Basic Plan for Agriculture, Forestry and Fisheries Research

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The Agriculture, Forestry and Fisheries Research Council

The Ministry of Agriculture, Forestry and Fisheries, Japan

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Chapter 2　Key Targets of Agriculture, Forestry and Fisheries Research

1. Research and Development for Promptly Solving Problems Faced by Producers with the Aim of Increasing Income in Agriculture, Forestry, Fisheries and Rural Communities

Basic Concept

【Background to formulating the New Basic Plan】

Today, international food supply and demand have become increasingly instable due to the increase in global population, climate change and other factors. As manifested by price increases for some food items using imported cereals and other imported ingredients, the situation has never been more urgent.

Agriculture, forestry and fisheries have played a variety of roles by supporting regional economies as key industries and contributing to the maintenance of communities, succession of traditional cultures, recharge of water sources, formation of beautiful landscapes and conservation of national land. They have also played the basic role in reliably supplying high-quality food to consumers by improving the self-sufficiency rates of agricultural, forestry and fishery products and more efficiently using our farmland.

However, the weakening of the production base due to an aging population and the declining number of workers in agriculture, forestry and fisheries has led to a significant shortage of successors. Therefore, it is urgent that the industries fully exert their roles and functions, including the role of consistently supplying safe and reliable products to consumers into the future.

In response, the Plan to Create Dynamism through Agriculture, Forestry, and Fisheries and Local Communities (the Headquarters on Creating Dynamism through Agriculture, Forestry, Fisheries and Local Communities)[1] was published in December 2013. Aiming to double agricultural and rural incomes in the next 10 years, it restructures policies by focusing on the following four pillars: (1) An expansion of domestic and international demands; (2) Establishment of the value chain from farmers to consumers for adding values to products; (3) Strengthening the production sites through cost-cutting by farmland intensification and other measures; and (4) Maintenance and exertion of the multifaceted functions of rural areas, thereby creating strong aggressive agriculture, forestry and fisheries as well as beautiful and lively rural areas.

Under the previous Basic Plan, a range of research findings supporting its realization, including the following results, were obtained:

(1) Research findings that would create new demands for domestic agricultural, forestry and fishery products, including the successful breeding of *Yumechikara* (a wheat variety used for

[1] The Plan to Create Dynamism through Agriculture, Forestry, and Fisheries and Local Communities: http://www.kantei.go.jp/jp/singi/nousui/pdf/plan-honbun-kaitei.pdf

making bread and Chinese noodles), a feat considered impossible in Japan; the development of cross-laminated timber (CLT) manufacturing technologies for use in the walls and flooring of mid-to-high-rise wooden buildings; and the development of technologies for preventing red tide damage to yellowtails, the export of which is expected to grow.

(2) Research findings that add value to domestic agricultural, forestry and fishery products and contribute to the establishment of the value chain from farmers to consumers by adding strengths to said products. These include the discovery of functional health substances such as β-cryptoxanthin (found in *Citrus unshiu*) and identification of lactic acid bacteria with senescence-retarding activity.

(3) Research findings contributing to strengthening production sites, such as breeding high temperature-tolerant, global warming-adaptable rice variety (e.g., *Tsuyahime*) and feed rice varieties adaptable to local climate; the development of power assisting suits for agricultural work, greatly decreasing the labor load of principal farmers (*Ninaite*), particularly female farmers; the abolition of methyl bromide (a soil disinfectant abolished in 2012 as an ozone-depleting substance); fumigation through successfully breeding plant pest-resistant stocks for vegetables; and developing a quick-testing method for evaluating highly pathogenic avian influenza in four hours (previously requiring over 24 hours).

For agriculture, forestry and fisheries to transform into more attractive industries through an increase in workers' income and other improvements, we need to actively implement research and development tailored to the industries' needs. We should consider the production and distribution circumstances and policy issues for individual agricultural, forestry and fishery products as well as accelerate our efforts for swiftly transferring research findings to industries.

The Comprehensive Strategy on Science, Technology and Innovation 2014[2] decided on by the Cabinet in June 2014 emphasized the importance of creating science, technology and innovation as the driving force for ensuring the economic revitalization of Japan and as a breakthrough for future sustainable development. It is also important for agricultural, forestry and fisheries research to actively pursue innovations in agriculture, forestry, fishery and food sectors in line with such government policies on science and technology.

Additionally, the promotion of locally oriented agricultural, forestry and fishery research will create new industries and employment as well as revitalize and advance agricultural, forestry and fishery industries and rural areas/communities, thereby contributing to a current key government policy:

[2] The Comprehensive Strategy on Science, Technology and Innovation 2014: http://www8.cao.go.jp/cstp/sogosenryaku/2014/honbun2014.pdf

"Overcoming Population Decline and Vitalizing Local Economy."[3]

【Concepts of formulating the New Basic Plan】

Against this background, by clarifying policies and tools supporting the promotion of agriculture, forestry and fishery research, the New Basic Plan will focus on the following items:

(1) By setting "research and development for promptly solving problems faced by producers" as a priority theme with specific research and development targets for individual fields and items in agriculture, forestry, fishery and food sectors, and aiming to promote research and development directly linked to the needs of industries and accelerating technological development and extension closely linked to the points of production, efforts will be made to enhance the functions of regional agricultural research centers. For example, the National Agriculture and Food Research Organization (NARO) Hokkaido Agricultural Research Center (hereafter, regional agricultural research centers) is under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries. Additionally, locally oriented agricultural research in collaboration with extension systems and the producers will be promoted.

(2) With the rapid advancement of information and communication technology (ICT) and robot technology, which create potential innovations in agriculture, forestry and food industries, innovative technology seeds will be created by actively adopting knowledge and technologies from other fields. A new system of industry-academia-government collaborative research will also be established where such technology seeds are connected to the value chain from farmers to consumers.

By systematically using the knowledge, information and technologies obtained, we aim to create strong, aggressive agriculture, forestry and fisheries. From there, industries can transform into more advanced knowledge and information industries, and into those attractive to young people and which provide hope to their workers.

We believe that agriculture, forestry and fisheries industries that attract hopeful and motivated young people can stably supply safe and reliable agricultural, forestry and fishery products to consumers into the future while meeting the diverse needs of consumers.

To address issues from medium- to long-term viewpoints, such as changes in consumption trends caused by global warming and an aging society with declining birth rates, depletion of resources

[3] The Headquarters for "Overcoming Population Decline and Vitalizing Local Economy": http://www.kantei.go.jp/jp/headline/chihou_sousei/

and energies, and the spread of transboundary infectious diseases, knowledge is gathered from industries, academia and government. Necessary research and development are implemented under a certain strategy systematically by setting the following six basic directions of agricultural, forestry and fisheries research:

- Stably supplying safe and reliable food, thereby contributing to the health and longevity of people.
- Innovating a production and distribution system in agriculture, forestry and fisheries, thereby drastically cutting costs.
- Creating new industries and employment in rural areas.
- Improving yield/quality of agriculture, forestry and fisheries products, building on existing strengths.
- Promoting sustainability and stability of agriculture, forestry and fisheries.
- Addressing global food and environmental challenges, thereby contributing to the international society.

Additionally, by steadily promoting basic and fundamental research and development in line with these basic targets, we will improve the quality of people's life in conjunction with *Shokuiku* (food education) and will contribute to global food, environmental and energy problems as an advanced country.

Regarding the restoration and reconstruction efforts after the Great East Japan Earthquake (the Japanese Government collectively refers to the disasters caused by the 2011 Tohoku Earthquake and the accompanying nuclear plant accidents as "the Great East Japan Earthquake"), we have been working on the demonstration of large-scale, land-extensive farming using cutting-edge technologies; the demonstration of facility horticulture sophistication technologies restoring horticultural facilities; and the development of decontamination technologies for farmland contaminated with radioactive cesium in affected areas. We continue our research and development efforts so that affected people in the agricultural, forestry and fisheries industries can resume operation as soon as possible. We do so by advancing our efforts on the movement of radioactive substances in farmland, forests and ocean, which were released by the accident at the Fukushima Dai-ichi Nuclear Power Station of the Tokyo Electric Power Company (hereafter, Fukushima Dai-ichi Nuclear Power Station).

Furthermore, considering the Tokyo 2020 Olympic and Paralympic Games as the best opportunity to transmit the fruit of our agricultural, forestry and fisheries research to the world (a showcase of technologies), we will contribute to the global developments of agricultural, forestry, fisheries and other associated industries, including the promotion of exports of domestic agricultural, forestry

and fishery products, by actively introducing Japan's technologies for agricultural, forestry, fisheries and food-related industries as well as various environmental initiatives to the world.

Chapter 1　Basic Policies for Promoting Research on Agriculture, Forestry and Fisheries

1. Reform of Research and Development Management

(1) Strategic Development of Research and Development Directly Linked to Needs

In promoting agricultural, forestry and fisheries research, it is important to steadily advance necessary research and development without failing to address medium- to long-term problems such as global warming. Current policy issues must also be responded to properly.

Therefore, the New Basic Plan proposes:

(a) To attain the current important targets of increasing agricultural income and transforming agriculture, forestry and fisheries into attractive, hopeful industries for young people through promotion of "research and development for promptly solving problems faced by producers" as a priority.

(b) To address future problems such as global warming and an aging society in a planned manner, research areas have been set for "Research and development to be steadily promoted under medium- to long-term strategies," where key targets of research and development are set for each area (see Chapter 2).

In addition, targets directly linked to the needs of producers and society have been set using a backcast approach in which research and development projects in need of promotion are determined based on current or future policy issues.

The following problems have been identified in the previous Basic Plan:

(a) Association between the key targets and yearly research/development budgets was unclear, making the process control for attaining the targets inadequate.

(b) Concepts of role sharing and collaboration among the national government, National Research and Development Agencies,[4] local governments and private companies were not clearly defined, resulting in weak promotion of private fund-driven research and development.

(c) Amid dwindling research and development budgets, there were cases in which "selection of and concentration (priority allocation of budgets to truly necessary research topics)" were inadequate.

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[4] National Research and Development Agencies: As part of restructuring the Independent Administrative Agency system by the government, Independent Administrative Agencies that primarily conduct research and development, including NARO, will become National Research and Development Agencies in April 2015.

(d) Research and development based on the opinions of producers and improvement of research findings were inadequate.

Therefore, to reach key targets with the aim of strategically implementing research and development more directly linked to the needs, research and development management will be reviewed:

(a) A new roadmap will be created to clarify the association between the key targets and yearly research and development budgets, and to allow overseeing research and development efforts aimed at reaching the key targets. Necessary research and development will also be comprehensively promoted while listening to the opinions of people from the agriculture, forestry, fisheries and other associated industries, outside experts, and extension organizations. Regarding research and development themes to be steadily promoted under medium- to long-term strategies, research and development strategies will be developed as appropriate.

Additionally, research and development projects that have been independently carried out by local governments' research institutes (hereafter, prefectural research institutes) and other organizations will be identified as appropriate and incorporated into the roadmap to allow role sharing and collaboration with the people involved as well as the efficient implementation of such projects. The participation of farmers, extension organizations, etc. in research will be encouraged to promote research and development directly linked to the needs of production sites.

(b) Furthermore, research and development information overseas and seed information from other fields such as medicine, pharmacology and engineering will be actively collected and analyzed. By aggressively incorporating the results into the aforementioned process management, e.g., to review the targets and roadmap based on the results, research and development management will be implemented more strategically.

(c) Additionally, regarding the administration of individual commissioned project studies, more efforts will be made to concentrate and prioritize budgets on truly necessary research themes by reflecting the opinions of the project steering committee comprised of government departments/agencies and outside experts on the next year's budget. A system will be introduced in which the validity of such efforts is assessed by the third-party committee members at the interim and final evaluation stages.

(2) Collaboration with Other Government Ministries and Strengthening Interdisciplinary Research

Today, expectations are high for creating scientific and technological innovations for strengthening

Japan's competitiveness and realizing the sustainable development of society and economy. The importance of interdisciplinary research, joining researchers with a range of expertise beyond the bounds of existing fields to bring together technologies, knowhow and ideas, has been emphasized.

In particular, ICT and robot technology, Japan's strengths, have potential for providing a breakthrough for the producers in the agriculture, forestry and fisheries industries, where aging and the decline in worker numbers are increasingly serious issues. Such technologies will be essential for transforming agriculture, forestry and fisheries into attractive industries that appeal to young people.

Molecular biology and genome engineering technologies have achieved remarkable advancement in recent years (e.g., iPS cells in regenerative medicine). In the future, such knowledge will be applied to breeding and epidemiology in agriculture, forestry and fisheries to attain the highest possible yields in agricultural, forestry and fishery products, breeding innovative new varieties with high disease or pest resistance or other beneficial traits, and developing techniques to prevent epidemics and pests. In addition, higher-quality diets can be offered to people in collaboration with medicine and nutrition science by developing new food products containing functional substances that prevent lifestyle-related diseases or have other benefits.

To actively and swiftly incorporate the knowledge and technologies from other fields into agricultural, forestry and fisheries research, we will promote the following items in collaboration with the Ministry of Economy, Trade and Industry, the Ministry of Education, Culture, Sports, Science and Technology under the Council for Science, Technology and Innovation, the "control tower" for government's science and technology policies:

(a) We will participate in the Cross-ministerial Strategic Innovation Promotion Program (SIP)[5] in which the Council for Science, Technology and Innovation distributes budgets beyond the bounds of ministries and research fields. It promotes research and development from basic research to the "exit (commercialization)" and work on developing innovative agricultural, forestry and fishery technologies contributing to the creation of the next-generation agriculture, forestry and fisheries industries. These include the application of ICT and robot technology to agriculture, forestry and fisheries research; developing new plant breeding techniques[6] that use genome sequencing and DNA markers; developing varieties with unique strengths; identifying functional health substances contained in agricultural, forestry and fishery products;

[5] Cross-ministerial Strategic Innovation Promotion Program (SIP): http://www8.cao.go.jp/cstp/gaiyo/sip/index.html
[6] Current status and challenges of new plant breeding techniques (NPBTs): http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-22-h140826.pdf

developing new functional foods using such substances; developing technologies for converting unused agricultural, forestry and fishery resources into industrial and other materials; extending the life of irrigation facilities; and establishing disaster prevention/mitigation systems.

(b) Moreover, regarding the research fields in which quick commercialization is feasible by the participation of private companies ("Promotion of integration research for agriculture and interdisciplinary fields, announced in August 2013"),[7] the Ministry of Agriculture, Forestry and Fisheries will promote industry-academia-government collaborative research by securing relevant budgets (e.g., the project for creation of innovative technology).

(3) Effective Evaluation System

In efficiently and effectively promoting research and development and fulfilling our accountability to the people of Japan, it is important to properly evaluate the government's research and development activities.

Currently, in accordance with the National General Guidelines on the Method of Evaluation for Government Research and Development (decided by the Prime Minister in December 2012),[8] in principle four evaluations have been conducted for a project: the pre-evaluation at the planning stage of the project, the interim evaluation during the project, the post-project evaluation and the follow-up study evaluating the effects of the project after a certain period of time.

Moreover, in carrying out the evaluations, the research and development purposes and paths to attain them are clarified by us and then assessed by the third-party evaluation committee. This includes representatives from the agriculture, forestry and fisheries industries, and people with a private-sector background. Among other tasks, they review the rationality of the purposes, progress and results.

Amid this situation, to maximize research achievements, it has become increasingly important to preferentially allocate budgets on truly necessary research themes ("selection and concentration") in accordance with subsequent changes in circumstances, even if projects are ongoing. It is also necessary to review how outside evaluations are implemented from such viewpoints.

Regarding the evaluation of National Research and Development Agencies, the independent administrative agency evaluation committee was previously established at each ministry,

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[7] Promotion of integration research for agriculture and interdisciplinary fields: http://www.s.affrc.go.jp/docs/ibunya/pdf/ibunnyasennryaku.pdf

[8] National General Guidelines on the Method of Evaluation for Government Research and Development: http://www8.cao.go.jp/cstp/output/20121206sisin.pdf

which consists of external experts using their own evaluation standards. However, starting in 2015, the competent ministers will evaluate the activities of National Research and Development Agencies in accordance with the government-wide guidelines[9] established by the Ministry of Internal Affairs and Communications as part of the government reform of independent administrative agencies.

Based on these circumstances, the evaluation system for research and development activities is reviewed for its more effective implementation:

(a) The evaluation of commissioned project studies will be reviewed so that efforts for concentrating and prioritizing budgets are evaluated by the outside evaluation committee at the interim and post-project evaluation stages for their validity (see 1-(1)).

(b) Regarding the evaluation of National Research and Development Agencies falling under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries (hereafter, competent legal entities), under the government-wide guidelines established by the Ministry of Internal Affairs and Communications, we will properly evaluate the efforts of competent legal entities for maximizing research achievements based on the opinions of outside experts and provide guidance on necessary changes every year.

(c) Results of these evaluations are made public[10] on websites or by other means to fulfill our accountability to the public.

2. Acceleration of Technology Transfer

(1) Strengthening the Function as a "Bridge"

(A) Technological Innovation by Integration and Utilization of "Knowledge"

In recent years, advanced Western countries have begun focusing on the creation of innovations where knowledge, technologies and ideas are brought together beyond the bounds of existing research fields. Consequently, business sectors generate innovative technology seeds and provide valuable products and services.

In addition, in this increasingly globalized and informed society and economy with strong competition in research and development, it has become increasingly necessary to commercialize research and development findings by quickly conducting research and development.

[9] Guidelines on the Goal Setting by Independent Administrative Agencies: http://www.soumu.go.jp/main_content/000311662.pdf
Guidelines on the Evaluation of Independent Administrative Agencies: http://www.soumu.go.jp/main_content/000311663.pdf
[10] Evaluation of research policies: http://www.s.affrc.go.jp/docs/hyoka.htm

The importance of an open industry-academia-government collaboration in research and development has been emphasized.

The Agriculture, Forestry and Fisheries Research Council has appointed full time coordinators at its branches nationwide to promote the industrial use of research findings obtained by commissioned project studies. It has been attempting to match researchers/developers and users (producers, companies, etc.) by hosting the annual Agribusiness Creation Fair [11] and other events. However, considering the need to strengthen research exchanges beyond the bounds of existing research fields, organizations and business sectors, as well as the time taken to commercialize research findings, it is necessary to review the current system of industry-academic-government collaborative research in light of current circumstances.

On the other hand, amid the recent advancement of ICT and robot technology, it is hoped that applying these advanced technologies to agriculture, forestry and fisheries will bring innovations to these industries currently facing various problems due to an aging and declining population.

Additionally, we are preparing to properly respond to the rapidly aging domestic market by developing and providing various food products and services that utilize the strengths of domestic agricultural, forestry and fishery products through enhanced collaboration with domestic food-related industries. We also seek to develop new markets by expanding exports to other parts of Asia, where the food market is expected to grow in the future, and to the large markets of the West.

Furthermore, regarding other domestic industries, we have been exploiting new markets and demands by proposing consumer-first valuable products and services by establishing the value chain from farmers to consumers. Progress of such efforts has been slow in agriculture, forestry and fisheries, but we are hopeful about transforming them into growth industries by using existing know-how and business models.

Therefore, while referring to innovation models used in other advanced countries and other fields/business sectors, we will produce innovative technology seeds by introducing the knowledge and technologies used in other fields to the agricultural, forestry, fisheries and food industries. We will also promote new industry-academic-government collaborative research for establishing the value chain from farmers to consumers for domestic agricultural, forestry and fishery products by swiftly commercializing the technology seeds. To this end, the following efforts will be made:

[11] Agribusiness Creation Fair: A technology exhibition and networking event held by domestic industrial and academic organizations where the latest research findings in agricultural, forestry, fisheries, food and other fields are explained through exhibitions and presentations in an easy-to-understand manner. This promotes collaboration among research organizations and between research organizations and businesses.

(a) In the future, we will create a research platform where businesses motivated to exploit domestic and international markets and demands in the agricultural, forestry, fisheries and food industries are matched with universities and National Research and Development Agencies who possess innovative technologies for other fields (a platform accumulating and using knowledge) and will develop basic concepts to set research themes in 2015.

(b) In line with these basic concepts, we will establish a section promoting the creation of the research platform within the Secretariat of the Agriculture, Forestry and Fisheries Research Council (the Tsukuba Office is slated to be reorganized as the Industry-Academia Collaboration Support Center). This will organize seminars introducing innovative technologies of other fields owned by private companies to farmers and agricultural researchers. This will also organize workshops in which problems faced by producers in agriculture, forestry and fisheries are shared with businesses in other fields, university researchers, etc. Thus, we will work toward the swift commercialization of such technologies by inviting interested businesses, including those in other fields, from across the country.

(c) In collaboration with technology "connoisseurs" who are also familiar with innovative technologies in fields beyond agriculture, forestry, fisheries and food, we will promote the matching of people in industry, academia and government, including researchers in the fields of agriculture, forestry, fisheries and food as well as farmers and people in other fields/business sectors. This will be done by employing coordinators with private-sector research background or individuals highly capable in the management and commercialization of industry-academia-government joint research. Research platforms will be created in many regions based at National Research and Development Agencies and universities, thereby carrying out market needs-driven joint research aimed at the commercialization of results.

(d) By further examining the effective operation of intellectual property rights owned by legal persons under our jurisdiction and measures for encouraging financial institutions to participate in the research platform, we will in the future implement various measures for comprehensively promoting industry-academia-government collaborative research and the commercialization of research findings.

(e) Regarding numerous research findings that have been produced, we will develop human resources capable of promoting the use of such findings aimed at commercialization.

(B) Technological Development and Extension through Collaboration among Research and Development Institutions, Extension Services and Producers

Production of research findings truly useful for producers in the agriculture, forestry and fishery industries requires transforming developed technology seeds into technological systems with high local adaptability. This is accomplished through promoting seamless efforts beginning with research and development, then progressing to production site demonstration and extending to the producers.

Therefore, the Agriculture, Forestry and Fisheries Research Council regularly hosts the Regional Matching Forum[12] for researchers at regional agricultural research centers and other prefectural research institutes, extension officers and people from the agriculture, forestry and fisheries industries. The council also regularly hosts research organize extension liaison meetings in regional blocks with the aim of facilitating the exchange of opinions and information for the extension and commercialization of research findings. Moreover, every year since 2007, important research findings expected to be introduced to the production points have been selected as the "New Agricultural Technologies 200X,"[13] thereby promoting their prioritized extension in the cooperative agricultural extension services and supporting their introduction through subsidized projects.

Consequently, some research findings that were highly adaptable to the production points have been implemented, e.g., *Yumechikara* (an extra-strong wheat variety that can be used to make bread and Chinese noodles by mixing with varieties for Japanese noodles) and the FOEAS (a groundwater-level control system for preventing excess moisture, injury and droughts).

However, annual research and extension liaison meetings are inadequate for researchers and producers to communicate with each other, and distance still exists between the producers' and government's research and development. A system has been proposed in which people in agriculture, forestry and fisheries industries and extension organizations who are familiar with producers' needs can participate in research and development.

Amid the recent weakening of the research system of local government prefectural research institutes due to administrative reforms and other reasons, there is increasing need for regional agricultural research centers to play a leading role in establishing role-sharing and collaborative relationships with prefectural research institutes, universities and private companies and to

[12] Regional Matching Forum: A place for participants to exchange opinions and technical consultations to facilitate the extension of technologies.

[13] New Agricultural Technologies 200X: Important research findings that need to be quickly introduced to producers are selected and announced annually ("200X" means the year in which a particular technology is selected).

efficiently promote research and development at the regional level.

Therefore, it is necessary strengthen regional agricultural research and promote research and development directly linked to producers' needs through a system in which people in agriculture, forestry and fisheries industries, extension organizations, etc. participate in research and development, providing feedback (e.g., the problems expected upon introduction to the production sites). Improvements continue to be made based on such feedback, accelerating the extension of research findings. Accordingly, the following efforts will be made:

(a) To incorporate the voice of producers in their research and development, regional agricultural research centers will establish an advisory board consisting of progressive local principal farmers. They will also appoint communicators who will identify producers' needs and problems by regularly exchanging information and opinions with local people concerned, including agricultural innovation support officers of prefectural governments. Additionally, we will enhance the hub functions for regional agricultural research by establishing a section that plans and coordinates joint research with regional prefectural research institutes, universities, extension organizations, businesses, etc.

(b) Regarding our commissioned project studies, particularly those aimed at solving problems faced by producers, we will promote field demonstration research in collaboration with regional agricultural research centers, prefectural research institutes, prefectural extension organizations, or local principal farmers and producer groups by requiring the mandatory participation of agricultural, forestry and fisheries producers and extension organizations in commissioned research groups.

(c) By hosting the Regional Matching Forums, providing information on the latest agricultural technologies, holding research and extension liaison meetings in line with above (a) and (b) at the Regional Agricultural Administration Office level and transferring technologies through producer groups, efforts will continue toward the smooth dissemination of research findings addressing local needs.

(2) Promotion of Strategic Intellectual Property Management

The Agriculture, Forestry and Fisheries Research Council formulated in 2007 the Agricultural, Forestry and Fisheries Research Intellectual Property Strategy[14] in order to ensure that research findings obtained from commissioned projects will be utilized in agriculture, forestry, fisheries and food industries and their effects will be promptly returned to society. This presents to legal entities

[14] Agricultural, Forestry and Fisheries Research Intellectual Property Strategy: http://www.s.affrc.go.jp/docs/intellect.htm

under our jurisdiction our ideas on the rights acquisition for research findings and the protection and use of intellectual properties. It has since provided necessary guidance to them.

Currently, while the legal entities under our jurisdiction possess many intellectual property rights including patents, the sublicensing and publicity targeting domestic businesses, local governments, etc. are not necessarily sufficient.

The need is emerging among producers to differentiate agricultural, forestry and fishery products (e.g., branding) by exclusively using patents (for new technologies) and plant breeders' rights (for new varieties) and combining trademarks or cultivation technologies with these intellectual property rights, thereby creating new markets.

Furthermore, in other industries and developed countries, a variety of intellectual property management strategies supporting diverse business models have been adopted. These include cases in which: 1) Even for important technologies, patents are acquired and such technologies are made widely available to domestic and international users free of charge or for reasonable fees, thereby standardizing the technologies and taking control of market development; and 2) For technologies that can be used in product development at private companies, they are kept secret for a certain period of time instead of getting patented and widely licensed. Peripheral technologies are jointly developed with promising companies to facilitate commercialization, thereby promoting investment in said companies and accelerating market development. Such strategic efforts have also become increasingly important in the area of agricultural, forestry and fisheries research.

In light of these circumstances, the current Agricultural, Forestry and Fisheries Research Intellectual Property Strategy will be fundamentally reviewed and intellectual property management will be promoted by the legal persons under our jurisdiction based on the following concepts:

(a) Under the basic concept that "research findings are valuable if they are used by the producers in the agriculture, forestry and fisheries industries," we will effectively and efficiently promote future research and development with an intellectual property strategy effective for commercialization developed at the planning stage of research and development. This will include the questions such as "who will benefit from the outcome of this research?" and "in what form should intellectual properties be given to the users?"

(b) Regarding the use of research findings, we will provide guidance and support for the review of intellectual property management at research organizations to ensure adoption of the most appropriate method in terms of accelerating contribution to society through commercial

success from a wide range of options such as acquiring patents, keeping secret or publicly announcing them at the time of invention, making patents available to the public and exclusively licensing patents.

(c) Furthermore, in addition to improving the system used by intellectual property sections by legal persons under our jurisdiction, we will establish a section promoting industry-academia-government collaboration at regional agricultural research centers and other organizations. From this, full time coordinators will publicize intellectual properties held and coordinate the use of intellectual property rights through such means as licensing. They will actively collaborate with outside technical "connoisseurs" and people familiar with business models and intellectual property management, promote joint research with businesses working on the commercialization of intellectual properties and collaborate with venture capitals.

(3) Improving and Strengthening Regulatory Science, etc.[15]

In the field of agriculture, forestry and fisheries research, regulatory science has been promoted so that administrative measures such as those on food safety, pest and disease control in animals and plants are accurately conducted on scientific grounds. We will improve and strengthen it as well as promote research and development in response to regulation in an integrated manner through the following efforts:

(A) Promotion of Regulatory Science

To accurately implement scientifically sound measures on food safety as well as pest and disease control in animals and plants, the Ministry of Agriculture, Forestry and Fisheries in 2010 formulated the Regulatory Science Research Promotion Plan.[16] It has since promoted regulatory science through accumulating scientific knowledge necessary for risk management, research on the development of new technologies/techniques and enhanced collaboration with research institutes.

However, in the field of agricultural, forestry and fisheries research thus far, efforts on regulatory science have been mainly made by the legal entities under our jurisdiction. Efforts by agricultural, forestry and fisheries universities and businesses have been limited and the awareness of and efforts by individual researchers on regulatory science are insufficient. Therefore, the following efforts

[15] Regulatory science: A field of science that coordinates and regulates the application of science/technology to human life and society in desirable ways and by extension, supports safety administration.

[16] Regulatory Science Research Promotion Plan: Formulated to promote the research in an integrated and planned manner, the outcome of which can be used to plan and promote policies and measures on food safety as well as pest and disease control in animals and plants (regulatory science) under the close collaboration of relevant sections of the ministry. These include the Food Safety and Consumer Affairs Bureau and the Secretariat of the Agriculture, Forestry and Fisheries Research Council.

will be made:

(a) The New Regulatory Science Research Promotion Plan will be established. This clearly identifies research themes and problems in need of addressing. The plan will be shared with stakeholders and its progress will be regularly reviewed.

(b) Through active exchange of opinions between government agencies and research institutes, and through the active transmission of research needs by government agencies, the awareness and understanding of researchers on the importance of regulatory science will be raised. Consequently, regulatory science research will be expanded to universities and private companies.

(c) Research and development agencies and regulatory agencies will continue to make joint efforts at promoting research necessary for risk management, including the management of hazards in food products, animal diseases and plant pests. In addition, because researchers must sufficiently understand the needs and duties of government agencies in conducting their research, we will systematically hold regular meetings between government agencies and research institutes. This will strengthen their collaboration through the exchange of human resources, the development of scientists who can participate with government officers in regulatory administration and the development of international standards, among other initiatives.

(B) Promotion of Regulation-Compliant Research in an Integrated Manner

To smoothly return research outcome to society, it is important to adopt an approach that considers the whole picture from research/development to commercialization to dissemination, thereby systematically solving problems that may occur during these processes.

However, commission project studies have traditionally tended to focus on obtaining research outcomes without considering the various regulations necessary for commercializing those outcomes and putting them into practical use. Consequently, it has often been the case that research findings cannot be easily returned to society due to regulations. In the future, to promote research and development as well as regulation-compliant research in an integrated manner, the following efforts will be made:

(a) In planning commissioned project studies bringing together a wide range of researchers to tackle research questions comprehensively and systematically, we will plan projects to allow the integrated promotion of research and development and regulation-compliant research. This will be accomplished by analyzing the possible future introduction of regulations on food

safety, production materials (e.g., agricultural chemicals, fertilizers/feed and animal drugs), occupational safety and biodiversity including ways to address these regulations while overlooking the path to commercialization. In addition, government agencies will provide intermediate support for such regulations with a request from project outsourcees. They will also actively promote the collection of information to prepare for introducing regulations, thereby supporting the practical application of technologies.

(b) We have successfully used genetic recombination technologies to introduce traits that cannot be introduced using conventional breeding techniques (e.g., insecticidal functions of microorganisms) to agricultural and other products while observing regulations and guidelines on food safety or biodiversity effects. In this situation, it is becoming possible to use genetic recombination technologies to streamline the breeding of field crops by, for example, shortening the breeding period of fruit trees by systematically accelerating flowering and inducing mutations, and to quickly breed innovative field crops by maximizing their potential. Regarding the field crops created through such new breeding technologies, we will promote consensus-building domestically and internationally by accumulating scientific findings, including comparison data with conventional crops needed to determine whether genetic recombination regulations should be applied.

(4) Promotion of Public Understanding

Amid the rapid advancement of ICT, robot technology and genomic engineering in recent years, the acquisition of innovative research findings and creation of innovations are expected in the field of agriculture, forestry and fisheries research taking advantage of these latest technologies.

However, as witnessed with genetically modified field crops, some concerns have been raised about the rapid advancement in research and development.

On the other hand, considering people's dietary patterns, various food-related problems are emerging, such as obesity and lifestyle-related diseases attributable to poor diet and dietary habits. It is challenging for the public to obtain knowledge on food and the ability to choose the right foods.[17] Moreover, public understanding and interest in the roles of agriculture, forestry and fisheries industries in rural areas and communities, or the suppliers of food, are declining.

Under these circumstances, it is important to provide easy-to-understand explanations to the general public to quickly return the findings of agricultural, forestry and fisheries research to society and help promote the agriculture, forestry, fisheries and food industries for improving

[17] Basic Program for *Shokuiku* Promotion: http://www8.cao.go.jp/syokuiku/about/plan/index.html

people's lives. At the same time, we must engage in two-way communication with them regarding the research findings obtained, sincerely listen to people's expectations or concerns and incorporate them in subsequent research and development and commercialization processes.

This two-way communication both contributes to promoting scientifically sound rational consumption behavior of the public as well as the public understanding of agriculture, forestry and fisheries industries in rural areas and communities.

With these in mind, the following efforts will be promoted:

(a) We will appoint at regional agricultural research centers and other organizations a communicator who will promote communication with the public by explaining the meanings of research and development, research findings, etc. in an easy-to-understand way. We will hold symposiums for farmers and the general public, dispatch researchers to schools, present public lectures, publicize research findings to the media and strengthen outreach activities[18] by researchers through presentations at various events.

(b) Scientific knowledge on the safety, nutrition and functionality of food will be improved, and the food literacy of young people will be enhanced through promoting correct knowledge of food in collaboration with people involved in medicine, nutrition and food education.

(c) Regarding genetically modified crops, communication about their risks will be strengthened in collaboration with the Food Safety Commission and other entities. Information on the food safety regulation system and the state of use of genetically modified field crops by the public will be accurately transmitted. In future commercialization of research findings, we will promote the usefulness of genetic recombination technologies to the public with priority placed on flowers/ornamental plants and raw materials for clothing and medicines through actively dispatching researchers to local events such as the Science Café to promote two-way communication with the public.

3. Environmental Arrangement for Creating Diverse "Knowledge"

(1) Reform of National Research and Development Agencies

As part of the outcome of the government review[19] of the Independent Administrative Agency System, Independent Administrative Agencies specialized in research and development under

[18] Outreach activities: Two-way communication conducted by researchers targeting the general public with the aim of increasing their interest in research activities and science/technologies; and understanding the public's needs through communication with them.

[19] Basic policies for reviewing the system and organization of the Independent Administrative Agency: http://www.cao.go.jp/gyouseisasshin/contents/03/pdf/120120_khoshin.pdf

the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries, including NARO, will become National Research and Development Agencies starting in April 2015. Preparations are underway for the merger of four Independent Administrative Agencies (three agricultural agencies: NARO; the National Institute of Agrobiological Sciences; and the National Institute for Agro-Environmental Sciences; with the National Center for Seeds and Seedlings) and the merger of two Independent Administrative Agencies (the Fisheries Research Agency and the National Fisheries University), both planned for April 2016.

These two post-merger legal entities and the Forestry and Forest Products Research Institute will be the country's largest research institutes in their respective fields and are expected to play central roles in realizing this Basic Plan by further increasing their research potentials.

On the other hand, improper accounting practices and other problems have recently occurred among legal entities under our jurisdiction. Thus, it is urgent to strengthen the internal control of our legal entities and improve researchers' awareness of compliance.

Therefore, the following efforts will be promoted among our new legal entities:

(a) The research system will be improved for the legal entities to maximize their merger effects as legal entities with broad research potential for the agriculture, forestry and fisheries industries ranging from basic research to applied and practical application research. Additionally, through collaboration with outside organizations such as universities, and by improving research support for prefectural governments and private companies, research by agricultural, forestry and fisheries will be promoted on a national level.

(b) To maximize research and development results, the management and other aspects of the new legal entities will be fundamentally improved with a particular focus on strengthening the involvement of farmers/foresters/fishing operators in research promotion and for needs-driven research in collaboration with private companies. Industry-academia-government collaborative functions and comprehensive research for solving local problems should also be drastically enhanced.

(c) Under the leadership of directors and other management staff, the legal entities will strengthen their internal control and improve risk management, including information security and compliance. In addition, throughout the medium- and long-term target periods of the new legal entities, their organization, administrative work and projects will be streamlined.

(2) Improvement of Research and Development Base

(A) Effective Operation of Research Funding System

We have been promoting agricultural, forestry and fisheries research in the following ways: 1) For research and development that requires comprehensive and systematic approaches using a wide range of expertise of researchers nationwide, or research and development projects requiring large amounts of research resources and a long-term perspective, budgets are secured using the commissioned project study category;[20] and 2) For research and development projects aimed at producing innovative technology seeds using the creative minds of researchers, the competitive funds category[21] has been used.

From the viewpoint of promoting research and development projects directly linked to producers' needs, strengthening multidisciplinary research and promoting the swift diffusion and practical application of research results while maintaining these research funding schemes, the following reviews will be made:

(a) Regarding commissioned project studies, to further promote research directly linked to producers' needs, the opinions of farmers/foresters/fishery business operators and industries will be widely incorporated starting at the project development (planning) stage. Field demonstration studies for establishing a technological system with high local adaptability will be strengthened by refining existing technologies in collaboration with extension organizations and the principal farmers. Additionally, even if projects are ongoing, efforts will be made to concentrate budgets on truly necessary research projects according to changes in circumstances (1-(3)).

(b) As for the competitive funds category, we will continue working on the effective administration of funds by aligning them with research funds under the jurisdiction of other ministries while ensuring seamless support from basic research to practical application research.

(c) To strengthen multidisciplinary research, we will actively promote joint research with research institutes under the jurisdiction of other ministries using SIP of the Council for Science, Technology and Innovation. Regarding the fields in which private companies can be involved to help accomplish swift commercialization, the Ministry of Agriculture, Forestry and

[20] Commissioned project study: Among studies important for developing agricultural, forestry and fisheries policies, refer to those requiring comprehensive and systematic promotion using a wide range of research expertise, extensive research resources and long-term perspectives that cannot be dealt with by individual research institutes, and that are planned by and focused on by carrying out the progress management each year by the Ministry of Agriculture, Forestry and Fisheries.

[21] Competitive funds: Research and development funds for which providers widely solicit research and development themes selected by multiple people including experts of relevant fields based on scientific and technical evaluations and that are provided to researchers and other entities.

Fisheries will promote industry-academic-government research by allocating relevant budgets[22] (1-(2)).

(B) Collection and Analysis of Research and Development Information

With the aim of efficiently promoting research and development using various scientific findings obtained domestically and from overseas in agricultural, forestry and fisheries research, the Agriculture, Forestry and Fisheries Research Council established the Agriculture, Forestry and Fisheries Research Information Center in 2008 in Tsukuba City. It has since collected research papers and developed the database for them,[23] and established the research information and communication network, among other efforts.

Such information and networks are widely disseminated to the universities and companies commissioned to do these project studies as well as researchers at the legal entities under our jurisdiction. They are now essential tools in promoting agricultural, forestry and fisheries research.

In the future, it will become increasingly necessary to improve a literature information system for different fields as well as improve the ability to analyze domestic and international research and development trends. In addition, recent cases of cyber attacks to our system through unauthorized access that exposed the vulnerability of the system confirmed the necessity of further improving information security measures.

(a) We will continue to improve our literature information database and maintain our networks with a particular emphasis on collecting information on research in different fields such as ICT and robot technology, thereby improving our research and development environment. Information security measures will also be enhanced.

(b) With the recent advancement of the pooled analysis of literature and patent information, we will introduce such technologies using bibliometrics to the analysis of domestic and international research and development trends for the benefit of our research and development strategy.

(C) Human Resource Development

Humans form the foundation for raising international competitiveness in agriculture, forestry and fisheries research and producing high-quality research findings. Therefore, it has increasingly

[22] Website of the Ministry of Agriculture, Forestry and Fisheries: http://www.s.affrc.go.jp/docs/ibunya/index.htm

[23] The Agriculture, Forestry and Fisheries Research Information Technology Center, through AGROPEDIA (http://www.agropedia.affrc.go.jp/top), provides literature on agricultural, forestry and fisheries research, information on research themes and results, basic numerical data, etc.

become important to foster creative and ambitious researchers.

To promote the systematic development of such researchers, the Agriculture, Forestry and Fisheries Research Council established the program for developing human resources for agricultural, forestry and fisheries research (decided in March 2006).[24] It has since promoted the training and acquisition of young and/or female researchers at the legal entities under our jurisdiction and local governments' prefectural research institutes; human-resource exchanges with universities and other organizations; and the development of human resources at research support sections including the intellectual property section, among other efforts. It has also continued promoting systematic efforts based on this program as necessary.

In addition, as a government-wide policy on science and technology aimed at allowing universities and National Research and Development Agencies of other ministries to exchange and utilize researchers beyond the boundaries of research fields, introducing the cross-appointment system has been considered. In this system, researchers simultaneously conclude employment contracts with universities, public research institutes and companies and engage in research under the responsibility of individual employers. It is expected to revitalize agricultural, forestry and fisheries research.

Furthermore, in response to a recent and continuous stream of dishonest behaviors such as fabrication of research data, the government has decided to invest further efforts in preventing such acts.

Based on the above, we will make the following efforts:

(a) We will continue to promote the training and acquisition of young and/or female researchers based on the human resource development program, human resource exchanges with universities and other entities and the recruitment from external entities including private companies. For researchers with certain experience, we will improve our system of training research support personnel and provide multiple career options so they can work as full time coordinators for industry-academia-government collaboration or communicators who pass on research findings to the producers.

(b) To further multidisciplinary research by applying innovative technology seeds possessed by universities or National Research and Development Agencies under the jurisdiction of other ministries to agricultural, forestry and fisheries research, we will actively promote the use of a cross-appointment system and other systems.

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[24] The program for developing human resources for agricultural, forestry and fisheries research: http://www.s.affrc.go.jp/docs/talent_promo/outline.htm

(c) Furthermore, through the commendation of young researchers and people of merit who contributed to promoting government policies, human resource exchanges with government, participation in international joint research, or the dispatch of human resources to international organizations, we will produce talented researchers who can meet the needs of society and government and have an acute international sense.

(d) From the viewpoint of preventing research misconduct, we will also promote the practice of higher ethics by researchers through commissioned research studies and other paths.

(3) Promotion of International Collaboration

With the increasing threat of various global problems such as world population increase, climate change, depletion of natural resources and energy and the transboundary spread of infectious diseases of livestock, the community of agricultural, forestry and fisheries research is witnessing an increase in research topics that should be promoted through international cooperation and collaboration.

To address these global problems, the Agriculture, Forestry and Fisheries Research Council is currently actively participating in global research networks, including the Intergovernmental Panel on Climate Change (IPCC)[25] and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES).[26] The council is also promoting bilateral joint research by concluding science and technology cooperation agreements, etc., with other developed countries.

Moreover, the Japan International Research Center for Agricultural Sciences (JIRCAS), National Agriculture and Food Research Organization (NARO) and other organizations are conducting research and development in developing regions of the world. Furthermore, we are promoting international research on agriculture, forestry and fisheries that contributes to solving global-scale problems with financial contributions granted to the Consultative Group on International Agricultural Research (CGIAR),[27] which includes the International Rice Research Institute (IRRI).[28] We provide support to research activities through the technical training of young researchers in the world's developing regions with financial contributions granted to the United Nations University (UNU) and the Office International des Epizooties (OIE).[29] We also have made

[25] Intergovernmental Panel on Climate Change (IPCC): A body established in 1988 by the World Metrological Organization (WMO) and the United Nations Environment Programme (UNEP) aimed at comprehensively evaluating human-induced climate change and its impacts as well as adaptation and mitigation measures from scientific, technical and socioeconomical viewpoints.

[26] Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES): A body established in April 2014 for strengthening the link between science and policies by scientifically evaluating trends related to biodiversity and ecosystem services.

[27] Consultative Group on International Agricultural Research: http://www.cgiar.org/

[28] International Rice Research Institute: http://irri.org/

[29] Office International des Epizooties (OIE): An intergovernmental body established in 1924 in Paris with the signature of 28 countries aimed at improving global animal health.

efforts to incorporate Japan's latest research findings into the international standards on pest identification and diagnosis to be formulated under the International Plant Protection Convention (IPPC).[30]

From now on, while aligning with international frameworks on climate change and government policies on development aid for African nations, we will focus on promoting the following:

(a) International joint research that contributes to reducing greenhouse gases and preventing transboundary infectious diseases of livestock such as the highly pathogenic avian influenza, among other problems, by actively participating in international research networks on climate change, transboundary infectious disease measures, etc.

(b) Continued research and development for developing regions worldwide in collaboration with CGIAR and other entities while ensuring consistency with the government's policies on development aid for Africa, the Ministry of Agriculture, Forestry and Fisheries' Global Food Value Chain Strategy and bilateral policy talks.

(c) As it becomes increasingly difficult to obtain genetic resources from overseas, we will work to improve the environment for facilitating the acquisition of international genetic resources by promoting the mutual use of plant genetic resources with other countries using the framework of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR),[31] the bilateral joint research with Asian countries on plant genetic resources (PGRAsia),[32] etc.

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[30] International Plant Protection Convention (IPPC): An international treaty that took effect in 1952 and aims to prevent the introduction and spread of pests (currently comprising 181 parties).

[31] International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR): http://www.planttreaty.org/

[32] Bilateral joint research with Asian countries on plant genetic resources (PGRAsia): This aims to promote characteristic analysis of and search for plant genetic resources through bilateral joint research and to improve the environment in which international genetic resources are collected and used.

Chapter 2　Key Targets of Agriculture, Forestry and Fisheries Research

1. Research and Development for Promptly Solving Problems Faced by Producers with the Aim of Increasing Income in Agriculture, Forestry, Fisheries and Rural Communities

To realize efficient and stable farming operations in individual regions and to solve production and distribution problems for different fields and items, as identified in the prospect of farming formulated along with the New Basic Plan for Food, Agriculture and Rural Areas (decided on by the Cabinet in March 2015), the following 21 key targets have been set. In addition, regarding research and development, through collaboration and sharing roles between the legal entities under our jurisdiction, universities, prefectural research institutes, private businesses, extension organizations and the principal farmers, we aim to attain technological development and practical application targets in the next five years or so through implementation of field demonstration studies and formulation of technology-based management models, followed by promptly introducing new technologies to the producers.

(1) Establishment of a Highly Profitable Paddy Farming System for Different Local Conditions

Effective use of paddy fields amid the declining domestic consumption of rice requires increased productivity of rotational paddy crops. This is accomplished through developing new varieties such as cereals, soybeans and feed crops, and developing production technologies as well as the demand-based production of staple food rice.

Therefore, under the previous Basic Plan were developed such varieties as *Satonosora*[33] (a wheat variety with a yield twice that of *Norin 61*), *Sachiyutaka A1*[34] (a shatter-resistant soybean variety with 10% lower combine-harvest loss than conventional varieties), *Iwaidawara*[35] (a high-yield feed rice variety with a yield in the order of 800 kg/10 a, developed for the Tohoku Region), among others. While quality loss of staple food rice due to global warming is becoming a problem nationwide, anti-global warming measures have steadily progressed with the development of new high-temperature varieties such as *Tsuyahima*[36] (grown in Yamagata and other prefectures), *Oidemai*[37] (grown in Kagawa and other prefectures) and *Koi-no-yokan*[38] (grown in Hiroshima and other prefectures).

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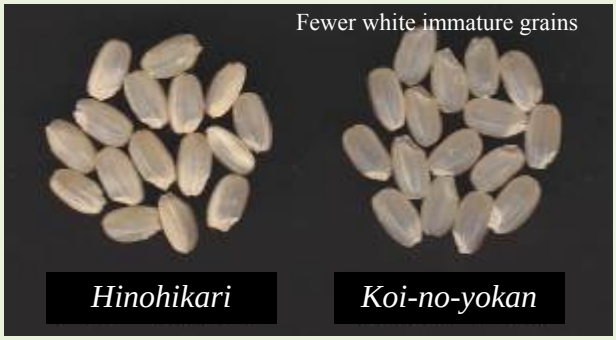
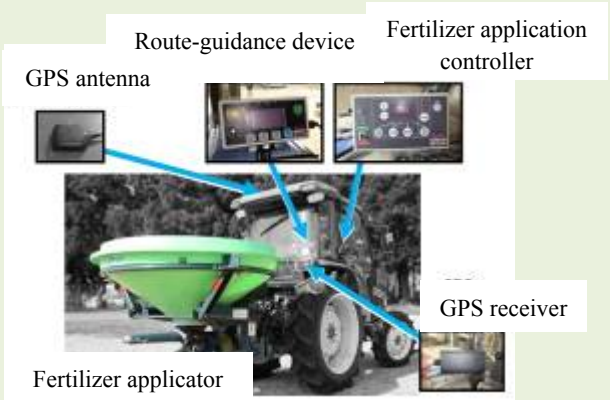
[33] *Satonosora*: http://www.maff.go.jp/tokai/seisan/nosan/mugi/pdf/satonosora.pdf
[34] *Sachiyutaka* A1: http://www.naro.affrc.go.jp/patent/breed/0100/0109/044708/index.html
[35] *Iwaidawara*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/tarc/048878.html
[36] *Tsuyahime*: http://www.tuyahime.jp/
[37] *Oidemai*: http://www.pref.kagawa.lg.jp/seiryu/oidemai/
[38] *Koi-no-yokan*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/warc/054028.html

In the field of farm machinery, several new developments have been put into practical use, including the route guidance device[39] that supports straight-line operation of tractors using GPS; the high-precision high-speed fertilizer applicator,[40] which allows even application of fertilizer regardless of the operator's skill level and field conditions; and the system for predicting the arrival of small brown planthoppers (a rice pest) from overseas.[41]



【High-temperature resistant variety *Koi-no-yoikan*】



【High-precision high-speed fertilizer applicator】

As further farmland concentration of the principal farmers is expected in the future after establishing the Public Corporation for Farm Consolidation[42] at a prefectural level, it is increasingly important to develop the environment in which principal farmers can freely choose their crops, varieties, farming system, etc. in consideration of such factors as market trends and geographical conditions to operate profitable paddy farming.

Therefore, we will promote further scale expansion of principal farmers and mixed farming by developing technologies for streamlining farm work (e.g., rice planting using an operation support system) and labor-saving harvesting technologies that use a manned machine-unmanned machine cooperative work system[43] by creating manuals for growing vegetables in paddy fields using drainage technologies (e.g., FOEAS).[44] We will also conduct research and development for securing farm work safety.

Additionally, we will promote the development of varieties and technologies to improve the productivity of paddy rotation cropping. This can be done through diverse methods: developing

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[39] Route-guidance device: http://www.naro.affrc.go.jp/project/results/laboratory/brain/2011/600b0_01_64.html
[40] High-precision high-speed fertilizer applicator: http://www.naro.affrc.go.jp/brain/iam/urgent/urgent200/043423.html
[41] System for predicting the arrival of small brown planthoppers: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/karc/052294.html
[42] The Public Corporation for Farm Consolidation: http://www.maff.go.jp/j/keiei/koukai/kikou/
[43] The manned machine - unmanned machine cooperative work system: http://www.s.affrc.go.jp/docs/youth/agri_science/as201408.htm
[44] Farm-Oriented Enhanced Aquatic System (FOEAS): A water level control system with water supply (water-level manager) and water drainage (water-level controller) control functions. It maintains the optimum water levels for different crops (between 30 cm below ground and 20 cm above ground) by draining water via conduits during a rain and irrigating water from underground during

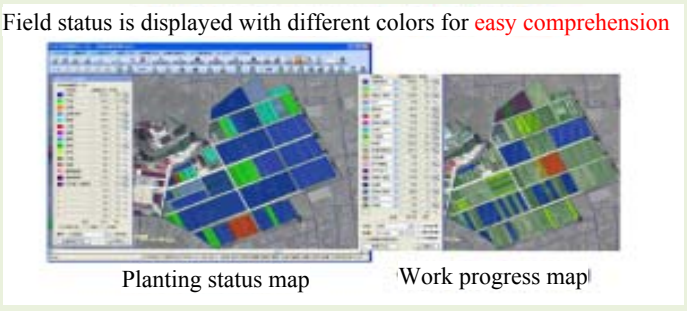
various high-yield rice varieties for processing and manufacturing uses and ultra high-yield feed rice varieties with a target unit yield of one ton; establishing labor-saving technologies; developing rice, cereal and soybean varieties resistant to multiple pest species; reducing costs through measures such as drainage improvement at upland fields converted from paddy fields; establishing new cropping systems that increase cereal and soybean yields; and developing simple soil diagnosis technologies that can be used by farmers.

Furthermore, as advancement of global warming is expected to negatively impact rice yields in the future, we will systematically work on breeding high temperature-resistant staple food rice varieties and developing an early warning system for high temperature injury in summer.

(2) Establishment of a Sustainable Paddy Farming System in Hilly and Mountainous Areas Using Local Strengths

In addition to the research findings mentioned above, several other technologies have been developed for farming hilly and mountainous areas. For example, we have the small combine harvester for multi-crops[45] loadable to trucks; the self-propelled weeding robot[46] (prototype) that can be operated on a ridge with a 40-degree incline; the farm work planning and management support system[47] in which detailed management for individual fields can be done from a smartphone or other mobile devices; and the reinforced greenhouse[48] that can be built at low cost on narrow terrace paddy fields.

【Weeding robot】



【Farm work planning and management support system】

Depopulation and aging are expected to progress rapidly among inhabitants of hilly and mountainous areas. Therefore, to promote sustainable use of paddy fields and highly profitable paddy farming based on the strengths of hilly and mountainous areas, we will improve and

a drought, thereby mitigating wet and drought damages and increasing crop yield and quality.

[45] Small combine harvester for multi-crops: http://www.naro.affrc.go.jp/project/results/laboratory/brain/2011/600a0_01_59.html

[46] Weeding robot (prototype): http://www.naro.affrc.go.jp/org/tarc/seika/jyouhou/H22/suitou/H22suitou021.html

[47] Farm work planning and management support system: http://www.naro.affrc.go.jp/publicity_report/publication/files/naro-se/06_paddy_manual_pms.pdf

[48] Reinforced greenhouse: https://www.naro.affrc.go.jp/project/results/laboratory/warc/1999/wenarc99-009.html

sophisticate the weeding robot; breed high-quality and high-yield varieties of local crops such as buckwheat and rapeseed; establish a new mixed paddy farming model combining vegetables and local crops; develop processing technologies for promoting AFFrinnovation; refine the Integrated Pest Management (IPM)[49] system for supporting production of high value-added farm produce such as organic vegetables; and develop efficient and effective wildlife trapping techniques that consider the characteristics of individual animal species and techniques for scaring off wildlife.

(3) Establishment of Upland Farming System for Hokkaido Region that Allows Scale Expansion and Highly Productive Farming

Turning to Hokkaido's upland farming, which is growing in scale, conserving labor in the cultivation of sugar beets (rotation crop) is a challenge. Therefore, several developments were based on the previous Basic Plan, including the high-precision direct seeder[50] aimed at spreading the direct seeding of sugar beets (to around 10% of the total cultivation area) and *Hokkai-mitsuboshi,*[51] a sugar beet variety resistant to three major diseases including brown spot. Additional developments include, but are not limited to *Yumechikara,*[52] an ultra-strong wheat variety used to make bread and Chinese noodles by blending with medium-strong wheat such as *Kitahonami*; *Toyomizuki,*[53] a soybean variety with high processing suitability for tofu; *Kueru-gold,*[54] an onion variety with heat processing suitability and high antioxidative quercetin content; and *Kitanokirameki,*[55] a rapeseed variety lacking erucic acid (a potential inducer of heart diseases). The expansion of their sales routes for processing and manufacturing uses is expected.

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[49] Integrated Pest Management (IPM): An integrated approach in which methods other than agrochemicals, e.g., rotation cropping, pest-resistant varieties, physical control using heat disinfection and machinery, and natural enemies and pheromones, are combined to eradicate pests.

[50] High-precision sugar beet fertilizer drill: http://www.naro.affrc.go.jp/project/results/laboratory/brain/2010/brain10-05.html

[51] *Hokkai-mitsuboshi*: https://www.naro.affrc.go.jp/publicity_report/publication/files/harc20150106Hmituboshi.pdf

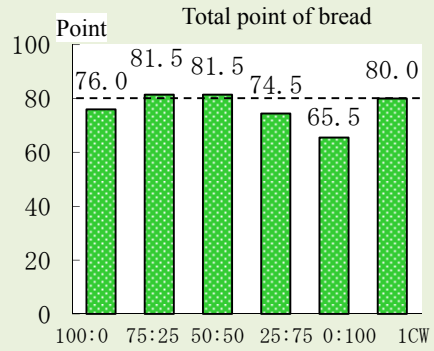
[52] *Yumechikara*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/harc/013071.html

[53] *Toyomizuki*: http://www.maff.go.jp/j/seisan/ryutu/daizu/d_ziten/pdf/62_toyomizuki.pdf

[54] *Kueru-gold*: http://www.naro.affrc.go.jp/patent/breed/0300/0308/048447/index.html

[55] *Kitanokirameki*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/tarc/044533.html

Occurrence of wheat yellow mosaic
Left: Conventional variety (The above ground part is infected with the virus, which shortens the plant height.)
Right: *Yumechikara* (The above ground part is not infected and the plants are growing healthily.)



Data: National Agriculture and Food Research Organization (NARO)
Note:
1) Horizontal axis – mixing ratio of *Yumechikara* to domestic medium-strong wheat.
2) Evaluated by setting the score for 1CW (Canadian high-quality wheat for bread) as 80.

【*Yumechikara:* The first ultra-strong, high-quality wheat variety bred in Hokkaido】

【High-precision direct seeder for sugar beets】

In the upland farming areas of Hokkaido, the number of farmers leaving the industry is expected to continue to increase, especially among elderly farmers and those with no successors. Thus, it is necessary to establish conditions in which the principal farmers take over abandoned farmland and enjoy stable crops and efficient farming while expanding their operation scale.

Therefore, we will support the realization of stable crops and efficient farming for large-scale upland farmers. This includes establishing a high-yielding technological system for sugar beets. This is based on the widespread adoption of direct seeding cultivation as labor-saving measures for spring and autumn when farmers are busy; development of a variable rate fertilizer application technology allowing accurate fertilizer management in accordance with soil fertility and uneven growth, among other factors, in an upland rotation farming system; breeding wheat, soybean and potato varieties with resistance to multiple pests, red bean varieties with machine harvest suitability, or vegetables such as onions for processing and manufacturing uses with direct seeding suitability; and developing a simple soil diagnosis technology for use by farmers.

(4) Establishment of a Highly Profitable Upland Farming System in Southern Kyushu and Okinawa

Regarding the main crop of sweet potatoes in the Southern Kyushu Region, a new sweet potato seedling planter[56] has been developed. This variety reduces labor hours from seedling production to planting by 40%. *Konamizuki,*[57] a sweet potato variety used for producing starch with unique characteristics (e.g., water holding capacity) has been developed, and its supply to the makers of Japanese cakes has recently begun.

As for sugarcane, a major crop in Okinawa Prefecture and the Ryukyu Islands of Kagoshima Prefecture, developments include Ni22,[58] a high-yielding, early-maturing, high-sugar content variety that can be harvested in December and is suitable for labor-saving ratooning; and *Nanaharuka,*[59] a zero-erucic acid rapeseed variety for the Southern Kyushu Region that can be harvested before the rainy season in early summer.

【Small seedling planter for sweet potatoes】

【Sugarcane variety Ni22 (right)】

Considering the aging of farmers and weakening of the production base for these key crops, it is important to strengthen their production base as well as promote mixed farming with vegetables or other crops. This can be accomplished through the continued promotion of sustainable and highly profitable upland farming while responding to meteorological disasters such as typhoons under unique soil conditions.

Therefore, we will promote the development of sweet potato varieties resistant to soil pests such as root-knot eelworms and sugarcane varieties that better withstand typhoon damage, are drought tolerant, have high sugar content, are high-yielding and have machine suitability. We will also establish a new, highly profitable rotation cropping system in which sweet potatoes (in summer) and vegetables for processing and manufacturing uses (in winter) are combined; develop a mechanized continuous work system; and create a collaborative system between sugarcane and

[56] Sweet potato seedling planter: http://www.naro.affrc.go.jp/project/results/laboratory/brain/1998/narc98-441.html
[57] *Konamizuki*: http://www.naro.affrc.go.jp/project/results/research_digest/digest_kind/digest_poteto/027255.html
[58] Ni22: http://www.naro.affrc.go.jp/project/results/laboratory/karc/2005/konarc05-03.html
[59] *Nanaharuka*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/tarc/050801.html

livestock farmers.

(5) Increase in Tea Demands through Joint Product Development with Tea Companies, and Establishment of Efficient Farming System

For tea, a healthy beverage for which the importance of reduced pesticide cultivation continues to increase, we have been promoting research and development for reducing pesticide use through several avenues. They include the development of *Nanmei,*[60] a new variety with resistance to white peach scales and multiple diseases including gray blight; the preparation of a manual for whitefly control using natural enemy bees;[61] and the development of a low-volume pesticide applicator,[62] among others. Other new varieties include *Kirari 31,*[63] a superior example suitable for "*Sencha,*" "*Kabuse,*" and "*Gyokuro*" green teas; and Sun Rouge,[64] a variety with high anthocyanin content and possible antioxidative and eyestrain recovery effects, raising expectations for the demand and expansion of Japanese tea varieties.

Variety	White peach scale	Gray blight	Anthraxnose
Nanmei	Strong	Strong	Medium
Yabukita (conventional variety)	Weak	Weak	Weak

【*Nanmei*: A variety resistant to white peach scales and multiple diseases】

Amid declining demands for tea and its resultant sluggish prices domestically, it is necessary to export Japanese tea overseas and stimulate tea demands in collaboration with beverage makers.

Therefore, we will promote breeding tea varieties with anti-allergic effects (e.g., anti-hay fever effect); developing cultivation systems and processing technologies for such varieties; breeding specialty varieties suitable for powdered green tea and powered tea for export; establishing a low-pesticide cultivation system that uses a cultural pest control method; developing an unmanned, self-propelled tea harvester; or developing a work management support system that can be used to manage individual tea fields.

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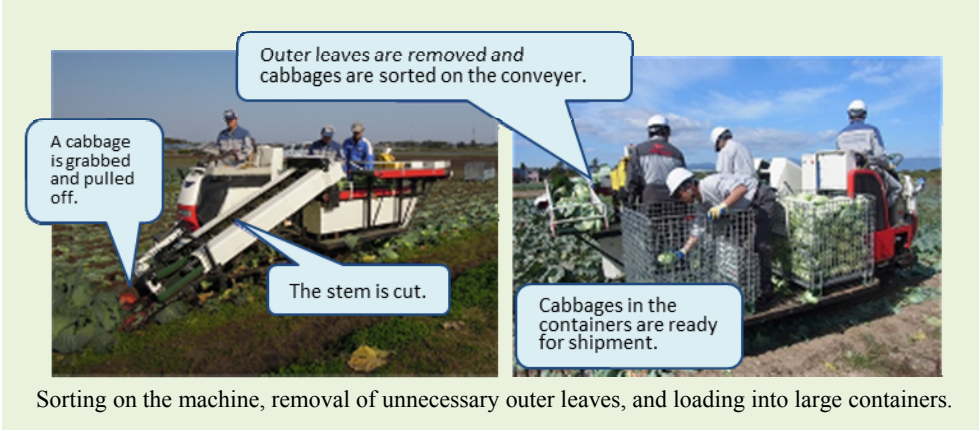
[60] *Nanmei*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/vegetea/043908.html
[61] Whitefly control manual: http://www.maff.go.jp/j/syouan/syokubo/gaicyu/siryou2/index.html
[62] Low-volume pesticide applicator: http://www.naro.affrc.go.jp/project/results/laboratory/vegetea/2004/vegetea04-01.html
[63] *Kirari 31*: http://www.m-tea.jp/information/upload-directory/1402978327.pdf
[64] Sun Rouge: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/vegetea/013117.html

(6) Establishment of a LowCcost Production and Distribution System for Vegetables to Meet Demands for Processing Uses and Food Businesses

As for vegetables grown outdoors, a labor-saving and low-cost harvest system combining cabbage harvesters with large containers[65] and FOEAS-based cultivation systems[66] for summer-harvesting Welsh onions and fall-harvesting broccoli, among other crops, have been established. A system for automating the root- and leaf-cutting process of onions following storage drying[67] has been developed, advancing mechanization and labor-saving in the production of vegetables grown outdoors and improving the production base for crops grown on drained paddy fields. Additional developments include *Yumewarabe,*[68] a short-leaf Welsh onion variety whose cultivation period is short (thus, saving labor) and which also satisfies consumer needs; and *Akimeki,*[69] a Chinese cabbage variety resistant to multiple diseases including clubroot (using DNA marker-assisted breeding).[70]



Sorting on the machine, removal of unnecessary outer leaves, and loading into large containers.

【Cabbage harvester】

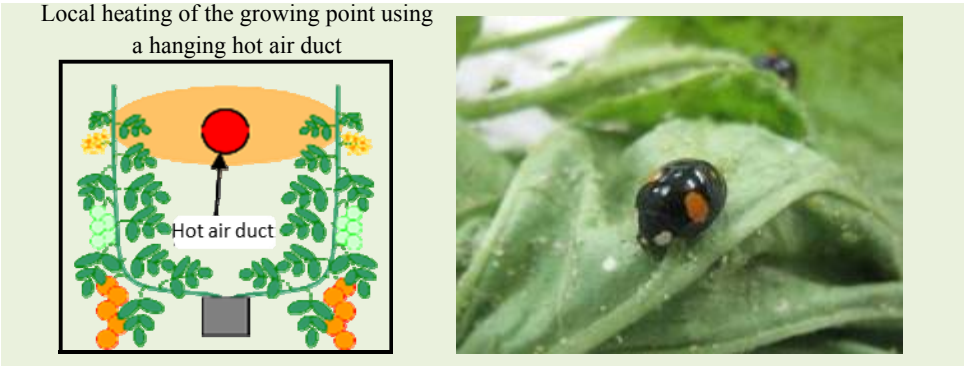
To promote the future establishment of a system of production and distribution that precisely responds to the trends in vegetable demands, including increasing demands for those used in processing and manufacturing, we will promote breeding new varieties of cabbage and other crops. This aims to eliminate periods of short supply; develop cropping types suitable for the characteristics of those varieties; further improve the mechanized continuous work system; and develop the system for coordinating shipments with which fixed quantities are shipped by production areas that share growth prediction information using cloud services. Additionally, we will promote research and development focusing on functionality as well as the quality and

[65] The labor-saving and low-cost harvest system that combines cabbage harvesters with large containers: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/brain/042659.html
[66] Manual for using the FOEAS for paddy rotation cropping: http://www.naro.affrc.go.jp/narc/contents/foeas/
[67] The system for automating the root- and leaf-cutting process of onions: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/brain/018126.html
[68] *Yumewarabe*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/vegetea/041824.html
[69] *Akimeki*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/vegetea/015515.html
[70] DNA marker-assisted breeding: This breeding technique uses a DNA marker that is a DNA sequence with a known location on the genome and can be used as a landmark for a useful gene on the genome.

freshness of domestic vegetables. This further utilizes their strengths through the development of reduced pesticide cultivation techniques using LED and natural enemies; the breeding of vegetable varieties rich in functional substances such as carotenoids;[71] the establishment of a cultivation system for quantitatively controlling the content level of such components; and the development of freshness retaining technologies and low-cost transportation technologies, among others.

(7) Development of Models of Next Generation Greenhouse Horticulture, Realizing Energy and Labor-Saving Technologies and High Yield

Soaring oil prices and increased resistance of pests to agrochemicals have become serious problems associated with greenhouse horticulture. Recently obtained research results on these issues include the development of a local heating technique[72] that cuts fuel costs by locally heating around the shoot apex of tomatoes and other vegetables; the breeding of a flightless strain of the ladybird beetle, *Harmonia axyridis*,[73] for controlling aphids in greenhouses; and the publication of a manual for controlling eggplant pests using native natural enemies.[74] Additionally, labor-saving and cost-reduction technologies have advanced, as evidenced in the development of the strawberry harvester robot[75] that harvests strawberries 24 hours/day by automatically detecting their color; and the breeding of *Anominori 2*,[76] a parthenocarpic eggplant variety not requiring artificial pollination. Cultivation techniques that do not rely on methyl bromide[77] (soil disinfectant; as an ozone-depleting substance, phased out until 2012 in Japan) were established through advancements such as new varieties of stocks resistant to soil-borne diseases. These have been introduced to vegetables such as eggplants and green bell peppers grown in greenhouse facilities.



【Local heating technique】 【Flightless strain of ladybird beetle (*Harmonia axyridis*)】

[71] Carotenoids: A group of natural pigments that widely occurs in plants, animals and microorganisms having yellow, red, purple or rarely blue binding proteins.
[72] Local heating technique: http://www.naro.affrc.go.jp/project/results/laboratory/vegetea/2010/vegetea10-09.html
[73] Lady beetles that cannot fly (multicolored Asian lady beetles): http://www.naro.affrc.go.jp/publicity_report/season/042309.html
[74] Manual for controlling eggplant pests using native natural enemies: http://www.nrs.pref.yamaguchi.lg.jp/hp_open/a172010/00000003/露地ナス土着天敵活用マニュアル.pdf
[75] Strawberry harvesting robot: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/brain/046905.html
[76] *Anominori 2*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/vegetea/053978.html
[77] Cultivation methods that do not rely on methyl bromide:

In the future, we will promote development of the model of next generation greenhouse horticulture (which includes plant factories) aimed at achieving energy conservation, labor-saving and producing high-yields in an integrated manner using various sensing technologies and cloud services while considering the climate characteristics of Japan (e.g., frequent occurrence of typhoons; high temperatures and high humidity in summer). To this end, we will work on developing an efficient heating technology that utilizes geothermal or other renewable heat sources; an advanced environmental control technology that controls temperature, humidity and CO_2 at different growth stages; and reduced pesticide cultivation techniques that utilize LED illumination and/or natural enemies. In addition, we aim to breed new varieties suitable for greenhouse horticulture and establish high-yield cultivation systems, among other items.

(8) Development of Labor-Saving and Fast Orchard Establishment Techniques for High-Quality Fruits that Support Orchard Scale Expansion

Regarding fruit trees, the power assist suit for farm work[78] has been developed. This is a wearable robot that reduces the burden of loading/unloading harvest containers or other work. A Japanese pear variety called *Rinka*[79] that can be stably grown in warm regions; *Mori-no-kagayaki,*[80] a yellow apple variety for which leaf removal for inducing even-coloring is not necessary; and *Mihaya,*[81] a peel puffing-resistant citrus variety have been successfully bred. In addition, as evidenced in the development of the technique for controlling spider mites in mandarin orange fields using native natural enemies and the technique for curing white root rot (soil-borne disease) using hot water,[82] the transition to environmentally friendly farming is gradually progressing.

【Power assist suit】

【*Mori-no-kagayaki* (yellow apple variety)】

http://www.naro.affrc.go.jp/publicity_report/press/laboratory/narc/044566.html

[78] Power assist suit for farm work: http://www.wakayama-u.ac.jp/~eyagi/roboticslab/

[79] *Rinka*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/fruit/049431.html

[80] *Mori-no-kagayak*i: http://www.naro.affrc.go.jp/org/fruit/kih/data/ringo/morinokagayaki.html

[81] Mihaya: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/fruit/030082.html

[82] Manual for treating white root-rot using hot water (devised): http://www.naro.affrc.go.jp/publicity_report/publication/files/onsuitiryou_man_2013.pdf

The decreasing number and aging of producers and the impacts of global warming are expected to worsen in the future. Therefore, to allow the principal farmers to continue expanding their operation scales and engage in carefully crafted quality management, we will further develop labor-saving tree canopies and cultivation systems (early fruiting techniques) in accordance with the characteristics of individual tree species. We will also develop labor-saving harvesting and transportation techniques; breed new varieties that can withstand increased global warming; establish stable production techniques that consider the characteristics of those varieties; and develop pest control techniques that utilize native natural enemies.

To keep up with the changes in consumer demands and the expansion of exports, we will promote breeding of new varieties with superior processing suitability (e.g., the apple that does not turn brown after cutting); application of the peeling technique that uses an enzyme[83] for various fruits; and the development of long-term storage technologies and freshness retention technologies to enable year-round supply of fruits.

(9) Development of Techniques to Breed Various Flower Varieties and to Preserve Quality during Transportation

Breakthrough results have been obtained in flower breeding, including the breeding of *Karen Rouge,*[84] the world's first carnation variety with resistance to bacterial wilt that can cause serious damage to carnation cultivation; and breeding of the fluorescent *Torenia fournieri*,[85] whose petals exhibit fluorescence, using genetic recombination technology. Additionally, as a technique for reducing heating cost of facility cultivation in winter, the EOD-heating treatment technique[86] (heating/lighting cost is reduced by brief heating or the irradiation of far red light immediately after sunset) has been developed and put to practical use.

【*Karen Rouge*】

【Fluorescent torenia】

[83] The peeling technique that uses an enzyme: http://www.naro.affrc.go.jp/fruit/kousohakuhi/index.html
[84] Karen Rouge: http://www.naro.affrc.go.jp/project/results/research_digest/digest_kind/flower_vegetables/027310.html
[85] Fluorescent torenia: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/flower/048489.html
[86] EOD-heating treatment: http://www.naro.affrc.go.jp/project/results/laboratory/flower/2010/flower10-01.html

In the future, to further strengthen Japan's strength in variety development and to develop new demands for international and domestic markets, we will promote the breeding of various flower varieties that meets market needs by identifying genes associated with flower colors, shelf life and disease resistance. We also plan to develop DNA markers for such genes, breed the mother plants and then swiftly transfer such technologies to private breeding companies. We will contribute to flower exports by developing quality-preservation and transportation techniques along with other techniques/technologies.

(10) Establishment of Dairy Farming System, Allowing Labor-Saving and Precision Livestock Farming

Research and development in dairy farming aimed at strengthening the domestically produced forage base nationwide are progressing, as seen in the development of the manual on feed preparation and supply[87] (following the identification of maximum supply levels for feed rice, etc.) and the breeding of *Tachiayaka*,[88] a whole crop silage (WCS) rice variety with high contents of forage and water soluble carbon (WSC) that are easily digestible by cattle.

Moreover, research findings contributing to the boosting demands for dairy products have been obtained. These include the development of parameters for judging the genetic capacity of dairy cattle with high lactation persistency (the ability to sustain peak milk yield),[89] a new mastitis prevention drug[90] and Lactococcus lactis H61,[91] a strain of lactic acid bacteria with moisture enhancing effects for the skin.

【*Tachiayaka*: WCS rice variety】

As the number of dairy farmers is expected to continue decreasing, thus creating the need to further expand the scale of operation to maintain raw milk production nationwide, we will promote the

[87] Manual on feed preparation and supply: http://www.naro.affrc.go.jp/nilgs/project/jiky_pro/029451.html
[88] *Tachiayaka*: http://www.naro.affrc.go.jp/project/results/laboratory/warc/2011/120a0_10_01.html
[89] Parameters for judging the genetic capacity of dairy cattle: http://www.naro.affrc.go.jp/project/results/laboratory/harc/2012/130f0_01_15.html
[90] New mastitis prevention drugs: Mastitis prevention drugs with different action mechanisms from those of antibiotics are on the market.
[91] Lactococcus lactis H61: http://www.naro.affrc.go.jp/project/results/laboratory/nilgs/2012/310c0_01_55.html

development of an accurate husbandry system with milking robots at its core. This reproduction management technology uses the estrus detection sensor designed to increase conception efficiency, technology for judging the capacity of semen to be used for artificial insemination, technology for identifying diseased animals using wear prevention and accident rate reduction sensors and highly effective mastitis vaccines.

We will continue promoting research and development aimed at strengthening the domestically produced forage base by establishing a labor-saving pasture management system and a system for producing and using new self-supplying concentrated feed such as ear-corn.[92] We will identify functional substances contained in dairy products, thereby contributing to boosting their demands.

(11) Establishment of Efficient Breeding and Fattening System for Beef Cattle Based on Self-Supplying Forage

For beef cattle, there is a need for a grazing-based labor-saving production system that also uses domestically produced feed as much as possible. Therefore, a manual for the integrated grazing system for scattered small pasture,[93] an approach to grazing that allows year-round outdoor rearing of animals by combining the cultivation of feed rice in paddy fields with the conversion of abandoned cultivated land to grassland, has been developed as a fattening method for Japanese Brown Cattle steers through year-round grazing.[94] Measures against livestock diseases that can affect the productivity of beef cattle farming have also advanced with the commercialization of a highly sensitive genetic diagnosis kit for Johne's disease,[95] an important disease affecting cattle, and the development of improved vaccines for preventing abnormal labor due to Akabane disease.[96]

【Forage rice grazing in paddy field】

【Genetic diagnosis kit for Johne's disease】

[92] Ear-corn: Also known as corn on the cob.
[93] Manual on the integrated grazing system for scattered small pasture: https://www.naro.affrc.go.jp/project/results/laboratory/warc/2009/wenarc09-04.html
[94] Fattening method for Japanese Brown Cattle steer by year-round grazing: http://www.naro.affrc.go.jp/project/results/laboratory/karc/2010/konarc10-25.html
[95] Johne's disease testing manual: http://www.naro.affrc.go.jp/niah/disease/files/NIAH_yone_kensahou_130329.pdf
[96] An improved vaccine for preventing abnormal labor due to Akabane disease: Vaccines effective against a wide range of viruses are available on the market.

To strengthen the stable production system of Wagyu based on the domestically produced forage base, we will in the future promote the field demonstration of a regional division type large-scale breeding system in which contract feed producers collaborate with TMR[97] centers that prepare feed and calf fattening centers. We also plan to endorse the sophistication of pasture management techniques for year-round grazing; breed ultra-high-yielding feed rice varieties with a unit yield of one ton; establish labor-saving and low-cost cultivation systems that consider variety characteristics; and develop technologies for identifying diseased animals using sensors for preventing attrition and reducing accident rate, bovine leukemia early identification technologies and new vaccines for bovine viral diarrhea and mucosal disease, among others.

Moreover, we will support the local branding of beef cattle by developing added-value parameters other than marbling, such as deliciousness and methods for measuring them.

(12) Establishment of Swine and Poultry Farming Models to Make Maximum Use of Domestic Feed Ingredients

The farming of pigs and poultry relies heavily on imported feed. Therefore, to strengthen the supply base of domestically produced feed, two varieties have been developed: *Iwaidawara,*[98] a high-yield feed rice variety with a yield of 800 kg/10 a (for the Tohoku Region); and *Kanto 264*, a high-yield feed rice variety with a yield of 900 kg/10 a (for the Kanto Region and westward). A manual that sets maximum supply levels of feed rice in pig and poultry farming[99] has also been created.

Developments in pig farming include a new artificial insemination technique using frozen semen[100] and a quick and sensitive genetic testing technique to detect European porcine reproductive and respiratory syndrome (PRRS)[101] virus. A new testing technique for highly pathogenic avian influenza[102] has been developed for poultry farming, shortening the procedure to four hours (conventionally requiring over 24 hours).

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[97] TMR (total mixed rations): Mixed feed containing all necessary nutrients such as roughage, concentrated feed, minerals, vitamins and additives. TMR has an advantage of allowing low-cost production of high-quality feed based on the design of the mix.

[98] *Iwaidawara*: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/tarc/048878.html

[99] Manual that sets maximum supply levels of feed rice: http://www.nrs.pref.yamaguchi.lg.jp/hp_open/a172010/00000003/飼料用米の栽培・給与マニュアル.pdf

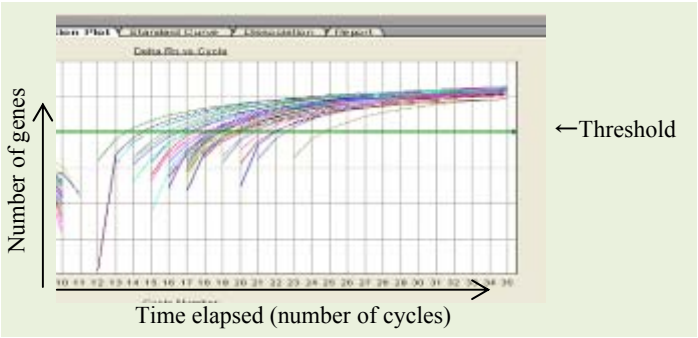
[100] Artificial insemination technique using frozen semen: http://www.s.affrc.go.jp/docs/researcher_praise/pdf/h22_okazaki.pdf

[101] Quick and sensitive genetic testing technique to detect porcine reproductive and respiratory syndrome (PRRS) virus: https://www.jstage.jst.go.jp/article/jvms/76/10/76_14-0010/_pdf

[102] New testing technique for highly pathogenic avian influenza: http://www.s.affrc.go.jp/docs/project/information/pdf/torihuru-seika2.pdf

Variety	Rough brown rice weight (kg/10 a)
Kanto 264	940
***Takanari* (conventional variety)**	877

【Kanto 264: Feed rice variety】



【Quick testing technique for avian influenza virus】
*Level above the threshold (green line) is considered positive.

To respond to future reduced productivity due to livestock diseases and offensive odors while using local resources including feed rice and "eco-feed"[103] as much as possible, we will promote the breeding of ultra-high-yield feed rice varieties with a unit yield of one ton; the establishment of labor-saving and low-cost cultivation systems that consider variety characteristics; the differentiation of animal products (e.g., by increasing oleic acid content of meat); the development of new feeding methods for value addition; and the development of technologies for identifying diseased animals using sensors for preventing attrition and reducing accident rate, new vaccines for diseases such as PRRS, a quick diagnosis technique for porcine epidemic diarrhea and a technology for reducing offensive odor during manure treatment.

(13) Development of Techniques that Strike a Balance between Production Efficiency and Environmental Conservation, and Visualization of Introducing their Benefits

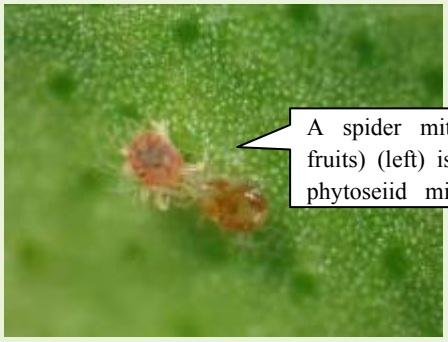
To promote environmentally conscious sustainable farming, several biological and physical pest control techniques not reliant on chemicals were developed under the previous Basic Plan. These include the flightless strain of the ladybird beetle, *Harmonia axyridis*, used for controlling aphids in vegetable cultivation in greenhouses; a technique for controlling spider mites in mandarin

[103] "Eco-feed": Feed made from food residues.

orange fields using native natural enemies;[104] and a technique for controlling paddy field weeds using rice bran.[105]

With the aim of reducing chemical fertilizer use, a vegetable transplanting machine equipped with a spot fertilizer applicator[106] was developed, reducing fertilizer use in outdoor vegetable cultivation by more than 50%. Other developments include a local fertilizer applicator for tea to prevent groundwater pollution caused by nitrate nitrogen[107] and a technology for converting pig manure into a phosphate fertilizer substitute by carbonization treatment.[108] Additionally, development of "biodiversity indicators"[109] used for measuring biodiversity based on the status of particular characteristic species identified to constitute the ecosystem in a region is ongoing.

【Pig manure carbonization system】



A spider mite (pest to citrus fruits) (left) is being eaten by a phytoseiid mite (native natural

【Pest control using natural enemies】

To continue approaching ecological farming that considers environmental conservation and biodiversity, we will push several advances. These include developing agrochemicals with minimum effects on non-target organisms and techniques for using the agrochemicals; developing pest control techniques using native natural enemies and artificial light; and improving conditions that allow the application of IPM for various crops with a desirable balance between farming efficiency and environmental conservation. We also promote the development of simple soil diagnosis techniques allowing farmers to manage their fertilization use levels in accordance with soil fertility and other factors.

We will also develop evaluation indicators with which the introduction benefits of such techniques/technologies can appeal to farmers and consumers in an easy-to-understand way.

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[104] Spider mite controlling technique: http://www.naro.affrc.go.jp/karc/prefectural_results/byougai/025818.html
[105] Technique for controlling paddy field weeds using rice bran: http://www.naro.affrc.go.jp/org/narc/seika/kanto13/05/narc0105g34.html
[106] Planter equipped with a spot fertilizer applicator: http://www.s.affrc.go.jp/docs/project/genba/pdf/120112_22301.pdf
[107] Local fertilizer applicator for tea: http://www.agri-exp.pref.shizuoka.jp/photo00024.html
[108] Technology for converting pig manure to phosphate fertilizer substitute: http://www.pref.ibaraki.jp/nourinsuisan/noken/seika/h22pdf/documents/gj6.pdf
[109] Survey and evaluation manual on biodiversity indicator species useful for agriculture: http://www.niaes.affrc.go.jp/techdoc/shihyo/index.html

Expansion of farm crops produced using environmentally friendly agricultural practices will also be promoted.

(14) Advancement of Technologies for Forestry Utilization and Development of New Demands for Forestry Products

We developed a continuous work system for the Kyushu Region ranging from land preparation with extraction machines to logging/planting with container seedlings to support the logging of planted forests that are ready to be logged and the subsequent reforestation of such forests. To promote the use of domestic logs, we also developed manufacturing and processing technologies for cross-laminated timbers (CLTs),[110] which are increasingly used for the walls and floors of mid- to high-rise wooden buildings in Western countries. These are tailored to the characteristics of domestic cedar logs[111] and the strength performance of such CLTs ("Japanese version of CLTs") was determined, thereby contributing to the establishment of the Japanese Agricultural Standard. Other advancements include the development of wooden single-layer trays[112] using logging residues as a substitute raw material for plastic food containers; the breeding of various low/no-pollen cedar varieties[113] suitable for local conditions; and the development of second-generation plus trees[114] for increasing yield and streamlining reforestation and breeding.

Photo: Courtesy of Forestry and Forest Products Research Institute

【Appearance of a cedar CLT】

Low-pollen cedar

Photo: Forest Tree Breeding Center, Forestry and Forest Products Research Center

Normal cedar

【Low-pollen cedar variety】

In the future, it will be necessary to continue recycling forest resources and fully utilize the multifunctionality of forests in a sustainable manner. This can be done through practicing wood demand-based systematic logging as well as efficient and reliable reforestation; by reducing the cost and labor of forest management practices; and by creating new demands for wood and forest

[110] CLT: Cross Laminated Timber: A new wood product developed in Europe. CLT is a thick panel consisting of multiple layers of lumber where the adjacent layers are cross-oriented and bonded with adhesive.
[111] Manufacturing and processing technologies tailored to the characteristics of domestic logs: https://www.ffpri.affrc.go.jp/pubs/seikasenshu/2014/documents/p16-17.pdf
[112] Wooden single-layer tray: Thin veneers 1–2 mm thick and containing moisture are molded using a hot press without any adhesives.
[113] Low/no-pollen cedar varieties: https://www.ffpri.affrc.go.jp/press/2013/20130321.html
[114] Second generation plus trees: Plus trees with superior growth selected from trees obtained by crossing plus trees with good growth and material traits.

products.

To this end, we will promote the establishment of efficient logging practices according to geographical conditions; the application of robot technology to forestry; the development of a low-cost reforestation technology using container seedlings; the development of a technique for producing forestry seedlings with superior growth in a short time; and the establishment of a system for converting a conifer forest into a broad leaved forest, thus contributing to the promotion of diverse forest development. In addition, to create new demands for wood and forest products, we will endorse the development of new wooden components and construction methods (e.g., CLTs); the development of techniques for using large-diameter logs based on the growth conditions of Japan's forest resources; research on quantifying the meanings of wood use; and the development of forest products such as mushrooms and new amenity products using tree components.

(15) Technological Development for Realizing Attractive Fisheries and Aquaculture

In response to a decline in fishery resources and the tightening of international fishing regulations, we have successfully collected the eggs of bluefin tuna and the Japanese eel. We reared[115] the hatched fish for the first time in the world, an important initial step toward their full life-cycle aquaculture. Based on the expected growth in future exports of yellowtails, an early shipment technology using hatchery-reared fries[116] has been developed to avoid summer red tide damage and is increasingly used by fish farmers. In the field of vessel-based fishery, advancements have been made in areas such as the practical application of LED fishing light[117] and the release of *Dr. Shoene*[118] (Dr. Energy-Saving), a software platform fishermen can use on their smartphone to estimate fuel-efficiency.

【School of bluefin tuna juveniles hatched in a water tank】

【A leptocephalus of Japanese eel】

[115] Collection of the eggs of bluefin tuna and Japanese eels and the rearing of the hatched fish: http://www.s.affrc.go.jp/docs/report/report26/no26_p3.htm
[116] Early shipment technology that uses hatchery-reared fish: http://www.maff.go.jp/j/pr/aff/1303/spe1_03.html
[117] LED fishing light: Fishing light that uses light emitting diodes.
[118] Software "*Dr. Shoene*": http://ecofish.job.affrc.go.jp/

In the future, to transform the current fishing industry suffering from the aging and shortage of its principal operators into an attractive industry, we will promote several advances. These include the development of mass production technologies for hatchery-reared seedling fish used to realize the full life-cycle aquaculture of bluefin tuna and Japanese eels; the breeding of various fish species such as yellowtails for aquaculture and the development of seedling fish mass production technologies for those species; the development of energy and labor-saving technologies for vessel-based fishery as well as for the processing and distribution stages of fishery products; the sophistication of safety and quality control technologies; and the breeding of heat-tolerant seaweed species that can endure global warming.

(16) Technological Development for "Affrinnovation" Contributing to Local Employment and Income Growth

In the area of AFFrinnovation[119] technologies, a wide range of research results have been obtained. These create new strengths in domestic agricultural, forestry and fishery products, develop high-value added processed food products in collaboration with local food businesses and contribute to establishing the value chain from producers to consumers. Examples include identifying functions of the components of domestic agricultural products such as β-cryptoxanthin[120] found in *Citrus unshiu* and methylated catechin[121] found in green teas; the search for lactic acid bacteria with skin moistening effects;[122] the development of "rice gel"[123] made by cooking and gelatinizing rice under special conditions that can be used as an ingredient in cakes and bread; and the breeding of a new sweet potato variety with a low-temperature gelatinization property.[124]

Advances have been made in bioethanol technologies. Developments include a method for producing ethanol from reducing sugar, which is produced as an inhibitor during the process of producing and refining sugar from sugarcanes. This represents the world's first technology for efficiently producing sugar and bioethanol simultaneously.[125]

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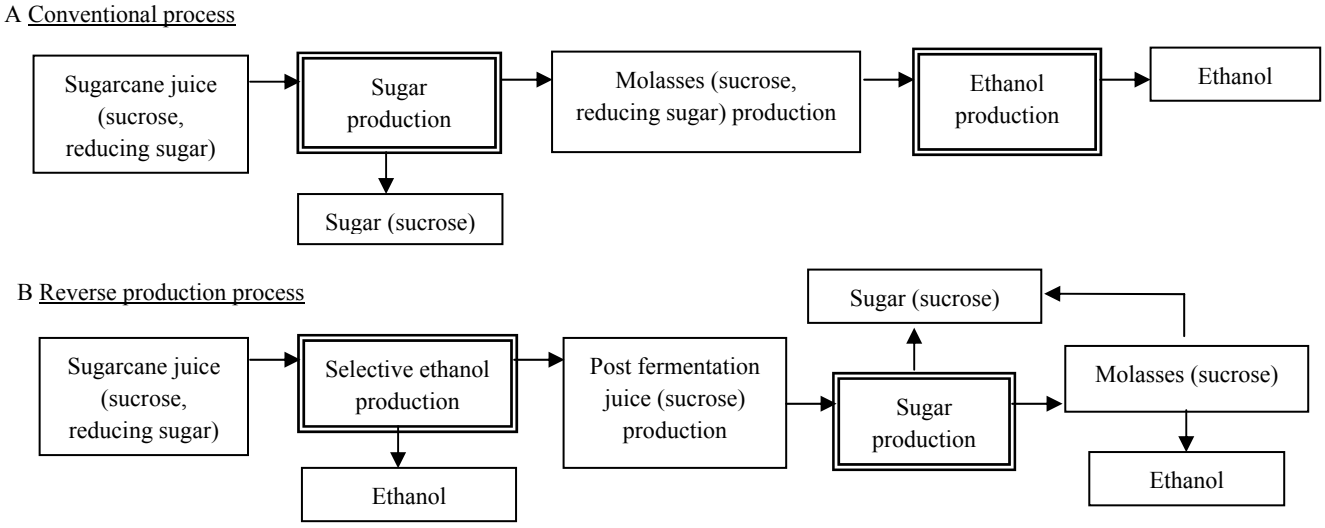
[119] AFFrinovation: abbreviation of invented terms Agrinovation, Forestinovation and Fisherinovation. This means adding value to agriculture, forestry and fishery products in innovative ways by making new combinations and creating a value chain.
[120] β-cryptoxanthin: One of six main carotenoids found in human blood believed to contribute to promoting human health.
[121] Methylated catechin: A type of polyphenol found in tea leaves and abundant in tea varieties *Benifuuki*, *Benifuji* and *Benihomare*.
[122] Lactic acid bacteria with skin moistening effects: http://www.naro.affrc.go.jp/project/results/laboratory/nilgs/2012/310c0_01_55.html
[123] Rice gel: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/nfri/048823.html
[124] A sweet potato variety with new starch properties: http://www.naro.affrc.go.jp/patent/breed/0100/0102/001538/index.html
[125] A technology for efficiently producing sugar and bioethanol simultaneously: http://www.naro.affrc.go.jp/publicity_report/press/laboratory/karc/013017.html



【Simultaneous production of sugar and ethanol】

Based on the future implementation of the new functional labeling system in food products and in collaboration with medical practitioners, we will promote investigation into the functional components found in various agricultural, forestry and fishery products such as rice, cereals, soybeans and vegetables. We will also endorse the development of new varieties with such strengths as well as products such as unique fermentation foods in collaboration with local food businesses.

To promote processed food products to which high values are added making use of local resources, we will promote the wider application of enzymatic peeling technologies for cut fruits in collaboration with local food businesses and other entities. We plan to support the development of functional silk materials with properties similar to those of light and strong spider threads as well as seedling propagation technologies for local traditional vegetables.

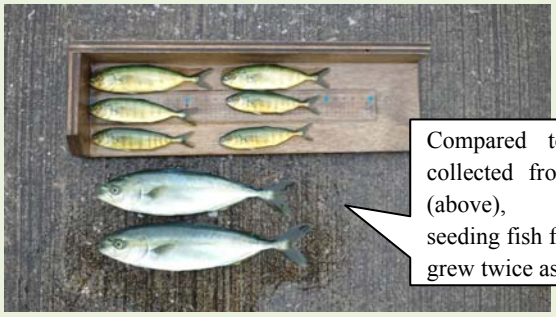
(17) Development of Export-Related Technologies for Supporting the Realization of Country-by-Country and Item-by-Item Export Strategy for Agriculture, Forestry and Fishery Products

Regarding the promotion of exporting agricultural, forestry and fishery products, advancements include the development of a cyclone suction cleaner[126] that removes pests using wind and water pressures and functions as a pest control machine used for producing organic tea for export; a pest control system model using the IPM of tea based on residual chemical standards in export destinations; a freshness retention technology for supporting the overseas export of gentians;[127]

[126] Cyclone section cleaner: http://www.maff.go.jp/j/seisan/gizyutu/hukyu/h_zirei/2013/pdf/83_kgsm_cy_clone.pdf
[127] Freshness retention technology for gentians: http://www2.pref.iwate.jp/~hp2088/repo/h22/repo_545.html

and an early shipment technology for yellowtails used for avoiding the red tide damage to export this fish.[128]

【Cyclone suction cleaner】



【Early shipment technology for yellowtails】

In accordance with the export strategies for specific countries and items formulated in 2013 and in response to specific technical quarantine and export-related problems, we will promote the future establishment of cultivation methods and processing technologies meeting the animal and plant quarantine rules and the residual chemical standards in export destinations. In addition, we will support the development of new transport and preservation technologies allowing the export of high-quality domestic agricultural, forestry and fishery products by sea without freshness loss; the breeding of aquaculture fish such as yellowtails and amberjacks, which are expected to grow in export demand; producing new flower varieties; and the development of fry supply technologies.

(18) Development of Techniques to Improve Food Safety and to Control Pests and Diseases in Animals and Plants

To reduce various health risks associated with agricultural, forestry and fishery products from production, distribution, processing and retail sites, we have developed, for example, a rice variety that absorbs little cadmium[129] during its growth; as well as a testing technique that can simultaneously detect multiple food poisoning bacteria including O157 (enterohemorrhagic *E. coli*) and salmonella.[130]

Other advancements include the development of plant vaccines against viruses infecting green bell and chili peppers;[131] rapid and sensitive genetic analyses for detecting highly pathogenic avian influenza and *European* genotype PRRS virus and new mastitis drugs to prevent occurrence and prevalence of livestock diseases.

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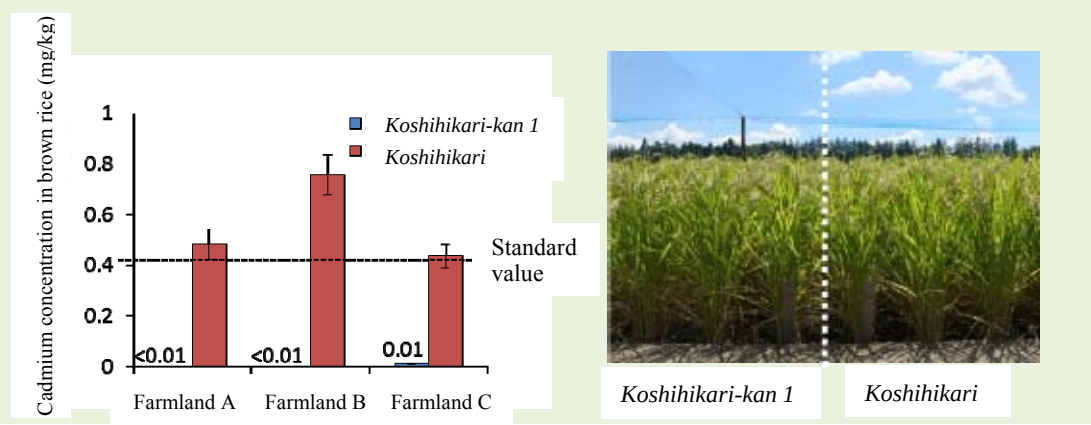
[128] Early shipment technology for exporting yellowtails: http://www.s.affrc.go.jp/docs/project/2014/project_2014_1.htm
[129] Rice variety that absorbs little cadmium during growth: http://www.niaes.affrc.go.jp/techdoc/press/140130/
[130] Testing technique to simultaneously detect multiple food poisoning bacteria: http://www.naro.affrc.go.jp/collab/cllab_report/docu/report05.html
[131] Plant virus vaccines: http://www.naro.affrc.go.jp/project/results/laboratory/narc/2012/152a0_01_25.html



【Development of *Koshihikari-kan 1*, a rice variety that absorbs little cadmium during growth】

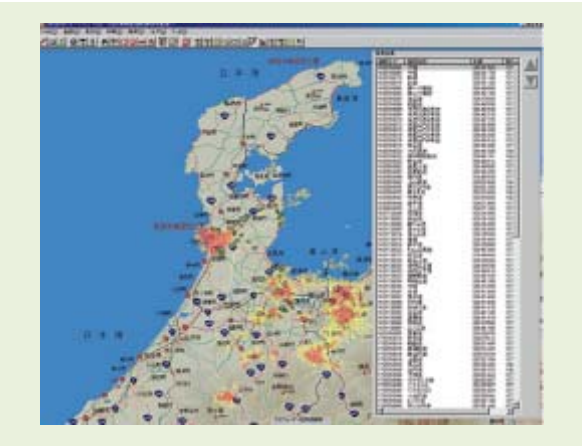
Considering that livestock diseases and pests can strongly influence the foreign trade of farm products, and taking the international code of practice and standard values by the Codex Alimentarius Commission and OIE into account, we will systematically promote the future development of technologies for reducing arsenic concentration in rice; those for managing the risk of toxic substances such as mycotoxins in cereals, acrylamide in processed food and hazardous organisms such as O157 and Campylobacter; the development of monitoring technologies for supporting efforts by small- to mid-size food businesses to implement HACCP.[132] We examine the effects of "farm HACCP"[133] by comparing the results of enforcing or not enforcing farms and evaluate its effective factors. We are also developing prevention techniques for emerging pests from overseas, learning how to diagnose foot-and-mouth diseases and developing vaccines against highly pathogenic avian influenza.

(19) Development of Efficient Farm Water Management Technologies, Effective Technologies for Maintenance and Management of Agricultural and Rural Infrastructure, and Information System for Natural Disaster Prevention and Reduction for Rural Areas

In response to the aging agricultural infrastructure such as waterways and irrigation ponds, a simple repair technology[134] allowing farmers and local residents to independently repair waterway leakages has been developed. Another advance involves a disaster prevention system[135] that

[132] HACCP: A system for food business operators to predict hazards such as microbial and metal contamination (and analyze hazard factors) during all stages from the ingredient acceptance to final product stages. It also allows continuous monitoring and recording of importance processes leading to hazard prevention (critical control points).
[133] Farm HACCP: An approach to controlling hazards at farms by setting control points for preventing the occurrence of hazards (microorganisms, chemicals, abnormal substances, etc.) based on the HACCP concepts, aiming to improve hygiene management at livestock farms.
[134] Simple repair and management technology: http://www.naro.affrc.go.jp/disaster/ad_tec/tec0100/tec0102/018221.html
[135] A disaster prevention system that automatically transmits the break risk of irrigation ponds and predicted flood areas: http://www.naro.affrc.go.jp/disaster/ad_tec/tec0100/tec0102/018223.html

estimates the break risk of irrigation ponds during a heavy rain or an earthquake and automatically transmits information to the manager.



【A disaster prevention system predicting the break risk of irrigation ponds during a heavy rain and an earthquake】

With the increasing necessity for labor-saving and efficient maintenance/management of agricultural and rural infrastructure, we will promote the future development of remote control and automation technologies for water management in paddy fields that use ICT and robot technology. We also support creation of labor-saving sensing technologies for non-destructive testing and evaluation as well as repair and reinforcement technologies for the difficult-to-access sections of agricultural and rural infrastructure.

Considering the rising trend in natural disasters such as heavy rains and earthquakes in recent years, we will develop a real-time hazard prediction technology for rural infrastructure including irrigation ponds and develop a rapid communications system for early warning information on disasters.

(20) Establishment of Effective and Efficient Damage Control Techniques according to Wildlife Characteristics

Damages to agriculture, forestry and fishery products caused by wildlife are having serious impacts on rural communities. For example, they reduce the motivation of operators in those industries and increase the amount of abandoned cultivated land. Such damage is estimated at 20 billion yen per year, affecting 9,000 ha of forests in 2013 and impacting the fisheries industry by feeding on caught fish and damaging fishing equipment.

Therefore, using ICT, various sensor technologies and drugs, we will establish community-wide damage control technologies by developing efficient and effective damage control technologies. We will also develop wildlife trapping and control technologies according to specific wildlife

species (e.g., deer, boars, monkeys, great cormorants) and the behavioral characteristics of target animal populations.

In addition, we will develop technologies for enabling the effective use of wildlife as a resource (e.g., game animals such as deer and boar) by establishing efficient wildlife processing methods.

(21) Solutions to Technical Problems Hampering the Resumption of Farming and Forestry Work of the Affected Farming or Forestry Households and Fishery Operation of the Affected Fishery Households

To support the resumption of operation by agricultural, forestry and fishery business operators affected by the Great East Japan Earthquake, we have been strenuously making efforts in collaboration with concerned people and organizations in affected areas. These efforts include the demonstration of large-scale, land-extensive farming using cutting-edge technologies in affected areas;[136] the demonstration of sophisticated technologies in facility horticulture aimed at reviving a horticultural facilities complex;[137] the demonstration of the introduction of cutting-edge technologies to fishery and aquaculture facilities;[138] the establishment of decontamination technologies for farmland contaminated with radioactive cesium;[139] the development of technologies for reducing the absorption (transfer) of radioactive materials to crops such as rice and mushrooms;[140] the development of technologies for reducing the volume of agricultural and forestry waste including contaminated rice straw;[141] and the implementation of research on the movement of radioactive materials into marine organisms in coastal and offshore waters.[142]

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[136] Demonstration of large-scale land-extensive farming: http://www.ais-sentan.jp/pamphlet/H24pamphlet%20PDF/H24-1-01.pdf
[137] Demonstration of facility horticulture sophistication technologies for reviving a horticulture facilities complex: http://www.s.affrc.go.jp/docs/research_fund/pdf/03h23-horticulture.pdf
[138] Demonstration of the introduction of cutting-edge technologies to fishery and aquaculture facilities: http://www.iwate-suigi.jp/subject/upimg/1362625573_01.pdf
[139] Establishment of farmland decontamination technologies: http://www.s.affrc.go.jp/docs/press/110914.htm
[140] Technologies for reducing the absorption (transfer) of radioactive materials: http://www.pref.ibaraki.jp/bukyoku/nourin/noken/seika/H23%20PDF/G3.pdf
[141] Technologies for reducing the volume of organic wastes: http://www.naro.affrc.go.jp/project/results/laboratory/narc/2012/510a0_02_72.html
[142] Research on the movement of radioactive materials to marine organisms: http://www.jfa.maff.go.jp/j/sigen/housyaseibussitutyousakekka/pdf/digest.pdf

【Farmland decontamination technology】

【Horticultural facility for demonstration studies (Yamamoto-cho, Watari-gun)】

【Local heating technology for strawberry crowns】

In the future, to help agricultural, forestry and fishery business operators affected by the nuclear disaster resume their work as soon as possible, we will conduct studies on the dynamics of radioactive materials in forests and the prediction of their impacts on nearby farmland and field crops via rivers. We will also aim to develop scientific indices used by farmers to resume their normal operation and judge the timing of ending potassic fertilizer application that has been done to reduce the adsorption of radioactive cesium by crops; develop technologies for reducing the absorption of radioactive materials by crops in which radioactive cesium levels still exceed the standard levels; create grassland decontamination technologies for difficult-to-plow land such as steep slopes; and generate technologies for promoting the treatment of contaminated wastes. We will also continue to investigate the movement of radioactive materials into marine organisms in coastal, offshore and inland waters.

2. Research and Development to Be Steadily Promoted under Medium- to Long-Term Strategy

Several significant problems should be addressed from medium- to long-term viewpoints. These include progress in adapting to global warming; changes in consumption trends associated with the falling birth rate/aging population; depletion of natural resources and energy; and the epidemic of transboundary infectious diseases. Thus, 11 key targets have been set under the following six basic directions of agricultural, forestry and fishery research:

To promote future research and development, we will set clear milestones for individual key targets for the next five and 10 years; create the paths and research and development activities toward attaining the goals in a road map; and promote necessary research and development comprehensively and systematically while consulting the agriculture, forestry and fishery producers, relevant industries and outside experts. Regarding particularly important research and development themes, and in accordance with current policy needs, we will comprehensively collect and analyze research and development information domestically and from abroad, including information possessed by private companies and universities. We will also develop appropriate research and development strategies for promoting necessary research and development in a focused and strategic manner.

[Stably Supplying Safe and Reliable Food, thereby Contributing to the Health and Longevity of People]

The population of Japan has been on the decline after peaking in 2008. The proportion of elderly citizens (65 years or older) is expected to exceed 30% in 10 years (2025),[143] representing the world's most aged society.

With further aging of the population, women's social advancement and an increase of single households, more people are expected to eat out, eat simple meals and eat individually. To continue stably supplying safe and reliable food to consumers, we need to sophisticate our food safety management in accordance with circumstantial changes.

In response to rising health consciousness among people, the markets of various food services aimed at preventing lifestyle-related diseases, nutrition and functional foods, or care foods are expected to grow in the future. This requires increased scientific knowledge on the nutrition and functions of food products and the development of basic technologies supporting such emerging food businesses.

[143] Website of the Ministry of Internal Affairs and Communications: http://www.stat.go.jp/data/topics/topi721.htm

Furthermore, in response to the international popularization of Japanese food following its addition to the UNESCO's Intangible Cultural Heritage list in December 2013,[144] we must promote research and development supporting expanding exports of agriculture, forestry and fishery products and other food products as well as the activities of the country's food industry in overseas markets.

Therefore, to continue to stably supply safe and reliable food to consumers while meeting their various needs (e.g., demand for foods promoting good health and long life) and further improving quality of life through improving people's dietary habits, we will comprehensively promote necessary research and development by setting the following two key targets:

(22) Thorough Safety Management from Production to Table, and Development of Techniques to Protect Animals and Plants from the Introduction and Spread of Pests and Diseases

To establish a system for improving food safety in response to future changes in socioeconomic circumstances, we will continue developing technologies for reducing hazards associated with food from farm to table, including hazards recently identified through scientific advancement. For example, we aim to develop low arsenic absorbing crops by elucidating the plants' mechanism of substance absorption and transportation; and sensitive detection and identification technologies for harmful substances by applying them to the olfactory reception system of insects.

To prepare countermeasures against emerging livestock diseases and plant pests, we will constantly and systematically develop diagnosis techniques, vaccines and antiviral agents. In addition, we will contribute to establishing more effective preventive measures by analyzing and examining the entry routes and distribution factors of these diseases and pests. Overseas diffusion of these technologies will contribute to expanding the exports of domestic farm products.

We will promote the development of technologies for tracing the geographical origin of agricultural and food products to secure consumer confidence in Japanese food products that will contribute to the monitoring and controlling of deceptive production place labeling. We will target processed foods starting with low-processed ingredients such as rice cake and boiled vegetables, followed by raw materials such as rice and leeks.. These will contribute to the monitoring and regulation of deceptive labeling of production places starting from low-processed ingredients such as rice cake and boiled vegetables. To regain public trust lost after the government's mishandling of radioactively contaminated foods following the Fukushima Dai-ichi Nuclear Plant accident, we will continue investigating how radioactive materials are incorporated into agricultural, forestry and

[144] Website of the Ministry of Agriculture, Forestry and Fisheries: http://www.maff.go.jp/j/keikaku/syokubunka/ich/

fishery products and how they behave in the environment. These findings will be made public.

(23) Technological Development for Supplying Nutritional and Functional Agriculture, Forestry and Fishery Products that Support Healthy and Long-Living Society

To provide correct information on dietary habits and meals supporting our healthy and long-living society and to supply agricultural, forestry and fishery products and other foods with superior nutrition and functionality, we will work on accumulating scientific knowledge on the functionality of these products and foods contributing to the extension of people's lifespans. We will also focus on the three functions of food (nutrition, deliciousness and functionality) in collaboration with medical and nutritional experts. This will facilitate development of new functional foods and agricultural, forestry and fishery products with various functional substances useful for slowing aging, preventing lifestyle-related diseases and improving our immunity by improving the intestinal environment, among other benefits.

In collaboration with experts in medicine, exercise and sports, we will also promote the development of technologies contributing to the provision of various food services that utilize these research findings. Coupled with the promotion of food education, these contribute to the spread of high-quality dietary habits and the realization of a society in which people can maintain their health into old ages and live an energetic life.

[Innovating a Production and Distribution System in Agriculture, Forestry and Fisheries, thereby Drastically Cutting Costs]

Currently, approximately 60% of core persons mainly engaged in farming are aged 65 years or older in Japan. Numbers of farmers are expected to decline in the future and they are aging rapidly. Thus, to continue to stably supply safe and reliable food to consumers, it is important to transform the agricultural, forestry and fisheries industries into attractive industries, thereby increasing the number of principal farmers including younger individuals.

The New Basic Plan for Food, Agriculture and Rural Areas (decided on by the Cabinet in March 2015) sets a 10-year target of realizing the agricultural structure, where 80% of all farmland is used by the principal farmers (they currently use 50%) by accelerating the intensive use of farmland by farmers using the Public Corporation for Farmland Consolidation.

To this end, it is necessary to establish a technical platform on which such principal operators can comfortably engage in agriculture, forestry and fishery without feeling the limit to scale expansion.

Amid this situation, the Robot Revolution Realization Conference[145] was established at the Office of Cabinet Secretariat in September 2014 with hopes of providing solutions to various challenges faced by the country. These include the need to improve productivity by introducing ICT and robot technology to service sectors such as medicine and nursing care as well as agriculture, forestry and fisheries. A government policy decision required developing the ICT and robot technology industry into a trail-blazing industry in the world market.

Under the government policy, the agriculture, forestry and fisheries industries will be transformed into attractive industries appealing to young people. This can be accomplished by innovating the current production and distribution systems by introducing cutting-edge technologies such as ICT and robot expertise to agriculture, forestry, fisheries and food industries. By achieving drastic cost cuts and establishing the value chain from farmers to consumers, we will comprehensively promote necessary research and development by setting the following key targets:

(24) Technological Development for Innovating Agriculture, Forestry and Fisheries Production/Distribution

To realize ultra-laborsaving, large-scale farming overcoming the scale limit that existed under traditional farming; and to create agriculture, forestry and fisheries industries not requiring many years of experience or intuition and are accessible to new entrants including women (realization of "smart" agriculture, forestry and fisheries), we will develop basic technologies to innovate the current production system. These technologies include the multi-robot system in which multiple farm machines work in cooperation using artificial intelligence; the mechanization of hard and dangerous work such as forest management; the next-generation cultivation support system that identifies the cultivation method most suitable for a particular crop in terms of quality and yield by combining a large amount of sensing information (e.g., growth information for individual fields) with crop growth models; the next-generation farming management system that integrally manages robot operations in many fields on the map; and automation and labor-saving technologies for irrigation facilities.

We will also innovate the distribution system for agricultural, forestry and fishery products by developing a scheme for transmitting and providing various information that contributes to the consumer purchase decision. This includes production history data and methods for predicting market trends by analyzing the distribution system for agricultural, forestry and fishery products on a large scale.

[145] Robot Revolution Realization Conference: http://www.kantei.go.jp/jp/singi/robot/

[Creating New Industries and Employment in Rural Areas]

Japan's population is declining due to an aging public and falling birth rates. This trend is particularly pronounced in hilly and mountainous areas whose main industries comprise agriculture, forestry and fisheries; it is also weakening local agriculture, forestry and fisheries as well as community activities. There are concerns this will cause the deterioration of farmland and forests as well as the collapse of the settlement base.

To return vitality and people to these hilly and mountainous areas, it is important to revitalize and promote local agriculture, forestry and fisheries while creating new industries and employment by nurturing innovations using untapped local resources.

The realization of such recycling-oriented rural communities will also lead to the creation of public expectations for and attractions to rural areas.

Based on the above, we will comprehensively promote necessary research and development by setting the following key targets:

(25) Technological Development for Creating New Industries Using Local Resources

To create new local industries utilizing local unused biomass resources, we will develop technologies for manufacturing and using high-value added products that use cellulose nanofiber,[146] lignin[147] and other materials extracted from forestland remainder materials; and technologies for efficiently converting agricultural and livestock wastes into energy (electricity, hydrogen fuel, etc.) and fertilizer.

Taking advantage of the geographical benefits of hilly and mountainous areas or isolated islands, we will promote the development of technologies (including genetic modification) to modify plants and silkworms to produce drugs and functional materials; the breeding of superior medicinal crop varieties and establishment of their cultivation systems; and the development of technologies for efficiently producing useful substances from algae.

[Improving Yield/Quality of Agriculture, Forestry and Fishery Products, Building on Existing Strengths]

To supply future agricultural, forestry and fishery products to compete against cheap import

[146] Cellulose nanofiber: A material composed of nanosized fibrils with an average width up to 20 nm and an average length between 0.5 and several μm; it is made from wood pulp or other materials using chemical and mechanical treatments.
[147] Lignin: A material comprising approximately 30% woody biomass and a byproduct of the manufacturing process of woody bioethanol and pulp for paper.

products while responding to changes in food consumption trends due to an rapidly aging population and other factors, it is important to increase unit yields by reducing production costs without compromising product quality—our strength—and continuing to create innovative varieties with new added values such as functionality.

To respond to the destabilization of crops and quality due to the progress of global warming and the occurrence of new pests, we must sophisticate existing breeding technologies for maximizing the genetic potential of organisms. We must also improve conditions for smoothly obtaining mutation-rich genetic resources (breeding materials) from Japan and abroad.

In the field of agricultural crop breeding, genome sequencing has been completed,[148] and several useful genes have been identified for about 40 crops and forest tree species. We are preparing to use DNA marker-assisted breeding and other genetic technologies for creating promising new varieties in a short period of time using the DNA sequence information we have. Genetic recombination technologies have been used to transfer the traits of other organisms such as microorganisms to crops (e.g., insecticidal function); these tasks cannot be done with conventional breeding methods. Use of genetic technologies has recently increased, for example, to shorten the breeding period of fruit trees by accelerating flowering and to intentionally create mutations, dramatically shortening the breeding period of crops, which used to take over 10 years.

Based on the above, we will comprehensively promote necessary research and development by setting the following key targets:

(26) Development of World-Class Agriculture, Forestry and Fishery Products

Considering overseas markets and responding to environmental changes such as global warming and the appearance of new pests, it is essential to consistently develop innovative and advantageous rice varieties (e.g., ultra high-yield and with good taste), vegetables, fruit trees, flowers, livestock products, forestry products and fishery products. With this aim, we are accelerating the genome sequencing and functional analysis of valuable genes for various species of agricultural crops, animals, forestry trees and fishes; and developing breeding methods combining the technologies of DNA marker-assisted breeding, genome editing[149] and "omics" analysis.[150] Additionally, we will systematically develop technologies to breed livestock efficiently; accelerate the breeding of forest trees and breeding fish for aquaculture; and improve conditions for introducing genetic resources

[148] NIAS DNA Bank HP: http://www.dna.affrc.go.jp/jp/

[149] Genome editing technology: A type of genetic engineering in which genome DNA is cut sequence-specifically using a DNA cleaving enzyme called artificial nuclease and uses mutations that incidentally occur during the repair process of the cleavage sites.

[150] "Omics" analysis technology: An approach to research where you comprehensively study life phenomena by global analysis rather than separately studying the changes in genes, mRNA, proteins, etc. in cells.

from overseas.

We exploit the genetic potential of agricultural, forestry and fishery products (e.g., increase rice yield three-fold [to 1.5 t/10 a]), shorten the breeding period of fruit trees to under 10 years (previously requiring 50 years), and breed fish species such as tuna that are suitable for aquaculture. Through these efforts in conjunction with the participation of private sectors in breeding projects, new advantageous varieties and breeds that we can proudly offer to the world will be developed successionally. To prepare for future food, environmental and energy needs, we will also steadily proceed with the research and development of genetically modified crops to transfer the traits of other organisms such as microorganisms (e.g., with pest resistance).

[Promoting Sustainability and Stability of Agriculture, Forestry and Fisheries]

The Fifth Assessment Report of IPCC[151] predicts the strong likelihood that by the end of this century, the average world temperature will increase by up to 2.6ºC–4.8ºC. The frequency of abnormal weather will also increase. It is possible that in the future, suitable areas for crop cultivation, fishery environment, ocean currents, habitats of plants and animals, etc. will significantly change, seriously affecting the agriculture, forestry and fisheries industries worldwide.

It is also predicted that an increased risk of occurrence and spread of new pests and diseases, along with the frequent occurrence of abnormal weather such as heavy rain and drought will destabilize food supplies in the future.

Additionally, Japan currently imports most production materials such as fertilizer, feed and fuel. Considering the increased demands for such materials in emerging countries and the predicted future depletion of resources, it is inevitable that the prices of such materials will increase and their acquisition will become difficult.

As for the forestry industry, to promote the increased use of forest resources, it has become very important to ensure that forests maintain their multifunctionality including land conservation, water source recharge and global warming prevention functions through appropriate forest improvement and conservation measures.

As for the fisheries industry, international fishery resource regulations have become increasingly strict in response to increased global demands for fishery products. As the world's largest consumer of seafood, Japan must play a leadership role in promoting sustainable use and management of fishery resources.

[151] Fifth Report of IPCC: http://www.env.go.jp/earth/ipcc/5th/index.html

Therefore, aiming to realize sustainable and stable agriculture, forestry and fisheries, we will comprehensively promote necessary research and development by setting the following five key targets:

(27) Development of Agriculture, Forestry and Fishery Adaptive Techniques in Response to Climate Change (Some Overlap with the Key Target 26)

To mitigate the effects of advancing global warming on the agriculture, forestry and fisheries industries, we will develop high-accuracy methods for predicting and assessing the effects on individual fields and items. Based on the prediction results, we will systematically breed climate change adaptation varieties/breeds and develop stable production technologies in a planned manner.

(28) Improvement of Prevention Techniques for Plant Pests and Infectious Diseases of Livestock (Some Overlap with the Key Target 22)

Amid concerns about the entry and spread of new pests associated with climate change and other factors, as well as the occurrence of pesticide resistance, pest control is expected to become increasingly difficult in the future. Under such circumstances, the realization of environmentally friendly and sustainable agriculture, forestry and fisheries and further promotion of organic farming are necessary. Thus, it is important to establish new IPM technologies combining physical, chemical and biological control methods.

For these reasons, we will continue to refine technologies for monitoring the occurrence of pests. We will also promote the establishment of cultural control methods suiting the characteristics of individual crops; the development of environmentally friendly agrochemicals with low probability of resistance development and fewer impacts on biodiversity, and techniques for utilization of such chemicals; and the development of new physical and biological control methods using light, native natural enemies, etc. Furthermore, we will develop effective control technologies against forest pests such as pine wilt disease.

To prepare countermeasures against the entry and spread of emerging livestock diseases triggered by climate change and other factors, we will constantly and systematically develop methods for collecting disease information, surveillance systems, accurate and rapid diagnosis methods and labor-saving and effective preventive materials such as vaccines to fight epidemics.

(29) Establishment of Recycling-Oriented, Sustainable Agriculture, Forestry and Fishery Systems (Some Overlap with the Key Target 25)

To fully utilize rural resources and to establish recycling-oriented, sustainable agriculture, forestry and fisheries systems, we will develop diverse technologies such as methods of using the surplus heat of woody biomass power generation for heating greenhouses; and the low-cost conversion of agricultural waste and livestock manure into energy and fertilizer. We will also develop a decentralized autonomous cooperative energy system using diverse renewable energies in rural areas.

(30) Development of Technologies for Sustainably Maintaining, Utilizing and Managing Rural Infrastructure and Forests by Maximizing the Multifunctional Roles of Rural Areas

To enhance the resilience of rural infrastructure and extend their lifetimes, we will develop the next-generation farm irrigation system that can adapt to ICT-based labor-saving farming and changes in irrigation facility management systems; develop low-cost life extension technologies for irrigation and drainage facilities using new materials and new building techniques; and promote rural infrastructure for disaster risk reduction. To promote the sustainable development of rural areas and communities, we will also conduct research and development for maintaining and demonstrating the multifunctional roles of agriculture and rural areas.

To sustainably use and manage forests into the future while maximizing the multifunctional role of forests such as land and water resource conservation and global warming prevention functions, we will develop technologies for identifying the mechanisms of predicting changes in water circulation in forests; forestry management and distribution systems as well as wood supply and demand adjustment systems for promoting the effective and efficient distribution of domestic logs; a new wood distribution system using ICT; an innovative forestry production technology combining laser measurement with robot technology; and a processing system to handle large-diameter wood, among others. Furthermore, we will elucidate the mechanism of disasters such as locally frequent surface failure and use the findings for creating hazard maps. We also plan to develop technologies for preventing disasters in mountainous areas.

(31) Development of Marine Ecosystem-Friendly Fishery Technologies that Support Sustainable Use of Marine Resources

To promote the environmentally conscious, sustainable use of fishery resources and the stable supply of a variety of seafood to support Japanese dietary culture, we will sophisticate marine environment monitoring technologies using high-resolution satellite data and data obtained from

the metagenomics[152] of marine microorganisms. We will also develop a new fish finder to identify the size and type of fish; and sophisticate the evaluation and management methods for fishery resources.

To promote aquaculture production, we will develop seedling fish production technologies for a wide range of fish species. We will also develop superior breeds, low fishmeal feed and closed recirculating aquaculture technologies, thereby establishing an advanced aquaculture production system that is less dependent on natural resources.

[Addressing Global Food and Environmental Challenges, thereby Contributing to the International Society]

According to the United Nations estimate,[153] the world's population will reach 9.6 billion in 2050, representing 1.3 times the current population. Together with the projected economic growth and income growth in emerging countries, there are concerns that global strains in supply and demand of food may occur in the medium- to long-terms. In this situation, targeting developing regions where the full potential of agricultural production has not been exploited, it is necessary to promote sustainable agricultural production activities while considering the local natural environment, thereby increasing global food production.

The conditions of the world's agricultural production are predicted to be disrupted in the future due to the increasingly frequent occurrence of abnormal weather, the spread of emerging and reemerging livestock diseases and pests and water resource shortages associated with global warming. Under such circumstances, we are expected to promote research addressing global issues such as the mitigation of and adaptation to climate change under international collaboration, thereby actively making international contributions.

Based on the above, we will comprehensively promote necessary research and development by setting the following key targets:

(32) International Research in Response to Global Challenges Such As Climate Change and Stable Food Production in Developing Countries

We aim to realize environmentally friendly, highly sustainable agriculture, forestry and fisheries industries while committing to international frameworks on global climate change, biodiversity conservation and the prevention of transboundary infectious diseases. Therefore, we will

[152] Metagenomics: The study of genetic material collected directly from an environmental sample and used to identify characteristics of the microbiota of the particular environment.
[153] Website of the United Nations: http://esa.un.org/unpd/wpp/Excel-Data/population.htm

systematically promote the development of global warming mitigation technologies (e.g., technology for reducing methane generated from paddy fields); elucidation and evaluation of ecosystem services related to biodiversity; elucidation of the spread patterns and distribution of diseases such as foot and mouth disease and highly pathogenic avian influenza; and research on the multifunctionality of forests such as global warming prevention and land conservation functions.

In collaboration with international agricultural research institutes and other entities, we will breed rice and other crops that can grow in poor environments (e.g., unfertile soil in Africa and under drought conditions); establish cultivation systems for such crops; conduct joint research with neighboring Asian countries concerning transboundary infectious diseases; develop advanced utilization technologies for unused biomass such as cassava pulp; and develop evaluation methods and countermeasure technologies for forest decline and deterioration, thereby promoting sustainable and efficient agricultural, forestry and fishery activities in developing regions where the effects of global warming are particularly strong.