# Conservation Tillage: A Viable Option for Sustainable Agriculture in Eurasia

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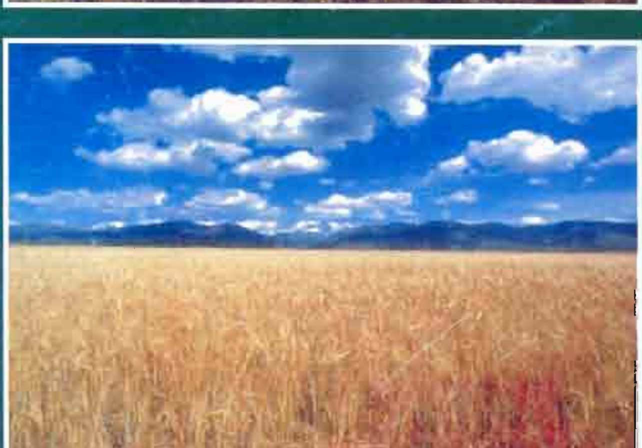

# Conservation Tillage: A Viable Option for Sustainable Agriculture in Eurasia

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Food and Agriculture Organization of the United Nations (FAO)

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International Center of Agricultural Research in Dry Areas (ICARDA)

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# TABLE OF CONTENTS

# ACKNOWLEDGEMENTS

The idea for a meeting on conservation tillage in Eurasia originated between FAO, CIMMYT and ICARDA to jointly sponsor and organize the workshop with the assistance of the Baraev Kazakh Institute of Grain Farming. As with most efforts like this, many other institutions were involved.

Alexei Morgounov, CIMMYT; M.K. Suleimenov, ICARDA; Josй Benites and Theodor Friedrich, FAO; and A. Kurishbaev, Director KGPRI were instrumental in providing direction, support and technical opinion. Also valuable was the work done by colleagues from United States and Canada and a wide array of technical officers in several national and international institutions, whom contributed much technical perspective on the subject. Many had been working directly or indirectly with conservation tillage for some time but had not had the opportunity to meet.

The convening parties express their gratitude to all participants who worked hard during the entire workshop and committed themselves to further promote conservation tillage in their respective home countries.

# FOREWORD

Land degradation and soil fertility deterioration are two of the main causes of agricultural production stagnation and decline in the Eurasian Region. The situation is serious and to maintain economic development, Eurasian countries cannot afford further destruction of their natural agricultural resource base. Clear policy decisions and concerted actions are required to introduce sustainable and productive land husbandry practices in the shortest time possible.

Tillage practices which invert the soil using heavy machinery with high ground pressures, and agricultural practices that neglect to supply sufficient organic material to the soil can result in soil erosion and the loss of soil fertility and organic matter. It is estimated that intensive tillage practices in Eurasia have reduced soil fertility by as much as 50%. An estimated 327 million ha of land in Eurasia have been severely affected by wind and water erosion, causing further problems for agricultural production.

Approximately 170 million ha of land have been affected by soil compaction, often caused by inflexible procedures which demand tilling and plowing during wet periods. Ineffective machinery often requires several passes to prepare the seedbed. Estimated production losses resulting from soil compaction differ. Conservative estimates calculate a production loss of 15 million tons of grain, two million tons of sugar beet and 500,000 tons of maize. Others calculate a 16-27% decrease in production as a result of soil compaction, with a loss of 50 million tons of grain production alone.

Much of the agricultural machinery in Eurasia is obsolete or in a state of disrepair and replacing it with conventional technology would require heavy investment. However, replacing this machinery with conservation tillage equipment would be considerably cheaper and would help to improve agricultural production and sustainability.

Conservation tillage is an umbrella term which looks beyond *soil preparation* in the narrow sense. Its focus is on the broader concept of *Conservation Agriculture*, since this embraces not only seedbed preparation, but also the nutrient content of soils and their structure and biological status. Such factors are important determinants of agricultural productivity as a result of farm management and land husbandry practices.

A recent World Bank paper highlighted constraints, opportunities and elements of conservation tillage strategies. Nevertheless, work is needed for the elaboration and implementation of conservation tillage practices. Importantly, a clear policy statement is required to direct all available efforts toward development and adoption of conservation agricultural systems. This involves not only research and extension but also an active involvement of farmers, farmers' organizations, the commercial input supply sector and, last but not least, the international donor community. Efforts to rehabilitate agriculture in the Eurasian region have so far been uncoordinated, some of them even promoting unsustainable, although 'modern', tillage practices which result in the inefficient use of invested resources. In view of the magnitude of the problem, it is doubtful whether the region can afford this diversity of approaches.

Other key areas requiring close examination are the differing levels of conservation tillage practiced within Eurasian countries, and long-term needs when viewed against short-term problems (e.g. machinery supply).

# INTRODUCTION

## Scope and Focus of the Workshop

Focussing on this situation a workshop on conservation tillage as viable option for sustainable agriculture in Eurasia has been jointly organized and carried out by the A.I. Baraev Kazakh Research Institute for Grain Farming in Shortandy, CIMMYT, FAO and ICARDA.

The workshop was part of a process to develop and implement conservation tillage national action plans in selected Eurasian countries (Armenia, Azerbaijan, Georgia, Belarus, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan). The workshop intended to bring together national stakeholders as well as potential conservation tillage experts from similar agro-ecosystems, especially from North America, donor countries and organizations, and agricultural research centers from various Eurasian Countries engaged in conservation tillage in order to identify needs, gaps and roles of partners and donors in the elaboration national conservation tillage action plans. Institutions from other countries interested in the workshop are also welcome to participate.

The Workshop had the following objectives:

- Review successes and success factors, share national, regional and world-wide experiences; discuss lessons learned in promoting and supporting farmers' improvement of land productivity; and review and improve on processes leading to expanded national actions supporting the conservation tillage, for the predominant agricultural production systems in Eurasia;
- Strengthen and broaden partnership mechanisms supporting the implementation of the action plans and the exchange of experiences with on-going programs and activities among countries within Eurasia, with other regions and with donors and conservation tillage partners;
- Identify principles and approaches leading to policy, social, economic and institutional improvements facilitating the dissemination and adaptation of the conservation tillage leading to sustainable agriculture.

The workshop objective where met producing following outputs:

- Common perspective and understanding of conservation tillage
- Clear definition of roles (nationals, donors, international conservation tillage experts): who is doing what, when and where
- Methods of conservation tillage developed or used by countries
- Networking and partnership for conservation tillage co-ordination

The workshop was attended by senior representatives from each participating country, by representatives from donor countries, international experts, representatives from commercial companies and from international conservation tillage institutions. The workshop developed in sessions with presentations of papers about soil management problems and solutions. In separate workgroup sessions the information presented in the papers was then analyzed, problems, strategies and action plans developed.

**Workshop Results - Summary**

The workshop consisted of three major components: one part in which experiences and concepts of conservation agriculture from other parts of the world were presented and brought into relation to the situation in the participating Eurasian Countries, one part in which soil science research papers from the region were presented and a workshop component, in which the participants were split up into three workgroups to discuss the key problems related to soil conservation and suggest solutions. The details of the workgroup results are listed in Annex I.

## 1. Recommendation and Conclusions

**Constraints**:

A great deal of research has been carried out in Eurasian region of the former Soviet Union on conservation farming. In the 1980s elements of conservation farming, namely utilization of conservation tillage machinery were adopted on 60 million ha in Russia, Kazakhstan, Ukraine, and other parts of the former Soviet Union. Recent development, however, resulting form the improved conservation practices, such as no till, widely adopted in many countries of the world. The reasons of these are as follows:

- The transition period to market oriented economy has not been completed and a true private sector has not been established. Farming became unprofitable in most countries hindering an adoption of new technologies.
- Lack of understanding about no-till concept of farming
- Lack of awareness of public and government about advantages of conservation tillage
- Lack of policies to support successful farming
- Lack of proper machinery and chemicals to implement conservation tillage practices
- Extension and consulting services are not in place
- Real free market activities are not established
- Contact with other parts of the world is explored on conservation tillage
- There is a lack of data base

**Strategies and Activities**

- Improve government policies that helps agricultural producers such as:
  -Ensuring better prices for the agricultural products
  -Promoting the establishment of private sector (agri-business)
  -Security for foreign and internal investment in agriculture
  -Removing import taxes on agricultural inputs
- Conduct experiment on-farm conservation tillage (including zero tillage) in different eco-regions of the Eurasian countries to identify the cost effective technological options that enhance the productivity
- Educating public and government about advantages of conservation tillage
- Establish the Eurasian co-ordination center for conservation tillage techniques
- Provide advisory services to government to formulate a policy regarding the privatization of land for more market oriented agriculture

- Establish conservation tillage technology network in the region, identify contact person from each country for the network, and elect an institution to co-ordinate the network
- Promote the creation of *Framers Group* on conservation tillage
- Promote establishment of the government and private extension and consultancy services

## 2. Establishment of a network

The participants (total 46 participants) have elected the Kazakh Grain Farming Institute in Shortandy and asked Dr. Kurishbayev, The Director of the Institute to act focal point for ***No-Till Technology** network for **Eurasia**.* Dr. Kurishbayev was asked to arrange appointments of the contact persons from each country.

## 3. Place of the next meeting

Following a proposal and discussions, the participants agreed on the next workshop to take place in Altay , near Barnaul, Asian part of the Russian Federation in July 1999 and Mr. Jens von Bargen (GTZ) would be the local coordinator.

Mr. John Gehrer and Mrs. Angelika Gehrer from, Manitoba, Canada have agreed to prepare a Newsletter. Interested participants are expected to provide short information about their works related to conservation tillage to support the regional network

## 4. Other items for discussions

Great potential exist in the region. External consultancy and support are needed to develop market oriented sustainable agriculture in Eurasia.


Map 1.  Central Asia and the Caucasus  (Source:  www.graphicmaps.com)


Map 2. Kazakhstan (Source: www.graphicmaps.com)

# CURRENT STATUS AND MEASURES TO OVERCOME THE CRISIS IN THE KAZAKH AGRICULTURE SECTOR

**Azimkhan Satybaldin[1], Tolkyn Dzhunisbekova[2] and A. Bektayev**

Large-scale changes have occurred in Kazakhstan's agricultural sector during the past decade. Political, economic and social aspects of these changes have been pervasive. The transformation of previously state owned property into privately owned or privately managed (i.e., state-owned land managed with the privately supplied inputs and privately controlled outputs) and the establishment of a legal framework for the market economy constituted the political outcome of these reforms. The economic outcomes of the reforms embraced property privatization and change in the system of land management; liberalization of market pricing and monetary lending systems; establishment of a competitive infrastructure for the marketing of agricultural products and inputs; and, reconstruction of the national institutional establishment. In the social aspect, the ideology of the reform relieved the rural population of governmental paternalism and relieved the state from individual financial security and responsibility.

These reforms were implemented in order to create secure competitive producers capable of supplying food and agricultural raw materials to the country, as well as to improve the social status of the rural population. However, after several years of reformation, this objective has yet to be fully realized. On the contrary, agricultural production has plummeted, and rural standards of living and life expectancy have deteriorated.

By 1994, gross agricultural product had reduced by 2.4 times. National per capita consumption constricted for meat and meat products (-41%), milk and diary products (-33%), eggs (-65%), vegetables and melons (-17%), and fish and fishery products (-60%). The affect these reductions will have on physiological and nutritional need and psychological desire are yet to be seen, however, demographically birth rate per 1000 people has declined by 32%, death rate has increased by 36% and natural population growth has decreased by 3 times. Contrary to these reductions, national per capita consumption of cereal and bread products has increased two-fold. Disparity in rural per capita income is 2.3 times lower versus urban wages.

## Causes of Decline in National Agricultural Production

The acreage of arable crop land under cultivation is being reduced due to the lack of seed, inputs, fuel and lubricants and machinery. Farmers with fields favored with irrigation are experiencing higher costs for water and energy, as well as due to deterioration of soil properties . Many low fertility soils continue to be cultivated with crops which may not be suitable for the specific agro-landscape conditions, or the economic potential returns to investment required for immediate and longer-term sustainability and profitability.

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The reduced productivity is further exasperated by a failure to implement recommended regional crop production technologies due to lack or excessive cost of required inputs, improperly implemented technological procedures due to limited or obsolete farm machinery, poorly compensated professional farmers, or inexperienced new land owners. In addition, recommendations in production technology may need to be reassessed, re-evaluated or developed anew given the input/output limitations farmers currently face.

There is currently no reliable system to organize and supervise seed production, and product end-user quality and market demand. In 1998 seed of "unknown origin" was used on 20%, and "uncertified" seed was sown on a further 25% of land planted to cereals. Currently, the only formal link in the national seed production system is the production of elite seed by national agricultural scientific institute experimental farms, and the necessary systematic production of improved seed exists only on paper.

Rural unemployment has increased, as agricultural production and processing ability has decreased. The disruption of the rural social infrastructure has exasperated migration, particularly of youth, from the countryside and remote regions, to cities. Disrupted production and processing capacity has led to economies of scale which do not effectively compete with imported food products.

**National Agricultural Potential**

The natural and demographic potential of agriculture in Kazakhstan is high. In early 1999, 4.25% of the population of Kazakhstan was involved in agricultural production, though nearly 45% of the population live in rural areas. The variety and potential of soil and climatic zones, the genetic potential of crop varieties and animal breeds has provided an opportunity for successful development of the national agricultural sector. Mechanical tractor capacity will allow 16 million ha of land to be tilled, while combine harvesters are available to harvest approximately 8 million ha.

The Kazakh Scientific Research Institute of Agricultural Sector Economics and Organization has estimated that to achieve agricultural self-sufficiency, Kazakhstan will require an annual production of: 1.15 million tons of grain, 1.9 million tons of potatoes, 1.4 million tons of vegetables and melons, 160 thousand tons of vegetable oil, 1.0 million tons of meat, 5.8 million tons of milk and dairy products, 150 thousand tons of fish, and 3.7 billion eggs.

**Prerequisites and Objectives of Agricultural Policy Adjustment**

Policies promoting revival of the agricultural sector should be comprehensive, addressing the needs of all the areas of agriculture and all the regions of the Republic, and should emphasize economic, technical and organization improvement. Development of new state agricultural policy should encompass the following provisions: 1) Pricing of agricultural products will always be limited by purchasing power; 2) the Ministry of Agriculture should be consulted when planning and implementing tax and credit systems; 3) private ownership needs to be accompanied by a range of economic regulations which foster profitability by producers, suppliers, processors and consumers.

## Measures Required to Stabilize Crop Production

The grain sector is the backbone of Kazakh agro-business and grain has become an important strategic resource for the country. In order to organize grain production, storage, transportation and marketing, long-term governmental vision, policy and programs are required to regulate and stabilize the production and marketing environment and the relations between the various partners and stakeholders. The program should allow governmental interventions when necessary (e.g., export-import regulation, quality standards for grain and processed products, certification of grain businesses and measures, statistical collection and reporting, etc.), lending and credit facilities for program participants, fostering establishment of an effective market infrastructure and support to grain commodity research organizations.

The following actions are required to strengthen existing, and promote a more efficient national grain production strategy in Kazakhstan:

- An inventory and classification of actual and potential agricultural landscapes in the country is essential to plan and organize proper land use and conservation;
- Expand of acreage, and diversification of crops grown under intensive, irrigated conditions; Investigation of landscape and socio-economic specific cultivation and production technologies;
- Fostering national nitrogen and mineral fertilizer production industries;
- Organization of large-scale seed production involving private industry and farmer certified seed production schemes;
- Subsidization of input costs incurred for extra-ordinary use of fertilizers, herbicides, lubricants or replacement of agricultural machinery;
- Amortization mechanisms for long-term payment of water consumption recognizing immediate investments required for intensive production establishment and diversification;
- Retain of state ownership for large-scale water management systems;
- Expansion in the capacity of national strategic grain reserves up to 2 million tons.

It will also be necessary to change the attitude of policy makers, industry leaders and farmers towards effective technological policy. It is necessary to diversify production options available to traditional grain farmers and to expand oilseeds production, processing and marketing options: sunflower in Pavlodar and Kostanai oblasts, rape in the North Kazakhstan and Kostanai oblasts, mustard in Akmola and Kostanai oblasts, millet and buckwheat in Pavlodar, Kostanai and Akmola oblasts, winter rye in the foothills and forest-steppes of Akmola, Kostanai and North Kazakhstan oblasts.

In the transition to effective private enterprise farms, rationalization of farm size to commodities produced is essential (e.g., grains, oilseeds, sugar beet and cotton production is more profitable recognizing larger economies of scale, while production of potatoes, vegetables, fruits, berries, melons is more appropriate by smaller farms or household plots.

## Measures Required to Stabilize Livestock Production

In order to meet the demand of the population in animal products, it is necessary to increase livestock productivity through use of superior breeding livestock and better use of available feed stuffs and improved pastures. Livestock production development should concentrate on target farms situated in suitable zones. For example, large ruminant rearing operations could be situated where extensive pastures are available, whereas dairy or poultry farms would be situated closer to urban centers where food processing facilities and labor are available and market demand is higher.

In the future pork and poultry production should be developed on the industrial basis. Sheep, goat, horse and camel production should be developed through maximum utilization of natural pastures. In order to stimulate the production of animal products it is necessary:

- to provide affordable, long-term loans;
- to established guaranteed, equitable state supported purchase quotas;
- to establish effective veterinary services;
- to provide extension services which promote improved animal production and marketing practices.

### Funding, Lending and Pricing Policies

Currently the state provides financial support for seed and breeding stock production, plant protection chemicals and fertilizer purchase. In practice, however, this support is untimely, extremely limited and inappropriate for the current requirements and needs of farmers. As of early 1999, national agricultural debt amounted to 127.7 billion tenge, with little possibility for repayment. The measures required to secure profitable agriculture include:

- Prioritization of agricultural sectors and commodities in terms of investment requirements and returns;
- Establishment of government target programs and bench mark guaranteed prices ensuring producer subsistence. The first programs of this kind may target: "Grains", "Sheep Production", "Milk" and "Irrigated Areas". It will not be possible to engage all spheres of the agricultural sector within the framework of these programs, however prioritized commodities and their production, processing and storage industries should benefit and act as a spring board for independent development beyond the mandate of these programs;
- The marketing of agricultural products through formal commodity exchanges, auctions and wholesale markets will allow transparent and fare compensation, and facilitate levy or tax collection by governmental fiscal agencies;
- Indirect subsidization for purchase of scarce products (for example agricultural machinery) through application of lower tax rates should be used to foster investment in production and processing industries;
- Establishment of specialized agro-business banks and mortgage corporations is required to allow farmers and processors to gain more control over their investment and operations decision making;
- Provision of export incentives for agricultural products.

### Policy Related to Different Types of Agribusiness Enterprises

The current multi-structured rural economy has evolved as a result of collective and state farm restructuring and is represented by:

- the large corporate farms, agricultural production cooperatives, management partnerships or joint stock companies;
- middle-size, small farms or small cooperatives;
- household farms;
- state-owned enterprises.

Each producer level should benefit from government policies to ensure economic and social equity.

**Foreign Trade**

Considering the specific nature of our domestic production and marketing capacity, and given the state of transition, flux or uncertainty farmers or entrepenuers are experiencing, it is necessary to:

- Protect domestic production against imported product dumping which artificially destabilizes domestic prices. Such rules will not be applied to products that are not manufactured in the country or which are manufactured in small quantities;
- Protect domestic market against products manufactured or exported with subsidy support through compensatory fees payable in case there is any damage inflicted upon domestic production;
- Introduce a system of privileges (tariffs, tax rates, etc.) for the producers who sell high quality products to the foreign markets;
- Monitor the world commodity markets;
- Promote enhanced development of the joint agricultural market for the CIS countries.

# IMPACT OF MANAGEMENT SYSTEMS ON CROP PRODUCTION IN THE EURASIAN STEPPES OF KAZAKHSTAN

**Ahmet R. Mermut**[1]

As in the North America, large areas of the virgin and marginal steppes of Eurasia were converted to cropland after World War II. While semi-desert and desert landscapes occupy a large area of Eurasia, Black soils (Chernozems or Mollisols) rich in organic matter and naturally fertile are common in the Boreal Steppe ("Prairies" in the North American context). The continental divide transecting Kazakhstan and extending into the Russian Federation experiences somewhat higher precipitation. Southern zones are drier, desertic and form a closed basin, whereas the northern rivers flow to Arctic Ocean.

The objective of this paper is to analyze the impact of crop management techniques on soil resources and crop production, focusing specific reference to grain production in Kazakhstan, hopefully will set a stage for discussions during this workshop.

## Soils and Climate

Major soils of the Eurasian steppes are known as Black soils, Chrenozems, or Mollisols (USDA, 1999) and commonly occur throughout Ukraine, Russia, and Kazakhstan. As in the North American Prairies, these soils developed under grass ecologies though arboreal ecosystems may have occurred in the distant past. In addition to North America and Eurasia, Black soils are extensive in Europe and South America. They are derived from mainly carbonate rich parental foundations, have thick black topsoil horizons with a pH of approximately 7 and high base saturation. They are rich in organic matter and nutrients, and can support good crop production. These soils lie generally between arid region Aridisols and more humid climate Spodosols or Alfisols.

The area covered by Black soils in the Eurasian Steppes is approximately 90 million ha. About half of this area, 42 million ha, were virgin land cultivated between 1954 and 1964; 25 million ha in Kazakhstan alone (Gossen, 1998). The area of arable land in North Asia east of the Ural Mountains (Nachtergeale, pers. comm.) exceeds 175 million hectares with only 61% of this total cultivated. Limited moisture availability constrains expansion of agriculture. Canada has 68 million ha of arable land, with approximately 33 million ha devoted to annual crop production. With nearly 293,000 farms nationwide, the average farm size in Saskatchewan is about 450 ha.

Climatic conditions in North America are similar to those in the Eurasian Steppes. Cold semi-arid regions of the Northern Great Plains receive about 350-400 mm precipitation per annum, analogous environments to those in the Eurasian Steppes. Precipitation in Saskatchewan varies from 250-450 mm per year, with an annual frost-free growing season of 100-120 days (Cameron and Oram, 1995).

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Northern Kazakhstan receives an annual average precipitation of approximately 300mm. In Shortandy, annual precipitation is approximately 350 mm (Souleimenov, 1992), close to the average received in the Canadian Prairies. Precipitation decreases in the central and southern arid and desert zones, and increases in the eastern and southeast mountain regions (Figure 1; Gossen, 1998). Figure 2 illustrates the average monthly precipitation and temperature averaged across five locations in Kazakhstan (Longmire and Moldashev, 1998). This pattern is also similar to the Northern Great Plains of North America, specifically Saskatchewan.

**Recent Cultivation History and Management Technologies Used**

Cropping pattern and yield in Kazakhstan has changed dramatically since 1946. While average realized grain yield reached 1 t $ha^{-1}$ between 1986-1990, it has declined to about 0.65 t $ha^{-1}$ in 1994-1996. Implementation of comprehensive production strategies developed at the Baraev Kazakh Research Institute of Grain Farming played a key role with the relatively higher yields observed. Close contact and cooperation has existed between the Baraev Institute, and Canadian research institutions enabling sharing of research experiences and transfer of technologies between these core research centers.

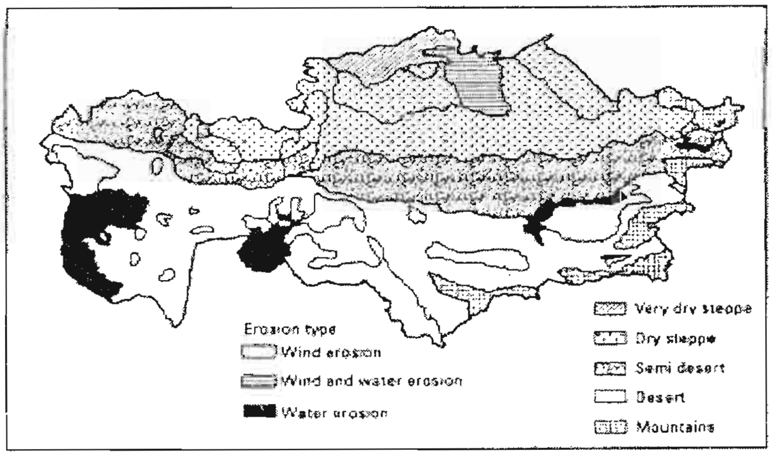
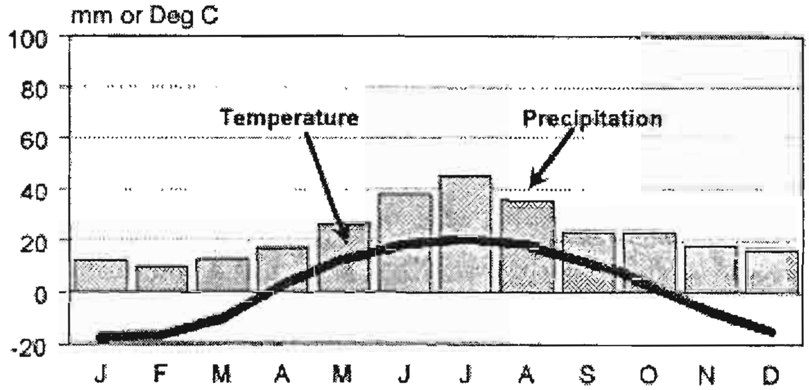



**Figure 1. Main ecological zones in Kazakhstan (from Gossen, 1998).**

Gossen (1998) has provided an interesting historical review of agricultural cultivation and grain production practices in Kazakhstan, and past successes should be used as a basis when setting new strategies for sustainable agricultural development in Kazakhstan. Table 1 presents the total land area cultivated, grain production and yield by important historical period during the past 50 years. Period I represents the initial state of virgin land grain farming. The Period II represents expansion of development of virgin and marginal lands. In this period, the realized yield per ha was higher (0.70 t $ha^{-1}$), however lower than the expected potential of the land. Souleimenov (1992) attributed this to the use of a single type of farming system. Realized yield potential was highest during Phase III due to the application of fertilizers and plant protection agro-chemicals, and because of application of soil conservation measures and crop rotations (1.0 t $ha^{-1}$). Period IV was marked with dramatic reduction in the use of fertilizers and herbicides. Considering the extent of dryland areas (Figure 1), the national should be able to produce in excess of 20 million t of grain per year. These production levels would strengthen Kazakhstan's position and leverage as a world grain producer. Sustainable increases in crop production will support the country's general, overall economic development. Marginal lands should be returned to native pastures, encouraging diversification of the rural agricultural economy through the inclusion of livestock production and enhanced biodiversity, as has been practiced during the past 20 years in Canada.




**Note: Total annual precipitation is 277mm. Mean annual temperature is 1.6 degrees C. Locations are Astana, Kostanai, Aktobe, Pavlodar, Petropavlovsk**

**Figure 2. Average monthly precipitation and temperature of five selected locations in Northern Kazakhstan (Longmire and Moldashew, 1998).**

### Impact of Management Systems on Soil Quality

> The FAO statistics show that there is a direct correlation between the population density land degradation in developing countries. A positive aspect that one may think is the density of population in the Eurasian steppes, but overgrazing can be an import factor. It is not the population density, but the percent of population that makes living on agriculture important. Percent of population on agriculture in developing countries is much higher than those of the developed

Farmers can attest to observations made my researchers worldwide, that soil fertility and organic matter is declining due to long term use of conventional crop management techniques (Putterbaugh, 1993; Acton and Gregorich, 1995). The loss of soil fertility and organic matter are the two major factors that cause the reduction of soil quality, and affect agricultural sustainability. Commercial fertilizers can be applied to correct the soil fertility, but this will not directly influence soil organic matter content. Loss of organic matter will increase erosion due to a spiraling decline in soil fertility, soil quality and the capacity to sustain healthy plant growth. Low fertility will produce less biomass, contributing faster decomposition of soil organic matter.

> There is a strong need to establish the current stage of soil quality, especially levels of soil organic matter and fertility in comparison with virgin lands so that a sound strategy can be developed for sustainable crop production in Kazakhstan.

Use of heavy machinery has increased the wide spread occurrence soil compaction, contributing further to the decline of soil quality. The estimates of economic losses due to compaction for the Eurasian Steppes differ, but are certain to be significant (Nazarenko, 1993; Liber, 1995). In light textured soils, the loss of organic matter also accelerates surface crusting, which reduces stand establishment, and in some cases, results in a total loss of the crop. Deterioration of soil structure, aggregate stability, and loss of porosity are other parameters of soil quality loss. Diminished soil biodiversity is another component of soil degradation processes.

Retention and improvement in soil organic matter content is essential to combat soil degradation. New land use management technologies and practices have been developed which reduce soil quality degradation and increase soil organic matter. Figure 3 indicates the influence of two of these new management technologies currently widely used by farmers in the Canadian Prairies.

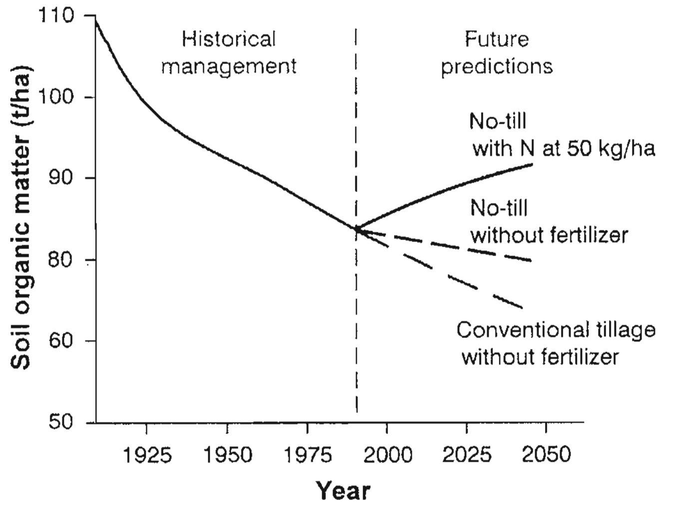



**Figure 3. Soil organic matter levels under three management practices in the Canadian Prairies (unmeasured values were computer predicted).**

Conservation farming practices that encourage organic matter retention and accumulation in Canada are summarized below (Acton and Gregorich, 1995):

- Use of permanent crop covers;
- Use of crops or pasture species which contribute large amounts of organic matter to the soil (e.g., through larger fibrous root architectures);
- Addition of manure and other organic amendments to the soil, and;
- Use of fertilizers to enable high crop biomass production.

Conservation tillage plays a significant role as part of the mitigation technology to restore the soil quality and productivity for sustainable land use.

## Major Area of Research in the semi-arid regions in Kazakhstan

Major areas of soil conservation research suitable for the semi-arid regions of Kazakhstan (Souleimenov, 1992) include; Drought control, wind erosion, management of soil fertility, weed control, water erosion and amelioration of salt affected soils. Souleimenov (1992) further states that the principle factor limiting stable crop production is insufficient moisture.

## CONCLUSIONS

Research addressing conservation tillage has not received enough attention in the Eurasian Steppes. To fill this gap, recent efforts by the Baraev Kazakh Research Institute of Grain Farming (through support of FAO, CIMMYT and ICARDA) are very timely and have focused appropriate attention on conservation tillage suitable for conditions in Kazakhstan. A common perspective and understanding of conservation tillage is germane for the success of the crop production, specifically in arid and semi-arid regions of the world. To improve efficiency and achieve profitability in agriculture in Eurasia, conservation tillage farming systems, such as those developed in North America, can serve as an alternative to existing available technologies. Great potential exist for increasing agricultural production in the Eurasian Steppes in a sustainable and economical manner, however research addressing constraints experienced by farmers' today is required to ensure production tomorrow.

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**Table 1. Cultivated area, yields, and totals crop production in Kazakhstan, 1946 –1996.**

| Period | Cultivated Area (million ha) | Yield (t/ha) | Grain Production (million t) |
|---|---|---|---|
| **I. 1946-1954** | **7.0** | **0.56** | **3.9** |
| **II. 1954-1964** | **24.6** | **0.70** | **17.2** |
| **III. 1964-1994** | **23.9** | **0.95** | **22.8** |
| **IV. 1994-1996** | **18.3** | **0.65** | **12.4** |

# CONCEPTS AND STRATEGIES OF CONSERVATION TILLAGE

**Donald C. Reicosky**[1]

Agriculture, the major industry for food and fiber production, is known to cause emission and storage of greenhouse gases. Intensification of agricultural production is an important factor influencing greenhouse gas emission. More than 97% of the world's food supply is produced on land that emits greenhouse gases when intensively tilled and fertilized or grazed to support animal production (Lal *et al.*, 1998). While agriculture is generally thought of as a minor source of greenhouse gases, increasing world population dictates the challenge of increased agricultural production without increasing the risks of greenhouse gas emissions and possible environmental consequences. This review will focus on the role of agriculture as a means of sequestering soil carbon (C) to minimize possible environmental consequences associated with intensive agriculture and will address elevated soil C loss as caused by intensive tillage. Thus producers, scientists and planners are faced with the challenge to increase agricultural production without accentuating the risks of greenhouse gas emissions and their impact on environmental quality. Other recent reviews on the greenhouse gas emissions are presented by CAST (1992), Enquete Commission (1995), Paul *et al.* (1997), Paustian *et al.* (1997a,b), Lal (1997), Lal *et al.* (1998) and Rosenzweig and Hillel (1998).

Energy is required for all agricultural operations. Modern, intensive agriculture requires much more energy input than traditional farming methods since it relies on the use of fossil fuels for tillage, transportation, grain drying, and the manufacture of fertilizers, pesticides, and equipment used as agricultural inputs, and for generating electricity used on farms (Frye, 1984). Tillage and harvest operations account for the greatest proportion of fuel consumption within intensive agricultural systems. Frye (1984) found fuel requirements using no-till or reduced tillage systems were 55 and 78%, respectively, of that used for conventional systems that included moldboard plowing. On an area basis, savings of 23 kg C $ha^{-1}$ $yr^{-1}$ in energy costs resulted from the conversion of conventional till to no-till. For the 186 million ha of cropland in the US, this translates to a potential C savings of 4.3 MMTCE (million metric tons C equivalent) $yr^{-1}$. Kern and Johnson (1993) calculated that conversion of 76% of the cropland planted in the US to conservation tillage could sequester as much as 286 to 468 MMTCE over 30 years and concluded that US agriculture could become a net sink for C. Lal (1997) provided a global estimate for C sequestration from conversion of conventional to conservation tillage that was as high as 4,900 MMTCE by 2020. Combining economics of fuel cost reductions and environmental benefits of conversion to conservation tillage is a positive first step for agriculture toward decreasing C emissions into the atmosphere.

Agriculture is believed to cause environmental problems, especially related to water contamination, soil erosion, and greenhouse effect (Houghton *et al.*, 1983; Schlesinger *et al.*, 1985). Recent results suggest scientific agriculture can also be a solution to environmental issues in general and to mitigating the greenhouse effect in particular. In fact, agricultural practices have the potential to sequester more C in the soil than farming emits through land use and fossil fuel combustion (Lal *et al.*, 1998). This understanding of agricultural production systems leads to the effectiveness and efficiency of agricultural practices in

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sequestering soil C that must be considered in evaluating agriculture's sustainability. Thus sustainable agricultural systems involve soil, crop and water management techniques that increase production while enhancing soil C sequestration in the soil through the improved management of crop residue, conservation tillage, nutrient management, precision farming, water management and restoration of degraded soils. One practice that combines many of the above factors is direct seeding with limited soil disturbance during the planting operation that provides a multitude of environmental benefits.

Soil organic matter or C is the critical component associated with agro-system productivity. Long-term data records indicate that intensive cultivation and tillage usually causes a decrease in soil organic C content (Paul *et al.*, 1997; Odel *et al.*, 1984; Peck, 1989; Wagner, 1981, 1989; and Paustian *et al.*, 1997a,b). No tillage or direct seeding has been proposed as an alternative to conventional cropping systems for reducing soil degradation and minimizing soil erosion. Direct seeding generally leads to a soil C increase in the top 5-10 cm of the soil profile relative to moldboard plowed soils.

Recent studies involving a dynamic chamber, various tillage methods and associated incorporation of residue in the field indicated major C losses immediately following tillage (Reicosky and Lindstrom, 1993). The short-term impact of moldboard plow and various tillage methods on $CO_2$ loss from the soil was measured using a portable dynamic chamber designed to measure canopy photosynthesis and mounted on the front end of a 4-wheel drive forklift for portability. Reicosky and Lindstrom (1993) found that the moldboard plow had the roughest soil surface, the highest initial $CO_2$ flux and maintained the highest flux throughout the 19-day study. High initial $CO_2$ fluxes were more related to the depth of soil disturbance that resulted in a rougher surface and larger voids than to residue incorporation. Lower $CO_2$ fluxes were caused by tillage associated with low soil disturbance and small voids with no-till having the least amount of $CO_2$ loss during 19 days. Similarly, Ellert and Janzen (1999) used a single pass with a heavy-duty cultivator that was relatively shallow and a small dynamic chamber to show that fluxes from 0.6 hours after tillage were 2 to 4 fold above the pre-tillage values and rapidly declined within 24 hours of cultivation. They concluded that short-term influence on tillage and soil C loss was small under semi-arid conditions in agreement with Roberts and Chan (1990) and Franzluebers *et al.* (1995a,b). On the other hand, Reicosky and Lindstrom (1993) concluded that intensive tillage methods, especially moldboard plowing to 0.25 m deep, affected this initial soil to flux differently and suggest improved soil management techniques can minimize agricultural impact on global $CO_2$ increase.

The literature holds considerable evidence that intensive tillage decreases soil C and supports increased adoption of new and improved forms of conservation tillage or direct seeding to preserve or increase soil organic matter (Lal *et al.*, 1998; Paul *et al.*, 1997; and Reicosky *et al.*, 1995). Based on the soil C losses with intensive agriculture, reversing the decreasing soil C trend with less tillage intensity should be beneficial to agriculture and the global population by gaining better control of the global C balance (Houghton *et al.*, 1983; Schlesinger *et al.*, 1985). The environmental and economic benefits of conservation tillage and direct seeding demand their consideration in the development of improved management practices for sustainable production. Thus, the objectives of this review were (1) to evaluate the longer-term impact of various residue management options (corn silage removal) on $CO_2$ loss, (2) to continue analysis of seasonal effects of strip tillage, and (3) to independently verify tillage-induced $CO_2$ loss without the portable chamber. The data and results will be related to environmental benefits of soil C storage.

## MATERIALS AND METHODS

The studies reported in this review were conducted in West Central Minnesota, USA on rich soils high in soil organic C (Reicosky and Lindstrom, 1993, 1995; and Reicosky, 1997, 1998). Similar soils were used in all the studies and will all be described once. The experiments were conducted at the USDA-Agricultural Research Service, Swan Lake Research Farm, USA (45° 41' 14" N Lat. and 95° 47' 57"W Long.). A typical soil selected was a relatively uniform Barnes loam (fine, loamy, mixed, Udic Haploborolls) formed on a glacial till under tall grass prairie vegetation. The surface horizon is generally very dark with relatively high organic C (typically 2 to 3 g C $kg^{-1}$) and developed over subsoil high in calcium carbonate.

The $CO_2$ flux from the tilled surfaces in these studies was measured using a large, portable chamber described by Reicosky (1990) and Reicosky *et al.* (1990) in the same manner as described by Reicosky and Lindstrom (1993) and Reicosky (1997 and 1998). Measurements of $CO_2$ flux were generally initiated within one minute after the tillage pass and continued for various times. The $CO_2$ flux from the soil surface was measured using this large, portable chamber described by Reicosky and Lindstrom (1993). Briefly, the chamber with the mixing fans running was placed over the tilled surface or the no-tilled surface, the chamber lowered and data collected for one-second intervals for a total of 60 sec to determine the rate of $CO_2$ and water vapor increase inside the chamber. The chamber was then raised, calculations completed and the results stored on computer diskette. The data included the time, plot identification, solar radiation, photosynthetically active radiation, air temperature, wet bulb temperature, output of the infrared gas analyzer measuring $CO_2$ and water vapor concentrations in the same air stream. After the appropriate lag and mixing times, data for a 30-sec calculation window was selected to convert the volume concentrations of water vapor and $CO_2$ to a mass basis, then regressed as a function of time using linear and quadratic equations to estimate the gas fluxes. These fluxes represent the rate of $CO_2$ and water vapor increase within the chamber from a unit horizontal land area as differentiated from soil surface basis caused by differences in soil roughness. Only treatment differences with respect to tillage methods, tillage type or experimental objectives will be described with the results.

## RESULTS AND DISCUSSION

### Corn silage removal and carbon loss

Crop residue management practices have included many agricultural practices to reduce soil erosion runoff and off-site sedimentation. Reduced labor and machinery costs are economic considerations that are frequently given as additional reasons to use crop residue management practices. Reicosky *et al.* (1999) has shown that removal of corn stover as silage for 30 years as compared to returning the residue and removing only the grain resulted in no difference in the soil C content after 30 years of continuous corn and moldboard plowing. Fertility level had no observable effect on $CO_2$ losses. The tillage-induced $CO_2$ flux data that represents the cumulative gas exchange for 24 h for all treatments are summarized in Figure 1. The pre-tillage $CO_2$ flux from the same area not tilled averaged 0.29 g $CO_2$ $m^{-2}$ $h^{-1}$ for the high fertility plots at the start of measurements. This compares to the largest flux after tillage of 45 g $CO_2$

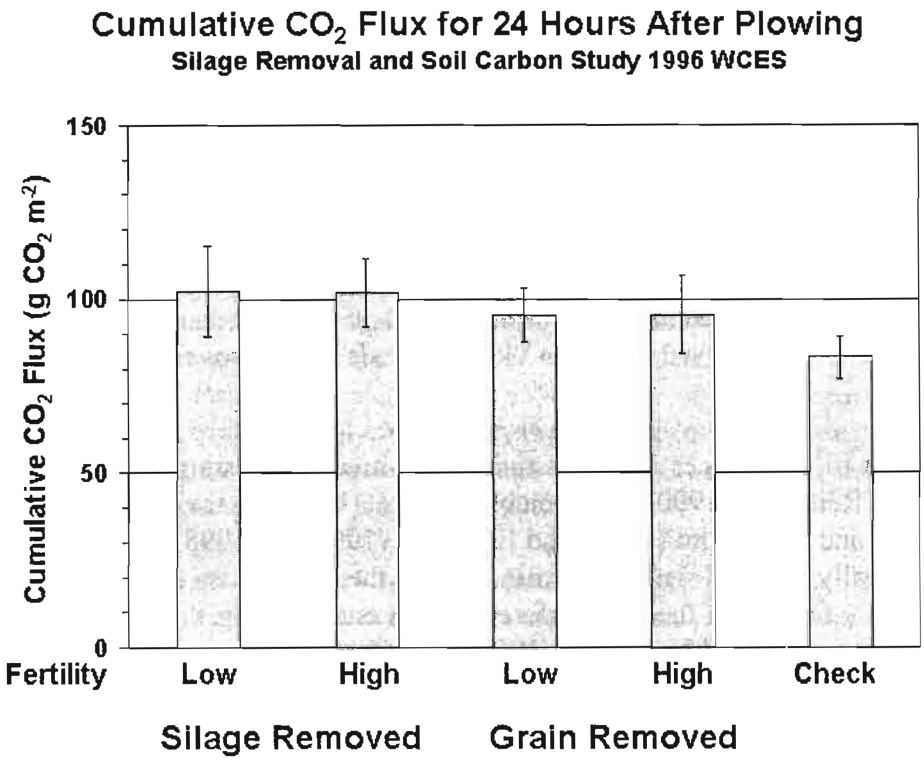


**Figure 1. Cumulative carbon dioxide loss 24 hours after plowing treatments with silage removed and only grain removed. Error bars represent +/- 1 standard error of the mean.**

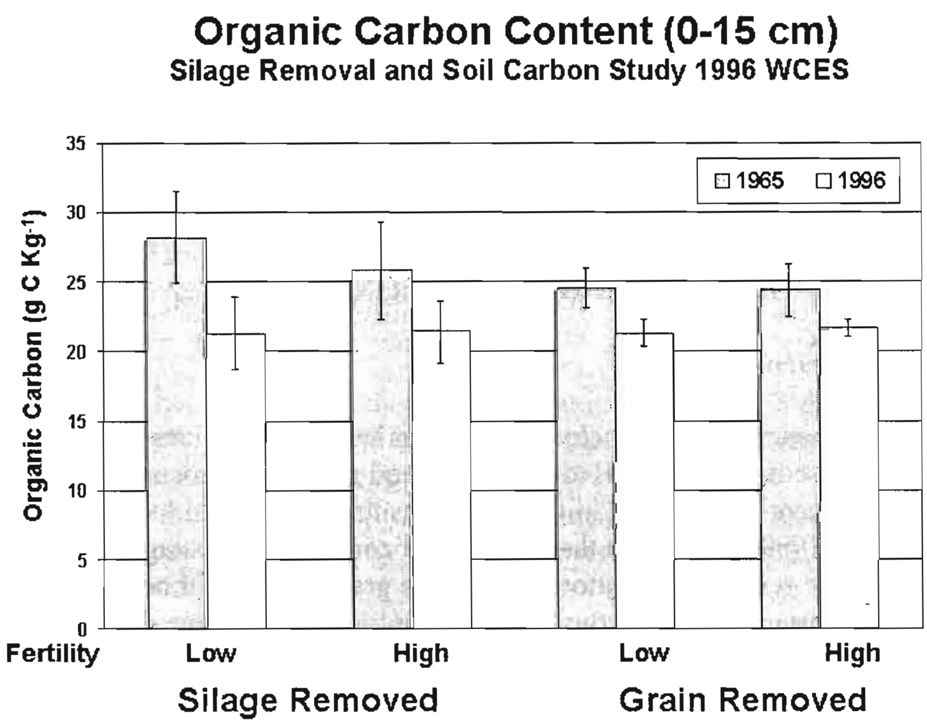


**Figure 2. Soil carbon content at the start (1965) and the end (1996) for silage removed and only grain removed. Error bars represent +/- 1 standard error of the mean.**

$m^{-2}$ $h^{-1}$ on a low fertility grain plot. The $CO_2$ flux showed a relatively large initial flux immediately after tillage and then rapidly decreased four to five hours after tillage. The $CO_2$ flux decrease continued as the soil lost $CO_2$ and dried out to 24 hours where values were lower, but still higher than that from the no-till treatment. The flux 24 h after tillage on the same plots above was approximately 3 g $CO_2$ $m^{-2}$ $h^{-1}$, an order of magnitude higher than the pre-tillage value. The temporal trend was similar for all treatments suggesting the physical release controlled the flux rather than the imposed experimental treatments.

The initial flux was somewhat lower than that measured in previous studies looking at fall tillage (Reicosky and Lindstrom, 1993) on a similar soil and may be attributed to the fact that measurements were made in the spring when the soils were slightly wetter and cooler (Reicosky, 1997). In this work, the soil temperatures at time of tillage ranged from 10 to 12 °C at the 10-cm depth and the water content ranged from 260 to 270 g $kg^{-1}$ on all treatments. Temperatures were about 3 °C higher than those reported by Reicosky (1997) for the 10-cm depth. The water content for the 10 to 20-cm depth averaged 300 g $kg^{-1}$. Water contents were generally higher than those normally associated with spring tillage that may partially explain the lower $CO_2$ fluxes.

The organic C results from the four treatments (0-15 cm soil depth) are summarized in Figure 2. The data show little treatment difference in organic C in the upper layer after 30 years. At this depth the total N was small compared to that in the surface layers. Organic C decreased slightly (data not shown) only in the check treatment (no fertilizer for 30 years). In all other treatments, the organic C and total N in the surface layers were essentially the same. As a result of this similarity in C and N, the C:N ratio for the surface layers was nearly the same at 11.2 for all four treatments. The results suggest C added in the form of stover returned as opposed to silage removed resulted in little difference in the soil C:N ratio (data not shown). The consistency of the C:N ratio across all four treatments suggests little effect of residue removal or addition and that moldboard plow masked the effects of residue removal as silage or only grain removal and above-ground stover returned. Intensive tillage with the moldboard plow overshadowed any residue management aspects and resulted in essentially the same lower C content at the end of 30 years. The results suggest that intensive tillage with the moldboard plow overshadowed any beneficial effect of residue management that might be considered in a cropping system.

**Strip Tillage Effects on $CO_2$ Loss**

Intensive tillage decreases soil C and supports increased adoption of new and improved forms of conservation tillage to preserve or increase C. The large gaseous losses of soil C following moldboard plowing compared to relatively small losses with no-till have shown why crop production systems using moldboard plowing have decreased soil organic matter and why no-till or direct seeding crop production systems are stopping or reversing that trend (Reicosky and Lindstrom, 1993). Reversing the trend of decreasing soil C with less tillage intensity will be beneficial to agriculture as well as the global population through better control of the global C balance. Thus, the general objective of this work was to determine the impact of strip tillage on the magnitude of $CO_2$ loss (Reicosky, 1998). The specific objective was to characterize the tillage-induced $CO_2$ loss after five different strip tillage tools at three times in the growing season.

The $CO_2$ flux as a function of time for each tillage method for the first five hours showed the moldboard plow (MP) had the highest flux that was as large as 35 g $CO_2$ $m^{-2}$ $h^{-1}$ then rapidly declined to 6 g $CO_2$ $m^{-2}$ $h^{-1}$ five hours after tillage. The second largest $CO_2$ flux was 16 g $CO_2$ $m^{-2}$ $h^{-1}$ following the subsoil shanks (SS) that also slowly declined. The least $CO_2$ flux was measured from the no-till treatment with an average flux of 0.2 g $CO_2$ $m^{-2}$ $h^{-1}$ for the five-hour period. The other forms of strip tillage were intermediate and only a small amount of $CO_2$ was detected immediately after the tillage operation with the Residue Manager (RM = residue cleaning and 13-wave coulter). The Mole Knife (MK) started as high as 8 g $CO_2$ $m^{-2}$ $h^{-1}$ and gradually declined to approach no-till (NT) values within five hours. The Yetter L-128 fertilizer knife (YK) had 3 g $CO_2$ $m^{-2}$ $h^{-1}$ immediately after tillage and declined as the soil dried toward no-till values. These results suggest a direct relationship between the magnitude of the $CO_2$ flux that appears to be related to the volume of soil disturbed.

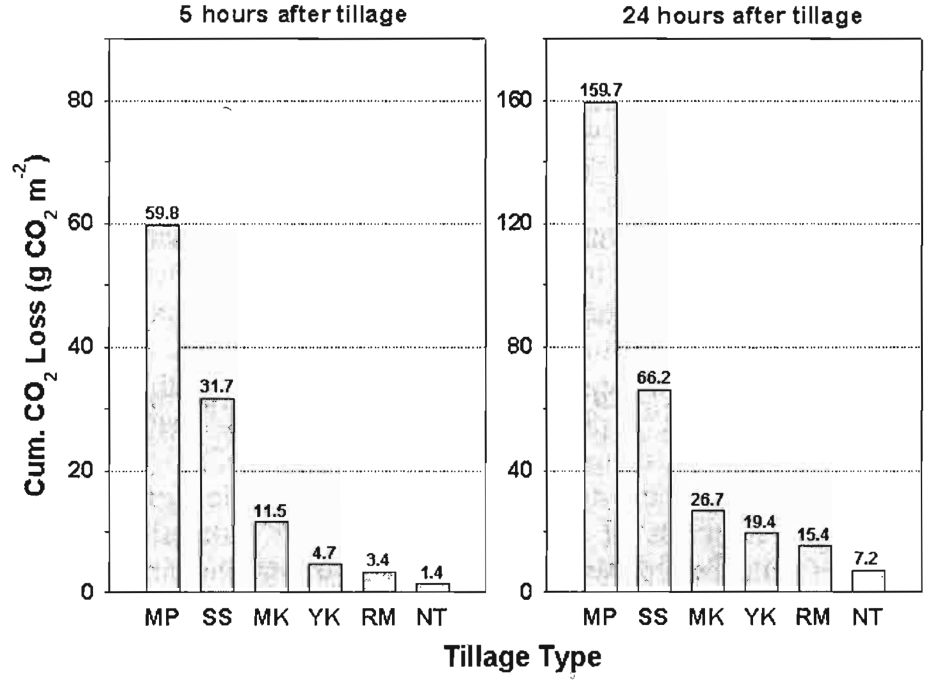


**Figure 3. Cumulative carbon dioxide loss for 5 and 24 hours after various forms of strip tillage in the early season 1997.**

The cumulative $CO_2$ losses calculated by integrating the flux as a function of time for both 5 and 24-h periods are shown in Figure 3. The cumulative $CO_2$ evolved after tillage was calculated using a simple numerical integration (trapezoid rule). This method assumes linear interpolation between the measured fluxes over the time interval which area was summed to give a total $CO_2$ evolved as a first approximation. The values for 24 hours may be subject to error due to the long time between the last two measurements and tillage-induced drying that may have caused the tilled treatments to dry out faster than the no-till treatments. The cumulative flux for the first five hours after tillage for the moldboard plow was 59.8 g $CO_2$ $m^{-2}$ decreasing to 31.7 g $CO_2$ $m^{-2}$ for the subsoil shank to a low of 1.4 g $CO_2$ $m^{-2}$ for the no-till treatment. The Residue Manager had slightly more $CO_2$ loss than no-till, but slightly less than the Yetter fertilizer knife and Mole Knife. Similarly, the cumulative data for the 24-h period reflects the same trend. The maximum release by the moldboard plow was 159.7 g $CO_2$ $m^{-2}$ decreasing to 7.2 g $CO_2$ $m^{-2}$ for no-till. The other forms of strip tillage were intermediate between these that paralleled the five-hour data. The results suggest cumulative

$CO_2$ loss was directly related to the soil volume disturbed by the tillage tool. The narrower and shallower soil disturbance caused less $CO_2$ loss.

The cross-sectional areas of the soil disturbed by the tillage were estimated from field measurements drawn to scale using graphical techniques. The drawings were then cut out and run through an area meter. The cumulative $CO_2$ fluxes for 24-hours were then plotted as a function of these soil areas disturbed in Figure 4. The results show a nearly linear relationship between the 24-hour cumulative $CO_2$ flux and the volume disturbed by tillage. These results suggest intensive tillage fractured a larger depth and volume of soil and increased aggregate surface area available for gas exchange. This increased area for gas exchange contributed to the vertical flux that was largest following moldboard plow.

The short-term $CO_2$ flux in the strip tillage study was generally the largest for the moldboard plow and the not-tilled treatment the least $CO_2$ loss. Other forms of strip tillage were intermediate and only a relatively small amount of $CO_2$ was detected immediately after tillage with limited soil disturbance. All methods declined as the soil dried toward the not-tilled values. The 5-hour cumulative $CO_2$ fluxes following strip tillage for 3 days in 1997 are summarized in Figure 5 for early, mid-season and late season tillage events. The relative magnitudes of the cumulative $CO_2$ fluxes were essentially the same with the exception that the 24 Sept. data showed moldboard plow flux was slightly lower than the subsoil treatment. The cause for the low value of moldboard plow on this day is not known. Relative differences between other methods of strip tillage on all three dates were comparable with largest absolute fluxes during mid-season when soil temperatures and day length were near maximums. The relatively large amounts of strip tillage-induced $CO_2$ emitted mid season suggest a strong association with biological activity directly related to the water content and soil temperatures at the time of tillage. The relative magnitude of the flux on each day appears to be directly related to the volume of soil disturbed by each of the strip tillage implements (Reicosky, 1998). These data showed seasonal variation directly related to a given set of soil water and temperature conditions.

The results from the strip tillage study suggest that to minimize the impact of tillage on soil and air quality, volume of soil disturbed must be minimized. This suggests tilling the soil volume necessary to get an effective seedbed and leaving the remainder of the soil undisturbed to conserve water and C to minimize soil erosion and $CO_2$ loss. Limited tillage can be beneficial and do much to improve soil and air quality, minimize runoff to enhance water quality and minimize the greenhouse effect. The energy savings represent an additional economic benefit associated with less disturbance of the soil. The results suggest environmental benefits of strip tillage over broad area tillage that need to be considered when making soil management decisions.

## Tillage-induced $CO_2$ Loss in the Absence of the Chamber

Much of the previous research reviewed here on tillage-induced C losses has used a dynamic chamber that may affect natural $CO_2$ fluxes and as a result be of concern (Reicosky and Lindstrom, 1993; Reicosky, 1997, 1998; and Reicosky *et al.*, 1997). Recent evidence suggests caution in interpreting soil gas fluxes measured with static and dynamic chambers (Hendrix *et al.*, 1988; Conen and Smith, 1998; Lund *et al.*, 1999; and Reicosky *et al.*, 1997). Concern for possible "chamber effects" on soil gas fluxes led to a study to qualitatively evaluate tillage-induced $CO_2$ loss from a plowed line source without using the portable dynamic chamber. The research plots were in a remote rural area with minimal extraneous

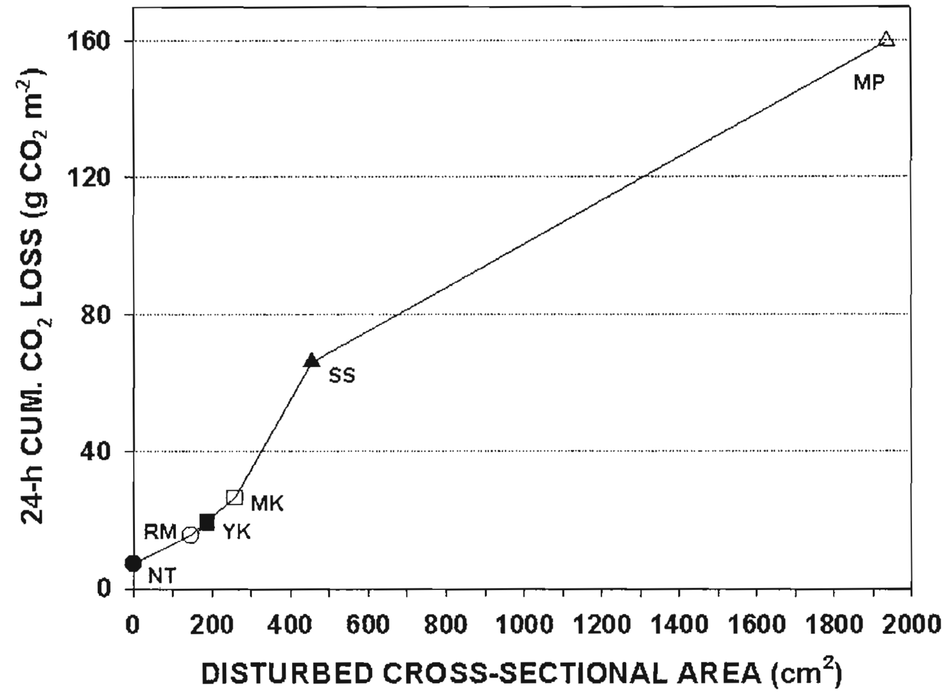


**Figure 4. Cumulative carbon dioxide loss versus disturbed soil cross sectional area in different forms of strip tillage.**

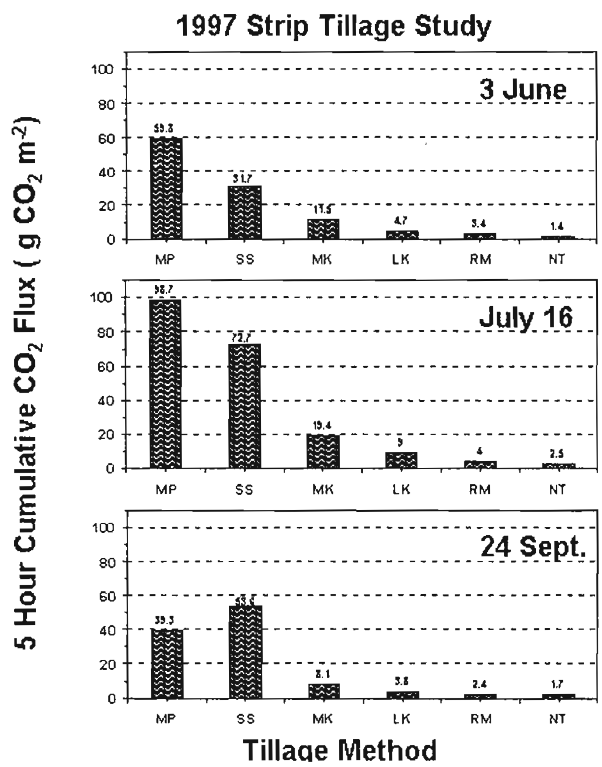


**Figure 5. Cumulative carbon dioxide loss from various forms of strip tillage at three times in 1997.**

$CO_2$ from upwind vehicle exhaust either controlled or noted. A strip of soil 50 to 60-m long was plowed in 1997 perpendicular to the prevailing wind direction using the 4-bottom plow (1.83 m wide) to give a total width of 3.7 or 5.5 m to a depth of 0.25 m shown schematically in Figure 6. The total time required for 3 passes was typically 5 to 7 min plowing the soil upwind and leaving the dead furrow on the downwind edge of the tilled strip. The immediate upwind fetch area in 1997 consisted of actively growing soybean and corn plots. To minimize weed and volunteer wheat effects on the $CO_2$ exchange rate, the entire area to be plowed was sprayed with a glyphosate herbicide.

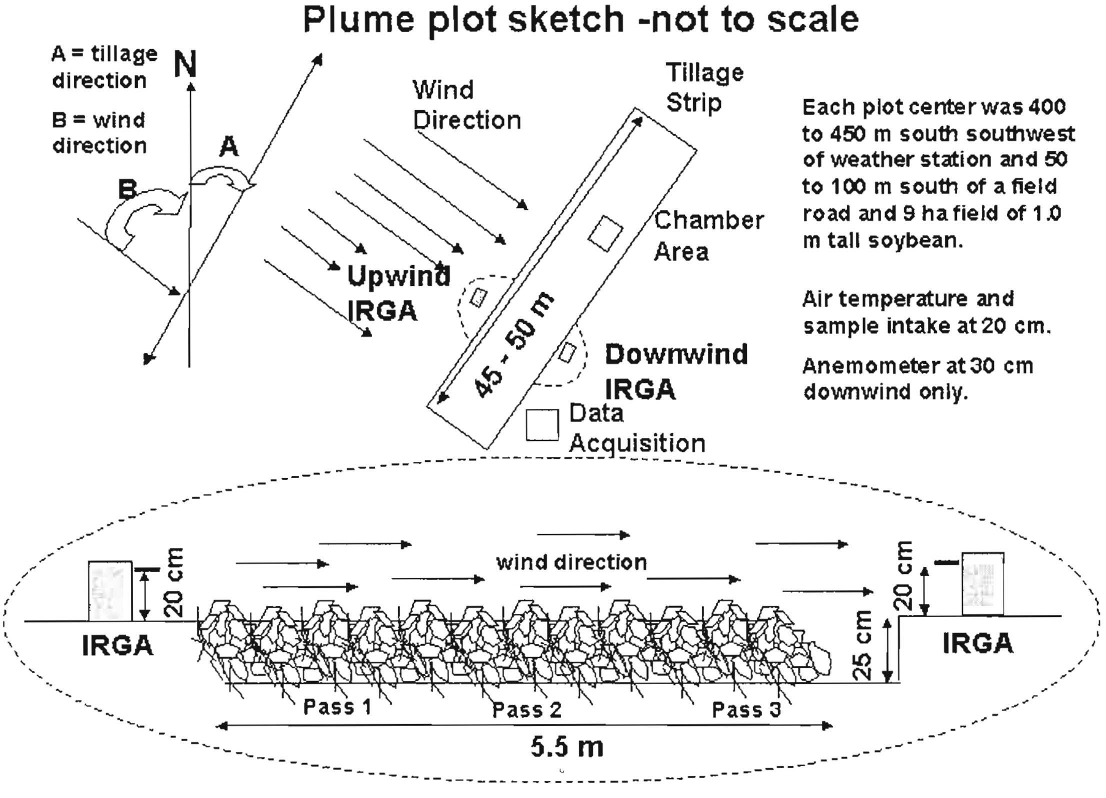


**Figure 6. Schematic representation for measuring upwind and downwind concentrations from a plowed line source of carbon dioxide.**

Ambient $CO_2$ concentrations were measured on the upwind and downwind edges of the tilled strip using infrared gas analyzers (IRGA) operated from a portable generator. Two Li-Cor[■] Model 6262 IRGAs and Model 670 Flow Controllers were located about 7 m apart, programmed to measure in absolute mode and calibrated for $CO_2$ concentration in the 0 to 1000 $\mu$mol mol $^{-1}$ range ( 0.4 $\mu$mol mol $^{-1}$ resolution). The shielded thermocouples for air temperature and intake for the gas samples were set at 0.2 m above the untilled soil surface. The upwind and downwind gas concentrations and air temperatures at the sampling height were recorded twice s$^{-1}$ along with the output of the hotwire anemometer at 0.3 m on the downwind side using a Campbell 21X data logger. Data was collected for a 10 to 12 min. interval and then simultaneously downloaded to a laptop computer into spreadsheet files for further analysis.

[■] Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may be suitable.

A general outline for an experimental run was as follows. The equipment was set up so the alignment of the two IRGAs and sample intake was perpendicular to the wind direction at the time of tillage. Pre-tillage measurements (~ 1 h) were used to measure the $CO_2$ concentration of the intended "footprint" without any upwind contamination or tillage effect to determine the temporal variation in the undisturbed $CO_2$ flux. Just prior to tillage, one pass with the tractor and plow in the up position was made between the IRGAs to test for exhaust from the tractor emitted 3 m above the soil (generally not detected). After ~1 h of pre-tillage data, the tractor was driven along the transect between the IRGAs and the area plowed. The tractor was then quickly returned to the end of the plot and a second pass made in the same direction, followed with the third pass if needed. Data collection continued for another hour after primary tillage. In summary, data collection consisted of two approximate 1-h periods: one

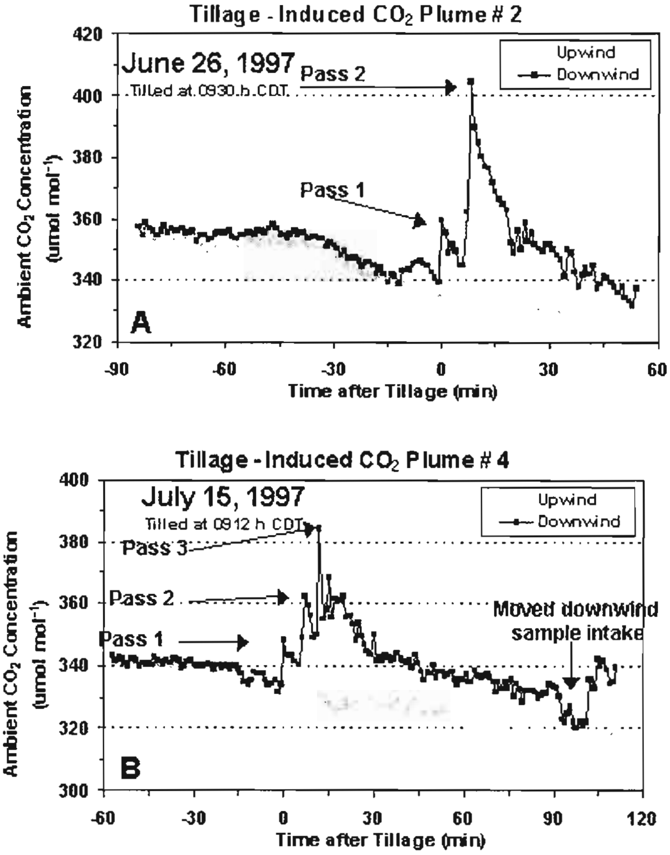


**Figure 7. Upwind and downwind carbon dioxide concentrations from a plowed line source: A) 26 June, 1997, B) 15 July, 1997.**

prior to tillage with no soil disturbance and one immediately after moldboard plowing. Even though data were collected twice per second, 1-min averages were used to smooth temporal variations and random noise. The standard deviation of the 120 concentration values was a large as ± 29 μmol $mol^{-1}$ immediately after plowing that declined to a range of ± 2 to 7 μmol $mol^{-1}$ 2 h after plowing. Before tillage the standard deviation ranged from ± 1 to 2 μmol $mol^{-1}$ for both up and downwind on all days. The instantaneous concentrations were averaged for 1 min to calculate downwind minus upwind differences.

The tillage-induced plume of $CO_2$ from a plowed strip perpendicular to the prevailing wind was demonstrated in several experimental runs and illustrated with selected examples in Figures 7a and b. Instantaneous $CO_2$ concentration differences decreased with time after tillage and were as large as 140 $\mu mol\ mol^{-1}$ immediately after tillage. On 26 June, 1997, data collection started at 0800 hours with tillage 90 min later (Figure 7a). Only two tillage passes were used. Both upwind and downwind concentrations (1 min averages) were initially about 375 $\mu mol\ mol^{-1}$ and declined to 340 $\mu mol\ mol^{-1}$ at tillage when the downwind concentration increased to 360 $\mu mol\ mol^{-1}$ after the first pass and then to 403 $\mu mol\ mol^{-1}$ after the second pass. With no further tillage, the downwind concentration decreased rapidly to approach the upwind value 1 h later. The upwind concentration showed a continued gradual diurnal decline to 330 $\mu mol\ mol^{-1}$ as a result of active crop photosynthesis upwind of the test area.

A second example of tillage-induced $CO_2$ loss is illustrated on 15 July in Figure 7b with 3 tillage passes. Prior to tillage, the 1-min average $CO_2$ concentrations on 15 July decreased from 345 to 332 $\mu mol\ mol^{-1}$, reflecting the diurnal change in $CO_2$ concentration caused by actively growing crops upwind of the study site. Immediately after three tillage passes the downwind concentration increased to 383 $\mu mol\ mol^{-1}$ or a 51 $\mu mol\ mol^{-1}$ increase over the upwind concentration and then gradually declined to 10 $\mu mol\ mol^{-1}$ difference about 1 h after tillage. Each of the three tillage passes, spaced 5 to 7 min apart in this example, show an increase in $CO_2$ that rapidly declines as the ambient concentration was diluted by the upwind air. Measurements of the upwind and downwind $CO_2$ concentration differences support the effect of intensive tillage on gaseous C loss first identified with the portable chamber (Reicosky and Lindstrom, 1993). The rapid increase in the downwind concentration after tillage confirms the tillage-induced $CO_2$ loss without the chamber and illustrates the dynamic nature of soil gas exchange.

**Environmental Benefits of Soil Carbon**

Agriculture has an opportunity to offset some $CO_2$ emissions and will be a small, but significant player in sequestering C. Preliminary assessments indicate that soil C sequestration can be a tool in offsetting C emissions from burning fossil fuels. All potentially important technical options need to be explored. We in agriculture play a significant role because of the large amount of soil C in the C cycle within agricultural production systems. The limited use of crop rotations combined with the intensive tillage decreases soil quality and soil organic matter. Any operation that removes or incorporates crop residue contributes to the decline of soil C through increased biological oxidation. The drive to maximize profit in food and fiber production has created environmental problems that have slowly crept up on conventional agriculture that now requires new knowledge, research and innovation to overcome these concerns.

The main benefit of direct seeding or conservation tillage is the immediate impact on soil organic matter and soil C interactions. Soil organic matter is so valuable for what it does in the soil, it can be referred to as "black gold" because of its vital role in physical, chemical and biological properties and processes within the soil system. Agricultural policies are needed to encourage farmers to improve soil quality by sequestering C that will also lead to enhanced air quality, water quality and increased productivity as well as mitigating the greenhouse effect. Soil C is one of our most valuable resources and may serve as a "second crop" if global C trading systems becomes a reality. While technical discussions related to C trading are continuing, there are several other secondary benefits of soil C impacting environmental quality that should be considered. In agricultural production systems, many decisions are made based on farmer experience and economic considerations. However, the recent emphasis on environmental concerns requires a balance between economic and environmental factors that have caused soil organic matter management decisions to rise to a high-level priority. Thus, the recent interest in soil C sequestration.

Carbon sequestration means to "capture and secure" in this case soil C. Agriculture can be converted from a source of $CO_2$ with intensive soil tillage operations to a sink of $CO_2$ with direct seeding techniques which help store and sequester the C in a form that will minimize the impact on the environment. Preliminary assessments indicate that soil C sequestration can be a tool in offsetting C emissions from burning of fossil fuels (Lal *et al.*, 1998). The main goal is to enhance C fixation through photosynthesis and to reduce soil C emissions by securing and storing C that might otherwise be lost to the atmosphere. The soil contains two to three times as much C as the atmosphere. In the last 120 years, intensive agriculture has caused a C loss between 30 and 50 percent. By minimizing the increase in $CO_2$ concentration through soil C management, we minimize the production of greenhouse gases and minimize potential for climate change. Agriculture, in general, has an opportunity to offset some $CO_2$ emissions and make a small but significant change in the total C cycle. All potentially important technical options need to be explored.

Soils contain relatively small amounts of C that could be considered analogous to a catalyst or to the tip of the iceberg where a small amount visible has a big impact. Soil C performs many important beneficial functions with respect to environmental enhancement. Farmers are the primary soil managers who each have a tremendous responsibility to maintain soil organic matter for environmental benefit of the global population. Thus, farmers who use direct seeding techniques or conservation tillage techniques are helping to maintain environmental quality for all of society. Quality food production and economic and environmentally-friendly management practices that are socially acceptable will lead to sustainable production and be mutually beneficial to farmers and all of society. Enhanced soil C management is a win-win strategy. Agriculture wins with improved food and fiber production systems and sustainability. Society wins because of the enhanced environmental quality. Enhanced soil C management also helps the environment win as improvements in soil, air and water quality are all enhanced with increased amounts of soil C within the soil. The win-win scenario will increase productivity, improve soil quality, and mitigate the greenhouse effect. It is important, therefore, that C loss from the soil system through historical land use of farming practices be restored to its natural potential using direct seeding and conservation tillage methods.

Soil C can be considered the central hub of an environmental sustainability wheel that supports secondary environmental benefits represented by the spokes of the wheel. The spokes of this wagon wheel are the incremental links to C that lead to the environmental improvement that supports total soil resource sustainability. Each of the various items listed in Figure 8 can be considered secondary benefits that emanate from soil C for environmental enhancement through improved soil C management. Important spokes that emanate from C as the hub of this environmental wheel are the spokes that increase water holding capacity and water use efficiency. Increased soil organic matter is known to increase the water holding capacity along with increasing infiltration so that it has a tremendous effect on soil water management. Soils relatively high in C, particularly with crop residues on the soil surface, are very effective in increasing soil organic matter and in reducing soil erosion loss. Under these situations, the crop residue acts as tiny dams that slow down the water runoff from the field allowing the water more time to soak into the soil. Infiltration is increased by worm channels, macropores and plant root holes that are left intact. Soil organic matter contributes to soil particle aggregation that makes it easier for the water to move through the soil and enables the plants to use less energy to establish to root systems. Intensive tillage breaks up soil aggregates and results in a dense soil making it more difficult for the plants to get nutrients and water required for their growth and production. Enhanced environmental quality is achieved by reducing or eliminating runoff that carries sediment from fields to rivers and streams.

The reduction in soil erosion leads to enhanced surface and ground water quality, another secondary benefit of higher soil organic matter. Crop residues on the surface help hold soil particles in place and keep associated nutrients and pesticides on the field. The surface layer of organic matter minimizes herbicide runoff, and with conservation tillage, herbicide runoff can be reduced as much as half. The enhancements of surface and ground water quality are accrued through the use of conservation tillage and by increasing the soil organic matter. Increasing the soil organic matter and maintaining crop residues on the surface reduces wind erosion. Depending on the amount of crop residues left on the soil surface, soil erosion can be reduced to nearly nothing as compared to the unprotected, intensively tilled field.

Another spoke in the wagon wheel of environmental quality is improved soil tilth and structure that enhances the gas exchange properties and aeration required for nutrient cycling. This concept of what soil C can do is so critical in environmental issues and needs to be understood by everyone, especially farmers. It is the combination of many little factors rather than one single factor that results in comprehensive environmental benefits from soil organic matter management. The many attributes listed in Figure 8 suggest new concepts on how we should manage the soil for the long-term sustainability.

Another benefit not often considered is the increase in soil water-holding capacity. The enhanced soil water-holding capacity is a result of increased soil organic matter that more readily absorbs water and releases it more slowly over the season to minimize the impacts of short-term drought. Leaving the crop residue on the surface also reduces water evaporation in the top few inches of the soil and thus, conserves water for the dry periods. Other forms of conservation tillage can make additional water available during the growing season that can make or break the final yield.

Soil organic matter can be influential in decreasing soil compaction. While most compaction occurs during the first trip over the field, reduced weight and horsepower requirements associated with forms of conservation tillage can help minimize compaction. Additional field traffic required by intensive tillage compounds the problem by breaking down soil structure. The combined physical and biological benefits of soil organic matter can minimize the affect of traffic compaction and result in improved soil tilth.

Another secondary benefit of less tillage and increasing soil organic matter is reduced air of pollution. $CO_2$ is the final decomposition product of soil organic matter and is released to the atmosphere. Research has shown that intensive tillage, particularly the moldboard plow, releases large amounts of $CO_2$ as a result of physical release and enhanced biological oxidation. With conservation tillage, crop residues are left more naturally on the surface to keep plant C on the soil surface for use in slow conversion to soil organic matter. Intensive tillage releases soil C to the atmosphere as $CO_2$ where it can combine with other gases to contribute to the greenhouse effect. These results illustrate management's options to reduce agriculture's contribution to the greenhouse effect and point to needed future research to minimize the impact on environmental quality.

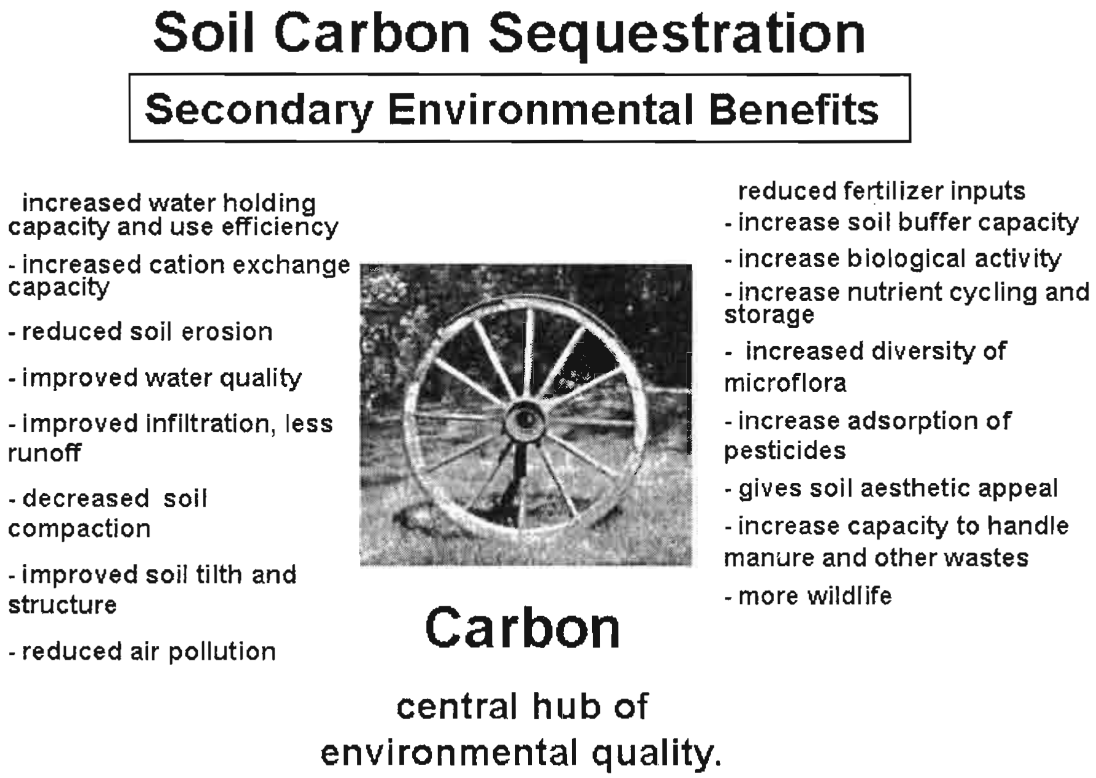


**Figure 8. Secondary environmental benefits of soil carbon sequestration. Benefits are represented as spokes of the wagon wheel emanating from the soil carbon hub.**

Conservation farming or direct seeding saves time, saves money, and can be useful in saving the planet. Eco-efficient farming is economically competitive and environmentally friendly that maintains the sustainability of food and fiber production. This requires a certain level of environmental consciousness and a normal part of doing business in modern day agriculture. We must reduce pollution and use our resources in line with the earth's caring capacity for sustainable production of food and fiber. The responsibility lies on the shoulders of the farmer to maintain a delicate balance between the economic implications of farming practices and the environmental consequences of using the wrong practices. This responsibility entails producing food and fiber to meet the increasing population and still maintain the environment for a high quality of life.

Agriculture is believed to be the cause of some of the environmental problems, especially those related to water contamination from sedimentation and the greenhouse effect with tillage-induced $CO_2$ losses. Improved management techniques have shown that scientific agriculture can also be a solution to these environmental issues in general and specifically to mitigating the greenhouse effect. Improved agricultural practices such as direct seeding or conservation tillage can have the potential to sequester more C in the soil than farming emits through land use and fossil fuel combustion. Thus a combination of the economic benefits of enhanced soil management through reduced labor requirements, time savings, reduced machinery and fuel savings with direct seeding, combined with the environmental benefits listed above has universal appeal. Indirect measures of social benefits as society enjoys a higher quality of life from environmental quality enhancement will be difficult to quantify. Agriculture, using direct seeding techniques, can be of utmost benefit to society and can be viewed as both "feeding and greening the world."

In summary, while we learn more about soil C storage and its central role in direct environmental benefits, we must understand the secondary environmental benefits and what they mean to production agriculture. Increasing soil C storage can increase infiltration, increase fertility, decrease wind and water erosion, minimize compaction, enhance water quality, decrease C emissions, impede pesticide movement and enhance environmental quality. Incorporating C storage in conservation planning demonstrates concern for our global resources. This concern presents a positive role for agriculture and conservation that will have a major impact on our future quality of life.

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# CONSERVATION TILLAGE: AN ENTRY POINT FOR SUSTAINABLE AGRICULTURE IN EURASIAN COUNTRIES

**Josй Benites[1], Theodor Friedrich[2] and Alexandra Bot[3]**

Land degradation and the deterioration of soil fertility are among the main causes of a stagnation or decline of agricultural production in most countries in Eurasia[4]. Land degradation results in loss of soil nutrients, organic matter and soil erosion, and is a significant factor adversely affecting agricultural growth and rural poverty reduction throughout the Eurasian region.

The situation is serious and the economic development of the Eurasian region cannot afford a further destruction of the agricultural production resources. Immediate action is required. The technologies for this are available but a clear policy decision and concerted action is required to introduce sustainable and productive land husbandry practices in the shortest time possible.

Existing practices and heavy machinery are leading causes of soil erosion, soil compaction, decreased fertility, and loss of organic matter. Ridged tillage operation procedures and short time windows for tillage and harvest coincide with extreme weather, which often result in tillage operations during wet periods. Ineffective machinery needs to make, on average, several passes over the soil to prepare it for seeding. Approximately 170 million ha of land has been affected by soil compaction (Srivastava and Meyer, 1998). Estimated production losses as a result of soil compaction differ. Conservative estimates calculate a production loss of 15 million tons of grain, two million tons of sugar beets, and 500,000 tons of maize. While others calculate a 16-27% decrease in production as a result of soil compaction, with a loss of 50 million tons in grain production alone.

Conservation tillage is a practicable approach for agricultural systems looking beyond *soil preparation* in the narrow sense, focusing on the broader concept of *Conservation Agriculture*, since this embraces not only the seedbed preparation but also nutrient content of soils and their structure and biological status that are important determinants of agricultural productivity as a result of farm management and land husbandry practices.

Much of the agricultural machinery in the Eurasian region is in a state of disrepair or obsolete. The use of this machinery plays a significant role in unsustainable agriculture. A renovation of the machinery park with conventional technology requires heavy investment. Replacing this machinery with conservation tillage equipment would help to improve agricultural production and sustainability. The farm power and thus the investment requirements for this option are likely to be considerably lower than for conventional technology.

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FAO is supporting world wide the use of conservation tillage and improved soil management. Together with other international and regional organizations FAO has been organizing international workshops to create the awareness of policy makers about the importance of better land husbandry, to develop regional action plans and to draft an international code of conduct on conservation agriculture. FAO can play a crucial role in promoting conservation tillage in the Eurasian region bringing together national stakeholders as well as the potential conservation tillage experts from similar agro-ecosystems, especially from North America.

The purpose of this paper is to review and outline the basic principles of conservation tillage as an entry point for better land husbandry in the Eurasian region, which offer practicable ways of reaching agronomic, social, economic and environmental objectives more rapidly, securely and sustainably than in the past.

**Eurasian Land Qualities and Limitations**

The vast land resources (about 2.513 million ha) of the Eurasian region include a variety of soil characteristics, landscapes and climates that affect their potential for crop, pasture and forest production.

The geographical extent of agricultural environments, soil constraints and human-induced degradation in the Eurasian region are shown in Annex 1.

**Drylands.** Drylands are defined as those areas with an arid, semiarid and dry subhumid climatic zone, which are calculated based on the length of growing period[5] (LGP). Dryland areas are 'fragile' in that they are extremely vulnerable to land degradation resulting from over-grazing and other forms of inappropriate land use.

The Eurasian region is dominated by semi-arid and dry subhumid conditions (79%). Approximately thirty percent of the area lies in the dry subhumid climatic zone, which has a dry/cold season of 6 to 8 months (LGP 120-179 days). Fifty percent of the region is located in the semiarid climatic zone, which is characterized by a dry/cold season of 8-10 months (LGP between 60-119 days), and in more than 10 percent of the area the growing season is limited to a period of two months (arid climatic zone). Four percent of the territory is even located in desert areas (LGP 0 days) (Bot and Nachtergaele, 1999). Because of the climatic characteristics, soil moisture is limited during the growing season unless irrigated. Planting date should take into account the flush of nitrogen at onset of rain. For Georgia, Kyrgyzstan, Russian Federation and Tajikistan the temperature is probably a more limiting factor than lack of rainfall.

**Steeplands.** The Eurasian region is characterized by undulated topography. About 29 percent of the region have slopes ranging from 8 to 30%. Eleven percent is dominated by slopes >30%. At country level, Armenia, Georgia and Turkey have more than 70 percent of their territory on steep slopes with serious constraints related to natural resources and socio-economic conditions.

As a result of this seventeen percent of the region is prone to soil erosion, taking into account the slopes combined with an abrupt textural contrast in the soil profile. High priority should

[5] Length of growing period (LGP) for annual crops: period during which the soil profile remains humid and the temperature doesn't drop to temperatures which don't permit crop growth

be given to better land husbandry to prevent or control erosion, especially in areas with shallow soils, which cover about 14 %, and high rainfall.

**Major Soil Constraints**

Hydromorphic characteristics, wetness in the soil profile year around or for part of the year, are governed mainly by physiography. Such land is generally flat and low-lying with respect to the surrounding land. Common environmental characteristics, each presenting distinctive management problems, include alluvial and coastal plains, deltas, and river valleys. Peat bogs are also extensive, mainly but not exclusively in the temperate and sub-polar zones, including on elevated plateaus under high rainfall. These lands occupy 24% of the region. Denitrification frequently occurs in anaerobic subsoil; land preparation and other management practices and certain crops may be adversely affected by excess of sub surface water unless drainage is improved. When under agricultural management, hydromorphic soils are often used for rice production in the tropics, and permanent grassland in the temperate zone.

Salinity and sodicity are important chemical constraints for agricultural production. Saline and sodic (natric) soils occur naturally on low-lying sites in semi-arid to arid regions. They are caused by accumulation of free salts in the profile (salinity), or dominance of the exchange complex by sodium ions (sodicity), covering three and seven percent respectively. At country level, Kazakhstan has 40% of its soil resources affected by sodicity. The presence of high amount of soluble salts will require drainage, but is generally uneconomic or impractical, owing to the cost or unavailability of non-saline water, and special management for salt-sensitive crops. Mildly saline soils can be used for salt-tolerant crops (e.g. date palm, barley, cotton).

Soils, which present aluminum toxicity, are soils in which the exchange complex is dominated by aluminum. This is associated with a soil reaction of pH <5.5, often <5.0, and although technically less correct, the problem is commonly described as one of strongly acid soils. The main cause is strong leaching, resulting from high rainfall. Regionally this constraint occupies only three percent, but covers an area of 12 percent of the total land area of Georgia. Liming is a technically feasible solution, but at the levels of lime required, may not be economic.

**Land Degradation**

Intensive cultivation, overgrazing and deforestation have resulted in different types of land degradation and its consequences, of which water erosion is the most important one, followed by chemical deterioration of the soils. At regional level 55 percent of the land is degraded to some extent, of which 27 percent is severely or very severely degraded. Twenty percent of this degradation is caused due to agricultural activities (Bot and Nachtergaele, 1999).

**Inadequate Soil Management Leads to Loss of Top Soil**

Lack of vegetative soil cover as a result of poor land management leaves the soil aggregates exposed to the direct impact of raindrops of high kinetic energy, which in turn encourages the loss of pore space (or loss of structure). A result of loss of soil porosity is the formation of superficial crusts of about 1mm thickness on the soil surface, which drastically reduce the infiltration of water and cause an increase in surface runoff. The lack of vegetative soil cover is a result of traditional practices such as:

**Soil compaction.** The continuous use of the same tillage implements, namely plows and disk harrows at the same depth creates compact soil layers known as "plow pan" or "harrow pan" at 20-25cm or 10-12cm depth. The frequent repetition of these operations, passage of machinery and operations carried out on wet soils are adding up to the effects of the tillage implements so that the compacted layers can sometimes reach far beyond the plow sole itself into the subsoil. These compacted layers are not only physical barriers but inhibit, due to their low oxygen content, the growth of plant roots. They also reduce drastically water infiltration into the subsoil with a simultaneous increase in surface runoff, loss of soil, nutrients, organic matter, calcium and seeds. The microbial activity in the soil is as well affected (see Box 1).

**Deforestation.** The loss of forests removes the natural protection of soils against sunrays and the direct impact of raindrops. There is a reduction in the infiltration of water into the soil and a simultaneous increase in surface runoff; the levels of organic material are also reduced. These factors combined with planting on steep slopes, the natural susceptibility of certain soils to erosion, and the coincidence of land preparation with erosive rainfall, accelerates the erosion process and consequently intensifies land degradation.

**Burning crop residues.** Burning crop residues leaves the soil exposed to erosion and at the same time eliminates the major source of energy for the survival of micro-organisms. Although soil temperature next to the stubble during burning can be higher than 200 C, the population of micro-organisms is relatively little affected. However the population of meso- and macro-fauna (worms, insects) that inhabit the surface soil is completely destroyed, and this can subsequently cause a disequilibrium between the predatory organisms of cultivated plants (which cause infections and diseases) and their natural enemies. Being a quick burn, the evaporation of water causes soil temperature to be maintained at a lower level than that in the straw during the burn. Therefore there are no pronounced changes in the population of soil micro-organisms, and the magnitude of the reduction does not become significant because the population density is rapidly restored to its original level. The biggest changes are observed in microbial activity, which is slightly stimulated in areas where burning is very light. However when burning is more intense, microbial activity is slightly reduced. The initial stimulus of burning on microbial activity, due to the greater speed of mineralization of partially burnt residues and organisms, soon disappears.

**Maintenance of exposed soil between harvests.** With conventional systems of land preparation it is common to leave the soil exposed between successive summer crops (i.e. during the winter period). Straw and other residues are not left on the surface. Often the land is maintained without any type of vegetative cover, including spontaneous cover, due to plowing and harrowing operations, and soils are left exposed to the direct action of raindrops and sunrays. Occasionally the plowed soil is left on purpose exposed to the rain in order to catch the water in the topsoil. This concept is doubtful as soils under zero tillage have proven to make better use of rainwater and provide better growing conditions for plants particularly under dry conditions.

Poor rangeland management, is characterized by excessive stocking rate, poor quality grasses, continuous grazing, and is generally located on steep slopes. Being often located at higher altitudes than the arable crops, the is not adequately protected soil leads to significant loss of rainwater, which runs over the arable land below, causing serious erosion.

**Box 1. The destructive effect of ploughing**

Ploughing is the most power demanding and time consuming operation in farming, particularly on dry soils with high clay content. The entire topsoil is cut, lifted, inverted and moved sidewards. Internal and external friction, bending and acceleration breaks the soil structure up and leaves it, depending on soil type and moisture content in larger or smaller clods. The organic matter is diluted throughout the entire topsoil, soil life is severly damaged and the soil surface is exposed without protection to the atmospheric forces. The coarse soil structure after ploughing requires subsequent secondary tillage operations, during which the soil particles are mechanically broken down to small fractions. In this way the soil structuring elements, particularly organic humus colloids, are destroyed and mineralized. As a consecuence the soil will compact more easily and the loosening efect of tillage will last everytime less. More energy is required for tillage and subsoiling and the soil becomes more susceptible to wind and water erosion.

When an exposed and pulverised soil is hit by the force of big raindrops from heavy rain showers the weak aggregates get further crushed and a seal is formed, preventing water from entering the soil, resulting in run-off and erosion. When drying, the seal is transformed into a hard crust which affects aeration and plant formation.

The upper soil temperature of an exposed and pulverised soil before/after planting may, during a hot day, reach 55°C. This can be highly detrimental to young seedlings. The ploughed land is levelled and flat after some rains and the wind speed at ground level can be relatively high. Rainwater will easily flow away even on gentle slopes and the wind will increase evaporation losses.

When ploughing virgin land the organic matter accumulated close to the soil surface is thoroughly mixed into the soil, thinning the organic matter content and starting an accelerated process of mineralisation. The previous balanced state of decomposition is disturbed resulting in a flush of released crop nutrients. The nutrients that the crop will fail to utilise will be leached out into the soil water and percolate to lower levels and/or be lost through run-off or fixation. The organic matter content, if not replaced, will drastically change the properties of the soil.

It is common to burn the crop residues to enable smooth ploughing. Ploughing makes the virgin land become gradually more compact due to loss of organic matter and soon a level is reached where heavy tillage is required to be able to create a seedbed. It is possible to end up in a vicious circle of worsening soil conditions to a level where it is not possible to grow a crop.
The high speed of tractor ploughs, the weight of the tractor and implement, high tyre pressure and the slippage of worn-out tractor tyres will add further destruction of the soil structure, compaction and hardness to the pan. A common name for the impermeable layer is "hardpan". Ploughing at the same depth will worsen the hardpan effect.

Particularly dangerous are disk ploughs and disk harrows. In addition to the general effects of a mouldboard plough as discribed above, they have a much more intensive mixing and crumbling action due to the rotation of the disks. These characteristics make them particularly popular with farmers as they are easy to use allround tools but they lead also to rapid degradation of the soil structure. Disk implements also tend to compact the subsoil. Those compactions over the years gradually build up and can lead to compacted horizons reaching from 10 to 50 cm.

The destructive effect of ploughing under semi-arid conditions is well documented and for example in Zimbabwe there are even plans to ban the plough in order to save the soil and to avoid future famine in rural areas.

Incorporation of crop residues, green manures and cover crops. When the residues of wheat and other grain crops are not burned, farmers incorporate them into the soil with plows or disk harrows. When green manure is introduced in some areas due to the soil problems farmers continue to incorporate all of the biomass produced into the soil. By mixing and loosening the soil at the same time a high degree of mineralization of the organic matter was obtained. The green manure in this way is understood rather as a mineral fertilizer than as a soil-structuring component. This incorporation of biomass leaves also the soil exposed and accelerates the process of land deterioration, because of the intense rainfall of high erosive potential, which occurs during this period.

**Monoculture.** It is common in the Eurasian region and elsewhere to plant the same crop, particularly a cash crop, on the same land in successive years. Monoculture systems therefore give few opportunities to alternate the type of root systems and their depth of penetration, which impedes the improvement of soil aeration, and so affects the diversity of microbial life, and favors plant pathogens and pests, and a more intensive use of pesticides.

## Conservation Tillage

Conservation tillage systems prevent the erosion of the soil by wind and through improved water penetration into the soil profile. This gives greatly improved moisture utilization by plants and thus subsequent improved crop profitability. Conservation Tillage is widely used in the United States of America, South America, Australia and, to lesser extent, in Europe.

Conservation tillage systems are not just different methods of tillage or no-tillage, but rather complete systems of crop production. Therefore at least the following aspects have to be taken into consideration:

- Crop rotations and practices
- Minimum or zero soil surface disturbance
- Planting
- Weed management
- Residue management
- Soil fertility building and cover crops

Conservation tillage promises to be a potential strategy for further improvements in crop production efficiency. Its potential value is not only of evident relevance with regard to soil erosion and its related problems but as a part of a concept for alleviating traffic-induced excessive soil compaction and reducing costs by minimizing deep mechanical soil loosening.

Conservation tillage has great potential benefits in the semiarid regions where rainfall is erratic and soils are highly variable and subject to wind and water erosion. Maintaining vegetative cover on the soil surface is the simplest way of controlling wind and water erosion. With proper management, more surface residues are retained which will reduce runoff, sediment loss, air pollution, and protect surface soils from wind erosion. Without surface residues, tillage is frequently needed after a rain to break the soil surface crust, to control wind erosion, or to facilitate seedling emergence.

Under conservation tillage, crop residue is a part of the previous year's production that needs to be saved until the new crop develops a canopy to break forces of rain and wind. Tillage objectives vary greatly, depending on crop, soil type, degree of slope, moisture availability, and farmer choice. The engineering challenge is to provide machines that work soil or move it, or disturb it just enough to provide a measured amount of weed control, fertilizer and chemical incorporation, seedbed preparation, etc., without burying crop residue.

## Development of Zero Tillage Concepts

It is not sufficient to maintain the soil covered and to use tillage systems that cause minimum soil disturbance. Zero tillage provides the opportunity to replace traditional agriculture by a new concept of conservation agriculture. The correct term would be zero-mechanical-tillage, because in conservation agriculture mechanical soil tillage is not simply abolished but it is replaced by biological soil tillage in which the various components of the soil life take over the task of tilling, i.e. mixing, loosening and structuring of the soil.

**Soil rehabilitation as a transition stage from conventional to zero tillage**

Where erosion of topsoil has occurred, and soil layers of poorer quality for root growth have become exposed, it is essential to rehabilitate and restore this degraded soil to bring it up to good productive capacity, because this will be the habitat for future crops. The quality of the soil, which is remaining, should be of even greater concern than the quantity and quality of soil, which has been lost. Therefore, damaged soils should be rapidly restored to their former levels of productivity as soon as possible after the event, and former inadequate soil-management practices modified, making them more conservation-effective and the soils more productive in satisfying needs of plants (Benites *et. al.*, 1999).

Therefore, in a situation where soil has been degraded by many years of conventional tillage and furthermore might be severely eroded, it should not be attempted to introduce a no-till system directly, that means without passing through some transitory stage first. The aims to be achieved are:

**Removal of compacted soil horizons.** Depending on the depth of eventual compaction zones in the soil subsoiling might be necessary to break up compacted layers beneath the topsoil. Subsoiling of compacted and degraded soils can bring spectacular effects due to higher water infiltration and can result in immediate increase of yield of up to 30%. However, subsoiling is a very energy demanding operation. In degraded soils it can easily lead to a recompaction of the soil which could be even more severe than the original compaction. Therefore subsoiling should only be undertaken in combination with other structure building operations and very much care should be taken not to recompact the loosened soil. Depending on soil properties, subsoiling might have to be repeated after some years even under a no-till system.

With shallower compaction horizons, deep chiseling of the entire plot might be required during the first and maybe second year before changing to a true minimum tillage or no-till system. Care should be taken to select tools that loosen the soil with a minimum of disturbance or soil movement. Particularly the transport of clods to the soil surface should be avoided.

Biological chiseling, using different species of deep rooting plants to break hardpans is a cheaper and more sustainable option as the structuring elements of the "chiseling" remain in the soil in form of root-channels.

**Leveling.** Before converting a field to zero tillage, care should be taken that the soil surface is as even as possible. Plow furrows, tracks of machines and tractors or any other contour should be eliminated, as this will in future not be possible any more.

**Building soil organic matter content.** On severely degraded soils it might be necessary to growth a heavy crop of green manure and incorporate it deeply into the topsoil. Later the management of biomass should be carried out without its incorporation into the soil. In this way organic matter can be built up in the soil, which has great influence on the activity and the population of the microorganisms. Increased levels of biomass through green manure will enhance the macro and microbial population of the soil. The management of green manure as a soil cover can be done with mechanical methods (knife rollers or in special cases, mowers or choppers) and/or with chemical methods (desiccation with herbicides).

**Correction of nutrient imbalances.** Severe nutrient deficiencies should be corrected incorporating mineral fertilizers into the soil in order to facilitate the establishment of soil life. Al toxicity, salinity or other severe soil chemical or physical anomalies might require besides chemical remedies also deep plowing. However, these actions should be considered as serious interventions and the parameters of the operation, defined on a case by case bases, should be strictly observed.

**Weed management.** Weed management is critical for a successful transition. Weed growth must be controlled not only during but also between cropping seasons to prevent multiplication of weed seeds. This can be achieved either by using cover crops or by chemical weed control.

**Strategies Fostering the Adoption of Conservation Tillage Practices**

Good land husbandry can be defined as: the active process of implementing and managing preferred systems of land use in such ways that there will be an increase - or, at worse, no loss of productivity, stability, and usefulness for the chosen purpose (Shaxson, 1993). It involves the active management, by farmers and other land users, primarily of rainwater, vegetation, slopes, plant nutrients and soils. It is applied at a variety of scales, from the field to the landscape, and embraces land under planted crops, pastures and plantations, and under native vegetation of every sort.

A production system consists of various components, e.g. land preparation, tillage, crop rotation, sowing, application of pesticides including herbicides, fertilization, harvesting, storage of grain crops, management of crop residues, machinery, implements and equipment, systems of drainage and irrigation, soil conservation and others. If the introduction of a new management system requires changes in some components of the production system, it could signify changes in other components. For example, in systems of zero tillage, the greater part of the crop residues stays on the soil surface, which demands a well planned crop rotation to avoid the occurrence and proliferation of certain diseases and pests, which have a greater incidence in mono-cropping.

A focus on better land husbandry would increase the efficiency of water use (rain and soil humidity) and the use of soil nutrients by plants through:

- maintenance of a good soil cover;
- increase in water infiltration in the soil profile (obviously in soils susceptible to waterlogging drainage is still required);
- the management of soil fertility by encouraging the recycling of nutrients; and
- better exploitation of the soil profile by plant roots.

On the basis of the experiences of various countries, it is notable that the sustainable adoption of direct planting systems is only possible if a production system is used, which is based on crop rotations, an integrated management of the agronomic aspects, the organization and commercial development of farmers, and the availability of equipment adapted to the needs of farmers, equally small and large ones. Organizations of field extension services can also play an important role. It is also necessary to involve regional local authorities.

Amongst the mechanisms needed to implement integrated strategies of management to drive the adoption of conservation tillage are:

- national and international agreements to elaborate integrated policies on conservation and the use of resources such as soil, water and plant nutrients, and above all to evaluate the limitations and potential of these resources in a wider context, in which *in situ* and *ex situ* factors are integrated;
- technical co-operation between farmer-farmer at the local level;
- appropriate reforms in institutional and social infrastructures;
- participation of all actors and pertinent institutions to plan and stimulate a better collaboration at all levels including the private and commercial sectors;
- co-ordination between national and local governments through consultative forums to facilitate the implementation of actions;
- monitoring to evaluate the effects of plans and policies, and changes that these produce, on the population and its natural resources.

**Key Steps for Required for Adoption by Farmers**

First, it is very important to initiate an awareness campaign on environmental problems in the public sector, which lead to concrete actions taken to minimize problems mainly related to soil erosion.

Second, the involvement of the commercial input supply sector is important from the very beginning. Conservation tillage demands different inputs than conventional farming. This is particularly true for farm implements. Special equipment is necessary for the management of crop residues or cover crops, for planting and for weed control. In many cases it will not be possible to adapt existing equipment, like planters, for the new cropping system or the required equipment does not exist at all. It is therefore very important that the required equipment is accessible for the farmer. In the beginning imported technologies might be the only commercial options to start with conservation tillage. However, when the technology is adopted in a larger scale it has proved to be of advantage to develop local or regional manufacturing capacities. This can provide additional job opportunities and income for rural areas. In any case the development and introduction of a new concept of agriculture which depends on technology is only possible with an early and direct involvement of the manufacturers and suppliers of this technology.

Third, the search for new alternatives for agriculture, and added value for goods produced on the farm such as:

- better administration of farms
- better production technology
- organized farmers
- value added to products

Therefore, it is not sufficient to introduce merely new technologies, such as zero tillage for reduced and better distributed farm labor, or to reduce the long term costs of production, or to reduce the pollution of surface waters by erosion etc. It is absolutely essential to improve farm administration, add value to harvested products, search for alternative markets, and to diversify agricultural production, but without diluting production through a multiplicity of activities.

Also the utilization of zero tillage technology might require new forms of farmer's organizations. Zero tillage equipment is usually expensive but produces high output rates. It is therefore ideally suited for contractor work or shared operation. The way under which the machinery sharing is organized will depend very much upon the local preferences of the farmers.

Fourth, Value is added to agricultural production, by the farmers themselves processing the products, sometimes on an individual basis, but preferably through organized groups, associations or co-operatives. However, this will only be possible with the support of appropriate legislation, which enables the establishment of small rural industries, which are economically viable.

**Participation of Farmers and their Organizations**

Participation of farmers' organizations in the planning and implementation of conservation-effective agriculture programs is essential. The same accounts for the decentralization of the decision making from the government headquarters to the rural communities at local level.

**Catchment or micro-catchment commissions.** Each catchment or micro-catchment forms a commission with the aim of self-management, made up exclusively of farmers representing all the communities. Among the commissions other objectives are to assess whether the program's incentives have been properly applied, to co-ordinate actions such as buying machinery, equipment and inputs for communal use, and to administrate communal activities such as the operation of grain dryers.

**The Municipal Council of Rural Development.** This modality has been introduced successfully in Southern Brazil where practically all municipalities have a Municipal Council of Rural Development in which the syndicates, co-operatives, and leaders of the rural sector participate. One essential requisite is that farmers from all the communities are represented in this council. The fundamental role of the council is to define and implement the Municipal Rural Development Plan, and of promoting the collaboration of the various public and private organizations interested in rural environmental activities.

**Rural Syndicates.** The rural sector without representation is always discriminated against in the formulation of government policies. The rural syndicates and its representative bodies facilitates the access of farmers to needed services such as credit, markets and inputs as well as the construction of community silos, the purchase of equipment, marketing of products, the acquisition of inputs and other similar activities.

**Agricultural and Rural Credit Co-operatives.** The co-operative system provides services such as credit and support to marketing, purchases and sales. Some co-operatives also operate rural agro-industries such as dairy plants and slaughterhouses combined with meat processing and the preparation of animal feed and concentrates.

**Partnership between Farmers and the Private Sector.** Besides the co-operation in the supply and development of technology, which was mentioned as one of the initial steps, a long-term collaboration between farmers, their organizations and the commercial input supply sector, can be of mutual benefit. Input suppliers can provide seasonal credits in kind as well as technical assistance having a natural interest in the economic healthiness of their clients, the farmers. Only if all involved parties, the farmers and the input suppliers can make attractive profits out of their operation they will be willing to progress and introduce further developments.

**Research Needs and Requirements**

During the last three decades intensive work has been carried out on tillage research, to better understand the physical, chemical and biological effects of different tillage alternatives on the soil and plant environment.

Various aspects of conservation tillage including reduced, minimum and no-tillage systems have been covered, and the use of mulch and crop residue management as an essential component of a tillage system has been given special attention. Some areas require still more research as for example local soil types and climatic factors (especially rainfall characteristics), management of crop residues and equipment development, particularly designed for the needs of local farmers. The parallel development of appropriate agricultural machinery and equipment would enable the farmer to effectively apply any recommended technological package suitable to the particular soils, crops to be cultivated and socio-economic conditions (Benites and Ofori, 1993).

A concerted effort to understand and respond to the intertwine composed of (a) farmers, (b) crops and (c) soils from international as well as national research institutions will be essential in achieving the goal of increasing agricultural productivity while maintaining the soil resource on a sustainable basis. There is also a need to understand the local farmers' practices and direct additional research to improving these practices.

It is well established that management of crop residue on the soil surface is a key element of any reduced tillage system. A major constraint of residue management in some regions, however, still remains the quantity of residue available to be used as mulch. A no-tillage system cannot be adopted successfully without an adequate amount of residue mulch; the farmer is furthermore constrained by lack of economic resources to purchase herbicides. It is therefore important, particularly in the drier areas where animal husbandry is practiced, to study the effects of surface stubble management and tillage on the productivity of crop/livestock systems. Such studies may provide answers to the complex problem of the use of crop residues as fodder, as well as in soil management practices for erosion control and water conservation.

**Technology Transfer**

Country extension services need to pay more attention to those tillage practices developed by the farmers themselves, which have proven effective in soil and water conservation. But with the increasing average age of farmers as a result of the migration of youth to the urban areas, tillage practices as well as tillage equipment will need to be adjusted to these labor constraints, although this can only be achieved within the financial resources of the farmer. Furthermore, it has been found that some of the improved implements introduced to farmers for effective tillage have not been widely adopted, and it is necessary to ascertain the reasons for this (Benites and Ofori, 1997).

In very few cases has the official soil tillage research had major influence on tillage practices. Tillage practices have been influenced much more by technology developments from commercial manufacturers or occasionally by farmers' inventions. Most of these developments are rather conservative as revolutionary ideas carry usually very high commercial risks. This has in many cases led to the adoption of unsuitable and therefore unsustainable technologies resulting in world wide problems of soil degradation, erosion and compaction. Conservation tillage is certainly not attractive to manufacturers of plows, unless they manage to shift their focus to other implements. But also the tractor industry is not really attracted by technologies that require less power and extend the lifetime of tractors by up to 3 times.

Special attention is required if agricultural practices are to be changed to adopt more sustainable techniques. The system or systems introduced must fit into the farmer's production pattern and cropping system and show the clear benefits available to the farmer at acceptable cost/benefit relations. Adequate knowledge of the soils, climate and cropping systems is indispensable for the development and choice of appropriate tillage systems. One of the promising approaches to such informal technological exchange is through networking. This could provide inspiration while the actual conservation tillage system will have to be developed site - specifically with the local farmers.

Research and technology transfer networks are an effective way of using scientific resources, in addition to providing facilities for training technicians from participating countries. FAO is supporting the use of conservation tillage and improved soil management through the formulation of a code of conduct on soil management. Together with other international and regional organizations FAO has been organizing international workshops to create the awareness of policy makers about the importance of better land husbandry, to develop regional action plans and to draft an international code of conduct. A first workshop was organized in 1998 in Harare, Zimbabwe.

Besides the promotion of conservation tillage based systems of better land husbandry through a farmer to farmer extension, FAO is also applying this principle on an international level. Extension specialists from Brazil and other Latin American Countries have introduced the principles of conservation tillage to farmers in Central America, the Caribbean and Africa.

After this successful experience FAO now wishes to focus on the Eurasian region, to assist in reducing the damage caused by traditional tillage systems and other practices that impair agricultural sustainability, and to support modern agricultural systems that promote conservation tillage for the integrated management of soils, water and plant nutrients.

## Code of Conduct

To reduce damage caused by conventional tillage and other practices that affect agricultural sustainability, greater emphasis should be placed on the benefits obtained from focusing on modern agriculture which promotes the integrated management of soil, plant nutrients and water, based on the use of conservation tillage. In addition, it is necessary to improve the technical and administrative aspects of soil conservation programs to increase their cost effectiveness (Benites, 1997).

Elaboration of a code of conduct, with support from governments, at a world-wide level, will encourage research, promotion and adoption of conservation tillage. This can contribute enormously to define and clarify the necessary actions and responsibilities of different governmental and non-governmental actors involved in development, production, distribution, sales, financial activities, technical support, maintenance, and the use of tillage equipment and inputs.

To put the code of conduct into practice in order to promote the adoption of tillage practices acceptable from an environmental point of view, it is recommended to prepare guidelines on how to overcome the numerous factors that impede the widespread adoption of conservation tillage and other conservationist management practices by farmers, together with recommendations of required actions and responsibilities on the part of governments, the private sector and farmers (Benites, 1997).

The guidelines should also deal with problems of sale, distribution and supply of equipment and inputs, service structures for the repair and maintenance of equipment, financial mechanisms for producers, particularly for small ones, and the provision of information, technical advice and training.

Also needed are guidelines on the selection of conservation agriculture practices and improved soil management. These practices would be based on success stories of long-term tillage and conservation practices on commercial crops, such as those which are being implemented in the southern states of Brazil, which were achieved through the development of a strong integration among government, industry and progressive farmers' organizations.

It is equally important to formulate rules leading to legislation on soil conservation which could include:

- the inspection of tillage, soil management and conservation practices;
- procedures to organize training courses for operators of agricultural machinery to make them aware of the special features of conservation agriculture;
- warning programs and restrictions on the use and sale of inadequate agricultural equipment or of equipment causing soil degradation problems.

**National Programs of Conservation Tillage (NAPCOT)**

To put the code of conduct into practice, it is also recommended that a NAPCOT be prepared. National and private institutes for research, extension and the promotion of soil management and water conservation, plus farmer representatives, should review previous activities on the planning and development of national strategies concerned with the prevention and rehabilitation of degraded soils, research and technology transfer programs on conservation tillage and other conservationist practices, and the identification of ways to improve the present situation by supporting, rather than competing with, other ongoing programs (Benites, 1997).

It is also suggested that NAPCOTs compile success stories about the long-term use of conservation tillage for commercial crops as in the case of the southern states of Brazil, where success was achieved through the strong integration among government, industry, conservation organizations and progressive farmers. These successful experiences could serve as examples for producing and publishing guidelines on conservation tillage and improved soil management.

FAO has had for long time intensive contacts with national and regional networks on conservation tillage in Latin America. It has been promoting the adoption of technologies on field as well as on policy level and has given support to the exchange of information and experiences. After years of very slow development the conservation agriculture movement has reached in many Latin American countries exponential growth rates. Although it is still far from being the dominant farming practice all over the continent, it has proven to be attractive and practical and it has overcome in many countries a critical mass from where it will grow by itself.

As a further step FAO has moved to Africa, where in 1998 a workshop was organized in Harare, Zimbabwe, to create awareness and interest for conservation agriculture in Africa. As a consequence of this workshop a number of countries has started to formulate, or even implement projects and policies in support of conservation tillage. The African Network for Conservation Tillage (ACT) was created to facilitate the exchange of information within and outside of Africa.

It is expected that a similar dynamic can be achieved with the workshop in Kazakhstan for the Eurasian region.

## CONCLUSIONS AND RECOMMENDATIONS

Conservation-effective tillage can make a major contribution towards increased food production and intensification of agriculture in the Eurasian region via its effects on soil as rooting-medium and water storage. However, the agronomic and economic performances of tillage are extremely location-specific. Therefore, to be successful, a conservation-effective tillage program needs to be flexible enough to be adapted to a variety of economic, geographic, and land-use variables depending on scale, climate and preferences of the farmer in each specific location.

Research on conservation-effective tillage without an adequate interpretation of the soil and climate conditions where the research was conducted would severely limit the potential applicability. Local information on soil and climatic constraints should therefore be included in the diagnosis, design or improvement of conservation-effective tillage.

There are many ongoing investigations on conservation-effective tillage in various countries with similar financial resources available for research and development. Networking appears to be an appropriate operational model to meet the shortage of on-site trained personnel and the high operational costs and logistic problems of technology transfer. A concerted validation and extrapolation effort across the main agro-ecological zones will not only encourage interaction among participating institutions but also identify refinements and modifications, which should be pursued to improve existing tillage operations. While it is not anticipated that tillage expertise in national institutions will be fully implemented merely by participation in a network, it is fitting to consider supportive measures to ensure that experiences gained in the network are maintained and used in future national research endeavors. An important prerequisite for such an approach is therefore the development of country programs with adequate funding which could be supported by external inputs.

Greater effort must be directed to planning research programs embracing problems of interaction among soil, climate and management of crop residues in the tropics, in particular the semi-arid areas. Concurrently the development of simple tools within the financial reach of small-scale farmers could contribute to the adoption of proven technologies.

Elaboration of a code of conduct, with support from governments, at a world-wide level, will encourage research, promotion and adoption of conservation tillage. To put the code of conduct into practice it is recommended that a National Programs of Conservation Tillage (NAPCOT) be prepared during a national forum.

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Table 1. Area (ha) under no-tillage in various countries during three decades.

| Country | 1973/74 | 1983/84 | 1996/97 |
|---|---|---|---|
| USA | 2,200,000 | 4,800,000 | 19,400,000 |
| Canada | - | - | 6,700,000 |
| United Kingdom | 200,000 | 275,000 | - |
| France | 50,000 | 50,000 | - |
| The Netherlands | 2,000 | 5,000 | - |
| Japan, Malaysia, Sri Lanka | 200,000 | 250,000 | - |
| Australia | 100,000 | 400,000 | 1,000,000 |
| New Zealand | 75,000 | 75,000 | - |
| Brazil | 1,000 | 400,000 | 6,500,000 |
| Argentina | - | - | 4,400,000 |
| Mexico | - | - | 490,000 |
| Paraguay | - | - | 500,000 |
| Uruguay, Chile, Bolivia | - | - | 250,000 |

Source: Derpsch, R. 1999

# ANNEX 1

**Table 1 Area of major soil constraints in Selected Asian and European countries (FCC criteria)**

| Country | Total Area | Hydro-morphy | Low CEC | Aluminum Toxicity | Vertic Properties | Salinity | Natric | Shallow-ness | Erosion Risk | Soils without major constraints |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1,000 km² | % | % | % | % | % | % | % | % | % |
| Afghanistan | 649.5 | 0.4 | 6.3 | 0.0 | 0.0 | 5.7 | 0.8 | 33.4 | 21.5 | 27.3 |
| Armenia | 29.8 | 0.7 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 57.7 | 34.7 | 55.5 |
| Azerbaijan | 86.3 | 10.3 | 0.0 | 0.0 | 0.0 | 4.2 | 1.9 | 17.7 | 13.6 | 63.0 |
| Belarus | 206.9 | 36.9 | 0.3 | 3.8 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 51.3 |
| Georgia | 69.6 | 6.2 | 0.0 | 11.5 | 0.0 | 0.0 | 0.0 | 32.5 | 34.7 | 46.2 |
| Iran | 1643.3 | 1.5 | 0.0 | 0.1 | 0.1 | 14.7 | 2.3 | 22.0 | 19.8 | 22.6 |
| Kazakhstan | 2714.6 | 8.6 | 0.0 | 0.0 | 0.0 | 7.9 | 39.5 | 14.2 | 2.9 | 22.3 |
| Kyrgyzstan | 198.3 | 0.8 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 53.8 | 28.3 | 22.9 |
| Moldova | 33.6 | 14.9 | 0.0 | 0.0 | 0.0 | 21.4 | 5.6 | 0.0 | 0.6 | 78.3 |
| Russian Federation | 17043.8 | 31.7 | 0.0 | 4.6 | 0.0 | 0.4 | 3.4 | 12.7 | 18.5 | 45.0 |
| Tajikistan | 143.1 | 3.3 | 0.1 | 0.0 | 0.0 | 4.6 | 0.0 | 47.5 | 25.9 | 25.8 |
| Turkey | 777.9 | 1.8 | 0.0 | 5.2 | 2.0 | 1.1 | 0.0 | 24.2 | 33.6 | 48.4 |
| Turkmenistan | 486.6 | 3.1 | 2.3 | 0.0 | 0.0 | 14.9 | 4.2 | 7.2 | 1.4 | 6.7 |
| Ukraine | 601.9 | 12.8 | 0.0 | 2.5 | 0.0 | 0.8 | 16.3 | 0.4 | 3.8 | 75.5 |
| Uzbekistan | 446.1 | 8.7 | 0.0 | 0.0 | 0.0 | 14.0 | 10.2 | 8.7 | 3.0 | 15.9 |
| Total | 25131.3 | 23.5 | 0.2 | 3.4 | 0.1 | 2.9 | 7.4 | 14.4 | 16.5 | 40.1 |

(Column headers "Hydro-morphy" through "Soils without major constraints" are grouped under "Soil constraint".)

**Table 2. Land degradation: severity of human-induced degradation for selected Asian and European countries**

| Country | Total area | None | Light | Moderate | Severe | Very severe | Cause | Type## |
|---|---|---|---|---|---|---|---|---|
| | '000 km² | % | % | % | % | % | | |
| Afghanistan | 649.5 | 4.9 | 11.5 | 55.5 | 19.5 | 8.2 | O | W |
| Armenia | 29.8 | 0.0 | 34 | 83 | 100.0 | 0 | A | W |
| Azerbaijan | 86.3 | 2.9 | 31 | 13 | 94.4 | 0 | A | C |
| Belarus | 206.9 | 0.1 | 38 | 56 | 6.4 | 0 | A,D | P,W |
| Georgia | 69.6 | 17.1 | 60 | 18 | 29.1 | 0 | A | C, W |
| Iran | 1643.3 | 7.8 | 5.7 | 28.2 | 40.9 | 17.1 | V,O,D | W,C,N |
| Kazakhstan | 2714.6 | 52.5 | 23 | 49 | 78.1 | 2 | D, O | N, W |
| Kyrgyzstan | 198.3 | 36.3 | 75 | 0 | 9.8 | 0 | O, (A) | W, (C) |
| Moldova | 33.6 | 0.0 | 0 | 0 | 99.7 | 1 | D | W |
| Russian Federation | 17043.8 | 51.6 | 31 | 33 | 80.5 | 4 | D, A | W |
| Tajikistan | 143.1 | 83.1 | 0 | 13 | 10.7 | 0 | A | C, W, (N) |
| Turkey | 777.9 | 0.7 | 0 | 0 | 69.4 | 30 | O,D,A | W, N, P |
| Turkmenistan | 486.6 | 74.6 | 1 | 29 | 31.6 | 4 | A | C, P |
| Ukraine | 601.9 | 1.4 | 1 | 22 | 64.5 | 27 | A, (I) | W, C |
| Uzbekistan | 446.1 | 75.2 | 5 | 24 | 44.4 | 0 | A | C, P |
| **Total** | **25131.3** | **45.0** | **23.6** | **33** | **71.7** | **6.0** | | |

| # | ## |
|---|---|
| A: agriculture | W: water erosion |
| O: overgrazing | C: chemical deterioration |
| V: overexploitation of veg. | N: wind erosion |
| D: deforestation | P: physical deterioration |

**Table 3. Deserts and dryland areas per selected Asian and European country.**

| Country | Total area ('000) km² | Desert | Drylands | | | |
|---|---|---|---|---|---|---|
| | | Hyperarid (lgp 0 days) | Arid (lgp 1-59 days) | Semi-arid (lgp 60-119 days) | Dry subhumid (lgp 120-179 days) | Total area of drylands ('000 km²) |
| | | % | % | % | % | % |
| Afghanistan | 649.5 | 20.5 | 25.3 | 53.5 | 0.7 | 79.5 |
| Armenia | 29.8 | 0.0 | 0.0 | 88.3 | 11.7 | 100.0 |
| Azerbaijan | 86.3 | 0.0 | 0.0 | 31.0 | 49.8 | 80.8 |
| Belarus | 206.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Georgia | 69.6 | 0.0 | 0.0 | 2.9 | 32.6 | 35.5 |
| Iran | 1643.3 | 38.8 | 13.5 | 41.4 | 4.9 | 59.9 |
| Kazakhstan | 2714.6 | 0.0 | 55.9 | 33.4 | 7.7 | 97.0 |
| Kyrgyzstan | 198.3 | 8.8 | 4.8 | 66.2 | 13.5 | 84.5 |
| Moldova | 33.6 | 0.0 | 0.0 | 1.5 | 80.4 | 81.8 |
| Russian Federation | 17043.8 | 0.3 | 2.1 | 54.8 | 39.6 | 96.5 |
| Tajikistan | 143.1 | 7.8 | 28.0 | 55.2 | 1.7 | 84.9 |
| Turkey | 777.9 | 0.0 | 0.3 | 64.5 | 20.8 | 85.7 |
| Turkmenistan | 486.6 | 3.0 | 48.8 | 34.1 | 0.4 | 83.4 |
| Ukraine | 601.9 | 0.0 | 0.0 | 20.6 | 23.2 | 43.7 |
| Uzbekistan | 446.1 | 7.2 | 55.7 | 27.9 | 0.5 | 84.0 |
| Total | 25131.3 | 3.6 | 11.1 | 49.6 | 29.7 | 90.4 |

**Table 4 Steeplands per selected Asian and European country.**

| Country | Total area ('000 km²) | Steep slopes 8-30% | Very steep slopes >30% | Total steeplands |
|---|---|---|---|---|
| | | % | % | % |
| Afghanistan | 650 | 34.5 | 21.3 | 55.8 |
| Armenia | 30 | 38.9 | 34.6 | 73.5 |
| Azerbaijan | 87 | 39.5 | 13.6 | 53.1 |
| Belarus | 207 | 15.7 | 0.0 | 15.7 |
| Georgia | 70 | 38.7 | 31.9 | 70.6 |
| Iran | 1643 | 31.4 | 18.9 | 50.3 |
| Kazakhstan | 2717 | 19.8 | 2.8 | 22.6 |
| Kyrgyzstan | 199 | 30.9 | 28.2 | 59.1 |
| Moldova | 34 | 32.4 | 0.0 | 32.4 |
| Russian Federation | 17044 | 30.0 | 10.2 | 40.2 |
| Tajikistan | 143 | 28.0 | 25.9 | 53.9 |
| Turkey | 779 | 51.9 | 26.9 | 78.8 |
| Turkmenistan | 488 | 17.8 | 1.4 | 19.3 |
| Ukraine | 604 | 18.9 | 1.4 | 20.3 |
| Uzbekistan | 447 | 21.8 | 3.0 | 24.8 |
| **Total** | **25141** | **29** | **10.5** | **39.6** |

## MODERN WAYS TO IMPROVE THE SYSTEM OF FARMING IN THE NEMETSKIY RAYON OF ALTAI

The first results of our research and general conclusions based on available data on soil fertility and rainfall dynamics in this zone reveal a powerful influence of the economic activity upon nature, leading it to degradation.

Humus content in soil has dropped

# TWENTY FIVE PRACTICAL LESSONS LEARNED FOR IMPLEMENTATION OF ZERO-TILLAGE IN BRAZIL

**John Landers**[1]

1. Maintenance liming of of zero-tillage (ZT) soils can be applied on the soil surface, however rates can be reduced compared to conventional tillage (CT).
2. Over-liming in surface applications leads to micro-nutrient imbalance (e.g., manganese in soybeans or zinc in maize), and appears to favor nematodes.
3. The fertilizer strategy used should aim at supplying sufficient nutrients to the system, *per se*, and not individual crops.
4. Crop rotations must contain grass summer crops for adequate biomass production.
5. Marking techniques for spraying must be adapted to the ZT situation, especially in the wet-dry tropics.
6. Phosphorus and potassium status improves under ZT and may permit reductions in the use of these nutrients.
7. On the other hand, surface crop residues sequester nitrogen when surface-applied and N rates on maize and upland rice need to be increased by 25 – 30% in the initial years of ZT use.
8. Surface-applied urea suffers high losses under ZT conditions in the tropics because crop residues may contain urease which volatilizes the fertilizer as ammonia – N side dressings should be used to reduce these losses.
9. Water economy under sprinkler irrigation varies from about 15 to 25% in tropical regions, depending on the thickness of the crop residue layer.
10. Diseases, pests and weeds should be primarily controlled by crop rotations.
11. Integration of crops and pastures in a rotation increases total income and profit for both and recuperates soil structure.
12. Application of lower rates of desiccant herbicides after the summer crop help reduce weed problems in the following summer crop – such herbicide costs could be imputed to the following crop cycle.
13. Cover crops preceding main crops reduce and sometimes eliminate post-plant herbicide requirements, e.g., early millet before soybeans.
14. Rolling of black or white oats (*Avena strigosa* and *A. sativa)* between panicle initiation and the milk stage kills the crop without recourse to herbicide - this does not function with pearl millet which tillers at different plant development stages.
15. Grazing or cutting of pearl millet before panicle initiation provokes re-sprouting and tillering.
16. Soybeans can be successfully zero tilled into degraded or native pasture providing a small tine is used (12-15 cm deep) to open the seed drop furrow space.
17. Soil cover of 70% eliminates most erosion.
18. If the timing of entry into ZT coincides with the need for heavy replacement costs of tillage machinery or tractors, considerable economy can accrue to the non-purchase of this equipment and purchase or adaptation of ZT planters and/or drills instead.

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19. Either plant immediately after desiccation (before green plants lose turgidity) or wait until the residue is dry and brittle – wilted green stalks are hard to cut and "hairpin" into the seed furrow slot; this is more a problem of systemic herbicides. Planting before desiccation is risky because if weather or breakdowns impede application until seedling emergence the extra costs or yield penalties are high.
20. Decompaction should never be necessary with adequate biomass generation – in Brazil, a heavy clay soil has been continuously zero-tilled for 27 years and tests with sub-soiling have been inconclusive.
21. In an extreme case where ZT was started without removing a hardpan, a chisel plow or sub-soiler fitted with a trash disc will leave up to 70% or more of the residue on the surface.
22. Winter frost kills summer weeds and volunteers in the sub-tropics – not so in the tropics.
23. Always use fungicide seed treatment in ZT and insecticide treatment for dry planting.
24. Weed fallow is very variable and generates low biomass – it is a last resort.
25. Slug problems can occur under tropical irrigated conditions and sub-tropic conditions with high biomass – carbaryl or other baits are effective but labor intensive. A high amount of sugar in residues may encourage slugs therefore millet may be better than maize.

# CONSERVATION AGRICULTURE IN EUROPE: A NEEDED CHALLENGE

**Luis Garcнa-Torres**[1]

The objective of this report is to briefly outline the importance of soil erosion and degradation in Europe, a key environmental problem caused by conventional agriculture, and the state of development of conservation agriculture techniques to overcome it. Discussion of the European Conservation Agriculture Federation (ECAF) objectives and activities are also indicated.

Soil erosion and degradation in Europe are key environmental and economic problems. There is an obvious interdependence between agriculture and our environment. Indeed, in the European Union, 50.5% of the total territory is agricultural with a further 27.9% wooded land. In the last decade, the EU Common Agriculture Policy (CAP) has promoted the modernization of agriculture throughout its member countries. However, this modernization has been accompanied by damaging effects to the environment. In fact, conventional agriculture, mainly characterized by straw burning and/or removal and intensive soil tillage, is still commonly used in Europe and has consistent negative effects on soil, water and air quality, global climate, biodiversity and landscape.

In Europe, soil degradation due to erosion and compaction is probably the most important environmental problem caused by conventional agriculture, seriously affecting nearly 157 million ha (16% of Europe, nearly 3 times the area of France). Average soil erosion rates per year in Europe (17 t $ha^{-1}$ $yr^{-1}$) greatly exceed the average rate of soil formation (1 t $ha^{-1}$ $yr^{-1}$). Most EU countries are affected by this problem. In the Mediterranean area, soil erosion is very severe, moderately to seriously affecting 50-70% of agricultural land. Conventional agriculture intensification (increased mechanization and plowing) over the past 50 years has contributed substantially to this trend, increasing the risk of desertification in the most vulnerable areas.

The erosion problem has a strong economic impact on the affected agricultural land, and off-site on the surrounding civil public infrastructure. Estimates indicate that erosion increases agricultural production costs by about 25% each year (53 EUR $ha^{-1}$). Further, if on-site and off-site costs are combined, the total annual cost of erosion from agriculture can be estimated at about 85.5 EUR $ha^{-1}$.

Conservation agriculture is the correct answer. Conservation agriculture refers to several practices which permit the management of soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from erosion and degradation. Conservation agriculture includes direct sowing/no-tillage, reduced tillage/minimum tillage, non-or surface-incorporation of crop residues and establishment of cover crops in both annual and perennial crops.

Generally, with conservation agriculture the soil is protected from rainfall erosion and water runoff; the soil aggregates, organic matter and fertility level naturally increase, and soil

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deformation under heavy wheel load is reduced. Furthermore, less contamination of the surface water occurs, the emissions of $CO_2$ to the atmosphere are reduced and the biodiversity consistently increases. A strong body of scientific and technological research supporting the environmental benefits and agronomic performance of conservation agriculture has been developed world-wide in the past few decades.

The economics of conservation agricultural techniques is another important factor to be considered. In conventional agriculture, tillage operations require considerably higher inputs in machinery investment and maintenance, fossil combustibles, and labor inputs as compared to conservation agriculture (especially when compared to direct sowing/ no-tillage). For example, in a non-tillage olive crop the estimated fuel saving is about 60-80 l $ha^{-1}$ and in annual crops it is 31.5 l $ha^{-1}$. Generally, conservation agriculture reduce the energy consumption and work rate of farming operations in the range of 15-50% and increase the energetic productivity (i.e., the yield output per energy input) by 25-100%.

Conservation agriculture has an increasingly prominent role to play in world agriculture as farmers seek to develop Integrated Crop Management (ICM) systems that benefit the environment and enhance farm profitability.

Unfortunately, agricultural conservation in Europe is at the moment very little developed (estimated at <1-2% of its agricultural land), far behind the countries previously mentioned. Currently, France and Spain are the two countries in Europe where these techniques are practiced the most, with about 1.0 and 0.6 million hectares of annual crops under conservation techniques in 1998, respectively. However, the validity of these methods has already been demonstrated in most other European agricultural situations.

**EU agri-environmental and conservation agriculture policies.** Many relevant EU documents clearly state the environmental problems caused by conventional agriculture and the need to look for solutions:

- Agriculture and Environment, Directorate General VI (DGVI), EU Commission
- Fifth European Commission (EC) Environmental Action Program
- Agenda 2000: Common Agricultural Policy vs. Agri-Environmental instruments
- COM (98)353 and Kyoto Protocol
- Europe's Environment: The Second Assessment (1998)
- Directions towards sustainable agriculture (1999)

To mention a few statements from theses relevant documents:

- The European Environment Agency clearly recognizes that: "soil degradation is a key environmental problem in Europe in which little development of policies or an unfavorable development of the state of the environment have occurred in the past years", and that "soil erosion/ degradation .... remain serious problems in many areas particularly around the Mediterranean".
- "The most obvious progress in reducing pressure on the environment has been made in those areas where an efficient international framework for action has been established. The absence of any such pan-European framework, for example for soil degradation, has delayed progress, even for the assessment of such problems.".
- "EU need to redefine the relationship between agriculture and environment to move towards sustainable agriculture ..." . Specific analysis/comments on environment problems derived from current agricultural practices are made on "water quality (nitrates and phosphates), land use and soil erosion and degradation, lack of effective erosion

control measures in production systems", "burning of crop residues", .....), among many other statements.

Furthermore, the widespread adoption of conservation agriculture in the last decade has been consistently increasing in several countries (e.g., USA, Canada, Brazil, Argentina, among others) but notably not in Europe. The EU greatly needs to change its agricultural technology from one that destroys its soil (conventional) to one that conserves, and even "regenerates", the soil, water and air resources (conservationist).

**The European Conservation Agriculture Federation (ECAF).** The ECAF brings together six national associations which promote among Europe's farmers the soil management "best practice" aspects of conservation agriculture. With member associations in France, Germany, Italy, Portugal, Spain and the United Kingdom, ECAF represents the interests of well over three-quarters of the European Union's cropped farmland.

ECAF objectives at the national level aim to: a) improve technology transfer to farms; b) promote agricultural and environmental policies supportive of sustainable soil management; c) improve information exchange in the research, policy and practitioner communities; and d) research, develop, evaluate and promote soil management systems to improve crop production and protection of the environment.

ECAF operates to reinforce the aims of its members at European level via: a) the principal point of contact for discussions on conservation agriculture with European policy makers. Thus ECAF will work with EU Commission, Parliament and Environment Agency officials on the design and implementation of the agri-environment provisions of Agenda 2000. b) A clearinghouse at European level to collect and spread information to farmers and agrarian technicians about conservation agriculture. c) A focus for encouraging the investigation, development, and teaching of all aspects of conservation agriculture.

ECAF undertakes the following specific activities: a) publication of bulletins, newsletters, technical reports, and books; b) organization of international workshops, seminars, congresses and training programs; c) information exchange between its member associations.; d) collaboration with other international and national organizations that have related and complementary objectives

**ECAF- LIFE-Environment Project 98-E-308.** ECAF is currently coordinating a project funded by the EU LIFE program (D.G. XI, Environment, EU Commission) to share and promote conservation agriculture knowledge between its member associations and their respective farmer audiences. This project will be developed from 2000 to 2003 with a budget of 2.8 million Euro, half from the LIFE Program and half contributed from "own sources", mainly donors and supporting members.

ECAF, as a non-profit association, is open to collaborate with any European farmers' associations, private companies and administration departments interested in promoting conservation agriculture. ECAF does not endorse any specific commercial products, or trademarks.

## CONCLUSIONS

Soil erosion and degradation and related environmental problems of agricultural land are very important in Europe. Up to now the Common Agricultural Policy has not really supported sound environment friendly agricultural practices. In the light of present technology, conservation agriculture can efficiently contribute to the solution of environmental problems across Europe's agricultural land base. These problems are basically the erosion and the loss of the production capacity of soils, the pollution of surface water, the emission of $CO_2$ and other greenhouse gases, and the progressive global warming of the atmosphere, and the loss of biodiversity. Furthermore, conservation agricultural techniques can fit into the "continuum" of different farming systems that are appropriate within the EU.

However, it should be pointed out that if farming practices are to consistently change from conventional agriculture towards conservation agriculture, farmers will need to be convinced that a new way of farming (conservation) is needed, which is quite different to their traditional or conventional methods that have been used for decades. For instance, new techniques for weed management and direct sowing need to be learnt and farm equipment has to be adapted and/or reorganized to correctly implement conservation techniques. Therefore, a tremendous effort at the administrative and technology transfer level is needed.

Agenda 2000 must become the turning point for integrating good environmental and agricultural practices into the Common Agricultural Policy, and, although it is not an easy task, this must include implementation of conservation agriculture practices in order for the reform to be effective in meeting both the economic and the environmental needs of European agriculture. Direct sowing and minimum cultivation systems are already in widespread use in North and South America and other parts of the world. ECAF can help Europe to catch up.

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# FARMERS' AND EXPERTS' OPINIONS ABOUT ZERO-TILLAGE IN WESTERN EUROPE AND NEBRASKA (USA)

**Friedrich Tebrьgge[1]**

Economic cycles are increasingly influenced by globalization, as is European agriculture. To improve competitive ability in regional and international markets, drastic measures are necessary to decrease of costs of production while maintaining soil fertility and yield. Currently in Europe, adoption of zero-tillage systems is low in spite of scientific results indicating its positive effects on the agro-ecosystem including soil conservation and income maintanence. In the USA, Canada and South America, more than 30 million ha are cultivated using zero-tillage practices.

## METHODS

Scientists, technical advisers and farmers in the European Union have formally discussed experiences and results of experiments concerning the applicability of zero-tillage crop production at the European level and in connection with an EU-financed concerted action project (AIR 3-CT 93-1464, 1994-1998). Results from four zero-tillage workshops held in Giessen (D), Boigneville (F), Silsoe (GB) and Evora (P) are available as Proceedings I-IV, a final report and a far reaching data-bank on CD-ROM.

A main emphasis of the concerted action was to carry out a survey by common questionnaire with the participation of 6 member countries of the EU and Switzerland. The aim was to record and analyze the experiences of farmers (n=111; 53,000 ha) as practitioners of zero-tillage cultural methodologies as well as the attitudes of technical experts (n=176) working in the fields of research, advice and industry (Tables 1 and 2).

Previously, farmers were surveyed by questionnaire on a national level in France, Italy and Spain (EC-Workshop Proceedings I, III, IV). The responses were largely identical with those of the colleagues from the participated 6 EU countries here, however, these results could not be taken into consideration for the interpretation because of the different structure of the questionnaire.

A separate survey of farmers (n=50; 20,000 ha) and technical experts (n=18), using the same EU-questionnaire, concerning opinions and experiences regarding the application of zero-tillage was conducted in Nebraska, USA.

## RESULTS

European Union farmers (average surveyed farm size 340 ha) and technical experts favor zero-tillage methodologies primarily due to agronomic advantages, with reductions in working time (98%), costs (98%), fuel consumption (86%) and horse power requirement (79%), and a higher trafficability (88%) cited as very important (Figure 1).

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Motives concerning soil and environmental amelioration due to zero-tillage practices were of less importance for the farmers, according to a frequency of 50% or less for arguments such as reduced soil erosion, higher soil biological activity, increased earthworm populations, improved water conservation, reduced nitrate leaching and a higher infiltration rates. Technical experts rates these motives higher (61-88%). This is nearly the same level which was given to agronomic motives by the experts, however they valued a reduction in work time most highly (97%).

Motivation by farmer in Nebraska to adopt zero-tillage practices is in contrast to their EU counterparts, with a greater emphasized on soil and environmental criterions such as improved water conservation, improved soil structure, reduced erosion, reduced nitrate leaching and higher organic matter content. The Nebraska technical experts' answers concerning these criteria were largely identical to those of the Nebraska farmers, as well as to the EU technical experts (Figure 2). Only Nebraska farmers rated higher profit as a decisive motive (93%) for application of zero-tillage systems.

The experiences and opinions concerning the influence of zero-tillage on the change of inputs of fertilizer, herbicides, fungicides and other plant protection (e.g., against slugs and mice) compared with conventional tillage packages differed greatly, especially in case of herbicides. Whereas the majority of the farmers (64%) estimate a herbicide input of the same or decreased level, 70% of all experts suggest that an increased input will be required. Levels of application of all other pesticides, as well as nitrogen fertilizer, at levels of usage similar with conventional tillage practices, are given with a high frequency by the EU-experts (65%) and the EU-farmers (80%) (Figure 3). Whereas 2-18% of the farmers' naming apportion on an increase and 8% on a decrease of agrochemicals with the exception of herbicides, in dependency of the products 27-43% of the EU-experts are of the opinion, that no-tillage is in comparison to conventional tillage connected with an increased use of agrochemicals.

A comparison of the answers of the EU farmers with farmers from Nebraska leads to a diametrical picture concerning the input of herbicides. Whereas 56% of the EU-farmers give an unchanged input, the zero-till farmers from Nebraska answered to the contrary with herbicide input being unchanged (34%), decreased (6%) or increased (57%) through use of zero-tillage practices.

Concerning the affect of zero-tillage on crop yields, there are as well visible differences in the assessment. Fifty four percent of farmers estimate that yield will remain unchanged, while 21% predict decreased and 22% increased levels. Technical experts believe that crop yields will remain unchanged 36%), increase (12%), or decrease (47%) with long-term application of the no-tillage system (Table 3).

The technical experts expect that yields of leguminous crops will remain unchanged (62%) or increase (69%) under no-tillage conditions in comparison to conventional tillage. The technical experts also anticipated decreased sugar beet, rapeseed and maize yields under zero-till conditions.

This topic has been investigated by the Justus-Liebig-University (JLU) in Giessen since 18 years on five differing pedogenetic locations. These results, and literature concerning yields obtained from zero-tillage across European level, suggest that these expert opinions are pessimistically negative, and are not congruent with most of the zero-tillage farmers' experiences.

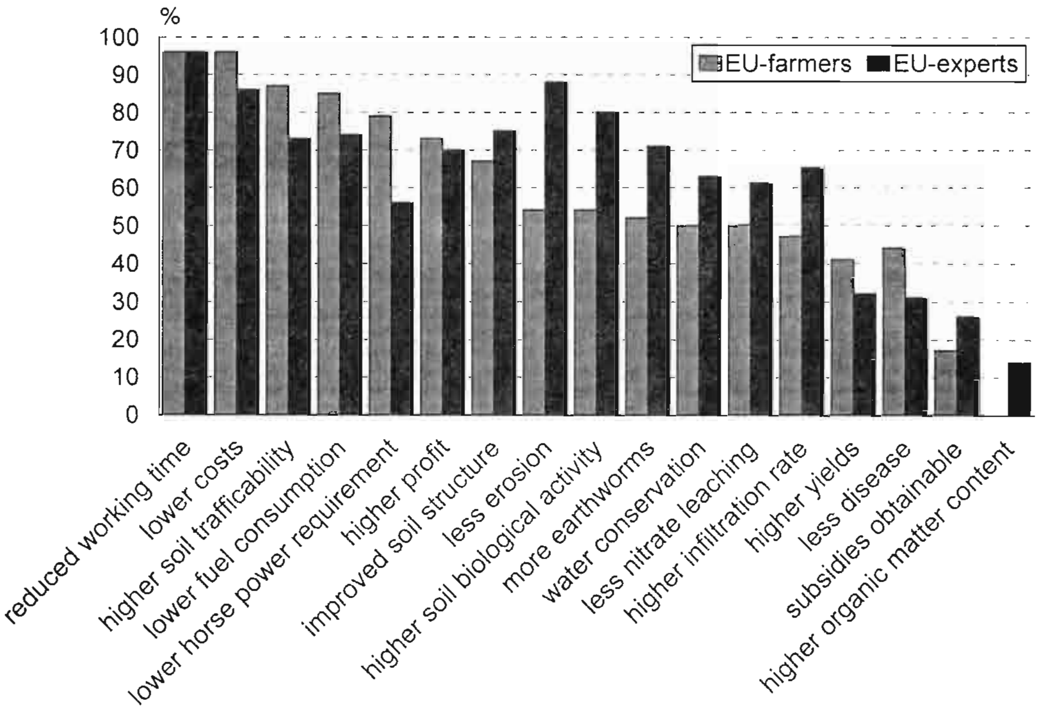


**Figure 1. Structure of motivation of no-tillage farmers and experts in the EU concerning application of no-tillage.**

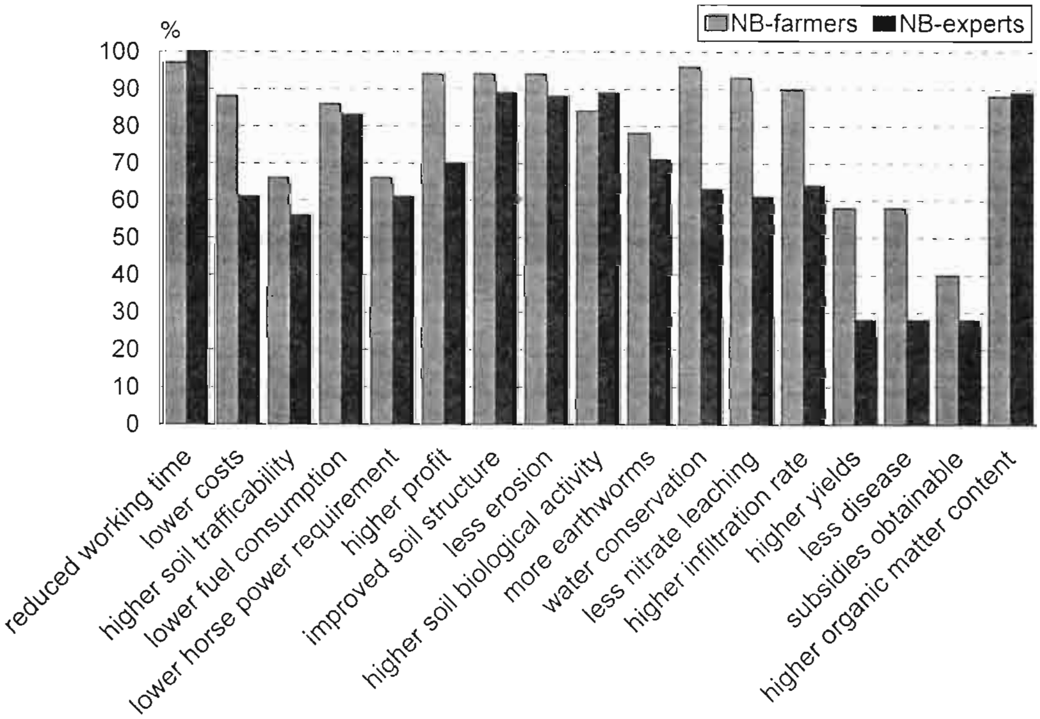


**Figure 2. Structure of motivation of no-tillage farmers and experts in Nebraska (NB), USA concerning application of no-tillage.**

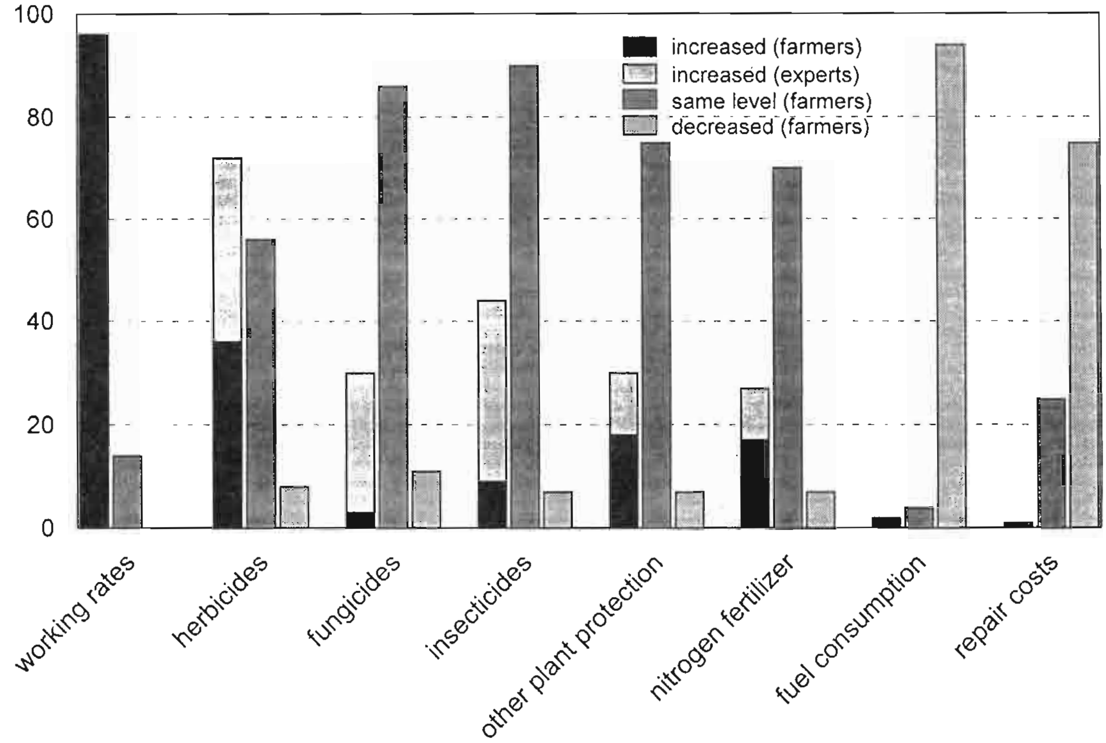


**Figure 3. Change of input in case of no-tillage in comparison to conventional tillage.**

Reasons given by farmers for the relatively low acceptance of zero-tillage practices indicate insufficient advice (73%), insufficient experience (65%) and high equipment purchase costs (61%) as primary constraints. With a decreasing frequency (56-50%), fear of reduced yields, problems with weeds, higher management requirements and a lack of analysis of the production costs were also cited as constraints by farmers (Figure 4).

In contrast, expert considered constraints to relatively low acceptance of zero-tillage involving reduced yields (93%), insufficient knowledge by the farmers (88%), and higher production risks (85%) as arguments why farmers not to adopt zero-tillage practices. Arguments considered of lesser constraint included insufficient analysis of production costs (76%), higher equipment purchase costs (73%), insufficient technique (68%), insufficient scientific results (65%) and the lack of economic necessity (62%) (Figure 5).

Nebraskan technical experts revealed a different evaluation in the structure of motivation. They considered priority constraints to adoption including tradition, fear of reduced yields and high equipment purchase costs (72% on average). Of moderate constraint were issues such as reputation of neighbors and acceptance by landlords (56%). Insufficient scientific results (33%) as well as insufficient techniques (22%) were in comparison to the EU-experts (68%) only a secondary role.

EU farmers believed that the long-term effects of zero-tillage systems would increase (54%), remain unchanged (39%) or decrease (7%) income levels versus conventional tillage systems. Their Nebraska counterpart, generally with more experience in zero-tillage use, assess the influence on the income more optimistically with 83% anticipating increased, and 17% anticipating unchanged levels of income.

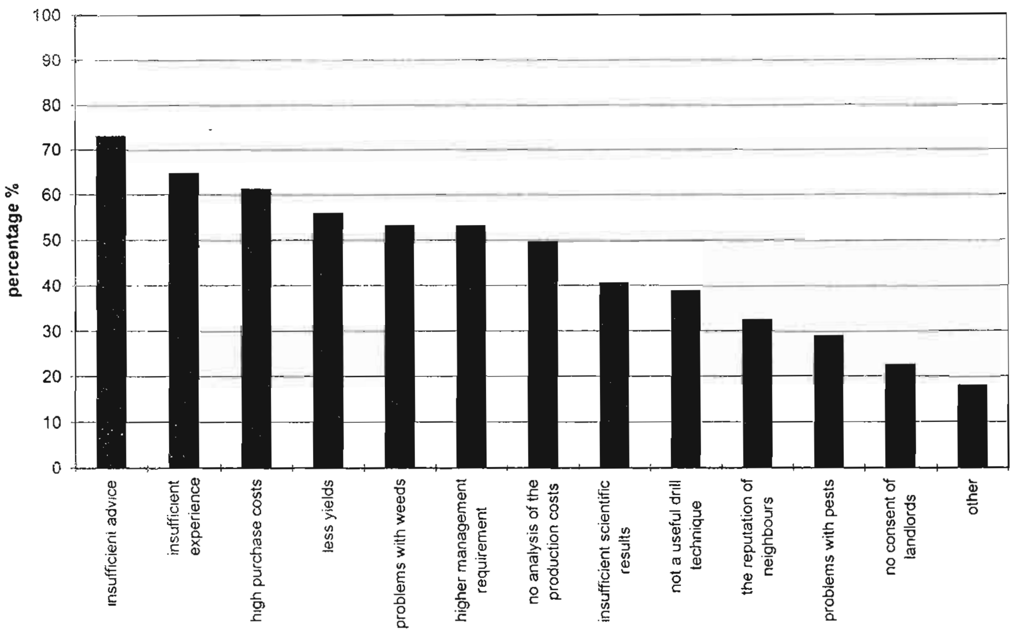


**Figure 4. Important arguments for other farmers not to use no-tillage Farmers' answers, percentage [%] of all farmers' replies.**

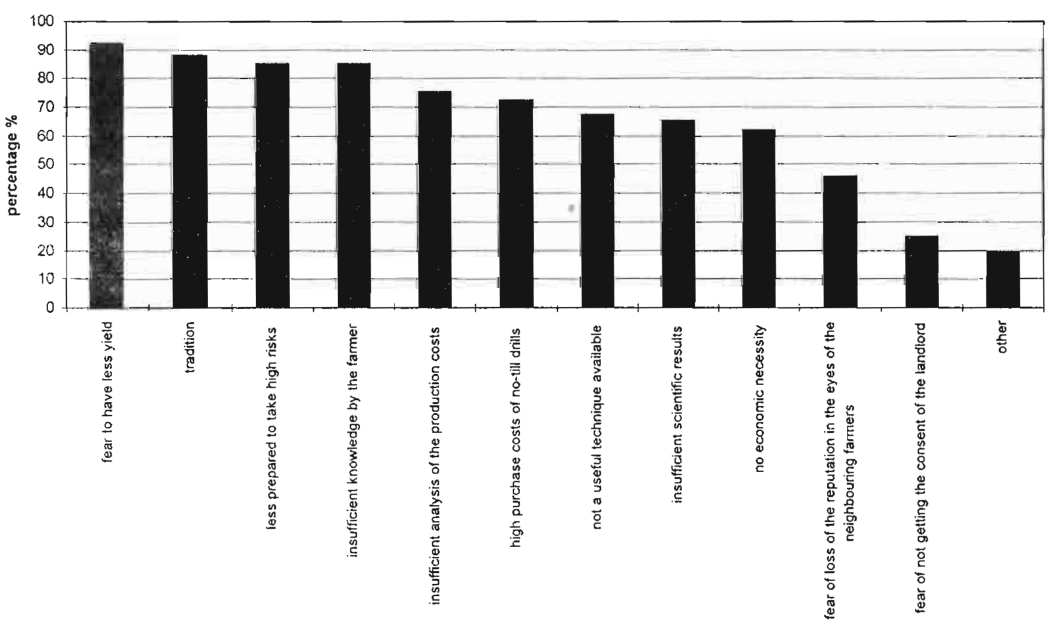


**Figure 5. Important reasons for the relatively low acceptance of no-tillage Experts' opinions, percentage [%] of all experts' replies.**

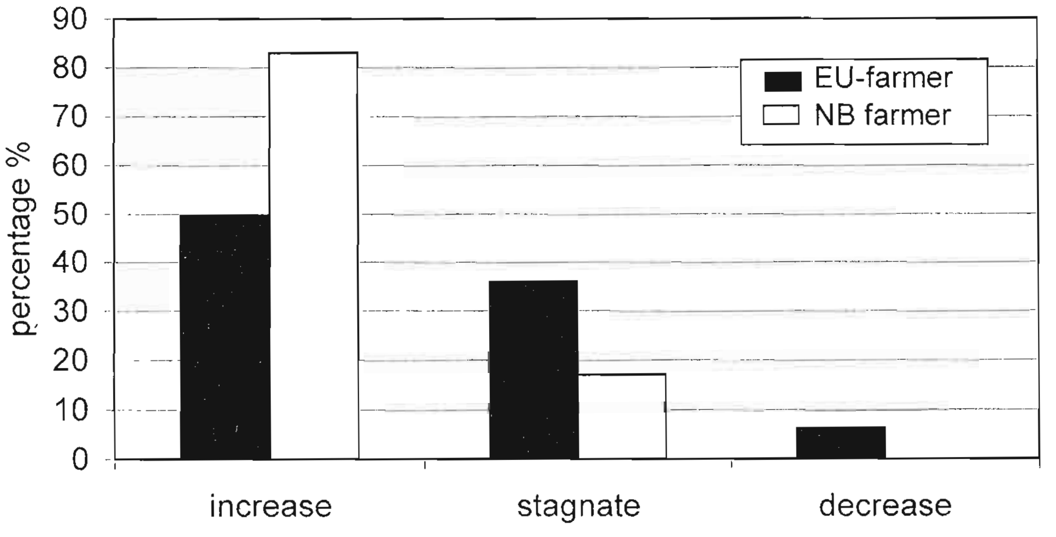


**Figure 6. Anticipated changes by farmers in income with long-term application of zero-tillage practices.**

The EU technical experts estimated 34% of the arable land in their countries, approximately 23 million ha, would be suitable for zero-tillage crop production. The Nebraska technical experts estimated 75% of arable cropland in Nebraska, approximately 6 million ha (Table 4) would be suitable for zero-tillage practices.

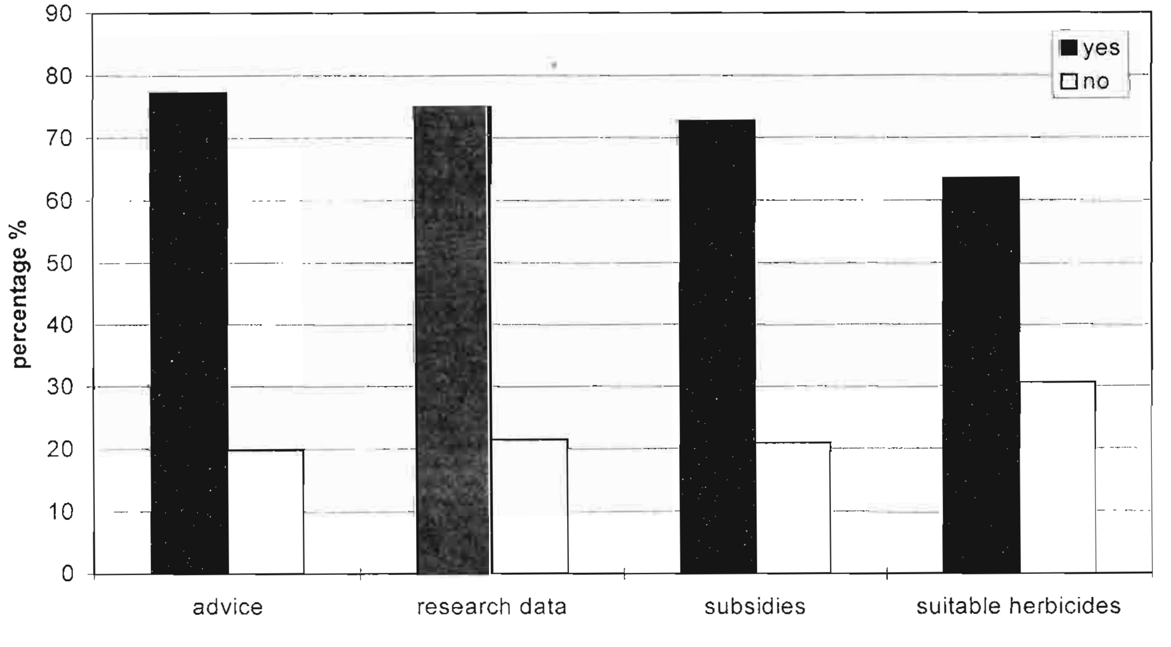


**Figure 7. More farmers would adopt zero-tillage if greater advice, research data, subsidies or suitable herbicides were available, as determined by expert opinions.**

Technical experts believed that farmers could be encouraged to use zero-tillage if greater extension advice, stronger confirming research results were available, increased subsidies were paid, and more suitable herbicides were recommended (Figure 7).

## CONCLUSIONS

Farmers in Europe and Nebraska consider the most important factors for successful adoption of zero-tillage to include reduced production costs and working hours. Awareness of greater sustainable utilization of soil and environment were also important issues. Obstacles for the widespread adoption of zero-tillage practices included higher management requirements, insufficient advice and experience with the new techniques, higher costs for seeding equipment and the fear of lower yields.

Technical experts working in the field of rural extension and research were more negative regarding zero-tillage adoption constraints, as compared with zero-tillage practicing farmers. Although they agreed on the ecological and economical benefits of zero-tillage, the so-called experts expect increased problems with weeds, diseases and pests, soil compaction and lower yields. For them the main reasons for the low acceptance of zero-till by the farmers are the fear of lower yields, maintenance of traditional methods, insufficient technical knowledge and analysis of the real production costs.

The contradiction between research results and the opinion of "experts" and farmers indicates that it is necessary to overcome the apparent impediments for the adoption of zero-till in order to achieve the goal for a reduction of environmental pollution and increase of the production efficiency.

## ACKNOWLEDGEMENTS

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**Table 1. Basis dates of no-tillage farms in the EU (n=111) and Nebraska, USA (n=50).**

| | | | Cultivation structure of crops in % of the arable land | | | |
|---|---|---|---|---|---|---|
| | AF-ha | % NT | Cereals | Maize | Legumes | other |
| **Switzerland** | 20 | 33 | 46 | 16 | | 38 (sugar beets/rape/potatoes.) |
| **Germany** | 394 | 65 | 60 | 3 | 5 | 32 (sugar beets / rape /alfalfa) |
| **Denmark** | 409 | 44 | 73 | | 2 | 25 (rape /grass/alfalfa) |
| **Britain** | 519 | 23 | 65 | | 9 | 25 (rape) |
| **Italy** | 646 | 15 | 23 | 20 | 15 | 42(sugar beets /sunflowers) |
| **Netherlands** | 14 | 25 | | (75) | | 25 (potatoes) |
| **Poland** | 380 | 30 | 63 | 8 | | 30(sunflowers) |
| **USA-NB** | 397 | 69 | 8 | 50 | 34 | 13(Sorghum/alfalfa) |
| ***∅EC*** | *340* | *34* | *58* | *12* | *8* | *( sugar beets or rape ca.20%)* |

**Table 2. Basis dates of the experts (%) (EU n=176, USA-NB n=18).**

| | | Experts' fields of work | | | |
|---|---|---|---|---|---|
| **Advice** | **Science** | **Industry** | **Other** | | |
| 52 | 26 | 7 | 15 | | |
| | | **Experts' areas of competence** | | | |
| **Soil Tillage** | **Crop Production** | **Engineering** | **Fertilization** | **Plant Protection** | **Economy** |
| 57 | 47 | 42 | 29 | 22 | 21 |
| | | **Sources of experts' experience** | | | |
| **Literature** | **Own Experience** | **From Farmers** | **From Colleagues** | **Own Scientific Research** | |
| 73 | 59 | 54 | 36 | 35 | |

**Table 3. Farmers' experience and experts' opinion in EU countries about yield effected by no- and conventional tillage.**

| | Farmer | Expert | Farmer | expert | Farmer | expert |
|---|---|---|---|---|---|---|
| Yields: | Decrease | | Unchanged | | Increase | |
| **Cereals** | | | | | | |
| **% of answers** | 18,7 | 37,9 | 69,2 | 49,7 | 12,1 | 12,4 |
| yield % | 12,9 | 11,2 | +/- 0 | +/- 0 | 12,4 | 10,7 |
| Maize | | | | | | |
| % of answers | 27,0 | 35,7 | 32,4 | 35,7 | 40,5 | 11,9 |
| yield % | 20,7 | 14,7 | +/- 0 | +/- 0 | 19,6 | 13,2 |
| winter-rape | | | | | | |
| % of answers | 31,8 | 57,8 | 50,0 | 35,9 | 18,2 | 6,3 |
| yield % | 13,9 | 13,3 | +/- 0 | +/- 0 | 13,3 | 13,3 |
| Leguminosae | | | | | | |
| % of answers | 16,2 | 30,8 | 65,2 | 46,0 | 16,7 | 23,1 |
| yield % | 18,6 | 14,5 | +/- 0 | +/- 0 | 12,5 | 11,7 |
| sugar beets | | | | | | |
| % of answers | 10,0 | 74,0 | 60,0 | 15,5 | 30,0 | 10,3 |
| yield % | 13,9 | 17,2 | +/- 0 | +/- 0 | 10,0 | 11,0 |
| ***TOTAL*** | | | | | | |
| % of answers | 21,2 | 47,2 | 54,2 | 36,6 | 23,5 | 12,8 |
| yield % | 14,2 | 14,2 | +/- 0 | +/- 0 | 13,6 | 12,0 |

**Table 4. Percentage of arable land suitable for no-tillage crop production, assumed by experts.**

| Nationality | Arable land[1] ('000 ha) | Arable land suitable for no-tillage (%) | Arable land suitable for no-tillage ('000 ha) |
|---|---|---|---|
| **CH** | | **49.0** | |
| **D** | **11,805** | **37.1** | **4,381** |
| **DK** | **2,510** | **44.0** | **1,104** |
| **E** | **13,954** | **45.5** | **6,349** |
| **F** | **18,302** | **31.8** | **5,820** |
| **GB** | **5,949** | **17.8** | **1,058** |
| **GR** | **2,250** | **37.0** | **833** |
| **I** | **9,030** | **22.5** | **2,032** |
| **NL** | **899** | **26.3** | **236** |
| **P** | **2,326** | **45.0** | **1,047** |
| Total/average EU | 67,025 | 34.1 | 22,859 |
| Nebraska USA | 8,000 | 75.0 | 6,000 |

[1] **Source: Statistical Office of the European Communities (ECSC-EC-EAEC, Brussels, Luxembourg, 1996).**

# LESSONS LEARNED IN DEVELOPING AND IMPLEMENTING MINIMUM TILLAGE TECHNOLOGY WITH FARMERS IN NORTHERN KAZAKHSTAN

**Richard W. Hicks**[1]

The concept of minimum tillage has been developed throughout North and South America, Europe and Australia since the early 1970's. Considerable experience has been gained and developed under a wide range of climatic and agricultural systems. Northern Kazakhstan appears ideally suited to the introduction and wide adoption of minimum tillage. Climatic, geographic and cropping systems closely resemble those in other parts of the world, and in particular the Canadian provinces of Alberta and Saskatchewan where minimum tillage has been successfully practiced under commercial conditions for many years.

From 1992 to 1995, minimum tillage techniques were introduced and tested under Kazakh conditions, particularly in northern parts of the country. From practical experimentation and experience, some application rates and practices required modification to suit local Kazakh conditions. However, excellent results were obtained throughout the areas cultivated using minimum tillage, with both economic savings and crop yield benefits achieved.

This paper notes practical lessons learned (e.g., most effective chemical rates, admixtures and application timing), and constraints to the wider adoption of minimum tillage in Kazakhstan.

## Cropping Systems in Northern Kazakhstan

The majority of the cropping areas of northern Kazakhstan were developed as a result of the "Virgin Lands" programs of the 1950's. The prevailing system was based on mono-culture wheat/fallow rotations. Multiple deep fallow cultivations (often 6-8 cultivations at 15-25cm per season) were followed by the planting of one or two subsequent years of spring wheat or spring barley. Hybrid maize (cut for cattle fodder or silage), alfalfa, sunflower, sugarbeet or chickpeas were also (rarely) cultivated. Roadside verges and uncultivated fields were grazed by cattle and sheep (supervised by cowboys/shepherds), and meadow hay was cut and "loose-carted" from the field back to the animal barns and stacked for animal feed during the long winter period.

Cultivation implements included deep blade plows, mould-board plows and off-set disc plows. Planting was undertaken using tyned planting machines, generally comprised of 4-5 independent units assembled into one unit pulled by a K700 or K701 tractor. Tractors with tracks (rather than wheels) were also used for both planting and cultivation operations.

In northern Kazakhstan, wheat planting is generally undertaken from mid- to late-May. Successful planting and early crop establishment is dependent on soil moisture conditions at planting. Spring rains are generally light and unreliable, and significant falls often only occur from mid-June onwards. A pre-plant cultivation was generally necessary for weed control, but resulted in significant soil moisture loss. Snow moisture conservation techniques were developed to retain as much snow-melt precipitation as possible (e.g., snow ridging/plowing

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and planting widely-spaced rows of rapeseed across fallow fields in summer to act as a snow trap barrier). Snow trapped by these techniques significantly added to the spring, pre-plant soil moisture status.

Harvest generally commenced in mid-August for four weeks duration. Early onset of frost and snows severely reduced both grain quality and harvest duration.

In recent years, the productivity and profitability of wheat production in Northern Kazakhstan has dramatically declined, as farms are unable to finance (or source) essential production inputs, including fertilizers, fuel and lubricants, pesticides, spare parts and replacement of machinery. From 1993, farmers have been forced, due to economic and input constraints (eg, shortage of fuel and lubricants, and spare parts to repair the fleet of aging tractors and agricultural implements) to reduce the number of fallow cultivations. This has lead to a proliferation of annual and perennial weeds. In both the fallow and crop situation, weed spectra and density has dramatically and significantly increased since 1993, as farms have been forced to reduce herbicides applications and cultivations for weed control. Annual and perennial sowthistle has become so widespread that many fields of Kazakh wheat resemble cotton fields when the sowthistle seed formation begins!

In addition, wild oats (which had previously been successfully controlled using triallate (e.g., Avadex BW® applied pre-plant then incorporated) has became prevalent and widespread. Most common weeds found in cereal and fallow fields in northern Kazakhstan include:

| **Latin Name** | **Common name** | **Сорняки** |
|---|---|---|
| *Sonchus arvensis* | Sowthistle | осот |
| *Agropyron repens* | Couch | пырей |
| *Avena fatua* | Wild oats | овсюг |
| *Amaranthus retroflexus* | Amaranthus | щирица |
| *Polygonum convolvulus* | Wild buckwheat | гречишка татарская |
| *Convolvulus arvensis* | Bindweed | вьюнок |
| *Festuca ovina* | Green fescue | овсяница |
| *Chenopodium album* | Lamb's quarters | марь белая |
| *Euphorbia* spp. | Spurge | молочай |
| *Lactuca taraxacifolia* | Wild lettuce | молочай татарский |
| *Artemisia vulgaris* | Mugwort | полынь |
| *Acroptilon repens* | Russian knapweed | горчак |
| *Phragmites communis* | Phragmites/cane | тростник |
| *Salsola ruthenica* | Russian thistle | солянка, курай |

Average wheat yields since 1993 have declined from 1.5-2.4 t $ha^{-1}$ to 0.4-0.8 t $ha^{-1}$. Farm profitability has declined accordingly.

Most former State Farms are now financially bankrupt, due in a large part to "paper" debts accumulated during the chaotic period from 1992-1994, when they were forced to deliver grain to fulfil national wheat quota requirements, but never received financial compensation from the federal government. Farms which should have been financially viable were, in reality, raped by the federal system and inconsistent, nepotistic and corrupt officials and policies (e.g., state production quotas, export license restrictions, etc.). Farms were forced to sell wheat to opportunistic "businessmen" at below international prices (e.g., US\$30-35 $t^{-1}$).

## Minimum tillage in northern Kazakhstan, 1992-1995

In Kazakhstan, multiple cultivations can be replaced by minimum tillage where weed control is accomplished through application of broad-spectrum systemic herbicides. Deep tillage implements can be replaced by shallow cultivations using tyned implements, resulting in significant reductions in tractor draught, fuel requirements and damage to soil structure. Additional saving can be made in tractor repairs, as tractors are required to work less tractor hours each season.

In 1992, Monsanto Agricultural Group established a team of professional agricultural research and extension staff to introduce and promote the adoption of minimum (conservation) tillage in Kazakhstan. In association with Dzhambul Khimprom, an "agro-center" based at Georgievka rayon, Dzhambul Oblast incorporating 6 farms and 15,000 ha was established. In 1993, a second "agro-center" based at Sergeevka Rayon, North Kazakhstan Oblast incorporating portions of 6 former State Farms and a total area of 20,000 ha was established. However, due to lack of government and farms financial input, both "agro-centers" were phased down after only one year of operation.

Monsanto, in cooperation with KazNIIZh and KazNIIZR, also financed and supervised the scientific evaluation of glyphosate (Roundup®) in a large range of agricultural situations and cropping systems in both Northern and Southern Kazakhstan. These results enabled registration of Roundup, and its use has expanded through refinement to suit particular Kazakh conditions.

From 1992-1995, minimum tillage demonstration and experimental areas were established throughout the principal cropping areas of Northern Kazakhstan. In addition to the 20,000 ha "agro-center" at Sergeevka, North Kazakhstan Oblast, more than 30 demonstration areas (10-20 ha each) were established on government research institutes and stations and former State Farms, viz. Kustanay (and Arkalyk), Akmola, North Kazakhstan (and Kokchetau), Pavlodar and Karaganda Oblasts. In addition, 5-7 field days and seminars were conducted annually throughout the region, with the participation of government officials from the federal and oblast ministries, senior farm personnel and agribusiness specialists.

Minimum tillage techniques widely practiced in other areas of the world were introduced and tested under Kazakh conditions, particularly in Northern Kazakhstan. From practical experimentation and experience, some application rates and practices required modification to suit local Kazakh conditions. All herbicides were imported from commercial sources in western Europe.

The "agro-centers" relied on the use of local Soviet-era tractors and equipment for cultivation/planting, but all herbicides were applied using large boom sprayers imported from Canada. These boom sprayers had a boom width of 30 m and 4,000 l capacity tank mounted on either single or dual axle chassis, and were pulled by local tractors. Demonstration areas were prepared using local equipment, and herbicides were applied using a portable trailer-mounted boom sprayer, with 8 m boom width and independent motor. Excellent results were obtained throughout the areas, with significant economic savings and crop yield benefits achieved.

**Minimum Tillage in Northern Kazakhstan, Lessons Learned**

- Three 1 $ha^{-1}$ Roundup (36% glyphosate) provides excellent control (80-85%) of most annual and perennial weeds present during the fallow phase. Application timing was critical, with best results obtained when sowthistle was 20-30 cm tall (usually mid-June).
- Better control of *Convolvulus* spp. (present in the fallow) was achieved using FallowMaster® (glyphosate + Dicamba) at 3.0 l $ha^{-1}$ or LandMaster® (glyphosate + 2,4-D at 3.0 l $ha^{-1}$.
- One (and sometime two) cultivations were important for control of later germinating annual grassy weeds (e.g., fescue). Best results were obtained by cultivation 4 weeks post-spray application.
- Addition of a sulfuron urea (e.g., Grandstar® or Glean®) to glyphosate (tank-mixed immediately prior to application) gave long-term control of later-germinating summer grassy weeds.
- Addition of Cowboy® (Russian-formulated sulfuron urea) gave wildly varying results, from good additional control to no effect.
- Control of hard-head thistle was achieved using 10.0 l $ha^{-1}$ glyphosate. Addition of Lontrel® appeared to improve control.

**Constraints to Adoption**

- Inadequate local equipment. Local boom sprayers were unsuitable due to small (metal) tank capacity, narrow boom width, lack of boom height adjustment and boom stabilizers, unmatched (generally worn brass) nozzles, leaky hoses/joints, difficulty to adjust pump pressure and no foam markers.
- Lack of farmer expertise and extension systems. Farmers were impatient for results, and often cultivated fallow soon after spraying (reluctant to wait for glyphosate to control weeds).
- Farms are (technically) financially bankrupt and operationally non-viable.
- Farms were forced to sell wheat to opportunistic "businessmen" at below international or production prices.
- Inconsistent, nepotistic and corrupt officials and policies.
- Need for acceptable collateral and land ownership policies to enable farms to source credits for sector development.
- Reluctance on the part of some research scientists to endorse/promote minimum tillage.

# INVESTING IN CONSERVATION TILLAGE: CHALLENGES AND OPPORTUNITIES

**Francois Dauphin**[1]

There are important benefits to be expected from adopting conservation tillage (CT) principles in the CIS region, for farmers as well as for national economies and for the environment. This is attested by a number of large-scale successes, some of which relate to regions ecologically close to Central Asia (Srivastava and Meyer, 1998). However, many other countries have had more limited success. In CIS countries, there has been little progress on this front and possibly some back-tracking, partly because of the collapse of support institutions and because CT had been imposed rather than convincingly demonstrated to farmers (Libert, 1995). Analyzing lessons of other countries should provide clues on the key ingredients that can make strategies successful.

There are long lists of factors that prevent adoption of conservation practices, ranging from lack of knowledge and ingrained attitudes, to non-conducive policies and tenure rights, and from inadequate public institutions to absent private sector. In Africa, the main reasons for lack of adoption of improved soil management practices can be summarized as follows (after Donavan and Casey, 1998):

- Lack of knowledge, because of poor communications, sporadic extension contacts and a weak network of farm input retailers;
- Limited resources: financial, with no access to credit, labor constraints, or insecure tenures precluding long-term investment;
- inability of farmers to bear risk;
- limited profitability, as farm conditions differ from research conditions;
- unavailability of techniques or inputs.

For the CIS countries, a World Bank study suggests the following hierarchy of constraints (Srivastava and Meyer, 1998):

**Cultural barriers**
- Reluctance to reduce plowing
- Fear of switching to a new production system

**Economic barriers**
- Initial cost of tillage machinery
- Potential increased herbicide use

**Management barriers**
- Weed management
- Pest management
- Disease management
- Residue management
- Fertilizer management
- Maintaining yields
- Soil temperature and moisture

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Each of these listings captures relevant constraints, but whereas the first list is more descriptive, the latter lends itself readily to a translation in terms of practical remedies. These need encompass awareness building, education and training, incentives, research and technology dissemination. It also rightly places the emphasis on management, and this in turn has profound implications in terms of the type of knowledge required and the way such knowledge should be disseminated.

The conditions that favor adoption of improved land management techniques have also been considered by a number of authors (see *interalia*, World Bank 1994; Srivastava 1998) and include:

- A crisis situation, recognized by farmers and the wider public. This was particularly the case for Brazil when the first World Bank/FAO Land Management Projects (in the states of Paraca and Santa Catarina) were prepared after the dramatic floods of 1983. Mobilization for better land management in Australia resulted from a widespread perception that irreversible environmental damage was occurring, which also affected farm profitability. As a result of such situations, farmers were aware of the degradation of land and were sensitized to over long-term sustainability issues; there were farmer groups debating land conservation issues and raising consciousness, and there was popular concern over some of the wider effects of land degradation (floods, water pollution, health issues);
- An existing research and technology base to build upon, including the existence of reference farms practicing alternative cultivation techniques; moreover, proposed conservation practices based on soil cover increase, bring quick visible returns to farmers, as well as environmental benefits. "Win-win" technology development and dissemination;
- Public support for conservation practices by way of credit or grants, and supportive political leaders; the costs of change are initially shared between farmers and government.

Reflecting on the successes of improved land management projects in Brazil, colleagues in the FAO Investment Center added the following favorable factors which underline the social dimension of change in practices affecting conservation:

- conservation projects should be planned in a participatory way at the scale of micro-watersheds (each of a few thousand hectares);
- public support is made available to groups, not to individual farmers.

**Reversing the Plow? - Elements of a Strategy**

It took centuries in Western Europe for the mouldboard plow to replace the antique symmetrical ploward. The transition may have started in the Roman times and, in many parts of Europe, was only completed in this century. Ensuring clean, weed-free fields and better drainage in heavy soils, the mouldboard plow had become synonymous to modern, scientific agriculture, and still is in many places. Clean fields, obtained through repeated and heavy tillage operations, were the mark of good farmers. Abandoning the plow is perceived as going back to middle-age agriculture, and relinquishing hard-gained control over nature. This perception is a real obstacle to introducing conservation tillage, and should not be underestimated. It is erroneous and must be rectified. Where the mouldboard plow was developed, soil organic matter content was high and could be maintained at a high level because of relatively high rainfall that produce large amounts of biomass, while cool temperatures slow the rate of decomposition. Carried outside its domain, the mouldboard plow has produced environmental disasters in the USA – the infamous "Dust Bowl" in the 1930s, in Africa where "modern" plantations used it carelessly in the 1950s, and in the frontier lands of Latin America and Australia. This is because intensive tillage in semi-arid and tropical climates buries crop residues, exposes the top soil, quickens the decomposition of crop residues and organic matter, and breaks the soil structure, resulting in loss of organic matter and nutrients as well as physical erosion. In the words of an Australian pioneering environmentalist (Tepper 1895, quoted by Chan and Pratley 1998):

> We plow and fallow like our European forefathers. Moreover, before doing so, we feed off all the weeds and stubble and rake them together and then burn ... leaving the soil as bare as a floor. Under the mistaken idea that it needs a rest, that weeds exhaust it, that the soil requires to be aerated ... acting on such fallacious ideas, we only succeed in converting our fields into deserts and blasting our future, for the causes which operated in reducing the 50 bushels per acre in early years to 5 at present are still acting and will reduce the 5 to less still, till not even grass or weeds will be able to exist.

In spite of this dire warning, it was only in the mid-1980s that Australia understood the real measure of the problem, recognizing land degradation as a mainstream issue, and launched movements such as "Landcare" and the "Total Catchment Management".

Placing the plow at the center stage of the debate is not to say it should entirely disappear. It still has a role in certain domains encompassing a range of agro-ecological situations as well as socio-economic circumstances and because of the latter factors, that domain is not fixed. Its use has already started to decrease and may be decreasing further in the future. Rather, singling out this tool which has been so central to European agriculture should help understand the difficulty of thinking of different agriculture techniques and of displacing the plow where its use is a threat for sustainable agriculture. Besides the complex cultural and psychological barrier, reducing the use of the plow forces changes in the whole sequence of cultural operations, as new issues of weeds, pests, disease, crop residues may occur. To take a slightly different perspective, the history of agriculture has been that of a progressive domestication and artificialization of nature. By and large, the mouldboard plow represents a culmination in that process. Conservation tillage is an effort to compose with nature rather than to dominate it; to accept and adopt CT requires a different attitude, new representations and new knowledge.

Because the change is so fundamental and pervading, it will not happen unless there is a large-scale effort, a paradigm shift which strategically addresses major obstacles to its implementation. Let us examine some elements of the needed strategy: knowledge; awareness, incentives; and policies.

## Building upon Knowledge

Conservation tillage is more knowledge intensive than many input based technologies, for the reason that there is no single solution to management issues. Managing weeds and other pests depends on knowing principles, species, and the local environments; and on being able to form diagnostic solutions to select among a range of possible alternative actions for full or partial implementation, to monitor their impact against relevant criteria, and to adjust the course of action according to the results of observation, either during the same cropping season or in subsequent cycles. Clearly, it is not sufficient to have knowledge in a research center and good mechanisms for disseminating recommendations: the knowledge has to be shared by land managers who take day-to-day decisions. There is a need to move away from 'techno-centric' extension models and to embrace 'empowerment' models as the basis for developing extension programs for landholders (Goldney *et al.*, 1995).

The concept of agricultural knowledge and information systems (AKIS) is useful to remind that the production and dissemination of knowledge involves multiple actors, including researchers, universities and advisory services, but also farmers, the private sector and NGOs. Ensuring that the whole AKIS is mobilized in pursuit of technology development for conservation farming is essential. The contribution of machinery equipment manufacturers and input companies has been crucial in North America as well as in Latin America. The mobilization and revitalization of AKIS can be obtained through competitive research grant funding. Such grants can finance awareness building and technology dissemination as well as pure research and are opened to any capable operator, whether public or private. Whether this approach is sufficient to generate sustainable networks effectively linking science institutions with traders, input supply firms, farm organizations, environmental groups etc., remains to be seen. Participatory research networks are needed for rapid, efficient technology development and adoption.

The need for participatory research, i.e. planned involving all system stakeholders with the support of research scientists does not need to be emphasized. Nor should that of on-farm demonstrations, which provide concrete reference, and a focal point where practitioners, input suppliers and scientists discuss problems and solutions. Clearly, the demonstrations are far more convincing if they involve real farms, rather than government sponsored plots. Less trivial, perhaps, but also essential, is the need for developing decision support systems for land managers. Farmer decisions are based on a number of indicators which allow corrective actions when needed. Indicators, threshold levels, and options for remedial action need to be chartered for new environments. The starting point is to develop indicators which will allow farmers to become aware of problems and which will help them monitor the effects of remedial treatments. For example, simple soil structure indicators are needed that can be used by farmers to monitor trends in soil structure dynamics (Chan and Pratley, 1998).

**Achieving Public Awareness**

Awareness is required at the farmer, rural and urban general public levels. Conservation practices will not be adopted unless farmers perceives a problem or advantage – hence the role of crisis in facilitating adoption. If the symptoms are more subtle and the effects of degradation only very progressive, the problem may not be perceived, and even less the relationship between current farm practices and accumulative soil degradation. Farmers who participate in the process of identifying soil and water conservation problems on their own land and in identifying solutions to those problems will be more likely to apply the information to their own situation and continue to use the practice when outside assistance is no longer available (Osgood 1992).

Osgood (1992) also notes that it is not enough for the individual farmer to perceive that a problem exists. It is also important for the community at large to understand the problem. When the community understands the problem, there are more opportunities for group efforts and support. If a conservation practice is consistent with community values, it probably will be more acceptable to the farmer; if not, few farmers will adopt. Moreover, working together, community members can identify the specific benefits of conservation practices for their own situation, or perceive that the tools for adaptation are readily at hand. They can also appreciate the different impacts which adoption can have on different segments of the community and work out ways of helping out those which would benefit less or have more difficulty in adoption. These remarks are consistent with the importance of groups in analyzing and planning changes in conservation practices.

There are also ecological reasons justifying the need for a community approach if conservation tillage is promoted in a perspective of soil and water conservation. No farm is an isolated island (Goldney, 1998). Every farm is under the influence of the land surrounding it and the ecological processes operating over the landscape, and practices in one farm will affect others. Since "no land-manager can be an island", all should participate in developing local and regional catchment plans. This is at the root of the Landcare philosophy in Australia as well as of the micro-catchment approach in Brazil.

**Incentives and Subsidies**

No farmer will adopt a new technology unless there is an incentive to do so. Subsidies can be used to raise the incentives and facilitate adoption. However, economists are cautious about the use of subsidies which often result in unwanted, perverse effects; they are inefficient, expensive, and tend to outlive their utility (Giger, 1996). If needed over the long-term, this serves as evidence that the proposed technology is not viable. Therefore, the main reason for envisaging subsidies is to overcome fear of risk by farmers and enable them to take advantage of a new technology. Such subsidies should be phased out when farmers have had their first experience using the new technique. Another case justifying subsidies is when the society stands to gain from farming activities which are not compensated by market prices, (e.g. watershed protection). If possible, the costs of these subsidies should be borne by those who actually benefit from the change in practices.

The need for temporary subsidies to facilitate adoption of conservation tillage in the CIS region can be argued on two accounts. Firstly, there is a significant investment cost linked with the change of machinery and equipment, which most farmers would be unable to afford, particularly in the absence of functioning credit systems. Secondly, there is a transition period during which yields may initially decline, before possibly exceeding previous levels. This is because the biologic processes which will sustain the new system take time to build up, while the earlier benefits of intensive tillage (particularly in terms of weed control) have disappeared. In some situations, the soil is too compact for a direct move towards reduced cultivation, and deep ridging might be initially needed. Finally, the farmer himself undergoes a period of training and adjustment, during which he is bound to make mistakes that will affect his income.

The principle of sharing transition costs between farmers and government as has been practiced in Brazil. The same principle is also used in the soil conservation programs of the United States and in some of the Australian Landcare programs. In all cases, the decision to grant a subsidy is decided on the basis of a farm plan or a catchment management program and involves a contract between a public agency and the individual or community manager.

## The Role of Policies

Large scale adoption of conservation tillage in the United States is generally attributed to aggressive policies to protect soil and water, linking production price support to conservation behavior of farmers, in particular through the 1985 and 1990 US Farm Bills. In addition to financial incentives, the various federal conservation programs also provide considerable support to research, extension and training. In 1998, total USDA administered programs for conservation exceeded US$2.8 billion (Vasavada and Warmerdam, 1999). Of this, US$1.8 billion went to the Conservation Reserve Program (CRP) providing rental payments to farmers who retire environmentally sensitive land; US$0.54 billion for Conservation Technical Assistance (CTA); and US$200 million for the Environmental Quality Incentives Program (EQIP). However, certainly the main incentive for conservation tillage has been provided through the Conservation Compliance principle established by the Food Security Act of 1985. Under Conservation Compliance, farmers who grow crops on highly erodible land are required to implement an approved soil conservation plan to remain eligible for an array of farm program payments.

A review of those programs indicates that the area where conservation tillage was practiced increased from 72 million acres in 1989 to 99 million acres in 1994 (Sandretto, 1996). Although this is an impressive progression[2], it also suggests that CT success did not wait for the 1985/1990 farm bills. An interesting confirmation, given in the same report, is seen in the fact that the use of mouldboard plows[3] declined from 20 percent in 1988 to less than 10 percent in 1994. A report by the World Resources Institute provides a different view on the role of US agricultural policies in the 1980s (Faeth *et al.*, 1991)[4]. The authors argue that commodity price support programs have encouraged chemical intensive mono-cultures, which deplete soil nutrients and affect ground and surface water. In this view, the 1985 Farm Bill can be seen as an effort to counteract the disincentives to sustainable agriculture created by agricultural support payments (amounting annually to US$12 billion, 1982-1988). However, even as improved by the 1990 Farm Bill, the new legislation still maintained the distorting effect of commodity programs on most land, according to this report.

In Europe, the task of redesigning the Common Agricultural Policy (CAP) to rationalize support for the delivery of environmental goods is by no means simpler and has hardly begun. Because environment is now high on the European political agenda, many farmers receive several payments related to the environmental protection. The system is costly both to farmers and governments. One of the difficulties in designing environmental contracts is the information asymmetry between farmers and regulators. Ewa Rabinowicz (1999) emphasizes the role of rural development groups in that respect, noting that such groups have an information advantage with better local knowledge of the environmental impact of specific policies and opportunity costs. The penalty for defaulting on contracts with the local community is probably, she remarks, much higher than for cheating the bureaucracy.

It would surely not be difficult to find around the world, including in the CIS region, many examples of agricultural policies that contribute to land degradation. In Australia, perhaps the best examples are in the settlement schemes that established inappropriate property sizes, the subdivision of marginal land, government support for irrigation schemes, and vegetation

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[2] Particularly spectacular for no-till systems which went from 5% of agricultural land in 1989 to 15% in 1996.
[3] As measured by the USDA annual Cropping Practices Surveys.
[4] See also Steiner (1990) for a discussion of the unintended impact of agricultural policies in the U.S.

clearing promoted by taxation incentives (Curtis and Lockwood, 1998). Reviewing the Australian experience in designing and implementing natural resource conservation policies, the same authors concluded that this provides a useful model for:

- establishing the roles and linkages between local community groups and regional planning bodies;
- developing cost sharing principles for allocating public funds for private investment where there are community benefits;
- creating effective community-agency partnerships;
- effectively supporting volunteer groups.

However, some authors suggest that more radical measures than currently used may be needed to bring to a halt land degradation in Australia[5].

These cursory remarks into a particularly complex field first point to the need to thoroughly analyze existing agricultural policies[6] and understand how they affect agricultural practices, as a first step to policy changes. They also confirm the positive, probably essential role of local community groups in implementing sound land improvement policies.

**Role of Financing Institutions**

At this stage it should become clear that promoting CT requires an integrated strategy based on an understanding of cultural aspects and of collective action, and emphasizing a critical review of policies, awareness building, support to decentralized research, training and extension, as well as incentives to facilitate adoption. Financing Institutions, International Agencies and donors can help in financing a package of measures. They have also acquired expertise in the preparation and implementation of such projects[7]. Successful projects have incorporated all the above elements and provide, if not models, at least useful references. This is in particular the case of the various Land Management Projects financed in Brazil with World Bank support since the mid-1980s (described below). Clearly, there is not one approach, and even within Brazil the techniques promoted differed from one state to another and from large motorized farms to small holders using labor and animal traction. In Africa, the World Bank, in cooperation with FAO, are still looking for viable approaches to land improvement through the Soil Fertility Initiative.

**Anatomy of a typical land management project in Brazil.** The project cost structure provides a short summary of what was envisaged and what means were mobilized. In the case of Land Management I (Paraca State), total cost was estimated at US$150 million covering a total project area of 5 million ha, of which 1 million ha of farmland would directly benefit. The costs were shared between government, World Bank and farmers and covered research (13%), extension (including awareness building, training and education: 18%), incentives (18%), redesign of roads (an important factor in soil erosion: 26%), soil liming (4%), studies and mapping (14%), and project management (7%). The incentives were managed through a Soil Conservation Fund, and involved participating communities under a contract for implementing a micro-watershed management plan, as a share of the costs. The

[5] Despite the success of the Landcare movement in creating global awareness and enrolling some 30% of all farmers in groups devoted to conservation activities, Goldney and Bauer (1998) argue that this is still "too little too late".

[6] Bromley (1991) provides useful recommendations on how the policy analyst should proceed, avoiding the false pretence of rigorous scientific objectivity.

[7] Obviously, most of the expertise, technical and managerial, regarding implementation of CT programs resides in those countries which have successfully adopted.

level of subsidy depended on farm size: from 70% for small farms to 30% for larger farms in year 1, and decreased with time for phase out after 6 years. The total amount of direct subsidies came to US$25 $ha^{-1}$ for the entire period. The subsequent projects in Santa Catarina and Sгo Paulo states had essentially the same components, including the establishment and financing of a soil conservation fund, with a per ha cost of direct subsidies ranging from US$15-40.

Costs would obviously differ in the CIS region, but the Brazilian examples indicate an order of magnitude of CT promotion requirements. While significant, such costs are affordable, given the returns to farmers and to the economy as a whole (cf., Sorrenson, 1998). However, direct subsidies were only one part of the package. The major share in all these projects went to research extension and education (31% of all costs in Paraca state). The relative requirements for research and extension could be higher in the CIS region. For reference, a small project prepared by the Investment Center in 1998 for demonstrating conservation tillage in Mongolia amounted to US$123,000 for 2,000 ha (or US$60 $ha^{-1}$); herbicides (22%), machinery (19%), and professional expertise (54%). While it is emphasized that such figures are only indicative since a full scale project involves much more than demonstrations, they show that investing in CT should not be out of reach for CIS countries.

## CONCLUSIONS

This paper attempted to identify some common marks of successful case of conservation tillage adoption, which, it is hoped, can be useful when planning a strategy for promoting CT in the region. Subsidies are crucial, but may represent only a fraction of what is needed in terms of investment, and are always to be used cautiously. Appropriate techniques are obviously pivotal, but cannot be developed centrally by scientists alone. Often underestimated, social and cultural aspects are what makes change possible – or on the contrary virtually impossible. To be sure, this should not be interpreted as simply the need for understanding farmers and their culture. The proposed change also implies a radical shift in the culture and attitudes of scientists, technicians and politicians.

The reasons to move towards CT are not merely the direct economic and environmental benefits of adopting this new technology which should ensure high rates of return to any sound program. There are at least three compelling reasons to envisage CT in the CIS (probably more will be identified during the workshop). One is that the stock of farm machinery is aged and partly unserviceable. It is the right time to look at what equipment is now needed, knowing that CT requires less power than conventional tillage. A second reason is that, in a number of countries, irrigation had been expanded in the previous decades to areas which are now not economically serviceable (in particular where high-lift pumping is involved). Without irrigation, many villages may have to be abandoned, or otherwise financed at great cost to the country. Wherever rainfed farming can be considered instead, CT has considerable advantage over dryland farming systems in terms of rainfall water infiltration and conservation for use by the crop (Stewart *et al.*, 1993). Finally, the level of intensification reached during Soviet times may not be affordable for main, low value crops. CT and land conservation practices are more economical of chemical inputs, as they emphasize biological processes (including N fixation) and reduce nutrient losses.

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# CONSERVATION TILLAGE IN WEST ASIA AND NORTH AFRICA

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The world's population will alarmingly rise to 7-8 billion people within 30 years, and this will demand a doubling of food production. This growth has already considerably outpaced agricultural production beyond the capacity of available production systems to satisfy the demands of this growing population for food and other agricultural commodities. Therefore, more attention has to be given particularly to reduction in the natural resource degradation and improving soil, water and nutrient management (CGIAR, 1992; IDRC, 1993).

Land available for expansion of agricultural area is limited (El-Beltagy, 1997). Both marginal and fertile lands are currently undergoing varying degrees of degradation, including soil erosion, and reduction of soil water retention (El-Beltagy, 1997; van Divenbooden, 1999). International studies estimate that nearly a quarter of the world's agricultural, pasture and forestland has been degraded since the mid-1900's. Rather, soil quality and quantity, fertility and water supplies need to be managed effectively, conserved through husbandry of natural resources, and through land-improving investments. Effective soil, water and nutrient management requires action not only at the farm level, but also at community, watershed, regional and national levels (SWNMI, 1996).

Sustainability issues in agriculture have become an important way of looking at production systems all over the world during the last decade, because of the rapid degradation of natural resources (Follet and Stewart, 1985; Lal, 1998). Since its establishment in 1977, ICARDA has incorporated a strong farming systems component into its research with its multidisciplinary and multi-commodity mandate focusing on the drier, less productive and more risky agro-ecological zones in the West Asia, North Africa (WANA) region. Its goal in integrated natural resources management are to promote greater efficiency, integration and sustainability of production; to enhance resource quality and quantity; and to display transparent contributions to poverty alleviation and better food security (EPMR, 1999).

ICARDA objectives in integrated natural resource management research in relation to optimizing soil water use (OSWU, 1998) are:
**Adaptive and Participatory.** Land-surface and soil/crop husbandry practices developed and under test on farmers' fields that optimize output per unit of available water within sustainable production systems that match climate characteristics (especially patterns of rainfall and evaporative demand) and production and livelihood aspirations at household, community and national level, integrating a) the management of land surfaces to optimize the retention of rainwater, b) the management of cropped soils and crops to minimize losses of water to deep drainage, surface evaporation and weed transpiration, c) choices of crops (and cultivars), crop and fallow sequences, and cropping practices to optimize the efficiency of soil water use in the production of economic yield.
**Applied and Generic.** Research activities established at selected locations to study key problems of soil-water-plant processes general to dry-area cropping systems.

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ICARDA research program combine different levels of research, conducted at different scales in key target areas, as a matrix of activities across national, regional and international research institutions. The main venues for applied and adaptive research are the sub-sets of field experiments, on both the research station and farmers' fields, ongoing or newly established with Project support, undertaken by national institutions in participating countries in ways that match local conditions, priorities and research strengths. These activities are conducted in multidisciplinary, systems contexts, with the participation, where appropriate, of the farming community and extension services. Care is taken to ensure that all experimental sites are well characterized in respect of climate, soil and utilization history.

For ICARDA, policy of current research to ensure that the generation of problem-solving and output-raising technologies is planned and conducted with a sustainability perspective through a new research front on resource conservation and land management. Conservation tillage has a special emphasis within the overall integrated natural resources management approach of ICARDA as the positive results obtained from its long-term tillage research (Pala *et al.*, 2000). The experience of the last three decades has shown that increased crop productivity is only part of the solution to feeding the world. A comprehensive approach to agriculture, an awareness of both the long- and the short-term effects of any given farming practice, is critical for sustainable agricultural production (Jones, 1991).

However, large quantities of fuel are also used on cultivation of agricultural land. The use of tractors has become widespread during the last 40 years, and over much of the region, it is the usual practice to plow, with a disc or mouldboard to a depth of 20 to 30 cm each year as replacing the shallow tillage applied mostly by small holders. Not only deep tillage itself costly in fuel use, but it necessitates another cultivation to prepare the seedbed. Furthermore, it tends to destroy soil structure, prejudicing the long-term maintenance of the soil itself (Jones, 1991).

In 12-year trial in Syria on the cracking clay soils, no yield advantage was found from deep tillage compared with reduced tillage or no-tillage; and although this result might be site- and soil-specific, it suggests that the use of deep tillage should be more critically appraised wherever it is used (Pala *et al.*, 2000). For long-term sustainability, the aim of ICARDA is to collaborate with national agricultural research and extension services to reduce all cultivations to no-tillage or to a minimum tillage depending on a given environmental conditions of production systems and the availability of the implements. However, limited funding is a main concern for the implementation of such research activities at a larger scale in the region.

**Experiences with the Introduction of Conservation Tillage in Central Asia**

ICARDA previously did not have any project on natural resource management, including conservation tillage in Central Asia. However, ICARDA participated in an International Symposium on "Conservation tillage practices for grain farming in semi-arid regions" organized by Kazakh Research Institute of Grain Farming in Shortandy, Kazakhstan during 7-9 July 1992. Since then we had no interaction on the field scale with the Central Asian countries in relation to tillage research. Last five years ICARDA started to get involved with Central Asian Countries through the Highland Research Project conducted through ICARDA, Ankara Office in Turkey and this has accelerated our cooperation in time.

Analysis of the biophysical and socio-economic conditions of Central Asia could be summarized as follows (ICARDA, 1999):

- Agriculture is of paramount importance in the region as a whole. On average it is the source of employment for a third of the labor force and its percentage contribution to GDP has increased since the republics gained their independence. The five republics in Central Asia encompass a vast total area of 400 million hectares of which about 75% is classified as agricultural land. Of this, only 14% are arable land, of which almost 70% used to be irrigated. In the past these republics provided much of the former Soviet Union's requirements for wheat, cotton and livestock products. In spite of the agricultural potential of the region, both yields and production of crops and livestock are variable between years and generally below those of other regions of the world with similar agro-ecologies.
- Because of the differences in physical environments and biophysical resources it is difficult to generalize when discussing the agricultural sector in the region. The region can be divided into basic ecological zones determined by latitude, which determines climate, particularly temperature (cold winters but higher rainfall in the north, milder and drier in the south) and altitude (plains, mountains and upland valleys). Adding to this the availability of water (major river systems) which determines the primary land use, four agro-ecological zones can be defined: lowland rainfed; lowland irrigated; lowland semi-arid rangeland; and mountains (mountain pastures supporting extensive livestock, with irrigated crops in the valleys). Production constraints differ by agro-ecological zone.
- In rainfed areas, inputs are low and problems are developing in maintaining soil fertility under the predominant cereal-based systems in the absence of fertilizers. The emerging small farmers need assistance with enterprise development and the introduction of new crops and rotations. Under the extensive cropping systems of the former Soviet Union, the predominant rotations included annual fallow and large areas remain unsown each year. The opportunity exists to intensify production by replacing fallow with alternative crops. Considerable potential exists for developing mixed farming based on the integration of crop and livestock production.
- In mountain areas, foothills and upland valleys support dryland farming. Productivity is low and the farming communities are among the poorest in the region. Harsh conditions promote out-migration and land abandonment. Subsistence is obtained from drought resistant crops, such as barley, and trans-humant flocks of small ruminants that move to the mountain pastures in the summer. Much of agriculture is conducted on sloping land and soil erosion by water run-off is a localized but major problem. More productive, but resource conserving, modes of land use are needed.

Efforts towards implementing structural adjustment and particularly in the privatization of large-scale state and collective farms (and the subsequent move of production to the smaller private holdings) have resulted in a variety of problems. There is a lack of suitable small-scale equipment and the new landowners, which have been drawn from the cadre of specialized state-farm workers and non-agricultural support staff lack the skills needed for assuming the management of complex privatized small holdings. The new rural small holders have been further disadvantaged, some to levels of severe poverty, by the lack of the state supported social and welfare services (housing, health. education etc.) that the collectives had previously provided. Therefore food security, land use and land tenure have become important issues with conservation tillage, which is an important factor in this.

Under the former Soviet Union the importance of agricultural research in providing the technology for productivity gains was well recognized and there was a long history of successful research based upon enormous intellectual resources. The agricultural research system was centrally directed and tended to focus on the limited irrigated areas, where returns to investment and intensification were greatest. The abundant supply of well trained scientists benefited from the cooperation and communication that existed between the research institutions located in what are now the independent republics. Today financial stringency has caused problems in the NARS that have superceded the centralized system and all are suffering from benign neglect. Operating funds have been cut, salaries have stagnated in an environment of inflation, and research management has declined in efficiency. There has been a resultant exodus of qualified staff from the NARS as they seek more remunerative employment. In addition the creation of independent NARS has increased isolation of the scientific community, both from each other and from the scientific community at large, so that many scientists are now unaware of modern developments in their research fields.

Recently, as an outcome of a series of initiatives by the CGIAR beginning with the Ministerial-Level Meeting in Lucerne at which it was recommended that the CGIAR should consider involvement with the agricultural research needs of the southern part of the former Soviet Union. A Task Force commissioned by the CGIAR in 1996 to assess the potential for research collaboration with Central and Eastern Europe and the Former Soviet Union proposed an expansion of the geographic mandate of CGIAR and the development of an overall strategy for Central Asia and the Caucasus (CAC). A series of workshops and consultations between the CGIAR and the National Agricultural Research Systems (NARS) of CAC have outlined problems facing the research systems of the CAC countries, possible research activities in need of additional support, and a strategy by which CGIAR could assist the NARS in both institutional development and the development of technologies and policies to support the revival and future development of the agricultural sector.

Based on an analysis of constraints and opportunities for agricultural production and agricultural research in the CAC region, and drawing on the various consultations with the national research programs of CAC, research priorities of relevance to the CGIAR mandate have been identified. These priorities provided the framework for the development of a regional collaborative research program. Nine CGIAR Centers have agreed to collaborate on research activities of relevance to CGIAR in CAC, with ICARDA acting as focal point for the CGIAR.

During 1997 and 1998 ICARDA took the lead in developing a proposal for a Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus. The program is organized around five main "themes", each with sub-activities, corresponding to the five main activities within the CGIAR approved research agenda, as follows: (1) Improving Productivity; (2) Protecting the Environment; (3) Conservation of Biodiversity; (4) Socio-economics and Public Policy; (5) Strengthening National Agricultural Research Systems. This system-wide program was approved by the CGIAR Finance Committee during the Mid-term meetings in May 1998, and allocated seed funding to support start-up and development of further initiatives.

In regard to this, ICARDA has initiated a project proposal on "On-farm soil and water management for sustainable agricultural systems in Central Asia", which is presented within the context of the System-wide Collaborative Research Program for Sustainable Agricultural Development in Central Asia and the Caucasus, under the themes of 'Cropping Systems Management and Agricultural Diversification', and 'On-Farm Soil and Water Management'. This is a 3-year project to support the Central Asian Republics in developing applied research programs focused on the identification and adaptation of existing technology, and the development of appropriate farm-level soil, water and cropping system management strategies. The detail of this project is given later in this paper.

**Analysis of Problems which Influence Conservation Tillage**

The Greenland Report (Greenland *et al.*, 1994) and the TAC study on Priorities and Strategies for Soil and Water Aspects of Natural Resource Management Research in the CGIAR (TAC, 1995) conclude that to promote more widespread use of sustainable systems requires a change in the research approach.

These research principles call for a new organizational approach. This approach must first ensure that the whole range of stakeholders, including land users, community organizations, development actors, extension agents, researchers and policy makers, is involved in the generation and promotion of improved land-use practices. Secondly, the approach must generate synergies and efficiencies from the involvement of multiple partners, making use of existing national, regional and international capacities and their comparative advantages (SWNMI, 1996).

Regarding technology development and adoption, the major problem in general is the transfer gap between the research results and farmers' fields. The wealth of information and equipment available worldwide through the many appropriate or intermediate technology networks and organizations is not being fully tapped. Technologies appropriate for small-scale farmers need to be identified and collected widely, under consideration of farmers' indigenous technologies, screened for local suitability, tested under farmers' conditions, and their local manufacture promoted. Their adaptation has to be done in a participatory manner so that the chances of their adoption and their appropriation will be high. Some research for technology development is still necessary where there is a lack of it and also to keep up with the changing conditions.

Given the ever growing population in arid and semi-arid regions with their erratic and variable rainfall, and the limited possibilities to increase the area cultivated, the agricultural priority across all dry-area farming systems in West Asia and North Africa (WANA) is to increase biological and economic yield per unit of water. In rainfed fields, improvement can come only from conserving rainfall water in the rooting zone of crops (including shrubs and trees), and from managing the field and the crops to use this water more efficiently. The past several decade have witnessed a change from traditional to more intensive agriculture in dryland farming systems of West Asia and North Africa (WANA). This has led to an assessment of tillage systems for *efficiency*, and rotations for *enhanced productivity* and *sustainability* and their integration.

One key research and development issue in this context is soil surface management to promote and increase infiltration and decrease run-off and evaporation for conservation of water within the soil profile. Another possibility to optimize crop water use is the manipulation and adaptation of cropping systems. Under Mediterranean conditions in WANA, the efficiency trade-offs between using water immediately and attempting to store it in the soil for the next crop (function of type of soil, rainfall pattern, and annual temperature regime) will determine the use of fallow and/or crop sequences with a proper soil management systems to sustain the productive capacity of the soil.

The environment and the farming systems of West Asia and North Africa region (WANA) within which ICARDA works has been described in detail by previous reviews (Cooper et al. 1987; Harris et al. 1991; Harris 1995). In WANA, precipitation is received during winter and is distributed erratically over a period of approximately six months, characterized for the most part by relatively low evaporative demand (1-4 mm $d^{-1}$). In the region, except in the driest desert fringes, soils are usually loams, clay loams or even clays, and the clay minerals are mainly of the 2:1 montmorillonitic (or smectite) type. The soils are often high in calcium carbonate with a high pH, and salinity may represent an important problem. Solutions to the runoff problem may be sought at different scales. At the scale of the soil itself, the standard prescription to improve structure by enhancing organic matter content, though valid, is almost always frustrated by the non-availability of substantial amounts of otherwise unwanted organic materials, like crop residues, to incorporate into the soil or apply as mulch. More practicable in the long term may be the encouragement of a positive feedback loop by which enhanced crop growth feeds the soil with a greater volume of root residues, and mineralization is minimized through reduced-tillage systems (Jones *et al.*, 1998).

Within the region in which ICARDA works, tractors have been introduced widely and most primary and much secondary tillage is mechanized. Equipment was originally imported from Europe and North America, but the disc and mouldboard plows, disc and spike toothed harrows, and chisel plows and sweeps which are the main implements used, are now largely made locally (Tully, 1989; Cooper *et al.*, 1987).

The landscape of much of the region contains relatively few streams, which suggests that only limited runoff occur. However, in recent years an increase population has led to an expansion of cultivation on steeper marginal lands. At the opening of the rainfall season, when there is no protective vegetation following the arid summer, intense thunderstorms are not uncommon. In some places and years severe soil erosion, resulting from runoff from storms, can be seen on steeper hillsides. It is not clear that the type of tillage has much effect in these cases. The direction of cultivation, which for convenience is often with the slope, is probably the dominating factor.

Many of the soils used for cropping in the region are self-mulching clays which are plastic when wet, and crack extensively when dry (Cooper *et al.*, 1987). Compaction and plow layers can develop on such soils if they are worked with heavy equipment when they are too wet (Hodgson and Chan, 1984; McGarry, 1984). This is mainly a problem on irrigated land, and, with the relatively small equipment used in the ICARDA region, is probably unlikely to be a major problem in rainfed agriculture. In lighter soils, where the surface structure is inherently weak, cultivation rapidly leads to surface degradation, reduced infiltration, and failure of crops to emerge through the heavy crusts, which form. There are many such soils in WANA, and widespread evidence of the ensuing problems can be seen, particularly towards the drier margins of the cropped area (Cooper *et al.*, 1987); if these same soils are cultivated when they are dry, their poor structures renders them very susceptible to wind erosion.

In much of the region it is regular practice to plow, with a disc or mouldboard, to a depth of 20 to 30 cm each year, and then to prepare seedbed with either a harrow or tined implement. The reasons given by researchers and farmers for deep plowing: increased water and soil conservation through prevention of runoff; disruption of a plow layer in the soil; weed control through deep burial of weed seeds; and diseases and insects control through solar energy. However, the equipment available, though largely locally made, essentially follows European and North American designs developed for more humid and temperate areas. The appropriateness of such equipment in the region, and the circumstances and timing of its use, deserve closer scrutiny. In particular, the need for annual deep plowing is open to question, depending on the locality; deep tillage is always costly in terms of fuel and time (Pala *et al.*, 2000). However, in low lands of the region where continuous cropping applied, the loss of water through evaporation is likely to be a small amount because of dryness of the soil during the deep tillage applied mostly in summer. In cereal-fallow systems of the region (mostly in highland areas) deep tillage in heavy clay soils is still the best for soil moisture conservation through soil mulch systems (Pala , 1991; Guler *et al.*,1991).

Concerns over such factors have stimulated research on conservation farming worldwide. In WANA, stubble retention is controversial because stubble is valued as summer grazing for sheep and goats. Though relatively low quality feed, wheat straw often plays an important role in supporting livestock, either by direct grazing after harvest or by baling for the winter use. About 60% of wheat dry matter are straw which may well remain on the field if farmers do not find it possible or profitable to graze or bale. In recent years, however, an increase in stubble burning has been observed in several countries, particularly in Syria (Tutwiler *et al.*, 1990). The reason for the increase is not clear, but it does suggest that there is now excess stubble, and the potential should exist to introduce stubble management alternatives if advantages can be demonstrated. Then, field burning of straw may become the main method of disposal to allow for easy soil preparation for the following crop. Since tillage operations are costly, the question arises as to whether stubble burning will help in the application of minimum tillage or no-till systems. However, long-term trial of 37 years under 330-350 mm rainfall conditions in Uzbekistan visited in 1998 showed that zero-tillage for soil conservation purpose has been experimented but weeds became the major problem. This was observed also in cereal-fallow systems in Turkey that soil mulch systems using deep plowing as initial tillage reduced the grassy weeds density to 100 plants per meter square from 300 weeds per meter square under stubble mulch systems (Durutan *et al.*, 1991). Pala *et al.* (2000) also reported from a three course rotation of wheat-lentil or chickpea-watermelon as mean of a 12-year period that the no-till system was proper for legume crops but gave lower productivity in wheat, due to a build up of grassy weeds, and was not suitable for watermelon. Minimum tillage using sweep after the first initial rains, with its higher energy-use efficiency and yield levels equal to or even slightly above those of deep-tillage systems by mouldboard, appeared promising for lowland areas of the West Asia-North Africa region.

For the driest environments, it may be advantageous to rethink the cropping pattern and its relation to the tillage requirements for water infiltration and weed control. Currently, most staple cereals (wheat mainly) continue extracting soil moisture beyond the end of the rainy season, so that after harvest many soils are unworkable until the next season. One solution is to give priority to the basic needs of the tillage operation (rather than those of a particular crop), and to increase the flexibility of the cropping system by introducing new varieties and species of shorter growth cycle. The underlying logic in all cases should be soil management to optimize the provision of water to crops most able to utilize it productively (Jones *et al.*, 1998).

Where dryland arable land is cropped every year, inter-season management may significantly affect soil moisture. The post-harvest control of weeds, by tillage or grazing, is important whenever the crop, perhaps a shallow-rooted species or harvested pre-maturity, leaves moisture residual at depth. Even in the absence of weeds, soil mulches of the type mentioned by Guler *et al.* (1991) that might have application in some situations. In contrast, in the US, systems utilizing no-tillage, reduced-tillage and/or crop residue retention treatments have been credited with reducing evaporation, as well as improving infiltration and reducing erosion under cereal/fallow systems (Bolton 1991; Papendick *et al.*, 1991). Such results have proved hard to reproduce in lowlands of Syria (Jones, 1997). Over six years of continuous barley and vetch-barley rotations, any effect of zero tillage, with retention of stubble and straw, on the dry-season soil moisture economy was negligible. Small improvements in crop performance occasionally observed may reflect a marginal reduction in evaporation in young plant stands drilled directly into the standing stubble. However, conservation of soils would be affected positively under reduced tillage, which is directed to conserve the soil resources.

Conventional weed control practices rely on clean tillage and maximum surface disturbance, and indeed clean tillage has a strong historical basis in many rainfed cropping areas of the world; but it may often conflict with good erosion control practice (Richardson and Burnett, 1983). The choice of tillage system must accommodate the need to conserve soil and water. Alternatives to conventional tillage include 'zero-till' and 'conservation tillage' systems. The no-tillage (or zero-till) system is a useful approach to solving the problems of soil erosion, soil fertility and soil with low water-holding capacity (Lal, 1976). It can produce yields that are usually as high or higher than those from crops produced by conventional tillage (Campbell *et al.*, 1984), but it can also create other long-term challenges, such as weed and pest infestations.

Conservation tillage, a rather recent development, includes those farming practices that retain plant residues from previous crops on the soil surface. Conservation tillage has been variously defined; but the broad concept includes many different management practices, depending on the agroecological environment (Blevins and Frye, 1993), and more widely, include any tillage system that reduces loss of soil or water relative to conventional tillage, including forms of non-inversion tillage that retain protective amounts of residue mulch on the surface (Mannering and Fenster, 1983).

Stubble mulch tillage, which is widely used in the Great Plains, is a type of conservation tillage which has a potential to control erosion of many soils, because plant residues shield the surface from high winds and raindrops and prevent the loosening and carrying away of soil particles (Cruse and Erbach, 1981; Bolton, 1991). However, Allmaras *et al.* (1985) reports that conservation tillage does not exclude use of the moldboard plow when needed to produce surface roughness for soil erosion control under special conditions. Their definition of conservation tillage concentrates on the use of such implements as chisel plows, sweeps, rod weeders, discs, mulch or skew threaders, and planters designed to move through residues and precisely place seed and fertilizers under conditions more adverse than on bare seedbeds.

A conservation tillage system is an organized integrated whole made up of diverse but interrelated and independent parts. Thus, tillage must be integrated with other parts (inputs) into a conservation tillage system. Moreover, some input can only be applied by integration with the conservation tillage system. The crop rotation (or sequence) is essential to the operation of a conservation tillage system because crop and pest interactions, fertilization, and timeliness of operations are just a few of many factors to be considered during the planning needed for successful adoption of a new conservation tillage. For example, with crop rotation as part of the conservation tillage system, mouldboard plows and discs can be used when the danger of erosion is slight or non-existent in some part of the rotation. Non-inversion type equipment can be used when necessary to meet conservation objectives in other parts of the rotation. Systematic and greater use of no-till methods is also facilitated in rotations.

In the long-term, tillage can be expected to cause breakdown of the surface structure and increased crusting. In soils where the surface structure is inherently weak, cultivation rapidly leads to surface degradation, reduced infiltration, and failure of crops to emerge through the heavy crusts formation. There are many such soils in the region and widespread evidence of the ensuing problems can be seen, particularly towards the drier margins of the cropped area (Cooper *et al.*, 1987). If these same soils are cultivated when they are dry, the lack of structure renders them very susceptible to wind erosion. Again, observations in the region suggest that this is a problem, but its severity is unquantified.

Adoption of conservation tillage in the region has been relatively slow because of implement availability and farmers' tradition, which governs most of their practices in relation to soil and crop management. Direct drilling under zero-till system without prior cultivation offers potential advantages for crop growing but often leads to reduced seedling vigor in cereals which in turn can be associated with reduced yield (Fisher *et al.*, 1994).

Conservation tillage practices using chisel have been used in Jordan with a satisfactory results in increased water storage, decreased in soil erosion as leaving the residues on the soil surface compared with mouldboard plowing (Jaradat, 1988; Suleiman, 1994; Al Bakri, 1996). Conservation tillage techniques (no-till, minimum tillage, and chemical fallow) was reported to generate higher wheat grain yields with more water storage and higher water use efficiency in Morocco (El Mehahed, 1993; Kacemi *et al.*, 1994). It was also reported by Pala *et al.* (2000) that possibility of soil loss has to be kept in mind in relevant areas where no-till system may be needed. The decreased soil erodibility associated with no-tillage appears to be caused primarily by the lack of soil disturbance rather than runoff, since it is often similar for zero-tillage and conventional tillage. And the erodibility of the soil determines soil loss as well. Therefore, under the same conditions decreases in erodibilty of soils by a zero-tillage system would lead to conservation of soil resources.

However, disadvantages that may be associated with no-till systems would include higher herbicide costs, more difficulty in controlling weed infestation, particularly grassy weeds, and reduced infiltration. In light of the above mentioned point, reduced (minimum) tillage system under these conditions has a promising future for productivity, energy and water use efficiency and increased net revenue with its environmentally friendly nature. More importantly, tined implements (sweeps) for minimum tillage system are available in the region in contrast to direct drilling implement, which would hardly be made available for farmers. The minimum tillage or no-till system which is relevant to west Asian lowlands conditions should be extended to other parts of the region as well as to Central Asia in addition to what has already been started by some of the national programs such as Algeria, Iran, Jordan, Morocco, Syria and Turkey, but these efforts should get greater support to be extended to other soils under different agroecological conditions with greater current and potential problems of wind and water erosion.

## ICARDA's Future Activities in the Area of Conservation Tillage In Central Asia

ICARDA's overall policy for sustainability of the farming systems as given in the introduction section is also valid for central Asia because of the expansion of the center's activities into this region in the last few years. ICARDA's research strategy to cope with the biophysical and socio-economic forces on the natural resources such as soil and water is still evolving as comprising three interlinked strands: a) technical options for developing, testing and adapting for local environments, b) socio-economic background including customary laws, government policies, and landuser perceptions concerning the agricultural use of natural resources, and c) information handling including development of an information base from the actual work and from the other sources for better informed decision-making, implementation of new innovations and prioritizing the research and development activities for sustainable resource use.(Jones, 1991).

Biophysical problems have been identified for WANA and potential solutions have been devised in the region and elsewhere as indicated above. The workshop on "Conservation tillage practices for grain farming in semi-arid regions" held in 7-9 July 1992 at Shortandy, Kazakhstan has brought some possible solutions to the problems in land use and its management. However, efforts towards implementing structural adjustment and particularly in the privatization of large-scale state and collective farms (and the subsequent move of production to the smaller private holdings) have resulted in a variety of problems as indicated above. Therefore food security, land use and land tenure have become important issues with conservation tillage, which is an important factor in this.

Therefore, the need is adaptive research, taking basic concepts, such as reduced tillage, stubble mulching, contour farming, and terracing and modifying them to local environmental conditions. This requires technical experimentation backed up by an understanding of local community—who are the new land users, how do they interact in land and water management, what are their goals and objectives?

ICARDA, through its collaborative projects on soil and water management, crop diversification and feed/livestock integration improving forage and pasture production and rangeland rehabilitation, is emphasizing the conservation of land and water through improved management practices to be studied as adaptive research. The goal of the soil and water management project is to contribute to achieving the overall goal of food security, economic growth, environmental sustainability and poverty alleviation in the Republics of Central Asia by assisting them to achieve sustainable increases in the productivity of crop and livestock systems through the adaptation and transfer of production technologies and natural resource management and conservation strategies, and by strengthening agricultural research and co-operation among the Republics and with international research organizations.

Immediate objectives for relevant soil and water conservation in rainfed areas (ICARDA, 1999) are: 1) Application of soil and crop management technologies that improve water and nutrient use efficiency, 2) Human resource development: Training of personnel in multidisciplinary approaches to soil and water management and agronomic research.

<u>Expected Outputs under Objective 1:</u>

- Management principles for choice of crop, crop rotation, input use and husbandry practice with respect to farm output, water- and nutrient-use efficiency.
- On-farm tested soil and crop management techniques for increased crop water- and nutrient-use efficiency
- Methods and recommendations for efficient capture and utilization of rainfall in drier environments (Water-harvesting).

<u>Planned Activities under Objective 1:</u>

- Review existing research results and identify promising technologies for evaluation in the new farming systems
- Evaluation of existing farm soil, water and crop husbandry practices and their effect

on productivity and efficiency of the systems, soil water dynamics and water-use efficiency.

- Measurement of soil nutrient and water balances under different soil and crop management practices in on-station trials
- Testing of promising soil and crop management practices under on-farm conditions.
- Evaluate environmental impact of proposed land use types or management practices.
- Investigate the potential and constraints for supplemental irrigation and current local practices in major rainfed areas with available water for irrigation
- Collect, document and synthesise information on indigenous systems of water harvesting and utilization
- Develop methodologies for identifying potential sites and suitable methods of water harvesting
- Selecting and testing water-harvesting techniques at various sites in the region integrated in their farming systems.

Expected Outputs under Objective 2:

- Personnel trained in multidisciplinary research approach in soil and cropping system management, the development of productive and sustainable technologies and in appropriate on-farm water management techniques.

Planned Activities under Objective 2:

- Specialised training courses in research methods and approaches, in soil, water and crop management principles,
- Workshops/conferences to exchange information.
- Travelling workshops to relevant research trials in the region.

This project will be implemented within the overall umbrella of the CGIAR Systemwide Collaborative Research Program for Sustainable Agricultural Development in Central Asia.

This project has not been directed to conservation tillage practices directly, however, overall strategy of ICARDA's research in soil and crop management has been designed for conservation of natural resources such as soil and water with improving their productive capacity through proper tillage and crop sequences for sustainable farming system.

**Recommendations**

- The main issue is the identification of the most appropriate tillage and stubble management systems for soil and water conservation, crop growth and sustainable production, which are technically feasible, economically viable and environmentally acceptable by different stakeholders such as farmers, researchers, decision-makers, and other relevant private and non-governmental organizations.
- Researchers (soil scientists and agronomists) in close linkage with extension services and farmers should work on the identification of the problems in relation to land degradation and possible causes due to the use of implements, depths and time of tillage operations under different cropping systems.
- According to the knowledge obtained from the two points above, adaptive research for testing most suitable tillage options should be designed and conducted in farmers' fields with the participation of farmers,
- In the mean time, research and development on the appropriate tillage implement and planters should be planned in close linkage with the local manufacturer and importing of

no-till equipment for further testing under different agro-ecological conditions should be considered if locally not available or impossible for manufacture.

- Availability of spare parts and technical know-how about setting and maintaining machinery should be considered carefully in close linkage with all the stakeholders.
- There should be long-term, multi- and inter-disciplinary, multi-factor trials on the major soil types of the Central Asia on the basis of the problems identified in a holistic approach adopted.
- Biophysical, economic and social factors should be monitored carefully during the research and extension activities to link the use of conservation tillage compared with traditional practices to the conservation of soil and water resources for the sustainable development of the farming system.
- Long-term commitment and continuity in research and development should be supported by government from the beginning and this should also be linked with overall development plans in agriculture including the other related services and organizations.
- Machinery manufacturers should be in touch by the researchers for the best options of implements used in tillage to be designed and tested before the mass production.
- Special project research funding has to be provided by the national governments or external sources to implement long-term conservation practices as needed.
- Training of researchers and extension agent and support staff is a fundamental issue if the integrated conservative technologies for soil and water resources to be successfully applied at larger scales for sustainable production systems for today and future generations.

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# SUSTAINABLE WHEAT AND MAIZE PRODUCTIONS SYSTEMS IN DEVELOPING COUNTRIES

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Most approaches to sustainable crop production management include conservation, minimum or zero tillage practices, crop residue retention, diversified crop rotations, targeted fertilizer application methodologies that minimize nutrient losses, and integrated insect, disease, and weed management practices to provide minimal or no use of pesticides. In many developing countries, the use of these crop management strategies has bypassed most small farmers for several reasons: a) the lack of small-scale planters that are compatible with two-wheel or small four-wheel tractors, or with draft animals, and appropriate for sowing into residues in reduced or zero tillage systems; b) the need of many farmers to use crop residues for livestock feed or to remove residues for cooking fuel; c) the lack of knowledge by small farmers about how best to apply fertilizers efficiently (when and where, with main emphasis on nitrogen fertilizers) to minimize losses while complementing farm level nutrient sources, including farmyard manure/composts and/or green manure, especially when combined with reduced or zero tillage systems; d) the largely unknown ramifications of these practices, which may modify insect, disease, and weed incidence. Table 1 lists some major reasons for the lack of adoption of zero-tillage planting systems by small wheat-producing farmers in developing countries.

Reduced tillage practices offer wheat and maize farmers in developing countries an ecologically and economically sound approach to increase productivity, conserve natural resources (including water and nutrients, but also fuel and tractor parts), and reduce risk over the long term. CIMMYT has served as a catalyst for different kinds of research on reduced tillage with national program partners throughout the world. What these researches have accomplished is impressive. They have worked in the field with farmers, amassing considerable experience with reduced tillage in a range of settings: 1) they have developed alternative approaches to tillage and crop residue management, 2) started to quantify the biophysical performance of these different options, 3) fostered farmer participatory research to tailor the most attractive options to farmers` circumstances, and 4) they have anticipated (through modeling) and measured (through monitoring) longer-term consequences for productivity and sustainability. By virtue of this experience, national programs have identified tillage, rotation, residue, and fertilizer strategies that should be truly sustainable over the long term. These new strategies will help farmers realize the yield potential of improved cultivars, and will reduce their production costs and increase their profits. As a result, farmers and consumers should benefit from reduced food costs, improved food security, and a reduction in poverty. Reduced burning of fuel and burning of residues will lessen carbon emissions and reduce the risk of global warming. These systems also help by

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increasing water efficiency and reducing the water needed to grow a crop. Water will be a major constraint to food production in the future. A series of potential advantages of zero tillage planting systems are summarized in Table 2 (Phillips and Phillips, 1984; Sayre, 1998).

In this paper we will focus on the impact that the National Agricultural Research systems in collaboration with CIMMYT have had in parts of Latin America and South Asia. CIMMYT conducts many other kinds of strategic agronomic research with partner organizations throughout the world, although we cannot describe every initiative here.

**Research in Latin America**

In many areas of Latin America, reduced tillage practices could be extremely valuable, especially for poor smallholders. A growing number of studies in Latin America are forming the basis for a broader understanding of issues and potential options for reduced tillage in maize and wheat production systems. Major activities to date include researcher-managed on-station and on-farm tillage and bed planting research in Mexico; tillage systems for rainfall use efficiency in Bolivia; and simulation modeling.

**Reduced tillage technology for irrigated environments: Sustainable "bed" planting**

A reduced tillage system developed by farmers and researchers in Mexico`s Yaqui Valley is showing its potential in the Yaque Valley and other irrigated wheat production environments. In this system, a crop is grown on raised beds that are divided by furrows for irrigation. No soil inversion tillage is used on the beds. Crop residues are chopped and left on the surface of the beds. The system has several advantages for farmers and the environment (Table 3).

Prototype machinery specifically for this bed planting system has been designed and tested in Mexico and in Asia. The prototypes are modifications of standard agricultural equipment and are expected to be affordable for poor farmers. However, more efficient systems are needed that will require close collaboration between researchers, farmers, extension workers and local manufacturers.

Mexican farmers reportedly save 30% on their production costs when they use the bed planting system. Some 10,000 farmers are thought to use the system in Mexico, and the number of farmers who are using bed planting is growing in South Asia and China as well.

**Tillage trials in Central Mexico**

A sustainability trial initiated in 1991 at CIMMYT`s headquarters research station provides evidence of the benefits of conservation tillage in maize and wheat farming systems and the processes underlying success. As discovered in similar work by CIMMYT in other parts of Mexico, the prerequisite for success is the combination of conservation tillage and crop residue retention after harvest. A consistent 25% yield advantage has been found for the 1996, 1997, and 1998 cycles for cereal rotations under conservation tillage (CIMMYT Impacts, 1999). Table 4 presents the wheat and maize yields for the various treatment combinations used in this trial averaged over the 1996 and 1997 crop cycles (Sayre, 1998).

It appears obvious that for either continuous or rotated maize or wheat, when zero tillage was used combined with crop residue removal, yields were consistently lower than when residue was retained. Furthermore, in most cases, the zero-till yields for either crop – regardless of rotation – were also lower than when conventional tillage with residue removal was practiced (this is more clearly illustrated by the residue management/tillage means given in Table 5).

In addition to evidence of added soil organic matter, trial data suggest an increased presence of fluorescent pseudomonads (microbes that are useful in the biological control of soilborne pathogens) and decreased incidence of root rot in zero-tillage/residue-retention systems.

Conservation tillage reduces runoff of valuable water. A five-fold increase in water infiltration under conservation tillage compared to more traditional tillage is evident in another trial at CIMMYT headquarters.

**Research on rainfed maize systems in Mexico**

CIMMYT researchers at La Tinaja, a low rainfall site in Jalisco, Mexico, have documented similar evidence of the advantages of conservation tillage. Since 1994, CIMMYT, INIFAP (Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico), and CIRAD (Center de Cooperation Internationale en Recherche Agronomique pour le Developpement, France) have studied the potential benefits and drawbacks of conservation tillage within the Mexican context.

After five years of conservation tillage, the reduction in erosion, combined with the effects of returning crop residues to the cropping system, resulted in a significant increase in soil organic matter in the upper part of the soil profile (0-5 cm), representing an additional sequestration of 0.7-1.0 t carbon $ha^{-1}$ $yr^{-1}$ on average during the first five years in the top 0-20 cm. The C sequestration and indirect effects on global warming are less dramatic perhaps than in systems without biomass exportation (such as forests), but they are very impressive for cereal cropping.

**Tillage systems for rainfall use efficiency**

In Bolivia, where moisture stress is the major limitation to wheat productivity, the potential for reduced tillage technology is being studied in two contrasting settings: the high inter-Andean valleys, where small-scale farmers (2-5 ha) produce one crop of wheat each year in monoculture or in rotation with potatoes, faba beans, peas, and/or barley; and the lowlands, where wheat is grown on large, mechanized farms in the winter in a double-crop system with summer soybeans.

The national programs and CIMMYT have redirected the research agenda toward practices that increase rainfall use efficiency. Although the principles of moisture conservation are the same in the highlands and the lowlands, the practical solutions differ because of the great variation in farm size, availability of capital, and farmers` ability to assume risk.

Research in the highland areas concentrates on evaluation of straw cover to increase rainfall use efficiency. Results are extremely encouraging: crop residue retention generally increases yields and reduces risk – two important objectives for Bolivia`s small scale, subsistence farmers. Farmers show marked interest in returning crop residues to the fields after sowing, despite the alternate use of the straw for animal feed. Researchers also participate in a project to develop a small, animal-drawn, no-till seed drill for sowing cereals into surface residues. Initial results with the drill are very positive.

In the lowlands, research concentrates on increasing rainfall use efficiency in wheat-based systems through zero tillage and crop rotations, as well as on identifying and solving problems that may arise in the fields of farmers using these conservation systems. The area under zero tillage has grown rapidly in the last five years, and now approximately 25% of the area seeded to annual crops is untilled. So far, the chief impact of zero tillage has been to reduce costs and allow farmers to seed more of their land at the optimum time. Research indicates a large interaction between zero tillage and crop rotations, though few lowland farmers use rotations. The incorporation of a crop rotation into zero tillage practice should have a major impact on crop productivity.

**Impact in South Asia**

One example of a large area where reduced tillage options are beginning to have an impact is in South Asia, where researchers are evaluating the potential of several practices to foster a more productive, sustainable, and socially equitable agriculture. All of the practices are aimed at establishing wheat on time, with less cost after rice in rice-wheat systems in the Indo-Gangetic Plains. All of them slash tillage costs, enable farmers to sow much earlier, improve water and nutrient use efficiency, improve wheat yields – and sometimes make space in cropping pattern for a third crop. This research is being carried out in conjunction with the Rice-Wheat Consortium for the Indo-Gangetic Plains (a CGIAR Eco-regional Program), comprised of national research programs in the region, relevant international centers, and selected universities in the North. The tillage practices are:

- Chinese two-wheel Hand Tractors with implements capable of drilling wheat and other crops into standing rice stubble in a single pass (suitable for resource-poor farmers with small fields in the eastern Indo-Gangetic Plains).
- Surface seeding practices requiring no machinery or implements (suitable for even the poorest farmers).
- Inverted-T, zero-till seed drills for four-wheel tractors (suitable for farmers in the western Indo-Gangetic Plains). With the development of suitable machinery for planting into residue this area will further expand.
- Bed Planting systems, which make use of permanent raised beds for growing crops, will enable farmers to retain crop residues and carry out more precise and ecologically appropriate water, nutrient, and weed control (also suitable for farmers in the western Indo-Gangetic Plains).

Where needed, prototype equipment has been developed by national program researchers in collaboration with local manufacturers. CIMMYT has imported still other equipment prototypes into South Asia. With partners in national programs, CIMMYT has trained farmers in the use and maintenance of this new equipment. By working on this technology with farmers, researchers have empowered farming communities to make a realistic assessment of the ups and down, and the costs and benefits, of the new tillage practices. Where this paradigm was used the first year was used to demonstrate zero-till in farmer fields. In the second year farmers loaned the machinery to plant his farm and in the third year bought his own implement, planted his entire farm and then rented it out to his neighbors. More than 8,000 ha in Haryana, India and 5,000 ha in Punjab Pakistan was planted to zero-till this year. There would have been even more if the zero-till drill had been available in more numbers. Next year will see an explosion of this technology. Bed planting has been demonstrated this year and should have a similar success in the next few years, especially in non-rice-wheat systems such as cotton, soybean and maize-wheat areas.

## Surface Seeding and Zero Tillage

Surface seeding-zero tillage practices are important in Nepal, eastern India, and Bangladesh, especially where waterlogging and heavy soils are a problem. At some test sites in Nepal surface seeding made the difference between a yield of 4 t $ha^{-1}$ and absolutely no yield at all. Fields were too wet for farmers to use conventional tillage practices, so they could not even sow their crops. Surface seeding, in contrast, enabled farmers to plant directly onto saturated soils. This zero tillage system and the inverted-T system above enables farmers to conserve water, because the practice makes it easier for farmers to flood the fields with water when the fields are not plowed. Because wheat is planted earlier in zero-tillage systems, at a time when there is more moisture in the soil, farmers also use less water for the first irrigation of the wheat crop. Researchers working on zero tillage practices are also examining the benefits of leaving crop residues on the soil surface as mulch, and results have been encouraging. The main priority is to develop an efficient implement for planting into residues. Farmers would then not have to burn the residues in order to plant their crops and together with fuel saving greatly reduce carbon emissions to the atmosphere and reduce the risk of global warming.

## Generalizations

Conservation/zero tillage and residue management practices are among the most effective approaches to improve the productivity and sustainability of wheat and maize systems (Rajaram, 1998; CIMMYT, 1999). However, for the most part, those crop management strategies have by-passed small farmers. The reasons for this are many and varied, depending on whether the cropping environment is irrigated or rainfed (Alesli, 1996; Hobbs et al., 1997; Sayre, 1998; Wall, 1998).

Conservation tillage research has focused mainly on rainfed situations, where crop residue retention to enhance both erosion control and moisture retention is of paramount importance. In contrast, the application of conservation tillage to irrigated cropping systems, especially those including rice and wheat, has been very minor throughout the world. Since the beginning of 1990-1991 CIMMYT has been working on a bed-planting system that combines reduced or zero tillage with residue retention, providing unique opportunities to reduce tillage and manage crop residues in irrigated cropping systems.

Planting wheat on beds with conventional tillage under irrigation is not new. However, researchers and farmers have dramatically changed the technology over the past 20 years. Its success in the Yaqui Valley region (more than 90% of farmers have adopted it) has prompted CIMMYT researchers to investigate its potential in other parts of the world.

As part of that effort, CIMMYT explores the application of permanent beds to wheat-based rainfed production systems. We are finding that permanent beds can provide small-scale wheat farmers in rainfed environments with a valuable technology that allows them to reduce tillage, conserve moisture, and use a major part of the crop residue for fodder. Based on these positive results, we are convinced that bed planting offers a sustainable method for planting wheat in both rainfed and irrigated conditions that small-scale farmers will adopt and continue to apply well into 21st century.

Genuine constraints do exist that inhibit the realistic development of appropriate technologies, but they are not insurmountable if researcher common sense is combined with farmer knowledge and participation in the development process. Work on wheat bed-planting system at CIMMYT, which strives to combine the remarkable flexibilities and alternatives provided by the method with the potential to markedly reduce tillage and to properly manage crop residues is hopefully a step in the right direction.

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**Table 1. Main constraints affecting the adoption of zero-tillage planting systems for wheat and other crop by small farmers.**

1. Lack of appropriate small-scale planters.
2. Crop residue management issues:
   - removal of residues for fodder and/or fuel;
   - inadequate residues in low yield environments;
   - excess residues in high yield environments;
   - uncontrolled community grazing of residues;
   - lack of appropriate small-scale equipment to chop and evenly distribute residues;
   - lack of suitable equipment to plant into residues;
   - burning is easy and so used by farmers but with negative environmental effects.
3. Problems associated with fertilizer application/management including both chemical and organic fertilizer sources.
4. Potential development of new or intensification of existing weed, disease, or insect problems.

**Table 2. Potential advantages of zero tillage planting systems.**

1. Erosion can be dramatically reduced when zero tillage is combined with proper crop residue management.
2. Moisture conservation is normally improved in low precipitation, rainfed conditions.
3. Savings in water are found in irrigated systems by as much as 20-25% through faster water flow in the first irrigation and in some cases, no need for the pre-planting irrigation
4. Crop turn-around times are reduced leading to higher yields.
5. Soil physical characteristics are improved.
6. In many cases, production costs are reduced significantly leading to more profit.
7. There is significant savings in fuel for tractor powered systems that reduces c-emissions and reduces global warming effects. It also reduces a countries fuel bill.
8. These systems allow crops to be planted into residue so energy is not needed to incorporate or remove the residues and burning can be prohibited leading to even less c-emissions.
9. Residue retention provides a good habitat for beneficial insects that survive to help control non-beneficial insects.
10. In rice-wheat systems of Asia, less soil is disturbed in 0-till and less weeds occur enabling herbicide use to be reduced.
11. In rice-wheat systems, yellowing of plants after the first irrigation does not occur.
12. Less lodging has been observed in 0-till wheat fields in rice-wheat areas.

**Table 3. Advantages of permanent bed-planting systems for wheat production.**

1. Facilitates reductions in tillage and provides opportunities for crop residue management in gravity irrigation systems.
2. Improves irrigation water management and efficiency as compared to flood irrigation. 30% savings in water are found.
3. Can reduce the dependence on crop residue retention under dry, rainfed conditions to conserve rainfall when combined with tied-ridges.
4. Provides drainage system, where waterlogging conditions can occur.
5. Establishes a defined controlled traffic system by restricting machinery and animals to the furrows eliminating compaction in the seeded area on top of the bed.
6. Facilitates field access allowing:
   - Opportunities for mechanical weed control, thereby reducing herbicide dependence;
   - Opportunities to band apply nutrients (especially N) when and where they can be most efficiently used.
7. Usually allows use of lower seeding rates compared to conventional planting systems. This is important in seed multiplication fields and where hybrid seed is contemplated.
8. Usually reduces crop lodging compared to conventional planting systems.
9. Leads to rapid turnaround times between crops when a bed width common to all crops in rotation is used.
10. Leads to improvements in chemical, physical, and biological soil characters especially for the untilled surface of the bed.
11. The beds can be used cycle after cycle. Farmers avoid the financial and environmental costs of making repeated passes with a conventional plow during land preparation.

**Table 4. Effect of tillage, crop residue management, and crop rotation on mean maize and wheat yields under rainfed conditions at El Batan, Mexico, 1996 and 1997 crop cycles.**

| | | | | Yield (kg/ha at 12% m.c.) | |
|---|---|---|---|---|---|
| **Tillage** | **Residue** | **Rotation** | **Crop** | **Wheat** | **Maize** |
| Zero | Retain | Continuous | Maize or wheat | 4985 | 4894 |
| Zero | Remove | Continuous | Maize or wheat | 3857 | 2503 |
| Zero | Retain | Rotated | Maize | 5082 | 5197 |
| Zero | Remove | Rotated | Maize | 2781 | 4870 |
| Conventional | Incorporate | Continuous | Maize or wheat | 4132 | 3425 |
| Conventional | Remove | Continuous | Maize or wheat | 3477 | 3753 |
| Conventional | Incorporate | Rotated | Maize | 4592 | 3358 |
| Conventional | Remove | Rotated | Maize | 3853 | 4031 |
| MEAN | | | | 4095 | 4004 |

Growing cycle total rainfall: 1996 = 509 mm; 1997 = 436 mm.

**Table 5. Effect of crop residue management and tillage on maize and wheat yields under rainfed conditions at El Batan, Mexico (average yields for the 1996 and 1997 crop cycles).**

| | | Yield (kg/ha at 12% m.c.) | |
|---|---|---|---|
| **Tillage** | **Residue** | **Wheat** | **Maize** |
| Zero | Retain | 5034 | 5046 |
| Zero | Remove | 3319 | 3687 |
| Conventional | Retain | 4362 | 3392 |
| Conventional | Remove | 3665 | 3892 |
| MEAN | | 4095 | 4004 |
| LSD (0.05) | | 814 | 528 |

# DEVELOPMENT OF SOIL TILLAGE SYSTEMS IN NORTHERN KAZAKHSTAN

**Mekhlis K. Suleimenov**[1]

Farming in the steppe areas of Kazakhstan began to develop rapidly in the period of 1954-1956 when over 25 million ha of virgin grasslands were plowed to introduce and maximize spring wheat grain production. The beginning of virgin land development coincided with a period of certain democratization in the social, economical and scientific environments of Soviet society as associated with the dismantling of the Stalinistic personality cult. As distinct from the Stalin era, opportunities appeared to criticize dogmatic theories in various areas, including soil and crop management.

Before 1954, Soviet Union dominated soil and crop management systems were based on crop rotations with obligatory legume-grass fields and mouldboard plowing. This system was applied throughout the country, including Kazakhstan. These practices were not criticized due to fears associated with the fate of N. Tulaikov who paid with his life for denouncing grass based systems in the steppes of Volga area in the 1930s.

As early as 1954, the All-Union Workshop on newly developed soil and crop management systems, suggested by a collective farm agronomist, T. Maltsev, was held in Shadrinsk District, Kurgan Region of Russia. Summing up his own observations as well as studies of the Shadrinsk experimental field, T. Maltsev rejected both main components of the grass based system for Western Siberia. He indicated that soil fertility can be maintained by sowing several years with continuously annual grain crops and the application of non-mouldboard soil tillage. In his fields, in particular, he used deep non-mouldboard plowing in a summer fallow field and shallow autumn diskings in other fields of the rotation. The perennial grass based 10-course crop rotation was replaced by a 5-course rotation removing the perennial grass component of the former series. Therefore a rotation of summer fallow with grain crops resulted.

In line with Soviet traditions, a scientific recognition of his theory, including non-mouldboard soil tillage was follow-up recognition of Maltsev's achievements at the level of the Central Committee of the Communist Party and its First Secretary Mr. N. Khrushchov. It should be borne in mind that T. Maltsev worked in a forest-steppe zone and the advantage of the non-mouldboard tillage he considered only in a context of soil fertility in the course of continuous growing of annual cereals. After these 1954 studies, non-mouldboard soil tillage techniques were spread throughout the country. To this end, ordinary mouldboard plows were used with mouldboards removed whilst Maltsev suggested his own design of the equipment for this tillage. Besides, disk plows were used extensively for soil tillage.

Studies assessing non-mouldboard soil tillage techniques were conducted in Kazakhstan as well. Early experiments showed promising results on this soil tillage method as compared to conventional plows. However in the conditions of the open steppe, it was necessary to address more issues of water accumulation and soil conservation against wind erosion. These

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goals could be achieved by use of equipment which conserve surface residues, for in the steppe area of northern, central, western and eastern Kazakhstan limiting factors for grain yields are low rainfalls (200-350 mm $yr^{-1}$), entrapment of winter precipitation (one third) and intensive wind activity.

Sub-surface soil tillage was found to be superior in addressing these production limiting factors. Initially in the 1950s, this method was termed "non-mouldboard soil tillage" and enabled conservation of crop residue or stubble. Canadian (Noble from Alberta) planter and tillage machinery served as prototype equipment, namely for stubble drill SZS-9 and blade KPP-2.2 units.

It would be incorrect, however, to imply that the soil conservation farming system developed under a leadership of academician A. Barayev was a copy of any Canadian system. Firstly, autumn soil tillage is not practiced in Canada, while it is the main soil tillage practiced in conservation tillage systems in Kazakhstan using discs and cultivators in order to reduce excessive residue which can interfere with spring cultivation and sowing. Secondly, "Noble" equipment was not formerly and is not now widely used by Canadian farmers. After modification for adaptation to conditions in North Kazakhstan, these refined machinery were used on millions of hectares. For deep sub-surface tillage, a unique sweep was developed having no analogues outside of Kazakhstan.

Studies on sub-surface soil tillage started in all agricultural research stations in the 1960s. As a rule, they were conducted in 4-course, 5-course and 6-course grain-fallow or grain-row crop-fallow rotations. Thus, in the All-Union Research Institute of Grain Farming, a long-term experiment was started in 1961 in the fields of the 5-course fallow – 4 grains rotation. The main treatments were: fall deep mouldboard plowing at a depth of 20-22 cm or 25-27 cm in all fields; deep fall subsurface tillage at the same depth in all fields; shallow fall subsurface tillage at 12-14 cm in all fields; or rotation of deep and shallow tillages.

## Main Soil Tillage

Autumn sub-surface tillage provides overwhelming advantages versus mouldboard plowing (Table 1), principally due to improved moisture storage prior to spring seeding as a result of snow trapping. In spite of possible increased weed infestation, sub-surface tillage resulted in increased grain yield of 35-65 percent. Later studies (Chmil, 1996), however, indicated a 10 per cent advantage in favor of deep sub-tillage, whereas continuous shallow sub-tillage proved worse that mouldboard plowing (Table 2).

These experiments were conducted on a southern light clay black soil at Shortandy. There are several reasons of yield gain reduction due to a continuous sub-surface tillage. Firstly, continuous sub-surface tillage resulted in increased weed infestation, especially after shallow tillages. Secondly, long-term shallow sub-tillage caused soil compaction and consequently worsened water intake during the spring snow thaw. Besides, the soil fertility status changed over a period of more than three decades. Under these conditions, one could see in special fertilizer treatment experiments an increasing respond to nitrogen which was not the case in earlier studies in the 1960s and 1970s. In this regard the mouldboard plowing has preponderance against shallow sub-surface tillage.

In numerous studies conducted on lighter textured ordinary black soils, the most efficient tillage method was shallow sub-tillage, or often no autumn tillage at all (Blisov, 1950; Ivanov *et al.*, 1978; Kudaibergenov, 1979). At the same time annual deep sub-tillage was found to be more efficient on compacted Solonetzic soils (Priadka and Laznik, 1975). Thus, in dry conditions when moisture is a main yield limiting factor, adequate autumn soil tillage is preferred ensuring better snow accumulation and infiltration during the spring thaw (Bakayaev, 1975; Vasko, 1976). Snow retention management is of utmost importance. If no or improper snow management practices were conducted, the efficiency of deep fall tillages is reduced. Conversely, if snow ridging resulted snow packs of 40-50 cm depth, autumn deep fall tillage significantly increased melt-water infiltration. It is worthwhile to consider that besides water intake issues, for most soils, except Solonetzic, there is little need for deep soil loosening to adjust soil density.

Depth and direction of soil tillage is important to prevent or limit excessive run-off of melt-waters. In Northern Kazakhstan, even at low incident slopes intensive run-off of thawing snow can occur on heavy textured soils. In such cases, deep sub-surface tillage with sweeps or chisel plows at a depth of 25-27 cm across slope direction are recommended (Tleuov, 1988).

A great deal of discussion has focused on soil fertility as it relates to soil tillage methodology. There is little doubt that fertility can be lost after mouldboard plowing due to wind erosion. Soil tillage methods, however, can cause different distribution of nutrients across soil layers. Sub-surafce tillage results in a differentiation of the arable layer on fertility. According to some studies, total nutrient content is improved after sub-tillage (Okhinko and Tatoshin, 1986). This phenomenon of soil fertility differentiation in the arable layer became the basis for a theory recommending the periodic turnover of soil layers for better utilization of inherent soil fertility. S. Sdobnikov (1968) was one of the first to justify this concept for Northern Kazakhstan suggesting a periodical (once in several years) plowing would result in dramatic yield increases. Periodic plowing was most promising in summer fallow situations, but provide disadvantageous when applied during autumn plowing due to subsequent yield reductions because of lower water storage.

Studies at KazRIGF (Zinchenko and Zinchenko, 1997) indicated that it is expedient to use mouldboard plow in the fallow field to control annual weeds such as wild oats, wild buckwheat, red root foxtail and setaria. Inversion of wild oats seeds to a depth of 20 cm dramatically decreased infestation establishment (Table 3).

Zinchenko and Zinchenko (1997) report that the effect of plowing during summer fallowing on the wheat yield depended on a weed infestation prior to fallowing. Yield increases in favor of plowing amounted to only 2.6 per cent on weed-free fields whereas it increased to 8.4 per cent on heavily infested fields (Table 4).

K. Orazbayev (1975) reported that on southern light clay black soils, plowing of a field before a maize crop, in a rotation of small grains with maize, reduced weed infestation of maize by half and increased yield (Zinchenko and Zinchenko, 1997).

**Summer Fallow Tillage**

Fallow is known to control weeds and allow the accumulation of moisture. To effectively control weeds, tillage system employed should focus on general weed type. As indicated earlier, mouldboard plow is effective in control of annual weeds. Blades are suitable to destroy perennial, rhizomoniferous weeds (e.g., thistles). Fields infested with quack grass benefit from frequent chisel plowing. For wheatgrass "ostrets" with horizontal rootstocks at a depth of 25-30 cm, deep non-mouldboard plowing in dry, hot weather, followed by cultivations at 10-12 cm are required for effective control (Zinchenko and Zinchenko, 1997).

Tillage during summer fallow can eliminate surface residue thus increasing soil susceptibility to wind and water erosion. Strip fallows effectively control wind erosion, however its use is often associated with negative factors: all field operations are conducted in one direction, yield losses increase, occurrence of water erosion increases.

Soil conservation during summer fallow can be achieved through replacement of tillage weed control with herbicide application. Long-term experiments at KazRIGF, Stepnoishimskaya Experimental Station indicate Roundup, 2,4-D and other chemicals are effective and recommended for reduced and zero-tillage systems during summer fallow. These technologies unreservedly solve soil conservation issues. However, for water accumulation and conservation, the data is more controversial (Soil Conservation Practice, 1985). The practical use of chemicals is closely tied with production profitability, and it is thus premature to speculate regarding promotion of expanded use of inputs when farmers face deep economic crisis and potential financial insolvency.

### Seed Bed Preparation

A widely held concepts of good seed bed preparation recognizes the importance of early spring "dust mulching". Harrowing of soil in the early spring is not always justified, and numerous observations have not substantiated the importance of dust mulching. In addition, on heavy soils, autumn deep sweeping can produce large clods which need to be reduced in size prior to planting. Therefore the dust mulching is not an absolute compulsory component of proper planting protocols and should be used only for a leveling of the field surface. In Canada, dust mulching is not practiced. Spring tillage is conducted with cultivators or diskers and stubble cultivator-drills conduct simultaneously cultivation, sowing and packing.

In spite of the fact that our stubble drills are equipped with cultivating shovels, in most cases cultivators or disc plows are used separately to destroy weeds. In my opinion, in most cases it was used too much to cut weeds several times during the course of a few hours. This practice could be afforded only under socialism. Except for cases with heavy weed infestation, one pass of the cultivator-drill should suffice. Cultivator-drills were inefficient because of the practice of a deep seed placement (10 cm) resulting in the replanting of cut weeds.

## DISCUSSION

Soil conservation practices developed by scientists of the KRIGF and other institutions, including a system of subsurface conservation tillages, have insured protection of the soil against erosion, better moisture accumulation and increased yield potential of field crops. Many theoretical and practical issues of soil tillage however remain pending. Moreover due to the radical socio-economical changes which have occurred in the agricultural sector, appropriate and affordable crop cultural practices are needed.

Firstly, it is necessary to reevaluate all previously obtained research data with consideration of our changing farming conditions, in particular recognizing the need to fit producer production costs inline with market "rewards". Under the socialist system, production *per se* was the principle goal and managers were rewarded from higher yields. Under such system, any activity which increased yield and production could be justified.

Snow management practices are currently no longer used as tied with deep soil tillage in the autumn. Therefore, issues concerning the depth of autumn tillage should be readdressed, as well as the concept of autumn tillage, *per se*. There is a great deal of data contradicting the necessity of this operation. In the past, however, avoidance of some field practices was considered as a simplification of recommended cultural practices, untidiness and inaccurate.

The issue summer fallow plowing to break differentiation of the arable soil layer to improve fertility is not clear. The use of the plow to control weeds should be considered as any other agronomic practice, however there is no need to ban use or manufacturing of this equipment.

Seedbed preparation strategies need to be reevaluated. Not going into details, I believe that many agronomic practices could be dropped because of unproven efficiency. The same is true for summer fallow management. Previous recommendations considered 4-6 cultivations in summer as optimal. Today, 4 fallow tillages are rare, and many fallow fields lie under no-till conditions. Is there any reason to name these fields summer fallow?

As distinct from the past, recommendations should be more flexible, and should apply to various soil-climatic and socio-economic conditions so that farmers can select for themselves the best production alternatives for their own needs. It will be necessary to continue the improvement of soil tillage machinery for various natural zones with consideration of our new socio-economic environment.

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**Table 1. Spring wheat yield (t $ha^{-1}$) in a 5-course grain-fallow rotation as affected by methods of main soil tillage on southern calcareous chernozem (A.I. Barayev, 1978).**

| Soil Tillage Method | Crop after summer fallow | | | |
|---|---|---|---|---|
| | 1st | 2nd | 3rd | $4^{th}$ |
| Plow | 1.59 | 0.97 | 0.77 | 0.76 |
| Sub-tillage | 1.65 | 1.31 | 1.21 | 1.26 |
| Gain (%) | +3.8 | +35.0 | +57.1 | +65.8 |

**Table 2. Spring wheat yield (t $ha^{-1}$) as affected by main soil tillage on southern calcareous chernozem, 1980-1993 (A.N. Chmil, 1996).**

| Soil Tillage Method | On fallow | | On stubble | |
|---|---|---|---|---|
| | Yield (t/ha) | Change (%) | Yield (t/ha) | Change (%) |
| Plow | 1.79 | - | 1.31 | - |
| Subtillage at 12-14 cm | 1.63 | -9.0 | 1.21 | -7.6 |
| Subtillage at 25-27 cm | 1.85 | 3.4 | 1.45 | 10.7 |
| Alternate subtillage | - | - | 1.40 | 6.9 |

**Table 3. Effect and carry-over of plowing in summer fallow on weed infestation of spring wheat in a 5-course grain-fallow rotation (average for 1984-1988, KazNIIZKH, I.G. Zinchenko and S.I. Zinchenko).**

| Soil Tillage System | Weeds | Weeds before fallow, (per m$^2$) | Field after fallow | | | |
|---|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd | 4th |
| Subtillage:<br>--in fallow, 25-27cm,<br>--in other fields, 10-12 cm | Total, including | 47,2 | 14,1 | 18,2 | 23,1 | 44,6 |
| | Wild oats | 15,1 | 2,3 | 4,4 | 7,1 | 12,1 |
| | Setaria | 14,4 | 0,5 | 2,4 | 8,1 | 15,1 |
| | Wild buckwheat | 10,6 | 1,4 | 2,0 | 6,1 | 8,4 |
| | Rhyzomes | 6,8 | 0,5 | 0,9 | 2,3 | 8,4 |
| Plow:<br>--in fallow, 25-27 cm,<br>--in other fields subtillage at 10-12 cm | Total, including | 50,4 | 6,4 | 10,1 | 17,4 | 23,8 |
| | Wild oats | 17,0 | 0,5 | 1,2 | 4,1 | 7,3 |
| | Setaria | 15,7 | 0,1 | 2,3 | 5,2 | 6,1 |
| | Wild backwheat | 10,5 | 2,6 | 1,5 | 3,8 | 4,4 |
| | Rhyzomes | 7,2 | 1,6 | 1,2 | 2,7 | 3,6 |

**Table 4. Wheat yield (t ha$^{-1}$) as influenced by a main soil tillage method in grain-fallow rotation depending on weed infestation by annuals (I.G. Zinchenko and S.I. Zinchenko, VNIIZKH).**

| Weed infestation before fallow | Main tillage during fallow | Years | Wheat yield in rotation (t/ha) | Change (%) |
|---|---|---|---|---|
| Low | Subtillage | 1975-1979 | 1.84 | |
| Low | Plow | | 1.89 | 2.6 |
| Heavy | Subtillage | 1974-1978 | 1.55 | |
| Heavy | Plow | | 1.68 | 8.4 |

# INTERACTIONS OF CONSERVATION TILLAGE AND NO-TILL ON SOIL PROPERTIES: ENVIRONMENTAL AND ECONOMIC BENEFITS

**Friedrich Tebrügge**[1]

## ABSTRACT

The impact of intensive soil tillage treatments on soil physical properties is described by means of selected data obtained through long-term, up to 18 years of investigations, interdisciplinary research. Tillage intensity of the systems considered decreases in the following sequence: Conventional plough tillage (CT), reduced tillage (RT), and no-tillage (NT). In general, bulk density in the upper layer of NT soils is increased, resulting in a decrease in the amount of coarse pores, and a lower hydraulic conductivity when compared with the CT and RT soils. Surface cover by crop residues, higher aggregate stability, and increased infiltration rates under NT protect soil fertility by avoiding surface sealing and erosion. Lateral losses of herbicides are also reduced under NT conditions. Accumulation of organic matter and nutrients near the soil surface under NT and RT are favorable consequences of not inverting the soil and by maintaining a mulch layer on the surface. Those improvements accompany enhanced biological activities in NT and RT top soils. Increased earthworm activity in NT treatments builds up a system of continuous macropores which improves water infiltration rates and supports decomposition and incorporation of straw. Soils which have not been tilled for many years are more resistant to vehicle passage; consequently, the compaction by traffic is lower. Penetration resistance curves indicate that a uniformly stable structure has developed over the years in NT soils. Economical effects of different tillage systems are also assessed.

## INTRODUCTION

Recent European Union negotiations about agricultural policy may force farmers to consider reducing tillage intensity and other purchased inputs in order to remain economically competitive. Benefits of conservation tillage systems from the ecological point of view are assumed in agricultural practice, administration, advice, and research in Germany. Conservation tillage methods will likely become the favored approach in many regions of Germany because of economical and ecological influences. This paper presents results from research addressing the effects of decreasing tillage intensity.

Three tillage systems were considered: Conventional tillage (CT) using a moldboard plough; Conservation or reduced, non-inversion tillage (RT); and, No-tillage (NT) where the only soil disturbance is caused by planting. The comparison between tillage extremes of CT and NT was considered to clearly reflect effects of tillage intensity on soil properties.

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## MATERIALS AND METHODS

Five field sites were selected that had differing soil properties (Table 1). Full-sized plots (200 m long, 12 m wide) in two replicated experiments are used to compare the tillage treatments. The tillage treatments were applied to cereal crops, sugar beet, maize, or winter rape (canola) consecutively to the same plots for several years (Table 1).

Penetration resistance [$N \cdot cm^{-2}$] was measured with a hand-operated penetrologger (60° cone , 12.83 mm in diameter and with an area of 130 mmI) to a depth of 50 cm at 5 cm profile intervals. Soil pore volume was determined from 100 $cm^3$ samples of undisturbed soil cores representing 2-6, 12-16, 20-24, and 36-40 cm profile intervals. After saturation with water, the samples were drained using a pressure plate outflow method with pressures of -2.5, -6, -10, -30, and -100 kPa (Richards and Fireman, 1943). Pore size distribution was estimated according to the water desorption characteristic, as suggested by Hartge (1978).

Trafficability was determined using a soil stress pressure gauge (Bolling, 1987). A tractor with a front wheel load of 20.85 kN and a rear wheel load of 13.50 kN was used for the tests. Soil stress at 20 and 40 cm depths was determined with ten replicates per pass. In addition to these measurements, soil samples were taken before and after each passage and analyzed for bulk density and pore size distribution.

Air permeability was measured to determine pore continuity (Kmoch, 1965): A fixed volume of air, dependent on soil texture and structure, was pressed through 100 $cm^3$ undisturbed soil cores with the time taken for the air to flow through each sample recorded. These measurements were standardized to coarse pores, according to a drainage pressure of -10 kPa.

Aggregate stability was determined using a single drop rainfall experiment for the aggregate size class 5.6 mm – 6.0 mm (Farres and Cousen, 1985; Roth, 1991). Furthermore, stability of moist aggregates was determined using Horn and Dexter (1989) and Mitschke *et al.* (1991) crush test.

The organic carbon content was determined by wet oxidation (Schlichting and Blume, 1966) from soil samples taken at 0-2.5, 2.5-5, 5-10, 10-15, 15-20 and 20-25 cm profile intervals (10 replicates).

Abundance of earthworms and their channels were determined from small plots (0.25 $m^2$) treated with formalin. Worms which appeared on the soil surface 30 min. after formalin application were collected and tallied (Friebe and Henke, 1992). The number of earthworm channels were counted at 20 and 40 cm soil depth (Edwards *et al.*, 1988). Visible biopores (III > 1 mm ) were quantified by digital image analysis.

Runoff, soil erosion and lateral losses due to herbicides were determined from eight small inclined-plot experimental plots (1.8 x 4.3 m; 12.75% slope) using a rainfall simulator (Kainz and Eicher, 1990) with 63 mm $h^{-1}$ precipitation applied. For estimation of herbicide losses, plots were treated with herbicides (isoproturone, terbuthylazine, and metolachlor) two hours prior to artificial rainfall simulation. Sorption kinetic studies revealed that sorption of triazines and phenylureas initially occurred rapidly, followed by slower sorption rates under equilibrium conditions (Kookana *et al.*, 1992). However, under the given conditions some sorption of the herbicides will occur, so differences among herbicides with different properties should be evaluated. The herbicides were chosen according to their solubility in water, affinity to soil, and their relevance in agricultural practice (Table 2).

## RESULTS AND DISCUSSION

### Organic Carbon Content

Tillage method, the affect of tillage implement to the soil (from CT to NT), and their influence on agrotechnical parameters are illustrated in Figure 1. Accumulation of organic carbon in the upper soil layer was evident under long-term no-tillage conditions as has shown by others (Blevins *et al.*, 1983; Rhoton *et al.*, 1993; Singh *et al.*, 1994). The difference in soil organic matter distribution due to CT and NT is presented in Figure 2.

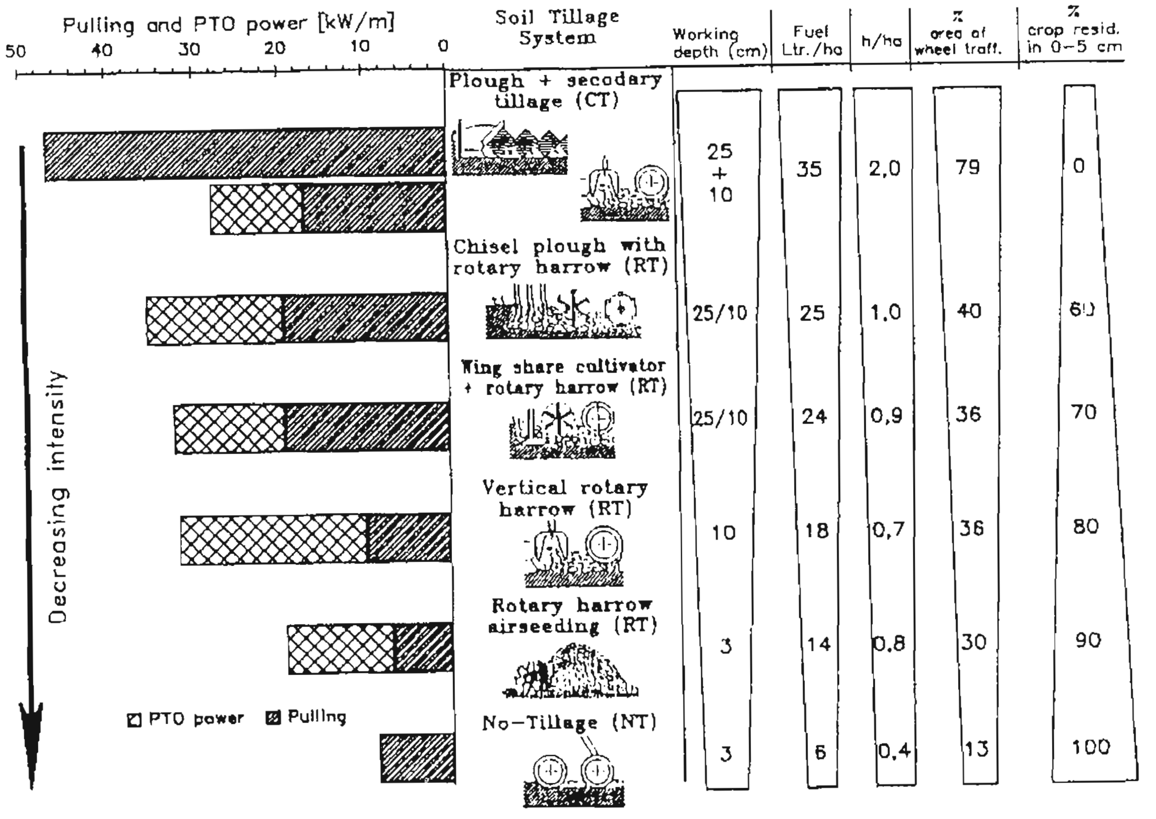


**Figure 1. Applied tillage systems and their effects on performance and requirements. Impact on soil depth and soil surface.**

Stratification of organic matter was likely due to plant residue cover on the soil surface (cf. Figure 1) which favors the accumulation of organic matter near the soil surface. (Tebrьgge *et al.*, 1991). Surface litter on non-ploughed soils can be considered as a key factor for promoting microbial activity, improving aggregate stability, protecting against erosive water forces, and herbicide behavior.

### Dynamics of Bulk Density and Penetration Resistance

Decreasing tillage intensity generally resulted in an increase in bulk density of the upper soil. Natural compaction by deposition of NT soil was found at all locations, especially at 3-10 cm soil depth. However, immediately below the arable layer (25 - 30 cm soil depth), bulk density of the tilled soils usually was higher than in the non-tilled treatments. Compaction in conventionally tilled soils in 25 - 30 cm depth is illustrated in Figure 3 by the bulk density and the regression curve for penetration resistance. Penetration resistance [$N \cdot m^{-2}$] of the soil may be a factor determining the quality of this structure. No change in resistance with increasing soil depth under no-tillage contrasted with lower resistance under plowing in the upper soil zone (Figure 3). At the 25 - 30 cm depth, where compaction due to tractor traffic can occur, compaction of the soil (1.51 $g \cdot cm^{-3}$) could be confirmed by means of this technique, whereas compaction was not observed in NT treatments (1.41 $g \cdot cm^{-3}$).

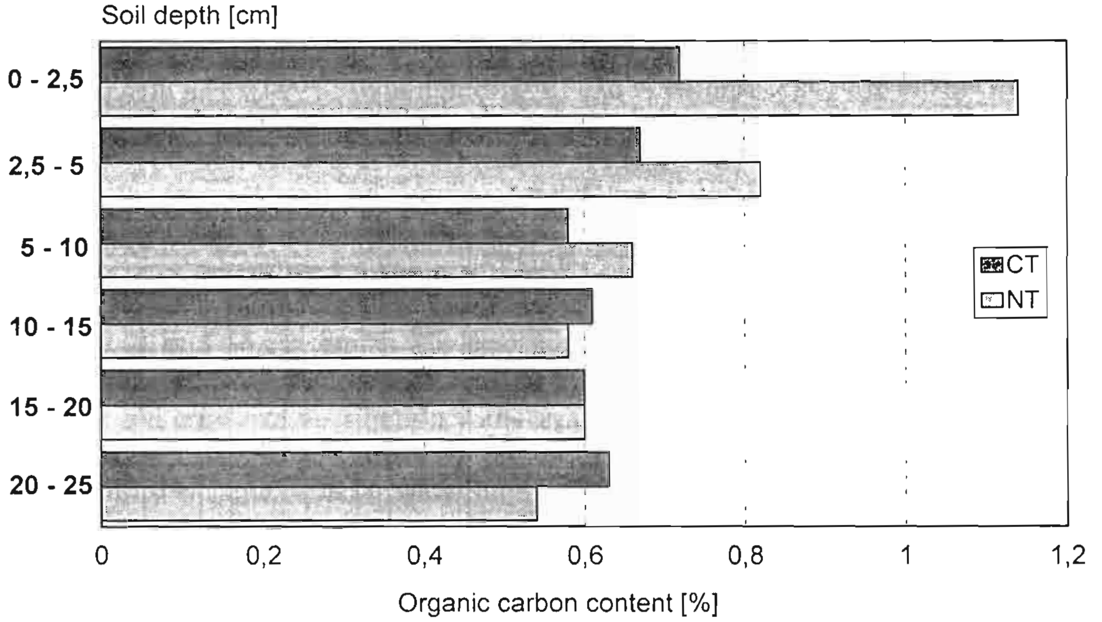


**Figure 2. Effect of long-term applied tillage systems on organic matter contents in soil, expressed by the content of organic carbon in the top soil of the Eutric Cambisol (acc. Grocholl).**

These measurements, taken like a snapshot in time, do not give an accurate impression of the dynamics of soil structure over the entire growing season. As shown in Table 3, bulk density after conventional tillage in October was low, further reduced by soil freezing in December. Later through May, a constant increase of bulk density was observed. In contrast, during the same period, the higher initial bulk densities of the NT-system were progressively reduced perhaps due to a self-mulching effect of the clay soil and/or an increase of soil biological activity as soil temperature increases in springtime.

Autumnal recurring tillage in CT creates an artificial inter-aggregate pore system in the topsoil horizon. However, these macropores (>120 μm) are labile as indicated by a reduction in volume observed during the winter period. NT plots on Eutric Luvisols showed lower total pore volume over the same period with relatively constant values of pore size >10 μm (Figure 4).

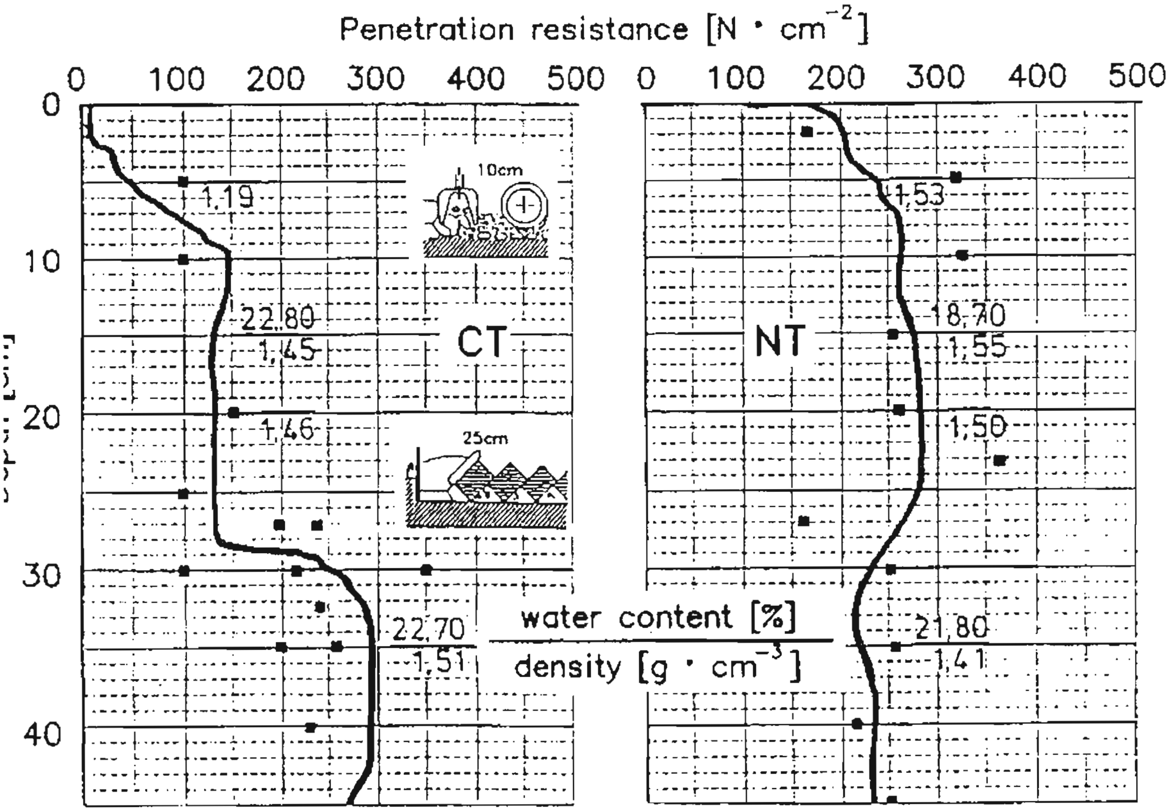


**Figure 3. Penetration resistance, water content, and bulk density in soil dependent on tillage intensity and soil depth - Luvic Phaeozem.**

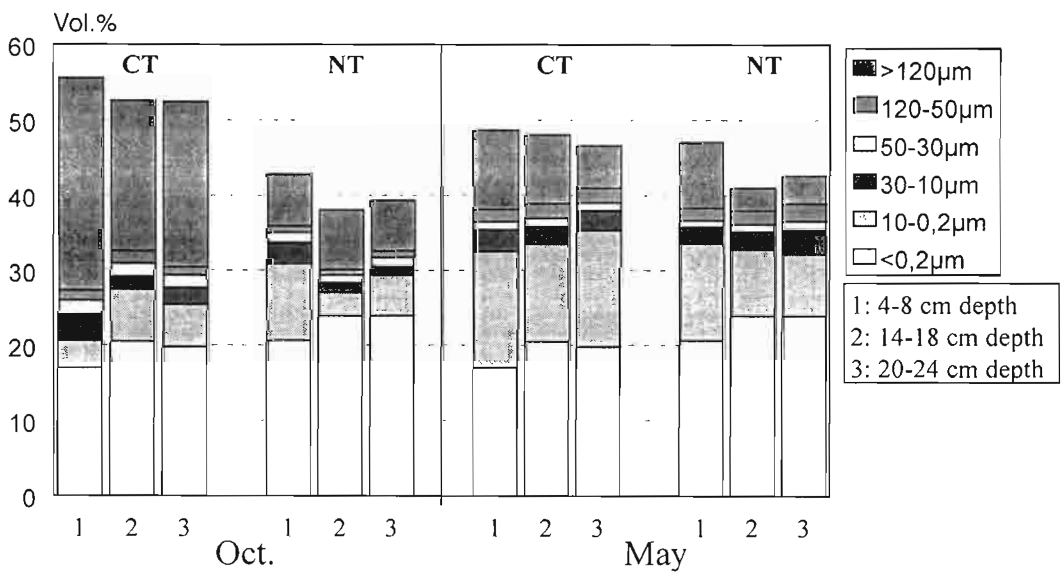


**Figure 4. Pore size distribution in different depths at different times of conventionally (CT) and non-tilled (NT) soil - Eutric Fluvisol.**

## Trafficability

Comparison of pore size distribution in Luvic Phaeozem trials before and after heavy tractor traffic provided evidence of the varying effects of different tillage systems on soil structure (Gruber,1993). A greater reduction n pore area, down to a depth of 40 cm, was observed after one tractor pass in CT versus NT treatments. Up to 50% of the volume of wide coarse pores (>50 μm) was reduced by tractor traffic in the CT-system. Hence, the pore surface area where soil gas exchange, water drainage and root development occurs was reduced. The reduction of pore volume by a single pass in the NT plots was only 10% at 12 cm depth and 20% (from a higher total volume) at 20 cm depth. No influence of traffic loading was measured at 40 cm depth (Figure 5). Rut depth, which can be taken as a measure of soil surface damage, showed distinctly lower values in NT plots (1 cm) compared to CT (8 cm). Regarding the driving distance which is necessary for conventional tillage operation (approximately 3 fold when compared to NT) the resulting compaction which may occur is a serious inherent problem of the CT-system (Tebrьgge and Wagner, 1995).

Under laboratory conditions triaxial tests gave detailed information concerning stress states as they appear in a soil under load (Gruber and Tebrьgge, 1990). Samples taken from ploughed plots reacted to the exerted pressure with the highest volume change, with fracture occurring at an axial pressure of less than 0.3 MPa. Soil samples from non-tilled plots were characterized by a smaller volume change and therefore had the highest load resistance, with fracture only occurring at an axial pressure of 0.7 MPa. Comparing stress conditions, the NT treatment axial pressure was twice as high than the CT sample (Figure 6). Lower soil stresses and track depths confirm this phenomenon, as well as the negligible changes observed in macropore volume on soil loading (Figure 5).

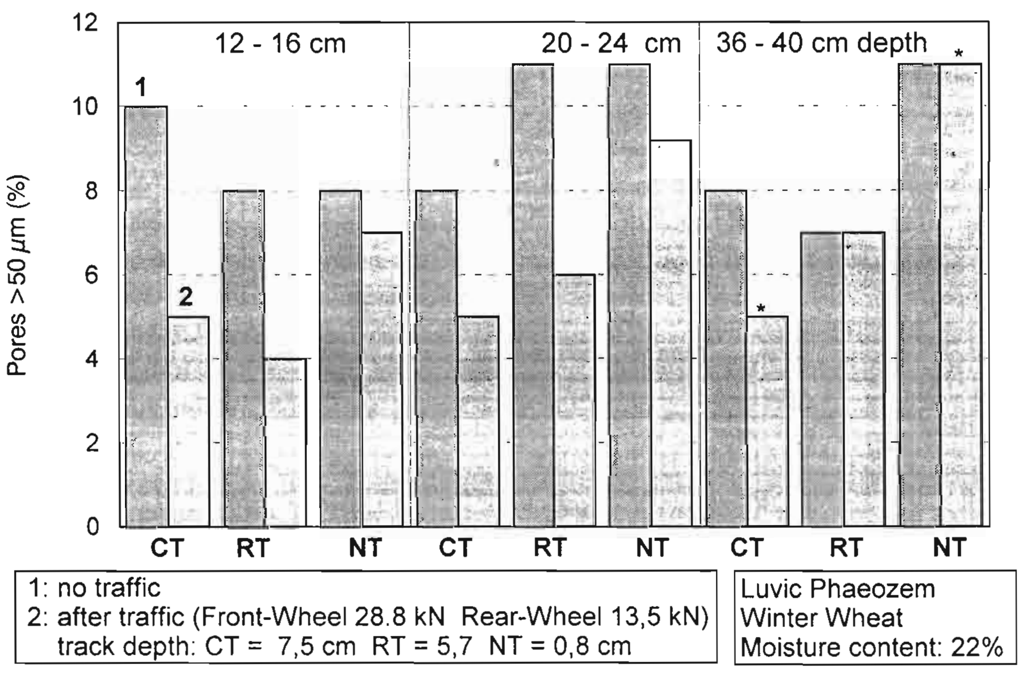


**Figure 5. Pore size distribution before and after traffic in a conventionally tilled (CT) and a non-tilled (NT) soil (Luvic Phaeozem). * Significant differences (0.05 level).**

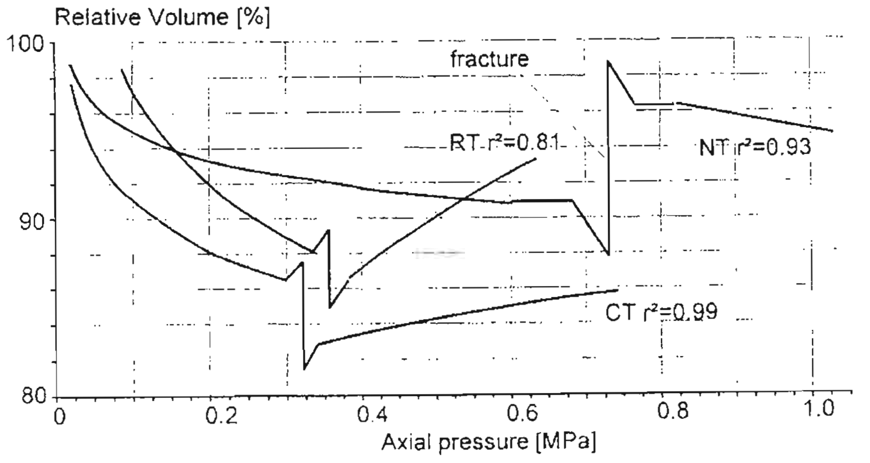


**Figure 6. Relative alteration of volume of soil samples (2 - 12 cm) of different tillage systems (triaxial-test) - Eutric Fluvisol, silty loam (Gruber, 1993).**

### Abundance of Earthworms and Channels

The intensity of soil tillage strongly influenced earthworm population density and, by their activity, the amount of biopores. Long-term application of RT and NT resulted in significantly higher population densities (Figure 7). On Luvic Phaeozem soils, these affects were nearly 7 times higher in NT treatment than with CT (Friebe and Henke, 1992).

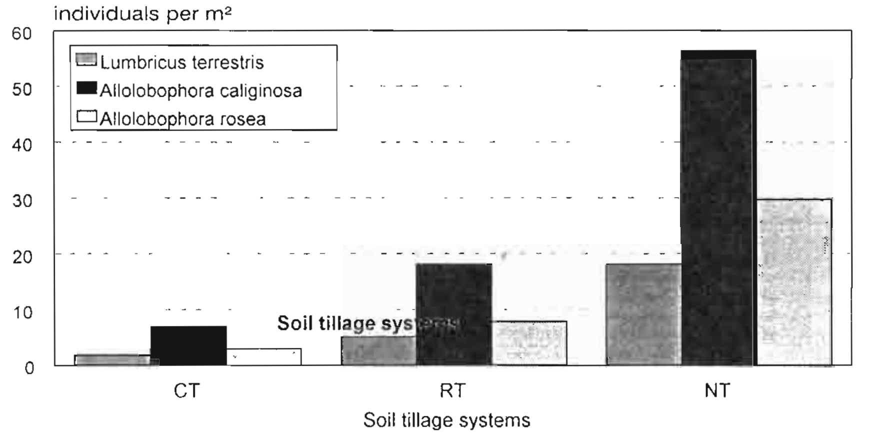


**Figure 7. Earthworm population under the influence of different soil tillage system.**

NT treatment had a greater abundance of visible biopores than other tillage treatments. At 25 and 45 cm depths, significant differences were observed between the tillage treatment (Figure 8). Deep digging worms (e.g., *Lumbricus terrestris,* Figure 7) can build continuous vertical biopores and were detected ten times more frequently with NT, where the plant residues remained on the soil surface, than with CT. In NT treatments, especially at the boundary between topsoil and subsoil, there are considerably more biopores visible than with CT. These biogenic macropores, vertically oriented, have an positive effect on deep root development and are particularly resistant to pressure loading (Figure 5).

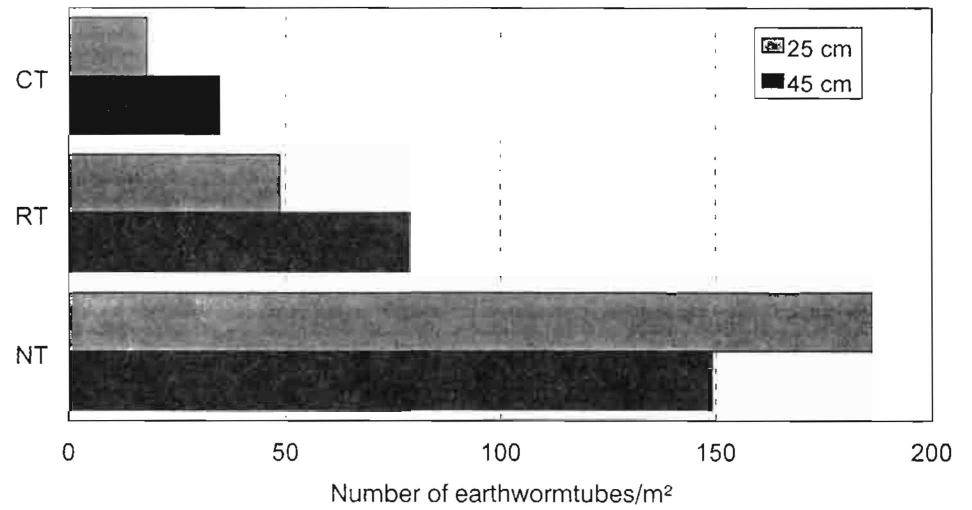


**Figure 8. Number of earthwormtubes per ml (20 and 45 cm depth) in dependency on soil tillage intensity -Luvic Phaeozem.**

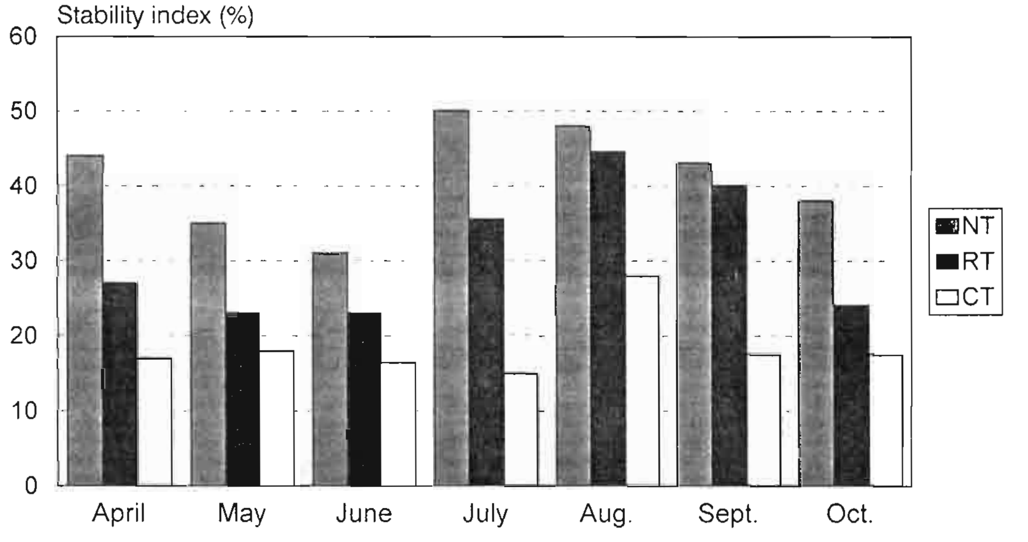


**Figure 9. Dynamic of aggregate stability on the Luvic Phaeozem. (Aggregate-size-class 5.6-6 mm - single drop rainfall simulation.)**

## Aggregate Stability and Surface Sealing

Aggregate stability on all soils examined was lowest for the CT system (Figure 9). However, with increasing clay content, differences in aggregate stability between the treatments decreased.

In addition, resistance of the aggregates against the impact of raindrops was assessed on a monthly basis throughout the growing period on the Luvic Phaeozem soil. For all treatments, the aggregate stability was characterized by a clear dynamism during the course of time. Despite these fluctuations, increased aggregate stability from CT to RT to NT was observed. Related to aggregate stability, soil crusting was examined for the tillage systems after the sowing of sugar beets (GroЯ,1996). Surface crusts are characterized by a low hydraulic conductivity in comparison to the undisturbed soil. Because of these crusts, the potential for surface runoff and soil erosion, and loss of agrochemicals on such sealed soils is increased (Figure 10).

**Runoff, Soil Erosion, and Lateral Losses of Herbicides**

Water erosion can cause severe soil conservation problems in Germany, especially on silty soils. The adaphic factors responsible for susceptibility to erosion include: Surface sealing due to poor aggregate stability; Decreased infiltration of water due to subsoil compaction; Lack of pore continuity; Poor buffer capacity of the soil during heavy rain showers.

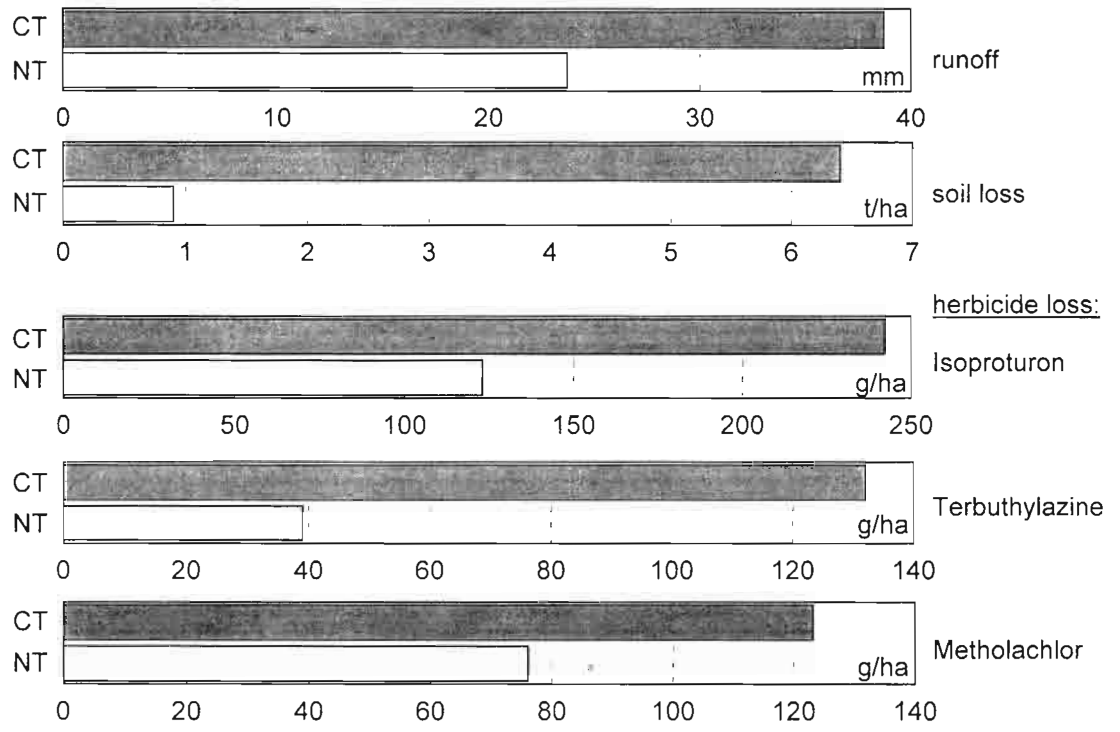


**Figure 10. Runoff, soil loss, and herbicide losses via lateral translocation in a rainfall simulation experiment (63 mm·h$^{-1}$ for one hour); comparison of two different tillage treatments on the Luvisol (according to Fischer *et al.*, 1995).**

The simulation experiments revealed a strong influence by tillage intensity on erosion, as has been shown by others (Packer *et al.*, 1982; van Doren *et al.*, 1984; Radcliffe *et al.*, 1988). The soil protective effect of the no-tillage system was confirmed by significantly lower amounts of runoff and sediment loss (Figure 10). The amounts of runoff after one hour of precipitation were 39 mm (CT) and 24 mm (NT), with sediment losses of 6400 kg·ha$^{-1}$ (CT) and 900 kg·ha$^{-1}$ (NT) calculated highlighting the soil protective potential due to no-tillage systems (Fischer *et al.*, 1995).

Lateral herbicide loss is directly related to erosion. The proportions of loss herbicides lost when compared to the application rates are presented in Figure 10. Reductions in lost of up to 30% could be achieved from NT versus CT. However, increased infiltration rates and the phenomenon of preferential flow via the macropores may, under certain conditions, increase the downward movement of herbicides applied under NT conditions (Isensee *et al.*, 1990; Edwards *et al.*, 1992; Sigua *et al.*, 1993). This effect may be reduced by enhanced adsorption for which there is some proof in the soils under study (Dьring, 1996). Furthermore, increased microbial activity (Bцhm *et al.*, 1991; Grocholl, 1991) along with accelerated degradation of herbicides (Levanon et al., 1994) and resistance against inhibitory effects of herbicides on the microflora (Fernau, 1996) can reduce losses due to leaching. A European-wide investigation to determine the relationship between soil tillage and herbicide dissipation was undertaken recently (Borin *et al.*, 1997).

**Economical Benefits**

Reduction of the production inputs due to alteration of conventionally practiced tillage methods should be a strong incentive for the use of no-tillage or other conservation tillage systems. In the study discussed here the total operating costs for no-tillage crop production were lower compared to the conventional tillage system. Approximately US\$150$\cdot$ha$^{-1}\cdot$yr$^{-1}$ can be saved, on average, by using the no-tillage system. Affect on crop yield (Table 4) revealed that no-tillage is a competitive cultivation practice for well-drained soils. Long-term tillage experiment show that profitable and environmentally sound production can be achieved by tillage systems which reduce deleterious impact to soil.

For large farms (>500 ha), it could be a useful alternative to have two different types of equipment (e.g. conventional as well as a no-tillage system). The total process costs of three different farming systems on a 500 ha-farm using no-tillage (100%, 50% or 33% of the arable land are sown by no-tillage) in comparison to the conventional system (Figure 11). Using the conventional system on 500 ha the total process costs are approximately US\$225 ha$^{-1}$, with a savings of US\$175 ha$^{-1}$ obtained by using no-tillage on an entire farm (system I). If the farm were equipped with both tillage systems, sowing 250 ha with no-tillage (system II) results in costs of approximately US\$145 ha$^{-1}$ or US\$170ha$^{-1}$ if when only one third of the arable land is sown by no-tillage (system III).

The acceptable yield depression by using the three different tillage-management systems without any loss in profit compared to the conventional system (100% CT) is pointed out for different yield levels (dt ha$^{-1}$) and two different product prices (US\$ ha$^{-1}$) in Figure 12. The acceptable yield depression reaches from 28% with a yield of 60 dt ha$^{-1}$ and product price of US\$10 dt$^{-1}$ winter wheat, to approximately 4% with yields in the range of 100 dt ha$^{-1}$ and a product price of US\$15 dt$^{-1}$.

## CONCLUSION

Within the given experimental conditions, several soil properties were improved as a consequence of decreased disturbance and the maintenance of crop residue covers in reduced or no-tillage systems. Soils that have undergone long-term no-tillage are characterized by a higher resistance against stress from vehicle load and by a higher stability of aggregates against the impact of raindrops. Lower susceptibility for soil crusting and erosion and a high abundance of vertically oriented continuous earthworm burrows result in increased infiltration rates and reduced soil losses. Moreover, losses of agrochemicals via the lateral path may be clearly reduced under no-till conditions. However, under certain conditions, such as short time intervals between application and a heavy shower event, the downward movement of plant agro-chemicals may be increased. Further research is needed in this field through the cooperation of soil tillage experts and those who study the fate of the various pesticides. Tillage systems which reduce the impact on the soil structure have ecological as well as economical benefits.

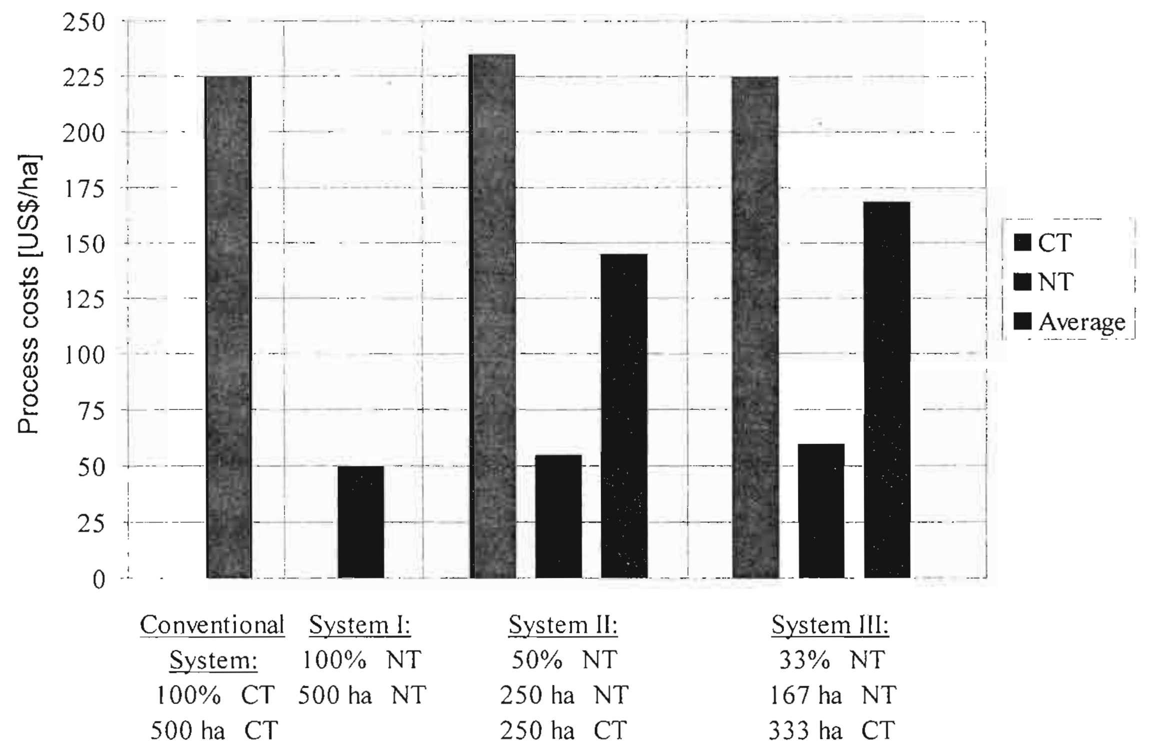


**Figure 11. Process costs [US$ ha$^{-1}$] of different farming systems using no-tillage (NT) with 100%, 50% and 33% portion in comparison to the conventional system with plough tillage (CT) on the whole arable land (model for cost calculation: 500 ha farm size.**

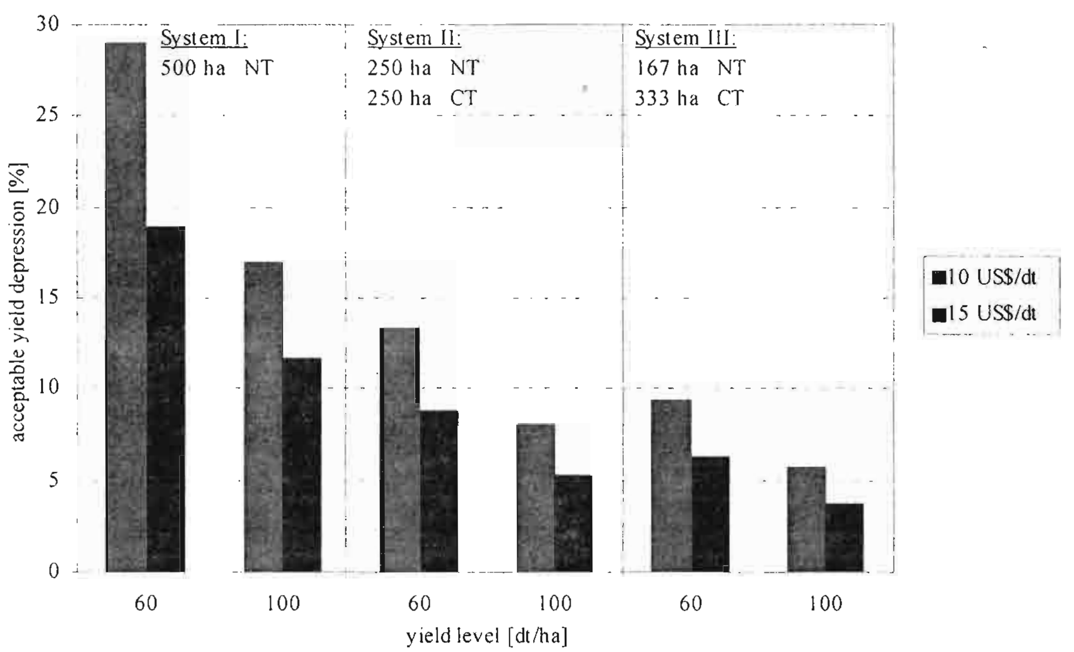


**Figure 12. Acceptable yield depression [%] for farming systems using no-tillage by different crop yield and market price levels, break even point = equal profit to the conventional plough tillage.**

## ACKNOWLEDGEMENTS

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**Table 1. Characteristics of the field sites under investigation.**

| Soil | Texture | | | Soil type | Precip. [mm/year] | Mean Temp. [°C] | Crop rotation (no. of years) | Beginning Year |
|---|---|---|---|---|---|---|---|---|
| | **Clay** | **Silt** | **Sand** | | | | | |
| silty loam | 31 | 53 | 16 | Eutric-Fluvisol | 600 | 8 | cereal (8) silage maize(3) | 1986 |
| loam | 26.5 | 55.9 | 17.6 | Stagnic Luvisol | 625 | 7.6 | cereal(14) Rape (3) | 1980 |
| loam | 21.2 | 67.3 | 11.5 | Luvic Phaeozem | 575 | 9 | cereal(13) sugar beet(4) | 1980 |
| loam | 13.8 | 66.7 | 19.5 | Luvisol | 630 | 8 | cereal(7) rape(2) | 1980 CT,RT, |
| sand | 5.7 | 29.3 | 65.0 | Eutric Cambisol | 600 | 9 | cereal(8) sweet maize(4) sugar beet(5) | 1980 |

**Table 2. Water solubility, sorption index (Koc), and half lives of the herbicides used (Tomlin, 1995).**

| Common name | Isoproturone | Metolachlor | Terbuthylazine |
|---|---|---|---|
| Chemical name | 3-(4-isopropylphenyl)-1,1-dimethylurea | 2-ethyl-6-methyl-n-(2-methoxy-1-methyl-ethyl)-chloro-acetanilide | 2-tert.-butylamino-4-chloro-6-ethylamino-1,3,5-triazine |
| Application rate | 2000 g $ha^{-1}$ | 1680 g $ha^{-1}$ | 840 g $ha^{-1}$ |
| Water solubility [$g \cdot l^{-1}$] | 0.06 | 488 | 0.0085 |
| Sorption index ($K_{oc}$*) | 72 – 158 | 121 - 309 | 162 - 278 |
| Half life in soil [days] | 6 – 29 | ca. 30 | 30 - 60 |

***$K_{oc}$ = Soil sorption index: Index of the degree of adsorption of a compound to soil normalized for carbon content; the higher the Koc value, the stronger the compound is adsorbed to soil. Immediately after sample collection, soil and sediment fractions were separated, then extracted for each herbicide and analyzed by HPLC (Dьring, 1996).**

**Table 3. Dynamic of bulk density in different depths of a differently tilled soil (n=12), Eutric Fluvisol.**

| Tillage Treatment | Soil depth [cm] | October | December | March | May |
|---|---|---|---|---|---|
| | | Mean value/range [$g \cdot cm^{-3}$] | | | |
| CT | 4 – 8 | 1.18/1.1-1.24 | 1.03/0.96-1.07 | 1.17/1.09-1.21 | 1.36/1.21-1.45 |
| CT | 20 –24 | 1.26/1.18-1.51 | 1.18/0.96-1.24 | 1.29/1.19-1.35 | 1.42/1,33-1,49 |
| NT | 4 - 8 | 1.52/1.37-1.67 | 1.5/1.43-1.56 | 1.37/1.25-1.49 | 1.4/1.15-1.61 |
| NT | 20 - 24 | 1.61/1.52-1.67 | 1.45/1.38-1.52 | 1.48/1.39-1.53 | 1.52/1.47-1.59 |

**Table 4. Differences in yield and profit of the no-tillage system related to the conventional tillage system. (Average over the crop rotation since its beginning.)**

| | Luvic phaeozem | Eutric cambisol | Eutric fluvisol | Stagnic luvisol | Luvisol |
|---|---|---|---|---|---|
| Differences in yield [%] of: | | | | | |
| Winter wheat | 1.4 | 0.3 | -0.6 | -5.6 | 3.1 |
| Winter barley | 1.7 | | 14.2 | 1.1 | -5.2 |
| Winter rye | | | | -4.3 | |
| Winter rape | | | | 5.4 | 10.9 |
| Oats | | | -11.8 | 1.6 | |
| Summer barley | | | | -5.6 | |
| Peas | | | | -9.0 | 13.8 |
| Sugar beet | 13.8 | -15.4 | | | |
| Silage maize | | | -12.4 | | |
| Sweet maize | | -0.7 | | | |
| Differences in profit [%] | 20.7 | 6.9 | 15.4 | 9.9 | 22.9 |

# NO-TILLAGE SEEDING: CRITERIA, MACHINES AND PERFORMANCE

**Keith Saxton**[1]

## ABSTRACT

Conservation tillage farming is becoming a very popular and effective farming system in many regions of the world. Key to this farming system is a seeding machine which can manage effective and timely seeding in a largely non-tilled soil with remaining surface residues from previous crops. Many early machines were slightly modified versions of former ones used under tilled soil conditions, but recent developments have shown much improved effectiveness with machines developed specifically for conservation tillage. This paper provides a summary of the criteria and performance to be met by an effective conservation tillage seeding machine and broad categories of the current machines in use.

Conservation tillage farming systems in which most soil tillage is omitted and crop residues remain on the soil surface have been shown to be very effective for an improved economical method of crop production while also reducing wind and water erosion (Darby, 1985). To change to a conservation tillage system of farming provides the opportunity to omit many to the conventional farming operations such as plowing, disking and seedbed smoothing. Seed drilling remains as one of the main operations to be accomplished, however, the requirements are more demanding than in conventional bare, tilled soils.

Non-tilled soils are often more firm requiring more machine cutting capability, and surface residues must be accommodated and managed. Conservation tillage is most beneficial when all or most crop residues remain on the surface to protect against wind and water erosion and for soil moisture conservation. However, these surface residues create an impairment to seeding drills which must be overcome by wide spacing of the seed openers, cutting or brushing the residues aside from the opener track.

### Practical Considerations

**Seeding criteria.** When choosing seeding machines for conservation tillage, their capability must successfully meet the following five criteria:

1. Precisely meter and place a wide variety of crop seeds at a uniform and intended depth and maintain the soil environment for successful seed germination and seedling emergence.
2. Seed on a soil surface which has crop residues from previous crops without destroying this residue and leaving it in an optimum configuration for soil, water and crop protection.

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3. Simultaneous place fertilizer in a parallel band with the seed row to provide the most efficient use of the fertilizer by the seedling and growing plants while minimizing utilization by weeds.
4. Possess good mechanical durability to maintain the precise seeding performance throughout a long economic life without significant wear and maintenance.
5. Have a viable economical purchase cost relative to the machines capability, durability and annual life-time usage.

Each of these criteria will be discussed in more detail. While there are many other smaller considerations in the design and selection of seeding capability, these will provide the first broad evaluations.

**Seed placement.** Precision seed placement into the soil is now recognized as one of the most critical processes in crop production. Accomplishing this in non-tilled soils with surface residues provides an even greater challenge than with conventional farming where considerable tillage effort is expended to prepare the soil surface into a "seed bed". Many of the original conservation tillage seeding machines were modifications of those used with conventional tillage and often were often only modestly successful. Consistent penetration to seeding depth and avoiding difficulties with the surface resides were the largest problems. In recent years, more modern designs have overcome most of these defaults.

Precision seed placement requires all seeds to be at a uniform soil depth and soil coverage. With this depth control, seeds germinate and emerge uniformly in time, thus younger plants do not compete with older, more mature plants, thus making a very uniform crop stand. Minimal soil disturbance is preferred to conserve soil moisture in the seed zone and reduce soil ridging. The seed coverage and furrow side walls must be firm but free of compaction and "smearing" to allow free seedling emergence and easy root penetration.

The machine component which engages the soil surface to provide the seed furrow and seed placement is the drill "opener". These openers can be classified into general categories according to their method of operation and type of seed furrow they provide. The two most popular openers around the world have been the hoe or chisel openers and the double disk opener. A more recent accomplishment has been the development of single disk openers.

Chisel and hoe openers provide a U-shaped seed furrow by ripping the soil from the surface to the seed depth. Most have a small tube down their rear section through which the seed drops into the furrow bottom, and then the soil falls back over the seed as the chisel passes. Some hoe openers are followed by closing and or press wheels to firm the soil over the seed. Fertilizer can be simultaneously placed with hoe openers either with separate openers or in combination with the seed opener fitted with separate drop tubes.

Double disk openers have been very popular for conventional tillage. The two disks running at a small angle to each other and close together force the soil apart in a V-shape furrow to the seeding depth. A seed drop tube is placed between the disks to allow the seed to drop to the furrow bottom. As the opener passes, the soil is expected to flow back over the seed, and as in the hoe openers, a closing press wheel often follows to firm the soil over the seed. Fertilizer placement may be with the seed, although this must be minimal to avoid germination and seedling damage. Most often, fertilizer is placed with a separate set of openers.

Single disk openers have been successfully designed and used for conservation tillage seeding in recent years. One design utilizes a single disk running at a slight angle to the direction of travel to cut a seed furrow with a U-shape and drop the seed along the rear side of the coulter as it travels forward. Depth may be controlled from a rigid attachment to the drill frame, but more often by a depth gauging wheel attached to the spring mounted coulter frame. Since the furrow soil is moved to one side of the furrow as the coulter passes, seed coverage requires this soil to be dragged back over the open furrow and firmed by wheels following the furrow opener. These openers have been shown to not perform well on steep slopes due to down hill slipping, thus misalignment of the forward motion of the opener.

A more innovative single disk opener has been developed which utilizes a single large disk running straight ahead to cut a single vertical soil slot. Two adjacent side blades rubbing against either side of the leading edges of the disk cut horizontal soil slots at seeding depth. This combination of disk and side blades form an extended inverted T-slot, or more correctly a +-slot (Cross-Slot), in the soil (Saxton *et al.*, 1991; Baker *et al.*, 1996). Seed and fertilizer drop tubes place the seed and fertilizer entirely separately, one on each side of the disk, between the disk and side blade as the opener passes. The lifted soil then drops directly back into its original place as it clears the disk. Press-depth wheels then firm the soil and residue directly back over the seed furrow. This opener is one of the most versatile and effective now available.

Each seeding furrow shape has varying capabilities and may be suitable to different soil and residue conditions. Generally dry soils can be seeded with U-shaped furrows by hoe and single disk openers, which allows the soil to flow back over the furrow for seed coverage. In these dry, hard soils, single and double disk openers may have more penetration and thus depth control problems.

In wet soil conditions, both hoe and double disk openers often have furrow closing and seed coverage problems. The hoe openers gather the wet soil and thus make ragged, uneven furrows. Double disk openers make a compacted furrow which is difficult to close. The Cross-Slot opener is likely the most effective for wet soils with its minimal soil disturbance and positive furrow coverage

Conservation tillage drills often use seed metering to the openers in a similar fashion as conventional tillage drills. Seed boxes with metered dispensers for each opener can be of a variety of styles depending on the seed type and seeding rate. While placing the meter boxes above the openers for gravity flow to the openers has been the most common drill configuration, a more modern method has been to use a single meter into an air stream which moves the seeds through tubes and dividers to the individual openers. These newer air seeders are particularly suited to wide drills used in large, relative flat fields. While most popular with hoe openers, air delivery has been adapted to almost all of the opener styles.

**Residue management.** Conservation tillage is most effective for soil and water conservation and crop production because of careful management and utilization of the crop residues. Numerous studies have shown that residues will significantly reduce wind erosion, (Horning *et al.*, 1998), water erosion (Laflen *et al.*, 1985; Norton *et al.*, 1985;) and soil water evaporation (Pannkuk *et al.*, 1997). However, leaving crop residues on the soil surface creates a new challenge to subsequent farming operations and other crop hazards such as weeds and diseases. Nearly all of these residue related difficulties have been overcome by recent innovations.

Reside management begins at harvest of the crop which provides the residues. Complete and uniform residue spreading by the harvester is the first requirement for both the longer straw and smaller particles of chaff. Partial removal or harvesting of residues often is beneficial if they are in large quantity. Complete removal or burning is generally not encouraged due to loss of conservation protection and nutrients for soil organic matter development.

Surface residues must be managed by the seeding openers to avoid interfering with the seeding operation and to leave the residues for soil and crop protection. Most seeding would desire to leave the residue largely uniform over the surface, either standing or flattened, and close to the seeded row for crop protection. This can generally be accomplished by using cutting disks in front of the seeding openers to allow the openers free passage through the residues. There are cases, for example in regions with cold soils, where removing the residues from the seed row results in more rapid warming and germination. Small raking wheels running in front of the opener to move the residue aside from the opener track have been effective to this style of residue management.

**Fertilizer placement.** Fertilizers for enhanced crop production in conventional tilled farming have been provided by surface broadcasting with subsequent tillage to mix the fertilizer into the surface soils. In conservation tillage farming, this is not possible. And it has been conclusively shown that fertilizer broadcasting is less efficient than precision placement.

Conservation tillage seeders should have the capability to simultaneously place seed and fertilizer. Placing the fertilizer in a parallel band with the seed row has been shown as the most effective configuration. There are still questions about the optimum spacing of the seed and fertilizer rows for various crops, but repeated trials have shown significant crop response to fertilizer within a few centimeters of the seed row for nearly all major crops. Some conservation seeders use separate openers for the fertilizer while others place both seed and fertilizer with a single opener and two drop tubes. Only very limited amounts of fertilizer should ever be placed directly in the seed furrow due to seedling growth damage. Almost all fertilizer forms, such as granular, liquid and gaseous, have been accommodated with similar results.

**Drill durability and performance.** Seeding conservation tillage crops requires a more sturdy and durable drill than conventional tillage seeding. No-till seeder frames and openers are generally heavier to accommodate the added penetration requirements and to carry both seed and fertilizer. This generally results in the drills being less width and thus seeding less area per day, but it must be remembered that this drilling operation is substituting for several field operations in more traditional tillage farming.

Modern no-tillage seeding generally accomplishes a higher precision of seed and fertilizer placement than traditional drill. This requires all drill components to be manufactured with improved precision and for these components to remain equally study with good performance over the life of the unit. Wear of the ground contacting openers is often the cause of poor seeding if these units are not repaired or replaced in a timely manner. Loose bearings and worn pivots can allow the opener components to shift or miss-align with resulting poor seeding precision. As a result, the durability of the seeder unit must be capable of withstanding the expected seeding conditions, and must be frequently inspected for continued precision no-tillage seeding.

**Economic cost.** The initial cost of conservation tillage seeding drills and planters varies widely. The buyer must be well aware of the machine capabilities which are needed and not be biased by a name on a lesser machine labeled as a "no-tillage" seeder. Many seeding machines are slightly modified versions of those used in conventional tillage farming and are far too light weight, have no fertilizer capability or have openers with poor penetration and residue handling capability. At any price, these machines have generally proven economically ineffective because of their poor performance in no-tillage seeding.

Some no-tillage seeders have been new designs incorporating extreme size and weight but had generally effective performance because of their capability. However, these machines have generally resulted in a poor economic investments because of their high initial cost and operating expense for the required tractor size. Evaluate each machine design to insure that it will accomplish the seeding criteria outlined earlier, then judge the price for the machine compared to its capabilities, versatility, durability and expected life performance, including repair availability and price.

## CONCLUSIONS

Seeding drills are extremely critical to the success of conservation tillage farming systems because this is a single operation replacing several operations typically used in conventional tillage farming systems. Precision seeding for conservation tillage farming systems requires a seeding machine with added capability and performance from that traditionally used in tillage farming. Non-tilled soils are somewhat more difficult to penetrate, surface residues must be accommodated and fertilizer generally placed simultaneously with seeding.

New seeding drills and planters have been developed during recent years which are proving very effective for no-tillage seeding. New innovations such as opener size and configuration, drill frame weight and opener configuration on the frame, and fertilizer attachments all have been developed to provide effective seeding into non-tilled soils. As a result, conservation tillage seeding is now being successfully accomplished in a wide variety of farming systems.

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# THE ROLE OF RESIDUE MANAGEMENT IN ADOPTION OF CONSERVATION TILLAGE

**John Morrison**[1]

The practice of conservation tillage includes the use and management of several subsystems. The relative importance of various subsystems to the successful adoption of conservation tillage might be debated, with the exception of residue management. This is because we can not establish or maintain functional conservation tillage without appropriate management of protective surface residues. It is the maintenance of protective surface cover on cropping fields that makes it possible to sustain production without major soil-disturbance tillage.

It is well established that the maintenance of significant amounts of soil coverage by residues reduces wind and water erosion, produces cleaner surface runoff water, increases water infiltration for storage for reduced crop water stress, improves soil quality, and stores atmospheric carbon for improved air quality. Therefore, the benefits are obvious to the scientist, the environmentalist, and many others, but not necessarily to the farmer! Conservation tillage, and especially residue management, must be packaged into easily-adopted technology transfer schemes. To better understand the elements of residue management, we need to understand the potential sources of crop residues, the impact of using those residues for soil protection and not for other traditional uses, the value of fencing livestock away from harvested fields to protect residue cover, as well as the benefits from appropriate management.

The sources of protective drop residues are very limited. Residues are left in the field after the harvest of grain, fruit, or root crops. And, residues are the produced by cover crops. Crops can be selected for rotations, which will provide year-around soil protection, and especially for protection during periods of high-intensity wind or rainstorm events. High-residue crops may be rotated with low-residue crops to provide such long-term protection. But, the source of soil protection is what is grown on the land and not removed with harvest.

The amount of residue (above-surface biomass) available for soil protection is then, either the total biomass not harvested, the biomass not removed with harvest, the biomass not removed for forage, the biomass not foraged by grazing livestock, the biomass not buried by tillage operations, or the biomass not deteriorated or eaten by varmints, earthworms, and other in-situ life forms. We know that the amount of total biomass produced in usually proportional to the crop yield. Before any losses, this value is 50-60% for many crops. More than 2 t $ha^{-1}$, and as much as 10 t $ha^{-1}$, of surface residues are needed to provide adequate soil protection. Therefore, it is important for conservation tillage farmers to manage their crops for high yields of residues as well as for harvestable products. This means that the yield expectations of many subsistence farmers around the globe must be raised to levels, which will provide adequate amounts of residues, before or in conjunction with the adoption process.

Year-around soil protection is ideal, but there are critical periods when cover is necessary to keep the system sustainable. Critical periods include periods of high-intensity rainfall,

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periods of high winds, fallow periods between crop seasons, and periods following planting when the growth of protective plant canopies is minor. The most easily-taught residue management scheme is year-around maximum soil coverage.

We must be able to demonstrate that there is value for the farmer to maximize the soil coverage. The farmer must not harvest or graze residues for forage. He should grow forage crops for livestock; this is a conservation practice, because forage fields are not tilled, making them protected from erosion. He should leave at least the critical minimum amount of residues on the field, if he must harvest a portion of it for forage.

Field operations which seem to be in conflict with the practice on conservation tillage and residue management are weed control, subsurface fertilizer applications, and crop seeding. Weed control within the maximum-coverage theme may be by non-incorporated herbicide applications, low-disturbance shallow cultivation, and/or by manual clean-up of weed-infested areas in fields. A farmer's weed control program may include all of these procedures. Special attention should be given to the potential use of low-disturbance cultivation as an appropriate technology. Such cultivators are now available. These implements cut the residue ahead of a low-disturbance shank, which supports a shallow-operating cultivation sweep. A depth gage wheel controls the depth to minimize soil disturbance. Weed control is a critical subsystem in conservation tillage and should be demonstrated and taught as step-by-step preventative procedures to avoid the financial hazard and set-back to adoption from weed infestations.

Fertilizer applications should be made into the soil to prevent the loss of fertilizer materials in surface runoff water and losses to volatilization. Aside from the environmental pollution from such losses, the farmer will suffer financial losses for each portion of costly fertilizer materials that are not used by the crop. Therefore, we must limit fertilizer applications to subsurface operations. This is directly in conflict with the maximum soil coverage theme, but must be done. The current-technology options to accomplish low-disturbance fertilizer applications are to apply either with an applicator knife, a coulter-nozzle device, at seeding with a soil opener near the seed furrow, or at cultivation with a low-disturbance weed cultivator. Each of these options can include the use of rolling coulter blades to cut through surface residues and depth gage wheels to control and minimize application depth and soil disturbance. The knife applicator is the only viable option for deep-placement of fertilizer materials, although the need for this practice should be verified before recommending it as a field procedure.

Seeding must also be a low-disturbance field operation to preserve the residue cover. Current technology is the use of one-pass or two-pass seeding systems. Two pass systems seem to be beneficial for wet, cold, adhesive soils which need to have the residue moved aside from the path of the furrow and to be loosened to some degree for drying and warming prior to seeding. Fertilizer materials may be applied with this operation. The depth and intensity of this operation should be minimized to conserve energy and to be compatible with the low-disturbance scheme. One-pass seeding is appropriate for many soils, but the seeding equipment should include residue clearing devices and soil loosening devices ahead of (or in combination with) row seeding units. Seeding is a critical operation. There have been and continue to be problems with achieving full crop plant stands with conservation tillage. Some of this problem has been relieved by the commercial development of improved residue-clearing devices positioned ahead of seeder row units. Depth control is also a problem, largely associated with the variability of thickness of residues on the soil surface interacting with depth gage wheels. Seed covering devices do not function well in combination with some other component options. Seed firming wheels and rear press wheels are sometimes only marginally functional or incorrectly adjusted. In general, technical problems with seeders for conservation tillage are mainly caused by incompatibilities between chosen components and field conditions.

## CONCLUSION

Workable residue management procedures must be identified before attempting to encourage the adoption of conservation tillage by farmers.

# THE NEW HOLLAND / FLEXI-COIL COMMITMENT TO CONSERVATION TILLAGE IN THE COMMONWEALTH OF INDEPENDENT STATES

**John Gehrer and Angelika Gehrer[1]**

New Holland is one of the world's largest manufacturers of tractors, combines, and hay harvest equipment. The Flexi-coil division is a leader in conservation tillage and seeding equipment for large scale farms throughout the world. More recently Flexi-coil has introduced a line of zero till equipment for smaller farms such as in Europe.

New Holland/Flexi-coil supported a project that promoted the production of rapeseed in Northern Kazakhstan (1994-1996) by providing a 10 meter pneumatic seeder and a field boom sprayer. The seeder was so successful that the Flexi-coil seeder seeded 2500 ha on the kolkose every year, seeding rapeseed, cereals, buckwheat and peas. The minimum tillage project demonstrated over a three year period that it is practical to produce rapeseed in areas where the precipitation is about 350-400mm per year and the yield was about one t ha$^{-1}$ even when no fertilizer was used.

The kolkoses in Northern Kazakhstan realized that one Flexi-coil air seeder and one sprayer can replace the tillage and seeding equipment of one brigade. However because there is no system of land ownership the kolkoses are not able to get credit and therefore are not able to purchase a Flexi-coil seeder. Therefore the kolkoses have to use old equipment which means that they are not able to finish seeding quickly, and they get lower yields, and they also cannot practice zero tillage with local equipment. If the kolkoses use the local equipment to practice zero till they will fail and say that zero tillage does not work.

When a proper system of land ownership will exist in the future, and the new farms will be able to get credit to purchase equipment and chemicals, New Holland/Flexi-coil will be very interested to open dealerships and possibly a joint venture to manufacture some parts locally.

Flexi-coil air seeders are very versatile because they can seed with a shovel to control weeds, and when more herbicides become available such as Roundup, then it can be converted to a narrow spike seeder for pure zero till applications. Also it can place fertilizer with the seed or beside the seed once fertilizer becomes available.

The local farm workers learned the benefits very quickly, and the agronomists understood that one Flexi-coil air seeder can replace 5-10 pieces of old equipment, therefore reducing fuel consumption drastically.

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# PROSPECTS OF NO-TILL WHEAT IN ROTATION WITH RICE OR COTTON IN CENTRAL AND SOUTH ASIA

**Mohammad Ashraf Choudhary[1], Mushtaq Ahmed Gill[2] and Alim Pulatov[3]**

Adoption of soil resource management and agricultural practices that seek to conserve soil resources and minimize environmental degradation is attracting overwhelming interest among scientists and general public (Choudhary and Baker, 1994). Most agricultural soils deteriorate under continuous cropping and this often results in declining soil quality and crop yields. No-tillage practices, an extreme form of conservation tillage system, can help improve soil and environment quality.

Research in several countries has shown that tillage intensity has an overwhelming effect on soil structure and erosion (Lal, 1993; Choudhary *et al.*, 1997), and that the adoption of no-tillage practices is likely to maintain soil physical characteristics and soil quality at levels similar to those under permanent pasture (Guo *et al.*, 1999). Soil bulk density, water content, infiltration, penetration resistance, earthworm population and soil pH are among the best indicators of soil physical conditions (Karlen *et al.*, 1994).

Janson (1984) reported that soil physical characteristics were proving remarkably stable under conventional tillage and no-tillage systems, and differences were developed between those two tillage systems in the levels of earthworm population and organic matter. Horne *et al.* (1992) found higher soil bulk density, larger soil aggregates and lower total porosities under no-tillage practices than those under conventional tillage management after ten years of maize (*Zea mays* L.)/oats (*Avena sativa*, L.) rotation.

Soil erosion is one of the most serious environmental problems facing world agriculture. A number of reports have highlighted the alarming degradation of the land by erosion and salinization. In the tropics generally, and in the humid tropics in particular, soil erosion is perhaps the most serious mechanism of land degradation. For example, over half of the agricultural land in Australia needs treatment for at least one form of degradation, most commonly salinisation (Edwards, 1993). Water erosion affects over half of Argentina's land area, and wind erosion does nearly as much (McTainsh and Boughton, 1993)

Worldwide, with the current low financial returns from arable farming, some of the land which was previously unaffected by soil erosion is being intensively farmed and therefore becoming more susceptible to soil erosion and a cause of non-point source pollution. Soil erosion throughout the world is proceeding largely uncontrolled, with minimum conservation. Sediment is the biggest pollutant of surface water. The sediment itself can alter stream channel characteristics and adversely affect aquatic plant and animal life.

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Agriculture is often singled out for contributing high levels of nutrients to runoff. The concentration of the nutrient nitrogen (N), phosphorus (P), and potassium (K) in surface water and groundwater is of environmental and economic concern. Fertilizers in agriculture play an important role in nitrogen pollution of surface waters and groundwater reservoirs. Good water management and lower quantities of nitrogen application during the growing season can reduce nitrogen losses to groundwater and surface waters from a field. Nitrogen fertilizers can contaminate water supplies and, together with phosphorus, cause eutrophication of lakes and rivers. Because the increase in nutrient concentrations in water has coincided with an increase in the use of fertilizers, it is often assumed that these fertilizers are the major contributing factors (Steenvoorden, 1989). But a major source of nutrients in drainage water from agricultural land is often due to mineralization of organic N following cultivation, rather than from the fertilizer itself (Follett and Walker, 1989). The intensity and duration of rainfall can also greatly affect nitrogen concentrations in runoff water.

The concepts of soil and water quality have been suggested as a tool for assessing long-term sustainability of agricultural land management. Because soil is a limited resource, agricultural production is dependent on improving soil quality. Improved soil quality also has an impact on water use, as high quality soil more effectively collects and stores water, reducing the need for irrigation.

This paper outlines case studies in two countries; Uzbekistan and Pakistan. It is argued that in these ecosystems no-tillage technology has tremendous potential for growing winter crop (wheat) following either rice or cotton, and minimize irrigation water use.

**Uzbekistan**

In 1997, approximately 27% of GDP were generated in agriculture, 16% in industry, and the rest in mining, construction, and services. Uzbekistan is the world's third largest cotton exporter and cotton fiber makes up 48% of its exports. The country is rich in natural resources such as gold, oil, natural gas, coal, silver and copper, and it is among the ten largest natural gas suppliers in the world.

Irrigation efficiencies are generally low, as there are no water tariffs for agricultural users, and large quantities of drainage water are generated. Upstream diversions for irrigated agriculture deplete the flows of the major rivers, Amu Darya and Syr Darya, and drainage flows to the rivers bringing with it large quantities of salt and chemicals, creating serious pollution problems in downstream reaches. As a result of the expanded irrigation, flows into the Aral Sea have reduced, which has created the current environmental situation in the Aral region.

A distinctive feature of the Republic has been the extensive development of the agriculture sector on the basis of widespread use of irrigation technologies for its cotton producing areas. Since a majority of the cultivated land was allocated to cotton and cereal growing (Table1), there was a high demand for land development, irrigation network construction, and river flow regulation. This unsustainable pattern of agricultural development was the main contributor to the present water crisis in the region.

Many years of intensive production of cotton and other crops along with over-irrigation has resulted in serious water quality problems. Introduction of an intensive cotton (monoculture) production scheme coupled with yield targets that were very high, encouraged the use of large amounts of fertilizers and pesticides. Agricultural chemicals used in crop production have dramatically polluted water and soil resources in the last 30 years. All the above-mentioned factors, along with such factors as the lack of ecologically clean technologies and effective water treatment plants, contributed to considerable pollution of the surface and groundwater resources, air, soil and plant life of the country.

Even though the use of pesticides, like DDT, was abandoned in Uzbekistan in 1983, more than 50 percent of soil samples taken recently exceeded Maximum Contamination Level (MCL) by 2 to 5 times. Nitrogen contamination of surface and ground water resources also exceeds MCL. The poor quality of water and wind blown chemicals has had an adverse impact on human health. An increase in salinity and chemical pollution caused substantial losses to the fishing resources of the Aral Sea.

More than 2 million hectares of arable land have been degraded to a point where they have severely limited agricultural use due to the problems of water logging, salinization and wind erosion. Soil organic matter (OM) contents have declined by 30-50 percent due to intensive land use in the last 40 years. Today's soils with poor and very poor OM content (from 0.4 to 1 percent) make up about 40 percent of the irrigated area.

**Pakistan**

In Pakistan, agriculture remains the most important sector for employment and income generation in the country. The sector, including forestry and fishing, accounts for about 25% of the country's GDP and more than 45% of employment. The sector is also important for the country's manufacturing industries, both as a source of raw materials and as a consumer of locally manufactured goods. It generates directly and indirectly about 70% of the country's export earnings, including raw and processed cotton, rice, leather, textiles and carpets. Productivity improvements have been achieved in the past due to increased investment in irrigation facilities, production and distribution of fertilizers and mechanization.

Water sector efficiency is particularly important in Pakistan, as about 90% of crop production depend on irrigated land. The sharp deterioration of the vast irrigation and drainage system, due to improper management of watershed areas and deforestation, has become a serious threat to the sustainability of agricultural growth. Major problems of water logging and salinity are also affecting the production potential on approximately 30% of irrigated land. Inefficient management of water systems and consequent low delivery efficiency and inequitable distribution, and insufficient cost recovery has also plagued the sector.

Both Uzbekistan and Pakistan have major water management problems that are common to each country. In particular, poor irrigation and agricultural practices have resulted in soil salinization, water logging and chemical pollution. Significant areas (20 – 30% of arable land) have production suppressed due to these effects. Such yield suppression directly affects the income of the rural families and communities in the affected areas.

The foregoing demonstrates a large number of similarities between Pakistan and Uzbekistan in terms of agriculture and the importance of on-farm water management and resource conservation technology. It is argued that development and use of no-tillage technology is essential for growing wheat crop in rotation with rice and cotton. This would enhance crop production and improve water use-efficiency of irrigation water.

## Zero-tillage Technology

Opportunities to increase crop production from the limited land area in Central and South Asia are partly constrained by the problems associated with adequate and timely crop establishment. An alternative is to use resource conservation technology (RCT) to establish crops following 'puddled' rice and cotton crops. This would allow utilization and conservation of antecedent soil moisture, time saving due to early planting, less dependence on weather to provide suitable working days, and minimizing yield declines attributed to soil structural breakdown under continuous cropping practices.

Pakistan's agricultural lands suffer from serious problems of land degradation, a decline in production and decrease in the soil organic matter as a consequence of improper soil use and management related to intensive tillage practices. Conventional tillage practices are an impediment to sustainable agriculture, as they frequently cause soil compaction, affect soil physical properties, provoke biological degradation, and as a consequence, cause soil degradation.

Resource conservation tillage, and particularly no-tillage, has considerable potential to contribute to sustainable, low-cost food production on a global scale due to its multiple benefits. Some examples of the adoption and proliferation of conservation tillage technology in the major crop production areas is shown in Table 2.

However, farmers and extension workers in Uzbekistan and Pakistan face a number of constraints, which include:

- A general lack of knowledge and information among farmers about NT and scientists and tractor owners/operators are not adequately trained to use the new technology.
- No tillage drills designed and manufactured outside of the region are unsuitable to work under previously puddled and untilled soil conditions. Therefore, design modifications and local testing are required before such drills can be recommended for use.
- Because extension workers and farmers lack adequate information and awareness of no tillage technology, there has been inadequate dissemination of promotion strategies.
- A lack of understanding concerning the value of soil cover for conservation, control of weeds under cover, insects and pathogens in the mulch, and in the use of pesticides.
- Knowledge is limited among scientists, and almost non-existent among farmers and extension workers, of agronomic and soil management of no-till crops i.e. crop rotation, management systems, plant density, fertilizer management.
- Inappropriate approaches to technology generation and testing and weak linkages between research, extension, and farmers.
- Lack of 'tailor-made' packages, understanding of economies of scale, and lack of linkages with indigenous technologies/ systems.
- Lack of participatory approach in the application of technology.
- Lack of decision support systems based on available soil/ climatic/ resources databases and predictive models for selecting conservation tillage technology under different ecosystems.
- A general lack of expertise, funds for research and dissemination, and training facilities.

Resource conservation practices have been successfully trialled in the paddy fields of Punjab in Pakistan (Anonymous, 1998). Second season's results (Anonymous, 1999) on 304 small farmers' fields covering 877 ha have demonstrated that the provision of biologically tolerant no-tillage technology is capable of adoption to wide range of soil and climatic conditions. Farmer-level field experiments have shown that no tillage methods not only increased wheat yields following rice, but also were a better option in puddled rice fields (Table 3) as it has numerous advantages, viz.:

- Time of sowing of wheat is saved by about one to two weeks, thereby allowing early sowing of wheat crop.
- Saves cultivation cost by about Rs.1,375 per ha (78% less than that with conventional tillage).
- Water saving by 21-63% during first irrigation, and 6-45% in subsequent irrigations.
- Stem borer infestation is insignificant.
- Weed germination is less as compared with that of conventional tillage method.
- Enhances wheat productivity by about 577 kg $ha^{-1}$, 17% increase over conventional tillage.
- Increases net farmer income by about 78%.

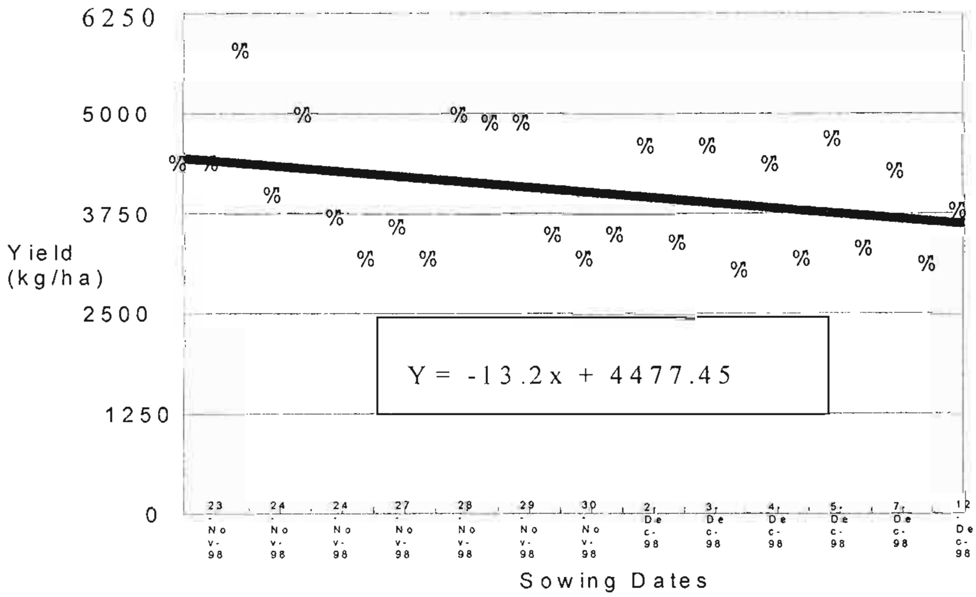


**Figure 1. Trend of wheat yield penalty if sown with no-tillage technology after 20th November.**

There were significant yield penalties if winter crop was planted late. It is important to note that in these trials wheat sowing dates of no-tillage and conventional tillage fields were almost the same. Altogether the spread of planting time was from 26 th October to 12th December. Figures 1 shows yield penalty of approximately 13 kg $day^{-1}$ or 0.8% $day^{-1}$ if planted with no-tillage after 20 th November. Similarly, Figure 2 indicates reduction of 7.4 kg $day^{-1}$ or 0.5% $day^{-1}$ in wheat yield planted with conventional method after 20 th November. It is clear from these data that time of planting is one of the major factors influencing wheat yield. Other factors include, quality of seed, soil condition, fertilizer application rate, weed control, time and quantity of irrigation water. Therefore, timely sowing of wheat is imperative along with improvements in other agronomic practices for winter crop production.

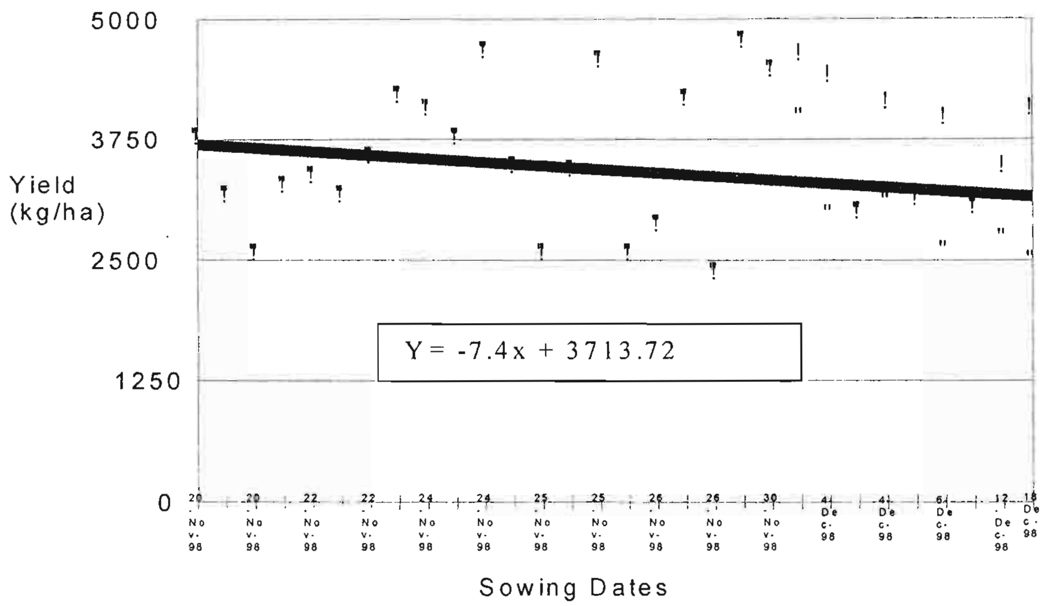


**Figure 2. Trend of wheat yield penalty if sown with conventional tillage technology after 20th November.**

Such results have been confirmed in an independent qualitative study (Mirza, 1999). This author suggested that no-tillage technology has great potential in enhancing wheat productivity because of the following reasons. These include (a) saving in cultivation and energy costs, (b) early sowing is assisted, (c) saving of 30-50 % irrigation water, (d) water and fertilizer efficiency is enhanced, (e) weed infestation is reduced, and (f) rice stubble decaying process is enhanced, which improves soil microbial activities.

These studies have concluded that farmers are enthusiastic to adopt this technology. However, the yields need to be stabilized for the benefit of the country. Pakistan Punjab's 1.3 million ha of rice and 2.5 million ha under cotton-wheat rotation are obvious candidates for adoption of no-tillage technology.

Similar conditions exist in Uzbekistan and other ecosystems in Central Asia where no-tillage could usefully be employed to grow winter crops following rice and cotton.

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**Table 1. Total area under cultivation and grain and seed cotton yield in Uzbekistan (1995)*.**

| | Area ('000 ha) | Production ('000 t) |
|---|---|---|
| **Total cultivated** | **4,200** | **--** |
| **Grain crops** | **1,790** | **3,000** |
| **Wheat (total)** | **1,313** | **1,800** |
| **Wheat (irrigated)** | **972** | **n.a.** |
| **Barley** | **300** | **300** |
| **Maize** | **20** | **n.a.** |
| **Rice** | **170** | **500** |
| **Cotton seed** | **1,490** | **4,000** |

* Source: Government of Uzbekistan Officials, and 1995 press reports.

**Table 2. Adoption of no-tillage cropping (1997/ 98).**

| Country | Area *(million ha)* | Percent of total cropland |
|---|---|---|
| *USA* | 20 | *16** |
| *Brazil* | *10* | *20-80*** |
| *Western Australia* | *8* | *50* |

***Area under no-till increasing by 4 % yearly. Area under conservation tillage is about 40 % of 120 million ha of cropland (No-Till Farmer)**

****Varies greatly from region to region.**

**Table 3. No-till wheat production parameters following puddled rice in Punjab, Pakistan.**

| Parameters | Crop year (1997/98) | | Crop Year (1998/99) | |
|---|---|---|---|---|
| | No-till | Conventional tillage | No-till | Conventional tillage |
| No. of sites sown | 90 | 90 | 304 | 304 |
| Total area sown (ha) | 216 | Not recorded | 877 | Not recorded |
| No. of weeds found $m^{-2}$ | 22.6 | 29.2 | 3.83 | 5.3 |
| No. of rice stem borer larvae $m^{-2}$ | 5.6 | 5.9 | # | # |
| Savings in time of sowing in no-tillage vs. conventional tillage (days) | Not recorded | Not recorded | 4-11 | - |
| Savings in irrigation water used in no-tillage vs. conventional tillage (%) | Not recorded | Not recorded | 38% first irrigation, 25% subsequent irrigations | - |
| Average yield (kg $ha^{-1}$) | 3,644 | 3,496 | 3,980 | 3,402 |
| Cost of land preparation and sowing (Pak. Rs $ha^{-1}$)* | Not recorded | Not recorded | 370 (=US$ 7.4) | 1,750 (=US$ 37) |
| Net income (Rs $ha^{-1}$) | Not recorded | Not recorded | 9,703 (=US$ 193) | 5,444 (=US$ 108) |

*** There were minimal or no weeds present in the untilled fields after rice harvest, hence no herbicide application was required prior to no-till sowing of wheat. All other post-sowing agronomic practices were similar in both systems. # There were too few rice stem borer larvae to report.**

# PROMOTION OF RESOURCE CONSERVATION TILLAGE TECHNOLOGIES IN SOUTH ASIA

**Mushtaq AhmEd Gill**[1]

Asia covers about 23 percent of the total land and accommodates 61 percent of the total population of the globe. It constitutes 26.6 percent of the world's agricultural area with arable land ranging to 36 percent. Nature has blessed this part of the world with abundant agricultural production and human resources. The diversity in agricultural resources, climate, people and socio-economic conditions has given rise to varying farming systems. Agriculture can be broadly categorized as irrigated, rainfed and dry-land farming. Often rainfall, soil and other characteristics determine ecological influence on various farming systems. Rice-wheat cropping is one of the largest grain production systems in South Asia and contributes significantly in grain production of the world. Asia produces about 43 percent of the total wheat produce in the world, and shares about 91 percent of it's total rice production.

South Asia's Indo-Gangetic plains constitute, agriculturally, one of the most productive regions of the continent. The "Green Revolution Technologies" introduced in this region between mid 1960s and 1970s led to dramatic increase in the yields and production of wheat and rice, the two most important staple food grains. In the first decade of green revolution and so after introduction of improved varieties of rice and wheat, grain production grew rapidly, mainly due to increased cropped area and high yielding varieties (HYV). Afterwards, the area devoted to rice and wheat crop has been stabilized and further expansion in these areas, at the moment, is not possible.

The need for higher yields has become more acute just as evidence is accumulating that growth in rice and wheat yields has started slowing down in the high potential agricultural areas of the north western India and Pakistan. These slower rates of yield growth may have resulted from degradation of the resource base devoted to rice-wheat systems, caused by the mining of soil nutrients, declining organic matter, increasing salinity, falling water tables, and the buildup of weed, pathogen, and pest population (Hobbs *et al.*, 1997). The other important factors in stagnation of productivity are traditional way of cultivation, which is not efficient to achieve potential yields and to address the site-specific issues scientifically. The low productive agricultural areas in eastern India, Nepal, Bangladesh and Pakistan, where yields are presently well below potential also require attention from research, because, increased production in these areas would relieve some of the pressure on the high-potential areas. Throughout the region, yield increase obtained through greater efficiency would be most valuable, since they would minimize production costs without raising food costs for the poor urban population (Hobbs *et al.*, 1997)

## Establishment of the Rice-Wheat Consortium for the Indo-Gangetic Plains

To focus attention on productivity/sustainability problems of South Asian rice-wheat system, a Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC) was constituted in the early 1990s. The RWC considers four research themes that are essential to raise the productivity

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and sustainability of rice-wheat systems i.e. (i) tillage and crop establishment, (ii) integrated nutrient management, (iii) integrated pest management (IPM), and (iv) water management.

The RWC is composed of the following partners:

- National agricultural research programs from four South Asian countries (Bangladesh, India, Nepal and Pakistan).
- International Agricultural Research Centers, among them the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center (CIMMYT), the International Crops Research Institute for Semi Arid Tropics (ICRISAT), and the International Irrigation Management Institute (IIMI).
- Advanced research institutes, such as Cornell University.

The Main objectives of RWC are to promote research on issues that are fundamental to enhance the productivity and sustainability of rice-wheat cropping systems in South Asia. These objectives are planned to be achieved through:

- Setting priorities for focused research on problems affecting many farmers.
- Promoting linkages among rice-wheat research specialists and other branches of research and extension.
- Encouraging interdisciplinary team approach to understand field problems and to find solutions.
- Fostering quality work and excellence among scientists,
- Enhancing the transfer of improved technologies to farmers through established institutional linkages.

Financial support for the Consortium's research agenda currently comes from many sources, including the governments of Australia, Netherlands, Sweden, Switzerland, and the Department for International Development (DFID), the International Fund for Agricultural Development (IFAD), the United States Agency for International Development (USAID), and the World Bank.

**Major Development Constraints in the Indo-Gangetic Plains**

The population in Indo-Gangetic Plains (IGP) is 35 percent of the total population in the Asia. These plains produce 35 percent and 31 percent of the total wheat and rice produced in the Asian continent, respectively despite various constraints. Some of the major constraints to the development and sustainability of food supply are as given below:

**Population pressure.** It is natural that tremendously increasing population competes with agriculture also on land and water resources. More land is required for the people to build their residential and other amenities and more water is required to meet their drinking, washing, cleaning, etc. demands. The trend in the change of arable land per capita per annum and irrigated area per capita per annum are shown in Figure 1 and Figure 2, respectively. It is evident from these figures that growth rate of arable land and irrigated area is not consistent to ensure sustainable agricultural development until and unless population pressure is controlled. Moreover, the housing pressure is continuing to increase due to incremental demand and migration from rural to urban areas. This trend is resulting in expansion of urban areas limitlessly.

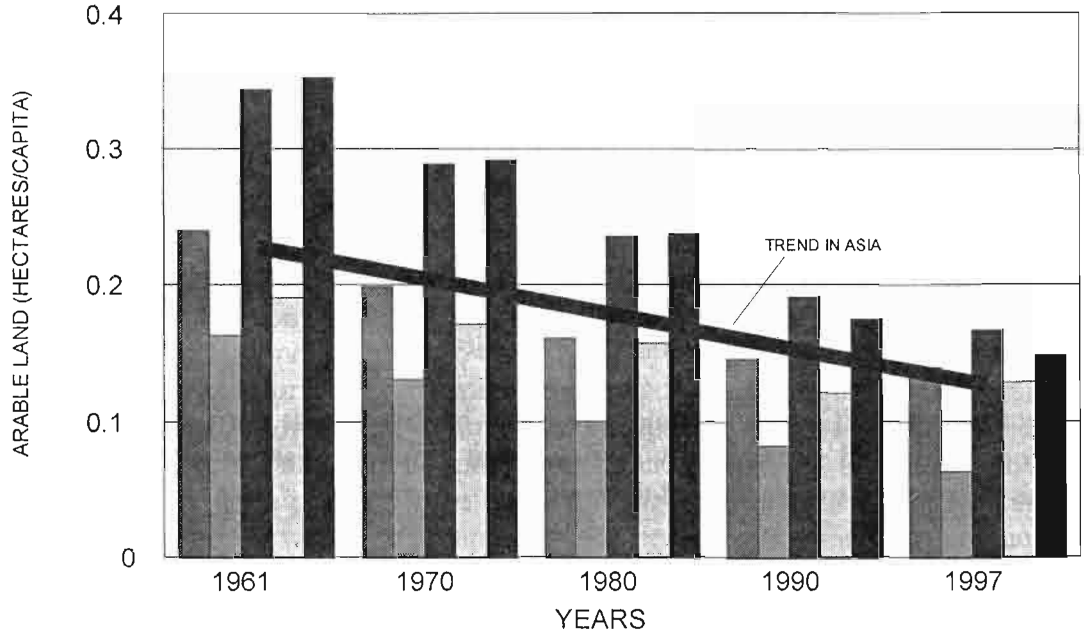


**Figure 1.** Arable area per capita in South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).

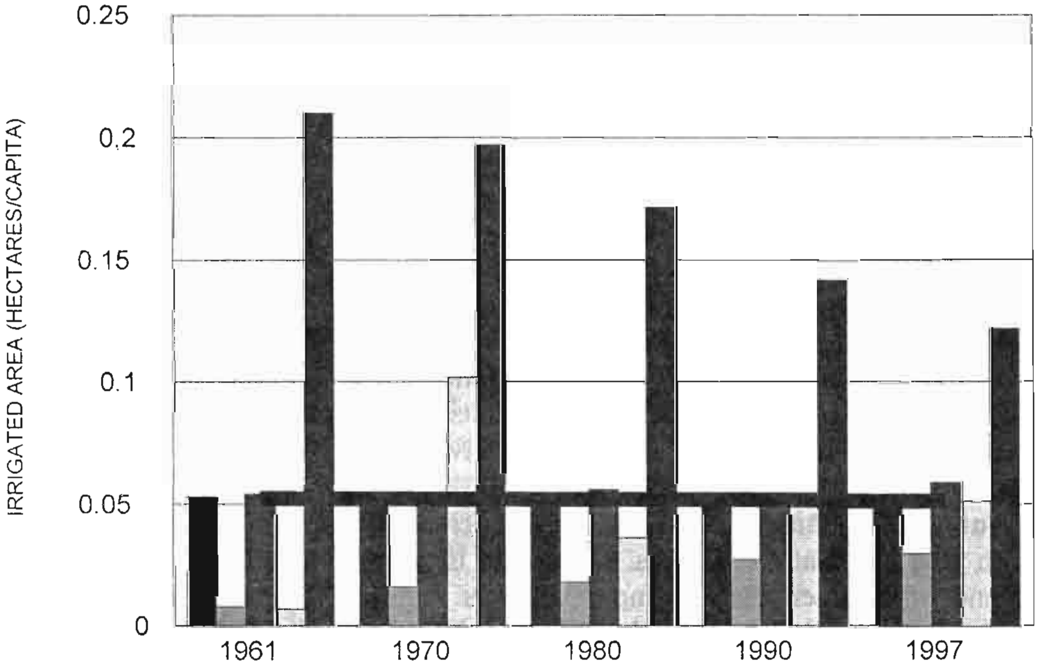


**Figure 2.** Irrigated area per capita in South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).

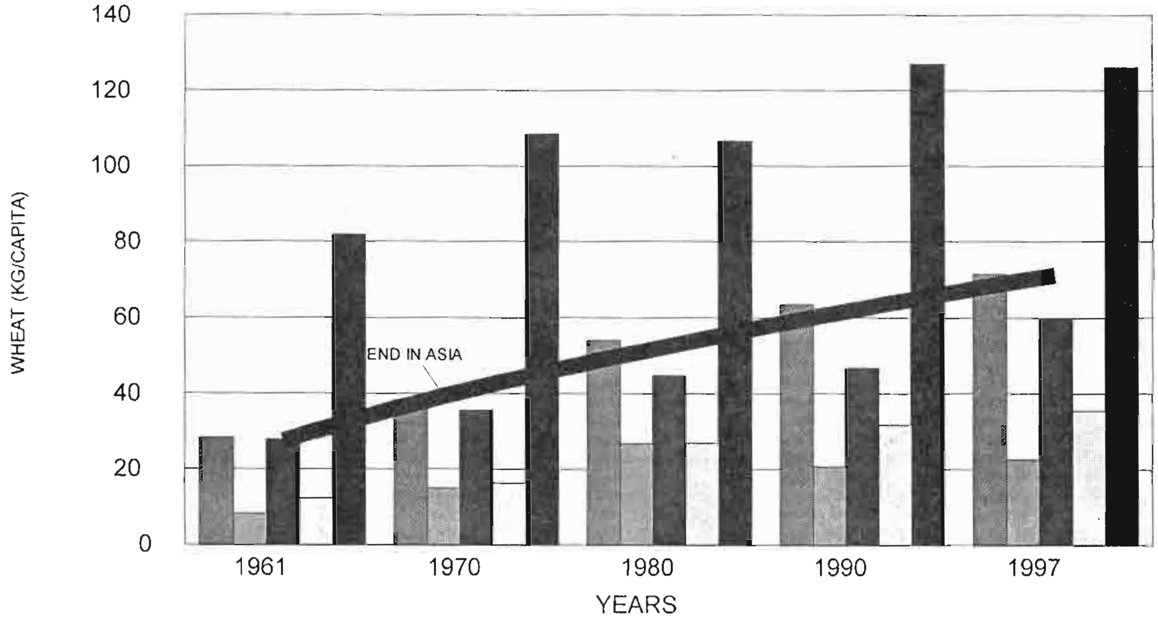


**Figure 3. Per capita wheat availability in South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).**

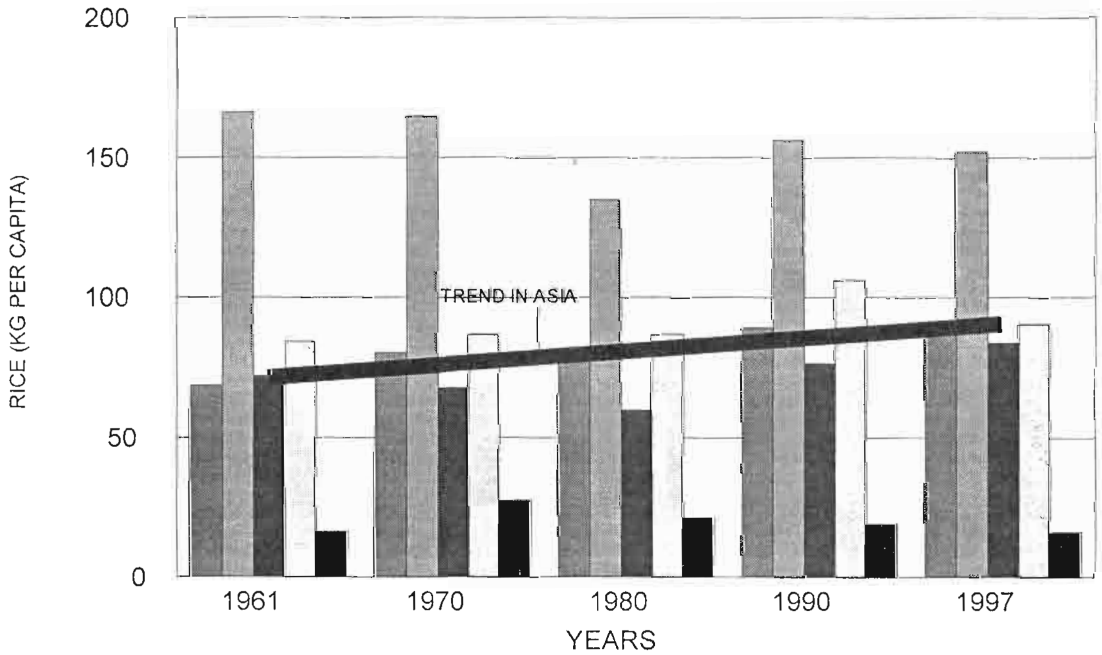


**Figure 4. Per capita rice availability in South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).**

The aggregate per capita availability of essential food items in physical as well as in terms of calories and proteins has increased during the past forty years in all most all Asian countries but in majority of the countries these are not up to a satisfactory level. The same is also true for RWC member countries. It can, however, be anticipated that availability of nutrients is almost going side by side. There is, however, no marked increase in per capita availability food grains (Figures 3 and 4) and any disaster in agricultural sector, at any time, can not cope with the tremendous population growth rate. Moreover, majority of the farmers in Asian countries is still following traditional crop production techniques, which are not conducive to meet food demands of the ever increasing population.

**Rice-Wheat cropping system.** It can be seen from Figures 5 and 6 that wheat and rice yields grew rapidly from 1960s to early 1980s. Afterwards, there is stagnation in their growth rate. It can also be observed from Figure 5 that average wheat yield of Asia at some places are higher to those of the most RWC member countries. This is clear indication that RWC countries are not achieving potential yields of wheat in the region. Similarly, average rice yield of Asia is also higher as compared to RWC countries. For example, China and Korea are producing 3.7 t ha$^{-1}$ and 4.0 t ha$^{-1}$ of wheat, and 6.0 t ha$^{-1}$ and 6.9 t ha$^{-1}$ of rice, respectively. There is, therefore, potential for achieving higher yields of wheat and rice in the region.

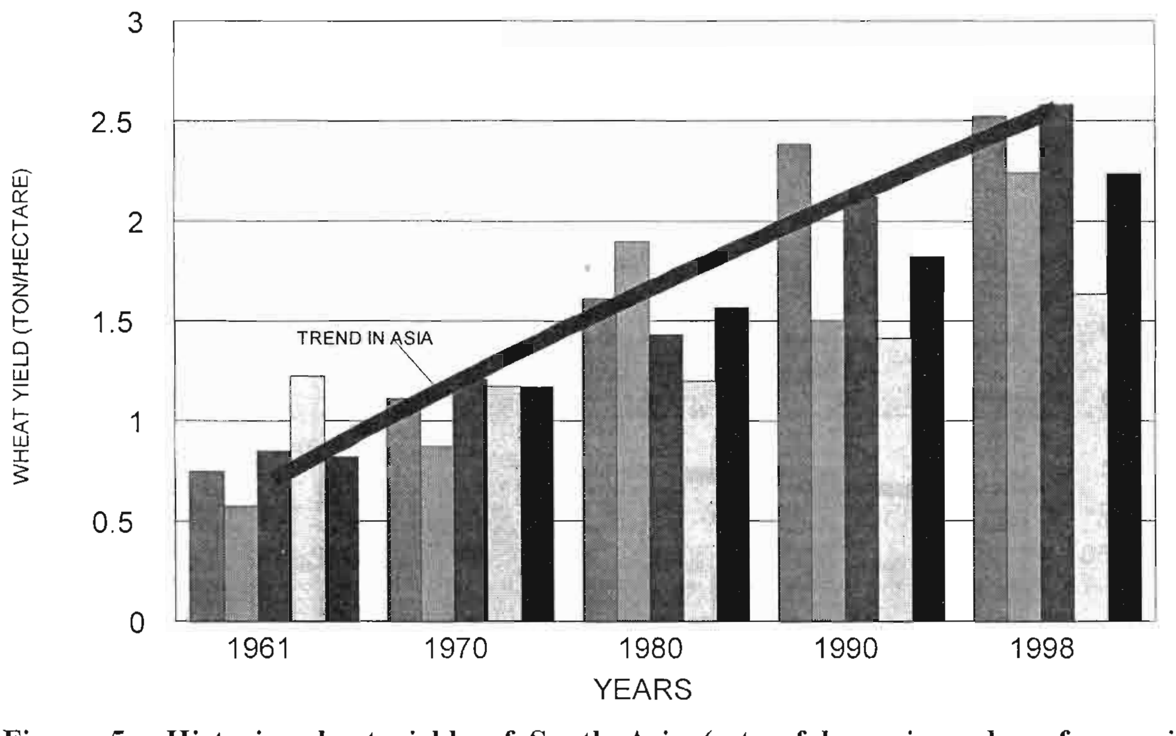


**Figure 5. Historic wheat yields of South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).**

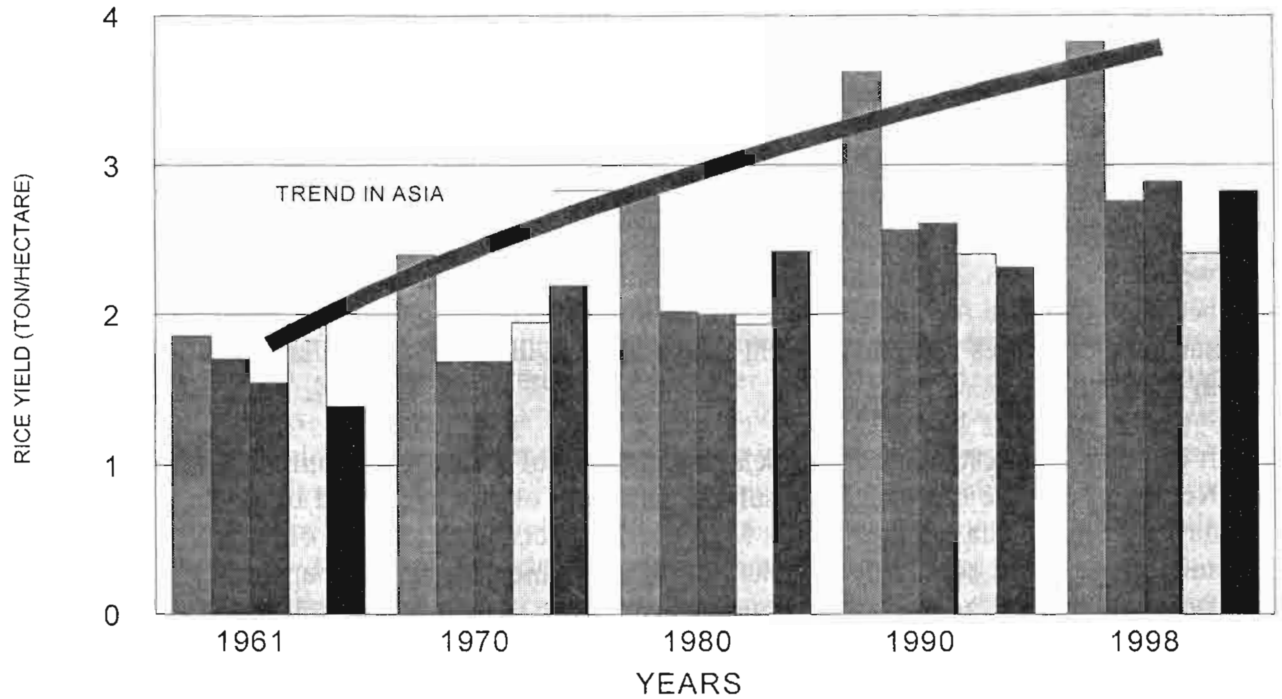


**Figure 6. Historic rice yields in South Asia (sets of bars, in order of grouping, represent Asia, Bangladesh, India, Nepal and Pakistan, respectively).**

**Major Production Constraints in the Indo-Gangetic Plains**

Some of the major production constraints in rice-wheat cropping system in South Asian countries are discussed as below:

**Late sowing of wheat crop.** The rice-wheat cropping system, which is one of the major cropping systems of South Asia and parts of East Asia, presents special problems in management. Rice requires puddled compacted soils to hold standing water during the growing season, while wheat grows best in well-drained soils, which allow deep penetration of the root system. Hence for rice cultivation, the puddling operation to form hardpan is important for water retention, but unless this hardpan is broken, wheat may suffer problems of waterlogging.

One obvious cause of late planting of wheat crop is the late harvest of the preceding rice crop or, in some instances, a short duration third crop is planted after rice. Farmers in some parts of the Indo-Gangetic Plains grow basmati rice (a long duration, photosensitive, high quality rice that matures late). Farmers prefer to grow basmati rice despite its lower yields, because of its high market value, good straw quality (livestock feed), and lower fertilizer requirements. It is planted over 52% of the total rice cultivated area in Pakistan. Basmati varieties can not be readily replaced by a shorter duration rice variety, and the rice harvest is inevitably delayed.

In some areas of the Indo-Gangetic Plains, high yielding, modern rice varieties are grown and their planting dates can be manipulated so wheat planting is not delayed. In Indian Punjab, modern rice varieties are planted early, harvested by October and wheat is planted by November.

It has been observed that wheat is planted late on 40, 25-35 and 40 percent of the total wheat cultivated areas in Pakistan, India and Nepal, respectively. As indicated earlier that the conflict between rice and wheat management is further aggravated by the dominance of the late maturing basmati rice variety. Accordingly, there is short window of time is available for land preparation for establishing wheat due to late maturing long grain rice varieties of the preceding crop. It is also experienced that the turnaround time normally takes 1-5 weeks (2-3 weeks, 2-6 weeks, 2-5 weeks under Pakistani, Indian and Nepali conditions) for rice fields to become workable for land preparation due to antecedent moisture. Reduced day length and sunshine decreases soil and ambient temperature at the time which delays planting of wheat in paddy tracts.

It has also been established that delay in planting of wheat after optimal sowing time ($20^{th}$ November in case of Pakistan) results in reduction of potential yield by about 1-1.5 percent $day^{-1}$ in South Asia (Hobbs, 1985). Moreover, farmers cultivate land often without achieving suitable seed-bed conditions for planting wheat, which results in poor crop yields. Another factor, hindering achieving optimum wheat yield in paddy areas is that wheat seed is generally broadcast leading to much reduced plant emergence. It is not surprising that wheat yields in the rice-wheat area are significantly lower than in any other irrigated areas of the Pak-Punjab and are also more variable. Rice yields are also stagnated despite steadily increasing dosages of fertilizers. Presently, the most critical causes of low productivity in rice-wheat system are low plant population and undulated fields in case of rice fields and timeliness losses in yield of wheat, captivated after harvest of rice crop.

**Low plant population of rice per unit of land.** Low rice plant population has been identified as one of the main constraints in improving rice yields. Like other South Asian countries, rice crop in RWC member countries is also established by hand transplanting of young rice seedlings. The nature of job is backbreaking and involves enormous drudgery and human stress in sweltering weather. The operation is also very laborious as it takes 110-125 labor-hours per acre or 40 percent of the total labor requirement for the crop. In the recent past with the onset of industrialization in urban area, employment opportunities increased and an acute shortage of labor is often experience during transplantation. Non-availability of labor has further compounded the situation and paddy transplanting has emerged as the stark problem in the whole paddy growing areas. Optimum plant density and timeliness of transplanting operation in paddy is considered essential for optimizing paddy yields and this can be achieved if dependence on hired labor is minimized.

**Undulated topography.** A considerable amount of water is being wasted during application to unleveled fields. Studies have indicated that a significant (20 to 25%) amount of irrigation water is lost during its application at the farm due to poor farm designing and uneven fields. This problem is more pronounced in case of paddy fields. It has been noted that most of the farmers apply irrigation water until the highest point in a field is covered, this leads to over-irrigation of low-lying areas and under-irrigation of higher spots which results in accumulation of salts in such areas. Over irrigation leaches soluble nutrients from the crop root zone, makes the soil less productive, and degrades groundwater quality. Moreover, layout of most of the farms is based on traditional flood basins comprising of a number of unwanted dikes and ditches covering a length of over two kilometer in each square (observed in Pak-Punjab). The fields being not properly leveled, cause wastage of land, low irrigation efficiencies, and ultimately results is substantially lesser yield than the potential.

**Resource Conservation Tillage Technologies**

A technological break through is imperative to address all the problems in rice-wheat production to meet requirement of ever increasing population. Some of the technologies being tested on pilot basis in Indo-Gangetic Plains to address specific problems of rice-wheat system are discussed as below:

**Reduced and zero tillage.** The notion of reduced or zero tillage systems is not new. Many developed countries use these technologies, which are often found to generate higher yields, reduce production costs, and reduce erosion and other forms of land degradation with corresponding benefits for the natural resource base. Zero tillage for wheat after rice generally results in yields that are better than or equal to yields obtained using conventional practices. The zero tillage technology is a special technique of establishing crops without tillage and seedbed preparation. The implement use for this purpose is known as direst drill which is capable to seed through the residue cover and provide a firm seed soil contact. The technique has been found useful specially for raising crops in the rice harvested fields where uncertain rains and excessive soil moisture do not permit timely sowing of wheat. Besides this, the technology also saves expenditure involved in seed-bed preparation. Post-sowing weed control in this conservation tillage technology requires use of herbicides similar to the conventional sowing system.

Some of the reduced and zero tillage option that have been observed in South Asia include surface seeding, reduced tillage with two and four wheel tractors and furrow-bed irrigation systems.

**Surface seeding.** Surface seeding refers to placement of seed on the soil surface without any land preparation. Wheat seed is either broadcast before the rice crop is harvested or afterwards. Farmers in parts of eastern India and Bangladesh commonly use this practice to establish wheat.

**Reduced tillage with two-wheel tractors.** Reduced tillage applies a seeder (Chinese) for use with a 12 horsepower, two wheel tractor that prepares the soil and plants the seed in one operation. It can even plant in the standing rice stubble on heavy soils. Hobbs *et al.*, 1997 investigated that this system in Nepal can generate yields equal to those obtained through surface seeding, and the net return surpass returns to farmers' current practice, because land preparation costs are lower. The main drawback of this technology at the moment is that tractor and the various implements are not available in sufficient numbers.

**Zero-tillage with four-wheel tractors.** This technology which is being tested in Pakistan, is presently being tested in other areas of the Indo-Gangetic Plains, including India and Nepal. This technology is more suitable for the higher yielding, more mechanized areas of north western India and Pakistan, where most land is prepared with four wheel tractors.

It has been observed that this technique considerably reduce use of tractor and implements for land preparation thus compaction and hardpan development problems are reduced to a great extent leading to better root development and enhanced crop yields. Furthermore, conventional tillage specially, which uses plows, exposes organic matter to atmospheric air, This leads to organic matter loss in the form of carbon dioxide. Loss of soil organic matter results in low soil fertility and poor bondage of soil particles resulting in high soil erosion and global warming.

It has also been observed that conservation tillage operation positively affects on fertilizer use efficiency as nitrogen and phosphorous uptake increases because of fertilizer placement in close proximity to seeds. Also, conservation tillage provides better environment for surface accumulation of organic matter already present in the soil. Presence of organic matter in soils improves soil structure, water holding capacity, infiltration rates, facilitates cation exchange, and makes the primary plant nutrients available.

Initial research experiments with zero tillage drill in Pakistan were carried out by Pakistan Agricultural Research Council in mid 1980s. These proved quite successful, but because of lack of funding and other resources, its wide scale replication could not be promoted. Limited field trial for wheat establishment with this technique were undertaken in the rice growing areas of the OECF/Japan financed On-Farm Water Management Project in the provinces of Punjab and Sindh in 1996. Results of these trials indicated that conservation tillage method of planting wheat resulted in 28 percent higher yields compared to that with conventional method. In addition, a saving of Rs.1,828 $ha^{-1}$ (US\$37 $ha^{-1}$) was noted in production cost as result of no land preparation.

Keeping in view the positive impact of zero tillage technology in Punjab province of Pakistan, zero tillage trials on 218 hectares (540 acres) was conducted during 1997-98 in the province. M/S Halcrow Rural Management conducted the impact assessment of RCT technology during Rabi 1997-98 and found that:

- mean wheat yield increased by 148 kg/ha over conventional method of cultivation.
- CT technology can lead to an increase in stem borer larvae population in some areas, but this increase is relatively insignificant compared with the increase in population numbers when rice stubble is left in fallow fields.

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**Table 1. Population (millions) in RWC countries, 1961-1997.**

| Year | Bangladesh | India | Nepal | Pakistan |
|---|---|---|---|---|
| 1961 | 52.7 | 452.5 | 9.4 | 51.3 |
| 1970 | 66.7 | 554.9 | 11.4 | 65.7 |
| 1980 | 88.2 | 688.9 | 14.5 | 85.3 |
| 1990 | 109.5 | 850.8 | 18.8 | 119.2 |
| 1997 | 122.7 | 966.2 | 22.4 | 144.0 |

# A STRATEGY FOR SOIL CONSERVATION FARMING IN NORTHERN KAZAKHSTAN

**Akhylbek K. Kurishbayev**[1]

The sustainability of grain production in northern Kazakhstan is related to the adoption of soil conservation farming systems which are based on ecologically sound, balanced and stable dry-land farm management. The problems faced by grain farmers involve not only drought, but also:

- Decreased realized yield potential, associated with concomitant reduction in acreage.
- Increased variability in realized yield.
- Deterioration of grain milling and baking quality due to the inefficient use of soil-climate resources.
- Reductions in soil fertility due in part to the non-observance of recommended soil conservation practices leading to increased water and wind erosion. In addition, the humus content in the soil arable layer has decreased by 25-30% reducing the effectiveness of nitrogen application, utilization and residual capacity.
- Decreasing use of mineral fertilizers. Up to eighty percent of arable land may exhibit low availability of labile phosphorus within the next few years.
- Weed infestation of cereal crops remains severe with approximately 7 million ha infested with perennial root offset weeds, 3 million ha with wild oats, bristle grass and different sorghum-like weeds.
- Increased prevalence of cereal diseases including root rots, loose smut, Septoria blight, leaf and stem rusts, Helminthosporium blight, with grain yield potential reduced by 20-25% in bad years.

Severely handicapping farmers' efforts to economically maximize and sustain cereal production in Kazakhstan is the shortage of funds needed to implement the wealth of recommended production practices and extension technologies. Current farming systems applications should be answerable to the following requirement:

1. to meet consumer and market demand;
2. to meet the agro-ecological requirements necessary to profitably produce agricultural crops;
3. to efficiently utilize, while sustaining the soil-climate-agronomic-genotype-farmer potential;
4. to take into consideration technical logistics of commodity producers.

The existing ecological contradictions in agricultural production in Kazakhstan are related to the consequences of directive land management and excessive expansion of area seeded to cereal crops resulting in a disparity of the current national farming system and environment. Therefore a principle objective of sustainable farming is to optimize the structure of arable land use and to grow crops according to the conditions of specific regional or agro-landscape opportunities.

The arable land readily available in the Northern Kazakhstan is approximately 19 million ha, including 3.3 million ha with complex solonetz soils. These arable lands should be used for

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guaranteed production of cereal crops, legumes, oilseed crops, forage crops and other high profitable crops without need of additional inputs for reclamation. Spring wheat is grown on the fertile soils of this region which account for 8-9 million ha.

In addition, alkaline soils, where cereal production is 30-50% less than on more arable soils, should be used for forage production with salt-resistant, perennial grasses.

Conversion of these arable areas will increase the stability of grain production. Moreover, the research results and farmers' experience show that an increase of 30-40% in grain yield on chernozem soils of between 1.5-1.7 and 2.5-3.0 t $ha^{-1}$, and 1.2-1.5 to 2.0-2.2 t $ha^{-1}$ on dark chestnut soils, is realistic.

Only high quality wheat which meets marketing demand can ensure marketability. Strong northern Kazakhstan wheat can be used for improving the bread making quality of wheat grown in Belarus, Baltic countries, European Russia, and some Middle Asia countries. Northern Kazakhstan can readily produce 2.5-3.0 million t of strong, high quality wheat annually in the zone of southern chernozems and dark chestnut soils with an annual average precipitation of 250-360 mm.

Crop diversification is important to stabilize farm income due to erratic production and marketing conditions. The potential of the Northern Kazakhstan in growing oil seed crops and grain legumes can be clearly seen when compared to the agro-ecosystems of the Canadian province of Saskatchewan which has the similar soil and climate conditions.

The climate conditions and the agro-landscape of the Northern Kazakhstan make it possible to divide the territory in the following zones according to grown crops :

- **Ordinary Chernozems:** feed and malting barley, bread wheat, rape, peas, oats, winter rye, buckwheat, soybean, grain legumes and forage crops, perennial legumes, perennial grasses, early-ripening hybrids and varieties of maize;
- **Southern Chernozems:** strong, high quality bread and durum wheat, barley, peas, chickpea, mustard, oats, buckwheat, millet, sunflower, peavine, perennial grasses, combined sowings of perennial grasses and legumes;
- **Dark chestnut soils:** strong bread wheat, chick pea, mustard, millet, Sudan grass, foxtail millet.

In addition, 4 categories of agro-landscape on chernozem soils can be mapped according to their susceptibility to erosion, soil fertility level and natural water accumulation. According to institute recommendations, the production of high quality commercial grain, oilseed, legume and other lucrative crops should be concentrated in the first two categories of agro-landscape (where the soils are less erosive and more fertile). The forage grain should be grown in the third category of agro-landscape and the fourth category (where the soils are the most subjected to erosion and the least fertile ones) should be occupied by perennial grasses.

Amelioration of soil fertility, *per se*, won't fully address the strategic issues of land management in the Northern Kazakhstan. Efficient use of the best soils for appropriate production systems in required, as well. In agro-landscapes with higher soil fertility, it is worthwhile to more intensively grow the crops that will result in increasing the profit and ensuring production stability.

A national or regional agricultural practice policy should address the follow points:

- The use of site specific land management taking into consideration agro-landscape;

- The use of recommended agricultural practices considering climate and marketing conditions;
- The maintenance of a balance in soil fertility;
- To ensure that weeds, pests and diseases are controlled considering Integrated Pest Management accepting economic threshold levels and environmentally sound means of control;
- To provide crop and production alternatives for farmers according to their input and marketing logistics and degree of diversification.

The development of effective, cost-saving agricultural machinery and techniques must consider the following points:

- Adaptive implements for subsoil tillage which decrease power requirements 15-20%;
- Tillage practices which improve snow trapping, and reduce erosion due to wind and water;
- Various types of seeders adapted to specific agro-landscape and socio-economic conditions;
- Wide-cut swathers for high volume cutting with minimal losses of grain harvested;
- High productive combine thrashers which allow formation of stubble strips;
- Efficient chemical spray applicators which optimize application rates;
- Seed cleaning, drying and treating equipment.

Thus the provision for sustainable grain production in the region is related to agro-landscape farming, zonal crop growing, optimization of soil fertility, introduction of adapted, consumer-oriented varieties, and power and labor saving technologies that will result in the better utilization of our bioclimatic resources and increase the efficiency of soil conservation tillage system, the base for grain production in the steppe regions of Eurasian continent.

# PROBLEMS OF ARABLE LAND UTILIZATION AND FERTILITY PRESERVATION IN THE REPUBLIC OF ARMENIA

**Armen Petrosyan[1], B. Simonyan[2] and E. Airapetyan**

The Republic of Armenia is a land-starved country with arable land constituting only 16.4% of it's total area, 0.12 ha capita$^{-1}$. Potential for expansion of arable area has been practically exhausted, while the currently utilized arable land is not endowed with favorable natural fertility. In order to raise the efficiency of land utilization, Armenia was among the first CIS countries to implement land tenure reform. In 1991 the Supreme Counsel of the Republic enacted the "On Farms and Collective Farms" law and a new land code, the statutes of which led to the institution of private land ownership, and the establishment of a legal foundation for land relations, land utilization regulation and governmental oversight.

The accelerated changes in land reforms, together with the changing social and economic situation, had a direct impact on land utilization and fertility preservation. At the moment, land relations in Armenia are undergoing a transition and many issues are controversial. The Government has been taking steps to regulate soils registration and land market formation. The situation with land utilization requires development and introduction of new soil conservation technologies. Major characteristics of land utilization include:

- Many small-sized, privately owned, commercial arable land plots. As of January, 1999, there were 361,200 farms in Armenia with an average size of 0.91 ha.
- As a result of the division of arable land into small plots, previously developed, appropriate farming technologies, especially conservation methods and strategies, have been discontinued. Examples of previously recommended practices which have been discontinued due to new land tenure include:
    - the areas under perennial legumes and grasses has decreased by 25%;
    - cereal mono-cropping has increased (especially with winter wheat);
    - phytopathological conditions have deteriorated and fields have become weedier;
    - the national productivity of crops has been reduced by more than half, as compared to 1990.

Experience has shown that farmer and consumer involvement in research priority setting fascinate appropriate technology development, and more rapid technology adoption. Routine involvement of product-oriented clients, and communications of research activities and results both formally through media and farmers' organizations meetings, and informally by use of demonstration plots or posters increases rate and extent of adoption.

Environmental impact of arable land utilization must recognize that revision of land laws is required in light of current socio-economic conditions in rural communities. Timely and repeated monitoring of research and implementation is a necessary tool to refine and maximize the efficiency of develop research-based environmental programs. In addition, a national soil and water resource management strategy is required to better coordinate research

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activities and development programs. The following priorities have been highlighted in the area of soil conservation and utilization pursuant to the Armenian National Scientific Research Program for 1998-2002:

- research targeted to prevent soil degradation;
- humus preservation;
- mapping areas prone to desertification and developing desertification prevention activities;
- utilization of soils in mountainous and high mountainous zones;
- efficient tillage operations;
- amelioration of alkali-saline soils.

Given the limited annual funding of research activities through the auspices of the Armenian National Program, it is impossible to provide the necessary levels of support appropriate for such a wide ranging research agenda. The following are some of the essential prerequisites for a joint research program with institutions such as ICARDA:

- allocation of tangible and intangible resources to the national program to address issues of joint concern;
- applicability of research outputs, and verification and demonstrations of resulting technologies;
- scientific and technical information exchange;
- involvement of qualified staff in implementation of these activities.

The joint programs will be subject to bilateral discussions attended by a representative from the Office of Science of the Armenian Ministry of Agriculture, and a special scientific team will be convened to develop the joint 3-5 year project proposals which will address transdisciplinary research among Armenia soil, agrochemistry, land reclamation, farming and plant protection scientists and partners.

# TILLAGE FOR WINTER CROPS: CURRENT STATUS AND PROBLEMS UNDER ARID CONDITIONS IN AZERBAIJAN

**Mazakhir Rzayev**[1]

Tillage is one of the most important components of the farming system. Farming couldn't have been developed without tillage. At present, farmers around the world perform tremendous amounts of work tilling soil repeatedly every year involving approximately 1.5 billion hectares. Tillage targets the creation of a favorable balance of heat, moisture, air and nutrients in soil for crops, controls weed infestations.

Azeri research institutes, including the Azeri Scientific Research Institute of Farming, have thoroughly investigated research in tillage suggesting that differentiated tillage throughout rotations with integration of deep, regular, subsoil and surface tillage performed by moldboard, disc, subsoil implements are the most appropriate tillage practices for intensive farming in the Republic. Black fallow practices are considered to be the best predecessor for winter cereals under rainfed, arid conditions. It is recommended to plow fields populated by perennial weeds to a depth of 30 cm, whereas eroded areas should be plowed as deep as the humus layer. Subsoil tillage should be appropriate for soils subject to possible erosion.

In arid rainfed areas, subsoil tillage after black fallow allows accumulation and retention of 200-250 $m^3$ $ha^{-1}$ more moisture compared to soils tilled conventionally with a moldboard plow. In dry years, sub-surface tillage minimizes summer moisture loss. The yield of winter wheat after black fallow and with a 30 cm subsoil tillage was 220 kg $ha^{-1}$ more than after conventional plowing in the experiments conducted in the rainfed region of Nagornaya Shirvan.

Timely and proper tillage practices are important to obtain optimum performance in winter crops after black fallow. The major objective is to provide enough moisture in the seeding layer in order to obtain quick germination and robust stand establishment. Black fallow requires early spring harrowing, followed by plowing and needle harrowing. The initial sub-soil tillage should be 12-14 cm deep. The subsequent tillage operations should be gradually reduced to a depth of 6-8 cm before seeding. When tilling fallow in late summer, it is desirable to avoid deep tillage due to accelerated moisture loss, and hence harrowing is preferred in most cases. It is best to harrow after rainfall when weeds are germinating or in the early seedling phase. Experience shows that timely harrowing is very effective.

Herbicides should be used to control fields badly infested with perennial weed species, thereby reducing the number of tillage operations. The method of main tillage for fallow is determined by the fallow crop, harvesting time and weather conditions. After an early crop harvested for green forage, the soil is plowed to a depth of 20 cm with optional further harrowing, provided there is sufficient moisture. In dry years when soil may become cloddy after fallow crop is plowed, subsoil tillage, 12 cm deep is recommended. Research has shown that chickpea yields are enhanced (average of 1.04 t $ha^{-1}$ over three years) with deep

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(30 cm) fall tillage preceding spring planting, as there is more moisture preserved in the soil and weeds are more effectively controlled.

Late summer to early fall are generally dry periods in the rainfed areas of Azerbaijan. Thus, after chickpea harvest, deep plowing of dry soils can result in soil clodding resulting in a negative impact upon subsequent seeding and stand establishment of winter cereals. Due to this, soils should be tilled by a sub-soiler for winter wheat following chickpeas. In practice, the best winter wheat yield was achieved after a 12 cm surface tillage with a double-disk harrow. Deep tillage (30 cm) is effective for winter wheat following stubble in years with wet autumn conditions. The deep tillage improves moisture and air balance in soil, enhances plant strength and root system development, and addresses weed control resulting in increased productivity and yields. It is difficult to perform satisfactory tillage with a single disking in years with dry autumn conditions. In such cases, it is recommended to use double disking, 8-10 cm deep for the first tillage, with disking at 6-8 cm depth for the second tillage.

It should be emphasized, that as a result of recent agricultural reforms, many small farms have been established. Existent large capacity tillage machinery is not appropriate for these new small-holder farmers, and is often in poor repair or obsolete. Six pilot farms have been established in different zones of the Republic to address the production constraints faced by farmers today.

# CONSERVATION TILLAGE IN THE MOUNTAINS OF KYRGYZSTAN

**Tynybek Abitov**[1]

Kyrgyzstan is a mountainous country, and it's agricultural faces significant problems associated with water runoff, wash-out and erosion. Of the 10 million ha of arable farmland, 64% is eroded, a third of which is severely affected. Annual damage caused by soil erosion has been estimated to roughly 1 million t of grain. Traditional crop husbandry involves use of moldboard plowing with furrow slice inversion, and more advanced, soil-conserving technologies have not yet gained wide acceptance.

Erosion reduction can be accomplished via proper land management, agricultural amelioration, forest and grassland reclamation, and hydro-technical constructions. All these techniques have been used in anti-erosion campaigns promoted in the late 1980s, with total investment cost exceeding 10 billion roubles. Currently, such a program cannot be extensively implemented. Therefore, a "bottom-up" or "grass roots" approach in soil conservation and erosion control is needed with general government supervision and encouragement.

Research has revealed that there have been general arrangements mandatory for all categories of land users in the Republic, including the following:

- For farms with slightly or medium eroded lands exceeding 70%, only cereals and perennial grasses should be grown. Farms with 50% of eroded land may use 20-30% of their land for row crops;
- With severely eroded fields, cultivation of agricultural crops should be prohibited and such areas should be sown exclusively to grasses for improved pastures;
- Slopes steeper than 10 degrees should not be used for irrigated farming. Slopes with recline of 5-10 degrees should be irrigated along the contour;
- Rainfed lands should not receive plowing on slopes steeper than 15 degrees. Clean fallow should not be used on slopes with recline of > 8 degrees in northern Kyrgyzstan, while in southern Kyrgyzstan, fallow can be used on such lands, but only in combination with special soil tillage practices such as damming and sub-soiling;
- Tillage (plowing, seeding, chiseling, harrowing and cultivation) should only be used along the contour of a slope;

Extremely irregular, undulating relief increases the potential for soil erosion thus making the cultivation of land with standard implements difficult. The mismatch of the width of a plow, planter and harvester with the width of land strips force farmers to use moldboard plows regardless of natural contour often in irregularly shaped fields, thereby increasing erosion potential. In this respect we were the first to identify anti-erosion effects of tillage practices applied in the Chui region on the basis of qualitative evaluation of erosion danger. A summary of the results indicated:

- an estimated potential annual outwash of soil on clean fallow slopes exceeding 15 degrees was 67 t $ha^{-1}$ on light chestnut soils and 35 t $ha^{-1}$ on dark chestnut soils;

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- moldboard fall plowing for continuous cereal cropping reduced the annual outwash on the above soils to 28 and 15 t $ha^{-1}$, respectively;
- four-field crop rotations with one field of clean fallow is not different from continuous cropping (27 and 14 t $ha^{-1}$) and does not protect soil from outwash;
- three-field crop rotation without clean fallow does not stop erosion, though it considerably reduces the amount of soil washed away (20 and 10 t $ha^{-1}$);
- when cereals and perennial crops are planted in proportion 1:1, outwash remained high on light chestnut soils, while it was nearly 8 t $ha^{-1}$ on dark chestnut soils;
- stripe sowing of the spring crops coupled with subsoil tillage and perennial grasses stopped the outwash on dark chestnut soils to the admissible level (<5.0 t $ha^{-1}$), though remained twice higher (10 t $ha^{-1}$) on light chestnut soils;
- cultivation of perennial grasses completely stopped the outwash and erosion of soil.

Anti-erosion projects in Kyrgyzstan have been carried out using quantitative research methods, i.e. the activities have been determined based on the area of land eroded. If no such data is available, then activities were identified according to slopes and soil type. The common opinion that erosion should be prevented on all lands prone to erosion, and not only on currently eroded lands was ignored. Thus, a more objective picture of territorial distribution of erosion prone lands is needed for qualitative models of outwash, which allow projecting the intensity of erosion potential and allow the development of a package of anti-erosion measures.

Research on mountainous pastures was conducted by direct examination and simulation of erosion processes using artificial rain simulation. Hydro-meteorological data allowed the calculation of potential annual soil outwash loss. Our team was the first to use the qualitative evaluation of erosion hazards to forecast a potential hazard of erosion (PHE) coefficient for the Chui valley. The following factors were assessed in the process of calculation: relief (length and recline of a slope); properties of soil (mechanical composition, humus content, water resistance and water permeability); index of rain for 30 years with 20% supply; soil protective properties of the crop (crop rotation) and agronomy (conservation tillage). Soil protection coefficients of a cover crop in summer and winter were used for assessment of soil loss on meadows and pastures.

Calculation of annual amount of soil loss made it possible to evaluate theoretical losses of humus horizon of soils, depending upon the methods of land utilization. With continuous cultivation of spring cereals or with introduction of a 4-field crop rotation with a field of clean fallow, the humus horizon of light chestnut soils may be lost in as little as 100 years and that of dark chestnut soils in 220 years. Exclusion of clean fallow from crop rotation extends this period for light chestnut soils to 140 years and on dark chestnut soils to 400 years.

When sowing spring cereals in combination with perennial grasses (50:50 ratio) the humus horizons of light chestnut soils may be lost in 212 years versus over 1000 years with dark chestnut soils. It should be noted that these calculations present maximum possibilities because with the substantial amount of soil loss, lower horizons of poorer fertility soils are involved in cultivation accelerating the process of soil erosion.

# SUSTAINABLE AGRICULTURE IN THE 21$^{ST}$ CENTURY IN RUSSIA

**Alexander Nikolaevich Kashtanov**[1]

In a one and half years, mankind will enter the 21$^{st}$ century. For many past millennia, life has progressed along a complicated evolutionary path. Leaving the 20$^{th}$ Century has been most troublesome for many people, with the preservation of natural environments and cultural civilizations, predicated on sustainable development, of greatest concern. The UN Rio de Janeiro (COONOSR) conference held in June, 1992, with participation of 179 countries, discussed and adopted the "Declaration on Environment and Sustainable Development". The Declaration states, "It is expected that in 2025 the Earth's population will reach 8.5 billion people. Starvation has been a constant threat for many people. The productivity of large regions which produce food is decreasing while demand for food, fiber, and fuel is increasing".

As an alternative to this menacing threat, the concept of sustainable agricultural production is proposed. The Declaration further states, "Sustainable development of agriculture and rural regions require tangible changes in agricultural, ecological and economic policy of all countries and at international level". For several years, scientists have been working on an Encyclopedia of Life Support Systems (EOLSS). At the beginning of 1996, the Russian Academy of Sciences (chairman – academician G.I. Marchuk) established the Russian working group on the Encyclopedia. Academician A.N. Kashtanov was appointed as the head of the group for the chapter "Food Stuffs and Agriculture". Coordination of specific topics is conducted by the following academicians: A.A. Zhuchenko (plant breeding), L.K. Ernst (animal husbandry), L.P. Kormanovsky (mechanization, power engineering), E.I. Sizenko (storage, processing), B.S. Maslov (water resources, land amelioration), N.A. Moyseev (forestry), A.A. Shutkov (economics, social sphere) and other scientist of Russian Academy of Agricultural Sciences.

Problems associated with sustainable agriculture development has been a priority in Russia and CIS countries in recent years. Its successful implementation is the basis for addressing economic, social, ecological, food and other issues. In general we consider sustainability as a steady-state condition of various phenomena, processes in nature, economy, manufacture, etc. For example, sustainable balance in an agro-ecosystem or agro-landscape results in economic stability. Non-sustainable agriculture can result from the impact of natural factors (e.g. frequent droughts, cold and moist years, water and wind erosion, salinity, increased acidity of soils, sensitivity to drought, frosts, lodging, diseases, or pests) or anthropogenic (technogenic) factors (e.g. non-balanced (destroyed) agro-landscapes, agro-ecosystems, crop rotations, poor technology of soil tillage, fertilizer applications, irrigation, sowing, harvesting and storage; problems of soil compaction by machines; problems of environmental pollution by agrochemicals, heavy metals, use of poor quality seed, growth of weeds).

It is obvious that progress of agricultural production in the coming century will be dependent upon weakening or elimination of these negative tendencies and on the sustainable development of agriculture.

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Based on a thousand years of experience of Russian agriculture -- from very primitive forms to modern, progressive systems -- and the world experience, we offer a concept and the following factors of stability as an alternative to non-sustainable agriculture:

- Establishment of ecologically balanced, high productive, sustainable agro-landscapes and agro-ecosystems;
- Landscape adapted ecological safety systems of agriculture, taking into account the properties of natural landscapes, relief, soil, plants and bioclimatic potential;
- Adapted, stress-tolerant, and pest-resistant crop varieties;
- Adapted, energy-saving, environment friendly technologies of soil tillage, cultivation of agricultural crops, use of fertilizers, irrigation and harvesting;
- Ecologically safe, energy-saving and economically profitable machine systems for agriculture;
- Favorable economic conditions and social organization of village.

This is an outline of principal concept for prospective Russian agriculture based on scientific approaches.

The special program of basic and priority research of Russian Academy of Agricultural Sciences, "Development of the Scientific Basis for the Organization of Sustainable and High Productive Agro-landscapes and Development of New Landscape Systems of Agriculture for the Major Environmental Regions of Russia", was initiated in 1992. The new recommendations and methods prepared during 1992-1999 were reported in "The concept of establishing high-productive ecologically sustainable agro-landscapes and modernization of agriculture systems at landscape level" (1992), "The recommendations for landscape systems in agriculture" (1993), "The basis of landscape ecology and agriculture" (1994), "Methods for development of agricultural system based on landscape" (1996), and "Agro-ecology of soil slopes" (1997) and others. These publications have assisted in the development and application of new regional landscape systems of agriculture for all types of enterprises to maintain and increase soil fertility, introduce sustainable, environment-friendly agriculture and preserve biodiversity.

# VIABLE OPTIONS FOR STABLE AGRICULTURE IN TURKMENISTAN

**Orazmurad Karakhanov**[1]

In Central Asia, Turkmenistan is a country with immense land resources. It's territory stretches from east to west for more than 800 km, in the south it borders with the mountain range of Big and Small Balkhan, "Kopetdag" and in the north with the Karakumy desert. Dashoguz velayat is in the zone of Aral Sea ecological catastrophe. The steppe territories are located on Turan lowland. In the mountainous part of the country, there is a sub-tropical zone of Karakala and Esenguly, where valuable varieties of fruit trees, grapes and nuts are cultivated. There are no forests on the territory of Turkmenistan. Eastern and western winds freely penetrate the territory aggressively affecting the climate. Northern winds distribute dust from the dried sea bed of the Aral Sea, negatively affecting the environment of Dashaguz velayat.

Nationwide, the average annual rainfall is about 70 mm, with it reaching only 100-120 mm in the mountainous regions. Under such conditions, rainfed agriculture is problematic with the yield of cereal crops, in favorable years, rarely exceeding 0.6-0.8 t $ha^{-1}$. Thus, agriculture is practiced only under irrigated conditions. With 12-17 million ha of potentially arable land, at present, only 8% of this land is currently used. Crops are annually sown on 600,000 ha, with an additional 500,000 ha devoted to cotton production. More than 1.5 million t of grain, and 1.3 million t of raw cotton produced in 1999.

The soils of Turkmenistan are mainly meadow, meadow-swamp, gray, takyr and desert-sands. Development of soil took place on re-deposited products of weathering brought from mountainous regions: alluvial, proluvial, deluvial and irrigation deposits. Loamy sandy deposits have been developed on proluvium-deluvium loess rocks laid under by pebble water-bearing horizon, or less frequently on loamy horizons. Soil-forming rocks are loess loams brought by floods to the plains.

These lands, in most cases, border the Karakumy desert and are subject to wind and water erosion. They are different in mechanical compositions, vegetative cover, level of water table, salinity, fertility, time of cultivation and, therefore, require different approach for cultivation and preservation. In the irrigated agriculture of Turkmenistan, it is important not to allow secondary salinity caused by improper and untimely agronomy, which can result in yield loss exceeding 25-30%.

In order to exclude undesired phenomena when developing virgin lands, a number of agro-technical and land improvement activities are carried out aiming at preservation of natural fertility and protection of soil from harmful salts. One of the main measures in this case is a combined plowing, when an upper 20-25 cm layer of soil is tilled with moldboard plough while a lower 25-40 cm layer characterized by low fertility is broken up without furrow slice inversion. Such plowing technology promotes the diminution of filtration properties by 1.5-2.0 times and increases the soil penetration capacity by 30-40% compared to plowing by a plough with skim-coulter. The crop yield is increased by 25-30%.

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It is recommended to repeat subsoil tillage every three years, and in the meantime plowing at 25-30 cm. On newly reclaimed, desalinized lands after 1-2 year of cultivation, the depth of plowing should be 30 cm with simultaneous sub-soiling at 12 cm. This technology prevents turning over low fertility layer to the surface, improves water-physical and agrochemical properties of soil and increases the yield of agricultural crops.

On desalinized, sloped lands good effect is observed when sowing winter cereals on furrow ridges. Depending upon the method of pre-sowing soil cultivation, the yield of wheat can reach 4 t $ha^{-1}$. In case of sowing on ridges, reduction of field works allows to save 50 kg of fuel and lubricating materials per hectare.

In case of zero cultivation, i.e. direct sowing along the preserved ridges, the yield of wheat is 3.7 t $ha^{-1}$ and the labor costs reduction is 2.5-3.0 times, with a fuel consumption reduction of 5-6 times. On meadow soils irrigated for a long time, the highest yield of winter cereals (5.4 t $ha^{-1}$) was received with plowing 25 cm deep and with sub-soiling at a 12 cm depth. On similar soils, good effect has been observed with double-layer plowing which resulted in favorable soil structure with small particles allowing accumulation and preservation of moisture, timely planting, accelerated the development and maturity of the crops and good to control weeds, pests and diseases. On soils of hard and average mechanical composition the double-layer plowing is carried out at a depth of 35 cm, on those of light mechanical composition at 30 cm and on meadow and meadow-swamp soils - depending on the depth of gray horizon – disturbance of not more than 2-3 cm.

Soils having gypsum in upper layer (e.g. near the Kopetdag sub-zone) as well as heavy textured, highly compacted soils with a sub-soil plough layer, are preliminary tilled at a depth of 50 cm or more by deep sub-soilers with the subsequent plowing at 30 cm. This deep tillage is repeated every 3-4 years. On soils with close bedding of pebbles and sand, shallow plowing is carried out not to bring to surface pebbles or sand.

Distribution of weeds is a big obstacle to obtain high yields of agricultural crops. Soils becoming populated with perennial weeds reduce the yield by 25-30% or more. Based on research conducted by Research Institute of Agriculture and Water Resources a number of effective agrotechnical and chemical measures were developed:

- Combing out of perennial weed rootstocks by soil cultivation with chisels and harrows for 20-22 cm without furrow slice inversion;
- Two-layer plowing at 35-40 cm, which reduces weeds by 65-70% compared to regular tillage by a plough with skim-coulter.

These measures are the main principals of soil protection against weeds, sanitation of soil and environment. While creating favorable conditions for maximum elimination of weeds, two-layer plowing also improves soil fertility due to even distribution of organic substance all over the profile of arable layer. In this case, the soil improvement takes place not only in a plough layer but in sub-plough layer as well. Annual deep plowing at 40 cm, both regular and two-layer, results in rapid mineralization of organic residues in soil and unproductive waist of nutrients. From the perspective of more rational utilization of alfalfa in crop rotation, the most effective is an alternating depth of plowing, i.e. for alfalfa furrow the plowing should be carried for the depth of 40 cm with inversion and in the third year after plowing – for the depth of 20-25 cm, in the fourth and fifth year – for 30-35 cm and in the sixth year – for 40 cm. With this tillage the process of decomposition of alfalfa organic matter with gradual sub-soiling takes place uniformly at a slowed rate. Thus, humus content in 0-30 and 30-40 cm horizons in the sixth year after plowing of alfalfa with annual two-layer plough for 40 cm was

0.93 and 0.84%, respectively, while with gradual sub-soiling – 1.10 and 0.86%. The method and depth of soil tillage allows to regulate the process of decomposition of alfalfa organic mass. It also affects the rate and degree of humification and mineralization providing favorable conditions for growth and development of agricultural crops.

Substantial yield potential is lost due to inadequate leveling of irrigated fields. On badly leveled fields, the quality of agronomic operations and water supply worsens sharply. Elevated parts of a filed have less moisture while lower parts and hollows have excess of water. As a result, alkaline spots may appear on which the crop has thin stand and low yield and in most cases there are no plants at all. The alkaline spots are difficult to level and plough because of high compaction. Prior to leveling, the spots are broken up by plough without moldboard or deep rippers for the depth of 50 cm or more and then other required work is carried out.

Before independence, Turkmenistan mechanization of all agricultural processes was oriented at the machinery made in other CIS countries. For the last years, a good deal of work has been done with respect to improvement of technology of agricultural crops cultivation. Close relationship has been established with such companies in the USA such as John Deer and Case. The principal branch of the country's agriculture – cotton and grain production has been equipped with tractors, planters, cultivators and harvesters made in the USA and CIS.

Despite the extensive, high quality research which has been done during the past years, pre-sowing tillage still remain labor-intensive and imperfect. Chisel-cultivators do not completely meet the requirements of agronomists, especially on soils with heavy mechanical composition as well as on meadow and meadow-swamp soils with high water table. Tilling these soils with chisel is difficult and in some cases results in big and solid soil structures which require a lot of additional labor to make suitable for planting. In other cases, moist mass is turned out, it dries very quickly, becomes hard and it is very difficult to brake it by harrows, disks or other tools. In case of sowing into poorly prepared soil, the seedlings appear to be very thin and yield is low. Taking this into account, improvement of technology of washing out and pre-sowing irrigation will allow to eliminate the seedbed preparation connected with the soil tillage and especially with chiseling.

Existing cultivators/fertilizer applicators do not meet modern requirements for regular and by-layer fertilization. In the future, development of combined row-crop tractors for execution of a number of technological operations is worth considering and in this respect it is advisable to develop joint activity with international institutions, which can provide certain funds for development of such technologies and their implementation into practice.

There is an urgent need to improve use and implementation for small size tractors and accessories and their testing under various soil conditions. Cooperation with international organizations such as FAO, CIMMYT and ICARDA may ensure good progress in this respect. We think that in the future it is necessary to develop the exchange of advanced technologies of cultivation of cereal, legumes and other agricultural crops. Mutual visits, training with the purpose of learning and exchange of experience are required.

A special program for protection of soil against degradation when plowing, inter-row tilling, leveling, irrigating and conducting other operations needs to be investigated and developed. Soil is significantly damaged by water and wind erosion, which result in the loss of the fertile layer from the surface hampering further soil treatment.

# SOILS AND THEIR STATUS IN GEORGIA

**Tengiz F. Urushadze[1] and T.T. Urushadze**

Prof. V. Dokuchaev rightly called Georgia a natural soil museum. More than 50 soil types have been described in the country and this soil diversity is a result of complex bioclimatic, lithological and geomorphological conditions. Some of the soil types were first described in Georgia and only later distinguished in other countries. Diverse conditions of soil formation are complicated by the influence of man's disruptive activities. In some regions of the country, irrigated agriculture has a long history while in other regions crop husbandry is more recent. Many scientists have investigated the soils of Georgia, and as a result, a number of main principles of modern Soil Science arose including vertical soil zones, the foundations of the theory of provinciality and foothill soil zones, and the notion of the soil metamorphism.

The soils of Georgia are classified in several geographic groups. The soils of Dry Subtropics are mainly observed in the eastern part of the country typified by cinnamon, gray-cinnamon, meadow-cinnamon, meadow-gray cinnamon soils. The soils of Humid Subtropics are observed in western Georgia, typified as Podzolic-yellow, Podzolic-yellow-gray, yellow, red, yellow –brown soil. The Forest Soils of the Temperate Zone include gray-forest, brown-forest, brown-black, Podzolic-brown, humus-carbonate soils. The Steppe Soil of the Temperate Zone dominate in the plains of southern Georgia and are connected with the plateau having the cold continental climate where Chernozems and meadow-Chernozems soils are found characterized as red, yellow, Podzolic-yellow, cinnamon, meadow-cinnamon, gray-cinnamon, Chernozems.

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# CONSERVATION TILLAGE IN UKRAINE

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The history of conservation tillage in Ukraine recognizes I.E. Ovsinsky (ca. 1899) was one of the first to doubt the need of annual plowing. Instead of plowing he suggested soil scuffling (harrowing) to the depth of 3 cm, retaining the more fertile upper layer intact. However, evaluation of this method on a station in Poltava and in other regions (V.P. Gordienko and others, 1998) did not confirm any advantages of shallow non-moldboard tillage primarily due to high weed population. Further comparative investigations of the efficiency of traditional moldboard plowing and non-moldboard tillage confirmed the advantage of the former method (L.N. Barsukov, 1937). The widely recommended practice of non-moldboard tillage (ca. 1950s – 1960s), advocated by I.C. Maltsev, was not readily adopted in Ukraine because results from different regions were often negative (F.O. Popov, 1996). The method of non-moldboard tillage with cover residues was developed under the guidance of A.I. Baraev (1976) for Northern Kazakhstan and Western Siberia. Evaluation of this method showed its efficiency in controlling erosion in Southeast Ukraine, however, in other parts of the country results were more discrepant (F.T. Morgun, N.K. Shikula). Thus, research and farmers experience in Ukraine over the past 100 years have shown an advantage of moldboard tillage with numerous pre-sowing and tillage operations. Nevertheless, since the 1950s, views toward conservation tillage have become less categorical and more experimental data are allowing a revision of the established system of tillage. The possibility of not plowing soil for winter wheat after row crops and peas has proved promising. Gradually the theoretical and practical bases of the new conservation tillage system are evolving.

The principle achievement concerning conservation tillage in Ukraine has been the recognition of optimum soil bulk density. Field experimentation has determined crop requirements for soil bulk density in various soil levels (e.g., over-seed, seed, and subsurface) (V.V. Medvedev, 1989). Sugar beet, fodder beet, and potato need loosened bulk densities; winter and summer grain crops – intermediate, perennial grasses and millet – moderately compacted. Optimum bulk density parameters differentiate depending on soil granulometric composition, availability of nutrients and moisture. In favorable conditions, the range of optimum parameters is wider than in unfavorable situations. The most strict requirements of field crops for bulk density are in the seed and under-seed layer, and less strict in a subsurface, and minimal in the surface layers. Comparison of optimum and equilibrium bulk density determined perspective zones for introduction of minimal tillage (Chernozems typical and modal, medium and heavy loamy granulometric composition).

Arable layers differentiate according to the bulk density, biological, physical, chemical properties, and nutrients, with differentiation of an arable layer under non-moldboard tillage undoubtedly useful for water retention regimes because it “locks” ascending nonproductive movement of moisture within the profile. The rate of organic matter mineralization is decreased, important for many crops, especially small cereals. Importantly, soil erosion is reduced. In contrast, constant use of non-moldboard tillage results in negative consequences

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of differentiation (surface root system development, decrease of organic and mineral fertilizers efficiency).

The research has allowed formulation of the concept and applied principles of optimal root layer formation. The model is postulated with the purpose to choose rational technologies and technical means of tillage. The model is supposed to determine the optimum parameters of agronomically important soil properties and their maintenance during vegetation period. The following parameters are important: actual soils properties formed by existing soil tillage machines and their dynamics during vegetation, the impact of tillage optimize soils properties, and demands of field crops to soil parameters. The consideration of numerous factors in the system "soil properties-technology and means of tillage-crop yield" shows that existing technologies and technical means can not reproduce the optimal model in real conditions. The realization of the model is partial only at the moment of sowing. It lends to operating at the following stages of growth and crops development. The principally new approaches in searching of technologies and technological means are required.

Combined tillage implements were developed and tested under field conditions (V.V. Medvedev and V.F. Pashenko, 1994). The working units of the machine are combined for formation of optimal soil composition in the seed layer and optimal bulk density and nutrient regime in the under-seed layer.

Ukrainian Chernozems are well-structured soils, susceptible to mechanical compaction especially in the springtime. Exceeding of permissible load levels (on average, 1.0 kg $cm^{-2}$ in the autumn, and 0.5 kg $/cm^{-2}$ in spring) results in irreversible deformation, with the dis-compaction of such soils lasting many years. Over-compaction (with dehumidification and erosion) is the most common type of soil degradation. It is also the main cause of slow realization of principles of sustainable land-use. The problem of over-compaction is unfortunately underestimated in Ukraine, though many methods are available to decrease compaction including standards of permissible specific pressure of new machines on soil, the technology of minimization of compacted area under crops cultivation, active working units for soil dis-compaction and new types of elastic tires.

A new soil-agrosoil zones classification has been initiated in Ukraine. It divides the territory according to factors which determine efficiency of agricultural machinery utilization (e.g., granulometric resistance). Delineation of soil-technological zones was carries out as a series of element maps (M 1:750,000 - 1:2,500,000) and a summary synthetic map 1:2,500,000. Elaboration of the system has not been finished, however its main features are the following:

- Recommendation of moldboard and non-moldboard tillage methods, choice depending on soil climatic and relief, danger of degradation, preceding crop, field crop, and weeds density;
- Input optimization which strives to reduction tillage and deep plowing, reducing the primary tillage depth, decreasing of number of pre-sowing tillage and inter-row cultivations, and uniform routing of tractor passes to diminishing the affects of compacted area;
- Application of new crop husbandry techniques, including integral tractors which permit combined technical operations thereby reducing specific pressure on soil.

Today, agro-ecological and social-economic situations in Ukraine require the use of conservation tillage. Experimentation has shown its advantage in reducing soil degradation processes such as erosion, dehumification and over-compaction, and in power savings.

Implementation of the "Development of geo-information system of technologies and technological means of soil conservation tillage" program is require:

- A broader diversity of field experiments carried out in all soil-climatic zones of Ukraine;
- Recognition of the considerable previous experience in development of zone and region tillage systems;
- Adequate soil cartographic and analytical base data (e.g., soil, agrochemical, geo-morphological, geological);
- Skilled personnel and computerization capacity to enable analysis, database development, map preparation, and extension expertise and capitol.

The aim of the program is to (1) to collect information about the efficiency of technologies and the instruments (tools) used in conservation soil tillage; (2) to develop appropriate methods (e.g., GIS) for extrapolation of recommendations; and (3) to classify and prioritize by district the utility of the technology and instrumentation. Related tasks could be the support of stationary experiments in soil-climatic zones and provinces, support of new market infrastructure in the agrarian section (farm, rent, joint-stock, machine-experimental stations), support of pilot-farm demonstration plots in cooperation with research. The following groups will be involved in this integrated research program: Institute of Soil Science and Agrochemistry (Kharkov), Institute of Farming (Kiev), Institute of Steppe Agriculture (Dnepropetrovsk), Institute of Non-Chernozem Agriculture (Zhitomir), Institute of Western Region Agriculture (Lvov), and regional experimental stations.

# TILLAGE TECHNOLOGIES FOR COTTON PRODUCTION IN UZBEKISTAN

**Shermat Nurmatov[1]**

Soil protection and conservation is an important environmental issue and the most crucial aspect of further growth of agricultural production in Uzbekistan. Examples of outrageous malpractice, an unrestrained race for greater volumes of raw cotton, a negligent attitude towards science based technologies and cotton monoculture has led to a significant degradation of arable land in the irrigated zone of the Republic, resulting in a decline and stagnation in cotton production and has aggravated the capacity to supply food crops. Negative tendencies in cotton production (i.e. intensive tillage, deforestation for the sake of expansion) has resulted in intensive soil erosion, particularly in the zone subjected to strong winds.

Conservation tillage is poorly developed in the irrigated cotton growing areas, and the role of plowing, secondary and especially inter-row tillage has been insufficiently studied. Inter-row tillage is currently an integral component of cropping, determining the severity of wind erosion, yield output, soil fertility and production cost. Options to inter-row tillage for cotton cultivation have been developed in relation to the depth and frequency of tillage, and in general there is a consensus about combining different operations performed within the growing period and about application of herbicides for weed control.

Despite numerous studies, recommendations for inter-row tillage based on soil type, subtype, texture and deflation severity have not been established. In this connection we studied the efficiency of different tillage methods for cotton cultivation (regular 30-32 cm deep; rotary tillage; zero tillage; planting cotton into furrow ridges formed either in fall or in spring) for light-meadow, medium loamy deflated soils in the Fergana valley. Soil texture tests showed that regular wind erosion resulted in lighter soil texture, i.e. clay-silt fractions were deflated. This suggests that the surface soil layers should not be substantially compacted. The number of water-resistant macro particles exceeding 0.25 mm is reduced in the surface layer and subsurface layer due to lighter texture of soil caused by deflation processes and repeated tractor passes. Increased number of macro particles in deep layers is caused by heavier soil texture.

It should be noted that methods of seedbed preparation for cotton have an impact on the density of soil texture. The volume weight varied within the range of 1.2–1.4 g $cm^{-3}$, which is optimal for this soil. There was insignificant difference in volume weights in different tests after irrigation. Rotary tillage, regular inter-row tillage and zero tillage (when a tractor is used just for fertilizer application between rows) provided comparably better germination and growth. The influence of tillage on the growth and development is reflected on the yield of cotton bolls, with the best yield (3.91 and 3.82 t $ha^{-1}$) harvested after rotary and zero tillage – 0.22 and 0.13 t $ha^{-1}$ more than check yields, respectively. The best quality fiber was produced on the plots where the regular primary and rotary tillage was performed.

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The following scheme was used to study the depth and the frequency of inter-row tillage used for cotton growing areas on light-meadow light-loamy and light-meadow medium loamy deflated soils:

1. Control tillage: cultivation depth and frequency accepted for this soil: the first cultivation – respectively 25-26 and 18-20 cm deep; the second and the third – 18-20 and 16-18 cm deep; followed by 10-12 cm deep cultivation.
2. Regular cultivation depth – 5-6 cm,
3. Regular cultivation depth – 10-12 cm,
4. Cultivation depth: the first one – 10-12, followed by – 15-16 cm;
5. Regular cultivation depth – 15-16 cm;
6. Regular cultivation depth – 18-20 cm;
7. Cultivation depth: the first one – 10-12, followed by – 18-20 cm;
8. Cultivation depth: the first one – 10-12, followed by – 25-26 cm;
9. Cultivation depth: the first one – 5-6, followed by – 10-12 cm;
10. Cultivation depth: the first one – 10-12, followed by – 5-6 cm.

Prior to anti-erosion measures, the soils of the test sites were systematically exposed to wind erosion, due to which the soil texture in the surface layers became lighter and the soils became less structured (i.e., less water resistant) and poor in nutrients. As a result of the repeated cultivation accepted by farmers (as a standard), macro particles > 0.5 mm are destroyed, and 0.25-0.5 and < 0.25 mm fraction sizes increased as compared with the control samples. This was facilitated by a low humus content and lighter texture of the soils under study. The volume weight in the surface layers was similar for all variants prior to the first cultivation. A certain degree of compaction is found in all variants before the second inter-row cultivation, except for variant 1 (cultivation depth varies from 10-12 to 25 cm). However, the volume weight was near optimal, even though inter-row tillage operations performed on test sites were 3 and 5 times less frequent than standard.

The best growth and development of cotton was observed at the depth of the first cultivation - 10-12 cm, followed by 15-16 cm cultivation and regular 15-16 cm cultivation. Cotton plants were 84-86 cm tall as of August 1, as compared to control 75 cm, number of bolls (as of September 1) was 5.1 and 5.7, respectively; and 4.3 pieces. The highest yield was recorded after four cultivations, the first one - 10-12 cm deep, followed by 15-16 cm cultivation and regular 15-16 cm cultivation. The yield was 4.28-4.30 t $ha^{-1}$ as compared to the control 3.93 t $ha^{-1}$. Comparatively, low yield was harvested after shallow tillage - 3.90–3.92 (variants 2 and 10) and after very deep (25-26 cm ) inter-row tillage, 3.91 t $ha^{-1}$. The best quality fiber was obtained from the variants where the first cultivation was 10-12 cm deep, followed by three cultivation 15-16 cm deep and regular 15-16 cm deep cultivation.

## CONCLUSIONS

Efficient and expanded fertility reproduction for the irrigated deflated soils can be achieved by use of rotary tillage at the depth of 30 cm, as well as zero tillage, as a main soil preparation on light meadow and medium loamy soils. In order to obtain a high yield of raw cotton, it is recommended to conduct 4 cultivations, instead of the standard 7 on light meadow deflated soils, and 5 cultivations instead of the standard 10 at the regular depth of 15-16 cm and at the variable depth, with the first cultivation at the depth of 10-12 cm subsequently followed by at the depth of 15-16 cm. Around 50% less frequent cultivation provide a positive impact upon water regime, soil density and texture, preserve soil fertility, minimize soil erosion, save labor and energy costs, reduce production cost.

# AGRICULTURAL AND ECOLOGICAL PROBLEMS IN KAZAKHSTAN

**Zeirolla Dusenbekov**[1]

The agricultural and ecological problems we face today are not of recent origin, but are a historical consequence of mans' interaction with nature. Avenues available toward sustainable solutions include use of soil conservation techniques such as conservation and zero cultivation technologies. What stands in the way of their dissemination? What interferes with their development and implementation?

Land organization during the Socialist period was based on a rigid topographic structure involving large fields, straight boundaries (which may not have corresponded to natural boundaries and agricultural landscapes), and controlled rotations. Today, these designs may be less appropriate given changed land tenure and access to inputs and implements, and because of a renewed recognition and evaluation of landscape. Agricultural landscape systems were used in their primitive sense long ago. They were developed in conformity with natural laws, and provided harmonious interactions between humans and nature. Once again, landscape planning should be treated as an effective tool for ecologically oriented crop husbandry. The Republic has begun to develop landscape planning methodology taking into consideration specific features of a region. With organization of a large number of small production units, problems of soil protection and rational utilization arise more acutely. There is also concern that division of land into smaller units may lead to ineffective utilization, losses in production and non-sustainable maintenance.

For cultivation technologies used in the recent past, many of which were then considered progressive, current market forces have proven to be unprofitable and non-competitive. This has led to a break down of the recommended sowing structure, crop rotation and land utilization system at large. Attention to crop rotation has dropped sharply in response to the current market realities. Long-term rotation trials have shown that mono-cropping will eventually cause sharp yield decline, increase of weeds, and soil erosion intensification, however, short-term objectives now rule.

Commercial farmers, by their nature and circumstance, universally try to find cost effective cultural practices. Aspiration for general applicability, however, has not always been successful. Consequently, region or situation specific recommendations based on nature and topography proven most useful.

In many lower productivity crop-growing zones more attention needs to be paid to protection of the environment. These omissions have led to cropping systems which are dangerous for agro-ecologies, and in some regions catastrophic consequences have resulted, particularly through the contamination of environment with fertilizers, pesticides and their by-products as well as decreased soil fertility, humus and soil erosion. Nevertheless, this evaluation is conditional, scope of evaluation indicators is not perfect, and evaluation criteria are not substantiated methodologically.

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In the past, poor agricultural production was considered a fault of insufficient research, poor methodology and defects in practical technology application. In defining efficiency of regional cropping systems the central objective is soil, its fertility and reproduction, as well as ecological issues. Cropping system analysis shows that simplified approaches considering a combination of technological processes and operations often leads to irrational utilization of natural resources and inputs affecting ecology. Reasons for the deterioration of the ecological cropping environment include:

- insufficient consideration of natural balance which is caused by unbalanced approaches to the utilization of separate elements of intensive crop cultivation;
- irrational utilization of chemicals (fertilizers and plant protection agents);
- intensive soil tilling leading to decrease organic matter, deterioration soil characteristics and erosion;
- underestimation of full utilization of organic waste in agriculture.

In order to improve the agro-ecological situation, it is necessary to prepare ecological standards for agricultural activities:

1. standard levels of optimal soil fertility, humus, and agricultural and physical indicators (which will influence choice of crops and crop rotation);
2. standards for erosion processes, tillage and irrigation;
3. study of movement of biological and chemical substances, efficient utilization of chemical and safety procedures;
4. products quality, sanitary and hygienic standards.

Although there have been negative consequences of the transformation to a market economy, positive affects have included price increases for fuel, fertilizers and pesticides have led to a decrease of cultivated land primarily by excluding less fertile and more eroded fields. Utilization of agricultural equipment has improved and deep soil tillage without turnover is used more widely, consuming less power and resulting in a more ecologically friendly environmental practice. The use of pesticides and inorganic fertilizers have decreased significantly, lessening the danger of natural environment contamination. Conversely, it is wrong to consider these consequences as fully positive given the concomitant decreases in grain yield due to increased diseases, pests and weeds pressure and lack of nutrients. However, this situation creates realistic preconditions for a transformation to a new cropping system where every field, every agricultural landscape, technology and choice of crops will correspond and harmonize with one other. The new cropping systems must recognize a compromise between natural ecology and immediate human needs and aspirations.

# PERENNIAL GRASSES: AN IMPORTANT ELEMENT OF SUSTAINABLE FARMING

**Kasim Asanov**[1]

Recently, proper consideration of soil texture has been unjustifiably neglected by many farming practices. This vital component of soil fertility is especially significant in regions of Kazakhstan where soils are prone to soil erosion. Important agricultural practices used to control erosion and to foster conditions for sustainable farming development include formation of a tight soil texture by preserving organic matter and preserving soil surface cover with use of cultivated grasses or crop residues.

Good-textured soil will absorb and retain moisture more readily resulting in a soil which is more resistant to the erosive power of water and wind. Tight soil texture is formed after cultivating grass mixtures (including cereals) and legumes. Perennial grasses increase soil organic matter, improve soil texture and strengthen stickiness of lighter soils.

Perennial grass cultivation may be performed by either using crop rotations which involve perennial grasses or by regular exclusion of particular fields from rotation and planting them with perennial grasses. Rotations which alternate pasture meadows with tilled fields could accommodate 10 m ha in Kazakhstan. Species involved in these rotations would include wheat grass, sainfoin, awnless brome grass and biennial sweetclover, with use of alfalfa restricted to specific conditions such as those encountered in Kokshe, Krasnozavodskaya bogarnaya, etc.

Today it is not uncommon to see once arable fields returning to areas covered by non-productive weeds and serving as habitat for malicious pests such as Asian Locust and Italian Prust. Cultivation of perennial grass on meadows and in rotation with tilled fields is an important option for sustainable farming in Kazakhstan. Organization and development of meadow and pasture grasses seed production will be an essential prerequisite to meet the demand for this conservation methodology.

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# OPTIMIZATION OF CROP PROTECTION

**Tleu Nurmuratov**[1]

Plant protection based on natural ecology requires thorough knowledge of the ecosystem as a whole. The dynamics of organism populations and their establishment and development is the necessary basis for the development of effective plant protection systems. Recent agrarian changes have led to expansion of cereal cropping in the south and southeast of Kazakhstan, into situations favorable for the development of septoria diseases. In addition, the unprecedented recent outbreak of locusts may relate to poor agronomic practices, insufficient mechanical tillage, increased non-cultivated land area, and to some extent decreased number of livestock, especially sheep.

Plant protection is necessary and important component of farming system. Technology will never realize potential crop yield if insects, diseases and weeds negate advances. Effective crop protection is based on skilled application of organizational, biological and preventive methods. Chemical control should only be used in extraordinary, last-resort cases.

Damage inflicted from various diseases, weeds and pests has increased in a number of regions recently. Reforming the agricultural sector will require design of new farming systems which recognize the requirements and standards of the economy and environmental protection. However, any farming system can not exist without plant protection as an important factor. Dependent on weather conditions, agro-ecological, anthropogenic and other factors they can be depressed or reach epidemic level. Therefore, specificity of establishment and development of agro-ecosystems has strong effect on the numbers and damage by insects, mites, diseases and weeds.

Soil protective farming systems were developed for rainfed lands of Northern Kazakhstan based on conservation tillage, direct seeding, short-term crop rotations, use of fallow, soil fertilization and effective usage of plant protection measures. However, during the first years of plowing huge areas of virgin lands and with mono-cropping, unique conditions were created for mass propagation of the American bollworm and dominating of other harmful species. As a consequence, the recommended agronomic methods – several pre-sowing soil tillage in spring – destroyed larvae and chrysalides of the American bollworm and weed seedlings, especially wild oat. Nowadays the decrease of crop area, especially cereals in the north and east of the republic, and appearance of vast non-cultivated areas of land have led to the break-out of locust population and treatment of large areas with chemicals pesticide. From the point of view of the plant protection, the agronomy methods of pest control provide good yield and are preferable.

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# PRINCIPLES OF SOIL FERTILITY IN NORTHERN KAZAKHSTAN

**Rakhimzhan Eleshev[1] and Abdulla Saparov[2]**

Agricultural development in Kazakhstan reached its peak 1986-1990 when its share of GNP was 34.7%. Grain and livestock production were high priority areas. The national average annual grain production reached 26.4 m t, and meat production exceeded 1.5 m t. However, during the recent economic reforms, agricultural production has reduced by over half, and now represents only 8.4% of GNP. The area of cultivated land has been sharply reduced, and the productivity of crops has declined. One of the reasons for low crop productivity is poor soil fertility. In 1998, most of the cultivated land did not receive fertilizer application, resulting in a decreasing balance of humus in the primary cropping regions of the Republic with recent losses of humus exceeding 25-30% of the base level.

Researchers at the A.I. Barayev Kazakh Research Institute of Cereals have developed a "Concept of development program of agro-industrial complex of Kazakhstan until the year 2000", with support of the Kazakh Academy of Agricultural Sciences. The concept note was aimed at soils with light mechanical structure, low moisture equivalent or poor water-retaining capacity resulting in large potential losses of moisture. Alternative cropping solutions were oriented towards optimization of fallow, selection of crops and varieties which can efficiently use moisture, and nutrient regimes which will contribute to an increase of productivity and sustainability.

Preservation and increase of soil fertility in soil-protective farming depends on use of organic fertilizer and plant residue. Crop residues affect soil fertility through the formation of water-stable aggregates thereby regulating mineral nutrition and decomposition of pesticides. Agronomic landscapes and biological agriculture result from a combination of related measures ensuring maintenance of soil and guaranteeing ecologically clean production through regulated use of fertilizers and pesticides. However, an increase of effective soil fertility will require use of appropriate mineral fertilizers, particularly to meet phosphorus requirements relevant for soils in Northern Kazakhstan. Research involving the interaction of phosphorus and nitrogen regimes, in connection with varietal genotype by environment interactions, is required to optimize mineral nutrition and extension recommendations.

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# ECOLOGICAL NICHES FOR AGRO-BIODIVERSITY AND PRODUCTION STABILITY IN NORTHERN KAZAKHSTAN

**Ervin Gossen**[1]

Agriculture in Kazakhstan requires soil and water use efficiency technologies to enable stable production. Optimization of soil protection systems has been realized in Eurasia as exemplified in Dokuchaev, Poltava, Stavropol, Povolzhje, South-Ural, Kazakhstan, West Siberia, Altay, Khakassiya, Buryatia and Mongolia with soil-protecting technology recommended and applied on more than 60 m ha during the 1990s.

Agro-geographically, within the boundaries of Russia and Kazakhstan chernozem soils in steppe and dry steppe zones stretch from Voronezh to Barnaul and from Ural to Irtysh. Statistics from the V.V. Dokuchaev Soil Institute indicate that the area of cultivated lands in Eurasia is 91.6 m ha, including 47 m ha in Ural, Siberia and Kazakhstan, out of which 30 m ha are in Kazakhstan. This entire area is vulnerable to water and wind erosion and desertification. The urgency of these potential problems have been mentioned in international conventions of the UN concerning the changes of the climate, spread of deserts and preservation of biodiversity. Thus, one of the main conditions of preservation of arable land for sustainable grain production is protection of the soil against all types of erosion.

Specific features relevant to cereal production in Eurasian agro-climatic regions dictate early sowing in the Volga region with later sowing required for Northern Kazakhstan; utilization of warm, humid conditions after harvest for elimination of weeds; and black fallow rotations for Kazakhstan and Siberia. Stubble crop residues prevent soil deflation and allow accumulation of moisture during winter. Distribution of annual precipitation is most uniform in Saratov. In Akmola, monthly precipitation reaches a maximum in late June, however a significant amount of moisture in the form of snow is received. In Khakassia (Minusinsk), most precipitation is received during the summer months, from late May through early August. These regions are also distinguished by agro-climatic indicators after harvesting (Table 1).

The above-listed agro-climatic indicators serve as justification for cultivation of winter and spring crops and precise identification of soil protection measures as well as determination of the anti-erosion role of crop residues, winter crops and perennial grasses, mechanical composition of soil and its dispersion. These provisions deal with the cut-and-flat treatment of soil, justification of agro-technical requirements to the complex of anti-erosion technique and to the soil protective cultivation in general.

In regions of Volga and North Caucasus where winter wheat predominates, stubble and residue protect the soil. Tillered winter wheat can protect soil from deflation during autumn, winter and spring becoming a soil protection crop when planted in strips (buffer strips).

Monthly precipitation in Astana, Kazakhstan versus Saskatoon, Saskatchewan is presented in Figure 1. Winter precipitation is less in Saskatoon, and as a result the relative significance of snow retention is reduced. In North Kazakhstan, winter precipitation is more important, and

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snow management and utilization of windbreak crops and preservation of stubble are required. Because of earlier summer precipitation, farmers in Saskatchewan may sow spring crops earlier and hence realize earlier harvests. In Kazakhstan, critical crop development phases need to be timed to maximize July precipitation and, hence spring sown crops are harvested later. In general, the climatic conditions of Saskatchewan are more favorable for cultivation of small cereals than those of North Kazakhstan.

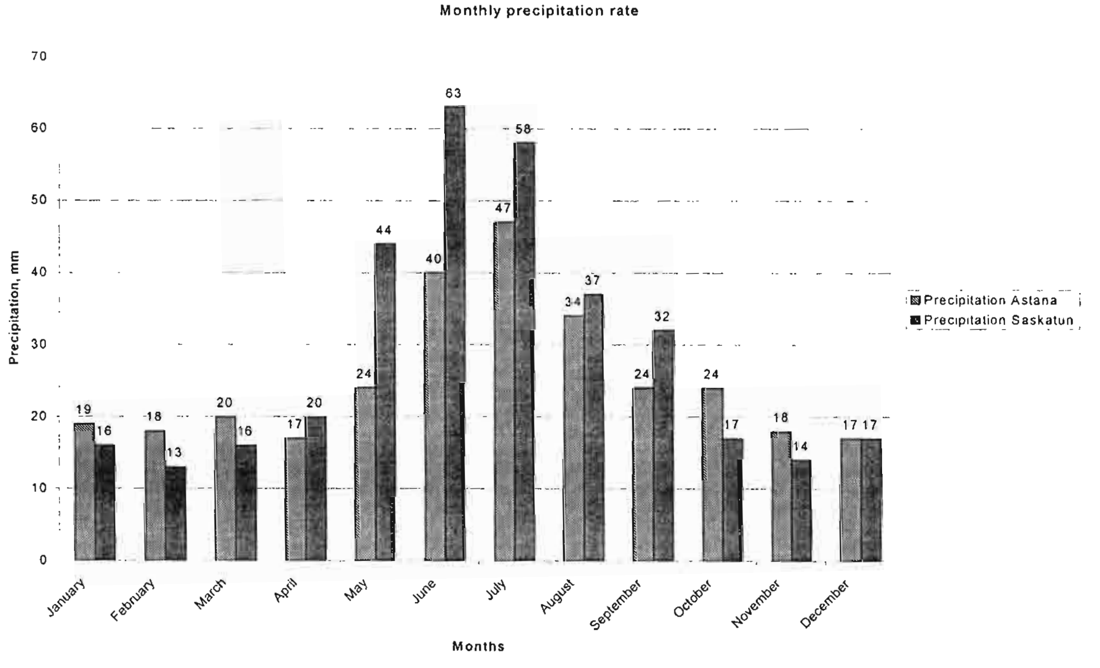


**Figure 1. Characteristics of post-harvest period prior to air temperature reduction below + 5 degrees.**

Current economic conditions require cropping decisions based on ecologically and economically justified natural and ecological niches and agro-landscapes. In Northern Kazakhstan it is necessary to carefully select ecological niches for sustainable preservation of agro-biodiversity and agricultural production. The principle of agro-landscape cropping is based on four indicators: Height of snow cover; Soil humus content; Soil topographical relief and exposure; and, Average, long-term cereal yield (N.K. Azarov, 1996) (Table 2).

Depending on the landscape and the length of the frost-free period, the following crop rotation options can be considered for cereals production in Northern Kazakhstan:

<u>**Option 1**</u>
1. Fallow with minimum tillage and fertilizer
2. Spring durum wheat
3. Spring bread wheat

<u>**Option 2**</u>
1. Fallow with minimum tillage, fertilizer and windbreaks
2. Winter wheat
3. Peas-oats green forage
4. Winter rye

**Option 3**

1. Fallow with minimum tillage and fertilizer
2. Spring rapeseed for oil
3. Spring malting barley
4. Spring high lysine barley

**Option 4**

1. Peas-oats mixture green fallow
2. Maize for silage
3. Sunflower

**Option 5**

1. Peas-sudan grass mixture green fallow
2. Sugar beet
3. Sugar sorghum

Agro-landscape cropping implies that the balance of organic matter and humus in the soil is maintained and minimum tillage is applied to conserve the soil. The machinery combining several operations is very important especially to control weeds (Table 3).

## REFERENCE

Azarov NK (1996) Grouping of Lands into Agro-landscapes According to the Conditions of Cultivation of Cereals for the regions of North Kazakhstan. PhD thesis.

**Table 1. Post-harvest agro-climatic indicators (Azarov, 1996).**

| Location | Post-harvest period (days) | Precipitation after harvest (mm) | Growing degree days, after harvest |
|---|---|---|---|
| Voronezh | 87 | 136 | 1078 |
| Saratov | 94 | 110 | 1123 |
| Astana | 48 | 39 | 553 |
| Barnaul | 46 | 52 | 525 |
| Minusinsk | 45 | 37 | 500 |

**Table 2. Agro-landscape groups as developed by researchers at the A.I. Baraev Kazakh Research Institute of Cereals (Azarov, 1996).**

| Agro-landscape groups | Snow cover (cm) | Humus content (%) | Slope (degrees) | Yield (t $ha^{-1}$) |
|---|---|---|---|---|
| Good | > 41 | > 4.5 | < 0.2 | 1.6-2.0 |
| Average | 31-40 | 4 - 4.5 | 0.2 - 0.5 | 1.2-1.6 |
| Poor | 21-30 | 3 – 4 | 0.5 - 1.0 | 0.8-1.2 |
| Extremely poor | < 20 | < 3 | > 1.0 | < 0.8 |

**Table 3. Soil physical and technological properties, structure of root systems determining design of working tools for agronomic and chemical measures for weed control.**

| Zone and type of soil | Predominant weeds | Soil physical properties | Type and depth of root system | Reduction of weeds by: | | Type of tillage implements and depth of tillage |
|---|---|---|---|---|---|---|
| | | | | Mechanical | Chemical | |
| Steppe, Northern Kazakhstan.• Standard and southern Chernozem | Sowthistle | High humus content, porous | Root suckers 8-25 cm | By layer cutting | Spraying in the stage of rosette | Cultivator and scuffle knife, 8-25 cm by layers |
| | Wild oats | Loamy | Fibrous, 2-3 cm (at tillering) | Cutting and throwing on surface or embedding in soil in the two-leaves phase | Soil herbicides or spraying in two-leaves phase | Cultivator knife + boom or combination of disc and needle-shaped working tools with sprayer boom 8-10 cm in fallow field - 3-5 cm, application of soil herbicide; 6-8 cm before sowing |
| Dry steppe, Kazakhstan. Dark chestnut soils | Wheat grass | High stickiness, density and alkalinity of soil | Tap Root, 12-16 cm | Combing out of rootstocks | Soil herbicides | Spring cultivator working tool-comb our with a file or sweep or half-sweep, 12-16 cm |
| | Sedge | Clay, heavy textured | Tap Root, 25-27 cm | Turning out to surface and combing out of rootstock | Soil herbicides | Same with preliminary plowing 25-27 cm + 12-16 cm (combing out) |
| Dry steppe, Kazakhstan. Chestnut soils of light mechanical composition | Bristle-grass, Russian thistle | High abrasive properties and density of soil (light, sandy loam) | Fibrous, 2-3 cm (at tillering) | Cutting and pulling out | Spraying at two-leaves stage | Cultivator sweep - blade, scuffle knife in combination with needle disk. Boom sprayer. Before sowing for depth of seeds planting, 4-6 cm in a fallow field. |

# GRAIN PRODUCTION TECHNOLOGIES FOR THE STEPPE REGIONS OF THE ALATAISKIY KRAI

**Vladimir Belyaev**[1]

Rational utilization of land resources based on the modern scientific and technical achievements is a baseline for the development of agricultural and industrial sector. New cropping technologies for different regional environmental conditions are being developed for this purpose. Successful application of such technologies is feasible provided there are modern resource-saving conservation tillage machines and implements providing an opportunity to observe proper agricultural practices and to maintain sustainable farming despite negative external factors.

At present, a number of enterprises in Alatay region have begun to manufacture new generation machinery. The Rubtsovskiy machine building plant is one of the enterprises producing tilling and planting machines (e.g., the PPK-12.4) which allow up to five operations with one pass: cultivation, seeding, fertilization, rolling and leveling. However, often there are no guidelines for optimal parameters and working modes for this machinery and tractor equipment used with the available and prospective tractor modifications. There are no zonal recommendations to increase efficiency of seeding, optimize crop seeding rates and speed/capacity modes for machinery and tractor equipment in compliance with the appropriate requirements of tilling practices. And, this is why there is a necessity to supervise the production, assess the efficiency of new technologies and the system providing for the usage of these technologies under various soil and climatic conditions.

In cooperation with the Development Society "Galbshtadt", we have implemented a scientific project to provide a comprehensive evaluation of the efficiency of PPK-12.4 (tillage and planting machine) use in the steppe regions of the Altay region. The major objectives of the research are:

- to conduct agronomic, technical and power-efficiency assessment of the machine when used with K-701 tractor;
- to conduct comparative testing of two optional technologies for spring wheat production: with the use of PPK-12.4 and traditional technology with the use of SZP-3.6 planters;
- to determine the influence of the seeding rate, PPK-12.4 tilling and compacting impacts on agri-physical properties of soil and wheat yields;
- technical and economic assessment of typically used (SZP-3,6 planter) and new (PPK-12.4) spring wheat production technologies.

The study was conducted on fields in two counties (rayon) -- Blagoveschenskiy and Pankrushikhinskiy -- where climatic conditions are very much similar to the Nemetskiy National rayon. The first stage of the research incorporated agri-technical and power-efficiency assessment of the aggregate consisting of K-701 tractor and PPK-12.4 machine tested on the stubble field (without fall tillage). Initially the machine was idly driven across the field with the gear-lever shifted back and forth (4 levels) to determine how much fuel is consumed to operate the machine. Then, each of the three levels of average tillage depth was separately tested with gear shifted through 2-3-4, providing machine's operation in a set

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capacity mode. The following indicators were studied: average fuel consumption for the engine, working speed of the machine, net productivity and fuel consumption per unit of the plowed area, tillage depth and ridge variation of the field surface covered by the machine.

Results indicated that the tested tilling and seeding machine is very power-consuming. The average capacity of K-701 tractor varied within the range of 37.2-74.4 kH when operated at working speeds of 3.25-1.82 m $s^{-1}$ and average tillage depth of 2.0-8.0 cm. Analysis of the average fuel consumption, operational speed of the machine and tillage depth allowed to determine rational operational modes for the machine in order to utilize potential capacities of the tractor found that at the depth of tillage equal to 4.0 cm the machine is operated at a required speed. Thus, in order to provide an efficient operation of the machine and K-701 tractor, it is required to use a smaller operational coverage or parts with smaller traction resistance per unit of weight.

The depth of tillage significantly varies throughout the pass. Whenever an average tillage depth increased from 2.0 to 8.0 cm and the operational speed of the machine decreases from 3.25 m $s^{-1}$ to 1.82 m $s^{-1}$, variation of tillage depth reduces from 140 to 45%. The degree of field ridge variation varied even more significantly after tillage. Variation coefficient was reduced from 269 to 119%. Given that an average depth of tillage used on the farm equals 6.0 cm, the machine K-701+PPK-12.4 has a maximum average capacity of 24.8 $m^2 s^{-1}$ consuming 0.55 g $m^{-2}$ of fuel per unit of the plowed area, that is respectively 3.3% and 2.2 times more as compared to the conventional aggregate T-4A+SP-11+3SZP-3,6.

Comparative evaluation of two optional wheat production technologies (with the use of PPK-12.4 and SZP-3,6) was conducted on a stubble field (with no fall tillage) tilled by KPSH-9 subsoiler at the depth of 16-18 cm. Wheat and maize were the preceding crops. Wheat variety Altaiskaya (first reproduction seed) was sown on May 16-20. As soon as the first field experiments were started, the following measurements were taken: soil density and moisture in the soil layers of horizon 0-100 cm, soil density, hardness and moisture inside and outside the furrows in the layer 0-40 cm, tillage depth and field surface ridge variation throughout the coverage of the machine, aggregate soil composition in the surface layer inside and outside the furrows. Seed distribution and seeding depth throughout the coverage was assessed after germination.

Growth and development of plants was studied throughout the growing period. Wheat yielding characteristics will be determined at harvest on the basic testing plots and in each row 1.0 m long within the width of planter coverage. Processed data shows that given comparable average seeding depths, their variation within the width of planter coverage with the use of PPK-12.4 was 11-15% higher as compared to SZP-3,6 seeding machine. This is an indicator of a higher depth variation of the new machine, first of all, due to hard frame sections, that do not allow to contour the field relief.

Analysis of wheat plant distribution proves that kernel number is slightly higher when PPK-12.4 is used, versus use of SZP-3,6. However, the primary determining factor here was the average seeding rate.

After the soil density parameters in horizon layers were compared, it was determined, that K-701+PPK-12.4 significantly compacts the soil, especially along the tractor wheel and machine bunker track. Average compactness in 0-40 cm horizon layers was 0.13–0.20 g $cm^{-3}$, with initial compactness of 1.05-1.22 g $cm^{-3}$. Soil density after T-4A tractor pass is comparable to the compactness after PPK-12.4 bunker wheels. Evaluating the hystograms of soil fractions distribution in the surface layer for different seeding options, we conclude, that there are some differences in the fractions smaller than 2.0 mm. When seeding with SZP-3,6 there are 2.5-3.6 % more fractions smaller than 1.0 mm as compared to PPK-12.4, and 7.0% less of 1.0-2.0 mm fractions.

It should be stressed that there is a great number of particles subject to erosion in both cases amounting to 28.4 and 32.0% of weight in average after the primary tillage on the field with stubble. After the aggregate soil composition of a field without fall tillage inside and outside the track of K-701+PPK-12.4 was compared, it was found that under experimental conditions there is twice as much particles subject to erosion inside the furrow as there is outside the furrow.

The specified differences of two tilling and seeding options condition the change in general physical properties of soils, the direction of nutrients mobilization and their influence on wheat yields when different wheat production technologies are used. The final conclusion about the expediency of PPK-12.4 use as a part of a new wheat production technology will be made after the experiments with crop rotations are completed, yielding characteristics for the compared options are determined, agri-technical assessment of soil samples is accomplished and operational costs are estimated.

# MODERN APPROACHES TO IMPROVE FARMING IN THE NEMETSKIY (GERMAN) RAYON OF ALTAI REGION

**Anatoly Konev**[1]

Unfortunately, there seems to be a powerful influence of economic activity upon nature resulting in general degradation. Within the past 100 years, soil humus content has declined by 2-3 times (from and initial 6-8% to a current level of 2-3%), capillary moisture holding capacity of the top soil layer has decreased from 25-30% of full holding capacity to 8-12%, and nitrate content in the top layer (0-40 cm) was found to be drastically decreasing.

Farmers are now forced to resort to considerable seeding depth (7 cm) as the top soil layers dry quickly in the spring. Deep seeding negatively affects stand establishment, reduces crop strength, inhibits and prolongs tillering because of the lack of nitrogen, and results in low productivity (often 0.6-0.8 t $ha^{-1}$). In this connection we have identified the ways to improve the system of farming, including:

- Reduce seeding depths for fallow from 10-15 cm to 4-5 cm, apply modern cultivators and remodel old planters (e.g., the SZS-2.1).
- Practice direct seeding into undisturbed stubble. Undisturbed stubble was found to contain 50% more moisture in the layer of 0-20 cm, and twice as much moisture in the layer of 20-40 cm compared to a fallow field.
- Use of sweet clover to turn black fallow into green-manure fallow.
- While practicing direct seeding, try shallow planting and raking of dry soil together in between the rows. This seeding technique used for perennial grasses in the region for 7 years and has proven to be reliable.
- Use berry and shrub windbreak strips to "irrigate" intensive crops by snow retention.
- Select early-maturing wheat varieties to produce grain containing no less than 35-37% of gluten.
- Reduce direct costs of cereal production 2-3- times and increase profitability from 10-15% to 50-70% through minimization of tillage and application of organic approach to farming.
- Reduce arable land area to restore the appropriate balance of meadows, forests and fields.
- Till abandoned arable land in neighboring regions.

The research and implementation program was designed for 3 years. The first results of 1999 show that the objectives have been identified correctly

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# STRATEGY OF AGRICULTURE AT THE BORDERLINE OF THE 21st CENTURY

**Rahim Urazaliev[1] and Serik Kenebaev[2]**

In Kazakhstan, the final decade of the twentieth century witnessed a decline in production of agricultural commodities and a deterioration of conditions and living standard of farmers. Cultivated area decreased by 9.7 million hectares compared to 1993. In 1998, of the potential 2.3 m ha of irrigated arable land, only 1 m ha were used. The national average yield of cereals was 0.56 t $ha^{-1}$, 1.5 times less compared to 1986-1990. The main reason of low yield was a significant deterioration of field productivity. Land privatization and disintegration of farming organizations (collective and state farms) resulted in many small-holder farmers who were often poorly equipped or serviced, or lacked the technical means for cultivation of many agricultural crops. Sharp rises in the costs of inputs (e.g., fuel, herbicides, pesticides and fertilizers) resulted in poor agronomic practices. As a consequence, there has been a general decline of soil fertility and increased degradation of arable lands.

Continued degradation of arable land is due to technological practices which are not adapted for landscape, ecological and current economic conditions. In past years, scientists developed zonal systems of agriculture for rainfed and irrigated conditions in Kazakhstan. However, these technologies catered to large farming organizations grouped by natural and economic zones, sub-zones, administrative oblasts (regions) and less frequently, rayons (counties). Farmers applied these recommendations automatically without due respect to relief, hydrology, land improvement and other ecological conditions, often resulting in ineffective production practices and ecologically deleterious conditions.

Utilization of land on the basis of internal economic projects and zonal technologies will not only cause further decrease of soil fertility and agro-ecology, but may intensify deterioration of climate, desertification, acid rainfall, environmental pollution and changes in the biosphere. Hence, sustainable agricultural production must recognize the effective utilization of land resources on the basis of landscape ecology, recognizing the following provisions:

- Inventory of arable land with respect to susceptibility to erosion, pollution, over-compacting and other factors;
- Agro-ecological zoning of cultivated land and crops at local and regional levels.
- Optimization of the internal structure of agro-landscapes and their association with natural landscapes.

Agricultural scientists must recognize the importance of organic (or biological) agriculture, and its application to our modern farming systems. Biological agriculture relies on crop rotations, cultivation of perennial grasses, green-manure crops, double cropping, and use of organic fertilizers. Mineral fertilizers and pesticides are used in an integrated manner when required by economic thresholds. On irrigated light chestnut soils, an 8-field grass-cereals-row crop rotation (e.g., 25% sugar beet, 50% cereals and 25% alfalfa) ensured maintenance of soil fertility and production of ecologically sound commodities. On rainfed gray soils,

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incorporation of manure and green-manure crops allowed amelioration of soil fertility and an increase in productivity.
Numerous investigations by foreign scientists have identified the effectiveness of minimum and zero soil tillage, and as a consequence, soil productivity increases due to preservation of organic residues and improved water-retention.

Our research on rainfed gray soils has found that in extremely dry years, direct sowing of barley into stubble without soil tillage in the autumn was not inferior in yield to chisel tillage and was 0.12 t $ha^{-1}$ higher than plowing. In years with sufficient moisture, direct sowing of barley sowing exceeded fall chisel tillage. Minimum or zero tillage options can reduce energy consumption by 2-3 times. Implementation of this progressive and economic technology, however, requires its comprehensive examination and adaptation to different soil types. Minimum and zero tillage under dry conditions is possible provided that the following conditions are met:

- Strict technological discipline in cultivation of agricultural crops;
- Intensification of weed control by application of herbicides;
- The method should be applied on fields with relatively uniform relief.

Scientific and technical progress in tillage requires development of new crop varieties and hybrids which are resistant to abiotic stresses, diseases and pests, characterized by high quality of grain meeting the requirements of international standards. Under the new economic situation, Kazakh farmers will require crop and production diversification adapted to specific soil and climate conditions.

In conclusion, adaptive technologies based on zonal systems of agriculture stipulate:

- Sequencing of crops in rotation;
- Use of high-yielding varieties and hybrids which are well adapted to environmental conditions and characterized by good end-use quality;
- Adoption of tillage methods, chemical control and anti-erosion activities to specific landscape and environment;
- Optimization of internal structure of agro-landscapes;
- Application of integrated pest and disease management and weed control;
- Application of research based systems of fertilizers use, and the study of all aspects of biologization of modern agriculture.
- Reliable protection of soils against water and irrigation erosion and deflation;
- Introduction of systems of machinery, especially flat cutters and stubble seeders, which ensure good execution of technological operations and protection of soil.

# SOIL AND HUMUS TECHNOLOGY TRANSFER CENTER: TRENDS AND OBJECTIVES IN KAZAKHSTAN

**Anthony Umo**[1]

The Soil and Humus Technology Transfer Center (SH&TTC) focuses research on soil and water conservation. The primary objectives of SH&TTC are:

- To create partnerships in innovative research addressing environmentally sustainable agriculture.
- To encourage farming practices which result in increased soil humus and improved soil conservation.
- To facilitate information exchange between farmers, biologists and ecologists.

Our mission is to investigate and popularize new farming technologies which reduce humus degradation. Our research team includes experts from Kazakhstan Institute of Agriculture and Soil Research, and farmers who have perfected organic farming techniques.

The only viable remedy for problems related to soil infertility and environmental damage caused by excessive reliance on synthetic agricultural chemicals is through the large-scale use of organic fertilizers and soil conditioners.

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# PHYTOSANITARY ASSESSMENT OF SOIL-PROTECTIVE CROPPING IN KAZAKHSTAN

**Murat Koishibayev**[1]

The soil-protective farming systems, developed by Academician A.I. Barayev and widely practiced in Northern Kazakhstan, have made significant impacts on cereal phytosanitary agrocoenosis, especially where wheat is a dominant crop. Blade cultivation which retains crop residues enables better accumulation of moisture and reduces soil erosion. However, accumulation of crop residues can foster development of some cereal crop pathogens, in particular septoria and helminthsporium leaf spots and root rots. Before the 1970s, septoria leaf spot was rarely found on spring wheat in Northern Kazakhstan. Now, however, the gradual accumulation of pathogenic populations have resulted in local epiphytotics every 2-3 years. Moreover, spring wheat planting recommendations suggest that later sowing dates, particularly in the second and third decades of May, increase effective use of rainfall in July and lessen the incidence of common bunt (*Tilletia caries*).

During the past twenty five years, the Kazakh Scientific and Research Institute for Crop Protection has carried out comprehensive assessments of soil-protective cultivation technologies which affect seasonal and yearly pathogen dynamics. Studies conducted on rainfed Sierozem of the Southeast region showed that root rot dynamics are affected by preceding and current crop, and the principle methods of soil cultivation. In five-year crop-fallow rotations with perennials (fallow-winter wheat- winter wheat-barley-perennials), soil cultivation did not have any significant effect on the development of the root rot of the winter wheat planted after fallow or the second crop after wheat. With soil-protective rotations using strip planting of crops (1-5 perennials, 6-7 –barley, 8-fallow, 9- winter wheat, 10-barley), blade cultivation resulted in increased infection of wheat by *Bipolaris sorokiniana*. Analysis, however failed to show a correlative link between crop residue quantity on the soil surface and root rot development.

Further assessment of soil-protective cropping was continued in the steppe and forest-steppe zones in Northern Kazakhstan: Torgai GoSKHOS (1981-1985); North-Kazakhstan GoSKHOS (1986-1990); OPH Zarechnoye of Kostanai Scientific and Research Institute of Agriculture (SRIA) (1991-1995), and Kazakh Scientific Research Institute of Cereals Production (1996-1999). Studies conducted in Torgai GoSKHOS showed that in five-year crop-fallow rotations with the a spring wheat share of 60%, no significant infection by root rots were observed on the wheat as the second and third crops after fallow. Barley, which is more susceptible to root rots, can increases the quantity of the pathogen in the soil. In four-year cereals rotations (sweet clover-wheat-wheat-Sudan grass) and cereals-fallow rotations with fallow planted by the strips of tall crops to accumulate snow, the infection of the spring wheat by the root rot decreased 1.3-1.8 times.

Astabilizing factor in crop rotation root rot dynamics is the presence of antagonistic microflora, e.g., *Penicillium*, *Aspergillus*, *Trichoderma*, *Chaetomium* and actinomyceses. *Penicillium* fungi are often detected in continuously cropped wheat crop and often become

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mono-dominant. Because of the antagonistic activity of fungi and actinomyceses, incidence of root rot diseases gradually decrease.

Preceding crops may also affect the distribution and development of septoria and helminthsporium leaf spots. At Torgai GoSKHOS in a five-year crop-fallow rotation, leaf spot infection with the third, second and first planting of wheat after fallow was 28.5, 21 and 5.3% respectively. Similarly, on barley the distribution of *Rinchosporium* leaf blight on the second crop after fallow reached 90-100% however if planted after sweet clover (14.5%) or after wheat (12.5%) reductions were observed.

Studies conducted at the North-Kazakhstan GoSKHOS on dry-steppe, carbonaceous black soil investigated the affect moisture accumulation techniques on cereal root rots in cereal-fallow (fallow-wheat-wheat-barley) and cereal-forage (corn-wheat (peas/oats mixture-wheat) rotations. In dry years, incidence of root rots increased for both rotation regimes where moisture accumulation occurred but no fertilizer application was used. Super-phosphate ($P_2O_5$ at 80 kg $ha^{-1}$) application decreased subsequent incidence of root rots.

Incidence of root rots decreased in fields where herbicide application (2.4-D amine salt, triallat and illoxan) occurred on cereals-fallow and cereals-grass rotations.

Development of septoria leaf spot on wheat is influenced by the preceding rotation crop or field treatment. However, neither preceding crop, moisture accumulation method, nor mineral fertilizer application significantly effected incidence of rust infection.

The effect of the spring wheat cultural practices on incidence of rust and septoria disease development was investigated at the OPH Zarechnoye of Kostanai Scientific Research Institute of Agriculture. Disease development was found to be more affected by weather conditions and cultivar than cultural practice. With early disease development (e.g., beginning during tiller elongation) and favorable climatic conditions resulting in epiphytotic development, losses due to leaf rust on susceptible wheat cultivars exceeded 30%. Losses exceeding 40% were observed under conditions which favored development of leaf rust and septoria diseases.

Damage due to leaf rust was reduced with organic (manure, 20 t $ha^{-1}$) and super-phosphate (80 kg $ha^{-1}$) fertilizer application. Date of planting and seeding rate, depending on the year, had a variable effect on disease development. In wet years, diseases appeared on earlier sown wheat with higher seeding rate. In favorable years, pathogens first appeared on early sown wheat with high seeding rates.

Long-term research in Northern, Southeastern and Eastern regions of the Republic have shown that crop rotation, methods of moisture accumulation, sowing density and fertilizer application do not have any significant effect on the development of airborne or seed transmitted diseases.

In order to prevent possible crop losses due to disease, chemical protection of cereal crops has proven effective in various soil-climate zones of the Republic. Many seed and foliar fungicides were tested with their effect on dominating pathogens determined, as well as optimal dosage and timing of application. In cooperation with the North-Kazakhstan GoSKHOS and Kostanai SRIA, chemical combination was studied in multifactor experiments, including the protective block of plants when using intensive technologies of spring wheat cropping (Koishibayev and Dubina, 1995; Koishibayev, Gudov and Son, 1995).

In 1996-1999, phytosanitary assessment of components of soil protective cultivation technologies were conducted at the Kazakh Scientific Research Institute of Cereals Production. The effect of preceding crops were taken into consideration concerning the biologization of the farming agriculture and the diversification the grain production. Use of intensive cropping technology was found to decrease root rot infection of wheat and barley. On continuous cropping of barley in wet years, increased development and incidence of helminthsporium spot disease was observed. For crop protection, the best preceding crops for wheat were peas-oats mixture, rape, oats and sweet clover.

# AGRO-ECOLOGICAL SOIL CULTIVATION FOR MOUNTAINOUS FARMING IN SOUTHEASTERN KAZAKHSTAN

**Naziya Suleimenova**[1]

Farmers use methods of repeated and careful soil cultivation to mobilize fertility and to control weeds, recognizing the over-riding importance of soil conservation and maintenance of fertility, particularly through humus accumulation. Effective soil cultivation practices should recognize local environment, specific crop needs, and farmer/market resource availability. Reduced number of tillage operations, and diminished use of the moldboard plow have been proved effective methodologies to achieve these means. In mountainous farming, justification for minimization of the soil tillage is based on the necessity to reduce the impact and use of large tractors, and reduce energy and labor inputs. For weed control, use of herbicides and combined machines with active working tools has good potential.

Appropriate systems of tillage should reduce losses of water due to evaporation and control weeds. Conventional plowing in autumn for spring planted barley results in fewer weeds compared with non-moldboard tillage techniques. However, early autumn frosts result in a low efficiency of autumn plowing for subsequent weed control. Decreasing soil tillage operations saves time, improves labor productivity and results in more timely field operations.

We studied the impact of minimizing soil tillage operations on cereal yield in mountainous farming systems. Yield was primarily dependent on soil moisture availability and weed contamination. During periods of drought, planting after non-moldboard tillage increases yield by 0.24 t $ha^{-1}$ with planting directly into stubble providing a yield advantage of 1.9-2.2 t $ha^{-1}$.

Minimal tillage (zero tillage or non-moldboard tillage) was found to result in an increase in the number of weed seedlings observed in the first years after inception (up to 580-650 plants per $m^2$), and this is a principle concern restricting immediate adoption of minimal soil tillage practices. Herbicide weed control may be required to control the initial flushes of weed growth, and for recurrent infestations of perennial weeds. Application of Triallat (3 l $ha^{-1}$) coupled with disk cultivation before planting was found to be effective for weed control and crop establishment, increasing yield by 0.48 t $ha^{-1}$ (41.3%). Illocsan application during the crop season (2 l $ha^{-1}$) provided very effective post-emergent weed control, with barley yielding 1.82 t $ha^{-1}$, 56.8% greater than the weed infested control.

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# AGRO-ECOLOGICAL CONSERVATION TILLAGE IN SOUTHEASTERN KAZAKHSTAN

**Anatoli Iorgansky**[1]

Farming by use of industrialized methods relying on heavy machinery has generally resulted in a deterioration of agrarian and natural landscapes and soil ecology. As a consequence, soil humus and nutrient content has decreased on an average by 25-30% compared to virgin lands, and erosion, compaction, pollution and other types of soil degradation have occurred. Currently, more than 40% of cultivated land demand melioration improvement. Violation of scientific and ecological principals of agriculture have led to yield decreases, and non-sustainable farming systems.

Agro-landscapes degradation and reduced crop productivity are the result of failing to observe the interaction between nature and society, a simplified approach to agricultural practices, and insufficient conformity of utilized crop-growing technologies to landscape and ecological conditions. Utilization of land on the basis of administrative provinces and regions will certainly cause greater soil and climate deterioration, desertification, acid precipitation and environment pollution.

Ecological approaches to land use development should be based on the following principle: crop-to-climate specific cultural recommendations focusing on humus retention and development recognizing the soil-ecological conditions of the region.

Development of sustainable technologies for suitable and sustainable land tillage technologies must recognize the following components:

- A thorough inventory of arable land quality, resistance to erosion, pollution, recompression and other anthropogenic factors;
- Divisions of crops into groups according to local and regional use;
- Soil fertility models suitable for different production levels;
- Development of maximum adapted technologies for humus reproduction, especially under minimum tillage;
- Agro-landscapes structure and setting;
- Development of integrated crop management practices;
- Development of soil ecology criteria and conditions for sustainable use of low and high productivity agro-landscapes;
- Development of long-term soil erosion reduction schemes recognizing soil deflation and recompression properties and restoration of eroded soils;
- Optimum parameters of soil microorganisms population development;
- Development of data bank on arable soils and their fertility regulation.

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# APPENDIX I

## THE WORKSHOP WORKING GROUP RECOMMENDATIONS

**QUESTIONS:**

1. What are the constraints which hinder the spread of conservation tillage in Eurasia with regard to:
   - **Conservation tillage technology?**
   - **Approaches for dissemination and extension?**
   - **Policy factor?**

2. What are the potential strategies to overcome these constraints with regards to:
   - **Conservation tillage technology?**
   - **Approaches for dissemination and extension?**
   - **Policy factor?**

3. What are the potential steps/activities to develop and implement these strategies and what external support are needed with regard to:
   - **Conservation tillage technology?**
   - **Approaches for dissemination and extension?**
   - **Policy factor?**

## Working Group 1

### Constraints (conservation tillage technology)

-Lack of technology that can be used by farmers, both in plains and mountain regions
-Lack of appropriate research in many countries
-Insufficient profitability; inputs are high and outputs are low
-Lack of awareness and application of conservation tillage is insufficient
-Lack of suitable equipment to test in different ecological regions.
-Lack of crop diversification program and access to computer modelling

### Strategies (conservation tillage technology)

-Establish mechanisms to access the available information technologies
-Graduate training in agricultural institutions in the area of technology development
-Identify critical research needed for each agro-ecozones
-Increase input efficiency and productivity
-Awareness campaigns
-Testing and evaluating the local and imported machines to find out the suitable one for conservation tillage
-Identify sustainable diversified cropping systems

### Activities (conservation tillage technology)

-Contact with established research institutions and farmer associations
-Identify donors for financing international and local expertise needed for graduate training
-Conduct critical research in Eurasian countries on conservation tillage
-Select efficient land and crop management and conservation tillage techniques
-Develop televisions, radio programs, organize seminars and file days, establish farmer field schools, publish brochures, newsletters etc.
-Import sample machinery and test in different agro-ecozones
-Test improved cropping systems with conservation tillage

### Partners (conservation tillage technology)

-CGIAR organizations, CTIC, ECAF
-Farmers associations, NGO
-Private sector
-International donors
-Partnership with appropriate national and private institutions
-Joint venture with national and international organizations
-National agricultural research centers
-Media

## Working Group 2

### Constraints (conservation tillage technology)

1. Lack of motivation.
   - A) Decision makers
     - Insufficient information on food security, macro-economic benefits and positive environmental impact of new conservation tillage technology;
     - Lack of effective exchange of information on new technologies
   - B) Research & Extension
     - Lack of on-farm testing of conservation tillage technologies
     - Lack of effective information of detailed aspects of zero tillage technology and its benefits
     - Insufficient exchange of technical information and lack of filed visits to demonstrate successful conservation tillage, and alternative minimum tillage technologies in other countries
     - Lack of adequate funding for on-farm research and interaction with farmers
   - C) Farmers
     - Little or no participation of farmers in decision making, planning, implementation and evaluation
     - Unpredictable supply of key inputs (machinery, fertilisers, pesticides) free of charge
     - Lack of opportunities for field and study tours inadequate working capital and shortage of diesel fuel
2. Lack of implementation.
   - A) No conservation tillage oriented regional technical/implementation manager/executing agency
   - B) Insufficient or no funds for on-farm and on-research station research and development
   - C) No specific regional network
   - D) Poorly structured extension mechanism
3. Lack of training.
   - A) Involve private sector within the framework of project training courses
   - B) Trainers (farm agronomists, farm managers)
   - C) Training of agronomy students
   - D) Exchange of trainers intra and inter-regional involving farmer/researcher/extension workers
   - E) Little exchange of information
   - F) No demonstration areas for conservation tillage and alternative minimum tillage technologies
   - G) Lack of farmer to farmer contacts and insufficient farmer-researcher

### Strategy (conservation tillage technology)

1. Motivation
   - A) Generate information to influence all the stakeholders
   - B) Set up country executive groups with participation from private sector, farmers and government agencies; the chairmen of these group would come from either farmers or private sector to ensure the emphasis on production led activities
   - C) Create incentives (financial and professional) for research support to country programs
   - D) Provide finance for key inputs
2. Implementation
   - A) Set up regional network for on-farm testing of zero tillage and alternative zero tillage technology based on starting from existing technologies in other countries
3. Training
   - A) Training of trainers, who will train technical personnel for implementation of test-demo areas and for execution for in-country training
   - B) Develop country specific training aid

### Actions (conservation tillage technology)

1. Motivation
   - A) Study tours for decision makers, technicians and farmers, mixed group, to see examples of successful zero tillage and alternative minimum tillage system
   - B) Having effective control of the executive group would motivate farmers and private sector.
2. Implementation

A) The network would produce a world-wide review of applicable technology for testing, according to demand for each country
B) Funding for the network would be sought from international sources based on five years network plan, incorporating the country subprograms
C) Country executive officers with technical training would execute country subprograms and be supported by a regional program manger.

2. Training
   A) Training for implementation of test-demo areas would include the international and in country training
   B) From year three onwards-successful test areas would be used for demonstration for farmers.
   C) Farmers should be taken on excursion to see other farmers already practising new Technology
   D) Emphasis given to methodologies which were proven to maximise the production and farmer to farmer exchanges, including the involvement of farmer clubs or associations
   E) Visual aid and technical manuals will be developed for each country

## Partners (conservation tillage technology)

Farmers
CIMMYT, ICARDA, other CGIAR organisations
Funding organisations
FAO, IFAD, IBRD, EBRD, etc
Bilateral donors
NGOs
Agribusiness
Country MOA
Universities/Agric. Schools
Country research and extension organisation
Rice-Wheat Consortium
Overseas specialists

## Working Group 3

### Constraints (conservation tillage technology)

-Policy
-Transition process to privatize is not completed
-Government still involved in decisions
-Low profitability of farming, and slow adoption of conservation farming
-Government awareness of C.F benefits is inadequate
-Advisory and extension service is not in place
-Conservationist, zero till groups, unions are not in place

### Strategies (conservation tillage technology)

- Accelerate the process of privatization and the policy development
- Reduce direct government decisions on farms
-Improve legal system
-Educate government and public on *Conservation Farming*
-Establish advisory, extension services
-Establish conservation tillage unions

### Activities (conservation tillage technology)

-Provide advisory service to government to formulate policy
-Establish farm association,
-Establish private agri-business
-Contact, FAO, CGIAR organizations, and other donors
-Breeding plants to support conservation tillage
-Land title and land survey
-Suitable import tax or no tax policy for farmers
-Secure investments
-Establish a working insurance policy
-Publish brochures, bulletin, newsletters and develop TV programs
-Develop legislation for extension
-Encourage the development of private consulting
-Establish farmers federation to work with local administration, university, and private sector

### Partners (conservation tillage technology)

-Government
-Parliament
-NGO
-Private sector
-Farm associations
-Local experts
-International organizations (FAO, CGIAR organisations, and other donors)

# APPENDIX II

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