# Driving Strategies and Mechanical Technologies for Conservation Agriculture in Korea

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## ABSTRACT

Agriculture has continued as a life-industry in harmony with the ecosystem by reproduction using solar energy in a material cycle system. Agriculture in Korea, however, has increased environmental load or damage due to intensive production systems with limited natural resources.

To solve these problems and realize sustainable agriculture while keeping the balance in ecosystems, Korea has been continuously promoting environmental-friendly agriculture. The long-term goal of reduction in chemical fertilizers and pesticides was set up and pursued, land area and household for environmental-friendly crop production were increased, and amount of certified environmental-friendly agricultural products were increased gradually.

As an alternative to realize environmental-friendly agriculture, Korea has been developing technologies related to precision agriculture, and promoting applicable models suitable for Korean situation. Precision agriculture differs from organic agriculture that does not use any chemical agricultural materials, but is expected to settle as a low input sustainable agriculture. This is due to the practical aspects that precision agriculture conducts with regard to scientific agriculture using sensors and machinery, which is also suitable for large-sized farming. In addition, various technologies have been developed and applied to farming for conservation agriculture (CA).

The obstacles that Korean agriculture faces in CA are small-sized farming plot, petty farming structure, aging of agricultural labour, and farmers' lack of environmental-friendly business mindset. In spite of these obstacles, Korea has put much effort in developing and applying policy and technology for CA, based on high-level IT and BT, research and development capabilities. Therefore, environmental-friendly agriculture is expected to be a major trend of Korean agriculture in the near future.

## 1. INTRODUCTION

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For CA, Korea puts focus on developing and fostering environmental-friendly agriculture, mainly based on the concept of sustainable agriculture. The Rio Declaration in 1992 defined sustainable agriculture as "accomplishment of sustainable economic growth in harmony of environment conservation with economic development". The field of agriculture defined sustainable agriculture in the practice agenda, based on the UN Agenda 21 as "agriculture minimizing environmental damage while securing long-term productivity and profitability". The meaning can be stated also as "environmentally sound, economically viable, and socially acceptable agricultural production activity".

Korea has pushed ahead with plans for fostering and developing environmental-friendly agriculture on a full-scale since the mid-90s. The background of these Korean activities includes the following: (1) rearing up of environmental friendly agriculture as a core strategic area of future development; (2) increase of consumers' preference to land environment and safety of agricultural products, and (3) expansion of need of agricultural transformation for environment conservation instead of high-input agriculture for productivity.

In addition, as a way to realize environmental friendly agriculture, Korea has been conducting basic experiments and developing technologies related to precision agriculture. As a farming strategy for low input sustainable agriculture, it involves agriculture with machinery based on soil, crop, and weather information collected using sensors.

This paper describes the strategy driving Korean CA for environmental friendly agriculture, previous achievements, and future issues to be solved. The paper also looks into the current mechanical technologies, including precision agriculture, required to realize environmental friendly agriculture.

## 2. POLICY FOR ENVIRONMENTAL FRIENDLY AGRICULTURE IN KOREA

### 2.1 Goals of Environmental Friendly Agriculture in Korea

Korea has been pursuing "environmental friendly agriculture fostering goals" such as reduction of chemical fertilizers and pesticides application, increase of certified environmental-friendly agricultural products, build-up of systematic structure for a nature circulation type environmental friendly agriculture, in which sowing and livestock farming are linked.

One of the critical issues to be addressed for sustainable agriculture is reduction of the amount of chemical fertilizers and pesticides application.

As shown in Table 1, the amount of over-applied fertilizers as compared with that of recommended standard fertilizer was approximately 26 per cent in paddy rice production as of 2002. Over-applied ratio (percentage) by component were 29.7 per cent, 25.6 per cent, and 21.9 per cent for phosphorous, nitrogen, and potassium, respectively.

Table 1. Estimated over-applied fertilizer for paddy rice production (as of 2002).

| Component | Recommended rate (kg/10a) | Applied rate (kg/10a) | Over-applied rate (kg/10a) | Over-applied ratio (%) |
|---|---|---|---|---|
| Nitrogen | 11.0 | 14.8 | 3.8 | 25.6 |
| Phosphorous | 4.5 | 6.4 | 1.9 | 29.7 |
| Potassium | 5.7 | 7.3 | 1.6 | 21.9 |
| Total | 21.2 | 28.5 | 7.3 | 25.7 |

Korea is pursuing a goal to reduce the amount of chemical fertilizers applied by 40 per cent from 375 kg/ha in 2003 to 225 kg/ha by 2013. The goal for pesticides application is also reduction by 40 per cent to 7.4 kg/ha by 2013 as compared with 12.4 kg/ha in 2003.

Table 2. Reduction goals for chemical fertilizer and pesticide application.

| | 2003 | 2005 | 2008 | 2010 | 2013 |
|---|---|---|---|---|---|
| Rate per ha (kg/ha) | (100%) | | | | (60%) |
| Chemical fertilizer | 375 | 374 | 290 | 260 | 225 |
| Pesticide | 12.4 | 11.8 | 10.1 | 9.1 | 7.4 |

Also, Korea plans to increase the ratio of certified environmental friendly agricultural products from 4.0 per cent of total agricultural products in 2005 to 7.5 per cent in 2008 and to 10 per cent in 2010.

Table 3. Goal of environmental friendly agricultural products (Unit: thousand ton, %)

| | 2005 | 2006 | 2008 | 2010 |
|---|---|---|---|---|
| Environmental friendly products (A) | 798 | 940 | 1,400 | 1,850 |
| Total agricultural products (B) | 18,800 | 18,700 | 18,600 | 18,500 |
| Ratio (A/B) | 4 | 5 | 7.5 | 10.0 |

With the policy to promote environmental friendly agriculture, land area and number of farming households practicing it are expected to cover 114,000 ha and 120,000 households by 2010, as compared with 58,000 ha and 61,900 household in 2006.

### 2.2 Strategies to Foster Environmental Friendly Agriculture in Korea

In Korea, sympathy for the need of environmental friendly agriculture is expanding among government, producers, and consumers. It should also be noted that consumers' selection criteria of agricultural products are changing from price to quality and safety, indicating stabilization of positive conditions for environmental friendly agriculture.

Meanwhile, the encroachment and intimidation of Korean organic farming market is increasing due to imported organic agricultural products, and quality deterioration and violation of certification standards. Factors such as weakness of distribution infrastructure, and difficulty in securing market, are threatening the expansion of environmental friendly agriculture are present. Therefore, Korea is practicing strategies in various areas to solve these problems, use the change, and develop environmental friendly agriculture (EFA). Promotion strategies by area are summarized as follow:

1) Production area

□ Establishment of nature circulation type agriculture linking sowing and livestock farming
- ○ Environmental friendly organic livestock product: increase to 1 per cent out of total livestock product by 2010

□ Stabilization of farmers' income through increase of EFA direct payment unit cost
- ○ Expansion of environmental friendly livestock farming direct payment to 20 per cent of total registered livestock farming by 2013

□ Establishment of whole year production system through support of EFA technology and material

- ○ Expansion of insect control through natural enemy to 50 per cent (50,000 ha) of the protected horticulture by 2013

2) Distribution area

□ Reduction of distribution cost by construction of distribution centre dedicated for EFA products

□ Control of supply-consumption by self-reliance fund for EFA products; activation of publicity

□ Rearing of 30 regional production-distribution base organizations, diversification of distribution channels

3) Consumption area

□ Publicity extension of EFA products; improvement of reliability through after-service control
  ○ Introduction of recall system for entire EFA products by 2010
□ Security of large-volume demand of EFA products (e.g., school meal supply)
□ Developing a way for foreign exports of EFA products

4) System area

□ Modification of EFA certification system (e.g., revision of EFA fostering law)
  ○ Abrogation of low-pesticide certification by 2010
□ Transfer of EFA certification to private organizations, rearing of private certification organizations
□ Expansion of traceability system on a full-scale for EFA products
  ○ Operation of full-scale traceability system for organic farming households by 2008

5) Agricultural materials area

□ Introduction of verification and management of environmental friendly agricultural materials (EFAM), Rural Development Administration (RDA)
□ Analysis of characteristics and effects of EFAM
□ Establishment and operation of laws for management and utilization of livestock waste or manure

6) Technology development area

□ Technology development and extension by RDA and research groups
  ○ Development and extension of EFA standardized technology necessary in the farming fields
□ Resource-making of livestock manure, development of environmental friendly pesticide control technology
□ Development and expansion of processed food using EFA products

7) Local agriculture area

□ Achievement of nutrient balance for regional field units and reinforcement of agricultural environment resource management
□ Promotion of urban consumers' experience of EFA and interchanges between urban and rural societies

□ Encouragement of participation of local governments (e.g., by awarding an EFA prize)

Korea actively promotes projects such as the establishment and expansion of EFA implementation infrastructure, development and extension of on-farm technology, expansion of nature circulation type EFA linking sowing and livestock farming, support for EFA rearing and income security for EFA practicing households, improvement of consumers' reliability for EFA products and activation of distribution, reduction of rural environmental pollution and reinforcement of international cooperation, and rearing of environmental friendly forestry.

## 3. TECHNOLOGY DEVELOPMENT FOR CONSERVATION AGRICULTURE

### 3.1 Precision Agriculture (PA) in Korea

#### 3.1.1 Precision Agriculture Technology Development

Korea puts much effort to develop PA technology and feasible application models, as an alternative to realize EFA. PA enables environmental friendly high-quality agriculture in a scientific and effective way using agricultural machinery based on information about soil, crop, and weather. Basic IT-applied PA technologies were developed mainly by the National Institute of Agricultural Engineering, RDA, and it is now on a stage of on-farm performance tests for partial implementation of the results.

Technologies and devices developed or under development are (1) sensors for bio-environment measurement such as soil sampling system, soil strength measuring device, crop growing condition measuring device, and yield monitoring system that measures rice yields; (2) mapping software to create electronic maps; and (3) initial variable rate and additional fertilizer application system.

Soil strength measuring device measures soil strength, an important soil physical property used frequently for hardpan detection and optimum tillage, mechanically and reliably. Commercialization and application to actual farming is expected in the near future.

Fig.1. Digital soil strength

One of the devices under on-farm performance test for application to actual farming is an electronic map-based variable fertilizer applicator attachable to a transplanter. The unit uses positioning information (e.g., GPS) and electronic fertilization application map prescribed by soil testing results to apply fertilizer variably by location, and could save 17 per cent of the conventional fertilizer application amount without yield loss.

Fig.2 Map-based variable fertilizer applicator attachable to a transplanter.

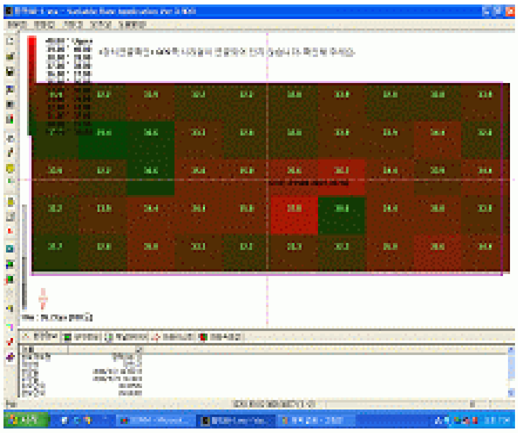


Fig.3 Fertilizer application map by mapping S/W.

A representative sample of an actual on-farm application is the "Ubiquitous-based PA promotion strategy" by Pyeongtaek City. Pyeongtaek conducts projects for development and stable extension of PA technology for environment conservation and high-quality safe agricultural products which consumers prefer.

Other local governments have a big interest in PA and show activities for business plan embodiment and technology adoption. Expansion of PA-based farming operations with technical support is expected.

### 3.1.2 Obstacles and Perspectives for Korean PA

As described above, Korean PA is in the stage of basic technology development and on-farm performance tests. However, for practical application and confirmation of the positive effects, there is a need for an expansion in the understanding on PA and development and improvement of Korean-specific application models.

Conceptual approach is more important than technical approach in PA. Instead of simultaneous and full-scale application of the entire technology, it would be better for Korean agriculture with small-sized paddy rice fields to start with the application and verification of each technology. Then, this would be expanded step-by-step based on bio-environmental information.

Through this application strategy, Korea, the country which over-applies chemical fertilizers and pesticides, would reduce the amount application amounts and contribute to sustainable agriculture for production of environmental friendly and safe agricultural products.

## 3.2 Soil erosion prevention technology

### 3.2.1 Status of Soil Erosion in Korea

Most upland fields are located in sloping areas, and soil erosion is an important issue since it deteriorates crop productivity and causes environmental pollution. It is reported that in natural conditions, soil erosion less than 1 MT/ha equilibrates with soil development. In agricultural fields, soil erosion should be less than 13 MT/ha to maintain fertility. Removal of natural vegetation, however, increases soil erosion several hundred times, and researchers warned annual soil loss up to 485 MT/ha in upland fields using the Universal Soil Loss Equation (USLE).

Loss of fertile ground surface soil causes loss of nutrients. It was reported that in Korean corn fields with a 20 per cent slope, there was a loss of 15.5 kg of nitrogen, 10 kg of phosphorous and 21.5 MT of soil particles. Therefore, soil erosion should be recognized as an important issue for EFA and carefully managed. Tillage system is critical to prevent soil erosion, and research results showed that no-tillage for soil conservation could save 62 per cent of soil erosion and 32 per cent of nutrient loss.

### 3.2.2 Strip-Tillage Equipment to Reduce Soil Erosion

Strip-tillage equipment that could till only strips to be seeded and the rest of the field covered with chopped rye to reduce soil erosion was developed, and the performance of erosion reduction was evaluated.

#### 3.2.2.1 Strip-Tillage Equipment

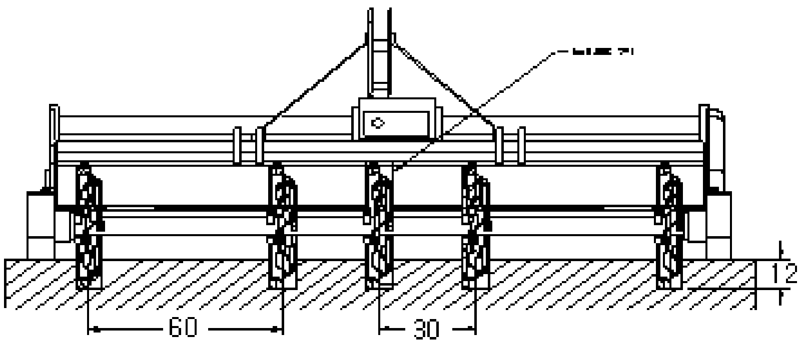
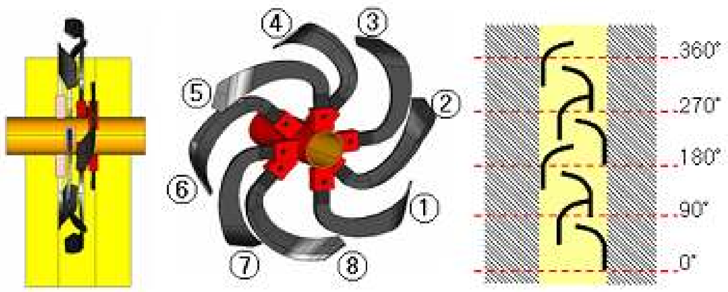



Fig. 5 Strip-tillage equipment.

The strip-tillage equipment used 8 fodder-chopper type rotary tillage blades for each row to till only strips to be seeded. The row width, tillage depth, and row spacing were 8, 12, 60 cm, respectively, and rotary tillage blades were arranged in inwards direction so that scattered soil could be in the seeding furrow.




(a) Top view (b) Isometric view (c) Sequence of soil cutting

Fig. Tillage blades of strip-tillage equipment.

(a) Conventional tillage (up and down).

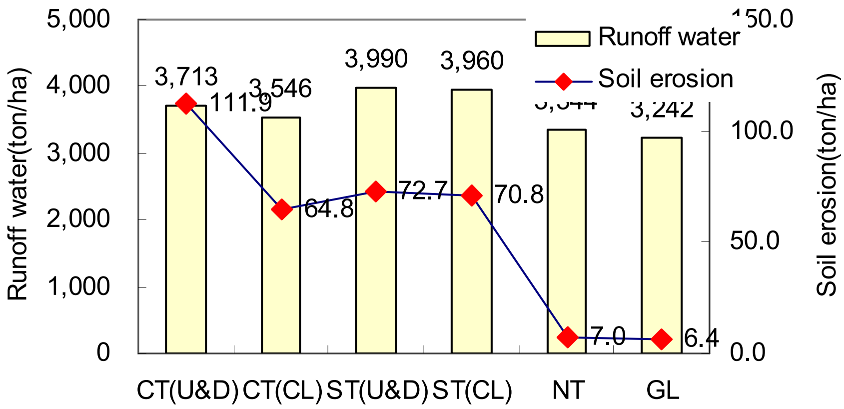
(b) No-tillage and conventional tillage (contour line).

(c) Strip-tillage (contour line).

(d) Strip-tillage (up and down).

### 3.2.2.2 Effect of Soil Conservation by Tillage Method

Strip-tillage along contour lines caused soil erosion of 70.8 ton/ha, which was 37 per cent less than 111.9 ton/ha for conventional tillage in the up-down direction. The erosion, however, was a little higher than that of conventional tillage along contour lines. Most effective way to reduce soil erosion was to grow cover crops and combine strip-tillage technique.




(CT: Conventional tillage, U&D: Up and down, CL: Contour line, ST: Strip-tillage, NT: No-tillage, GL: Grassland)

## 4. VARIOUS MECHANICAL TECHNOLOGIES FOR CONSERVATION AGRICULTURE

### 4.1 Weeding Machine for Rice Production

A walking type three-row weeding machine that could remove and root out weeds inter- and within-rows was developed for environmental friendly rice production. The walking-type weeding machine for rice production could adjust operating width from 18 to 24 cm according to weeding time, and field capacity was about 10a/h. In a paddy field with a water depth of 1 cm, the use of the prototype was effective in removing weeds, showing a rate of weed control of 97.2 per cent, which was similar with that of conventional manual weeding operation. This indicated that the prototype could save 94 per cent of weeding labour, and was suitable for EFA with no use of herbicides.

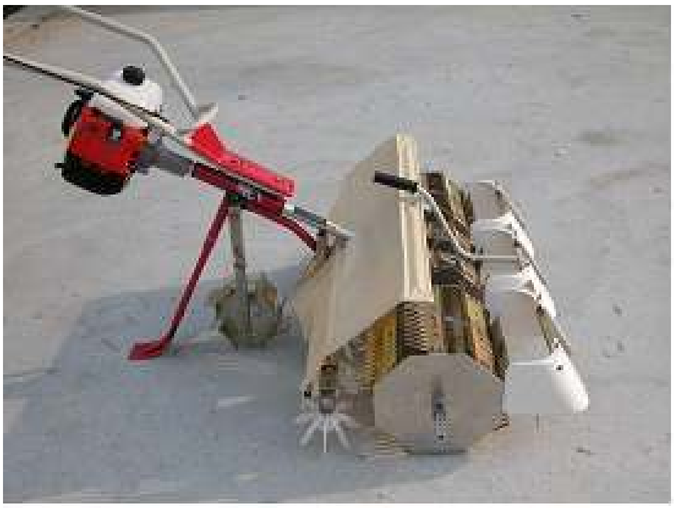


Fig. 9 A weeding

### 4.2 A Paper-Mulching Rice Transplanter

A paper-mulching rice transplanter was developed to grow rice in an environmental friendly way, by preventing weed growth using paper mulching material, instead of herbicides.

Weed-preventing mulch paper was developed in cooperation with a company. The bio-degradable paper (PES, 10 ㎛) was decomposed naturally in 55-60 days after transplanting, and there were no residues in the environment and crop after decomposition.

Field performance of the paper-mulching transplanter showed that weed control value was 98 per cent and rice yield was 502 kg/10a, with no significant difference from 504 kg/10a for conventional transplanter, indicating that the paper-mulching rice transplanter could contribute to EFA with no use of herbicides.

Fig.10. A paper-mulching rice transplanter.

### 4.3 A Strip-Tillage Rice Transplanter

A strip-tillage rice transplanter that could apply slow-release fertilizers at the time of transplanting was developed to save labour and cost for rice production. The unit could save tillage energy by tilling only the strips to be transplanted. Fertilizer utilization is also increased by applying slow-release fertilizers in front of the strip-tillage blades and covering the slow-release fertilizer with soil.

Fig.11. A strip-tillage rice transplanter.

Field performance tests showed that sufficient irrigation for 10-20 days before transplanting resulted in reduction of misplanted rate and increase of rice yields (about 7 per cent) and could save fertilizer application by about 20 per cent compared with conventional transplanting.

### 4.4 Manual and Automatic Type Inlets and Outlets for Water Management in Paddy Fields

Manual and automatic type inlets and outlets (irrigation gates) replacing conventional soil gates were developed to save labour for water management in paddy fields. Developed gates were of the manual type that could control inflow and outflow by rotating angles (0-90°) of elbow pipes, and automatic type that could open and close gates according to the signal of water level sensors.

These developed gates made flow and water level controls easier, and reduced water management labour and amount of irrigation water significantly. Also, soil loss was minimized by drain starting from surface water. This was done by adjusting rotational angle of the elbow pipes. In addition, irrigation water could be saved when field levees are prevented from water leakage by controlling water level automatically, especially during heavy rainfall.

Test results showed that gate management capacity were 18.0 h/ha for manual gates and 3.7 h/ha for automatic gates. They were 67 per cent and 14 per cent for conventional soil gates (26.8 h/ha). Operational stability and response of water level sensors were fairly good, and water leakage was reduced by 12 per cent for manual type and 93 per cent for automatic type as compared with conventional type.

Fig.12. Automatic type inlet (left) and outlet (right).

### 4.5 Water Proof Material to Reduce Water Leakage through the Levee and Weed Growth

Water leakage through field levee was reduced by installing water proof materials (e.g., tarpaulin sheet, gum sheet, P.V.C hard panel, and light-burned magnesia flour) available easily at farming sites.

Fig.13 Weed growth status

(a) No treatment plot

(b) Water proof material treatment plot

The material is installed to a 20 cm depth in the field side to save levee fail and 75 per cent of water leakage. Weed appearance was reduced significantly for levees with tarpaulin sheet, resulting in reduction of weed control labour and time.

## 5. CONCLUSIONS

Korea continuously promotes environmental friendly sustainable agriculture with well-developed and detailed policy and goals since the mid 1990. It has planned to reduce application of chemical fertilizers and pesticides by 2013, and to also expand certified environmental friendly agricultural products gradually by increasing area and number of farming households practicing EFA. To achieve these goals, Korea established promotion strategies by area and seven core projects.

Korea is also trying to develop basic technologies for precision agriculture, as an alternative way for EFA, and suitable implementation models for Korean situation. Precision agriculture differs from organic agriculture and does not use any chemical agricultural materials, but is expected to settle as a low input sustainable agriculture. Due to practical aspects, precision agriculture conducts scientific agriculture using sensors and machinery which are also suitable for large-sized farming.

In addition, mechanical technology developed or which are under development for Korean conservation agriculture includes a strip-tillage equipment to reduce soil erosion; a weeding machine and a paper-mulching rice transplanter to prevent and remove weeds without herbicides; and a strip-tillage rice transplanter to save energy and fertilizer application. Irrigation gates to manage water and water proof materials to reduce water leakage and weed occurrence were also developed. Various technologies have been developed and applied in farming for conservation agriculture.

With the continuous development and distribution of policy and technology for conservation agriculture, Korean agriculture is becoming more environmental friendly and sustainable.

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