary farming tool to a tool of marginal usefulness. Another area of potential conflict could be with tractor manufacturers, especially if they are operating within saturated markets. As a result of the introduction of zero-tillage based cropping systems, the demand for tractor power and tractor numbers will decrease. In addition, the tractors will have a longer life and reduced maintenance costs due to less wear. This is beneficial for the farmer but detrimental to the business prospects of the manufacturer and service provider.

The reactions of those sectors can be varied, ranging from open controversy to ambiguous support. An example is when zero tillage is promoted as a viable option for a number of crops and years, stressing that at least after 5 years a ploughing operation would be beneficial if not necessary to maintain crop growth. Such a system would avoid that the full benefits of Conservation Agriculture which start after about 5 years become visible, whereas at the same time the farmer has to keep the farm power and machinery for a full tillage operation.

On the other side there are also manufacturers or dealers with the vision to promote zero-tillage, even though they represent the above mentioned sectors of potential conflict. While admitting that their immediate business might decline, these entrepreneurs recognize and understand that zero-tillage based systems might be the only alternative a farmer has to stay in business at all, and they have the foresight to serve tomorrow's farmers while accepting that they might sacrifice today's revenue.

3 Socio Economic Factors

This paper will only briefly mention some of those socio-economic factors that are related to the mechanization and farm power requirements in farming and the implications Conservation Agriculture might have on it.

3.1 Farm labour

The situation regarding the availability of farm labour is very diverse from country to country and region to region. Whereas in many countries farm labour is generally short, in others it appears to be abundant, at least in some parts of south Asia. However, even there it is more and more difficult to find farm labour for certain operations and at certain times of the year. For example problems with keeping up with optimum planting dates can be a symptom of a lack of farm power.

One of the major benefits of zero-tillage based cropping systems is the overall saving in time and farm power requirements. This saving can range between 30 and 60% which is generally beneficial in systems with a high degree of family labour, which can then be released from farm work and yet maintain the same or even higher farm income. This opens up the

possibilities for better education or the development of other income generating activities. For regions with a high incidence of HIV/AIDS, zero-tillage based cropping systems might well be the only solution to carry on farming with a dramatically reduced working population. Even in regions with a high percentage of landless farm workers, such as in parts of India and Pakistan, social conflicts are not really foreseen. In both cases tillage operations are already highly mechanized, and in both countries with the increasing mechanization the demand for rural labour even increased. The major savings in time and labour in the zero-tillage systems are actually during land preparation and planting, while the other operations remain, or could even increase due to the higher yields, which in turn increases the demand for labour at harvest work. Another result which would increase the demand for labour could be the increased intensification and diversification of agriculture.

However this can lead to an area of potential conflict of interests in the sector of contractors or hired purchase operators. In the conventional system they would typically be specialized in offering ploughing or general tillage operations. Shifting to zero-tillage the farmer will dispense with tillage and might decide to do the planting directly him-/herself. However, in markets which are not oversaturated, contractors might recover at least part of the lost tillage business by offering planting or other services under the new system.

3.2 Production cost

In most, if not all countries of the region farmers are desperate to reduce their production costs in order to be able to maintain even their existing subsistence level and as well to eventually progress. Zero-tillage based production systems eliminate one of the largest cost factors in cropping, which is land preparation, and at the same time improve the long term yield stability and even yield levels. Reductions in cost and time for tillage and seedbed preparation will have an immediate impact on seasonal operation costs. In the long term investment requirements are also reduced, because the necessity for investment in tractors will be reduced over time and in value (size). Also the need to maintain a general range of equipment on the farm will be reduced in the long term. Although some of the equipment, such as zero-tillage planters, might be more expensive than the respective equipment for conventional farming, the equipment usually can cover a much larger area under zero-tillage planting, which gives the opportunity to hire out services to other farmers. Any remaining tillage equipment will be used with such a low frequency that it might be left for shared use among a group of farmers. As a consequence, over the years, capital tied up in machinery will be reduced on a zero-tillage farms when compared to conventional farms.

3.3 Energy and fuel

Energy savings due to the introduction of zero-tillage based cropping systems are globally in the range of 40-50% as compared to conventional farming. Direct savings occur through the reduction in fuel used for conventional tillage. This brings not only benefits for the farmer, but also for the national economy as well as for the environment. Because of their requirements for high inputs of power tillage operations have, within a cropping season, the largest air pollution effects of all the mechanized farm operations.

Apart from direct energy savings in the farming operations, reduced long term requirements for machinery per hectare will lead to reduced energy requirements for the manufacturing of that machinery. Other energy savings are possible through an improved efficiency in the use of synthetic farming inputs such as fertilizer and pesticides. In the long term, fertilizer use tends to decline in zero-tillage systems due to reduced losses through erosion and leaching and due to better nutrient dynamics in the soil. Also long-term pesticide use tends to decline,

provided proper crop rotations are maintained. Contrary to general opinion, the use of herbicides will not necessarily increase with the introduction of zero-tillage based systems compared with conventional intensive farming. With a proper crop rotation and the use of cover crops, herbicide use in the long term might even be lower than in conventional farming systems, leading to subsequent energy savings in the system.

4 Government's Role and Interest

4.1 Incentives

As explained above, the introduction of zero-tillage based cropping systems is usually of direct benefit to the farmer. However, there are a number of impediments which make the adoption difficult, especially if the concept is completely new in a region. But on the other hand Conservation Agriculture brings a number of benefits to the general public and the national economy. It is therefore in the interest of governments to promote the introduction of Conservation Agriculture especially where the adoption process is not picking up spontaneously.

In the initial phase a number of investments will probably be necessary for the farmer, which will range from preparing the soil for the transition to investing into new equipment. At the same time the existing equipment might become obsolete and unsaleable. In this situation a government might decide to provide incentives to the farmer in order to facilitate the first steps and to lower the risk and costs of the transition. These incentives can be provided indirectly through very close technical assistance, research and extension, or as subsidies or direct payments. However, the subsidizing of inputs should be avoided, as this might distort the calculations of the production costs and might even be counterproductive for the long term sustainable establishment or strengthening of the commercial input supply sector.

In particular the donation of equipment or price subsidies for equipment should be avoided. The real cost of equipment as well as the economic and financial aspects should be viable. It should be possible to finance the equipment with the income from agricultural production. The subsidizing of equipment would eventually allow for other mistakes in the system plus it would also give wrong signals to the manufacturing industry as to which cost an implement could be sold on the market. Once the transitional subsidies phase out, which should always be clearly understood, the manufacturing sector might suffer in the same way as the farming sector.

General incentives or subsidies for the introduction of Conservation Agriculture should not be misunderstood as handouts to the farmers. In the design of the incentive systems it should be reflected that these are in reality not direct subsidies to farmers, but a reimbursement for services those farmers deliver to the community. The services are contributing to better water quality, less cost for treatment, reduced road maintenance cost and others.

4.2 Credits

Credits might often be a more suitable way to assist farmers in the adoption of Conservation Agriculture practices. While the investment costs as such should be borne by returns from the cropping system, this income might not materialize in the first years and the investment capital available to the farmer might not be sufficient to start the process. It is here where the farming sector could be supported with well-defined credit schemes. Besides other areas like land melioration, these schemes will be of particular importance for investment in new

equipment, which is absolutely necessary for the introduction of zero-tillage based cropping systems.

4.3 Legislation (Soil Law)

Apart from the promotion, awareness creation and provision of incentives, it is helpful to assist the process of the introduction of zero-tillage cropping systems by an adequate legal base in the form of legislation covering soil use and conservation. In fact, the combination of incentives and regulation seems to be the best way to induce change. This legislation could define procedures and limit the use of potentially damaging practices, such as ploughing on steep slopes or in wind erosion zones. It could also restrict the use of certain implements to well justified cases. However, a law which is too demanding and going beyond the actual capacities for implementing, monitoring and follow up would be counterproductive. The formulation of an international code of conduct on soil management could assist countries in formulating a national policy and legislation.

Conclusions

Conservation Agriculture stands for a group of technologies that, when applied and adopted, provide a viable sustainable alternative to conventional agriculture. Conventional agriculture on the other hand, relying on inversion tillage, is proving to be unsustainable.

Through the provision of suitable equipment agricultural engineering provides key inputs which make the introduction of Conservation Agriculture viable. The development of these inputs depends on a multidisciplinary approach in which the commercial manufacturing sector plays an important role.

The impact of the introduction of Conservation Agriculture in general, and of the corresponding engineering inputs in particular, are proving to be demonstrably positive from a micro- and macro-economic, environmental and socio-economic point of view. Conservation Agriculture is therefore called a win-win concept with very little real conflict potential.

However, the introduction of Conservation Agriculture and the development of the agricultural engineering input supply sector to serve for this purpose require an enabling policy environment and very often some supportive measures. Governments can, with effective policies, assist the farmers and the commercial sector in choosing this way which in the end proves beneficial to the general public.

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