CONTROLLED ENVIRONMENT AGRICULTURE CAPTURING GROWING INTEREST

— THE ACCELERATING EXPANSION OF URBAN AGRICULTURE —

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SUMMARY

- As the environment surrounding agriculture changes, controlled environment agriculture (CEA) is attracting growing interest. CEA refers to protected cultivation, a process of growing crops in a controlled environment (where factors such as light, CO_2, temperature/humidity, and airflow are regulated) and includes cultivation in vertical farming and greenhouses where environmental factors are tightly controlled. Because CEA grows cops indoors, it is labor-saving, allows for the reduced use of pesticides, and can be set up just about anywhere.
- In order to solve CEA production and distribution issues, initiatives are being pursued to reduce costs, such as by optimizing operations, improving quality, and shortening transportation times.
- Going forward, CEA operations are expected to expand in urban areas. If solutions can be found for the challenges presented from the circular economy perspective, in addition to production and distribution issues, new business opportunities may open up.

1. THE ENVIRONMENT SURROUNDING AGRICULTURE

1-1. World population growth and climate change

According to the United Nations, the world's population was estimated at 7.7 billion in 2019 and is forecast to reach 9.7 billion by 2050. In view of continuing population growth and urbanization, 68% of the world's population is expected to be living in urban areas by 2050. There are also concerns about the impact of climate change on agriculture. Farmers are being directly affected by the detrimental consequence of climate change. For example, the progression of global warming is influencing crop production, with high temperatures disrupting growth and causing a deterioration in quality. Furthermore, it is thought that an increase in pest infestations and expansion of the habitat distribution area could exacerbate the damaging impacts. From the viewpoint of ensuring stable food supplies, it is essential to boost production efficiency per area of land and production efficiency per agricultural worker.

1-2. Changing food needs

The food needs of consumers are growing increasingly diverse. Worth mentioning in particular has been the appearance of consumer demand for high value-added foods in developed countries. In recent years, in emerging countries as well, there has been a growing trend of consumers seeking out high value-added foods, reflecting their rising income levels. Giving further impetus to this tendency is the heightened health consciousness amid the COVID-19 pandemic. For example, sales of organic packaged foods in 2020 increased by 11% year on year (source: Euromonitor), growing despite the economic downturn caused by COVID-19 and the relatively high price of organic products. Behind this is the fact that COVID-19 has reinforced consumer motivation toward improving their dietary habits and selecting foods grown with the use of lower amounts of pesticides in order to improve their health.

1-3. Need for stable food supplies

Given the disruptions to supply chains caused by the COVID-19 crisis that began in 2020, local production for local consumption is regaining attention as one means of ensuring reliable food supplies. For example, community supported agriculture (CSA) is becoming popular, mainly in Europe and the US. CSA is a production system that directly connects local producers with consumers. Consumers can pay the producers in advance and purchase fresh vegetables and other produce from them on a regular basis. In addition, as consumers know who the producers are, they can feel reassured of product traceability. Meanwhile, as mentioned above, it is predicted that 68% of the world's population will be living in urban areas by 2050. For that reason, agriculture in urban areas is expected to become important from the standpoint of securing stable food supplies.

In the environment surrounding agriculture as described above, controlled environment agriculture (CEA) is attracting attention. CEA is expected to become a market worth more than approximately US$140 billion by 2024 (source: Fast.MR) and has the following characteristics: (1) indoor growing conditions are tightly controlled, (2) labor-saving can be promoted easily by utilizing technologies such as AI and robotics, (3) crops are less susceptible to weather and natural disasters because growing is done indoors, (4) control of the crop growing environment allows reduced use of pesticides and other agricultural chemicals, (5) growth history data is readily available, and (6) it is possible to produce crops in the vicinity of consumers such as urban areas. This report describes the classifications, challenges, and prospects of controlled environment agriculture.

2. CONTROLLED ENVIRONMENT AGRICULTURE DRAWING ATTENTION

Controlled environment agriculture refers to protected cultivation, which is a process of growing crops in a controlled environment (where factors such as light, CO_2, temperature/humidity, and airflow are regulated). Specifically, it includes vertical farming and greenhouse cultivation facilities equipped with environment control systems. CEA makes it possible to optimize the growth of crops by purposefully controlling the indoor environment through the introduction of hydroponics and other cultivation techniques, plant physiology, and computer management. It also allows for agricultural operations in the suburbs where there are many consumers but a limited availability of arable land. The most commonly cultivated crops using CEA methods include lettuce and other leafy vegetables, strawberries, tomatoes, and mushrooms. In addition, CEA is also used for cannabis cultivation in areas where cannabis is legal, such as for medicinal purposes.

CEA can be classified according to cultivation method, cultivation format, and location (Figure 1). Among the classifications of cultivation methods, in addition to the method using soil, there are hydroponics (method of growing plants in a nutrient solution instead of soil) and aeroponics (method in which atomized nutrient solution is sprayed on the roots of plants). The features of these methods include the ability to minimize the amount of input resources, such as water and nutrient solution, and because the weight of the growing medium can be

Figure 1: Classifications of controlled environment agriculture

Classification			Overview
Cultivation method	Soil cultivation		A cultivation method using soil in which soil water content and other factors are controlled.
	Hydroponics		A cultivation method of growing plants in nutrient solutions instead of soil. Commonly used to grow tomatoes and other vegetables.
	Aeroponics		A cultivation method of spraying nutrient solution, for which a pump or air compressor is required. Since the plant-growing medium is more lightweight, it is suitable for multi-stage cultivation.
	Aquaponics		A cultivation method that combines aquaculture, such as for farming tilapia, and hydroponics. Fish excrement is used as fertilizer.
Cultivation format	Greenhouse		Uses sunlight as the light source needed for crop growth.
	Vertical farming		The use of an artificial light source, such as LED lighting, makes it suitable for multi-stage cultivation.
	Location	Warehouse model	A cultivation system using an unused or old warehouse.
		Container model	A modular-type cultivation system using a shipping container, etc.
		Kitchen garden model	A small cultivation system that can be installed in condominium units in urban areas.

Source: Compiled by MGSSI based on Lux Research materials reduced, they are suitable for multi-stage cultivation. In addition to these, there is also aquaponics, which is a combination of hydroponics and aquaculture. There are two classifications of cultivation format: greenhouse and vertical farming. Greenhouses mainly use sunlight, while vertical farming uses artificial light, such as that from LED grow lamps. The use of sunlight lowers the cost of electricity, compared to growing with artificial light. Vertical farming using artificial light has been expanding along with lowering LED costs and its rising performance. This is because in vertical farming, “fields” are stacked in the vertical direction by adopting LEDs that generate less heat, making it possible to increase crop-production density. Vertical farming can be further classified by location into the following models: (1) warehouse, (2) container, and (3) kitchen garden. In (1), the warehouse model, infrastructure such as an unused or old warehouse is used. 2), the container model, is a modular cultivation system using containers. This type of system could, for instance, use a shipping container that can be installed in a small space, such as on the rooftop of a building like a grocery store or a parking lot. The kitchen garden model, (3), is a small household system suitable for condominium units in urban areas.

3. CHALLENGES (PRODUCTION/DISTRIBUTION) AND INITIATIVES IN CEA

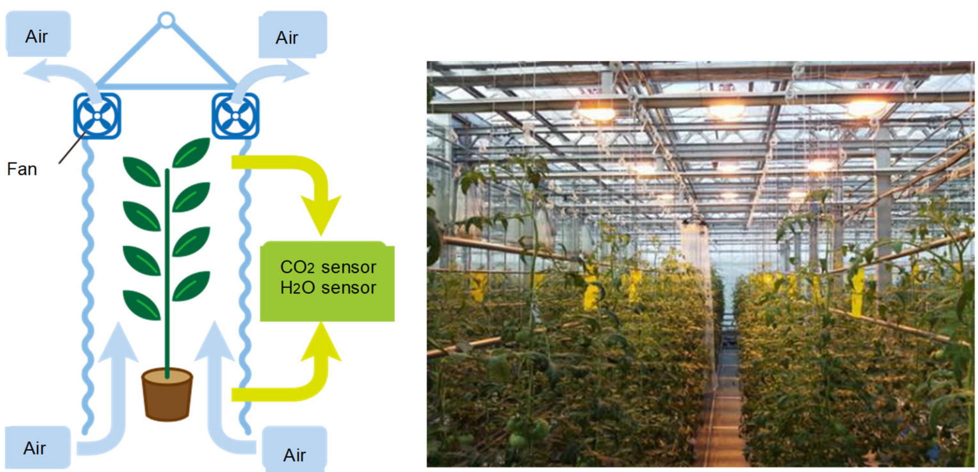
3-1. Initiatives for addressing production issues

A major issue in CEA is the high level of costs. Of total costs, labor and electricity tend to account for a large proportion, and labor-saving initiatives are being actively pursued by optimizing operations and utilizing robotics and AI (details are provided later in the sections on cost-cutting initiatives (1) and (2)). The sharing of large volumes of data can also contribute to cost reductions. However, it has been pointed out that there is a need to create a mechanism for the utilization of large volumes of data because the data is contained within each company. There is a movement to support private companies by creating a data platform for sharing research data and utilizing machine learning and AI (cost-cutting initiative (3)). Furthermore, efforts are underway to develop plant varieties suitable for CEA (quality improvement initiative).

3-1-1. Cost-cutting initiative (1): Optimization of operations

To optimize operations, efforts are being made to combine high-precision sensing technologies for plant ecology with AI. For example, the Japanese company PLANT DATA has developed technologies for visualizing plant ecological information, such as with real-time measurements of photosynthesis and measurements of chlorophyll fluorescence, which can indicate even slight degrees of stress on plants (Figure 2). By incorporating the growth information obtained with these technologies into the growth environment parameters, an improvement in yield can be expected. Furthermore, visualizing the photosynthesis of plants and monitoring the growth rate in this way will make it possible to apply fertilizer more efficiently and predict the harvest time with greater accuracy. Cost-cutting is being tackled with efforts toward optimizing operations such as these.

Figure 2: Real-time measurements of photosynthetic-transpiration activity



Schematic diagram | Setting for actual recording of measurements

Source: PLANT DATA website (https://www.plantdata.net/photosynthesis.html)

3-1-2. Cost-cutting initiative (2): Promotion of labor-saving measures

In the Autonomous Greenhouse Challenge jointly held by Wageningen University & Research (the Netherlands) and Tencent (China) from 2019 to 2020, teams competed to remotely cultivate cherry tomatoes in a greenhouse using AI. The results, compared to conventional cultivation by farmers, were excellent in terms of profitability and the amount of heat and electricity used in growing, demonstrating that automated cultivation by AI is promising and realistic. In addition to such automated cultivation using AI, advancements are being made in R&D for robots with the ability to assess the maturity of crops and harvest only those crops ready for picking. The combination of remote monitoring made possible by the use of AI and automation of work with the use of robots will make it possible to minimize human involvement.

3-1-3. Cost-cutting initiative (3): Data sharing

In CEA, data is collected daily. The sharing of such data makes it possible to more efficiently improve profits and productivity. In the US, the Controlled Environment Agriculture Open Data (CEAOD) project was established with the aim of facilitating data sharing to accelerate CEA research. CEAOD is working on developing tools for data standardization, sharing, and analysis to collect researcher best practices and make them easily available. Plenty Unlimited (US), one of the promising startups in the field of vertical farming, has also started to participate in this initiative by providing data. The data can be accessed free of charge by anyone through the CEAOD website.

3-1-4. Quality improvement initiative: Development of plant varieties suitable for CEA

Efforts have begun to develop plant varieties suitable for CEA with the application of genome editing and other technologies. For example, Bayer (Germany) established Unfold in the US to develop plant varieties adapted to vertical farming. The US genome editing startup Inari is also developing plant varieties for indoor agriculture. Furthermore, Kalera (US), a vertical farming company, acquired Vindara (US), a developer of seeds for indoor farming, for US$23.7 million.

3-2. Initiatives to ensure speedy distribution

With regard to distribution, the challenges include shortening the fresh food transportation time. Retailers are currently working with companies engaged in CEA on delivering fresh vegetables to consumers while they are still fresh. For example, Ocado Group (UK), which develops systems for online supermarkets, aims to supply customers with fresh produce within a few hours after harvesting by combining its logistics-related automation technologies, which are based on the company's AI and robotics expertise, with vertical farming facilities set up near distribution centers. To this end, in 2019, it purchased a 58% equity stake in Jones Food Company (UK), a vertical farming business. Ocado has also set up a joint venture with greenhouse automation company Priva (the Netherlands) and the vertical farming startup 80 Acres Farms (US).

Efforts are also being made to integrate production and sales by cultivating crops in retail stores that are situated even closer to consumers than distribution centers. For instance, Infarm (Germany) has introduced a small in-store production system for supplying fresh vegetables grown without the use of pesticides. The company's system is adopted in more than 30 cities and 10 countries. Data from the production system at each store is collected on the cloud and constantly updated with the latest cultivation recipes.

In addition, farmers are starting to make use of vacant properties in urban areas to achieve the shortest possible delivery time for shipments to consumers in urban areas. For example, Wilder Fields (US), a company engaged in vertical farming, began redeveloping a vacant Target store in 2020 for use in vertical farming. In August 2020, the Singaporean government announced plans to promote the conversion of surplus parking lots for use in building housing, restaurants, and indoor farms.

4. PROSPECTS: EXPANSION OF CEA

In the CEA domain, the development of robots, utilization of AI, and advancement of sensing technologies are about to transform agriculture from the conventional science that uses “tacit knowledge” into one that uses “explicit knowledge.” In addition, as the number of unused commercial properties increases, it is expected that utilization of those facilities will lead to an expansion in CEA operations in urban areas. Moreover, bearing in mind circular economy interests, it is important to incorporate technologies that facilitate waste circulation. For example, as production volume increases, the processing of waste will emerge as an issue, such as the root part of lettuce that is cut off and discarded in preparation for packaging. It will likely become necessary to design CEA to include the utilization of such organic waste and the recycling of rainwater. If the attractiveness of CEA can be advocated in terms of not only production and distribution improvements, but also by presenting the additional value of low environmental load, there is a possibility of new business opportunities opening up in urban agriculture.