International Development Opportunities — Hot Spots for Future Development[1]

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Conservation tillage has been quietly expanding, and evolving, around the globe for the past 3-4 decades. Defined as reduced tillage systems that leave a certain percentage of crop residues on the soil surface after planting, conservation tillage, or any of the many common synonymous descriptors (zero tillage, no-till, direct seeding, reduced tillage, etc.) are being replaced by the more generic term, conservation agriculture. The United Nations' FAO describes conservation agriculture as: *Involving a process to maximize ground cover by retention of crop residues and to reduce tillage to the absolute minimum while exploiting the use of proper crop rotations and rational application of inputs (fertilizers and pesticides) to achieve a sustainable and profitable production strategy for a defined production system*." The FAO definition integrates residue management with cropping systems and production inputs and appears to best explain its successful adoption in many countries around the world. Conservation agriculture is more inclusive than conservation tillage, with zero tillage as its cornerstone. For our purposes, zero tillage and conservation agriculture will be used interchangeably in this discussion.

There are few countries where conservation agriculture is not practiced successfully by at least some farmers. Derpsch and Friedrich (2009) report that conservation agriculture is carried out on farms from 60º N latitude (e.g. Finland) to the Equator (e.g. Kenya, Uganda) to 40º S (e.g. Argentina, Chile), from sea level to 3000 m elevation (e.g. Bolivia, Colombia), and from extremely dry conditions (200 mm rain; e.g. western Australia) to extremely wet (e.g. 2000 mm in Brazil, 3000 mm in Chile). Conservation agriculture is applied on farms of all sizes, including small landholders (< 0.5 ha) and on soils that vary from 90% sand (e.g. Australia) to 80% clay (e.g Brazil's Oxisols and Alfisols) and in all crops, including root crops. The wide ranging conditions of climates, soils, and geographic conditions where conservation agriculture has been successfully implemented will ensure further interest and development of this technology.

Zero tillage is now estimated to be practiced on over 105 million hectares (M ha) worldwide, mostly in North and South America (Derpsch and Friedrich, 2009). South America leads with 47% of the world's zero till acreage followed by 38% in North America, 12% in Australia/New Zealand, and 2% in Asia. South America will continue to be the hot spot for future development, but Asia and Eastern Europe also have great potential.

South America

Brazil is a world leader in successful adoption of conservation agriculture. No-till was introduced to Brazil in the early 1970s, some 10 years after it was started in the U.S. Brazil now has 25.5 M ha under no-till, or 60% of its cropped acreage, compared to 26.6 M ha in the U.S. (Derpsch and Friedrich 2009). Brazilian farmers have pioneered the use of cover crops in no-till systems. No-till was relatively easy to apply when it was first introduced in the humid subtropical southern states where two crops a year can be harvested. However, when initiated in

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the arid cerrado regions where only one crop per year is possible no-till was only successfully adopted by planting a cover crop (e.g. *Brachiaria ruziziensis*) to provide surface residue during the six month dry season.

Brazil's no-till acreage will likely increase as the cerrado is one of the few places left in the world where cultivated acreage can be expanded. Brazil has over 100 M ha of pasture and rangeland in the cerrado region potentially suitable for field crops that has yet to be developed. A survey of leading agricultural scientists in Brazil suggested the following challenges and opportunities for future development of conservation agriculture in this country:

1) Adjustment in production systems. In many areas of Brazil, especially in the cerrado, conventional production systems result in loss or no accumulation of soil organic matter. Additions of crop residues from no-till production systems are necessary to build and maintain organic matter in these soil systems and are critical to soil quality and a more sustainable agriculture.
2) Development of new varieties and higher quality seed. It will be necessary to develop new varieties aiming to increase carbon input into the soil (e.g., plants with more lignin) and to permit seeding at different times of the year to allow the shortest possible period between harvest and planting. Low quality seed is a major limiting factor to further adoption of no-till. In soybean, lack of seed quality and introduction of diseases like fusarium and anthracnose is a significant concern.
3) Better extension of no-till information for farmers. Many problems in no-till come from inadequate management of the cropping system. Adequate technical assistance to farmers and training of labor on large farms is necessary for further widespread development of conservation agriculture.
4) Grassland rejuvenation and integrated crop/cattle production. Over 50 M ha of degraded grasslands in Brazil could be managed and improved with conservation agriculture, but federal input is necessary. In many areas integrating no-till crop production with cattle production on the same lands is fundamental.
5) Better equipment. No-till in many areas of Brazil is only possible with the use of green manure cover crops, crop rotation, and the maintenance of surface crop residues, which requires specialized equipment. New machinery will be needed to further advance no-till in some areas.

Argentina has been among the most successful countries adopting conservation agriculture. They have 19.7 M ha under zero-tillage, which represents about 70% of Argentina's total cropped area. Initial adoption of the technology was slow due to inexperience, lack of knowledge, seeding equipment, and limited herbicide availability. However, since 1990 acreage has steadily increased, largely due to the extension efforts of the Argentinean Association of No-till Farmers (AAPRESID) and research by the National Institute of Agricultural Technology (INTA).

Acreage of conservation tillage in Argentina appears to be leveling off at about 20 M ha. Future increase in no-till acreage depends on the opening of new agricultural land in the northeastern and northwestern regions of the country. Development of agriculture in these regions is currently under discussion because it would take place at the expense of native forest and savanna ecosystems. Another region of potential increase for no-till is the Southern Pampas, where adoption has been low compared to other areas of the Pampas mainly because of cold soils. The problems of seeding and crop establishment, because of residue accumulation on the soil surface due to slow residue decomposition rates under cool weather, continue to limit adoption.

Adoption of conservation agriculture in other Southern Cone countries has been quite high, so further expansion is not expected. No-tillage is the main soil management system for annual cropping in Paraguay. It has been adopted on an estimated 2.4 M ha, or 90% of their mechanized agriculture. Even small farmers have been adopting the technology with manual no-till on at least a part of their farms. About 70% of the grain production area of the Eastern Plains of Bolivia is under no-till; continuous soybean is the main no-till crop. However, it is believed the trend will continue as alternative crops such as corn, wheat, and sunflower replace soybean acreage. About 670,000 ha or 82% of the cropland in Uruguay are managed with zero-tillage. Conservation agriculture has not been adopted in Chile as in other Southern Cone countries. The main constraints are the low temperatures and management of the heavy residues produced in the wheat cropping systems.

Asia

Where farm size in North and South America is large, farms are very small, on average, in Asia. In addition to small land holdings, most farmers have no other employment. This means a life of poverty and struggle simply to feed one's family and survive with life's basic essentials. Conservation tillage practices have been studied and promoted in many areas of Asia. Conservation agriculture in China has developed relatively slow due to the small scale of agriculture (average farm size is less than 0.1 ha) and lack of proper equipment. While research and application of conservation agriculture dates back to the 1970s, more work has been done in Northwest China and other arid and/or rainfed cropping systems. There is 158.5 M ha of cropped area in China, of which 19% is in paddy. With an estimated area of 1.33 M ha in no-till (Derpsch and Friedrich 2009), this represents only 1% of non-paddy cropped area.

In South Asia, including the Indo-Gangetic Plains of Bangladesh, India, Nepal, and Pakistan, no-till is estimated to be practiced on about 5 M ha of wheat, double cropped with rice (Derpsch and Friedrich, 2009). However, no-till is not applied to the rice phase of the rotation. No-till has been successfully adopted in the wheat because tillage following the rice takes time and for each day planting is delayed beyond the optimum, wheat yields are reduced 1 to 1.5%.

In Asia the biggest issues with no-till management is farm size, equipment and crop residues:

1) Farms are small in most of Asia, with south Asia having the smallest holdings of 0.5 ha or less on average. These farmers grow 2 to 3 crops/year with often little time between the harvest of one and planting of the next. This rapid turn-around between crops makes handling of crop residues a challenge when working with animal power. This is the reality in most of south Asia. Poverty is also the norm for most south Asian farmers. An example from West Bengal in India showed that farmers in 2007, on 0.5 ha of land, growing two crops of rice and one crop of mustard, made a net income of about US$1.75/day.
2) Equipment options for no-till seeding are commonly found in Asia, for everything from one plant at a time to row planting using animal power. While this equipment exists, its availability and affordability is another issue. This is the reality for small farmers. A major aspect that needs to be addressed for growing area farmers is how to adapt larger implements to small tractors.

3) The removal of crop residues in many parts of Asia is a reality which is a major challenge to deal with. Work by CIMMYT showed clearly that residue retention in the field was critical to the successful implementation of conservation tillage benefits to the farmer (Sayre et al., 2001). People use residues for heating, livestock feed, and as income in most of these south Asian countries. Many landless poor in south Asia will actually harvest a crop for a farmer if they can have all the residues left in the field for their livestock — and this includes pulling out the stubble from the field. It is potentially a long way down the road for many south Asian countries, but increasing farm size is the main factor which will ultimately lead to fewer residues being used for alternative purposes and more residues being left on the land to build soil quality and support nutrient cycling.

China is well on the way to promoting no-till in the semi-arid and sub-humid regions, particularly where rice is not grown. The concept and equipment have been developed for small holders to use with small tractors. The issue in China remains residue management— their equipment is small and therefore not well suited to passing through heavy crop residues, so in many cases they remove some of the field residues. In other cases they remove all residues, leaving only anchored crop residues. The Chinese government is also promoting the renting of land, so that those who want to leave to work can do so, renting to those who want to stay and farm. This, of course, is the age old rural depopulation scenario which has played itself out in most of the northern hemisphere. Time will tell how far this trend will go, but we are very optimistic about this in that the good farmers stay behind to farm larger tracts of land, and in so doing raise the productivity in these countries. These larger farmers are also well equipped to implement many of the efficiency technologies which improve both yield and profitability.

India, Bangladesh, and Pakistan are very different from China, mainly due to the high unemployment rates keeping large numbers of people in rural areas. They really have nowhere to go for employment; lack of jobs, their lack of education, and lack of money make it difficult to be mobile. As a result, land continues to be subdivided in south Asian families and people struggle to grow enough crop to survive while selling some crops to generate minimal income. The barrier in these systems is the lack of currency — no one has any residual cash, be it for personal items or crop production inputs. All of the available currency is used to buy food and medicines when required. Simple no-till tools have been developed in many of these countries, and in most cases demonstrated to be effective in growing crops without tillage. However, the vast number of farmers, and grossly deficient extension systems, really mean that most farmers have no access to this new information. Surveys conducted in India show clearly that most farmers get their advice from neighbors and input suppliers, with extension agents coming in at a very low level (K. Majumdar, personal communication). The growth of input suppliers as part of the fertilizer industry, with university educated staff in the dealership, holds great promise in advancing technology directly to farmers. As has happened in North America, it will be industry which will become the principle agent of technology delivery in future agriculture.

Eastern Europe

The government estimates the Ukraine has 250,000 ha of conservation agriculture, but other estimates range from 30,000 to 1.1 M ha. Derpsch and Friedrich (2009) estimate 100,000 ha is in low disturbance no-till, with the balance under a high disturbance direct seeding system. In Russia, resource conservation agriculture comprises various combined technologies including minimum tillage and to a lesser extent, no-tillage (V. Nosov, personal communication).

Resource conservation technology was believed practiced on 35% of the sown acreage in Russia in 2008 and is expected to increase to 50% of sown acres in the next few years. According to various estimates there is about 2 M ha under no-till in Russia, which represents less than 3% of planted acres. The region Samara Oblast, located in the drought-prone Volga area, is regarded as the pioneer in the adoption of resource conservation technologies. Conservation agriculture in this region was used on 70% of cereals in 2007. It's worth noting that the production of machinery for minimum tillage operations started in Samara Oblast in 1998. Constraints to further adoption of conservation agriculture in Russia include inadequate use of fertilizer, low crop yields, and insufficient supporting research:

1) The use of mineral fertilizers and other agrochemical inputs is far from where it should be. Kazakov et al. (2005) reported that conservation tillage decreased grain yield of spring wheat by 12 to 14% if mineral fertilizers and other agrochemicals were not applied. This field experiment was conducted on a typical Chernozem in Samara Oblast (Volga region) where attainable grain yields of spring wheat range from 1.91 to 2.68 t/ha without irrigation. Low use of mineral fertilizers is considered a serious limitation for the successful development of conservation tillage technologies in Russia.
2) Without large scale adoption of modern agricultural technologies, crop yields in Russia are still low (the average grain yield of wheat was 2.02 t/ha during last the 5 years: 2004 to 2008). Hence, low levels of crop residues are left on the soil surface, reducing any potential benefit from conservation tillage practices. These problems often occur in drought affected areas (for instance, in the drought-prone Volga region).
3) No-till and minimum till technologies were not found to be appropriate on heavy textured Chernozem soils in some areas (Western Siberia, South Ural) in terms of excess soil moisture accumulation in spring. Non-uniform distribution of precipitation throughout the year, for example in Western Siberia, where significant amounts of precipitation occur in winter season, creates a need for autumn tillage on heavy textured soils (Kiryushin, 2006). Otherwise, the content of soil moisture may be negatively affected. Long-term field experiments conducted at the Siberian Research Institute of Agriculture in Omsk Oblast (Western Siberia) demonstrate that minimum till and no-till practices decrease productive moisture reserves in the 0 to 100 cm soil layer after snow melt by 18 to 25% (Khramtsov, 2008). Moreover, minimum tillage on slopes causes increased erosion of heavy textured soils.

Large farm size is going to be the dominant form of commercial agriculture in the former Soviet Union. We are not likely to see a resurgence of small farms in this region given the massive changes which have occurred in the society and economy. In our opinion, this is a potentially positive factor in that it will allow the operators of larger land holdings to implement new technologies, including conservation agriculture.

Concluding Comments

In many instances, the greatest barrier to adoption of conservation tillage technology by farmers is the mindset developed regarding the role of excessive tillage in their farming system (Hobbs et al., 2000). In addition, the attitude and buy-in by extension workers can often help overcome some of the challenges with adoption by farmers. As has been the case in the developed world, innovative approaches to scaling up research trials to the farm level, and involving the participation of farmers and extension advisers, is critical to adoption. Once the technology has been demonstrated and adapted to local conditions, the development of economical conservation tillage seeding equipment that will allow the effective establishment of crops in fields with residue mulch cover becomes a necessity.

Sustainable cropping systems are dependent on high yielding cultivars that will provide adequate crop residues for both conservation goals as well as alternative fodder, fuel, and construction uses. This is of particular importance in regions where crop biomass residue has traditionally sustained livestock feed and home cooking/heating requirements. Innovative approaches to cultivar selection for crop height, methods of partial residue removal, and management of remaining residue mulch cover are required. As always, once the benefits of maintaining residue cover on crop yield are demonstrated, farmer innovation will result in strategies to achieve a balance in residue use between the household and cropping systems.

It is clear from our review of conservation agriculture in many parts of the developing world that adoption and implementation is largely a function of farm size and the demand for crop residues for alternative uses or income. Where you have large farms established, or being developed, we can see that conservation tillage crop production is the only economic and sustainable management system to adopt. Excellent examples of this are South America and the former Eastern Bloc countries. However, where farm size is very small, crop residues are in demand for alternative household and economic value, and poverty and poor education is endemic amongst the rural population, the process of adoption for conservation tillage will be a struggle. The best example of this is south Asia. China likely holds the greatest potential at this time for an increase in conservation tillage adoption, coming in tandem with increasing farm size.

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