Food and Agriculture Organization of the United Nations

Strategies for the promotion of conservation agriculture in Central Asia

Proceedings of the International Conference, 5–7 September 2018, Tashkent, Uzbekistan

Strategies for the promotion of conservation agriculture in Central Asia

Proceedings of the International Conference,
5–7 September 2018, Tashkent, Uzbekistan

Editors:
Prof. Dr. Hafiz Muminjanov,
Prof. Dr. Emilio Gonzalez

Food and Agriculture Organization of the United Nations

Tashkent, 2020

Required citation:
FAO. 2020. *Strategies for the promotion of conservation agriculture in Central Asia Proceedings of the International Conference, 5–7 September 2018,* Tashkent, Uzbekistan. Tashkent. https://doi.org/10.4060/ca8659en

ISBN 978-92-5-132418-9

Cover photograph:
©FAO/Hafiz Muminjanov

Contents

Figures

Tables

Foreword

Dear Mr. Minister,
Dear participants of the international conference,
Dear colleagues and friends,

Please allow me to greet you all on behalf of the Food and Agriculture Organization of the United Nations (FAO) and on my own behalf and convey to you the best greetings of the FAO Director General.

FAO's mandate is to combat hunger and malnutrition, which continue to affect nearly 800 million people, or about 12 percent of the world's population. Our organization, in partnership with member States, national and international research institutes, is making great efforts to solve this problem. FAO also assists member countries in poverty alleviation and in the conservation and efficient use of natural resources.

We all know that the "green revolution" has contributed to a significant increase in food production in the world through the introduction of intensive varieties of crops and the significant use of means of production and energy. However, to meet the current and future needs of a growing population for food and nutrition, agriculture must be based on "sustainable intensification". This approach includes a number of measures to conserve natural resources and means of production, such as water, soil and biodiversity. The technical guidance on sustainable crop production intensification developed by FAO is based on the "Save and Grow" paradigm, which aims to increase production with less cost and conserve resources and the environment.

The key principles of the "Save and Grow" concept are sustainable management aimed at restoring and maintaining the natural fertility of soils, preserving natural resources and integrated plant protection, reducing the use of pesticides that are harmful to the environment and human health.

This approach also covers conservation agriculture, which is one of the main activities of FAO in the region.

Therefore, I welcome this International Scientific and Practical Conference on the Further Implementation and Dissemination of conservation agriculture in Central Asia and congratulate the participants for their excellent contribution and exchange of the latest scientific information.

The international conference was jointly organized by the FAO and the Government of the Republic of Uzbekistan, in particular, by the Ministries of Agriculture and Water Resources and the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers. I take this opportunity to express my sincere gratitude to the Government of the Republic of Uzbekistan and all our partners and colleagues for their contribution to the organization and holding of the conference at a high level.

FAO successfully collaborates with the Government of the Republic of Uzbekistan in the implementation of projects and programs for the sustainable development of agriculture and rural areas. Last year we jointly held a large international conference on the development of organic agriculture in Tashkent and Samarkand. The proceedings of the conference were published by FAO and today are also presented to the participants of this conference. Recently, in Samarkand, we launched a program of cooperation between FAO and the government of Turkey on the development of forestry in the region. A number of projects on agricultural diversification, sustainable use of land and forest resources, and others are also being successfully implemented.

Representatives of approximately 20 countries came to the conference today to discuss lessons learned in the process of adopting and promoting conservation agriculture. Interactive discussions at the Conference will allow participants to analyze the status and prospects of conservation agriculture in their countries. The conference will also aim to develop a strategy to accelerate the spread of conservation agriculture in the region, taking into account environmental, economic, social, political and institutional factors. This will help make conservation agriculture more efficient and sustainable not only in Central Asia, but will also create influence in other regions.

I would like to thank the Organizers of the Conference, once again warmly welcome you all and wish you a very productive meeting, hoping that this conference will be the opening for a series of conferences in Central Asia.

Viorel Gutu
FAO Sub-regional Coordinator for Central Asia
FAO Representative in Uzbekistan

Foreword

Dear guests of the International Conference!
Ladies and Gentlemen!

On behalf of the Ministry of Agriculture of the Republic of Uzbekistan, let me express my gratitude to the participants and organizers of today's international conference "Strategies for the Promotion of conservation agriculture in Central Asia".

Taking this opportunity, I would like to express special gratitude to the Food and Agriculture Organization of the United Nations (FAO) for organizing this International Conference.

Also, we are honored to see the participation of specialists and experts from more than 20 countries of the world, including delegations from Australia, Brazil, European countries, Middle East, Central and East Asia at this conference.

Our meeting today is extremely urgent, which will address the development of conservation agriculture in Central Asia. During the conference, our foreign experts will also be able to get acquainted with the experience and achievements of Uzbek colleagues in the field of conservation agriculture.

By the way, I would like to draw your attention to the fact that today's conference is being held in one of the leading Higher educational institutions and the scientific-research centers of the Republic, which is the Tashkent Institute of irrigation and agricultural mechanization engineers.

Among the main activities of the Institute are training and research activities, a special place is occupied by questions of improvement of mechanization and modernization of agriculture, the problem of energy efficiency and use of renewable energy sources in agriculture and water management, introduction of resource saving technologies, developing a framework of improving the efficient use of land resources of the Republic of Uzbekistan and the organizational and economic bases of use of land and water resources in irrigated agriculture.

Dear participants!

I want to emphasize that agricultural sustainability and food security are at the center of attention on the 2030 Sustainable Development Goals agenda.

We, as representatives of agriculture, are particularly aware of our role in ensuring food security and eradicating hunger worldwide in the context of global climate change, land degradation and desertification.

Taking this opportunity, let me briefly acquaint you with the state of agricultural production and priority directions of Uzbekistan in the field of food security.

Currently, Uzbekistan is implementing an Action Strategy for the five main directions of the country's development in 2017–2021. This Strategy covers all issues related to the creation of conditions for the comprehensive and accelerated development of the state and society.

One of the priority areas of the Strategy for the modernization of the country and the liberalization of all spheres of life is the modernization and development of agriculture in the republic.

Agriculture of Uzbekistan is one of the largest sectors of the national economy of the country and the well-being of the people and the sustainability of economic development depend on its condition.

The share of our industry in gross domestic product is not much more than 17 percent. More than half of the residents of the republic live in rural areas.

This explains the special attention of the leadership and the government to improving the agricultural sector of the economy of Uzbekistan.

With a view to sustainable development of our industry, ensuring Food security, year-round supply of fresh fortified products to the population of the republic and increasing the export potential of agriculture, a number of measures are being taken to diversify crops.

Due to the reduction of more than 220 thousand hectares of cultivated area from cotton and grain crops, intensive-technology orchards, vegetable growing, melon, oilseed, soybean, walnut and other crops will be developed.

The leadership and government of the country also focus on improving activities (farms, dekhkan farms and homeowners), developing rural infrastructure, improving rural areas, setting up agricultural processing plants, special attention is paid to creating high value-added products.

One of the important promising areas is the introduction of modern resource-saving and water-saving agricultural technologies in the context of climate change, land degradation and desertification.

It should be emphasized here that annually more than 100 million USD in equivalent are allocated from the budget of the republic, funds for the implementation of measures to improve the land reclamation state. For these purposes, numerous funds from International Financial Institutions, International Organizations, and funds from developed countries for the implementation of investment projects are used.

For example, at the end of 2015, a presidential Decree was issued, which defined a long-term strategy for crop diversification and intensification of agricultural production (PD №2460 of December 29, 2015 "On measures for further reform and development of agriculture for the period 2016–2020"). According to the Decree, in the period 2016–2020, more than 170 000 hectares of cotton and 50 000 hectares of wheat will be modernized for the production of potatoes, vegetables, fruits in intensive gardens, fodder crops, oilseeds and other crops.

Today Uzbekistan, successfully developing agriculture, has achieved not only self-sufficiency in food of the population of the country, significantly exceeding medical standards of consumption at times, but also was able to expand the export of many agricultural products, including vegetables, fruits and wheat. And in this direction there is still an undisclosed potential for further development.

We are actively developing biological methods of plant protection, reducing the use of pesticides, the introduction of international quality standards such as "Global gap", "Halol", organic agriculture and other standards.

Dear colleagues!

Undoubtedly, the use of conservation agriculture technologies contributes to the sustainable management of land resources in a changing climate, land degradation and desertification.

Conservation agriculture is one of the most promising areas of land use developed in our time. Conservation agriculture is more an approach than technology, because it consists of a variable and changing set of technologies aimed at minimizing disturbance of soil cover, soil moisture, and loss of nutrients, and preserving the many environmental functions that natural soil has to provide in the natural ecosystem.

Conservation agriculture has many proven benefits and covers millions of hectares of land in South and North America, as well as parts of Asia. The introduction of conservation agriculture is reflected in its rapid development by farmers in all parts of the world. According to the FAO, if in 1999 conservation agriculture was used on 45 million hectares of the world in the world, then by 2018 this figure reached almost 180 million hectares.

Given the importance and relevance of the practice of conservation agriculture for the countries of the Central Asian region, the Government of the Republic of Uzbekistan together with the FAO initiated the organization of the International Conference "Strategies for the Promotion of conservation agriculture in Central Asia".

This conference is scheduled to consider:

- The state of conservation agriculture in the countries of the Central Asian region;
- Analysis and determination of opportunities and limitations for the introduction of conservation agriculture, including the diversification of agricultural systems and the improvement of agricultural techniques in Central Asia;
- As well as opportunities and strategies for the widespread dissemination of conservation agriculture at the regional level.

During the three-day conference, specialists and scientists will exchange:

- Work experience to improve soil protection measures;
- The introduction of new agricultural technologies to improve the structure of soils;
- The introduction of resource-saving technologies and suggestions for their improvement, as well as the opportunity to study best practices on these issues, exchange experiences on these issues, and on the last third day a trip will be organized to a demonstration site located in the Tashkent region.

We hope that this International Conference will accelerate the implementation of conservation agriculture in Central Asia and other regions of the world.

I wish all participants of the Conference fruitful and creative work, good health, and success in your noble cause!

Thank you for your attention!

H.E. Mr. Bakhodir Yusupov
Minister for Agriculture
Republic of Uzbekistan

Keynote presentation

©FAO/Hafiz Muminjanov

Keynote Presentation

Chapter I
Conservation agriculture
a sustainable agricultural paradigm

Chapter II
Rehabilitating degraded soils
with conservation agriculture

Chapter III
Conservation agriculture
and climate change mitigation

Chapter IV
Machinery adapted to
conservation agriculture

Chapter V
Conservation agriculture
and water management

Chapter VI
Socio-economic and policy
aspects of conservation agriculture.
Upscaling the system

Annexes

Conservation agriculture: a win-win option for food security, land management and livelihoods

Hafiz Muminjanov[1]

Abstract

Conservation agriculture (CA) is acknowledged to maintain and improve soil health and ecosystem services, and thus is a key element to ensure agricultural production and food security under climate change and increasing world population. FAO developed and described the concept of CA that comprises the practical application of the following three interlinked principles: 1) minimum soil disturbance, 2) permanent soil cover, and 3) crop species diversification, in conjunction with other complementary good agricultural practices of integrated crop and production management. The CA concept described by FAO is well recognized by the farmers, researchers, and agriculture and extension specialists worldwide. In the research papers and presentations, the reference made to the FAO's website on CA (http://www.fao.org/conservation-agriculture/en/) as the global information system. Based on the available statistics, currently CA is practiced in 78 countries on over 180 million hectares, corresponding to about 12.5 percent of the total global cropland.

Key words: Conservation agriculture (CA), no-till, diversification, mulch, ecosystem.

Introduction

Currently, as never before, we are facing with the food security challenges due to the urbanization and rapid increase of population. In addition to that, the pressure of climate change and degradation of biodiversity and natural resources is increasing. It is impossible to achieve food security by the traditional approaches and old farming practices. Therefore, we need to think it over, because conventional farming has already caused an enormous damage to the environment, which has led to climate change, soil degradation and loss of biodiversity. A clear example of anthropogenic impact to the nature is the tragedy of the Aral Sea. The President of Uzbekistan H.E. Mr. Shavkat Mirziyoyev, speaking at the UN General Assembly, pointed out this problem and noted that the sea area from 60 900 km^2 in 1960 shrank to 8 600 km^2. As a result, salt storms became more frequent and a huge diversity of genetic resources of plants and animals is lost.

Despite developing modern technologies as vertical gardening, soilless and protected cultivation, we still need soils to produce food. However, today ¼ of the total arable land is degraded. Annually, million hectares and tons of fertile soil are lost due to improper cultivation and soil misuse. Many research documents have proved that tillage-based agriculture facilitates degradation of soil through water and wind erosion. Besides, this type of management causes the loss of soil organic matter, degradation of soil structure, destruction of life and biological processes in the soil. Tillage facilitates CO_2 emission and through it, agriculture contributes to climate change and global warming.

With the purpose of responding to these challenges, FAO is promoting the concept on sustainable intensification of cropping systems that is very well described in the publication "Save and Grow". The key principle of the concept is to produce more with less and save ecosystem.

Conservation agriculture as a paradigm of real sustainable agriculture

The core of the Save and Grow concept is conservation agriculture (CA) that has three interlinked principles:

1. Minimum soil disturbance. In practical terms, farmers grow crops with no-tillage.
2. Permanent soil cover by crop residue or cover crops. At least 30percent of soil must be covered with mulch after seeding.
3. Diversification of cropping system. Crop rotations.

Theoretically, and practically, in the CA system, mechanical tillage is replaced by a biological "tillage" carried out by earthworm and other soil fauna. CA rehabilitates soils, through an improved structure, porosity, increased organic matter and health. However, CA cannot solve all problems alone.

Sustainable intensification of crop production should be based on the three principles of CA, but in addition to that, other good agricultural practices, like integrated water management, integrated pest management, use of superior crop varieties and high quality seeds, development of organic production, etc. should be applied for development of sustainable food production.

Review of the CA history takes us to early 1930s, when huge cities in mid-West of the USA were covered by dust bowls. This was the result of cultivating the

Figure 1. Three principles of Conservation Agriculture

virgin land and forced the development and testing no-till technologies for soil protection. The first no-till drills were invented by 1940's and the concept was formulated. At the end of 1960's the first no-till farmers were registered in US and adoption of no-till started in Brazil and other countries. In some countries, like China, farmers were applying the elements of no-till. However, the research based experiments and adoption started during 1990s. Rapid adoption of CA is registered for the last 10 years.

Adoption of conservation agriculture worldwide

While tillage-based cultivation has the history of centuries, CA has only about 50 years. Today CA is practiced on more than 180 Mha that makes about 12.5 percent of total arable land. This achieved thanks to the interest, enthusiasm and efficient collaboration of researchers, farmers and extension specialists. The excellent work allowed developing the improved modern CA equipment suitable for wheat, maize and rice-based cropping systems.

Conservation agriculture is adopted in 78 countries for different cropping systems, climate and soil, large and small size farming systems. For instance, in

North America, Argentina, Russia and Kazakhstan, large farms are dominating in practicing CA. In Africa and South Asia – more small scale and small holders. In India CA is dominantly under irrigated conditions, in the Middle East and Central Asia – in drylands. Among the regions, South and North America, Australia and New Zealand have the largest area under CA. In average, CA is practiced on 28 to 63 percent of arable land. Area under CA is also growing in Russia and Asia. Today about 50 percent of total CA area is based in the developed regions and 50 percent in the developing countries. Area under CA is annually increasing by 10.5 Mha (Kassam *et al.*, 2018).

The leading countries on CA in the South America are Brazil and Argentina. CA adoption is also increasing in other countries like Venezuela, Uruguay. However, in Brazil monocropping of soybean is affecting good CA during recent years. Area under CA is still growing in USA and Canada. The USA are the leading country in the world. In Europe CA is boosting in all countries. Currently we have the CA statistics for about 25 countries. Area under CA is also increasing in Africa. Only during the last 7–8 years the area under CA increased more than 2 times (Kassam *et al.*, 2018).

In Asia, the champions are China and Kazakhstan, because the governments are strongly supporting the adoption of CA by farmers and communities. The suitable policies, strategies and the roadmaps are developed to protect soils and increase production through adoption of CA. Further wider promotion of CA requires more support from the Governments. CA adoption is also rapidly increasing in India, Iran and Turkey. Government of Iran is allocating a considerable budget for the wider adoption of CA.

What are the driving forces for adoption of CA?

In most cases and countries, it is erosion, drought, cost of production, soil degradation, ecosystem services and benefits from adopting CA, climate change adaptation and mitigation, promotion of sustainable intensification, etc.

FAO has been working with farmers, agricultural and extension specialists, researchers and policy makers in Asia, South America, Europe and Africa helping to adopt CA and develop policies and strategies. In 2012, FAO, together with CIMMYT, ICARDA and national partners, conducted a study on the status of CA in Central Asia. The outputs of the study allowed to formulate the regional strategy that served as a basis for formulation of the national policies and road maps for further adoption and promotion of CA.

The experiences demonstrated that farmers like CA first for economic benefits, e.g. saving more than 50 percent fuel. Even if other practices, like minimum or reduced tillage, might be appealing to farmers, we must highlight that min-till is not a valid practice for CA, as all soil surface is ploughed. Therefore, a proper communication to help farmers protect soils through adoption of CA is needed. Moreover, there should be suitable equipment, policies and strategies supporting the farmers who practice and promote CA.

So far, most of no-till drills available are heavy and focused for large-scale production. Most of the farmers also do not have sufficient funding to procure the field equipment. In this situation, Governments can provide subsidies and incentives for adoption of CA, as it was done in Kazakhstan. It is important also to adjust available drills for no-till planting. Developing jab and hoe planter is an excellent approach. Farmers in deferent parts of the world are using these tools in the small-scale crop production under CA systems.

There are different opinions about CA, especially with regard to weeds, pests and disease control. The practical experiences of many farmers assure that following the three key principles of CA allows an optimized application of chemicals, i.e. fertilizers and herbicides.

Wider adoption of CA requires raising awareness and cooperation. Capacity development through developing manuals, guidelines and curricula for university and extension training. Important to strengthen the research centers and to establish the CA Associations. For instance, Conservation Tillage Research Center (CTRC) and European conservation agriculture Federation (ECAF) are playing key role on adopting CA. Similar association is established in Turkey.

CA farmers and researchers established an alliance in Central Asia and a website is opened to share the information. Farmers also share photos and videos on adoption of CA and its advantages through the social networks. Conservation agriculture can provide significant ecosystem services. Covering the soil surface with mulch allows reducing the water table and salinity of soil. Large-scale adoption of CA in Brazil reduced erosion and allowed to purify water resources in Parana River.

Conclusions

Our major conclusion is that CA is the key for sustainable development of agriculture. It has a number of economic, ecologic and social benefits. It reduces soil erosion, increases water use efficiency, improves soil structure and soil organic matter, reduces CO_2 emission and supports to mitigate and adapt to climate change, etc.

Today CA is adopted in all regions for different types of soils and farms. Proper crop rotation is essential to avoid a higher pressure of pests, diseases and soil compaction.

Agricultural machinery innovations are the driving force towards achieving more sustainable and efficient promotion of CA.

Policy and institutional support is needed for faster adoption of CA to ensure best performance.

Join the initiatives and efforts for promotion of CA to protect soil, water, environment and our planet.

Reference

Kassam A, Friedrich T, Derpsch R (2018). Global spread of conservation agriculture. International Journal of Environmental Studies. https://doi.org/10.1080/00207233.2018.149492.

Conservation agriculture:a worldwide revolution

Amir Kassam[2]

Abstract

Conservation agriculture (CA) comprises the practical application of three interlinked principles, namely: no or minimum mechanical soil disturbance, biomass mulch soil cover, and crop species diversification, in conjunction with other complementary good agricultural practices of integrated crop and production management. CA represents a new paradigm of sustainable agriculture, and it is now spreading in all continents, constituting a revolutionary change in the way agricultural land is managed. In 2015/16, CA was practised globally on about 180 Mha of cropland, corresponding to about 12.5 percent of the total global cropland. In 2008/09, the spread of CA was reported to be about 106 Mha. This change constitutes an increase of some 69 percent globally since 2008/09. In 2015/16, CA adoption was reported by 78 countries, an increase in adoption by 42 more countries since 2008/09 respectively. The average annual rate of global expansion of CA cropland area since 2008/2009 has been some 10.5 Mha. The largest extents of adoption are in South and North America, followed by Australia and New Zealand, Asia, Russia and Ukraine, Europe, and Africa.

Key words: degradation, paradigm, sustainable, transformation, Central Asia

Introduction

Tillage-based agricultural production systems everywhere have contributed to decrease in input factor productivity, and in excessive use of seeds, agrochemicals, water and energy, in increase in cost of production, and in poor resilience. They have led to largescale abandonment of agricultural land, some 400 Mha globally over recent decades, and created dysfunctional ecosystems, degraded ecosystem (and societal) services, including poor water quality and quantity, nutrient and carbon cycles, suboptimal water, nutrient and carbon provisioning and regulatory water services, and loss of soil and landscape biodiversity. These negative impacts on food, agricultural and environmental costs are being passed on to the public and to future generations. Thus, conventional tillage farming has become unfit for the future in achieving sustainable production and ecosystem services.

In response, agriculture has been transforming worldwide to an alternate paradigm of conservation agriculture (CA) that can: (i) mobilize greater crop and land potentials sustainably to meet future food, agriculture and environmental demands; (ii) maintain highest levels of productivity, efficiency and resilience ('more from less'); and (iii) rehabilitate or regenerate degraded and abandoned agricultural land and ecosystem services. CA has shown in all continents to be able to address the weaknesses of the conventional tillage agriculture. This is because CA is an agro-ecosystem approach to regenerative agriculture and to sustainably managing the natural resource base and ecosystem functions, to mobilizing maximum crop and land productivity potentials, to developing natural resilience to biotic and a biotic stresses, and to optimizing the use of agrochemicals. Consequently, CA pays special attention to: (i) soil as a living biological and multi-functional system; (ii) root systems and their relationship with soil life; (iii) biodiversity in the soil and above the ground; and (iii) landscape ecosystem functions and services at the farm, landscape, community and territorial level.

Global spread of CA

Conservation agriculture is now practiced in all continents and in most land-based agro-ecologies, both rainfed and irrigated, non-organic and organic systems. CA systems include annual cropland systems, perennial crop systems including orchard and plantation systems, pasture systems, mixed annual and perennial systems, agro-forestry systems, and rice-based systems.

In 2013/14, CA annual cropland systems covered some 157 Mha, or 11 percent of the total global annual cropland, with the spread being split equally between the industrialized regions and the developing regions (Kassam *et al.*, 2015). In 2008/09, the CA annual cropland area was 107 Mha (Kassam *et al.*, 2009). Between 2008/09 and 2013/14, the global CA annual cropland area expanded at an annual rate of some 10.5 Mha.

Continental distribution of CA land in 2013/14 was: South America, 66.4 Mha (60 percent of total cropland in the CA countries); North America, 54.0 Mha (24 percent); Australia & NZ, 17.9 Mha (35.9 percent), Russia & Ukraine, 5.2 Mha (3.2 percent), Asia, 10.3 Mha (3 percent), Europe, 2 Mha (2.8 percent), and Africa 1.2 Mha (0.9 percent) (Kassam *et al.*, 2015).

The CA annual cropland information base was recently updated for 2015/16 (Kassam *et al.*, 2018) based on several sources: official statistics; no-till farmer organizations; Ministry of Agriculture, NGOs, and well-informed individuals from national and international research and development organizations.

The update shows that the global total CA cropland area in 2015/16 is 180.44 Mha, corresponding to some 12.5 percent of the total global cropland, with the spread being more or less equally split between the industrialized regions (52.7 percent) and the developing regions (47.3 percent). The continental distribution of the CA cropland area is shown in Table 1.

The change in the CA cropland area in the different continents since 2008/09 has been: 41.0 percent in South America, (from 49.6 Mha to 69.9 Mha); 57.9 percent in North America (from 40.0 Mha to 63.1 Mha); 86 percent in Australia & NZ (from 12.2 Mha to 22.7 Mha); 429.7 percent in Asia (from 2.6 Mha to 13.9 Mha); 5000 percent in Russia and Ukraine (from 0.1 Mha to 5.2 Mha); 211.0 percent in Africa (from 0.5 Mha to 1.5 Mha) and 127.4 percent in Europe (from 1.6 Mha to 3.56 Mha).

Overall, the increase in the global CA cropland area since 2008/09 has continued at an annual rate of about 10.5 Mha, from 107 Mha in 2008/09 to 180.4 Mha in 2015/16 (Figure 2). The global CA cropland area increased by some 69.4 percent since 2008/09, and since 2013/14, the increase has been some 15.2 percent, from 157 Mha, based on the information for 2015/16.

Table 1. Area of annual cropland under CA by continent – 2015/16

Continent	Cropland under CA (Mha)	Percent of global CA area	Percent of arable cropland of reporting countries
South America	69.90 (49.6)	38.7 (40.9)	63.2
North America	63.18 (40.0)	35.0 (58.0)	28.1
Australia & NZ	22.67 (12.2)	12.6 (86.1)	45.5
Asia	13.93 (2.6)	7.7 (407.7)	4.1
Russia & Ukraine	5.70 (0.1)	3.2 (5000)	3.6
Africa	1.51 (0.5)	0.8 (447)	1.1
Europe	3.56 (1.6)	2.0 (56.3)	5.0
Global total	180.44 (106.51 in 2008/09)	100 (69.42 percent change since 2008/09)	12.5* * percent global cropland 7.4 percent in 2008/09

Source: 2008/09 FAO AquaStat; 2015/16 Kassam *et al.* (2018)

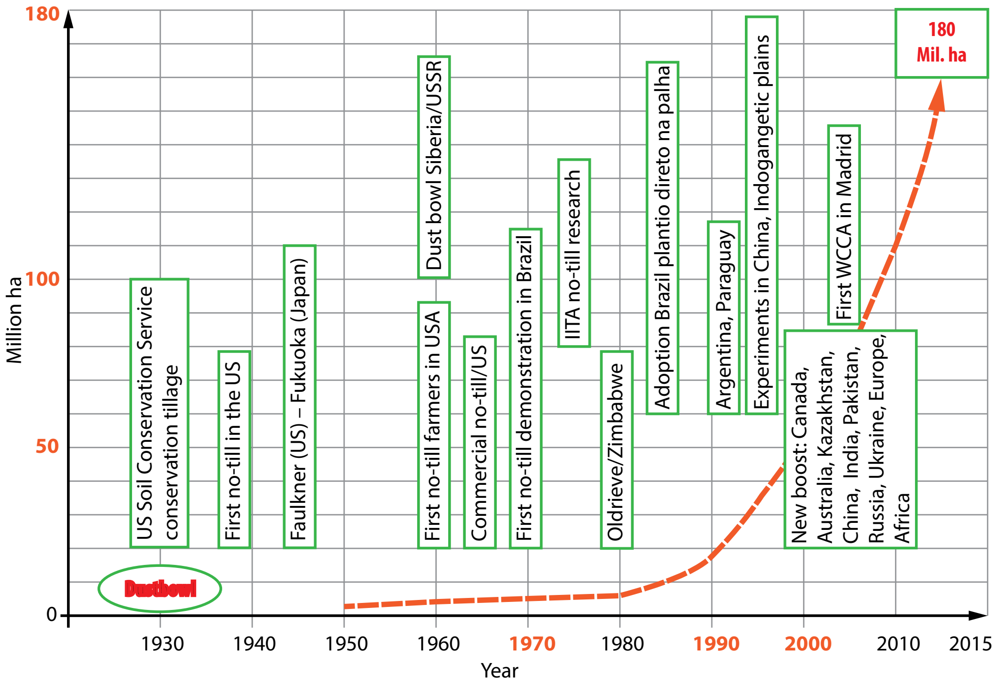


Figure 2. History of global adoption of conservation agriculture annual cropland systems since 1974

Uptake of CA in Asia Increased from 2.6 Mha in 2008/09 to 13.9 Mha (7.7 percent of the global CA area, and 4.1 percent of the cropland area in Asia) in 2015/16, an increase of 430 percent. Most of the increase in the CA area since 2008/09 has been in China, Kazakhstan, India and Pakistan. In south Asia, CA-based rice-wheat systems in the Indo-Gangetic Plains are being adopted. In 2008/09, CA area in Asia was reported for China and Kazakhstan only, but in 2015/16, there were 18 countries in Asia reporting CA area, namely: China, Kazakhstan, India, Pakistan, Iran, Kyrgyzstan, Turkey, Syria, DPR Korea, Iraq, Lebanon, Uzbekistan, Azerbaijan, Tajikistan, Bangladesh, Laos, Cambodia and Vietnam.

In Central Asia region, tillage agriculture has led to widespread land degradation, including erosion and salinity, and loss in productivity and agricultural land area. Countries in Central Asia quite rightly are taking steps to promote the adoption of CA to address these threats. However, to establish a sustainable process of transformation from tillage agriculture to CA anywhere in the world requires the engagement and support of the whole industry, including the farmers themselves, and the public, private and civil sectors. Mobilizing policy and institutional support from government and from research, education and service providers can be a slow process, but when farmers themselves and their organizations are leading the transformation, there is much higher probability of success.

In Africa, most of the increase since 2008/09 has been in South Africa, Zambia, Malawi, Mozambique, Morocco and Tunisia. However, farmers in at least 22 African countries are promoting CA (Kenya, Uganda, Tanzania, Rwanda, Sudan, Ethiopia, Swaziland, Lesotho, Malawi, Madagascar, Mozambique, South Africa, Namibia, Zambia, Zimbabwe, Ghana, Burkina Faso, Senegal, Cameroon, Morocco, Tunisia, Algeria). CA has also been incorporated into the regional agricultural policies by NEPAD, and it is recognized as a core element of climate-smart agriculture.

In Europe, Spain, Italy, France, Finland, Romania, Poland, Switzerland and the UK have shown significant increases in their CA area in recent years. In 2008/09, CA was reported in 11 countries in Europe but in 2013/14, this increased to 15 countries, and in 2015/16 to 29 countries.

Since 2008/09, the number of countries where CA adoption and uptake is occurring has increased from 36 to at least 55 in 2013/14 and to 78 in 2015/16. Also, the area of CA systems based on perennial crops such as in orchards and plantations or mixture of annual and perennial crops such as trees in association with annual crops, or agroforestry systems, or crop-livestock-tree systems, or pasture systems are not included in the total CA area reported in this paper.

Such CA systems with perennial crops are on the increase in all inhabited continents. CA orchards and vines concern crops such as olive, grape, fruit and nut trees. CA plantation systems concern crops such as oil palm, cocoa, rubber, tea, coffee, coconut but also sugar cane. Thus, the CA cropland areas reported in this paper are conservative estimates of global CA land use.

There are now a multiple set of drivers supporting the adoption and spread of CA globally. In the early years, particularly in North and South America, and in Russia and China, the main driver for change was soil erosion and degradation (the dust bawls in America and elsewhere), and this has continued to be so today given the extensive soil erosion and degradation caused by conventional tillage agriculture.

Even in the earlier years, drought would exacerbate the situation because degraded and eroded agricultural soils would be more vulnerable to dry periods during the rainy season. This too has continued to be so today, given that there is an increase in the occurrence of extreme events (i.e. droughts) due to climate change.

Since the 1970s, there has been continuing increase in the cost of energy from fossil fuels, and cost of machinery and labor, as well as the cost of production inputs such as mineral fertilizer and biocides (herbicides and all forms of pesticides). Consequently, farmers have been trying to reduce their production costs, and CA has allowed farmers to not only reduce production costs but also minimize erosion, degradation and effects of droughts.

Since 2000, more attention has been paid to combating the loss of ecosystem services and resilience to biotic and abiotic stresses arising from the practice of conventional tillage agriculture. Damage to ecosystem services include: pollution of water due to runoff and erosion, leaching of plant nutrients into the water systems, disruption of all parts of the water, nutrient and carbon cycles, increased emission of CO_2 from the soil into the atmosphere, loss of biological nitrogen fixation, and loss of biodiversity and the constituent food webs and food chains below and above the ground, leading to loss wild life and of natural biological control of pests and of pollination services. Through the adoption of CA systems, farmers are bale to reverse these negative externalities and enhance the productivity and resilience of their production systems.

Above drivers of CA adoption and spread are now also serving the global need to mitigate and adapt to climate change, as well as to intensify production sustainably. Equally important is the fact the CA production systems have shown to be relevant and important in pro-poor agriculture development strategies for small-scale farmers particularly in Asia and Africa, but also in Latin America and Europe.

Despite the existence of several constraints to adoption, farmers in different parts of the world are continuing to find local solutions to support the spread of CA as well as to innovate with new practices and management methods to maximize the benefits. Major constraints to the adoption of CA practices continue to be: knowledge about the existence of CA and on how to do it (know how), mind-set (tradition, prejudice), inadequate policies, for example, commodity based subsidies (EU, US) and direct farm payments (EU), unavailability of appropriate equipment and machines (many countries of the world), and of suitable management strategies to facilitate weed and vegetation management, including mechanical, biological and chemical options as herbicides (especially for larger farms in low income countries). Other area-specific constraints in semi-arid areas during the transformation to CA system relate to initial low supply of crop and vegetation biomass for soil mulch cover development; to initial short-term competition for crop residue as livestock feed; and to initial adoption of new manual weed management practices when the soil mulch cover and integrated weed management practice is being established.

Yet farmers who do become seriously interested in adopting CA develop local solutions to all these barriers. Many such cases have been reported for smallholder and large-scale farms in all continents (see list of publications at: www.fao.org/ag/ca). Further, more international and national organizations have increased their support for CA as they have increased their awareness of its effectiveness in sustainable production intensification. These organizations include: FAO, IFAD, World Bank, EU, AU-NEPAD, CIRAD, ACT, some CGIAR Centers (CIMMYT, ICARDA, ICRISAT, ICRAF), NGOs, some governments in the North and the South, national and multi-national corporations, the growth of no-till/CA organizations worldwide, farmer to farmer support, even across continents, and bilateral and multi-lateral donors, Thus, the continuing spread of CA globally is creating a need for effective national and regional policy and institutional support.

So far most of the CA development has been in rainfed annual cropping systems and some in irrigated crops in combination with rainfed crops such as the rice-wheat cropping system in the Indo-Gangetic Plains. The same CA principles apply for strengthening the ecological and economic sustainability of irrigated systems, including those in arid and semi-arid areas, with the additional benefit of improving water use efficiency and avoiding or minimizing salinization problems. This is happening in the tropics and sub-tropics with irrigated rice based systems in Brazil, Argentina, Pakistan, India, Bangladesh, and with other cropping systems such as irrigated cotton-based systems in Uzbekistan, and in irrigated systems in Spain and Italy.

As indicated earlier, CA principles and practices are also applicable for orchards, plantations and vine crops with the direct sowing of associated field crops, cover crops and pastures beneath or between rows, giving permanent ground cover and biomass production, controlling soil erosion, improving soil health and biodiversity, water infiltration and retention, and soil aeration. In the dry areas of Africa, there is an increase of agroforestry systems integrating nitrogen fixing trees such as *Faidherbia albida* with CA systems. Orchard crops and vines are being converted into CA systems in Europe. Plantation tree crops such as oil palm, rubber, cocoa, citrus and coconut are also being successfully managed under CA systems in several countries such as Malaysia. In India, the area under CA rice-wheat and rice-maize cropping systems has significantly increased during the last ten years or so.

Conclusion

The global spread of CA is nothing short of a revolution which has been ongoing worldwide especially since 1990. While North and South America and Australia have led the agricultural transformation, Asia, Europe and Africa have become part of the global change process towards sustainable agricultural land use. CA represents a different paradigm of agriculture, and CA systems are becoming increasingly recognized as being climate-smart, and fit naturally as a core production component of climate smart agriculture, offering simultaneously the ability to achieve sustainable production intensification, improve climate change mitigation and adaptability, harness ecosystem services, strengthen food and agricultural security, and contribute to rural livelihoods and national economic growth.

References

Kassam AH, Friedrich T, Shaxson F, Pretty J. (2009). The spread of conservation agriculture: justification, sustainability and uptake. International Journal of Agricultural Sustainability 7(4): 1–29.

Kassam AH, Friedrich T, Derpsch R, Kienzle J. (2015). Overview of the Worldwide Spread of conservation agriculture. Field Actions Science Reports 8. Available at: http://factsreports.revues.org/3966.

Kassam AH, Freidrich T, Derpsch R. (2018). Global spread of conservation agriculture. International Journal of Environmental Studies. https://doi.org/10.1080/00207233.2018.1494927.

Chapter 1

Conservation agriculture – A sustainable agricultural paradigm

©FAO/Hafiz Muminjanov

Conservation agriculture evolution in Brazil 1972–2018

Rafael Fuentes Llanillo[3]

Abstract

The history of the Brazilian No-Tillage Revolution is very well described in literature. Three articles, Bolliger et al. (2006), Casão Jr et al. (2012) and Fuentes-Llanillo (2013), among others, permit comprehensive Anglophone description of the development of No-Tillage System and conservation agriculture in Brazil and how land degradation and a huge erosion process in the 1960/1970/1980s was stopped with the great adoption and scale-up of No-Tillage System in subtropical Southern Brazil and spread to the tropical Brazil in the early 1980s till now. Today Brazil with more than 32 million hectares of CA (Kassam et al., 2018; IBGE, 2018), challenges changed and a continuous improvement is needed to keep sustainable intensification.

Key words: No-Tillage, Minimum Soil Disturbance, Permanent Soil Cover, Crop Rotation.

Introduction and historic review

Conservation agriculture started in farm scale in Brazil and Latin America with the initiative of the pioneer farmer Herbert Bartz in Rolândia, Paraná State, Brazil, in summer 1972, when he has sown the first 200 ha. He was inspired by the existence of direct seeders in UK and the visit he made to USA to meet the farmer Harry Young and the extension agent Shirley Phillips that were doing No-Tillage System (NTS) in Christian, Kentucky, since 1962. Two cycles of new followers in 1974 and 1976 at Maua da Serra and Ponta Grossa, Paraná State, increased the surface under NTS and reached the first 1 000 ha. In 1976 also started the pioneer NTS modern research at IAPAR – Instituto Agronômico do Paraná, a public agricultural research institution. In 1972–1979 period there was only pioneer farmers and pioneer research (Figure 3). In 1980 NTS surface reached 10 000 ha.

The period between 1979–1991 was a time that is called "NTS Age of Studies" when farmers, public and private research and equipment and agrochemical industries studied all possibilities in developing NTS. In 1981 the IAPAR – Instituto Agronômico do Paraná launched the first book over the theme. Research was enhanced by several institutions like state and private research institutions, public and private universities and few unities of the national research institution.

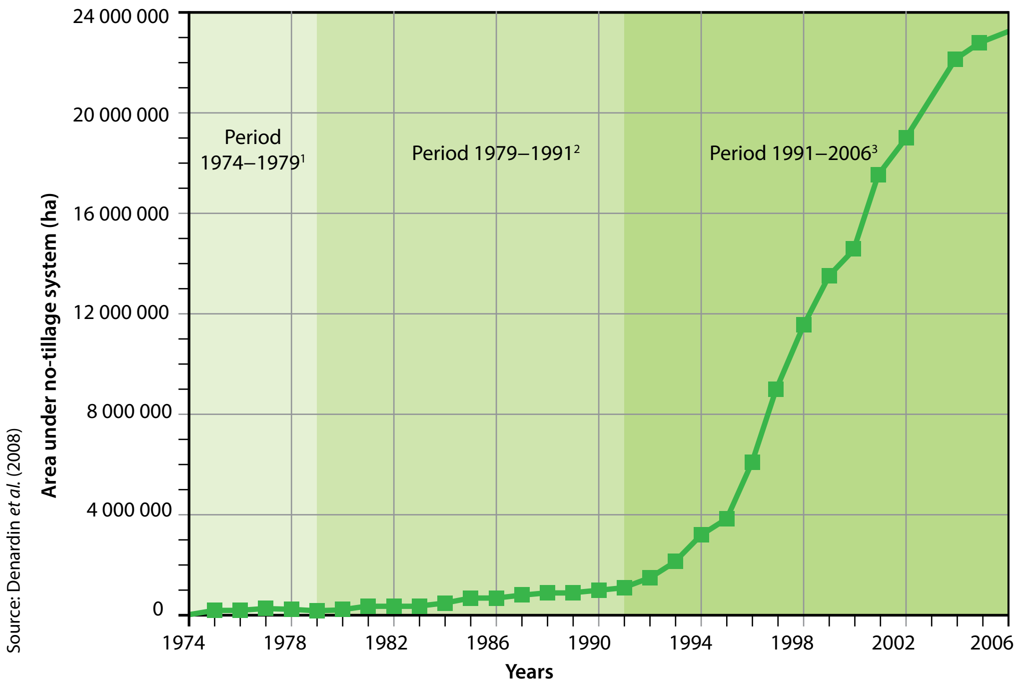


Figure 3. Surface under No-Tillage System in Brazil between 1974-2006

Chemical Industries developed and tested glyphosate and other desiccation herbicides for NTS viabilisation. Brazilian industries of equipment strongly developed appropriate seeders, sprayers and knife-rollers. This synergy enabled NTS to reach 1 million ha in 1991(Denardin *et al.*, 2008).

When cheap glyphosate and suitable seeders were available in the beginning of 1990s, together with the technological advances achieved in the previous decade, the objective conditions for massive expansion were present. The stopping erosion capacity of the system added to an unequivocal economic advantage of withdrawal of land preparation launched a strong process of farmer-to-farmer communication. At this point the creation of Brazilian No-Till Farmers Federation FEBRAPDP in 1992 articulated the action of the former Soil Friends' Clubs created to support NTS expansion since 1979. Hundreds of training events were carried out mainly the National NTS Meetings. During the 1990s some States of Brazil maintained public policies to spread NTS and Soil Conservation measures at the watershed level. There was credit support to buy and adapt NT seeding machines, reduction of costs of insurance and loans for NTS adopters and subsidies for adoption of soil conservation practices. This connection of factors increased NTS surface from 1 million ha in 1992 to approximately 25 million ha of NTS and Mixed Minimum

Tillage Systems in 2006 (Denardin *et al.*, 2008; Fuentes Llanillo *et al.*, 2013). This phenomenon is known as Brazilian No-Tillage Revolution.

According Fuentes Llanillo *et al.* (2013) in 2006 by the first time No-Tillage System area was officially surveyed in total number of farms in Brazil in the Agricultural Census of IBGE. Authors concluded there was 17.9 million ha of NTS, 3.8 million ha of Minimum Tillage and 3.1 of Mixed Conservation Tillage and still 11.8 million ha of Conventional Tillage in total area of 36.6 million ha of annual crops. Approximately 48.8 percent of annual crops are in CA, 19 percent intermediate systems of Conservation Tillage and 32.2 percent is still in Conventional Tillage. Recent data of Agricultural Census 2017 of IBGE (IBGE, 2018) shows that between 2006 and 2017, there was a growth of 84.0 percent in the area of NTS (CA) in Brazil from 17.9 to 32.9 million hectares while total area of annual crops increased 51.0 percent from 36.6 to 55.2 million ha. Presently 60 percent of annual crops in Brazil are in CA (NTS). There is a potential progress of CA in sugar cane, rice and cassava with an expressive surface of almost 13 million ha of total area with low adoption of CA.

Present situation and perspectives

The huge adoption of the system was not done with the desirable quality. The GMO technologies created and adopted after 2000 in Brazil also created an environment of permissiveness in the use of glyphosate and in the absence of refugees for pests and diseases that promoted natural resistances that are burning these technologies. World market of commodities is provoking monoculture of soybean crop putting in risk the accomplishment of CA second and third principles. Brazil has, with more than 32 million hectares of CA (Kassam *et al.*, 2018; IBGE, 2018), old and new challenges to overcome as:

1. Because of dominance of soybean crop in summer, there is a lack of crop rotation and low permanent soil cover;
2. Increase in water and soil losses because of removal of terraces and soil compaction led to excessive reliance in no-till and increase of equipment scale;
3. Bad management of GMOs, resistant weeds and "burning" of transgenic events;
4. Strong infestation with nematodes and high chemical utilization for control pest and diseases due to low biodiversity;
5. Needing of improvement of No-Till System to Sugar Cane, Cassava and Irrigated Rice among others crops;
6. Crisis in Public System of Agricultural Research and Seed Production of Cover Crops and Green Manures.

There are few barriers in the technological side and problem solution is dependent greatly on a mix of public policies, economic incentives for crop diversity and changes in farmers' attitudes. It´s necessary to make more research on biological aspects to replace herbicides and chemical control of pests and diseases. Brazil and South Cone neighbors as Argentina, Paraguay, Uruguay and Bolivia are responsible for almost 20 percent of world food market and can make much more to face challenges of world demand of food in close future.

References

Bolliger A, Magrid J, Amado T J C, Skóra Neto F, Ribeiro M F S, Calegari A and De Neergard A (2006): Taking stock of the Brazilian "zero-till revolution": a review of landmark research and farmers' practice. Advances in Agronomy. Volume 91, p. 47–110.

Casão Junior R, Araújo A G and Fuentes Llanillo R (2012): No-Till Agriculture in Southern Brazil: Factors that facilitated the evolution of the system and the development of the mechanization of conservation farming. Londrina, Paraná, Brazil: FAO & IAPAR, 77p. ISBN 978-92-5-107102-1.

Denardin J E, Kochhann R A, Bacaltchuk B, Sattler A, Denardin N D, Faganello A and Wiethölter S (2008): Sistema Plantio Direto: fator de potencialidade da agricultura tropical brasileira. Passo Fundo, Rio Grande do Sul, Brazil: CNPT, EMBRAPA, 23p.

Fuentes Llanillo R, Telles T S, Soares Junior D and Pellini T (2013): Tillage systems on annual crops in Brazil: figures from the 2006 Agricultural Census. Semina: Ciências Agrárias, Londrina, V. 34, n. 6, supplement 1, p.3691–3698.

INSTITUTO AGRONÔMICO DO PARANÁ (1981) Plantio Direto no Estado do Paraná. Londrina, Paraná, Brazil: IAPAR. (IAPAR. Circular Técnica 23), 244p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE (2018): Agricultural Census: 2017. Rio de Janeiro: IBGE, 750 p.

Kassam A, Friedrich T and Derpsch R (2018): Global Spread of conservation agriculture. International Journal of Environmental Studies, DOI: 10.1080/00207233.2018.1494927.

Adoption, advancement and impact of conservation agriculture in Kazakhstan

Muratbek Karabayev[4]

Abstract

Ploughing up of the virgin lands in the mid of 1950s in northern Kazakhstan has led to the dramatic losses of soil health and fertility combined with extensive soil erosion. In the beginning of 2000 CIMMYT, National Agricultural Research System (NARS), the Ministry of Agriculture (MoA), FAO, World Bank in cooperation with farmers initiated large-scale activities based on conservation agriculture (CA) in Kazakhstan. Due to these efforts, the area under conservation agriculture-based practices has been increasing from virtually none to an estimated area of 2.7 Mha in 2017 with continued increase in area. The utilization of CA-based technologies has become an official state policy in agriculture in Kazakhstan. Since 2008, the government of Kazakhstan has been subsidizing farmers who are adopting CA-based technologies. With this Kazakhstan is now included among the top ten countries with the largest areas under No-tillage in the world.

Key words: no-till, climate change, food security, soil, wheat.

Introduction

Industrial activities have often regrettably caused serious consequences for the environment, which now threatens normal life on Earth. Degradation, desertification, pollution, salinity, wind and water erosion and loss of soil fertility constitute a long but still incomplete list of the problems facing the humanity today. Sustainable use of natural resources, rehabilitation of land fertility, while improving quality and increasing annual crop production should become integral parts of national policy and a basis of sustainable economic development of every country and region of the world. Kazakhstan is characterized by a rich diversity of climatic conditions and soil types. The existing plant production systems in terms of grain crops include the following:

- Rainfed agriculture dominated by spring grain crops (northern and central parts of the country);
- Rainfed agriculture dominated by winter grain crops (southern and south-eastern parts of the region);
- Irrigated agriculture (mostly in the southern parts of the region).

The most part of the area where the major grain crops are produced, the main of them being wheat, is located in the zones with unfavorable climatic conditions. The climate of Kazakhstan is sharply continental, and a large part of the territory is affected by wind and water erosion. The concern about drought and salinity is growing. Soil fertility has decreased dramatically throughout the region. Humus content in the topsoil reduced significantly, and weed infestation of cereal fields has increased. Water deficiency and insufficient soil moisture levels remain among the major problems of the national agriculture. It becomes increasingly clear that in the existing conditions the improvements in plant production should be achieved through implementation of the agricultural production system based on conservation and sustainable use of water, soil, energy and other natural resources and the whole environment. Today, such system is the key to survival of farmers producing agricultural crops, and, in particular, wheat, which is the major export food commodity of Kazakhstan.

The world experience shows that the traditional farming systems, even if highly productive, lead to soil degradation and reduced input use efficiency. Negative components of the traditional farming systems are intensive tillage, returning little organic matter to the land and monoculture. Conservation agriculture (CA) means overcoming these negative components of conventional farming systems including three basic principles: minimal soil disturbance, permanent soil cover with crop residues and crop rotation. With this way and approach we look at and talk about CA. Essentially, CA is the further development and improvement of the conventional systems, includes all of the other principles of sound crop management, but excludes their negative components. But we must recognize that even with the apparent simplicity of such formulation, CA is a complex technology, it implies changes in a number of technological components of the existing traditional systems of agriculture. It is necessary to change two basic paradigms: the paradigm of soil tillage and the paradigm of linear knowledge flow.

Many agricultural research and extension systems are based on a linear model of knowledge flow, with new knowledge being developed in research organizations, passed on to agricultural extension agents who in turn pass on the new knowledge and information to farmers. While this model may be applied to simple technology, it does not always effectively work with complex technologies, especially when research institutes do not have the capacity to develop functional packages of multiple technological components for all farmer situations. Innovative systems on the basis of complex technologies are needed in adaptation, system development process and promotion. Innovative systems (platforms) are based on networks of multiple agents, including farmers-innovators and decision-makers, all utilizing their own knowledge, external information and policy support to help overcome problems and develop functional systems for local farming conditions and farmer circumstances. Successful adaptation and promotion of CA in Kazakhstan can be considered as an example of this approach.

Approaches towards the adoption of conservation agriculture technologies in Kazakhstan (zero/minimum soil tillage, leaving crop residues in the fields, direct seeding with narrow chisel and disk openers, permanent bed-planting and furrow irrigation, etc.) were initiated in 2000. Thanks to the joint efforts of scientists and farmers, international organizations (CIMMYT, FAO, ICARDA, World Bank, etc.), support by the state and government bodies, the areas under no-till have been increasing from virtually none to an estimated area of 2.7 Mha in 2017 with continued increases in area. The utilization of CA-based technologies has become an official state policy in agriculture in Kazakhstan. Since 2008, the government of Kazakhstan has been subsidizing farmers who are adopting CA-based technologies. As a result Kazakhstan is now included among the top ten countries with the largest areas under No-tillage in the world.

CIMMYT, FAO and the World Bank [FAO WB Report 2012] experts analyzed current state of CA adoption and wheat production in Kazakhstan and made the following conclusions:

- Yields of spring wheat under no-till are, in average, 48 to 58 percent higher in comparison with the conventional technologies. The advantages of CA/No-till technologies are especially evident in the years of drought.
- In 2012 Kazakhstan was ranked first in Europe and Central Asia region, and 9th in the world for No-till adoption.
- In the severe dry year of 2012, in Kazakhstan wheat production was estimated at 11.0 million tons. Wheat no-till area (only 80 percent of the no-till area) has produced an estimated 1.8 million tons of wheat. Incremental wheat production only because of no-till area is thus about 0.72 million tons, equivalent to around 200 million USD.
- Increased income and food security during the last 3 years:
- ▪ An estimated 580 million USD incremental income;
- ▪ Satisfied cereals requirements of about 5 million people annually.
- Climate Change mitigation: Kazakhstan contributes to the annual sequestration of about 1.3 million tons of CO_2.
- Adopted in Kazakhstan CA and No-till technologies, according to the data and characteristics, fully comply with the requirements for innovative technologies and systems.

Conclusion

Kazakhstan, possessing rich land resources, high research capacity and well-developed economic infrastructure, has wide opportunities for increasing agricultural production and becoming the world's leading exporter of high-quality grain and other types of agricultural production. At present, Kazakhstan is considered to be one of the world's most important region for global food security. As per official analytical data, by 2025 the level of cereal production should reach 3 billion tons in order to feed the 8 billion of population. In order to achieve that goal, annual increase in production of wheat, the most important food crop, should amount to 2 percent (against the existing annual increase of 1.3 percent).

This increase should be achieved against the growing influence of negative factors in the background, such as decrease of water supply, drought, temperature increase, land degradation, emergence of new highly dangerous diseases, increasing use of crops and biomass for fuel and livestock production. Without doubt, successful overcoming of these negative factors and sustainable growth of agricultural production in Kazakhstan and the whole world will primarily depend on new technologies and development of research and science. In the modern world, technologies and innovations are crucial for the country's competitiveness and food security.

Conservation agriculture in the European Union (in the case of the visegrad countries)

Khabibullo Pirmatov[5], Alim Pulatov[6], Elena Horska

Abstract

The goal of the paper is to analyze the arable area under conservation agriculture (CA) in the European Union, namely the Visegrad (V4) countries (Czech Republic, Hungary, Poland and Slovakia) as well as provide recommendations for its further development in the region. Despite of the advantages of CA such as cost reduction, carbon sequestration, soil and water conservation, the overall adoption levels of the following agricultural practices remain low in the European Union. The V4 is the selected four countries of the Central European region, where the implementation of CA is different in each country based on the farm types and the size of holdings. The paper presents the distribution of CA in the V4 countries, including the data of Food and Agriculture Organization of the United Nations (FAO) and The Statistical Office of European Union (Eurostat).

Key words: agricultural practices, conventional tillage, development, sustainable, zero tillage.

Introduction

The economic importance of agriculture within the European Union (EU) economy has been in almost continuous decline over the last 50 years, but it is still considered as a crucial sector (Eurostat, 2015). More than 77 percent of the EU's territory is classified as rural (47 percent is farmland and 30 percent forest) and half its population are living in rural areas (Schwartz *et al.*, 2016). Moreover, the total costs of land degradation in EU-25, which assess for erosion, organic matter decline, salinization, landslides and contamination, are up to 38 billion euro annually (Montanarella, 2007). conservation agriculture (CA) is able to reduce land degradation and increased food security in a more sustainable way. The EU's common agricultural policy (CAP) pay also attention to the sustainable development of rural areas and put forward this issue as one of main objectives to achieve.

Based on the definition of Food and Agriculture Organization of the United Nations (FAO), CA is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species. Moreover, it is mentioned that it enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production (FAO, 2018).

CA in European countries is different from one another. Most of the farmers connect CA with different levels of reduced tillage, which is leading to a general confusion in Europe. Only few farmers within Europe has adopted this technology as it is explained by FAO (Friedrich, *et al.* 2014). Practice of CA gives positive impulse to develop sustainable land management at the same time increases yields. For this reason, it is very important to explain this technology to the farmers with details and practical cases. CA is a combination of several agricultural practices. There is need to note that zero tillage, conservation (minimum or reduced) tillage, direct planting and organic farming are not conservation agriculture, but these practices (Table 2) can be the components of CA, which support to implement its core principles.

Table 3 shows the comparison of the effect from both conventional agriculture and conservation agriculture. Conservation agriculture has more advantages with the exception of weeds issue. Weed and pest problems are obstacle especially at the beginning of the CA adoption, with time the following issues can be solved or use herbicide and pesticide applications. Moreover, the crop rotation as the one of

Table 2. Selected agricultural practices.

№	Agricultural practices	Definitions
1.	Conventional tillage	This tillage practice involves inversion of the soil, normally with a mouldboard or a disc plough as the primary tillage operation, followed by secondary tillage with a disc harrow.
2.	Zero tillage (ZT)	Zero tillage does not involve tillage operations on the soil.
3.	Conservation(minimum or reduced) tillage	These tillage operations leave at least 30 percent of the soil surface covered by plant residues in order to increase water infiltration as well as cut down on soil erosion and runoff.
4.	Direct planting	Using NT drill equipment to plant seeds directly into crop residues left on the soil surface without preparing a seedbed beforehand.
5.	Organic farming	Organic agriculture does not permit the use of synthetic chemicals to produce plant and animal products, relying instead on the management of soil organic matter (SOM) and biological processes.

Source: Author's development based on the definitions of worldwide conservation agriculture Knowledge Resources and Eurostat, 2018

Table 3. Comparison between Conventional and conservation agricultures

№	Issues	Conventional agriculture	Conservation agriculture
1.	Soil organic matter (SOM)	Lower	More
2.	Soil biological health	Lower	More
3.	Soil temperature	More variable	Moderated
4.	Soil compaction	Increased	Reduced
5.	Infiltration	Lower	More
6.	Erosion	Maximum	Less
7.	Weeds	Lower	More
8.	Cost	More	Lower

Source: Author's development

the main principles of CA is preventing crops from spreading different plant pests, which commonly appear in monoculture.

CA technology is a climate resilient technology and management system that has demonstrated potential to secure sustained productivity and livelihoods improvements for millions of climate-dependent farmers. This technology is win-win situation, as it encourages sustainable agricultural development including itself environmental, economic and social values.

Materials and methods

Despite of the advantages of CA such as cost reduction, carbon sequestration, soil and water conservation, the overall adoption levels of the following agricultural practices remain low in the EU. Figure 4 shows the share of the tilled arable area by tillage practices within EU-27 as well as Iceland (IS), Norway (NO), Switzerland (CH), Montenegro (ME) and Croatia (HR) in 2010. Bulgaria (BG) and Cyprus (CY) use more conservation agriculture practices than conventional, while Malta (MT) and Montenegro (ME) practice only conventional tillage. In 2010, Bulgarian arable land was essentially dedicated to the production of cereals from 1.8 million ha and industrial crops from 1.1 million ha (Eurostat, 2010).

Most of farmers use CA for growing grain crops. However, CA can successfully implement to a wide range of crops. The average use of conservation agriculture for EU-27 is 26 percent. The top 5 EU countries by practicing CA are located in different agro-ecological zones. It proves that CA is implementable for a variety of agro-ecological zones and farming systems.

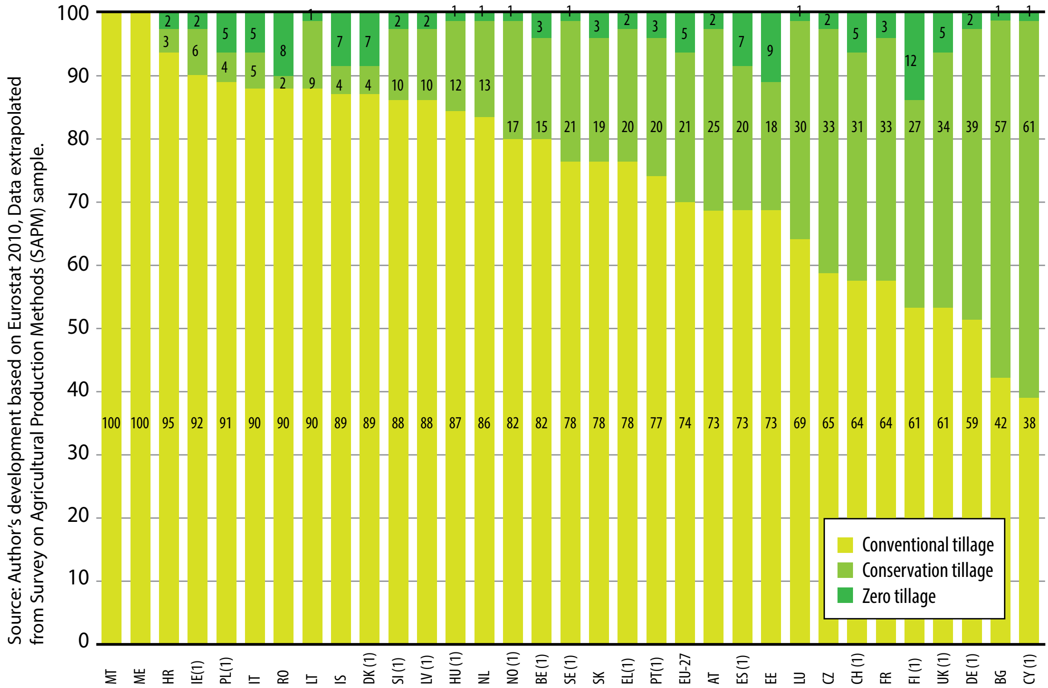


Figure 4. Tilled arable area by tillage practices within EU-27 as well as Iceland (IS), Norway (NO), Switzerland (CH), Montenegro (ME) and Croatia (HR) in 2010

Conservation agriculture in V4 countries

The Visegrad Group (also known as the "Visegrad Four" or simply "V4") reflects the efforts of the countries of the Central European region to work together in a number of fields of common interest within the all-European integration. The Czech Republic, Hungary, Poland and Slovakia have always been part of a single civilization sharing cultural and intellectual values and common roots in diverse religious traditions, which they wish to preserve and further strengthen (Visegrad Group, 2018). Unsustainable use of land resources and improper agricultural management lead to the land degradation. The main land degradation issues in Slovakia connected with water erosion and soil compaction. Almost half of the agricultural land and 90 percent of forestland suffered with water erosion. Soil compaction accounts for approximately 30 percent of the agricultural land. Soil sealing, loss of humus and contamination is also in the top of agenda in Slovakia (Table 4). The other V4 countries also meet with such as issues. In addition, land degradation processes are exacerbated by human activities. In order to slow down these negative processes, there is need to use CA, as this technology is able to reduce land degradation.

Table 4. Threats due to soil degradation in Slovakia

Type of degradation	Extent	Threat
Soil sealing	Up to 5-7 ha per day	Medium threat
Water erosion	Almost 50 percent (agricultural land) 90 percent of forest land	Very strong threat
Wind erosion	5-6 percent of the agricultural land area	Weak threat
Loss of humus	Around 60 percent (agricultural land area)	Medium threat
Soil compaction	Around 30 percent (agricultural land area)	Strong threat
Contamination	30 thousand ha above the limit	Medium threat
Acidification	10-15 percent of the agricultural land area	Weak threat
Salinization	Minimum occurrence	Weak threat

Source: Bandlerova, A. *et al.*, EU Land Policy "The Pathway Towards Sustainable Europe" 2016

There has been conducted the study report on conservation tillage versus conventional tillage for long-term effects on yields in western Hungary (Madarász, B. *et al.*, 2016) during 10 years (2003–2013). The study shows that during the first three years (2003–2007) the yield was decreasing by 8.7 percent due to technological changes, the next seven years (2007–2013) was increasing by 12.7 percent. Therefore, coming to this phase, the soil fertility has been improved. While implementing CA technology, there are need to pay careful attention on residue, pest and weed managements and follow the main principles of CA.

Analyzing the tilled area by the tillage practices in V4 countries, The Czech Republic (33 percent), Slovakia (19 percent), Hungary (10 percent) and Poland (5 percent) are in descending order by practicing conservation tillage. The average use of conservation and zero tillage is 19 percent in V4 countries. Zero tillage is insignificant percentage in Hungary, The Czech Republic and Slovakia.

Conservation tillage and zero tillage have the same proportion (5 percent) in Poland. Among V4 countries, the Czech Republic and Slovakia have higher percentage of conservation agriculture practices (Figure 5). The member of European conservation agriculture Federation, Slovak No-Till Club, makes its contribution in the promotion of CA in the region. The implementation of CA in V4 countries is different in each country based on the farm types and the size of holdings.

In V4 countries, CA is mostly preferred to implement in the farm type specialized on producing cereals, oilseed and protein crops ranging from 32 percent to 58 percent.

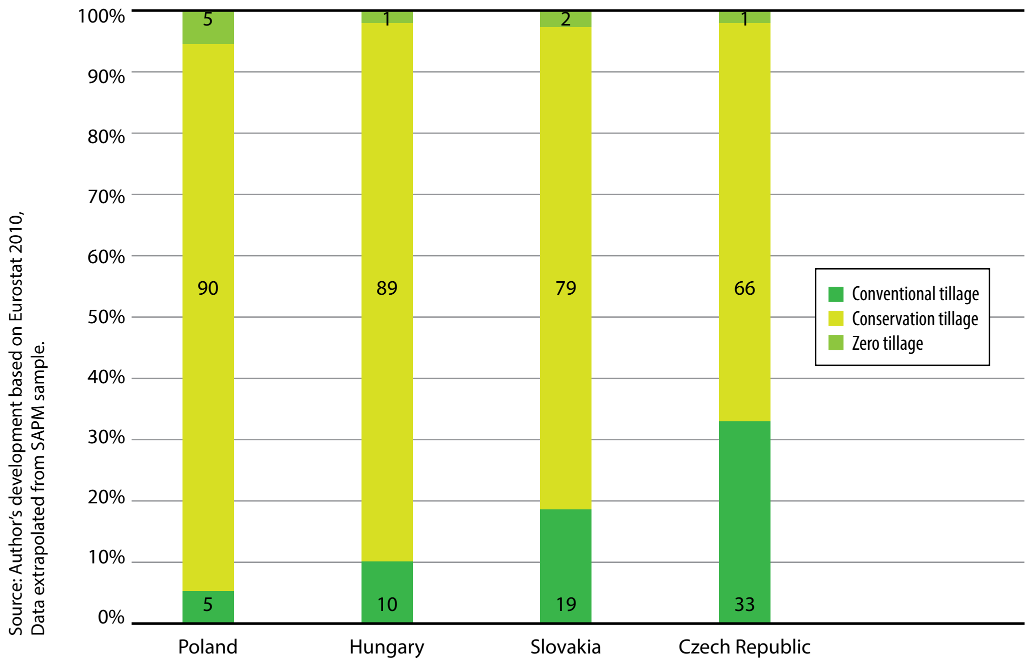


Figure 5. Tilled arable area by tillage practices in V4 countries

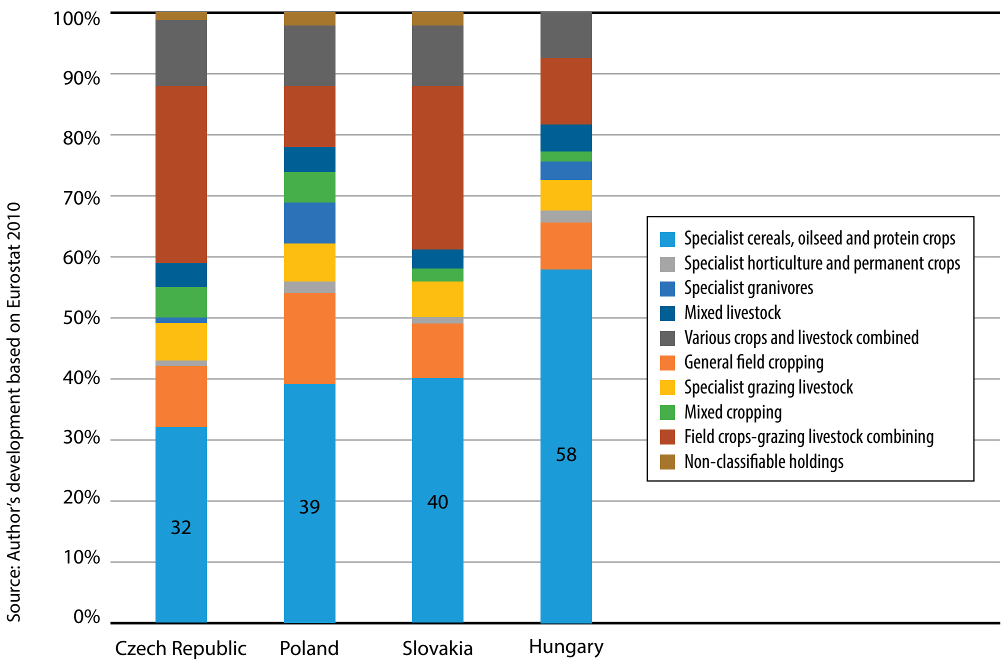


Figure 6. Arable land on which conservation and zero-tillage is practiced by farm types in V4 countries

Field crops-grazing livestock combining in the Czech Republic and Slovakia under conservation agriculture is more 25 percent, while in Hungary and Poland is more than 10 percent. The lowest share (1–2 percent) of arable land under conservation agriculture is related to the farm type specialized in horticulture and permanent crops (Figure 7), as in general horticulture crops are intensively cultivated. The share of specialized grazing livestock (around 6 percent) and various crops and livestock combined (around 10 percent) under CA is close proportions in all V4 countries.

Arable land under conservation and zero-tillage with the size of holding from 150 ha or over is 96 percent in the Czech Republic and Slovakia. However, CA can use for both large and small-scale farms. To facilitate farmers' work for direct seeding or planting, there is equipment specialized for CA. It can be run manually, animal or tractor powered. The same size of holding in Hungary accounts for 75 percent. In Poland, less than 29.9 ha (43 percent) and from 150 ha or over (42 percent) as well as from 30 to 79.9 ha (8 percent) and from 80 to 149.9 ha (7 percent) have close percentages (Figure 7).

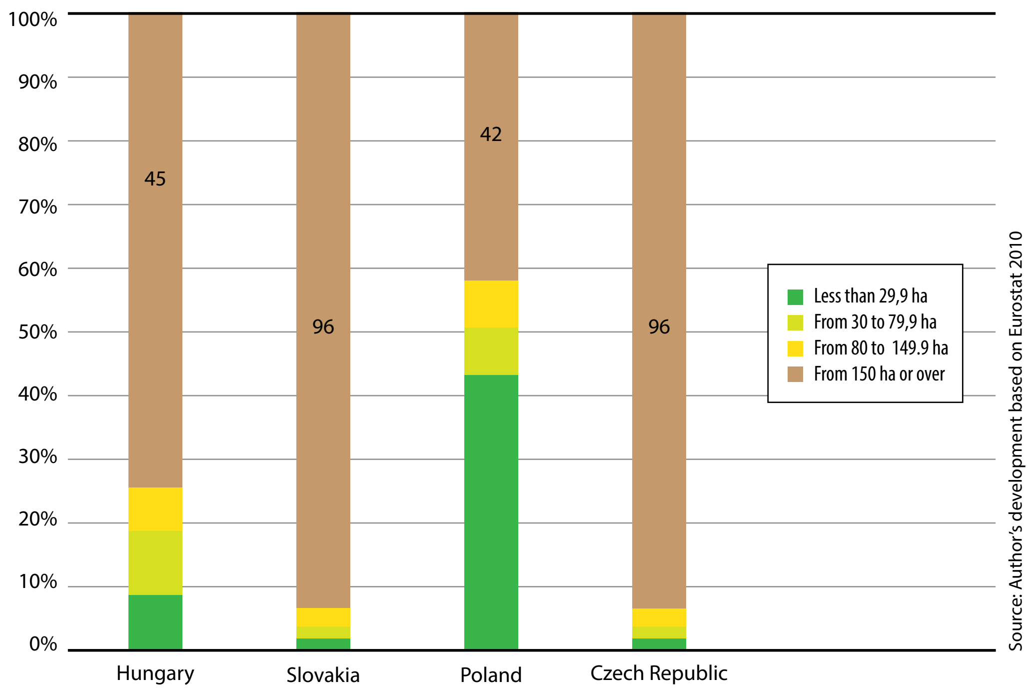


Figure 7. Arable land on which conservation and zero-tillage is practiced by size of holding (ha arable area) in V4 countries

Results

Despite of the advantages of CA such as cost reduction, carbon sequestration, soil and water conservation, the overall adoption levels of the following agricultural practices remain low in the European Union. The average use of conservation agriculture practices for EU-27 is 26 percent, in case of V4 countries, it accounts for 19 percent. Bulgaria (BG) and Cyprus (CY) use more conservation agriculture practices than conventional, while Malta (MT) and Montenegro (ME) practice only conventional tillage. The top 5 EU countries by practicing CA are located in different agro-ecological zones. It proves that CA is implementable for a variety of agro-ecological zones and farming systems. In V4 countries, CA is mostly preferred to implement in large-scale farms (from 150 ha or over), as well as the farm type specialized on producing cereals, oilseed and protein crops ranging from 32 percent to 58 percent.

Discussion

Analyzing CA in the EU, there are several common misconceptions among farmers about these agricultural practices. Firstly, most of the farmers connect CA with different levels of reduced tillage, which is leading to a general confusion. Secondly, CA is appropriate for basic grain crops such as wheat and maize, by contrast, CA can successfully implement to a wide range of crops. Thirdly, CA can only work for large-scale farms, but in fact, CA can be practicing in both small and large-scale farms. In order to promote CA practices, support and policy by government as well as specialized trainings by extension service agencies, the mass media and non-governmental organizations (NGOs) are required nowadays. These institutions play an important role for disseminating CA practices, as there is prospective future for developing CA in the EU including V4 countries.

Acknowledgment

I would like to express my deep gratitude to my supervisors, prof. Elena Horska and Dr. Alim Pulatov, as well as Food and Agriculture Organization of the United Nation (FAO) for presenting great an opportunity to participate in the International Conference on “Strategies for the Promotion of conservation agriculture in Central Asia”.

References

Bandlerová, A. (2016). EU Land Policy “The Pathway towards Sustainable Europe”, Slovak University of Agriculture in Nitra, Slovakia 2016.

Books, E. S. (2010). Eurostat regional yearbook 2015.

Cornell University, College of Agriculture and Life Sciences. (2018) Conservation agriculture: Global Research and Resources, Retrieved July 4, 2018, from http://mulch.mannlib.cornell.edu/pages/aboutca/whatisca.html

Food and Agricultural Organization. (2018). Conservation agriculture. Retrieved August 12, 2018, from http://www.fao.org/conservation-agriculture/en/.

Friedrich, T., Kassam, A., Corsi, S., Jat, R. A., Sahrawat, K. L., & Kassam, A. H. (2014). 6 Conservation agriculture in Europe. Conservation agriculture: global prospects and challenges, 127–179.

Madarász, B., Juhos, K., Ruszkiczay-Rüdiger, Z., Benke, S., Jakab, G., & Szalai, Z. (2016). Conservation tillage vs. conventional tillage: long-term effects on yields in continental, sub-humid Central Europe, Hungary. International Journal of Agricultural Sustainability, 14(4), 408–427.

Montanarella, L. (2007). Trends in land degradation in Europe. In Climate and land degradation (pp. 83-104). Springer, Berlin, Heidelberg.

Pirmatov K., Horská, E., Pulatov, A. (2016) Advantages of conservation agriculture. In Young Researchers of Agro-Industrial and Forestry Complexes to Regions. Vologda State Milk Academy named after N.V.Vereshchagin, p. 14–21.

Pirmatov K., Pulatov, A., Horská, E. (2016) Comparative Analysis of Conventional and conservation agriculture. In The Agri-Food Value Chain: Challenges for Natural Resources Management and Society: International Scientific Days 2016, Nitra: Slovak University of Agriculture, p. 156–162.

Schwarcz, P. (2016) European Agricultural and Environmental Policy, Slovak University of Agriculture in Nitra, Slovakia 2016.

Statistical Office of European Union. (2010). Agri-environmental indicator – tillage practices. Retrieved November 10, 2017, from http://ec.europa.eu

Visegrad Group. (2018). About Visegrad Group. Retrieved July 10, 2018, from http://www.visegradgroup.eu/about.

Conservation agriculture in perennial crops

Antonio Holgado-Cabrera[7], Julio Roman-Vazquez[8], Paula Trivino-Tarradas, Maria Pilar Jimenez-Donaire, Emilio Jesus Gonzalez-Sanchez[9]

Abstract

Conservation agriculture (CA) is a suitable alternative to conventional methods of farming. It is often perceived as exclusively synonymous with direct seeding for annual crops, however this is a common misconception. While no-tillage does in fact form the basis of this approach, many fail to acknowledge CA's applicability to perennial crops through the use of groundcovers. The use of permanent groundcovers is always effective in perennial crop soil protection, most importantly in cases where orchards are situated on long slopes, or are very steep and thus more vulnerable to erosion and the formation of gullies. In this way, CA takes on a much more holistic and comprehensive approach to sustainable agriculture. The use of groundcovers in perennial or woody crops results in several agronomic and environmental benefits. Control of soil erosion, improvements in soil structure and fertility, increased soil water storage, better water quality and increases in carbon sequestration are a few of the many advantages associated with the implementation of CA through the use groundcovers in perennial crops. There are several types of groundcovers. The choice of the best adapted groundcover to a farm, can also be tailored to different characteristics depending on the previous soil management, the skills of the farmer, and the availability and access to inputs such as machinery, plant protection products and fertilizers. A combination of the previous, among other, allows for the most efficient and effective groundcover. Most of the groundcovers are grasses that grow in-between the tree lines, but also pruning residues have provided promising results to be considered a valid option in many cases.

In light of climate change and exponential population growth, the demand for a sustainable agricultural approach that protects the environment while maintaining or increasing yields of perennial crops is high, further justifying the need for a global adoption of CA.

Keywords: Agronomic benefits, environmental benefits, groundcovers, grasses, residues.

Introduction

The implementation of groundcovers in perennial crops provides a great agronomic advance in the protection of the soil of the farms. The use of vegetable covers also has notable environmental benefits: soil structure is improved, organic matter is increased, atmospheric carbon is fixed, fertility is improved and soil water content is increased. The use of groundcovers also leads to the improvement of water quality of water and to the increase of biodiversity in the farm. Any change gives raise to some concerns and the implementation of groundcovers in perennial crops is no exception. It requires the farmer to make some important decisions, being the type of cover that better suits to his farm and investment possibilities the one that will most affect them in the future. This document aims to inform about the benefits of the implementation of groundcovers as well as about different types of groundcovers that farmers can use in their farms. Benefits of the use of groundcovers in perennial crops

Soil conservation

The impact of raindrops in the soil leads to the break of soil aggregates into small elements or particles that are easily carried away by the current (Figure 8). This process is more accentuated in long and steep slopes, where the dragging capacity of water is increased because water volume and speed are higher.

The implementation of groundcovers perpendicular to the slope, splits the length of the slope in shorter stretches. As a consequence, water flow is slowed down and water infiltration is enhanced, instead of running off.

In this regard, the results of experiments carried out by the "Spanish Association for conservation agriculture Living Soils (AEACSV, in Spanish)" in olive orchards in Spain during the season 2003–2004 are very revealing and clarifying. In Figure 9 it is shown the soil erosion in 3 different farms, comparing plots with groundcover (GC) and without groundcover (NO GC). Rainfall during the experiment period in the 3 farms was 616 mm, 598 mm and 596 mm respectively. The effect of the groundcovers is evident, with erosion reductions of 92.5 percent, 84.3 percent and 94.6 percent in farms A, B and C respectively (Rodríguez-Lizana *et al.*, 2004).

Increase of soil organic matter content

Organic matter (OM) has a great influence on soil physical, chemical and biological properties, necessary for the development of its functions (Bauer and Black, 1994; Magfoff and Weil, 2004). The loss of OM from a soil, in addition to a negative effect on the balance between the different carbon pools, also affects the quality of the soil and its fertility can be seriously compromised.

Figure 8. Water and soil splashed by the impact of a raindrop

Organic matter is fundamental for the physical fertility of a soil because it improves the formation and stability of aggregates (Gajri *et al.*, 2002). For this reason, this parameter can be considered as an indicator of soil health status.

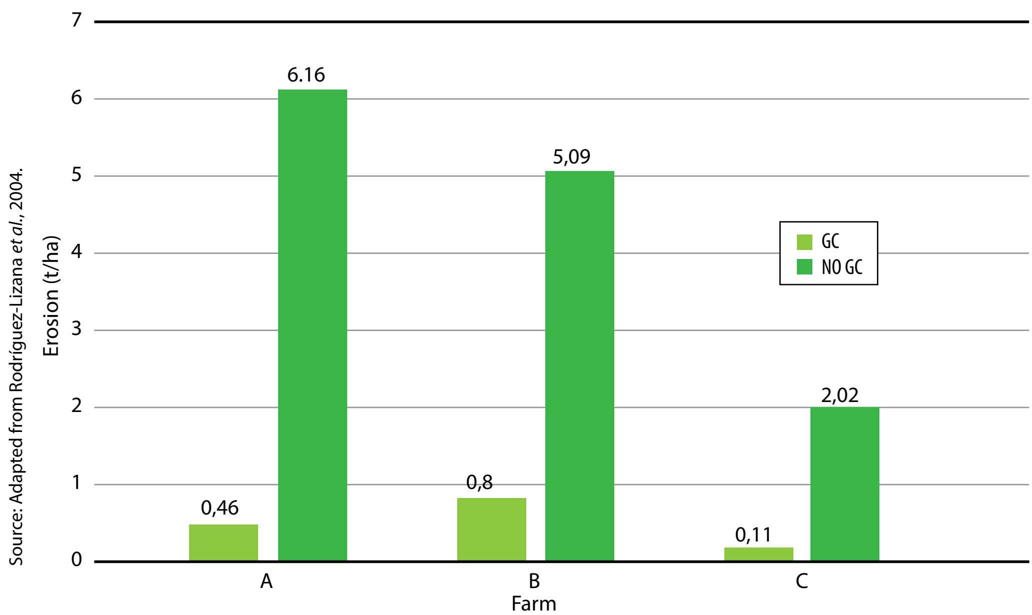


Figure 9. Comparison of soil erosion in plots with and without groundcovers in 3 different farms

The evolution in Soil's Organic Matter (SOM) content is determined by the balance between the inputs and losses. In perennial crops, the inputs can be the residues of the groundcover, the pruning remains, and/or the application of organic fertilizers (compost, manure, animal slurry, etc.). SOM losses are caused by decomposition by microorganisms or by leaching of soluble organic compounds. Tillage practices increase CO_2 emissions, decreasing the amount of organic matter (OM) in the soil (Schlsinger and Andrews, 2000; Lal, 2004; Álvaro-Fuentes *et al.*, 2007; Cabrera, 2007; Lopez-Garrido *et al.*, 2019). As a general rule, most of the agricultural soils in semiarid areas loss half of their OM content after 15–20 years under intensive tillage (Kinsella, 1995; Heenan *et al.*, 2004).

In CA in perennial crops, groundcover residues and/or pruning biomass are slowly degraded, resulting in an increase in soil OM content. Its increase in the first centimeters of the soil surface increases the nutrient reserves (González, 1997; Rhoton, 2000), which can be released gradually and at a different rate than in tilled soils (Fox and Bandel, 1987).

Avoiding surface water contamination

Phosphorus, nitrates and plant protection products in agricultural areas are the main elements that can generate diffuse agricultural pollution (Davenport, 1994). It happens when they are improperly applied or when erosion and runoff processes are not controlled through adequate soil management systems.

As a general rule, the loss of nitrates correlates directly with the water runoff due to the high solubility of nitrate (Francia *et al.*, 2006). This means that the reduction of water runoff achieved through the implementation of groundcovers will directly imply a reduction in the nitrates contamination of water bodies close to orchards.

A research conducted by the AEACSV in 8 fields comparing olive plots under conventional soil management with others with groundcovers showed the importance of the use of groundcovers in the reduction of dispersion of nitrates and phosphorus. As shown in Figure 10, the average reductions achieved due to the implementation of groundcovers were 54.5 percent for nitrates and 41.3 percent for phosphorus.

Increase of carbon sequestration

The impact of the soil management system in permanent crops can have an important effect in climate change mitigation. Non disturbed soils act as a carbon sinks

Table 5. Comparison of losses of nitrates and phosphorus in plots under conventional soil management and plots with groundcovers percentage of reduction of losses

		Plot 1	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Plot 8**	**Average reduction**
Nitrates losses	Groundcovers (Kg $NO^{-3/ha}$)	1,57	1,36	1,29	2,34	3,14	0,91	20,26	19,83	
	Convent. management (Kg $NO^{-3/ha}$)	3,12	5,64	3,48	2,88	7,57	1,21	72,69	75,81	
	Reduction (%)	49,0%	75,9%	62,8%	18,8%	58,5%	25,0%	72,1%	73,8%	54,5%
Phosphorus losses	Groundcovers (Kg P/ha)	0,09	0,08	0,06	0,06	1,44	0,04	0,06	0,04	
	Conventional management (Kg P/ha)	0,14	0,13	0,09	0,12	2,17	0,03	0,08	0,1	
	Reduction (%)	34,0%	37,7%	38,5%	51,4%	33,6%	51,7%	26,7%	56,6%	41,3%

Source: Adapted from Rodríguez-Lizana *et al.*, 2004)

because the lack of tillage operations avoid the release of C into the atmosphere and because the C fixed in groundcovers is incorporated to the soil due to the action of microorganisms. In a meta-analysis carried out by Vicente-Vicente (2016) it is determined that, through the implementation of groundcovers, in the Mediterranean region there can be sequestered 1.1 tons of C per hectare and year in olive groves, 0.78 tons of C per hectare and year in vineyards and 2.0 tons of C per hectare and year in almond groves. Taking into account these figures and other considerations, González-Sánchez *et al.* (2017) estimated that by shifting all suitable permanent cropland area from conventional soil management to groundcovers, there could be sequestrated more than 14 Mt of Carbon per year. In other words, around 6 percent of the CO_2 reductions committed by the EU for 2030 in the Paris Agreement can be achieved every year through the change of soil management system in perennial crops.

General remarks about groundcovers

Bearing in mind that the main function of the groundcover is to protect the soil from erosion, different type of groundcovers can be identified. Some conditions that covers must comply are:

- Low height development: This will not difficult the transit through the farm and will minimize risk of fire.
- Fast growing: It will makes the soil to be covered quickly after germination of the groundcover.

- Shallow roots: If so, the groundcover will not explore the profile and extract water that will remain available for the crop.
- Avoid pest host species.

In order to optimize the consumption of water and to maintain the final productivity of the crop, an adequate management of the groundcovers is crucial, especially in dry climates, like Uzbek one, in which the annual precipitations pattern is markedly seasonal, with a dry period in summer. Therefore, the soil water balance must be taken into account in the decision making process for the management of the cover, being critical for this the method and the moment of mowing. Consumption of water by the groundcover has to be minimized, especially at the moments of maximum need for the crop. The control of the groundcover is also very important to avoid competition for nutrients between the crop and the groundcover. It is therefore necessary to exercise control over the growth of the cover to prevent these negative effects.

The control of the groundcover can be achieved by one or a combination of the following methods:

- Mechanical mowing: To achieve an effective control of the cover by means of a mechanical mowing operation, it is necessary that the species used have, on the one hand, a low regrowth power, to minimize transpiration after mowing and, on the other hand, a great capacity to produce biomass so that, after mowing, the remains effectively cover the soil and reduce evaporation, thus preserving the water content in the soil. The capacity of regrowth of the species decreases as their phenological cycle is more advanced, therefore species with a short phenological cycle are the best adapted to this type of management. For example, in cruciferous species, white mustard (*Sinapis Alba*) showed the shortest phenological cycle and a low regrowth capacity after both early and late mowing, while the Eruca vesicaria and the cultivated species of radish (*Raphanus sativus*) and Ethiopian mustard (*Brassica carinata*) reached significant rates of regrowth (Alcántara *et al.*, 2004; Alcántara, 2005). Excessive regrowth reduces the water and nutrient content and affects the production of olive trees.
- Grazing: Letting livestock graze is an option for steep areas, where the slope makes it difficult the access for machinery. Monitoring of soil moisture when animals enter the plot is very important, since they can cause compaction.
- Chemical mowing: This is an effective tool. For the control of the groundcover it is recommended to use non-residual and low environmental impact herbicides at a low volume. It is very important to check the equipment with which the product is applied to ensure efficient and safe work.

Classification and management of groundcovers

Attending to the type of plants comprising the groundcover they can classified as follows:

Spontaneous vegetation groundcovers

They are formed by the field flora (weeds) in the farm. The farmer may leave this flora free for natural growth or may select some species. In the second scenario, the most suitable species are those producing more biomass with a low level of competition with the crop. The selection of gramineous plants can be a good choice.

In the case of gramineous selected spontaneous groundcovers, it is needed to use grass-selective herbicides (e.g. fluroxipir), and to repeat the applications when broad-leaved weeds are detected. If late cycle weeds appear, they must also be controlled (AEACSV, 2001). When the rainy season starts, the field plants from the seed bank are growth. This groundcover will protect the soil from future precipitations. It is recommended to apply a topdressing of nitrogen to the cover. When rainy season finish, to avoid the competition with the crop, the groundcover must be controlled following one of the options mentioned before, depending on the type of weed, the crop, the availability of cattle, the investment possibilities, etc.

Spontaneous vegetation groundcovers	{ Spontaneous weeds Selected weeds
Sown groundcovers	{ Gramineous Leguminous Cruciferous
Inert groundcovers	{ Pruning residues

When the method used to control the groundcover is the chemical one, leaving untreated a strip (around half a meter) of the groundcover is recommended. The purpose of this strip is for the cover to complete its cycle and to produce seeds that will be the seedbank for the groundcover of the next season. In practice, it can be done by clogging a nozzle in the sprayer. The most suitable herbicides to control the groundcover must be checked in the herbicides catalogue, bearing in mind the species to be controlled. Glyphosate-based formulations are the most widespread. Monitoring of the status of the sprayer is highly advisable. Nozzles should be replaced when the product is not properly distributed.

When grazing or mechanical mowing is employed keeping the strip is difficult, so the presence of groundcover must be monitored in the next years and, if necessary, seeding any specie.

Spontaneous vegetation groundcover is convenient for soils with harsh conditions of sowing because of the topographic features. Also for soils historically ploughed, which usually count on a lot of species that will provide a dense protective groundcover. This kind of groundcover implies savings is costs such as seeds, sowing and selective herbicide treatment. One of its disadvantages is the great diversity of the species (presenting different growth patterns or sensitivity to herbicides).

It should be noticed that the groundcover must be controlled so that it does not interfere with the crop production. In mountain areas it is suggested the grazing when the soil moisture is not high and thus soil compaction is avoided. In the case of plots with a moderate slope chemical or mechanical control can be performed.

The main issues to control this type of groundcover are:

- Chemical mowing: It is needed a higher herbicide dose than used in gramineous groundcovers, thus higher costs.
- Mechanical mowing: Vegetation may evolve towards perennial species with high regrowth power and creeping; all of them being difficult to control with brush cutters.
- Grazing: Risk of compaction if livestock enter the plot under high soil moisture conditions.

1. Sown groundcovers

1.1. Gramineous sown groundcover

The management of this type of groundcover is very similar to the one of the gramineous selected spontaneous groundcovers. This groundcover crop is composed by one or several species that can be sowed with a conventional seeder or by scattering the seed with a centrifugal broadcaster, which is cheaper. In this case, if possible because of the plot slope, it is recommended to use a harrow to bury the seed. There is no need of certified seeds so they are not expensive.

This type of groundcover is recommended in plots with high erosion rates or previously managed under no-till without groundcover (using pre-emergence herbicides). In these cases the seed bank is insufficient and, usually the species of the seed bank are those difficult to control. The population of these species will be diminished due to the competition with the gramineous of the groundcover.

As an orientation, the dose of seeds can be 100 kg/ha of groundcover for crop species such as oats, barley or rye. For "wild" species such as rye grass or brome grass the dose can be 15 kg/ha of groundcover.

1.2. Leguminous sown groundcover

They are of great environmental interest because they fix nitrogen and thus they "fertilize" the crop. The problem of this type of groundcover is that, due to their low C/N ratio, their degradation is fast and they do not cover the soil long enough to remain during the rain periods to protect soil from erosion.

Usually the weed control is more difficult and expensive than in gramineous groundcovers. However, mechanical mowing is efficient, in particular for species with low regrowth power (e.g. vetch) and in late mowing (being the plant in the blooming phase).

1.3. Cruciferous sown groundcover

It is a suitable choice to be used in rotation with gramineous groundcovers because after a few years using the same specie as groundcover, it deteriorates and, consequently, diminishes soil protection, increases compaction and appears flora alteration towards species that are difficult to control.

Furthermore, there is a series of additional advantages of cruciferous species such as:

- They are known by farmers and they are frequently found under natural conditions.
- They use to grow quickly and they produce a big quantity of biomass, essential features for a proper erosion control.
- Many cruciferous species count on a taproot system that favors water infiltration thus increasing soil water storage and makes of them suitable species for the deep soil decompaction (Wolfe, 2000).
- They present great potential as controllers of soil diseases (Smolinska & Horbowicz, 1999), weeds (Boydston & Hang, 1995; Al-Khatib *et al.*,

1997) and nematodes (Mojtahedi *et al.*, 1993), thanks to their content of glucosinolates-sulfur compounds of the secondary metabolism of this plants with a great herbicide, insecticide, nematicide and fungicide power.

Deciding the right moment to cut the cover crop to avoid competition for water with the crop is complicated, especially when the method selected to do it is the mechanical one. As there are a lot of factors to have into account, it is difficult to establish common patterns useful for every place and climatic condition. Early mechanical mowing leads to important losses of water from soil profile due to excessive regrowth, too fast decomposition of groundcover remains and appearance of weeds. In contrast, late mechanical mowing leads to less regrowth and to an increase of the amount and persistence of groundcover remains. These factors make the soil moisture to be kept because soil is properly covered, and the appearance of weeds hindered. Nevertheless, in low-rainfall seasons, the delay in the mechanical mowing is not recommended. Global understanding of all the factors will provide to the technician or farmer the appropriate criteria to determine the moment for the mowing in every particular case.

2. Inert cover crops

They are made of non-living components (pruning residues or stones).

2.1. Chopped pruning remains

Pruning remains are scattered on the soil surface and while slowly decomposing, they offer prolonged and sufficient protection to the soil. Over time layer will be formed increasing the water infiltration on the soil. It is convenient the control of weeds by herbicides, as it is more difficult the control through mechanical mowing or grazing. It should be emphasized that the pruning remains increase organic matter in upper soil layers, increase the soil water content and improve the soil structure in its first centimeters.

Discussion

Groundcovers bring both agronomic and environmental benefits in CA. There is no ideal groundcover suitable for all situations and, not all types of groundcovers are suitable for each specific goal. The system success will depend on the choice of species and several factors shall be taken into account. First of all is needed to determine the main objectives for implementing a groundcover, and to know the particular characteristics of the perennial crop where groundcover will be established. The chosen species must be adjusted to the crop cycle and it should not difficult the carrying out of the crop operations. Additionally, we have to take into account farmers preferences for those species to which cycle and management they are familiar with (Saavedra, 2003). Bearing in mind the aforementioned reservations, the gramineous groundcover is recommended in most conditions, because of its high biomass, its high persistence on soil, its easy control with low doses of low-toxicity products and the expertise of the farmers on them. According to recent studies, it would be interesting to include cruciferous species on rotation.

References

Alcántara C (2005) Selección y manejo de especies crucíferas para su uso como cubiertas vegetales en olivar. Tesis Doctoral. Departamento de Ciencias y Recursos Agrícolas y Forestales. Universidad de Córdoba.

Alcántara C, Sánchez S and Saavedra M (2004) Siega mecánica y capacidad de rebrote de cubiertas de crucíferas en olivar. Phytoma 155, 14–17.

Al-khatib K, Libbey C and Boydston R (1997) Weed suppression with Brassica green manure crops in green pea. Weed Science 45, 439–445.

Álvaro-Fuentes J, Cantero-Martínez C, López MV, Arrúe JL (2007). Soil carbon dioxide fluxes following tillage and semiarid Mediterranean agroecosystem. Soil and tillage research, 96, 331–341.

Asociación Española Agricultura de Conservación/Suelos Vivos (AEAC/SV) (2001) Agricultura de Conservación en el olivar: Cubiertas vegetales. AEAC/SV. Córdoba. 36 pp.

Bauer A, Black AL (1994). Quantification of the effect of soil organic matter content on soil productivity. Soil Science society of America Journal 58(1), 185–193.

Boydston RA and Hang A (1995) Rapeseed (Brassica napus) green manure crop suppresses weeds in potato (Solanum tuberosum). Weed Technology 9, 669–675.

Cabrera F (2007). Materia orgánica del suelo: papel de las enmiendas orgánicas. In: Componentes del suelo: estructuras y funciones en la agricultura y medio ambiente. 275–291.

Davenport TE (1994). EPA's perspective-You need to protect water quality. Journal of Soil and Water Conservation, 49(2), 14.

Fox RH, Bandel VA (1987). Nitrogen utilization with no-tillage. In: Spragne MA and Triplett GB (ed). No tillage and surface tillage agriculture. Wiley interscience publication. New York, 115–148.

Francia-Martínez JR, Durán-Zuazo VH and Martínez-Raya A (2006). Environmental impact from mountainous olive orchards under different soil-management systems (SE Spain). Science of the Total Environment, 358(1–3), 46–60.

Gajri PR, Arora VK, Prihar SS (2002). Tillage for sustainable cropping. International Book Distributing Co. Lucknow, India.

Gonzalez P (1997). Efecto del laboreo sobre la materia orgánica y las propiedad químicas del suelo. In: García L and González P (ed) Agricultura de Conservación AEAC.SV. Córdoba, 41–49.

González-Sánchez EJ, Moreno-García M, Kassam A, Holgado-Cabrera A, Triviño-Tarradas P, Carbonell-Bojollo R, Pisante M, Veroz-González O, Basch G (2017). Conservation agriculture: Making Climate Change Mitigation and Adaptation Real in Europe. European conservation agriculture Federation (ECAF). Brussels (Belgium).

Heenan DP, Chan KY, Knight PG (2004). Long-term impact of rotation, tillage and stubble management on the loss of soil organic carbon and nitrogen from a Chromic Luvisol. Soil and Tillage Research. 76, Issue 1: 59–68.

Kinsella J (1995). The effects of various tillage systems on soil compaction. In: Farming for a Better Environment: A White Paper. Soil and Water Conservation Society, Ankeny, IA: 15–17.

Lal R (2004). Carbon emission from farm operations. Environment International 30: 981–990.

López-Garrido S, Madejón E, Murillo JM, Moreno F (2010). Soil quality alteration by mouldboard ploughing in a commercial farm devoted to no-tillage under Mediterranean conditions. Agriculture, ecosystem and environment.

Magfoff F, Weil RR (2004). Soil organic matter management strategies. Soil organic matter in Sustainable Agriculture. 45–65.

Mojtahedi H, Santo GS, Wilson JH and Hang AN (1993). Managing Meloidogyne chitwoodi on potato with rapeseed as green manure. Plat Disease 77, 42–46.

Rhoton FE (2000). Influence of time on soil response to no-till practices. Soil Sci. Soc. Am. J. 64, 700–709.

Rodríguez-Lizana A, Ordóñez-Fernández R and González-Sánchez, EJ (2004) Agricultura de Conservación en cultivos leñosos (olivar): Cubiertas vegetales. Cualidades y tipos principales. In: Gil-Ribes JA, Blanco-Roldán GL and Rodríguez-Lizana A (eds.) Técnicas de Agricultura de Conservación, Madrid, p 113–124.

Saavedra M (2003) El Manejo de la Cubierta Vegetal en el Control de la Erosión en Olivar. In: Bienes R and Marqués MJ (eds.) Perspectivas de la Degradación del Suelo. I Simposio Nacional sobre el Control de la Erosión y Degradación del Suelo, Madrid, p 43–54.

Schlsinger WH and Andrews JA (2000). Soil respiration and the global carbon cycle. Biogeochemistry 48(1), 7–20.

Smolinska U and Horbowich M (1999) Fungicidal activity of volatiles from selected cruciferous plants against resting propagules of soil-borne fungal pathogens. Journal of Phytopathology 147, 119–124.

Vicente-Vicente JL, Garcia-Ruiz R, Francaviglia R, Aguilera E and Smith P (2016). Soil carbon sequestration rates under Mediterranean woody crops using recommended management practices: a meta-analysis. Agriculture, Ecosystems & Environment, 235, 204–214.

Wolfe D (2000) Summer covers relieve compaction. In: Clark A (coord.) Managing Cover Crops Profitably, 2nd ed, Sustainable Agriculture Network, Beltsville p 84.

Effects of different soil tillage systems on yield of winter wheat and summer crop under irrigated condition of Central Anatolia, Turkey

Erdinc Savasli[10]

Abstract

The objective of this study was to determine the effect of bed planting, zero tillage and conventional planting systems on yield under irrigated and rotation system in (semi-arid) Turkey irrigation conditions. The study was carried out between 2005–2007 on Transitional Zone Agricultural Research Institute. The experimental layout was split plots in the randomized complete block design with 4 replications, where main plots were crop species, subplots were planting systems. After wheat production, sunflower, corn, and dry-bean were planted by pneumatic planters under zero tillage, zero tillage on permanent beds and conventional tillage without any problem. There was no significant yield difference between all tillage systems. It observed that wheat yield was higher in plots where the previous crop was dry-bean.

It concluded that pneumatic planter can be used to plant sunflower, dry bean and corn on zero tillage and zero tillage on permanent beds. However, after summer crops, wheat planting was difficult due to straw and planter.

Key words: Wheat, Permanent beds, Zero tillage, Rotation

Introduction

Conservation agriculture (CA) is a conservation practice that can save on irrigation, labor and fuel costs. Studies show a producer can save at least 30 percent of water consumption per hectare by changing from conventional tillage to CA (Asadi, M. E., 2017). As in Mexico and many parts of the world, these crops can be sown by zero tillage and bed planting, saving many inputs such as irrigation water, fertilizer, and energy. Also, since the second crops can be added very easily without tilling the existing bed planting after the harvest of the winter crops, the most important constraint, time, will be solved. For this purpose, summer crops (beans, sunflower, and corn) will be sown with protective soil cultivation techniques after winter wheat and the most suitable planting method will be determined. CA improves soil aggregation, infiltration is generally higher and runoff reduced, thus soil moisture is conserved and more water is available for crops in CA compared to conventional systems (Sayre and Govaerts 2012). Bed planting does not usually result in immediate, large yield increases for irrigated production conditions but provides improved production/input use efficiencies and reduced production costs (Sayre *et al.,* 2005).Burning wheat stubble has gained popularity among farmers due to some expected benefits and this has become a common concern of the whole society. Although it is prohibited by the government through a law (in Turkey), farmers continue this practice since they do not have many alternative choices presently. Despite some facilities it offers, stubble burning is known to be harmful to soils and environment and development of new systems is needed to end this practice. The field experiment in China investigated the effects of full straw incorporation on soil fertility and crop yield in a rice-wheat rotation. As results, the straw incorporation significantly increased the wheat yield by an average of 58 percent compared with straw removal (Zhao *et al.,* 2019).It is stated that in recent years, some of the advantages of the seed sowing method, which has been introduced in some countries, have made water use more effective and have reduced some inputs in version and weed control. Beds planting systems are formed at a height of 8–10 cm and 70 cm (back to center) and irrigation is carried out between the bed planting. The planting is done on the bed in the form of 2 rows with the seeder. It is considered to be an alternative practice because the soil is being sown in the past and the aim is to prevent burning stubble. In an 11-year study conducted in the USA, stubble mulching has been reported that in the 15–30 cm layer of soil, the organic matter has increased significantly and that the soil structure has improved (Tanchandrphongs and Dawidson, 1970). The experiment in iran, reduced tillage was higher wheat yield and maize (*Zea mays* L.) biomass. The data presented in this study in Iran demonstrated significant effects of tillage on soil properties, crop yield, and water productivity (Khorami *et al.*, 2018).

One of the most commonly used conservation tillage systems for stubble mulching is tillage, in which the stubble are homogeneously distributed to the soil surface and then the soil is spread with a suitable tillage so that a large stubble part of the soil remains on the soil surface. This type of soil treatment is usually applied in arid and semi-arid areas. Wheat stubble, corn cobs, straw and similar plant residues are the most used for this purpose (Erşahin, 2001). Hobbs *et al.* (2008) conclude that agriculture in the next decade will have to sustainably produce more food from less land through the more efficient use of natural resources and with minimal impact on the environment in order to meet growing population demands.

Objective of this study was to determine the influence of different tillage systems on crop yield within the common crop rotation Of Central Anatolia, Turkey.

Material and methods

Material: In this study, Doge (silage) corn variety, Tarsan1018 sunflower variety, Akman dwarf) dry bean variety and Yıldız98 winter bread wheat variety were used as the material.

Method: 2-year crop rotation system was applied in the research, two sets of products (wheat and summer crop) were put on trial to obtain the yield from each product every year. In the first set, only one kind winter bred wheat (Yıldız98) – experiment was established, while in the second set summer crop (corn, sunflower, and dry bean) experiment were established from rotation products (Figure 10).

<u>First year:</u> 2005–2006 SET 1 Wheat (Previous fallow)
2006 SET 2 Summer Crop (Previous fallow)
<u>Second year:</u> 2006–2007 SET 2 Wheat (Previous Summer Crop)
2007 SET 1 Summer Crop (Previous wheat)

2005-2006																	
SET 1 (Wheat)																	
Replication 4									Replication 3								
A2			A3			A1			A3			A1			A2		
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	1	2	1	2	3	2	3	1	3	1	2	1	2	3	2	3	1
Replication 1									Replication 2								
A1			A2			A3			A2			A3			A1		
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
1	2	3	2	3	1	3	1	2	1	2	3	2	3	1	3	1	2

2006																	
SET 2 (Dry Bean, Sunflower, Corn)																	
Replication 4									Replication 3								
A2			A3			A1			A3			A1			A2		
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	1	2	1	2	3	2	3	1	3	1	2	1	2	3	2	3	1
Replication 1									Replication 2								
A1			A2			A3			A2			A3			A1		
B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
1	2	3	2	3	1	3	1	2	1	2	3	2	3	1	3	1	2

A-Main Plot (Crop Rotation) SET1	A-Main Plot (Crop Rotation) SET2	B-Sub Plot (Planting Method) SET1
A1. Wheat	A1. Dry Bean	B1. Conventional system
A2. Wheat	A2. Sunflower	B2. Permanent Zero tillage
A3. Wheat	A3. Corn	B3. Permanent beds planting

Figure 10. The experiment plans the description of different tillage practices in the crop rotation (Wheat and Summer crop)

Experiments in the Split-Plot trial design in random blocks, 6 m×12 m in 72 m^2 plot with 4 replications. The main plot; plant species (wheat and summer crop), sub-plot; Zero tillage (direct), sowing, beds planting and conventional sowing methods. Bread wheat was sown at October by planter at a depth of 4–5 cm and 20 cm row-to-row spacing with 24 row per plot. Bread wheat was harvested at July. Summer crop was sown at April by the zero-till planter at a depth of 4–5 cm and 70 cm row-to-row spacing with 8 rows per plot. Summer crop was harvest at August and September.

B1) In conventional tillage, after the harvest of preceding crop, plots were plowed with a disc harrow twice and cultivator twice followed by planning in preparation for sowing the next crop. Wheat conventional tillage; Wheat residues were plowed under soil. Conventional tillage (disk incorporation of wheat straw residues following harvest and prior to planting). summer crop conventional tillage (disk incorporation of corn sunflower and dry bean straw residues following harvest and prior to planting). Conventional tillage without straw retention (CT) was taken as the control.
B2) Permanent beds planting; continual reuse of existing beds, which were reformed as needed. wheat residues were kept on the soil surface. Wheat and summer crops were planted on 0.70 m raised beds with wheat in two rows seeded 20 cm apart and dry bean, sunflower, maize in one row.
B3) Permanent zero tillage; Wheat and summer crop residues were removed by baling on the soil surface. Summer crop residues were removed by harrow rake on the soil surface. Conservation tillage is any tillage system that wheat, corn, sunflower and dry bean stubble at least 20–30 percent of the soil surface covered with crop residue after planting.

In conventional wheat sowing, a standard seed of 450 seeds/m^2 was used, with 350 seeds/m^2 sowing in bed planting and 500 seeds per square meter sowing in zero tillage. Total herbicide (Glyphosate amine salt) was used in weed control before sowing (2 weeks).

Experimental soils have clayey texture with low organic matter (1–2 percent) levels. Soils had either medium (5–15 percent) or high (15–25 percent) lime contents, slight alkaline reaction and were non-saline. Experiments were carried out in the same field in different years.

Data analysis Data were analyzed with JMP statistical software (JMP, SAS Institute, Cary, NC). General linear model (GLM) of the software was used for variance analysis. Student's t-test was used to compare the means.

Table 6. Precipitation data – 2006/2009

YEARS	September	October	November	December	January	February	March	April	May	June	July	August	Annual Total (mm)
Long-term	14.7	25.2	30.6	45.6	38.4	32.6	33.3	35.0	42.1	29.3	13.8	6.5	347
2006–2007	58.4	46.8	13.3	7.8	45.5	16.5	39.7	19.4	36.9	20.4	20.0	0.0	324
2007–2008	0.0	19.2	92.4	49.9	15.7	1.0	42.4	38.5	11.7	9.3	0.0	5.5	286
2008–2009	30.7	6.4	49.6	34.5	66.3	82.0	40.9	28.0	15.4	10.2	19.4	2.0	385

Results

While there was no statistically significant difference between wheat yields and direct and conventional sowing plots on the fallow first year, wheat yield was lower in sowing method (Figure 11). One of the most important reasons for this situation is that it cannot close the soil surface early and consequently the efficiency of radiation usage is low and it is seen as adversely affecting wheat development and yield. R.A. Fischer *et al.* (2005) some of the wheat varieties were able to cover up to 44 cm of row spacing and solar radiation (light capture) they cannot make up for it and for this reason they tend to lose about 10 percent efficiency. After 1980, some advanced lines were able to compensate themselves for solar radiation capture and surface closure even in 55 cm row spaces.

The wheat grain yields obtained between 2006 and 2007 are summarized in Figure 11. Statistically, there was no statistically significant difference between wheat grain yields between zero tillage, bed planting, and conventional seeding methods. The sowing method explained the probable reasons mentioned above and the lower yield of wheat grain compared to the direct sowing and conventional sowing method, due to the low radiation utilization efficiency.

In the year 2005–2006 (Set 1) the wheat grain yield after fallow was 7.81 tons/ha in zero tillage, 7.55 tons/ha in conventional and 6.81 tons/ha in beds planting, wheat yield after the fallow was 7.42 tons/ha in zero tillage, 7.30 tons/ha in conventional and 6.64 tons/ha in beds planting, wheat yield after fallow was obtained at 7.50 tons/ha in zero tillage, 7.49 tons/ha in conventional method and 6.90 tons/ha in bed planting, No statistically significant difference was found between the methods of planting (Figure 11 and Table 7).

In the year 2007 (Set 2) the wheat grain yield after sunflower was 2.85 tons/ha in zero tillage, 3.34 tons/ha in conventional and 2.10 tons/ha in beds planting,

Table 7. Effects of different soil tillage systems on the yield of wheat, corn, dry bean, and sunflower

Wheat (tons/ha)	**Wheat yield (tons/ha) 2006 (SET 1)**						
	Previous **Crop**	Zero **tillage**	Conventional	Bed **planting**	MEAN	CV (%)	LSD 0.05
Wheat yield (tons/ha)	Fallow	7.81	7.55	6.81	7.39	7.5	N.S
	Fallow	7.42	7.30	6.64	7.12	6.7	N.S
	Fallow	7.50	7.49	6.90	7.30	5.0	N.S
	Wheat yield (tons/ha) 2007 (SET 2)						
	Sunflower	2.85	3.34	2.10	2.76	18.5	N.S
	Dry bean	2.78	3.18	2.67	2.87	18.1	N.S
	Corn	2.11	2.93	1.83	2.29	23.9	N.S
Summer crop (tons/ha)	**Summer crop 2006 (SET 2)**						
	Previous **Crop**	Zero **tillage**	Conventional	Bed **planting**	MEAN	CV (**percent**)	LSD 0.05
Sunflower	Fallow	2.45	2.30	2.34	2.36	7.6	N.S
Dry bean	Fallow	2.29	2.01	2.08	2.13	10.3	N.S
Corn	Fallow	8.59	8.15	8.70	8.48	15.4	N.S
Crop (tons/ha)	**Summer crop 2007 (SET 1)**						
Sunflower	Wheat	2.72	2.87	2.84	2.81	13.7	N.S
Dry bean	Wheat	1.19	1.22	1.59	1.33	19.3	N.S
Corn	Wheat	9.33	9.48	10.07	9.63	7.0	N.S

*significant at P<0.05 and **significant at P<0.01

wheat yield after the dry bean was 2.78 tons/ha in zero tillage, 3.18 tons/ha in conventional and 2.67 tons/ha in beds planting, wheat yield after corn was obtained at 2.11 tons/ha in zero tillage, 2.93 tons/ha in conventional method and 1.83 tons/ha in bed planting. No statistically significant difference was found between the methods of planting (Figure 11 and Table 7).

There is no statistical difference in yield between conventional and zero tillage in the research. It is important to show that direct sowing of wheat is possible with pneumatic sowing in summer products (sunflower, bean, and corn) after wheat. Also, it was observed that the corn and sunflower had a more positive the effect on the yield of the wheat after it.

In the year 2006 (Set 2) the sunflower grain yield decreased was 2.45 tons/ha in zero tillage, 2.30 tons/ha in conventional and 2.34 tons/ha in beds planting, the dry bean yield decreased was 2.29 tons/ha in zero tillage, 2.01 tons/ha in conventional and 2.08 tons/ha in beds planting, corn forage biomass yield were also obtained at 8.59 tons/ha in zero tillage, 8.15 tons/ha in conventional method and 8.70 tons/ha in

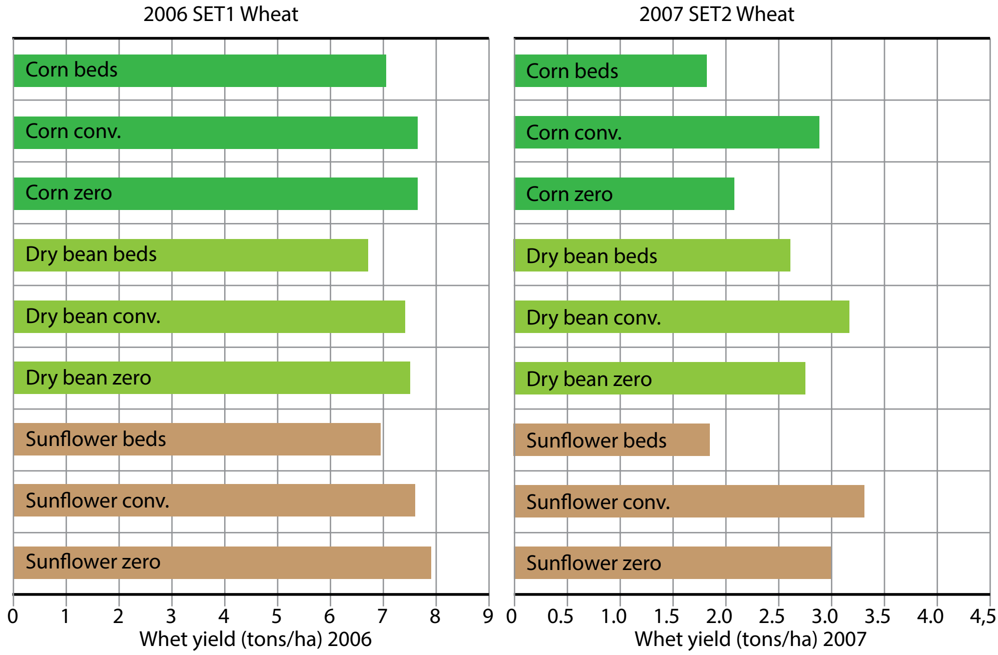


Figure 11. Effects of different soil tillage systems on the yield of winter wheat

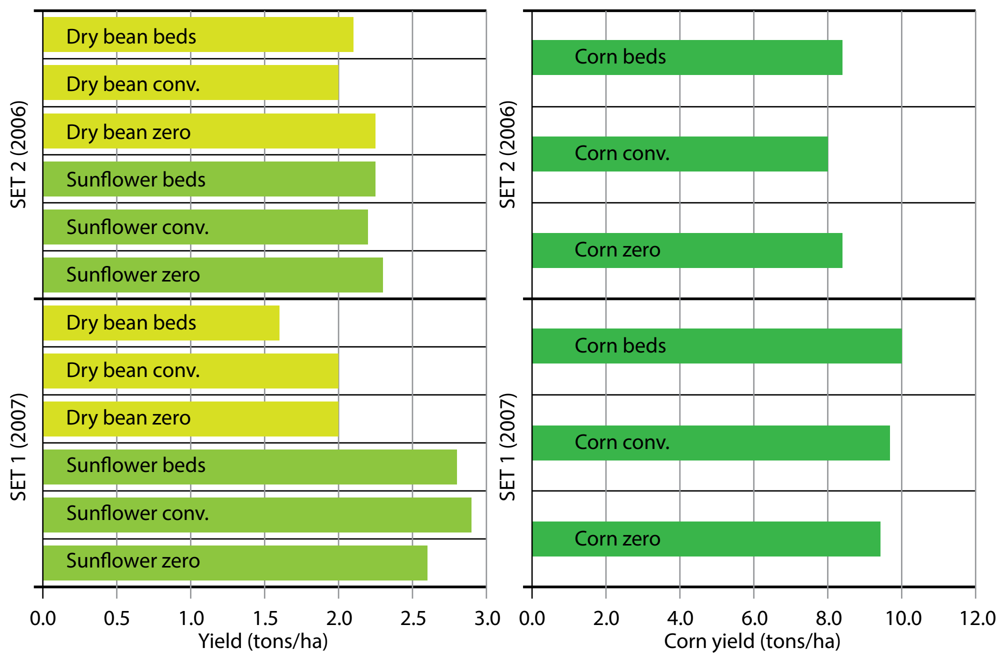


Figure 12. Effects of different soil tillage systems on the yield of corn, dry bean, and sunflower

bed planting. No statistically significant difference was found between the methods of planting (Figure 10 and Table 7).

In the case of 2007 (Set 1), the yield of sunflower seeds was 2.72 tons/ha in zero tillage, 2.87 tons/ha in conventional and 2.84 tons/ha in bed planting, the dry bean yield was 1.19 tons/ha in zero tillage, 1.22 tons/ha in conventional and 21.59 tons/ha in beds planting, corn forage biomass yield were measured at 9.33 tons/ha in zero tillage, 9.48 tons/ha in conventional method and 10.07 tons/ha in bed planting, (Figure 10 Table 7.) and no statistically significant difference was found between sowing methods.

According to these results; it is important that the planting of summer crops such as corn, beans, sunflower can be done without any soil tillage on the wheat.

After the harvest of wheat, the problem of weeds is increasing in the remaining field before the tillage in April. For this reason, 15–20 days after total herbicide application, zero tillage and bed planting is possible with pneumatic seeder (if the soil is too dry after irrigation and the soil pans are brought).

Discussion

The bed planting and furrow irrigation system practiced recently in increasing scale in some parts of the World, has been studied in Central Anatolia under irrigated wheat conditions since 2001. In this system, the beds are formed 70 cm bed spacing for 2-row sowing on top of beds. The most useful outcome expected from this study is information related to a more economic wheat farming through zero tillage and Bed Planting systems. These farming systems are more economical and environment-friendly. Another advantage of these two systems is the fact that they facilitate the early planting of spring-sown rotation crops following wheat. According to the results of two years, pneumatic seeder and sunflower, corn and bean plants can be zero tillage and bed planting sowing while the soil is moisture over the wheat stubble. At the same time, the findings indicate that total herbicide can be applied before sowing. It was observed that wheat yields, in which the bean is a better alternative than the sunflower and corn, is higher in conventional, zero tillage and bed planting methods.

It has been determined that there is a lot of problems in wheat cultivation after sunflower, bean and especially corn harvest, and more detailed researches are needed in this regard. After sunflower and corn harvesting, the soil was drier and cut, making it difficult to soil tillage the soil and wheat yields due to delayed corn harvest at the same time. For this reason, it is necessary to sowing the alternative plants after the harvesting and within the month of October. Because in Central Anatolia, if a late heading wheat variety is sowing in November, a yield loss of 30–40 percent is expected. For this reason, it is recommended for sowing early wheat varieties in late sowing and to increase the amount of seed by 20–30 kg/ha more.

There is a need to work on planting feet within the system of crop rotation. Mechanization problems have to be solved. There is a need to work on harms and struggle with weeds. Bromination problems in zero tillage plots have been observed in previous studies. Economics studies are needed. It is necessary to increase the amount of seed according to the norms recommended in zero tillage and bed planting sowing method. Silage corn can be preferred due to the late harvest of grain corn in Central Anatolian conditions. In zero tillage and bed planting treatments, weed infestation and field rodent damage have been observed in addition to mechanization problems. Stubble density at planting was highest in corn and sunflower.

References

Asadi M E, (2017). "Healthy Soils with conservation agriculture Systems" In collaboration with Saeedeh Sadeghi (MS), book Soil sciences graduated from Gorgan University of Agricultural Sciences, Natural Resources February (2017)

Erşahin S. (2001). Sustainability and Environmental Quality in Soil Management GOP Üniv..Z. F. Lecture Notes No:21.

Fischer R A, Sayre K, and Ortiz M I, (2005). The effect of bed planting on irrigated wheat yield as influenced by variety and row spacing. Page 1–11. Evaluation and performance of permanent bed cropping systems in Asia, Australia and Mexico edited by C.H. Roth, R.A. Fischer and C.A. Meisner ACIAR Proceedings No. 121 1–3 March.

Hobbs P R, Sayre K, and Gupta R. (2008) The role of conservation agriculture in sustainable agriculture Phil. Trans. R. Soc. B.363, 543–555.

Khorami S S, Kazemeini S A, Afzalinia S and Gathala M K (2018): Changes in Soil Properties and Productivity under Different Tillage Practices and Wheat Genotypes: A Short-Term Study in Iran. Sustainability 10, 3273; doi:10.3390/su10093273.

Sayre K, Limon A. and Govaerts B. (2005). Experiences with permanent bed planting systems CIMMYT, Mexico Page 12–25. Evaluation and performance of permanent bed cropping systems in Asia, Australia and Mexico edited by C.H. Roth, R.A. Fischer and C.A. Meisner ACIAR Proceedings No. 121 1–3 March.

Sayre K and Govaerts B. (2012). "The principles of conservation agriculture" Page 164–174. Wheat Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation. Edited by M. Reynolds, A. Pask, and D. Mullan; CIMMYT, Mexico.

Tanchandrphongs S and Dawidson J M, (1970). Bulk Density, Aggregate Stability, and Organic Matter Content as Influenced By Two Wheatland Soil Management Practices, Soil Sci. Soc. Amer. Proc. Vol:34, S:302–305.

Zhao X, Yuan G, Wang H, Lu D, Chen X and Zhou j (2019): Effects of Full Straw Incorporation on Soil Fertility and Crop Yield in Rice-Wheat Rotation for Silty Clay Loamy Cropland. Agronomy 2019, 9, 133; doi:10.3390/agronomy9030133.

Conservation technologies in modern agriculture

Buriev Salimjon[11]

Abstract

In the last decade, many countries of the world have switched to arable farming – to minimum surface cultivation at a depth of 5–7 cm and to cultivate crops without plowing, known as No-Till. However, these methods, without taking into account the soil-climatic and other conditions of certain territories, do not always give positive results. In 2016–2017, we conducted field experiments on the cultivation of a hybrid of corn Korasuv-350 AMB for grain after winter wheat against the background of zero technology in meadow soils of the Central Chirchik district of Tashkent region. It was established that despite a slight decrease in the yield of corn against the background of zero tillage, in general, the volume of production obtained per unit area is 25–30 percent higher compared to traditional methods.

Key words: zero tillage, corn, meadow soils, irrigation, productivity.

Introduction

Minimum tillage is a scientifically based tillage that provides a reduction in energy costs by reducing the number and depth of the treated field surface, as well as combining several operations and techniques in one working process. Soil processing technology is used when growing primarily row crops-corn, soybean, cotton, as well as wheat, sorghum and other crops. The first steps in this direction are taken by some developing countries.

In the past decade, arable land, cultivated using minimal and zero technology, the so-called No-Till, which first began to be used in Brazil in 1971, has been increasing from year to year abroad. Currently, in South America, Canada and the USA, up to 90 percent of the sown area of grain crops is cultivated using minimal technology, including zero till-up to 50–60 percent.

The system of zero tillage technology, also known as No-Till, is a modern farming system in which the soil is not cultivated and its surface is covered with specially ground plant residues – mulch. Since the topsoil does not loosen, such a farming system prevents water and wind erosion of the soil, and also saves water much better.

Materials and methods

Judging by the results of international experience, it is advisable to use zero tillage in arid zones, as well as on fields located on slopes, in humid climates, and also in areas where the traditional method of farming with disturbance of the surface layer is impossible or prohibited. For the successful application of zero technology, it is necessary to differentiate it depending on the soil and climatic conditions of the region, the availability of appropriate farm facilities and the material and technical base.

The results of published works indicate that crop yields under this system are often lower than when using existing methods of traditional farming. But with such tillage, significantly less labor and fuel are required. Zero soil cultivation technology is a new and complex farming system that requires special equipment and technology compliance and is by no means reduced to a simple rejection of plowing. A comparative analysis of the results of applying traditional technology and No-Till technology shows the best results in favor of the latter.

For Uzbekistan, agriculture is an essential part of the state's economy and makes a significant contribution to ensuring the food security of the population of the republic. The stable development of agriculture, the increase in agricultural production and the growth of the well-being of the population mainly depend on the condition and fertility of the soil. However, over the past decades, the land allotted for the cultivation of plants is increasingly subject to degradation. This in turn leads to a loss of fertility of agricultural land, and subsequently to a decrease in yield and production efficiency in general.

Land degradation is a direct result of irrational farming based on traditional tillage, as a result of which the fertile layer is subjected to intense mechanical stress. As a result of this process, the structure of the soil is seriously disrupted, and tangible harm is caused to the living organisms that inhabit the soil ecosystem. Arid conditions, complex terrain, differences in vertical zonality and the increasing impact of climate change over time will only exacerbate the situation. In this regard, it is necessary to take active measures to preserve the integrity of the soil cover, the accumulation of moisture and create optimal conditions for the life of soil organisms. These measures should include reducing the mechanical impact on the soil through direct sowing and zero tillage, protecting the surface of the soil, increasing the moisture and organic matter reserves by preserving the mulch cover, and also improving agricultural techniques for cultivating and introducing crop diversification. All of the above measures are the basis of the principles of conservation agriculture (CA) – a modern approach to managing agro-ecosystems in order to increase productivity and ensure their sustainability. The CA can become the basis for the future development of ecologically and economically sound crop cultivation, as well as help in solving problems of ensuring food security, optimizing livelihoods in rural areas and reducing energy costs, etc.

Results

Understanding the importance of this problem, in 2016–2017 we conducted field experiments on growing corn for grain after winter wheat against the background of zero technology on meadow soils of the Urta-Chirchik district of Tashkent region. After harvesting winter wheat on the ridges in the first ten days of July, direct corn sowing was carried out to a depth of 6–7 cm with a sowing rate of 23–25 kg/ha of the Korazuv-350 AMB hybrid corn. Corn is known to be very sensitive to nutrient deficiencies in the soil. Cultivated corn should receive an uninterrupted supply of nitrogen at all stages of growth up to the phase of grain formation. Nitrogen deficiency in corn plants in the early stages of growth significantly reduces grain yield. Young corn plants also require increased amounts of phosphorus. Therefore, nitrogen fertilizer is introduced during sowing of seeds along with phosphorus. In the experiment, the application rate of nitrogen and phosphorus, respectively, was 180–200 and 100 kg/ha. The first dressing – 30 days after sowing, and the second dressing – at inflorescence emerge. At the stage of development of 3–5 leaves, the field was treated with a herbicide to control weeds at a flow rate of 250–300 l/ha. It was found that herbicides reduce the weight of weeds by an average of 80–82 percent, which allows to do without operations such as post-emergence harrowing or a single interrow cultivation, as well as without weeding the weeds manually.

After harvesting winter wheat, pre-sowing irrigation was carried out with a water flow rate in the range of 400–500 m^3/ha, depending on the type and structure of the soil. It is established that for the rational use of irrigation water when cultivating corn against the background of zero tillage technology, as well as to maintain soil moisture during the growing season at a level of 70–75 percent of the field's moisture capacity, it is advisable to saturate the soil with moisture to a depth of 0.5–0.7 m. When cultivating corn to maintain soil moisture at a level of 70–75 percent of the field moisture capacity, it is recommended to irrigate 3–4 times with a total water flow of 3 000–3 200 m^3/ha. Studies have shown that cultivation using zero technology using CA techniques is guaranteed to reduce the total water consumption by 20–25 percent compared to traditional cultivation techniques. Corn for grain was harvested in the phase of full ripeness.

Conclusion

With zero tillage technology, yield was noticeably lower than with traditional tillage. Nevertheless, when corn is cultivated for grain against the background of zero tillage after winter wheat, farm incomes are significantly higher due to an increase in total production per unit area during the year.

References

FAO. Investing in Sustainable Crop Intensification: The Case for Soil Health // Report of the International Technical Workshop, FAO, Rome, July 2008. – Integrated Crop Management, 2008, Vol. 6, Rome.

FAO. Conservation agriculture in Central Asia: Status, Policy and Institutional Support, and Strategic Framework for its Promotion. – FAO-SEC, Ankara, Turkey, 2012.

Nurbekov, A., Akramkhanov A., Lamers J., Kassam A., Friedrich T., Gupta R., Muminjanov H., Karabayev M., Sydyk D., Turok J., Bekenov M., Conservation agriculture in Central Asia: Past and Future // Conservation agriculture: Global prospects and Challenges // Editors: Ram A Jat, Kanwar L Sahrawat and Amir Kassam. Conservation agriculture in Central Asia: Past and Future. – CABI, Wallingford, 2013. – pp. 223–248.

Nurbekov, A., Ziyadullaev Z., 2012. Adoption of no-till technology for sustainable agriculture in the drought-affected regions of Karakalpakistan. International Conference on improving soil fertility through adoption of resource saving technologies in agriculture. 5–6 December 2012, Tashkent, Uzbekistan. – pp. 101–105.

Nurbekov, A., Manual on conservation agriculture Practices in Uzbekistan. – Tashkent, Uzbekistan, 2008. – 40 с.

Нурбеков А., Кассам А., Сыдык Д., Зиядуллаев З., Джумшудов И., Муминджанов Х., Фейндель Д., Турок Й. Практика почвозащитного и ресурсосберегающего земледелия в Азербайджане, Казахстане и Узбекистане. Анкара, Туркия, 2016. – 24–26 с.

A soil-protective, resource-saving method of sowing corn on eroded soils and its effect on the physical properties of the soil

Bakhtiyor Abdullaev[12]

Abstract

The article presents data that this bed-furrow method of sowing corn with a single application of nitrogen fertilizers reduces the number of cultivations, has soil protection value, helps maintain soil fertility, reduces soil erosion, and increases yield. For the first time, for the conditions of irrigation-eroded soils of the Samarkand region, a method and norms for the application of nitrogen fertilizers were developed for bed-furrow sowing of corn.

Key words: physical properties of the soil, soil density, bed-furrow method of sowing, soil washout, irrigation soil erosion, nitrification inhibitors.

Introduction

Conservation agriculture has become very popular and very practical for farmers, and especially is widely distributed in the work of the FAO (A. Nurbekov, 2018). Soil compaction occurs under the influence of natural factors – rain, irrigation, especially in the absence of vegetation, gravity, as well as the mechanical impact of the undercarriage of tractors, combines, tillage machines, means for introducing organic and mineral fertilizers into the soil. As the capacity and mass of agricultural machinery increased, the negative aspects of soil tillage began to appear to a greater extent, the contradictions between its agrotechnical necessity and the negative impact on fertility increased, manifested, first of all, in the strengthening of the erosive state of the soil and its over-compaction to a greater depth. According to M.N. Zaslavsky (1979), minimal tillage on eroded soils is necessary to preserve the humus content and potential fertility.

Materials and methods of work

In our experiments, different methods of sowing corn on eroded soils were compared. It is known that the specifics of irrigated agriculture is the need for continuous cultivation of the topsoil after each irrigation. In maize farming, the soil is treated 3–5 times during the growing season. Processing includes the cultivation and cutting of irrigation furrows, simultaneously with the introduction of mineral fertilizers in the form of fertilizing. If we add to this plowing, grinding, harrowing and machine cleaning, then the number of passes of the unit along the same track increases significantly. Scientists note that after the tractor simultaneously passes through a moistened field, the topsoil is compacted to 1.52–1.60 g/cm, against 1.34 in the initial state. With the comb-furrow method of sowing corn and a single application of nitrogen fertilizers, the number of cultivations is reduced, which has soil protection value, helps to maintain soil fertility, reduces soil erosion, and increases yield.

The result of research

The data obtained as a result of studies with the dashed wide-row and new bed-furrow method of sowing corn indicate that when conducting inter-row cultivations after the first and second irrigation in versions with dashed sowing, the soil is compacted, by periods of 0.1–0.2 g/cm^3.

With the bed-furrow sowing method, it is not possible to conduct inter-row treatments, since the plants are located on the ridge, on the sides and at the bottom of the furrow. In connection with the transition to single-dose, sowing annual dose of nitrogen fertilizers at two depths and due to combining them with slow-growing fertilizer (IN), there is no need for feeding.

In the area where the main mass of roots is located, starting from a depth of 20–30 cm, there is a noticeable increase in soil bulk mass to 0.07 g/cm^3 after the first and to 0.15 g/cm^3 after the second watering with the dotted sowing method. At the end of the growing season, the difference is somewhat smoothed out and amounts to 0.07 g/cm^3.

The effect of aggregate passage on soil density increases at a depth of 50 cm of the layer, where it increases markedly over the years.

It is known that increasing the density of the addition of the arable horizon of the soil to 1.5 g/cm^3 causes not only a deterioration in its physical properties, but also inhibits the activity of microorganisms and sharply reduces the crop yield.

Many scientists have studied the problems of preventing soil erosion, these works are devoted to the specifics of the demonstration of irrigation erosion, the development of ways to increase fertility, optimize processing, identify the best furrow length and a stream of water at different slopes.

In our studies, sowing methods have a significant effect on the size of soil erosion during irrigation along furrows. The volume of solid soil runoff with waste water during the bed-furrow sowing method decreased, compared with the dotted one.

The increase in the difference in soil washout volume from the first to the third watering, in our opinion, is associated with the development of the root system of plants located on the bottom of the furrow during bed-furrow sowing.

Findings

Based on the above materials, it can be said that the practical value of this work lies in the fact that in conditions of soils subject to erosion, recommendations have been developed on the doses and timing of the application of nitrogen fertilizers in the bed-furrow method of sowing of corn.

The bed-furrow method of sowing corn is an effective means of protecting the soil from erosion, which allows to reduce runoff, loss of nutrients, compared with the dotted by 4–5 times, and also due to the rational use of the nutrition area, creates an opportunity to increase the density of plants, provides yield increase.

References

Абдуллаев Б.Н., Минимализация обработок и разовое внесение азотных удобрений в условиях эродированных почв. Автореферат кан. дисс. Самарканд – 1990 г.

Нурбеков А., Шаги почвозашитного земледелия в Ферганской долине. Информационный бюллютень №8. 01.01.2018 г. Земля энергия биоразнообразие.

Заславский М.Н., Эрозия почв. Мысл, 1979 г. – с. 244.

Yield of grain crops at minimal treatment of soil

G.O. Uzakov[13], U. Tilavov, A. Abduazimov, N. Khalilov[14]

Abstract

On the irrigated lands of Uzbekistan, the main precursor for crops is cotton. To avoid late sowing of winter wheat during irrigation, crops are used on row spacing of cotton. Improving physical and chemical properties is an important aspect for the production of agricultural products both using the traditional method and using the soil protection technology (SPT) method. Productivity of grain crops largely depends on the norm, timing and methods of sowing grain crops. Sowing with the help of a new type of Brazilian seeder model Fankhauser-2115 makes it possible to uniformly seeding seeds on the aisle of cotton. Due to this, a normal productive stalk per unit area is achieved than when planting seeds using a conventional SZU-3.6 grain seeder. In the early stages of sowing in various ways, the yield of winter wheat varieties was higher than in the middle and late sowing periods. In addition, fuel and lubricants and other costs are reduced, the level of profitability of grain production is increased. With late sowing, the growth and development of plants is delayed, and productivity is decreased.

Key words: Resource-saving technologies, methods, norms, sowing dates, after cereal crops, cotton aisle, productivity, seeders.

Introduction

Grain yields are increasing due to the creation and introduction of new varieties and the application of intensive grain production technology around the world. In recent years, resource-saving technologies have been used in many countries. The main purpose of resource-saving technologies is to increase the production of grain per unit area with minimal costs of fuel and lubricants, effectively use water resources and mineral fertilizers [1].

Soil is a limited natural resource on which human agricultural activities are carried out. Recently, there are processes of degradation and dehumidification under the influence of anthropogenic desertification, compaction, pollution and erosion. In the last 100 years alone, erosion has washed away about 50 percent of the topsoil, largely due to unsustainable agriculture associated with traditional soil management systems. [2]

The direct seeding method, which involves leaving the stubble of the previous crop on the soil surface, helps to control soil erosion and preserve our land resources indefinitely, as plant mulch protects the soil surface from strong winds and rains and prevents the loss of soil elements [3].

Improvement of physical and chemical properties is an important aspect for agricultural production using both the traditional method and the soil protection technology (SPT) method, but improvement of biological qualities is especially important for SPT, since the biological environment of the soil is formed mainly by the type and level of plowing. Soil treated with zero technology is generally wetter and less aerobic (oxygen exchange rate is lower) than its counterparts, especially in regions with humid climates [4].

Nitrogen released from the decomposition of plants and animal residues is an important factor for plant nutrition in SPT, worms, fungi and bacteria are involved in the decomposition process. The physical properties of the soil are an important factor in maintaining the productivity of the land. Deterioration of these qualities has significant consequences for the growth, yield and quality of crops regardless of the level of soil nutrients required for plants [5].

With a system of minimal cultivation and direct seeding, soil flora and fauna can create and maintain a porous soil structure. The flora and fauna of the soil decomposes the remains of plants and promotes fertility, nutrient metabolism, improves soil structure, water penetration, moisture retention, and soil aeration [6].

Cotton is the main precursor for grain crops in irrigated lands of Uzbekistan. In the southern regions, sowing is carried out after grain crops mainly in September, and sowing after or on cotton rows begins in early October.

Getting a high yield of winter wheat largely depends on the timing of sowing. In the Republic, the harvest of raw cotton is mostly completed on November 10–20; winter wheat sowing after November 10–20 usually gives low yields. To avoid late sowing of winter wheat during irrigation, crops are used on cotton aisle. The technology for preparing cotton aisles for sowing cereals differs from the traditional preparation of soil for sowing. When preparing cotton rows between crops for sowing with the SZU-3.6 seeder, the soil is cultivated only by a cultivator in two tracks, there is no plowing, chiseling, praying, and planning. When sowing wheat with the Fankhauser-2115 seeder, there is no tillage. Sowing is carried out in a direct way i.e. without tillage. At the same time, all expenses on soil treatment are excluded.

Sowing wheat with the Fankhauser-2115 seeder belongs to zero tillage. Therefore, when growing winter wheat with zero tillage, energy and resources are saved, and the cost of grain is also reduced than when sowing wheat after wheat.

Methodology

The experiments were carried out in 2015–2017 in the southern region of the republic on irrigation zones, light gray-earth soils of the Kashkadarya region. We studied the timing, methods and norms of sowing new varieties of winter wheat Yaksart, Gozgon and Bunyodkor with the help of a seeder of various grades (grain seeder SZU-3,6 and the Brazilian seeder Fankhauser-2115) on 17 cm cotton aisles. Before sowing by seeder SZU-3.6 soil was cultivated by a cultivator in two tracks. When sowing the Brazilian seeder Fankhauser-2115 sowing was carried out without tillage.

Soil, water and plant analyzes, as well as the technological quality of grain and flour, were determined in the laboratory of the Kashkadarya branch of the scientific-research institute of grain and leguminous crops using the methodology for the technological assessment of grain crops (1976).

Productivity by options was determined in 3 places from each plot of 1 m^2, as well as by direct combining. The resulting crop was transferred to 100 percent purity and 14 percent humidity. Mathematical processing was carried out according to the method of Dospekhov (1985).

Research results and discussion

Crop yield depends on the biological characteristics of the variety, weather conditions, daylight hours, water and nutrient regimes, predecessors, as well as on the applied agricultural measures. Various environmental factors and applied agricultural technology directly affect the productivity and quality of grain of winter wheat. When applying the optimal cultivation technology, taking into account the biological characteristics of the varieties, you can get the maximum yield with high grain quality. Applied agricultural technology must meet the requirements of each stage of plant organogenesis. The main methods of cultivation technology that affect the yield and quality of grain include timing, norms and methods of sowing.

Productivity is the total addition of plant productivity from a certain unit of area. If the number of plants per unit area is less, then the productivity per plant will be greater, but the overall yield will be low. With an increase in stalk per unit area, productivity per plant decreases, but productivity per unit area increases. With optimal stalk productivity, the yield is highest, and when increased from optimal stalk, productivity decreases on the contrary.

Some scholars point out that there is a direct relationship between yield, timing and method of sowing.

Along with the biological feature of the variety, the yield depends and changes on a number of other factors (soil and climatic conditions, light regime, methods and timing of sowing, on the predecessor, the depth of seed placement, nutrient and water regime).

The results of our research show that the yield of winter wheat depends not only on the methods and norms of sowing, but also directly depends on the timing of sowing. From the tabular material it is seen that in the early stages of sowing in various ways, the yield of winter wheat varieties was higher than in the middle and late sowing periods.

In terms of productivity, the highest results were observed for the options on cotton row-spacing sown with the Fankhauser-2115 seeders with a sowing rate of 6.0 million germinating seeds and with an early sowing period (67.0 c/ha).

The average yield of the studied varieties was, respectively, according to the sowing norms with the Fankhauser-2115 seeder after grain crops with an early sowing period ranged from 59.5 to 63.3 kg/ha, with the SZU-3.6 seeder from 55.3 to 59.0 kg/ha, and in the row-spacings of cotton with the Fankhauser-2115 seeder from 63.3 to 67.0 kg/ha, with the SZU-3.6 seeder from 58.9 to 62.4 kg/ha.

With a medium sowing period with different methods and sowing rates, depending on the biological characteristics of the varieties, the highest yields were observed for the options on cotton aisle sown with the Fankhauser-2115 seeder with a sowing rate of 6.0 million germinating seeds (58.8 c/ha).

Analysis of the study shows that with a delay in sowing dates, the yield for all options decreased. With a late sowing period, the average yield of the studied varieties was respectively according to the sowing norms with the Fankhauser-2115 seeder after crops of 35.6–38.5 kg/ha, with the SZU-3.6 seeder slightly higher than 43.7–47.8 kg/ha, and on the aisle of cotton, the Fankhauser-2115 seeder was 47.6–51.8 kg/ha, the SZU-3.6 seeder was 39.4–40.7 kg/ha. At the same time, the yield

Table 8. Dependence of winter wheat crop on norms, methods and sowing dates – 2015/2017

Options			Productivity, t/ha		
			Early period (October 10)	Medium period (October 20)	Late period (November 1)
After cereals	On the seeder Funkhauser 2115	5 million pcs	55,3	51,5	42,5
		5,5 million pcs	57,7	53,4	45,0
		6 million pcs	59,0	55,1	46,3
	On the seeder SZU-3.6	5 million pcs	59,5	54,4	44,8
		5,5 million pcs	62,2	56,0	46,6
		6 million pcs	63,3	57,8	48,7
Cotton Aisle	On the seeder Funkhauser 2115	5 million pcs	63,3	55,1	45,8
		5,5 million pcs	65,7	57,3	46,9
		6 million pcs	67,0	58,8	48,2
	On the seeder SZU-3.6	5 million pcs	58,9	51,8	38,3
		5,5 million pcs	60,9	53,5	40,1
		6 million pcs	62,4	55,7	41,6

Sx = 1,30 Sd = 1,84 HCP05 = 3,00

decreased in comparison with the early sowing period by 12.7–20.8 kg/ha, and with a medium sowing period by 8.4–14.1 kg/ha.

Results

Due to the uniform seed placement in the soil with the Fankhauser-2115 seeder, the number of plants and productive stems per unit area was 8–11 percent more than when sowing with the SZU-3.6 seeder. It was established that with a delay in the sowing period in all cases, the yield decreases. An early sowing period ensures the normal growth and development of plants, a high graininess of an ear and the formation of a high yield with good quality.

With late sowing, the growth and development of plants is delayed, and productivity decreases. With a late sowing period (November 20) after grain crops, as well as on cotton aisle, the maximum yield can be obtained with a sowing rate of 6 million germinating grains with the Fankhauser-2115 seeder.

References

Saturnino, H.M. and Landers, J.N. The environment and zero tillage APDC/FAO, 2002. – p 144.

Mirzajanov K. M. Soil erosion in arid zone in Uzbekistan. T. 1971. – p 40.

Bot A, Benites J. The importance of soil organic matter, key to drought-resistant soil and sustained food production. FAO Soils Bulletin 80. Rome (Italy): FAO, 2005. – p 45.

Nurbekov A., Suleimenov M., Friedrich T., Taher F., Ikramov R., Aibergenov B. Yield of winter wheat on zero processing depending on soil moisture and application of different doses of manure // No-Till and Fruit-Fundamentals of Agrarian Policy support of resource-saving agriculture for the intensification of sustainable production. sci. conf. 8–10 July. 2009. – Astana-Shortandy. – p 33–34.

Nurbekov A. Methods of application soil conservation and resource-saving technologies in agriculture in Uzbekistan. Tashkent. 2008. – p 9–11.

Donald C. Reicoski. Resource-saving technologies and protection of the environment/Resource-saving agriculture. – No. 1, 2008. – p 35–38.

Effect of tillage methods on productivity of double-cropped mungbean in Karakalpakstan

Nurbekov Aziz[15], Rukhangiz Nurbekova[16], Shukhrat Azizov[17]

Abstract

In the era of the Soviet Union, Autonomous Republic of Karakalpakstan of Uzbekistan specialized in rice production, and was one of the main rice-producing regions in the country. After 1991, specialization in Karakalpakstan did not change, and continued to be Uzbekistan's largest rice producing region. Because of these water allocation to Karakalpakstan was high, 12 km^3 annually. Double cropping or the addition of a second crop in the annual cropping system can address the above-mentioned challenges of food insecurity, degradation, resource scarcity and land reform. In the irrigated areas of Uzbekistan, farmers usually finish harvesting winter wheat and barley during the period mid-June through mid-July, and they undertake next planting of these winter cereals during the first fortnight of October. Thus, the land remained idle for more than three months after the wheat harvest, and efficient of the land could be made through double cropping for example with forage crops. Climatic conditions of the Uzbekistan allow the production of various kinds of crops and also it allows growing two crops per year. Multiple cropping (growing two or more crops in one year or a single growing season) offers a good opportunity to increase annual production. Multiple cropping is one of the most important modern agricultural developments for production intensification. In double-cropping, timing of planting of the second crop becomes limited along with pressures of harvesting of the mature crop on time.

Key words: Double-cropping, no-till, conventional till, variety, grain, yield and benefit.

Introduction

The recent introduction of new technology, such as the no-till system, offers an opportunity to increase double cropping in the irrigated conditions of Uzbekistan, and increase land use efficiency. Nowadays, fuel has become an expensive input for agricultural production and no longer is available in unlimited supply. By using no-till and multi-cropping technique, two crops can be planted with the use of the same fuel required for one conventional crop. Farmers and researchers agree that double cropping can increase grain or forage production in Karakalpakstan. Besides increased production, the overall cost of production will be reduced. Equipment under this method is used less frequently and labor requirements spread more evenly throughout the year.

Material and methods

The research on double cropping with mungbean varieties under no-till was initiated in the experimental site in Karakul settlement, Korauzak district, Karakalpakstan, in order to improve land use efficiency, save irrigation water, and reduce the cost of cultivation.

The experiment was carried-out in randomized complete block design with four replications. Plot size was 100 m^2 (20×5 m). The following treatments were tested within this research activity:

- Control – tillage 25–30 cm – Mungbean variety "Durdona".
- Control – tillage 25–30 cm – Mungbean variety "Marjon".
- Control – tillage 25–30 cm – Mungbean variety "Local".
- No-till – Mungbean variety "Durdona".
- No-till – Mungbean variety "Marjon".
- No-till – Mungbean variety "Local".

In KK, about 80 percent of the irrigated land is saline land including 48 percent with high salinity. At present, share of salinized irrigated areas accounts for 100 percent in Mo'ynak district and 95 percent in Shumanay district. The strong- and medium-saline areas increased for the last 24 years from 38.5 percent to 58.4 percent against a background of ineffectively open shallow drainage network. However, against a background of progressive deep under-drainage in Sirdarya province high- and medium-saline areas increased for the same period from 25.7 percent to 53.7 percent as well. Considering this, if appraisal for salinity is not made for crops with strong salt resistance, then salinization intensity and its damage would be catastrophically unpredictable for the crops with weak-and medium-salt resistance.

The climate of Karakalpakstan is classified as severe continental with hot summers and cold winters. The average summer temperatures is 30°C often surpass 45°C; the average winter temperature in January is about −5°C, with absolute minimum as low as −40°C. The annual long-term precipitation is 110 mm, distributed as 18 mm in fall (September-November), 60 mm in winter (December-March), 24 mm in spring (April-May), and 8 mm in summer (June-August).

Results

In double cropping system, decreasing tillage is very important due to the limited time for seedbed preparation and to keep the production cost low (Limon-Ortega *et al.*, 2002; Wilhelm *et al.*, 1986). It has become possible to grow two crops (cotton and winter wheat) by growing winter wheat in standing cotton, which provides higher net returns to the farmers than a single crop of cotton or winter wheat. Cotton-based systems are the major crop rotation systems in Uzbekistan (Conrad *et al.*, 2010). The first year results indicate that the double-cropped mungbean under direct seeding has germinated well and grain yield ranged between 250–596 kg ha^{-1}. A two-year yield data showed that mungbean variety "Durdona" had the highest yield under no-till method compared to other varieties and tillage methods, while variety "Marjon" had highest yield under conventional tillage in 2015 (Figure 13). This indicates that varieties had both positive and negative effect under different tillage methods.

Economic information on double-cropped no-till mungbean cultivation is not readily available for Uzbekistan. Therefore, recent introduction of new technology

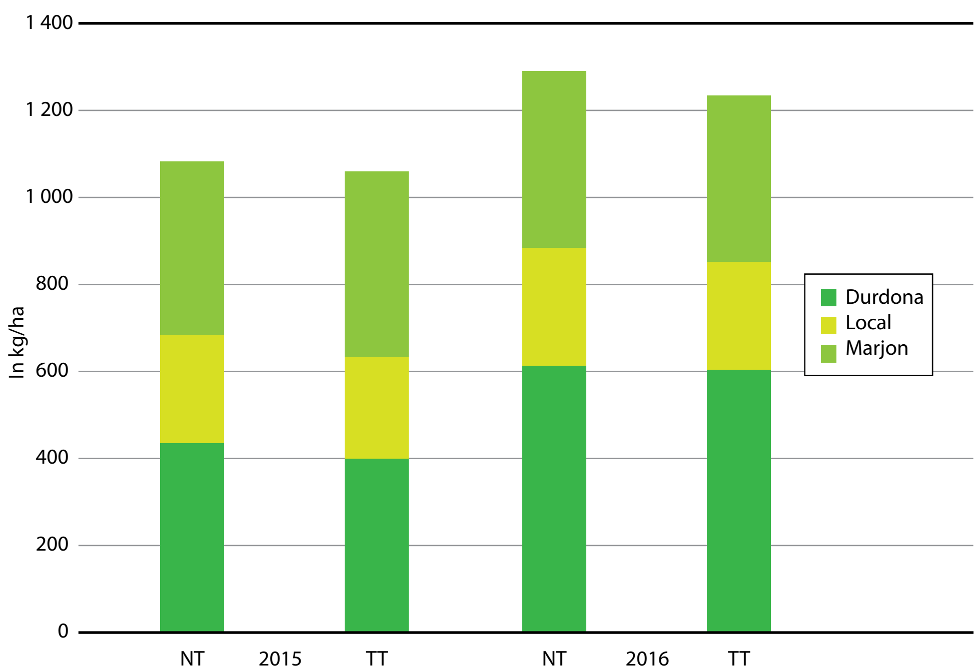


Figure 13. Double cropped mungbean grain yield affected by tillage method in Uzbekistan, kg ha^{-1}

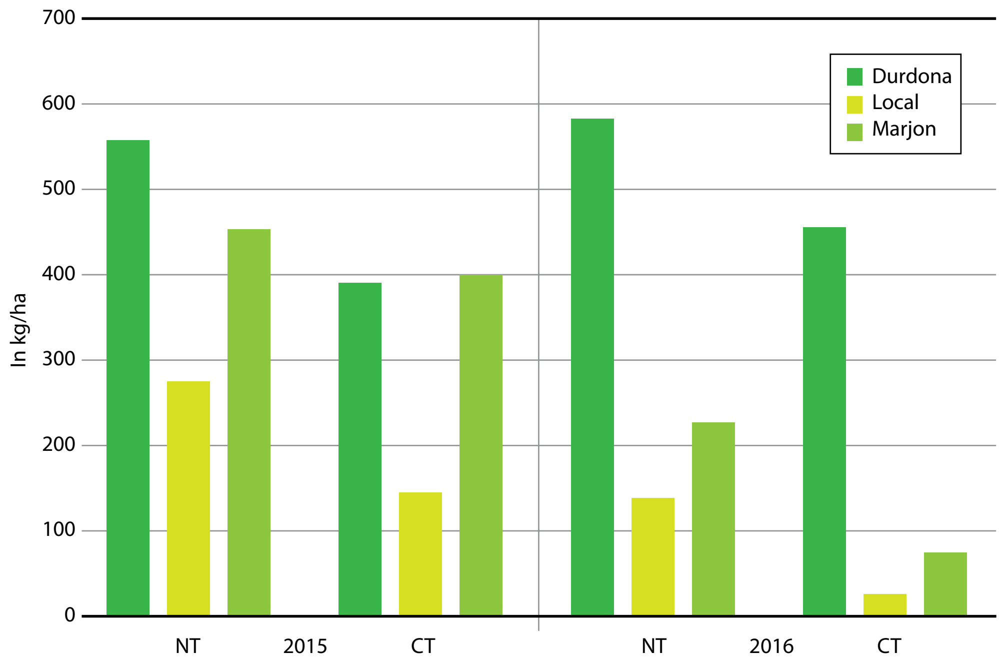


Figure 14. Benefit-cost ratio for double-cropped mungbean under no-till and conventional tillage in Uzbekistan

such as the no-till system offers an opportunity to increase farmers' income. No-till is significantly more profitable and efficient than conventional tillage for growing mungbean in north part of Uzbekistan. The net benefits from production of mungbean variety "Durdona" under no-till (NT) and conventional tillage (CT) were USD 327/ha^{-1} and USD 162/ha^{-1} respectively, which shows that returns under no-till is almost double higher compare to the conventional method (Figure 14).

Conclusion

Mungbean can be double-cropped after the winter wheat harvest under no-till and conventional tillage. The mungbean harvest provided 20 percent yield advantage after the no-till wheat, which is a very significant difference. The results have to be considered as a preliminary. More detailed studies of the factors influencing farmers' choice and preferences are required. The results can be used to identify suitable varieties for no-till planting in Karakalpakstan. Consultations with the neighbor farmers around project demonstration site showed that farmers would be willing to introduce no-till practices in their farmer households.

Reference

Limon-Ortega, A., K.D. Sayer, R.A. Drijber and C.A. Francis, Soil attributes in a furrow- irrigated bed planting system in northwest Mexico. // Soil Tillage Res. – 2002, V. 63, – P. 123–32.

Wilhelm, W.W.J., W. Doran and J.F. Power. Maize and soybean yield response to crop residue management under no tillage production systems. //Agron. Journal – 1986, V. 78, – P. 184

Conrad C, Fritsch S, Zeidler J, Rücker G and Dech S Per-field irrigated crop classification in arid Central Asia using SPOT and ASTER data.// Remote – 2010.

Effects of tillage methods on productivity of crops in Karakalpakstan

Nurbekov Aziz[18], Rukhangiz Nurbekova[19], Shukhrat Azizov[20]

Abstract

*Conservation agriculture practices greatly influence the environment on a positive way. Crop rotation is one of main the principles of CA, while short-term cereal-legume crop rotation system is good for farmers and good for the environment as well, and also have a great potential to increase agricultural production through implementation of no-till practices. Additionally, short-term crop rotation system can improve soil quality by increasing soil organic matter levels in the upper layers of the soil. Within a crop rotation, different root systems influence different soil horizons and improve the efficiency of the soil nutrient use. In general, the soil structure becomes more stable (Bot and Benites 2005; Suleymenov and Akshalov 2009). The experiment was conducted with the use of randomized complete block design with three replications. Plot area is 100 m^2 (20*5). Analysis of variance (ANOVA) was used to determine the treatment and forage yield effect. Crop production under no-till method had a little higher or similar yield compared to the crop yield under conventional tillage. Maximum forage yield of 16 340 kg ha^{-1} was recorded under no-till pearl millet in 2015, while minimum forage yield, 1 596 kg ha^{-1}, was produced by forage pea conventional tillage also in 2015. The results show that the introduction of conservation agriculture as a no-till forage crop production will help livestock producers to have access to low-cost forage resources and thus improve the efficiency of livestock production in Uzbekistan, and perhaps in other Central Asian countries as well. This beneficial aspect of crop rotation with integration of livestock sector should be further investigated in the Aral Sea basin.*

Key words: Crop rotation, no-till, grain yield, cost benefit analysis.

Introduction

Crop rotation is an integral part of the crop production system. The greatest benefit of a good crop rotation is increased yields and improved soil fertility. A well-planned crop rotation will help in insect and disease control, and will help in maintaining or improving soil structure and organic matter levels. A well-planned crop-rotation system under conservation agriculture can help producers avoid many of the problems associated with traditional tillage such as increased perennial weeds, plant diseases, insects, etc. Using a variety of crops, we can reduce weed pressures, spread the workload, reduce and combat soil erosion. Legume crops in the rotation have become more valuable with the increased cost of nitrogen due to their nitrogen fixation capacity. Research and experience have proved that a good crop rotation will ensure more consistent yield and increase profit potential.

Materials and methods

A cereal-legume crop rotation experiment initiated in 2015 in Shakhob farm, Korauzak district, Karakalpakstan. Within this study five forage crops, received from the germplasm collection of ICRISAT-ICARDA and collected in Uzbekistan, Kazakhstan and Tajikistan, have been evaluated for dual purposes under no-till and conventional tillage (dry fodder and grain) to enhance fodder availability during winter season in Karakul demonstration site, Korauzak district in Karakalpakstan. The experiment was conducted with the use of randomized complete block design with three replications. Plot area is 100 m^2 (20*5). Analysis of variance (ANOVA) used to determine treatment and forage yield effect. Proposed models for crop rotation are as follows:

- No-till – sorghum, maize, pearl millet, Sudan grass and field pea.
- Traditional tillage – sorghum, maize, pearl millet, Sudan grass and field pea.

The soils are sierozem, gray-brown, brown desert, takyr-like, and in the irrigated area -meadow-marshy, mostly saline with salt amount of 33 to 325 t ha^{-1} in 2 m layer and humus content of 0.609 to 1.156 percent in the cultivated layer. The soil of experimental site is rather dense with the bulk density fluctuating between 1.4 and 1.6 g cm^3. The highest bulk density was noted in the depth of 20–40 cm. All soil parameters were analyzed by the method developed in Uzbek Research Institute of Cotton (UzRIC, 1973). Over the past 12 years, more than 50 percent of fields in the whole Qorao'zak district have been ranked as low to very low in P_2O_5, K_2O and humus content.

Qorao'zak's climate is classified as severe continental with hot summers and cool winters. Summer temperatures are often surpass 45°C; winter temperature in January on average is about −8°C, with absolute minimum as low as −40°C. According to the data of the Karakalpak Research Institute of Crop and Land Management (KRICLM) located in Qorao'zak, the annual long-term precipitation is 110 mm, distributed as 18 mm in fall (September–November), 60 mm in winter (December–March), 24 mm in spring (April–May) and 8 mm in summer (June-August).

Results

There are few number of experiments conducted to study the role of crop rotation in weed suppression under conventional agriculture systems with herbicides. They studied the impact of different type of herbicide used, rather than other factors associated with crop rotation. Liebman and Gallandt (1997) reported that rotation without herbicides have generally more diverse systems with lower density of problem weeds but a greater diversity of weed species (Lovett Doust *et al.*, 1985). This is reasonable, since the variation in cultural practices during the rotation will tend to disrupt the life cycle of each particular weed species but create niches for a greater variety of species.

Crop rotation is the one of the main principles of conservation agriculture. Short-term cereal-legume crop rotation system have a great potential to increase agricultural production through implementation of no-till practices. Some newly introduced forage crops are performed well under both no-till and conventional method in spite of serious drought and salinity in the experimental site.

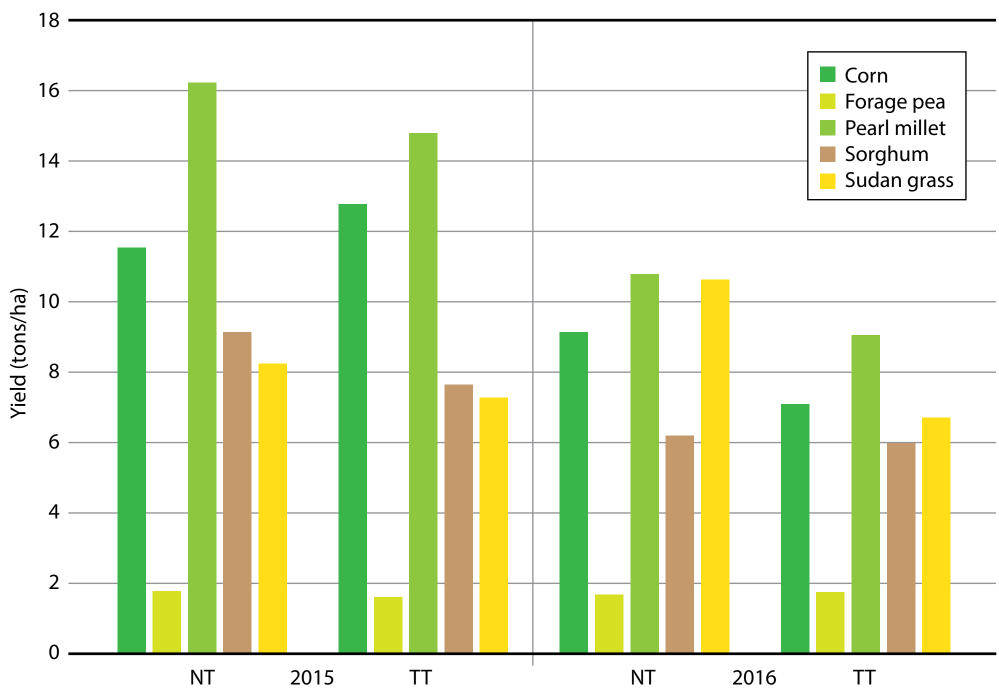


Figure 15. Effect of tillage method on productivity of different forage crops

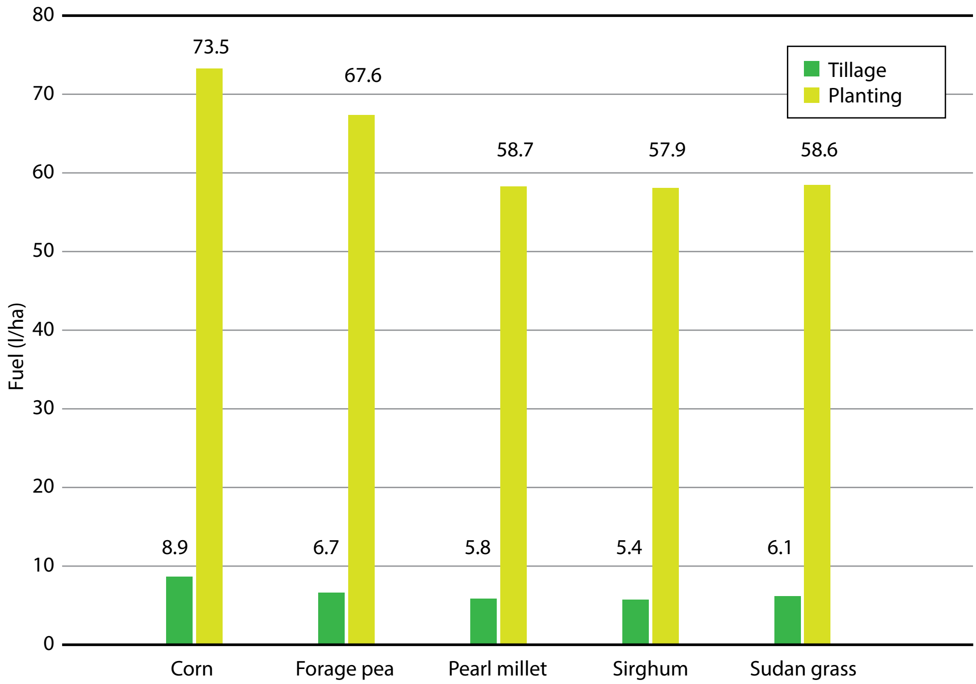


Figure 16. Spent fuel for tillage and planting, l/ha.

Crop production under no-till method had a little higher or similar yield compared to the crop yield under conventional tillage (Figure 15). Maximum forage yield of 16 340 kg ha^{-1} was recorded under no-till pearl millet in 2015 while minimum forage yield, 1 596 kg ha^{-1}, was produced by forage pea conventional tillage also in 2015. However, no-till method clearly demonstrated advantages in terms of conservation of energy and labor resources (Figure 16). Farmers in Uzbekistan has already adopted alternative ways of decreasing fuel consumption due to its high price. Cost benefit analysis of tested forage crops under different tillage methods in drought and salt affected regions of Aral Sea basin was conducted to estimate economic returns of tested tillage methods for forage crops production. The highest profit was recorded under conventional tillage of maize – USD 1 098.64 ha^{-1} as corn had highest yield in 2015, while negative profit was under conventional tillage for Forage pea – USD 14.84 ha^{-1} (Figure 17).

Conclusions

The results obtained in this experiment for different methods of forage crops cultivation indicate that tillage reduction in surface irrigated production systems reverberate in the same positive way in terms of production profitability and

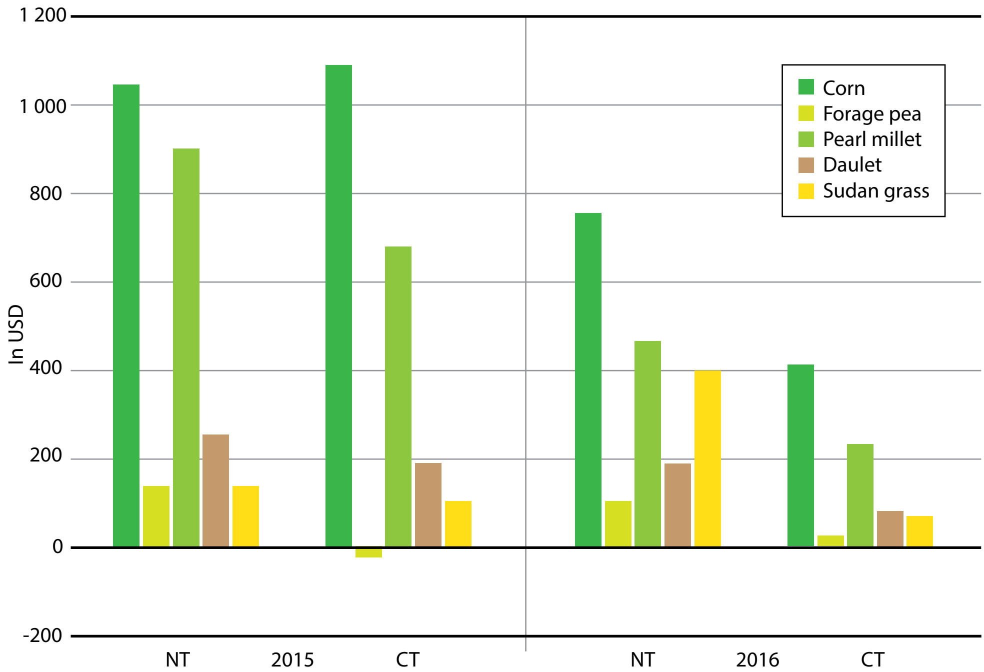


Figure 17. Cost-benefits of different forage crops under no-till and conventional till.

sustainability of crop production. The new forage crops under no-till practices can help to improve soil fertility and increase crop productivity. And developed crop rotation schemes including forage crops were recommended to livestock feeding during the winter period. The results show that introduction of conservation agriculture as a no-till forage crop production will help livestock producers to have access to low-cost forage resources and thus improve the efficiency of livestock production in Uzbekistan, and perhaps in other Central Asian countries as well. This beneficial aspect of crop rotation with integration of livestock sector should be further investigated in the Aral Sea basin.

Reference

Bot, A. and J. Benites. The importance of soil organic matter: the key to drought resistant soil, sustained food and production. FAO Soils Bulletin – 2005, No.80. http://www.fao.org/docrep/009/a0100e/a0100e00.htm.

Suleymenov M.K., Akshalov K.A. (2009). Vzaimodeystviye sevooborota i urovnya agrotekhniki vozdelivaniya polevikh kultur// Nou-till i plodosmen-osnova agrarnoy politiki poddarzhki resursosberegayuĭego zemledeliya dlya intensifikatsii ustoychivogo proizvodstva. Mezhdunarodnaya konferentsiya, 8–10 iyulya 2009 goda. Astana-Shortandy. – p. 252–258.

Liebman, M., and E. R. Gallandt. Many little hammers: Ecological management of crop-weed interactions.// In Agricultural Ecology, L. E. Jackson, ed., – 1997, – p. 291–343. San Diego, CA: Academic Press.

Lovett Doust, L., A. MacKinnon, and J. Lovett Doust. Biology of Canadian weeds. 71. Oxalis stricta L., O. maizeiculata L., O. dillenii Jacq. ssp. dillenii and O. dillenii Jacq. ssp. filipes (Small) Eiten. //Canadian Journal of Plant Science – 1985, No. 65, – p. 691–709.

Conservation agriculture: making sustainable agriculture real in Uzbekistan

Aziz Nurbekov[21], Emilio J. Gonzalez-Sanchez[22], Hafiz Muminjanov[23]

Abstract

The individual conservation agriculture principles have been practiced by farmers for a long time. What is unique about the modern concept of conservation agriculture is the conjunction of all three principles that are applied simultaneously through locally devised and tested practices. For production intensification, these core conservation agriculture practices need to be strengthened by additional best management practices, particularly: (i) use of well-adapted good quality seeds; (ii) enhanced crop nutrition, based on healthy soils; (iii) integrated management of pests, diseases and weeds; and (iv) efficient water management.

Conservation agriculture is considered very suitable for all major farming systems of Central Asia, including the irrigated fields of wheat, rice and cotton of Uzbekistan. State policies should help in the promotion of conservation agriculture together with the implementation of demonstration projects that evidence the suitability of conservation agriculture at local level.

Key words: no-tillage; groundcovers; environment; benefits

Introduction

Ancient cultures based their agriculture on sowing on virgin soil with sticks or other pointed elements to make small holes to place seeds (Derpsch, 1998). For centuries, the soil disturbance by sowing was minimal, without producing soil losses by preparatory tasks. In the 20th century, the conventional soil management system turned to tillage. But conventional tillage-based agriculture is incapable to provide many of the environmental ecosystem services because of its high and externalities as well as its inability to serve the needs of resource-poor farmers (Kassam *et al.*, 2009). Soil tillage affects negatively soil structure and soil organic matter as well as the associated soil life and biodiversity, and many of the soil-mediated ecosystem functions that provide, regulate and protect environmental services (Montgomery, 2007). Conversely, conservation agriculture (CA) spearheads an alternative agro-ecological paradigm that is making an increasing contribution to sustainable production intensification in many regions of the world.

A brief explanation of CA principles and the benefits that CA could bring to Uzbekistan are revised in this short communication.

Principles of conservation agriculture

Conservation agriculture benefits are based in the application of the three linked principles (FAO, 2017):

- Minimizing soil disturbance by mechanical tillage and thus seeding directly into untilled soil, and keeping soil disturbance from cultural operations to the minimum possible.
- Maintaining year-round organic cover over the soil, including specially introduced cover crops and intercrops and/or the mulch provided by retained residues from the previous crop.
- Diversifying crop rotations, sequences and associations, adapted to local environmental conditions, and including appropriate nitrogen fixing legumes; such rotations contribute to maintaining biodiversity above and in the soil, contribute nitrogen to the soil/plant system, and help avoid build-up of pest populations.

The individual CA principles have been practiced by farmers for a long time (Derpsch, 2004). What is unique about the modern concept of CA is the conjunction of all three principles that are applied simultaneously through locally devised and tested practices. For production intensification, these core CA practices need to be strengthened by additional best management practices, particularly: (i) use of well-adapted good quality seeds; (ii) enhanced crop nutrition, based on healthy soils; (iii) integrated management of pests, diseases and weeds; and (iv) efficient water management.

Since the main technical basis of the CA is the maintenance of groundcover, which reduces soil erosion and feeds it from organic matter it is necessary to discard techniques that are based on the soil tillage to prepare the seedbed. It is therefore very important to know what practices meet these requirements and, therefore, can be included in the CA. This is particularly relevant at times when we have to respond to global challenges such as climate change, the fight against desertification and soil degradation, and the preservation and improvement of water and biodiversity. The combination of the three pillars of CA can provide ecosystem with services needed to improve the current situation.

The lack of terminology in some cases, or the laxity in precision when identifying techniques, lead to farms where the depth of moldboard plough is 15 cm, instead of the traditional 20 cm or more, which is presented as suitable equipment for soil conservation and minimum tillage. Also, equipment that prepares the seedbed in a single pass over the field by plowing the soil in a conventional manner, is shown as no-till equipment (Gonzalez-Sanchez *et al.*, 2015). Table 9 shows several common techniques and their synonyms with an indication of whether they can be considered as eligible for CA.

While, nowadays, the agri-environmental benefits of no-tillage and groundcovers for permanent crops are widely recognized, many issues lie at the heart of the minimum tillage concept. The principle of minimum soil disturbance is sometimes misunderstood by minimum tillage. The soil cover principle is not possible to be met by minimum tillage, since tillage greatly affects the maintenance of the stubble. In addition, ploughing passes increase the groundcover loss. For example, moldboard plough, used in conventional agriculture, buries between 90–100 percent of stubble. The chisel plough, common ly known as chisel, is a primary type plough that is used in minimum tillage, and in a single pass buries about 50 percent of the groundcover. As it is not possible to make the sowing bed with a single primary tillage pass, minimum tillage requires the secondary tillage passes (between 2 and 4 or more) which greatly difficult to keep at least 30 percent of the minimum residue on the soil.

Key benefits of conservation agriculture

Sustainable crop production intensification based on CA is the combination of all improved practices applied in a timely and efficient manner. They offer farmers

Table 9. Agricultural practices, their synonyms and eligibility within conservation agriculture.

Crops	Technique	Synonyms	CA?	Observations
Annual	No-tillage	No tilling	Yes	Normally more than 30 percent of the surface is covered with crop residues after sowing.
		Zero tillage	Yes	
	Minimum tillage	Reduced tillage	No	The minimum tillage usually includes 3 or more plow passes, which do not allow to leave more than 30 percent of the crop residues.
	Strip-till		Yes	Shallow tillage done only in the rows of planting. It is used on coarse grain crops (corn, sunflower,…).
Permanent	Goundcovers		Yes	More than 30 percent of the soil is covered by cover crops.

Source: Gonzalez-Sanchez *et al.*, 2015

Figure 18. Principles of conservation agriculture

many possible combinations of practices to choose from and adapt, according to their local production conditions and constraints. The relationship between components of CA and desired soil and agro-ecosystem conditions are listed in Table 10. For example, many of the benefits that are 'ticked' in the second column under the no-till component and in the third column under the mulch cover component are not necessarily possible under tillage agriculture.

Over the past 40 years, empirical and scientific evidence from different parts of the world in the tropical, sub-tropical and temperate regions has been accumulating to show that CA principles, translated into locally devised practices to address prevailing ecological and socio-economic constraints and opportunities, can work successfully to provide a range of productivity, socio-economic and environmental benefits to the producers and the society at large (Kassam *et al.*, 2012). This is also true for Uzbekistan (FAO, 2009; Nurbekov *et al.*, 2008).

Not only CA has benefits for the environment, but also for the farmers. Yield differences resulting from improved soil moisture and nutrient availability have been reported in the range of 20–120 percent and more between CA systems and tillage

Table 10. Agro-ecosystem service features in relation to component practices of conservation agriculture applied simultaneously with good crop and cropping system management for intensification.

System component relevant features of agro-ecosystem	No tillage (minimal or no soil disturbance)	Mulch cover (crop residues cover-crops, green manures)	Crop rotation (for safety biodiversity, profit, etc.)
Simulate optimum 'forest-floor' conditions	√	√	
Reduce evaporative loss of moisture from soil surface	√	√	
Reduce evaporative loss from soil upper soil layers	√	√	
Minimize oxidation of soil organic matter, CO_2 loss	√		
Minimize compactive impacts by intense rainfall, passage of feet, machinery	√	√	
Minimize temperature fluctuations at soil surface	√	√	
Maintain regular supply of organic matter as substrate for soil organisms' activity	√	√	√
Increase, maintain nitrogen levels in root-zone	√	√	√
Increase CEC of root-zone	√	√	√
Maximize rain infiltrations, minimize runoff	√	√	
Minimize soil loss in runoff, wind	√	√	
Permit, maintain natural layering of soil horizons by actions of soil biota	√	√	
Minimize weeds	√	√	√
Increase rate of biomass production	√	√	√
Speed soil-porosity's recuperation by soil biota	√	√	√
Reduce labor input	√	√	
Reduce fuel-energy input	√		√
Recycle nutrients	√	√	√
Reduce pest-pressure of pathogens			√
Re-build damaged soil conditions and dynamics	√	√	√
Pollination services	√	√	√

Source: Kassam *et al.*, 2012

Table 11. Comparison of different agricultural practices regarding environmental problems.

Crops	Intensity of environmental benefit regarding environmental problems							
	Soil management	Erosion	Soil organic matter	Compaction	Climate change mitigation	Biodiversity	Water quality	Safety of plant protection products application
Annual	CT*	+	+	++	-	-	+	+
	MT	+	+	++	-	++	++	++
	DS	++++	++++	++++	++++	+++	++++	++++
	DS+GC	+++++	+++++	+++++	+++++	+++++	+++++	+++++
Permanent	GC 30 percent	++	++	++	++	++	++	+++
	GC 60 percent	+++	+++	+++	+++	+++	+++	++++
	GC 90 percent	+++++	++++	+++++	+++++	+++++	+++++	+++++

Abbreviations: CT: Conventional tillage; GC: Groundcovers; DS: Direct Seeding; MT: minimum tillage. GC 30 percent: Groundcovers present in 30 percent of the surface between the rows of trees; GC 60 percent: idem 60 percent; GC 90 percent: idem 90 percent. Effect on the environment: + slightly positive; +++++ very positive; - negative or indifferent.

Source: Gonzalez-Sanchez *et al.*, 2015

systems in the dry climates in different continents (Mrabet, 2000; 2002; Crabtree, 2010; Fernández-Ugalde *et al.*, 2009; Piggin *et al.*, 2011).

Improvements in the soil's porosity under CA are thought to have two effects: a greater proportion of the incident rainfall enters into the soil; and the better distribution of pore-spaces of optimum sizes results in a greater proportion of the received water being held at plant-available tensions (Shaxson, 2006). Thus, after the onset of a rainless period, the plants can continue growth towards harvest – for longer than would previously been the case – before the plant-available soil water is exhausted. Also, the combination of improved porosity and the lowering of evaporation due the soil cover serves to buffer the plants from dry spells that frequently occur during the rainy season in the dry Mediterranean-type climate. In western Australia, Crabtree (2010) reports that CA farmers regularly state that their water use efficiency has nearly doubled after 10 years of no-till. In addition, increased quantities of soil organic matter result in improved availability of plant nutrients, and duration of their release into the soil water. Thus, the availability of both water and plant nutrients is extended together.

Machinery and fuel costs are the most important cost item for mechanized producers and so the impact of CA on these expenditure items is critical. Most analyses of mechanized production suggest that CA reduces energy and machinery costs and improves energy efficiency and profit (e.g., Crabtree, 2010; Piggin *et al.*, 2011). CA systems require much less input of energy per unit area, per unit output, and lower depreciation rates of equipment. Over time, less fertilizer is required for the same output. Long-term research and practice have shown that after many years of CA, the soil has a higher amount of biological nitrogen and a greater ability to release nitrogen than a tilled soil has (Lafond *et al.*, 2008). Better soil protection by mulch cover minimizes both runoff volumes and the scouring of topsoil, carrying with it seeds and fertilizers, representing waste and unnecessary cost. Production costs are thus lower, thereby increasing profit margins as well as lessening emissions from tractor fuel. CA systems are less vulnerable to drought because of better soil and plant conditions, and organic soil cover, provide greater biotic diversity of potential predators on pests and diseases, while crop rotations break insect pest and pathogen build-ups. Here, much of the cost of avoiding or controlling significant pest attacks is diminished because of it being undertaken by healthier plants, breaks in pest life cycles and natural predators, and allelochemicals (Settle and Whitten, 2000; Blank, 2008; Wolfarth, 2011).

Research reported from long-term CA trials in the Canadian Prairies which have biophysical similarities to continental dry climates in Central Asia has shown that crop rotation and short-term green manure cover crops during the summer fallow period can reduce the cost of herbicides drastically, due to reduction in weed infestation over time, although there can be a shift towards more perennial weeds (Blackshaw *et al.*, 2007; Harker and Blackshaw, 2009). Similar studies conducted in northern Kazakhstan have shown that reducing and gradually eliminating summer fallow with legume cover crops is feasible (Suleimenov and Akshalov, 2006).

The economic benefits for farmers who have adopted CA have been striking. According to Crabtree (2010), crop production in western Australia has lifted 30–50 percent since the widespread adoption of no-tillage systems. Without the adoption of no-till farming many farmers could not have survived the recent long string of droughts. Effects of CA have been shown to be cumulative over space, and can accumulate over time from degraded condition to improved stabilized condition, with yields and income rising over time, as in this example of mechanized wheat production under CA in the dryland conditions in northern Kazakhstan. Analysis of historical data over 14 years by Fileccia (2009) of the increase in wheat yields and income benefits after changing from conventional tillage to no-till agriculture shows an internal rate of return to investment (IRR) of 28 percent. In a wheat-sunflower crop rotation in southern Spain, González-Sánchez *et al.* (2010) reported € 234.82 extra benefits for no-tillage farms in comparison to the conventional system based on soil tillage, due to higher yields, less costs and public agri-environmental subsidies.

Conclusions

The adoption of CA in many parts of the world has been driven by necessity. In rainfed areas, crop cultivation depends directly on rainfall and, therefore, it is vulnerable to moisture loss of the soil. In irrigated crops, a better water balance result in significant water savings. This is the case for many central Asian countries. Good examples in the region comes from Kazakhstan, where CA has showed that zero tillage and crop rotation, have the potential to produce higher yields of wheat and reduce labour costs and gas compared to conventional tillage farming. Conservation agriculture is considered very suitable for all major farming systems of Central Asia, including the irrigated fields of wheat, rice and cotton of Uzbekistan. State policies should help in the promotion of CA together with the implementation of demonstration projects that evidence the suitability of CA at local level.

Acknowledgment

Conservation agriculture is being promoted by FAO in Uzbekistan in the framework of the project Demonstration of Diversification and Sustainable Crop Production Intensification (FAO/TCP/3601), which contribution is considered very sensible.

References

Blackshaw, R. E., Harker, K.N., O'Donovan, J.T., Beckie, H.J., Smith E.G., 2007. Ongoing Development of Integrated Weed Management Systems on the Canadian Prairies. Weed Science 56(1), 146–150.

Blank, D., 2008. A fresh look at life beneath the surface, in: Goddard, T., Zoebisch, M., Gan, Y., Ellis, W., Watson, A., Sombatpanit, S. (eds.), No-Till Farming Systems. pp. 73–81. Bangkok: World Association of Soil and Water Conservation, Special Publication No. 3, WASWC, Bangkok, 540 pp.

Crabtree, B., 2010. Search for Sustainability with No-Till Bill in Dryland Agriculture. Crabtree Agricultural Consulting, Australia. 204 pp.

Derpsch, R., 2004. History of crop production, with and without tillage. Leading Edge 3(1): 150–154.

FAO, 2017. Conservation agriculture. www.fao.org/ca.

FAO, 2009. Conservation agriculture in Uzbekistan. Crop and Grassland Service Working Paper 2, FAO, Rome.

Fernández-Ugalde, O., Virto, I., Bescansa, P., Imaz, M.J., Enrique, A., Karlen, D.L., 2009. No-tillage improvement of soil physical quality in calcareous, degradation-prone, semiarid soils. Soil and Tillage Res. 106, 29–35.

Fileccia, T., 2009. Conservation agriculture and food security in Kazakhstan. Working Paper, Plant production and Protection Division. FAO, Rome.

González Sánchez, E., Pérez García, J.J., Gómez Ariza, M., Márquez García, F., Veroz González, O., 2010. Sistemas agrarios sostenibles económicamente: el caso de la siembra directa. Vida Rural. 312, 24–27.

Gonzalez-Sanchez, E.J., Veroz-Gonzalez, O., Blanco-Roldan, G.L., Marquez-Garcia, F., Carbonell-Bojollo, R., 2015. A renewed view of conservation agriculture and its evolution over the last decade in Spain. Soil and Tillage Research, 146 (PB), pp. 204–212.

Harker, K.N., Blackshaw, R.E., 2009. Integrated cropping systems for weed management. Prairie Soils Crops J. 2, 52–63.

Kassam, A.H., Friedrich, T., Shaxson, F., Jules, P., 2009. The spread of Conservation agriculture: Justification, sustainability and uptake. International Journal of Agriculture Sustainability 7(4), 292–320

Kassam, A., Friedrich, T., Derpsch, R., Lahmar, R., Mrabet, R., Basch, G., González-Sánchez, E.J., Serraj, R., 2012. Conservation agriculture in the dry Mediterranean climate. Field Crop Res 132, 7–17.

Lafond, G.P., Walley, H., Schoenau, J., May, W.E., Holzafel, C.B., McKell, J., Halford, J., 2008. Long-term vs. short-term conservation tillage. Proceedings of the 20th Annual Meeting and Conference of the Saaskatchewan Soil Conservation Association, 12–13 February, Regina, Saaskatchewan, pp. 28–43.

Mrabet, R., 2000. Differential response of wheat to tillage management systems under continuous cropping in a semiarid area of Morocco. Field Crops Research 66(2), 165–174.

Mrabet, R., 2002. Wheat yield and water use efficiency under contrasting residue and tillage management systems in a semiarid area of Morocco. Experimental Agriculture 38, 237–248.

Montgomery, D., 2007. Dirt: The Erosion of Civilizations. University California Press, Berkeley, Los Angeles.

Nurbekov, A., Suleimenov, M., Freidrich, T., Taher, F., Ikramov, R., Nurjanov, N., 2011. No-till practices in the drought and salt-affected region of Uzbekistan. Fifth World Congress on conservation agriculture, 26–29 September, Brisbane, Australia, pp. 410–412.

Piggin, C., Haddad, A., Khalil, Y., 2011. Development and promotion of zero-tillage in Iraq and Syria. 5th World Congress on conservation agriculture, 26–29 September 2011, Brisbane, Australia. pp. 304–305.

Pretty, J., 2008. Agricultural sustainability: concepts, principles and evidence. Phil Trans Royal Society of London B 363 (1491), 447–466.

Settle, W.H., Whitten, M.J., 2000. The Role of small-scale farmers in strengthening links between biodiversity and sustainable agriculture. XXI International Congress of Entomology, Iguazu Falls, Brazil, 20–26 August.

Shaxson, F., 2006. Re-thinking the Conservation of Carbon, Water and Soil: A Different Perspective. Agronomie 26, 1–9.

Suleimenov, M., Akshalov, K., 2006. Eliminating summer fallow in black soils of Northern Kazakhstan, in: Lal, R., Suleimenov, M., Stewart, B.A., Hansen, D.O., Doraiswamy, P. (Eds.), Climate Change and Terrestrial Carbon Sequestration in Central Asia. Taylor and Francis Group, New York, NY, USA, pp. 267–279.

Wolfarth, F., Schrader, S., Oldenburg, E., Weinert, J., Brunotte, J., 2011. Earthworms promote the reduction of Fusarium biomass and deoxynivalenol content in wheat straw under field conditions. Soil Biol. & Biochem. 43:1858–1865.

Winter chickpea cultivation using no-till methods under rainfed conditions in Tajikistan and Uzbekistan

A.I. Nurbekov[24], R.A. Nurbekova[25], X.K. Allanov and L.D. Khudoykulov[26]

ABSTRACT

In Tajikistan and Uzbekistan, chickpea is one of the most important cash crops and source of protein for farmers in rainfed areas. Chickpea is also highly preferred by farmers because of its good marketing crop that enables farmers to get immediate cash income compared other agricultural crops in the region. The experiment conducted Tajikistan and Uzbekistan to better understand the impact of location and climate variability on winter chickpea growth and yield under different tillage methods. The study sites were located at the altitude of 850 m and 980 m above sea level in Gissar district and in Qamashi district in Tajikistan and Uzbekistan respectively. The experiment was established in 2014 and continued in 2015. Results on grain yield revealed that no-till treatment in both locations gave highest grain yield 1 687 and 2 255 kg/ha in Gissar and Qamashi districts respectively. Grain yield was lowest for minimum tillage 1 222 and 1 230 kg/ha in both sites. Lower grain yield was observed in Gissar district. It can be concluded, that climatic conditions of Gissar and Qamashi districts are favorable to grow winter chickpea under no-till method. The results of this experiment proves that tillage methods have not significant effects on dry mass and grain yield in winter chickpea. Tillage methods was significantly superior in influencing days to maturity. No-till winter chickpea can be an entry point for adoption of conservation agriculture in Tajikistan and Uzbekistan. It could be concluded from the present study that winter chickpea no-till method should be studied according to the areas of their adaptability for increased productivity per unit area in different soil and climatic conditions of rainfed agriculture in the region.

Key words: chickpea, rainfed, no-till, conservation agriculture, yield and soil

Introduction

There is a need for crop diversification with legumes to improve sustainability as well as to provide protein-rich grains. Introducing legumes into CA rotations is an essential component of successful CA systems. Food legumes enrich the soil with nitrogen and are very important for sustainable production intensification. In addition to providing nitrogen, legume crops also improve soil quality, thus positively affecting the performance of the ensuing crop. Nitrogen fertilizer requirement for the succeeding crop is reduced in a cropping system that includes legumes, which results in lower cost of production. In Tajikistan and Uzbekistan, chickpea is one of the most important cash crops and source of protein for farmers in rainfed areas. Chickpea is also highly preferred by farmers because of its good marketing crop that enables farmers to get immediate cash income compared other agricultural crops in the region.

So far, no research has been conducted on determination of optimum tillage methods for production of winter chickpea in Tajikistan and Uzbekistan. In rainfed agriculture, no-till technology facilitates sowing of chickpea at proper time. Due to winter sowing chickpea productivity can be increased by 1.5 time which is very important to achieve food security in Tajikistan where there is a need to increase agricultural production to cope with growing demand for food. Cox (1986) studied the effect of different methods of soil preparation and two different types of wheat varieties on wheat grain yield. No significant difference was observed between treatments. Touchton and Jonson (1982) conducted an experiment on the effect of three different methods of tillage (chisel, moldboard plow and no tillage) on the yield of wheat and soybean. Yield of soybean under chisel and no tillage were similar, but wheat yield under chisel plow was less than moldboard plow. The development of tillage practices for dryland crop production has been and will be a dynamic process. Winter sowing is not common in Central Asia including Tajikistan and Uzbekistan. Therefore, there is a need to acquire of information on influences of tillage methods in growth, dry matter yield and yield component of winter chickpea in study area. Thus, this study was initiated with the following objectives:

- To evaluate the effect of different tillage methods on growth, dry matter yield and yield components of winter chickpea,
- To study the effect of different tillage methods, impact of location and climate variability on the productivity of winter chickpea under the rainfed conditions of Tajikistan and Uzbekistan in two different locations.

Material and methods

The experiment conducted Tajikistan and Uzbekistan to better understand the impact of location and climate variability on winter chickpea growth and yield under different tillage methods. The study sites were located at the altitude of 850 m and 980 m above sea level in Gissar district and in Qamashi district in Tajikistan and Uzbekistan respectively. The experiment was established in 2014 and continued in 2015.

The soils of the target region in Tajikistan are sierozem meadows (brownish gray surface color with a lighter layer below; a carbonate or hardpan layer; found in cool to temperate regions with arid climates), with half of the having loam and low-saline characteristic. Soil in Qamashi district of Kashkadarya province is light sierozem with heavy loamy. Humus content is low in different soil layers and ranged between 0.211–0.612 percent.

According to the data of the Tajikistan Meteorological Service, the average frost free period is 225 days. Little snow falls during the winter period, but the winters can sometimes be severe. The climate is classified as severe continental with hot summers and cold winters. The mean annual long-term precipitation is 596–613 mm.

Average long term precipitation ranges widely among foothill, mountain and desert zones between 350–400 mm. Average annual air temperature is +16.8°C, January average is 1.2°C, and July average is +31.7°C.

The experiment was carried out in randomized complete block design with four replicates. All statistical analyses done using Genstat 18th edition (Genstat 2017). There were three different tillage options; conventional till (CT), minimum till with disking (MTD) and no-till (NT). Monitoring over the crop growth and development was conducted from the time of the starting (10 percent) and full completion (75 percent) of the different stages during crop season. Field observations on germination, number of grains per spike, number of grains per m^2, thousand kernel weight, plant height, days to heading, days to flowering, days to maturity, dry matter and grain yield (SVTCAC 1989). Ammophous 30 kg/ha was applied before planting. Ammonium nitrate was used as a nitrogen fertilizer (34 percent) depending on weather conditions.

It would be needed to include some information on the soils and weather conditions of the seasons (average, dry, wet?)

Results

Tanaka's findings (1989) on the comparison of the yield of pea while using different tillage treatments including no tillage, reduced tillage and conventional tillage (moldboard plow) support the obtained results in the present study, as it was indicated in their study that the yield difference for the mentioned tillage treatments was not significant and even no tillage showed a better yield trend.

Days to maturity differed between tillage methods, locations and years and ranged from 180 to 199 days. Maximum days to maturity (199) were recorded in Gissar district in 2014 with conventional tillage technology while minimum days to maturity was observed for Qamashi district in 2015. In general, days to maturity in 2014 was higher compared to 2015 year, as it is depending climate conditions of the region (Figure 19).

ANOVA showed that there were significant differences in winter chickpea within different locations (Table 12). This indicates that tillage methods do not significantly affect chickpea grain yield under rainfed conditions of Tajikistan and Uzbekistan.

Results on grain yield (Figure 20) revealed that no-till treatment in both locations gave highest grain yield 1 687 and 2 255 kg/ha in Gissar and Qamashi districts respectively. Grain yield was lowest for minimum tillage 1 222 and 1 230 kg/ha in both sites. Yield reduction was associated with tillage methods. Lower grain yield was observed in Gissar district. It can be concluded, that climatic conditions of Gissar and Qamashi districts are favorable to grow winter chickpea under no-till method.

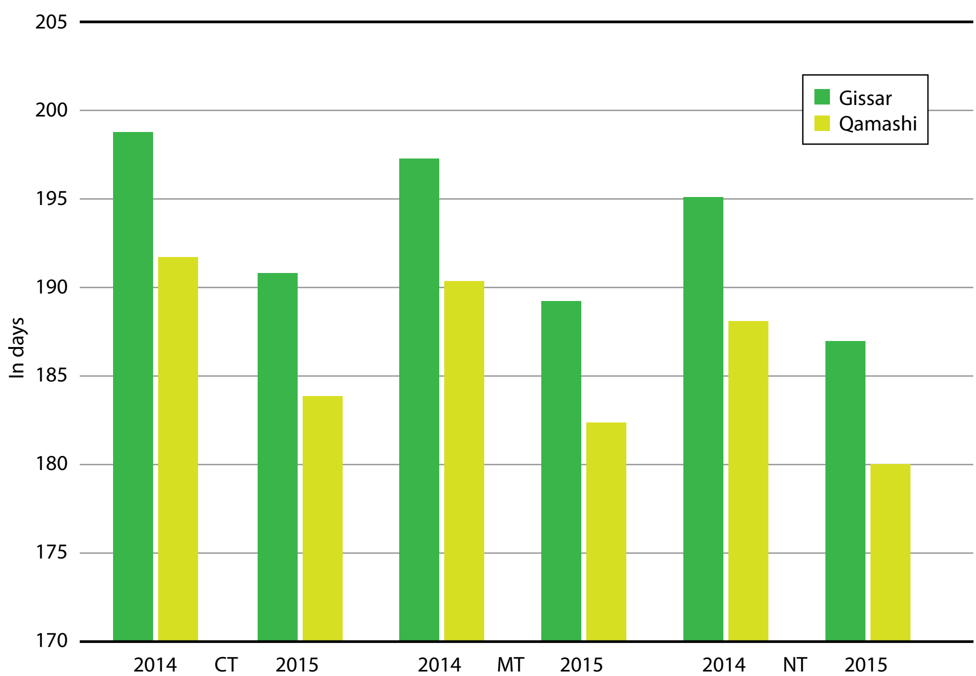


Figure 19. Effect of tillage on days to maturity of winter chickpea in Tajikistan and Uzbekistan.

Table 12. Analysis of variance grain yield.

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square	Variance ratio	F Value
Location	1	2 245 973	2 245 973	14.28	<.001
Treatment	2	2 175 181	1087 590	6.91	0.003
Year	1	543 789	543 789	3.46	0.071
Location. Treatment	2	265 928	132 964	0.85	0.438
Location. Year	1	543 789	543 789	3.46	0.071
Treatment. Year	2	28 865	14 432	0.09	0.913
Location. Treatment. Year	2	28 865	14 432	0.09	0.913
Residual	36	5 663 110	157 309	–	–
Total	47	11 495 499	–	–	–

Figure 20. Effect of tillage on productivity of winter chickpea.

Discussion

The results of this experiment proves that tillage methods have not significant effects on dry mass and grain yield in winter chickpea while days to maturity had significant effect. No-till winter chickpea can be an entry point for adoption of conservation agriculture in Tajikistan and Uzbekistan.

It could be concluded from the present study that winter chickpea tillage methods should be studied according to the areas of their adaptability for increased productivity per unit area in different soil and climatic conditions of rainfed agriculture in the region.

References

Cox J.K. 1986. Winter survival response of winter wheat: Tillage and cultivar selection. Agron J., 78: 795–801.

Genstat (2017). GenStat Version 16.1.0.10916. Lawes Agricultural Trust, Rothamsted. Experimental Station, UK.

Tanaka, D.L. (1989): Spring wheat plant parameters as affected by fallow methods in the Northern Great Plains. Soil Sci. Soc Am. J., 53: 1506–1511.

Touchton, J.T., J.W. Jonson (1982): Soybean tillage and planting methods effects on yield of double-cropped wheat and soybean. Agron. J., 74: 57–59.

SVTCAC (State Variety Testing Commission of Agricultural Crops) (1989): The methodology of State Variety Testing Commission of Agricultural Crops. Vol. 2. Cereals, small grains, leguminous, maize and forage crops. M.. 194 p.

Experience of application of soil-protective and resource-saving agro-technologies and irrigation technologies in the Republic of Kazakhstan

Karl Anselm, Meirjan Esanbekov[27]

Abstract

It has been proven that the use of resource-saving agro-technologies and water-saving irrigation techniques significantly increases the yield of agricultural crops, while reducing material and technical costs and the time of production work.

Key words: stubble, crop residues, crop rotation, alternation of crops, drip irrigation and sprinkling

Introduction

The Republic of Kazakhstan is located in the center of the Eurasian continent. From the north it borders with the Russian Federation, from the east with the People's Republic of China, and from the south with the Central Asian republics. In terms of the area of its territory, Kazakhstan is the 9th country in the world. The population is about 18.5 million people.

Agricultural land accounts for more than 80 percent of the country's territory. Arable land occupies 24.8 million hectares, which is mainly rainfed (without irrigation). The share of irrigated land is 8.9 percent of arable land [1].

According to the climatic conditions, 82.2 percent of the country's territory belongs to semi-desert and desert zones. A significant part (182.2 million hectares) of agricultural land is located in the zone of insufficient moisture (rainfall less than 200 mm per year [2].

About 67 percent of arable land is located in the three northern regions of the country, where crops are mostly cultivated without irrigation. In this region of the country, for 2 million hectares out of 19 million hectares of sown areas, grain crops are cultivated using resource-saving technologies.

At 9.3 million hectares, farmers apply minimal tillage using chisel plows with cultivation to a shallow depth [3,4].

The introduction of resource-saving farming methods in the northern regions of Kazakhstan is caused by a pressing need. Despite the fact that the country has extensive land resources for the cultivation of wheat, the yield is entirely dependent on precipitation.

Results

Already in the 1960s, farmers began to introduce methods of gentle tillage during the cultivation of wheat in order to cope with significant losses of the fertile soil layer due to wind erosion [5].

In 2000, CIMMIT and FAO, together with scientists and farmers from Kazakhstan, launched a program to introduce resource-saving farming methods in rainfed areas of the country.

Field trials in the north showed that under zero processing conditions, wheat yields were 25 percent higher than on plowed land, while labor costs decreased by 40 percent, and fuel consumption by 70 percent [6].

When processing fields without turning a layer to control weeds, farmers are forced to resort to the use of herbicides. However, many of them have found that combining zero tillage with maintaining a constant soil vegetation cover also helps in suppressing the growth of weeds.

Crop residues in the fields in northern Kazakhstan also contribute to soil moisture retention and improve the water availability of crops. The annual rainfall in this region of Kazakhstan ranges from 250 to 300 mm, while winter snow cover is about 40 percent. In windy weather, snow is carried away from the fields by wind, and the surface of the soil remains bare and dry. Preserving stubble and crop residues from the previous harvest retains snow, which thaws when warming, saturating the soil with moisture. Field studies have shown that the use of crop residues to trap snow along with zero treatment can increase yields by 58 percent.

The alternation of crops, as the main element of resource-saving agriculture in the northern regions of Kazakhstan, is slow, as the growing season in these areas is short, with a high frequency of dry years. At the same time, in non-snowy years, the areas occupied by summer couples are reduced as farmers occupy them under the crops of sunflower, peas, lentils and buckwheat. Sorghum crops showed high efficiency in retaining snow and moisture accumulation in the soil. Sowed at the end of May with the harvest in August, Sorghum not only provided feed for sale or for silage, but also left a solid stubble that delayed the precious winter snow. Along with research on the application of conservation agriculture technology in rainfed conditions of northern Kazakhstan, field experiments were also carried out on bedded wheat under irrigation conditions, which gave a positive effect.

More than 70 percent of the republic's irrigated lands are located in four southern regions where rice, cotton, vegetables, melons, grain and forage crops, orchards and vineyards are cultivated during irrigation. At an area of 205.1 thousand hectares with irrigation, soil-protective and water-saving irrigation technologies are applied to crops, such as drip irrigation, sprinkling, irrigation along mulched furrows, furrow irrigation and discrete irrigation technology. A particularly high effect is provided by drip irrigation technology. Up to 80 tons of tomatoes per hectare were obtained on stony, low-power soils, and up to 100 tons of sugar beet on sandy floodplain lands. Irrigation by sprinkling gives a good effect when irrigating crops in semi-hydromorphic and hydromorphic conditions of soil formation [7].

To encourage farmers to use water-saving and resource-saving technologies in Kazakhstan, they provide state support in the form of subsidizing the cost of purchasing equipment for these purposes.

Conclusion

The introduction of resource-saving methods of farming (Conservation agriculture) in Kazakhstan made it possible to increase annual wheat production by 2 million tons, which is enough to provide food for about 5 million people. State support gave an incentive to farms in northern Kazakhstan to invest approximately 200 million USD in equipping their enterprises with agricultural equipment for zero tillage and for the development of drip irrigation systems in the south of Kazakhstan on an area of 60 thousand hectares [8].

References

Сводный аналитический отчет о состоянии и использовании земель Республики Казахстан за 2017 год: **МСХ РК КУЗР,** стр. 48–51.

Сводный аналитический отчет о состоянии и использовании земель Республики Казахстан за 2017 год: **МСХ РК КУЗР,** стр. 77–78.

Karabayev M., Morgounov A., Braun H-J. Effective Aproaches to Wheat Improvement in Kazakhstan conservation agriculture. Journal of Bahri Dagdas Crop Research (1–2); 50–53, 2014.

FAO. 2012. Conservation agriculture in Central Asia: Status, policy, institutional support, and strategic framework for its promotion. FAO Sub-Regional Office for Central Asia. December 2012. Ankara.

Карабаев М., P.Wall, K.Sayre, CIMMYT: Ресурсосберегающие технологии в Казахстане, 2012 г., Баку, Азербайджан.

Karabayev M., Suleimenov M. 2010 Adoption of conservation agriculture in Kazakhstan. In: Lead papers 4th World Congress on conservation agriculture: Innovations for improving efficiency, equity and environment. 4–7 February 2009. New Delhi.

Мухамеджанов Ш.Ш., Имашева Г., Хасанова Н. Водосбережение в странах Центральной Азии: опыт прошлого и ориентиры на будущее. Сборник научных трудов Сети водохзяйственных организаций Восточной Европы, Кавказа, Центральной Азии, вып. 11. – Ташкент: НИЦ МКВК, 2018. – стр. 180–209.

World Bank. No.-till: A climate smart agriculture solution for Kazakhstan. Agricultural Competitiveness Project. 8 August 2013.

Evolution of the adoption of conservation agriculture in China

Mao Zhenqiang, Du You[28]

Abstract

This paper briefly introduces the extension progress and current situation of conservation agriculture, mainly focused on the (better: conservation agriculture system), in China. And the experiences of the extension, the main limiting factors affecting the extension of the (same as before) technology were also revised. Recommendations were given to those country' government wishing to use (same as before) locally. Government and government-led organizations should conduct programs to well localize the technologies and supporting tools, which might be well used abroad, before a large-scale extension.

Key word: Conservation Tillage, Extension, Government-led Extension System

Introduction and background

The application of conservation agriculture in China started at the beginning of 1990s, and has developed rapidly since 2002, when the Central Government began to set up special funds to promote the demonstration and promotion of protective farming techniques. Since 2005, the Central Government's No.1 document has made it an important task to vigorously develop and promote protective farming techniques. Since 2003, there has been an accelerated increase in the area used for conservation farming in China (Figure 21). As a result, the area used for (same as before) reached 8 648.27 thousand hectares, an increase of approximately 65 times over 2003.

Overall, however, there is still much room for conservation farming in China. In 2016, about 6.9 percent of the country's total arable land was covered by conservation farming. and even concentrated on the rainfed farmland, the proportion was about 10.9 percent.

Geographically, (same as before) has been applied relatively rapidly in North, Northeast and East China, and needs to be further expanded in Central and Northwest China (Figure 22). Due to the constraints of the natural environment, agronomic traditions etc, it is not suitable for a large-scale implementation in

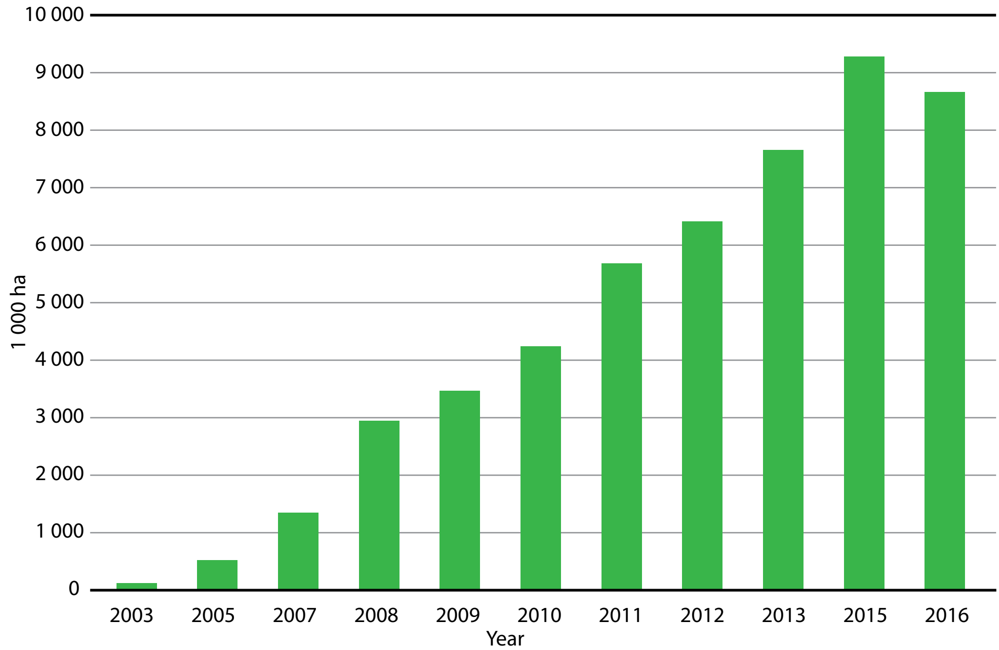


Figure 21. Increase in the area used for conservation farming in China

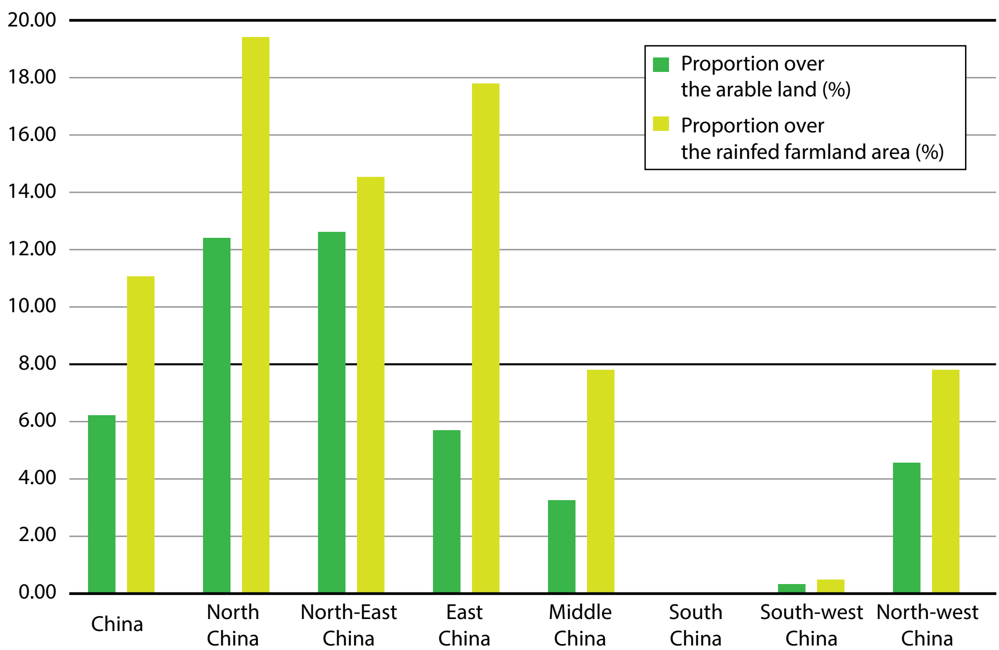


Figure 22. Converted land to conservation agriculture

the South and Southwest of China. As can be seen from Figure 22, even in North and Northeast China, where the application of (same as before) is relatively good, the proportion of conservation tillage area is yet less 12.5 percent over the total cultivated land in the region.

Experiences in extension and application of CA

The achievements of Chinese conservation farming can be mainly attributed to the support of the government. Effective support systems, and machinery improvement.
(1) Government support and strengthening top-level design.
Government supports can be attributed to planning and project support.

Making plans

As a national plan, it requested governments at all levels to adopt the extension of CA into their assessment indicators. As a result, governments at all level gave strongly financial support to the extension of CA.

There are four national plans related to conservation tillage application made by the Central government of China since 2009 (Table 13). In 2009, The Ministry of Agriculture made the "The plan for conservation tillage project construction (2009–2015)", which put forward to build 600 demonstration areas and covered more than 13.3 million hectares.

By 2015 and 2016, three long periods for agricultural development plan were made by different Ministries. They all stressed the importance of conservation tillage, and

Table 13. The plan for conservation tillage

Planning name	Related content
The plan for conservation tillage project construction (2009–2015)	600 conservation tillage engineering areas (20 million acres) were built.
The plan for national agricultural sustainable development (2015–2030)	Taking deep ploughing, conservation tillage, straw returning, organic manure and green manure to increase soil organic matter and improve soil fertility.
The plan for national agricultural modernization plan (2016–2020)	Accelerating the popularization and application of mechanized technology such as deep loosening, conservation tillage, straw mechanization and returning to the field.
The plan for national land (2016–2030)	Strengthening conservation tillage in the north dry fields.

proposed to vigorously promote the application of conservation tillage techniques, to protect the deteriorating ecological environment and improve the sustainability of agriculture and land use.

Project promoting

Since 2002, the Ministry of agriculture has launched the experimental demonstration of conservation tillage. After the continuous exploration and practice of more than 600 project counties, the popularization and application of conservation tillage has been accelerated and the implementation area has been continuously expanded, also the transformation from single technical test demonstration to technological innovation and collection has been realized.

Effective technology support systems

Law of the People's Republic of China on Agricultural Technology Extension request government to build sound system to promote the application of advanced agricultural technology. And the extension of CA was endowed to Agriculture Mechanization Technology Development & Extension system, which covered from nation, provinces, prefecture-level cities, and counties. There are 2 535 organizations, most of which are at counties level, by 2016. The average personnel is 5.5 per organization engaged in CA promotion (Figure 23).

As government-led organization, they mainly work in Non-Profit CA experiments, demonstrations, propaganda, consult and technology trainings in different areas. Farmers were usually invited to take part in the experiments and demonstrations.

As a result, they can evaluate the effects and decided to adopt or not. Experts form the organization usually gave Professional advices when the farmers decided to adopt CA, to ensure the success of the adoption.

Besides the Government-led extension system mentioned above, there are thousands of agricultural machinery enterprises, universities and colleges engaged in CA promotion. Universities are good at solving all kinds of technical problems. And enterprises are focused on machine demonstration. The cooperation has increased rapidly in recent years among the Government-led extension system, enterprises and universities. Innovation and the constantly improved performance of machinery. Advanced and applicable agriculture machinery are important for the extension and application of conservation tillage. Through continuous development

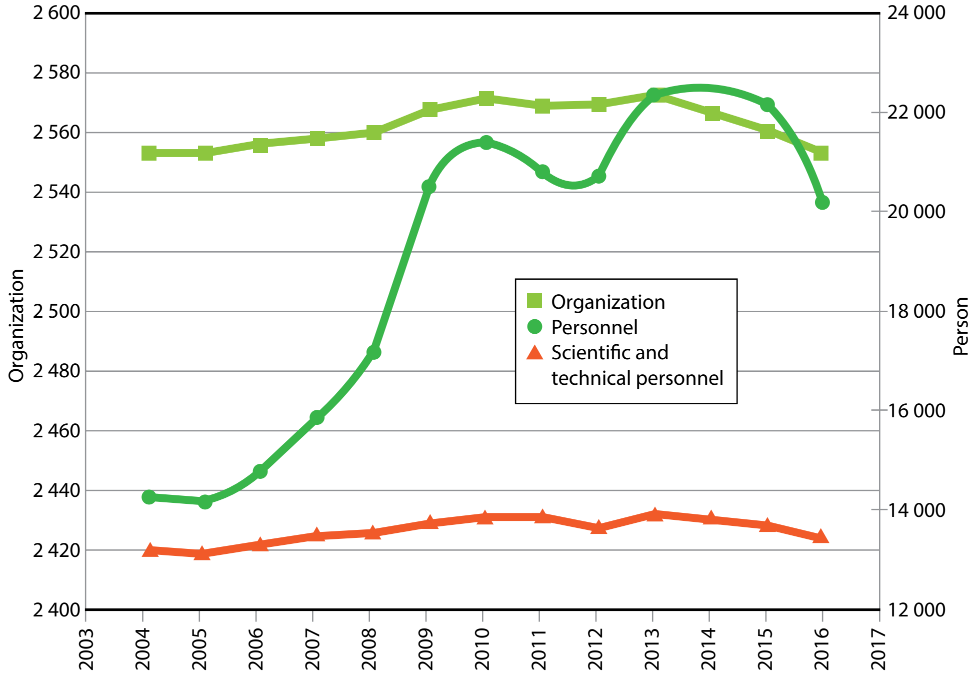


Figure 23. Extension services of conservation agriculture in the country

of suitable agriculture machinery for different regions, such as no-tillage seeders and straw choppers, we have upgraded our equipment and ensured the quality and effectiveness of conservation tillage.

Constraints and challenges to adoption and promotion of conservation agriculture

The extension and application of conservation agriculture effectively improved soil fertility and drought resistance, realized the combination of land use and land cultivation, protected the ecological environment, promoted sustainable land use and sustainable agricultural development. However, the following problems still existed in the application process, which include: 1) The insect pests and weeds tend to be aggravated in some areas. The soil is not turned over for a long time, and the crop straw is required to cover the surface of the earth during the conservation tillage, places for overwintering insect eggs emerged; 2) The quality of the machinery needs to be strengthened. The performance of some machinery cannot meet the needs of production well, and there are some problems such as low efficiency, poor effect and high price; 3) Insufficient understanding by farmers. Traditional farming practices are deeply rooted in farmers, and quite a few farmers have doubts about conservation agriculture.

Recommendations

In order to overcome the abovementioned constraints, the author suggests the following points:

1. Advancing the integrated development of farm machinery and agronomy, monitoring and prevention of pests and weeds, and further optimization of technical systems.
2. Tackling key problems together, further improving the quality of machinery and reducing the costs of production.
3. Strengthening propaganda and training, increasing the recognition and acceptance of conservation agriculture.

Chapter 2

Rehabilitating degraded soils with conservation agriculture

©FAO/Ken Sayre

Aspects of the use of conservation agriculture to improve soil fertility in arid conditions of the Republic of Karakalpakstan

Bakitbay Aybergenov[29]

Abstract

The reasons for the decrease in soil fertility and soil degradation in the arid conditions of Karakalpakstan are the depletion of humus in the soil, an increase in the salt content of the soil and the loss of the fertile soil layer as a result of deflation and erosion.

With the presence of a mulching straw cover (plant residues) on the soil surface and the use of CA for two years, the seasonal accumulation of salts in the rhizosphere decreased by 1.5–4 times compared to conventional multiple tillage, the organic matter content increased by 0.02 percent, soil moisture remains longer, increases biological activity, which indicates an improvement in soil fertility. In addition, in the process of adapting CA for the arid soil and climatic conditions of Karakalpakstan, we have developed effective measures to combat weeds and pests, as well as a method of cultivating repeated crops.

Key words: Biological activity, soil moisture, salinization, conservation agriculture

Introduction

Recently, the population of Karakalpakstan, living especially in the northern regions, are experiencing difficulties due to frequently repeated low-water flows, which are most acutely felt in the northern regions located in the lower reaches of the Amu Darya River. Since the main source of income for the rural population of Karakalpakstan is livestock and crop production, the stability of the socio-economic situation depends on sustainable farming in this arid region. In this regard, the issues of combating soil salinization, soil fertility preservation and water conservation during irrigation are becoming particularly relevant today.

When studying the soils of the irrigated lands of the studied territory, the humus content in the upper 0–10 cm level averaged 0.58 percent, which corresponds to the low availability of soil to organic matter. The lower soil levels of irrigated lands correspond to a very low supply of soil with humus, that is, the content of humus varies between 0.22–0.30 percent. By the end of the growing season, the soils of irrigated lands of Karakalpakstan become saline from medium to strong degree as a result.

In our opinion, the most optimal solution to the above causes of problems can actually be the use of conservation agriculture. Nowadays there is a tendency to expand the areas of use of conservation agriculture all over the world.

Our research has shown that one of the most important methods of conservation agriculture is the preservation of plant residues on the soil surface, and it contributes to the improvement of the fertile properties of the soil, reducing the accumulation of salts in the root zone of the soil.

In addition, in the process of adapting CA for the arid soil and climatic conditions of Karakalpakstan, we have developed effective measures to control weeds and pests, as well as a method of growing repeated crops. We hope that our developments will help to expand the areas of use of conservation agriculture in Karakalpakstan, as a measure of restoring lost soil fertility and preventing further soil degradation.

Materials and methods

The studies were carried out in the framework of the projects of the Ministry of Agriculture and Water Management of the Republic of Uzbekistan and the FAO named “Practice of sustainable agriculture in the Karakalpakstan region affected by drought”, the GEF Small Grants Program “Implementation of soil-protective, resource-saving technologies”, ICARDA CAC “Improving the sustainability of salt-resistant forage crops through diversification of crops” in the Chimbay, Karauzyak and Kanlykul districts of the Republic of Karakalpakstan.

Soil conditions (humidity, salinization, mechanical composition) were studied by generally accepted methods (L.N. Alexandrov, O.A. Naidyonova, 1986) by laying soil pits, taking soil samples, followed by laboratory research. The protease activity in the soil was studied by the method proposed by E. I. Mishustin *et al.* (1982). A qualitative assessment of soil properties was carried out using the Visual Soil Assessment method developed by G. Shepherd (2000) and adapted by J. Benites. The method allows you to visually assess the quality of the soil structure, porosity, color, the presence of worms, the depth of the arable layer, and soil cover plant residues.

Identification and accounting of the number of the most common summer pest – spider mite (*Tetranychus urticae* Koch.) was carried out in the Mungbean fields during the flowering period of the plants. Spider mite multiplying massively will cause significant damage to planting in the phase of budding and flowering. Accounting for the number was performed by counting ticks on the leaves with a magnifying glass on trial plots embedded in a certain interval along the diagonal of the field. The economic threshold of spider mite harmfulness on crops of mungbean is 5 copies per leaf, or the population of 10 percent of plants, and in our case, the population was 35 percent of plants.

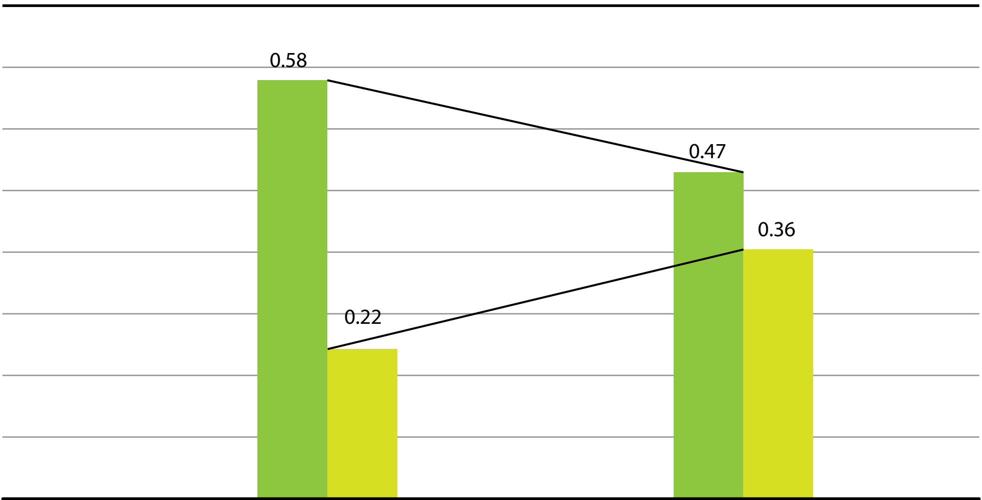
Accounting for weeds on crops was carried out using the standard eye-numerical method of A.I. Maltsev (A.N. Orlov, O.A. Tkachuk, 2011).

Results

The climate of Karakalpakstan is characterized by sharp continental and dry air, high temperatures in summer and harsh cold winters. The soils of the irrigated zone of Karakalpakstan are meadow-alluvial, meadow-marsh, meadow-takyr and meadow-desert light sierozems [1]. The humus content in the soil of the studied plots on the top 10 cm of the soil horizon was only 0.58 percent, which corresponds to the low availability of soil by humus, and in the 10–40 cm horizon, this figure varies from 0.22–0.34 percent, which corresponds to very low soil availability of humus. In areas with normal tillage on the upper 10 cm horizon, after two years a noticeable decrease in the humus content is observed (from the original 0.58 percent to 0.47 percent), while in the lower 10-40 cm layer there is an increase in the humus content (Figure 24). Apparently, the plowing with the turnover of the layer contributed to this.

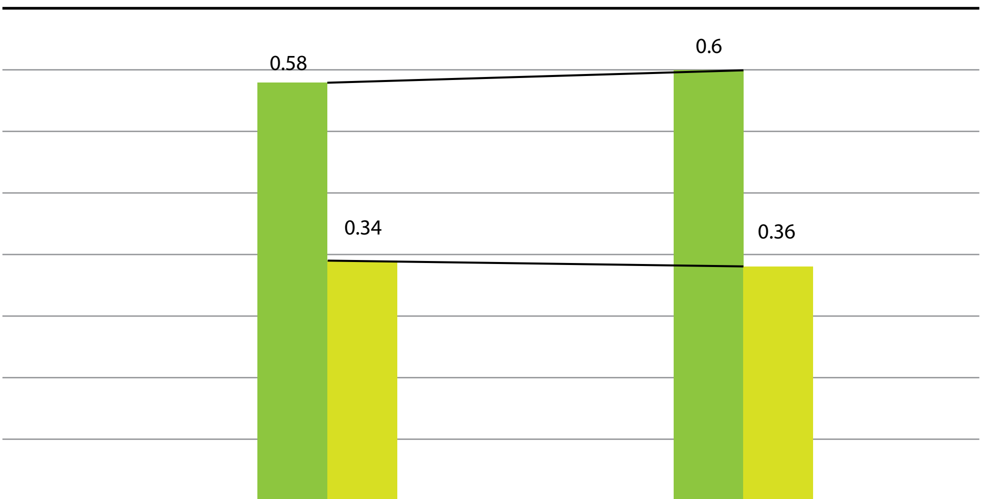
In areas where they used Conservation agriculture, an increase in the humus content is observed, especially in the upper horizon, at the same time, there is a slight decrease in humus in the lower 10–40 cm horizon (Figure 25). The increase in organic residues on the field contributed to an increase in the biological (protease) activity of the soil on the field with CA. So, our observations showed that the protease activity of the soil on the field where CA was used for two years increased almost twice.

Preserving plant residues (straw and stubble) on the surface of the soil creates the full effect of mulching, which reduces the evaporation of moisture from the soil, as a result of which the seasonal accumulation of salts in the rhizosphere is reduced. Thus, on the site where conservation agriculture was used, the dry matter content



	Initial humus content during normal plowing, %	Humus content during normal plowing after 2 years, %
0–10 cm	0.58	0.47
10–40 cm	0.22	0.36

Figure 24. The change in the content of humus at the annual plow processing



	The original content of humus, %	Humus content 2 years after application of CA, %
0–10 cm	0.58	0.6
10–40 cm	0.34	0.36

Figure 25. Changes in the content of humus in the soil as a result of two years of use of CA

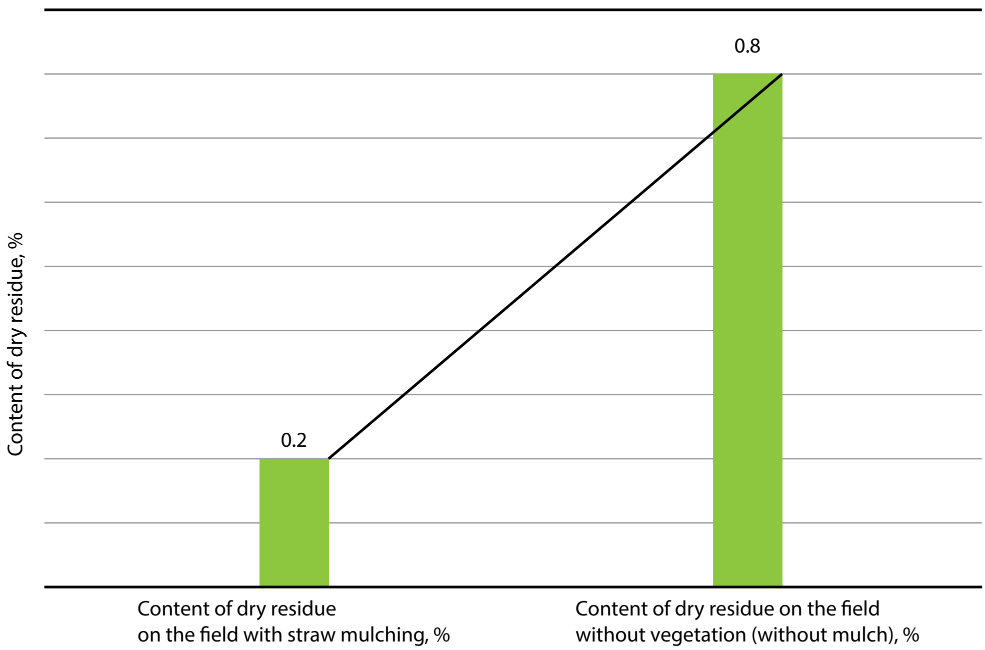


Figure 26. Reduction of seasonal salt accumulation under the influence of the mulch cover

averaged 0.2 percent (degree – non-saline), while at the site without mulch this figure was 0.8 percent (degree – slightly saline) (Figure 26).

In the qualitative assessment of the soil, it has been established that the two-year use of the CA has led to an improvement in the properties of the soil, including the structure, that is, from 17 points to 22 points. (Figure 27).

In the course of introducing conservation agriculture for soil and climatic conditions of Karakalpakstan, we also developed measures to control weeds and pests. Thus, in the fight against grass weeds on broadleaf crops, it is advisable to use the herbicide Zelledek-extra (haloxyfop-p-methyl, 10g/l) at a rate of 1 l/ha, and to fight with dicotyledonous and perennial weeds, the use of the herbicide entoglyphos (potassium salt glyphosate 50 percent) in the consumption rate of 5 l/ha immediately after sowing is recommended.

At the end of July – at the beginning of August, the spider mite (*Tetranyhus urticae* Koch), multiplying massively, caused significant damage to the mungbean plants (*Vigna radiata*), damaging up to 40–50 percent of the plants. In the fight against spider mites on crops of repetitive crops (Mungbean and beans), the most effective

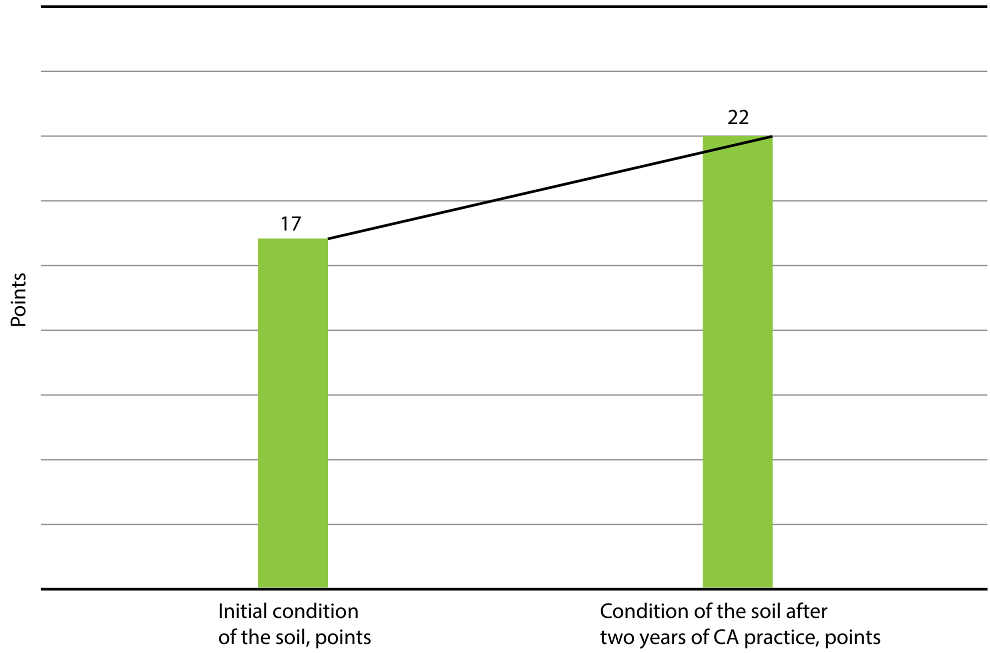


Figure 27. Improvement of soil parameters in the visual soil assessment (VSA)

Figure 28. Damage to leaf of mungbean (*Vigna radiata*) by spider mite (*Tetranychus urticae* Koch.)

drugs were the acaricides entomite (57 percent propargite) at a rate of 1.5 l/ha and akaragold (66 percent propargite + 6 percent hexythiazox) at a rate of 0.4 l/ha, with an efficiency of 78 percent and 75 percent, respectively.

Discussions

Preserving plant residues (crop residues and part of straw) on the soil surface improves the soil's fertile properties, preserves soil moisture, reduces salt accumulation in the root zone of the soil, which is especially important for arid conditions of the Republic of Karakalpakstan. In dry conditions after watering, moisture evaporates quickly and this leads to excessive soil compaction, which prevents the growth and development of the root system of plants. In our opinion, by maintaining optimum soil moisture, such adverse effects can be avoided. Currently, research in this aspect is ongoing. In the process of adapting CA for the arid soil and climatic conditions of Karakalpakstan, we have developed effective measures to combat weeds and pests, as well as a method of cultivating repeated crops. We hope that our developments will help to expand the areas of use of conservation agriculture in Karakalpakstan, as a measure of restoring lost soil fertility and preventing further soil degradation.

References

Александрова Л.Н., Найденова О.А. Лабораторно-практические занятия по почвоведению. «Агропромиздат», Ленинград, 1986.

Опытное дело в полеводстве. Под общей ред. **Никитенко Г.Ф. «Россельхозиздат», Москва,** 1982. 184 с.

Интегрированные системы защиты с.-х. культур от вредителей, болезней и сорняков. Под ред. **Сороки С.В. – Мн.:** 2003.

А.Н.Орлов. Земледелие. Пенза. 2011.189с.

Visual Soil Assessment. Fiel Guide. Shepherd G.2000, adapted by **Benites J.**

Мамбетназаров Б., Шамшетов С., Медетуллаев Ж., Торениязов Е., Айбергенов Б. и др. Научно обоснованная система земледелия в Республике Каракалпакстан. «Билим», Нукус, 2003. 228 с.

Integrated fertility recovery technology degraded pastoral and agricultural lands

Marat Aldabergenov[30], Amankeldi Sadanov[31], Nursultan Orinbaev[32]

Abstract

Over 15 years of joint research work with FAO (2002–2017) in Kazakhstan, the area under conservation agriculture (CA) increased from 0 to 2.2 million hectares, and the country entered the top ten countries by area. The basic research on CA is carried out on the basis of the theory and research methodology of the PhD on agricultural sciences, Professor Hafiz Muminjanov.

The integrated technology of restoring the fertility of degraded pastures and arable land is a continuation of this method, aimed at promoting CA in irrigated agriculture. The proposed technology provides for the production of liquid organic fertilizer under economic conditions with waste sterilization using a three-stage bioreactor installation and the subsoil application of agronomically valuable microorganisms (EM technologies) by embedding culture suspension of 1 × 109 CFU/ml and plowing. As a result of the tests carried out, an increase in soil fertility was found, while the nitrogen content in soils increased 2.0–2.5 times, the salinity of the soil filtrate decreased from pH 8.15 to a neutral value (pH 6.12), which provides for the restoration of fertility and an increase in the productivity of degraded pasture and arable land in the South-East of Kazakhstan and all of Central Asia.

Key words: integrated technology, restoration of fertility, pasture and arable land.

«A nation that destroys its soil destroys itself»
(Franklin Roosevelt)

Introduction

The Law of the Republic of Kazakhstan “On the Production of Organic Products” dated November 27, 2015 No. 423-V ZRK, in the production of organic products establishes the following conditions: the use of healthy animals and plants, safe production and raw materials of animal and vegetable origin and the exclusion synthetic substances, pesticides (toxic chemicals), hormones, antibiotics and food additives, with the exceptions stipulated by the rules of production and circulation of organic products [1].

The law also provides for the rejection of the use of pesticides, synthetic mineral fertilizers, growth regulators, artificial food additives, and also prohibits the use of GMOs. The production of organic products is accompanied by the maintenance and improvement of soil health, natural ecosystems, minimizes the threats associated with the instability of development, creates conditions for the health and well-being of the population. One of the main tasks of the State Program for the Development of the Agro-industrial Complex of the Republic of Kazakhstan for 2017–2021 [2], developed in accordance with the instruction of the Head of State, given at the enlarged meeting of the Government of the Republic of Kazakhstan dated September 9, 2016, and in accordance with the strategic development goals of the Republic of Kazakhstan, designated in the Plan of the Nation "100 specific steps" and the Strategy "Kazakhstan-2050", is the development of crop production, increasing its productivity and competitiveness. For a long time, FAO has played a leading role in introducing conservation and resource-saving agriculture (CA) over large areas by demonstrating, educating and convincing farmers, agricultural specialists and implementation services, as well as helping countries to develop national strategies for implementing CA and attracting investment. An example of successful cooperation between CIMMYT, FAO, the World Bank and the Government of the Republic of Kazakhstan is the introduction of CA in the country. As a result, over 15 years of joint efforts with FAO (2002–2017) in Kazakhstan, the area under CA increased from 0 to 2.2 million hectares and the country entered the top ten countries by area [3].

Currently, in Kazakhstan there is a steady trend of degradation of pasture land, which is associated with unregulated cattle grazing, a reduction in the area of watering pastures, lack of control over the state and use of pastures and non-compliance with land legislation. Over the past 50 years, due to excessive use of pastures, the majority (48 million hectares) of pasture ecosystems are seriously impaired, the loss of humus in them reaches 50–70 percent [1].

In some areas of the South-East of Kazakhstan, changes have become irreversible, that is, self-restoration of pastures is impossible or this requires large investments. Such a state of pasture land raises an urgent problem – the restoration of the fertility of degraded pastures [4].

The restoration of fertility and the increase in the productivity of degraded pasture land is a pressing issue for the republic's grazing livestock. To solve this problem, we recommend an integrated approach involving a combination of different areas of research: the use of agronomically valuable microorganisms (EM technologies) and the mechanization of waste treatment processes, the production of liquid fertilizer, subsoil introduction with microorganisms and pasture water supply to restore degraded fertility pastures and the introduction of CA for irrigated areas of the southern regions.

Materials and methods

Our research is aimed at accelerating the restoration processes of degraded pasture and irrigated arable land, using CA for the Southern and Southeast region, with the improvement of water supply systems, the production of liquid fertilizers and the introduction of the technology of subsoil fertilization by microorganisms. At the same time, the principles of CA [3], described by Doctor of Agricultural Sciences, Professor Hafiz Muminjanov, are supported.

To clarify the parameters of technology and technical solutions, equipment was selected and the above processes were organized on experimental plots located on degraded pastures of "A. Babayev" farm, Ili district of Almaty region [5, 6].

Studies conducted in accordance with GOST 17.4.4.02-84. In the surveyed area of agricultural land (field), test sites of 10 × 10 m in size were laid for every 0.5–20.0 hectares using the envelope method. The following indicators were measured along the diagonals of the site: the number of plants (pcs/m^2), the average growth of plants (cm) and the number of plant species (pcs/m^2) were taken in fivefold repetition in accordance with the theory and methodology of research of Doctor of Agricultural Sciences, Professor Hafiz Muminjanov and described in the works of Rayburg, S., Govaerts, B. [7, 8].

The soil was analyzed for the content of macro- and microelements, the content of accessible forms of macroelements (P_2O_5, K_2O); content of ammonium and nitrate nitrogen; determination of acidity and electrical conductivity of the soil (Ec, TDS, pH); determination of the content of available forms of microelements (Fe, Cu, Zn, Mo). The results of the analysis are shown in Table 14.

A visual view of the state of biodiversity of pastures in the spring period of the year in a peasant farm is shown in Figure 29.

According to the degree of salinity of the soil suspension, these samples of soil samples taken from the experimental plot (degraded pasture) are non-saline soil (Its – 0.19 m cm/cm; total salt content – 93 mg/l; pH aq. – 8.15). The reaction of the aqueous soil sample is alkaline. The average alkalinity is unfavorable for the growth and development of most plants. Alkaline soils generally have low fertility, adverse physical properties and chemical composition.

Table 14. Results of analysis*

№	Determined parameters	Detected concentrations, mg/kg	Providing soil with nutrients	N. D. on research methods
1	P_20_5 (movable forms)	19.56	Very low	GOST standard 2620591
2	K_20 (movable forms)	198.68	Medium	GOST standard 2620591
3	$N—NO_3$	3.53	Very low	GOST standard 26489
4	$N—NH_4$	9.73	Medium	GOST standard 26489
5	pH acid exchange	7/15	Slightly alkaline	GOST standard 26489
6	Fe (movable forms)	45.76	Heightened	GOST standard P50686
7	Cu (movable forms)	2.15	Medium	GOST standard P50686
8	Mo (movable forms)	36,5	High	GOST standard 50689
9	Zn (movable forms)	90,76	Very high	GOST standard 50686

*Note – for conducting monitoring studies of soil condition, analyzes are required at least three times a year.

1. General view of the boundaries of degraded pastures;
2. Natural pastures;
3. Degraded pastures.

Figure 29. The state of biodiversity of fodder crops of pastures in the spring period of the year in the farm "A. Babaev" of the Ili district of Almaty region

The approbation of the work on the development of EM associations and their use in the integrated technology of restoring the fertility of degraded soils of the South-East of Kazakhstan were carried out in field experiments on the restoration of the fertility of degraded soils under the cultivation of sugar beet on the basis of the "Kayinda" farm located in T. Ryskulov district of Jambyl region. A visual view of the state of biodiversity of fields under sugar beet sowing during the growing season of the year in a peasant farm is shown in Figure 30.

In this regard, we have developed a technology for the production and use of liquid organic fertilizers from animal waste. This organic fertilizer is environmentally friendly, does not contain chemical compounds that pollute the environment. The obtained organic fertilizer together with the EM associations will be introduced into the subsoil layer of the arable horizon using special technical means.

To obtain organic fertilizers, it is planned to use special bioreactor installation. After conducting a systematic analysis of the development of world practice, it was found that similar studies are being conducted in foreign countries – China, India,

1. Degraded tillage; 2. Sugar beet sowing field.

Figure 30. General view of degraded arable fields and sowing field for sugar beet

Germany ("Ubitec GmbH", "Eltaga laisensing GmbH", "Brachthfluser GmbH", "Agri. capital CmbH"), Denmark, UK (ANOX), USA and Japan [9, 10].

Such a technology is developed in Israel, where the technology "ArrowBio" is patented, which allows producing biogas from household waste that can be used in power plants. This technology was approved by experts from the USA and other countries as the most efficient and cost-effective for the processing of municipal solid waste (MSW) compared with the traditional technologies currently used [11].

To date, there are two main types of devices intended for biotechnological processing of concentrated organic substrates with a moisture content of 92–96 percent. Their technological scheme is closest to the proposed bioreactor installation [10].

For substrates with rapid degradation, which, because of this, are prone to oxidation, it is recommended to provide a separate tank for hydrolysis and oxidation, so that decomposition products are metered out to the fermenter (two-step technology).

In most biogas plants, the processes of splitting occur in parallel, that is, they are not separated either geographically or in time. Such technologies are called single-stage (Figure 31).

The advantage is maintaining the efficiency of bacteria through the creation of optimal living conditions (primarily the pH level).

From the point of view of accelerating the processes of anaerobic fermentation and sterilization of harmful microbes in bioreactors, the three-stage bioreactor model is the most effective (Aldabergenov M.K., 2017). In contrast to the two-stage, instead of the hydrolysis stage, a three-stage bioreactor provides a capacity for preparing the substrate and then 2 fermenters with a heating temperature up to 70°C, providing a thermophilic mode, as well as a sterilizer for an ultra-thermophilic mode, which sterilizes microbes [12].

The temperature of the substrate in bioreactors corresponds to the thermophilic mode and super-thermophilic mode – 40...95°C, the biogas consumption for heating is 6.2 m^3/day, the loading dose is 10 percent, the density of the fertilizer obtained is 864.9 kg/m^3, mass fraction of dry matter – 10.7 percent, the efficiency of disinfection of manure – 98 percent.

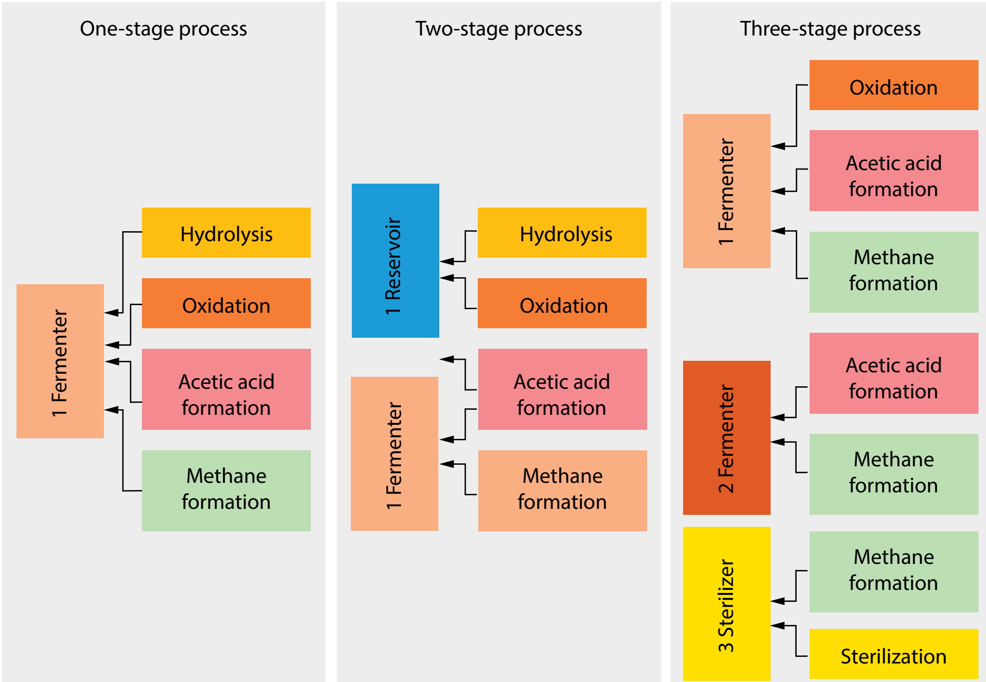


Figure 31. One-, two- and three-stage processes

The result of chemical analysis of organic fertilizer, conducted in the certified laboratory of "Chemical Analysis" LLP at "Kazakh Scientific Research Institute of Soil Science and Agrochemistry named after W.W. Uspanov", showed the following composition: total humus – 32.8 percent; gross phosphorus – 2 300 mg/l; total nitrogen – 1.456 mg/l; gross potassium – 1 500 mg/l).

Subsoil application of liquid fertilizer is carried out with the help of special equipment with a system of pumping and injection pumps, pipelines, tank carriage, pumped over by a pump, and with the help of hoses are fed into the working distribution bodies of the machine. In the studies of Dr. Claudia Wagner-Riddle from the Gulf University of Antario (Canada) (http://www.uoguelph.ca/research/) [13] (Figure 32) four methods were proposed for introducing the substrate into the soil.

The results of the analysis of existing technologies and machines for the application of liquid fertilizers on meadows and pastures suggest that they are equipped with openers, cut a groove in the soil, into which the liquid organic fertilizer is fed.

Given the poor equipment of the peasant farms in the region, it is not possible to recommend equipment with such technical means. Therefore, we recommend

Figure 32. Four methods of introducing the substrate into the soil: application to surface with spray splashing (1), subsoil application (2), with filling from hoses (3) and trailer colter (4)

that the technological process of the subsoil application of liquid fertilizers to be carried out with the help of an outfit consisting of a trailer tank with a pressure pump and a distributor along the racks of the working parts, aggregated by tractors T-40 and MTZ-80, which are available to peasant farms. In the layout of the working bodies there are 5 rippers with openers located on two rows (2 on the first and 3 on the second) with a working width of 3 m, and with a depth of introduction from 0.10 to 0.20 m.

Production of the domestic system for automating the processing of animal waste in the livestock industry will provide the necessary level of food security of the country, create new jobs in the regions, help develop export of animal products, improve the quality of crop production and its competitiveness.

Results

Processing the obtained results of calculations, monthly averaged values of the number and types of plants, we constructed graphs describing the dynamics of changes in indicators on deserted experimental pasture plots by calendar time.

The time-wise change of indicators on degraded pasture areas for March-November is shown in Figure 33.

As can be seen from the figure, the dynamics of changes, the average number of plants directly depends on the changes in the natural moisture on the pasture.

Processing the obtained results of calculations, monthly averaged values of the number and types of plants, we built graphs describing the dynamics of changes in the indicators on the medium-normal (control) areas by calendar dates.

Time-wise change of indicators on medium-normal (control) pasture areas for March-November is shown in Figure 34.

The dynamics of changes, the average number of plants on medium-normal areas of pasture depends directly on the amount of precipitation during the year. The established regularities will further allow to determine the optimal time for processing pasture surface to restore fertility.

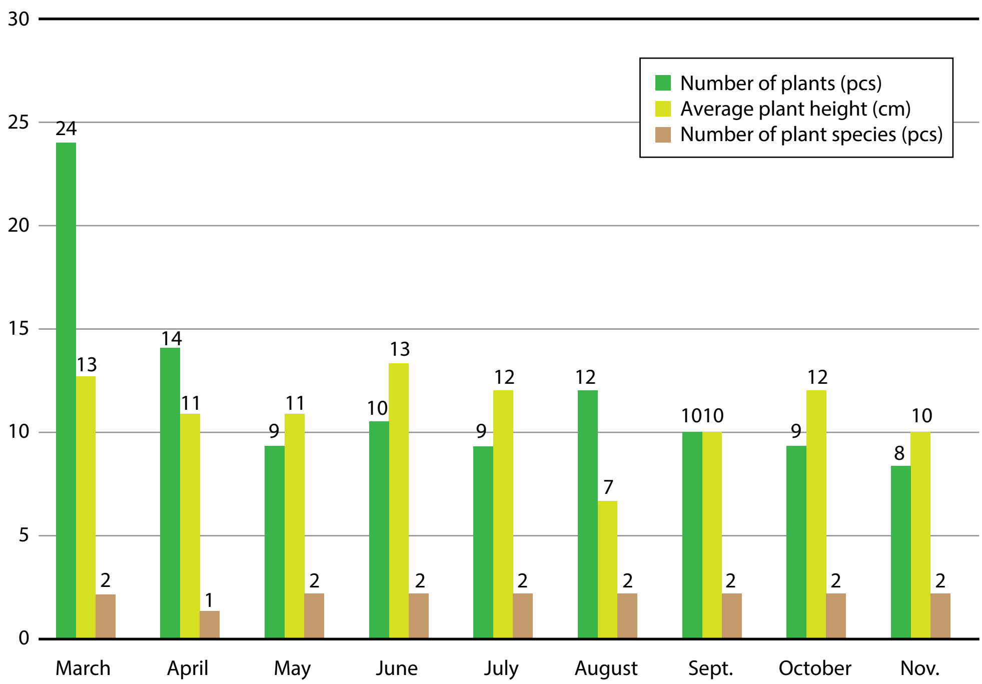


Figure 33. Time-wise change of indicators on degraded pasture areas

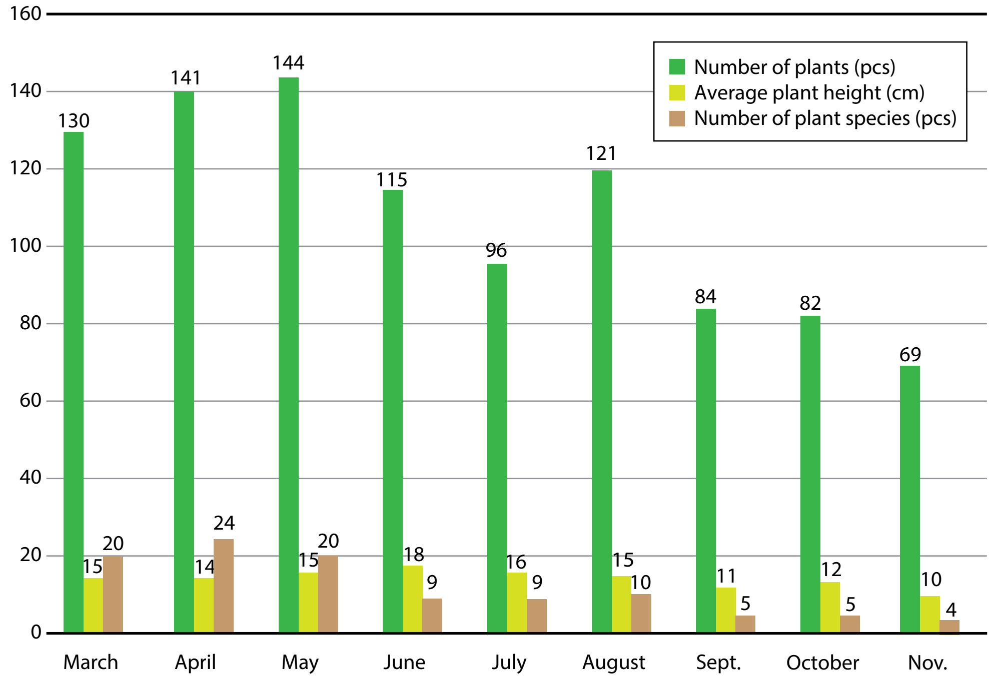


Figure 34. Time-wise change of indicators on medium-normal areas of pastures

The results of counting the number of plant species (biodiversity) (units/m^2) in the experimental (deserted) areas indicate a 10-fold decrease (from 20 to 2 units/m^2), which is an indicator of more than 10-fold degradation of the green cover relative to the average normal (control) plot of pasture.

The integrated technology of restoring the fertility of degraded pastures (Aldabergenov M.K., Sadanov A.K., 2017) provides for the production under economic conditions of liquid organic fertilizer with waste sterilization using a three-stage bioreactor plant and the subsoil application of the EM-drug by backlog-culture suspension of the drug 1×109 CFU/ml together with liquid organic fertilizer, using special equipment with loosening working bodies, providing simultaneous introduction and sealing of the drug in the soil, as well as conducting irrigation of pasture surface [14].

As a result of the tests carried out, an increase in soil fertility was found, while the nitrogen content in soils increased 2.0–2.5 times, the salinity of the soil filtrate decreased from pH 8.15 to a neutral value (pH 6.12), which provides the restoration of fertility and increase in the productivity of degraded pasture and arable lands of South-East Kazakhstan and the whole of Central Asia.

Conclusion

The developed technology for the production and use of organic fertilizers and EM associations for restoring the fertility of degraded soils allows speeding up the implementation of CA for the irrigated areas of the southern regions of Kazakhstan.

The complexity of these activities lies in the use of EM associations of agronomic valuable microorganisms to create a "healthy" soil microflora (EF technology), develop and implement mechanization processes for the production of liquid fertilizers based on animal waste and to carry out irrigation and drainage measures to optimize water supply. The introduction of this technology will lead to the restoration of pasture land fertility, an increase in labor productivity in peasant farms by 20–30 percent and a decrease in environmental tensions in rural areas.

References

Комитет по статистике Министерства национальной экономики Республики Казахстан. Официальный сайт www.stat.gov.kz.

Государственная программа по борьбе с опустыниванием в Республике Казахстан на 2005–2015 гг: [Электронный ресурс]. URL: http://savesteppe.org/ru/archives/2774 19.09.2005.

Почвозащитное и ресурсосберегающее земледелие: теория и методика исследований //Русский вариант публикации подготовлен под общей редакцией доктора сельскохозяйственных наук, профессора Хафиза Муминджанова (2015). – **Субрегиональное отделение Продовольственной и сельскохозяйственной организации Объединенных Наций по Центральной Азии.** – Анкара, 2015 «Myriad Pro». – 188 с.

Государственная программа по борьбе с опустыниванием в Республике Казахстан на 2005-2015 гг. [Электронный ресурс]. URL: http://savesteppe.org/ru/archives/2774 19.09.2005.

Саданов А.К., Смирнова И.Э., Сабденова А.А., Султанова А.Ж., Нурмуханбетова А.М. Создание ЭМ-ассоциаций, изучение их влияния на пастбищные культуры и биологическую активность деградированных почв // Вестник КазНУ. Серия биологическая. – 2016. – №2 (67). – С. 160–166.

Саданов А.К., Алдабергенов М.К., Смирнова И.Э., Орынбаев Н.М. Разработка технологии производства и применения органических удобрений и ЭМ-ассоциаций для восстановления плодородия деградированных пастбищ //Сб. трудов Междун. научн.-практ. конф. «Вклад микробиологии и вирусологии в современную биоиндустрию», посвященной 60-летию Ин-та микробиологии и вирусологии (3 июня 2016). – Алматы. – С. 206–211.

Verhulst, N., Kienle, F., Syare, K.D., Deckers, J., Raes, D., Limon-Ortega, A., Tijerina-Chavez, L., Govaerts, B., 2010. Soil quality as aff ected by tillage-residue management in a wheat-maize irrigated bed planting system. Plant Soil. 340. – P. 453–466.

Neave, M., Rayburg, S., 2007. A field investigation into the effects of progressive rainfall-induced soil seal and crust development on runoff and erosion rates: The impact of surface cover. Geomorphology 87. – P. 378–390.

Werner H. *et al*. Economical and Environmental analysis of a biogas plant within a context of a real farm //The Royal Veterinary and Agricultural University Denmark. – 2004. – 456 p.

«Biomass Energy Systems», **ACRE, the Australian CRS for Renewable Energy Ltd,** http:// wwwphys.murdoch.edu.au/acre/.

How small bio-digesters can improve nutrient recycling in agriculture, reduce emissions of greenhouse gases and improve local energy services. Prepared for IAC by **ETC Energy.** – 2000. –234 p.

Алдабергенов М.К., Бекбосынов С.Б., Орынбаев Н.М., Рамазанова Г.Т. Рекомендации по технологиям производства сухого органического удобрения с использованием отходов животноводческого комплекса. – Алматы: Інжу-Маржан, 2017. – 90 с.

Wagner-Riddle C, Thurtell GW, Kidd GE, Beauchamp EG, Sweetman R. Estimates of nitrous oxide emissions from agricultural fields over 28 months. Can J Soil Sci 77:135–144. doi:10.4141/S96-103.

Алдабергенов М.К., Саданов А.К., Смирнова И.Э., Орынбаев Н.М. Рекомендации по внедрению и адаптации комплексной технологии восстановления плодородия деградированных пастбищ для Юго-востока Казахстана. – Алматы: Інжу-Маржан, 2017. – 48 с.

Author information

Алдабергенов Марат Карлович – кандидат технических наук, доцент экологии.

Саданов Аманкелди Курбанович – академик Казахстанской национальной академии естественных наук, доктор биологических наук, профессор.

Орынбаев Нурсултан Маратулы – ведущий инженер, магистр сельскохозяйственных наук, докторант.

The main priorities of creating resource-saving technologies and technical means for soil protection

Omar Tedoradze, R.M. Makharoblidze[33]

Abstract

Some priorities of developing resource-saving technologies and technical means for restoring soil fertility and for protecting against erosion and degradation are presented. To determine the degree of resource saving of machine technologies and technical means, growing crops, we must evaluate the entire technological cycle on the basis of unified energy criteria that are not subject to market conditions. An analysis of the energy efficiency of new market resource-saving technologies should be carried out for the first time at the planning stage, on the basis of technological maps, and for the second time after harvesting, when the yield and actual energy costs are already known.

Key words: fertility, erosion, humus, machine technology.

Introduction

The main role in maintaining soil fertility belongs to primary processing, which is the most energy-intensive operation. There cannot be a unified system of tillage for all regions of Georgia, which requires a differentiated zonal approach. The annual "total" plowing in all regions does not contribute to the maintenance and improvement of soil fertility, since frequent overturning and loosening of the arable layer causes its degradation, mineralization of humus, and in the conditions of mountain slopes – increased erosion.

Justification of the priorities

Plowing is indispensable in the development of virgin and fallow lands, for plowing of green manure and weeds. The plow takes its place with minimal processing technology as well. Indeed, in addition to the fact that plowing provides turning of the layers, loosening and mixing of the soil, plowing of residues and weeds, it also carries out the removal of small colloidal nutrient particles that have fallen as a result of rains into the lower part of the arable layer, and the demolition of the upper devoid of structure dusty layer in their place. As a result of this movement, soil structure is restored.

In Georgia, plows are used, with which you can plow only in the dump and decay when a defective track appears in all pens. The use of chiseling is required. A certain ratio between the width of the chisel and the thickness of the strut of the working body, as well as a slope of 25... 300 of the cutting plane, contribute to the appearance of a ridge groove, as a result of which the hardened layer remaining after processing with a ploughshare or plane cut is crushed, and moisture is collected in the recesses of the groove base. This eliminates, or significantly reduces the runoff of water along the slope and water erosion, promotes the development of the root system of plants, reduces the temperature in the layer of 10... 30 cm in the hot season.

On the other hand, a chisel instrument is not intended to destroy weeds and to plant loose fertilizers during primary tillage. At the same time, it is considered positive if, when used on the field surface, 70... 80 percent of the stubble background is preserved.

In order to expand the operational and technological capabilities of cultivating the soil with an instrument with a chisel, the wings of the plow (without ploughshare) [3] are fixed on its risers [3], which overturn the upper, already loosened, nutrient layer of soil at a depth of 15... 20 cm, which contributes to the planting of weeds, the old stubble crops and residues of roots, as well as loose fertilizers. We recommend chisels to combine with the wings of the plow rotating in the horizontal plane, which will exclude landfill and defective furrows on the soil surface. Based on this, a soil-working chisel-wing working unit will be obtained, which will combine all the positive anti-erosion properties of chisel processing technology, and smooth plowing of a rotary plow, as well as resource-saving requirements.

One of the most promising directions of increasing resource conservation and soil fertility is considered to be the unification of all operations with combined units, which in one pass perform the operations of preparing the soil for sowing.

Current requirements to reduce energy consumption when processing soils imply a higher level of combination of operations, when the combined units are not sequential arrangement of instruments, and such a combination of different working tools, which both affect soil specific volume in the stress-strain state. One of the characteristics of the rheological properties of the soil is the relaxation time. During this period, in view of the repeated impact on it, less energy consumption is the occurrence of a large number of cracks and fragmentation of high quality. Fighting on slopes with water erosion is ineffective using various restraining irregularities formed on the surface of the soil. A more effective means is strip processing and furrowing with vertical mulching, when a gap dug in the soil is filled with various types of organic material (straw, leaves, stubble remnants, peat, etc.).

It is desirable that in parallel with the furrowing and vertical mulching, the so-called underground tillage (while leaving stubble) is carried out. The surface of the soil treated by this technology for a long time retains the ability to absorb water. [1]

Among other directions of tillage on slopes it is necessary to pay attention to search of such energy-saving technologies and technical means which rely on use of gas-dynamic, hydrodynamic and electro-hydrodynamic effects. These effects are particularly interesting for the development of energy-saving technologies for loosening hardened soils and suspension of water runoff from slopes.

Main part

The quality of resource saving of machine technology and performing their technical means can be judged according to the bioenergy coefficient.

$$e = E_1/E_{2,} \ (1)$$

Where E_1 is the amount of energy received from the system per unit time, g·j;
E_2 is the amount of energy that went in the direction of the system, g·j.

Indicator e is actually a coefficient of bioenergy efficiency, the numerator of which is the solar energy accumulated by the plant in the process of photosynthesis, and the denominator is the energy spent on the cultivation of such a plant.

The energy cost of the crop E_1 is determined by the following formula:

$$F_1 = Y \cdot K_{y,} \ (2)$$

Where Y is the crop yield, *C/ha*;
K_y is the energy equivalent of 1 centner of the main product.

It is advisable to conduct an analysis of the energy efficiency of growing crops using new and basic machine technologies for the first time at the planning stage, with the aim of adjusting according to the technological maps, and the second time after the harvest, when both the yield and the actual energy costs will be known in connection with production [2].

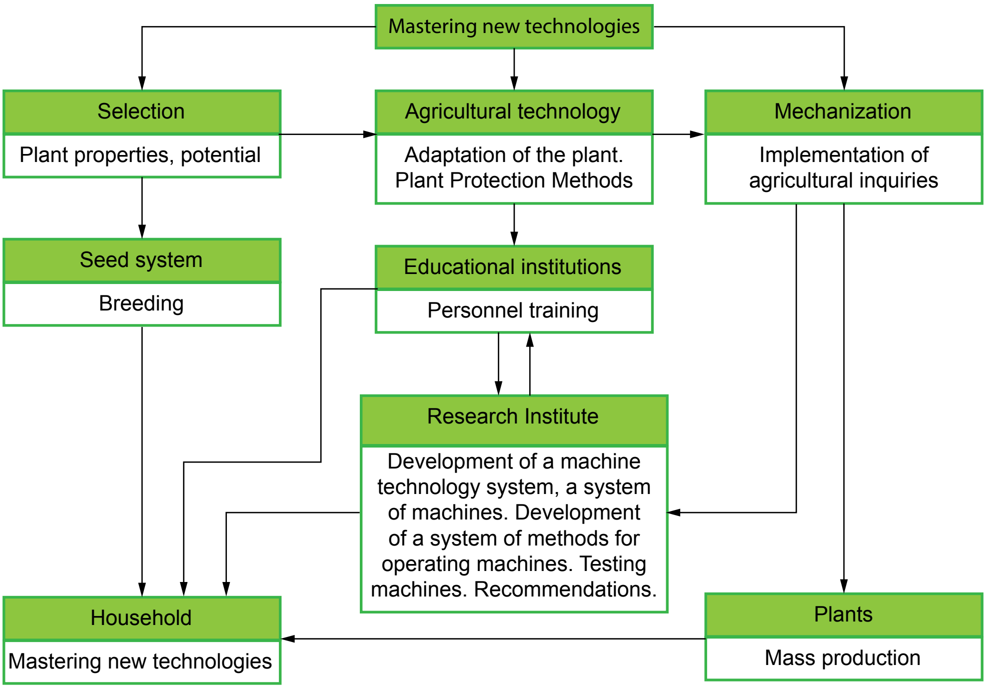


Figure 35. Flowchart of the development of new agricultural production technologies

After that, it is necessary to develop model (typical) Flowcharts (Figure 35) for the care and cultivation of crops according to the zones that can be used for a particular field and the analysis of the effectiveness of the technology to make appropriate adjustments if necessary. The total energy cost of a complete technology of care and cultivation of crops (E_t) is determined by the sum of energy costs for the implementation of separate technological operations:

$$E_c = E_1 + E_2 + \ldots + E_N, \quad (3)$$

Where $E_1, E_2, \ldots E_N$ – energy costs during the execution of *1, 2,... N* technological operations, g·j.

According to separate technological operations direct and indirect energy costs are taken into account:

$$E_c = (E_1^{\Pi} = E_1^{0}) + (E_2^{\Pi} + E_2^{0}) + \cdots (E_N^{\Pi} + E_N^{0}) = \sum_{i=1}^{N} (E_i^{\Pi} + E_i^{0}), \quad (4)$$

Where E_1^d, E_2^d,..., E_N^d direct energy consumption during *1, 2,... N* technological operations, m·j

E_1^0, E_2^0,..., E_N^0 – indirect energy consumption during the execution of *1, 2,... N* technological operations, m·j.

For its part, during the i -th technological operations, direct energy consumption ($E_i^{П}$) is calculated by the following formula:

$$E_i^{П} = З_i^{Г} \cdot K_i^{Г} + З_i^{Т} \cdot K_i^{Т} + З_i^{Э} \cdot K_i^{Э} \text{, (5)}$$

Where E_i^f – expenses of fuels and lubricants during the i-th technological operations, kg;
C_i^l – labor costs during the execution of the i-th of technological operations, people/hour;
C_i^e – the cost of electricity during the execution of the i-th of technological operations, KW/hour;
K_i^f – energy equivalent of a unit of fuel and lubricants during i-n technological operations, MJ/kg;
K_i^l – the energy equivalent of unit labor costs during the execution of the i-th of technological operations, MJ/person·hour;
K_i^e – energy equivalent unit cost of electricity during the execution of the i-th of technological operations, MJ/KW·h.

Materialized (amortized) energy costs of material and technical means (fixed assets) are costs in energy units of tractors and agricultural machines and units in a unit of time or volume of work performed (Ha, T, etc.). Therefore, to calculate the embodied energy consumption, the operating time, annual load, annual output of the technical means and the corresponding energy equivalent of the unit (tractors and agricultural machines), which is determined based on the energy costs of its manufacture, are used [4].

In this case, the amortization energy consumption of the unit, received to perform the i-th technological operation, is calculated by the following formula:

$$E_i^0 = t_1^T \cdot K_i^T + t_i^M + K_i^M \text{, (6)}$$

Where E_1^0 – amortization energy costs for i-th technological operations, MJ;
ti^T – tractor operating time, hours;

ti^M – working time of agricultural machinery, hours;
Ki^T – depreciation energy equivalent during tractor operation MJ/h
Ki^M – depreciation energy equivalent during operation of agricultural machines MJ/h

During the use of agricultural machinery depreciation energy equivalents embodied energy costs are determined by the following formula:

$$A_Э = \frac{З_П + З_{K \cdot \rho}}{T_A \cdot t_2}, (7)$$

A_E – hourly energy rate of depreciation, MJ; C_P is the cost of energy resources for the production of equipment, MJ; $C_{M \cdot R}$ is the amount of energy costs for major repairs, MJ; T_D is the time of depreciation service, year; t_2 is the estimated annual load of equipment, hours. Energy costs embodied in tangible working capital (seeds, fertilizers, pesticides, lime, etc.) and used in a particular year are calculated by the following formula:

$$E_i^{об} = m_i^{об \cdot} K_m, (8)$$

Where $E_i^{об}$ – energy consumption during the execution of the i-th of technological operations, MJ;
mivo – weight (volume) of working capital used during the i-th technological operations, kg (m^3);
K_m – energy equivalent of the mass of working capital (MJ/kg, MJ/m^3);

The formula for calculating energy costs for the repair of machines and their maintenance is as follows:

$$E_i^o = \left[\frac{M_m \cdot K_{pm}}{B_m \cdot W_m}(K_{mm} + K_{um}) + \frac{M_T \cdot K_{pT}}{B_T \cdot W_T}(K_{mT} + K_{uT})\right] 0{,}667, (9)$$

Where E_i^O – energy costs for repair and maintenance, MJ/ha;
$K_{rm}.K_{rT}$ – coefficients of energy costs for repair of tractors, agricultural machinery and maintenance as a percentage (percent)
M_m – weight of agricultural machine, kg;
M_T – weight of tractor, vehicle, electric motor, kg;
B_T – annual output of all machines, hours;

W_m – machine capacity, Ha/h;
W_T – productivity of all other machines, ha/h;

K_{mm}, K_{mT} – energy equivalent of the cost of producing 1 kg of metal of all machines, MJ;
K_{um} – the energy equivalent of the cost of manufacturing a machine from metal, MJ/kg.

Thus, the total energy consumption for the care and cultivation of crops is determined by the following formula:

$$E_2 = E_c = \sum_{t=1}^{N}[З_i^{Г}.K_i^{Г} + З_i^{T}.K_i^{T} + З_i^{Э}.K_i^{Э}) + (t_i^{T}.M_i^{T} + t_i^{M}.K_i^{M} + m_i^{об}.K_m)] + E_p$$

Conclusion

Analysis and comparison of new and basic machine technologies according to the above methodology will allow to determine, in the case of leaving and growing crops using the new technology, the degree of resource saving in energy units per unit of output.

The issue of rational use of resources in agriculture cannot be resolved only within the framework of the agronomic and engineering sphere. A comprehensive solution to the problem is needed, starting with breeding, agricultural technology, land use, and ending with solving the problems of agricultural engineering and training.

References

Шило И.Н., Дашков В.Н. ресурсосберегающие технологии сельскохозяйственного производства. Монография, (.2003 г). 183с. Минск.

Шпилько А.Н., Дрогаисев А.В. Морозов Н.М. и др. Экономическая эфективность механизации сельскохозяйственного производства. (2001 г). 346с. Монография, Москва.

Борисенко И.Б., Пындак В.И. Комплексное орудие для основной обработки почвы. (2009 г). Москва, ж.МЭСХ, N 1, с 9...10.

Махароблидзе Р.М.– основные приоритеты создания ресуросберегающих технологий и технических средств для механизации сельского хозяйства. 2010 г. Тбилиси – Сборник научных трудов НИИМЕСХ стр. 7–27.

Application of Geographic Information Systems (GIS) in effective management of the land resources

Shukhrat Bobomurodov[34]

Abstract

The article analyzes the opportunities of effective land management using geographical information systems. The perspectives of the using of geo information systems in the efficient use of agricultural lands especially in the development of recommendations for improving the reclamation of saline soils are given. The development of algorithms for the provision of relevant regulatory recommendations on the state of the lands in the studied area and the creating of salt washing norm maps based on GIS technologies have been studied.

Key words: soil quality condition, soil salinity, salt washing norms, geo information systems, geostatistics analysis.

Introduction

As you know, today agricultural production and provision of food to the population are one of the most pressing issues in the world. This is due to the high increase of the world population, various environmental problems (land degradation and soil erosion, quantitative and qualitative changes in water resources, climate change) and many other socio-economic issues.

Agricultural lands are key component of the ecological system of our earth that is closely linked to other parts of nature, such as water, forest, animal and plant world, minerals and other underground resources. Without lands and soils, other natural resources cannot be used. Therefore, as a result of non-efficient use of lands, the entire environment can be damaged in the immediate and future, which can lead to degradation of not only the surface layer also to problems of soil degradation, their erosion, soil salinity, water logging, chemical and radioactive contamination and environmental degradation. That is why protection of lands appears to provide conditions for the sustainable development of society and to ensure human life and activities. Therefore, all lands irrespective of agricultural or non agricultural designation should be protected, where priority is given to agricultural lands.

The main forms of land degradation are the natural and climatic factors also human activity that cause desertification and degradation of the land, which include:

- Desertification, loss of forests and other events;
- Secondary salinity, water logging, excessive softening of the ground in the conditions of irrigated agriculture;
- Water and irrigation erosion of soils in mountainous and sun mountainous regions;
- Wind erosion (deflation) and degradation of pasture lands in regular livestock-breeding areas;
- Man-made desertification of lands for agricultural and industrial purposes;
- Soil pollution and loss of fertility according to agrochemicals, industrial and household waste disposal;
- Soil salinization due to drying factors in the Aral Sea and so on.

Application of advanced technology to address land degradation problems remains a topical issue. One of the topical issues of today is the use of information and communication technologies in the field, effective management and monitoring of agricultural enterprises based on them. In particular, there is a need for an information system that provides storage, processing and delivery of data at different levels and levels in the field of effective land and soil resources management. By developing such systems, the field data can be easily evaluated, stored, updated and analyzed in terms of using and storing land resources.

Research methods

The researches were carried out at Yangiobod farms in Mirzaobod district of Syrdarya region. Soil samples were taken from sierozem meadow soils in the area. The location of the soil samples was recorded using modern GPS equipment. Field surveys were carried out on the basis of "Instruction on soil survey and soil mapping for the State Land Cadastre". Laboratory-analytical and cameral studies were developed and conducted on the basis of commonly used techniques developed by Research Institute of Soil Science and Agrochemistry. Geographic information system analyzes were carried out using ArcGIS 10 software and its Geostatistical Analyst modules.

Research results

It is well known that the successful solution of the problems of land reclamation, first of all, in the development of agricultural production of the republic, including the improvement of agricultural land productivity, requires the development of scientific and practical recommendations based on scientific and applied research, including complex surveys on mapping saline soils on irrigated soils, identification and accountability of each region, the formation of soil salinity maps.

It is known that, soil salinity is considered one of the main factors, which has negative influence on soil fertility. Soil salinity has negative impacts on the development of agricultural crops, and decreases harvest from them significantly. Soil salinity is one of the most urgent problems, in particular, in our research areas, and most parts of the irrigated lands of Sirdarya region is considered as less and medium saline soils.

In creating maps of the parameters of salinity block of soil fertility model, solid residues and amount of sulphate and chlorine salts were determined. Based on these indicators, soil salinity maps were created with GIS, by interpolation method.

In determination of soil salinity washing norms the study of soil salinity of territory is primarily taken into account. Because saline washing norms are formed in different groups in accordance with the conditions of different regions of our republic. For example, the Syrdarya region, which is engaged our research, is located in Jizzakh, Tashkent and Samarkand regions group. Once determined the region, the mechanical composition of the soils and the amount of chlorine ions are compared then differentiated to the relevant recommendation groups. For example, if the soil in Syrdarya region is medium and light loamy according to the mechanical composition, and chlorine ion concentrations are in the range of 0.01–0.04, salt washing norms as follows:

- Common salt washing norms – 3 000–3 500 m^2;
- Number of salt washes – 1;
- Period of salt washing – October–December.

After the above salinity parameters have been identified according to soil salinity and at the next stage spatial analyzes were performed using a several indicators. At the same time, a map of soil salinity washing norms for the territory has been created, based on the soil mechanical composition and the amount of Cl salts. (Figure 36).

From the materials of the salinity maps created for this purpose used for following:

- Fast (operative) soil salinity mapping of farming massives;
- Determination of the current salinity washing norms for each irrigated land plots;

Figure 36. Map of soil salinity washing norms of irrigated soils of Yangiabad area of Mirzabad district of Syrdarya region

- Control over meliorative condition of agricultural lands;
- Comparative comparisons of soil fertility and salinity dynamics in previous periods.

Conclusion

As a result of the research, a wide range of opportunities for researchers to create thematic maps based on the soil research results using Spatial Analyst and Geostatistical Analyst modules of ArcGIS software are determined. In summary, it should be noted that the use of modern geoinformation technologies in the effective management of land resources can provide accurate and timely information, increase their operational processing and storage capacity, and creating relevant database will ultimately provide an excellent analysis of the state of the land resources.

References

Savin I.Yu. "Analyze of soil resources based geoinformation technologies", Moscow, 2005. (In Russian).

FAO. 1993. Guideline for Land Use Planning. FAO Development Series, No:1, FAO, Rome, 96 pp.

"Computerized Land Resources Appraisal for Agricultural Development", **World Soil Resources Report,** Rome, 2003.

Rhind D., Wyatt B., Briggs D., Wiggins J. The creation of an environmental information system for the European community. – Nachr. Karten- und Vermessungsw, 1986. – R.2. – N 44. – P. 147–152.

Sh. M. Bobomurodov. Studying of soil properties and development of their geo-information database using geoinformation system technologies. Reports of the Academy of Sciences of Uzbekistan. 2014, Issue 6. (In Uzbek)

Macarenko E.L., The experience of creating electronic maps of soil resources assessment for agricultural purposes // Cartography of the 21st century: theory, methods, practice: Reports of the II All-Russian Scientific Conference on Cartography. Moscow, October 2-5, 2001 – Moscow: Institute of Geography, Russian Academy of Sciences, 2001. (In Russian).

Maxsudov B.Yu., Gadoev J., Creation of geographical database of irrigated lands reclamation fund. Ecological Report of Uzbekistan, Issue 11, 2012. 5 pages. (In Uzbek).

Soil degradation and erosion effects on soil agrochemical properties

Obid Hakberdiev[35], Tulkin Shamsiddinov

Abstract

The article considers the problem of soil degradation in the southern mountainous regions of the Republic of Uzbekistan and the protection of soils from erosion, as well as the effect of erosion on the agrochemical and chemical properties of typical and dark gray soils. The aim of the research is to study changes in the agrochemical properties of soils under the influence of water erosion in foothill and mountain conditions, taking into account the elements of the slope and the exposure of the slopes.

Key words: degradation, mountainous areas, soil protection, soil erosion, agrochemical properties, typical and dark gray soils, crop rotation, minimal cultivation, steepness, slopes.

Introduction

Soil-based systems can be productive, but in the long run are unstable in environmental and economic terms. Because the degree of soil degradation (from erosion and other forms of decreasing soil fertility) is usually higher than the degree of natural soil formation and the ability of the soil to independently recover (Nurbekov, A. *et al.*, 2013). Soil degradation is a set of processes that lead to changes in soil functions, quantitative and qualitative deterioration of its properties, gradual deterioration and loss of fertility. Soil degradation occurs due to the loss of soil organic matter and life forms associated with soil, as well as the destruction of its structure due to the excessively high oxidation state resulting from plowing (Nurbekov, A. *et al.*, 2013). The relevance of CA to agricultural development at the international, national and local levels lies in its distinction from systems based on plowing. The essence of this difference is that it simultaneously contributes to increasing the productivity of crops, as well as preserving the ecosystem, such as soil improvement, erosion control, clean water, carbon breakdown, nutrient, carbon and water metabolism cycles, protecting plants from pests and diseases (Nurbekov, A. *et al.*, 2013).

The problem of protecting soil from erosion is relevant for many countries in the arid zone of the world, including Uzbekistan. Currently, of the total area of the Republic of 44896.9 thousand hectares, agricultural land accounts for 20 388.9

thousand hectares and of which more than 4 700 thousand hectares are not affected by cultivation, it is spread on the slopes of the mountains, foothills and adyrs. In especially dangerous sizes, this type of erosion is manifested on sloping lands occupied by rainfed arable land or pastures. In mountainous and foothill areas, water erosion develops as a result of deforestation and intensive grazing. In the current state of nature conservation, the development of scientifically based methods for managing biological systems for the reproduction of natural resources and the restoration of destroyed landscapes becomes most urgent.

In this regard, there are problems of protection and clarification of areas of intense impact on nature. Scientific research related to the complex study of mountain and foothill ecosystems, raising their productivity, and more rational exploitation of mountain resources should be expanded. All these issues in the conditions of independent Uzbekistan are solvable, because soil conservation measures are aimed at further improving living conditions, as well as at achieving the environmental well-being of future generations.

Materials and methods

The aim of our research was to study changes in the agrochemical properties of soils under the influence of water erosion in foothill and mountain conditions, taking into account the elements of the slope and the exposure of the slopes.

Organic matter is one of the most important elements of soil fertility. The processes of structure formation, the state of water-air and thermal regimes of soils, the provision of plants with nutrients depends on the qualitative and quantitative composition of organic matter. In the process of flushing the upper, most fertile horizons, significant changes in its agrochemical and agrophysical properties occur. Eroded soils, in comparison with the indelible soils of the watersheds and broad-wave plains, are characterized by a lower thickness of the humus layer and a lower content of humus.

The erosion process sharply worsens the agrochemical properties of soils. This reduces the content of humus and forms of nitrogen, phosphorus and potassium. So, as the data show, in uncleaned typical and dark gray soils in the arable horizon of humus contains 0.90–1.35 percent, in weakly washed soils – 0.86–1.10, in medium washed soils – 0.65–0.99 percent. Soils located in southern exposures are especially depleted in humus, where its amount in a typical and dark gray earth in the arable horizon is 0.65–0.82 percent, and their decrease downward is rather sharp, and in indelible soils its content decreases in depth more or less evenly. Such a low humus content of typical and dark gray soils, especially in soils located on the southern slopes in all studied soils, is associated with the process of erosion, the totality of the vegetation cover, and the dryness of the upper soil layer.

It should be noted that the high susceptibility of typical and dark gray-earth soils to erosion is the result of a large steepness of the slopes, weak grass cover and the absence of an erosion control measure in a large part of the territory, especially on rain-fed arable lands.

In the examined soils, the content of gross nitrogen varies in close connection with the content of humus. Most of it is accumulated in the upper humus horizons. In the washed away differences of sierozems, its content sharply decreases. In rainfed eroded sierozems, in addition to humus and nitrogen, the content of certain nutrients, in particular gross and mobile forms of phosphorus and potassium, is reduced.

Results

The data show that the differences in the content of gross phosphorus and potassium in the arable horizons of poorly washed and unwashed soils are not very large, but a slight decrease in their total amount is observed on average washed-out differences. This is due to the approach to the surface of the lower soil horizons, poor in phosphorus and potassium.

So, under the influence of storm erosion, the content of gross phosphorus in the arable horizon of typical gray soils decreases from 0.200 percent, in poorly washed soils – 0.176 percent, in medium washed soils – 0.115 percent, in dark gray soils – 0.215 percent, 0.206 percent, 0.145 percent, respectively.

Conclusion

Mountain and foothill lands occupy mainly slopes with a steepness of more than 100, rainfed arable lands – 5–100 or less.

The distribution of land according to the steepness of the slopes must certainly be taken into account when distributing different types of crop rotation and the use of minimal cultivation on rainfed lands and when designing a system of anti-erosion measures.

Table 15. The effect of erosion on the agrochemical and chemical properties of rainfed typical and dark gray soils.

№	Section and name of soils, degree of erosion, steepness of the slope	Depth, cm	Humus, percent	Nitrogen, (percent)	Gross, (percent)		Movable kg/mg	
					Phosphorus	Potassium	P_2O_5	K_2O
	Typical sierozems, loamy, Syrob							
1	R-9. Typical gray soils, unwashed soil. Slope 1–2°	0–25 25–47 47–67 67–93 93–125	0.98 0.80 0.60 0.50 0.42	0.081 0.066 0.058 0.048 0.040	0.200 0.125 0.180 0.165 0.160	1.68 1.55 1.50 1.47 1.15	8.60 6.30 5.10 3.25 2.64	153 140 150 136 110
2	R-3. Typical gray soils, slightly washed away. Slope 3–4°	0–22 22–38 38–60 60–86 86–120	0.86 0.71 0.65 0.56 0.50	0.074 0.065 0.060 0.060 0.051	0.176 0.255 0.189 0.169 0.165	1.65 1.60 1.54 1.52 1.47	7.05 5.43 3.50 2.65 2.64	165 150 125 123 114
3	R-8. Typical gray soils. Medium washed soil, 5°	0–22 22–35 35–57 57–85	0.65 0.60 0.57 0.42	0.058 0.045 0.065 0.040	0.115 0.175 0.177 0.155	1.60 1.55 1.51 1.05	7.50 6.50 5.35 4.64	80 110 122 113
	Dark gray earth, loamy, rainfed, Padang							
5	R-5. Dark sierozems, unwashed soil.	0–20 20–52 52–75 75–110 110–150	1.35 1.05 0.80 0.65 0.50	0.097 0.065 0.062 0.055 0.040	0.215 0.225 0.165 0.140 0.155	1.80 1.75 1.60 1.80 1.60	8.00 6.60 4.05 5.10 6.15	200 186 109 – –
6	R-6. Dark gray soils, slightly washed, steepness 2-3°.	0–20 20–42 42-70 70–91 91–112 112–150	1.10 0.60 0.55 0.50 0.40 0.35	0.088 0.075 0.055 0.050 0.049 0.035	0.206 0.228 0.360 0.400 0.418 0.355	2.03 1.85 1.80 1.70 1.45 1.52	6.53 8.00 5.33 5.20 4.05 5.00	120 105 140 105 98 85
7	R-20 Dark sierozems, rainfed, moderately washed soil, slope steepness 5–6°	0–21 21–35 35–52 52–74 74–110	0.99 0.95 0.84 0.53 0.56	0.088 0.066 0.050 0.075 0.059	0.145 0.200 0.220 0.240 0.300	1.75 1.65 1.55 1.48 1.25	6.05 5.65 5.33 5.00 –	240 172 95 – –

References

Махсудов Х.М., Гафурова Л.А., Турапов И.Т., Ханазаров А.А. – Горные и предгорные почвы Узбекистана, их генетические особенности и охрана. Т., 2000-й.

Хакбердиев О.Э. – Химические свойства типичных эродированных почв. Международная научно-практическая конференция, посвящённая году экологии в России. с. Соленое Займище, ФГБНУ “ПНИИАЗ”, 2017 г. 18–19 мая.

Nurbekov A., Akramkhanov A., Lamers J., Kassam A., Friedrich T., Gupta R., Muminjanov H., Karabayev M., Sydyk D., Turok J. and Bekenov M., "Conservation agriculture in Central Asia: Past and Future" Conservation agriculture: Global prospects and Challenges. Editors: Ram A Jat, Kanwar L Sahrawat and Amir Kassam. Publisher: CABI 2013. 350–400. ISBN 978-1-78064-259-8.

Chapter 3

Conservation agriculture and climate change mitigation

©FAO/Emilio Gonzalez

Climate change mitigation through conservation Agriculture

Emilio Jesús González-Sánchez[36,37], Óscar Veroz-González[38], Gordon Conway[39], Amir Kassam[40], Manuel Moreno-García[41], Rafaela Ordoñez-Fernandez, Jesús A. Gil-Ribes, Julio Román-Vázquez, Antonio Holgado-Cabrera, Paula Triviño-Tarradas, Rosa María Carbonell-Bojollo

Abstract

Historically, intensive tillage of agricultural soils has led to substantial losses of soil C that range from 30 percent to 50 percent. These CO_2 losses are related to soil fracturing which facilitate the movement of CO_2 out of the soil and oxygen into it. Conventional agriculture operations (mouldboard ploughing) bury nearly all the residue and leave the soil in a rough, loose, and open condition resulting in maximum CO_2 losses and a consistent reduction of the C sink effect of the soil.

Conservation agriculture (CA) 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. It is based in three interlinked principles: minimum soil disturbance; permanent soil cover; and crop rotations and diversification.

With regards to climate change, the characteristics of CA make it one of the best systems able to contribute to climate change mitigation by reducing atmospheric GHGs concentration. On the one hand, the changes introduced by the CA related to the C dynamics in the soil, lead directly to an increase in soil C. This effect is known as soil's carbon sink. On the other hand, the drastic reduction in the amount of tillage and the mechanical non-alteration of the soil, reduce CO_2 emissions derived from the energy saving and the reduction of the mineralization processes of the organic matter. Soils high in organic matter protect productivity and reduce water pollution by resisting erosion, absorbing and partitioning rainfall, and degrading or immobilizing agricultural chemicals, wastes or other pollutants.

Conservation agriculture is more than a promising sustainable agricultural system, as it can effectively contribute to mitigate global warming, being able to offset agricultural CO_2 emissions. Studies reveal a potential of 190 M t of CO_2 per year for Europe and 533 M t of CO_2 per year in Africa. This figure represents about 95 times the current sequestration rate in some regions. To put this figure into context, according to the

United Nations Framework Convention on Climate Change, South Africa's national emissions by 2025 and 2030 will be in a range between 398 and 614 Mt CO_{2-eq}.

Key words: Carbon sequestration; no-tillage; groundcovers; cover crops.

Introduction

If there is any productive activity that depends directly on the climate and its variability, it is undoubtedly agriculture. A change in temperature and rainfall patterns or an increased concentration of atmospheric CO_2 will significantly affect crop development. For good reason it is estimated that, globally, climate variability is responsible for between 32 percent and 39 percent of variability in yields (Ray *et al.*, 2015).

Although some aspects of climate change, such as longer growth seasons and a rise in temperature, can be beneficial, the lack of water availability and the more frequent occurrence of extreme weather phenomena will in turn have negative and adverse effects on agriculture. Based on the above, if there is no adaptation over time and measures are not taken to mitigate the effects of global warming, there could be considerable economic, social and environmental consequences, taking into account the important role that agriculture plays, both as a food supplier and as an environmental asset and service. This becomes even more significant when considering forecasts for growth in the demand for agricultural products over the coming decades due to growth in world population numbers.

In agricultural systems, one of the natural resources that may be the most determining factor with regard to climate change is soil. Its potential for capturing CO_2 from the atmosphere and incorporating it in the form of organic carbon (OC) makes it a powerful mitigation tool. Proof of this is that soil is the greatest reserve of carbon (C) in terrestrial ecosystems (Lal, 2008) and the second in the world behind the oceans, accumulating three times more than the atmosphere (Smith, 2004) and aerial biomass (Sommer and Bossio, 2014).

Accordingly, soil management systems have a great deal of potential in terms of crop management. Management systems based on tilling can lead to a reduced OC content, with a consequent shrinkage in their carbon sink potential. Several authors agree on this matter, stating that soil disturbance from tilling is one of the major causes of reduced OC in soil (Balesdent *et al.*; 1990, Six *et al.*; 2004, Olson *et al.*; 2005). Thus, some studies confirm that intensive farming contributed to a loss of between 30 percent and 50 percent of OC in soil in the last two decades of the 20th century (Reicosky, 2011). Taking into account soil's storage capacity of C and the ongoing systematic loss of C for decades, it could be thought that any strategy aimed at increasing the OC content of soil, however small those increases may be, will have a positive impact on mitigating climate change. At this point, it is worth bearing in mind that soil's capacity to store C is limited and that a point therefore comes when a balance is reached between the carbon captured and the carbon released through decomposition of organic matter. It can be unequivocally stated that this balance in agricultural ecosystems is a long way from being reached, according to currently available carbon loss figures, so farming practices that help increase the sink effect clearly still have a long way to go.

On the other hand, tilling has a direct influence on emissions of CO_2 from the soil into the atmosphere both in the short term (immediately after ploughing) and in the long term (during the crop season). This is because tilling stimulates the production and accumulation of CO_2 in the soil's porous structure through processes of organic matter (OM) mineralization. The mechanical action of tilling involves breaking down soil aggregates, with the consequent release of the CO_2 trapped within them, and which is then emitted into the atmosphere.

Furthermore, the energy consumption associated with different farming practices (tilling, applying fertilizers and amendments, irrigation, phytosanitary treatments, etc.) is essentially based on the use of fossil fuels, particularly fuel oil, which means inevitable emissions into the atmosphere of greenhouse gases (GHGs).

Based on all these considerations, mitigation measures in the agricultural sector involve fixing the C found inside the oxidized compound in the soil while reducing GHG emissions in general. In turn, if the measures adopted cannot only mitigate climate change but also improve water balance and soil quality, as well as increasing biodiversity, it will be possible to confirm that these measures will help crops adapt to scenarios involving a lower availability of water resources, a higher incidence of extreme weather conditions that increase the risk of erosion, and the incidence of new pests and diseases.

In this context, conservation agriculture (CA) is a sustainable agriculture system, able to produce food and fiber in all agroecologies (Kassam *et al.*, 2018). According to the Food and Agriculture Organization of the United Nations (FAO, 2018), CA is a farming system that promotes continuous no or minimum soil disturbance (i.e. no tillage), maintenance of a permanent soil mulch cover, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, so contributing to increased water and nutrient use efficiency and productivity, to more resilient cropping systems, and to improved and sustained crop production. Conservation agriculture is based on the practical application of three interlinked principles:

1. Avoiding or minimizing mechanical soil disturbance involving seeding or planting directly into untilled soil, eliminating tillage altogether once the soil has been brought to good condition, and keeping soil disturbance from cultural operations to the minimum possible.
2. Maintaining year-round biomass mulch cover over the soil, including specially introduced cover crops and intercrops and/or the mulch provided by retained biomass and stubble from the previous crop.
3. Diversifying crop rotations, sequences and associations, adapted to local environmental and socio-economic conditions, and including appropriate nitrogen fixing legumes; such rotations and associations contribute to maintaining biodiversity above and in the soil, add biologically fixed nitrogen to the soil-plant system, and help avoid build-up of pest populations. In CA, the sequences and rotations of crops encourage agrobiodiversity as each crop will attract different overlapping spectra of microorganisms and natural enemies of pests.

Therefore, agricultural practices such as CA, the benefits of which on soil, water and air resources mean it can be considered a practice to help mitigate climate change and adapt crops to the effects of that change, are strategies that form part of what has come to be known as climate-smart agriculture.

Material and methods

The results presented in this paper are based on a literature review of scientific articles published in peer reviewed journals. The terms “Conservation agriculture; carbon sequestration; climate change mitigation, no-tillage, groundcovers” have been consulted at the scientific databases sciencedirect.com and webofknowledge.com.

This revision has been carried out based on the different biogeographic regions of Europe (Figure 37) and focused on CA management practices, carbon sequestration based on current area of CA adoption in European countries, and potential of carbon sequestration based on conversion of conventional agriculture to CA across Europe.

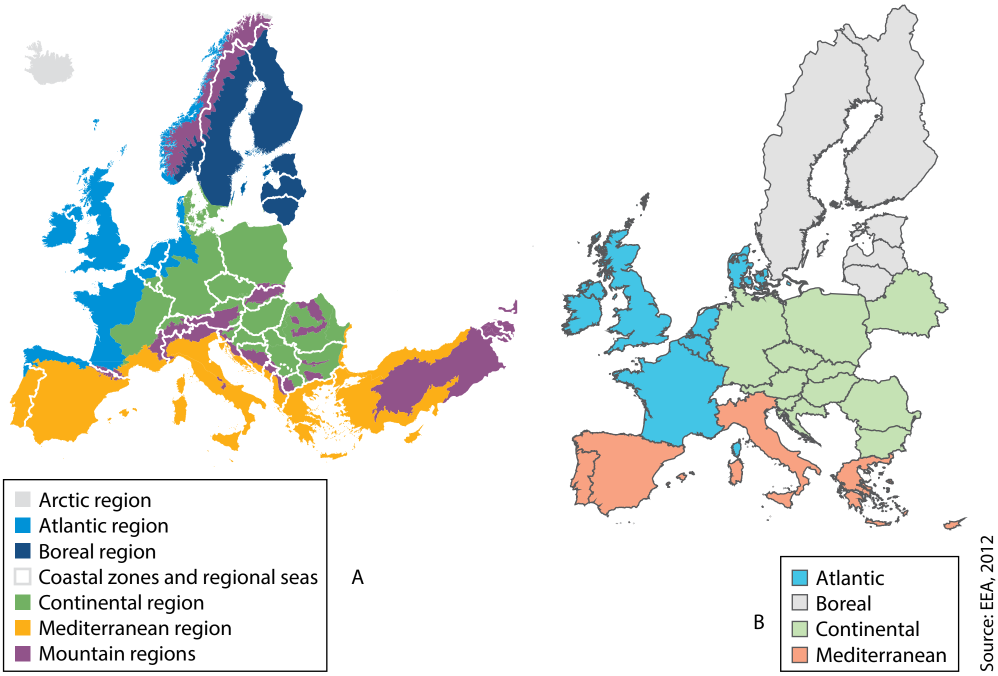


Figure 37. Cataloging of each European country (B), of the main European biogeographic region (A).

In particular, two countries have been selected to carry out the bibliographic review in the continental, Atlantic and Mediterranean biogeographical regions. While in the Boreal region, after noticing in written documents that there is less influence of CA regarding tillage, only data from one country have been taken. These countries have been:

- Boreal Region: Sweden.
- Continental Region: Germany and Poland.
- Atlantic Region: France and the United Kingdom.
- Mediterranean Region: Spain and Italy.

The methodology for obtaining the carbon sequestration rates is described in González-Sánchez *et al.*, 2012. The description of the methodology to obtain potential areas of CA is as follows. Country statistics of crops were obtained from EUROSTAT (EC, 2018). Among the annual crops, those best adapted to no-tillage CA systems were selected: cereals, pulses, industrial crops and fodder crops. Most of the woody perennial crop areas were found suitable for CA.

In climate change international agreements, emissions are referred to carbon dioxide; however, soil carbon studies refer to carbon. For transforming carbon into carbon dioxide, the coefficient of 3.67 was used. The atomic weight of carbon is 12 atomic mass units, while the weight of carbon dioxide is 44, because it also includes two oxygen atoms that each weigh 16. So, to switch from one to the other, one tonne of carbon equals 44/12 = 3.67 tonnes of carbon dioxide.

Results

Average rates of carbon sequestration by CA in agricultural soils for each biogeographical region in Europe are presented in Table 16. Currently, the total carbon sequestration estimated for the whole of Europe thanks to CA, of 4 327 863 t C yr-1 is shown in Table 17. This relatively high figure is because degraded soils are 'hungry' for carbon, as the degradation caused by years of tillage and crop biomass removal has resulted in a drastic reduction of soil's organic matter (Reicosky, 1995; Jat *et al.*, 2014; Kassam *et al.*, 2017). Figures 38 and 39 show the total amount of potential carbon sequestration for Europe, for each biogeographical region in annual and perennial crops, with respect to current carbon sequestration status. In total, the potential estimate of annual carbon sequestration in European agricultural soils through CA amounts to almost 16 M t of C per year, that is 189 M t of CO_2 per year. These figures represent about 25 times the current sequestration figure in no till systems and about 5 times the current sequestration figure in groundcovers.

Finally, Figure 40 shows the potential increase of CO_2 sequestration per country regarding the current CO_2 sequestration rate.

Table 16. Carbon sequestration rates in conservation agriculture (CA) for each climatic zone.

Biogeographical region	CA Practice	Increase of soil organic carbon ($t\ ha^{-1}\ yr^{-1}$)
Boreal	No-Tillage	0.02
	Groundcovers	ND
Continental	No-Tillage	0.42
	Groundcovers	0.40
Atlantic	No-Tillage	0.32
	Groundcovers	0.40
Mediterranean	No-Tillage	0.81
	Groundcovers	1.30

Source: Authors diagram based on the papers reviewed and listed in the references

Table 17. Current and potential soil organic carbon (SOC) and CO_2 fixed annually by CA cropland systems compared to systems based on tillage agriculture in Europe

Country	Current COS fixation through CA ($t\ yr^{-1}$)	Current CO_2 fixation through CA ($t\ yr^{-1}$)	Total Potential COS fixation through CA ($t\ yr^{-1}$)	Total Potential CO_2 fixation through CA ($t\ yr^{-1}$)
Austria	11 927	43 731	550 746	2 019 403
Belgium	87	320	213 352	782 291
Bulgaria	6 946	25 470	1 403 453	5 145 996
Croatia	7 805	28 619	390 742	1 432 719
Cyprus	219	803	93 058	341 213
Czech Republic	17 185	63 010	1 023 412	3 752 510
Denmark	807	2 959	718 035	2 632 794
Estonia	843	3 090	11 573	42 435
Finland	4 000	14 667	38 254	140 265
France	60 000	220 000	3 915 986	14 358 615
Germany	63 441	232 617	4 833 813	17 723 982
Greece	629 798	2 309 258	2 653 406	9 729 155
Hungary	28 105	103 051	1 584 533	5 809 954
Ireland	646	2 367	323 700	1 186 900
Italy	360 765	1 322 806	7 193 068	26 374 586
Latvia	227	832	22 033	80 788
Lithuania	386	1 414	42 593	156 173
Luxembourg	185	679	26 327	96 532
Malta	ND	0	6 439	23 611
Netherlands	2 373	8 700	238 619	874 935
Poland	164 632	603 650	4 197 788	15 391 891
Portugal	55 948	205 142	1 740 610	6 382 238
Romania	245 779	901 191	3 250 066	11 916 910
Slovakia	11 734	43 024	559 761	2 052 459
Slovenia	1 044	3 828	84 467	309 713
Spain	2 491 335	9 134 893	14 440 308	52 947 794
Sweden	316	1 160	46 493	170 474
United Kingdom	161 331	591 548	1 964 637	7 203 670
Total Europe	4 327 863	15 868 829	51 567 274	189 080 005

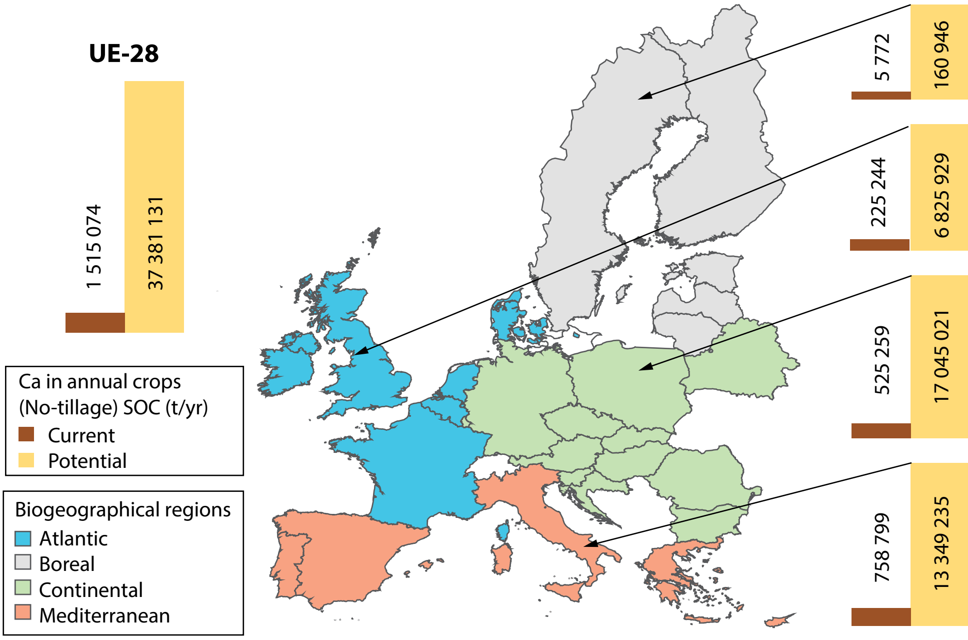


Figure 38. Current and potential SOC fixed by CA in annual crops compared to systems based on soil tillage in EU-28 and in the different biogeographical regions.

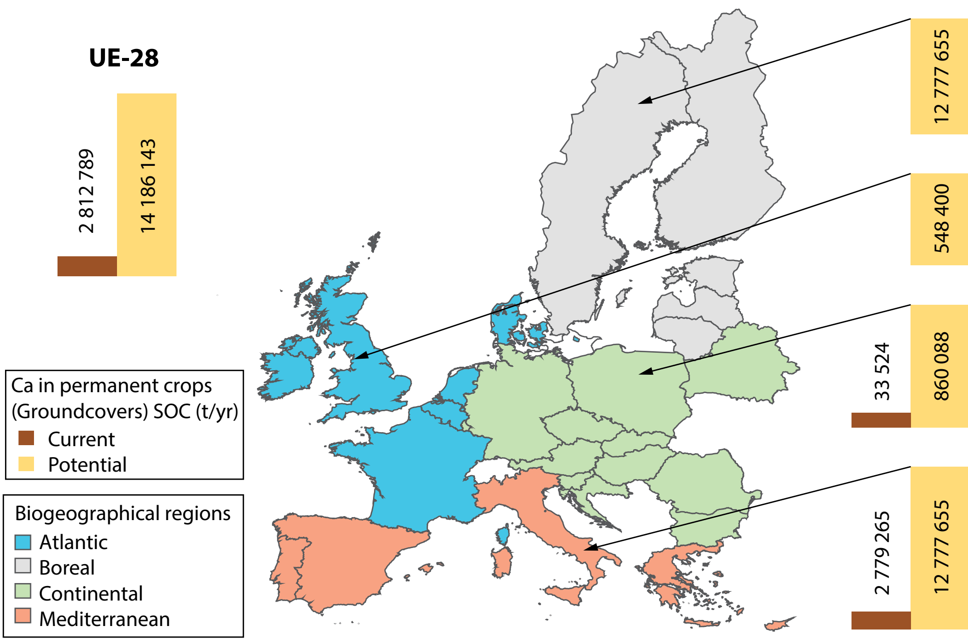


Figure 39. Current and potential SOC fixed by groundcovers compared to systems based on soil tillage in EU-28 and in the different biogeographical regions.

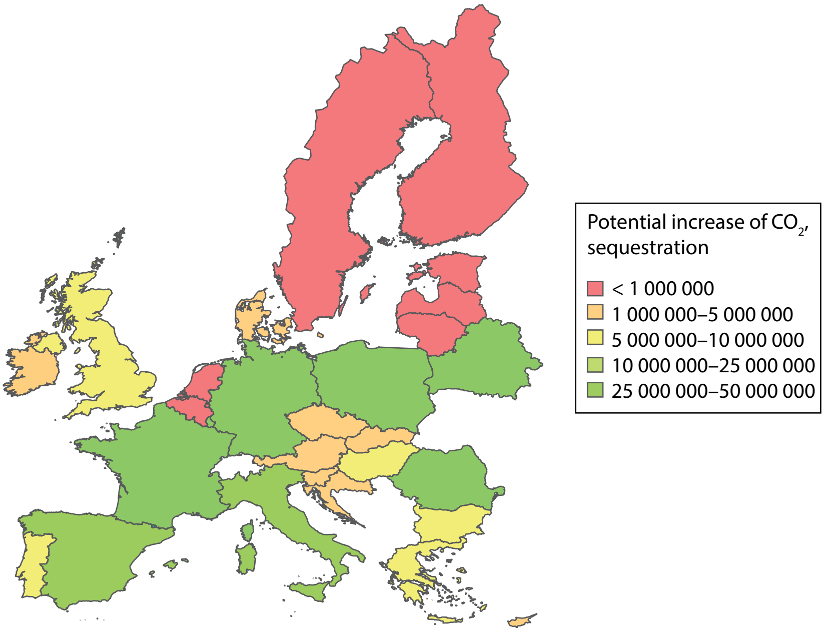


Figure 40. Potential increase (potential – current) of CO_2 sequestration in Europe through CA.

Discussion

Based on the results obtained, conservation agriculture is a sustainable agricultural system that can contribute to reduce GHG emissions by storing CO_2 as organic carbon in the soil. The use of these agricultural practices could promote to fulfill the international agreements and initiatives related to climate change mitigation and adaptation, such as Paris agreement on climate change and 4p1000 among others.

Therefore, considering overall European figures, carbon sequestration that could take place on farm land under conservation agriculture would help achieve around 22 percent of the necessary reductions in the non-ETS sectors by 2030, and almost 10 percent of the total emissions still allowed in the non-ETS sectors. This achievement would could give the signing member countries some margin in the emission reduction in other sectors such as housing or transport.

A similar study done recently in Africa (Gonzalez-Sanchez *et al.*, 2018), is aligned with the present study, and shows that the potential estimate of annual carbon sequestration in the agricultural soils of this continent through CA amounts to 145 M t of C per year, that is 533 M t of CO_2 per year. As a result of that, the carbon dioxide sequestration potential of CA for Africa is much higher than for Europe, being the African figures almost 3 times higher than de European ones.

Acknowledgement

The authors would like to thank the LIFE financial instrument of the European Union for co-financing the LIFE+ ClimAgri project "Best agricultural practices for Climate Change: Integrating strategies for mitigation and adaptation" LIFE13 ENV/ES/000541, and the support of the Plan Propio de Fomento de la Investigación (Internal University Research Plan) (2018) of the Universidad de Córdoba that allowed the first author visiting the Imperial College London.

References

Balesdent J, Mariotti A, Boisgontier D (1990). "Effects of tillage on soil organic carbon mineralization estimated from 13C abundance in maize fields". Journal of Soil Science 41, 584–596.

European Commission (EC) (2018). EUROSTAT website. https://ec.europa.eu/eurostat (accessed 20 August 2018).

European Environment Agency (EEA) (2012). Climate Change, impacts and vulnerability in Europe 2012 Inform.

FAO (2018). Conservation agriculture website. http://www.fao.org/conservation-agriculture/en/ (accessed 20 August 2018).

González-Sánchez EJ, Ordóñez-Fernández R, Carbonell-Bojollo R, Veroz-González O, Gil-Ribes JA (2012) Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. Soil and Tillage Research 122, 52–60.

Gonzalez-Sanchez EJ, Mkomwa S, Conway G, Kassam A, Ordoñez-Fernandez R, Moreno-Garcia M, Repullo-Ruiberriz de Torres M, Gil-Ribes J, Basch G, Veroz-Gonzalez O, Triviño-Tarradas P, Holgado-Cabrera A, Miranda-Fuentes A, Carbonell-Bojollo R. (2018). Making Climate Change Mitigation and Adaptability Real in Africa with conservation agriculture. Eds: African Conservation Tillage Network (ACT) – European conservation agriculture Federation (ECAF). pp 143. DOI: http://dx.doi.org/10.13140/RG.2.2.32722.20161

Jat RA, Sahrawat KL, Kassam AH (2014). Conservation agriculture: Global Prospects and Challenges. CABI, Wallingford.

Kassam A, Friedrich T, Derpsch R (2018). Global spread of conservation agriculture. International Journal of Environmental Studies. https://doi.org/10.1080/00207233.2018.1494927

Kassam A, Mkomwa S, Friedrich T. (2017) Conservation agriculture for Africa: building resilient farming systems in a changing climate. CABI. Wallingford, UK, xxviii + 289 pp. ISBN 9781780645681.

Lal R (2008). "Carbon sequestration". Philosophical Transactions of the Royal Society B: Biological Sciences 363, 815–830.

Olson KR, Lang JM, Ebelhar SA (2005). "Soil organic carbon changes after 12 years of no tillage and tillage of Grantsburg soils in southern Illinois". Soil and Tillage Research 81, 217–225.

Ray DK, Gerber JS, MacDonald GK, West PC (2015). Climate variation explains a third of global crop yield variability. Nat. Commun. 6, 5989.

Reicosky DC (1995) Impact of tillage on soil as a carbon sink p. 50–53. In: Farming for a Better Environment, A White Paper, Soil and Water Conservation Society, Ankeny, Iowa, USA, pp.67.

Reicosky DC (2011) Conservation agriculture: Global environmental benefits of soil carbon management. In Fifth World Congress on conservation agriculture. Vol. 1. Canberra. ACIAR; 3–12.

Six J, Elliott ET, Paustian K (2000). "Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture". Soil Biology and Biochemistry 32, 2099–2103.

Smith P (2004). "Carbon sequestration in croplands: the potential in Europe and the global context". European Journal of Agronomy 20, 229–236.

Sommer R and Bossio D (2014) Dynamics and climate change mitigation potential of soil organic carbon sequestration. Journal of Environmental Managemement 144, 83–87.

Modeling of soil organic carbon and carbon balance under conservation agriculture in Kazakhstan

Elena Valkama[42], Gulya Kunypiyayeva[43], Rauan Zhapayev, Muratbek Karabayev, Erbol Zhusupbekov[44], Marco Acutis[45]

Abstract

Traditional farming systems, involving intensive tillage, returning the low amounts of organic matter to field and frequently monoculture, lead to a decrease in soil organic carbon (SOC) and land degradation. In contrast, conservation agriculture (CA) has a large potential for carbon sequestration. However, the efficacy of no-till agriculture for increasing C in soils has been questioned in recent studies. These doubts stem from the facts that previous literature on soil C stocks has often discussed effects of tillage, rotations, and residue management separately. The objectives of this study are (1) to assess the potential of each CA component for soil C sequestration in Almaty state (Kazakhstan), proposing a methodology that could be extended to other conditions in Kazakhstan; and (2) to estimates CO_2 balance and possibility to obtain carbon credits. Modeled results showed that no tillage with crop rotation and residue retained and/or cover crop increased SOC by about 300–1 000 kg^{-1} ha^{-1} yr^{-1} in the ploughing layer. It seems that the contribution of each CA element into SOC stock decreased in the following order: cover crops > residues > rotation. In particular, attention should be paid to cover crops, which seem to have significant role in C sequestration, but are not yet widely spread in practical farming in Kazakhstan. Conservation agricultural practices involving, in addition to no-tillage, crop rotation, residues retained and/or cover crops allowed achieving the objective of 4 per 1 000 initiatives. The initiative claims that an annual growth rate of 0.4 percent in the soil carbon stocks, or 4‰ per year, would halt the increase in the CO_2 concentration in the atmosphere related to human activities. In addition, these CA practices had the negative total carbon balance indicating reduction of GHG emissions and indicating possibility to obtain carbon credits.

Key words: no tillage, residues, cover crop, rotation, carbon market.

Introduction

Traditional farming systems, involving intensive tillage, returning the low amounts of organic matter to field and frequently monoculture, lead to a decrease in soil organic carbon (SOC) and land degradation. In contrast, conservation agriculture

(CA) has a large potential for carbon sequestration. According to FAO definition, conservation agriculture (CA) is a farming system that promotes maintenance of (1) minimum soil disturbance avoiding soil inversion (i.e. no tillage or minimum tillage), (2) a permanent soil cover with crop residues and/or cover crops, and (3) diversification of plant species through varied crop sequences and associations involving at least three different crops. In the Americas, CA occupies more than 50 percent of agricultural land. In Kazakhstan, the areas under no-till have been increasing from virtually nothing in 2000 to 2.5 million ha in 2016 that is, however, only about 1.1 percent of agricultural lands. Therefore, FAO consider Kazakhstan to be “high” in terms of the potential area for the further spread of CA.

However, the efficacy of no-till agriculture for increasing C in soils has been questioned in recent studies. This is a serious issue after many publications and reports during the last two decades have recommended no-till as a practice to mitigate greenhouse gas emissions through soil C sequestration (Ogle *et al.*, 2012). Only about half the 100+ studies comparing soil carbon sequestration with no-till and conventional tillage indicated increased sequestration with no till; this is despite continued claims that conservation agriculture sequesters soil carbon (Palm *et al.*, 2014). Some studies suggested that no-tillage only stratified SOC; a near-surface increase in SOC was offset by a concomitant decrease in the subsurface (Du *et al.*, 2017). Moreover, results at global scale are different according to different climatic conditions.

These doubts stem from the facts that previous literature on soil C stocks has often discussed effects of tillage, rotations, and residue management separately. According to Palm *et al.* (2014) it is important to recognize that these CA components interact. For example, the types of crops, intensity of cropping, and duration of the cropping systems, cover crops determine the amount of C inputs and thus the ability of CA to store more C than conventional tillage.

Cover crops, legume or non-legume, are not productive crops, useful to protect soil avoiding bare soil periods. To date, cover crops have been in the scientific focus mainly for their capacity to improve soil quality and thereby to foster crop production. Inclusion of cover crops in cropping systems is a promising option to sequester carbon in agricultural soils. Many studies and previous projects (Poeplau and Don, 2015; Perego *et al.*, 2019) have demonstrated that soil organic carbon storage can be increased in cover crops based farming systems by 0.3–0.6 t ha^{-1} yr^{-1}, especially if at the same time intensity of tillage is reduced and diversification of crop rotations is enhanced.

Since SOC change is a very slow process, long-term experiments (at least 10 years) are required to obtain reliable data and to assess the carbon sequestration of agricultural systems. There is a need to evaluate the performance of alternative cropping systems in different pedo-climatic conditions, and to assess their potential in terms of the SOC increase.

Moreover, CA cropping systems may be suitable for carbon markets, which is continuously growing. Governments and industry need to offset CO_2 emissions that they are generating. The carbon credit system (1 credit = 1t CO_2 reduced) allows the compensation of the release of greenhouse gases (GHG) by funding emission reduction projects. In agriculture, some initiatives related to carbon credits already exist from longtime, but at local scale. In 2007, the Alberta state (Canada) created an organization to allow farmers to sell carbon credits created in biogas production process from anaerobic digestion. In 2012, conservation agriculture was adopted for the carbon markets under defined protocols. In 2017, a new door in carbon markets was opened for agriculture, when Microsoft bought carbon credits from US rice farmers.

The objectives of this study are:

1. To assess the potential of each component of CA for soil C sequestration in one Kazakhstan site, proposing a methodology that could be extended to other conditions in Kazakhstan;
2. To estimates CO_2 balance and possibility to obtain carbon credits.

Material and methods

We performed a comparative assessment of SOC changes over 20 years under CA and traditional cropping systems in the Almaty site by using the dynamic simulation model ARMOSA that simulates the cropping systems at a daily time-step at field scale (Perego *et al.*, 2013). The model simulates agrometeorological variables, the water balance, the carbon and nitrogen balance, and the crop development and growth. As input for ARMOSA, we used a set of daily data of maximum and minimum temperature and rain from 2002 to 2011. The soil used for the simulation was silt loam texture and a 1.41 percent of organic carbon in the 0–30 cm surface layer. Barley was fertilized with 60 kg N ha^{-1} at sowing.

For model validation, we used soil and yield data from the long-term experiment (2002–2009) located in Almaty involving no-tillage and conventional tillage treatments for spring barley (*Hordeum vulgare*) monoculture. Barley yields were measured annually. Dry bulk density and SOC content were measured annually at 0–30 depths.

We simulated the following cropping systems (Table 18):

- Conventional 1: ploughing at 0.25 m, spring barley monoculture, and crop residues (straw) removed;
- Conventional 2: ploughing at 0.25 m, spring barley monoculture, residues retained;
- CT 1: no tillage, crop rotation: winter wheat (*Triticum aestivum*) – winter wheat – spring barley – chickpea (*Cicer arietinum*), residues removed and no cover crop;
- CT 2: no tillage, monoculture, residues retained and no cover crop;
- CA 1: no tillage, crop rotation, residues retained and no cover crop;
- CA 2: no tillage, crop rotation, residues removed and Italian ryegrass (*Lolium multiflorum*) as cover crop undersown in spring;
- CA 3: no tillage, crop rotation, residues retained and cover crop.

We evaluated carbon balance by using SALM method (Verra organization, 2013; Tennigkeit *et al*., 2013). The method takes into account the dynamics of carbon stored in soil and the direct emission of N_2O due to use of fertilizers (organic and mineral) and CO_2 emission due to chemical fertilizer production, the effect of the use of N-fixing species, the amount of fuel used in tillage and other field operation. The CH_4 emissions and the effect of burning biomass were not included since these

Table 18. Simulated annual SOC changes in 0–30 cm soil depth for the different cropping systems

Cropping system	Tillage	Crops*	Residues	Cover crop**	kg ha^{-1}	percent
Conventional 1	+	monoculture	-	-	-560	-1.03
Conventional 2	+	monoculture	+	-	-477	-0.87
CT 1	-	rotation	-	-	-392	-0.60
CT 2	-	monoculture	+	-	10	0.01
CA 1	-	rotation	+	-	296	0.45
CA 2	-	rotation	-	+	493	0.75
CA 3	-	rotation	+	+	992	1.52

*Monoculture: spring barley (H.*vulgare*); Rotation: winter wheat (*Triticum aestivum*) – winter wheat – spring barley (*Triticum aestivum*) – chickpea (*Cicer arietinum*)
**Cover crop: Italian ryegrass (*Lolium multiflorum*)
Bold values indicate the objective of 4 per 1000 initiative achieved.

sources of emissions were not applicable for the cropping systems studied in this paper. We used the IPCC emission factor of 0.011 (IPCC 2006) for the N_2O emission from fertilizers, and for its CO_2 equivalence we used the coefficient of 298 proposed by IPCC 2013. We estimated the carbon changes stored in soil by the ARMOSA model. The fuel consumption (kg ha-1) was estimated, as rough approximation, from the Gazzetta Ufficiale della Repubblica Italiana n.50 – 01-03-2016 and the factor of emission used of 3.15 t of CO_2 per ton of diesel was taken from the Swiss environment department (Bundesamt fur Umwelt, 2016).

Results

The model simulated well organic carbon dynamics (RMSE, 8.6 percent; bias, -4.3 percent; modeling efficiency EF, 0.81, N=40), as well as barley yields, indicating sound prediction for the amount of residues. Simulations of SOC changes showed that both conventional systems, with either residue removed or retained lost SOC during 20 years (Table 18).

The decrease of SOC in conventional systems stems from straw removal, which is not compensated by the carbon in the roots and from ploughing, creating SOC oxidation. Likewise, no tillage with crop rotation, but with residues removal and lack of cover crop (CT 1) resulted in decrease of SOC.

However, if residues were retained (CA 1), it allowed to improved C stock significantly. When acquisition of straw is needed for animal feeding or bioenergy production, carbon loss could be compensated by sowing of cover crop that supplies soil additional organic matter (CA 2). However, the largest effect was gained when both components – residues and cover crop – were presented in the cropping system as a source of additional C input (CA 3). Comparison between CT 2 and CA 1 shows the role of crop rotation in C sequestration that allowed increasing of SOC from 10 (in monoculture) to 296 (in rotation) kg $ha^{-1}yr^{-1}$.

Annual total CO_2 balance and estimated carbon credits are shown in Table 19. Conventional systems clearly caused positive CO_2 balance, indicating GHG emissions. Conservation tillage (CT 1 and CT 2) with a limited amount of additional organic matter resulted in positive carbon balance as well. Only CA practices involving, in addition to no-tillage, crop rotation, residues retained and/or cover crops had the negative total carbon balance, indicating reduction of GHG emissions. Moreover, all CT and CA cropping systems reduced total CO_2 balance compared to Conventional 1 (baseline), signifying possibility to obtain carbon credits equal to 24–130 € ha^{-1} y^{-1} (Table 19).

Discussion

Conservation agriculture involves complex and interactive processes that ultimately determine soil C storage making it difficult to identify clear patterns, particularly, when the results originated from a large number of independent studies. To solve these problems, we used a model approach to assess the contribution of each component of CA in soil C storage for Almaty site in Kazakhstan. It seems that the

Table 19. Annual CO_2 balance and the values of carbon credits for different cropping systems

Cropping system	CO_2 balance (kg CO_2eq ha $^{-1}$)						Carbon credits (€ ha-1y^{-1})*
	Soil storage	N fertilizer used	Chemical fertilizer production	N-fixing species	Fuel	Total CO_2 balance	
Conventional 1	2 622	337	162	0	496	3 617	0
Conventional 2	2 300	337	162	0	496	3 295	7
CT 1	1 854	253	122	25	208	2 461	24
CT 2	523	337	162	0	233	1 255	50
CA 1	-666	253	122	24	221	-48	77
CA 2	-1 398	253	122	24	221	-779	92
CA 3	-3 218	253	122	25	233	-2 586	130

*1 credit = 1t CO_2 reduced = 21 € (price in December 2018).
Carbon credits are calculated respect to baseline (Conventional 1).

contribution decreased in the following order: cover crops > residues > rotation, according to the amount of organic matter remaining by the system. In particular, attention should be paid to cover crops, which seem to have significant role in C sequestration, but are not yet widely spread in practical farming in Kazakhstan.

Moreover, no tillage may not store more soil C than conventional tillage if the amount of residues is limited. For example, a meta-analysis showed that no tillage with residue retention increased SOC by 3.9–10.2 percent compared to conventional tillage with residue removed (Zhao *et al.*, 2017). In contrast, reduced/no tillage alone without straw incorporation or mulching led to a negligible increase in SOC stock (Zheng *et al.*, 2014; Powlson *et al.*, 2014). High-residue producing crops may sequester more C than crops with low residue input. Intensification of cropping systems such as increased number of crops per year, double cropping, and addition of cover crops can result in increased soil C storage under no tillage (West and Post, 2002).

By using CENTURY model, Ogle *et al.* (2012) suggested where C inputs decline by more than 15 percent, then SOC stocks would also decline with adoption of no tillage, and that where C inputs decrease by less than 15 percent (or C inputs increase), then SOC stocks would be expected to increase. Consequently, a reduction in residue C inputs under no tillage, where they occur, does provide a mechanistic explanation for a lack of increase in SOC with no-till adoption, and therefore no-till will not always serve to mitigate greenhouse gas emissions.

The results of this paper showed that CA practices including residues retained and/or cover crops would allow achieving the objective of 4 per 1 000 initiative. The initiative claims that an annual growth rate of 0.4 percent in the soil carbon stocks, or 4‰ per year, would halt the increase in the CO_2 concentration in the atmosphere related to human activities. The total carbon balance considering all CO_2 emission sources was assessed to be negative only under CA practices including residues retained and/or cover crops (effective reduction of CO_2 in atmosphere). Estimation of carbon credits indicated that, compare to the conventional cropping systems, all CA systems, regardless additional C inputs (residues, cover crop), allowed for a reduction of CO_2 emissions, indicating possibility to obtain carbon credits.

Conservation agriculture has a large potential for C sequestration in Kazakhstan. Increase in SOC could increase crop yield and reduce yield variability since the SOC accumulation not only sequestrated atmospheric CO_2 but also increased soil fertility and soil water holding capacity (Franzluebbers, 2002). Therefore, future studies should be aimed to assess the performance of the cropping systems during field experiments in different climatic zones in Kazakhstan. Also there is a need to develop a concept of carbon credits from agriculture, since Europe recognizes voluntary carbon credits only from afforestation/reforestation projects. Development and implementation of agriculture-based carbon offset projects would ensure climate change mitigation and food security in Central Asia.

Acknowledgment

The project “Innovative cropping systems for carbon market” was funded by Natural Resources Institute Finland (Luke).

References

Bundesamt fur Umwelt (2016) URL: https://www.bafu.admin.ch/.../co2.../fattori_di_emissionedico2secondolinventariosvizz Date Accessed: December 08, 2018.

Du Z, Angers DA, Ren T, Zhang Q, Li G (2017): The effect of no-till on organic C storage in Chinese soils should not be overemphasized: A meta-analysis. Agriculture, Ecosystems and Environment 236, 1–11.

Franzluebbers AJ (2002): Water infiltration and soil structure related to organic matter and its stratification with depth. Soil and Tillage Research 66, 197–205.

Goidts E, Van Wesemael B, Crucifix M (2009) Magnitude and sources of uncertainties in soil organic carbon (SOC) stock assessments at various scales. European Journal of Soil Science 60, 723–739.

IPCC, 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Accessed: December 08, 2018.

IPCC, 2013, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Ogle SM, Swan A, Paustian K (2012): No-till management impacts on crop productivity, carbon input and soil carbon sequestration. Agriculture, Ecosystems and Environment 149, 37–49.

Palm C, Blanco-Canqui H, DeClerck F, Gatere L, Grace P (2014): Conservation agriculture and ecosystem services: An overview. Agriculture, Ecosystems and Environment 187, 87–105.

Perego A, Giussani A, Sanna M, Fumagalli M, Carozzi M, Alfieri L, Brenna S, Acutis M. (2013): The ARMOSA simulation crop model: Overall features, calibration and validation results. Italian Journal of Agrometeorology 3, 23–38.

Perego A, Rocca A, Cattivelli V, Tabaglio V, Fiorini A, Barbieri S, Schillaci C, Chiodini ME, Brenna S, Acutis M (2019): Agro-environmental aspects of conservation agriculture compared to conventional systems: a 3-year experience on 20 farms in the Po valley (Northern Italy). Agricultural Systems 168, 73–87.

Poeplau C and Don A (2015): Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis. Agriculture, Ecosystems and Environment 200, 33–41.

Powlson D, Stirling C, Jat M, Gerard B, Palm C, Sanchez P, Cassman K (2014) Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change 4, 678–683.

Smith P (2004) How long before a change in soil organic carbon can be detected ?. Global Change Biology 10, 1878–1883.

Tennigkeit T, Solymosi K, Seebauer M, Lager B (2013). Carbon Intensification and Poverty Reduction in Kenya: Lessons from the Kenya Agricultural Carbon Project. Field Action Science Report 7, 2013.

Verra.org (2013). VM0017 Adoption of Sustainable Agricultural Land Management, v1.0. URL https://verra.org/methodology/vm0017-adoption-of-sustainable-agricultural-land-management-v1-0/ Date Accessed December 08, 2018.

West TO and Post WM (2002): Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. Soil Science Society of America Journal 66,1930–1946.

Zhao X, Liu S-L, Pu C, Zhang X-Q, Xue J-F, Ren Y-X, Zhao X-L, Chen F, Lal R, Zhang H-L (2017): Crop yields under no-till farming in China: A meta-analysis. European Journal of Agronomy 84, 67–75.

Zheng CY, Jiang Y, Chen CQ, Sun YN, Feng JF, Deng AX, Song ZW, Zhang. WJ (2014): The impacts of conservation agriculture on crop yield in China depend on specific practices, crops and cropping regions. The Crop Journal 2, 289–296.

Chapter 4

Machinery adapted to conservation agriculture

©FAO/Aziz Nurbekov

Crop residue management in conservation agriculture Systems in China

Zhang Yufan, Li Hongwen, Lu Caiyun, He Jin[46], Wang Qingjie

Abstract

The crop residue yield has kept growing and maintained a high level with the agricultural productivity development in China in recent years. It is urgent and meaningful to deal with a large number of crop residue reasonably. Conservation agriculture (CA) with straw mulching has proven to be an effective, sustainable and promising agricultural technology. CA cannot only help to consume substantial crop residue every year, but also improve field water-holding capacity, decrease soil erosion and greenhouse gas (GHG) emission, reduce input of chemical fertilizer, increase yield and income. Despite the obvious benefits of integrated straw management and CA, the consumption ratio of crop residue is constrained unless all obstruction factors are understood and addressed in specific area. Verifying what the status, trend and bottlenecks are is vital to formulate reasonable developing strategies. This paper presents :(a) the type, distribution, total yield and various management patterns of crop residue in China; (b) beneficial impacts on economy, society and ecology of straw integrated utilization and conservation tillage in China; (c) agricultural machinery applied to conservation tillage, especially no-tillage seeder with anti-blocking technology.

Key words: agricultural machinery, beneficial impacts, residue integrated utilization

Introduction

Conservation agriculture (CA) is an advanced agricultural technology which can reduce soil erosion and greenhouse gas (GHG) emission. It can also improve soil fertility and crop yield through a set of soil management practices that minimize the disruption of the soil structure, composition and natural biodiversity. CA includes no-tillage, minimal tillage, integrated crop residue management and topsoil tillage technology (Cornell University, 2015). Crop residue production can be generally calculated by straw-grain ratio. There is a wealth of crop residue resources in China: maize, wheat and rice straws were estimated to be about 442, 174 and 266 Mt/yr, respectively (MOA, 2016). However, straw burning is hard to manage, which will not only result in ecological environment pollution, but also increasing security risks. These discarded crop residue were burnt by farmers after harvesting or before planting due to lack of appropriate methods and machines, shortage of rural labor, and weak environmental awareness, etc. In recent years, this problem has become more and more serious. Hence, improving crop residue consumption ratio, reducing crop residue burning cannot only improve the agricultural ecological environment, but also develop rural economy, increase farmers' income and promote sustainable development of agricultural production (Kassam *et al.*, 2014). Currently, crop residue is mainly used as fertilizer, fodder, new energy resource, base stock and industry material in China (He *et al.*, 2018b). In all patterns, direct crop residue returning is the most prevalent. Considering that a large number of crop residue are returned to the field, the phenomenon of straw blocking is hard to completely eradicate during sowing. Lots of Chinese scientists are developing various no-tillage seeder in order to reduce the frequency of straw blocking in different surface condition. So no-tillage seeder with anti-blocking technology is a vital part in CA research field.

1. Crop residue management in China

1.1 Type, distribution and yield of crop residue

The main types of crop residue in China is maize straw, rice straw, wheat straw and potato residue. At the end of 2015, China's total crop residue yield is 1.04 Bt. The straw of maize, rice and wheat nearly reached 412, 180 and 234 Mt, respectively. Potato residue was about 104 Mt. These four kinds of crop residue account for 89.2 percent of the total straw yield (MOA, 2016). Other typical crop residue include: peanut residue, cotton straw, bean residue and rape residue. China covers a wide area, and the crop types vary from different climate, cropping system and socio-economic conditions. Therefore, the distribution of residue in different regions is various. According to the geographical and climatic division, main crop residue in northeast China are maize straw, rice straw and potato residue; maize and wheat straw in North China and Huanghuaihai region; maize, wheat and cotton straw in Northwest region; and rice straw, wheat straw and rape residue in Yangtze valley.

1.2 Utilization patterns of crop residue

There are mainly five patterns to consume crop residue in China: fertilizer, fodder, new energy resource, base stock and industry material. The consumption ratio of crop residue in China is 65 percent at present (Wang *et al.*, 2018). Crop residue is a fertilizer resource with high nutrient value, which can be achieved by crop residue returning. Crop residue returning can balance soil nutrients and increase soil organic matter content. Crop residue used as fertilizer can be classified into: direct returning and indirect returning. This pattern accounts for 43.2 percent of total available straws (MOA, 2016). Crop residue contains all kinds of feed ingredients needed by ruminant livestock. The palatability, nutrient value and restoring period of straw can be improved after process treatment. Straw used as fodder can be divided into: ensilage, briquetting, ammoniation treatment. The consumption ratio of this pattern is 18.8 percent (MOA, 2016).

Crop can storage 50 percent of the energy in crop residue through photosynthesis. With high contents of carbon, hydrogen, oxygen and other nutrients and low nitrogen and sulfur. Crop residue can be used as energy source by converting into briquetted fuel, power generation, biogas production and gasification fuel. Consumption ratio of this way is 11.4 percent (MOA, 2016).

Crop residue can be used to produce organic solid materials which can provide favorable conditions for the growth of animals, plants and microorganisms. The base stock produced by residue includes edible fungus culture substrate, plant cultivation substrate, bedding materials in animal feeding process. This mode makes up 4 percent of total available residue (MOA, 2016).

Straw fiber is a natural cellulosic fiber with good biodegradability and it can be used to produce paper, panel, art ware, activated carbon and xylitol. This pattern only occupies 2.7 percent of total available crop residue (MOA, 2016).

2. Benefits of CA

Since 1992, a long-term field experiment was established in wheat-one-crop-a-year region of Linfen, Shanxi Province. In 2002, the MOA had carried out the demonstration project of CA, and set up 10 monitored bases of CA effects in Northern China. By long-term field experiment, the benefits of CA on economy and ecology were monitored and researched.

2.1. Economic benefits

The economic benefits were investigated and analyzed at the 7 sites in one-crop-a-year regions and 3 sites in two-crop-a-year regions, respectively, selected from the demonstration sites supported by the MOA during the years from 2002 to 2007 (Table 20).

Table 20. Economic benefits (USD ha-1) for TA and CA in 10 monitoring sites

Site		Crop	Input (USD ha^{-1})		Output (USD ha^{-1})		Farmer income (USD ha^{-1})	
			TA	CA	TA	CA	TA	CA
One-crop-a-year regions	Fengning, Hebei	Maize	221.8	194.4	1158.4	1 235.2	936.6	1 040.8
		Spring wheat	174.7	143.8	520.7	565.5	346.0	421.7
		Naked oats	88.7	70.2	790.7	848.0	702.0	777.8
	Lingyuan, Liaoning	Maize	359.6	277.4	864.8	876.7	505.2	599.3
	Yanggao, Shanxi	Broomcorn millet	380.1	313.4	634.5	675.0	254.4	361.6
		Bean	384.2	315.5	1 950.4	2 612.8	1 566.2	2 297.3
		Millet	350.7	302.5	612.9	631.8	262.2	329.3
	Chifeng, Inner Mongolia	Corn-irrigated	312.2	240.8	1 713.9	1 826.2	1 401.7	1 585.4
		Corn in upland	258.3	188.5	512.2	545.7	253.9	357.2
		Millet	199.3	154.5	729.0	823.5	529.7	669.0
		Mung bean	795.4	709.4	3091.2	3 275.2	2 295.8	2 565.8
	Wuchuan, Inner Mongolia	Naked oats	61.6	43.2	553.9	584.5	492.3	541.3
		Broomcorn millet	123.3	98.6	407.7	432.0	284.4	333.4
	Pucheng, Shaanxi	Winter wheat	133.6	90.4	288.6	317.9	155.0	227.5
	Xifeng, Gansu	Winter wheat	86.3	59.6	1 027.7	1 224.6	941.4	1 165.0
		Maize	129.5	32.9	1 359.3	1 444.0	1 229.8	1 411.1
Two-crop-a-year regions	Changping, Beijing	Maize	338.1	223.1	1 384.9	1 420.4	1 046.8	1 197.3
		Winter wheat	507.6	413.2	906.8	1023.8	399.2	610.6
	Baodi, Tianjing	Maize	311.3	208.5	1 444.0	1 436.1	1 132.7	1 227.6
		Winter wheat	487.4	375.2	1 191.5	1 201.2	704.1	826.0
	Gaocheng, Hebei	Maize	297.9	208.2	1 404.6	1 424.3	1 106.7	1 216.1
		Winter wheat	452.2	340.4	1 117.4	1 170.0	665.2	829.6

Source: Jin He *et al.*, 2010

The results from the 10 demonstration sites suggest that, compared with traditional agriculture (TA), CA decreased the production cost significantly. In one-crop-a-year regions, CA increases farmers' incomes ranging from 49 to 731.1 USD ha^{-1} with an average of 157.9 USD ha^{-1} compared with TA. In two-crop-a-year regions, CA produced higher farmers' incomes ranging from 94.9 to 211.4 USD ha^{-1}with an average of 142.1 USD ha^{-1}compared with TA. In sum, CA provided significant savings in production cost and enhance incomes.

2.2 Ecological benefits

By using the Big Spring Number Eight (BSNE) samplers and wind tunnel (Figure 41), wind erosion was monitored at the five MOA demonstration sites

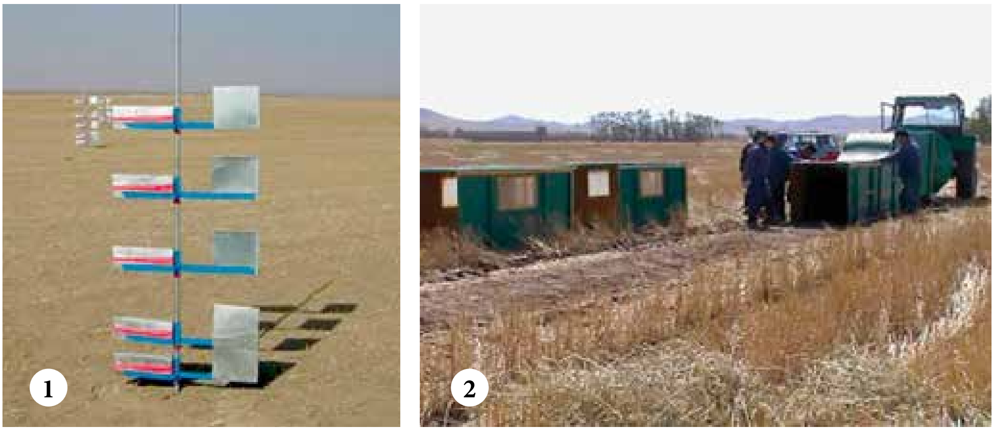


Figure 41. The big spring number eight dust sampler (1) and portable wind tunnel (2)

located in the 3 main routes traveled by the dust storm in northern China during the spring of 2002 to 2005. The specific monitoring data is shown in Table 20.

At Fengning, TA land produced 42.46g of wind-blown sediment transport per sample, whereas CA land produced 12.72 g per sample, which indicated that CA reduced 70 percent wind erosion compared with TA. Similarly, at other monitoring sites, the CA land produced 61.6 percent, 34.2 percent, 37.3 percent, and 12.1 percent less dust, respectively. The results indicated that the CA effectively protected soil surface and reduced wind erosion by slowing the wind owing to increased roughness of surface and decreasing the exposure of the soil to wind.

Water erosion was studied in Shouyang, Shanxi from 2003 to 2007. There was heavy storm in 2004 and 2006, the runoff in these two years for CA was 19 mm and 58 mm respectively, and for TA was 40 mm and 96 mm respectively. However, in normal years, the runoff was no significant difference between CA and TA (Figure 42).

Table 21. Wind-blown sediment transport (g per sample) in five monitoring sites

Sites	Collection time	TA	CA
Fengning, Hebei	2002, 3.22-2002, 4.21	42.46^{a}	12.72^{b}
Wuchuan, Inner Mongolia	2003, 3.26-2003, 4.6	7.43^{a}	2.85^{b}
Chifeng, Inner Mongolia	2003, 4.22-2003, 5.3	7.08^{a}	4.66^{b}
Lingyuan, Liaoning	2004, 3.25-2004, 4.3	16.32^{a}	10.23^{b}
Changping, Beijing	2005, 3.28-2005, 4.17	19.00^{a}	16.70^{a}

Source: Jin He *et al.*, 2010

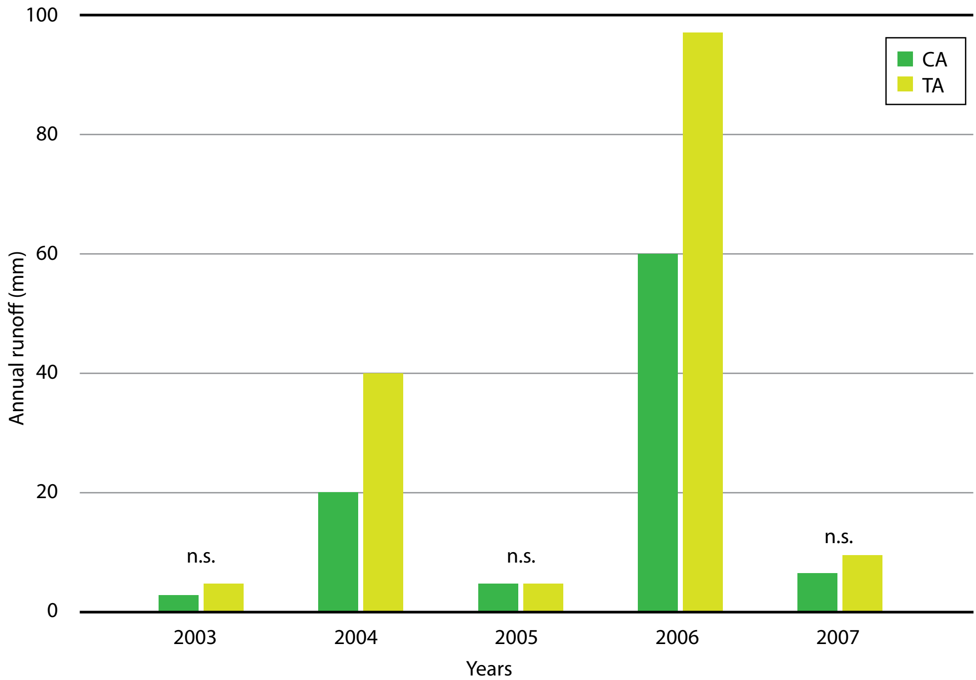


Figure 42. The mean annual runoff in TA and CA land in Shouyang, Shanxi province

These results indicated that CA could effectively reduce runoff and control water erosion in agricultural production in the arid area, particularly in heavy storm years.

Above all, compared with TA, CA has the advantages of decreasing wind erosion and water erosion, which is beneficial to protect environment.

3. Study on no-tillage seeder

While conducting filed works, scientists focus on research and application on CA equipment which are suitable for China's land scale and economic condition, especially no-tillage seeder. There are 4 different kinds of no-tillage seeder.

3.1. Manual and animal force no-tillage seeder

This kind of no-tillage seeder is mainly used by the combination of manual and animal force. Li Seeder (Figure 43) is a typical manual seeder for seeding in no-till maize and soybean. It can be used in sloppy and small croplands. The total weight of Li seeder is 2.2 kg and one farmer can seed 0.2–0.3 ha/day.

Figure 43. The Li Seeder

3.2. Anti-blocking no-tillage seeder based on straw-flowing technology

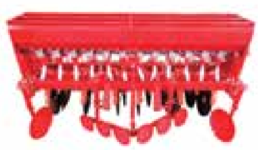
This kind of no-tillage seeder is suitable for the cropland on which there are less straw coverage. When the no-tillage seeder is operated, the straws can go through smoothly in the machine, and the straw blocking frequency can be decreased to some extent.

The main methods to strengthen the fluidity of straws include multi-row furrow openers arrangement and anti-blocking device installed in the front of the furrow opener. In recent year, based on the above anti-blocking methods, some scientists designed new devices, such as, grass moving disc, grass guide roller, grass moving wheel and drive roller (He *et al.*, 2018a). Some typical straw-flowing and anti-blocking no-tillage seeders are shown in Table 22.

3.3. Powered anti-blocking no-tillage seeders

The powered anti-blocking no-tillage seeder is mainly adaptable to the area with numerous straw coverage. Its principle is to use the tractor's conveyer driven shaft to drive the anti-blocking device to crush straws. The research on powered anti-blocking device can be divided into several forms according to operational principle,

Table 22. Typical anti-blocking no tillage seeders based on straw-flowing technology

Mode number	Type	Physical object	Technical characteristics
SD-1504 No-tillage seeder	4 rows furrow openers		The machine is arranged with four crossbeams. Each crossbeam is equipped with a row of furrow openers and a pressing roller. Operation width is 6m, the mass is 5 660 kg
Eco XL series No-tillage seeder	6 rows furrow openers		The machine is arranged with three crossbeams. Each crossbeam is equipped with a row of seeding units, and each seeding unit is staggered with two furrow openers and a pressing roller. Work efficiency is 10 hm^2/h
NTA-2007 Type pneumatic No-tillage seeder	2 rows of furrow openers and 3 cutting discs		The machine is arranged with 2 crossbeams. Each seeding and drilling unit is staggered. It adopts three discs structure. Operation width is 6.1 m, seeding depth is 0-3.5 cm, the mass is 10 200–15 800 kg.
2B-9 wheat seeder	Grass moving disc		6 concave disk is symmetrically arranged in front of the machine. Straws are guided to the two sides of the machine by grass moving dis. Machine width is 1.42 m, the number of sowing row is 9, row spacing is 17 cm.
2BYSF-3 bucket wheel maize seeder	Grass guide roller		There are straw guide rollers installed vertically to the ground in front of each furrow opener, which can reduce the contact between straw and furrow opener. The number of sowing row is 3, row spacing is 53–68.3 cm, fertilizer depth is 6–8 cm, seeding depth is 3–5 cm.
2605 air-aspiration type no-tillage precision seeder	Grass moving wheel		The machine adopts double disc opener. Grass moving wheels are arranged in front of furrow opener, which can assign straw to the two sides of furrow opener. Operation width is 2 m, the number of sowing row is 6 and row spacing is 55–70 cm, the mass is 1 762 kg.

such as strip tillage, crushing straw, cutting straw and throwing straw, etc. Strip tillage is the most common form.

The operational principle of strip tillage is to install rotary tillage blades in front of the furrow opener. The typical process includes: stripe shallow tillage → crushing and breaking straw and stubble → preparation for seedbed and insuring sowing quality (He, 2018a). Table 23 shows some typical powered anti-blocking no-tillage seeder with strip tillage technology.

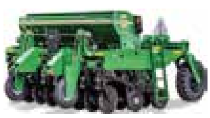
3.4. Anti-blocking no-tillage seeders based on gravitational cutting

This kind of no-tillage seeder mainly use furrow opener as the core component. The anti-blocking principle is that the furrowing disc rotates at high speed under the gravity of the entire machine itself, rolling and cutting the straw, the stubble

Table 23. Typical powered anti-blocking no tillage seeders with strip tillage technology

Mode number	Physical object	Technical characteristics
2BXS-16 No-tillage fertilizer seeder		Rotary tillage and stubble breaking can be carried out on the surface of the front part of the furrow opener, which is better adapted to the uneven surface. The number of the sowing rowsare16, the number of fertilizing rowsare 8. Machine width is 3.25 m, machine mass is 1030 kg, matching power is 66.2–88.3 kW, working efficiency is 0.9–1.6 hm^2/h
2BFM-18 No-tillage fertilizer seeder		The machine adopts straight blade and narrow arrow furrow opener, which reduces the disadvantage that the rotary tillage blade breaks the stubble with a large amount of soil disturbance. It also improves the performance inploughing. For wheat sowing, the number of the sowing row is 16, row spacing is 25 cm; For maize sowing, the number of the sowing rowsare5, row spacing is 40cm. Machine width is 2m, machine mass is 790 kg, matching power is 62.5–73.5 kW, working efficiency is 0.2–0.6 hm^2/h
2BMYF-18 (6) No-tillage fertilizer seeder		Each furrow opener is matched with a group of rotary tillage blades to crush the stubble on the sowing row. For wheat sowing, the number of sowing rows are 18, row spacing is 20 cm; For maize sowing, the number of sowing rows are 6, row spacing is 45–75 cm. Operation width is 3.6m, machine mass is 1 480 kg, matching power is more than 73.5 kW

Table 24. Typical gravitational stubble cutting and anti-blocking no tillage seeders

Mode number	Disc type	Physical object	Technical characteristics
DIRETTA series strip tillage seeder with no-tillage			The crisscrossed seeding units are arranged in two rows. The downward pressure on the notched disc (diameter is 475 mm, thickness is 6mm) is 2–2.3 kN, which can chop straw and stubble effectively. The depth-limiting wheels on both sides of the disc are tapered, and the operation depth of the notched disc can be adjusted by changing the size of the depth-limiting wheels. Operation width is 3–4m, mass is 3 900 kg, matching power is 88.3–110.3 kW, working efficiency is 3–4 hm^2/h
3P1006NT No-tillage seeder			This machine has 3 discs. Two discs are furrow opener sand another one in front of two discs is corrugated disc which is used to crush stubble. The corrugated disc is subjected to the downward pressure of 2 kN to crush stubble and plough during working. Two discs start to sow seeds under the pressure of 408–816 N. Row spacing is 19.05 cm, the number of sowing rows are 15, operation width is 3.05 m, mass is 2476 kg, matching power is 73.5 kW
1590 series strip tillage seeder with No-tillage			The furrow opener is a flat disc (diameter is 46 cm, edge angle is 20°) with an angle of 7° in the forward direction. It adopts a profile modeling spring to provide 740–1 810 N pressure for each furrow opener to crush stubble and plough. Operation width is 3.05–6.1 m
CIRRUS 6002 SUPER No-tillage seeder			Two groups of inclined concave discs (diameter is 460mm) are installed in front of machine to loosen and smooth the soil; Disc furrow opener (diameter is 320 mm or 400 mm) is installed back of machine. Row spacing is 12.5 or 16.6cm. Operation width is 6 m, transport width is 3m, mass is 7 200–8 000 kg, matching power is 161.8 kW
2BMZF series No-tillage seeder			The front part of machine is double disc furrow opener. Notched disc is used to crush stubble; A disc furrow opener with stubble separating device is installed back of the notched disc. The number of sowing row includes: 2, 3, 4, 5 and 6, etc, matching power is 22.1–99.3 kW

and the soil to achieve smooth sowing and fertilization. The advantage of this technology is that the work pieces roll along the ground and have good anti-blocking performance. However, due to the large positive pressure required by the disc opener, the seeding unit of the no-tillage-seeder is relatively heavy and the ability to distribute fertilizer is relatively poor. According to the disc structure, it can be divided into notched disc, corrugated disc, flat disc, concave disc, turbine disc, etc (He, 2018a). Typical gravitational stubble cutting and anti-blocking no tillage seeders are shown in Table 24.

Conclusion

There are nearly 7.33 million ha cropland applied CA in China currently. Direct straw returning is encouraged and promoted in China as a vital CA technology. According to some long-term experiments and on-site observation, direct straw returning has been proven to be an effective pattern which can increase farmers' income and decrease wind and water erosion. No-tillage seeder with various anti-blocking technology can reduce the frequency of straw blocking during sowing.

References

Conservation agriculture Group at Cornell University, 2015. What is conservation agriculture (CA). [Online] Available at: http://conservationagriculture.mannlib.cornell.edu/pages/aboutca/whatisca.html.

He Jin, Li Hongwen, Chen Haitao, Lu Caiyun and Wang Qingjie, 2018a. Research Progress of Conservation Tillage Technology and Machine. Transactions of The Chinese Society of Agricultural Machinery. (in Chinese).

He Jin, Li Hongwen, Wang Qingjie, Gao Huanwen, Li Wenying, Zhang Xuemin and Milt McGiffen, 2010. The adoption of conservation tillage in China. Annals of the New York Academy of Sciences, 1195(s1), E96–E106.

He Jin, Zhang Zhiqiang, *et al.*, 2018b. Status of Straw Management in Asia-Pacific and Options for Integrated Straw Management. ANTAM Publications. Centre for Sustainable Agricultural Mechanization (CSAM), ESCAP, UN.

Information Office of the Ministry of Agriculture (MOA), 2016. The comprehensive utilization rate of main crop straw in China is over 80 percent.

[**Online**] Available at: http://jiuban.moa.gov.cn/zwllm/zwdt/201605/t20160526_5151375.htm.

Kassam A., Li Hongwen, Y. Niino, Theodor Friedrich, He Jin and Wang Xianliang, 2014. Current status, propect and policy and institutional support for conservation agriculture in the Asia-Pacific region. International Journal of Agricultural and Biological Engineering 7(5), 1–13.

Wang Changbo, Ping Yinghua, Liu Xiancai, Yang Zi and Wang Zhenwei, 2018. Research Progress on utilization of straw resources in China. Journal of Anhui Agricultural Sciences 46(7), 22–26, 29. (in Chinese).

Chapter 5

Conservation agriculture and water management

©FAO/Aziz Nurbekov

Crop water productivity of soybean and maize under conservation agriculture

Mohammad Esmaeil Asadi[47]

Abstract

Conservation agriculture (CA) based on minimal soil disturbance, crop residue retention, and crop rotations have potential solutions to raise crop water productivity (CWP). In order to evaluate CA practices effects on CWP of soybean and silage maize in Golestan Province of Iran two field experiments were conducted as strip plot in a randomized complete block with three crop residue management and three tillage methods in three replications in two successive years of 2010 and 2011. Wheat residue treatments were kept as main plots and tillage treatments as sub plots. Wheat residue treatments were burnt management (R1), 50 percent residue (R2), and 100 percent residue (R3). Tillage treatments were conventional tillage (T1), reduced tillage (T2) and no tillage (T3). Sprinkler and border irrigation systems were used for soybean and maize respectively in both years for all plots. For soybean the results showed that crop residue management had significant at 1 percent level on CWP. The highest and lowest irrigation water used was obtained in R1 and R3 with 3 950 and 2 690 m^3 ha^{-1} respectively. As for the tillage treatments, T3 and T1 had the highest CWP value (0.98) and the lowest value (0.85) respectively. There were no significant differences between T3 and T2. For silage maize the results imply that the highest and lowest average water consumption during the growing season was R1 and R3 treatments, respectively with 3737.9 and 2 968.7 m^3 ha^{-1}. The higher water volume used in R1 treatment can be attributed to evaporation of more moisture from the soil surface. The research also revealed that maintaining crop residues can improve yield and CWP of silage maize significantly. The lowest and the highest value of CWP were R1 as 7.2 and R3 as 10.2 kg m^{-3} respectively. So that CWP values in R1 treatment was 29.4 and 21.7 percent lower than R3 and R2 treatments respectively. That's why, it can be concluded that keeping crop residue is the most effective factor in CWP increment.

Key words: Golestan Province, Iran, Tillage, Residue management.

Introduction

Maize and soybean has been grown under conventional agricultural practices for centuries. Together with rice and wheat, maize provides at least 30 percent of the food calories of more than 4.5 billion people in 94 developing countries (Von Braun *et al.*, 2010). The combined challenges increasing demands, continuing poverty and malnutrition, water resources depletion and climate change will require doubling the productivity and dramatically increasing the sustainability and resilience of maize and soybean-based farming systems, on essentially the same land area and as climates change and the costs of fertilizer, water and labor increase. This challenge can only be met through an adoption of conservation agriculture (CA) practices allowing for a more efficient use of water. The basis of conventional tillage is annual plowing or tilling of the soil, but this is usually supplemented with a number of other practices, including the removal or burning of soil residues, land leveling, harrowing, fertilizer application and incorporation, inter-row cultivation, etc. All of these practices cause soil disturbance, compaction, and deterioration. Consequently, in many areas conventional agriculture has led to a decline in crop yields and profitability. CA is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (i.e. no tillage or NT), and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production. CA is based on the practical application of three join principles of continuous no or minimum mechanical soil disturbance (NT or zero tillage seeding), permanent maintenance of soil much cover, and diversification of cropping system (rotations) (Kassam *et al.*, 2017., Asadi, 2018).

CA is now practiced in all continents and in most land-based agro-ecologies, both rainfed and irrigated, non-organic and organic systems. In 2013/14, CA annual cropland systems covered some 157 Mha, or 11 percent of the total global annual cropland, with the spread being split equally between the industrialized regions and the developing regions (Kassam *et al.*, 2015). In 2008/09, the CA annual cropland area was 107 Mha (Kassam *et al.*, 2009). Between 2008/09 and 2013/14, the global CA annual cropland area expanded at an annual rate of some 10 Mha. The incomplete update shows that the global total CA cropland area in 2015/16 is at least 180 Mha, corresponding to some 12.5 percent of the total global cropland, with the spread being more or less equally split between the industrialized regions (52 percent) and the developing regions (48 percent) (Kassam *et al.*, 2017).

Overall, the increase in the global CA cropland area since 2008/09 has continued at an annual rate of about 10 Mha, from 107 Mha in 2008/09 to 180 Mha in 2015/16 (Kassam *et al.*, 2017). The global CA cropland area increased by some 69 percent since 2008/09, and since 2013/14, the increase has been some 15 percent, from 157 Mha, based on the interim information for 2015/16.

In recent years, the popularity of conservation tillage, including NT, has grown steadily in all over the world because of reduced cost and improved soil conservation. The spread of CA systems on more than 180 million ha world-wide shows the great adaptability of the systems to all kinds of climates, soils and cropping conditions. CA is now being practiced from the Arctic Circle over the tropics, from sea level to 3 000 m altitude, from extremely rainy areas with 2 500 mm a year to extremely dry conditions with 250 mm a year like Iran.

NT is the most common form of conservation tillage. The no-till or reduced-till techniques, which are replacing conventional tillage in many parts of the world, disturbs soil surface only at planting when seeds are placed in a small slit made in the residue-covered soil. Greater bulk densities can be expected under NT versus conventional tillage conditions (Lal., 1994). Because the infiltration rate is also higher, it implies that the pore space in conservation tillage systems is more effective in transmitting water than in the plowed soil. This is due to the lack of crust, better pore continuity, and more predominant biopores. Cracks and other macropores created by plant roots and animal activity tend to persist in a NT system because they are not disrupted by tillage operations. By virtue of their size and continuity, these macropores can conduct a considerable volume of water through the soil and at a relatively high velocity.

Other aspects related to tillage systems are moisture availability, crop water productivity (CWP) which is generally defined as crop yield per cubic meter of water consumption, including 'green' water (effective rainfall) for rain-fed areas and both 'green' water and 'blue' water (diverted water from water systems) for irrigated areas, and N use by the crop. CA is not well evaluated in terms of crop N use or CWP. The impact of a CA system on conserving soil moisture is documented in some countries. In an Iowa study (Karlen *et al.*, 1994), the gravimetric soil moisture in the top 5 cm of soil was 32.4 percent for NT and between 23.1 and 25.5 percent for conventional practices and moldboard plow systems. NT and other conservation practices can increase grain CWP and yields (Wiese *et al.*, 1998; Norwood, 1999, 2000). Norwood (1999) showed CWP of maize (Zea mays) and sunflower increasing by 28 and 17 percent, respectively, when the production system moved from a conventional tillage system to a NT system in a winter wheat spring crop fallow rotation.

Tillage moves moist soil to the surface, increasing losses to drying (Hatfield *et al.* 2001). Soil evaporation is determined by two factors: how wet the soil is and how much energy the soil surface receives to sustain the evaporation process (Hsiao *et al.* 2007). The amount of energy the soil surface receives is influenced by canopy and residue cover. Greb (1966) found that residue and mulches reduce soil water evaporation by reducing soil temperature, and reducing the wind speed gradient at the soil-atmosphere interface. The presence of residue on the surface reduced soil water evaporation by 34 to 50 percent (Sauer *et al.*,1996). Soil mulching decreased soil water loss on average by 0.39 mm d^{-1} compared to the unmulched control during the two weeks after wheat harvest on a loess soil in Germany (Dahiya *et al.*,2007). The total soil water evaporation fluxes in Iowa were 10 to 12 mm for a 3-day period following each cultivation operation in the spring, while the total evaporation fluxes from zero tillage fields were <2 mm over this same period (Hatfield *et al.* 2001).

Soil management practices that increase the organic matter content of the soil could have a positive impact on the soil water holding capacity (Hatfield *et al.* 2001). The effect of mulching and tillage was determined on soil water content in a clay and a sandy soil under maize cultivation in Zimbabwe (Mupangwa *et al.*,2007). Mulching helped conserve soil water in a season with long periods without rain at both experimental sites. Soils under NT with residue retention generally had higher surface soil water contents compared to tilled soils in the highlands of Mexico (Govaerts *et al.* 2009).

The major concerns about irrigated agriculture are low CWP, soil structural degradation and accelerated erosion. The low CWP is mainly due to surface evaporation of soil moisture, deep percolation and tail water runoff losses, which cause individual field efficiency to be low.

Understanding the CWP under different tillage methods on soybean and maize is essential to properly manage water resources use in irrigated area. The challenges associated with water scarcity for irrigated crops in Iran in well drained soils with surface irrigation prompted this research to provide an alternative tillage system that would address both soybean and maize production concerns. Therefore, the objective of this study was to determine CWP of soybean and maize under different tillage and residue management.

Material and methods

1.1 Experimental sites

To evaluate the effect of various tillage practices and wheat residue management on crop water productivity of soybean and maize two independent field experiments were carried out at the two separate site of Golestan Province which is situated in north part of Iran (longitude 54.46 E°, latitude 36.54 N° and elevation above sea level 150 m) in 2010 and 2011. For both site and both years wheat was the preceding crop. At the first site crop was silage maize and the soil texture was clay loam with an average water field capacity of 26 percent, wilting point of 15 percent, soil bulk density of 1.35 g cm^{-3} and infiltration rate of 1.05 cm h^{-1}. The irrigation water source was a deep groundwater well. At the second site the crop was soybean and the study was performed at the Gorgan agricultural research station of the Golestan province of agricultural and natural resources research center, Gorgan, Iran. The farm is located at an altitude of 5.5 m above mean sea level. The region has a warm and moderate climate, with an average annual rainfall of about 400 mm which of 70 percent is in autumn and winter seasons. The soil at the second experimental site was silt clay loam with 32 percent clay, 50 percent silt and 18 percent sand. Average field capacity, 27 percent; permanent wilting point, 13.1 percent; dry bulk density, 1.44 g cm^{-3}; pH 7.1 at 0–100 cm soil depth. Water suitable for irrigation (pH 7; EC 0.5 dS m^{-1}) was obtained from a deep well in the experimental area.

1.2 Experimental procedure

Both experiments were laid out in a randomized complete block design with strip plot arrangement where each treatment was replicated three times. Wheat residual treatments were kept as main plots and tillage treatments as sub plots. Wheat residue treatments were burnt management referred to as R1, 50 percent residue (R2), and 100 percent residue (R3). Tillage treatments were conventional tillage (T1) (moldboard plow with depth of 25–30 cm, three times of disk harrowing + sowing), reduced tillage (T2) (application of combined tillage with depth 10 cm equipments+sowing), and no tillage (T3) (planting with no-till planter). Field experimental layout is shown in Figure 44.

Maize (Zea mays L.,) was planted in the first experimental field on July 18 in 2010 and July 20 in 2011. The distance between rows was 0.50 m and 0.18 m between grains in the row. Each plot was irrigated separately based on soil moisture deficit (50 percent of management allowable deficit) using border irrigation (surface irrigation). For both site the total experimental area including 27 plots (tillage and residue treatments) was 0.8 ha, each, (6 m width with 50 m long) (Figure 44).

Irrigation season of maize ended two weeks before harvest. Maize was harvested on October 16 in 2010 and October 19 in 2011. For all plots, fertilization and weed and

	6 m	6 m	6 m	3 m	6 m	6 m	6 m	3 m	6 m	6 m	6 m
50 m	R1T1	R1T3	R1T2		R2T2	R2T3	R2T1		R3T3	R3T2	R3T1
3 m											
50 m	R2T1	R2T3	R2T2		R3T2	R3T3	R3T1		R1T3	R1T2	R1T1
3 m											
50 m	R3T1	R3T3	R3T2		R1T2	R1T3	R1T1		R2T3	R2T2	R2T1

R1= 0 percent Residue T1= Conventional Tillage
R2= 50 percent Residue T2= Reduced Tillage
R3= 100 percent Residue T3= No Tillage

Figure 44. Field experiment layout

pest control applications followed recommendations of the agricultural and natural resources research center of Golestan Province.

Soybean was sown on July 11 in 2010 and June 29 in 2011. The distance between rows was 0.40 m and 0.18 m between grains in the row. Each plot was irrigated separately based on soil moisture deficient using classic sprinkler irrigation method. During two successive years 7 and 5 times irrigation were used respectively.

Irrigation season of soybean was ended two weeks before harvest. Soybean was harvested on November 7 2010 and November 1 2011. For all plots, fertilization and weed and pest control applications followed recommendations. A statistical analysis of the strip plot experiments design was carried out to understand the impact of the different treatments on water applied, total water used, CWP and growth parameters of soybean and maize, which were irrigated with sprinkler and surface irrigation system respectively.

Results

Results showed that in both years the highest harvest index, biological yield, grain yield and one thousand seed weight were obtained from R2 treatment. So that the grain yield of soybean that is the most important component, in R2 was 42.7 percent higher than R1 (Table 25). Also in terms of tillage, the highest biological yield, grain yield and one thousand seed weight was obtained from T3 treatments. So that the grain yield of T3 with a maximum yield, was 17.4 percent higher than T1. The results indicate that both no-till and 50 percent maintaining crop residues treatments had best production efficiency in terms of grain yield; and there were significant differences at the 5 percent level of probability between wheat residue treatments. The highest and lowest amounts of used water were 3950 m^3 and 2690 m^3 from R1 and R3 respectively; and water used in R3 and R2, was 46.8 percent and 41 percent lower than R1, respectively. No significant differences were found between tillage treatments in terms of water used. Significant difference between R2, R3 and R1 treatments at 5 percent level, but no significant difference between R2 and R3 in CWP (Table 25). Maximum and minimum CWP were 1.13 and 0.55 kg m^{-3} from R2 and R1, respectively. These results revealed that the one of the most important management of irrigation water use efficiency and reduce evaporation, is keeping crop residue on the soil surface. As for the tillage treatments, T3 and T1 had the highest CWP value (0.98) and the lowest value (0.85) respectively. There were no significant differences between T3 and T2.

In the maize experiment the results showed that the highest and lowest average water consumption during the growing season was R1 and R3 treatments, respectively with 3 737.9 and 2 968.7 m^3 ha^{-1} (Table 26). Also there was no significant difference between treatments of R3 and R2 in terms of volume of water. Comparison of yields between different treatments of R shows that the aboveground biomass production

Table 25. Comparison of soybean CWP mean in different treatments of residue and tillage management, and two years of experiment

Treatment		Soybean Grain Yield (kg ha^{-1})	Total water used (m^3 ha^{-1})	CWP (kg m^{-3})
Residue	R1	2206.2C	3950A	0.55B
	R2	3148.6A	2800B	1.13A
	R3	2712.6B	2690C	1.03A
Tillage	T1	2519.7B	3146.6A	0.85B
	T2	2589.2B	3146.6A	0.87AB
	T3	2958.4A	3146.6A	0.98A
Year	2010	2833.7A	3360A	0.88A
	2011	2544.5A	2933B	0.92A

or forage yield in R3 was 29655.6 kg ha^{-1} and was higher than R2 and R1 significantly ($p>0.05$) (Table 26). Comparison of CWP between different treatments of T and R

Table 26. Comparison of maize CWP mean in different treatments of residue and tillage management, and two years of experiment

Treatment		**Maize silage Yield (kg ha^{-1})**	**Total water used (m^3 ha^{-1})**	**CWP (kg m^{-3})**
Residue	**R1**	26212.9C	3737.9A	7.2C
	R2	27638.9B	3099.9B	9.2B
	R3	29655.6A	2968.7B	10.2A
Tillage	**T1**	29122.3A	3200.3A	9.6A
	T2	28457.2A	3283.7A	8.8A
	T3	25927.8B	3322.5A	8.1B
Year	**2010**	26657.5B	3207.4A	8.8A
	2011	29014.1A	3330.3A	8.9A

shows significant difference ($p>0.05$). The lowest and the highest value of CWP were R1 with 7.2 and R3 with 10.2 kg m^{-3}, respectively. So that CWP values in R1 treatment was 29.4 percent and 21.7 percent lower than R3 and R2 treatments respectively.

In a column, numbers followed by same letters are not significantly different by least significant difference (LSD)

In a column, numbers followed by same letters are not significantly different by least significant difference (LSD)

Discussion

In many irrigated areas of Golestan Province which is situated in northern part of Iran, under scarce water conditions, farmers still use traditional methods of tillage and irrigation. Irrigation consumes more than 90 percent of the province's water budget for cultivating approximately 230 000 ha (50 000 ha soybean and 10 000 ha maize) with an annual crop area about 650 000 ha. On about 95 percent of the cultivated area farmers use conventional tillage and irrigate by primitive surface irrigation methods with low on-farm water application efficiency (30–40 percent). In some parts traditional tillage (conventional) accompanied by burning crop residue is used to remove weeds, shape the soil into rows for row crops and furrows for irrigation. Low application efficiency, waterlogging, soil compaction, loss of organic matter, increases of evaporation from soil surface, degradation of soil aggregates, decline of soil microbial activity and other organisms (mycorrhiza, arthropods, and earthworms) and soil erosion are the main problems inherent to conventional tillage and traditional surface irrigation. Given the strategic importance of soybean and maize crops and the significant role of tillage practices and crop residue management in its production, also limits the Golestan Province water resources, two independent field experiments were conducted to determine the crop water productivity (CWP) of soybean and silage maize in 2010 and 2011. No significant differences were found between tillage treatments in terms of water used. Therefore, it can be concluded that due to less water consumption of summer soybean (against spring soybean), as a result of crop residues, and lack of significant differences between tillage treatments, the presence of crop residue on the soil surface, regardless of the tillage system used, resulted in reduced evaporation and retaining more moisture in the soil has significant priority. The results revealed that the one of the most important management of CWP and reduce evaporation, is keeping crop residue on the soil surface. As for the tillage treatments, T3 and T1 had the highest CWP value and the lowest value respectively, therefore it can be concluded that minimum soil disturbance can enhance CWP and maintain better soil physical properties, and may result in higher crop yields.

For maize the higher water volume used in R1 treatment can be attributed to a higher evaporation from the soil surface. The research also revealed that maintaining crop residues can improve yield and CWP of silage maize significantly.

That's why, it can be concluded that keeping crop residue is the most effective factor in CWP increasement. According to these results, keeping crop residue for increasing CWP of irrigation water is strongly recommended. Residue management is very important than tillage management in irrigated and dry areas.

No-till farming avoids these effects by excluding the use of tillage. With this way of farming, crop residues or other organic amendments are retained on the soil surface and sowing/fertilizing is done with minimal soil disturbance. Goals were to use conservation tillage to preserve water used for irrigating the irrigated lands of the Golestan Province, increase the CWP, and alleviate the environmental impacts of conventional tillage methods and surface irrigation such as waterlogging and salinization. The results revealed that it is recommended to use conservation agriculture practices, keeping crop residues to obtain highest CWP of soybean and maize and highest yield in the irrigated area, especially in the areas that are under water scarcity conditions.

CA practices needs to be managed very differently in order to keep or increase CWP and yield on the field. Residue, weeds, equipment, crop rotations, water, disease, pests, and fertilizer management are just some of the many details of farming that change when switching to CA.

Acknowledgment

The research was funded by the Golestan Agricultural Organization (GAO). The author would like to thank GAO for supporting this research. Special thanks to contribution of Dr. Mokhtar Mohajer head of GAO, Mr. Karimifeizabadi, Mr. Sohrabilotfabadi, Mr. Feizbakhsh, Mr. Aboumardani, Dr. Razzaghi, Mr. Sadeghnejhad and Mr. Alimohammadzadeh for their assistance in the plot preparation and layout.

References

Asadi M E (2018) The necessity of conservation agriculture mechanization for small holders farming systems. Agri Mech Vol 3 (8) July 2018: p3.

Dahiya R, Ingwersen J and Streck T (2007) The effect of mulching and tillage on the water and temperature regimes of a loess soil: Experimental findings and modeling. Soil Till. Res. 96:52–63.

Govaerts B, Sayre K D, Goudeseune B, De Corte P, Lichter K, Dendooven L and Deckers J (2009) Conservation agriculture as a sustainable option for the central Mexican highlands. Soil Till. Res. 103:222–230.

Greb B W (1966) Effect of surface-applied wheat straw on soil water losses by solar distillation. Soil Sci. Soc. Am. Proc. 30:786.

Hatfield J L, Sauer T J and Prueger J H (2001) Managing soils to achieve greater water use efficiency: A review. Agr. J. 93:271–280.

Hsiao T C, Steduto P and Fereres E (2007) A systematic and quantitative approach to improve water use efficiency in agriculture. Irrigation Sci. 25:209–231.

Karlen D L, Wollenhaupt N C, Erbach D C, Berry E C, Swan J B, Eash N S and Jordahl J L (1994) Long-term tillage effects on soil quality. Soil Tillage Res. 32: 313–327.

Kassam A, Friedrich T, Shaxson F and Pretty J (2009). The spread of conservation Agriculture: justification, sustainability and uptake. International Journal of Agricultural Sustainability 7(4): 1–29.

Kassam A, Friedrich T, Derpsch R and Kienzle J (2015) Overview of the Worldwide Spread of conservation agriculture. Field Actions Science Reports (online), Vol.8.Online since 26 September 2015, connection on 30 April 2019. URL: http://journals.openedition.org/fastreports/3966.

Kassam A, Friedrich T and Derpsch R (2017): Global spread of conservation agriculture: Interim Update 2015/16. In: Proceedings of the World Congress on conservation agriculture (WCCA7), Rosario, Argentina. 1–4 Aug 2017. pp. 16–19.

Lal R (1994) Water management in various crop production systems related to soil tillage. Soil Tillage Res. 30: 169–185.

Norwood C A (1999) Water use and yield of dryland row crops as affected by tillage. Agron. J. 91: 108–115.

Norwood C A (2000) Water use and yield of limited-irrigated and dryland corn. Soil Sci. Soc. Am. J. 64: 365–370.

Sauer T J, Hatfield J L and Prueger J H (1996) Corn residue age and placement effects on evaporation and soil thermal regime. Soil Sci. Soc. Am. J. 60:1558–1564.

Von Braun J, Derek B, Colin C, Tom L, Norah O and Jeff W (2010) A Draft Strategy and Results Framework for the CGIAR, 20-March 2010. CGIAR, The World Bank, Washington D.C.

Wiese A F, Marek T and Harman W L (1998) No-tillage increases profit in a limited irrigation-dryland system. J. Prod. Agric. 11: 247–252.

Effective water distribution in the irrigation systems of the foothill zone of the Chu river basin – as a contribution of soil-protecting and resource-saving agriculture in the Chuy Depression of Kyrgyzstan

Bakytbek Askaraliev[48], Nataliya Ivanova

Abstract

The current state of irrigation systems is presented; the most appropriate solution to the problem of rational water distribution in irrigation systems today is the principles of integrated water resources management.

Key words: rational water distribution,
integrated water resources management, natural resources,
water users association.

Introduction

In the Soviet period, all irrigation was concentrated on the basis of state farms and collective farms with up to 7 thousand hectares of irrigated land, with an average size of about 2 thousand hectares. In modern conditions, land allotments are from 0.1 to 5 hectares. [1]. In addition, Kyrgyzstan quickly limited state intervention in agriculture. As a result, the number of small owners has sharply increased, and the lack of a state order for agricultural products has led to the fact that the sowing pattern of land users is not controlled.

On the one hand, this provided farmers with significant opportunities, and on the other hand, problems arose due to poor development of the agricultural product market and lack of marketing experience.

Notwithstanding the foregoing, there are wide opportunities in the Republic for developing a strategy for sustainable development and natural resource management. In this regard, it is very important to study the issues of rational use of water resources.

The Kyrgyz Republic has a huge supply of water resources – 47.4 km^3 [2]. About 20 percent of annual runoff is used in the national economy and energy sector of the republic, 80 percent – by neighboring countries [2.8].

The republic has sufficient water resources in large trans-boundary rivers, but, however, agriculture is based on the use of resources of small rivers, whose resources are limited. Moreover, the flow of many small rivers is completely dispersed within the borders of Kyrgyzstan [8].

The solution to the problem of water resources management affects, in our opinion, various aspects: legislative, institutional, socio-economic, technological, technical and environmental.

In modern conditions, a number of measures have been taken to reform water management [3, 4, 5]. These include the reorganization of the water administration, the creation of water user associations (WUAs) and the introduction of economic instruments such as fees for water services.

The reforms in the field of water management in Kyrgyzstan provide for the introduction of the concept of integrated water resources management (IWRM). This approach is based on the principles of integrating economic, environmental and social aspects in water resources management.

As noted in [10], "IWRM is the art of delivering the required amount of water of acceptable quality to the right place and at the right time." To implement IWRM, several interrelated elements are needed: engineering infrastructure (irrigation systems); organizational infrastructure (water management enterprises); management tools (legal and scientific-methodological base); monitoring system (hydrometric and information base). In addition, a system of appropriate funding and initiatives is needed.

The key principles of IWRM are water management within hydrographic boundaries, accounting and assessment of water resources, involvement of all interested parties in the management, their close coordination horizontally and vertically. Thus, IWRM is a complex (multifactor) process. The following are guidelines for the practical implementation of the above principles.

In Kyrgyzstan, the sectoral management principle is still used, in which the functions and responsibilities in the field of water relations are distributed between various ministries and departments. Republican structures and bodies of local state administration are also involved in the regulation of water relations. The structure of the Department of Water Resources and Land Reclamation (DWRLR) provides for 40 district water management departments (DWMD) and 7 basin water management divisions (BWMD). Such a structure was formed back in the Soviet period and basically coincides with the administrative territorial borders (Figure 45.).

However, water is subject to physical laws and does not recognize administrative boundaries. For example, the main waterway of the Chui valley of the Kyrgyz Republic – the Chui river originates in the Kochkor district of Naryn region, passes through 5 administrative districts of the Chui valley and goes to the territory of neighboring Kazakhstan.

In each region there are many small rivers of inter-district and inter-Republican scale, the waters of which are used by various economic entities, territorially located in different administrative boundaries. As a rule, the waters of these rivers are completely disassembled for irrigation and cannot always certify the needs of all water users. Almost all irrigation systems in such conditions adapt to the regime created by the officials of the DWRLR.

On the basis of this, a so-called limit water use plan appears, which does not allow farmers to get the harvest planned by them. In addition, there are cases of

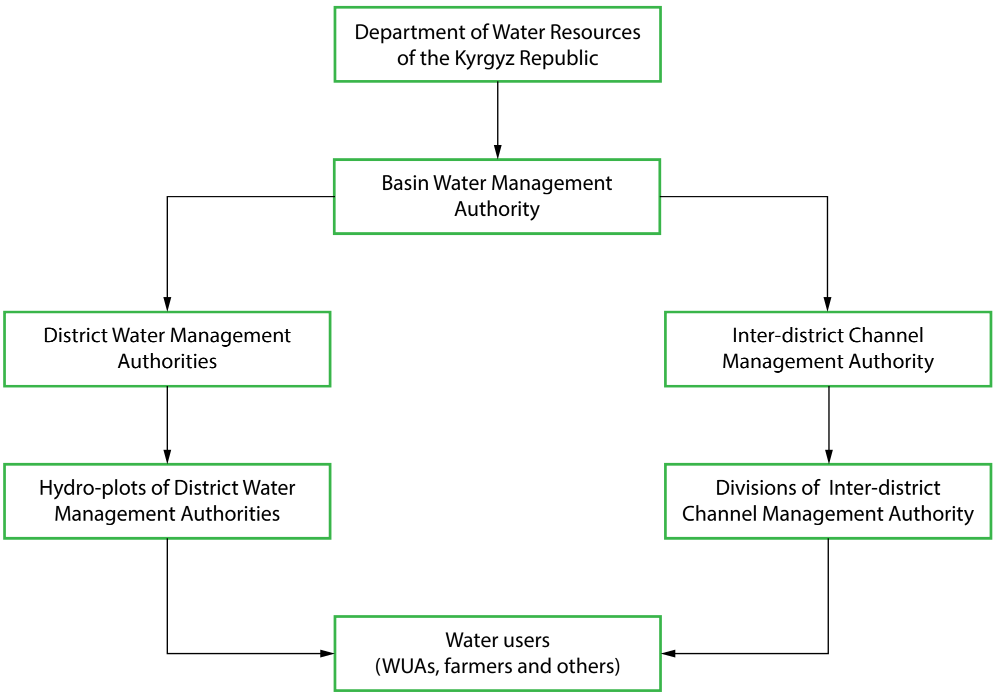


Figure 45. The existing structure of water management in Kyrgyzstan

influence of the district administration. All these episodic managers intervene in the process of water use without having full information about the state of WR use in the area of a given basin or IS.

Therefore, in our opinion, it is most expedient to introduce the hydrographic principle of water resources management. The restructuring of the water resources management system according to the hydrographic principle will require changes in the territorial boundaries between the regional water authorities. There are about 800 small rivers in Kyrgyzstan, therefore, it is impossible to establish their own management on each of them.

DWRLRM must be created around a relatively large river, and the adjacent small rivers will be included in it. For example, the water management complexes of the Jylamysh and Alaarcha rivers may be part of the Sokuluk DWRM [9]. When moving from an administrative management system to a hydrographic one, it is necessary to comply with the principle of corporate governance of WR, which will ensure that all water users are respected.

The proposed system of WRM, implemented in many countries of the world, ensures the preservation of the interests of the state and water users to the same extent, observing the priorities of water conservation and the environment within one hydrographic unit.

Thus, when implementing the principles of IWRM, the hierarchical chain of organizational structures should be as follows: DWRLRM -DWMD-BWMD-WUA-water users.

Another equally important aspect in the effective management of WR is the creation of WUAs as an adequate tool for implementing IWRM at the local level. The key problems in this area are the transfer of management functions on the on-farm IS from public services to non-public ones.

Such transmission can be carried out both at the level of distribution channels of various orders, and at the level of the entire IS [1, 3, 4].

Since independence, investment in irrigation infrastructure and in organizations serving the agricultural sector has been negligible. In this regard, there was a deterioration in the technical condition of irrigation systems and an increase in the area of dysfunctional lands for reclamation. Ineffective methods and principles of water distribution currently occurring in the IS of KR reduce the productivity of irrigated lands, worsen the socio-economic conditions of life for water users and the ecological situation in irrigated areas. Poor water management also affects the operation and maintenance of IS, which worsens their technical condition.

The on-farm (local) IS level is characterized by the same problems as the industry as a whole (Figure 46).

The technical level of water management in Kyrgyzstan during the Soviet period was relatively high. About 900 rivers with a flow of 10–11 billion m^3 were used for irrigation within the republic, while about 500 rivers were used for on-farm needs. The total length of irrigation canals [1, 6, 7, 9] amounted to 29 thousand km, of which only 7.1 thousand km with artificial anti-filtration coating.

For this reason, almost 47 percent of the water taken from the source is lost for filtration. Hydraulic structures, water intake points, water outlets, hydrometric posts taking into account the water supply were built and operated on IS. Of these, only 37 percent are engineering, and 32 percent are semi-engineering type [1.9].

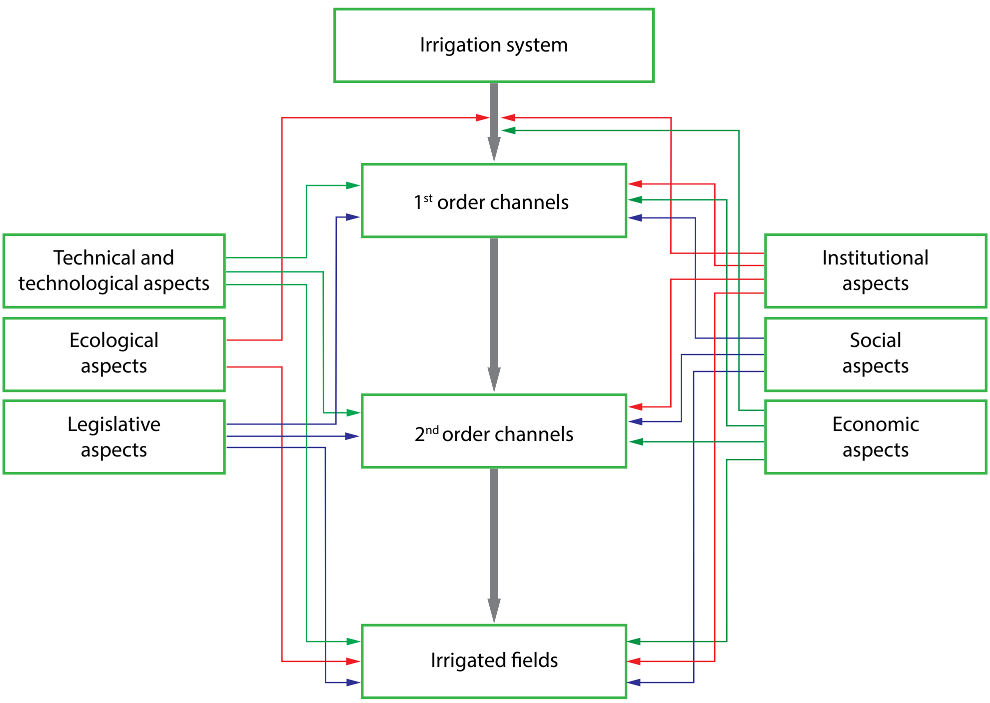


Figure 46. Water management scheme on irrigation systems.

Conclusion

The imperfection of the water distribution system with significant risk can bring not only economic damage, but also leads to accidents and destruction, as well as to the current unfavorable state of the environment and even to the ecological crisis.

As a result of the transition to IWRM, based on the above principles, taking into account the implementation of technical, institutional, organizational and other measures, as well as subject to sufficient funding, issues of sustainable water resources management in the irrigation systems of Kyrgyzstan can be resolved.

References

http://www.eco.kg/index.html (ноябрь 2009)

Маматканов Д. М., Водные и энергетические проблемы Кыргызстана // Наука и новые технологии, №4, – Бишкек, 2000. – с. 75–76.

Иванова Н.И., Аскаралиев Б.О., Биленко В.А., Обоснование выбора региона для исследования по устойчивому управлению водными ресурсами оросительных системах Чуйской долины Кыргызстана// Вестник Кыргызского аграрного университета. – 2004 г. с 254–258.

Аскаралиев Б.О., Анализ эффективности использования воды на оросительной системе бассейна реки Сокулук (БРС) Чуйской долины Кыргызстана // Вестник Кыргызского аграрного университета. – 2005 г. с 208–210.

Институциональный анализ министерства сельского и водного хозяйства. – Азиатский банк развития. – Бишкек, 2007. – 21с.

Иванова Н.И., Аскаралиев Б.О., Фролова Г.П., Биленко В.А., «Проблемы управления водными ресурсами на оросительных системах Кыргызстана в условиях рыночной экономики» Фундаментальные проблемы изучения и использования воды и водных ресурсов: материалы научной конференции. – Иркутск: Изд-во Института Географии СО РАН, 2005. 185–187с.

Инструкция по эксплуатации переносного водослива. Разработан и изготовлен НИИИР КР. (Сатаркулов С.С). 2с.

Биленко. В.А., Ершова Н.В., 2003. Основные особенности водного режима рек северного склона Киргизского хребта. // Сб. научн. тр. КРСУ «Архитектура и строительство», с. 277–284.

Руководство по эффективной организации водопользователей в Кыргызстане – **Азиатский банк развития.** – Бишкек. 1997. – 42с.

Соколов В., Принципы интегрированного управления водными ресурсами // Вода, земля, люди. – №36. – 2004 – с. 2–7.

Resource-saving, environmentally friendly technologies and the technique of irrigation

Gennady Olgarenko[49]

Abstract

The world and domestic experience of irrigated agriculture shows that reducing specific water and energy consumption is a major and multiplane task, the need to solve which is determined not only by the dry weather conditions of recent years and significant losses of irrigation water for discharge and infiltration (weighted average efficiency over irrigation systems does not exceed 0,7), leading to a negative impact on the environment, but also a significant increase in prices for material and energy resources, strengthening the requirements for energy and environmental safety of reclamation facilities. Improving the efficiency of water, material, technical and energy resources is achieved through the development and implementation of: automatic control systems of pumping and power equipment, information and advising systems of irrigation planning, resource-saving technologies and irrigation techniques, which can improve the efficiency of water use up to 80–90 percent, reduce the cost of material, technical and energy resources by 20–30 percent, while ensuring high productivity and environmental safety of agrobiocenosis.

FGBNU ARRI "Raduga" considers the most important scientific, technical and production task to develop resource-saving environmentally friendly technologies and technical means of irrigation, the most adapted to the soil and climatic conditions of the areas of application, while maximizing the criteria of economic efficiency, ergonomics, reliability, quality, environmental and technological safety.

The development of environmentally friendly and resource-saving technologies and irrigation technology is implemented through the creation of mobile irrigation complexes (systems) based on a modular layout principle, including: a mobile pumping station and equipment for applying fertilizer with irrigation water, a transporting and distribution network based on fast-assembled pipelines, typical irrigation modules of various irrigation areas, which are completed using commercially available process equipment, including: far-reaching sprinkling machines; irrigation kits including a fast-assembled distribution network and sprinklers; micro-irrigation systems, including: synchronous-pulse sprinkling, drip and pulse-drip irrigation, aerosol irrigation, technical means of micro-irrigation with water supply intensity equal to the current water consumption of agrobiocenosis; automated stationary irrigation systems with adjustable water supply.

Over the past 10 years, FGBNU ARRI "Raduga" has developed and implemented more than 35 types of new irrigation equipment, which by its scientific and technical level correspond to the foreign level of technology development, including: 20 new sprinkler (irrigation) machines and their modifications; 15 sets of micro-sprinkler systems, drip and sub-soil irrigation; 12 types of special technological equipment for application of organic and mineral fertilizers, trace elements and other chemicals along with irrigation water.

Developed standard technological modules and irrigation equipment were introduced in 37 regions of the Russian Federation, including Moscow, Tambov, Astrakhan regions and Krasnodarskiy Krai, where they ensured an increase in crop yields by 50– 60 percent, saving irrigation water by 20–30 percent, while reducing capital investments by 20–30 percent and energy costs by 15–30 percent compared with existing irrigation technologies.

Key words: water and energy consumption, irrigation quality, micro-irrigation, micro-sprinkling, irrigation technologies and techniques.

Introduction

Irrigation development is a characteristic feature of modern agriculture throughout the world, as irrigated land is one of the main factors for ensuring food security. In the world, on irrigated lands that make up less than 20 percent of arable land, more than 40 percent of crop production, including more than 50 percent of grain crops, is produced. The yield of products from irrigated hectares is 2–5 times higher than from rainfed land, and labor productivity, efficiency of use of natural and material and technical resources, including fertilizers, increase by 2–3 times, especially since in arid climatic conditions it is practically impossible to ensure profitable production of vegetables, fruits, feed, it is impossible to get rice and cotton crops in the zone without irrigation. The projected by FAO increase in food production by 2050 should be 60–70 percent, which will require an increase in world irrigated land by 1.0–2.0 percent per year, and eventually to 350 million hectares, grain yield by 25 percent, energy consumption by 50 percent, resources by 40 percent, fresh water reserves by 20 percent. Intensive development of irrigation leads to a shortage of water resources, the severity of which is caused both by the soil-climatic and hydrogeological conditions of the irrigated areas and by the specific water consumption in the cultivation of crops, which to a large extent depends on the technical level of irrigation systems, quality irrigation technologies and techniques [1, 2].

The world and domestic experience of irrigated agriculture shows that reducing specific water and energy consumption is a major and multiplane task, the need to solve which is determined not only by the dry weather conditions of recent years and significant losses of irrigation water for discharge and infiltration (weighted average efficiency over irrigation systems does not exceed 0,7), leading to a negative impact on the environment, but also a significant increase in prices for material and energy resources, strengthening the requirements for energy and environmental safety of reclamation facilities.

In Russia, where more than 70 percent of all agricultural lands are located in areas of insufficient or unstable natural moisture, a high and stable level of agricultural production can be achieved through the development of irrigated agriculture, which requires work on the construction and reconstruction of irrigation systems, modernization of production facilities and technological equipment involved in the industry of land reclamation and water management with the use of modern science and technology [2, 3].

Technique and technology of irrigation have a decisive influence on the quality of regulation of the water regime of the soil, and, consequently, on the yield of crops and the efficiency of water, soil-climatic, material-technical and energy resources, the ecological state of the environment. The use of the same type of irrigation technique for fundamentally different soil and climatic conditions of the areas also has a negative impact on the environmental situation and the effective use of water, material, technical and energy resources. Therefore, it is necessary to develop irrigation equipment and technologies for its operation to the greatest extent corresponding to the soil and climatic conditions of the application areas, based on the principles of environmental sustainability of natural objects, with the quality of artificial rain corresponding to the quality of natural rains of the "average" power most favorable for soil and plants, implementing the principles of water and energy saving [3, 4].

Materials and methods

The most important scientific and technical challenge is to increase the efficiency of water use in the on-farm irrigation systems through the development and implementation of: resource-saving technologies and irrigation techniques, information-advising irrigation planning systems, which can increase the efficiency of water use up to 80–90 percent, reduce the costs of material and technical and energy resources by 20–30 percent, while ensuring high productivity and environmental safety of agrobiocenosis [3, 4].

R&D includes the substantiation of engineering solutions, the development of design documentation, experimental studies and state tests, production of prototypes of small series of irrigation equipment at the production facilities at the institute. For the development of designs created by the new technology and assessing the quality of the generated rain, the “Spectrum” information-measuring system has been developed, allowing to measure and record size, speed, energy, as well as spectral, integral and average raindrops [3, 4].

The main results

The FGBNU ARRI "Raduga" has developed a concept for the development of irrigation technology and irrigation technique, and formed the main goal of research and development work on the development of resource-saving irrigation equipment – the creation of an automated, high-performance, environmentally safe irrigation technique while minimizing the costs of information support, logistical, energy, water, labor resources; reduction of dependence on human and climatic factors, and maximization of such criteria, as ergonomics, reliability, controllability, safety, aesthetics, and planning. Resource-saving, environmentally friendly irrigation technology should ensure the implementation of the technology of "accurate irrigation" in the formation of artificial rain, similar in quality to natural rain of "average" strength, with drops falling almost vertically, with a diameter of 0.5–1.0 mm, intensity less than 0.25 mm/min and a uniform distribution of the area of not less than 0.9.

Experimental design developments are aimed at improving the design of wide-sprinkling machines by: implementing engineering solutions for new cascade impact jet nozzles, improving the hydrodynamic parameters of the water-supplying belt and running system, modernizing the power carriage, modular layout, automation, expanding the range of applicability and functionality, reducing the influence of the human factor, the use of new materials and energy sources, the layout of the nodes of equal reliability and life cycle (coefficient of variation is not more than 0.2), the possibility of wide regulation of the mode of operation, the unification of the component nodes and structural elements.

Scientific research and development work is carried out on the theoretical substantiation and development of technological systems of a new generation – a mobile multifunctional irrigation complex, including a pumping station with a system of environmental protection, a quickly assembled transport network and a system of irrigated multifunctional modules of various irrigation areas, which may include as sprinkling machines of various types, as well as stationary systems, systems of synchronous-pulse sprinkling, drip and pulse-drip irrigation, equipment for aerosol irrigation and fertilizer application with irrigation water, technical means of “precise” irrigation and micro-irrigation with irrigation intensity equal to the current water consumption of agrobiocenosis, technology and equipment for combined irrigation, automated stationary irrigation systems with adjustable water supply.

One of the important areas are research and development work on: technologies and technical means of “precise” sprinkling and micro-sprinkling with a water supply intensity equal to the current water consumption, and the creation of environmentally safe technologies for the introduction of agrochemicals with irrigation water; technologies and techniques of combined irrigation, pulse-drip and drip irrigation techniques, automated surface irrigation systems with pulsed water supply.

FGBNU ARRI "Raduga" developed and implemented more than 35 types of irrigation equipment, which by their scientific and technical level correspond to the foreign level of technology development or exceed it, including: 20 new sprinkler (irrigation) machines and their modifications; 15 sets of micro-sprinkling systems, drip and subsurface irrigation; 12 types of special technological equipment for the application with irrigation water of organic and mineral fertilizers, trace elements and other means of chemicalization; more than 50 types and sizes of hydraulic fittings for agricultural water supply systems. Technical solutions for sprinkling and irrigation installations are protected by patents of the Russian Federation. We especially want to emphasize that all the above-listed developments have passed state tests, meet the requirements of technical conditions, and are recommended for mass production.

To improve the quality of irrigation, new sprinkling nozzles have been developed, their layout for wide-area multi-supporting sprinkling machines “Fregat-N” and “Kuban-LK1”, the effective irrigation ratio of which increased to 80–90 percent, the average droplet diameter decreased from 1.5 mm to 0.9–1 mm, and also their speed decreased from 7–9 m/s to 5 m/s, which increases the erosion-permissible rate of irrigation by 25–30 percent.

For the small business sector of Russia, which has more than 40 million land plots with a total area of 27.2 million hectares, characterized by small areas, complexity of configuration and dismemberment of the relief, the presence of various obstacles (low forest, roads, power lines, communications, etc.), it has been designed and conducted state tests for 24 types of equipment for low-volume irrigation of small-contour plots with complex terrain, in relation to areas from 0.06 to 10 hectares, including: system KI-5, set "Raduga" SOK-0.06, mobile sprinkler installation DSH-0,6P, hose sprinkler DSH-1, a set of low-intensity sprinkling "Rosinka" KMD-0.06, a set of micro-irrigation "Rain", a set of pulse-local irrigation ILO, a set of local-pulse irrigation CLIP; KMDT-0,1 modular irrigation kit. Technical modules for irrigation of orchards and berry plantations on small-contour plots of a complex configuration with gradients up to 0.3 have undergone experimental-industrial testing, including: set synchronous impulse sprinkler KSID-1; set impulse sprinkler KSID-R; oscillating action impulse sprinkler set AID-1; pulse micro-sprinkling set AID-1; pulse-local micro-irrigation system module. The developed modules are implemented in the Moscow, Tambov, Astrakhan regions and Krasnodarskiy krai, where they provided an increase in crop yields by 25–50 percent and irrigation water savings by 20– 30 percent, with a decrease in capital investments by 20–30 percent and energy costs by 17–30 percent. [4, 5].

Pulse micro-sprinkling Kits KIMD-0.1 for irrigation of green crops and seedlings, a set of equipment for discrete surface micro-sprinkling KPDM-0.4 for surface sprinkling, a set of pulse-local irrigation KILO-0.4 for local land irrigation and a set of local-pulse irrigation CLIP-36 for watering greenhouses and small size greenhouses (up to 36 m^2) in private farms had been developed and implemented for protected soil conditions. Irrigation technology provides water saving up to 30 percent, increasing yields by 50–70 percent, the degree of automation of the irrigation process up to 85 percent, reducing capital costs by 55 percent, and energy costs up to 50 percent. More than 4 000 sets were made and implemented in private farms of the population (Table 27).

To improve the scientific and technical level of surface irrigation, new water-saving irrigation technologies for furrows in areas of correct and complex configuration have been developed. Irrigated wheel pipelines TKP-90 and TKU-100P were created for distributed water supply to the furrows, operating at a pressure on a hydrant of up to 20–25 m with a seasonal load of up to 80 hectares. Irrigation machine TKP-M has been developed for irrigation on furrows with variable flow – a stationary automated irrigation device ASHU-4 has been developed for a transverse scheme and irrigation machine TKP-P, allowing for the supply of water to the furrows in proportion to the absorption capacity of the furrow, irrigation small-contour plots of open valves made of chutes or low-pressure pipelines, developed portable sets of automated pulse and discrete Surface watering type: KDP-C, KDP-K and KDP-U, operating at a head of 0.8 to 2.0 meters.

Table 27. Irrigation technique for small-contour plots

Name	Technical and operational characteristics
A set of pulse-local irrigation in the hangar (A) and block (B) greenhouses ILO-0.4A ILO -0.4B	Water pressure, ATM – 0.5 Consumption, l/s – 0.05–0.4 Irrigation area, m^2 – up to 1 000 Number of devices, pcs. – 816
Surface discrete micro-sprinkler set KPDM-0,4	Water pressure, ATM – 0.5 Consumption, l/s – 0.05–0.4 Irrigation area, m^2 – up to 1 000 Number of devices, pcs. – 510
Pulse micro-sprinkler set KIMD-0,1	Water pressure, ATM – 2.5 Consumption, l/s – 0.05–0.1 Irrigation area, m^2 – up to 1 000 Number of devices, pcs. – 16
Slow sprinkler set KMD-0,5	Water pressure, ATM – 1.5 Consumption, l/s – 0.5 Irrigation area, m^2 – up to 1 000 Number of devices, pcs. – 1
Irrigational set KI-5	Water pressure, m – 60 Consumption, l/s – 4.0…6.0 Irrigation area, ha – 5,04 Number of devices, pcs. – 4
Synchronous pulse sprinkling set KSID-10	Water pressure, MPa – 0.55…0.3 Consumption, l/s – 10 Irrigation area, ha – 10 Number of sprinklers, pcs. – 60
Pulse sprinkler DI-3	Water pressure, ATM – 2.5 Consumption, l/s – 0.1 Irrigation area, m^2 – 600
Local-pulse watering set KLIP-36	Water pressure, ATM – 0.9 Consumption, l/s – 2…60 Irrigation area, m^2 – 36
Stationary-movable set "DOJDIK"	Water pressure, m – 15–20 Consumption, l/s – 0.08…0.5 Irrigation area, m^2 – 600 Number of devices, pcs. – 1…6
Adjustable sprinkler "RADUGA»	Nozzle diameter, mm – 1.8; 4; 4; 1 Pressure, MPa – 0.15; 0.06; 0.3; 0.05 Consumption, l/s – 0.03; 0.1; 0.3; 0.09 Irrigation radius, m – 7.6; 2.8; 3.8; 3.2
Sprinkler hose DSH-0,6 P	Water consumption, l/s – 0.6 Pressure on the hydrant, MPa – 0.15 Irrigation area, m^2 – 201 Watering radius, m – 8.0
Sprinkler hose DSH-1,0	Water consumption, l/s – 1.0 Pressure on the hydrant, MPa – 0.2 Irrigation area, m^2 – 250 Watering radius, m – up to 10

The developed technologies and technical means of surface irrigation along the furrows made it possible to reduce water losses during irrigation and bring its use up to 75 percent; eliminate the occurrence of soil erosion; to ensure a uniform distribution of the irrigation rate along the length of irrigated furrows with a uniformity coefficient of 0.7–0.9, increase the yield of irrigation crops by 5–10 centner/ha and bring the level of mechanization on furrow irrigation to the level achieved during sprinkling. Technological automated surface irrigation modules can be used in the reconstruction of reclamation systems, to replace high-pressure sprinkler systems and new construction.

Findings

The introduction of scientific and technical developments of the ARRI "Raduga" into agricultural production on irrigated lands and the operation of irrigation systems has increased the efficiency of water use by 10–20 percent, the yield of agricultural crops by 25–50 percent, reduced the costs of material, technical and energy resources in an average of 20–30 percent, preventing the risk of water erosion and pollution of natural water sources, ensuring the preservation of soil fertility of reclaimed land.

The experience of research and development shows that the comprehensive scientific and methodological, regulatory and technical, engineering and consulting support of machine-building plants and agricultural producers will help develop the production of domestic irrigation equipment and ensure the scientific and technical level of domestic production in accordance with the standards of high technologies of developed foreign countries. The development of domestic production of resource-saving equipment will provide high economic efficiency for agricultural producers, as well as socio-economic efficiency for the state, which will help solve the objectives of the Doctrine of Food Security of Russia and the State Program for the Development of the AIC, ensuring the sustainable development of the Russian Federation.

References

Водные ресурсы и обеспечение продовольственной безопасности и питания. Доклад Группы экспертов высокого уровня по вопросам продовольственной безопасности и питания Комитета по всемирной продовольственной безопасности, Рим, 2015 г. www.fao.org/cfs/cfs-hlpe.

Государственная программа развития сельского хозяйства и регулирования рынков сельскохозяйственной продукции, сырья и продовольствия на 2013–2020 годы/ Подпрограмма «Развитие мелиорации земель сельскохозяйственного назначения России»// Утверждённая Постановлением Правительства Российской Федерации от 14 июля 2012 г. №717 (в редакции постановления Правительства Российской Федерации от 13 декабря 2017 г. N 1544).

Отчет о реализации 1 этапа (2014–2016 годы) Федеральной целевой программы «Развитие мелиорации земель сельскохозяйственного назначения России на 2014–2020 годы. – Москва: **ФГБНУ «Росинформагротех»** 2017 г.

Ресурсосберегающие энергоэффективные экологически безопасные технологии и технические средства орошения: Справочник. – М: **ФГБНУ «Росинформагротех»**, 2015. – 264 с.

Официальный сайт **ФГБНУ ВНИИ «Радуга»** – www.vniiraduga.ru.

Chapter 6

Socio-economic and policy aspects of conservation agriculture. Upscaling the system


©FAO/Furkat Ibragimov

Conservation agriculture as approach towards economically sustainable farming in constrained environments

Gottlieb Basch[50], Fernando Barros Teixeira[51], Emilio Gonzalez-Sanchez[52].

Abstract

The objective of this paper is to a) recall the specific constraints for farming in Central Asia regions, b) examine how conservation agriculture (CA) can address these constraints, c) showcase of the potential benefits that can be harnessed through CA systems with a special focus on yields and farm profits. Although rich in natural resources, global climate change poses serious threats to Central Asia's environment, ecological and socio-economic systems. Production in some agricultural commodity groups is reported to decrease and amount and quality of water resources are at risk of suffering severe effects of climate change. CA has been proposed as a promising approach towards climate-smart farming. Empirical and scientific evidence is presented to show that significant productivity, economic, social and environmental benefits exist that can be harnessed through CA in water-scarce environments. These benefits consist mainly in a higher water productivity through higher water intake, higher water retention in the soil and less evaporation, thus reducing the vulnerability of plants to erratic rainfall distribution. They also derive from enhanced soil quality and productivity through the reduction of soil erosion, increase in soil organic matter and better structure. Yet, to harvest the full benefits of CA, i.e. better soil quality, significant reduction of production cost through lower external inputs, machinery and labor, and the provision of additional ecosystem services, such as less erosion and greenhouse gas emissions, less off-site environmental impact, all three principles of CA need to be put in place concomitantly. CA has shown to provide benefits in most agroecological regions but especially in dry regions CA can be considered as the most viable option to continue farming sustainably and successfully.

Key words: Climate change, Central Asia, dry regions, productivity, resilience.

Introduction

Despite its contribution to GDP having dropped from 30 percent in 2000 to 17.6 percent in 2011, agriculture continues playing an important economic role in the development of Uzbekistan (Sutton and *et al.*; 2013). Around 49 percent of the population is still living in rural areas and 25 percent of the national workforce is directly employed in the sector.

Moreover, agriculture provides 90 percent of domestic demand for agricultural products and 70 percent of domestic trade. In 2010 agricultural output still accounted for 21 percent of total exports to which cotton contributed decisively (Hasanov and Ahrorov, 2013).

After independence in 1991 the strong effort to increase the self-supply of food crops made the area under wheat triplicate between 1991 and 2011 (in 2011: 1.43 Mha) and the area under cotton shrink by almost 25 percent (in 2011: 1.33 Mha). Both crops together occupy around 70 percent of annual cropland.

Whereas cotton productivity has stagnated, wheat yields are almost fourfold today when compared to 1991 (Source: State Committee of Statistics of Uzbekistan, 2012). Out of the total land use area in Uzbekistan only 2 percent is rainfed cropland whereas 10 percent is irrigated cropland (Djanibekov *et al.*, 2013).

Given this land use pattern and the agroecological conditions, above all the climate characteristics with predominately dry and cold regions and others with warm, but summer-dry continental and Mediterranean-type conditions, the main constraints for agricultural production can easily be identified: a) severe water scarcity under rainfed conditions; b) high water losses under irrigation as a result of the high evaporative demand in the warm summer season; c) associated to high evaporation rates high risk of salinization; d) risk of runoff, erosion and flooding due to the concentrated rainfall in late winter and early spring, especially on land destined to the establishment of summer crops.

Especially under dry conditions, whether in rainfed or irrigated production systems, the practice of conservation agriculture (CA) through its principles of: a) Minimal soil disturbance, b) Permanent organic matter cover of the soil, and c) Diverse crop rotations, sequences and associations (Kassam *et al.*, 2009), has shown to provide both opportunities to smooth the aforementioned natural constraints, to improve productivity and provide economic and environmental benefits (Kassam *et al.*, 2012).

Material and methods

To underpin the capability of CA principles in providing sustainable solutions to face the natural resource constraints, such as heavy soil erosion through high intensity rainfall on bare soil, generally low soil organic matter contents in agricultural soils and thus poor soil fertility, and excessive water losses through high evaporation in spring and summer, this paper presents some empirical and scientific evidence on how CA is capable to help overcome the specific natural constraints in summer-dry regions.

Results

In dry regions the solutions to alleviate water scarcity under rainfed conditions are intimately linked to a higher use efficiency of the so-called 'green' water, received by any form of precipitation. This starts by having as much as possible of the precipitation infiltrating the soil surface. Once in the soil, water has to be retained against gravity, which means to have the highest volume possible of medium-sized pores (0.2–50 μm). Water retention in the soil is also governed by the amount of soil organic matter (SOM) contained in it (Hudson, 1994). Under both rainfed and irrigated conditions, achieving higher water use efficiencies and reducing the amount of irrigation means to avoid as much as possible unproductive water losses through evaporation at the soil surface (Basch *et al.*, 2012).

In fact, the principles practiced under CA, especially minimum soil disturbance and permanent organic soil cover, are capable to impact on the processes and parameters affecting soil water, namely infiltration and runoff, soil water retention and evaporation. Permanent soil cover avoids the processes known as particle detachment, sealing, and crusting, which are caused by the kinetic impact of raindrops and the consequent breakdown of the soil aggregates (Li *et al.* 2009, Ben-Hur and Lado 2008). Under CA, this aggregate breakdown is further reduced by a higher aggregate stability found under no-till conditions. Numerous studies corroborate this effect of the combination of minimum soil disturbance and soil cover on enhancing water infiltration. The results of one of these studies is provided in Figure 47 (Landers *et al.* 2007). To overcome excessive runoff when precipitation or irrigation exceeds infiltration rates pitching or micro-basins are also used to increase the available time for infiltration. This however causes further soil disruption and costs.

As water retention and the share of plant-available water is mainly governed by pore size distribution, pore geometry and SOM, CA also contributes to an increase of plant-available water through both an increase of the volume of medium-sized pores and a higher organic matter content. On a vertic Cambisol after 6 years of differentiated soil management, Carvalho and Basch (1995) found an 80 percent increase of plant-available water in the topsoil (0–30 cm) under no-till when compared to plough tillage (Table 28).

Source: Landers *et al.* 2007

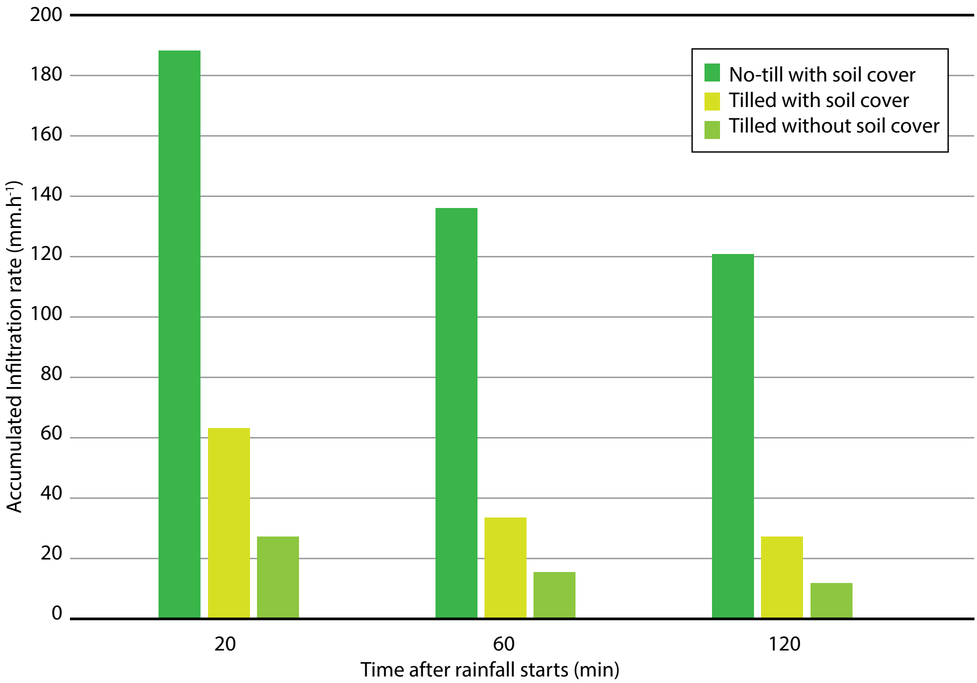


Figure 47. Infiltration rate as influenced by soil tillage and cover

The increase of SOM under CA favors in several ways a higher precipitation/irrigation use efficiency. Besides enhancing aggregate stability at the soil surface and thus contributing to a higher infiltration rate it also improves soil structure favoring the formation of medium-sized pores capable to retain plant-available water. Finally, SOM acts like a sponge retaining more water that it could be expected by the mineral soil matrix. Hudson (1994) found significant relationships between SOM content and plant-available water in soils of different texture classes (Figure 48).

Water evaporation from soil surfaces can be drastically reduced through effective soil cover. Klocke *et al.* (2009) found a strong relationship between the percentage of surface cover by corn residues and the evaporation measured (Table 29).

One of the major threats to crop production under Central Asian conditions is soil salinity/salinization and the use of saline water for irrigation. Avoiding unnecessary evaporation through mulching at a rate of only 1.5 t ha^{-1} of wheat straw has been found to reduce salt build-up in the soil even when irrigating with saline water. In a cotton-wheat rotation Bezborodov *et al.* (2010) found that by using appropriate

Table 28. Total porosity, pore size distribution, plant available water and soil organic matter content in a vertic Cambisol after 6 years under no-till (NT) and conventional tillage (CT)

Tillage	Depth (cm)	>50 µm (percent)	50–10 µm (percent)	10–0,2 µm (percent)	<0,2 µm (percent)	Total porosity (percent)	Available water (percent)	SOM (g kg^{-1})
NT	10	3.2	2.22	2.7	38.37	46.52	4.92	2.53
	20	0.86	3.91	5.22	36.16	46.15	9.13	2.15
	30	1.86	2.63	11.48	29.44	45.4	14.11	2.25
	0–30	1.97	2.92	6.47	34.66	46.02	9.39	2.31
CT	10	15.08	2.34	4.36	29.95	51.73	6.71	1.58
	20	2.67	1.32	2.31	39.95	42.25	3.63	1.7
	30	1.47	1.56	3.29	35.62	41.94	4.85	1.66
	0–30	6.41	1.74	3.32	35.17	45.31	5.06	1.65

Source: Carvalho and Basch 1995

combinations of water quality and mulching, there could be substantial increase in crop yield and water productivity resulting in water savings of up to 0.5 m^3 for each kg of cotton produced. Non-mulching increased surface soil salinity by 20 percent when compared to mulching. The authors further conclude that wheat straw

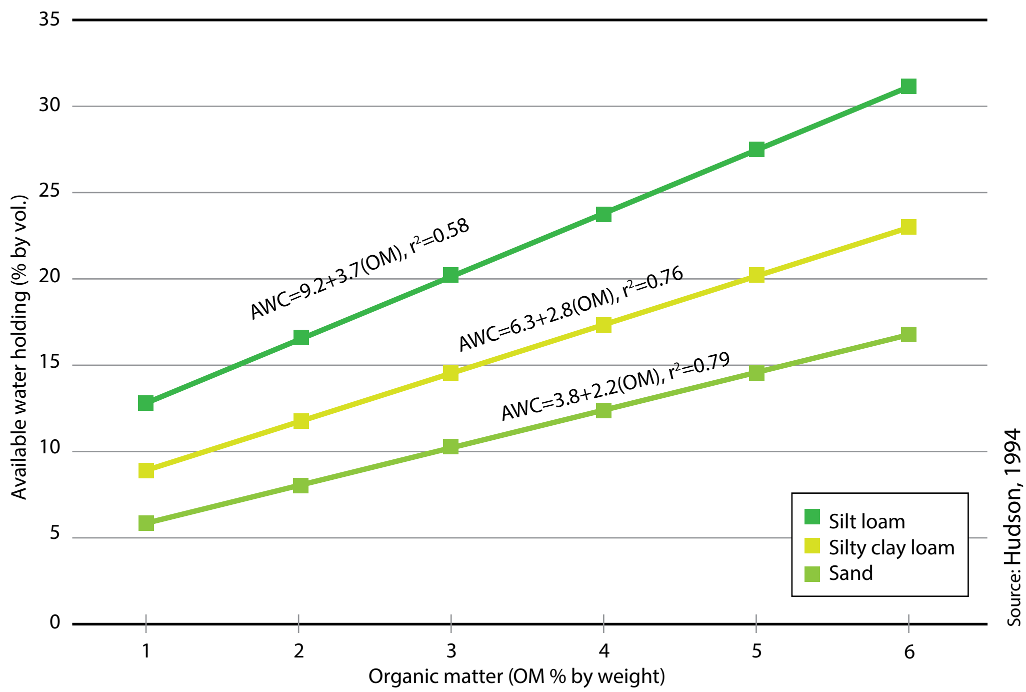


Figure 48. Available water holding capacity of different soils as affected by soil organic matter

Table 29. Soil water evaporation from bare soil and soil surface covered (initially) with different amounts of corn residue

Percentage cover (percent)	0	53	75	100
Cumulative evaporation (mm)	102.8	97.4	81.2	60.6

Source: (adapted from Klocke *et al.* 2009)

mulching at higher rates would need less time to effectively manage soil salinity and sodicity along with anticipated higher yield and water productivity of cotton.

With regard to economic sustainability several dimensions and aspects of agricultural land use have to be taken into account. At farm level it depends mainly on yields and productivity as well as on production costs including all necessary inputs whether generating fixed or variable costs. At the regional or even broader level environmental and social costs must also be considered. The latter perspective concerns mainly aspects such as land degradation but also the non-provision of further ecosystem services that could be expected under natural ecosystem's conditions. Mirzabaev *et al.* (2016) estimate the cost of land degradation as a share of GDP being 3 percent on average for the Central Asian countries reaching even 11 percent in the case of Kyrgyzstan. Effective soil and landscape conservation, including the provision of further ecosystem services, such as CO_2 emissions' mitigation, through widespread CA adoption could therefore boost the economic sustainability of agricultural land use.

At farm level, the shift to CA offers the opportunity to reduce external inputs, machinery and labor thus improving the profitability of the farming enterprise in the short, but especially in the medium and long term. Table 30 presents an example of the annual variable costs of a 350 ha farm working under rainfed Mediterranean conditions in South Portugal and performing a cereal-forage-legume crop rotation, before and after shifting to CA in 2001. Overall, this farm was able to reduce operating costs by around 70 percent while maintaining the yield levels.

Also in terms of fertilizer inputs, the increase in soil fertility through higher levels of soil organic matter (SOM) under CA allows for a reduction of fertilizer inputs. After 11 years of CA on a Luvisol and under Mediterranean rainfed conditions Carvalho *et al.* (2012) found an increase of SOM from 1 to 2 percent. The same authors compared the nitrogen fertilization response of wheat on the soil with 1 percent SOM (conventional) and 2 percent SOM (CA). Figure 49 impressively shows the effect of the SOM level on the possible nitrogen fertilization reduction and higher crop yields. The nitrogen level values (160 and 98 in italic) are relative to the most

Table 30. Variable production costs on a 350 ha farm in South Portugal
before and after changing to CA

	Conventional	CA	Reduction
	(Year 2000)	(Year 2003)	(percent)
Maintenance and repair of tractors	10 450,47 €	1 507,15 €	85
Maintenance and repair of tillage implements/drilling equipment	8 158,41 €	1 840,40 €	77,5
Fuel	17 460 €	7 110 €	60
Labor	25 000 €	15 000 €	40
Total annual	61 068,88 €	18 347,55 €	70

Source: Freixial and Carvalho, 2010

economical N level for each SOM value considered. The values for wheat grain yield (3 063 and 3 587 in italic) are relative to the respective yields obtained (adapted from Carvalho *et al.* 2012).

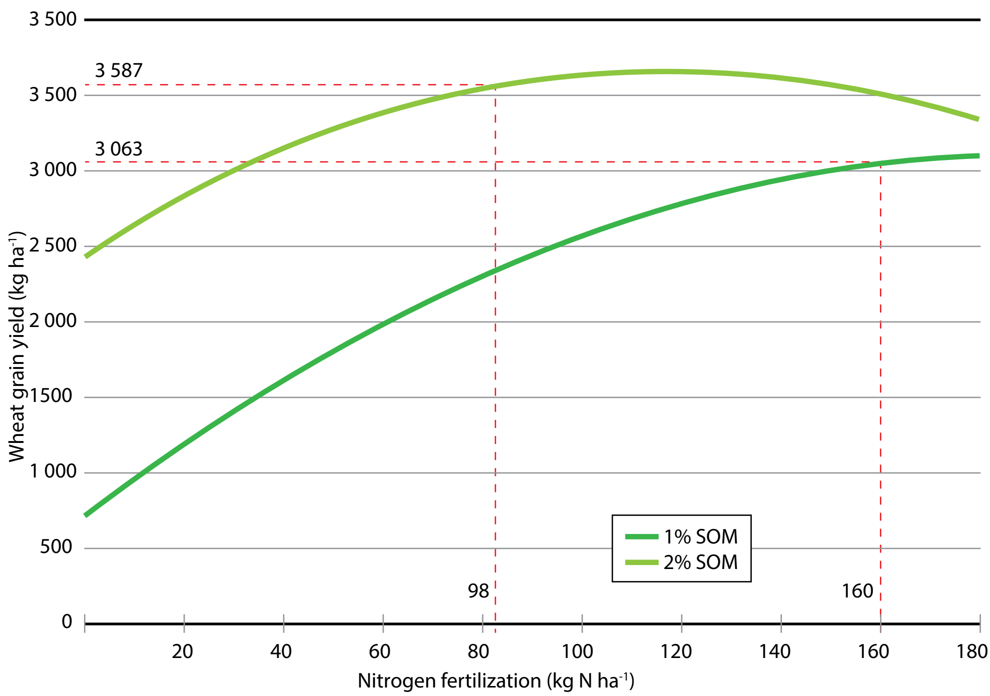


Figure 49. Effect of soil organic carbon (SOM) content (0–30 cm depth)
on the wheat response to nitrogen fertilization.

Conclusions

Sustainability of agriculture under constrained or suboptimal agroecological conditions depends on the capacity to adapt to or mitigate the limiting features of the respective environment. Also, the reduction of production costs is crucial for an economically sustainable farming. In Central Asia water scarcity, the risk of salinization and erosion, and low soil fertility are the major threats farmers have to cope with. As shown in the previous section CA provides promising opportunities to address and alleviate the aforementioned threats and to reduce effectively production costs. In many in dry regions, and especially under rainfed conditions CA has revealed the only viable option to maintain crop production an economically feasible activity.

References

Basch G, Kassam A, Friedrich T, Santos FL, Gubiani PI, Calegari A, Reichert JM and Dos Santos DR (2012): Sustainable soil water management systems. In: Lal, R & Stewart, B. A. (Eds). Soil Water and Agronomic Productivity, Advances in Soil Science. 229–289. CRC Press.

Ben-Hur M and Lado M (2008): Effect of soil wetting conditions on seal formation, runoff, and soil loss in arid and semiarid soils – a review. Australian Journal of Soil Research 46 (3):191–202.

Bezborodov GA, Shadmanov DK, Mirhashimov RT, Yuldashev T, Qureshi AS, Noble AD and Qadir M (2010): Mulching and water quality effects on soil salinity and sodicity dynamics and cotton productivity in Central Asia. Agric. Ecosyst. Environ. 138, 95–102.

Carvalho M and Basch G (1995): Effects of traditional and no-tillage on physical and chemical properties of a Vertisol. Proceedings of the EC-Workshop II: Experience with the applicability of no-tillage crop production in the West-European Countries, Silsoe, May 1995, 2, 17–23, F. Tebrügge, A. Böhrnsen (eds.), Wissenschaftlicher Fachverlag, Giessen.

Carvalho M, Basch G, Calado JMG and Barros JFC (2012): Long term effect of tillage system and crop residue management on soil carbon content of a Luvisol under rainfed Mediterranean conditions. Agrociencia, (Special Issue). 183–187.

Djanibekov U, Khamzina A, Villamor G and Lamers J (2013): Economic analysis of afforestation of marginal croplands in Uzbekistan. In: Ahmed, M. N. & Pawlowski, I. (eds.) Proceedings of the International Conference and Young Researchers' Forum "Natural resource use in Central Asia: Institutional challenges and the contribution of capacity building". No 64, Giessen, October 2013, p.137–147.

Freixial R and Carvalho M (2010): Aspectos prácticos fundamentales en la implantación de la Agricultura de Conservación/Siembra Directa en el sur de Portugal. In: ECAF, editors. Towards Agro-Environmental Climate and Energetic Sustainability. Proc. of the Eur. Congress on conservation agriculture, Madrid: Ministerio de Medio Ambiente y Medio Rural y Marino; p. 361–9. Spanish.

Hasanov S and Ahrorov F (2013): Uzbekistan's agriculture- status quo, challenges and policy suggestions. In: Ahmed, M. N. & Pawlowski, I. (eds.) Proceedings of the International Conference and Young Researchers' Forum "Natural resource use in Central Asia: Institutional challenges and the contribution of capacity building". No 64, Giessen, October 2013, p.189–203.

Hudson BD (1994): Soil organic matter and available water capacity. Journal of Soil & Water Conservation. 49. 189–194.

Kassam AH, Friedrich T, Shaxson F and Pretty J (2009): The spread of conservation agriculture: justification sustainability and uptake. International Journal of Agricultural Sustainability 7(4), 292–320.

Kassam A, Friedrich T, Derpsch R, Lahmar R, Mrabet R, Basch G, González-Sánchez EJ and Serraj R (2012): Conservation agriculture in the dry Mediterranean climate. Field Crops Research, 132, 7–17.

Klocke NL, Currie R and Aiken R (2009): Soil Water Evaporation and Crop Residues. Transactions of the ASABE (American Society of Agricultural and Biological Engineers). 52. 103–110.

Landers J (2007): Tropical Crop-Livestock Systems in conservation agriculture: The Brazilian Experience. In Integrated Crop Management, Vol. 5. Rome: FAO.

Li YX, Tullberg JN, Freebairn DM and Li HW (2009): Functional relationships between soil water infiltration and wheeling and rainfall energy. Soil & Tillage Research 104 (1):156–163.

Mirzabaev A, Goedecke J, Dubovyk O, Djanibekov U, Le QB and Aw-Hassan A (2016): Economics of Land Degradation in Central Asia. In: Nkonya E., Mirzabaev A., von Braun J. (eds) Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham, p. 261–290.

Sutton, WR, Srivastava JP, Neumann JE, Droogers P and Boehlert BB (2013): Reducing the vulnerability of Uzbekistan's agricultural systems to climate change: impact assessment and adaptation options (English). A World Bank study. Washington DC; World Bank.

The analysis of the barriers and financial benefits of crop diversification in Uzbekistan

Kuvatbek Sharshenovich Bapaev[53]

Abstract

The paper presents analysis of gross margins for selected alternative crops (kidney beans, onions, tomatoes) and investment models for orchards (apples, pears and apricots) to support country's growing diversification policy towards more profitable crops compared to traditional crops such as cotton and wheat. Crop diversification is one of the technologies used to enhance the effects of CA. It is very important that the government remains committed to implementing the crop diversification policy (cotton and wheat based cropping system) by promoting crop rotation and production of higher-value and export oriented alternative crops, including horticulture crops and pulses. The paper also discusses the barriers and obstacles to crop diversification and improved crop management techniques.

Key words: gross margin analysis, NPV, IRR, dehkan farms, diversification, investment

Introduction

The conservation agriculture is aimed at promoting conservation technologies for soil and other natural resources. The CA is gaining popularity due to the fact that it allows to preserve limited natural resources (e.g. soil) very much needed for

Table 31. Average yields of fruits and vegetables, (tons/ha) – 2010/2014

Commodities	France	Iran	Spain	Turkey	Uzbekistan
Apples	41.2	11.9	19.0	17.3	10.0
Apricots	12.1	15.4	5.8	8.3	10.7
Cherries	4.6	4.5	4.0	8.3	6.7
Cucumbers and gherkins	77.1	20.3	84.7	27.8	36.3
Grapes	7.8	9.8	6.5	8.9	10.6
Peaches and nectarines	22.6	26.2	16.0	17.5	12.7
Pears	24.9	11.3	17.5	14.9	8.0
Potatoes	44.3	28.7	30.8	31.3	27.1
Tomatoes	151.6	36.6	80.3	37.5	36.0

Source: FAOSTAT

sustainable agricultural production to feed constantly growing human population. Crop diversification is one of the technologies used to enhance effects of the CA.

The Republic of Uzbekistan is a land-locked, lower middle-income country (GDP per capita: USD2,009 (WB, 2016). The estimated country's GDP is at 67.22 billion USD (WB, 2016). Agriculture provides around 25 percent of the country's employment, and its share of the Gross Domestic Product (GDP) is estimated at around 18 percent (WB, 2016). A large share of its total population of 32 million (WB, 2016) is living in rural areas (around 64 percent) and is deriving income from agriculture-related activities. Around 13.6 percent of Uzbekistan's total population is characterised as poor, based on a unidimensional poverty line established by the government (i.e., the cost of a food basket). Seventy–five percent of the country's poor, under this measure, live in disadvantaged rural communities and regions. The low productivity of agriculture and the high level of informality of rural labor markets are associated with this poverty. Lack of access to productive assets, infrastructure, energy, land and water and technical and financial services, are among the causes of this limited productivity and poverty, which disproportionally affects rural women and young people. However, the country has an untapped potential for enhancing agricultural productivity in certain areas (crops/ commodities). The Table 31, presents yields of vegetables and fruits in Uzbekistan compared to the ECA/RNE countries.

As evidenced from the Table 31, Uzbekistan's yields in apples, peaches, pears, potatoes and tomatoes remain lower than in other countries (Turkey, Spain, Iran and France). Surprisingly, yields of grapes are higher than in other countries (Turkey, Spain, Iran and France). However, yields of apricots are higher than in Turkey by 29 percent and in Spain by 84 percent; cherries are higher than in Spain by 68 percent, in Iran by 49 percent and in France by 46 percent; and cucumbers are higher than in Turkey by 31 percent and in Iran by 79 percent though lower than in Spain by 233 percent and in France by 212 percent.

Cotton and grains are country's main crops occupying over 80 percent of irrigated land. While grains are grown to ensure country's basic domestic staple food requirements, cotton is an export crop and foreign exchange earner. Country has adopted a long-term program of crop diversification encouraging farmers to diversify from cotton production towards higher value crops (horticulture/ vegetables). The vegetable/horticulture and livestock industries are important sources of subsistence and income for rural communities. There are three types of agricultural producers in the country: (i) smallholder dehkan farms (household farms); (ii) private (commercial) farms; and (iii) shirkats (cooperatives). Some 4.7 million dehkan farms are responsible for country's bulk output with the balance from private farms and shirkats. As mentioned earlier, Uzbekistan's farming system is dominated by cotton and wheat, which account for 70 percent of cultivated land but less than 20 percent of gross agricultural output. Smallholder (dehkan) farms operate on less than 10 percent of land (approximately 0.42 million ha) but produce about 70 percent of gross agricultural output through horticulture and livestock*. For instance, dehkan farmers own about 95 percent of cattle and 83 percent of goats and sheep; and account for 95 percent of the total production of meat, 96 percent of milk and 89 percent of wool.

On February 7, 2017 by the Decree of the President of the Republic of Uzbekistan Mr. Shavkat Mirziyoev "The strategy of further development of the Republic of Uzbekistan in 2017–2021" was adopted. The strategy will include five main directions: (i) improvement of state and public affairs; (ii) ensuring the rule of law and further reforms of the judicial system; (iii) development and liberalization of the economy; (iv) development of social services; and (v) ensuring the security, inter-ethnic harmony and religious tolerance, the implementation of balanced, mutually beneficial and constructive foreign policy. The strategy explicitly seeks to increase the efficiency of the agricultural sector; improve the welfare of people nation-wide; reduce government's involvement in the regulation of the socio-economic development of the country, promote the role of the private sector, improve investment climate, attract investments, promote Public Private Partnerships and increase roles of non-governmental and public organizations; and expand cooperation with international development institutions. The main objectives for rural development include: (i) deepening of structural reforms within the agrarian sector and the diversification of agricultural production; (ii) accelerating the sector's modernization; and (iii) promoting the development of the food industry while increasing the processing levels of local agricultural raw materials. Financial support to small and medium-sized businesses, including dehkan farmers, is among the priorities for banking sector development.

The present TCP/UZB/3601 "Demonstration of diversification and sustainable crop production intensification" is aiming to address the issue of crop diversification and intensification. The project's impact will be diversified cropping systems and sustainable crop management practices applied by farmers. The project's outcome will consist of improved capacity of farmers, agriculture and extension specialists

* Page 19, WB Country Partnership Framework (2016–2020)

Table 32. Total areas of wheat, cotton, fruits (including intensive orchards) and vegetables (thousand, ha)

	Wheat	Cotton	Fruits	Intensive orchard	Vegetables
2010	1155.6	1450.3	235.4	10.11	173.1
2011	1149.8	1492.3	244.5	14.65	175.5
2012	1137.8	1472.3	250.9	21.93	183.8
2013	1154.9	1461.0	254.6	25.82	189.4
2014	1138.8	1478.6	261.9	31.76	191.9
2015	1145.0	1444.5	266.2	36.96	194.0
2016	1135.0	1423.1	279.6	40.48	206.0
2017	1120.0	1400.5	293	45.33	230.5

and researchers in developing locally adapted resource-saving, profitable and diversified crop production systems to enhance both crop productivity and ecosystem resilience. The project outputs will benefit farmers (especially rural women and youth who are central to the development of rural areas and to the national economy), agriculture extension specialists, researchers in research institutions and universities, and will have a catalytic effect on the sustainable

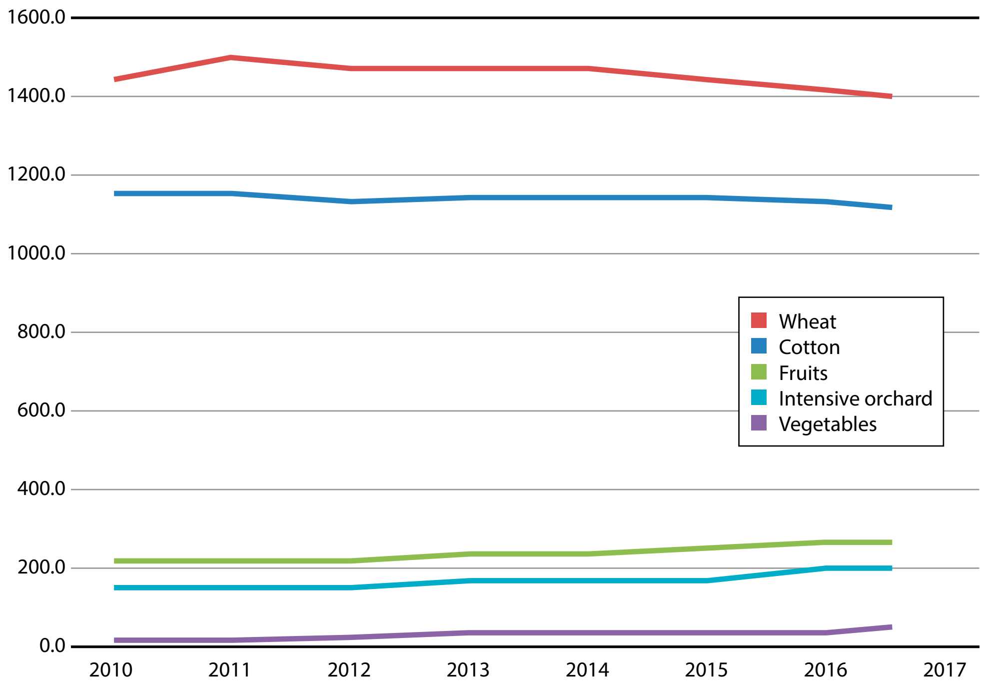


Figure 50. Chart of areas of wheat, cotton, fruits (including intensive orchards) and vegetables over a period from 2010–2017 (thousand, ha)

intensification and diversification of the cropping systems through the formulation of a national strategy.

The present report presents results of the following tasks delivered under the TORs:

- Conduct analysis and identify: (i) barriers to adopting improved crop management techniques and diversified cropping systems; (ii) enabling mechanisms that determine a profitable uptake of the selected practices in the specific contexts of the country.
- Carry out gross margin analysis and financial models for dwarf and semi-dwarf varieties of horticultural crops. This analysis will serve as a basis for scaling up the project's outputs. The results of the analysis will be used for the formulation of national strategies and policies to promote adoption of conservation agriculture and cropping systems diversification.

Country's diversification policy and trends. Main barriers to crop diversification and improved crop management techniques

Uzbekistan's agriculture is a main source of income and livelihoods for nearly 60 percent of people living in rural areas. Uzbekistan was the major cotton growing republic in the former Soviet Union allocating most of its best irrigated land to this crop. Under the centrally planned economy the country was forced to achieve certain production targets for key commodities, including cotton. It led to uncontrolled and unsustainable use of natural resources, including irrigation, which led to the man-made disaster – drying of the Aral Sea. Many years after, the Central Asian countries are still facing consequences and dealing with challenges of the disaster. After the break-up of the Soviet Union, cotton and wheat remain to be main crops occupying over 81 percent of the irrigated land. The Table 32 below presents the areas under the cotton, wheat, fruits (including intensive orchards) and vegetables over a period from 2010–2017.

As seen from the Table 32 between 2010 and 2017, the areas under two major crops (cotton and wheat) reduced respectively by 3.4 percent (50 thousand ha) and 3.1 percent (35.6 thousand ha). However, the areas under the fruits, intensive orchards and vegetables grew respectively by 24.4 percent (57.6 thousand ha), 348 percent (35.22 thousand ha) and 33.2 percent (57.4 thousand ha).

Some of the increased areas under fruits, vegetables and intensive orchards can be attributed to land freed from cotton and wheat production but some to new areas of unused, abandoned and waste land being brought to production. This is especially true for intensive orchards.

Given country's limited productive land resources, the size of the population and the pace of the population growth the country needs to adopt a long-term strategy for crop diversification and intensification to increase agricultural output and to enable rural communities to cope with the basic demand for staple food and livelihoods.

Table 33. Diversification of cotton and wheat in favor of vegetable crops and intensive gardens, (thousand ha) – 2016/2020

Uzbekistan	Total area to be diversified	Including		Distribution of area between diversified crops					
		Cot-ton	Irrigated cereals	Potato	Vegeta-bles	Inten-sive gardens	Fodder crops	Oil crops	Other crops
Republic of Karakalpaki-stan	7.0	7.0	–	1.5	2.2	0.5	0.7	0.9	1.2
Andijan	15.2	11.2	4.0	2.8	6.4	1.6	2.6	1.1	0.7
Buhara	15.0	10.0	5.0	2.4	7.1	1.2	3.1	0.8	0.4
Jizzak	27.5	22.5	5.0	4.0	11.0	1.5	7.8	1.6	1.6
Kashkadarya	22.4	18.4	4.0	2.3	9.7	1.8	5.1	1.8	1.7
Navoyi	3.4	3.4	–	0.5	1.4	–	1.0	0.5	–
Namangan	15.1	10.1	5.0	3.0	6.8	1.6	2.1	0.8	0.8
Samarkand	22.2	16.2	6.0	4.2	8.3	2.0	6.3	0.7	0.7
Surhandarya	19.3	14.3	5.0	3.0	8.7	1.8	4.0	1.2	0.6
Syrdarya	27.7	22.7	5.0	3.8	10.1	1.6	8.8	2.1	1.3
Tashkent	19.4	13.4	6.0	4.0	7.5	2.3	4.0	1.0	0.6
Fergana	17.5	12.5	5.0	4.1	7.0	1.8	3.3	0.6	0.7
Khorezm	8.8	8.8	–	0.4	4.8	0.3	1.5	0.9	0.9
Total	220.5	170.5	50.0	36.0	91.0	18.0	50.3	14.0	11.2

Source: Presidential decree on crop diversification №2460 "Measures on further reforms and development of agriculture in a period of 2016–202" dated 15th December 2015

The World Bank policy paper "Strengthening the horticulture value chain" dated December 2012[**] sets out a number of key recommendations for development of the horticulture sector of Uzbekistan. Recommendations were supported by the

[**] The WB report "Strengthening the horticulture value chain", December 2012 (http://documents.worldbank.org/curated/en/396111468301526337/pdf/942810WP0P12920iculture0value0chain.pdf)

comprehensive financial and gross margin analysis for selected crops. The key recommendations included:

1. Improve farm productivity.
1.1. Protect genetic resources and conduct related research.
1.2. Restoring land and improving water resource management.
1.3. Sustaining domestic improvements in production technologies.
1.4. Finding innovative ways to deliver extension services.
1.5. Sustaining support for new investments.
1.6. Expanding the successful program of granting farmers greater autonomy.
1.7. Facilitating land markets.
2. Support high value export markets.
2.1. Strengthening support for quality and food safety standards.
2.2. Building a brand for Uzbek horticulture products.
2.3. Continuing to improve private market access to quality and productivity enhancing equipment.
2.4. Continuing to remove obstacles to foreign direct investments to the sector.
3. Removing market restrictions and barriers.
3.1. Eliminating export restrictions.
3.2. Easing restrictions on the use of foreign currencies in trade.
3.3. Dropping the revenue tax on farm products.
3.4. Promoting competition by bringing more firms into the formal export chain.
3.5. Developing a baseline to evaluate the impact of policy changes through household and farm surveys.

Most of recommendations are still valid to date. The key recommendation 1.6 specifies that allowing farmers to diversify from cotton to other higher value crops can "… improve farmer incomes, reduce the demand for limited water resources and mitigate contentious labor practices".

The country is committed to diversify cotton and wheat production towards more profitable crops. The presidential decree No2460 "Measures on further reforms and development of agriculture in a period of 2016–2020" dated 29 December 2015 sets out the policy to diversify 170 thousand ha of cotton and 50 thousand ha of wheat in favor of higher value crops between 2016–2020. The following Table 33 presents the breakdown of areas by oblast and by crops.

The higher value crops included: potato, vegetables, intensive orchards, fodder, oil and other crops. There are evidences that the current figure of 220 thousand ha was

Table 34. Gross margins of cotton, wheat, tomatoes, onions and kidney beans (USD/ha, percent)

Crop	PF (USD/ha)	percent	DF (USD/ha)	percent
Cotton	57	12	N/A	N/A
Wheat	273	43	584	52
Tomatoes	2 166	57	2 806	70
Onions	2 031	46	3 123	65
Kidney beans	1 573	63	1 258	67

later increased by another 70 thousand ha (60 000 – cotton and 10 000 – wheat) totaling 290 thousand ha to be diversified.

The key barriers to adopting modern crop management techniques include:

- Lack of access to modern technologies, knowledge and equipment.
- Lack of access to finance to procure latest technologies and equipment.
- Lack of access to the proper extension system, including lack of awareness and exposure to modern crop management technologies and equipment.
- Lack of access to infrastructure and machinery (e.g. storage and handling facilities, certification systems, etc).
- Lack of access to quality inputs (e.g. seed, fertilizer, etc).
- Lack of cooperation between farmers to take advantage of economies of scale and bulk procurement of inputs and marketing opportunities.

Gross margin analysis of selected crops and investment models of orchards

The gross margin analysis and financial models for selected crops are prepared in support of the government's policy towards diversification of cotton and wheat production towards higher profitable crops. The gross margin analysis were prepared for cotton, wheat, tomato and onions. The idea is to demonstrate that planting alternative higher value crops can results in higher incomes for farmers which in turn contributes towards poverty reduction and higher food security and nutrition of the rural population. In addition, financial investment models of intensive orchards have been prepared for apples, pears and plums. The models demonstrate Internal Rate of Return (IRR), Net Present Value (NPV) and cash flows for selected crops.

Gross margin analysis

Table 34 presents gross margin analysis for selected crops (cotton, wheat, tomatoes, onions and kidney beans) for two types of producers: dehkan farms and private farms. The private farms (PF) are usually larger commercial farms which typically own over 30 ha of land used for crop and horticulture production. These farms have a status of legal entities, pay taxes and often enjoy low-interest loans from the government and subsidized inputs (fuel, fertilizer and seed). Dehkan farms typically own small landholdings (0.1–0.5 ha) and are mostly engaged in subsistence agriculture with a surplus of products being sold at the market. However, dehkan farms (DF), representing smallholder producers, are responsible for country's most agricultural output amounting to nearly 80 percent in fruits & vegetables and over 90 percent in meat and dairy products. A small share of dehkan farms are registered as legal entities and pay taxes and can have access to financial resources. The creditworthiness of dehkan farms remains to be an obstacle due to lack of legal status and lack of bankable collateral.

Cotton

Cotton is a major crop cultivated in Uzbekistan and is one of country's main hard currency earner. Cotton is cultivated by specialized private farms and all output is sold to the government at a fixed price (in 2016 – 1 160 000 UZS/ton). In return, farms get low interest loans and subsidized inputs (fertilizer, seed, fuel, etc.). In 2016, the total area of cotton plantation was estimated at about 1.423 million ha (Table 32). The total output of raw cotton was estimated at around 3.7 million tons and the average yield attained was at around 2.61 tons/ha. The total output of cotton lint was estimated at around 1.1–1.2 million tons of which roughly 50 percent is utilized domestically and about 50 percent is exported. The estimated export price is at around 1000 USD/ton depending on the quality of fiber. The gross margin analysis of cotton production is presented in Annex 1. The analysis show that the profitability is at around 57 USD/ha (12 percent). This is the lowest of gross margins compared to other crops (Table 34). Moreover, it once again proves that cultivating alternative and higher value crops is more profitable as it maximizes the profit per unit of production which is crucial in the situations where the land resources are limited and pressure to grow more foodstuff for the growing population is high. Thus, this analysis fully supports government's policy to diversify cotton towards higher value crops as per presidential decree dated 29.12.2015 mentioned above.

Wheat

Wheat is another major crop grown in Uzbekistan which is considered to be strategic in ensuring country's food security and nutrition. In 2016, the total are of wheat was 1.135 million ha (Table 32). The total output was estimated at 6.7 million tons and the average yield attained was at around 5.92 tons/ha. Wheat is considered a strategic crop in ensuring country's basic food security and is widely cultivated in the country. Dehkan farms grow wheat mostly for subsistence whereas private farms grow wheat at government orders. Private farms sell about 50 percent of the grain yield to the government at a fixed price (in 2017 – 503 000 UZS/ton) and the rest is sold at the market price (in 2017 – 1 500 000 UZS/ton). In return, private farms get low interest loans and subsidized inputs (fertilizer, seed, fuel, etc.). The gross margin analysis of wheat production is presented in Annex 1. The analysis show that the private farms attain profitability at around 273 USD/ha (43 percent) and dehkan farms – 584 USD/ha (52 percent). The higher profitability of dehkan farms is attributed to better crop management practices and application of fertilizer, including organic fertilizer. The overall profitability of wheat is higher than for cotton (Table 34) however lower than for other alternative crops (tomato, onions and kidney beans). This analysis once again fully supports government's policy of diversification from cotton and wheat towards more profitable crops.

Tomatoes, onions and kidney beans

Tomatoes, onions and kidney beans were selected as higher value alternative crops to cotton and wheat. The role of kidney beans (pulses) is crucial to ensuring soil fertility through a crop rotation. The pulses enable the soil to accumulate nitrogen which is essential to increasing crop yields. The purpose is to compare the profitability of these crops compared to cotton and wheat so that to demonstrate benefits in terms of gross margins. Both crops showed good profitability which was respectively for tomatoes: Private Farms (PF) – 2 166 USD/ha (57 percent), Dehkan Farms (DF) – 2 806 USD/ha (70 percent), onions: PF – 2 031 USD/ha (46 percent), DF – 3 123 (65 percent) and kidney beans: PF – 1 573 USD/ha (63 percent), DF – 1 258 USD/ha (67 percent). As evident from Table 34, tomatoes, onions and kidney beans yield higher gross margins compared to cotton and wheat.

For tomatoes, gross margins in case of private farms exceed cotton and wheat respectively by 38 and 8 times and in case of dehkan farms exceed wheat by 5 times. For onions, gross margins in case of private farms exceed cotton and wheat respectively by 35 and 7 times and in case of dehkan farms exceed wheat by 5 times.

Table 35. Results of the modeling for intensive apple orchard

Item	Investment costs (UZS)	NPV (UZS)	IRR (percent)	Benefit/ cost ratio
Intensive apple orchard (grafted to the rootstock of dwarf variety M9)	234 822 000	503 439 814	35	2.34

Table 36. Results of the modeling for semi-intensive pear orchard

Item	Investment costs (UZS)	NPV (UZS)	IRR (percent)	Benefit/cost ratio
Semi-intensive pear orchard	185 712 000	405 946 264	35	2.24

Finally, for kidney beans, gross margins in case of private farms exceed cotton and wheat respectively by 28 and 6 times and in case of dehkan farms exceed wheat by 2 times. This analysis once again demonstrate that growing vegetables can be a good alternative to cotton and wheat in terms of profits and therefore government's policy to gradually diversify from cotton and wheat into other higher value crops should be continued and even expanded.

Intensive orchards

Uzbekistan has been pioneering intensive orchards in Central Asia in the last 5–7 years and by far the leading region is Samarkand. Out of total country's 45 thousand ha of intensive orchards 7 thousand are located in Samarkand. Intensive orchards include apples, peaches, plums, cherries and other. Fruits are exported fresh and frozen and the main destination is Russia. Also the region has advanced handling and storage facilities. There were three orchard investment models prepared: apples (intensive), pears and apricots (semi-intensive).

Apples

An investment model was prepared for intensive apples (grafted to dwarf rootstock variety M9). The orchard allows for planting of 3 100–3 300 seedlings per ha which is three times compared to traditional varieties. The sources of seedlings are Poland, Ukraine and other countries. The drip irrigation system is normally used

Table 37. Results of the modeling for semi-intensive apricot orchard

Item	Investment costs (UZS)	NPV (UZS)	IRR (percent)	Benefit/cost ratio
Semi-intensive apricot orchard	185 712 000	304 987 860	30	1.95

to maximize efficiency of irrigation and water use. A small storage facility has been envisaged to be able to store produce and sell at a higher price especially during the off season. Other assumptions included: orchard starts yielding fruits in year 2–3 at 25 percent of projected yield, 4–5: 50 percent and 6-onward: 100 percent. The projected yield is estimated at 35 tons/ha. The optimal size of the orchard should be at least 10 ha and bigger to take advantage of economies of scale and to optimize costs. The following are results of the modeling:

The results show that intensive apple orchards produce good IRR, NPV and cost benefit ratio and therefore could be a good alternative to cotton and wheat growing as part of the diversification policy.

Pears

An investment model was prepared for semi-intensive pears. The orchard allows for planting of 1 000-1 250 seedlings per ha. The sources of seedlings are Poland, Ukraine and other countries. The drip irrigation system is normally used to maximize efficiency of irrigation and water use. A small storage facility has been envisaged to be able to store produce and sell at a higher price especially during the off season. Other assumptions included: orchard starts yielding fruits in year 2–3 at 25 percent of projected yield, 4–5: 50 percent and 6- onward: 100 percent. The projected yield is estimated at 25 tons/ha. The optimal size of the orchard should be at least 10 ha and bigger to take advantage of economies of scale and to optimize costs. The model is presented in Annex 2. The following are results of the modeling:

The results show that semi-intensive pear orchards produce good IRR, NPV and cost benefit ratio and therefore could be a good alternative to cotton and wheat growing as part of the diversification policy.

Apricots

An investment model was prepared for semi-intensive apricots. The orchard allows for planting of 1 000-1 250 seedlings per ha. The sources of seedlings are Poland, Ukraine and other countries.

The drip irrigation system is normally used to maximize efficiency of irrigation and water use. A small storage facility has been envisaged to be able to store produce and sell at a higher price especially during the off season.

Other assumptions included: orchard starts yielding fruits in year 2–3 at 25 percent of projected yield, 4–5: 50 percent and 6- onward: 100 percent. The projected yield is estimated at 25 tons/ha. The optimal size of the orchard should be at least 10 ha and bigger to take advantage of economies of scale and to optimize costs. The model is presented in Annex 2. The following are results of the modeling:

The results show that semi-intensive apricot orchards produce good IRR, NPV and cost benefit ratio and therefore could be a good alternative to cotton and wheat growing as part of the diversification policy.

Conclusions and recommendations

The following are conclusions and recommendations:

- Both the gross margin analysis and investment models show that government's policy on diversification of cotton and wheat towards higher value and more profitable crops is timely. Moreover, it should be further expanded and possibly accelerated in future once results of the first phase (2016–2020) of crop diversification policy are carefully monitored, analyzed and validated. In particular, the impact of diversification policy on farmers' incomes should be measured through household and farm surveys throughout the implementation process and necessary corrections need to be made in a timely manner. It is very important that the government remains committed to implementing the crop diversification policy (cotton and wheat based cropping system) by promoting crop rotation and production of higher-value and export oriented alternative crops, including horticulture crops and pulses. The horticulture sector presents untapped opportunities both for the domestic but especially for export markets where there is a huge unmet demand and tremendous marketing opportunities with Russia and other CIS countries being the ultimate market in the near future but also the European and other markets in the long run. For instance, beans represent a high interest for Turkish importers as evidenced from the successful growing and exporting of beans to Turkey by the Kyrgyz producers. Currently many companies are now going through the certification process to be able to access these upper-end consumer markets. Of course, no need to mention that ad-hoc export restriction practices by the government should be eliminated to enable strategic and long-term planning for exporters.
- One of the key obstacles to adopting modern crop management techniques remain to be the low awareness and lack of access to modern technologies, knowledge, equipment and effective extension system. In this regard,

demonstration sites supported by intensive training and farmers' field schools have proved to be an effective mechanism for ensuring such access on a pilot basis. The impact is further enhanced by dissemination of pilot results in the form of brochures, video and audio tutorials and other hand out materials ensuring the wider coverage of beneficiaries. Furthermore, the results of such demonstrations should be institutionalized through establishment of an effective agricultural extension system which should further disseminate such innovations to the wider community of farmers. Currently such system is not fully in place.

- Quite often farmers lack access to affordable finances to be able to introduce new technologies (e.g. new crop varieties, machinery, equipment, etc.). The government is exerting tremendous efforts to ensure such access i.e. there are several government and donor funded/lending programs however the outreach and the coverage of those programs remains to be low especially for smaller farms (e.g. dehkan farms).
- Another obstacle is the lack of access to infrastructure such as logistical centers, storage facilities, machinery, transportation (refrigerated trucks and railway carts), roads and other. Unless the government addresses the problem there will be little progress in effective adaptation of new technologies. Such infrastructure objects can be developed through public-private partnerships which proved to be very effective and are promoted throughout the world by international financial institutions (e.g. WB, IFAD, EBRD, etc.) For instance, is Kosovo the government is developing the horticulture sector by introducing new varieties and production technologies for pepper and cucumbers and by introducing aggregation centers for vegetables and fruits to promote exports and support domestic markets. The aggregation centers are established on a public-private partnership basis.
- The government needs to continue its efforts to promote investments, including private sector, into the agriculture sector of the country by improvements in the legislative and taxation framework to provide incentives for potential investors. With the new leadership of the country many obstacles to such investments are being removed through popular and timely reforms i.e. streamlining of the exchange currency rate for Uzbek Sum, removing tax/tariff privileges for selected foodstuff importers, liberalization of visa regime for visitors and others.
- To promote exports, especially to overseas markets, the country needs to develop a proper quality certification system both for final products and inputs to be able to meet safety and quality standards. Currently, companies able to export their products to Russia using existing certification system however to be able to access overseas market a more sophisticated certification system (e.g.

HACCP, ISO, green and organic certificates, etc.) needs to be in place supported by the respective infrastructure (e.g. laboratories).

- The majority of dehkan farms in Uzbekistan are smallholder producers and individually they face numerous problems i.e. access to new technologies and equipment, quality inputs (seed, fertilizer, etc.), irrigation and infrastructure but also experience difficulties with marketing their products since volumes of products produced are very small and qualities vary significantly. The government needs to promote cooperative and other forms of farmers' cooperation to enable them to take advantage of economies of scale i.e. to be able to jointly: (i) introduce new technologies, machinery and equipment; (ii) procure quality inputs; (iii) ensure quality and safety of products produced; and (iv) attain better prices in marketing their products through enhanced bargaining power. The World Bank in Armenia and other countries has successfully implemented this model through its Agricultural Commercialization Project.

References:

World Bank country statistical data for Tajikistan (www.worldbank.org).

Statistical data from **FAOSTAT** (www.fao.org).

Economic and ecological benefits of conservation agriculture in China

Liu Wenzheng[54], Liu Peng[55], Li Hongwen[56], Wang Qingjie[57], He Jin[58]

Abstract

China owns about 33 Mha of arid and semi-arid land which is mainly located in the 16 provinces of North China. In dryland farming of these areas, the problems of water shortage, erosion, poor soil fertility and straw burning constrains the local development of economy and ecology seriously. To solve these problems, Chinese government has taken actions to promote economy development and improve the environment. A vital approach is made use of conservation agriculture (CA). Since 2005, the action of CA has been supported by multi-ministry of China. By the end of 2018, the CA has been extended to over 6.66 Mha in China. This paper mainly reports the impacts of CA in promoting the development of economy and ecology by the means of comparing with traditional agriculture (TA). The results showed that, long-term CA has the advantages of enhancing yields, reducing the production cost, and improving economic efficiency. In addition, CA could avoid straw burning, control greenhouse gas (GHG) emission, decrease soil erosion, reduce farmland dust, and finally protect the environment. Due to its advantages, CA will be further adopted over wider areas in China.

Key words: China, conservation agriculture, ecological, economic, traditional agriculture

Introduction

China is situated in the southeastern part of the Eurasian continent, which is a big agricultural country. The traditional agriculture (TA) systems are still applied in most areas of China, which characterized by conventional cultivation, mouldboard plows and rotary hoes, and the removal/burning of crop residue straws for animal fodder and household fuel (Gao *et al.*, 1999). To support the nation's population of 1300 million, which is growing at an estimated annual rate of 4 million, the pressure on farmland to maintain high agricultural productivity has been increasing at a phenomenal rate. However, the area of farmland available for production has been decreasing because of the fast growing economy and urbanization (Li *et al.*, 2005). Consequently, the problems of water shortage, erosion, poor soil fertility and straw burning limit the suitable development of agriculture. The drylands became the most affected areas, which constitute about 52 percent of the nation's total land area and are occupied about 43 percent of the nation's population (Zhai *et al.*, 2000; Wang *et al.*, 2007). These lands are inherently fragile because of their low soil fertility and low annual rainfall that can cause drought in most years.

The severe land degradation and serious environmental problems have led the Chinese government to emphasize the need for the implementation of farming practices, which contribute to the conservation of soil and water, improving soil structure, enhancing soil fertility, avoiding crop straw burning, controlling GHG emission and so on. A vital approach is the use of CA, defined as "All conservation farm practices that leave a minimum of 30 percent of crop organic residues in the field." The key elements of CA in China are similar with FAO:

1. Minimum mechanical soil disturbance;
2. Permanent soil organic cover;
3. Species diversification.

Each of these elements is important. The benefits of CA can only be obtained through integration of these elements.

Since 2005, the central document №1 of China issued the CA related document each year, and the action of CA has been supported by multi-ministry of China. By the end of 2018, the CA has been extended to over 6.66 Mha in China.

This article mainly introduces and investigates the effects of CA on economy and ecology.

1. Effects of ca on economic benefits

CA is conducive to promoting economic benefit and increasing agricultural income, which is mainly reflected in increasing yields and saving production cost. The effects of CA on economic benefits in China was conducted and analyzed by Conservation Tillage Research Centre (CTRC) of the Ministry of Agriculture (MOA) for long-term experiment in different areas.

1.1 Yields

In China, CA was widely adopted in the North China Plain, North dryland areas (Loess Plateau, North China along the Great Wall), North-east and North-west regions (dryland area, oasis farming areas) due to various cropping systems, natural ecological conditions and other regional characteristics. Therefore, the effect of CA

Table 38. Mean crop yields (t·ha) for traditional agriculture (TA) and conservation agriculture (TA) at experimental sites around China

Areas	Site	Year	Crop	Treatment		Increase (percent)
				TA	CA	
North China Plain annual double cropping areas	Changping, Beijing	2002–2007	Maize	7.03	7.21	2.56
			Winter Wheat	4.65	5.25	12.90
	Daxing*, Beijing	2000–2007	Maize	5.78	5.93	2.60
			Winter wheat	4.71	4.88	3.61
	Daxing*, Beijing	2005–2011	Maize	6.27	6.53	4.15
			Winter wheat	4.77	4.85	1.68
	Baodi, Tianjing	2002–2007	Maize	7.33	7.29	-0.60
			Winter Wheat	6.11	6.16	0.80
	Gaocheng, Hebei	2002–2007	Maize	7.13	7.23	1.40
			Winter Wheat	5.73	6.00	4.70
	Fengning, Hebei	2002–2007	Maize	5.88	6.27	6.60
			Spring wheat	2.67	2.90	8.60
			Naked oats	2.07	2.22	7.30
	Dingxing*, Hebei	2002–2003	Maize	8.90	9.40	5.62
			Winter wheat	4.50	4.60	2.22
	Shenze, Hebei	–	Maize	6.89	6.99	1.45
			Winter wheat	4.92	5.03	2.24
	Xinmi, Henan	–	Maize	8.70	8.88	2.07
			Winter wheat	6.81	7.34	7.78
	Pingdu, Shandong	–	Maize	8.94	9.89	10.63
			Winter wheat	5.79	6.08	5.01
	Pucheng, Shaanxi	2002–2007	Winter Wheat	1.48	1.63	10.10
	Weinan, Shanxi	–	Maize	9.57	10.43	8.99
			Winter wheat	6.12	6.38	4.25
North dryland areas (Loess Plateau, North China along the Great Wall areas)	Linfen*, Shanxi	1992–2006	Winter wheat	2.04	2.81	37.75
	Linfen*, Shanxi	1998–2005	Winter wheat	3.05	3.25	6.56
	Shouyang, Shanxi	1993–2000	Maize	4.80	5.40	12.50
	Yanggao, Shanxi	2002–2007	Broom Maize millet	2.35	2.50	6.40
			Bean	5.30	7.10	34.00
			Millet	2.27	2.34	3.10
	Chifeng, Inner Mongolia	2002–2007	Maize-irrigated	8.70	9.27	6.60
			Maize in upland	2.60	2.77	6.50
			Millet	2.70	3.05	13.00
			Mung bean	8.41	8.91	6.00
	Wuchuan*, Inner Mongolia	2002–2007	Naked oats	1.45	1.53	5.50
			Broom Maize millet	1.51	1.60	6.00
	Wuchuan*, Inner Mongolia	1998–2008	Spring Wheat	1.27	1.40	10.24
North-east ridge tillage areas	Lingyuan, Liaoning	2002–2007	Maize	4.39	4.45	1.40
	Suijiatun, Liaoning	2005–2007	Maize	9.94	10.46	5.23
	Zhangwu, Liaoning	–	Maize	9.48	10.65	12.34
	Fuxin, Liaoning	–	Maize	9.53	10.85	13.85
	Lanxi, Inner Mongolia	2005–2007	Maize	9.75	9.97	2.26

North-west dryland areas	Xifeng, Gansu	2002–2007	Winter Wheat	5.27	6.28	19.20
			Maize	6.90	7.33	6.20
	Zhenyuan, Gansu	–	Winter wheat	6.02	6.56	8.97
North-west oasis farming areas	Zhangye, Gansu	2004–2009	Maize	11.36	11.80	3.87
			Winter wheat	5.90	6.00	1.69

Note: The data are from published and unpublished sources by the CTRC, MOA;*, different experiments in the same site; TA, traditional agriculture; CA, conservation agriculture.

on crop yields has been evaluated in these areas with data collected by the CTRC, MOA (Table 38).

Maize and winter wheat are the main food crops in the North China Plain annual double cropping areas. As can be seen in Table 38, the mean maize yield was 7.49 t·hm^{-2} under TA and 7.82 t·hm^{-2} under CA, an increase of 4.41 percent, and in particular CA can increase the maize yield by 10.63 percent in Pingdu. The mean winter wheat yield was 5.05 t·hm^{-2} under TA and 5.29 t·ha under CA, an increase of 4.75 percent, and in Changping and Pucheng the growth rate of winter wheat can be over 10 percent under CA. However, compared with CA, the maize yield of Baodi under TT was higher.

In North dryland areas (Loess Plateau, North China along the Great Wall areas), the main crops are maize, wheat, broom maize millet, bean and so on, which planted once per year. The experimental sites were mainly set in Shanxi and Inner Mongolia Province. Data from Linfen showed a mean winter wheat of 2.55 t·ha under TA and 3.03 t·ha under CA, an increase of 18.82 percent, which indicated that CA has the significant influence on the crop yield of winter wheat in Linfen. In addition, compared with TA, the crop yield growth rate of maize in Shouyang, bean in Yanggao, millet in Chifeng and spring wheat in Wuchuan under CA were all more than 10 percent.

The main food crop of North-east ridge tillage areas is maize. Lingyuan, Sujitun, Zhangwu, Fuxin and Lanxi are typical sites in this region. By several years' experiment, the mean maize yield under TA and CA can be obtained, which were 8.62 and 9.28 t·ha respectively. It can be calculated that the mean crop yield growth rate under CA was 6.50 percent, with individual increases ranging from 1.4 percent to 13.85 percent.

Dryland farming areas and oasis farming areas are the two main cropping areas in North-west China. Xifeng, Zhenyuan and Zhangye are the typical sites in this

Table 39. Economic cost benefit analysis of three tillage modes: TA, annual subsoiling with soil cover plus subsoiling once in 4 years for maize and wheat production in Shouyang and Linfen regions of Shanxi province

	Traditional agriculture		**Annual subsoiling with soil cover**		**Four-year no-till with cover +1 year subsoling**	
	Maize	**Wheat**	**Maize**	**Wheat**	**Maize**	**Wheat**
Inputs						
Seed (USD/ha)	28	84	28	84	28	84
Fertilizer (USD/ha)	75	87.5	75	87.5	75	87.5
Herbicide (USD/ha)	5.6	3.8	5.6	3.8	5.6	3.8
Salary (USD/ha)	85	62.5	70	46.9	70	46.9
Mechanical operation cost (USD/ha)	75	125	56	87.5	28	62.5
Taxes (USD/ha)	75	56	75	56	75	56
Total	343.6	418.8	309.6	365.7	281.6	340.7
Outputs						
Yield*(t/ha)	4.652	3.041	4.820	3.273	5.095	3.439
Price (USD/ha)	0.125	0.163	0.125	0.163	0.125	0.163
Income (USD/ha)	581.5	491.3	602.5	533.5	636.9	560.6
Farmer income (USD/ha)	237.9	72.5	292.9	167.8	355.3	219.9
Incremental improvement on traditional agriculture (percent)	–	–	23.0	135.3	49.3	209.2

Note: The data are the average values of yields from 1993 to 1996

region. Furthermore, maize and winter wheat are the main food crops in these areas. Several years' of data collection indicated a mean maize yield of 9.13 t·ha under TA and 9.57 t·ha under CA, an increase of 4.82 percent. Moreover, the mean winter wheat yield was 5.73 t·ha under TA and 6.28 t·ha under CA, an increase of 9.60 percent.

In conclusion, according to the long-term experiment in different areas, it can be concluded that CA has the function of increasing crop yields as compared to TA by 8.83 percent as average.

1.2 Production cost

In Shouyang and Linfen of Shanxi Province, a comparative experiment from 1993 to 1996 was conducted, and the comparative experiment consists of three treatments: TA, subsoiling with soil cover and no-till with soil cover (He *et al.*, 2007). Among which, the treatments of subsoiling with soil cover and no-till with soil cover belong to CA. TA included mouldboard ploughing without residue cover. Subsoiling with soil cover consisted of subsoiling after harvesting in autumn, and no-till planting with maximum soil cover from standing stubble and plant residue on the soil surface (>30 percent). No-till with soil cover consisted of no-till planting through the plant residue. The agronomic input costs and mechanical operation costs are shown in Table 39. The agronomic costs refer to expenses such as: seed, fertilizer, herbicide, salary and taxes. The mechanical operation costs include fuel, oils, salary, maintenance, depreciation and administration expense. Outputs refer to grain yield in kg/ha and income received in USD.

The annual subsoiling and no-till with subsoiling once in 4 years are vastly superior options than TA by economic cost benefit analysis (Table 39). Field operations (mechanical inputs) were reduced by 62.5 percent and 25 percent in 4-year no-till plus 1-year subsoiling and annual subsoiling, respectively. Maize yield were also improved under these treatments and improved farmer profit by 49 percent and 21 percent, respectively.

The economic benefit of no-till and subsoiling for wheat production was similar with maize production. As can be seen in Table 40, the profit of TA, subsoiling with soli cover, and 4-year no-till with cover plus 1-year subsoiling were USD 72.5 ha^{-1}, USD 167.8 ha^{-1} and USD 219.9 ha^{-1}, respectively. Besides, compared with TA, CA reduced the mechanical operation costs by 50.0 percent, 29.0 percent, and decreased the outputs costs by 14.0 percent and 5.5 percent respectively.

In summary, compared with TA, CA has the advantages of reducing operation procedure, decreasing the frequency of the machine enter the farmland, saving energy for the irrigation, and finally increasing farmer's income.

2. Effects of ca on ecological benefits

CA is conducive to promoting soil properties, decreasing the negative effect on wind/water erosion and GHG emission, and finally promoting the ecological benefits.

2.1 Soil properties

Soil properties can be defined as the soil organic matter (SOM) content, soil water content and soil bulk density and so on, which will affect soil fertility, structure, and finally has a vital influence on plant growth.

To study the long-term effects of CA on soil properties, a 10-year field experiment (He *et al.*, 2009) was carried out by CTRC in the semiarid agriculture-pasture transition region in Shang Tuhe village, Wuchuan, Inner Mongolia, China. In the experiment, four treatments were used: no-tillage with straw cover (NT), subsoiling (30–35 cm depth) with straw cover (ST), rototilling (5–8 cm depth) with straw cover (RT) and traditional ploughing (20 cm) (TA). Furthermore, NT, ST and RT belong to CA. Through this long-term comparison test, it can be found that CA increased soil organic matter in the top 20 cm by 21.4 percent, total N by 31.8 percent and Olsen's P by 34.5 percent in the 0–5 cm layer compared to TA. In addition, CA improved the mean percentage of macro-aggregates (>0.25 mm, + 20 percent) and macroporosity (> 60 µm, +52.1 percent) in the 0–30 cm soil layer significantly. CA also improved water use efficiency (WUE). In summary, these improvements in soil properties are of considerable importance for the seriously degraded soils in semiarid Inner Mongolia, as well as for sustainable agriculture and carbon storage in the farming-pasture transition regions of China.

To determine how tillage and soil type affected SOM stratification, CTRC conducted long-term experiments in four regions of northern China (Tailai, Wuchuan, Nailin, Yaodu) up to 21 years previously (Zhang *et al.*, 2015). The tillage systems comprised no-tillage with straw cover (NTSC) and traditional tillage with straw removal (TTSR), in which NTSC belongs to CA and TTSR belongs to TA. In these experiments, SOM content, total N (TN), soil water content (SWC) and soil bulk density in the 0–5, 5–15, 15–30 and 30–40 cm layers and the time since implementation of tillage treatments were evaluated. The results showed that, the top layer (0–5 cm) and total SOM content increased during the first 10 years following NTSC implementation, but the rate of increase was reduced in subsequent

Table 40. Wind-blown sediment transport (g per sample) collected in TA and CA plots in five monitoring sites during the springs – 2002/2005

Sites	Collection time	TA	CA
Fengning, Hebei	2002, 3.22–2002, 4.21	42.46[a]	12.72[b]
Wuchuan, Inner Mongolia	2003, 3.26–2003, 4.6	7.43[a]	2.85[b]
Chifeng, Inner Mongolia	2003, 4.22–2003, 5.3	7.08[a]	4.66[b]
Lingyuan, Liaoning	2004, 3.25–2004, 4.3	16.32[a]	10.23[b]
Changping, Beijing	2005, 3.28–2005, 4.17	19.00[a]	16.70[a]

Note: Means within a row followed by the same letters are not significantly different (P>0.05)

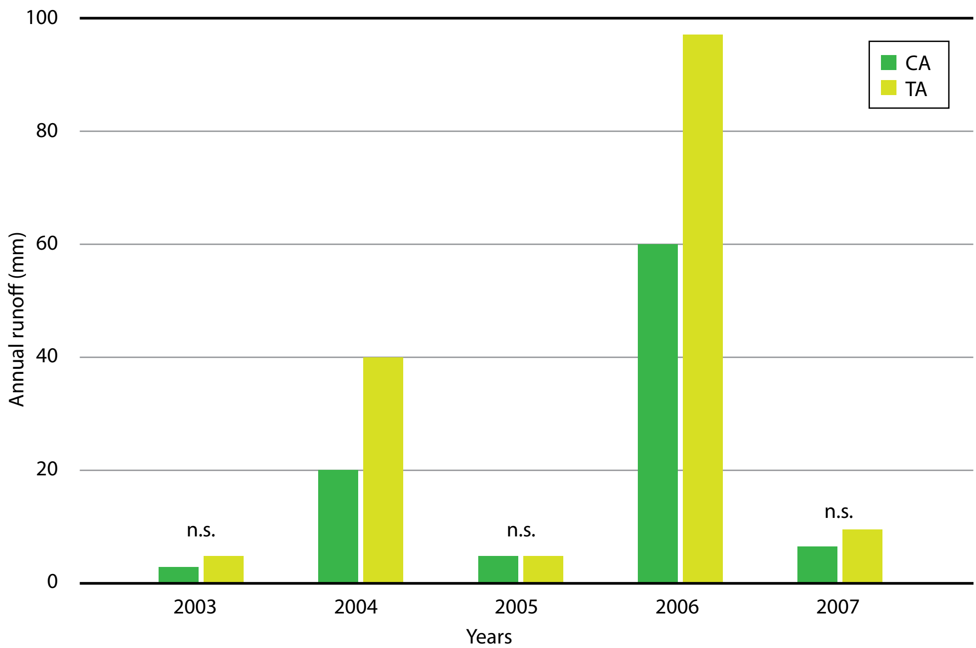


Figure 51. The mean annual runoff in TA and CA land in Shouyang of Shanxi province from 2003 to 2007

years. Besides, effects of conservation measures on SOM content were expressed by a stratification ratio, and the stratification ratio of SOM under long-term NTSC were >2 in most sites. These results from northern China, suggest that long-term CA improved topsoil conditions and whole of soil profile SOM significantly and this improvement was obvious in different layers.

A long-term study (1999–2011) was conducted in Paozi County, Liaoning Province to demonstrate that CA could reduce salinity accumulation and improve soil structure when compared with CA (Wang *et al.*, 2014). Among which, the CA treatment was no tillage with subsoiling and straw cover, and the TA treatment was conventional tillage with ploughing and straw removal. The results showed that CA reduced soil bulk density in the 0–30 cm soil layer, but more importantly the treatment increased total porosity by 20.9 percent, water stable aggregates and pore size class distribution. Compared with TA, CA enhanced soil structure and improved infiltration, which leaded to reducing soil salinity by 20.3–73.4 percent. Soil organic matter was significantly greater to 30 cm in CA, while total soil nitrogen was lower than TA; while the available P was significantly higher in the 0–5 cm soil surface. In conclusion, CA appears to be a more suitable approach to farming than TA.

To sum up, CA has many advantages in improving soil properties by long-term experiments in several sites, and is conducive to crop plant growth.

2.2 Wind/water erosion

The Big Spring Number Eight (BSNE) samplers and wind tunnel was applied at the five MOA demonstration sites located in the three main routes travelled by the dust storm in northern China in the spring of 2002 to 2005 to monitor wind erosion (He *et al.*, 2010). The results showed that CA reduced the transport of wind-blown sediment (Table 40). At the Fengning site of Hebei province, the TA land produced 42.46 g of wind-blown sediment transport per sample, whereas the CA land produced the value of 12.72 g per sample, a 70 percent reduction when compared to the TA land. Similarly, at Wuchuan, Chifeng, Lingyuan, and Changping, the CA land produced 61.6 percent, 34.2 percent, 37.3 percent, and 12.1 percent less dust, respectively. The results indicated that the CA system effectively protected the soil surface and reduced wind erosion by decreasing the exposure of the soil to wind and slowing the wind owing to the increased roughness of the surface.

Water erosion was studied in Shouyang of Shanxi province from 2003 to 2007 using the data of runoff, which is a significant indicator to evaluate CA's efforts on water erosion. The results showed that, annual runoff in heavy storm years (2004 and 2006), for the CA system (19 mm in 2004, 58 mm in 2006) was less than that for TA system (40 mm in 2004, 96mm in 2006), and in normal years (without heavy storm), the annual runoff were slightly different between CA and TA (Figure 51). During the experimental years from 2003 to 2007, the cumulative runoff in CA land was 88 mm, and in TA land was 153 mm, respectively, which representing a decrease of 40.9 percent in the no-tillage with straw cover system. These results indicate that CA, particularly in heavy storm years, could effectively reduce runoff and control water erosion in agricultural production in the arid areas. (He *et al.*, 2010).

In conclusion, CA can reduce water/wind erosion in dryland areas of China, which has importance effects on sustainable agriculture.

2.3 Greenhouse gas (GHG) emission

GHG emission reduction has been a research hotspot along with global warming. CO_2, CH_4 and N_2O are the main components of GHG, and the contribution rate of which to greenhouse effect reach 60 percent, 20 percent and 6 percent respectively (Bernard *et al.*, 2008). Farming production is a vital resource of GHG emission.

To identify the effects of agricultural productive mode on GHG emission, CTRC carried out several long-term experiments in different sites.

To evaluate carbon sequestration potential of paddy and reducing emission of GHG, tillage effects on CH_4 and N_2O emissions from paddy soil and the trade-off relationship CH_4 and N_2O were explored (Bai *et al.*, 2010). The closed chamber method was used to measure the CH_4 and N_2O emission from the paddy field with the treatments of conventional tillage (CT), rotary tillage (RT), no-tillage (NT) at Ningxiang County, Hunan Province during the time of 2005–2009. In which, CT and RT belong to TA, and NT belongs to CA. The results showed that CH4 emission mainly came from the late rice paddy, which accounted for 69 percent, 67 percent, 73 percent of the studied period under CTRT and NT, respectively. CH_4 emission of all treatments attributed to less than 1 percent in the winter-fallow season, while the differences of the emission among three treatments are significant with RT>CT>NT, and N_2O emission showed highly temporal variability that N_2O emission in early rice paddy is RT>NT>CT, while in late rice paddy is NT>RT>CT, and the N_2O is absorbed in winter-fallow season. Furthermore, CT is beneficial to decreasing N_2O emission during the studied period, while NT is beneficial to decreasing CH_4 emission. In conclusion, NT is beneficial to decreasing CH_4 emission, and the comprehensive greenhouse effect of N_2O and CH_4 was also decreased, though increasing N_2O emission appreciably.

To determine the variation of tillage on CO_2 and CH_4 fluxes from winter wheat fields in Bejing's suburb, different tillage methods includes no tillage (NT), subsoiling tillage (ST), rotary tillage (RT) and traditional tillage (TT) were experimented in Qingyundian Town, Daxing District, Beijing (Zheng *et al.*, 2010). Among which, NT and ST belong to CA, RT and TT belong to TA. Static chamber-gas chromatographic techniques were applied to measure CO_2 and CH_4 fluxes during two seasons of winter wheat (October 2011–July 2012 and October 2012–July 2013). The results showed that soils with winter wheat were the emission sources of atmospheric CO_2, and the sink of atmospheric CH_4 during crop growth seasons. In winter wheat fields, the seasonal mean CO_2 emission flux demonstrated as TT>RT>ST>NT, and the seasonal means CH_4 absorption flux demonstrated as RT>TT>NT>ST. Compared with RT and TT, NT decreased soil CO_2 emission flux by 23.3–27.1 percent, and increased soil CH_4 absorption flux by over 20 percent. Generally, all the four treatments (NT, ST, RT and TT) enhanced CH_4 assimilation at different levels, and no tillage would be a better tillage practice reduce CO_2 emission for winter wheat fields in Beijing's suburb.

In summary, CA has the function of reducing GHG emission, which is good for environment protection.

3. Conclusions

Following over 20 years of systematic experimentation, demonstration, and extension found that CA can increase crop yield, improve soil structure, increase the content of soil organic carbon and total N and Olsen's P, decrease soil bulk density and wind and water erosion and greenhouse gas emission. The Chinese government recognizes the importance of CA, and more and more farmers are accepting it. Although the problems exist in developing CA, it is believed that CA will be more adopted in China in the near future.

Acknowledgment

This work was supported by Innovative Research Team in University of China (IRT13039), and we thank all the members working at the Conservation Tillage Research Centre (CTRC) of the Ministry of Agriculture (MOA).

References

Bai X L, Zhang H L, Chen F, Sun G F, Hu Q, Li Y. Tillage effects on CH_4 and N_2O emission from double cropping paddy field. Transactions of the CSAE, 2010, 26(1): 282–289. (in Chinese)

Bernard Seguin B, Soussana J F. Greenhouse gas emissions and climate change: causes and consequences observed for agriculture and animal production. Courrier De l'Environnement De l'INRA, 2008, 55(1): 79–91.

Gao, H.W., H.W. Li & J.D. Chen. 1999. Research on sustainable mechanized dryland farming. Agric. Res. Arid Areas 1: 57–62 (in Chinese).

He, J., Kuhn, N.J., Zhang, X.M., Zhang, X.R. and Li, H.W. (2009b) Effects of 10 years of conservation tillage on soil properties and productivity in the farming–pastoral ecotone of Inner Mongolia, China. Soil Use and Management 25, 201–209.

He J, Wang QJ, Li HW, Liu LJ, Gao HW. (2009) Effect of alternative tillage and residue cover on yield and water use efficiency in annual double cropping system in North China Plain. Soil & Tillage Research 104, 198–205.

He J, Li H, Wang Q, *et al.* The adoption of conservation tillage in China. Ann N Y Acad Sci, 2010, 1195(s1): E96–E106.

He J, Li H, Wang X, *et al.* The adoption of annual subsoiling as conservation tillage in dryland maize and wheat cultivation in northern China. Soil & Tillage Research, 2007, 94(2):493–502.

He J, Li H W, Kuhn N J, Wang Q J, Zhang X R. Effect of ridge tillage, no-tillage, and conventional tillage on soil temperature, water use, and crop performance in cold and semi-arid areas in Northeast China. Australian Journal of Soil Research, 2010(48): 737–744

He J, Li H W, Rasaily R G, Wang Q J, Cai G H, Su Y B, Qiao X D, Liu L J. Soil properties and crop yields after 11 years of no tillage farming in wheat–maize cropping system in North China Plain. Soil & Tillage Research, 2011, 113(1): 48–54

He J, McHugh A D, Li H E, Wang Q J, Li W Y, Rasaily R G, Li H. Permanent raised beds improved soil structure and yield of spring wheat in arid north-western China. Soil Use and Management, 2012, 28(4): 536–543.

Li H, Wang Q J, He J, Li H W, Lu Z Y, Rasaily R G, Lu C Y, Zhang X C, Zheng Z Q. Permanent raised beds improved soil physical properties in an annual double-cropping system. Agronomy Journal, 2014, 106(1): 7–14

Li H W, Gao H W, Wu H D, Li W Y, Wang X Y, He J. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. Australian Journal of Soil Research, 2007, 45(5): 344–350.

Li H W, He J, Gao HW, *et al.* The effect of conservation tillage on crop yield in China. Frontiers of Agricultural Science & Engineering, 2015, 2(2): 179–185. Li, P & D. Su. 2005. Problems of preserving farmland in urbanization. J. NE. Agric. Univ. 3: 6–8.

Wang Q J, Chen H, Li H W, Li W Y, Wang X Y, McHugh A D, He J, Gao H W. Controlled traffic farming with no tillage for improved fallow water storage and crop yield on the Chinese Loess Plateau. Soil & Tillage Research, 2009, 104(1): 192–197

Wang Q J, Lu C Y, Li H W, *et al.* The effects of no-tillage with subsoiling on soil properties and maize yield: 12-Year experiment on alkaline soils of Northeast China[J]. Soil & Tillage Research, 2014, 137(3): 43–49.

Wang, X.B., D.X. Cai, W.B. Hoogmoed, *et al.* 2007. Developments in conservation tillage in rainfed regions of North China. Catena 93: 239–250.

Zhai, J. L. & W.Deng. 2000. Flooding, flood plain development and management in China. In Ecosystem Service and Sustainable Watershed Management in Northern China. International Conference. Beijing, China, 23–25 August, pp. 184–192.

Zhang X R, Li H W, He J, Wang Q J, Golabi M H. Influence of conservation tillage practices on soil properties and crop yields for maize and wheat cultivation in Beijing, China. Australian Journal of Soil Research, 2009, 47(4): 362–371.

Zhang Z Q, Qiang H J, Allen D. McHugh, He J, Wang Q J, Lu Z Y. Effect of conservation farming practices on soil organic matter and stratification in a mono-cropping system of Northern China. Soil & Tillage Research, 2016 (156): 173–181.

Zheng Z Q, Wang S D, He J, Wang Q J, Li H W, Zhang X C. Influences of Tillage Methods on Carbon Dioxide and Methane Fluxes from Winter Wheat Fields in Beijing's Suburb. Transactions of The Chinese Society of Agricultural Machinery, 2010, 26(1):282–289. (In Chinese).

Sustainability through Conservation and Organic Agriculture: basic principles, practices and standards

Uygun Aksoy[59]

Abstract

Intensification of the farming systems to respond to increasing and changing food demands is inevitable. The major challenge in today's agriculture and food systems is sustainability, addressed from social, economic and environmental perspectives or from different scales e.g. farm, regional, national or international. Many farming systems are developed as either principles or practices or governed by defined standards. The search for the best performing and applicable system or so-called adaptations are still ongoing. These systems either focus on one or few components or may have a holistic view of the agroecosystem or agri-food system. In this respect, the agroecology focus that is highly supported by FAO embraces both the physical and living components and put the farmer amidst the change. 'Organic Agriculture' is a holistic management system that puts forth health, ecology, fairness and care as its basic principles. The enlargement of the organic market and globalization after 1980s, required adoption of voluntary standards based upon these principles to develop a common language in the markets. Organic standards have a precautionary approach and ban or severely restrict the use of chemical inputs, GMOs, irradiation and sewage sludge. Promotion of ecological cycles and soil health are of major concern. The inputs and methods are restricted because of their possible long-term negative impacts on soil, living organisms and the planet as a whole. Organic movement goes beyond the market standards and is supportive of the agroecology and similar movements. The principles of 'conservation agriculture' takes soil health in its core and recommends principles and methods that help to sustain and enhance the agroecosystems for future generations. In this respect, all farming systems aiming at improved sustainability have to learn from each other. The paper summarizes the overlapping principles in depth and discusses the aspects that may differ between the two farming systems.

Key words: agroecology, precautionary principle, soil health, sustainability

INTRODUCTION

Humans have always been in search for food and shelter from time immemorial. However, the social structures and climatic conditions designed the food systems

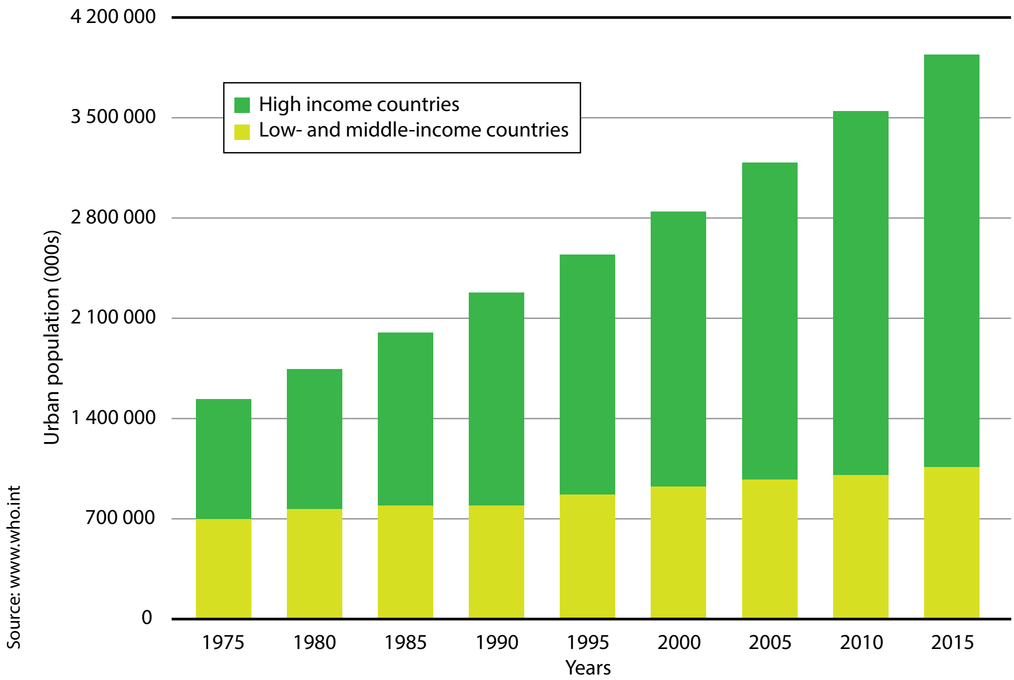


Figure 52. Urban population in high and low and middle income countries between 1975 and 2015

throughout history. The world food production and policies are designed to respond to the pressure of increasing population, the highest rate of population increase realized in 1962. Overall population increase is not the sole factor but its distribution also create bottlenecks. As a general trend of the 21st millennium, the rural population, including peri-urban areas, produces agri-food products for the consuming urban. In the world, the urban population exceeded in number those living in rural in 2008. In 2017, 54.7 percent lived in cities, and by 2050, this ratio is expected to increase to 68 percent putting more pressure on the production side. Additionally, the populations are aging in many countries due to the decreased birth rates and longer life expectancies. During the last 50 years, the elderly population has become more concentrated in urban areas. This situation varies between developed and developing countries. In developed countries as a whole, 73 percent of people aged 65 or over lived in urban areas in 1990 and projected to reach 80 percent by 2015. In developing countries, rural population's share is still high. Only one-third of people aged 65 or over lived in urban areas in 1990 and expected to reach 50 percent by 2015 (Kinsella, 2008). However, the figures put forth that the share of the urban population will continue increasing and aging in middle and low-income countries (Figure 52). Aging of the rural population due to domestic migrations are a major setback in agri-food production, effecting labor availability and adoption of technology and innovations.

Agri-food production should address not only challenges of today but also of future. The ecological footprint measures the demand on and supply of nature (Global Footprint Network, https://www.footprintnetwork.org/our-work/ecological-footprint). The calculation of the Ecological Footprint bases on the use of six categories of productive surface areas as cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land. The Footprint measures 'the ecological assets that a given population requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions'. On the supply side, biocapacity stands for the productivity of the ecological assets of a city, state or nation. All Central Asian countries display ecological deficit except Mongolia. This means that the capacity of their land and seas to produce goods and services exceeds their renewal capacity.

The agri-food system is a complex issue since it operates at multiple spatial scales and include production, distribution, and consumption components involving social, ecological, and economic relationships (Schipanski *et al.*, 2016). Sustainability of the farming systems are questioned through various parameters or calculations. Current agri-food systems must meet both production and environmental goals at all spatial scales. There are new and additional challenges in different parts of the world as water shortages, pesticide resistance, climate change, gender equality, and animal welfare and many others requiring close monitoring. The increasingly globalized markets create export opportunities for the still rural developing countries however, the complex trade rules and standards require extensive institutional changes e.g. farmers' organizations and capacity building at all levels. Setting up clear targets and developing strategies and supportive policies may strengthen the developing countries in the global markets.

Organic and conservation agriculture

Organic agriculture is developed by practitioners in early 20th century as an alternative system focusing strongly on soil fertility management after the role of the soil microbiota is revealed. During 1950's, insects were found to develop resistance to pesticides because of their overuse and abuse creating risks for the environment. In the later decades, Integrated Pest Management (IPM) which later paved the way to Integrated Crop Management (ICM) became the core concept. Parallel to the findings of research, 1970s were the turning points for developing rules and concepts for organic agriculture, as well. By 1980s, the increased demand for organic food and agricultural products forced trade to go beyond the borders of the European countries and widen the product range. Standards that govern the organic markets came into the seen as the distance between the producer and the consumer increased. The EU legislation triggered other major markets and both USA and Japan enforced their legislation after 2000.

During 1990s, consumer demands and quality concept underwent a significant change. Consumers started to question, and still are, the impact on environment. Sustainability became a common denominator in every fora. The focus shifts from a balanced system to a more emphasis on economic, environmental or social sustainability. Especially after the Sustainable Development Goals, sustainable intensification or ecological intensification became a key driver in agricultural systems and practices. Conservation agriculture is one of those systems brought as a solution especially for the small holders in Africa. The aim was to address climate change and find sustainable solutions that will replace unsustainable practices that undermine land and water resources. Different projects are carried out or still on-going in different parts of the World to deliver applicable and profitable solutions well adapted to the site-specific conditions.

Basic principles

Basic principles of organic agriculture aims at developing a strong and common basis for understanding the system and guide the development of standards. International Federation of Organic Agriculture Movements (IFOAM) defines organic agriculture as a ‘production system that sustains the health of soils, ecosystems and people; relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects; and combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. In 2005, IFOAM united the basic principles under 4 keywords: health, ecology, fairness and care. Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This principle points out that the health of individuals and communities cannot be separated from the health of ecosystems – healthy soils produce healthy crops that foster the health of animals and people. Organic agriculture roots within living ecological systems and based on ecological processes, and recycling prevailing under specific ecosystems. Management should be in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. All actors sharing a common environment have equal rights.

The basic principles of health and ecology of organic agriculture also apply for other sustainable production systems including conservation agriculture and agroecology. Conservation agriculture is based on enhancing natural biological processes above and below the ground. Conservation agriculture relies on three main principles: (1) a minimal soil disturbance or absence of deep plowing, (2) a permanent soil cover with green manure during the non-cultivation period and (3) diversification of crops in the rotation (FAO, 2018). These three principles overlap with the practices recommended in organic agriculture for preserving and enhancing soil health. The two systems overlap in the area of soil health and fertility management.

Standards and practices

Despite the overlap in soil health management, 'organic agriculture' and 'conservation agriculture' practices have differences. Organic systems and valid standards include the whole production system of animal and plant based food production including wild harvest, aquaculture, post-harvest handling and processing of foods and inputs. The production is carried out in accordance with the standards. In most cases, there is a third party inspection and a certificate accompanies the product showing compliance with the reference standard. In respect to scope, national standards vary as in the case of soilless systems. The European Union legislation does not allow soilless organic systems, Canadian regulation permits container-grown plants by defining a certain volume of soil, whereas USA still accepts soilless systems including aquacultures. On the other hand, there is no international reference standards or certification in conservation agriculture.

The two systems differ also in respect to the practices and allowed inputs. 'Care' is one of the basis of organic agriculture and precautionary approach roots from this principle. This approach foresees that the methods and inputs should be chosen with care, considering their long-term effect on human, animal and environment well-being. It is reflected in the standards as limitations on the inputs and methods used. The precautionary principle or limitations/bans apply until enough scientific evidences are present in respect to their health and environment safety. Thus, voluntary private standards or official legislations that govern the organic markets put severe limitations on synthetic chemical fertilizers, pesticides, growth regulators and food additives or ban use of genetically engineered seeds and inputs, irradiation and sewage sludge. Conservation agriculture does not have specific limitations other than the regulatory framework of the country.

The basic principles of health and ecology is not directly translated into the standards therefore sometimes farmers may obey the rules in the standards but be far from a sustainable organic soil management. As conservation agriculture spread and its performances became better known, the interest of organic farmers in adopting conservation agriculture principles and practices, including minimal soil disturbance, permanent soil cover and crop rotation started to grow. A survey was carried out in 10 European countries in 2012 to analyze the adoption of conservation agri-practices among European organic farmers for 3 years. Organic farmers were innovatively adapting conservation agriculture in their organic systems without using herbicides. For weed control, they used increased mechanical interventions and regulation by green manures. There were five diversified strategies ranging from intensive tillage without soil cover (far from conservation agriculture principles) to very innovative techniques with no-tillage and intercrops (closer to conservation agriculture principles). Geographic location, cropping systems and sources of information were the main external variables, which correlate to selection of strategies (Peigne *et al.*, 2015).

Conservation agriculture (CA), with reduced tillage, permanent soil cover and diversified cropping systems, is proposed in southern Africa to improve soil quality, reduce input costs and mitigate climate-induced risks. A study in Sub-Saharan Africa on organic nutrient management practices and their integration with mineral fertilizers revealed that a number of different organic nutrient management practices are technically and financially beneficial, but patterns of use vary considerably across heterogeneous agroecological conditions, communities and households (Placea *et al.*, 2003). Another study carried out in South Africa examined the effects of CA-related management practices on soil organic carbon (SOC) sequestration and productivity at two sites on a sandy soil (eight year trial) and clay soil (six years) in maize production. In the study, SOC increased in clay soils under reduced tillage whereas in sandy soils SOC changes were influenced by climatic conditions. The profitability of the CA management depended on soil conditions since the seasonal weather conditions were the main determinant variable (Swanepoel *et al.*, 2018).

Long-term conservation practices as no-tillage, manure addition, application of herbicides may contribute to increase of soil organic matter. However, these practices may also induce slight or significant soil water repellency (SWR), a property of soils that inhibits or delays infiltration as frequently reported for calcareous Mediterranean soils (Gonza´lez-Pen˜aloza *et al.* 2012). Soil water repellency in a citrus orchard in eastern Spain was studied under long-term practices comparing addition of plant residues and organic manure, no-tillage and no chemical fertilization (MNT), annual addition of plant residues and no-tillage (NT), application of conventional herbicides and no-tillage (H), and conventional tillage (CT). The results showed that no-tillage practices and manure addition with no fertilizer addition induced slight water repellency after 2 years due to input of hydrophobic organic plant residues and manure. No tilling practices combined with conventional herbicides or annual addition of plant residues triggered subcritical SWR after just 1–2 years of treatment, and this level was maintained during approximately 25 years of treatment.

Capia pepper is a summer vegetable in high demand in Turkey and consumed fresh, as paste, dried, or roasted in the domestic markets or exported. A 9-years-study aimed at determining the long-term performance of Capia pepper (cv. Yalova yağlık-28) under organic and conventional farming systems. In both farming systems, pepper was the main summer crop, but the preceding crop varied between the farming systems and over the years. Yields were statistically similar in the conventional and organic systems; however, significant yield variations occurred with respect to the yearly conditions. The farming system significantly influenced fruit quality. The fruit pericarp was thicker in the organic than in the conventionally grown ones and the total soluble solids content and red pulp color were more pronounced. The long-term trial showed that organic management helped to improve the soil organic matter content gradually and enhance fruit quality, especially from the perspective of processing (Duman *et al.*, 2018). In a trial carried out under Mediterranean conditions, two different pre-crops, broccoli and vetch were tested under an organic management system as compared to fallow during the autumn-winter period. The summer main crops were rotated between Solanaceous and Cucurbitaceous vegetables as tomato (2007), zucchini (2008) pepper (2009) and eggplant (2010). The experiment aimed at recommending sustainable rotation plans for organic vegetable growers in western Turkey. Broccoli represented the farmers' choice as a winter vegetable prior to the summer crop. Vetch (incorporated) was selected as leguminous green manure well adapted to the regional conditions. Soil fertility was maintained by incorporation of crop residues at the end of both cycles and addition of organic-certified commercial compost and compost tea during the main cycle as a standard amendment. Soil organic matter values showed significant differences before and after the winter or summer cycles. The variation in soil organic matter, N, P and K displayed similar trends during in the tested pre-crops and fallow control plots during the four–year period. Broccoli plots had lower K levels due to higher uptake rates. Weed diversity varied according to the annual climatic conditions however, broccoli exhibited a marked weed suppressing effect mainly due to shading and allelopathy (Bilen *et al.*, 2011).

The results of soil fertility management may appear differently in the short and long-term; it also varies according to the crop, climatic and/or soil conditions. The economic performance or profitability also differs. In a rotation trial aiming at delivering profitable vegetable rotation under Mediterranean conditions to recommend regional farmers, summer vegetables as main crops after broccoli was the most feasible combination bringing the highest revenue. In years where faba (broad) bean pods ripened earlier and could be sold as a crop, faba bean+summer vegetables had higher returns. Broccoli plants had additional benefits like adding a high amount of biomass to soil and suppressing weed growth (Bilen *et al.*, 2010).

As could be put forth through various research work, both the agronomic and the economic performances depend on site-specific factors and require long-term results before transferring the practice to the farmer.

Conclusion and recommendations

Today agri-food systems should endure different shocks whether be climate change, water scarcity, drought, trade bans, currency exchange rates or aging population. Resilience is defined as 'the capacity of a system to withstand shocks and external pressures while maintaining its basic structure, processes, and functions' (Schipanski *et al.*, 2016). This endurance is achieved by the buffering capacity, which is learned from past mistakes e.g. salinity or drought and which can be improved by planning and relying on locally adapted systems based on-farm (or available in the region) inputs rather than off-farm. This approach is important to elevate competitiveness and stabilize in the globalized markets. Advantage of the organic system is that today, the total market for organic food and beverages increases more than the conventional reaching to 89.7 billion USD in 2016. The organic agricultural land is 57.8 million ha with an additional 39.9 mio ha for wild harvest. In Asia, organic agricultural land is 4 897 837 ha, organic certified for wild harvest is 6 259 421 ha and 68 181 ha for aquaculture. The annual increase between 2015 and 2016 in certified land is 23.5 percent in Asia. Fourty percent of the world's organic producers are in Asia. China with 5.9 million Euros is one of the leading markets. (Willer and Lernoud, 2018). Opportunities in organic agriculture goes beyond organic management of agricultural land and provides access to the markets through value added products. Third party certification criticized for being costly for the small farmer, and complex process of accreditation and authorization are being discussed thoroughly and various solutions are sought. Certification systems now widen to encompass different products, and favor small holders by governments incorporating participatory guarantee systems and group certification in addition to third party certification. Organic urban horticulture despite the risks of pollution is seen as a solution to overcome distribution problems in metropolitan cities.

Developing sustainable systems basing upon long-term results requires strong multi-and trans-disciplinary studies evaluating site-specific factors as exemplified in the research work cited. In this respect, governmental policies supporting capacity building and research infrastructure and with problem focused national strategies become crucial especially in developing countries.

Basic principles and goals are common in almost all sustainable production systems. The differences are present in terms of practices, standards, labeling or market access. Organic agriculture community through Organics 3.0 strategy explores how to integrate the positive outcomes of other systems. Each agri-food system has some aspects that can add value to the other therefore cooperation and exchange of experiences at all levels help to build resilient systems and impact on reduction of the ecological footprint. The search for the best performing and applicable system or so-called adaptations are still ongoing in all parts of the world. These systems either focus on one or few components or may have a holistic view of the agroecosystem or the agri-food system. In this respect, the agroecology focus that is highly supported by FAO and widely practiced in South America and Africa embraces both the physical and living components and put the farmer amidst the change (FAO, 2018). Concerted actions and collaboration among Central Asian countries will surely help to improve capacities and open up gateways for the domestic, regional and international markets.

Acknowledgment

The author acknowledges the support of FAO for participation to the International Conference on Strategies for the Promotion of conservation agriculture in Central Asia.

References

Bilen E, Nazik CA, Ünal M, Bteich MR, Al-bitar L, and Aksoy U (2010) Performance of pre-crops in a three-year rotation program for organic vegetable production, ISHS Acta Horticulturae 933: XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on Organic Horticulture: Productivity and Sustainability DOI: 10.17660/ActaHortic.2012.933.41.

Bilen E, Özsoy N, Nazik Bayram CA, Ünal M, Kaya S, Duman İ, Aksoy U and Al-Bitar L (2011) Effect of vetch and broccoli in four-year rotation of organic cucurbitaceous and solanaceous vegetables under Mediterranean conditions. Paper at: V Balkan Symposium on Vegetables and Potatoes, Tiran, Albania, 9–12 October 2011.

Duman İ, Aksoy U, Altındişli A and Elmacı ÖL (2018) A long-term trial to determine variations in the yield and quality of a processing type pepper (Capsicum annuum L. cv.Yalova Yağlık-28) in organic and conventional farming systems, Organic Agriculture, Vol. 8 (1), pp 69–77.

Erb KH, Lauk C, Kastner T, Mayer A, Theurl MC and Haberl H (2016) Exploring the biophysical option space for feeding the world without deforestation, Nature Communications volume 7, Article number: 11382, DOI: 10.1038/ncomms11382.

FAO, Fao's Work on Agroecology, A pathway to achieving the SDGs, 28 p.

Global Footprint Network, Accessed August 2018, https://www.footprintnetwork.org/our-work/ecological-footprint/.

Gonza´lez-Pen˜aloza FA, Cerda A, Zavala LM, Jorda´n A, Gime´nez-Morera A, Arcenegui A and Reyes Ruiz-Gallardo J (2012) Do conservative agriculture practices increase soil water repellency? A case study in citrus-cropped soils, Soil Tillage Res. 124, pp. 233–239.

Kinsella KMA (2008) Urban and rural dimensions of global population aging: An overview, The Journal of Rural Health, https://doi.org/10.1111/j.1748-0361.2001.tb00280.x.

Peigné J, Casagrande M, Payet V, David C, Sans FX, Blanco-Moreno JM, Cooper J, Gascoyne K, Antichi D, Bàrberi P, Bigongiali F, Surböck A, Kranzler A, Beeckman A, Willekens K, Luik A, Matt D, Grosse M, Heß J, Clerc M, Dierauer H and Mäder P (2015) How organic farmers practice conservation agriculture in Europe, Renewable Agriculture and Food Systems: 31(1); 72–85, doi:10.1017/S1742170514000477.

Place F, Barrett CB, Freeman J, Ramisch J and Vanlauwe B (2003) Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems, Food Policy, Vol. 28 (4), pp. 365–378, https://doi.org/10.1016/j.foodpol.2003.08.009.

Schipanski ME, MacDonald GK, Rosenzweig s, Chappell MJ, Bennett EM, Bezner R, Blesh KJ, Crews T, Drinkwater L, Lundgren JG, Schnarr C (2016), Realizing Resilient Food Systems, BioScience, Vol. 66 (7), pp. 600–610, https://doi.org/10.1093/biosci/biw052.

Swanepoel CM, Rötter RP, van der Laan M, Annandale JG, Beukesa DJ, du Preeze CC, Swanepoel LH, A.van der Merwe A, and Hoffmann MP (2018) The benefits of conservation agriculture on soil organic carbon and yield in southern Africa are site-specific, Soil and Tillage Research, Volume 183, November, pp. 72–82, https://doi.org/10.1016/j.still.2018.05.016.

Thierfelder C and Siamachira J (2016) Building a sustainable future: A history of conservation agriculture in southern Africa, https://www.cimmyt.org/building-a-sustainable-future-a-history-of-conservation-agriculture-in-southern-africa/.

Willer H and Lernoud J (2018) The world of organic agriculture. Statistics and emerging trends 2018. Research Institute of Organic Agriculture (FIBL) Frick and IFOAM-Organics International Bonn.

http://data.worldbank.org/indicators/sp.urb.totl.in.zs (accessed August 2018).

FAO. Agroecology Knowledge Hub. Available at: http://www.fao.org/agroecology/en/.

http://www.fao.org/conservation-agriculture (accessed July 2018) http://www.who.int/gho/urban_health/situation_trends/urban_population_growth/en/index1.html (accessed August 2018).

Problems and prospects for long-term development of agriculture in the conditions of resource saving

Darya Ilyina[60]

Abstract

One of the main challenges facing governments at present is meeting the increased demand for economically and physically affordable food, while reducing the level of availability and quality of natural resources. This problem is also relevant for Uzbekistan. As the calculations show, in order to satisfy the aggregate needs (domestic and foreign markets) in food products, production will need to increase by about 2 times by 2030. The main shocks that will affect the development of agriculture in the near future include an increase in the natural and artificial shortage of water resources, changes in climatic conditions, and continued growth in prices for industrial products (agricultural machinery, fertilizers, fuels and lubricants, including gasoline, motor oil, diesel fuel, etc.). Under these conditions, the only way to support the growth rates of agricultural production achieved in recent years is the transition to a resource-saving development model based on active modernization of the industry.

Key words: forecast, land and water resources, gross output, development scenarios, modernization

Materials and methods

This study used statistical indicators of agricultural development in Uzbekistan according to the State Committee for Statistics and the Ministry of Agriculture. Predictive calculations are carried out using an econometric system of equations and optimization problems. When developing a forecast for the development of agriculture, the following factors were also taken into account: population growth; existing restrictions on the use of land resources; growing scarcity of water resources; availability of reserves and opportunities to increase the export potential of the industry.

Results

Thanks to structural reforms and the implementation of measures to support sustainable development and modernization of the agricultural sector, gross agricultural output for 2010–2017 increased by 1.5 times, and per capita – by 1.2 times (in 2017 prices).

The main factors that had a positive impact on the development of the industry in the period 2010–2017 were:

- The process of optimizing land plots of farms and the structure of sown areas with priority on the production of food crops;
- Implementation of measures to radically improve the system of land reclamation improvement;
- Implementation of further modernization, technical and technological re-equipment of agricultural production.

Due to the outstripping growth of industry and the service sector, a trend characteristic of rapidly developing economies is observed – a reduction in the share of agriculture, forestry and fisheries in GDP (from 19.8 percent in 2010 to 19.2 percent in 2017). At the same time, the average annual growth rate of agricultural products for the analyzed period amounted to 6.2 percent. (Figure 53).

The current policy of optimizing sown areas, regionalizing crops and introducing new technologies has made it possible, with relatively stable production volumes

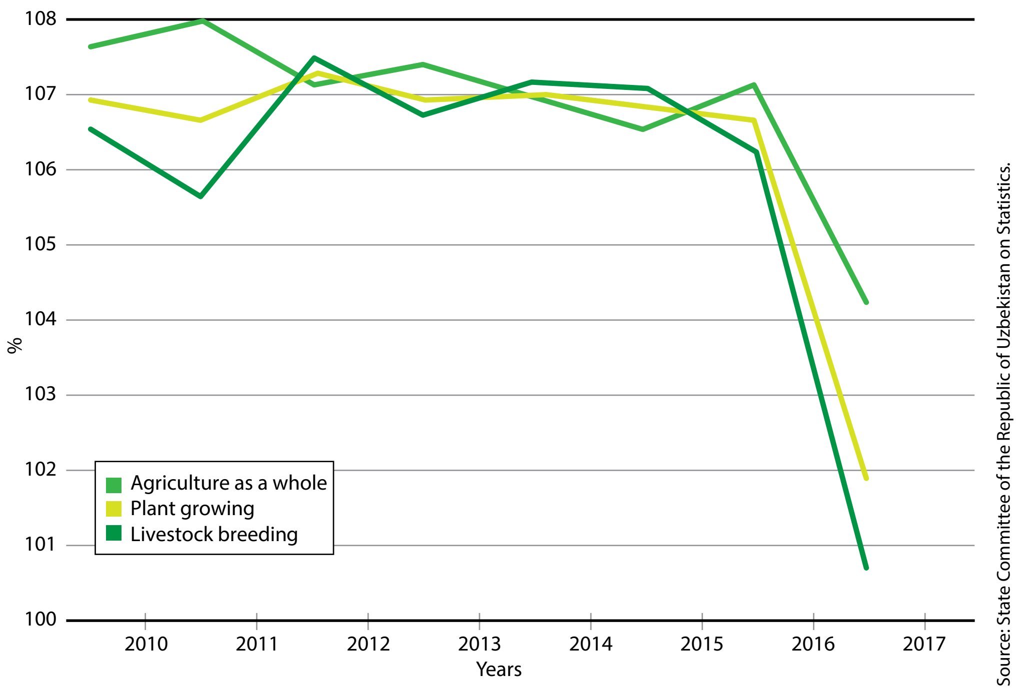


Figure 53. The growth rate of agriculture in 2010–2017, in percent

of the most important raw and export crop, cotton (about 3 million tons per year), to significantly increase the production of other crops. Compared to 2010, the production of vegetables, potatoes, grapes, fruits and berries, and melons increased 1.8 times.

The republic has achieved annual production of more than 21.0 million tons of fruits and vegetables, including vegetables (53.5 percent of the total production), fruits (14.4 percent), potatoes (14.2 percent), melons (9.8 percent) and grapes (8.2 percent).

The increase in per capita production for certain types of agricultural products for the analyzed period amounted to: vegetables – 96.8 kg, milk – 62 l, eggs – 80.6 pcs., fruits and berries – 25.9 kg (Figure 54).

In order to maintain a sustainable supply of fruits and vegetables throughout the year, prices and increase export opportunities from farmers and dekhkan farms and private entrepreneurs, 635 ha of greenhouses were created in 2017.In total, the country has 8.5 thousand hectares of greenhouses, of which 40 hectares of greenhouses using hydroponic technology.

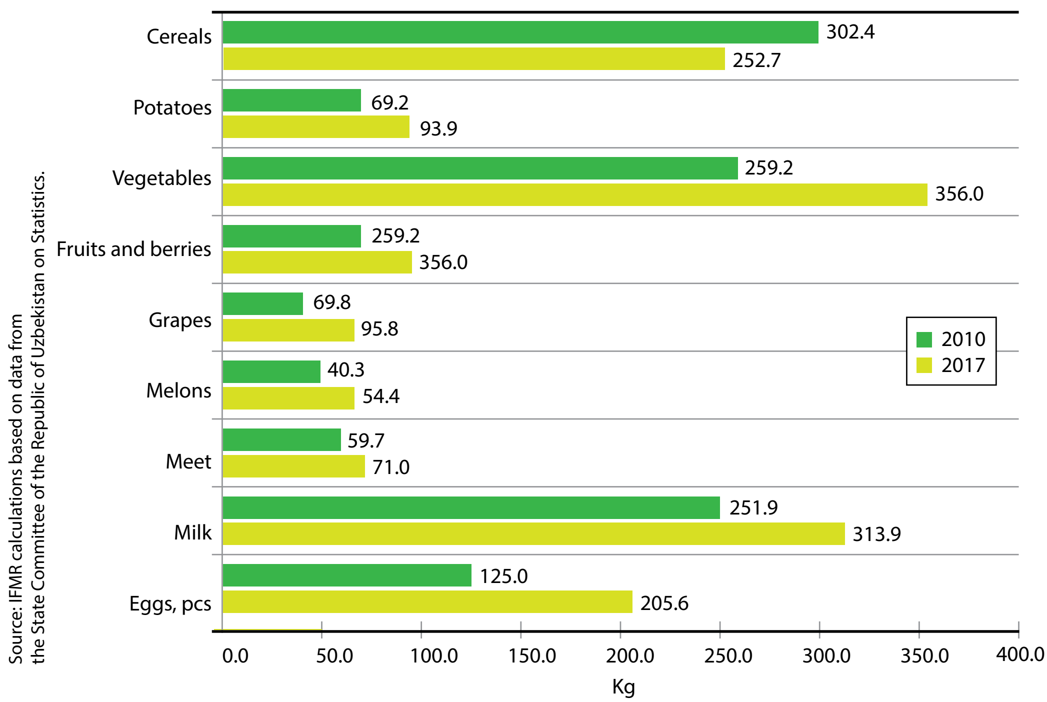


Figure 54. Production of agricultural food products per capita, in kg

In these greenhouses, more than 500.0 thousand tons of vegetables and citrus fruits are grown, which are delivered to the population in the winter.

Despite the prevailing for the period 2005–2017 favorable trends in the development of agriculture, there are a number of problems that hinder its further growth, which include the following:

- The imbalance in prices for agricultural products and "input" industrial products (fuels and lubricants, fertilizers, etc.) has led to a decrease in the share of value added in gross agricultural output from 75.7 percent in 2005 up to 58.1 percent in 2016. In the period of 2005–2016, the annual growth rate of the gross added value of the industry amounted to 104.2 percent, which is 2.1 percent lower than the average annual growth rate of gross output. In 2017 the share of value added in gross agricultural output increased sharply and amounted to 68.8 percent. (Figures 55, 56);
- 2 monocultures still prevail in the structure of sown areas: wheat (39.0 percent) and cotton (34.1 percent), which together occupy 73.1 percent of the total sown area. In 2005 cotton and wheat crops accounted for 80 percent of the total crops;

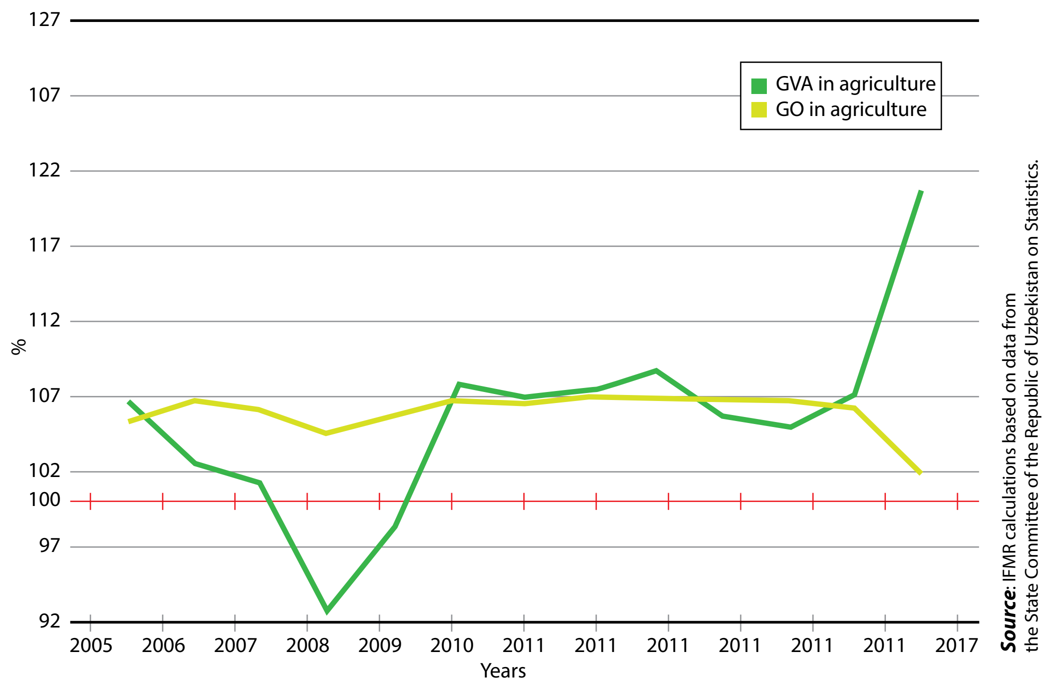


Figure 55. Growth dynamics of GVA and GO in agriculture

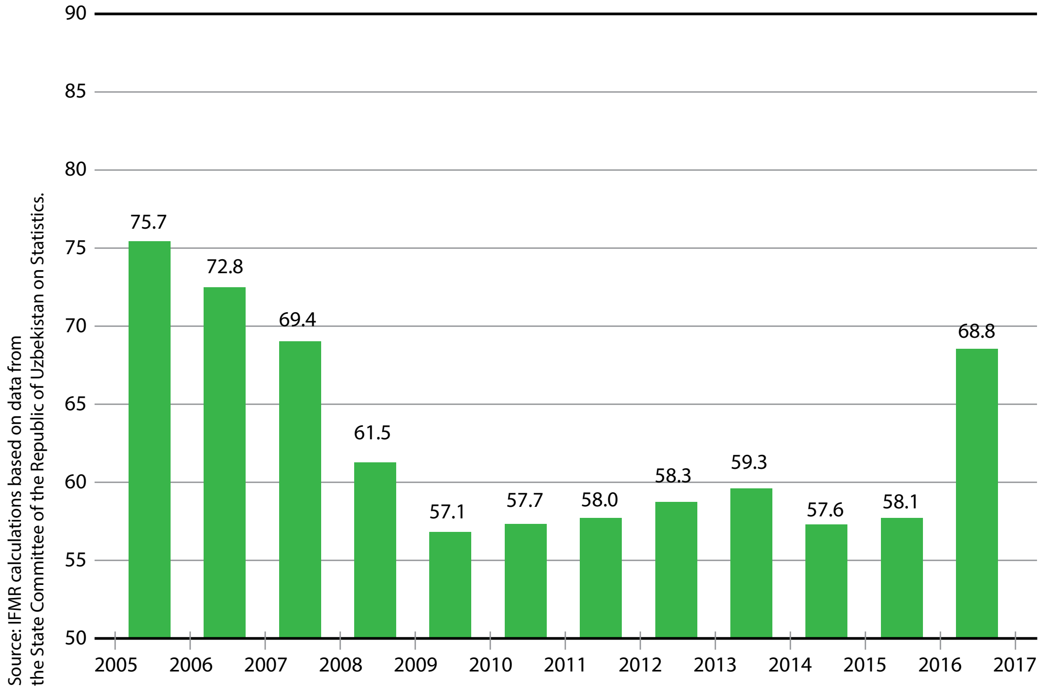


Figure 56. Dynamics of VA share in GO in agriculture

- Increasing shortage of water resources. The volume of water demand in the republic exceeds (especially in dry years) the amount of ecologically accessible water resources. Against the background of population growth, this poses a significant threat to the food and environmental security of Uzbekistan. Currently, the republic receives an average of about 51 billion cubic meter of water annually, while the annual water demand of Uzbekistan is about 65 billion cubic meter;
- Unfavorable reclamation state of irrigated lands. Of the total area of irrigated land, 18.4 percent (669.8 thousand ha) belong to the category of lands with a low score and lower than average;
- Insufficient feed production for the intensive development of animal husbandry due to the low share in the total sown area of forage crops (9.0 percent). As a result, the volume of livestock production (despite the steady growth rate of the industry) is insufficient to meet the rapidly growing demand of the population;
- Lack of stable and long-term partnership of agricultural producers with suppliers of raw materials and processors, as well as buyers in the domestic and foreign markets. During the harvest season, quickly marketing of all products fails, fruit and vegetable stores are not enough. As a result, a large part of perishable fruits and vegetables is lost;

- The predominance in export of a significant share of non-processed products, which reduces both the geography of exports and potential incomes;
- Insufficient volumes of investments attracted to agriculture, forestry and fisheries. Their share in the gross investment in 2017 amounted to only 3.3 percent. Foreign experience indicates that investing in agriculture is one of the most important and effective strategies for economic growth. At the same time, it is necessary to direct funds specifically to capital investments. According to FAO, the capital-labor ratio per 1 worker in the industry in Uzbekistan is 9–10 times lower than in economically developed countries.

World agriculture is also becoming increasingly dependent on market conditions, so developing countries are now able to take advantage of investments and obtain economic benefits, given the growing demand for food in these countries, the potential for increased production and comparative advantages in many world markets.

Thus, the sustainable development and modernization of agriculture is a key priority for any macroeconomic development strategy aimed at economic growth and improving the welfare of the population. Uzbekistan needs to switch from an inertial model of agriculture to an innovative model of management, the basis of which will be a high level of resource efficiency, implementation and development of modern technologies and innovations.

The main shocks that will affect the development of agriculture in Uzbekistan in the near future include an increase in the natural and artificial shortage of water resources, changes in climatic conditions, and continued growth in prices for industrial products (agricultural machinery, fertilizers, fuels and lubricants).

The most important task for the long term should be the creation of competitive agriculture with a high level of mechanization, resistant to climate change, ensuring the solution of the problem of ensuring food security, increasing the income of agricultural producers and the influx of financial resources into the economy from the export of agricultural products and at the same time rationally and efficiently using natural resources.

In this regard, it will be of great importance to conduct adequate policies aimed at improving the competitiveness of products, the development of service infrastructure, support for farmers and dehkan farms, the development of multi-profile farms, creating conditions for investment in the sector, especially in the development of high-tech and knowledge-intensive production processes, the development of non-productive areas – agricultural technologies, agricultural science and education.

This article takes two possible scenarios for the development of agricultural policy in Uzbekistan. The first scenario implies the continuation of the current policy and the chosen path of reform. In the second scenario, we consider the liberalization of the sector through gradual land reform, the introduction of paid water use, the abolition of public procurement practices, the introduction of conservation agriculture practices, etc.

The development of the fruit and vegetable sector in the framework of the first scenario is mainly due to the programs and strategies for development of the industry that are currently adopted.

Government Agribusiness Development Program for 2016–2020 determined the main directions for continuing structural transformations in agricultural production, introducing advanced agricultural technologies, integrated mechanization of agriculture and deepening the processing of raw materials. It provides for the phased optimization of the area under cotton with the subsequent placement on the released area of crops of fruits and vegetables, potatoes and other crops, as well as the organization of intensive gardens, the further development of selection and seed production.

At the same time, lands will be released where the cotton yield does not exceed 12–15 kg/ha (with an average yield of 24 kg/ha achieved in the country), and the wheat yield is not higher than 20 kg/ha (with an average of 42.2 kg/ha). It is also supposed to release saline lands and lands in foothill zones.

When placing crops on the lands released from cotton crops, the right to use the lands on long-term lease terms will provide mainly to economic entities:

- Having logistics centers (storage capacities, primary or deep processing of fruits and vegetables, agricultural machinery), as well as experience in selling fruits and vegetables in the domestic and foreign markets;
- With experience in the creation and operation of modern greenhouses and intensive gardens;
- Having own and attracted financial resources for organizing agricultural production along the value chain in cluster form;

- Accepting obligations to organize the cultivation, processing and sale of fruits and vegetables, including for export, the introduction of the most modern resource and water-saving technologies, the creation of new jobs.

Thus, the plans for the development of agriculture in Uzbekistan for 2016–2020 provide for the reduction of land used for the production of cotton and wheat by 220.5 thousand hectares over 5 years. The largest areas will be allocated for vegetables (an increase of 91 thousand ha after completion of the Program) and fodder crops (an increase of 50.3 thousand ha).

Experts' calculations show that the gradual reduction of cotton and grain crops on the total area of 220.5 thousand hectares and the placement of other food crops on them will allow to get on these areas annually additional income of more than 490 billion UZS instead of losses of more than 270 billion UZS, as well as to increase employment by 175 thousand people.

Also, the gradual replacement of existing old orchards and vineyards with intensive ones, as well as the creation of new intensive orchards and plantations of fruit and vegetable crops on the released lands with the use of high-tech agrotechnical measures will allow increasing the number of plantings and the share of high-yielding intensive orchards from 12 percent or 28 thousand hectares in 2015 to 28.3 percent or 78 thousand hectares in 2020, as well as increasing the yield of gardens at least 3–4 times.

In the framework of the implementation of the national Strategy for the further development of the Republic of Uzbekistan in 2017–2021, the following main priority areas of agricultural development were identified:

1. Deepening structural reforms and the dynamic development of agricultural production, further strengthening the country's food security, expanding the production of environmentally friendly products, significantly increasing the export potential of the agricultural sector;
2. Further optimization of sown areas, aimed at reducing the sown area for cotton and cereal crops, with the placement of potatoes, vegetables, fodder and oilseeds, as well as new intensive orchards and vineyards on the released lands;
3. Stimulation and creation of favorable conditions for development of farms, first of all multi-profile, engaged both in production of agricultural products, and processing, preparation, storage, sale, construction works and rendering services;

4. Implementation of investment projects for the construction of new, reconstruction and modernization of existing processing enterprises, equipped with the most advanced high-tech equipment for deeper processing of agricultural products, the production of semi-finished and finished food products, as well as packaging products;
5. Further expansion of the infrastructure for the storage, transportation and marketing of agricultural products, the provision of agrochemical, financial and other modern market services;
6. Further improvement of the reclamation state of irrigated lands, the development of a network of reclamation and irrigation facilities, the widespread introduction of intensive methods in agricultural production, primarily modern water and resource-saving agricultural technologies, the use of high-performance agricultural equipment;
7. Expansion of research work on the creation and introduction into production of new breeding varieties of crops resistant to diseases and pests, adapted to local soil and climatic and environmental conditions, and breeds of animals with high productivity;
8. The adoption of systemic measures to mitigate the negative impact of global climate change and the drying up of the Aral Sea on the development of agriculture and the life of the population.

Starting from 2018, it is planned to create 1–2 fruit and vegetable clusters in each region of Uzbekistan, providing for the formation of a chain according to the principle "seeds – seedlings – growing products – harvesting – storage – processing – transportation – delivery to the market" and involvement from 2019 in the cluster form of organization of agricultural production in all areas specialized in the cultivation of fruits and vegetables.

The strategy of export expansion is aimed at increasing production, developing a system for the procurement, storage, transportation and promotion of fresh fruit and vegetable products on foreign markets.

Efforts are also directed to the output of products from the fruit and vegetable industry that meets the requirements of foreign markets. The strategic goal is to bring the export of fruits and vegetables to 10 billion USD a year.

By 2020, the Government of Uzbekistan plans to establish 17 trade and logistics centers, which will have refrigeration and freezing equipment, associated with road and rail transport.

In the second scenario, the agricultural sector is expected to:

- Conducting a step-by-step land reform. The protection of property rights in agriculture is a key moment in the development of the industry and the efficient use of land in the long term. At the first stage, it is necessary to prescribe clear rules and criteria on how land use monitoring should be carried out, what indicators are recorded, how many times are recorded, what is considered a critical deviation from the norm and what deviations can raise the issue of unfair use of a land plot;
- Active introduction of market mechanisms in agriculture. Agribusiness is the same business as any other business. It is necessary to create free markets of resources for agricultural production (fuels and lubricants, seeds, machinery, etc.), as well as a free market for finished agricultural products. If you give farmers the right to decide for themselves what and how to produce, then they will choose the crops that are most advantageous for themselves and bring maximum income for themselves and the state in the form of taxes;
- Promoting competition by allowing more companies to enter official export channels. Uzbek farms and processing companies only won if qualified companies were allowed to freely participate in export activities, thereby creating a competitive environment for their products;
- The search for innovative ways of extension services. There is no extension service in Uzbekistan, although regional branches of research institutes participate in training specialists and conducting exhibitions and shows to demonstrate advanced agricultural technologies, and organizations such as USAID implement programs aimed at familiarizing themselves with basic principles of farming and growing a good harvest. Numerous agricultural equipment exhibitions are also held. It is very important, based on all these diverse practices, to find effective ways to convey information on the production and marketing of agricultural products to as many farmers in Uzbekistan as possible;
- Introduction of paid water use. The most effective method of managing water demand in world practice is the method of economic incentives for water conservation. Economic stimulation of water conservation is possible through the transition to paid water use and the improvement of the tariff policy. Establishing a paid water use regime would solve many problems. Agricultural producers would know exactly how much they pay for each cubic meter of consumed water and this would serve as an incentive for its savings. Water management organizations could more accurately plan the size of their incomes, and hence the costs of maintaining, reconstructing and building new irrigation and land reclamation facilities, based on the volume of water supplied to consumers.

These measures, together with current policies to modernize agricultural production, will accelerate the growth of the agricultural sector and make better use of the very limited natural resources available.

Thus, according to our calculations, gross agricultural production in the first scenario by 2030 will increase by 1.65 times (with an average annual growth rate of 104.0 percent). In the second scenario – 1.77 times (with an average annual growth rate of 104.6 percent) with the further prospect of faster growth.

Conclusion

Active population growth and limited natural resources make it necessary for Uzbekistan to switch from an inertial model of agriculture to an innovative model of management, the basis of which will be a high level of resource efficiency, implementation and development of modern technologies and innovations. Only this will create a reliable resource base for providing food to the country's population, as well as create additional opportunities for further increasing the export of fruits and vegetables, which will serve as a stable source of foreign exchange earnings for the country's economy.

References

Указ Президента Республики Узбекистан от 07.02.2017 г. № УП-4947 «О Стратегии действий по дальнейшему развитию Республики Узбекистан».

Указ Президента Республики Узбекистан от 29.03.2018 г. № УП-5388 «О дополнительных мерах по ускоренному развитию плодоовощеводства в Республике Узбекистан».

Постановление Президента Республики Узбекистан от 29.12.2015 г. N ПП-817 "О мерах по дальнейшему реформированию и развитию сельского хозяйства на период 2016–2020 годы".

Постановление Президента Республики Узбекистан от 19.03.2008 г. N ПП-817 "О Государственной программе мелиоративного улучшения орошаемых земель на период 2008–2012 годы".

Постановление Президента Республики Узбекистан от 19.04.2013 г. N ПП-1958 "О мерах по дальнейшему улучшению мелиоративного состояния орошаемых земель и рациональному использованию водных ресурсов на период 2013–2017 годы".

Постановление Президента Республики Узбекистан от 21.05.2012 г. N ПП-1758 "О Программе дальнейшей модернизации, технического и технологического перевооружения сельскохозяйственного производства на 2012–2016 годы".

Постановление Кабинета Министров Республики Узбекистан от 15.12.2015г. № 362 "О мерах по оптимизации размеров земельных участков, предоставленных для ведения фермерских хозяйств".

ПРООН – ЦЭИ Аналитический доклад – 2016/09 "Повышение производственного и экспортного потенциала плодоовощной отрасли Узбекистана: проблемы и перспективы" Ташкент-2016.

World Bank. 2007a. World Development Report 2008. Agriculture for development. Washington, DC.

Юрий Наумов, эксперт Center for Economic Development «О последних инициативах по развитию сельского хозяйства в Узбекистане» http://ced.uz/sobytiya/o-poslednih-initsiativah-po-razvitiyu-selskogo-hozyajstva-v-uzbekistane/.

АН «Podrobno.uz» Тохиржон Жалилов: все проблемы в экспорте плодоовощей мы создаем себе сами 22 июня 2018 https://podrobno.uz/cat/economic/tokhirzhon-zhalil/.

Conservation agriculture, sustainable development and strong communities

Jennifer Martin[61]

Abstract

Four decades have passed since the introduction of conservation agriculture research and development. We also mark forty years since the introduction of the Declaration of Alma-Ata at the International Conference on Primary Health Care, Alma-Ata, Kazakhstan, 6–12 September 1978. Furthermore, of significance to the future development of sustainable agriculture practices and healthy communities, is the introduction of the United Nations Sustainable Development Goals in January 2016. These follow on from the Millennium Development goals that will guide the United Nations Development Program policy and development unti l 2030. An Australian case study on conservation agriculture is presented examining the relationship between conservation agriculture, health and wellbeing and sustainable development. It is argued that an ecosystems approach is useful for strategic sustainable development to understand the connectedness and inter-relationship between climate change agricultural practices, sense of place, identity, health and wellbeing. Community development processes can assist to build strong communities through collaboration between farmers, farmer organizations, local experts, and national and regional public and private institutions.

Key words: Climate change, Ecosystems, Farmers, Identity, Health and wellbeing

Introduction

Globally, climate change has significant negative effects on health and wellbeing. Impacts are greatest for those with pre-existing mental illnesses with those living in less developed countries having greatest vulnerability. Direct consequences arise from natural disasters such as drought, bushfires, floods and cyclones resulting in post-traumatic stress disorder, depression and somatoform disorders with these impacts often not recognized (Martin, 2010). Indirect effects of climate change include migration and economic collapse. Forced mass migration is likely to result from flooding in some areas and scarcity of water in others. There is likely to be an increase in conflicts leading to displacement and increased mental illness in vulnerable populations (Page & Howard, 2010). Main challenges relate to people's environment, physical security and socio-economic systems (Nurse, Basher, Bone

& Bird, 2010). In less developed regions of the world, prolonged drought, and other weather extremes, can lead to hunger from food shortages, social unrest and conflict (Nature Publishing Group, 2015). Socio-economic, trade and technological changes also have a direct impact on agriculture. The development of land resources can lead to increased economic productivity yet at the same time having negative impacts on native vegetation and animal species, water quality and the erosion of ecosystem services. Sustainable development requires balancing conservation, development and social goals (Adams, Pressey & Alvarez-Romero, 2016). This requires the inclusion of those most-effected by proposed developments in land use consultation and decision-making processes. The aim is to build consensus for future planning of land use and wellbeing. Regional planning will generally include diverse stakeholders and complex issues regarding mixed land use (Adams, Pressey, & Alvarez-Romero, 2016).

Preparing farmers for the future

Sustainable agriculture is an urgent issue in a warming world. The challenges of climate change and population growth requires collaboration between farmers, scientists and government officials to ensure agriculture practices are sustainable. It also requires high levels of cultural empathy, trust and intuition. Regardless of the level of sophistication of climate and climate impact models, there still remains a degree of uncertainty with regard to strategic decision-making into the future (Nature Publishing Group, 2015). Farmers are faced with more erratic rainfall, extreme temperatures, drought, invasive weeds, soil erosion and resilient pests that they must adapt to and prepare for. Adaptations made by individual farmers cannot withstand the size and magnitude of the problems now faced. Collaborative efforts are required for sustainable irrigation schemes and farming systems. These will vary across different regions and localities according to soils, farm types, topography and local climate. The individual and collective voice of farmers is central to future developments and it is important that they are consulted and listened to. Communication challenges may arise if farmers are not convinced of arguments for new practices such as conservation agriculture if they cannot see any immediate benefits (Nature Publishing Group, 2015). Sustainable development requires close consultation with local farmer communities and local experts. Regional case studies, using locally sourced data that includes climate change socio-economic and technological development, can assist in the development of possible future scenarios for the development of models for local adaptations (Nature Publishing Group, 2015).

Conservation agriculture

Conservation agriculture is an alternative to intensive tillage farming and features minimal soil disturbance, diversification of crop species and use of organic mulch to cover the soil in addition to other crop management processes (Kassam, Friedrich, Derpsch & Kienzle, 2015). This is supported by other activities focuses on the integrated management of pests, weeds, water and plant nutrients. The goal of CA is "sustainable production intensification" (FAO, 2011). The main aims are to (1) reduce the impacts of climate change on crop production, (2) mitigate farming practices that cause climate change and (3) contribute to ecosystems improvements (Kassam, Friedrich, Derpsch & Kienzle, 2015). This is witnessed in farming practices that increase crop diversity, reduce leaching and erosion, limit the use of pesticides (including herbicides) and chemical fertilizers. Water quality is improved as a result of reduced erosion and use of chemicals. Australia is a main adopter of CA systems of agriculture in drought prone areas with a CA approach integrated into mainstream agriculture developments. Conservation agriculture requires changes in values and belief systems, knowledge and skills and commitment across a range of key stakeholders. This includes farmers, government, policy makers, scientists, social scientists, environmentalists and economists. Farmers require incentives and support services to adopt and improve CA practices over time.

In the 21st century, conservation agriculture (CA) is gaining global momentum as a farmer-led system of agricultural reform. However, in more recent years, some governments have been taking a more active lead role in national and regional policy development and institutional support for the adoption of CA practices due to increased drought and erosion, and energy and production costs. These countries include Kazakhstan, China, Canada, Switzerland, Zimbabwe, Zambia and Malawi. An example of this is the European Union Common Agriculture Policy provides incentives for farmers to adopt CA practices (Kassam, Friedrich, Derpsch & Kienzle, 2015). Kassam and colleagues (2014) contend that CA requires pro-active national policy and institutional support from a range of public and private services. Ideally, this would be mainstreamed in policies across environment, agriculture, education, industry and trade and commerce. They identify essential conditions for the adoption of CA. These include CA champions, institutional capacity, engagement with farmers and farmer organizations, education and knowledge development. This requires scientific inputs, mobilization and marketing strategies. Affordable and accessible equipment and inputs are needed for farmers, particularly at the early stages of CA adoption, to change production techniques with financial incentives and support strategies provided (Kassam, Hongwen, Niino, Friedrich, Jin, & Xianliang, 2014).

An ecosystems approach to conservation agriculture

An ecosystems approach to CA requires intensification practices that enhance the biodiversity of crop production systems above and below the soil, facilitating increased productivity and healthier environments (Kassam, Friedrich, Derpsch & Kienzle, 2015).

The past two decades have seen an increased emphasis on an ecosystems approach highlighting the interplay between ecological, economic and social considerations (Bohnet & Beilin, 2015; Kassam, Friedrich, Derpsch & Kienzle, 2015). The concept of "landscape" developed by the Welsh government highlights the diverse areas of interactions in relation to people and place including social/cultural, perceptual, natural and aesthetic as seen in Table 41.

Bohnet and Beilin (2015) highlight how sustainable development is a process that requires people to work together for innovative landscape design that will continue to evolve into the future. They identify two critical issues for the achievement of sustainable landscapes. These are (1) ensuring that place is considered alongside economic development and (2) civic discourse. Nurse, Basher, Bone and Bird (2010) employ a public health approach using evidence from neuroscience and psychology to argue that poor physical and mental health outcomes arise from disconnection to self, others and the environment. They adopt an integrated public health model based on the connection between climate change and mental health advocating for actions leading to improved climate and mental health outcomes.

This model reflects the Australian Aboriginal holistic concept of health that encompasses, physical, emotional, mental, spiritual and cultural aspects of wellbeing. This is an ecosystem that is based on harmony and working together, with this inter-relatedness essential for cultural wellbeing. Disharmony or disruption to these inter-relationships cause Aboriginal ill-health to develop and persist (Gee *et al.*, 2014).

Table 41. The concept of landscape. Place and people.

Natural	Aesthetic	Perceptual	Cultural/Social
Climate Air Soil Landform Geology Fauna and flora	Five Senses: sight, sound, touch, smell, taste. Color, texture, form, pattern	Memories Associations Preferences	Settlement Land use Enclosure

Source: Adapted from Tudor, 2014, p. 56

Results: case study of west australian wheatbelt

Wheat has been chosen as it is the crop of most importance for Australia. The Western Australia wheatbelt covers 154 862 square kilometers in the south-west.

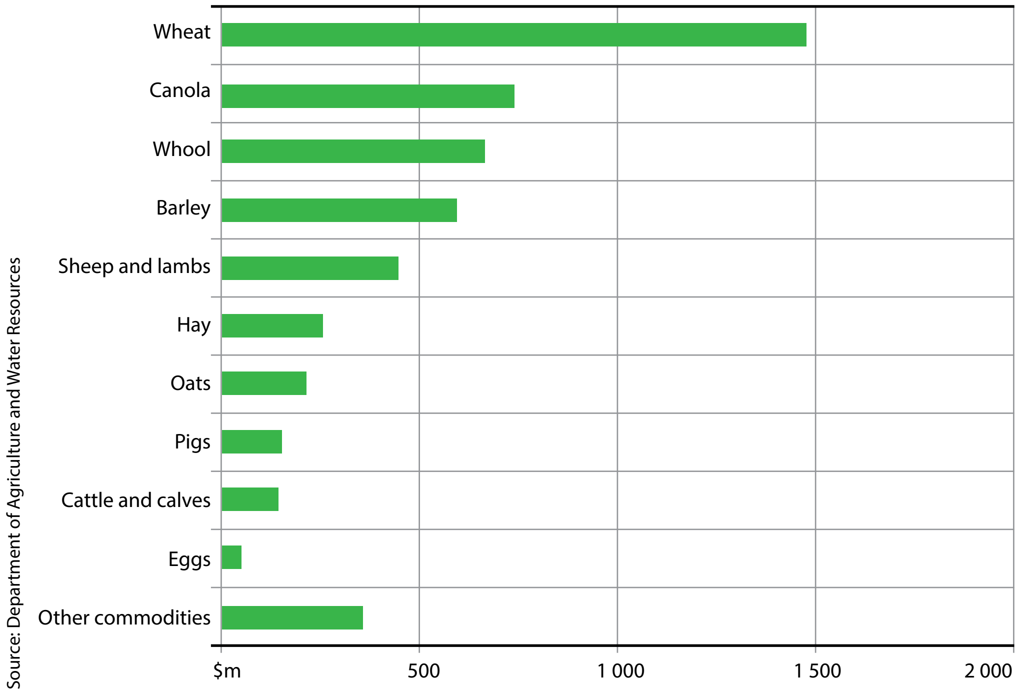
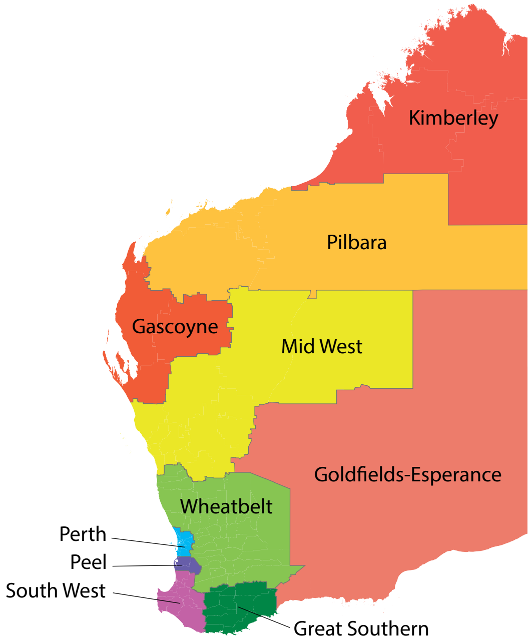


Figure 57. Western Australia wheatbelt profile

Ecosystems and farmer health and wellbeing in the wa wheatbelt

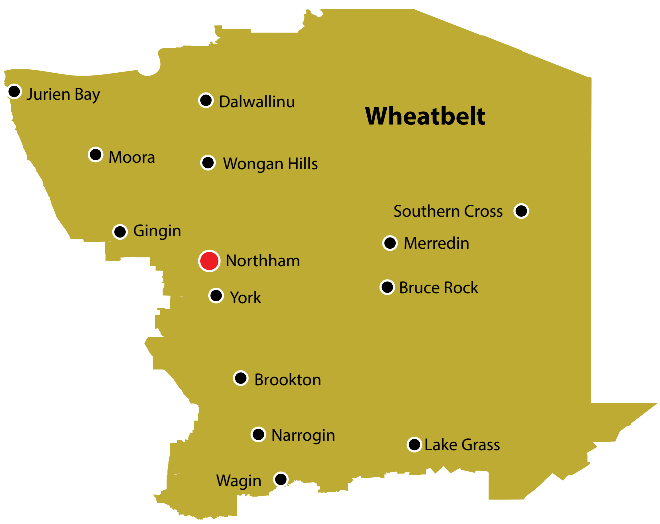
A qualitative case study, conducted by Ellis and Albrecht (2017) in the Western Australian wheatbelt in 2015, found that "sense of place" including personal and cultural aspects, is a central concept when analyzing climate change impacts on the mental health of farmers. This region has experienced severe and abrupt climate change in the past 40 years with decreased winter rainfalls since the 1970s, a rise in average temperature and more frequent and extreme weather events including frosts, heatwaves and droughts.

Ellis & Albrecht (2017) research findings revealed that farmers were increasingly worried about the weather contributing to heightened levels of distress and risk of depression and suicide. They felt they did not have control over their farmlands



Source: DPIRD, WA government
http://www.drd.wa.gov.au/regions/Pages/Wheatbelt.aspx

Figure 58. Regions of Western Australia



Source: DPIRD, WA government
http://www.drd.wa.gov.au/regions/Pages/Wheatbelt.aspx

Figure 59. Western Australia wheatbelt regions

and were fearful for their future. This manifested in anxious behaviors such as continually checking weather reports on the phone and computer. The connection between the land, local attachments and identity for positive mental health and wellbeing were emphasized and how climate change was eroding this. A local GP is reported as saying that many farmers are suffering from "seasonal affective disorder" from a lack of rain (cited in Brooks, 2015, p.1).

Conservation agriculture in the West Australia wheatbelt

Natural resource management in the WA wheatbelt is focused on the maintenance and development of productive and environmentally sustainable agriculture systems. The Australian government supports activities aimed at increased production, income generation and resilience while supporting biodiversity, water quality, soil health (Sustainable Industries, 2018). Activities that are promoted and supported by the Australian government are:

- Innovation in sustainable cropping and grazing.
- Promotion of soil nutrient practices that provide environmental benefits.
- Adoption of carbon farming practices.
- Support of demonstration and trial sites.
- Addition of perennial plants to improve biodiversity, soil and water quality.
- Supported decision-making processes to assist farmers to choose appropriate CA methods.
- Identification and development of innovative technologies to support CA.
- Development of community networks and capacity to increase knowledge and skills in CA.

This is underpinned by a change model approach to farmer decision-making for the adoption of CA practices that considers motivation, exploration and trialling and adoption of changed farming practice/s (Sustainable Industries, 2018).

Crop rotation trial in 2017

Shire: Dalwallinu.
Region: WA Wheatbelt.
Average rainfall: Low-less than 325 mm.
Enterprise mix: Cropping.
System constraints: Compaction, hard setting.

Crop rotations are being increasingly adopted in low rainfall regions of the northern and central wheatbelt. In particular, crops that include nitrogen-fixing pulses, have been found to protect wheat and other grain cropping systems from weed, insect and disease problems and reduce the need for use of pesticides or herbicides. The trail included crop rotations of (1) wheat on wheat, (2) wheat on field peas, (3) wheat on canola and (4) wheat on fallow (Ag Trials WA, 2018).

Outcomes included:

- Canola crops reduce crown rot in subsequent wheat crops.
- Canola on fallow result in increased subsequent wheat yields.
- Field peas and other pulses can reduce nitrogen fertilizer use.

The key messages reported from the trial were:

1. Crop rotation had the greatest influence on yield and quality in 2017.
2. High and low inputs did not significantly impact production in 2017.
3. Protein can be significantly impacted by the previous season's crop type and current seasonal conditions (and).
4. A low input system may perform well over several years but can increase the risk of high weed burden, disease and lower yields (Ag Trials WA, 2018, p. 1).

Discussion

Farmers have a close association to the land that directly impacts their identity, health and wellbeing. Climate change and increased population growth pressures for higher crop yields means that farmers worldwide have to explore new ways of managing land resources that balance conservation and development and build strong communities. Increased displacement and conflicts resulting from climate change can lead to increased mental illness in those who are vulnerable with those with a pre-existing mental illness at greatest risk. Conservation agriculture presents as a feasible alternative due to the focus on reducing and mitigating impacts of climate change while contributing to ecological, economic, social and cultural ecosystem improvements. An ecosystems approach highlights the interconnectedness between people and place with Australian Aboriginal holistic notions of health and wellbeing noting the importance of harmony, working together and inter-relatedness for cultural wellbeing. Sustainable development of conservation agriculture requires consultation and decision-making processes for collaboration with populations most directly affected that are responsive to their needs, concerns and fears. This requires community development processes for both land use and wellbeing that foster collaboration between farmers, farmer organizations and local experts. Scientific input, mobilization and marketing strategies are required for knowledge and skill development with support for farmers to trial new production approaches. This needs to be supported by national and regional policy with institutional support from public and private sources and farmer incentives.

References

Adams, V M, Pressey, R L, & Alvarez-Romero, J G (2016): Using Optimal Land-Use Scenarios to Assess Trade-Offs between Conservation, Development, and Social Values. Plos One, 11, 1–20.

Ag Trials WA (2018): Wheatbelt: Understanding the implications of crop rotations in a low rainfall zone. (accessed 25.8.18) https://www.agtrialswa.com.au/trial/understanding-the-implications-of-crop rotations-in-a-low-rainfall-zone/.

Bohnet, I C, & Beilin, R (2015): Editorial: Pathways towards sustainable landscapes. Sustainability Science, 102, 187–194.

Brooks, H (2015): Study: Climate change causing farmers mental anguish. In UPI News Current, 11 Dec. 2015. General OneFile, (accessed 24.8.18) http://link.galegroup.com/apps/doc/A437166807/ITOF?u=swinburne1&sid=ITOF&xid=75e9.

Ellis, N and Albrecht, G (2017): Climate change threats to family farmers' sense of place and mental wellbeing: A case study from the Western Australian Wheatbelt. Social Science and Medicine, 175, 161–168.

Food and Agriculture Organization (2011): Save and grow: A policy makers guide to sustainable intensification of smallholder crop production. Rome: Food and Agriculture Organization of the United Nations.

Gee, G, Dudgeon, P, Schultz, C, Hart, A and Kelly, K (2015): Aboriginal and Torres Strait Islander Social and Emotional Wellbeing. Chapter 4 In Dudgeon, P., Milroy, H., & Walker, R., Working Together 2nd Ed., ACT: Commonwealth of Australia (accessed 25.8.18) http://aboriginal.telethonkids.org.au/kulunga-research-network/working-together-2nd-edition-(1)/.

Kassam, A, Friedrich, T, Derpsch, R, and Kienzle, J (2015): Overview of the worldwide spread of conservation agriculture. Field Actions Science Reports. The Journal of Field Actions, 8, 1–11.

Kassam, A, Hongwen, L, Niino, Y, Friedrich, T, Jin, H, and Xianliang, W (2014): Current status, prospect and policy and institutional support for conservation agriculture in the Asia-Pacific region. International Journal of Agricultural and Biological Engineering, 7, 1–13.

Martin, J. (2010). Disaster planning and gender mainstreaming: Black Saturday bushfires. New Community Quarterly, 8, 3–9.

Nature Publishing Group (2015): Prepare farms for the future. Editorial, Nature, 523, 381.

Nurse, J, Basher, D, Bone, A and Bird, W (2010): An ecological approach to promoting mental health and well-being: A response to the challenge of climate change. Perspectives in Public Health, 130, 27–33.

Page, L and Howard, L (2010): The impact of climate change on mental health (but will mental health be discussed at Copenhagen?). Psychological Medicine, 40, 177–180.

Pettit, N E, Naiman, R J, Fry, J M, Roberts, J D, Close, P. G., Pusey, B J, . . . Davies, P M (2015): Environmental change: prospects for conservation and agriculture in a Southwest Australia biodiversity hotspot. Ecology and Society, 20, 10.

Tudor, C (2014): An approach to landscape character assessment. York, United Kingdom: Natural England, UK government.

Conservation Agriculture in Russia in the conditions of socio-economic contradictions

Daniil Kozlov[62]

Abstract

Given the high natural potential and recent records in the Russian agro-industrial complex, low agricultural efficiency is maintained in combination with uncontrolled degradation of soil and land resources. Socio-economic contradictions, the imperfection of the mechanisms of interaction between specialized institutions of science and production, the problems of staffing, the lack of service innovative structures determined the overall low level of agronomic culture. The extensive nature of agricultural production is accompanied by the depletion of soil fertility and the development of degradation processes. The curtailment of land management work on study, protect and improve land led to the deterioration of their condition. The lack of relevant information prevents the formation of common principles for the cadastral valuation of land, the development of the land payment market, mechanisms for land supervision over the use of land resources and their protection, determines the unsystematic nature of the measures taken in this area, and the inefficient use of budgetary funds and investments of business structures in the organization of land use. In the process of reforming science and higher education, the role of scientific, technical and educational support for the urgent tasks of production has noticeably decreased. At the same time, the progress of Russian agricultural science in recent decades is associated with the development of the theory of adaptive landscape agriculture, aimed at the complex solution of the conflicting tasks of intensification and greening of crop production, taking into account social needs, agro-ecological requirements of crops, natural-resource and production-resource potential, social infrastructure and environmental restrictions. Adaptive-landscape farming systems are formed by detailing the complex of agricultural technologies, organizational, economic and soil-protective measures as applied to agro-ecological groups of lands (upland, erosive, saline, sodic, etc.).

This methodology is the basis of the program of scientific and innovative support for technological modernization of agriculture in Russia. In addition to the implementation of the Program, the sustainable intensification of agriculture in Russia requires strengthening state regulation of land relations in terms of streamlining land use, land inventory, and the full-scale implementation of a program for agricultural land monitoring.

Key words: sustainable intensification of crop production, agricultural system, adaptive landscape agriculture, Russia

Agriculture of Russia in the contradictions of the market structure of land relations

Modern agriculture of the Russian Federation is developing in the face of acute contradictions. With high natural potential in the agro-industrial complex of Russia remains low efficiency of crop production in combination with uncontrolled degradation of soil and land resources (Analysis of land reform ..., 2016; Kiryushin, 2019). Socio-economic contradictions, the imperfection of the mechanisms of interaction between the specialized institutions of science and production, the problems of staffing, the lack of service innovative structures (autonomous or departmental) determined the general low level of agronomic culture of agriculture. According to existing estimates, crop rotations were violated on an area of 71 million hectares (89 percent of the sown area). The low level of use of mineral fertilizers is due not only to the lack of funds for their purchase, but also to their low profitability due to non-compliance or backwardness of the application technologies. In order to reduce costs, agricultural enterprises reduce tillage, often unreasonably switch to minimal tillage and zero-tillage. The level of pesticidal load is significantly higher than the level of agricultural crops. As a result, despite the records of recent years, wheat yields (31 kg/ha, Rosstat, 2018) did not reach the world average level (33 kg/ha) and lagged behind similar indicators of neighboring countries – Germany (75 kg/ha), European Union (55 kg/ha), China (53 kg/ha), Ukraine (40 kg/ha), Belarus (37 kg/ha).

The extensive nature of agricultural production is accompanied by the depletion of soil fertility and the development of degradation processes. In 2017, of the more than 20 million tons of mineral fertilizers produced in Russia, only 3.1 million tons were purchased by domestic agricultural producers to replenish the reserves of nutrient elements of the soil, annually alienated with the crop (8 million tons). Since the beginning of the 90s, the negative balance of nutrients in the soils of the country exceeded 140 million tons of active substance (Sychev, Saffron, 2017). The nitrogen deficit amounted to 56.3 million tons, phosphorus – 12.3 million tons, potassium – 75.9 million tons, i.e. a significant part of the crop is formed due to soil reserves, soil fertility is depleted. The results of agrochemical monitoring record a decrease in the share of arable soils adequately provided with nutrients and humus (Sychev, Saffron, 2017). Water erosion is affected by 17.8 percent of agricultural land in Russia, wind erosion – 8.4 percent, waterlogged and swampy lands occupy 12.3 percent, saline – 20.1 percent. The lands of 27 entities are subject to desertification on an area of more than 100 million hectares (National Report on the Status and Use of Lands, 2016).

These figures do not reflect the real state of soil and land resources, since they are based on the results of an inventory, carried out 25 years ago. The phasing out of land management works since 1991 on the study, conservation, development and improvement of land, as well as the chronic underfunding of these measures have led to a deterioration in their condition. According to existing estimates, over the past 25 years, the area of problem lands has increased by 23 million hectares (Analysis of land reform ..., 2016). The lack of up-to-date information on the state of agricultural land prevents the formation of common principles for cadastral valuation of land, the development of the land payment market, land supervision mechanisms for the use of land resources and their protection, determines the unsystematic nature of the measures taken in this area, and the inefficient use of budgetary funds and investments of business structures in land use organization.

State regulation of land relations is carried out at all levels of the legislative, executive power of the Russian Federation. But in many cases, legislation regarding the protection and rational use of soils is not implemented or is being implemented selectively. The current alarming situation is widely discussed in the expert community (Analysis of land reform ..., 2016; Volkov, 2017; Kiryushin, 2018; Shagaida, Alakoz, 2017;), at parliamentary hearings of relevant committees of the State Duma and the Council of Federations. Recent years have been marked by increased control over the targeted use of agricultural land (Presidential Order Pr-1240 of June 29, 2016), in the systematic work of the Analytical Center of the Ministry of Agriculture of Russia to improve the agricultural information system (Kozubenko, 2018), the intensification of the supervisory activity of the Rosselkhoznadzor and the implementation a number of regional programs for the biologization of agriculture (Lukin, 2016).

At the same time, in the process of reforming science and higher education, the coordination of research, design and survey works and educational programs in the system of agricultural institutes and educational institutions was disrupted. The role of science in solving the urgent problems of production has noticeably decreased. Often, agricultural producers, out of economic interests, master new agricultural technologies before they are tested in pilot farms and regional agricultural centers. Against this background, the concepts of resource-saving, environmental, organic, accurate, coordinate, etc., which replace the understanding of the agricultural system as a complex of interrelated organizational, agrotechnical, reclamation, and soil protection measures for the use of land and increasing soil fertility, are gaining unjustified popularity (GOST 16265–89). National and regional non-profit associations operate – the Union of Organic Agriculture (https://soz.bio), the National Conservation Agriculture Movement (http://rmrl.ru), the Union of Supporters of Zero-till of Agricultural Crops (Stavropol Territory), the Association of Supporters of Zero-till (Rostov region, http://aspp-rf.ru) and others.

The system of adaptive landscape agriculture as the basis of scientific and technical modernization of agriculture in Russia

At the same time, in recent decades the progress of Russian agricultural science is associated with the development of the theory of adaptive landscape agriculture (Agroecological assessment ..., 2005; Kiryushin, 2011; Kulik *et al.*, 2012; Models..., 2005; Kiryushin, 2019). This methodology is aimed at a comprehensive solution of the conflicting tasks of intensification and greening of crop production, taking into account all groups of factors: social needs; agroecological requirements of crops; natural resource and production resource potential; household structures, social infrastructure; environmental restrictions.

In the development of zonal farming systems, the development and implementation of adaptive landscape farming systems (ALSZ) occurs through further refinement of the complex of agricultural technologies (crop rotation, tillage, mineral nutrition systems and plant protection), taking into account the natural and production and resource potential of the agricultural enterprise and other factors. The higher the level of intensification of agrotechnologies (extensive, normal, intensive, high), the more agrotechnological parameters and the more detailed land assessment basis are taken into account (Kiryushin, 2018).

Extensive agricultural technologies focus on the use of natural soil fertility without the use of fertilizers or with very limited use. In addition to low productivity, they have very limited possibilities for producing products of optimal quality. Extensive agriculture is depleting in relation to soils and destructive in relation to landscapes.

Normal agricultural technologies are focused on the environmental stabilization of agrolandscapes and soils with the development of soil protection elements, ensuring a deficit-free or close balance of carbon and nutrients, and improving soil cultivation and product quality.

Intensive agricultural technologies are designed to form the planned high-quality crop in the system of continuous control of the production process by microprocesses of organogenesis using the tramline. Along with the technogenic regulation of phytocenoses, the problems of optimizing soil conditions are being solved. The use of intensive agricultural technologies is advisable only on prosperous, sufficiently cultivated soils. Maintaining soil fertility is carried out primarily due to the receipt of plant residues of high yields, as well as sealing crops, the introduction of organic fertilizers.

The level of high agricultural technologies is focused on the maximum use of the genetic potential of high-intensity varieties of crops, including transgenic; production of products of a given quality, with minimal environmental risks using precision methods for managing agrocenoses. Such technologies are distinguished by the widespread use of modern means of informatization, remote methods for the diagnosis of sowing and operational management of them. Individual elements of high agricultural technologies are actively developing in various institutes and companies under the heading "exact" or "coordinate" farming.

Adaptive landscape farming systems are formed by detailing the complex of agrotechnologies and organizational and economic measures in relation to agroecological groups of lands (flat, erosive, waterlogged, saline, etc.) taking into account their production and environmental restrictions. Land grouping is carried out according to the results of field soil-landscape mapping in accordance with the landscape-ecological classification, ordering the natural-resource diversity of lands in accordance with the requirements of modern agricultural technologies. The classification includes ten levels: agroecological groups of lands allocated according to the leading agroecological factor that limits agricultural production; agroecological subgroups – according to the degree of manifestation of limiting conditions; level of the first order – in absolute altitudes above sea level; level of the second order – according to morphological types of relief; classes – according to the genesis of parent rocks, subclasses – according to particle size distribution; types – according to the mesoforms of the relief, subtypes – according to the steepness and exposure of the slopes; species – according to the microstructure of the soil cover. The component composition of soil combinations is characterized by soil properties and their fertility. The latter is considered as an expression of the production and environmental functions of the soil (Kiryushin, 2018).

In development of the biosphere paradigm of nature management, Adaptive landscape agriculture (ALA) is aimed at maintaining the long-term environmental sustainability of agrolandscapes. In addition to environmental optimization of the agricultural technologies themselves (for example, minimizing soil cultivation and Zero-till, optimizing the use of fertilizers and plant protection products), ALA tools include forestry and land reclamation measures aimed at creating ecological frameworks that are maximally connected with the field infrastructure.

The general sequence of design and survey work includes five stages: 1) an inventory of the enterprise's soil and land resources based on office and field mapping methods on a scale of 1: 10 000, 2) agroecological assessment of land with identification of properties that reduce the productivity of crops and complicate the agrotechnical conditions of their cultivation, 3) the design of adaptive agrotechnologies of a normal and intensive level in relation to each agroecological group of lands (zoned, eroded, waterlogged, saline, etc.) 4) the calculation of environmental and economic efficiency of their implementation, 5) development of passports of industrial sites and routings for their cultivation. Implementation of work on the basis of geographic information systems ensures the integration of developed technological solutions into electronic agricultural production management systems.

ALA pilot projects have been developed for enterprises in all regions of the Central Black Soil Region of Russia and have been successfully implemented in Belgorod, Samara Regions, and Altai Territory. The regional program for the biologization of agriculture based on the principles of adaptive landscape agriculture is being successfully implemented in the Belgorod region (Lukin, 2016). Methodological manuals on adaptive landscape agriculture have been prepared for the regional conditions of Vladimir, Volgograd, Novosibirsk, Kurgan and some other areas. Today, soil-landscape and design surveys are carried out by scientific and scientific-educational institutions, agrochemical centers of the Ministry of Agriculture of Russia and commercial companies. To coordinate the scientific, methodological and organizational work, the Scientific Council of the Russian Academy of Sciences on Adaptive landscape agriculture was created. A program of scientific and innovative support for technological modernization of agriculture in Russia (Kiryushin, 2018), covering a wide range of scientific and methodological issues of environmental and economic optimization of agricultural nature management, the development of high-tech agricultural technologies, systems for agroecological assessment of land and soil fertility management, etc. has been prepared.

Conclusion

Sustainable intensification of agriculture for the national interests of Russia requires strengthening state regulation of land relations in terms of streamlining land use, land inventory and the full implementation of the monitoring program. This is not an easy task, since it is associated with overcoming the consequences of agrarian reform and other contradictions. A necessary condition for the modernization of agriculture is the training of agronomists, technologists, and the reconstruction of the scientific, educational and production base. This requires a serious update of educational programs, in which the scientific achievements of research institutes and universities should be concentrated, which requires the appropriate integration of scientific and educational activities. For the development of modern agricultural technologies, it is necessary to create a system of innovation centers at scientific institutions and universities, in which a demonstration of agricultural technologies, field training, consultations, and certification of specialists should be carried out.

References

Агроэкологическая оценка земель, проектирование адаптивно-ландшафтных систем земледелия и агротехнологий. Методическое руководство. – М.: **Росинформагротех,** 2005. 784 с.

Анализ земельной реформы и агропромышленного производства за четверть века. Почвенно-экологические, институциональные и инфраструктурные аспекты модернизации. Земельная служба. Доклад для органов высшей исполнительной и законодательной власти/**А. Л. Иванов, В. И. Кирюшин, Э. Н. Молчанов и др.,** М.: Почвенный институт им. В.В. Докучаева, 2016. 93 с. https://yadi.sk/i/nwJRC7pjzqQS2.

Валовые сборы и урожайность сельскохозяйственных культур в Российской Федерации в 2017 году // Бюллетени Росстата о состоянии сельского хозяйства (электронные версии) http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/ statistics/publications/catalog/doc_1265196018516.

Волков С.Н., Современное состояние земельных отношений, землепользования и землеустройства в Российской Федерации и научное обоснование основных направлений их регулирования в АПК: материалы к докладу на заседании Президиума Российской академии наук 28 марта 2017 года. М: ГУЗ, 2017. 72 с.

Кирюшин В.И., Теория адаптивно-ландшафтного земледелия и проектирование агроландшафтов. М.: КолосС, 2011. – 443 с.

Кирюшин В.И., Кирюшин С.В., Агротехнологии. СПб, Изд-во Лань, 2015, 464 с.

Кирюшин В.И., Задачи научно-инновационного обеспечения земледелия России // Земледелие. 2018. № 3. С. 3–8. DOI: 10.24411/0044-3913-2018-10301.

Кирюшин В.И., Актуальные проблемы и противоречия развития земледелия // Земледелие. 2019. №3. С.3–7. DOI: 10.24411/0044-3913-2019-10301/.

Козубенко И.С., Почвенная информация в Аналитическом центре Минсельхоза России // Бюл. Почв. ин-та им. В.В. Докучаева. 2018. Вып. 92. С. 3–15. doi: 10.19047/0136-1694-2018-92-3-15.

Кулик К.Н., Рулев А.С., Жданов Ю.М., Юферев В.Г., Кретинин В.М., Исупов Б.А., Тубалов А.А., Кошелева О.Ю., Дорохина З.П., Кошелев А.В., Юферев М.В., Адаптивно-ландшафтное обустройство земель сельскохозяйственного назначения лесостепной, степной и полупустынной зон европейской части Российской Федерации. Волгоград: ВНИАЛМИ, 2012. – 129 с.

Модели адаптивно-ландшафтных систем земледелия для основных природно-сельскохозяйственных регионов страны. Курск, **ВНИИЗиЗПЭ,** 2005. 80 с.

Национальный доклад о состоянии и использовании земель в Российской Федерации в 2015 году. – М.: **«Росреестр»,** 2016. – 202 с. https://rosreestr.ru/site/activity/sostoyanie-zemel-rossii/gosudarstvennyy-natsionalnyy-doklad-o-sostoyanii-i-ispolzovanii-zemel-v-rossiyskoy-federatsii/.

Сычев В.Г., Шафран С.А., О балансе питательных веществ в земледелии России // Плодородие, 2017, №1. С. 1–4. http://www.plodorodie-j.ru/journal/2017/nomer_one/2017-1-1-4.html.

Шагайда Н. И., Алакоз В. В., Земля для людей. Аналитический доклад Центра стратегических разработок, 2017. 28 с. https://www.csr.ru/issledovaniya/kak-ujti-ot-haosa-v-zemelnyh-otnosheniyah/.

Annexes

©FAO/Aziz Nurbekov

Annex 1.

Declaration of the international conference on "Strategies for the promotion of conservation agriculture in Central Asia"

5–7 September 2018, Tashkent, Uzbekistan

The Ministry of Agriculture of the Republic of Uzbekistan in cooperation with the Food and Agriculture Organization of the United Nations (UN FAO) organized the International Conference on "Strategies for the Promotion of conservation agriculture in Central Asia". The Conference was held during 5–7 September 2018 at the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers. The participants had an opportunity to visit experiences of conservation agriculture in practice at the field day organized at "AgroEcoPro" farm in Yukorichirchik district of Tashkent region.

The International Conference aimed at reviewing: (a) the status of conservation agriculture in the countries of the region, (b) analyze and identify opportunities for and constraints to adoption and spread of conservation agriculture, including the diversification of cropping systems and improved crop management practices; and (c) the opportunities and strategies for upscaling the adoption of conservation agriculture at the regional level.

Over 170 participants attended the International Conference. Out of this, about 60 participants were international (Austria, Azerbaijan, Brazil, China, Georgia, Iran, Kazakhstan, Kyrgyzstan, Moldova, Portugal, Russia, Spain, Tajikistan Turkey and United Kingdom). Representatives of international organizations, ministries, universities, research institutes and private companies joined the International Conference, and more than 40 farmers from Central Asia attended the event. About 500 students of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers joined the opening session, learning the key principles of conservation agriculture and the deliverables it offers to Central Asia in general, and to Uzbekistan, in particular. In the plenary sessions, over 30 presentations were delivered.

The three interlinked principles of conservation agriculture are (1) continuous no or minimum mechanical soil disturbance; (2) permanent mulch cover over the soil; and (3) crop diversification with rotations and/or associations. These principles must be applied concomitantly in conservation agriculture systems. Conservation agriculture embraces a holistic ecosystem concept of real sustainable agriculture, combining the basic elements of production with those of conservation and regeneration. Thus Conservation Agricultural was demonstrated and recognized as a sustainable agricultural paradigm, able also to rehabilitate degraded agricultural environments.

Accumulated positive experiences with conservation agriculture are leading to its increasing adoption worldwide, including Central Asia. Positive experiences of more than 10 countries were presented at the Conference, constituting the living proof that the adaptation of conservation agriculture to a diverse range of local agro-ecologies and conditions is feasible. Most of the experiences presented for conservation agriculture in Central Asia result in higher agricultural production at a reduced cost, compared to conventional tillage production systems. Therefore, these economic benefits are the basis for ensuring stable incomes for farmers and for sustainable production of sufficient food, biological raw materials and domestic energy for a growing population, while demonstrating significant potential as a strategy for poverty alleviation.

Conservation agriculture is the most appropriate system for rehabilitating degraded agricultural soils, and improving the production capacity of both rainfed and irrigated farming systems, in the current and future uncertain climate change scenario. It is applicable to both annual and permanent crops, which makes it viable for the whole agricultural sector.

Some of the key benefits for Central Asia presented at the Conference included the control of soil erosion and runoff, improved water management and salinity control, climate change mitigation and adaptation, improved biodiversity, and better productivity and income for farmers.

The mechanization challenges that no-tillage encompasses in conservation agriculture were also addressed, especially during the machinery and equipment demonstration. A common concern in the region of the integration of feed demand by livestock with the permanent soil cover principle of conservation agriculture was also addressed at the Conference, including during the field day.

The International Conference on conservation agriculture calls upon stakeholders of Central Asia countries to conceive and endorse appropriate long-term strategies to promote the adoption and spread of conservation agriculture, and to further develop this sustainable agriculture system with effective support from public, private and civil sector institutions and stakeholders including research, education and service providers. Policies in favor of conservation agriculture, and National Development Programs based on the current regional and international knowledge and experiences are recommended for the region.

Annex 2

Agenda
International Conference "Strategies for the promotion of conservation agriculture in Central Asia"

Tashkent, Uzbekistan
Venue: Tashkent Institute of Irrigation and Agricultural Mechanization Engineers

5–7 September 2018

Program
5 September 2018 – Wednesday

8^{00}–9^{00}	**Registration of participants**
9^{00}–9^{30}	**Opening Session** – Moderator Dr. Uktam Umurzakov, Rector of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Professor Welcome remarks by: • **Mr. Zoir Mirzaev**, Deputy Prime Minister of the Republic of Uzbekistan. • **Mr. Bakhodir Yusupov**, Minister for Agriculture of the Republic of Uzbekistan. • **Mr. Viorel Gutu**, FAO Subregional Coordinator for Central Asia.
9^{30}–10^{00}	**Keynote Speech** Conservation agriculture: a win-win option for food security, land management and livelihoods – **Dr. Hafiz Muminjanov**, FAO Sub-regional office for Central Asia, Turkey
10^{00}-10^{30}	**Group photo and coffee-break**

Session 1: Conservation agriculture: A Sustainable Agricultural Paradigm
Chairs: **Dr. Gottlieb Basch and Dr. Tohirjon Sultanov**

10^{30}–11^{00}	**Keynote Speech** Conservation agriculture: A worldwide revolution – **Dr. Amir Kassam**, Moderator of the FAO Global Platform for CA Community of Practice, UK

11^{00}–11^{20}	Conservation agriculture in Brazil: An overview of the 1972–2018 period – **Dr. Rafael Fuentes**, Institute of Agronomy of Parana (IAPAR), Brazil
11^{20}–11^{40}	Results of Long Term conservation agriculture Research and Development in Uzbekistan – **Dr. Alim Pulatov**, Central Asia and South Caucasus Consortium of Agricultural Universities for Development (CASCADE), Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Uzbekistan
11^{40}–11^{55}	Conservation agriculture – key to sustainable global food security – **Dr. Vasile Bumacov**, Ambassador of Moldova in Japan
11^{55}–12^{15}	Conservation agriculture in Konya, Turkey – **Mr. Seyfettin Baydar**, Director, Konya Directorate of Provincial Food Agriculture and Livestock, Turkey
12^{15}–12^{30}	Adoption, advancement and impact of conservation agriculture in Kazakhstan – **Prof. Muratbek Karabayev**, CIMMYT, Kazakhstan
12^{30}–13^{00}	Visit to the laboratories of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME)
13^{00}–14^{00}	Lunch
14^{00}–14^{15}	Promotion of conservation agriculture in Tajikistan – **Mr. Muhamadi Muminov**, Non-commercial Cooperative "Sarob", Tajikistan
14^{15}–14^{30}	Conservation agriculture in the European Union (in the case of the Visegrad countries) – **Mr. Khabibullo Pirmatov**, Slovak University of Agriculture in Nitra, Slovakia
14^{30}–15^{00}	Conservation agriculture in perennial crops – **Mr. Antonio Holgado**, European conservation agriculture Federation (ECAF), Belgium
15^{00}–15^{15}	Questions and answers

Session 2: Rehabilitating Degraded Soils with conservation agriculture
Chairs: **Dr. Emilio González and Dr. Alexey Morgunov**

15^{15}–15^{30}	Aspects of using conservation agriculture to improve soil fertility in arid conditions of Karakalpakstan – **Mr. Bakitbay Aybergenov**, UNDP, Tashkent
15^{30}–15^{45}	Assessment of soil properties in the Naryn Basin of Kyrgyzstan – **Prof. Ermek Baybagyshov**, Society of Soil Scientists of Kyrgyzstan, Kyrgyzstan

15^{45}–16^{00}	Rehabilitation of degraded soils with CA in high Mountains conditions – **Mr. Askarsho Zevarshoev,** Mountain Societies Development Support Programme (A project of Aga Khan Foundation), Tajikistan
16^{00}–16^{20}	Coffee-break
16^{20}–16^{35}	The complex technology of restoration of fertility of degraded pasture and arable lands – **Mr. Marat Aldabergenov**, Kazakh Research Institute of Mechanization and Electrification of Agriculture, Kazakhstan
Session 3: Conservation agriculture and Climate Change Mitigation Chairs: **Dr. Amir Kassam and Dr. Fatih Bozdemir**	
16^{35}–16^{55}	Climate change mitigation through conservation agriculture – **Dr. Emilio Gonzalez**, University of Cordoba, European conservation agriculture Federation (ECAF), Spain
16^{55}–17^{15}	Effect of climate change on variation of spring wheat yields at high latitude continental climate sites in North America and Eurasia in 1981–2015 – **Dr. Alexey Morgunov**, CIMMYT
17^{15}–18^{00}	Questions and answers
18^{00}	Closure of the Day – **Dr. Hafiz Muminjanov**
19^{00}	Gala Dinner
6 September 2018 – Thursday Conservation agriculture: National Strategy for Uzbekistan Chairs: **Moderator Dr. Alim Pulatov**	
9^{00}–9^{20}	Application of conservation agriculture in Uzbekistan: National Strategy – **Dr. Aziz Nurbekov**, FAO, Uzbekistan
9^{20}–10^{00}	Discussion
Session 4: Machinery adapted to conservation agriculture Chairs: **Dr. Rafael Fuentes and Dr. Muhammadjon Kosimov**	
10^{00}–10^{20}	Conservation agriculture and related machinery – a global perspective – **Mr. Josef Kienzle**, FAO Head-quarters, Italy
10^{20}–10^{30}	Crop stubble management and conservation agriculture in China – **Dr. Li Hong Wen**, China Agricultural University, China
Session 5: Conservation agriculture and water management Chairs: **Prof. Ibrahim Jafarov and Dr. Josef Kienzle**	
11^{05}–11^{20}	Impact of different tillage and crop residue practices to soil salinity in irrigated area of northwest Uzbekistan – **Dr. Oybek Egamberdiev**, Urgench State University, Uzbekistan

11^{20}–11^{35}	Crop water productivity of maize and soybean under conservation agricultural systems management – **Dr. Mohammad Esmaeil Asadi**, Golestan Agricultural and Natural Resources Research and Education Center, Iran
11^{35}–11^{50}	The efficient water distribution at the irrigation system of the foothill zone of the "Chu" river basin – as the contribution of the soil-protective and resource-saving agriculture in the Chuy Valley of Kyrgyzstan – **Dr. Bakytbek Askaraliev**, Kyrgyz National Agrarian University named after K.I. Skryabin, Kyrgyzstan
11^{50}–12^{05}	The impact of Zero-Till to the agrophysical property of irrigated soil – **Dr. Sanginboy Sanginov**, Centre for Sustainable Agricultural Mechanization (CSAM)
12^{05}–12^{30}	Questions and answers
12^{30}–13^{30}	Lunch

Farmers' Testimony Session: Economic and Environmental Benefits of conservation agriculture
Moderators: **Dr. Amir Kassam and Dr. Aziz Nurbekov**

13^{30}–14^{20} (10 minutes for each presentation)	Country presentations and panel discussion: Uzbekistan – **Mr. Alexey Volkov**; • Kazakhstan – **Mr. Karl Anzelm**; • Kyrgyzstan – **Mr. Zhigitaly Zhumaliev**; • Tajikistan – **Mr. Odiljon Khamidov**; • Turkey – **Mr. Irfan Gültekin**.

Farmers' Testimony Session: Economic and Environmental Benefits of conservation agriculture
Moderators: **Dr. Amir Kassam and Dr. Aziz Nurbekov**

14^{20}–15^{10} (10 minutes for each presentation)	Country presentations and panel discussion – Moderator: • Russia – **Prof. Dr. Gennadiy Olgarenko**; • China – **Prof. Li Hongwen**; • Moldova – **Mr. Marin Grama**; • Azer0baijan – **Prof. Ibrahim Jafarov**; • Georgia – **Dr. Giorgi Ghambashidze**.
15^{10}–15^{45}	Questions and answers

Session 6: Socio-economic and Policy Aspects of conservation agriculture. Upscaling the system
Chairs: **Mr. Marat Aldabergenov and Dr. Mohammad Esmaeil Asadi**

15^{45}–16^{05}	Conservation agriculture as approach towards economically sustainable farming in constrained environments – **Dr. Gottlieb Basch**, University of Evora, Portugal
16^{05}–16^{20}	Barriers to and socio-economic benefits of crop diversification in conservation agriculture in Uzbekistan – **Mr. Kuvat Bapaev**, FAO Sub-regional office for Central Asia, Turkey
16^{20}–16^{35}	Coffee-break
16^{35}–16^{50}	Effects of conservation agriculture on economy and ecology in China – **Prof. He Jin**, China Agricultural University, China
16^{50}–17^{05}	Sustainability through conservation and organic agriculture – **Dr. Uygun Aksoy**, Ege University Faculty of Agriculture Department of Horticulture, Turkey
17^{05}–17^{20}	Problems and prospects of long-Term development of agriculture in resource-saving conditions – **Ms. Darya Ilina**, Institute for Forecasting and Macroeconomic Research, Uzbekistan
17^{20}–17^{35}	Conservation agriculture, sustainable development and strong communities – **Prof. Jenny Martin**, Swinburne University, Australia
17^{35}–17^{50}	How to make farmers optimal for conservation agriculture? – **Ms. Birim Mor**, FAO Sub-regional office for Central Asia (FAOSEC), Turkey
17^{50}–18^{05}	Drivers and challenges of sustainable agriculture development in Ukraine – **Dr. Oksana Ryabchenko**, FAO, Ukraine
18^{05}–18^{45}	Questions and answers
18^{45}–19^{00}	Closure of the Day – **Dr. Hafiz Muminjanov**

7 September 2018 – Friday
Field activities: Conservation agriculture in practice

8^{00}–8^{45}	Travel from Hotel to the demonstration field (Tashkent region)
9^{00}–12^{00}	Water infiltration and soil management – Moderator **Mr. Julio Roman** and **Mr. Antonio Holgado** No-tillage in action: machinery – Moderator **Dr. Alim Pulatov** and **Dr. Aziz Nurbekov** Farmers to visit: **Mr. Ravshan Umarov** and **Mr. Tokhir Niyazov**

12^{00}–12^{45}	Transfer to Restaurant
13^{00}–14^{30}	Lunch, evaluation and closure of the Conference
14^{30}–15^{00}	Travel to Hotel
8 September 2018 – Saturday Departure of participants	

Annex 3.

Editorial committee

Dr. Hafiz Muminjanov, FAO
Dr. Emilio Gonzalez, Spain
Dr. Gottlieb Basch, Portugal
Dr. Uygun Aksoy, Turkey
Dr. Li Hongwen, China
Dr. He Jin, China
Dr. Alim Pulatov, Uzbekistan
Dr. Aziz Nurbekov, Uzbekistan

Annex 4.

Index

A

B

D

E

F

G

H

J

K

L

M

N

O

P

R

S

T

U

W

X

Z

Annex 5.
Footnote list

1	Hafiz Muminjanov	Agricultural Officer, FAO HQ, Italy
2	Amir Kassam	University of Reading, UK
3	Rafael Fuentes Llanillo	Researcher of Instituto Agronomico do Parana IAPAR, Chairman of the International Relations' Committee of the Brazilian No-Till Farmers' Federation FEBRAPDP, Brazil
4	Muratbek Karabayev	CIMMYT, Kazakhstan
5	Khabibullo Pirmatov	Slovak University of Agriculture in Nitra, Slovakia
6	Alim Pulatov	Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Executive Secretary of CASCADE, Head of EcoGIS center of TIIAME, Uzbekistan
7	Antonio Holgado-Cabrera	European conservation agriculture Federation (ECAF), Belgium
8	Julio Roman-Vazquez	ETSIAM, Universidad de Cordoba, Spain
9	Emilio Jesus Gonzalez-Sanchez	Asociacion Espanola Agricultura de Consevacion Suelos Vivos (AEAC.SV), Spain
10	Erdinc Savasli	Transitional Zone Agricultural Research Institute Eskisehir/TURKEY
11	Buriev Salimjon	Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME)
12	Bakhtiyor Abdullaev	Samarkand Institute of Veterinary Medicine, Uzbekistan
13	G.O. Uzakov	Kashkadarya branch of the scientific-research Institute of grain and leguminous crops (Kashkadarya branch SRIGLC)
14	N. Khalilov	Samarkand veterinary medical Institute, Uzbekistan
15	Nurbekov Aziz	Team leader and agronomist, Food and Agriculture Organization
16	Rukhangiz Nurbekova	Uzbek Research Institute of Agricultural Economics
17	Shukhrat Azizov	Independent Researcher, Tashkent State Agrarian University
18	Nurbekov Aziz	Team leader and agronomist, Food and Agriculture Organization
19	Rukhangiz Nurbekova	Uzbek Research Institute of Agricultural Economics
20	Shukhrat Azizov	Independent Researcher, Tashkent State Agrarian University

21	Aziz Nurbekov	FAO Uzbekistan
22	Emilio J. Gonzalez-Sanchez	FAO International Consultant on conservation agriculture
23	Hafiz Muminjanov	FAO Plant Production and Protection Officer
24	A.I. Nurbekov	Team leader and agronomist, Food and Agriculture Organization
25	R.A. Nurbekova	Uzbek Research Institute of Agricultural Economics
26	L.D. Khudoykulov	Tashkent State Agrarian University
27	Meirjan Esanbekov	Republican State Institution "South Kazakhstan Hydrogeological and Land Reclamation Expedition" of the Committee on Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan, Kazakhstan
28	Du You	Center of Agriculture Mechanization Technology Development & Extension, MOA, P.R. China
29	Bakitbay Aybergenov	"Ifoda" LTD
30	Marat Aldabergenov	Kazakh Research Institute of Mechanization and Electrification of Agriculture. Almaty, The Republic of Kazakhstan
31	Amankeldi Sadanov	Kazakhstan National Academy of Natural Sciences
32	Nursultan Orinbaev	Master of agricultural sciences, Doctoral candidate
33	R.M. Makharoblidze	Georgian Technical University, Georgia
34	Shukhrat Bobomurodov	PhD, senior researcher, Researcher Institute of Soil Science
35	Obid Hakberdiev	Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Uzbekistan
36, 37	Emilio Jesús González-Sánchez	Escuela Tecnica Superior de Ingenieria Agronomica y de Montes, Universidad de Cordoba, Spain. Corresponding author European conservation agriculture Federation (ECAF), Brussels, Belgium
38	Óscar Veroz-González	Asociacion Espanola Agricultura de Conservacion. Suelos Vivos (AEAC.SV), Cordoba, Spain
39	Gordon Conway	Centre for Environmental Policy, South Kensington Campus, Imperial College London, UK
40	Amir Kassam	School of Agriculture, Policy and development, Reading University, UK.
41	Manuel Moreno-García	Area of Ecological Production and Natural Resources, IFAPA Centro Alameda del Obispo, Cordoba, Spain.
42	Elena Valkama	Natural Resources Institute Finland (Luke), Bioeconomy and Environment, Sustainability Science and Indicators, Finland.

43	Gulya Kunypiyayeva	CIMMYT-Kazakhstan, Kazakhstan.
44	Erbol Zhusupbekov	Kazakh Research Institute of agriculture and crop production, Kazakhstan
45	Marco Acutis	Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy University of Milan, Italy
46	He Jin	China Agricultural University
47	Mohammad Esmaeil Asadi	Associate Professor, Agricultural Engineering Research Department, Golestan Agricultural and Natural Resources and Education Center, AREEO, Gorgan, Iran
48	Bakytbek Askaraliev	Associate Professor, Head of Molecular Insect Virology Lab., Biocontrol Dept., Iranian Research Institute of Plant Protection (IRIPP), Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran, Center of Excellence for Organic Agriculture.
49	Gennady Olgarenko	Doctor of Agricultural Sciences, Professor, FGBNU, All-Russian Research Institute of Irrigation Systems and Agricultural Water Supply "Raduga", Russia
50	Gottlieb Basch	Institute of Mediterranean Agricultural and Environmental Sciences (ICAAM), University of Eyora, Portugal,
51	Fernando Barros Teixeira	Rural Engineering Department, University of Cordoba, Edificio Leonardo Da Vinci. Campus de Rabanales, Ctra, 14014 Cordoba, Spain
52	Emilio Gonzalez-Sanchez	European conservation agriculture Federation, Brussels, Belgium
53	Kuvatbek Sharshenovich Bapaev	Investment Support Officer (TCIC), FAO SEC, Turkey, Ankara.
54	Liu Wenzheng	Graduate Student, College of Engineering, China Agricultural University, Beijing, China
55	Liu Peng	Graduate Student, College of Engineering, China Agricultural University, Beijing, China
56	Li Hongwen	Professor, College of Engineering, China Agricultural University, Beijing, China
57	Wang Qingjie	Professor, College of Engineering, China Agricultural University, Beijing, China
58	He Jin	Professor, College of Engineering, China Agricultural University, Beijing, China
59	Uygun Aksoy	Honorary President of the Turkish Association on Organic Agriculture, Ekolojik Tarım Organizasyonu Derneğ, İzmir, Turkey

60	Darya Ilyina	Institute for Forecasting and Macroeconomic Research, Uzbekistan
61	Jennifer Martin	Social Innovation Research Institute, Swinburne University, Melbourne, Australia
62	Daniil Kozlov	Soil Institute named after V.V. Dokuchaev, Moscow, Russia

ISBN 978-92-5-132418-9

9 789251 324189

CA8659EN/1/06.20