Conservation agriculture in China and the Democratic People’s Republic of Korea
Cover photograph:
Countryside near the west coast of North Korea in South Pyongan Province, Jungsan County
Theodor Friedrich, FAO
Conservation agriculture in China and the Democratic People’s Republic of Korea

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2007
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Contents

Acknowledgement vi
Foreword vii
Acronyms viii

Background 1
Conservation Agriculture 1
Agriculture in the project areas in Korea and China 1
Natural conditions for agriculture 1
The agricultural sector 2
Korea 2
China 2
Environmental impact of current production practices 2
Korea 2
China 3
Past initiatives to improve the sustainability of the production system 3
Korea 3
China 4

FAO projects to introduce conservation agriculture in the Democratic People’s Republic of Korea and China 5
Rationale for the project implemented in Korea 5
Rationale for the project implemented in China 5
Field work 6
Korea 6
China 6
Introduction of Conservation Agriculture technologies 8
Seeders and planters 8
Sprayers 11
Harvest and residue management equipment 11
Crop rotation and cover crops 13
Weed and disease control 14
Korea 14
China 14
Yields 15
Korea 15
China 16
Soil conditions 16
Nutrient status 16
Soil moisture dynamics 18
China 18
Soil loss 19
Economic analysis 19
  Korea 19
  China 19
Awareness creation, training and research 20

Conclusions and recommendations 21

Source materials 23
  Korea 23
  China 23

List of boxes

1. Natural conditions in DPRK 1
2. Main problems of DPRK’s agricultural sector 2
3. Technical features of the Vence Tudo SA 7300 seeder and planter 11
4. Functioning of a hand-drawn boom sprayer 11
5. Current farm machinery systems and practices 12
List of figures

1. Relative extent of crops and average yields in Jiangsu province 3
2. Effect of mulching system on the development of the weeds in maize field 14
3. Weed infestation in the wheat–paddy rice fields before and after treatment 15
4. Difference in maize yields by type of tillage and mulching 15
5. Yields under the diversified intercropping system 15
6. Grain and straw yields under the diversified cropping rotations 16
7. Comparison of wheat yield components in CA fields and conventional fields 16
8. Comparison of rice yield components in CA fields with low and high levels of rice stripe virus and conventional fields 17
9. Soil moisture in CA and conventional fields 3, 7 and 15 days after rains 18
10. SOM contents at different depths in the Chinese demonstration fields 18
11. Input costs for the wheat crop 19
12. Inputs for the rice paddy crop 20

List of tables

1. Crop management practices on the demonstration farms in DPR Korea 7
2. Crop management practices for wheat–rice intercropping in China 9
3. Wheat straw mulching and cover crop production 13
4. Cover crop species intercropped with maize 13
5. Soil chemical data in demonstration plots 17
6. Soil moisture contents in upland soil 18
7. Effect of straw mulching on soil loss 19
8. Inputs use by CA and by traditional farming 19
Acknowledgements

We would like to acknowledge the good and dedicated work of the national project teams in both countries as well as the support the projects had received from the national authorities of the Ministries of Agriculture and the national FAO offices.
Foreword

The present working paper is a joint report on the experiences of two FAO Technical Cooperation Projects, namely

- TCP/CPR/2905 Promotion of advanced straw utilization technologies in Jiangsu Province, China, operating from February 2004 until December 2005, and
- TCP/DRK/2903-3004 Conservation Agriculture for Food Security in the Democratic People’s Republic of Korea, operating from September 2002 until November 2005, including a second phase.

Although the purpose of the projects was to address different problems, the approaches and technologies applied were similar. Since the projects were dealing with the same range of crops it was decided to produce a joint report. This working paper describes experiences and first results of introducing Conservation Agriculture practices in eastern Asian diversified cropping systems, including both upland crops and lowland rice areas. Both projects were pilot projects to demonstrate the validity of Conservation Agriculture under the given agro-ecological conditions and to tune the technology to local conditions. The project reports are not subject to scientific analytical rigour but useful lessons were learned and are worth sharing with the wider public.

Both projects can be considered as stepping stones for advancing sustainable farming practices in both countries. Particularly in the Democratic People’s Republic of Korea the concept of Conservation Agriculture has, after the end of the project, been adopted under subsequent emergency rehabilitation projects and with the active support of the national authorities. But also in China Conservation Agriculture is now one of the priorities for the development of sustainable farming practices and addressing climate change adaptation and mitigation.

Shivaji Pandey
Director
FAO Plant Production and Protection Division
# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>Conservation agriculture</td>
</tr>
<tr>
<td>DPRK</td>
<td>Democratic People’s Republic of Korea</td>
</tr>
<tr>
<td>GMCC</td>
<td>Green manure cover crops</td>
</tr>
<tr>
<td>MOA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>RMB</td>
<td>Renminbi: Chinese currency. 1 US$ = 8 RMB</td>
</tr>
<tr>
<td>RSV</td>
<td>Rice stripe virus</td>
</tr>
</tbody>
</table>
Background

CONSERVATION AGRICULTURE
Conservation Agriculture (CA) is based on the integrated management of soil, water and agricultural resources in order to reach the objective of economically, ecologically and socially sustainable agricultural production. It relies on three major principles:
- Maintenance of a permanent vegetative soil cover or mulch to protect the soil surface;
- Minimal soil disturbance by direct planting through the soil cover without seedbed preparation;
- Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.

Inputs include cover crops, the use of knife rollers or herbicides to crush or kill weeds and cover crops, and no-till planters. These technologies do not need conventional tillage equipment such as disc harrows and ploughs. They reduce herbicide use, and spread crop residues and use green manure cover crops to control weeds, save soil moisture, increase soil fertility and protect the soil from wind and water erosion. More information is available at www.fao.org/ag/ca.

AGRICULTURE IN THE PROJECT AREAS IN KOREA AND CHINA
Natural conditions for agriculture
About 80 percent of the Democratic People’s Republic of Korea’s (DPRK) population live in rural areas and depend primarily on agriculture for their survival. The limited agricultural potential due to the continental climate with harsh winters and a limited growing period and the low soil fertility status (Box 1) are contributing causes for the annual grain production deficit of 1.5 to 2 million tonnes.

DPRK has suffered from several natural disasters since the 1990s, with severe hailstorms, floods and droughts, which have reduced yields.

About 30 percent of the soils in the agricultural provinces contain more than 2 percent organic matter, allowing a maize yield potential of 3 to 6 tonnes/ha; about 30 to 40 percent have less than 1 percent of organic matter, with a maize yield potential of less than 1.5 tonnes/ha. These soils also have very low exchangeable cation capacity (<6 meq/100g), base saturation (20 percent) and available phosphorus (5 to 10 mg/kg).

China’s Jiangsu Province also dominantly rural: 6.2 of its 8 million people live in rural areas. However, in contrast to DPRK, Jiangsu has favourable climatic and soil characteristics and is one of China’s most productive provinces. This coastal plain province has a warm temperate monsoon climate with about 1 000 mm annual rainfall, 70 percent of which falls between May and September, mean annual temperature 15 °C, and a frost-free period of 220 days, allowing a long growing season.

BOX 1
Natural conditions in DPRK
- Average temperatures ranging from -19°C in winter to +25°C in summer.
- Frost-free period of 130 days in the mountain provinces, and 170 to 190 days in the lowland areas.
- Average precipitation of 1,054 mm, with up to 85 percent of which as rainfall during July and August.
- Low soil organic matter content and phosphorus status, low pH.
Conservation agriculture in China and the Democratic People’s Republic of Korea

Background

**THE AGRICULTURAL SECTOR**

**Korea**

Rice and maize are the major grain crops produced in DPRK. During the 1980s, these staple crops yielded up to about 8 tonnes/ha, supported by high inputs (fertilizer, machinery, energy). But the collapse of the USSR and the Socialist Block in the early 1990s, combined with successive natural disasters, severely affected DPRK’s agricultural sector. Shortages of fuel, quality seeds, fertilizers, spare parts, pesticides and herbicides, and hailstorms, floods and drought led to a 50 percent decline in crop production within six years (Box 2).

Nevertheless, the area under cereals is still 70 percent of the cultivated area, with 600,000 ha paddy, 650,000 ha maize and 50,000 ha wheat and barley. The agricultural sector accounts for about 30 percent of DPRK’s GDP.

**China**

The annual cropping area in Jiangsu province is 1.256 million ha. The main crops are paddy, wheat, barley, rape, cotton, vegetables and fruits (Figure 1).

In Jiangsu province, as in other areas of the country, prior to the 1970s there were limited quantities of wheat and paddy rice straw, barely meeting the farmers’ demand for fuel and other purposes, because of low crop yields. Since the rural reform policy in the 1980s, yields and farmers’ living standards have improved greatly, in parallel with the rapid development of the national economy. The total volume of crop straw increased with the yields, while its use for fuel declined significantly because farmers increasingly switched to coal and fuel gases. Therefore, straw surpluses have started to accumulate. In 2000, an estimated 39 million tonnes of straw were produced in Jiangsu province, of which 20 percent was not utilized and burnt in fields or discarded into a river or on roadsides.

**ENVIRONMENTAL IMPACT OF CURRENT PRODUCTION PRACTICES**

**Korea**

Traditional soil management in DPRK includes ploughing to 20 cm depth, which leads to soil erosion by the rain and the wind, particularly on hillsides. The relaxation of former strict controls on encroachment into forest areas and encouragement to bring additional land under cultivation have caused damage to land resources, particularly to forests. Large areas of natural forests, often on steep slopes, have been cleared with subsequent erosion problems.
BACKGROUND

China

It is estimated that in the past three years, 23.4 million tonnes of straw have been wasted in Jiangsu Province, 32 percent of the total wheat and paddy rice straw produced. Such treatment of the surplus straw, prevailing in other parts of the country as well, not only wastes resources, but also pollutes the environment and endangers production, traffic, and living conditions and health of the residents.

Every June and October (summer and autumn harvest seasons), smoke from burning straw on farm fields blows into the urban area of Yancheng city, Jiangsu province, causing a nuisance as well as health problems for residents. Discarded straw pollutes rivers and water sources in rural areas, blocks navigation canals and reduces flood discharge capacity; straw piled in fields and left at roadsides provides habitats for rodents.

PAST INITIATIVES TO IMPROVE THE SUSTAINABILITY OF THE PRODUCTION SYSTEM

Korea

The DPRK government has been promoting double-cropping as one of the very few options to diversify agricultural production and to respond to emergency food needs in the context of the 1997 food self-sufficiency policy.
Double-cropping has expanded rapidly with winter wheat, barley or potato followed by paddy rice, maize or soybean, increasing the annual yields. However this programme also causes problems for farmers who can not afford the high demand for fertilizers and labour, particularly during the harvest of the first crop and the subsequent transplanting of the second crop in summer. In addition it increases the pressure on soil fertility.

**China**

The Jiangsu Provincial Government and local governments have implemented various policies and regulations and taken measures to raise awareness of the harm caused by burning straw and by discarding straw into rivers and canals and on roadsides. These policies also aim at encouraging better application of surplus straw, such as extension of the recycling-straw-to-soil technology (conservation tillage). The Yacheng Municipal Bureau of Agriculture conducted several straw utilization programs:

- Trial and demonstration of returning straw to the fields in 1998
- Demonstration of returning-straw-to-soil in 1999

National policies have laid the basis for comprehensive integrated straw utilization. In 1998, the National Environment Protection Bureau and the Ministry of Agriculture issued the “Administrative Methods for Prohibition of Straw Burning and for Comprehensive Straw Utilization”, by which the straw-burning region, the responsibilities of the related departments, and the approaches to comprehensive straw utilization are defined.
FAO projects to introduce conservation agriculture in the Democratic People’s Republic of Korea and China

RATIONALE FOR THE PROJECT IMPLEMENTED IN KOREA
The DPRK government has been paying primary attention to the rehabilitation of agriculture by the implementation of double cropping. These previous attempts, with conventional tillage, produced more food but impoverished the soil. The introduction of conservation agriculture technologies such as minimum and no-tillage was an opportunity to support the establishment of this double cropping system on a technically and environmentally sustainable basis and in an economically profitable way.

The immediate objectives of this pilot project were:
1. To make stakeholders aware of the advantages of conservation agriculture-based production systems in the selected pilot areas and present options for different improved cropping systems;
2. To train farmers in on-farm multiplication of quality seed;
3. To introduce CA equipment developed specifically to mechanize crop planting and harvesting under CA, cover crop management and the application of agrochemicals;
4. To demonstrate CA-based crop and land management practices;
5. To select suitable cover crops and introduce them into the crop rotation system;
6. To train farmers and cooperative managers and specialists in using conservation agriculture practices to sustainably improve crop production.

Major components of a suitable CA system for DPRK proposed by FAO were the introduction of diversified crop rotation under the double-cropping system including a green manure cover crop, as well as the replacement of conventional soil tillage by no-tillage technologies. Reduced tillage and a continuous soil cover with crop residues or a cover crop saves soil moisture and improves fertility. A diversified double-cropping system is also an effective way to tackle the problems of weeds, pests and diseases and herbicide resistance.

RATIONALE FOR THE PROJECT IMPLEMENTED IN CHINA
Agricultural technology research and extension departments were already engaged in promoting straw utilization, but major drawbacks were recognized during implementation, as well as the need for more appropriate techniques to increase acceptance by farmers. The introduction of conservation agriculture in Jiangsu province was an opportunity to increase the amount of straw returned to the field, and thus reduce the volume of waste straw damaging human life and the environment.

The immediate objectives of the project were:
1. To introduce, demonstrate and extend advanced on-farm technologies for efficient straw utilization such as conservation agriculture (recycling-straw-to-soil)
2. To train local technicians by enhancing their capacity to provide technical guidance to
3. farmers on the integrated utilization of straw
4. To conduct technical training for village-level technicians and local farmers to
enable them to adopt one or two key techniques of straw utilization and to increase their awareness of the harmful effects of the improper treatment of surplus straw and the importance of integrated straw utilization.

A major element of a suitable CA system for China proposed by FAO was the introduction of recycling straw-to-soil, which aimed at reducing rates of fertilizer application, improving the soil physical and chemical conditions and increasing agricultural output quantity and quality.

Besides the conservation agriculture component, the project included two other components: the use of processed straw as fodder to increase small ruminant livestock production; and the production of edible mushrooms on straw substrates for additional farm income. However, this report focuses only on the conservation agriculture component.

FIELD WORK
The project in DPRK was operational from December 2002 to December 2005 and the project in China from March 2004 to December 2005. Both projects focused on the training of farmers on demonstration plots in the appropriate use of conservation agriculture technology, on introducing the necessary new implements, and on spreading knowledge of conservation agriculture among farmers, researchers and government representatives.

Both in Korea and in China demonstration fields for conservation agriculture were established on different project farms, reflecting standard farming conditions of the project region in plot size and field characteristics. Crop growth and yield in the CA fields were compared with traditional fields. Planting operations were carried out at different dates on the project farms depending on the site-specific conditions.

The project teams provided technical assistance in direct seeding, equipment assembly, maintenance and calibration of fittings to the drills to reach optimal seeding depth and rate, as well as in crop management including weed and cover crop management and crop rotations. Soil conditions, weed growth, diseases and crop yields were monitored during project implementation.

Korea
In Korea, 50-ha demonstration fields were established on three cooperative farms. CA fields were compared with conventional fields, which were ploughed to 20 cm depth. Plate 5 shows the location of the project farms. The crop management practices on the three cooperative farms are presented in Table 1.

China
In each of the villages of Tongyu and Gangqiao near the city of Dongtai south of Yancheng, Jiangsu province, two 4-ha demonstration fields were established (location map Plate 8).

The project worked in two different cropping areas: the irrigated lowland area near Tongyu village with a paddy rice–wheat cropping system and the rainfed higher-lying lands of Gangqiao...
TABLE 1
Crop management practices on the demonstration farms in DPR Korea

<table>
<thead>
<tr>
<th>Upland fields</th>
<th>Paddy fields</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2003</strong></td>
<td></td>
</tr>
<tr>
<td>• April: direct seeding of maize and soybean in double cropping</td>
<td>September: planting wheat</td>
</tr>
<tr>
<td>• September: maize and soybean harvest, hairy vetch planted with no-till planter (25 September–5 October)</td>
<td></td>
</tr>
<tr>
<td><strong>2004</strong></td>
<td></td>
</tr>
<tr>
<td>• April: Cutting and threshing hairy vetch; after using the knife roller, direct planting of maize and soybean with no-till planter</td>
<td>June: wheat harvest, threshing; after using the knife roller on straw left in the field, direct planting of rice</td>
</tr>
<tr>
<td>• June: intercropped cover crop (6 to 9 varieties depending on the farm) with maize</td>
<td>October: rice harvest; the fields are put in fallow</td>
</tr>
<tr>
<td>• September: maize and cover crop harvest</td>
<td></td>
</tr>
<tr>
<td>• October: planting hairy vetch and wheat with a no-till seeder</td>
<td></td>
</tr>
</tbody>
</table>

Plate 6
*Emerging wheat in maize residues (Ryongchon)*
• November: spreading straw mulch on the hairy vetch fields

| **2005**      | |
| • May: cutting and threshing hairy vetch if practical, or hairy vetch management with the knife roller and herbicide | March: planting hairy vetch |
| • June: wheat harvest and stubble retention; planting soybean and maize with direct drill planter | April: cutting hairy vetch, threshing; after using the knife roller, direct seeding of rice. |
| | May: herbicide application on hairy vetch |
| | September: rice harvest and direct planting wheat |

Plate 7
*Wheat field in June (Ryongchon)*
• July: mulching and spreading hairy vetch on the maize field, combined with straw mulch |
• September: maize harvest |
• October: soybean harvest |

village with a crop rotation consisting of mainly wheat, maize, rape and cotton (Plate 9). In the two areas straw utilization technologies were tested and demonstrated, such as
Conservation agriculture in China and the Democratic People’s Republic of Korea

FAO projects to introduce conservation agriculture in the DPR of Korea and China

Plate 8
Dongtai and Yancheng city in Jiangsu province

Plate 9
Intercropping on upland with residue retention

Plate 10
Demonstration of lowland paddy–wheat double cropping

recycling straw to soil in conservation agriculture, feeding straw to livestock and growing mushrooms on straw medium. Here only the conservation agriculture fieldwork is discussed.

A wheat–paddy demonstration area was established in Tongyu village (Plate 10). Paddy was interplanted in wheat fields in summer and mechanically harvested with high stubble left and straw returned to the field in late October (Plate 11). Wheat was directly seeded in these paddy straw-covered fields in early November. Table 2 compares the crop management practices for the wheat–rice system with the conventional practices for rice monoculture in 2005.

The wheat–maize–rape–cotton rotation was demonstrated in Gangqiao village. Wheat or rape was directly planted in winter and maize or cotton in summer. In this village most of the work was done by hand, including harvesting. With exception of some of the residues used as fuel for cooking (cotton stalks) or as forage (rape straw), most of the residues were returned to the field after threshing (Plate 12).

INTRODUCTION OF CONSERVATION AGRICULTURE TECHNOLOGIES

The implementation of zero tillage technologies under CA requires equipment, which was provided to the farmers by the projects. Because of the rich Brazilian experience in affordable CA technology, equipment from that country was introduced in Korea (Plates 13 and 14) and China (Plate 15).

Seeders and planters

The seeders and planters delivered to both Korea and China were:

- Tractor-mounted no-till planter for maize and soya and seeder for wheat and rice (Vence Tudo SA 7300)
- Hand jab planter (Fitarelli)

Specific seeders and planters provided to each project were:

- Korea
  - Animal-drawn single-row planter (IADEL)
TABLE 2
Crop management practices for wheat–rice intercropping in China

<table>
<thead>
<tr>
<th>Date</th>
<th>No-till rice</th>
<th>Conventional practice rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 10</td>
<td>Soaking seeds</td>
<td></td>
</tr>
<tr>
<td>May 13</td>
<td>Soaking seeds for 72 h</td>
<td>Soaking seeds</td>
</tr>
<tr>
<td>May 20</td>
<td>Mixing seeds with river soil and dry soil</td>
<td>Seeding nurseries</td>
</tr>
<tr>
<td>May 24</td>
<td>Broadcasting seed–soil mixture at a seed rate of 112 kg/ha, overnight irrigation</td>
<td></td>
</tr>
<tr>
<td>May 25</td>
<td>Emergence of rice</td>
<td></td>
</tr>
<tr>
<td>June 6</td>
<td>Harvest of wheat crop in rice field</td>
<td>Harvest of wheat crop in rice field</td>
</tr>
<tr>
<td>June 15</td>
<td>Soaking seeds</td>
<td>Soaking seeds</td>
</tr>
<tr>
<td>June 17</td>
<td>Application of herbicide (grass and broadleaved weeds); application of urea at 75 kg/ha</td>
<td>Land preparation, power tiller puddling</td>
</tr>
<tr>
<td>June 18</td>
<td>Manual transplanting of rice</td>
<td>Herbicide application; application of Urea at 150 kg/ha and of NPK 15/15/15 at 225 kg/ha</td>
</tr>
<tr>
<td>June 25</td>
<td>Application of NPK 15/15/15 at 225 kg/ha</td>
<td>Application of urea at 150 kg/ha</td>
</tr>
<tr>
<td>July 10</td>
<td>Application of urea at 225 kg/ha</td>
<td>Application of urea at 225 kg/ha</td>
</tr>
<tr>
<td>July 28</td>
<td>Application of urea at 225 kg/ha</td>
<td></td>
</tr>
<tr>
<td>July 30</td>
<td>Application of urea at 225 kg/ha</td>
<td></td>
</tr>
<tr>
<td>August 10</td>
<td>Application of urea at 112 kg/ha and NPK at 112 kg/ha</td>
<td>Application of urea at 112 kg/ha and NPK at 112 kg/ha</td>
</tr>
<tr>
<td>October 20</td>
<td>Paddy rice harvest and straw returned to fields</td>
<td></td>
</tr>
<tr>
<td>November 5</td>
<td>Direct seeding wheat in paddy straw-covered fields</td>
<td></td>
</tr>
</tbody>
</table>
Tractor-mounted 3 row no-till planter for maize and soya (Fitarelli)

**China**
- Two BMF-6 no-till drills (manufactured by Hebei Nonghagha, China)
- K-30-20 ditch opener for drainage ditches in paddy areas.

Box 3 gives technical features of the Vence Tudo SA 7300 seeder and planter.

**Results in Korea**
The seeders and planters were successfully used even in high-moisture soil conditions, and a high demand for this machine was reported from surrounding farms.

However, in some cases the weight of the SA-7 300 no-till seeder presented a challenge for the lifting capacities of the Korean Cholima tractors. But even with the full seeder and without any extra front weight the tractor still retains a minimum load on the front axle, and adding additional front weight resolved at least the handling problems.

Problems of maintenance were observed, and appropriate training in the use of the machine was necessary to avoid premature equipment wear. This kind of implement is not known to Korean farmers, and they found it difficult to accept the new equipment at the start of the project.

**Results in China**
The planters and seeders introduced were welcomed by the Chinese farmers. However, the Chinese no-till seeder was rejected due to its poor quality and limited performance. The Brazilian no-till planter was largely preferred. It proved suitable after few modifications and adjustments and performed very well in thick straw layers. However, the equipment required additional training for both versions (seed drill and precision planter). Without technical support the project team could only make very limited use of the machine.
The locally manufactured ditcher was only used for 150 m of ditch as its performance under the rather wet soil conditions was not satisfactory.

Sprayers
The sprayers introduced in the project farms in Korea and China were:
- 80-litre animal-drawn boom sprayer (IADEL) (Plate 16)
- 20-litre hand-drawn boom sprayers (IADEL) (details in Box 4)
- 16-litre knapsack sprayers with spray booms

The animal-drawn and hand-drawn boom sprayers are a good alternative for the desiccation of the cover crop under CA, which facilitates the subsequent planting of the commercial crop. This kind of equipment worked very well in the field.

Harvest and residue management equipment
Several kinds of harvest and residue management equipment were introduced both in Korea and China:
- Knife rollers (hand-drawn and tractor-drawn)
- Mobile thresher
- Tractor-mounted front reapers
- Self-propelled rice and wheat picker-thresher.

The tank is placed on a chassis of a wheelbarrow or a frame to which two bicycle wheels are attached. For human traction the tank can contain 20–50 litres of liquid. One of the wheels is also used to operate the pump. The sprayer pump is activated via an eccentric transmission rod system from the wheel. As the sprayer is pulled rather than carried, the area sprayed can also be extended through the use of a multi-nozzle boom. Such a system can have up to 5 m working width and the spraying time can be reduced to 0.6–1 hour per ha.
The following equipment was provided to the Chinese demonstration farms:

- Ce-2M self-propelled combine harvester with straw chopper and spreader (manufactured by Yanmar Farm Lpt) (Plate 17)
- 4 LZ-160B1 conventional drum-type combine harvesters (manufactured by Liulin Co. Ltd)
- A small round baler
- PTO-driven tractor-mounted straw chopper
- 9 ZP-0.4 stationary chopper (China).

The knife roller is used to bend over and crush the weed, crop residue or cover crop prior to planting the following commercial crop, eventually resulting in the death of the cover crop. It consists of a cylindrical body that rotates freely around a horizontal axle. The knife blades are arranged at equal spacings around the cylinder. The distance between the blades determines the crushing length. Staggered knives and knives set at an angle to the radius of the cylinder improve the action and reduce the shock impact on the draft animals. The body is placed in a frame, which might also be provided with transport wheels and with a cover to protect the operator.

**BOX 5**

**Current farm machinery systems and practices**

**Farm machinery systems in Korea**

- Tractors used: 28 hp standard tractors (Cholima)
- Equipment capacities: low due to limited power; hydraulic lifting capacity nominally 1 000 kg, but actually lower; tractor only used for tillage in paddy rice and for transport.
- Problems: national farm equipment supply has collapsed; lack of implements and fuel. Widespread use of simple animal-drawn equipment.

**Agricultural practices in China**

- The current land preparation technologies create an extra cost of 1 500 RMB*/ha for straw handling, 250 RMB/mu for chopping and spreading, 3 750 RMB/ha for rotavating and incorporating and 6 750 RMB/ha for ploughing. In addition, a large proportion of the harvest is done by hand.
- Threshing is carried out with electrically driven stationary stripper-type threshers that require a minimum straw length to hold the bundles while threshing.
- Traditionally, the straw is not returned to the field.

* 1 US$ = 8 RMB (Renminbi or Chinese Yuan)
When pulled the cylinder rolls on the knife edges, bending over and crushing the vegetation.

There were no problems in the use of knife roller during the project, as this implement is quite simple to use and to maintain: missing knives could be supplemented locally. However, the tractor-mounted knife roller was rather heavy for the Korean tractors. Box 5 presents the current Korean farm machinery system and current agricultural practices in China.

CROP ROTATION AND COVER CROPS

In Korea, a diversified double cropping system with wheat–soybean, maize–soybean and wheat–rice was implemented including the use of a green manure cover crop (GMCC), according to CA principles.

In autumn 2003, winter wheat and winter hairy vetch were sown, which would provide straw mulch or a cover crop in order to evaluate the effect of conservation agriculture on the three farm sites. Table 3 summarizes the features and results of this practice. The results were satisfactory on the three farms; the soil cover resulted in a significant increase of beneficial fauna such as earthworms and spiders.

Various kinds of legume varieties brought from Brazil were sown in the three cooperative farms in 2004 in order to select suitable cover crop species under DPRK climate conditions. The results obtained with these varieties are shown in Table 4.

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>Extent (ha)</th>
<th>Yield (tonnes/ha)</th>
<th>Straw mulched (tonnes/ha)</th>
<th>Date of harvest</th>
<th>Seeder/planter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryongchon</td>
<td>Winter wheat</td>
<td>35</td>
<td>3.5</td>
<td>3.8</td>
<td>15 July</td>
<td>Vence Tudo</td>
</tr>
<tr>
<td></td>
<td>Hairy vetch</td>
<td>10</td>
<td>13 (FW)</td>
<td>13 (FW)</td>
<td>10 July</td>
<td>Fitarelli</td>
</tr>
<tr>
<td></td>
<td>Winter wheat</td>
<td>20</td>
<td>3.3</td>
<td>4.0</td>
<td>13 July</td>
<td>Vence Tudo</td>
</tr>
<tr>
<td></td>
<td>Hairy vetch</td>
<td>30</td>
<td>15 (FW)</td>
<td>15 (FW)</td>
<td>8 July</td>
<td>Fitarelli</td>
</tr>
<tr>
<td></td>
<td>Winter wheat</td>
<td>25</td>
<td>3.0</td>
<td>3.5</td>
<td>15 July</td>
<td>Vence Tudo</td>
</tr>
<tr>
<td></td>
<td>Hairy vetch</td>
<td>10</td>
<td>18 (FW)</td>
<td>18 (FW)</td>
<td>5 July</td>
<td>Animal-drawn</td>
</tr>
</tbody>
</table>

Table 3
Wheat straw mulching and cover crop production (Korea, 2003)

<table>
<thead>
<tr>
<th>Site</th>
<th>Variety</th>
<th>Sowing date</th>
<th>Initial establishment</th>
<th>Days to flowering</th>
<th>Cover crop (tonnes/ha FV)</th>
<th>Seed rate (kg/ha)</th>
<th>Mulch effect on next crop (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryongchon</td>
<td>Black mucuna</td>
<td>3 July</td>
<td>8 July</td>
<td>did not grow (ng)</td>
<td>50–80</td>
<td>60–90</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Green mucuna</td>
<td>3 July</td>
<td>8 July</td>
<td>(ng)</td>
<td>25–40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crotalaria juncea</td>
<td>3 July</td>
<td>10 July</td>
<td>100</td>
<td>5</td>
<td>25–40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dwarf pigeon pea</td>
<td>3 July</td>
<td>9 July</td>
<td>(ng)</td>
<td>100</td>
<td>120–180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jack bean</td>
<td>3 July</td>
<td>9 July</td>
<td>(ng)</td>
<td>40–50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pigeon pea</td>
<td>3 July</td>
<td>9 July</td>
<td>(ng)</td>
<td>40–50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grey mucuna</td>
<td>30 June</td>
<td>6 July</td>
<td>no record</td>
<td>10</td>
<td>50–90</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Dwarf pigeon pea</td>
<td>30 June</td>
<td>5 July</td>
<td>(ng)</td>
<td>25–40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crotalaria juncea</td>
<td>30 June</td>
<td>5 July</td>
<td>100</td>
<td>7</td>
<td>20–40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Pigeon pea</td>
<td>30 June</td>
<td>7 July</td>
<td>(ng)</td>
<td>40–50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horse peanut</td>
<td>30 June</td>
<td>8 July</td>
<td>(no flowering)</td>
<td>10</td>
<td>50–60</td>
<td>100 (not intercropped)</td>
</tr>
<tr>
<td>Jungsan</td>
<td>Crotalaria juncea</td>
<td>4 July</td>
<td>10 July</td>
<td>100</td>
<td>30</td>
<td>20–40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Mung bean</td>
<td>4 July</td>
<td>9 July</td>
<td>75</td>
<td>15</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pigeon pea</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td>40–50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mucuna</td>
<td>4 July</td>
<td>9 July</td>
<td>75</td>
<td>50–90</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Lablab purpureus</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crotolaria Spectabilis</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Songmun</td>
<td>Crotalaria juncea</td>
<td>4 July</td>
<td>10 July</td>
<td>100</td>
<td>30</td>
<td>20–40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Mung bean</td>
<td>4 July</td>
<td>9 July</td>
<td>75</td>
<td>15</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pigeon pea</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td>40–50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mucuna</td>
<td>4 July</td>
<td>9 July</td>
<td>75</td>
<td>50–90</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Lablab purpureus</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crotolaria Spectabilis</td>
<td>4 July</td>
<td>9 July</td>
<td>(ng)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Legume varieties intercropped with maize did not show good results, partly because of the high soil moisture due to heavy rainfall in July, and because of the heavy canopy of maize leaves. Only *Crotalaria juncea* could survive under the heavy shading of maize. Moreover, it was almost the only variety able to produce seeds, which would allow a sustainable green-manure cover-crop system without farmers having to rely on imported cover crop seeds.

**WEED AND DISEASE CONTROL**

Weed infestation under the current rice and wheat monocropping is a major problem in the East Asia. Intensive chemical weed control is not satisfactory, as rains may cause herbicide runoff resulting in water pollution. Conservation agriculture controls weeds by a combination of crop rotation, mulching and efficient, reduced herbicide use if and where needed.

**Korea**

Experience shows that the weed infestation decreases when CA is used for a longer period. The project farmers reported reduced weed pressure after only one year. Figure 2. shows a positive effect of mulch has been observed: reduced numbers and weight of weeds in maize fields of Jungsan Up Farm since the first year of the project.

**China**

In China, weed and pest management in the lowland paddy rice areas presented some problems. In 2005 a heavy attack of *Laodelphax striatellus*, which transmits the Rice Stripe Virus (RSP), was observed in Jiangsu province. Although conventional fields were attacked as well, there were indications that the CA-paddy would be more affected. The high stubble and straw left in the field made the control of the pest and disease harder. Some possible explanations for a higher incidence of this pest in the CA-paddy are:

- The conventional tillage helps to reduce *Laodelphax striatellus* populations;
- Under conventional management the soil is not covered in winter, and *Laodelphax striatellus* are killed by the low temperatures so do not survive to the next summer;
- The straw and high stubble made the use of pesticide and herbicide more difficult.

Since this pest appears periodically and is not a permanent problem, no final conclusion can be reached on the possible long-term effect of CA on this problem. Further attention and monitoring is necessary.

Three weeds were monitored in 2005 in the paddy fields of the wheat–paddy rice demonstration areas (*Echinochloa crusgalli*, *Eleocharis yokoscensis* and *Potamogeton distinctus A.Benn*) and two weeds in the upland demonstration areas with a wheat–maize–rape–cotton rotation (*Alopecurus aequalis sobol* and *Gralium aparine*). In the paddy rice crop there were initially more grass weeds in the intercropped rice than in the transplanted crop. However, after the first herbicide application the weed incidence was the same in both treatments. In the upland no difference in pest or weed incidence was observed between the CA and conventional plots. Only in winter wheat there was a higher weed infestation on the CA plots, which was difficult to control with herbicides.
because of the residue cover. However, the number of weeds in both fields was nearly the same after the second herbicide application. Figure 3 shows the weed infestation of the wheat–paddy rice demonstration fields.

Weed management in the lowland paddy areas requires special attention under CA in any case, including the appropriate conditioning of the straw residues and timing of chemical weed control.

**YIELDS**

In both Korea and China, field demonstrations showed that CA practices allowed better yields than conventional tillage.

**Korea**

The comparison of conventional tillage to 20 cm depth and CA (no-tillage, direct seeding in maize residue cover) demonstrated the efficiency of the CA system. The yields increased by 0.41 to 0.63 tonnes/ha. No-tillage without soil cover did not improve maize yields in 2003 in the three cooperative farms (Figure 4).

The diversified cropping system was compared with the conventional system on the Songmun and Ryongchon farms in 2004 (Figure 5). On the Ryongchon farm, CA maize yields were higher than traditional agriculture under an intercrop system with wheat and vetch cover. Such good results with a cover crop were not achieved on the Songmun farm because of the incomplete killing of vetch with the knife roller: vetch overgrowing the maize affected maize yields. Wheat yields were the same whether intercropped with maize or with soybean, so both intercrop systems appear to be suitable for wheat.

The Jungsan Up farm experiments in 2004 compared different crop rotation systems under conventional and conservation agriculture (Figure 6). Conservation agriculture showed improved grain and straw yields for most of the rotations. Concerning the crop rotation, the higher grain and
straw yield increase between ploughed and CA plots have been observed with maize directly planted after hairy vetch as a cover crop.

The lower grain yield under CA for the wheat-maize rotation can be explained by poor cover crop management. Farmers found that the knife roller had not killed all the vetch, and the surviving plants competed with maize in the early stages of its development. The DPRK project has thus demonstrated the effectiveness of CA practices (cover crop, crop rotation and no-tillage) on yields on the three demonstration cooperative farms.

China
In China, yields could only be analysed for the wheat–paddy rice fields, as a typhoon in August 2005 destroyed most of the maize planted in the fields with a wheat–maize–rape–cotton rotation. It was found that CA technologies such as direct seeding without tillage and interplant allowed an increase of wheat yields of more than 1 tonnes/ha, with 7.1 tonnes/ha in CA fields against 5.9 tonnes/ha in conventional fields. Figure 7 shows the wheat yield components under CA and conventional practices in 2005.

The disease which affected the paddy rice fields in 2005 resulted in a decrease of all rice yield components. However, it was found that a low level of disease almost did not affect the yields components, leading to the conclusion that if the incidence of rice stripe virus RSV) is relatively moderate it also does not create a problem under CA. Figure 8 shows the rice yield components for two different levels of RSV infection, compared with conventional practices in 2005.

SOIL CONDITIONS
Nutrient status
Both Korean and Chinese experiments demonstrated that conservation agriculture technology plays an important role in rapidly improving the physical, chemical and biological properties of the topsoil.
Nutrient content, pH and organic matter content in the soils of the Korean cooperative farms were generally low under conventional practices, and were increased under the CA cropping system. Table 5 presents the analysis of the topsoil (0–5 cm depth) in the demonstration plots.

CA practices improved soil pH, organic matter and available nutrient contents in most of the farms compared to conventional tillage:

- Organic matter content was raised by an average of 0.2 percent.
- The available nitrogen content was raised by 20–25mg/kg soil.
- The available phosphorous content went up by 10 mg/kg soil and in Songmun Farm it increased by a maximum of 30–40 mg/kg due to the rich cover of maize residue and hairy vetch. This could be the result of increased phosphorus mobilization by organic acids resulting from the build-up of soil organic matter.
- The available potassium content was also improved by 10–15 mg/kg soil.

In China, it was also found that returning straw to fields increases soil organic matter (SOM). But in the wheat–maize–rape–cotton fields this improvement was only observed in the surface layer. It was also observed that straw decomposed better and faster in the wheat–paddy fields than in the wheat–maize–rape–cotton fields (Figure 9).

### TABLE 5
Soil chemical data in demonstration plots (0-5 cm depth) (Korea, 2005)

<table>
<thead>
<tr>
<th>Farms</th>
<th>Type of field</th>
<th>pH</th>
<th>OM (% dry weight)</th>
<th>N (ppm)</th>
<th>P₂O₅ (ppm)</th>
<th>K₂O (ppm)</th>
<th>Crop residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryong chon</td>
<td>Traditional</td>
<td>6.5</td>
<td>1.7</td>
<td>7.8</td>
<td>15.0</td>
<td>13.0</td>
<td>Non-mulch</td>
</tr>
<tr>
<td></td>
<td>Wheat–maize</td>
<td>6.5</td>
<td>1.9</td>
<td>9.5</td>
<td>16.7</td>
<td>14.3</td>
<td>Mulch with wheat residue</td>
</tr>
<tr>
<td></td>
<td>Soybean–maize</td>
<td>6.7</td>
<td>1.9</td>
<td>10.3</td>
<td>15.7</td>
<td>14.5</td>
<td>Mulch with soybean residue</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>5.5</td>
<td>1.5</td>
<td>6.5</td>
<td>12.5</td>
<td>15.7</td>
<td>Non-mulch</td>
</tr>
<tr>
<td></td>
<td>Maize–Non-mulch</td>
<td>5.5</td>
<td>1.5</td>
<td>6.3</td>
<td>12</td>
<td>15.0</td>
<td>No-till, Non-mulch</td>
</tr>
<tr>
<td></td>
<td>Maize–mulch</td>
<td>5.6</td>
<td>1.9</td>
<td>8.7</td>
<td>15.7</td>
<td>16.8</td>
<td>No-till, mulch with maize</td>
</tr>
<tr>
<td></td>
<td>GM–maize</td>
<td>5.7</td>
<td>1.8</td>
<td>8.5</td>
<td>16.5</td>
<td>16.3</td>
<td>7 tonnes of GM–maize</td>
</tr>
<tr>
<td></td>
<td>Wheat–soybean</td>
<td>5.6</td>
<td>1.7</td>
<td>7.2</td>
<td>13.8</td>
<td>17.8</td>
<td>Wheat residue–soybean</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>6.8</td>
<td>1.5</td>
<td>5.7</td>
<td>8.8</td>
<td>20.0</td>
<td>Non-mulch</td>
</tr>
<tr>
<td></td>
<td>GM–maize</td>
<td>7.0</td>
<td>1.7</td>
<td>7.5</td>
<td>10.5</td>
<td>21.5</td>
<td>10 tonnes of GM –maize</td>
</tr>
<tr>
<td></td>
<td>Mulch–maize</td>
<td>6.7</td>
<td>1.9</td>
<td>6.9</td>
<td>9.2</td>
<td>21.1</td>
<td>3 tonnes of soybean residue–maize</td>
</tr>
<tr>
<td></td>
<td>Wheat–paddy</td>
<td>6.1</td>
<td>1.5</td>
<td>5.1</td>
<td>7.5</td>
<td>15.6</td>
<td>4 tonnes of wheat residue–rice</td>
</tr>
</tbody>
</table>
Soil moisture dynamics

The soil moisture analysis demonstrated that CA improved soil moisture in the Korea and China projects.

Korea

Soil moisture analysis of soil samples taken in 2003, 2004 and 2005 showed that the soil moisture content of fields under CA practice was higher than on fields with conventional tillage. In 2005, straw mulching increased the soil moisture by 10 to 20 percent at different soil depths (Table 6). This can be explained by the greater water infiltration and the reduced evaporation from the soil surface because of the soil cover. No-tillage and mulching allowed a better soil porosity and biological activity, with soil organisms creating macropores enabling water to penetrate deeper into the soil.

China

In China, the conservation agriculture fields contained more soil moisture than the traditional fields 15 days after the rains, and the difference was significant to 0.5 m depth (Figure 10). The better soil moisture retention can be ascribed to the soil cover maintained by conservation agriculture practices.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Traditional tillage or conservation agriculture</th>
<th>Moisture content (percent field capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before sowing</td>
<td>After sowing</td>
</tr>
<tr>
<td>Songmun</td>
<td>Traditional</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Conservation</td>
<td>63</td>
</tr>
<tr>
<td>Ryongchon</td>
<td>Traditional</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Conservation</td>
<td>82</td>
</tr>
<tr>
<td>Jungsan Up</td>
<td>Traditional</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Conservation</td>
<td>68</td>
</tr>
</tbody>
</table>

TABLE 6

Soil moisture contents in upland soil (Korea, 2005)
Soil loss

Soil loss was measured in 2003 and 2004 in the Jungsan Up farm, Korea. The results showed that mulching with winter wheat or spring barley residues and planting the next crop on the covered soil without ploughing reduces soil loss to 14–17 percent of the loss from the tilled fields (2004 results in Table 7). The improvement is due to the protection from raindrop impact provided by crop residues.

ECONOMIC ANALYSIS

Every new technology has to be economically viable in order to be adopted by farmers. Therefore, a comparative economic analysis of traditional and CA technologies was undertaken for the project farms.

Korea

The economics of CA and the traditional tillage system for Korea were compared by measuring the fuel consumption and labour hours used per ha and season on the three farms between 2003 and 2005 (summary in Table 8). CA practices allowed input savings of 30 to 50 percent. An average of 15.5 kg fuel per ha was saved by following the CA system, and the labour hours per ha were reduced to half to one-third.

China

In China, the different inputs under CA and conventional tillage were measured for the wheat crop in 2005. It was found that CA technologies such as direct seeding without tillage and interplanting reduced farmers’ inputs and increased their net income. The net income under conservation agriculture was twice that under conventional tillage (4100 against 1900 RMB/ha), mainly because of the reduced inputs (Figure 11).

The disease that affected the paddy rice fields in 2005 and reduced the rice yield did not affect the net income generated in CA fields, as the inputs were largely reduced (see figure 12). The net income generated in the interplanted fields was 8800 RMB/ha and 7900 RMB/ha in the conventional fields. So, even if the rice stripe virus was not very well controlled, CA technologies generated a higher income than conventional practices.
AWARENESS CREATION, TRAINING AND RESEARCH

An important factor for the widespread introduction of new technologies is teaching farmers and specialists. Because the introduction of conservation agriculture has been shown to work best if it is farmer-driven, on-farm demonstrations and training events such as workshops, field visits, overseas study tours and training courses were organized in both projects. A visit to North China in 2004 familiarized the Korean participants with the CA on-farm experience of a neighbour country with similar ecological and social conditions. Korean and Chinese specialists also travelled to Brazil in 2005, gaining knowledge and experience with CA in different cropping systems. These trips facilitated the exchange of new methods and revitalized the partnership between researchers.

In China, the implementation process of the project was published in local and provincial newspapers and television.
Conclusions and recommendations

The FAO projects introduced CA in Korea and China showed that CA is a technically viable, sustainable and economic alternative to current crop production practices. The scientific community, the ministry of agriculture and the farmers directly involved have been fully convinced of the economic benefits of crop rotation, no-tillage and straw mulching, which increased yields and reduced inputs. The project demonstrated the value of these CA practices for weed control, soil moisture retention and improvement of soil conditions for crop development.

However, investment in new machinery is required for CA to have a major impact. It will be necessary to build up local manufacturing capacity for CA equipment to produce the required number of seeders, planters, sprayers and other equipment suitable for the local soil and climatic conditions.

The projects created a wider interest in CA. The project farms in China expressed the wish to expand CA to the entire neighbouring area, and an additional 15 farms expressed a strong interest to start CA on their farm in Korea. Government involvement will need to be increased, and the establishment of an information network would help farmers to overcome any technical or agronomic problems arising during the transition to CA. As found in other regions, the advantages of CA may be expected to increase after a transition period, once the soil conditions have improved further and the farmers have gained experience with the new technologies.
Source materials

**KOREA**


FAO. Back-to-office-reports (from 10/12/02 to 01/10/05)

FAO and MoA. *TCP/DRK/2905 Project Conservation agriculture for sustainable food security*. Consultancy reports of 7/06 to 07/07 2004 and 25/09 to 09/10 2004 missions.

**CHINA**


Yacheng Testing Agricultural Centre. 2005. The testing report of the soil properties of the fields under CA conditions.

FAO. Back-to-office-reports (from 7/07/04 to 04/11/05)
This working paper describes the introduction of conservation agriculture in the Democratic People's Republic of Korea and China by two FAO projects. The technical components, design and results of the projects are summarized. This publication is addressed to readers with a background or an interest in agriculture or those with a development-related professional background.