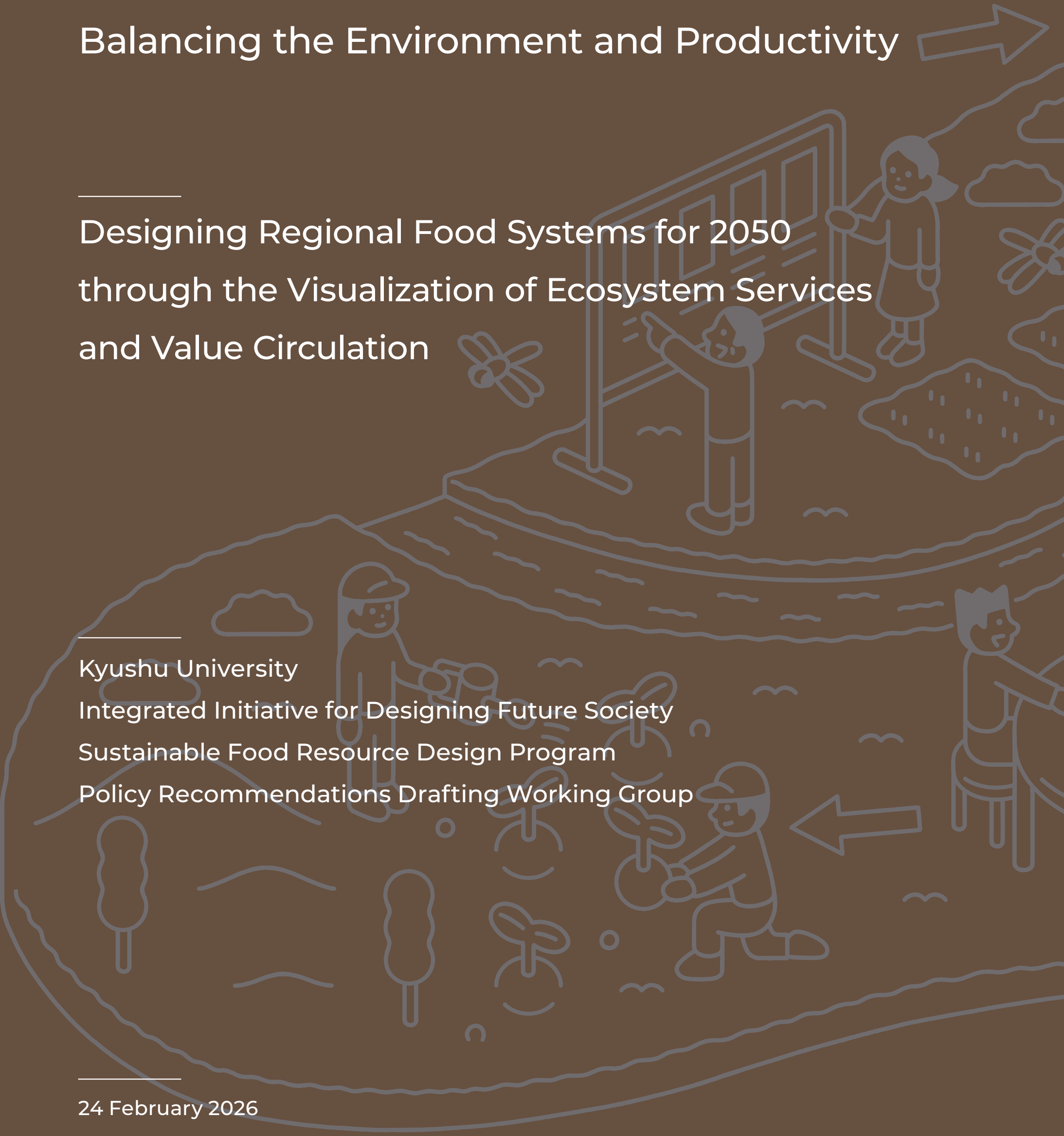
POLICY RECOMMENDATIONS

The ONE-Agri System:
Balancing the Environment and Productivity

Designing Regional Food Systems for 2050 through the Visualization of Ecosystem Services and Value Circulation



Kyushu University
Integrated Initiative for Designing Future Society
Sustainable Food Resource Design Program
Policy Recommendations Drafting Working Group

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Note to the reader:

This English version has been prepared as a text-only companion to the original Japanese edition, which includes figures and illustrations.
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SUMMARY OF THE RECOMMENDATIONS

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By 2050, global demand for food is projected to increase to about 1.3 times the 2020 level. At the same time, agriculture, forestry, and other land use account for roughly 22% of human-caused greenhouse gas emissions, meaning that reducing the environmental burden of food production is also an urgent challenge. To maintain sustainable food systems for future generations, we must promote ecosystem conservation and the efficient use of resources, and achieve both higher productivity and environmental conservation.

At Kyushu University's Integrated Initiative for Designing Future Society (In2FS), we have launched the Sustainable Food Resource Design Program, leveraging our research strengths in plant genetic resources, genome editing, fish reproductive engineering, insect science, and foodomics. Through activities such as discovering novel functional genes, developing new varieties, quantitatively evaluating biodiversity, and analyzing tastes and aromas, we aim to build sustainable supply systems for food resources with the Kyushu region as a core field. Based on discussions led primarily by members of this program, these recommendations propose two mechanisms necessary to realize sustainable food supply systems.

Future food production is expected to develop in three directions—large-scale production, decentralized production, and high-density production. A wide range of production models will coexist, each with different strengths and challenges. The concept proposed here to visualize causal relationships among environment, production, and consumption across these models, and to optimize them based on scientific evidence, is "ONE = Observable Natural–Economic Loop" (visualization of ecosystem services and value circulation). One mechanism proposed in these recommendations is the "ONE-Agri System," which links environment, production, and consumption through biodiversity assessment and food component analysis, and optimizes them through breeding, smart technologies, and resource circulation. We present this mechanism together with concrete scenarios for food production that make implementation possible.

The Kyushu region—where diverse climates, landscapes, and ecosystems coexist and agriculture, forestry, fisheries, and livestock industries are densely concentrated—is an ideal field for demonstration. It also offers strong potential in both research foundations and regional culture, as well as international collaboration. Implementing the ONE-Agri System requires not only technological development but also collaboration among universities, companies, and local governments—especially for human resource development and the formation of producing regions. These recommendations also propose a mechanism to circulate knowledge and technology by building a regional system with "dual cycles" of human resources and innovation, supported by a step-by-step ONE-Agri Talent Development Program that ranges from short-term training to long-term implementation.

These recommendations are intended for the general public, with a focus on companies, people engaged in food production, and government and municipal officials. We aim to implement the vision, concepts, and methodologies presented here in real-world settings through collaboration among universities, companies, and local governments, and to develop them further into new, regionally rooted food systems.

VISION: FOOD PRODUCTION SYSTEMS IN 2050

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1) Global challenges related to food production

Global food systems face serious sustainability challenges driven by intertwined factors such as population growth, climate change, and economic inequality.

By 2050, the world population is expected to reach 9.7 billion, and food demand is projected to rise to about 1.3 times the 2020 level. Meanwhile, agriculture, forestry, and other land use generate about 22% of human-caused greenhouse gas emissions, making it urgent to achieve both higher productivity and environmental conservation. In recent years, droughts, floods, and rising temperatures have destabilized yields of major crops. In regions that are especially vulnerable to climate change, the very foundation of production is weakening. At the same time, widening economic disparities are accelerating imbalances in supply and demand, and more than 700 million people worldwide continue to suffer from chronic malnutrition.

Even in developed countries, risks to food security are growing. While dependence on imports increases, aging producers and population decline are shrinking domestic production capacity, weakening supply. In countries with low self-sufficiency rates—such as Japan—international logistics disruptions and geopolitical risks can threaten stable food supply. In short, the world is being forced to address two challenges at once: ensuring enough food in quantity and ensuring sustainability.

To break through this impasse and secure stable food supply for future generations, it is essential to build new food systems that reconcile ecosystem conservation with efficient resource use. We need integrated approaches that combine multiple elements—technological innovation that achieves both productivity gains and environmental conservation, adaptive production models based on regional characteristics, and circular resource use and renewable energy. By optimizing the links among environment, production, and consumption based on scientific data, the most important task ahead is to establish sustainable food production foundations that support both local communities and the global environment.

2) Three directions that will support food production in 2050

Future food production is expected to develop in three directions in response to social change, environmental constraints, and technological innovation: large-scale production, decentralized production, and high-density production.

Large-scale production extends the path of industrialization. By using efficient mechanization and data-driven management, it increases output and supports stable food supply. With wide-area farmland management and smart agriculture technologies, it becomes possible to produce large volumes with fewer workers, underpinning society's food security.

Decentralized production, in contrast, builds flexible and diverse production systems rooted in local natural conditions, culture, and resource circulation. This direction strengthens resilience against environmental change and market fluctuations. Through small-scale operations that make use of regional resources and the coexistence of diverse producers, it aims to raise local self-reliance and sustainability while balancing environmental conservation and the economy.

High-density production is a new direction that produces food in urban spaces or controlled environments. Examples include plant factories, cultivated meat, and land-based aquaculture in urban areas. By using technologies that tightly control space and environmental conditions, production can be concentrated and stabilized, becoming less dependent on external factors.

These three directions are not competitors. They can function in complementary ways depending on diverse social conditions and values. Efficiency through mass production, sustainability through regional circulation, and stability through high-density production in urban space—each plays a different role, together supporting next-generation food systems. The key is not to set these directions against one another, but to link them in complementary ways while balancing society, environment, and technology. As these three vectors co-evolve and connect across regions and countries, they can achieve both productivity gains and environmental conservation and shape the future of sustainable food systems.

3) 3×3 model of food production

Major food production sectors—agriculture, fisheries, and livestock—will diversify along the three directions of large-scale, decentralized, and high-density production.

In large-scale production, industrial structures emphasizing efficiency and concentration will expand. In agriculture, this will include management of vast fields using autonomous tractors and drones, and yield prediction using AI. In fisheries, smart fisheries will become mainstream, including the sharing of wide-area operational data, optimization of fishing grounds, and data-driven management of large-scale aquaculture facilities with automated feeding and environmental control. In livestock, centralized production facilities will be equipped with sensing and automated control of rearing environments, and productivity will be maximized through integrated management including feed supply and health monitoring. This direction strengthens industrial foundations by aiming for both lower costs and stable supply.

In decentralized production, sustainable systems based on local resources and cooperative management will be crucial. In agriculture, diverse crops adapted to local soils and climates will expand, alongside cooperation through shared use of smart machinery and data. In fisheries, coastal communities will rebuild cooperative aquaculture and small-scale fisheries. In livestock, low-impact production will expand through grazing and regionally sourced circular feed. With ICT and sensor networks, regional co-creation models—where multiple small producers cooperate and share information and resources—will spread.

High-density production aims to maximize spatial efficiency and enable production even in cities and limited environments. In agriculture, plant factories and vertical farming will develop. In fisheries, recirculating aquaculture systems and aquaponics will expand. In livestock, cultivated meat and cellular agriculture are becoming realities. In all cases, precisely controlled environments—temperature, light, nutrients, and more—enable stable supply independent of seasons and location.

Although these three directions rely on different technological foundations, they can complement one another through integrated digital management and information circulation, becoming core pillars that support the diversity and sustainability of next-generation food production systems.

4) Benefits and risks of each production mode in the 3×3 model

To realize sustainable food production, achieving both higher productivity and environmental conservation is indispensable. However, the three directions—large-scale, decentralized, and high-density production—each have distinct benefits and challenges.

Large-scale production pursues efficiency and stable supply. By adopting smart agriculture and automation, it enables wide-area production with fewer workers. Data-based precision management reduces costs and increases yields, supporting stable national supply. At the same time, it requires large initial investments in land and facilities, and environmental burdens can become concentrated. To reconcile this direction with ecosystem conservation, new institutional design and environmental control technologies are needed. In addition, consolidation and exit of small and medium producers can weaken local communities, increasing the burden of maintaining production infrastructure.

Decentralized production builds diverse and flexible systems rooted in regional resources, even at small scale. Production grounded in local environment and culture increases adaptability to climate change and market shifts, and can revitalize local economies and communities. “Face-to-face” relationships and local production for local consumption can create high-value branding. However, economies of scale are harder to achieve, and the burden on individual producers can become heavy.

High-density production maximizes spatial efficiency and controllability. New technologies such as plant factories, recirculating aquaculture systems, and cultivated meat can provide stable food production less affected by external environments. This represents an innovative approach in that it enables production beyond climate and land constraints, including in cities and underutilized land. However, it may weaken the relationship with nature and raise new issues such as energy consumption and ethical concerns.

These three directions are not complete on their own. By functioning in complementary ways, they become the key to building sustainable supply systems while balancing productivity and environmental conservation. To leverage their strengths and overcome their challenges, both social and technological innovation are required.

CONCEPT: “VISUALIZATION” OF ECOSYSTEM SERVICES AND VALUE CIRCULATION

➢ pp.16–21

1) Challenges in achieving both higher productivity and environmental conservation

The 3×3 model of food production is expected to develop across agriculture, fisheries, and livestock by moving toward large-scale, decentralized, and high-density production. In this process, however, environmental impacts and benefits provided by ecosystems (ecosystem services) will differ greatly by model. One model may raise production efficiency while reducing dependence on natural resources; another may secure sustainability by coexisting with ecosystems. Such differences affect food characteristics—quality, flavor, and nutritional value—and should also feed back into the economy and policy through consumer evaluation and purchasing behavior, brand value, and the design of institutional support.

At present, however, the scientific basis for viewing environment, production, and consumption as an integrated whole remains insufficient. There are limited technologies to quantitatively measure diverse ecosystem functions as concrete environmental data. Mechanisms to comprehensively analyze food quality at the component level and directly link results to production conditions and environmental factors are also still developing. As a result, it is difficult to consistently visualize causal relationships—how environmental changes influence food quality and consumer behavior, and how consumption patterns feed back into production sites and ecosystems.

Moreover, information on environmental burdens, resource circulation, and flows of added value is fragmented across sectors and processes (agriculture, fisheries, livestock; production, distribution, consumption), and data formats and indicators are not standardized. Information sharing among government, companies, and research institutions is also partial, making it insufficient as a foundation for integrated management and policy decisions. This makes it hard to gain a strategic perspective on how to build complementary relationships across models and design an optimal food system as a whole. To achieve sustainable food production, we must scientifically visualize causal links connecting environment, production, and consumption, and build new evaluation and design frameworks based on these interconnections.

2) The ONE-Agri System: a framework to optimize the links between environment, production, and consumption

If we can scientifically visualize how the environment affects food quality in each production model, and how consumer behavior affects production and the environment, we can optimize the links among environment, production, and consumption based on data, and design concrete mechanisms that complement one another. For example, it is important to quantify causal relationships such as how ecosystem health is reflected in the taste, aroma, and nutritional components of crops, or how changes in consumer behavior influence energy use and resource circulation at production sites.

To achieve this, we must make observable the relationship between environment and production through biodiversity assessment and quantitatively grasp the value of ecosystem services for each region and production method. In addition, comprehensive analysis of food components can reveal chemical and sensory characteristics of foods, and by linking these to production conditions and environmental factors, it becomes possible to quantify the relationship between consumption and production/environment. By integrating these, a new framework can emerge for designing and managing environment, production, and consumption as one.

To optimize these relationships in practice, three elements are key: breeding, smart technologies, and resource circulation. Breeding can reconcile environmental adaptability with quality. Smart technologies enable data-driven production and distribution management. And circular systems that reuse by-products and waste as resources can minimize environmental burdens while maintaining both production efficiency and quality.

The concept that aims to scientifically "visualize" interactions among environment, production, and consumption and rebuild value flows in a circular manner is "ONE = Observable Natural–Economic Loop" (visualization of ecosystem services and value circulation). It is an attempt to reconnect the relationship between nature (Natural) and the economy (Economic) in an observable form. We call its implementation model the "ONE-Agri System." This system is conceived as a core mechanism for integrating environment, production, and consumption through data and technology and implementing sustainable food supply systems in society.

IMPLEMENTATION SCENARIOS FOR THE ONE-AGRI SYSTEM

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1) Visualizing environment and production: turning local biodiversity into product value

Using insects as indicators to operationalize ecosystem change and translate it into concrete actions needed for sustainable food production

By using environmentally sensitive insects as indicators to "visualize" ecosystem conditions, we can evaluate the environmental impacts of food production, set biodiversity target values for each production area, and connect measured gaps to concrete actions to close them. At the same time, we can assess how local biodiversity nurtures product quality and connect this to the creation of new value.

(Role within the ONE-Agri System)

Biodiversity loss—an essential foundation for sustainable food production—is becoming increasingly serious. Ecosystem functions supported by soil microorganisms, insects, aquatic organisms, and others are indispensable for maintaining productivity and stabilizing quality, yet climate change and land-use change are disrupting this balance. However, the relationship between biodiversity and food production is multi-layered and region-dependent. Due to complex interactions and a lack of observational data, it remains difficult to quantify the risks brought by biodiversity loss and the value created by ecosystems. As a result, it is hard to design effective countermeasures based on scientific evidence, and social mechanisms that achieve both higher productivity and environmental conservation are not yet sufficiently in place.

To overcome this, it is important to build mechanisms that reflect environmental impacts in product evaluation and market value. By visualizing product quality and brand value in connection with underlying ecosystem health, efforts to conserve biodiversity can be positioned in society as economic value. In other words, rather than separating environment and economy, we need to rebuild the circular relationship in which healthy environments produce high-quality products—and transform conservation actions themselves into a driving force for sustainable food supply systems.

(Roadmap)

To support sustainable food production, a mechanism is essential to correctly understand risks from biodiversity loss and connect them to effective countermeasures.

In the introduction phase, we incorporate the perspectives of local residents and producers, set biodiversity target values at the production-area level, and quantitatively evaluate ecosystem changes by selecting indicator insects and using automated monitoring with AI image recognition.

In the implementation phase, we standardize certification systems and labels based on evaluation results and expand mechanisms that consumers can use in their choices. This links biodiversity conservation efforts at production sites with market value and encourages continuous improvement.

In the expansion phase, we promote product development and regional branding rooted in biodiversity, communicating the "story" of how environmental factors create taste and quality, thereby increasing the value of regional resources. At the same time, by reflecting environmental impacts in product evaluation, we strengthen incentives for biodiversity conservation and establish pathways to reconcile food and the environment.

2) Visualizing production and consumption: quality assessment and branding through comprehensive component analysis

Making tastes and aromas visible through compositional analysis and AI, leveraging local natural environments to create scientifically validated branded products.

By combining laser desorption/ionization mass spectrometry (LDI-MS) a method that can image a wide range of hydrophilic and hydrophobic components at once with minimal sample preparation, with AI-based sensory prediction models, we can digitally visualize and quantify tastes and aromas and efficiently shape product strengths. In addition, high-precision quality control using these analytical technologies can deliver stable, high-quality products to consumers.

(Role within the ONE-Agri System)

As interest grows in food safety, health, and preferences such as taste and aroma, the importance of understanding food quality objectively and scientifically is increasing. However, conventional analytical techniques have struggled to measure food components comprehensively and rapidly, and available data has been limited. This has made it difficult to visualize the unique flavors and functional characteristics created by regional natural environments, and to connect them to higher added value and branding.

In response, new approaches are gaining attention that comprehensively analyze food components at the molecular level and scientifically capture sensory information and functional characteristics such as taste, aroma, and nutrition. These approaches can provide scientific support for characteristics nurtured by local climate, soil, water quality, and ecosystems, and clarify differences that were previously invisible through subjective evaluation alone. This enables the creation of brand value based on regional uniqueness and supports distribution and sales strategies grounded in objective quality data, strengthening competitiveness in export markets.

(Roadmap)

To respond to rising societal interest in food safety, health, and preferences, it is necessary to create value for regional products based on objective and detailed quality understanding.

In the introduction phase, we establish technologies that scientifically support freshness and the structure of tastes and aromas by combining component imaging through LDI-MS with AI-based sensory prediction models.

In the implementation phase, we use this approach to upgrade quality control, enabling optimized control of “best eating time” and distribution-stage management.

In the expansion phase, we scientifically visualize how production methods—such as environmentally friendly agriculture based on local characteristics—affect agricultural products and other goods, and establish distinctive flavors and strengths as brand value. Through these efforts, regional products can reliably deliver quality to consumers while being communicated domestically and internationally as differentiated brands.

3) A locally driven aquaculture ecosystem that protects marine genetic resources

Achieving both sustainability in fisheries and aquaculture and the development of regionally branded strains through collaboration and circulation between capture fisheries and aquaculture

By regularly introducing diverse wild populations secured through coastal fisheries as breeding resources, we can maintain genetic diversity in seafood while developing unique strains tailored to diverse consumer needs from each region’s genetic resources. At the same time, by “visualizing” environmental factors and harmful organisms that damage aquaculture—such as red tides and fish diseases—through sensors and AI analysis, we can make risks more predictable and preserve rich natural environments.

(Role within the ONE-Agri System)

Global demand for seafood continues to grow, and aquaculture is rapidly expanding as a pillar of food supply. At the same time, repeated breeding from a limited number of broodstock can reduce genetic diversity, increasing the risk of a “genetic bottleneck.” This may lower disease resistance and reduce adaptability to environmental change, potentially causing serious impacts on sustainable aquaculture operations. To address this, we must rebuild production and distribution systems based on harmony with the environment while ensuring diversity in genetic resources.

In parallel, we can scientifically analyze taste and nutritional structure through component analysis technologies and visualize these characteristics. This provides evidence for taste and quality improvements achieved through producer ingenuity—feed materials and composition, rearing methods, and more—allowing these efforts to be established as brand value. We can then institutionally embed resource management and environmental conservation, and build sustainable production cycles through collaboration among fishers, companies, and research institutions. Through this circulation, we can achieve both revitalization of coastal fisheries and stable seed/juvenile supply, maintaining healthy marine ecosystems supported by genetic diversity while improving sustainability and competitiveness across the fisheries sector.

(Roadmap)

By developing and introducing aquaculture technologies that utilize regional fisheries and breeding resources, we establish mechanisms that reconcile conservation of marine environments with the productivity of edible seafood.

In the introduction phase, we establish full-cycle aquaculture for high-productivity fish and develop foundational strains with tolerance to high temperatures and diseases using advanced breeding technologies. Where appropriate, genome editing and stem cell technologies are also used. In parallel, we develop growth systems and feed suited to production environments.

In the implementation phase, we use wild fish populations secured in coastal fisheries as a decentralized “gene bank” and build a circular supply model. This enables regular introduction of genetic resources while developing unique strains derived from each region. We also institutionalize resource management and environmental conservation to secure stable seed/juvenile supply.

In the expansion phase, we promote brand-oriented breeding rooted in regional resources, responding to diverse consumer needs while also enabling bred fish to become bearers of new food cultures. This ecosystem supports both revitalization of coastal fisheries and stable seed/juvenile supply, enhancing marine richness supported by genetic diversity and improving the sustainability of the fisheries industry.

4) Breeding and seed development that is resilient to climate change and responsive to global demand

Developing environment-adaptive varieties using geographical diversity, and nurturing domestic seed industries

Using genetic resources accumulated in regions, along with advances in genome editing and seed science, we develop environment-adapted varieties—such as high-temperature-tolerant strains—as well as local specialty products characterized by unique quality. By fostering domestic seed industries, we strengthen food security and aim to build future export industries.

(Role within the ONE-Agri System)

Advances in genome editing have made it possible to develop varieties with targeted traits in a short time, dramatically improving efficiency in agriculture and fisheries.

At the same time, climate change is destabilizing seed and seedling production: abnormal weather and rising water temperatures are seriously affecting growth and reproduction. In Japan, many seeds and seedlings are also imported, and growing geopolitical and logistics risks have highlighted the danger of supply disruptions. These issues demand urgent responses from the perspective of food security.

To overcome them, developing seeds and seedlings that can be produced stably under diverse environmental conditions, and promoting domestic production, are key. By using advanced technologies such as genome editing to develop varieties with improved environmental tolerance and nutritional value, we can create high-value domestic varieties adapted to local climates and soils. Building domestic supply systems also supports expansion into export industries and increases regional economic independence. Establishing new seed industries that maintain a balance between production and ecosystems while protecting local natural environments will become a foundation of sustainable food supply systems.

(Roadmap)

We aim to overcome climate-driven instability in seed/seedling production and security risks associated with import dependence, while building internationally competitive seed industries.

In the introduction phase, based on accumulated genetic resources and knowledge in seed science, we develop environment-adaptive and high-stress-tolerant varieties such as high-temperature-tolerant strains, and promote the use of idle farmland and smart technologies.

In the implementation phase, we establish long-term storage and transportation enabled by post-harvest innovations, and incorporate domestic seed production into agricultural standards to distribute risks associated with scaling up and secure stable supply. We also form inter-regional networks to increase the reliability of seed and seedling supply.

In the expansion phase, we promote export industrialization based on high-quality domestic seeds and seedlings, expand into international markets, and achieve branding of high-value varieties suited to local characteristics. In this way, we pursue both domestic production and export industrialization, achieving food security and economic development at the same time.

CHALLENGES AND NECESSARY ACTIONS TOWARD REALIZATION

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1) The role and potential of the Kyushu region as an implementation field

Kyushu is a region where especially diverse natural environments and food production forms coexist within Japan. Its geographic and ecological characteristics make it an ideal field for demonstrating and expanding the 3×3 model of food production. With climate zones ranging from warm and humid southern areas to cool highlands, and complex landscapes of plains, mountains, coasts, and islands, a wide variety of production systems—rice, field crops, fruit, livestock, and fisheries—are densely developed. This diversity means the Kyushu region has the conditions to compare, complement, and empirically test the three directions of large-scale, decentralized, and high-density production across agriculture, fisheries, and livestock within a single region. For example, large-scale livestock production in Kagoshima and Miyazaki, pasture-based production using the grassland ecosystem of Aso, and high-density plant factories and recirculating aquaculture developing near urban areas in Saga and Oita all coexist in reality. This creates an environment where their interactions can be observed and analyzed across the region.

The Kyushu region also already has cultural and economic foundations needed for the social implementation of the ONE-Agri System, including strong track records in branding that makes use of rich ecosystem services and unique local food cultures. Across the region there are many examples where natural environments are closely linked to food quality and regional brand value—such as livestock products connected to the grassland landscape of Aso, shiitake mushroom production that uses Oita's forests and climate, and sustainable fisheries in Amakusa and Nagasaki. By systematizing these existing efforts through data and technology, diverse regional production models can be connected in complementary ways.

Another major strength is the concentration of research institutions, including Kyushu University, and the capacity to develop biodiversity assessment, comprehensive food component analysis, breeding technologies, and smart resource circulation in an integrated manner. These scientific foundations can function as core technologies of the ONE-Agri System connecting environment, production, and consumption. In addition, the Kyushu region is geographically close to Asia and has extensive records of collaboration with ASEAN countries in agriculture and fisheries. This makes it possible to deploy knowledge gained through regional demonstrations to Asian countries and develop the Kyushu region as a hub for international collaboration.

2) A key challenge for implementation: the need for a mechanism that connects on-the-ground problem solving with innovation

To embed the ONE-Agri System in real regions and industries and develop it as a concrete set of scenarios, it is essential to advance social and human foundations in parallel with technological development. First, we must realize step-by-step innovations that connect environment, production, and consumption at each stage—from breeding and seed production, to production, distribution, processing, and quality management. Examples include developing varieties that are resilient to environmental change and stable in quality, data-driven smart production, processing and logistics designed for resource circulation, and quality evaluation systems that visualize environmental value. It is important not to stop at simply introducing technologies, but to integrate them with local production structures and distribution systems so that they take root as sustainable industrial systems.

At the same time, we need a perspective that advances on-the-ground problem solving and new industry formation together. Many production sites face urgent issues such as shortages of workers and successors, damage from wildlife and climate disasters, aging facilities, and delays in infrastructure development. These are not merely problems of labor or funding; they are tied to broader declines in regional social function and become major constraints on innovation. Therefore, alongside R&D and institutional design, we must rebuild local production foundations and create systems for human resource supply and education through cooperation inside and outside each region.

Furthermore, to continuously evolve the ONE-Agri System, collaboration among diverse stakeholders is indispensable. Producers, researchers, companies, government, consumers, and others must respect each other's experiences, knowledge, and values, and build relationships for mutual learning under a shared vision. Through this process, we can reorganize relationships among environment, people, and technology, and create new forms of industry and value creation while maintaining continuity with regional culture and past industrial accumulation. In other words, the core of the ONE-Agri System is a process of social implementation that builds regional foundations supporting circulation between environment and economy and evolves through both technology and human resources.

3) A regional innovation system built on a cycle between academia and practice

To implement the ONE-Agri System, we need not only technologies and institutions, but also mechanisms that create cycles of people and organizations that carry them. These recommendations propose a "dual cycle" structure: a talent circulation cycle and an innovation cycle.

The talent circulation cycle is a mechanism in which universities serve as knowledge hubs that send diverse people—students, researchers, and working professionals with interest in food production—into regions and production sites, helping them understand real challenges and acquire practical skills. While universities provide knowledge, they also incorporate feedback from the field into education and research, forming a learning ecosystem that moves back and forth between theory and practice. This mechanism is not limited to training new entrants; it also includes recurrent (continuing) education for existing human resources in companies, government, and local production. By linking experience-based knowledge cultivated in the field with advanced knowledge held by universities, it updates regional production activities as a whole and creates a circular model of human resource development.

The innovation cycle, meanwhile, is a mechanism in which universities (research organizations), government, and companies work closely together to progress step-by-step from solving urgent issues to forming new industries and production regions. For example, starting from field issues such as labor shortages or environmental burdens, efforts can develop continuously into R&D, technology implementation, institutional design, and business expansion. This prevents individual research outcomes or regional projects from ending as isolated efforts and makes the pathway to social implementation visible. By building complementary roles—universities providing “seeds,” companies refining technologies, and government offering institutional support—we can promote a chain of innovation across entire regions.

These two cycles complement one another: new knowledge and trust relationships created through the talent circulation cycle become the foundation for the innovation cycle. By creating an environment where knowledge and technology move between the field and research under a shared vision, this dual-cycle system can become a practical engine that supports the formation of sustainable food systems that can expand from regions to the world.

4) ONE-Agri Talent Development Program to drive regional innovation

Central to the talent circulation concept is a structured training program that enables diverse participants—students, researchers, and professionals—to engage progressively in production sites and develop through integrated learning and practice. This program treats food production not merely as an industry but as an interdisciplinary field where environment, society, and technology intersect. It sets six learning stages, ranging from short 1–3 day training programs to implementation and verification phases lasting one year or more. Each stage includes on-site practice, allowing participants to deepen expertise while gaining real-world understanding. Short programs provide introductory experiences for people interested in agriculture, fisheries, and related fields, functioning as entry points for new participation and career shifts. Medium- and long-term programs, in contrast, conduct research, demonstrations, and prototyping starting from real field issues, and develop next-generation leaders and practitioners through problem-solving projects. This establishes a new model of talent development in which people from different specialties collaborate while generating knowledge on site and advancing social implementation in parallel.

The program also serves as recurrent (continuing) education for existing producers, companies, and government staff. People with field experience can connect with cutting-edge knowledge and technologies at universities to redefine challenges and develop new solutions, forming a cycle of learning and innovation. Through such a back-and-forth learning environment, knowledge and technology circulate across regions, companies, government, and universities, nurturing a practical co-creation ecosystem.

In addition, shared visions and trust relationships created through the talent circulation cycle connect to step-by-step innovation cycles driven by collaboration among universities, government, and companies. This enables the creation of sustainable mechanisms that go beyond short-term problem solving and support new industries and the formation of new production regions using regional resources.

RESEARCH STRUCTURE AND CASE STUDIES

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1) Sustainable Food Resource Design Program

(related to Implementation Scenarios 1), 2), 3), and 4) of the ONE-Agri System)

Within the Environment and Food Unit of Kyushu University’s Integrated Initiative for Designing Future Society (In2FS), we are developing the Sustainable Food Resource Design Program, which integrates foundational research and social implementation to achieve both higher productivity and environmental conservation. This program brings together Kyushu University’s strengths—one of the world’s leading archives of plant genetic resources, highly efficient genome editing technologies, fish reproductive engineering, insect science, and foodomics—to build new science-and-technology systems that can stably supply high-quality food while adapting to environmental change. These foundational studies are key to increasing the sustainability of production while conserving ecosystem services.

For example, the plant genetic resource archive analyzes diverse genetic resources collected worldwide and supports the development of varieties that are resilient to climate change and diseases. Breeding using genome editing enables improvements that are difficult through conventional crossbreeding, accelerating enhanced functionality and added value in crops and marine resources. In fisheries, we are developing mechanisms that raise production efficiency while preventing resource depletion, including establishing full-cycle aquaculture technologies for marine fish and creating new strains. Research is also advancing on quantitative biodiversity assessment using environmentally sensitive insects as indicators, aiming to measure ecosystem health and visualize sustainable production conditions for each region. In addition, research is underway to chemically analyze sensory information such as tastes and aromas, providing insights that scientifically explain sensory value and contribute to consumer preferences and regional brand value.

These research activities are being developed in an integrated way using the Kyushu region—where diverse production forms coexist—as a model region, with strong emphasis on returning outcomes to real production sites through field demonstrations that leverage regional characteristics. Overall, this initiative connects advanced academic research to social implementation and seeks new balances among environment, production, and consumption.

2) Insect Science and Creative Entomology Center (ISCEC)

(related to Implementation Scenario 1) of the ONE-Agri System)

At the Insect Science and Creative Entomology Center (ISCEC), an affiliated center of the Faculty of Agriculture at Kyushu University, we promote research that addresses "environment, health, and food" in an integrated way through insects, aiming to build a sustainable society where people and nature can coexist without strain. Focusing on the high environmental sensitivity and diversity of insects, we are building scientific foundations to visualize and quantify environmental change, and advancing social implementation to translate results into industry and institutions.

In the "Insect Science Co-Creation Hub," a research project selected under JST's COI-NEXT (Co-Creation Field Formation Support Program, Incubation Type), we have developed a new framework that uses insects as "indicators (Insect Sensors) that measure and interpret environmental change," with the goal of overcoming trade-offs between food production and infection control on one hand, and biodiversity conservation on the other. Insects are the most diverse and abundant animal group on Earth, and are extremely useful models for detecting early signs of environmental change. Kyushu University houses about 4 million insect specimens and has a community of about 40 researchers, serving as one of Japan's leading bases for insect science. Under an industry–academia–government co-creation structure, Kyushu University Open Innovation Platform Co., Ltd. (Kyudai OIP) participates from industry, and Fukuoka Prefecture participates from government. As a shared backcasting goal, the project advocates "One Health" (integrated protection of the health of humans, animals, and the environment). With an eye to establishing technologies for quantitative biodiversity assessment using insects and expanding into social systems such as biodiversity credits, we aim to create new social systems grounded in natural capital.

We also actively pursue industrial applications of insects. Activities include joint research with the Kyushu University startup KAICO Ltd., as well as business creation that reconciles environmental considerations with economic rationality—such as edible insects, sanitary pest control, insect-derived fertilizers, and functional feed. In Kama City, we are demonstrating a circular model that uses underutilized bamboo forests and spent mushroom substrate to raise rhinoceros beetles, and returns insect frass as liquid fertilizer to local agriculture. Research is also progressing on using vitamin D–accumulating rhinoceros beetles as feed for chickens and fish, opening new possibilities for bioresource use, including fishmeal replacement and carbon credit utilization.

Through these efforts, we aim to detect risks arising from environmental change early and promote evidence-based decision-making and behavioral change, establishing a sustainable social model that achieves "human happiness and richness (diverse well-being)" without damaging biodiversity and the global environment.

3) Food Science Research Group, Environment and Food Unit, In2FS

(related to Implementation Scenario 2) of the ONE-Agri System)

The Food Science Research Group within the Environment and Food Unit of Kyushu University's In2FS promotes research aimed at creating next-generation food science through comprehensive analysis of food components based on mass spectrometry and their digitalization. In recent years, low-molecular-weight metabolites, peptides, lipids, aroma and taste compounds in food have become recognized as key elements supporting safety, deliciousness, and health-related functions. Establishing "foodomics" (comprehensive analysis of food components) is increasingly important.

This group has developed GRAMS (graphite sheet-assisted laser desorption/ionization mass spectrometry), an original analytical technology that minimizes sample preparation and enables rapid, simultaneous detection of compounds from hydrophilic to hydrophobic. This method achieves both comprehensiveness and speed that were difficult with conventional approaches. It allows compound information and abundance of food components to be comprehensively digitized, and is expected to contribute to new forms of food quality evaluation, flavor design, and advanced functional evaluation.

In addition, these advanced analytical technologies are being applied to metabolics analysis of biological samples. By comprehensively analyzing metabolite profiles in non-invasive samples such as urine, the group is also working on new diagnostic technologies for diseases including cancer. As an analytical foundation supporting both food science and medical science, we aim to integrate food and health at a fundamental level and promote R&D that will lead future food science.

4) Aqua-Bioresource Innovation Center (ABRIC)

(related to Implementation Scenario 3) of the ONE-Agri System)

Over the past 50 years, global per-capita seafood consumption has roughly doubled, and total consumption has increased about fourfold, with aquaculture expansion particularly notable. Fish efficiently convert feed into animal protein, making them highly valuable for food security. The Food and Agriculture Organization of the United Nations (FAO) also advocates “Blue Transformation,” calling for the promotion of sustainable aquaculture, effective fisheries management, and the development of aquatic food value chains.

Based on this global trend, the Aqua-Bioresource Innovation Center (ABRIC), an affiliated center of the Faculty of Agriculture at Kyushu University, conducts education and research to create new aquaculture industries covering everything from basic research and technology development to social implementation and distribution. Our goal is to contribute to the development of regional and national fisheries and to protein supply security. Faculty members from within and outside the university, including the Faculty of Agriculture, participate across disciplines, and ABRIC Karatsu Satellite in Karatsu City, Saga Prefecture, has been established as a facility for advanced aquaculture research.

At the Karatsu Satellite, working with local fisheries cooperatives and producers, we have commercialized “Karatsu Q Saba,” a fully farmed chub mackerel. It is valued as a high-quality branded fish with no risk of Anisakis parasites and consistently high fat content year-round. We are also advancing selective breeding for high growth and high-temperature tolerance based on genomic information, reproductive control using novel hormones, and the development of aquaculture systems such as sea-based and land-based aquaculture and aquaponics using ICT and AI in collaboration with private companies.

We also focus on feed challenges. In collaboration with ISCEC, Miyazaki University, and others, we have successfully reduced the ratio of fishmeal—currently about half of aquaculture feed—by substituting insect-derived components (such as silkworms) and plant-based ingredients. In addition, through industry–academia–government collaboration with research institutions and regions in Japan and overseas, we are promoting R&D on production systems for invertebrates such as sea urchins, sea cucumbers, and shellfish; countermeasures for red tides and fish diseases; evaluation of safety and functionality of seafood products; and building robust traceability. We are also working to commercialize strain management technologies using fish germline stem cells, and are preparing for the establishment of a startup.

Furthermore, in coordination with the Kyushu University Institute for Asian and Oceanian Studies (Q-AOS), we promote international collaboration with countries such as India, Vietnam, Bangladesh, and the Philippines, as well as international research institutions, jointly working on fisheries research and technology development. We also accept trainees from overseas, strengthening our role as a hub for Asian fisheries collaboration.

Through these efforts, we aim to transmit next-generation, sustainable, circular fisheries models from the Kyushu region to the world.

5) Crop Science Laboratory

(related to Implementation Scenario 4) of the ONE-Agri System)

The Crop Science Laboratory in the Faculty of Agriculture at Kyushu University is working to realize “Green Revolution 2.0” to support next-generation agricultural production, grounded in crop science and plant physiology. Major research targets include key staple crops such as rice, wheat, soybeans, and cowpea (a major legume crop in Africa). We analyze at the molecular level how external factors such as temperature, water stress, and atmospheric environments affect plant physiology and growth.

In a new goal proposal for Moonshot R&D Program promoted by JST, titled “Investigative Research Toward Realizing Green Revolution 2.0,” we propose technologies that detect plant conditions in real time and present optimal cultivation conditions. The idea is to embed sensors inside plants to measure temperature, pH, and metabolites, analyze “plant speaking,” and automate “plant recipe,” where AI adjusts environmental conditions. For plant speaking, we are developing a real-time physiological analysis system using internal plant sensors in joint research with Osaka University, and have succeeded in visualizing changes in internal temperature and pH using prototype needle-like devices.

In addition, under JST-Mirai Program, we are advancing technologies for “environmental memory” in seeds. Recognizing that Japan previously lacked research hubs focused on the functions of seeds themselves, we aim not merely to provide resources, but to develop technologies that allow seeds to store environmental memory, improve stress tolerance, and reflect environmental adaptability design into breeding to maximize growth potential.

For plant recipe, we are also researching how to apply DDS (drug delivery system) technologies—used in medical fields—to agriculture. We have demonstrated reductions of about 30% in fertilizer use and about 50% in pesticide use. This technology is expected to become a core technology for the planned agritech startup “SACMOTs Co., Ltd.” Furthermore, under Grant-in-Aid for Transformative Research Areas (A), we are conducting joint research with the Faculty of Engineering to apply plasma technologies to agriculture. Plasma can convert nitrogen (N2) in the air into nitrate (NO3^{-}), which can be used as fertilizer, and is also expected to enable growth promotion and disease suppression without pesticides.

Looking ahead, we aim to integrate these technologies into an AI-controlled automated cultivation platform. By bridging research and industry, we are transmitting from the Kyushu region a new crop production paradigm suited to an era of environmental change.

ABOUT THE INTEGRATED INITIATIVE FOR DESIGNING FUTURE SOCIETY (In2FS)

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In “Kyushu University VISION 2030,” Kyushu University sets forth its goal of becoming “a university that drives social transformation through comprehensive knowledge.” To realize this goal, the university declares its commitment to solving social challenges and promoting DX (Digital Transformation).

As a comprehensive university, Kyushu University spans a wide range of disciplines, from the natural sciences to the humanities and social sciences. It also uniquely includes the field of design in the form of the Faculty of Design—an academic domain that designs and proposes new systems for society—making it the only comprehensive university in Japan with such a field. Leveraging this distinctive foundation of people, systems, and campuses that create new social value not found at other universities, Kyushu University established the “Integrated Initiative for Designing Future Society (In2FS)” in April 2022. The goal is to generate integrative knowledge needed to solve social challenges and contribute to transforming society for the better.

By bringing together knowledge across Kyushu University’s diverse research domains—including the natural sciences, humanities and social sciences, and design—we will focus on social challenges in “decarbonization,” “medicine and health,” and “environment and food.” We will design both “the ideal future society” and “the process to reach that future society” necessary to solve these challenges, and then combine Kyushu University’s research outcomes and deploy and implement them in society. In this way, we aim to address increasingly diverse and complex social challenges.

In addition, based on the framework of Japan’s “Designated National University Corporation” initiative, the In2FS will identify social challenges, compile measures that contribute to solutions, and publish five or more items as policy recommendations during Kyushu University’s fourth medium-term objectives period. These recommendations are the second in that series. With the goal of realizing sustainable food supply systems, we design innovation processes that connect relevant research elements held by Kyushu University and communicate and share them with society.

For details on the Integrated Initiative for Designing Future Society (In2FS), please refer to the following URL:
https://in2fs.kyushu-u.ac.jp/

COLOPHON

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POLICY RECOMMENDATIONS

The ONE-Agri System: Balancing the Environment and Productivity

Designing Regional Food Systems for 2050 through the Visualization of Ecosystem Services and Value Circulation

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Kyushu University
Integrated Initiative for Designing Future Society

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