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CONSERVATION AGRICULTURE IN CHINA
INNOVATIONS
INVESTMENT OPPORTUNITIES
AND CHALLENGES

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CONSERVATION AGRICULTURE IN CHINA

INNOVATIONS
INVESTMENT OPPORTUNITIES AND CHALLENGES

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Foreword

The People's Republic of China faced significant challenges in meeting the food requirements for one-fifth of the world's population. Yet, over the past four decades, China has managed to reduce poverty, achieve food security and become the largest agricultural economy in the world.

However, China still faces many agriculture and rural development challenges.

In the drive to achieve the UN Sustainable Development Goals (SDGs), China is adopting ambitious "green growth" agriculture policies, strategies, institutional frameworks and technologies. The World Bank and the Food and Agriculture Organization of the United Nations (FAO) are engaging with China's green growth agrifood transformation through supporting better policies and better investments.

From 2020 to 2022, a Programmatic Advisory Service and Analytics (PASA) project on *Transforming Rural China: Greening Agricultural Modernization* was undertaken by the World Bank. The project aligns with the World Bank's Country Partnership Framework and FAO Country Programming Framework in China. The objective of the PASA was to demonstrate how existing rural development pathways, alongside the farming policies and strategies, can be reoriented to accelerate progress towards greener agricultural development in China.

One of the valuable approaches in this context is conservation agriculture (CA), a cropping system that can prevent soil losses while regenerating degraded lands. Agrifood systems transformation including CA can bring significant agronomic, environmental, and economic benefits.

Recognizing this, China enabled the policy environment to escalate the promotion of CA to farmers' fields through the adoption of a series of laws and regulations, such as the *Law on the Conservation of Black Soil of China and the Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025).*

China has invested in the development and manufacture of field machinery and equipment to support CA, and has issued comprehensive subsidies to encourage the uptake of modernized crop production systems. The country has acted to localize CA in various regions, and provided valuable opportunities for CA piloting and capacity development. These actions have proved essential in stimulating the adoption of CA in China by farmers.

Meanwhile, FAO, World Bank and other international organizations – for example, the Centre for Sustainable Agricultural Mechanization (CSAM) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) – have united to promote CA in China, including through the Guangdong Agricultural Non-Point Source Pollution Control Policy Research project on *Environmentally Friendly Planting Industry.*

Based on the studies conducted and the lessons learned, the World Bank China Office, the FAO Plant Production and Protection Division and the FAO Investment Centre have joined forces to develop this pivotal publication, drawing on the wealth of experience in the adoption and promotion of CA in China. It is one of a three-part Country Investment Highlights series on China, under FAO Investment Centre Knowledge for Investment (K4I).

This publication provides a timely overview by reviewing the opportunities and challenges of CA in China and providing essential investment recommendations. The aim is to advance innovation, technologies, resources, capacity and equipment, to further advance CA in China, and globally.

We are confident this publication will inspire governments and decision-makers in international and national financing institutions, as well as other donors and development partners, to take a fresh look at how supporting CA can accelerate sustainable agriculture and galvanize rural transformation.

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As one of the technical working papers, this publication was developed by Jin He (Professor, Deputy Director of China Institute for Conservation Tillage, China Agricultural University) and Shangchuan Jiang (Associate Professional Officer/Agriculture Specialist, Plant Production and Protection Division – NSP, FAO).

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Abbreviations and acronyms

8WCCA	Eighth World Congress on conservation agriculture
CA	conservation agriculture
CAAAP	Conservation Agriculture Alliance for Asia-Pacific
CAP	Common Agricultural Policy
CNY	Chinese yuan
CSAM	Centre for Sustainable Agricultural Mechanization
CTRC	Conservation Tillage Research Centre
ECAF	European Conservation Agriculture Federation
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas
ha	hectare
MARA	Ministry of Agriculture and Rural Affairs of the People's Republic of China
MOF	Ministry of Finance of the People's Republic of China
mu	traditional unit of land area in China (1 mu is about 1/15 hectare)
PTO	power take-off
R&D	research and development
SDGs	Sustainable Development Goals
SOM	soil organic matter

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Executive summary

While great progress has been made in agricultural production in China, there are still challenges affecting the sustainable development of agriculture. Conservation agriculture (CA) is a farming system that promotes minimum soil disturbance (i.e. no tillage), maintenance of a permanent soil cover, and diversification of plant species (crop rotation). The adoption of CA can bring agronomic, environmental and economic benefits, and is of great significance to the development of green agriculture in China.

This report focuses on the development path, opportunities and challenges, development suggestions, technology and equipment, experiences, case studies and future prospects of CA in China with the aim of supporting the extension and adoption of CA in China and globally.

THE DEVELOPMENT PATH, CHALLENGES, AND OPPORTUNITIES OF CONSERVATION AGRICULTURE IN CHINA

Development path. The development path of CA in China includes the following four stages: the preliminary exploration stage (1950s–1990), the systematic research stage (1991–2001), the demonstration, extension and prioritized research stage (2002–2008), and the rapid development stage (2009–present).

Main challenges. The challenges of CA development in China include attention to issues such as multiple technology integration, machinery and equipment, manufacturing technologies and materials for critical machine parts, identification of CA technical patterns and long-term effects, extension and demonstration.

Major opportunities. The Chinese government attaches great importance to CA development and provides policy support. Central government, ministries, and governments of different provinces, autonomous regions and municipalities formulated and promulgated relevant policies and regulations for the development and scaling up of CA. The *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* was issued, with the aim of adopting and implementing CA on an area of 9.3 million ha (140 million mu) by 2025, accounting for about 70 percent of the total arable land areas in Northeast China. A batch of available and accessible CA machinery and equipment suitable for national conditions in China has been successfully developed with independent intellectual property rights. CA patterns were basically developed that are suitable for different agricultural regions, including the black soil region in Northeast China, the Loess Plateau region in Northwest China, the oasis agricultural region in Northwest China, the Huang-Huai-Hai annual double-cropping region, and the plain region along the Great Wall in North China. A good socioeconomic environment has been developed for CA. National and local standards have been established for CA machinery and equipment. Furthermore, established experiences have been identified and drawn upon for the development and management of the CA programme.

SUGGESTIONS FOR THE DEVELOPMENT OF CONSERVATION AGRICULTURE

Policy support. It is necessary to formulate national-level CA promotion policies suitable for different agricultural areas. It is important to study and pilot the ecological benefits and subsidy policies of CA, and tax subsidies related to CA enterprises.

Multiple technology integration systems of CA. It is important to optimize and promote multiple technology integration systems to implement the main principles of CA and identify the long-term effects of CA. Additionally, it is necessary to optimize key technologies for uses such as direct seeding, crop diversification, fertilizer and water management, and plant protection (e.g. for weed, pest and disease control).

R&D of CA machinery and key parts. It is important to optimize the processing technology and materials of key parts of CA machinery and equipment; the level of intelligent monitoring and control, and precision management of CA; the operating performance of the no-tillage/low-disturbance seeders; and plant protection and mechanical weed management equipment suitable for CA systems.

Extension and demonstration. Capacity development for human resources is essential to develop a team of technical personnel with solid knowledge and skills for CA. It is important to strengthen the construction of demonstration areas; strengthen training of grass-roots technical staff and farmers; and establish a long-term promotion mechanism.

International exchanges and cooperation. Set up a fund for the international exchange of CA and learn from the good experiences of CA from all over the world.

TECHNOLOGY AND EQUIPMENT OF CONSERVATION AGRICULTURE

Currently, a range of CA machinery and equipment has been developed and applied at large scale in China.

Straw and stubble management and detection technologies and machinery. High-speed rotating chopping knives are usually used in straw and stubble management machinery and equipment. Image processing technology is used in the rapid detection system of straw cover rate.

Technologies and machinery for no-tillage and low-disturbance seeding. Anti-blockage technology lies at the core of no-tillage/low-disturbance seeders. The anti-blockage devices can be divided into gravity-cutting stubble type, power-driven type and straw-flowing type. In addition, innovation technologies such as machine vision, global satellite navigation systems, and no-tillage seeding with automatic guidance systems are applied to improve precision seeding. After several years of research and development (R&D), a series of no-tillage/low-disturbance seeders with high operational performance has been developed in China.

Technologies and machinery for subsoiling. Subsoiling employs a subsoiling shovel to loosen soil and break the soil compaction and plough pan resulting from previous tillage in an initial land preparation. Subsoiling technologies can be divided into the omnidirectional type, chisel type and vibration subsoiling type.

CONTRIBUTIONS OF CONSERVATION AGRICULTURE TO GREEN AGRICULTURAL DEVELOPMENT

CA contributes to achieving Carbon Peak and Carbon Neutrality Goals.
Energy saving and fertilizer reduction. CA effectively reduces agricultural inputs (e.g. fuel and fertilizer) by reducing the operation procedure and improving fertilizer use efficiency, thereby reducing greenhouse gas (GHG) emissions.

Cost saving. CA effectively decreases operation costs (e.g. mechanization operation costs, labour costs and fuel consumption) through the reduction of operation procedures.

Sequestrating carbon and reducing emissions. CA can minimize soil disturbance, thus increasing nutrient use efficiency, slowing down the rate of soil organic matter (SOM) decomposition, and improving soil fertility and soil carbon sequestration. Furthermore, soil cover can reduce straw-burning, and thus reduce greenhouse gas emissions.

CA contributes to decreasing soil erosion.
Decreasing wind erosion. Straw cover can reduce soil surface wind speed and keep soil in the field. Additionally, CA can improve soil aggregate stability and reduce the content of small particles, thus effectively reducing dust from farmland.

Decreasing water erosion. No-tillage/low-disturbance and straw mulching can effectively improve soil structure and enhance soil infiltration capacity during rainfall and irrigation.

CA contributes to improvement of soil structure and fertility. CA adopts no-tillage/low-disturbance, which can reduce soil structure damage caused by tillage, and contributes to the improvement of soil carbon sequestration and fertility. Furthermore, rotted straw and stubble can improve the physical and chemical properties of soil, increase SOM and enrich soil fertility.

CA contributes to soil water conservation and resilience to drought. CA can effectively improve the distribution of soil pores, increase aeration and water storage pores, improve soil hydraulic conductivity and enhance water conservation capacity. CA can improve soil infiltration, and significantly reduce runoff and ineffective soil moisture evaporation, thus contributing towards efficient water storage and conservation, and improving the effectiveness of drought resistance and water-saving measures on farmland.

EXPERIENCE IN PROMOTING CONSERVATION AGRICULTURE

Policy for promoting CA. CA has been addressed in the Chinese No.1 Central Document for 2005–2012 and 2020–2022. *The Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* was issued in 2020. The State Council, ministries and governments at all levels have promulgated relevant policies to promote CA development.

Role of key technologies and equipment for CA. A series of core technologies and machinery for CA (e.g. no-tillage/low-disturbance seeders, subsoilers, and straw retention machinery) suitable for China's national contexts have been developed.

Subsidies for purchasing CA machinery. CA machinery has been included in the agricultural machinery purchase subsidy catalogue.

Suitable technical patterns of CA for different regions. CA technical patterns have been developed according to agricultural conditions in areas such as Northeast China, North China and Northwest China.

Leading role of demonstration projects. Demonstration project funds were utilized effectively and priority supporting areas were determined at different stages of the project in line with the awareness levels of farmers.

Interest-driven mechanism. Multistakeholders were encouraged to promote CA driven by environmental benefits, subsidies and financial support.

Monitoring and evaluation of CA's implementation and impacts. It is crucial to optimize monitoring procedures and the layout of monitoring plots, clarify monitoring and evaluation indicators, and assign responsibility to specific units and individuals.

Training on CA technology. It is important to conduct capacity development activities for multistakeholders such as government officials, extension staff, technicians and farmers through class training, field demonstration of machinery operations and audio-visual materials.

TYPICAL CASES STUDIES OF CA PROMOTION

A large number of successful cases constantly emerged during extension of CA at the county level and the introduction of agricultural machinery at the mechanization cooperative level demonstrated CA's benefits in China. The case studies at the county level include Tailai and Qinggang Counties in Heilongjiang Province, and Bole City in Xinjiang Uygur Autonomous Region. The case studies at the mechanization cooperative level include the Huibin Agricultural Mechanization Specialized Cooperative in Xinbin County of Liaoning Province, the Changchun Agricultural Mechanization Specialized Cooperative in Shenbei District of Liaoning Province, the Xinde Agricultural Mechanization Cooperative in Changtu County of Liaoning Province, the Luwei Agricultural Mechanization Specialized Cooperative in Lishu County of Jilin Province, and Zhitao Agricultural Mechanization Specialized Cooperative in Qingdao City of Shandong Province.

REVIEW OF CONSERVATION AGRICULTURE-RELATED POLICIES WORLDWIDE

Relevant policies and strategies issued by countries in North America, South America and Europe have significantly promoted the development of CA. Meanwhile, projects carried out by international organizations that include the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the Centre for Sustainable Agricultural Mechanization (CSAM) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), have promoted the development of CA in China. Review of the related policies in the world provides the stimulus for the formulation of CA-related policies in China such as measures to increase subsidies for CA, protect the interests of small- and medium-sized farmers, establish a national long-term policy for CA promotion, and strengthen the function of CA in ecosystem services.

PROSPECTS OF CONSERVATION AGRICULTURE DEVELOPMENT IN CHINA

CA technology and equipment. Intelligent CA equipment with high performance and high operation quality will be developed and be at a leading level in the world.

CA technical patterns. Optimized CA technical patterns for different areas will be developed according to considerations such as soil, climate, and cropping systems to achieve high yield, high efficiency and cost savings.

Support policies for CA. Policies will be issued to support and promote CA suitable for agricultural regions in Northeast, Northwest and North China, and CA technology will develop rapidly.

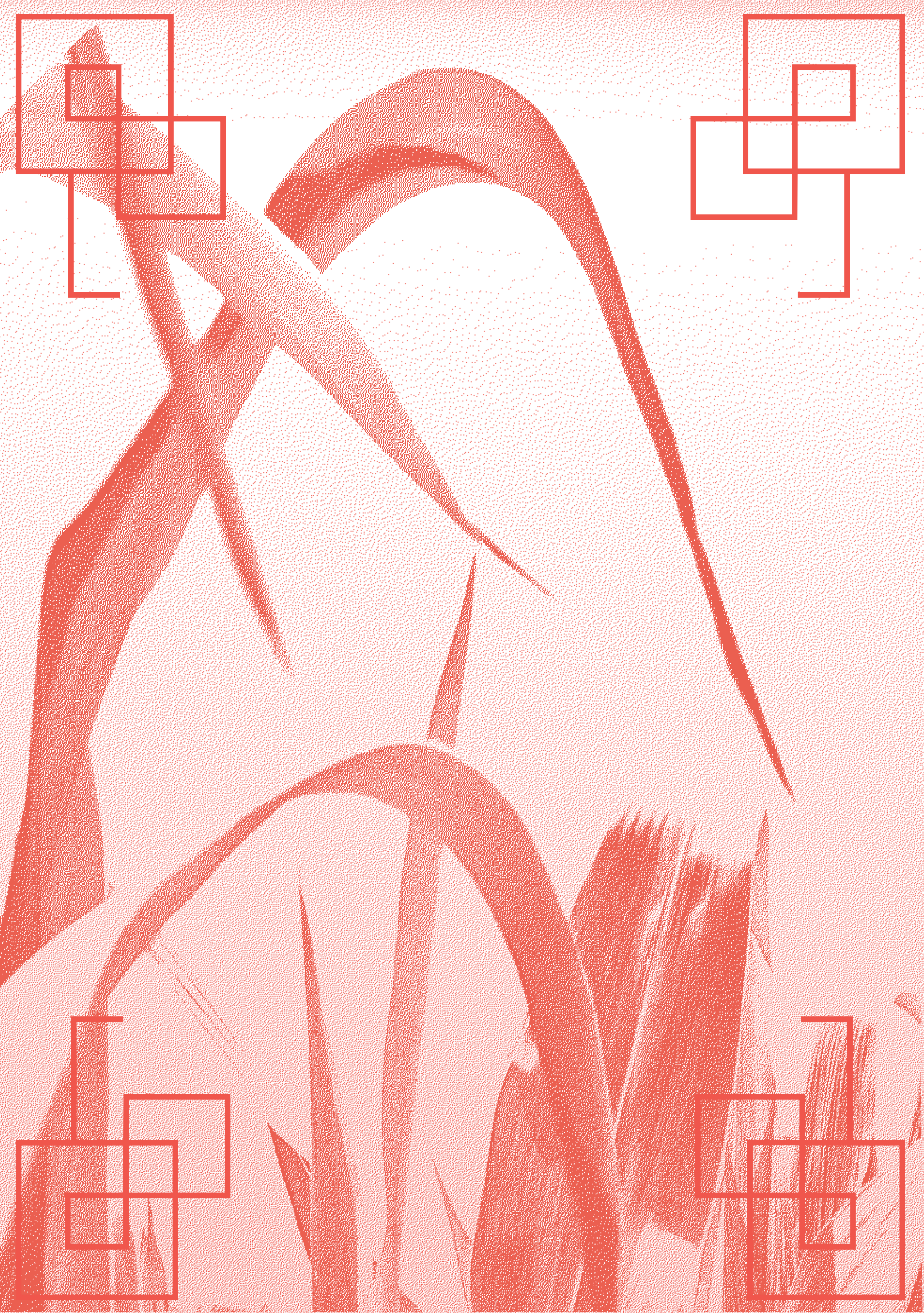
CA adoption. With the support of machinery and equipment, technical patterns and policies, CA will be adopted on a larger scale in China.

Introduction

Although there have been great achievements in agricultural production in the People's Republic of China, there are also challenges to face such as soil degradation, water shortages and agricultural environmental pollution that affect the sustainable development of agriculture. *The 14th Five-Year Plan for Economic and Social Development and Long-Range Objectives through the Year 2035 of the People's Republic of China* puts forward measures to promote the sustainable development of agriculture, including promoting the green transformation of agriculture, strengthening environmental protection and management in agricultural areas, developing water-saving agriculture and sustainable dryland agriculture, implementing actions to decrease the use of chemical pesticides and fertilizers, and promoting integrated straw management and the resource use of livestock and poultry manure.

Conservation agriculture (CA) is a farming system that promotes minimum soil disturbance (i.e. no-tillage), maintenance of a permanent soil cover, and diversification of plant species (i.e. crop rotation) (FAO, 2017). CA can decrease wind and water erosion and improve soil fertility and resilience to drought. It has additional advantages, such as water and moisture conservation, cost-saving benefits, and improvements in efficiency and soil fertility (MARA, 2008). Additionally, the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* was issued by the Ministry of Agriculture and Rural Affairs (MARA) and the Ministry of Finance (MOF). The adoption of CA can bring agronomic, environmental and economic benefits, and is of great significance to the development of green and sustainable agriculture in China.

This report focuses on the development path, opportunities and challenges, development suggestions, technology and equipment, experiences, typical case studies, and future prospects of CA in China, aiming to support the extension and adoption of CA in China and globally.



Chapter 1
The development path, challenges, and opportunities of conservation agriculture in China

China has diverse geographical and climatic conditions, thus cropping systems and agricultural development levels vary in different regions. Northern China is dominated by a temperate continental climate and temperate monsoon climate with low annual rainfall and uneven seasonal distribution across mostly arid and semi-arid regions. Although conventional agriculture guarantees crop production, it leads to environmental problems such as soil degradation and soil fertility decline, making it hard to achieve sustainable agricultural development. In this context, conservation agriculture (CA) was introduced into China in the 1950s.

This section focuses on the development path, opportunities and challenges of CA in China. The development path has four stages: the preliminary exploration stage, the systematic research stage, the demonstration, extension and prioritized research stage, and the rapid development stage. Additionally, the challenges of CA development in China include factors such as multiple technology integration, CA machinery and equipment, manufacturing technologies and materials for critical machine parts, identification of the technical patterns and long-term effects of CA, and extension and demonstration. Based on these considerations, the current major opportunities for CA development in China are discussed, including the importance attached and policy support provided by the Chinese government through the *Action Plan for*

Conservation Agriculture of Black Soil in Northeast China (2020–2025), availability and accessibility of CA machinery and equipment, applicable regional CA technical patterns, good socioeconomic environment, national and local standards established for CA machinery and equipment, and long-standing experiences for programme development and management.

1.1 DEVELOPMENT PATH

In the 1950s, China began to test the key elements of CA, such as no tillage, straw cover, and supporting technologies (e.g. subsoiling). Since 1991, with the integration of agricultural machinery with agronomy, systematic CA experiments and demonstrations have been conducted in northern China (i.e. Northwest, North, and Northeast China), and the rice-wheat cropping systems in southern China. In the twenty-first century, the central government and local governments at all levels have placed great importance on the research, demonstration and extension of CA. The development path of CA in China includes the following four stages.

(1) The first stage (1950s–1990): the preliminary exploration stage

From the 1950s, experiments on no-tillage wheat seeding were conducted in Heilongjiang, Jiangsu, and Shandong provinces (Kassam *et al.*, 2014). In the 1980s, some related technologies were studied in North China, including practices such as low-disturbance tillage in fields with high-standing wheat stubble in dryland areas, no tillage in fields with maize straw mulching in dryland areas, and no-tillage/low-disturbance cultivation in annual double-cropping areas. In Northeast China, studies of the no-tillage technologies were conducted on maize cropping systems, for example combining straw cover with ridge farming (Benites, Derpsch and McGarry, 2003). These studies were mainly aimed at increasing resilience to drought, improving crop yield and promoting the development of CA in China from many aspects, especially in the rapid development of no-tillage seeding technology for maize in North China. However, these studies were based mainly on the use of human labour and animal-powered operations. Because of the limitations of technology, equipment, the socioeconomic development level, and many other factors, these technologies were adopted by farmers only on a small scale.

(2) The second stage (1991–2001): the systematic research stage

Since the 1990s, systematic experiments with CA have been carried out in agricultural stations to integrate agricultural machinery and agronomy. In line with the conditions and constraints in agriculture in China at that time (e.g. small plots, low tractor power, and low economic purchasing power), a series of investigations were conducted on no-tillage seeders, subsoilers, and shallow-tillage machines suitable for dryland farming areas, and the power take-off (PTO) driven, no-tillage seeder suitable for annual double-cropping areas (Derpsch *et al.*, 2010; Kassam *et al.*, 2009). At this stage, CA adoption areas increased rapidly, and significant progress was made in CA machines and technologies suitable for the national conditions, which proved the adaptability of CA in China and the feasibility of mechanized CA in small plots.

In 1991, China Agricultural University started systematic experimental research on CA by integrating agricultural machinery and agronomy; long-term experimental sites have been established since then. In 1992, China Agricultural University, the University of Queensland, and Shanxi Agricultural Machinery Bureau started the China–Australia cooperation project on CA, and established a CA experimental site. Small- to medium-sized no-tillage seeders with structural features such as narrow openers, high clearance, and double beams were developed for small horsepower tractors and small plots, based on the wheat and maize production system in the one-crop-a-year region at the Loess Plateau of Northwest China. These types of machinery employed passive methods to prevent straw blockage during no-tillage seeding.

The research achievements of the no-tillage seeders laid a solid foundation for the development of CA machinery in the one-crop-a-year region in North China. The CA promotion mechanism was preliminarily established through trainings for rural households with CA machinery, agricultural households specialized in plant production, and agricultural mechanization hire service providers and organizations; several standardized long-term CA experimental sites were established. In 1999, the Conservation Tillage Research Centre (CTRC) of the Ministry of Agriculture and Rural Affairs of the People's Republic of China (MARA) was established at China Agricultural University.

In this stage, the achievements proved the adaptability of CA in China, and a series of small- to medium-sized CA machinery was developed.

(3) The third stage (2002–2008): demonstration, extension and prioritized research stage

i) Demonstration and extension in fifteen provinces, municipalities, and autonomous regions in North China

In 2002, the MARA held the first national CA meeting in Shanxi Province to demonstrate the CA achievements of the first and second stages; this marked the transition of development of CA in China from local technical research to large-scale demonstration. The national demonstration project of CA was launched in 2002 and CA was demonstrated and extended into 38 counties of eight provinces, municipalities and autonomous regions in North China. The development of CA then entered the third stage of demonstration, extension, and prioritized research.

Technical documents and management specifications were formulated, such as the *Implementation Essentials of Conservation Agriculture,* the *Implementation Specifications of Conservation Agriculture Project,* the *Implementation Effect Monitoring Specifications of Conservation Agriculture,* the *Code for Implementation of Conservation Agriculture Project and Key Technologies of Conservation Agriculture* (MARA, 2011). Various training materials and knowledge products were prepared and produced, such as *Training Materials of Conservation Agriculture Technology*, the *Conservation Agriculture Brochure*, the *Reference Catalogue of Conservation Agriculture Machinery*, and *Videos on Conservation Agriculture Promotion*. Proposals on CA development were prepared by many provinces, municipalities, and autonomous regions to vigorously promote CA. High-performance CA machinery was selected and recommended to farmers. Agricultural machinery departments of governments at all levels used publicity platforms to widely advocate CA technologies via television, radio, newspapers, and magazines. Farmers and local technicians were trained through events such as field workshops and exhibitions.

In 2005, the No. 1 Central Document, the first policy statement released each year by the Chinese central government, outlined measures for *Reforming Conventional Tillage and Developing Conservation Agriculture* (the Central People's Government of People's Republic of China, 2006). A national CA expert group was established by the MARA in 2005, and regional CA expert teams at the provincial and county levels were also set up. Monitoring sites were set up in typical areas to monitor the effects of CA. In 2007, the *Proposal on Vigorously*

Developing Conservation Agriculture (MARA, 2007) was launched. CA adoption areas had increased from about 0.07 million hectares (ha) in 2002 to more than 2.67 million ha by the end of 2008.

ii) Prioritized research: annual double-cropping areas and ridge farming areas

In this stage, in addition to researching and optimizing the CA technical system and machinery at the Loess Plateau in Northwest China, prioritized research for CA technologies was conducted in annual double-cropping areas in North China and ridge farming areas in Northeast China (Liang *et al.*, 2012).

Continuous CA in annual double-cropping areas in North China. At the end of the twentieth century the technology of no-tillage seeding for summer maize after wheat harvesting was widely promoted and adopted in most areas of North China, which played a significant role in preventing straw burning, saving costs, increasing efficiency, and contributing to sustainable agricultural development. However, it was difficult to achieve continuous CA throughout the whole growing season since conventional tillage was still applied for wheat seeding after the summer maize harvesting. CA was generally applied in the one-crop-a-year region, but there were not many well-established experiences and technologies of CA in the annual double-cropping practices.

Supported by the National Tenth Five-Year Scientific and Technological Project, as well as projects of the MARA and some provinces, CA technology and machinery research in annual double-cropping areas in North China was conducted on no-tillage/low-disturbance seeding for wheat after maize harvesting. The research focused on solving the challenges of no-tillage/low-disturbance seeding for wheat into heavy maize residues.

After nearly 10 years of research, enterprises were able to produce PTO-driven wheat no-tillage/low-disturbance seeding technologies and machinery suitable for different straw cover conditions, such as strip shallow-rotation and low-disturbance seeding, strip chopping and no-tillage seeding, and PTO-driven disc no-tillage seeding. About 20 enterprises were able to produce this type of machinery. As a result of these continuous CA technologies in annual double-cropping areas, China became both a leading force in efforts internationally and highly regarded by CA experts from the Food and Agriculture Organization of the United Nations (FAO), the International Soil and Tillage Research Organization (ISTRO) and others. Relevant Chinese CA researchers and technical experts were invited to introduce this technology at various international conferences.

CA in ridge farming areas in Northeast China. At the very beginning, CA technologies and machinery developed for the flat-land cropping areas were adopted in the ridge farming (where crops are planted into ridges formed in the land) areas in Northeast China. Although some positive results were obtained, the advantages of CA were not fully achieved in the ridge farming areas. Therefore, from the beginning of the *National Eleventh Five-Year Plan (2006–2010)*, research into CA technology and machinery for ridge farming areas was conducted with support from national and MARA projects. Researching CA operating processes and technical patterns solved problems in ridge farming areas such as straw blockage and ridge renovation. Thus, a set of suitable CA technology, machinery and equipment was developed in ridge farming areas for maize no-tillage/low-disturbance seeding.

During this stage, the first-generation CA machinery and technical patterns were basically developed, suitable for the one-crop-a-year region, annual double-cropping areas, and ridge farming areas. Some exploratory studies have also been carried out in the Yangtze River valley and the northwest oasis agricultural areas. The preliminary results showed that mechanized CA in the paddy rice areas of the Yangtze River valley was feasible, and the adoption of CA in this region also had advantages of saving costs, increasing economic efficiency, and improving soil fertility. The adoption of CA in the oasis farming areas in Northwest China can preserve water and soil moisture, increase resilience to drought, save irrigation water, decrease wind/water erosion, and increase crop yield as compared to conventional tillage with flood irrigation.

(4) The fourth stage (2009–present): rapid development stage

In the second and third stages, CA machinery and technical patterns suitable for different regions were generally developed in China. Nevertheless, some challenges still existed, including the lack of machinery types, lack of machinery of high performance, and poor adaptability of some technical patterns to specific local contexts.

In 2009, the *National Construction Program of Conservation Agriculture (2009–2015)* (MARA and National Development and Reform Commission, 2009) was developed to strengthen the construction of an enabling environment for CA research and extension. Since 2014, the central government has provided subsidies for subsoiling (one of the main technologies to remove soil compaction before starting CA) operations; and the machinery and equipment for subsoiling and land preparation were listed in the key category for subsidizing.

In 2020, the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* was issued by the Ministry of Agriculture and Rural Affairs (MARA) and the Ministry of Finance (MOF) (MARA and MOF, 2020). The action plan sets out the targets of CA development in China; it states, for example, that the application areas of CA should reach 9.33 million ha by 2025, accounting for about 70 percent of the total arable lands in suitable areas of Northeast China. Additionally, improved and integrated systems should be developed and refined for the sound and sustainable development of CA, including policy systems, technology and equipment systems, and extension and application systems. Promoting CA in Northeast China has become a national action, which is conducive to protecting black soil from degradation, improving soil quality, and consolidating the foundation of national food security. The action plan indicates that CA is prioritized by government from the top to grassroot levels in China.

Technical support for extension and adoption of CA has been gradually strengthened. CA technical systems have been developed that are suitable for different regions, different soil types, and different straw biomass. No-tillage/low-disturbance seeders and other CA machinery are also optimized. By the end of 2018, the area put to CA had reached 8.24 million ha in China (MARA, 2019).

1.2 MAJOR CHALLENGES

After decades of experiments and demonstrations, the feasibility of CA technology in China has been proven and technical patterns and machinery systems tailored for different areas have been basically developed. However, challenges still exist for the development of CA in China.

(1) Multiple technology integration

Currently, CA technologies, machinery and equipment are developed mainly focused on no-tillage/low-disturbance seeding, straw retention management, and subsoiling, as well as on the innovation of single technology. However, multiple technology integration and coordination is urgently needed in a combination of different operations to implement the CA principles in areas such as production to harvesting management, seeding quality control, cropping systems, fertilizer and irrigation management, and pest and weed prevention and control.

Seeding quality control technology. Existing no-tillage/low-disturbance seeders can generally conduct seeding operations in fields with heavy straw cover. However, it is essential to study the technology to ensure operating quality for high-speed no-tillage/low-disturbance seeding under straw cover conditions while still reducing soil disturbance.

Crop diversification in CA system. The adoption of species diversification (i.e. crop rotation and association involving at least three different crop species) under the conditions of no-tillage and straw mulching has been relatively slow in China.

Fertilizer and irrigation management technology. The adoption of CA increases topsoil fertility; however, improvement of fertility in deep soils is relatively slow. Currently, the stratification effect of no-tillage on nutrient availability across the soil profile and its impact on nutrient uptake by the crop is still not clear. Therefore, further studies should be carried out to understand such mechanisms and to optimize precision fertilization and nutrient use efficiency. Water-saving irrigation technologies feasible in CA systems, such as subsurface irrigation, should be further studied to conserve water while ensuring crop production.

Plant pests, disease and weed control. Because of the straw cover in a CA field, conventional plant protection technology, especially weed control, whether chemical or physical, is not suited to such conditions. Efficient and effective plant protection technology under straw cover conditions needs to be further studied to solve that problem.

(2) CA machinery and equipment

The studies of CA machinery and equipment in China mainly focus on no-tillage/low-disturbance seeders, subsoilers, and straw management machinery. Although the CA machinery and equipment basically meets the operating requirements under straw cover conditions, the operating quality needs to be improved. In addition, the existing no-tillage/low-disturbance seeders are mostly suitable for crops such as wheat and maize and dryland farming areas in North China, while machinery and equipment still need to be further researched and developed for more crop varieties such as coarse cereals and rapeseed as well as the crops in paddy fields in South China. Additionally, further development is needed for weeding machines and plant protection equipment for soil cover conditions. In addition, CA machinery and equipment using artificial intelligence, digital technologies and other cutting-edge technologies will be further researched in order to meet the increasing requirements for high-performance and smart agriculture.

(3) Manufacturing technologies and materials for critical machine parts

Under the conditions of straw cover, the operating conditions of no tillage, straw management, and subsoiling are complex and uncertain. During operations, critical machine parts such as anti-blockage parts, straw chopping parts (e.g.

chopping blades and discs) and subsoiling shovels often become worn. The cutter shaft, spring tooth, and other parts can be easily misshapen by high dynamic stress and impact load. Therefore, it is important to improve the processing technologies and materials for critical machine parts in equipment manufacturing through the following routes: (i) Processing technologies: Advanced processing technologies in equipment manufacturing can be employed to fully guarantee the operating performance of key parts, for example, gas metal arc welding, hard facing of wear-resistant materials, surface coating, and heat treatment. (ii) Materials: New materials featuring corrosion resistance, wear resistance, impact resistance, and fatigue resistance can be used for CA machinery as appropriate through interdisciplinary studies. The improvement of processing technologies and materials in equipment manufacturing is the key to improving the operating performance of critical parts of CA machinery.

(4) Identification of CA's technical patterns
China has developed some CA technical patterns suitable for different agricultural areas. However, China is huge with areas of different climatic and environmental conditions, soil types, cropping systems, machinery levels, and economic development levels. Thus, more technical patterns of CA should be developed to meet local conditions in various areas. It is necessary to refine and improve CA technical patterns that are suitable for different areas, and establish norms and standards for CA operations based on further field experiments and demonstrations to guide the extension and adoption of CA.

(5) Identification of CA's long-term effects
Some studies investigated the effects of CA in China on reducing soil erosion, improving soil structure and fertility, enhancing soil microbial population structure, and increasing crop yield. However, most studies were based on short-term experiments. The long-term effects of CA on crop yield, and the population structure of soil biodiversity in different regions, different environments, and under different cropping systems in China still need further research. The effects of multiple factors need to be further studied in CA fields, such as the effects of the straw returning method and straw cover quantity, subsoiling depth and interval, and species diversification (crop rotation/association) on crop yield, soil properties, and greenhouse gas (GHG) emissions from farmland.

(6) Extension and demonstration of CA
The current extension and demonstration of CA in China has made significant advances in enhancing understanding and raising awareness of CA among researchers, government staff, farmers, enterprise staff, mechanization hire service providers and organizations, and other stakeholders. Nevertheless, existing trainings and demonstrations should be improved to further address the challenges of inadequate knowledge and skills of technical personnel, inadequate farmer awareness, and insufficient demonstration effects.

Incomplete agricultural talent teams. The knowledge of agricultural professionals of CA equipment, technical patterns, and related theories should be improved; and CA technical personnel should be further strengthened through scientific research institutes, extension institutions at all levels, agricultural machinery enterprises and mechanization hire service providers. There are insufficient rural youth and women engaged in promoting CA through decent jobs and innovations, such as new agricultural business entities.

Inadequate farmer awareness. CA has been demonstrated for many years, but it will take time to raise awareness of farmers and change their mindset from conventional tillage. It takes several years to fully achieve the economic, agronomic and environmental benefits (e.g. increased yield and improved soil structure) of CA. Some benefits cannot be fully achieved because of inadequate CA technical patterns, incomplete CA machinery, and low operating quality. The advocacy and extension of CA should also take rural women and men, youth and vulnerable groups into consideration. All these factors affect the acceptance and adoption of CA by farmers.

Insufficient demonstration effects. Demonstration still needs to be strengthened. CA extension and development models should be improved, such as demonstration villages leading CA development in the townships, and demonstration townships leading the national development of CA, and other innovative models.

Incomplete long-term promotion mechanism. The long-term mechanism for CA promotion should be established. The profits of farmers and machinery enterprises must be ensured. The quality of machinery needs to be improved. Mechanization hire service providers and new agricultural business entities (e.g. cooperatives) should play a leading role in the adoption of CA by increasing the accessibility of sustainable mechanization to smallholder farmers.

1.3 MAJOR OPPORTUNITIES

(1) Importance attached and policy support provided by the Chinese government

With the extension and adoption of CA, its benefits were fully recognized by the central government and local governments at all levels. A series of laws and policies (Table 1) were issued to accelerate the development of CA. In 2022, the National People's Congress passed the *Law on Black Soil Conservation of the People's Republic of China* (National People's Congress of the People's Republic of China, 2022), as part of efforts to ensure the country's food security and protect the ecosystem. The Law requires people's governments at or above the county level to protect black soil by adoption and extension of CA and agricultural machinery. Since 2005, the No. 1 Central Document has made proposals more than ten times (2005–2012, 2020–2022) for the development and promotion of CA. At the same time, ministries and governments of different provinces, autonomous regions, and municipalities formulated and promulgated relevant policies and regulations. All of these factors significantly promoted the experiments, demonstrations and extension of CA in China.

(2) Action plan for conservation agriculture of black soil in Northeast China (2020–2025)

After years of effort, CA in Northeast China has made significant progress. The technical patterns have generally been developed, and critical items of machinery and equipment that perform well are available; these elements form the basis for large-scale extension of CA in Northeast China. To accelerate the application of CA in Northeast China, MARA and MOF jointly issued the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*. According to this action plan, the application areas of CA will reach 9.33 million ha by 2025, accounting for about 70 percent of the arable lands in suitable areas of Northeast China, and CA will be the mainstream agricultural technology and practice there.

Table 1
Selected policies for promoting CA in China

Types/agencies	Contents/names
National People's Congress	• The *Law on Black Soil Conservation (2022)* was enacted to protect the black soil.
No. 1 Central Document	• The No. 1 Central Document has made proposals more than ten times (2005–2012, 2020–2022) for the development and promotion of CA. Among them are the following: • *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* was issued in 2020. • *Implementation Plan of National Black Soil Conservation Project (2021–2025)* was issued in 2021.
State Council	• *Decision on Further Strengthening Desertification Control and Prevention (2005)* • *Notice of the State Council on Strengthening Land Regulation (2004)* • *Program of Action for Sustainable Development in China in the Early 21st Century (2003)* • *Opinions on Promoting the Sound and Rapid Development of Agricultural Mechanization and Agricultural Machinery Industry (2010)* • *China's Policies and Actions for Addressing Climate Change (2021)* • *National Agricultural Water-Saving Program (2012–2020)* • *National Agricultural Modernization Plan (2016–2020)* • *National Climate Change Program (2014–2020)*
Ministry of Agriculture and Rural Affairs, National Development and Reform Commission, Ministry of Science and Technology, Ministry of Finance, Ministry of Natural Resources, etc.	• *National Desertification Control and Prevention Plan (2011–2020)* • *National Construction Program of Conservation Agriculture (2009–2015)* • *National Agricultural Sustainable Development Plan (2015–2030)* • *Guidance Opinions on Accelerating the Development of Agricultural Circular Economy (2016)*
Shanxi Province, Hebei Province, Sichuan Province, Liaoning Province, Shandong Province, Henan Province, etc.	• *Planning for Poverty Alleviation and Development in Agricultural Industry (2011–2020)* • *Implementation Opinions of Hebei Provincial People's Government on Strengthening the Capacity Development of Grain Production* • *Notice on Implementation Plan of Agricultural Energy Conservation and Emission Reduction in Shandong Province*

SOURCE: Authors' own elaboration.

The counties (cities and districts) with a good basis for CA adoption should be selected preferentially for extension of CA at the whole-county level; in these counties, long-term and sustainable mechanisms with well-established CA technologies will be developed in about three years, and CA areas will cover more than 50 percent of the total area of cultivated land that is suitable for adoption of CA. In other counties (cities and districts), pilot demonstrations of CA will be carried out to gradually scale up the implementation area and extension of CA at the whole-village or township level if the conditions allow. A CA Expert Steering Group will be established to formulate the main technical patterns and standards, conduct technical trainings and exchanges, and guide the construction of CA experimental and demonstration sites to provide decision-making services and technical support for the action plan.

(3) Available and accessible CA machinery and equipment

Availability of CA machinery and equipment is indispensable to guaranteeing efficient adoption of CA. Research into such machinery and equipment has made great progress and several items of CA machinery and equipment have been developed with independent intellectual property rights that are suitable for different conditions in China, mainly no-tillage/low-disturbance seeders for wheat/maize, straw chopping and returning machines, and subsoilers. More than 100 enterprises in China are producing CA machinery and equipment, and the market share of domestic products exceeds 90 percent. Each year, MARA guides farmers in purchasing high-performance CA machinery and equipment. Availability of machinery and equipment provides the support for large-scale extension of CA in China.

(4) Applicable regional CA technical patterns
After decades of research, integration and innovation, various CA technical patterns have been developed that are tailored to the various climatic and soil conditions and cropping systems in different areas, including patterns suitable for the black soil region in Northeast China, the Loess Plateau region in Northwest China, the oasis agricultural region in Northwest China, the Huang-Huai-Hai annual double-cropping region, and the plain region along the Great Wall in North China. All these regional CA technical patterns have been scaled up in China.

(5) Good socioeconomic environment
Central government policy guidance has provided an opportunity to speed up technology promotion for resource conservation, environmental friendliness and the transformation of agricultural development, all of which offer opportunities for speeding up the extension of CA. Furthermore, the steady development of industrial manufacturing levels in China also contributes to the development of CA.

The amount of agricultural machinery and equipment continues to increase with agricultural mechanization operational level improving constantly in China. In 2019, the comprehensive mechanization rate of land preparation, seeding/planting and harvesting in China exceeded 70 percent, and the mechanized production of wheat, rice and maize has basically been achieved. Implementation of the central government's policy for strengthening and benefiting agriculture has been steadily enhanced. Farmers were highly motivated to purchase agricultural machinery and adopt advanced agricultural production technology, which creates a good opportunity for CA development.

(6) National and local standards established for CA machinery and equipment
China has formulated national and local standards that have promoted research and development (R&D) and the development of machinery and equipment for CA in the conservation tillage stage. Standards such as GB/T 24675.1-2009 conservation tillage equipment-shallow cultivator; GB/T 24675.2-2009 conservation tillage equipment-subsoiler; GB/T 24675.3-2009 conservation tillage equipment-spring-tooth harrow; GB/T 24675.4-2009 conservation tillage equipment-disc harrow; GB/T 24675.6-2009 conservation tillage equipment-straw-chopper machine; NY/T 2085-2011 technical specification for mechanized conservation tillage of wheat; and NY/T 2190-2012 terms for mechanized conservation tillage.

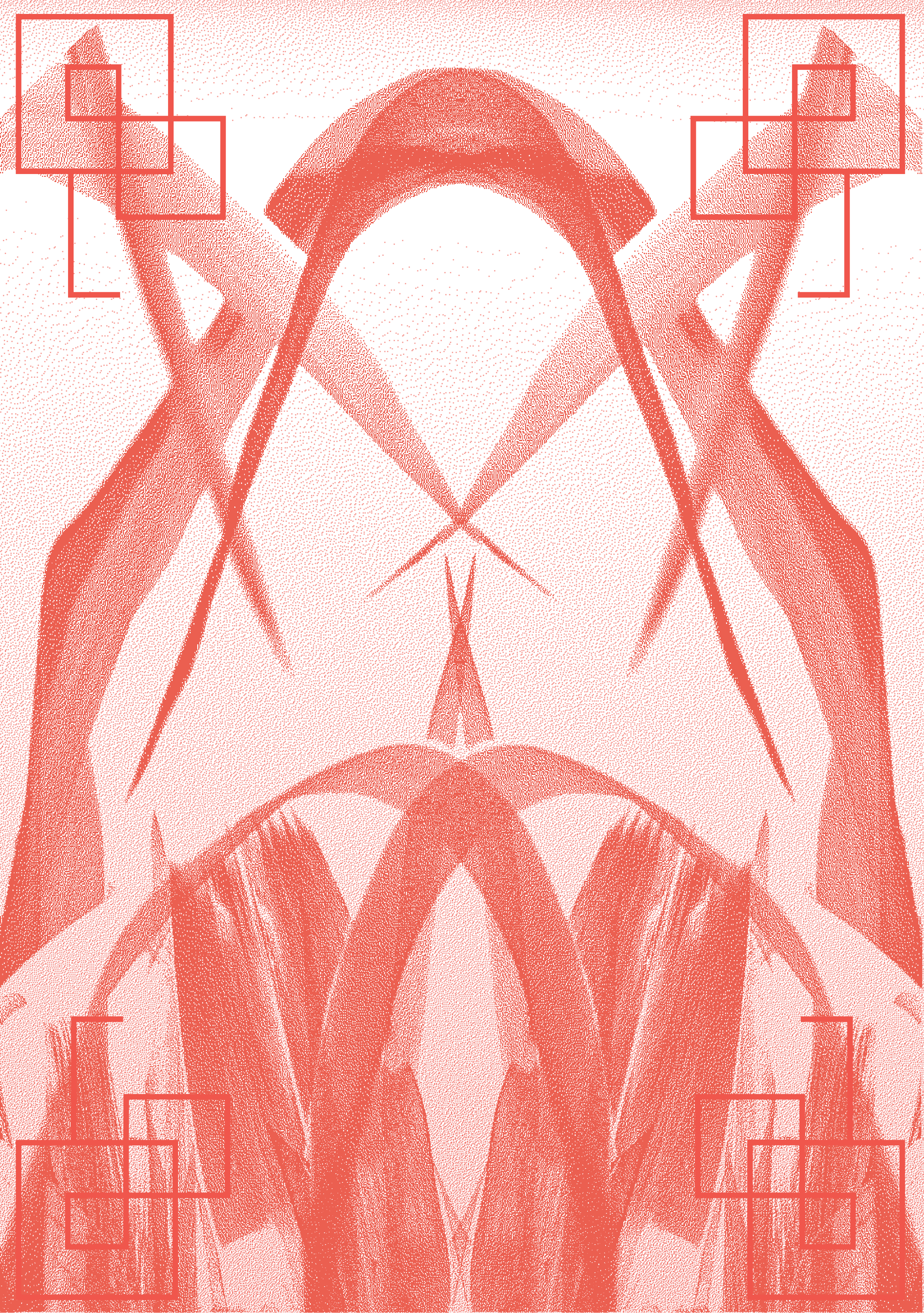
(7) Established experiences for CA programme development and management
Through long-term practice, a series of scientific, standardized, and institutionalized construction measures have been formulated for CA programme and project development and management, including the following:

i) Establishing complete rules and regulations. Technical documents and management specifications were formulated to strengthen the supervision and inspection of projects, such as *Implementation Essentials of Conservation Agriculture*; *Implementation Specifications of Conservation Agriculture Projects*;

Implementation Effect Monitoring Specifications of Conservation Agriculture; and *Methods for the Inspection and Evaluation of Conservation Agriculture Projects*. Expert groups were established to provide technical guidance.

ii) Attaching importance to publicity and training. Various trainings and advocacy materials were compiled and distributed, such as *Training Materials of Conservation Agriculture Technology*; *Questions and Answers for Conservation Agriculture Knowledge*; the *Reference Catalogue of Conservation Agriculture Machinery*; a *Conservation Agriculture Promotional Video*; and the *Conservation Agriculture Brochure*. Field meetings and various media were employed to widely publicize and advocate CA.

iii) Exploring the operating mechanism. A comprehensive service system of CA was preliminarily established. The comprehensive CA service system is promoted by the government with the involvement of farmers and multistakeholders. The specialized agricultural mechanization hire service organizations, and large-scale agricultural machinery households are the main players of the service system with the support of grass-roots agricultural machinery extension institutions and machinery maintenance and information consultation service organizations. The market-oriented service mechanism was also improved. These experiences have established a good foundation for the extension of CA.



Chapter 2
Suggestions for the development of conservation agriculture

After years of exploration, the CA technical patterns suitable for Northeast China, North China, Northwest China and other regions have been basically identified. Meanwhile, CA machinery and equipment have been developed; experimental and demonstration sites have been established; and several enterprises for the production of CA equipment have been established. All these lay a good foundation for the rapid development of CA in China. This section puts forward suggestions for the development of CA from, for example, aspects of policy support, multiple technology integration systems, R&D of CA machinery and parts, training and demonstration, and international cooperation and exchange.

2.1 POLICY SUPPORT

(1) Formulate national-level CA promotion policies suitable for different agricultural areas. To promote black soil conservation, MARA and MOF jointly issued the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)* in 2020, which strongly promoted the adoption of CA in Northeast China. However, in dryland farming areas (e.g. North China Plain and Northwest China), policy support at the national level is still lacking. Therefore, CA promotion policies suitable for different regional characteristics need to be formulated that are based on the implementation experiences of the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*.

(2) Study and pilot the ecological benefits and subsidy policies of CA. Most of the existing policies focus on subsidies for the purchase of CA equipment that motivate farmers to purchase machines. At present, with the implementation of the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025),* relevant subsidies are applied for CA adoption in the black soil region there. Therefore, it is recommended that environmental benefit subsidies (i.e. subsidizing CA for its positive effects in soil, water and environment) should be studied and piloted in other regions to fully motivate farmer engagement.

(3) Study and pilot tax subsidies related to CA enterprises. As CA machinery and equipment are different from traditional ones, a study and piloting of tax subsidy policies (such as tax-reductions and exemptions) for CA machinery and equipment enterprises, is recommended; farmer willingness to update machinery would be encouraged by reductions in the cost of CA machinery and equipment.

2.2 MULTIPLE TECHNOLOGY INTEGRATION SYSTEMS OF CONSERVATION AGRICULTURE

(1) Optimize integrated system and identification of long-term effects of CA. The following studies are needed: Studies of the effects of soil type, straw-returning amount, and returning method on the transfer of “light, heat, water, gas, and fertilizer” in the farmland environment and crop yield in different regions and cropping systems. Studies of areas such as the impact of long-term CA practice implementing the main principles (e.g. no tillage, organic cover of soil and crop diversification) on physical and chemical properties of soil, microbial community structure of soil, and crop yield, cost-benefits, and GHG emissions. It is indispensable to improve the design and implementation of crop diversification (e.g. rotations and intercropping) for CA systems according to the various objectives based on local context and value chain.

(2) Optimize key technologies for direct seeding. Studies are needed into the following: the effects of speed and vibration on seeding quality to develop seeding depth control systems in different regions and cropping systems; and the real-time monitoring system of seeding parameters and adjusting seeding rates in real time according to the information on soil fertility, expected yield, and climate.

(3) Optimize cropping fertilizer and water management technology. Studies are needed into the following: the effects of application years of CA on the distribution of nitrogen, phosphorus, and potassium in different regions and cropping systems; the effects of fertilizing rate, irrigation amount, and application time, frequency, and method on crop growth, yield, and soil fertility: and the fertilizer management and irrigation machines under the conditions of straw mulching.

(4) Optimize plant protection technology for weed, pest, and disease control. A study is needed into the effects of application quantity, type, and time of pesticides and herbicides, and developing plant protection equipment suitable for the conditions of straw mulching without soil engagement.

2.3 RESEARCH AND DEVELOPMENT OF CONSERVATION AGRICULTURE MACHINERY AND PARTS

(1) Optimize the processing technology and materials of key parts of CA machinery and equipment. The implementation of CA involves many operations and complex working conditions, so key parts such as soil-contact parts and seeding devices can be easily damaged. It is necessary to develop new materials with corrosion resistance, wear resistance, shock resistance, and fatigue resistance and improve processing technology of these parts to improve the operational quality of CA machinery and equipment.

(2) Optimize the level of intelligent monitoring and precision management of CA. Use electromechanical hydraulic control and machine vision to monitor key operations in real time, such as seeding, straw chopping, and plant protection. Use the technologies of satellite navigation and image processing to efficiently avoid the stubble rows during no-tillage/low-disturbance seeding. Apply automatic depth control technology for the real-time control of subsoiling depth. Establish an intelligent monitoring and control and digital information management system for CA equipment.

(3) Optimize the operating performance of the no-tillage/low-disturbance seeders. Improve the performance of current no-tillage/low-disturbance seeders to ensure good working quality for wheat and maize. Develop no-tillage/low-disturbance seeders suitable for different crops (e.g. miscellaneous grains, rapeseed, and soybean) to expand CA application.

(4) Develop and optimize plant protection and mechanical weed management equipment suitable for CA system. Under the conditions of straw mulching, apply remote-sensing technologies such as satellite positioning and image processing to accurately identify diseases, pests, and weeds. Develop and optimize plant protection equipment. Research the mechanism of anti-blockage and drag-reduction for soil-contact parts and develop and optimize non-soil-engaging mechanical weeding equipment.

2.4 EXTENSION AND DEMONSTRATION

(1) Strengthen capacity development for human resources. Skilled agricultural practitioners are the fundamental guarantee for successful CA adoption. Therefore, capacity development of human resources for CA is indispensable, including professional staff from government, enterprises, and extension centres as well as technicians and farmers. It is important to conduct capacity development covering key technology, equipment, and technical patterns of CA through various training methods (e.g. distributing training materials, online and offline training, field visits, group discussions, and workshops).

(2) Strengthen the construction of demonstration areas. Through effective planning and reasonable design, establish demonstration areas for CA demonstration, extension, and advocacy. Through these CA demonstration areas, formulate the main technical patterns and determine the selection of well-designed CA equipment.

(3) Expand the implementation scale. Expand the scale of CA implementation in areas with well-established technical patterns, high farmer acceptance, and an enabling environment. Select large-scale agricultural mechanized family farmers and professional farmers to lead the CA implementation in the region, with support from the relevant policies and technologies to motivate neighbouring smallholders to adopt and scale up CA.

(4) Strengthen trainings of grass-roots technical staff and farmers. Through the trainings, the grass-roots agricultural machinery technical extension staff can learn the key principles of CA technologies and improve extension methods, and farmers can use machines properly and master the essential techniques for CA. Encourage experts to go to the front line and solve problems during the extension of CA.

(5) Strengthen publicity and advocacy. Exploit the advantages of both traditional media (e.g. newspapers, television, and radio) and modern platforms (e.g. internet and social media) to strengthen publicity of the benefits of CA and guide farmers to adopt the approach. Use various methods to strengthen the effects of publicity via the technology and knowledge extension activities for farmers.

(6) Establish a long-term promotion mechanism. Establish a long-term CA promotion mechanism to support enterprises (including tax-reductions and exemptions, subsidies and project funding), mechanization hire service providers, cooperatives and farmers to extend CA and ensure their profits. Enterprises can improve machine performance by using advanced technology and manufacturing process. The mechanization hire service providers and new agricultural business entities (e.g. cooperatives) should play a leading role in demonstrations and training farmers. Additionally, it is important to strengthen the research–extension linkages, public–private partnership, multistakeholder coordination and investment for the long-term promotion of CA in China.

2.5 INTERNATIONAL EXCHANGES AND COOPERATION

CA has been adopted in more than 100 countries worldwide and has become one of the most effective and widely used farming systems and technologies for dryland agriculture. According to statistics, the total area of CA has reached 200 million ha, accounting for 15 percent of the world's total cropland area (Kassam, Friedrich and Derpsch, 2019). To accelerate the development of CA, an international exchange fund can be set up to learn about the good practices and experiences of CA from around the world. International experts can be invited for field visits and exchanges to explore the theoretical basis and long-term mechanisms of CA promotion and adoption in China.

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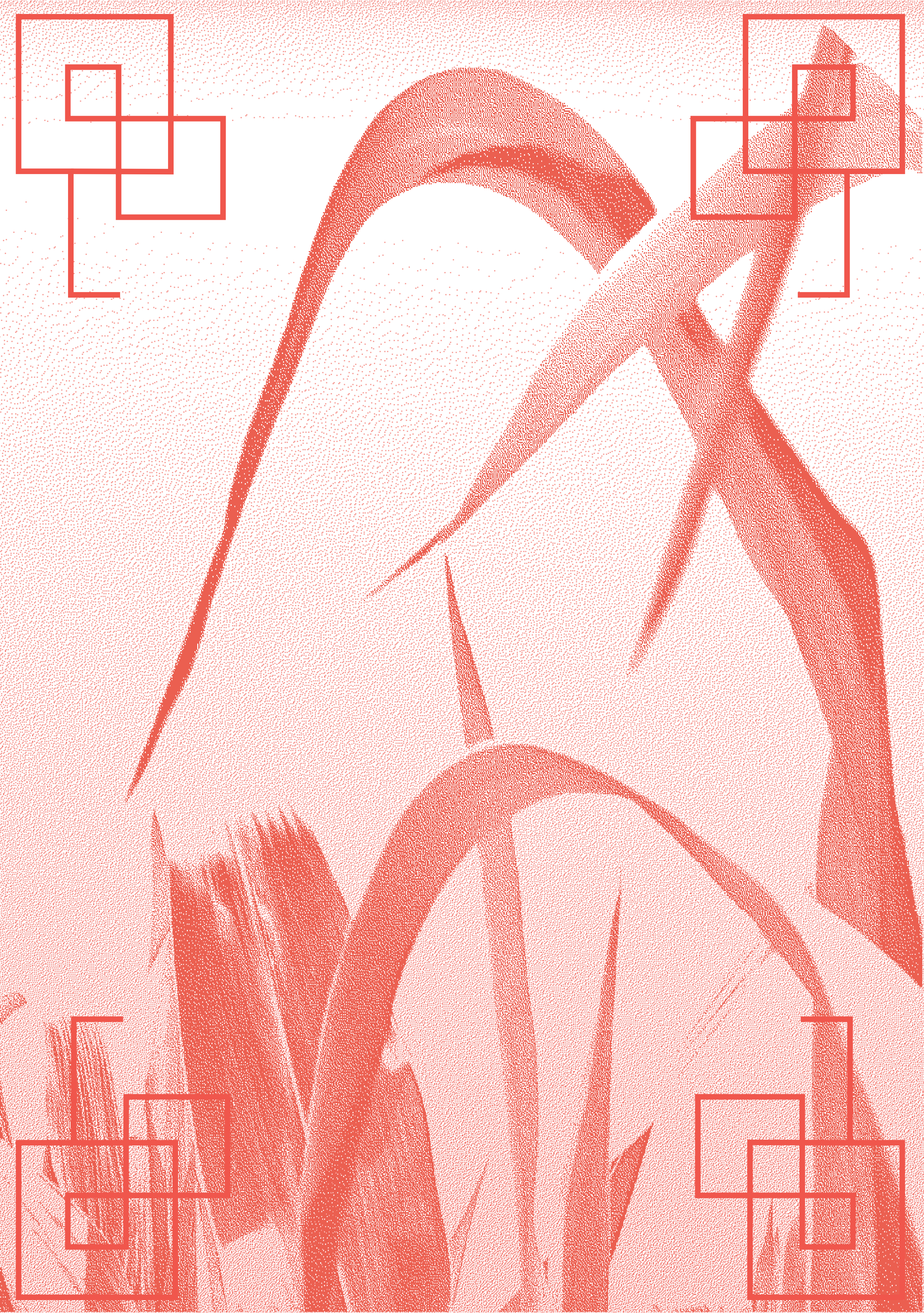


Chapter 3
Technology and equipment of conservation agriculture

CA machinery and equipment mainly consists of straw and stubble management machinery, no-tillage/low-disturbance seeders, and subsoilers (He *et al.*, 2018a). Straw and residue management is the foundation of CA, which directly affects its effective implementation. No-tillage/low-disturbance seeders allow seeding in fields with crop residue cover and the operation mainly relies on effective anti-blockage technology. Subsoiling is a soil loosening measure to break up the compaction and plough pan as initial land preparation for CA without any other alterations to the soil.

This section introduces CA technologies and machinery and equipment such as straw and residue management/detection machinery, weed management equipment, no-tillage/low-disturbance seeders, and subsoilers. Furthermore, the operating area monitoring system for CA machinery and equipment, based on monitoring methods, is also summarized.

3.1 STRAW AND STUBBLE MANAGEMENT AND DETECTION TECHNOLOGIES AND MACHINERY

(1) Straw and stubble management

CA requires efficient straw and stubble management to ensure the quality of straw-returning and no-tillage/low-disturbance seeding operations. Straw and stubble management machinery usually employs high-speed rotating chopping blades to hit, cut, shear, and crush crop straw and stubble into fragments and fibres, and then spreads the chopped straw and stubble on the soil surface. Straw and stubble management machines require high working quality and efficiency.

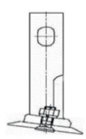
According to the straw chopping modes of the blades, the straw chopping and returning machinery can be divided into rotational chopping and vertical cutting modes. The operating mechanism of the rotational chopping mode is to hammer, cut, and knead the straw and stubble into segments by high-speed rotating chopping blades. The operating mechanism of the vertical cutting mode is to press down the straw and stubble in a forward direction of the machinery, and then the cutter, with reciprocating motion, cuts the straw and stubble.

When the machine is working, the rotating knife (i.e. rotovator) on the shaft rotates at a high speed, cuts the crop straw, and takes the straw into the casing under the action of negative pressure at the feeding inlet. The crop straw is smashed into segments or fibres after being cut, torn, and repeatedly rubbed. Finally, the chopped straw drops to the ground under the action of airflow and centrifugal force.

The blade is the key component of straw and stubble chopping and returning machinery. The structure of the blade has a significant effect on chopping quality, power consumption, and operating life (Fu *et al.*, 2011). The

Table 2

Straw and stubble management machinery and equipment blade type, structure, mechanism, characteristics, and application

Blade type	Structure	Operational mechanism	Characteristics	Application
Straight blade		Combined with fixed knife; high-speed shearing and impact on straw and stubble; high hitting frequency; low moment of inertia.	Advantages: high chopping quality and working efficiency; low fuel consumption. Disadvantages: poor performance in picking up and spreading straw and stubble.	Crops with soft straw (e.g. rice and wheat)
Y-shaped blade		Fixed with two blades with cutting edge; chops and cuts the straw and stubble with high rotational speed.	Advantages: high performance in picking up and spreading straw and stubble; low fuel consumption. Disadvantages: short operating life.	Crops with hard straw/stubble (e.g. maize and sorghum)
Hammer blade		Large mass; chops straw and stubble mainly by impact, accompanied by shearing and tearing.	Advantages: high chopping quality; high blade strength. Disadvantages: high fuel consumption.	Crops with hard straw/stubble (e.g. maize and cotton)
L-shaped blade		Single-sided and double-sided cutting edge; effectively chops the stubble and mixes stubble with soil by cutting edge.	Advantages: high performance in picking up stubble. Disadvantages: low structural strength.	Crops with hard stubble (e.g. maize, sorghum and cotton)
T-shaped blade		Crushes straw through horizontal and vertical cutting.	Advantages: high chopping quality; high moment of inertia. Disadvantages: complex structure; inconvenient to install, disassemble, and replace.	Hard straw/ stubble crops, small shrubs, etc.
V-L-shaped blade		A V-bending section is added to L-shaped blade.	Advantages: long operational life; high chopping quality and work efficiency. Disadvantages: complex shape; high machining requirements.	Maize

SOURCES: **Celli SpA.** undated. Multi-purpose fixed straw-chopper. Cited 30 April 2021. www.celli.it/en
Jia, H., Jiang, X., Guo, M., Liu, X. & Wang, L. 2015. Design and experiment of V-L shaped smashed straw blade (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31(1): 28–33.
Rasspe. undated. Straight blade. Cited 30 April 2021. www.rasspe.de
Xu, C.H. & Jie, Z. 2014. Design of T-type plate knife roller of straw returning machine (in Chinese). *Tractor & Farm Transporter*, 5: 50–51.

Table 3
Typical machinery for straw and stubble management

Model	Type	Structure	Technical characteristics
4YZ series maize combine harvester	Straw chopping and returning device + harvester		The whole machine is equipped with a straw chopping device. Working width: 1.85–2.10 m; working efficiency: 0.3–0.9 ha/h.
1JH series straw returning machine	Horizontal straw chopping machine		Direct chopping operation for hard straw crops (e.g. maize and sorghum) and soft straw crops (e.g. wheat and rice). Working speed: 2–5 km/h; Working efficiency: 0.23–0.80 ha/h.
4JH-140 type straw returning machine	Vertical straw returning machine		Working width: 1.4 m; chopping qualification rate: ≥85%; dispersion uniformity: ≥80%; supporting power: 25–36 kW; machine mass: 480 kg.

SOURCES: **Nongjitong**. 2022. 4JH-140 type straw returning machine. Cited 30 April 2022. www.nongjitong.com/product/shzxcs_4jh-140_straw_returning_machine.html
Weichai Lovol Heavy Industry Co., Ltd. 2020. 4YZ series maize combine harvester. Cited 30 April 2021. www.lovol.com/agricultural/yu-mi-ji.htm
YTO Group. 2017. 1JH series straw returning machine. Cited 30 April 2021. www.yituo.com.cn/cpzx/jjcp/jgj/201706/t20170620_156686.html

common commercial blades are bent blades (Y-shaped and L-shaped), straight blades, and hammer blades (Liu *et al*., 2008) (Table 2). The mechanized straw and stubble management method can efficiently complete the operation of chopping and returning straw and stubble to the field while saving cost. Some typical machinery is listed in Table 3.

(2) Rapid detection of surface residue coverage rate

Crop residue (straw and stubble) cover is one of the core technologies of CA that can decrease wind and water erosion of soil and increase soil moisture content and crop yield (Zhang *et al*., 2017). The straw coverage rate before or after seeding is significant for the assessment of CA and evaluation of the operational quality of CA machinery.

Aimed at addressing the challenges of low accuracy rate and improving the efficiency of surface crop residue recognition, S. Li and H. Li (2009) proposed a method of obtaining the surface residue coverage rate by segmenting crop residue with a threshold by analysing the texture difference between residue and soil. The detection error rate of the method was less than 10 percent. Su *et al.* (2012) used the maximum between-class variance method to automatically select the threshold to improve the accuracy of crop residue identification; and the recognition error was less than 4 percent. Wei *et al.* (2005) used the method of combining an artificial neural network and entropy value of texture to identify crop residue; and the recognition error of crop residue coverage rate was less than 5 percent. Yao *et al.* (2005) developed a vehicle-mounted surface straw coverage recognition system; and the recognition error of residue coverage rate was 4.55 percent. Liu *et al.* (2020) proposed an automatic segmentation method based on multithreshold image for the detection of surface residue coverage, and the recognition error was less than 8 percent.

Currently, the rapid recognition system of surface crop residue coverage rate still has the following problems. (i) Most CA field surface images are collected from particular locations and the sample is relatively limited. The accuracy and universality of detection methods still need to be further improved because of

Table 4
Statistics on no-tillage/low-disturbance seeders in major regions of China in 2020

Region	Subsidized seeder number			Sales		
	Total subsidized number (sets/units)	Powered anti-blockage machinery number (sets/units)	Percentage of powered anti-blockage machinery (%)	Total sales (sets/units)	Powered anti-blockage machinery number (sets/units)	Percentage of powered anti-blockage machinery (%)
Gansu	302	108	35.76	389	58	14.91
Xinjiang	317	99	31.23	210	210	100.00
Tibet	164	47	28.66	26	26	100.00
Sichuan	83	42	50.60	131	48	36.64
Shaanxi	96	48	50.00	1 696	99	5.84
Shanxi	304	100	32.89	937	319	34.04
Shandong	296	102	34.46	477	311	65.20
Qinghai	213	67	31.46	40	27	67.50
Inner Mongolia	514	85	16.54	3 187	55	1.73
Liaoning	243	56	23.05	2 222	13	0.59
Hubei	222	83	37.39	1 672	738	44.14
Henan	207	108	52.17	8 639	1 605	18.58
Hebei	337	98	29.08	2 240	39	1.74
Anhui	276	130	47.10	4 103	860	20.96
Nation	5 288	1 516	28.67	43 330	4 489	10.36

SOURCE: **Wang, X., Zheng,K., &Chen, L.Q.** 2021. Development status and trend of no-tillage planter in China. *Agricultural Machinery*, 3: 57–60.

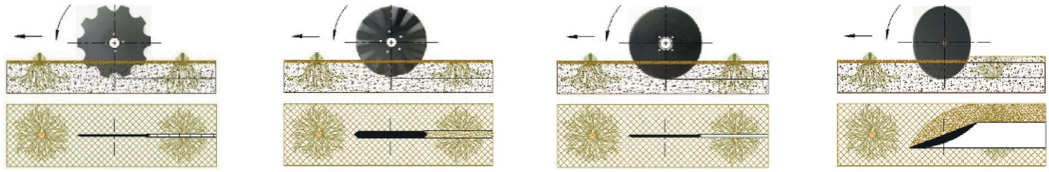
complex and uncertain illumination and the field environment during operations. (ii) Current recognition samples are mostly acquired from fields and then analysed in a laboratory. Nevertheless, it is necessary to develop and improve the vehicle-mounted real-time high-accuracy detection system.

3.2 TECHNOLOGIES AND MACHINERY FOR NO-TILLAGE AND LOW-DISTURBANCE SEEDING

No-tillage seeders perform no-tillage operations in fields with soil cover (e.g. straw and stubble residues), while low-disturbance seeders perform strip-tillage in those fields. The quantity of soil cover with crop straw and residue directly affects the operating quality of the seeders. Anti-blockage technology is at the core of both no-tillage seeders and low-disturbance seeders. The types of anti-blockage devices can be divided into gravitational straw cutting type, power-driven type, and straw-flow type. At present, China has developed a series of no-tillage seeders that can meet agricultural production demand. In 2020, the total sales of no-tillage/low-disturbance seeders in China reached 43 330 sets (Table 4). By the beginning of 2020, China had 1.03 million no-tillage/low-disturbance seeders (Wang, Zheng and Chen, 2021) .

(1) Passive cutting stubble anti-blockage technology

The furrow disc is the key component of passive straw cutting anti-blockage devices. The anti-blockage principle is that by the gravitational force of the machine itself, a furrow disc with a high rotational speed cuts through straw, stubble, and soil; with this method seeding and fertilizing can be smoothly implemented without straw blockage. The disc opener rolls along the ground

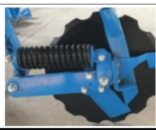


(a) Notched disc	(b) Ripple disc	(c) Plain disc	(d) Concave disc

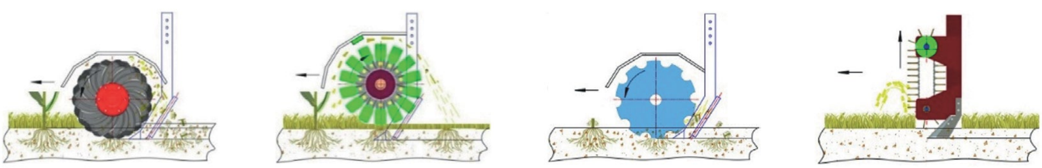
Figure 1
Diagram of gravitational straw cutting and anti-blockage technology

SOURCES: **He, J., Li, H., Chen, H., Lu, C. & Wang, Q.** 2018a. Research Progress of Conservation Tillage Technology and Machine (in Chinese). Transactions of the Chinese Society for Agricultural Machinery, 49: 1–19.

Table 5
Typical gravity-cutting stubble anti-blockage no-tillage seeders

Type	Disc type	Structure	Technological characteristics
2BMYFZQ no-tillage finger-clamp-type fertilization precision seeder			Multifunctional: side deep fertilization, straw cleaning and preparation for seedbed, precision seeding, soil covering, and compaction can be done in one go; seeding rows: 6; machine mass: 1830 kg; working speed: 6–10 km/h; working width: 4.2 m; working efficiency: 2.0–3.6 km^2/h
2BMQE no-tillage precision seeder			Seeding rows: 7; working width: 4.9 m; row spacing: 45–70 cm; fertilization ditching disc diameter: 450 mm; strong straw cutting ability
2BFM no-tillage precision seeder			Seeding rows: 6; fertilization depth: 10–15 cm; infinitely variable adjusted mass scope of fertilizer: 300–1000 kg/ha
2BMZ no-tillage precision seeder			Machine mass: 1620 kg; seeding rows: 4; working width: 2.6 m; working speed: 5–8 km/h; entering soil ability of the seeding unit is adjusted by four-bar spring tension
2BMZ no-tillage seeder			Opens furrow by double disc; cutting stubble by notched disc; positive pressure: 400–900 N (newton); disc opener installed with straw cleaning device at the rear; seeding rows: 2–6

SOURCE: **Nongji360**. undated. No-tillage seeders. Cited 30 April 2021. www.nongji360.com



(a) Strip-tillage anti-blockage technology	(b) Straw chopping anti-blockage technology	(c) Stubble cutting anti-blockage technology	(d) Straw poking anti-blockage technology

Figure 2
Diagram of power-driven anti-blockage technology

SOURCE: **He, J., Li, H., Chen, H., Lu, C. & Wang, Q.** 2018a. Research Progress of Conservation Tillage Technology and Machine (in Chinese). Transactions of the Chinese Society for Agricultural Machinery, 49: 1–19.

Table 6

Typical power-driven anti-blockage no-tillage / low-disturbance seeders

Model	Power anti-blockage type	Structure	Technological characteristics
2BXS-16 no-tillage fertilization seeder	Strip-tillage type		Cut straw and stubble and strip rotary tillage for seedbeds; used for uneven ground conditions. Seeding rows for wheat: 16; working width: 3.25 m; machine mass: 1030 kg; supporting power: 66.2–88.3 kW; working efficiency: 0.9–1.6 ha/h
2BFM-18 no-tillage fertilization seeder	Strip-tillage type		Employs rotary tillage straight blade for strip tillage; relatively low soil disturbance; seeding rows for wheat: 18; row spacing: 25 cm; machine mass: 790 kg; supporting power: 62.5–73.5 kW; operating efficiency: 0.2–0.6 ha/h
2BMYF-18 no-tillage fertilization seeder	Strip-tillage type		Each opener has one set of rotary tillage blades that cut and chop straw and stubble in seedbeds; seeding rows for wheat: 18, row spacing: 40 cm; seeding rows for maize: 6, row spacing: 45–75 cm; working width: 3.6 m; supporting power: >73.5 kW
2BDPM-12 no-tillage seeder	Stubble cutting type		The oblique discs installed in front of openers; disc diameter: 403 mm; low soil disturbance; seeding rows for wheat: 12, row spacing: 18 cm; seeding rows for maize: 6, row spacing: 54.5 cm; working efficiency: 0.43–0.86 ha/h
2BMQF-6/12 no-tillage fertilization seeder	Stubble cutting type		Strip saw-tooth-shaped anti-blockage device; suitable for wheat, maize, and soybean; spacing adjustable; machine mass: 860 kg; working width: 1.94 m; supporting power: 58.8–73.5 kW; working efficiency: 0.40–0.67 ha/h
2BMFJ no-tillage precision seeder	Stubble chopping type + poking and spreading type		The double-roller side-rotating straw clean device circularly cuts and spreads aside straw and stubble to realize anti-blockage. Seeding rows for maize: 4 or 6; supporting power: 51.5–81.0 kW

SOURCES: **Chen, H., Zha, S., Dun, G., Cong, G., Li, A. & Feng, Y.** 2016. Optimization and experiment of cleaning device of 2BMFJ type no-till precision planter (in Chinese). Transactions of the Chinese Society for Agricultural Machinery, 47(7): 96-102.
Luoyang Xinle Machinery Technology Co., Ltd. 2020. 2BMFJ no-tillage precision seeder. Cited 30 April 2021. www.lyxinle.cn
Mainongji. undated. 2BMQF-6/12 no-tillage fertilization seeder. Cited 30 April 2021. www.mainongji.com
Nongjitong. 2020. 2BXS-16 no-tillage fertilization seeder. Cited 30 April 2021. www.nongjitong.com/product/haofeng_2bxs-16_seeder.html
Shandong Dahua Machinery Co., Ltd. undated. 2BMYF-18 no-tillage fertilization seeder. Cited 30 April 2021. www.dhbl.net
Shanxi Hedongxiongfeng Agricultural Machinery. 2020. 2BFM-18 no-tillage fertilization seeder. Cited 30 April 2021. www.hedongxiongfeng.cn

and has good anti-blockage ability. However, as the disc opener requires high positive pressure, the seeding unit is relatively heavy.

Depending on disc structure, the types of furrow disc include the notched disc, fluted disc, plain disc, or concave disc (Figure 1). As the notched disc (Figure 1a) has an edge with a certain shocking effect, it has a high capacity to cut soil, straw, and stubble and is suitable for heavy clay soil. The undulated and ripple disc (Figure 1b) cuts and compresses the soil to form a wide and strip-loosened soil zone under gravity and spring preload, engaging with the soil for better turning. It is not suitable for heavy clay soil due to the requirement for high penetration force. Increasing the number of grooves and decreasing the length of the ripples of the ripple disc can decrease the furrow width. The plain disc (Figure 1c) just cuts the straw, stubble and weeds and opens a narrow ditch when its forward direction is the same as that of the seeder, and the other opener needs to be installed behind to open a wide furrow; however, when there is a certain angle between the plain disc and the forward direction of the seeder, the seeder can conduct seeding and fertilizing directly. The concave disc (Figure 1d) has a certain angle with the forward direction of the seeder. It can cut and throw aside straw and stubble, and open a narrow furrow ditch.

Some typical passive-cutting stubble anti-blockage no-tillage seeders are shown in Table 5.

(2) Power-driven anti-blockage technology

The power-driven anti-blockage technology of no-tillage/low-disturbance seeders employs an anti-blockage device driven by the PTO of a tractor to chop and spread straw and stubble, and is suitable for annual double-cropping areas with a high quantity of straw cover.

Depending on the operational mechanism, the power-driven anti-blockage device mainly includes strip-tillage, straw chopping, stubble cutting, or straw poking anti-blockage devices (Figure 2).

The operating mechanism of strip-tillage anti-blockage technology is that the rotary blades installed in front of the openers can do shallow strip tillage and chop the straw and stubble and prepare the seedbeds to ensure seeding quality (Figure 2a). The strip-rotary tillage type is widely used in China.

The operational mechanism of straw chopping anti-blockage technology is that the high-speed rotating chopping blades installed in front of (or beside) the openers can chop and throw the straw and stubble behind the openers to achieve anti-blockage (Figure 2b). During operations, the high-speed rotating chopping blades do not touch the soil and will not cause soil disturbance. In addition, these blades have a great ability to chop and throw the straw and stubble, and have high anti-blockage performance.

The operating mechanism of stubble cutting anti-blockage technology is that the rotational notched discs powered by a tractor can easily cut the straw and stubble, loosen soil, and open furrows with low positive pressure (Figure 2c). The disc can also push the straw and stubble aside and produce clean seedbeds to avoid blockage.

The operating mechanism of straw poking anti-blockage technology is that the straw chopping and spreading devices (driven by a tractor PTO) or poking fingers will throw straw and stubble behind the openers to produce clean seedbeds (Figure 2d).

Table 6 shows some typical power-driven anti-blockage no-tillage and low-disturbance seeders.

(3) Straw-clearing anti-blockage technology

Straw-clearing anti-blockage technology is mainly used in areas with relatively light straw cover. During no-tillage seeder operations, this mainly increases the flow of straw on the ground and decreases the probability of straw blockage. The common ways for increasing straw flow include mechanisms such as multibeam opener arrangements for the seeder and passive anti-blockage devices installed in front of or beside the openers.

Table 7
Typical straw-flowing anti-blockage no-tillage seeders

Model	Type	Structure	Technological characteristics
2BMS-9A no-tillage seeder	Multibeam		Employs tine openers distributed in two beams; seeding rows for wheat: 9; working width: 2.1 m; supporting power: >45 kW
2BYSF-3 maize seeder	Vertical rollers + multibeam openers		Passive vertical rollers installed in front of the openers for anti-blockage; seeding rows for maize: 3; row spacing: 53.0–68.3 cm; fertilizing depth: 6–8 cm; seeding depth: 3–5 cm; supporting power: 11.0–18.4 kW
2605 air-aspiration-type no-tillage precision seeder	Straw poking disc		Passive straw poking disc installed in front of the double discs for anti-blockage; working width: 2 m; seeding rows for maize: 6; row spacing: 55–70 cm; supporting power: 73.5–88.3 kW

SOURCES: **Hebei Nonghaha Machinery Group Co., Ltd**. undated. Maize no-tillage seeder. Cited 30 April 2021. www.nonghaha.com
Nongjitong. undated. No-tillage seeders. Cited 30 April 2021. www.nongjitong.com

With a multibeam opener arrangement, the effective means of anti-blockage is by increasing the distance between neighbouring openers to create enough space for straw flow. When the distance between neighbouring openers is great enough, the straw entangled on the shovels of openers falls off during seeding.

The passive anti-blockage devices such as straw poking discs, rollers, and grass dividers are installed in front of or beside the openers to clear straw and avoid blockage.

Table 7 shows some typical straw-flowing anti-blockage no-tillage seeders.

(4) Application of precision seeding technology in no-tillage and low-disturbance seeders

During no-tillage and low-disturbance seeding, the pass ability of machinery is low in fields covered by straw and stubble. In particular, thick maize stubble and roots can easily cause a blockage in machinery. Furthermore, the uneven surface of farmland easily results in poor straightness of operations, thereby affecting seeding quality. Therefore, no-tillage and low-disturbance seeders with a precision seeding system can guide the machinery to avoid overlap with previous plant rows, while also guaranteeing the straightness of operations.

Here, the application of precision seeding technology in the wheat-maize cropping system is discussed as an example. In this cropping system, the row spacing for wheat and maize is 20 cm and 60 cm, respectively. The radiation radius of maize roots is 3–5 cm and the average straightness error of maize root distribution is 0–2 cm. Therefore, the lateral deviation is only ± 5 cm between the outermost opener of the seeder and the centreline of the maize root row. If the lateral deviation is exceeded, the opener will easily hit the thick roots and thus cause a blockage.

The automatic precision seeding systems used by wheat no-tillage and low-disturbance seeders in fields with maize stubble consist of these three main types: contacting type, machine vision type, and satellite navigation type (Wang *et al.*, 2020). Table 8 shows a performance comparison of these three precision seeding systems.

Table 8
Performance comparison of three automatic precision seeding systems

Precision seeding system	Advantages	Disadvantages
Contacting type	Simple structure; high precision; low production cost; easy installation and maintenance.	Contact measurement, detection signal is easy to lose; can easily be affected by obstacles such as straw between seeding rows.
Machine vision type	Strong flexibility, no need to send out signals; collected images contain more comprehensive information; real-time navigation path planning during operation.	Affected by environmental factors such as sunlight and straw; data processing algorithm takes a long time and real-time performance cannot be guaranteed.
Satellite navigation type	Real-time dynamic positioning, high precision; all-day, wide areas of coverage; easy to integrate.	Drives according to a pre-planned route; signal is easily affected by environmental factors.

SOURCES: **He, Y., Jiang, H., Fang, H., Wang, Y. & Liu, Y.** 2018b. Research progress of intelligent obstacle detection methods of vehicles and their application on agriculture (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 34(9): 21–32.
Hu, J., Gao, L., Bai, X., Li, T. & Liu, X. 2015. Review of research on automatic guidance of agricultural vehicles (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31: 1–10.
Ji, C.Y. & Zhou, J. 2014. Current situation of navigation technologies for agricultural machinery (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 45(9): 44–54.

(i) Contacting type automatic precision seeding system for no-tillage/low-disturbance seeders. A maize stubble detection device is used to detect location information on stubble and roots. When the detection device detects stubble and roots, it generates an electrical signal and sends it to the signal processor. The signal processor analyses and processes the electrical signal to generate a steering command to send to the steering actuator. After receiving the steering command, the steering actuator drives the steering wheel of the tractor to avoid stubble and roots during seeding operations.

(ii) Machine vision type automatic precision seeding system for no-tillage/low-disturbance seeders. During operations, the vision sensor captures real-time images of maize stubble and root rows, after which the lateral deviation between the target stubble and root rows and the opening is computed by image processing technology. According to the lateral deviation and forward speed of the seeder, the expected lateral displacement distance is computed and the displacement signal is sent to the controller. The controller then converts the expected lateral displacement into an executable offset signal and sends it to the actuator. Finally, after receiving the offset instruction, the actuator drives the opener to avoid stubble and roots during seeding.

(iii) Satellite navigation type automatic precision seeding system for no-tillage/low-disturbance seeders. The location information on maize stubble and roots is collected to generate a prescription map based on the previous maize seeding. Guided by the satellite navigation system, the no-tillage/low-disturbance seeder can avoid previous maize stubble and roots according to the pre-planned paths during the seeding of the next crop.

(5) Seeding depth control

Consistent seeding depth is beneficial to crop germination and post-germination growth (Håkansson *et al.*, 2011; Nielsen *et al.*, 2018). No-tillage/low-disturbance seeders normally have a profiling mechanism (depth-control device) and mechanical spring installed to achieve consistent seeding depth. However, because the position of the profiling mechanism and the pre-tightening force of the mechanical spring are set in advance of seeding, the seeder cannot conduct real-time adjustments to seeding depth in response to the changing operating environment.

Table 9
Some typical subsoilers

Type	Model	Overall structure	Technical features
Omnidirectional subsoiler	1SQ-340 omnidirectional subsoiler		Contains three V-shaped shovels; subsoiling depth: 40–50 cm; supporting power: 73.6–88.3 kW
	1S-310 omnidirectional subsoiler		Contains six symmetrically installed side-bent shovels; subsoiling space: 52 cm; subsoiling depth: ≥30 cm; supporting power: ≥99.2 kW
Chisel-type subsoiler	1S-350 winged-shovel-type subsoiler		Contains three shovels in front beam and four shovels in rear beam; supporting power: ≥135 kW; working width: 3.5 m; working efficiency: 0.84–1.68 ha/h
	1S-300A winged-shovel-type subsoiler		Contains seven shovels with space of 42.8 cm; working speed: 2–4 km/h; supporting power: ≥96 kW; working efficiency: 0.6–1.2 ha/h
Vibrating subsoiler	1SZL-770 self-excited vibrating subsoiling and land preparation machine		Contains seven shovels with space of 60–70 cm; working width: 4.9 m; subsoiling depth: 24–40 cm; working efficiency: 2.0–3.4 ha/h; supporting power: ≥210 kW
	1ZS-180 forced-excited vibrating subsoiler		Employs vibrating mechanism; subsoiling depth: 25–40 cm; supporting power: 50–75 kW; working width: 1.8 m

SOURCES: **Nongji360**. undated. Subsoilers. Cited 30 April 2021. www.nongji360.com
Nongjitong. undated. Subsoilers. Cited 30 April 2021. www.nongjitong.com
Shandong Aolong Agricultural Machinery. undated. Subsoilers. Cited 30 April 2021. www.sdaljx.com

Current seeding depth control systems include a hydraulic adjustment type and air pressure adjustment type compatible with the structure of the adjusting device. The hydraulic adjustment device is widely used in intelligent control of seeding depth during CA machinery operations because of the advantages of fast response, strong thrust, and convenient installation. In addition to installing hydraulic and pneumatic adjustment parts for seeding depth control, Li *et al.* (2016) designed a linked control device for soil cover and compaction that employed an electrical push rod to adjust the amount of soil cover in real time to achieve consistent seeding depth. In terms of seeding depth detection, a variety of sensor-based detection methods have been developed and have achieved effective results, such as the profile sensor detection method (Cortes, Kataoka and Okamoto, 2013), the ultrasonic sensor detection method (Cai *et al.*, 2011; Kiani, 2012), the angle sensor detection method (Nielsen *et al.*, 2018), the pressure sensor detection method (Fu *et al.*, 2018; Jia *et al.*, 2019; Jiang, 2017) and the displacement sensor detection method (Zhao *et al.*, 2015).

(6) Compensating control system for missed-seeding of no-tillage and low-disturbance seeders

The development of a compensating control system for missed-seeding of no-tillage/low-disturbance seeders is significant for minimizing the missed-seeding rate, optimizing seeding quality, and reducing production costs. Installing a reseeding device is one of the effective ways to realize missed-seeding compensation. Kim and Gao (2002) designed a U-shaped tube reseeding device that employs air pressure to realize reseeding. Ding *et al.* (2015) developed a set of spiral-tube reseeding systems and the reseeding rate was close to 100 percent. Wu *et al.* (2017) designed a missed-seeding compensation system by installing a reseeding device and reseeding guide tube, and the reseeding rate was 96.5 percent. In addition, Zhu *et al.* (2014) studied a missed-seeding compensation system based on the one-way locking principle of the overrunning clutch, and the reseeding rate was 92.98 percent. Nevertheless, most of the existing studies of missed-seeding compensation control systems need to add an extra set of reseeding devices in addition to the normal seeding device; and the two sets of seeding devices are independent. There is a certain lag in reseeding position because the seed movement paths of regular seeding and reseeding are different.

3.3 TECHNOLOGIES AND MACHINERY FOR SUBSOILING

CA can avoid tillage and minimize soil disturbance. However, the operation of tractors and other agricultural machinery and equipment during seeding/planting, farm managing and harvesting can cause soil compaction, which may result in a decline in yield (Evans *et al.*, 1996). Subsoiling employs the subsoiling shovel to loosen soil and break the soil compaction and plough pan resulting from previous tillage in an initial land preparation operation. Within a CA system accidental compaction may occur and careful subsoiling can be a solution to this. However, this should not be a regular operation, and the necessity for subsoiling should disappear as the systems mature and the soil structure is improved.

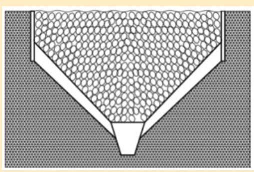


Figure 3
Schematic diagram of the V-shaped subsoiling shovel

SOURCE: Authors' own elaboration.

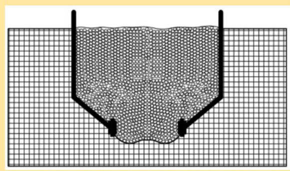


Figure 4
Schematic diagram of the side-bent subsoiling shovel

SOURCE: Authors' own elaboration.

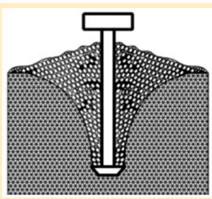


Figure 5
Schematic diagram of chisel-type subsoiling shovel

SOURCE: Authors' own elaboration.

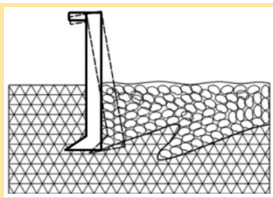


Figure 6
Schematic diagram of vibrating subsoiling shovel

SOURCE: Authors' own elaboration.

According to the machinery structure, subsoiling technologies can be divided into omnidirectional type, chisel type, and vibration subsoiling type.

Table 9 shows some typical subsoilers.

(1) Omnidirectional subsoiling

The omnidirectional subsoiler employs a subsoiling shovel to cut out trapezoidal cross-section soil ridges and put the soil back onto the field to create good soil conditions for crop growth and realize omnidirectional subsoiling. There are two main subtypes of the omnidirectional subsoiler: the V-shaped shovel (Figure 3) and the side-bent shovel (Figure 4). The V-shaped subsoiling shovel is composed of a bottom knife and two symmetrical side knives, whereas the side-bent subsoiling shovel features an L-shaped side-bent shovel. The omnidirectional subsoiler has a wide range for loosening soil, but its power consumption is high.

2) Chisel-type subsoiling

The chisel-type subsoiler (Figure 5) breaks soil by extruding and lifting it by the shovel tip and soil cutting by the blade part of the shovel handle. The subsoiling depth ranges from 30 to 50 cm, and the shovel spacing is 40–80 cm. The key part of the chisel subsoiler is the chisel shovel, which is projected in a forward direction and is always perpendicular to the field surface. According to the structure of the chisel shovel, chisel-type subsoilers include the regular chisel-type subsoiler or winged-shovel-type subsoiler.

(3) Vibrating subsoiling

When the vibration sources are installed on the subsoiling shovels of omnidirectional and chisel subsoilers, this achieves the effect of vibration subsoiling (Figure 6). Compared with a non-vibrating subsoiler, the vibrating subsoiler can reduce soil resistance by 6.9–17.0 percent (Zheng and Chen, 2016). According to the types of vibration source, the vibration subsoiler can be either a self-excited vibration subsoiler or a forced vibration subsoiler.

With the operating mechanism of the self-excited vibrating subsoiler, the shovel rotates around the connection point to lift the shovel tip up when the resistance force applied to the subsoiling shovel by the soil is greater than the pre-force of the elastic element. In this process, the elastic element is compressed to accumulate elastic energy. When the soil resistance is decreased, the elastic element releases stored elastic energy, thus making the subsoiling shovel rotate in reverse and shear the soil. Vibration of the subsoiling shovel is generated by the change in soil resistance so as to decrease the draft force.

With the operating mechanism of the forced-excited vibrating subsoiler, the PTO of the tractor transfers power to the subsoiler’s vibration mechanism, which converts the rotation into the specified frequency and amplitude of the subsoiling shovel. Meanwhile, the vibration of the subsoiling shovel causes soil vibration and thus the soil is loosened after periodic vibrations.

(4) Depth control of subsoiling operation

The stability of operation depth is an important indicator for evaluating the operating quality of subsoilers. This mainly employs angle sensors or ultrasonic sensors to detect operation depth in real time and the hydraulic system installed on tillage components to consistently control operation depth by adjusting the expansion and contraction of the hydraulic cylinder (Liu, 2019).

Research into operation depth control mainly focuses on the subsoiler. Du *et al.* (2008) developed an operation depth control system employing an electro-hydraulic proportional valve as the main control valve and automatically adjusted operation depth according to the set value of the draft force. Wang (2019) designed an operation depth control system that can independently control the operating depth of each subsoiling shovel.

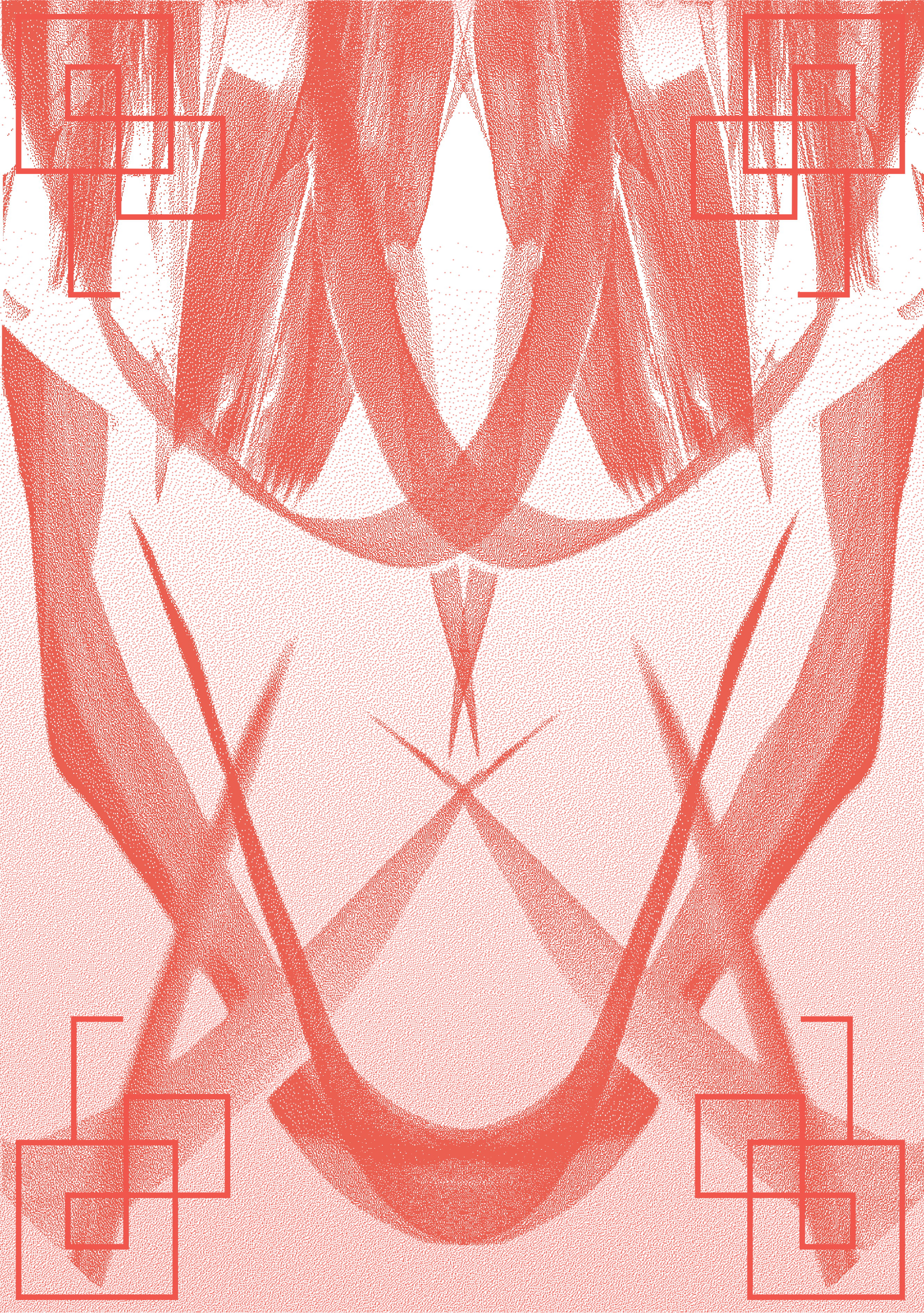
3.4 OPERATING AREA MONITORING SYSTEM OF MACHINERY AND EQUIPMENT FOR CONSERVATION AGRICULTURE

The working speed monitoring system is one of the most effective ways to solve the challenges of heavy workload and relatively low efficiency in the detection and statistics of operating areas. The working speed monitoring system is used to obtain information on the working speed, operating time, and operating width of the machinery. The principle is to calculate the operating area based on the machinery's operating speed, time, and width. Accurate monitoring of forward speed is the key to ensuring the accuracy of the operating area. There are two kinds of forward speed monitoring systems: one is based on sensors and the other is based on satellite navigation (Lu, 2020).

(1) Forward speed monitoring system based on sensors. In this system, the forward speed of the machinery can be calculated from the rotational speed of the ground wheel, which is detected by the sensor mounted on it. Currently, the Hall effect speed sensor and incremental encoder are widely used. The Hall effect speed sensor generates a pulse when the small magnetic steel piece pasted on the ground wheel passes through the Hall effect switch and then the forward speed of the machinery can be calculated according to the number of pulses per unit of time (Lu and Zhao, 2007). The incremental encoder is generally installed on the rotating shaft of the ground wheel and the forward speed can be calculated according to the number of pulses per unit of time of the rotating shaft (Wen and Zhao, 2013).

(2) Forward speed monitoring system based on satellite navigation. In this system, the positioning information of the machines (i.e. the tractor and implement) is obtained by the satellite navigation system and the forward speed is acquired by measuring the distance between the positions of the front and rear end of the machines. The operating area can then be calculated according to the forward speed, operating time, and operating width. This method not only avoids missed-seeding or redundant reseeding but also improves operating accuracy and efficiency.

In summary, the detection accuracy of a sensor mounted on the ground wheel decreases when the ground wheel is slipping; in contrast, the forward speed monitoring system based on satellite navigation has higher detection accuracy because the forward speed of the machinery is obtained according to the change in spatial position per unit of time.



Chapter 4
Contributions of conservation agriculture to green agricultural development

The 14th Five-Year Plan for Economic and Social Development and Long-Range Objectives through the Year 2035 of the People's Republic of China points out the need to accelerate the green transformation of development modes, comprehensively improve the efficiency of resource use, vigorously develop a green economy, promote green transformation of agricultural development, strengthen environmental protection and management of agricultural producing areas, and aim to achieve sustainable development of agriculture in China. Green transformation of agricultural development promotes sustainable agricultural development and increases the income of farmers while protecting the environment and ensuring green and pollution-free agricultural products.

Core CA technologies include no tillage/low-disturbance and straw returning. When compared with conventional tillage, CA can simplify agricultural operating procedures, thus minimizing mechanical power consumption and GHG (e.g. CO_2, CH_4 and N_2O) emissions. Because of the development of agricultural mechanization, high numbers of labourers have been liberated to engage in other decent jobs and migrant workers have been enabled to earn higher incomes. Straw returning not only increases soil organic matter and improves the soil environment but also avoids environmental pollution caused by straw burning and decreases the use of chemical fertilizer. The development of CA helps to achieve the Carbon Peak (a peak in carbon dioxide emissions) and Carbon Neutrality Goals (see below), and is conducive to increasing soil water storage and soil fertility, decreasing costs, and improving efficiency (Li, Chen and Chen, 2008).

This section introduces the contributions of CA to green agricultural development, including contributing to achieving Carbon Peak and Carbon Neutrality Goals, controlling and decreasing soil erosion, improving soil structure and fertility, and improving soil water conservation and resilience to drought.

4.1 CONSERVATION AGRICULTURE CONTRIBUTES TO ACHIEVING CARBON PEAK AND CARBON NEUTRALITY GOALS

The *Report on the Work of the Standing Committee of the National Committee of the Chinese People's Political Consultative Conference (CPPCC)* in 2021 clearly stated that China will achieve a carbon peak by 2030 and strive to achieve carbon neutrality by 2060. Carbon peak means that total carbon dioxide emissions will reach the historical peak at a certain point in time and then total carbon emissions will gradually and steadily decline. Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks, within a certain period of time, in order to achieve net zero emissions. All global GHG emissions will have to be counterbalanced by carbon sequestration and other carbon dioxide removal methods, for example, afforestation, energy conservation and emissions reduction, and industrial adjustment.

Current studies showed that CA can simplify agricultural operating procedures, decrease the use of agricultural inputs and GHG emissions, and effectively increase the carbon sequestration potential of farmland soil, hence contributing to achieving a win-win situation between food production and ecological protection, and to implementing climate-smart agriculture. The contributions of CA to achieving the Carbon Peak and Carbon Neutrality Goals follow.

(1) Energy saving and fertilizer reduction

CA can effectively reduce the use of agricultural inputs (e.g. fuel and fertilizer) by decreasing operating procedures and improving fertilizer use efficiency, so reducing GHG emissions.

Fuel: According to fuel consumption test results of fully mechanized agricultural production in annual double-cropping areas (winter wheat-summer maize) in North China by the China Conservation Tillage Research Centre (CTRC) of MARA, no-tillage practices had significant energy-saving advantages in both summer maize and winter wheat seasons compared with conventional tillage. No-tillage reduced fuel consumption by 42.5 percent in the summer maize season and by 69.6 percent in the winter wheat season. In summary, no-tillage reduced mean annual fuel consumption by over 20 kg/ha (18.8 kg carbon equivalent/ha) (Figure 7).

Fertilizer: According to the estimations of the Department of Agricultural Mechanization of MARA, CA can decrease the input of chemical fertilizer by about 10 percent compared with conventional tillage. Based on the average application rate for grain crops (N: 155 kg/ha, P_2O_5: 70 kg/ha, K_2O: 33 kg/ha) in different regions of China, CA saved 23.7 kg/ha of carbon in fertilizer input compared with conventional tillage. Kong (2020) found that straw retention can increase soil nitrogen contents and nutrient distribution in wheat-soybean cropping systems; the mean soil total nitrogen contents in the straw retention treatment group (1.06 g/kg) were significantly higher than those in the other treatments (36.59 mg/kg).

In addition, Lu (2017) found that in the winter wheat and summer maize rotation system in arid areas in Northwest China the energy input of conventional tillage and rotary tillage with straw-returning modes was 63.52 and 52.69 GJ/ha, respectively, which was 28.98 and 14.39 percent higher than that of no-tillage with straw mulching mode, respectively (Table 10).

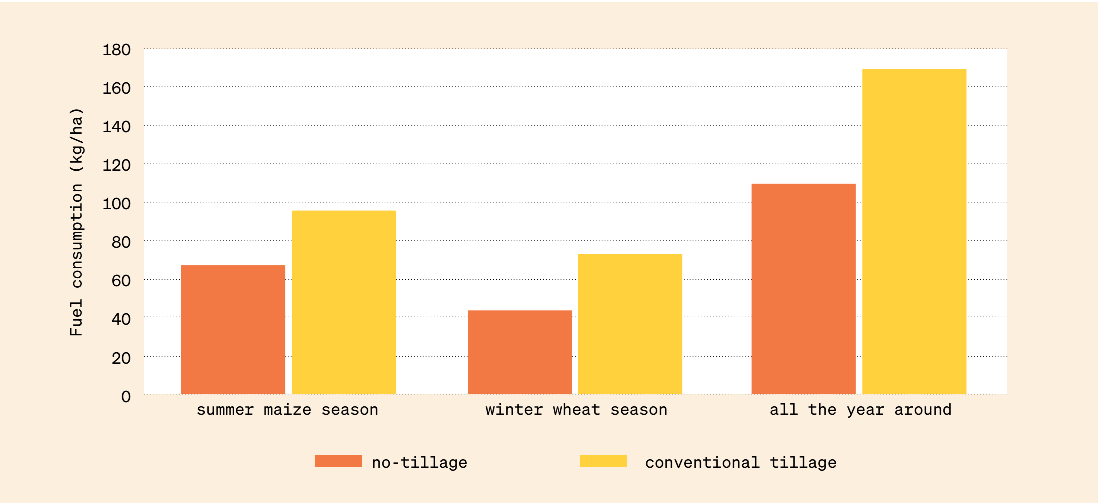


Figure 7
Comparison of fuel consumption of the whole mechanized operations in annual double-cropping areas (winter wheat-summer maize system) in North China

SOURCE: Authors' own elaboration.

Table 10
Energy input under different tillage modes (GJ/ha)

Content		CA (no-tillage with straw mulching)		Rotary tillage with straw returning		Conventional tillage	
		Winter wheat	Summer maize	Winter wheat	Summer maize	Winter wheat	Summer maize
Mechanical input	Rotary tillage	0.00	0.00	3.38	3.49	3.38	3.49
	Plough tillage	0.00	0.00	0.00	0.00	4.33	4.17
	Seeding	0.51	0.56	0.51	0.56	0.51	0.56
	Harvesting	2.53	2.82	2.53	2.82	2.53	2.82
	Mechanical energy consumption	0.71	1.04	1.08	1.43	2.01	2.31
	Sub-total	3.75	4.42	7.50	8.30	11.76	13.35
Other inputs	Pesticide	0.05	0.42	0.04	0.38	0.04	0.38
	N (fertilizer)	13.82	14.54	13.82	14.54	13.82	14.54
	P_2O_5 (fertilizer)	2.14	2.14	2.14	2.14	2.14	2.14
	Seed	3.27	0.47	3.27	0.47	3.27	0.47
	Labour	0.04	0.04	0.04	0.05	0.29	0.31
	Sub-total	19.32	17.61	19.31	17.58	19.56	17.84
Total		23.07	22.03	26.81	25.88	31.32	31.19

SOURCE: **Lu, X.L.** 2017. *Carbon balance and economic benefit of winter wheat-summer maize in the dryland of Northwest China under conservation tillage (in Chinese)*. Northwest A&F University, Yangling, China.

Table 11
Comparison of costs and benefits between no-tillage precision seeding with straw mulching and conventional tillage (CNY/ha)

Content		No-tillage precision seeding with straw mulching	Conventional tillage
Agricultural inputs	Seed	356.3	682.5
	Chemical fertilizer	750	750
	Herbicide	225	225
	Insecticide	225	225
Cost of labour	Seeding	270	750
	Fertilizing	0	150
	Thinning seedlings	0	900
	Plant protection	0	300
Other management		1275	1275
Total inputs		3 101.3	5 257.5
Outputs		14 977.5	14 523
Profit		11 876.2	9 265.5

SOURCE: **Zhao, Y., Xu, C., Yang, X., Li, S., Zhou, J., Li, J., Han, T. & Wu, C.** 2018. Effects of sowing methods on seedling stand and production profit of summer soybean under wheat-soybean system (in Chinese). *Crops* (4): 114–120.

(2) Cost saving

CA effectively decreases costs (e.g. mechanization operating costs, labour costs, and fuel consumption) by simplifying agricultural operating procedures. Zhao *et al.* (2018) found that no-tillage precision seeding with straw mulching significantly decreased total inputs by 41.0 percent through simplifying soybean production procedures and decreasing consumption compared with conventional tillage. The production benefit increased by 28.2 percent in the CA system (Table 11).

Li *et al.* (2019a) found that in the rapeseed-rice cropping system, rapeseed yield under no-tillage direct seeding decreased by only 3.8 percent compared with rotary-tillage direct seeding, while the rice yield under no-tillage direct seeding increased by 5.6 percent compared with rotary-tillage direct seeding. Additionally, with no-tillage direct-seeding technology, the rice yield in the rapeseed-rice cropping system increased by 13.7 percent compared with the rice monocropping system (winter fallow). In the rapeseed-rice cropping system, the total cost of no-tillage direct seeding was 12.0 percent lower than that of rotary direct seeding, and net income increased by 18.3 percent. The net income of the rapeseed-rice no-tillage direct-seeding system and rapeseed-rice rotary direct-seeding system increased by 58.1 percent and 33.6 percent, respectively, when compared with that of the no-tillage direct seeding of the rice monocropping system (winter fallow) (Table 12).

(3) Carbon sequestration and emission reduction

CA can minimize soil disturbance, increase nutrient use efficiency, slow down the rate of soil organic matter decomposition, and improve soil fertility and soil carbon sequestration. Furthermore, using straw as soil cover can decrease straw burning and thus reduce GHG emissions. GHG emissions can be decreased directly by lessening straw burning and improving soil carbon sequestration capacity.

For example, Lu (2017) found that carbon emissions declined by 22.11 percent under no-tillage with straw mulching mode compared with 11.21 percent under conventional tillage and rotary tillage with straw returning

Table 12
Comparison of economic benefit under different tillage modes

Content		No-tillage direct seeding of rapeseed-rice	Rotary-tillage direct seeding of rapeseed-rice	No-tillage direct seeding of rice monocropping (winter fallow)
Materials input (CNY/ha)	Seed	432	294	312
	Fertilizer	4718	4718	3240
	Pesticide	2100	1875	1650
	Ploughing	0	3000	0
	Ditching	675	675	0
	Harvest by machine	2400	2400	1200
Cost of labour such as seeding and fertilizing (CNY/ha)		4050	3375	2250
Total cost (CNY/ha)		14 735	16 337	8652
Price of rice (CNY/kg)		2.5	2.5	2.5
Equivalent rice yield (kg/ha)		12 989	12 655	8042
Total profit (CNY/ha)		32 472.5	31 638.0	20 105.0
Net profit (CNY/ha)		18 098	15 301	11 453

SOURCE: **Li, W., He, H., Cui, T., Li, C., Xiao, X., Tang, H., Tang, W. & Nie, Z.** 2019a. No-tillage and Direct Seeding Cultivation Technology of Rape-Rice and its Economic Benefit Analysis (in Chinese). *Hunan Agricultural Sciences* (7): 23–25.

mode (Table 13). The relative annual net carbon emissions of no-tillage with straw mulching mode and rotary tillage with straw returning mode were -1068.9 and -779.6 kg C/ha/year, respectively. The contribution of no-tillage with straw mulching mode to the decrease in carbon dioxide emissions is greater than that of conventional tillage and rotary tillage with straw returning mode (Table 14).

According to the research results of Shi *et al.* (2019), the total amount of straw burning in the open air was about 81.1 million tonnes in China in 2015, which produced about 34.5 million tonnes of carbon emissions. By the end of 2018, the area under CA in China (8.24 million ha) accounted for 6.10 percent of the national

Table 13
Carbon emissions from production inputs of the winter wheat-summer maize system under different tillage modes (kg C/ha/year)

Content		No-tillage with straw mulching	Rotary tillage with straw returning	Conventional tillage
Mechanical inputs	Plough tillage	-	-	93.78
	Rotary tillage	-	75.76	73.76
	Seeding	11.80	11.80	11.80
	Harvesting	58.99	58.99	58.99
	Sub-Total	70.79	146.55	238.33
Other inputs	Pesticide	8.61	1.65	1.65
	N (fertilizer)	402.58	402.58	402.58
	P_2O_5 (fertilizer)	58.48	58.48	58.48
	Seed	54.38	54.38	54.38
	Sub-Total	524.05	517.09	517.09
Total carbon		594.84	663.64	755.42

SOURCE: **Lu, X.L.** 2017. *Carbon balance and economic benefit of winter wheat-summer maize in the dryland of Northwest China under conservation tillage (in Chinese).* Northwest A&F University, Yangling, China.

Table 14
Relative net C emissions for the wheat-maize rotation system under different tillage modes (kg C/ha/year)

Content	No-tillage with straw mulching	Rotary tillage with straw returning	Conventional tillage
Soil carbon accumulation	−1090.7	−887.0	−191.4
Mechanical carbon emissions	+70.8	+146.6	+240.3
Carbon emissions from other agricultural inputs	+524.0	+523.2	+523.2
Net carbon emissions	−496.7	−207.4	+572.2
Relative net carbon emissions	−1068.9	−779.6	0

SOURCE: **Lu, X.L.** 2017. *Carbon balance and economic benefit of winter wheat-summer maize in the dryland of Northwest China under conservation tillage (in Chinese).* Northwest A&F University, Yangling, China.

cropping area (134.921 million ha) (MARA, 2019). According to this ratio, choosing CA over conventional tillage can result in a decrease in the total 4.9471 million tonnes per year of carbon emissions caused by straw burning.

4.2 CONSERVATION AGRICULTURE CONTRIBUTES TO DECREASING SOIL EROSION

Soil erosion caused by wind and water erosion is severe in China (Li, 2009; Ministry of Water Resources of the People's Republic of China, 2020). Wind erosion refers to the process by which surface soil and fine particles are stripped, transported, and deposited by the force of the wind. In this process, the soil particles, which have a diameter of no more than 100 μm, are blown upward, suspended in the wind, and then transported over long distances. This is the main component of dust storms. The dust storms in China are directly related to grassland degradation, water scarcity, and the inappropriate tillage mode in North China.

As the main technology of CA, straw and stubble mulching have the following advantages: (i) straw cover and stubble can decrease the soil surface wind speed and keep soil in the field; (ii) CA can increase soil moisture and enhance adsorption capacity in soil; and (iii) CA can improve soil aggregate stability and decrease the content of small particles, thus effectively lowering dust levels from fields. According to the monitoring results from CTRC in Fengning County of Hebei Province, Wuchuan County and Chifeng City of Inner Mongolia Autonomous Region, and Lingyuan City of Liaoning Province, CA can reduce dust from fields by 70 percent, 62 percent, 34 percent, and 37 percent, respectively (He *et al.*, 2010). Wu *et al.* (Wu, Niu and Lin, 2020) conducted wind tunnel simulation

Table 15
Wind erosion intensity of each measure under different wind speeds

Treatment	Wind erosion modules of various measures under different wind speeds at 30 cm height from surface (g/m2/h)				
	8 m/s	12 m/s	16 m/s	20 m/s	24 m/s
Maize stubble residue and straw mulching	5.6	12.5	70.0	187.5	262.5
Maize stubble residue	16.7	58.3	110.4	345.8	906.7
Maize straw mulching	10.6	40.3	87.5	295.5	552.5
Conventional tillage	18.8	100.0	234.1	467.5	1125.0

SOURCE: **Wu, S.S., Niu, J.Z. & Lin, X.N.** 2020. Effects of conservation tillage measures on soil wind erosion in Yanqing, the suburb of Beijing (in Chinese). *Science of Soil and Water Conservation* (1): 57–67.

Table 16

Sediment discharges at 0–100 cm, 0–50 cm, and 0–30 cm above surface of field under different tillage modes (grams)

Height (cm)	Treatment	2015		2016		2017	
		Spring	Winter	Spring	Winter	Spring	Winter
0–100	Conventional tillage	6.89	7.26	25.87	58.75	54.51	1.59
	No-tillage with no mulching	5.72	6.34	17.57	53.42	38.77	1.05
	No-tillage with straw mulching	5.95	6.31	17.89	50.75	40.05	1.25
0–50	Conventional tillage	3.02	3.10	11.16	26.44	26.65	0.91
	No-tillage with no mulching	2.30	2.70	7.17	21.47	15.83	0.57
	No-tillage with straw mulching	2.37	2.47	7.14	20.22	15.96	0.72
0–30	Conventional tillage	1.72	1.78	6.03	14.70	15.63	0.69
	No-tillage with no mulching	1.25	1.47	3.73	11.22	8.34	0.38
	No-tillage with straw mulching	1.27	1.34	3.85	10.89	8.57	0.54

SOURCE: **Li, Y., Li, J., Zhou, L., Liu, G., Zhang, J., Zhang, Z. & Zheng, Q.** 2019b. Effects of conservation tillage on soil wind erosion characteristics in the Hexi oasis irrigational area (in Chinese). *Chinese Journal of Eco-Agriculture*, 27(9): 1421–1429.

tests for fields in the suburbs of Beijing and found that the soil wind erosion intensity of different measures is "conventional tillage > maize stubble residue > maize straw mulching > maize stubble residue and straw mulching" (Table 15).

Li *et al.* (2019b) found that compared with conventional tillage, the sediment discharge at 0–30 cm from the field surface decreased by 17.4–46.7 percent under no-tillage with no mulching mode and 21.7–45.2 percent under no-tillage with straw mulching mode (Table 16).

Water erosion is the removal of the top layer of land by water, and it is highly affected by soil characteristics. The contributions of CA to reducing soil water erosion include: (i) the benefit of no-tillage/low-disturbance tillage and straw mulching effectively improving soil structure and enhancing soil infiltration capacity during rainfall and irrigation; and (ii) the advantage of soil cover, such as straw mulching, preventing raindrops from splashing, thus making it difficult for hard surface crusts to form on the soil surface. CA can effectively limit water erosion by hindering surface water flow and delaying runoff.

As shown in Figure 8, Bai *et al.* (2020) found that in the Loess Plateau, choosing CA (no tillage with straw mulch) or subsoiling over conventional tillage can result in a decline in the average runoff by 43.9 percent and 44.4 percent, a decline in soil loss by 58.4 percent and 44.8 percent, and delay of runoff starting time by 71.2 percent and 102.6 percent, respectively. In the black soil region of Northeast China, when compared to conventional tillage, the average runoff of no tillage with straw mulch compared with subsoiling decreased by 32.8 percent and 23.5 percent and the amount of soil loss declined by 72.7 percent and 37.9 percent, respectively. The runoff starting time was delayed by 11.7 and 10.9 minutes, respectively. In the sandy soil area of North China, when compared to conventional tillage the average runoff and soil loss under no-tillage with straw mulch declined by 20.8 percent and 67.9 percent, respectively. The average runoff and soil loss under subsoiling declined by 36.8 percent and 55.3 percent,

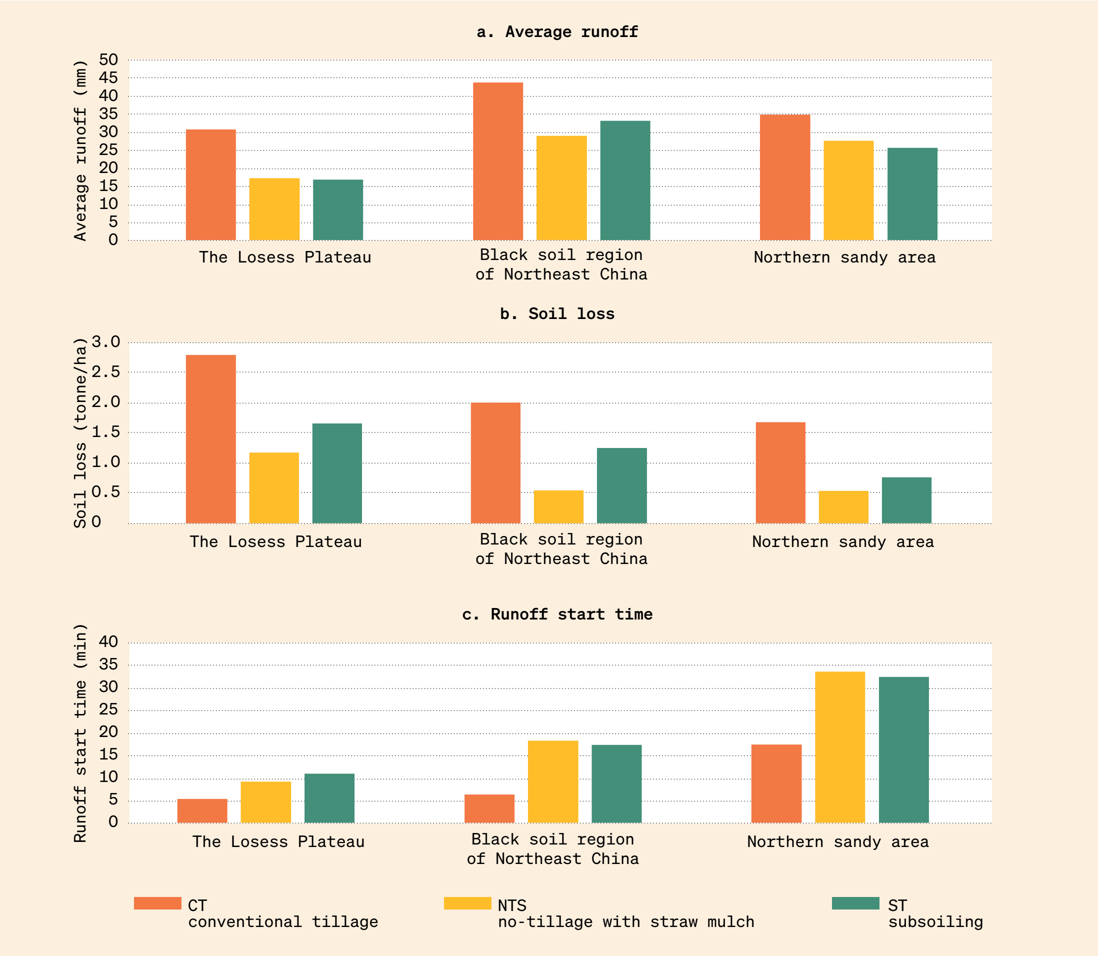


Figure 8
Effects of different tillage methods on water erosion

SOURCE: **Bai, X., Liao, J., Hu, H., Liu, Y., Xue, Y., Yan, Q. & Huang, S.** 2020. Effects of conservation tillage on soil and water conservation. *Agricultural Engineering*, 82(08): 86-92.

respectively. The runoff starting time under no-tillage with straw mulch compared with subsoiling was delayed by 16.3 minutes and 15.3 minutes, respectively.

He *et al.* (2020) found that in the black soil region of Northeast China, under conditions of rainfall intensity of 50 mm/hour, runoff under conventional tillage was 1.6, 2.3, and 3.0 times higher than with deep straw returning, straw mixed burying, and no-tillage with stubble mulching, respectively. Under conditions of rainfall intensity of 100 mm/hour, the runoff differences were 1.6, 2.0, and 2.9 times higher, respectively. As for the water erosion level, under conditions of rainfall intensity of 50 mm/hour, total erosion under conventional tillage was 7.8, 11.4, and 31.5 times higher than under deep straw returning, straw mixed burying, and no-tillage with stubble mulching, respectively; while under conditions of rainfall intensity of 100 mm/hour, the differences for water erosion were 5.8, 9.4, 31.0 times higher, respectively (Table 17).

Table 17
Runoff and erosion of sloping surface under different tillage modes

Mode	Rainfall intensity (mm/h)	Total amount of runoff (mm)	Total erosion amount (g/m2/h)	Flow reduction effect (%)	Sediment reduction effect (%)
Conventional tillage	50	42.2	884.4	0	0
	100	44.5	1850.0	0	0
Deep straw returning	50	26.6	113.6	37.0	87.2
	100	28.2	321.7	36.6	82.6
Straw crushing and mixed burying	50	18.1	77.8	57.1	81.2
	100	22.0	197.4	50.6	89.3
No-tillage with stubble mulching	50	14.1	28.1	66.6	96.8
	100	15.6	59.7	64.9	96.8

SOURCE: **He, Y.F., Shen, H.O., Zhang, Y., Zhao, Z. & Mou, T.** 2020. Analysis of soil and water conservation effects of different straw returning patterns in sloping farmland in the Chinese black soil region (in Chinese). *Journal of Soil and Water Conservation*, 34(06): 91–96.

Table 18
Effects of conventional tillage (CT) and no-tillage (NT) on stability indices of different soil structures

Soil depth (cm)	Content (%) of water-stable aggregates with diameter >0.25 mm		Average mass diameter (mm)		Average geometric diameter (mm)		Fractal dimension	
	CT	NT	CT	NT	CT	NT	CT	NT
10	54.91	68.31	0.63	0.80	0.37	0.48	2.35	2.25
20	48.02	68.33	0.65	0.86	0.33	0.52	2.56	2.39
30	45.52	69.84	0.57	0.66	0.28	0.41	2.61	2.39
40	44.61	46.22	0.49	0.49	0.27	0.27	2.46	2.51
50	36.82	67.41	0.28	0.71	0.19	0.42	2.49	2.50
60	42.13	49.74	0.31	0.35	0.20	0.22	2.55	2.54
70	42.73	46.93	0.40	0.38	0.24	0.23	2.50	2.49
80	21.74	43.72	0.31	0.34	0.18	0.21	2.58	2.42
90	41.71	40.03	0.29	0.29	0.17	0.19	2.71	2.57
100	21.73	40.74	0.22	0.38	0.15	0.22	2.60	2.58

SOURCE: **Yang, Y., Wu, J., Ding, J., Zhang, J., Pan, X. & He, F.** 2017. Effects of long-term no-tillage on soil structure and organic carbon distribution in different soil layers (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 48(9): 173–182.

4.3 CONSERVATION AGRICULTURE CONTRIBUTES TO IMPROVEMENT OF SOIL STRUCTURE AND FERTILITY

Soil fertility is the foundation of farmland productivity. According to the arable land quality results of the second national soil survey in China, the medium- and low-quality land areas covered 71 493 200 ha and 23 864 700 ha, which account for 52.9 percent and 17.7 percent of the total area of arable land in China, respectively (Ministry of Natural Resources of the People's Republic of China, 2018). CA adopts no-tillage/low-disturbance tillage, which can reduce soil structure damage caused by tillage and contribute to the improvement of soil carbon sequestration and fertility. In addition, rotted straw and stubble can improve soil physical and chemical properties, increase soil organic matter (SOM), and enrich soil fertility (Zhu and Lan, 2010).

Soil physical properties: According to the long-term fixed-point field test results from CTRC on the Loess Plateau (Linfen, Shanxi Province, results after 16 years) (Wang *et al.*, 2008a), North China (Beijing, results after 8 years) (Zhang *et al.*, 2009), and the agropastoral zone (Wuchuan, Inner Mongolia Autonomous Region, results after 10 years) (He *et al.*, 2009a), CA could decrease the bulk density of the 0–30 cm soil layer by 2.2 percent (Loess Plateau), 1.2 percent (North China), and 2.8 percent (agropastoral zone); increase the number of large-particle water-stable aggregates (diameter >2.0 mm); and decrease the number of small-particle water-stable aggregates (diameter <0.25 mm). In the case of Wuchuan (agropastoral zone), CA could increase the number of large-particle aggregates by 13–37 percent and decrease the number of small-particle aggregates by 25–59 percent compared with conventional tillage.

Yang *et al.* (2017) found that, when compared with conventional tillage, no-tillage is more conducive to increasing the content of large soil aggregates (diameter >0.5 mm), the stability of the soil structure improved significantly, and the soil was affected to a depth of more than 50 cm (Table 18).

Soil chemical properties: In Linfen, Beijing, and Wuchuan, compared with conventional tillage, long-term CA increased surface (0–10 cm layer) SOM by 21.7 percent, 10.5 percent, and 23.1 percent; total nitrogen (N) by 51.5 percent, 24.3 percent, and 23.8 percent; and available phosphorous (P) by 56.3 percent, 48.5 percent, and 10.5 percent, respectively (Table 19).

Yan *et al.* (2019) found that no-tillage could decrease soil bulk density, improve soil porosity, and increase total N, SOM, and available potassium (K) (Table 20).

A comprehensive long-term field experiment showed that three to five years after the adoption of CA, soil structure and fertility improved significantly. In particular, SOM increased by an average of 0.03 percent/year, soil changed from yellow to black, and earthworm numbers and soil biodiversity increased.

Table 19
The 0–20 cm depth SOM, total N, and available P under CA and conventional tillage (CT)

Location	Treatment	SOM (g/kg)		Total N (g/kg)		Available P (mg/kg)	
		Soil depth (cm)					
		0–10	10–20	0–10	10–20	0–10	10–20
Linfen (16 years), Loess Plateau	CA	18.2	11.1	1.03	0.67	35.0	10.5
	CT	15.0	13.8	0.68	0.66	22.4	22.9
Beijing (8 years), North China Plain	CA	16.5	15.9	1.38	1.02	20.2	16.9
	CT	14.9	14.0	1.11	0.86	13.6	13.9
Wuchuan (10 years), agriculture and animal husbandry interlinked area	CA	16.5	9.6	0.52	0.30	17.9	8.3
	CT	13.4	7.4	0.42	0.24	16.2	10.1

SOURCES: **Wang, Q., Bai, Y., Gao, H., He, J., Chen, H., Chesney, R.C., Kuhn, N. & Li, H.** 2008a. Soil chemical properties and microbial biomass after 16 years of no-tillage farming on the Loess Plateau, China. *Geoderma*, 144(3-4): 502-508. https://doi.org/10.1016/j.geoderma.2008.01.003
He, J., Kuhn, N., Zhang, X., Zhang, X & Li, H. 2009a. 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, Q., Li, H., Tullberg, J.N., McHugh, A.D., Bai, Y., Zhang, X., McLaughlin, N. & Gao, H. 2009b. Soil physical properties and infiltration after long-term no-tillage and ploughing on the Chinese Loess Plateau. New Zealand Journal of Crop and Horticultural Science, 37(3): 157-166.
Zhang, X., Li, H., He, J., Wang, Q. & Golabi, M. 2009. Influence of conservation tillage practices on soil properties and crop yields for maize and wheat cultivation in Beijing, China. *Australian Journal of Soil Research*, 47(4): 362-371doi.org/10.1071/SR08110

Table 20

Soil physical and chemical properties of different positions on slope before and after no-tillage

Soil properties	Soil depth (cm)	Before no-tillage			Second year of no-tillage		
		Top of slope	Middle of slope	Lower slope	Top of slope	Middle of slope	Lower slope
Total N (g/kg)	0–10	0.79	1.03	1.59	1.67	2.10	1.42
	10–20	0.68	1.13	1.38	1.54	2.25	1.73
SOM (g/kg)	0–10	14.16	18.37	28.34	29.68	37.47	25.30
	10–20	12.12	20.27	24.67	27.55	40.21	30.87
Available P (mg/kg)	0–10	50.02	28.04	46.84	22.85	19.58	30.72
	10–20	53.85	7.19	45.09	27.84	29.38	32.64
Rapidly available K (mg/kg)	0–10	137.10	71.51	101.54	174.01	110.02	150.03
	10–20	99.77	68.48	97.42	139.02	98.00	136.00

SOURCE: **Yan, L., Ji, X.N., Meng, Q.F., Jiang, X., Zhou, L., Li, S. & Chen, C.** 2019. Soil fertility quality evaluation of slope farmland under no-tillage in black soil area (in Chinese). *Journal of Northeast Agricultural University*, 50(5): 43-54.

4.4 CONSERVATION AGRICULTURE CONTRIBUTES TO SOIL WATER CONSERVATION AND RESILIENCE TO DROUGHT

China is a large country with high agricultural water consumption. In 2019, agricultural water consumption reached 368.23 billion m^3, accounting for 61.2 percent of total water consumption in China. However, water resources in China are scarce and the low use of effective irrigation restricts the sustainable development of agriculture (Yang, Qin and Wang, 2017). Through the application of straw cover and subsoiling, CA can improve soil water conservation and resilience to drought when compared with conventional tillage.

(1) CA can effectively improve the distribution of soil pores, increase aeration (>60µm) and water storage pores (2–60µm), improve soil hydraulic conductivity, and enhance soil water infiltration and water storage capacity.

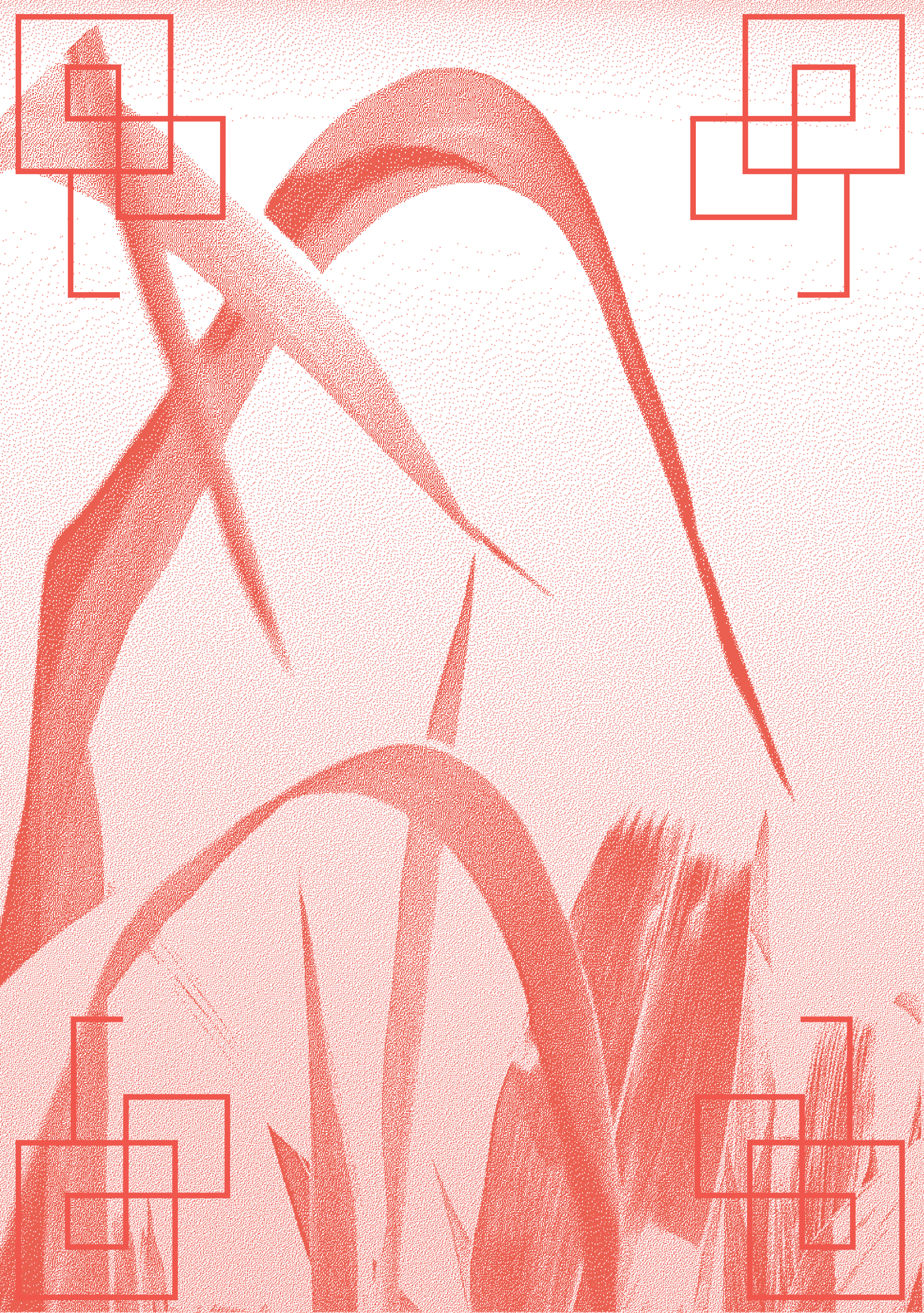
Regarding the effect of CA on soil moisture infiltration, from the results of CA experiments over many years in Wuchuan, Inner Mongolia, Xu and Jie (2014) showed that when compared with conventional tillage, CA could increase soil aeration porosity by about 40 percent and soil water storage porosity by about 9 percent in the 0–30 cm soil layer. From experimental results in Linfen, Shanxi Province, He *et al.* (2009b), Li *et al.* (2007), and Wang *et al.* (2009) showed that CA could increase saturated hydraulic conductivity by about 30 percent in the 0–30 cm soil layer, especially in the 15–30 cm soil layer, and significantly increase saturated hydraulic conductivity of the soil to nearly double that of conventional tillage. Therefore, CA can increase the soil stable water infiltration rate by about 26 percent during rainfall or irrigation compared with conventional tillage.

Regarding the effect of CA on soil water storage capacity, experimental results in Linfen, Shanxi Province, showed that CA could improve soil-holding capacity and the effect was particularly evident in the 15–30 cm soil layer when compared with conventional tillage (He *et al.*, 2009b).

(2) CA reduces soil runoff and water evaporation.

As discussed previously, CA can effectively decrease runoff in the field (Wang *et al.*, 2008b; Wen, Zheng and Shen, 2014; Zhang *et al.*, 2015; Zhu *et al.*, 2015). In addition, a number of studies showed that straw mulching lowers ground surface temperature, wind speed, and ineffective soil moisture evaporation. The measurement results of CTRC in Linfen showed that evaporation was 217.6 mm in conventional tillage and 197.9 mm in CA during the winter wheat fallow period, with CA reducing evaporation loss by 19.7 mm. The Irrigation Centre Experimental Station in Hebei Province reported that evaporation declined by an average of 56 mm in wheat straw residues during the summer maize growth season. Peng *et al.* (2018) found that CA significantly decreased evaporation between plants during the crop growth period and no-tillage with either plastic film mulching or straw cover can reduce evaporation by 14.4 to 50.8 percent, respectively, and decrease soil evaporation after rain when compared with conventional tillage.

CA can improve soil infiltration and significantly decrease runoff and ineffective soil moisture evaporation, thus enhancing the opportunities for water storage and conservation and improve water-saving on farmland and resilience to drought. Compared with general water-saving technology of dryland farming, CA is a comprehensive, stable and economic solution. Especially in arid Northwest China and the Loess Plateau, CA can increase soil water storage by more than 9 percent and improve water-use efficiency by more than 12 percent (He *et al.*, 2012; Li *et al.*, 2007; Wang *et al.*, 2009), both of which increase resilience to drought. In addition, the adoption of CA in irrigated areas can decrease irrigation water consumption and the water-saving effect is significant. According to monitoring data of CTRC during severe droughts in North China, the average soil water content of CA fields was 10 percent higher than that of conventional tillage fields, the wheat seedlings in CA fields were greener and stronger, and their growth status and resilience to drought were significantly better than in conventional tillage fields.



Chapter 5
Experiences in promoting conservation agriculture

The central government and all levels of government attach high importance to the extension and adoption of CA in China. CA entered a rapid development stage in 2009. The government, private sector, farmers, and research institutions have made concerted efforts to promote CA development and have accumulated rich experiences in this regard. This section summarizes the experiences and lessons in promoting CA in China for the reference of peers in other countries.

5.1 POLICY FOR PROMOTING CONSERVATION AGRICULTURE

Although CA has eco-friendly features and is a highly productive agricultural system, policy support from the top to grassroots is still crucial for its development and extension. CA has gained close attention from the government and society in China. From 2005 to 2012, use of CA was proposed in China's No. 1 Central Document for eight consecutive years. In 2020, the No. 1 Central Document proposed launching the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*. In 2021, the No. 1 Central Document, proposed carrying out the *National Protection Project of Black Soil*, which provides fundamental direction and guidance for the development of CA in China. In 2009, the State Council released the *Construction Program of Conservation Agriculture (2009–2015)*, indicating that CA had entered the rapid development stage. Since 2009, CA has been listed in dozens of national-level policies, such as the *National Agricultural Water-Saving Program (2012–2020)* and the *National Climate Change Program (2014–2020)*. In 2020, the Ministry of Agriculture and Rural Affairs and the Ministry of Finance printed and distributed the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*, with the aim of achieving CA adoption across an area of 9.3 million ha, which accounts for 70 percent of the total arable land in Northeast China. Additionally, a total of 19 provinces (autonomous regions and municipalities), including Beijing, Shanxi, Jilin, and Heilongjiang, have announced relevant policies and development plans to support the extension and application of CA. These enabling policies have been significant in promoting the development of CA in China.

5.2 ROLE OF KEY TECHNOLOGIES, MACHINERY AND EQUIPMENT FOR CONSERVATION AGRICULTURE

Appropriate technologies, machinery and equipment are indispensable for promoting and adopting CA. To promote the high-quality and high-efficiency development of CA, a range of CA machinery and equipment, mainly the no-tillage/low-disturbance seeder, subsoiler, and straw management machines, have been developed as a result of years of scientific research.

To overcome the problem of maize straw blockage in annual double-cropping (winter wheat-summer maize system) areas in North China, power-driven anti-blockage technology has been innovated and strip-tillage and strip straw chopping no-tillage/low-disturbance seeders have been developed. To solve the problem of straw tangling in openers during seeding operations of wide-row crops, passive anti-blockage technology has been designed and anti-blockage devices have been developed, such as straw separation discs and straw push gear teeth. To solve the problem of low straw chopping rates in furrows and straw blockage in ridge tillage areas in Northeast China, straw chopping as both ridge platform and ridge furrow technology has been innovated, and a series of no-tillage/low-disturbance seeders suitable for permanent ridge and furrow system areas have been developed. The R&D of key technologies and machinery has significantly promoted the development of CA in China.

A series of subsoilers have been developed, such as a chisel subsoiler, omnidirectional subsoiler, as well as a combined machine for subsoiling and no-tillage/low-disturbance seeding. Moreover, residue management (straw retention) equipment for different crops (e.g. wheat, maize, cotton and banana) has been developed which can fully chop straw and plant residue on field surfaces to meet the requirement to enhance no-tillage/low-disturbance seeding quality.

With the continuous deepening and optimization of R&D into CA machinery and equipment, CA machinery in China is now gradually developing in the direction of large-size combined operations and integration with digital and precision technologies. The novel machinery is continuously being optimized to provide support for the application of CA, such as the wheat/maize no-tillage precision seeder with subsoiling layered fertilization, and the combination machine that carries out subsoiling, no-tillage seeding and fertilizing.

5.3 SUBSIDIES FOR PURCHASING CONSERVATION AGRICULTURE MACHINERY

During the transition from conventional tillage to CA, it is vital to upgrade agricultural equipment. To increase the willingness of farmers to purchase CA machinery and accelerate the adoption of CA, MARA has included CA machinery in the subsidies catalogue of agricultural machinery (MARA, 2018) (Table 21). The *Guiding Opinion on Implementation of Agricultural Machinery Purchasing Subsidy 2021–2023* indicates that the subsidy proportion increases from 30 percent to 50 percent for large-size no-tillage seeders and intelligent combined operations and high-end products, and a large-size no-tillage seeder can be subsidized by up to CNY 150 000.

CA machinery has been included in the subsidy category, which improves the affordability of the machinery and thus the demand from farmers (MARA, 2018). From 2002 to 2018, the number of no-tillage seeders increased from

Table 21
Maximum subsidy from central financial fund for CA machinery (2018–2020)

CA machinery type	Category	Basic configuration and parameters	Maximum subsidy (CNY)
Subsoiler	≤3 shovels	≤3 subsoiling parts	1 400
	4–5 shovels	4–5 subsoiling parts	2 300
	≥6 shovels	≥6 subsoiling parts	3 400
	≤3 shovels with vibration source	Vibrating type, ≤3 subsoiling parts	2 800
	4–5 shovels with vibration source	Vibrating type, 4–5 subsoiling parts	3 100
	≥6 shovels with vibration source	Vibrating type, ≥6 subsoiling parts	4 900
No-tillage seeder	≤6 rows, no-tillage seeder	≤6 rows, working width ≤1 m	1 100
	7–11 rows, no-tillage seeder	7≤ rows, ≤11	2 700
	12–18 rows, no-tillage seeder	≤12 to ≤18 rows	4 100
	19–24 rows no-tillage seeder	≤19 to ≤24 rows	5 800
	≥25 rows, no-tillage seeder	≥25 rows	5 800
	2–3 rows no-tillage hole seeder	Normal metering device, 2–3 rows	900
	4–5 rows, no-tillage hole seeder	Normal metering device, 4–5 rows	1 600
	6 rows, no-tillage hole seeder	Normal metering device; ≥6 rows	3 000
	2–3 rows, no-tillage precision hole seeder	Precision metering device, 2–3 rows	1 000
	4–5 rows, no-tillage precision hole seeder	Precision metering device, 4–5 rows	1 800
	6 rows, no-tillage precision hole seeder	Precision metering device, ≥6 rows	6 200
	2–3 rows, pull-type no-tillage hole seeder	Precision metering device, 2–3 rows	12 300
	4–5 rows, no-tillage hole seeder	Precision metering device, 4–5 rows	23 300
	6 rows, no-tillage hole seeder	Precision metering device, ≥6 rows	36 500
Straw chopping and retention machine	≤1 m straw chopping and retention machine	Working width ≤1 m	200
	1.0–1.5 m straw chopping and retention machine	Working width ≤1 m to ≤1.5 m	900
	1.5–2.0 m straw chopping and retention machine	Working width ≤1.5 m to ≤2.0 m	1 900
	2.0–2.5 m straw chopping and retention machine	Working width ≤2.0 m to ≤2.5 m	2 200
	≥2.5 m straw chopping and retention machine	Working width ≥2.5 m	2 700

SOURCE: **MARA**. 2018. *Notice of the General Office of the Ministry of Agriculture on Printing and Distributing the "2018-2020 List of the Maximum Subsidy Amount of National General Agricultural Machinery Central Financial Funds."* Cited 15 April 2021. www.moa.gov.cn/nybgb/2018/201804/201805/t20180529_6143285.htm

220 000 to 1 003 000 units, with an overall increase of 355.9 percent and an annual increase of 20.9 percent. The number of straw chopping and retention machines increased from 335 000 to 926 000 units, with an overall increase of 176.4 percent and an annual increase of 10.4 percent. Additionally, the number of subsoilers increased from 86 000 units in 2008 to 289 000 units in 2018, an overall increase of 236 percent and an annual increase of 21.5 percent (Table 22).

Table 22
Amount of CA machinery from 2002 to 2018 (1000 units/sets)

Year	No-tillage seeders	Straw chopping and retention machines	Subsoilers
2002	220	335	-
2003	234	360	-
2004	276	440	-
2005	303	473	-
2006	334	546	-
2007	377	584	-
2008	560	398	86
2009	651	485	125
2010	732	559	141
2011	718	617	185
2012	776	655	205
2013	825	698	234
2014	868	758	225
2015	930	811	240
2016	967	856	268
2017	965	891	281
2018	1003	926	289

SOURCE: **MARA**. 2018. *Notice of the General Office of the Ministry of Agriculture on Printing and Distributing the "2018-2020 List of the Maximum Subsidy Amount of National General Agricultural Machinery Central Financial Funds."* Cited 15 April 2021. www.moa.gov.cn/nybgb/2018/201804/201805/t20180529_6143285.htm

5.4 SUITABLE TECHNICAL PATTERNS OF CONSERVATION AGRICULTURE FOR DIFFERENT REGIONS

China has a broad territory covering various agricultural regions with different soil, climate, cropping systems, and mechanization levels. In addition, the difference in agronomic requirements, production conditions, and planting traditions lead to the complexity and diversity in CA technical patterns. Therefore, understanding gained from experiments and demonstrations should form the basis for selection of the most suitable CA technical patterns for specific regional conditions.

After several years of experiments and demonstrations, CA technical patterns have been developed according to agricultural conditions.

The black soil region in Northeast China is arid and its soil fertility has been deteriorating. To address these challenges, many technical patterns have been developed, such as no-tillage/low-disturbance seeding with crop straw mulching technology and no-tillage seeding in permanent ridges with high stubble standing technology.

The Loess Plateau in Northwest China is arid and has large areas of sloping and hilly cropland, where soil erosion and water scarcity are severe. To solve these challenges, no-tillage seeding and stubble mulching technology as well as anti-evaporation and anti-erosion techniques with crop straw mulching in ridges have been employed for the sloping cropland.

Oasis farming in Northwest China consumes a large amount of water and is likely to cause desertification because of the water scarcity. To meet this challenge in Northwest China, no-tillage/low-disturbance seeding with straw mulching technology and no-tillage seeding with furrow ridge covering technology has been employed.

The region along the Great Wall in North China is arid in winter and spring and desertification is a serious issue in the region. To solve this challenge, no-tillage seeding with straw mulching technology and strip-seeding and strip-stubble mulching technology have been adopted.

In two-crops-a-year regions in the Huang-Huai-Hai Plain, the problems in agricultural production include straw burning, high multiple-crop index and water resource shortages. To solve these challenges, wheat/maize straw retention with no-tillage/low-disturbance seeding technologies have been developed.

5.5 LEADING ROLE OF DEMONSTRATION PROJECTS

Demonstration projects are indispensable in promoting CA. Through the establishment of CA demonstration plots, main CA technical patterns are determined, quality machines suitable for local conditions are selected, and technicians and farmers are trained for the extension and implementation of CA, which further accumulates experiences for large-scale promotion of CA.

The standards for the selection of demonstration plots are (i) a good foundation of agricultural mechanization, (ii) actual demand for CA technology, (iii) concrete support from local government, and (iv) sufficient technicians. These standards are vital for the success of demonstrations.

In addition, demonstration project funds need to be used effectively, mainly for capacity development and advocacy for farmers and field experiments. Households with large-scale machinery need to be supported to buy or improve agricultural machinery. At different stages of the demonstration project, supporting areas can be prioritized according to the level of farmers' awareness. The awareness and motivation of the local government can be increased to augment investment and conduct experiments and demonstrations, and the most excellent CA demonstration projects can be selected for national demonstration projects.

5.6 INTEREST-DRIVEN MECHANISMS

The beneficiaries of CA are most likely to promote the application of CA technology. The multiple stakeholders of extension and adoption of CA include agricultural research/education/extension institutions, enterprises, farmers, and agricultural machine drivers and technicians. Promoting the benefits of CA, such as improving the environment and enhancing the sustainable development of agriculture, obtains the support of extension institutions. Advocating for and demonstrating the agronomic, environmental and economic benefits of CA, such as improving soil fertility, decreasing operating costs and increasing crop yield and income, can motivate farmers to adopt CA. Promoting and applying novel CA machinery and equipment can reveal the potential market for machinery manufacturers, which will give full play to the driving force of these enterprises. Improving the operational quality and use rate of CA machinery to increase profits can attract the participation and recognition of machinery operators. Moreover, financial support and improved profits can encourage mechanization hire service providers and farmers’ associations to adopt and promote CA.

5.7 MONITORING AND EVALUATION OF CONSERVATION AGRICULTURE'S IMPLEMENTATION AND IMPACTS

It is crucial to optimize monitoring and evaluation procedures and the layout of monitoring plots, clarify monitoring and evaluation indicators, and assign responsibility to units and individuals for improving the timeliness and accuracy of monitoring and evaluation, and obtaining first-hand information during monitoring. Through demonstration, extension, and continuous monitoring and evaluation, the long-term benefits of CA technology can be further understood and illustrated. Monitoring and evaluation should focus on the impacts of CA on agricultural production and the environment, such as soil water, fertility and other physical, chemical, and biological variations, operating costs, variations in crop yield, and the dynamics of diseases, insect pests and weeds. Additionally, it is important to enhance the collection, analysis, and research of the monitoring results to scientifically evaluate the implementation effects. It is critical to exchange and share the monitoring data and thus make full use of the resource and provide scientific evidence for further research on CA.

5.8 TRAININGS ON CONSERVATION AGRICULTURE TECHNOLOGY

Once CA enters the demonstration stage, it is necessary to start preparing large-scale extension. All kinds of capacity development methods can be used to help farmers and other stakeholders gradually understand and master CA technology.

(1) Well-designed trainings and workshops

Within a defined period, organize and train the relevant personnel of the extension programme on-site (physical training) or online (virtual training). The training content needs to be adjusted according to the participants.

(2) Field demonstration of machinery operations

Field demonstrations (in various forms, including on-site and live streaming) of machinery operations provide a good opportunity for communication among farmers, researchers, agricultural enterprises, and government officers. Farmers can see the latest CA machinery for increasing operating efficiency. Researchers can introduce their study results to farmers, enterprises, and government officers, and thus promote the adoption and transformation of the agricultural research products. Agricultural machinery enterprises can exhibit and introduce their agricultural machinery to boost the purchasing willingness of farmers and mechanization service providers. Government officers can better understand the demands of farmers, researchers, and agricultural machinery enterprises.

(3) Audiovisual materials

Audiovisual materials, which can be handed out on-site or distributed online (Figure 9), include audio recordings, videos, and training handbooks. Extension personnel can record the lectures and reports of CA experts. Extension videos can present the content of CA and how to conduct CA step by step. Training handbooks can provide a range of information about CA, such as study results, application experience, technological regulations, and agricultural machinery and equipment (Figure 10).

Science popularization books use cartoon images to vividly present the concept, advantages, and operating procedures of CA. These can help farmers better understand the technology of CA (Figure 11).

Figure 9
Extension videos of CA

SOURCE: Author's compilation.

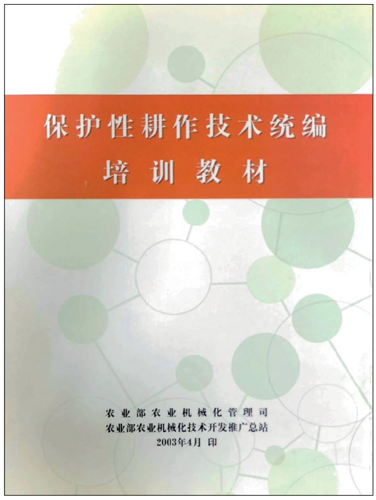
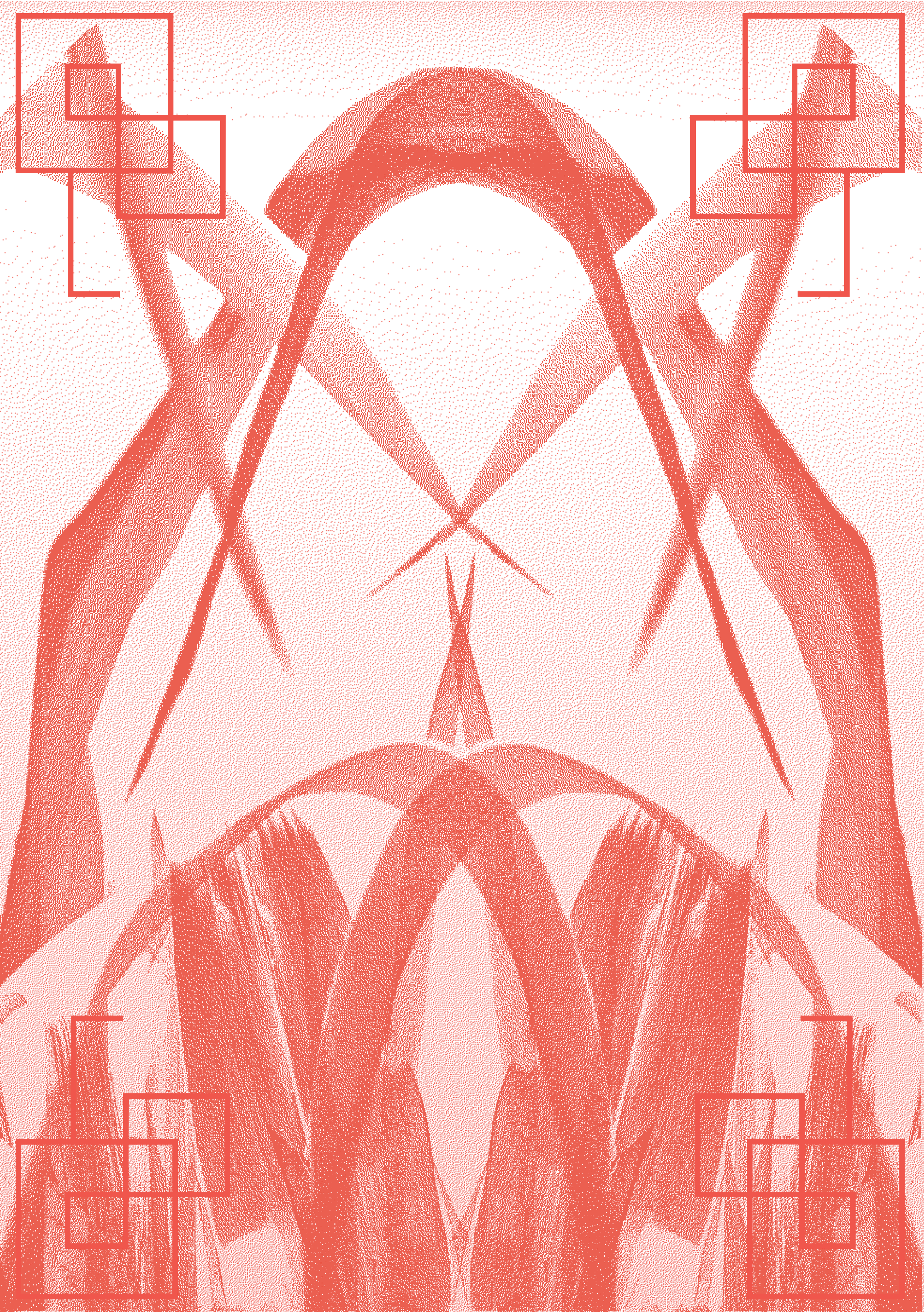


Figure 10
CA training book

SOURCE: Author's compilation.

Figure 11
Publications on CA

SOURCE: Author's compilation.



Chapter 6
Typical case studies of adopting conservation agriculture

China has attached great importance to the promotion and adoption of CA. CA adoption areas have been extended from dryland farming regions to irrigated agricultural regions, from farmland to pasture, and from northern to southern China. Successful cases have frequently emerged during extension; cases from two levels (i.e. extension at the county level and at the agricultural mechanization cooperative level) that demonstrate the adoption of CA and its benefits in China.

6.1 EXTENSION OF CONSERVATION AGRICULTURE AT THE COUNTY LEVEL

(1) Tailai county in Heilongjiang province
Tailai County is located in the southwest of Heilongjiang Province. Tailai County has a mid-temperate continental monsoon climate with an annual rainfall of 392.6 mm, with 80 percent of the rainfall occurring in the summer. The average evaporation rate in Tailai is 1765.7 mm/year; for almost nine of the ten years the climatic conditions in Tailai have been arid.

In 2007, Tailai County established a CA working group and dispatched many agricultural officers to study and be trained in relevant institutes. CA technology has been promoted through various initiatives since 2007, including TV lectures and documentaries, technical promotional conferences, trainings and field site meetings.

Three extension measures have been developed to encourage the expansion of CA. In the first scenario, the target crop yield is set and if the crop yield exceeds the targeted goal, the surplus belongs to the farmer; if the actual yield is less than the targeted amount, the village government compensates the farmer for their loss. Thus, the experimental risks are shouldered by the village government. In the second scenario, the same type of compensation is employed as described in the first measure, but this time the research institution bears the risk of compensating farmers if the targeted crop yield is not achieved. In the third scenario, the incentive is that the agricultural bureau provides free agricultural machinery and equipment services to farmers who participate in CA experiments voluntarily. These measures have significantly increased the enthusiasm and motivation of farmers to adopt CA.

More than ten years of CA practices in Tailai County have achieved good results. More than 5 000 labourers have been transferred to secondary and tertiary industries. Soil water and wind erosion declined by 60 percent and 80 percent, respectively. Soil water content increased by 14 percent, soil organic matter increased by 0.021 percent annually, and natural rainfall use efficiency increased by 20–28 percent. Compared with conventional tillage, CA shows good economic benefits and can reduce costs by CNY 2175/ha, increase crop yields by 1678.5 kg/ha, and increase benefits by CNY 4515/ha.

(2) Qinggang county in Heilongjiang province

Qinggang County is located in Heilongjiang Province. It has a temperate continental monsoon climate, with annual rainfall of 489.3 mm, an average annual temperature of 2.4–2.6 °C, and a cropland area of 170 867/ha. The county has an agricultural population of 377 000.

In 2015, as the crop straw retention pilot county for Heilongjiang Province, the CA demonstration area in Qinggang County covered 36.7 ha. From 2015 to 2019, the adoption area of no-tillage seeding with crop straw mulching was 3333 ha, 6000 ha, 8667 ha, 13 333 ha, and 49 333 ha, respectively for those years. In 2016, 2017, and 2019, additional subsidies for subsoiling operations were provided to the value of CNY 750, 300, and 450/ha, respectively. Qinggang County offered accumulation subsidies for agricultural machinery purchasing and the total subsidy reached 60 percent of the machinery price. In addition, the county government installed intelligent monitoring devices on the no-tillage seeders for farmers free of charge. To enhance the development of straw retention, a total of CNY 24.8 million was invested and 1157 straw retention machines were purchased. To support the application and extension of CA, Qinggang County has invested CNY 16 million.

In recent years, Qinggang County has actively organized trainings for CA techniques, and conducted experiments and demonstrations on CA. More than 10 technical training workshops and eight field exhibitions have been held, and more than 28 000 leaflets on straw retention technology and in excess of 2000 CA technical handbooks have been handed out. The county has established three high-standard experimental and demonstration sites at the county level and 15 high-standard demonstration parks at the village level. In the CA demonstration areas, soil moisture content has increased by 12 percent, soil organic matter (SOM) has increased by 0.47 g/kg, and productivity and yield has increased significantly.

(3) Bole city in Xinjiang Uygur autonomous region

Bole City is located in the northwest of Xinjiang (Baidu, 2021). It has a terrestrial arid semi-desert and desert climate. The annual average temperature is 5.6 °C and the annual average rainfall is 181 mm.

In 2009, Bole City started to explore no-tillage maize precision seeding technology, fertigation technology, and CA technology without plastic mulching film. In 2019, the promotion area of maize no-tillage seeding technology was

336 ha and the average crop yield in the CA system was 16 459.5 kg/ha, which was 1 819.5 kg/ha higher than that of the regular mulching film planting system. The income growth in the CA system was CNY 6480/ha higher than in the mulching film system. On 25 October 2019, witnessed by experts from the National Institute for Conservation Tillage at China Agricultural University, tests proved that the average maize yield of the CA system reached 19 720 kg/ha. In 2020, the adoption area of CA for maize was 2000 ha, with an average yield of 16 208 kg/ha, which is 1 505 kg/ha higher than the average maize yield in Bole City. Bole City planned to promote 4000 ha of maize under no tillage in 2021 (Tao, 2021).

6.2 PROMOTION OF CONSERVATION AGRICULTURE THROUGH HIRE SERVICES OF AGRICULTURAL MECHANIZATION COOPERATIVES

Hire services provided by agricultural mechanization cooperatives play significant roles in the adoption and extension of CA in China. Agricultural mechanization cooperatives are supported by government and collaborate with research institutes and machinery enterprises through financial and technical support, as well as with CA demonstration projects.

(1) Huibin Agricultural Mechanization Specialized Cooperative in Xinbin County, Liaoning Province

Huibin Agricultural Mechanization Specialized Cooperative is located in Xinbin Manchu Autonomous County, Liaoning Province. It has about 33.3 ha of cropland and its major crops are maize and rice. It has approximately 50 pieces of agricultural machinery. The cooperative played a leading role in CA extension, which promoted the adoption of CA in Xinbin County. It adopts no-tillage seeding technology with different models, such as no-tillage seeding with a narrow-wide row pattern and maize straw full retention, no-tillage seeding with high standing maize stubble retention, and no-tillage seeding in original ridges with maize straw full retention. Results showed that the cost of mechanized no-tillage seeding was only CNY 900/ha, which was CNY 1050/ha lower than the cost of the conventional tillage system (CNY 1950/ha). In the spring of 2021, because of the low temperature and heavy rainfall, the germination rate in the conventional tillage fields was widely low, while the germination rate in CA fields was as high as 98 percent. CA not only increases crop yield but also enhances the agricultural resilience to extreme weather by increasing soil organic matter content and improving soil structure.

(2) Changchun Agricultural Specialized Mechanization Cooperative in Shenbei New District, Liaoning Province

Changchun Agricultural Mechanization Specialized Cooperative is located in Shenbei New District in Shenyang City, Liaoning Province. It has 198 ha of cropland, more than 50 machines and tractors, and machinery garages that cover an area of 1000 m^2. The cooperative started adopting CA in 2014. From years of comparison between CA and conventional tillage, the results showed that the crop germination rate was higher and growth quality was better in CA fields. Compared with conventional tillage, CA increased yields by 10 percent (i.e. 1500 kg/ha) and increased profits by CNY 2250/ha.

(3) Xinde Agricultural Mechanization Cooperative in Baoli township, Changtu County, Liaoning Province

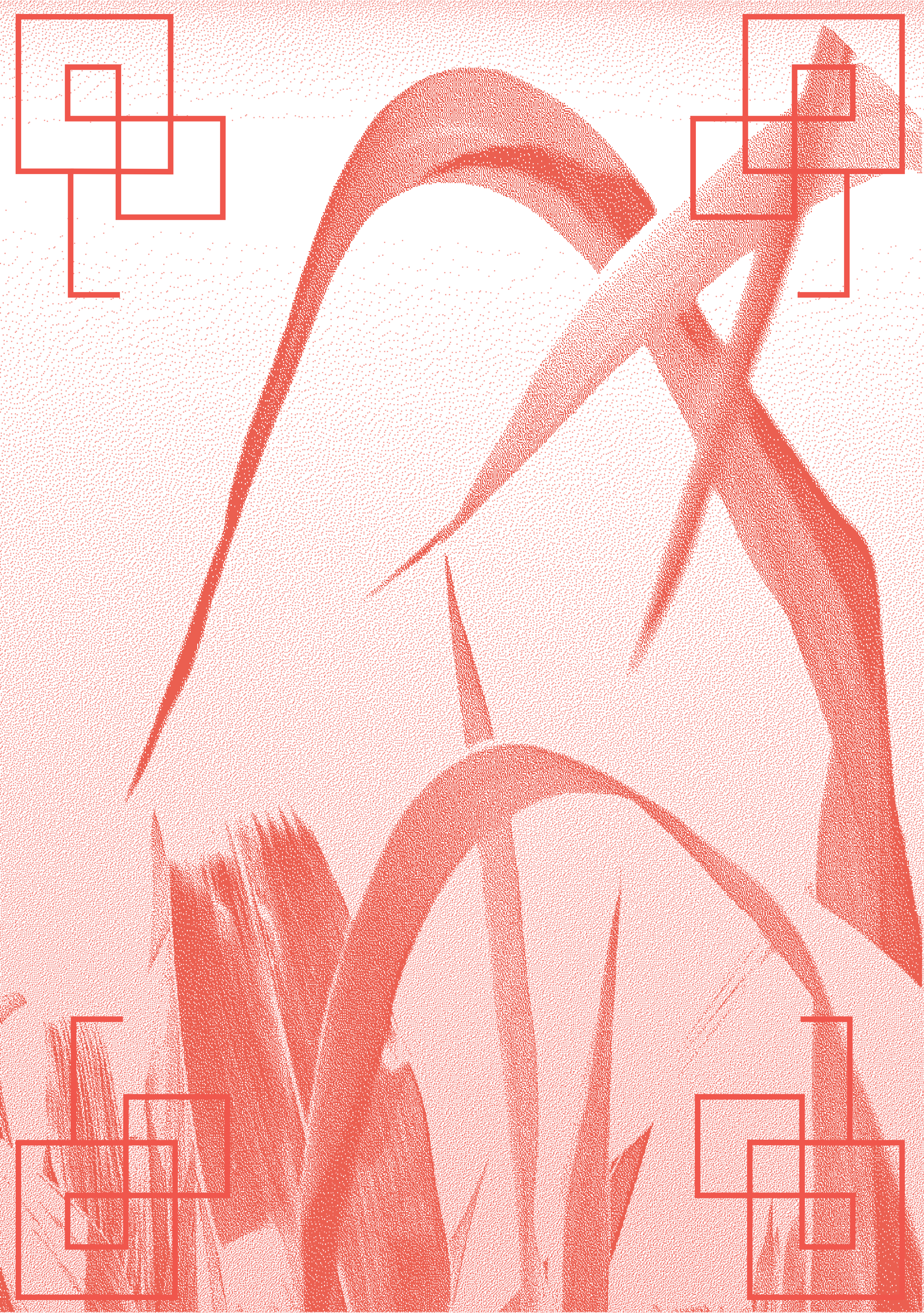
Xinde Agricultural Mechanization Cooperative adopted CA for 40 ha of farmland, employing full maize straw chopping and retention technology, and the maize seedling emergence rate in the CA demonstration fields was 94 percent. In 2019, when a severe drought occurred that lasted for more than one month before maize tasseling, the growth of maize in the CA demonstration fields was better than in conventional tillage fields. In addition, when the rainfall was heavy, runoff and maize lodging did not occur in the CA fields. Compared with conventional tillage, CA saved costs by CNY 420/ha, and increased yield by 885 kg/ha and profits by CNY 1500/ha, respectively. In total, the profits from the 40 ha of cropland under CA increased by CNY 76 980 in total. Furthermore, earthworm numbers in CA fields have increased significantly, which highlights the positive effects of CA on improving soil organic matter content and soil fertility.

(4) Luwei Agricultural Mechanization Specialized Cooperative in Lishu County, Jilin Province

Luwei Agricultural Mechanization Specialized Cooperative (Wang, 2021) is located in Lishu County, Jilin Province. It has 667 ha of cropland, which accounts for 86 percent of the village's arable lands. It started adopting maize straw cover and no-tillage seeding in 2013. Sustainable agricultural technologies have been adopted that can increase crop yield and profit, including soil testing and formula fertilization, subsoiling, CA, and green plant protection technology. CA significantly contributes to protecting black soil. Additionally, maize yield in CA fields was 10 000 kg/ha, which is 1000 kg/ha higher than in conventional tillage fields. The income from CA fields is about CNY 2000/ha higher than from fields with conventional tillage.

(5) Zhitao Agricultural Mechanization Specialized Cooperative in Qingdao City, Shandong Province

Zhitao Agricultural Mechanization Specialized Cooperative is located in Laixi in Qingdao City, Shandong Province. It has more than 80 ha of farmland (under land circulation), 14 sets of agricultural machinery, and more than CNY 13 million in fixed assets. The cooperative began implementing CA in 2012 and has been exploring the technology of straw as fertilizer since 2014. After seven years of continuous adoption of CA, soil structure and soil aggregate distribution have been improved, soil organic matter and earthworm numbers have been enhanced significantly, and soil water-storing and conservation have been increased. Since 2015, under the joint technical guidance of China Agricultural University and Laixi Agricultural Machinery Department, the cooperative combined CA with large-scale farming and integrated straw management technology (e.g. straw as fertilizer and feed), started experiments on the integrated model of CA with farming and animal husbandry, and has achieved remarkable results with CA. Since 2019, the cooperative has also been participating in a three-year pilot project initiated by the Centre for Sustainable Agricultural Mechanization (CSAM) (CSAM, 2019) on Integrated Straw Management through Sustainable Agricultural Mechanization, in collaboration with China Agricultural University, Qingdao Administration of Agriculture and Rural Affairs, and Laixi Administration of Agriculture and Rural Affairs (Also see Section 7.4).



Chapter 7
Review of conservation agriculture-related policies worldwide

Globally, CA has been developing rapidly in recent years. It is estimated that the application area of CA in 2008 was about 1.06 × 10^8 ha, accounting for 7.5 percent of the world's cropland. In 2015, the area of CA expanded to 1.8 × 10^8 ha, accounting for 12.5 percent of cropland in the world. The area of CA has increased by 7.4 × 10^7 ha in seven years (2008–2015), with a growth rate of 69 percent. More than 100 countries have now adopted CA technology. Moreover, the policies related to CA that have been introduced by various countries have significantly promoted the development of CA globally.

This section analyses the related policies that have emerged during the development of CA in different countries and regions and summarizes the specific measures of CA development in the United States of America, South America, and Europe. This section also analyses the influence of the Common Agricultural Policy in Europe and the European Green Deal on the development of CA. Furthermore, this section introduces the CA projects carried out by international organizations in China, and discusses the relevance to China's policies of the CA-related policies and laws of other countries.

7.1 THE UNITED STATES OF AMERICA

The United States of America was the first country to study CA because of the "black storm" event in the 1930s that shocked the world. In 1935, the President of the United States of America, Franklin D. Roosevelt signed the *Soil Conservation Act* and established the Soil Conservation Service, aimed at preventing soil erosion and protecting natural resources. In 1994, the Soil Conservation Service was renamed the Natural Resources Conservation Service. In 1995, the *Food*

Security Act was formally promulgated to prevent the Department of Agriculture of the United States of America from conducting agriculture on any land that was vulnerable to erosion without employing CA measures, thereby further strengthening the conservation of land for agricultural production. According to the Department of Agriculture of the United States of America's Census of Agriculture in 2012 and 2017, the area that applied cover crop technology increased from about 10 million acres in 2012 to more than 15 million acres in 2017, and the number of farms increased from 133 500 to 153 400. From 2015 to 2016, the United States of America had the largest area per country of CA in the world (Kassam, Friedrich and Derpsch, 2019).

7.2 SOUTH AMERICA

CA technology in South America has been developing rapidly. South America has the largest CA area per continent in the world. Brazil and Argentina are the two countries that most actively promote CA in South America.

CA-related policies in Brazil are as follows. In 1973, the Banco do Brasil (Bank of Brazil) provided subsidized loans to farms that purchased or modified no-tillage seeders/planters. In 1980, several projects on integrated soil management and soil conservation were implemented in southern Brazil under the auspices of the World Bank. In 1993, the Banco do Brasil included no-tillage within the scope of subsidized loans. In 1995, the government began agricultural financing to decrease loan interest rates and insurance premiums for no-tillage operations.

The CA-related policies in Argentina follow. In 1986, the *Conservationist Agriculture Project* was implemented and farmers who bought no-tillage seeders/planters or other CA equipment could access interest-free loans, with a repayment period of five years. In 1993, the government approved the cultivation of genetically modified crops to promote the extension and application of CA. Since 2000, in two-crops-a-year regions of Santa Fe Province, the land-renting tax for farmers who adopted no tillage has reduced by 60 percent.

7.3 EUROPE

In Europe, CA has brought significant economic and ecological benefits. According to data from the European Conservation Agriculture Federation (ECAF) website, the countries adopting the largest areas under CA in Europe are Spain (746 830 ha), followed by Romania (583 800 ha), the United Kingdom of Great Britain and Northern Ireland (562 000 ha), Finland (480 000 ha), Poland (403 200 ha), France (300 000 ha), Italy (283 900 ha), Germany (146 000 ha), Greece (91 000 ha), and Republic of Moldova (60 000 ha) (ECAF members, 2020).

In Europe, several factors influence CA adoption, including the following. (i) Top-down (through universities or vocational schools) and bottom-up (national farmer organizations for CA) activities or policies are driving the development of CA. (ii) Research is indispensable for the extension and adoption of CA, while agricultural extension services still need to be strengthened to help farmers' organizations or the private sector to become better at adopting sustainable agricultural knowledge and skills. (iii) Mechanization hire services and machinery suppliers specializing in CA are rare in Europe (Goddard *et al.*, 2020).

(1) Common Agricultural Policy

European agriculture faces many challenges, such as environmental pollution, climate change, biodiversity decline, and soil degradation. The Common Agricultural Policy (CAP) is one of the core policies to solve these challenges. Launched in 1962, the CAP is a partnership between agriculture and society and between Europe and its farmers. The CAP is a common policy for all European Union countries and it is managed and funded in Europe by the European Union budget (European Commission, 2021a). The CAP aims to support farmers and improve agricultural productivity, thus ensuring a stable supply of affordable food; safeguard European Union farmers to make a reasonable living; help tackle climate change and the sustainable management of natural resources; maintain rural areas and landscapes across the European Union; and keep the rural economy alive by promoting jobs in farming, agrifood industries, and associated sectors. The CAP proposes to promote CA and other measures to increase soil microbial diversity, prevent soil erosion, and avoid soil pollution and compaction.

In 2021, CA was included in a list of potential agricultural practices that the ecoschemes could support in a future CAP (European Commission, 2021b).

Europe complies with the CAP, which involves the protection of farmland soil. In order to improve soil microbial diversity, prevent soil erosion, and avoid soil pollution and soil compaction, the policy proposed carrying out CA and other measures actively. Furthermore, the European Union issued the *European Union Agrarian Law* in 1999 to ensure the implementation of the policy.

(2) European Green Deal

In 2019, the European Green Deal was proposed by the European Commission. The Green Deal covers various areas such as climate, environment, energy, agriculture, industry, and the economy and provides guidance to transform the European Union into a modern, resource-efficient, and competitive economy. The goal of the Green Deal is to ensure no net emissions of GHGs by 2050. One-third of the EUR 1.8 trillion in investments from the Next Generation European Union Recovery Plan and the European Union's seven-year budget will finance the European Green Deal to overcome challenges such as climate change and environmental degradation (European Commission, 2021c).

The Biodiversity Strategy for 2030 (European Commission, 2020a) and Farm to Fork Strategy (European Commission, 2020b) are core parts of the European Green Deal and will also support a green recovery and more resilient food system following the COVID-19 pandemic.

(3) European Conservation Agriculture Federation

The establishment of the European Conservation Agriculture Federation (ECAF) in Europe is one of the important driving forces of CA. The ECAF was constituted in Brussels in 1999 as a non-profit international association. It aims to encourage good practices in maintaining agrarian soil and its biodiversity by promoting CA in the context of sustainable agriculture. In 2001, ECAF and FAO organized the First World Congress on Conservation Agriculture. In June 2021, ECAF and Swiss No-Till organized the Eighth World Congress on Conservation Agriculture (8WCCA) with support from FAO and other institutions (8WCCA, 2021). The theme of the conference was The Future of Farming: Profitable and Sustainable Farming with Conservation Agriculture. The 8WCCA Congress (virtual events) provided an online platform for the international community of leading farmers, scientists, policymakers, entrepreneurs and agribusinesses, and international organizations, all striving to create solutions for actual and future agriculture.

7.4 CONSERVATION AGRICULTURE PROJECTS LED BY INTERNATIONAL ORGANIZATIONS IN CHINA

Recently, international organizations such as FAO, the Centre for Sustainable Agricultural Mechanization (CSAM) of the United Nations Economic and Social

Commission for Asia and the Pacific (ESCAP), and the World Bank have been actively cooperating with China to promote CA.

(1) CSAM pilot project on integrated straw management in China

CSAM initiated a three-year Pilot Project on Integrated Straw Management through Sustainable Agricultural Mechanization in China (CSAM, 2019). This pilot project is the joint initiative of CSAM, China Agricultural University, Qingdao Administration of Agriculture and Rural Affairs, Laixi Administration of Agriculture and Rural Affairs, and Qingdao Zhitao Agricultural Machinery Specialized Cooperative. To lessen straw burning and its negative impact on human health and agricultural ecosystems, the project aims to test, demonstrate, and promote circular agriculture of straw used as fertilizer (CA technology), fodder, and a base material for mushroom production. After two years of testing and demonstration between July 2019 and August 2021, positive outcomes have been achieved at the pilot site in Laixi: (i) 72 tonnes of wheat straw and 99 tonnes of maize straw were utilized as fertilizer rather than being burnt during the most recent year (ended August 2021) at the 10 ha pilot site, thus successfully demonstrating potential to reduce an estimated 220 tonnes of annual carbon dioxide emissions. (ii) Over the same period, in comparison to the pre-intervention levels in 2018, maize yield and wheat yield increased by 509 kg/ha and 1300 kg/ha respectively while the net income of the farmer cooperative under the various technical patterns increased by up to USD 602/ha. (iii) Soil Organic Matter increased from 2.1 percent in 2018 to 2.24 percent in 2021. Based on the encouraging results from the pilot in China as well as a related intervention undertaken in Viet Nam, CSAM is now expanding this initiative to other countries such as Cambodia, Indonesia and Nepal with financial support from the China–ESCAP Cooperation Programme.

(2) World Bank project of Guangdong agricultural non-point source pollution control

Titled as Guangdong Agricultural Non-Point Source Pollution Control Policy Research – Environmentally Friendly Planting Industry Project, the project (Guangdong Provincial Agricultural Non-point Source Pollution Control Project Management Office, 2021) is to form an available pattern and policy mechanism suitable for Guangdong and provide beneficial experiences and a policy basis for the treatment of agricultural non-point source pollution in Guangdong and in China. The research into CA in this project mainly focuses on direct-seeding for rice, CA for sweet maize, and related agricultural machinery demonstrations. The results showed that, compared with conventional tillage, CA significantly increased profits without decreasing yield, and fertilizer consumption each crop season declined by up to 750 kg/ha, which could help to decrease the potential risk of nitrogen and phosphorus losses (Ou, 2020).

(3) FAO projects on support to adoption and promotion of CA

FAO has made important contributions to the global promotion of CA through agricultural development and investment projects. The CA website of FAO (www.fao.org/conservation-agriculture) provides comprehensive information, knowledge, and global case studies related to CA. The FAO Conservation Agriculture Community of Practice (CA-CoP) provides an online platform and technical network for exchange and sharing of CA experiences globally. In Asia, FAO has implemented CA projects in many counties (China, India, Kazakhstan, Uzbekistan, and others). In 2020, the Twenty-seventh Session of the Committee on Agriculture (COAG27) of FAO formally endorsed The Global Action for

Sustainable Dryland Agriculture and CA was one of the key technologies for dryland agriculture worldwide (FAO, 2020). Additionally, in 2021 FAO launched the Global Action on Green Development of Special Agricultural Products: One Country One Priority Product (OCOP) (FAO, 2021a). This global action aims to develop green and sustainable value chains for special agricultural products, support small and family farmers to reap the full benefits of a global market, help the transformation of current agrifood systems and ultimately support countries in the achievement of the Sustainable Development Goals (SDGs). In this regard, CA is considered to be one of the green practices and technologies for green development in plant production under OCOP.

Some FAO projects related to the promotion of CA in China are the following:

- 2021–2023, Conservation and Sustainable Management of Black Soil in Jilin Province (FAO, 2021b). This project is complementary to the *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*. It aims to contribute to developing sustainable and appropriate technical guidelines and policy recommendations for sustainable black soil management in Northeast China through testing potential technical and management options as well as learning from experiences and knowledge such as the International Network of Black Soils (INBS).
- 2021–2023, Support to Sustainable Use and Management of Sugar Crop Residues for Sustainable Production and Natural Resources Conservation (FAO, 2021c). This project aims to effectively and efficiently return processed sugar production waste and residue as organic matter to crop fields, which will minimize the negative impacts of direct waste disposal on the environment, increase soil fertility, and decrease the application of chemical fertilizer.
- 2016–2022, Biodiversity Conservation and Sustainable Land Management in the Soda Saline-alkaline Wetlands Agro Pastoral Landscapes in the Western Area of Jilin Province (FAO, 2016). The project includes the promotion of CA around Chagan Lake in Jilin Province.
- 2015–2017, Promotion of Climate-Smart Agriculture through Improving Crop Residue Utilisation and Soil Fertility Management on the Huaibei Plains, Anhui Province (FAO, 2015). Because of the low local straw use rate in Anhui Province, the Chinese government requested assistance from FAO to transfer integrated straw management technology through capacity development, including farmer field schools in particular.
- 2004–2005, Promotion of Advanced Straw Utilization Technologies in Jiangsu Province (FAO, 2004). CA and other integrated straw management technologies were promoted in Jiangsu Province to decrease air and water pollution, improve the overall ecological environment, enhance soil fertility, and increase crop productivity and farmers' income.

Furthermore, in 2013, the Expert Consultation Workshop on Conservation Agriculture (CA) for formulation of CA policy and strategy for Asia was held in Beijing. More than 30 experts and personnel from international organizations from 16 Asia-Pacific member states, including ministries of agriculture, universities, agricultural machinery companies, and agricultural departments, attended the meeting. FAO Regional Office for Asia and the Pacific released the conference report Policy and Institutional Support for Conservation

Agriculture in the Asia-Pacific Region (FAO, 2013). The meeting also recommended the establishment of the Conservation Agriculture Alliance for Asia-Pacific (CAAAP) (CAAAP, 2021a). In May 2021, the online meeting for The Strategies for the Promotion of Conservation Agriculture in the Asia and Pacific Region was successfully held (CAAAP, 2021b). The experts shared experiences and the status of CA adoption and promotion globally, regionally (Eurasia, Latin America, Europe, Africa, Asia and the Pacific), and nationally (China). Agricultural officers at FAO stated that the CAAAP alliance plays an important role in promoting the common development of CA in the Asia-Pacific region and CAAAP should work more actively to strengthen cooperation, exchanges, and experience-sharing and to jointly promote the extension and adoption of CA in this region.

7.5 ENRICHMENT OF CHINESE POLICIES

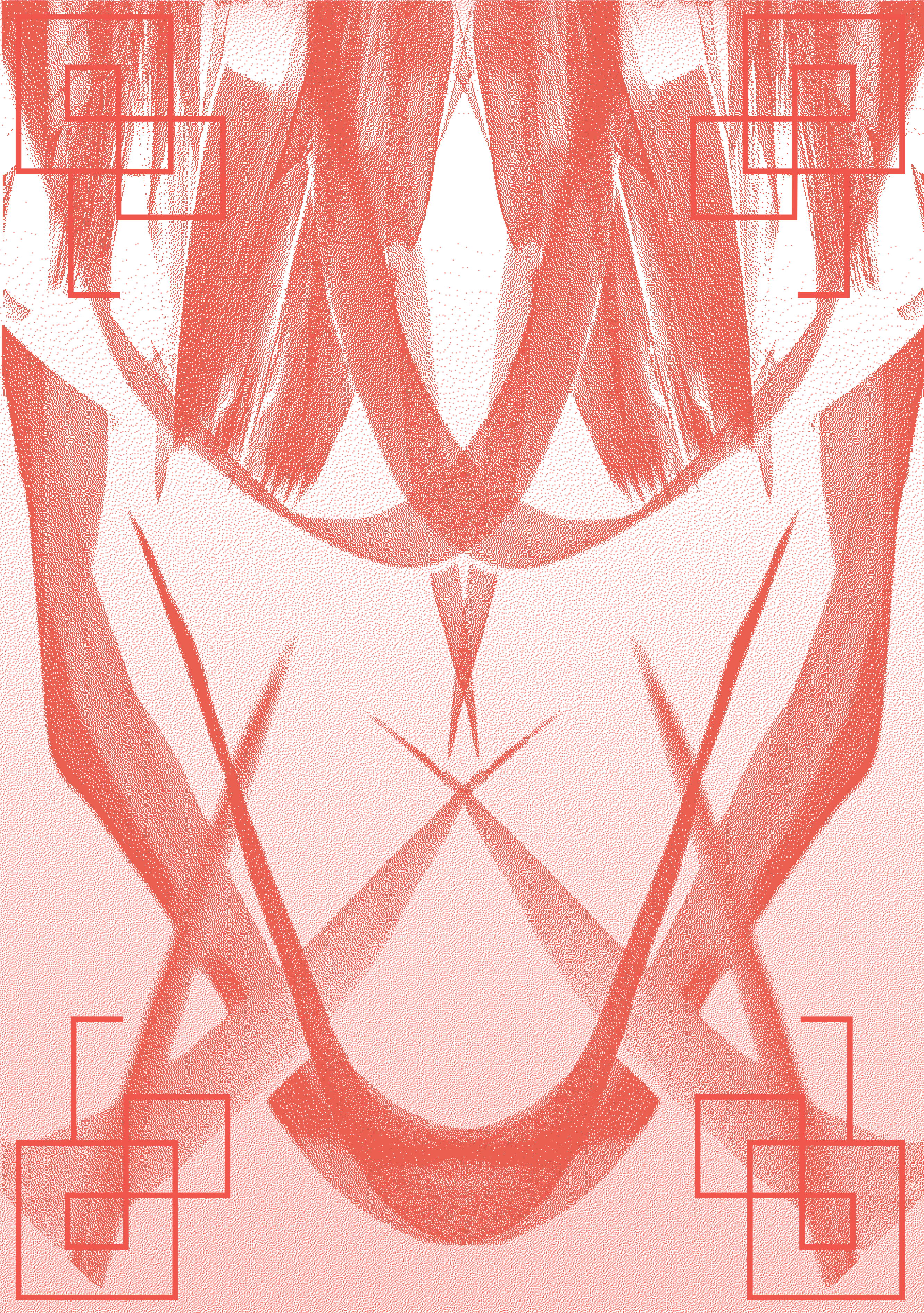
Relevant policies and strategies issued globally have significantly promoted the development of CA technology and green agriculture, which could provide enrichment for the formulation of CA-related policies in China.

(1) Increasing subsidies for CA. China has issued subsidy policies for CA machines and equipment. However, in the promotion process of CA, farmers were concerned about the possible risks of adopting CA, which limited farmers' enthusiasm and engagement to a certain extent. Therefore, relevant technology subsidy policies based on local conditions should be formulated for CA extension in suitable areas.

(2) Protecting the interests of small- and medium-sized farmers. The interests of small- and medium-sized farmers should be protected when formulating policies for ensuring food security and the extension of CA.

(3) Establishing national long-term policies for CA promotion. During the extension and adoption of CA in China, national long-term policies and long-term goals should be established, and the Common Agricultural Policy of the EU, for example, could provide direction.

(4) Strengthening the function of CA in ecosystem services. During the formulation of CA-related policies and standards, it is indispensable to minimize the use of chemical fertilizer and pesticides to strengthen the ecosystem services of CA.



Chapter 8
Prospects for conservation agriculture development in China

Based on the current development status of CA in China, this section discusses the prospects for CA development in China from the aspects of technology and equipment, technical patterns, policies, and adoption.

(1) CA technology and equipment optimized: Breakthroughs will be made in precision no-tillage/low-disturbance seeding technology, subsoiling technology with energy saving and resistance reduction, even straw chopping and retention technology, and precision and adjustable fertilizing technology. High-quality agricultural machinery and equipment will also be developed. The intelligent, digital, and information level of CA machinery will be improved and strengthened. The optimal working parameters of seeders, subsoilers, and straw retention machinery will be provided to ensure working quality based on field operating environments such as crops, soil conditions and types, and climate types. In terms of plant protection for CA, mechanical and chemical weeding methods can be complementary, and plant diseases, insect pests, and weeds will be accurately forecast to maximally protect healthy crop growth. In terms of water and plant nutrient management, precision and real-time fertilization and irrigation will be implemented based on crop growth demand, soil water and fertility status, and weather conditions.

(2) CA technical patterns optimized: Long-term experiments with CA in different regions will reveal the effects and mechanisms of no-tillage/low-disturbance, straw retention, crop diversification (e.g. rotation and intercropping), plant protection, irrigation, and fertilization on soil structure and fertility, soil microorganisms, yields, GHG emissions, and operating costs, based on the regional environment and cropping system. Furthermore, combined with local conditions such as climate, cropping systems, soil conditions, and mechanization levels, optimized CA technical patterns at the county level will be more specific and refined to achieve the potential of CA in ecosystem services and contributions to saving costs and improving effectiveness.

(3) Support policies for CA optimized: More support policies will be issued and further optimized for large-scale and rapid extension and adoption of CA in different agricultural regions of China (e.g. Northeast, Northwest, and North China). The support policies for CA include ecological subsidy policies for CA application, the purchase subsidy policy for CA machinery and equipment, the tax reduction policy for CA manufacturing enterprises, support policies for research institutions, and others. At the same time, national and local standards of CA will be further developed and improved.

(4) Large-scale adoption of CA promoted: After years of publicity, training, demonstration, and extension of CA, a specialized agricultural talent team with comprehensive techniques will be developed and farmers' willingness to adopt and promote CA will be enhanced. On the basis of the high quality of CA machinery and equipment and suitable CA technical patterns and with the support policies of the central government and local governments at all levels, CA will be adopted and promoted at a larger scale in China.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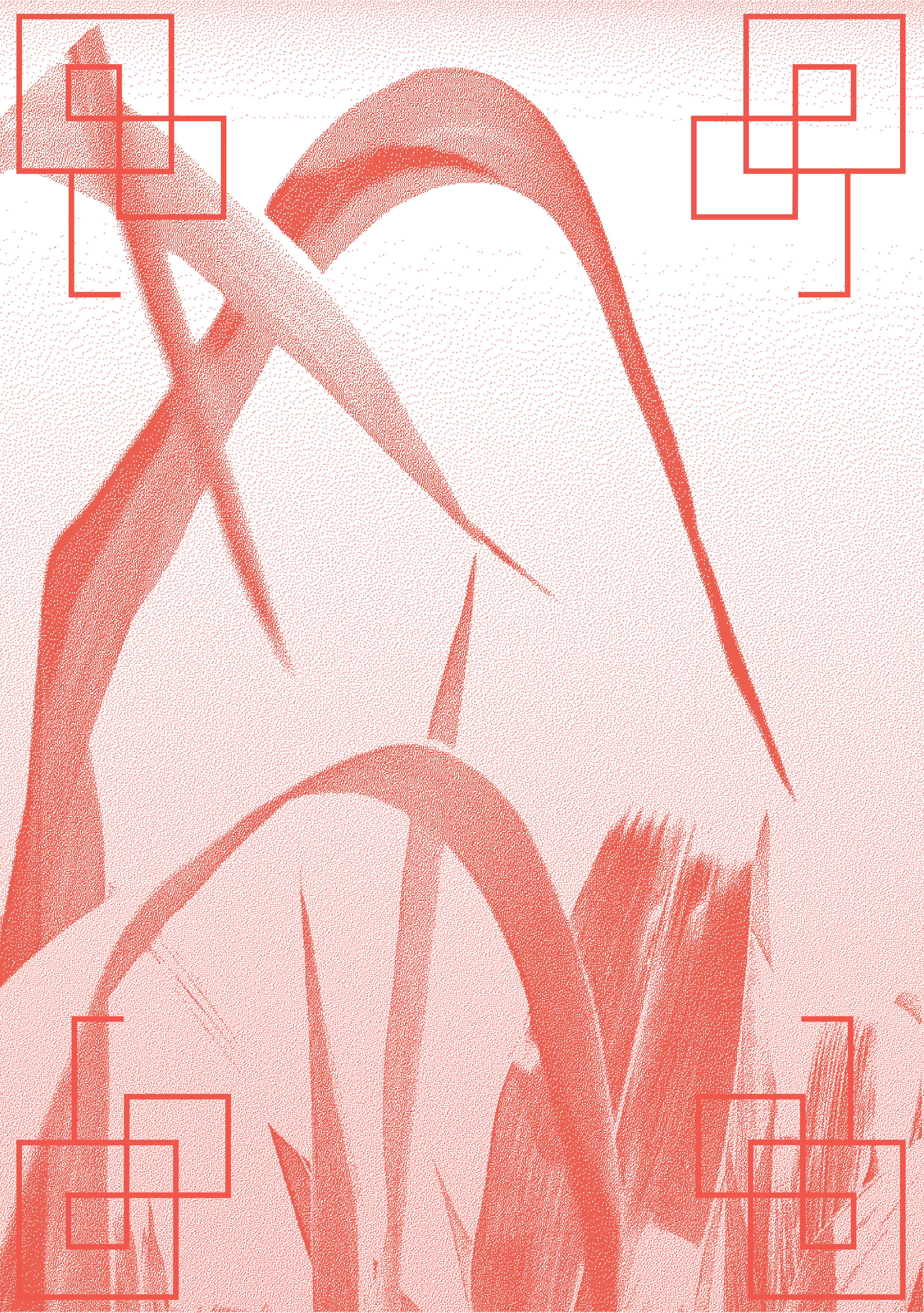

References

8WCCA. 2021. *8th World Congress on Conservation Agriculture (8WCCA)*. Cited 30 April 2021. https://8wcca.org

Bai, X., Liao, J., Hu, H., Liu, X., Xu, Y., Yan, Q. & Huang, S. 2020. Effects of conservation tillage on soil and water conservation (in Chinese). *Agricultural Engineering*, 82(08): 86–92.

Baidu. 2021. *Bole City*. Cited 15 April 2021. https://baike.baidu.com/item/博乐/946720?Fromtitle =博乐市&fromid=10701547&fr=aladdin#reference-[11]-51994-wrap

Benites, J.R., Derpsch, R. & McGarry, D. 2003. The current status and future growth potential of conservation agriculture in the world context. Conference presentation at *Proceedings of the 256 International Soil Tillage Research Organisation 16th Triennial conference, 13–18 July 2003, the University of Queensland, Brisbane, Australia*. pp. 120–129. Paper presented at 2003, Brisbane, Australia.

CAAAP. 2021a. *Conservation Agriculture Alliance for Asia-Pacific*. Cited 30 April 2021. www.caa-ap.org

CAAAP. 2021b. *The Strategies for the Promotion of Conservation Agriculture in Asia and Pacific Regional Online Meeting was successfully held*. In: CAAAP. Cited 30 April 2021. www.caa-ap.org/news/456.html

Cai, G., Li, H., Li, H., Wang, Q., He, J. & Ni, J. 2011. Design of test-bed for trenching depth automatic control system based on ATmega128 single microcontroller (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 27: 11–16. https://doi.org/10.3969/j.issn.1002-6819.2011.10.002

Central People's Government of People's Republic of China. 2006. *No. 1 Central Document of 2005: Opinions of the Central Committee of the Communist Party of China and the State Council on Several Policies for Further Strengthening Rural Work and Improving Comprehensive Agricultural Production Capacity (31 December 2004)*. Cited 11 May 2022. www.gov.cn/test/2006-02/22/content_207406.htm

Chen, H., Zha, S., Dun, G., Cong, G., Li, A. & Feng, Y. 2016. Optimization and experiment of cleaning device of 2BMFJ type no-till precision planter (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 47(7): 96–102.

Cortes, M.E., Kataoka, T. & Okamoto, H. 2013. Seeding Depth Regulation Controlled by Independent Furrow Openers for Zero Tillage Systems. *Engineering in Agriculture, Environment and Food*, 6(1): 13–19. https://doi.org/10.1016/S1881-8366(13)80010-9

CSAM. 2019. *Partner Engagement for Pilot Project on Integrated Straw Management in China*. Cited 30 April 2021. www.un-csam.org/news/partner-engagement-pilot-project-integrated-straw-management-china

Derpsch, R., Friedrich, T., Kassam, A. & Hongwen, L. 2010. Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*, 3(1): 1–26. https://doi.org/10.3965/j.issn.1934-6344.2010.01.001-025

Ding, Y., Wang, X., Liao, Q., Zhang, W., Zhang, X. & Cai, X. 2015. Design and experiment on spiral-tube reseeding device for loss sowing of rapeseed (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31(22): 16–24.

Du, Q., Xiong, X. & Wei, J. 2008. Design and experiment on the control system of electro-hydraulic plow depth of tractor hydraulic hitch mechanism (in Chinese). *Transactions of the Chinese Society of Agricultural Machinery*, 39(8): 62–65.

ECAF members. 2020. Adoption of Conservation Agriculture in Europe. In: *European Conservation Agriculture Federation (ECAF)*. Cited 15 April 2021. https://ecaf.org/adoption-of-conservation-agriculture-in-europe.

European Commission. 2020a. *Biodiversity strategy for 2030*. Cited 30 April 2021. https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en

European Commission. 2020b. *Farm to Fork strategy*. Cited 30 April 2021. https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

European Commission. 2021a. *The common agricultural policy at a glance*. Cited 30 April 2021. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#:~:text=Launched in 1962%2C the EU's,It aims to%3A&text=maintain rural areas and landscapes,foods industries and associated sectors

European Commission. 2021b. *Commission publishes list of potential eco-schemes*. Cited 30 April 2021. https://ec.europa.eu/info/news/commission-publishes-list-potential-eco-schemes-2021-jan-14_en

European Commission. 2021c. *A European Green Deal*. Cited 30 April 2021. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal

Evans, S.D., Lindstrom, M.J., Voorhees, W.B., Moncrief, J.F. & Nelson, G.A. 1996. Effect of subsoiling and subsequent tillage on soil bulk density, soil moisture, and corn yield. *Soil and Tillage Research*, 38(1–2): 35–46. https://doi.org/10.1016/0167-1987(96)01020-3

FAO. 2004. TCP/CPR/2905 (2004–2005). Promotion of advanced straw utilization technologies in Jiangsu Province, China.

FAO. 2013. Policy and institutional support for Conservation Agriculture in the Asia-Pacific Region. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand.

FAO. 2015. TCP/CPR/3504 (2015–2017). Promotion of climate-smart agriculture through improving crop residue utilisation and soil fertility management on the Huaibei Plains, Anhui Province, China.

FAO. 2016. GCP /CPR/048/GFF (2016–2022). Biodiversity conservation and sustainable land management in the soda saline-alkaline wetlands agro pastoral landscapes in the western area of the Jilin Province, China.

FAO. 2017. *Fact sheet on Conservation Agriculture*. Rome, FAO. www.fao.org/3/i7480e/i7480e.pdf

FAO. 2020. Towards a Global Programme on Sustainable Dryland Agriculture in collaboration with the Global Framework on Water Scarcity in Agriculture (WASAG) in a Changing Climate. *Twenty-seventh session of FAO Committee on Agriculture, 28 September–2 October 2020*. Paper presented at, 2020, Rome, Italy. www.fao.org/3/nd412EN/nd412EN.pdf

FAO. 2021a. *FAO launches Global Action on One Country One Priority Product*. Cited 28 February 2022. In: www.fao.org/news/story/pt/item/1438036/icode

FAO. 2021b. TCP/CPR/3806 (2021–2023). Conservation and sustainable management of black soil in Jilin Province, China.

FAO. 2021c. TCP/CPR/3804 (2021–2023). Support to sustainable use and management of sugar crop residues for sustainable production and natural resources conservation.

Fu, W., Dong, J., Mei, H., Gao, N., Lu, C. & Zhang, J. 2018. Design and Test of Maize Seeding Unit Downforce Control System (in Chinese). *Nongye Jixie Xuebao/ Transactions of the Chinese Society for Agricultural Machinery*, 49(6): 68–77. https://doi.org/10.6041/j.issn.1000-1298.2018.06.008

Fu, X., Li, M., Lu, J., Wang, J., Deng, Y. & Zhang, J. 2011. Research on the cutter of straw crushing machine to field (in Chinese). *Chinese Agricultural Mechanization*, 1: 83–87.

Goddard, T., Basch, G., Derpsch, R., Li, H., He, J. & Karabayev, M. 2020. Institutional and policy support for Conservation Agriculture uptake. Chap 12 In: A. Kassam, ed. *Advances in Conservation Agriculture Volume 1: Systems and Science*, pp. 38–39. Cambridge, UK, Burleigh Dodds Science Publishing.

Guangdong Provincial Agricultural Non-point Source Pollution Control Project Management Office. 2021. *Comprehensive information network of Guangdong agricultural non-point source pollution control project loaned by World Bank*. In: www.gdmy.org

Håkansson, I., Arvidsson, J., Keller, T. & Rydberg, T. 2011. Effects of seedbed properties on crop emergence: 1. Temporal effects of temperature and sowing depth in seedbeds with favourable properties. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, 61(5): 458–468. https://doi.org/10.1080/09064710.2010.506446

He, J., Kuhn, N.J., Zhang, X.M., Zhang, X.R. & Li, H.W. 2009a. 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(2): 201–209. https://doi.org/10.1111/j.1475-2743.2009.00210.x

He, J., Li, H.W., Wang, Q.J., Gao, H.W., Li, W.Y., Zhang, X.M. & McGiffen, M. 2010. The adoption of conservation tillage in China. *Annals of the New York Academy of Sciences*, 1195 Suppl: E96–106. https://doi.org/10.1111/j.1749-6632.2009.05402.x

He, J., Li, H., Chen, H., Lu, C. & Wang, Q. 2018a. Research Progress of Conservation Tillage Technology and Machine (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 49: 1–19. https://doi.org/10.6041/j.issn.1000-1298.2018.04.001

He, J., McHugh, A.D., Li, H.W., Wang, Q.J., Li, W.Y., Rasaily, R.G. & Li, H. 2012. Permanent raised beds improved soil structure and yield of spring wheat in arid north-western China. *Soil Use and Management*, 28(4): 536–543. https://doi.org/10.1111/j.1475-2743.2012.00445.x

He, J., Wang, Q., Li, H., Tullberg, J.N., McHugh, A.D., Bai, Y., Zhang, X., McLaughlin, N. & Gao, H. 2009b. Soil physical properties and infiltration after long-term no-tillage and ploughing on the Chinese Loess Plateau. *New Zealand Journal of Crop and Horticultural Science*, 37(3): 157–166. https://doi.org/10.1080/01140670909510261

He, Y., Jiang, H., Fang, H., Wang, Y. & Liu, Y. 2018b. Research progress of intelligent obstacle detection methods of vehicles and their application on agriculture (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 34(9): 21–32.

He, Y.F., Shen, H.O., Zhang, Y., Zhao, Z. & Mou, T. 2020. Analysis of soil and water conservation effects of different straw returning patterns in sloping farmland in the Chinese black soil region (in Chinese). *Journal of Soil and Water Conservation*, 34(06):91–96.

Hu, J., Gao, L., Bai, X., Li, T. & Liu, X. 2015. Review of research on automatic guidance of agricultural vehicles (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31: 1–10. https://doi.org/10.11975/j.issn.1002-6819.2015.10.001

Ji, C.Y. & Zhou, J. 2014. Current situation of navigation technologies for agricultural machinery (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 45(9): 44–54.

Jia, H., Jiang, X., Guo, M., Liu, X. & Wang, L. 2015. Design and experiment of V-L shaped smashed straw blade (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31(1): 28–33.

Jia, H.L., Zhu, L.T., Huang, D.Y., Wang, Q., Li, M.W. & Zhao, J.L. 2019. Automatic control system of sowing depth for no-tillage planter based on Flex sensor (in Chinese). *Journal of Jilin University (Engineering and Technology Edition)*, 49(1): 166–175. https://doi.org/10.13229/j.cnki.jdxbgxb20170988

Jiang, X.M. 2017. *Study on key technologies of precision seeding for maize no-tillage planter (in Chinese)*. Jilin University.

Kassam, A., Friedrich, T. & Derpsch, R. 2019. Global spread of Conservation Agriculture. *International Journal of Environmental Studies*, 76(1): 29–51. https://doi.org/10.1080/00207233.2018.1494927

Kassam, A., Friedrich, T., Shaxson, F. & Pretty, J. 2009. The spread of Conservation Agriculture: justification, sustainability and uptake. *International Journal of Agricultural Sustainability*, 7(4): 292–320. https://doi.org/10.3763/ijas.2009.0477

Kassam, A., Li, H.W., Niino, Y., Friedrich, T., He, J. & Wang, X.L. 2014. Current status, prospect and policy and institutional support for Conservation Agriculture in the Asia-Pacific region. *Internatioanl Journal of Agricultural and Biological Engineering*, 7(5): 1–13. https://doi.org/10.3965/j.ijabe.20140705.001

Kiani, S. 2012. Automatic on-line depth control of seeding units using a non-contacting ultrasonic sensor. *International Journal of Natural & Engineering Sciences*, 6(2): 39–42.

Kim, H. & Gao, H.W. 2002. Design of a microcomputer-controlled loss sowing compensation system for a maize precision drill (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 33(5): 44–47.

Kong, D.J. 2020. *Effect on nitrogen and carbon content and microbial community structure of wheat-soybean rotation soil under straw return and fertilizer application treatment*. Northwest A & F University, Yangling, China.

Li, B. & Li, H.W. 2006. Design and study of 2BMD-12 no-till planter for wheat (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 37(3): 41–44.

Li, C.D., Chen, L.D. & Chen, Y.Q. 2008. Developing conservation tillage to promote the development of green agriculture (in Chinese). *Jilin Agriculture,* (11): 16–17.

Li, H., Gao, H., Wu, H., Li, W., Wang, X. & He, J. 2007. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. *Australian Journal of Soil Research*, 45(5): 344–350. https://doi.org/10.1071/SR07003

Li, S. & Li, H. 2009. A counting method for residue cover rate in field based on computer vision. *Journal of Agricultural Mechanization Research*, 31(1): 20–25.

Li, W., He, H., Cui, T., Li, C., Xiao, X., Tang, H., Tang, W. & Nie, Z. 2019a. No-tillage and Direct Seeding Cultivation Technology of Rape-Rice and its Economic Benefit Analysis (in Chinese). *Hunan Agricultural Sciences* (7): 23–25.

Li, Y., Li, J., Zhou, L., Liu, G., Zhang, J., Zhang, Z. & Zheng, Q. 2019b. Effects of conservation tillage on soil wind erosion characteristics in the Hexi oasis irrigational area (in Chinese). *Chinese Journal of Eco-Agriculture,* 27(9): 1421–1429.

Li, Y., Meng, P., Geng, D., He, K., Meng, F. & Jiang, M. 2016. Intelligent system for adjusting and controlling corn seeding depth (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 47(S1): 62–68. www.nyjxxb.net/index.php/journal/article/view/184

Li, Z.G. 2009. Current condition and dynamic changes of soil erosion in China (in Chinese). *China Water Resources* (7): 8–11.

Liang, W.L., Gao, W.S., Xu, Q. & Huang, G.B. 2012. Historical and present usage of Shatian gravel mulch for crop production in arid and semiarid regions of Northwestern China. In: R. Lai & B.A. Stewart, eds. *Soil Water and Agronomic Productivity*, pp. 477–496. Boca Raton, FL, USA, CRC Press.

Liu, H., Jiang, G.M., Zhuang, H.Y. & Wang, K.J. 2008. Distribution, utilization structure and potential of biomass resources in rural China: With special references of crop residues. *Renewable and Sustainable Energy Reviews*, 12(5): 1402–1418. https://doi.org/10.1016/j.rser.2007.01.011

Liu, L.L. 2019. Research on tillage control system of rotary tiller depth based on AMESim and Simulink (in Chinese). *North China University of Water Resources and Electric Power*.

Liu, Y., Sun, J., Zhang, S., Yu, H. & Wang, Y. 2020. Automatic segmentation method based on multithreshold image for the detection of surface residue coverage. *Transactions of the Chinese Society of Agricultural Engineering*, 36(20):134–143.

Lu, R.C. 2020. *Design and experiment of large-width fertilizer and pesticide application vehicle for rows (in Chinese)*. Yangzhou University, China.

Lu, X.L. 2017. *Carbon balance and economic benefit of winter wheat-summer maize in the dryland of Northwest China under conservation tillage (in Chinese)*. Northwest A&F University, Yangling, China.

Lu, Z.X. & Zhao, L.Y. 2007. *Illustration of automobile sensor detection (in Chinese)*. Nanjing, China, Jiangsu Science & Technology Press.

MARA (Ministry of Agriculture and Rural Affairs of the People's Republic of China). 2007. Proposal on Vigorously Developing Conservation Agriculture. Cited 11 May 2022. www.moa.gov.cn/nybgb/2007/dwuq/201806/t20180613_6151894.htm

MARA. 2008. *Conservation Agriculture in China (In Chinese)*. Beijing, China Agriculture Press.

MARA. 2011. *Notice of the General Office of the Ministry of Agriculture on Printing and Distributing "Code for Implementation of Conservation Agriculture Project" and "Key Technologies of Conservation Agriculture*". Cited 11 May 2022. www.moa.gov.cn/nybgb/2011/dqq/201805/t20180522_6142772.htm

MARA. 2018. Notice of the General Office of the Ministry of Agriculture on Printing and Distributing the "2018–2020 List of the Maximum Subsidy Amount of National General Agricultural Machinery Central Financial Funds." Cited 15 April 2021. www.moa.gov.cn/nybgb/2018/201804/201805/t20180529_6143285.htm

MARA. 2019. *2018 National Statistical Annual Report on Agricultural Mechanization (in Chinese).* Beijing, China.

MARA & MOF. 2020. *Action Plan for Conservation Agriculture of Black Soil in Northeast China (2020–2025)*. www.moa.gov.cn/govpublic/NYJXHGLS/202003/t20200318_6339304.htm

MARA & National Development and Reform Commission. 2009. *Notice of the National Development and Reform Commission and the Ministry of Agriculture on Printing and Distributing the "National Construction Program of Conservation Agriculture (2009–2015)"*. Cited 11 May 2022. www.moa.gov.cn/nybgb/2009/djiuq/201806/t20180608_6151425.htm

Ministry of Natural Resources of the People's Republic of China. 2018. Statistical Bulletin of China's Land, Mineral and Marine Resources in 2017 (in Chinese). Beijing, China.

Ministry of Water Resources of the People's Republic of China. 2020. China soil and water conservation communique in 2019 (in Chinese). Beijing, China.

National People's Congress of the People's Republic of China. 2022. *Law on the Conservation of Black Soil of the People's Republic of China (Adopted at the 35th meeting of the Standing Committee of the 13th National People's Congress on June 24, 2022). www.npc.gov.cn/npc/c30834/202206/7f3fe789d6694b0294145714bfe91043.shtml*

Nielsen, S., Munkholm, L., Lamandé, M., Nørremark, M., Edwards, G. & Green, O. 2018. Seed drill depth control system for precision seeding. *Computers and Electronics in Agriculture*, 144: 174–180. https://doi.org/10.1016/j.compag.2017.12.008

Ou, Y. 2020. Conservation Agriculture (CA) Report for 12th Supervision. Guangdong, China.

Peng, Z.K., Li, L.L., Xie, J.H., Kang, C., Essel, E., Wang, J. B., Xie, J.H. & Shen, J.C. 2018. Effects of conservation tillage on water characteristics in dryland farm of central Gansu, Northwest China (in Chinese). *Chinese Journal of Applied Ecology*, 29(12): 134–140.

Shi, Z., Wang, F., Wang, J., Li, X., Sun, R. & Song, C. 2019. Utilization characteristics, technical model and development suggestion on crop straw in China (in Chinese). *Journal of Agricultural Science and Technology (Beijing)*, 21(5): 8–16.

Su, Y., Zhang, D., Li, H., He, J., Wang, Q. & Li, H. 2012. Measuring System for Residue Cover Rate Based on Automation Threshold (in Chinese). *Journal of Agricultural Mechanization Research*, 34(8): 138–142.

Tao, S. 2021. *No-tillage maize was planted successfully in Bole City, Xinjiang, China: 60,000 mu will be promoted in 2021*. Cited 30 April 2021. www.chinanews.com.cn/sh/2021/04-13/9453692.shtml

Wang, C., Li, H., He, J., Wang, Q., Lu, C. & Chen, L. 2020. State-of-the-art and prospect of automatic navigation and measurement techniques application in Conservation Tillage (in Chinese). *Smart Agriculture*, 2(4): 41–55. https://doi.org/10.12133/j.smartag.2020.2.4.202002-SA002

Wang, D. 2021. *The development road of Luwei Agricultural Machinery and Farmers Professional Cooperative in Lishu County, Jilin Pronvince*. Cited 30 April 2021. http://agri.jl.gov.cn/xwfb/sxyw/202102/t20210210_7940246.html

Wang, Q., Bai, Y., Gao, H., He, J., Chen, H., Chesney, R.C., Kuhn, N. & Li, H. 2008a. Soil chemical properties and microbial biomass after 16 years of no-tillage farming on the Loess Plateau, China. *Geoderma*, 144(3–4): 502–508. https://doi.org/10.1016/j.geoderma.2008.01.003

Wang, Q., Hao, C., Li, H., Li, W., Wang, X., Allen, M., He, J. & Gao, H. 2009. Controlled traffic farming with no tillage for improved fallow water storage and crop yield on the Chinese Loess Plateau. *Soil and Tillage Research*, 104(1): 192–197. https://doi.org/10.1016/j.still.2008.10.012

Wang, Q.Q., Zheng, K. & Chen, L.Q. 2021. Development status and trend of no-tillage planter in China (in Chinese). *Agricultural Machinery*, 3: 57–60.

Wang, X., Gao, H., Tullberg, J., Li, H., Kuhn, N., McHugh, A. & Li, Y. 2008b. Traffic and tillage effects on runoff and soil loss on the Loess Plateau of northern China. *Australian Journal of Soil Research*, 46(8): 667–675. https://doi.org/10.1071/SR08063

Wang, Y.X. 2019. *Research and experiment on a tillage depth control system for hydraulically self-excited subsoiler (in Chinese)*. China Agricultural University.

Wei, Y.F., Gao, H.W. & Li, H.W. 2005. Experiment and analyses of the adaptabilities of three wheat no-tillage drills on corn stubble in the areas with two ripe crops a year (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 21(1): 97–101.

Wen, D.Z.. & Zhao, X.F. 2013. *Principle and application of sensor (in Chinese)*. Beijing, China, Science Press.

Wen, L., Zheng, F., Shen, H. & Gao, Y. 2014. Effects of corn straw mulch buffer in the gully head on gully erosion of sloping cropland in the black soil region of Northeast China (in Chinese). *Journal of Sediment Research* (6): 73–80.

Wu, N., Lin, J., Li, B., Zhang, B. & Gu, S. 2017. Design and test on no-tillage planter reseeding system for miss-seeding (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 48(7): 69–77.

Wu, S.S., Niu, J.Z. & Lin, X.N. 2020. Effects of conservation tillage measures on soil wind erosion in Yanqing, the suburb of Beijing (in Chinese). *Science of Soil and Water Conservation* (1): 57–67.

Xu, C.H. & Jie, Z. 2014. Design of T-type plate knife roller of straw returning machine (in Chinese). *Tractor & Farm Transporter*, 5: 50–51.

Yan, L., Ji, X.N., Meng, Q.F., Jiang, X., Zhou, L., Li, S. & Chen, C. 2019. Soil fertility quality evaluation of slope farmland under no-tillage in black soil area (in Chinese). *Journal of Northeast Agricultural University*, 50(5): 43–54.

Yang, Q., Qin, W.J. & Wang, H.R. 2017. Regional difference and influencing factors of ecological footprint for agricultural water use in China (in Chinese). *Review of Economy and Management* (4): 135–144.

Yang, Y., Wu, J., Ding, J., Zhang, J., Pan, X. & He, F. 2017. Effects of long-term no-tillage on soil structure and organic carbon distribution in different soil layers (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 48(9): 173–182.

Yao, Z., Wang, X.Y., Li, H.W. & Di, Y. 2005. Modification and experiment on 2BMD-12 row-controlled no-till wheat drill (in Chinese). *Agricultural Research in the Arid Areas*, 23(5): 46–51.

Zhang, X., Li, H., He, J., Wang, Q. & Golabi, M. 2009. Influence of conservation tillage practices on soil properties and crop yields for maize and wheat cultivation in Beijing, China. *Australian Journal of Soil Research*, 47(4): 362–371. https://doi.org/10.1071/SR08110

Zhang, Y.F., Li, H.W., He, J., Wang, Q.J., Li, W.Y., Chen, W.Z. & Zhang, X.Y. 2015. Effects of maize straw mulching on runoff and sediment process of slope (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31(7): 118–124.

Zhang, Z., He, J., Li, H., Wang, Q., Ju, J. & Yan, X. 2017. Design and experiment on straw chopper cum spreader with adjustable spreading device (in Chinese). *Transactions of the Chinese Society for Agricultural Machinery*, 48(9): 76–87. https://doi.org/10.6041/j.issn.1000-1298.2017.09.010

Zhao, J., Liu, L., Yang, X., Liu, Z. & Tang, J. 2015. Design and laboratory test of control system for depth of furrow opening (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 31(6): 35–41.

Zhao, Y., Xu, C., Yang, X., Li, S., Zhou, J., Li, J., Han, T. & Wu, C. 2018. Effects of sowing methods on seedling stand and production profit of summer soybean under wheat-soybean system (in Chinese). *Crops* (4): 114–120.

Zheng, K. & Chen, W.Z. 2016. Research status and prospect of subsoiler (in Chinese). *Jiangsu Agricultural Sciences*, 449(8): 16–20.

Zhu, G.L., Huang, Y.H., Lin, J.S., Jiang, F. S., Shi, Y.Z., Chen, P.J., Zhuang, H.M. & Hou, Z.W. 2015. Effect of straw mulch on colluvial soil erosion and yield of runoff and sediment under simulated rainfall (in Chinese). *Journal of Soil and Water Conservation*, 29(3): 27–31, 37.

Zhu, L. & Lan, X. 2010. *Guide to use, maintenance and purchase of straw (stubble) crushing and returning machine (in Chinese)*. Beijing, China, China Agriculture Press.

Zhu, R., Ge, S., Zhai, C., Yan, X., Shi, Y., Li, C. & Huang, S. 2014. Design and experiment of self-seeding device for missed sowing of crops with large grain (in Chinese). *Transactions of the Chinese Society of Agricultural Engineering*, 30: 1–8

While the agricultural production in China has made great achievements, it is also facing challenges affecting the sustainable development of agriculture. Conservation agriculture (CA) is a farming system that promotes minimum soil disturbance (i.e. no-tillage and direct seeding), maintenance of a permanent soil cover (mulch or cover crops), and diversification of plant species (crop rotations that include leguminous species). CA has been adopted in more than 100 countries worldwide and has become one of the most effective and widely used farming systems and technology for dryland agriculture. The adoption of CA can bring agronomic, environmental and economic benefits, and is of great significance to the development of green agriculture in China. This publication focuses on the development path, opportunities and challenges, development suggestions, technology and equipment, experiences, case studies and future scenarios for CA in China aiming to support the extension and adoption of CA in China and globally. This publication is part of the Country Investment Highlights series under the FAO Investment Centre's Knowledge for Investment (K4I) programme.

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