Automated Crop Production For the 21st Century

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Abstract: After ten years of implementing the agricultural automation program in Taiwan, some positive effects and satisfactory results have been recognized by both the agricultural industry and local administrative bureaux. The automation of agriculture is a response to sophisticated demands for production and quality in countries with high labor costs. The development of sensor systems, control systems, precision agriculture systems, and engineering for plant culture systems will determine the degree of automation used for crop production in the 21st century. The engineering system will capitalize upon expertise from physiologists, pathologists, systems analysts, agronomists, horticulturists, computer programmers, economists, crop producers and managers in order to efficiently implement automated crop production.
Keywords: Automation, Precision Agriculture, Agricultural Machinery

Introduction

The taskforce for promoting agricultural automation in crops, fisheries, livestock production and agri-business service was initiated in 1991 in Taiwan. Its objectives are to promote economic, social, and environmental changes to increase farmers' income, to develop special agricultural zones, to fully utilize the land and water resources, to solve the manpower shortage and the aging problems in the villages, to provide nutritious, sanitary, and fresh high-quality agricultural products, to improve the shipping and distribution system for agricultural products, to improve the working environment and increase farming safety, to handle farm waste disposal and minimize environmental pollution, and to use energy resources more effectively(Fon, 1988; Lee, 1997).

Total investment in crop production automation was about NT$998 million during 1991~1998. After ten years of endeavour, some positive effects and satisfactory results have been recognized by both agricultural industry and local administrative bureaux. Automated crop production focuses on pesticide application, post-harvest processing, vegetable seedling production, planting and transplanting, greenhouse engineering, and other field uses of machinery.

The automation of agriculture is a response to sophisticated demands for production and quality in countries with high labor costs. Automation signifies the machine's capability to process information and execute tasks with minimum or no human supervision. In the 21st century, technology will advance to the point where present instrumentations or concepts will work properly or be adaptable to automated crop production.

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The objectives of this paper are to present the scenario and outline the potential technology for automated crop production in the 21st century.

Development of Agricultural Machinery

Machines for crop production have been well developed in the past years. To mechanize means to use machines to accomplish crop production in field operations or in postharvest processing. Human power, animal power, and mechanical or engine power have played important roles in agricultural mechanization. Power machinery, for example, a tractor which multiplies human power a thousand times (from 0.07 kw to 70 kw), makes possible a crop production several hundred times larger than what a farmer can produce manually. Agricultural machinery has progressed from utilization of hand-tools to automation technology. This evolution can be divided into the following stages(Rijk, 1999):

1. Improved hand-tool technology.
2. Draft animal power.
3. Stationary power substitution.
4. Motive power substitution.
5. Human-control substitution.
6. Adaptation of cropping practice.
7. Farming-system adaptation.
8. Plant adaptation.
9. Automation of agricultural production.

Due to the development of agricultural business, the scope of research and manufacturing in agricultural machinery has been expanded from field machinery to pollution control machinery, aquacultural machinery, and bio-industry machinery. The applications of Geographical Information System (GIS) and Global Positioning System (GPS) open a frontier for automatic machinery used in precision agriculture. The technology adopted in various stages of the development of agricultural machinery is illustrated in fig. 1. The supporting system for successfully implementing precision agriculture is diagrammed in fig. 2.

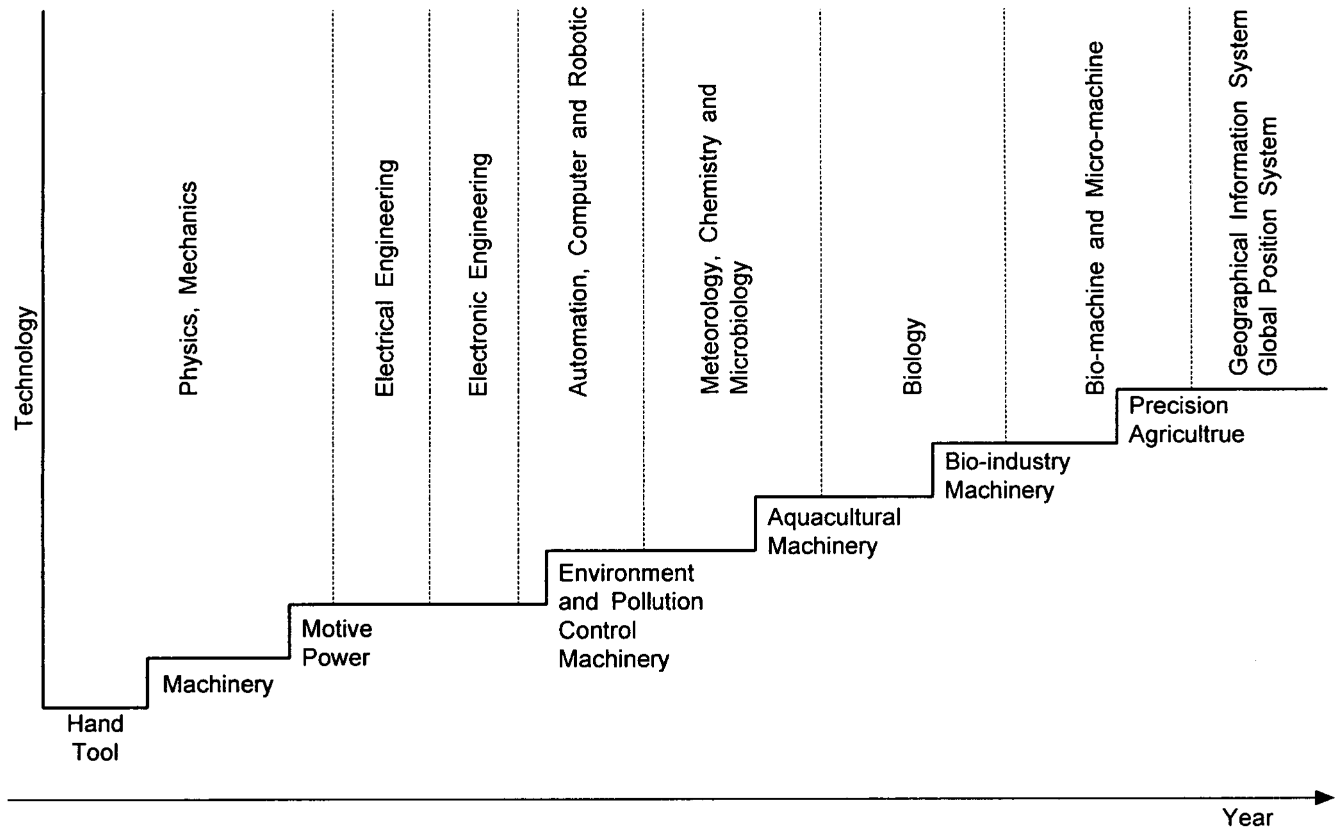

Fig. 1 Evolution of agricultural machinery.

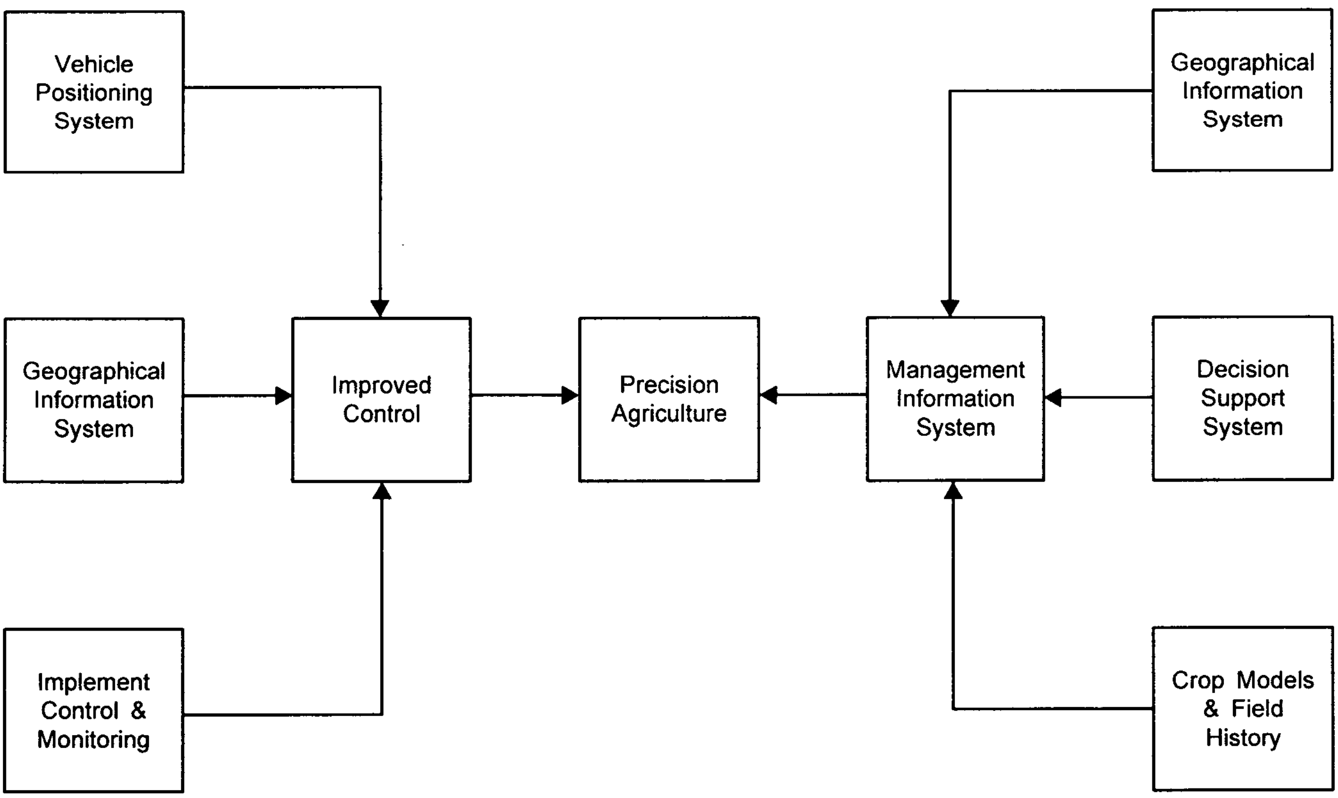

Fig. 2 Precision agriculture system [1].

The introduction of advanced technology developed for other industries is increasing the automation of crop production. The development of sensor systems, control systems, precision agriculture systems, and engineering for plant culture systems will determine the degree of automation used for crop production in the 21st century.

Technology Used in Automated Crop Production

1. Sensor systems

Sensor systems have the function of gathering information or measuring responses relevant to crop production. Items that need to be detected include mechanical, chemical, electrical, and biological properties. Such items as image texture (patterns of crops in field and weed detection), micrometeorology (crop, air, and soil temperature and moisture), soil survey (conductivity and nutrients), crop scouting (weeds, insect, ripeness), and others are key factors for promoting automated agriculture. Sensors for perception other than machine vision include range sensors (ultrasonic sensors, position-sensitive devices), proximity sensors (photosensing type, pneumatic type), tactile sensors (touch, pressure, and slip), ripeness sensors (photo, sonic, and gas sensors for fruits), and machine guidance sensors (fixed, semifixed, and free path). Internal sensors for mechanism control include position, angle, velocity, acceleration, inclination, and azimuth measurements.

The working environment for sensors sometimes includes severe conditions such as high temperature and humidity or dusty and windy fields. Direct attachment of sensors to plants may affect physiological measurements. Thus non-contact and non-destructive measuring systems are preferable (Criner et al., 1999; Kondo, 1998; Mitchell et al., 1991; Monta et al., 1998)

2. Control systems

Control systems are the portion of an automatic system where sensed information is used to influence the state of the system in order to meet a designated objective. Controls are one of the primary mechanisms used in engineering systems to maximize productivity, efficiency, and product quality. Effective application of controls is a critical concern in the design of all automated systems for crop production.

Fields may have irregular shapes and topography, with obstacles such as irrigation and drainage ditches. Some operator-driven machinery is equipped with automatic devices to regulate field operations such as plowing depth, threshing speed, cutting height, travelling speed, etc. Conventional control systems are designed with a fixed configuration and are unsuitable in agricultural systems (Stone, 1991). Application of fuzzy logic and neural network techniques will be important for achieving automated crop production. Autonomous machinery will be available for crop production in the 21st century.

3. Precision agriculture systems

Precision agriculture (other terms have been used, such as precision farming, satellite farming, in-field site-specific crop production, and variable rate application technology) entails the use of some high-tech equipment for assessing field conditions and selectively applying chemicals and fertilizers to a specific site. GPS and computer field mapping, coupled with on-board electronic controls, will provide new levels of automation for agriculture.

Precision agriculture will manage for each crop the input of fertilizer, limestone, herbicide, seed, etc. on a site-specific basis, to reduce waste, increase profits, and maintain the quality of the environment. Technology such as satellite positioning systems, electronic sensors, controllers, and sophisticated software is required to successfully and economically implement precision agriculture on large areas of mechanized farm land which have yield variation among plots due to different fertility status of the soil, insect pressure, and poor field drainage.

Precision agriculture techniques can be applied in the entire crop production cycle, from pre-planting to harvesting operations. Up to date and future technology will be available to improve soil testing, tillage, planting, fertilizing, spraying, crop scouting, and harvesting. Soil test results can be used to produce soil maps from the sampling position information provided by GPS. Information provided by soil sensor technology and GPS will instruct machines to vary tillage depth and plant residue left on the soil surface in order to reduce soil compaction and optimize soil temperature and moisture content for crop growth in conservation tillage systems. The seedling rate and planting depth for obtaining optimum planting population and germination rates can be regulated according to soil characteristics revealed in soil maps.

Automatically controlled sprayers can vary the amount of pesticide applied (patch spraying) while driving across the field, being guided by a weed map obtained from remote sensing. Weed infestations or crop health images can be acquired from satellites, airplanes, or remotely piloted vehicles.

Crop scouting uses satellite images and photographs taken from aircraft to identify patches of weed, drainage problems, insect stress, and other crop conditions. The fields can be surveyed from pickup, tractor, and combine cabs and on foot. Yield measurements document the result of previous farm activities and can be used to plan for the coming crop. Merging the yield sensor, moisture sensor with GPS in crop harvesting operations will record yields on a site-specific basis and produce a yield map through the use of mapping software on the office computer (Auernhammer et al., 1999; Kuhar, 1997; Meyer et al., 1997; Reetz, 1999; Tofte et al., 1991).

4. Engineering for plant culture systems

The engineering for plant culture systems is an integrated production system: the integration of mechatronics, automation, culture, crop model, and environment. The engineering system will capitalize upon expertise from physiologists, pathologists, systems analysts, agronomists, horticulturists, computer programmers, economists, crop producers and managers in order to efficiently implement automated crop production.

Automated crop production will have access to computational power and extensive databases to operate within real-time monitoring and response decisions. Decision-making requires strategies for optimizing crop production while maintaining soil quality and minimizing environmental damage.

Crop models are sets of mathematical equations defining physical systems to predict growth, development, and yield of a given crop. The primary objectives of a crop model are to describe stages of plant growth and to assist in management decisions. Crop performance can be evaluated on different soil types, cultivars, planting depths, densities, and irrigation and fertilization strategies by adopting an adequate crop simulation model. Crop management decisions will be made according to the simulated results of the crop model. An good example of this engineering system is controlled-environment agriculture (Giacomelli, 1991).

Conclusions

The taskforce for promoting agricultural automation in the crops, fisheries, livestock production and service was initiated in 1991 in Taiwan. After ten years of endeavors some positive effects and satisfactory results have been recognized by both agricultural industry and local administrative bureaux.

To successfully accomplish the goal of automated crop production systems in the 21st century, the technology required to be incorporated with traditional machinery includes sensor application, control system application, precision agriculture, and engineering for plant culture systems.

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