A Carbon Cultivation Hub Challenging the Limits of Carbon Negativity

The 21st Century Industrial Revolution:
Advancing from a Carbon Hunting to a Carbon Cultivation Society

Project Leader
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Realizing a Carbon-Negative Society through Carbon Cultivation

Aimed-for Society

Goals: By 2050, through carbon cultivation, storing the equivalent of 12 million tons of carbon from rice, 29 million tons from forests, and 3 million tons from algae, and creating industries from their use.

Sustainable Development Goals (SDGs)

Aims of the Hub

The essence of carbon cultivation is the active production, value creation, and recycling/reuse of biomass.
The Hub aims to give biomass carbon-negative characteristics by developing cultivation methods that greatly increase the amounts of fixed and accumulated carbon in biomass.
A further aim is to strongly promote creation of high added value of biomass, leading to the full conversion of land that was abandoned and underutilized for economic reasons into land for biomass production. The Hub will promote carbon cultivation mainly with technologies relating to rice, tree, and algae.

We will develop rice varieties with high CO_2 fixation and biomass production capacity.
This rice will also be beneficial for achieving food security in the event of a food crisis.

We will create a new short-cutting cycle, high-efficiency forestry industry that prioritizes the rate of carbon fixation.

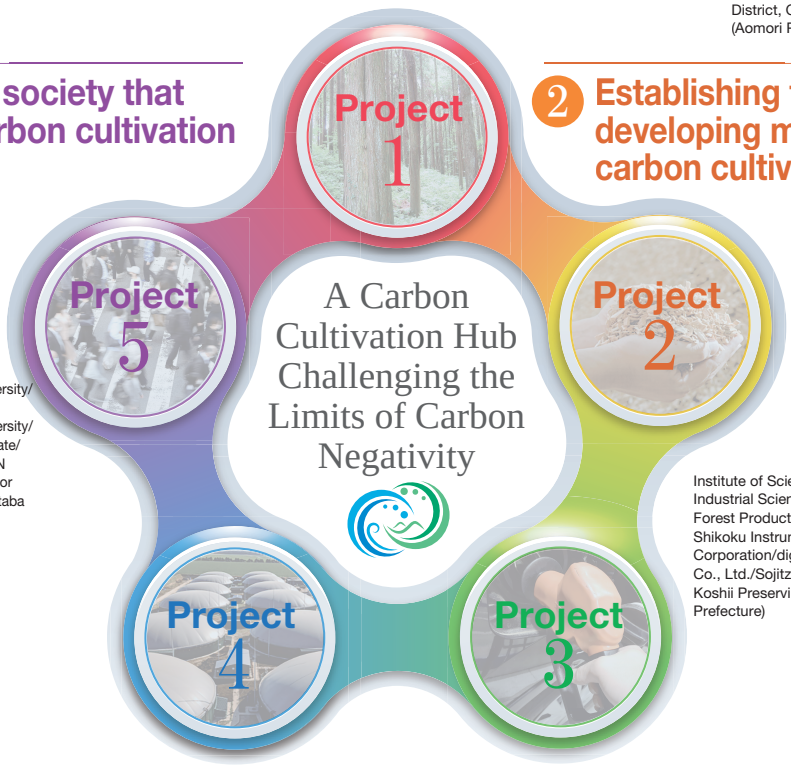
We will establish technology for producing fuel by carbon cultivation using algae, which has high potential for Japan, surrounded by

R&D targets to realize carbon negativity

1 Establishing carbon cultivation agriculture and forestry industries

R&D Leader **Taiichiro Ookawa**
Professor, Institute of Agriculture, Tokyo University of Agriculture and Technology

Tokyo University of Agriculture and Technology/University of the Ryukyus/Hirosaki University/Ehime University/Japan Agency for Marine-Earth Science and Technology/Forestry and Forest Products Research Institute/National Agri-culture and Food Research Organization(NARO)/TAIHEIYO CEMENT CORPORATION/NEWGREEN, INC/Ohama farm/TAKAMINE SYUZOSHO Co., Ltd./Taketomi Town (Yaeyama District, Okinawa Prefecture)/Hirosaki City (Aomori Prefecture)



5 Realizing a society that accepts carbon cultivation

R&D Leader
Yuji Nagai
Professor, Environmental Research Institute, Waseda University

Waseda University/The Engineering Academy of Japan/Ritsumeikan University/Tokyo University of Agriculture and Technology/Tokyo Kasei Gakuin University/FP Corporation/AEON/ AEON Agri Create/AEON Environmental Foundation/AEON RYUKYU CO., Ltd./Research Institute for Humanity and Nature/Hirono Town (Futaba District, Fukushima Prefecture)

2 Establishing technologies for developing materials based on carbon cultivation

R&D Leader
Makoto Yoshida
Professor, Institute of Agriculture, Tokyo University of Agriculture and Technology

Tokyo University of Agriculture and Technology/Nagaoka University of Technology/Hirosaki University/Institute of Science Tokyo/National Institute of Advanced Industrial Science and Technology (AIST)/Forestry and Forest Products Research Institute/Riket/AGC, Inc./Shikoku Instrumentation Co., Ltd./Nihon BioData Corporation/digzyme, Inc/Japan Investment Adviser Co., Ltd./Sojitz Institute of Innovative Technologies, Ltd./Koshii Preserving Co., Ltd./Hirosaki City (Aomori Prefecture)

4 Establishing technologies for reducing greenhouse gases and treating wastes generated in carbon cultivation

R&D Leader **Akihiko Terada**
Professor, Institute of Engineering, Tokyo University of Agriculture and Technology

Tokyo University of Agriculture and Technology/National Institute of Advanced Industrial Science and Technology (AIST)/Mitsubishi Chemical Corporation/EnBio Engineering, Inc.

3 Establishing technologies for producing fuel based on carbon cultivation

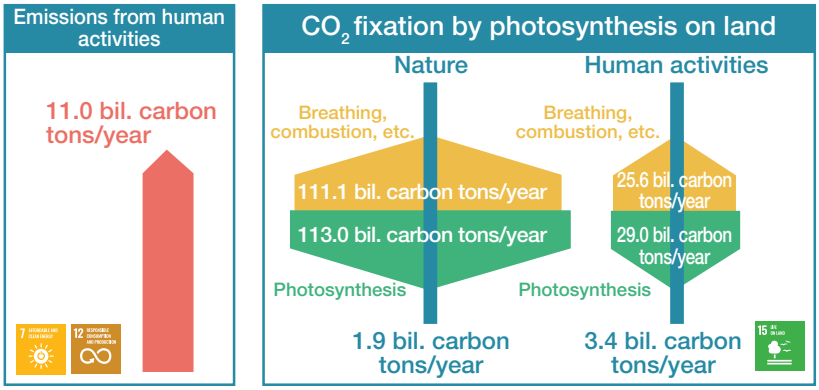
R&D Leader **Masayuki Inui**
Group Leader/Principal Research Scientist, Molecular Microbiology and Biotechnology Group, Research Institute of Innovative Technology for the Earth

Hirosaki University/Tokyo University of Agriculture and Technology/Research Institute of Innovative Technology for the Earth/Tsugaru Biomass Power Generation/TAIYO NIPPON SANSO CORPORATION/Tsugaru City (Aomori Prefecture)/Hirosaki City (Aomori Prefecture)

What is Carbon Cultivation?

Applying biotechnology to capture (fixate) carbon (CO_2) and produce, give value, and recycle/reuse materials and energy

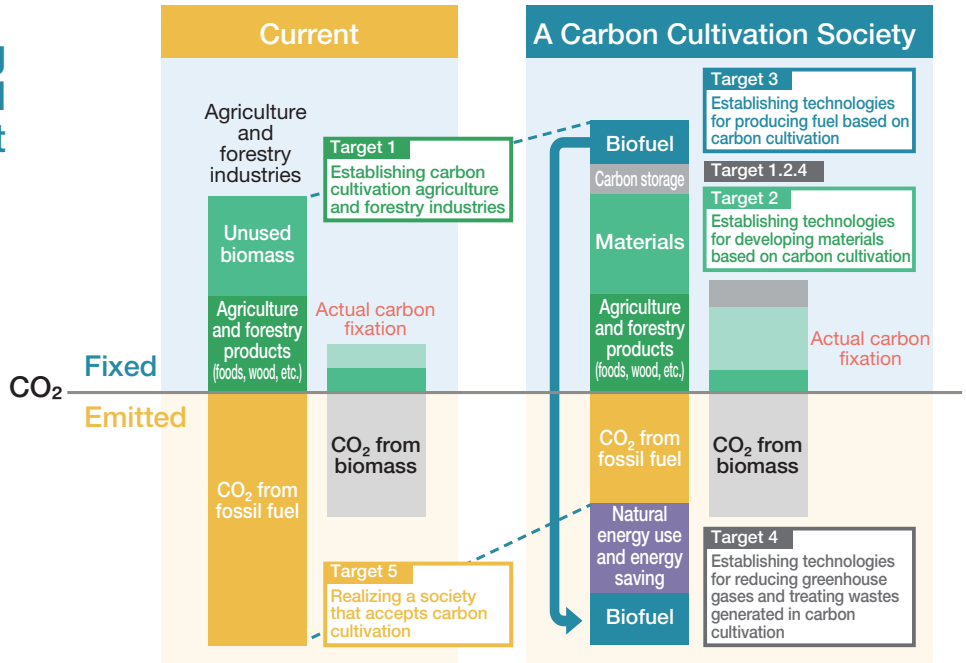
Humans transformed from a hunting society to a cultivating society by inventing agriculture, and succeeded in acquiring large amounts of food. Modern society, however, is still a carbon hunting society, dependent on fossil fuels--carbon resources fixed in the earth in ancient times--for its energy and materials. The development of modern civilization by use of fossil fuels has led to serious issues from increases in atmospheric CO_2. CO_2 fixation is possible only through photosynthesis, but the amount of CO_2 fixed by agriculture and forests in Japan is less than one tenth the emission amount. What's more, much of the fixed carbon is not being effectively used. Creating new technologies and societies for tackling these issues is an urgent need. The challenge we are taking on in the Hub is "realizing a 21st century industrial revolution" that will advance humankind from a carbon hunting to a carbon cultivation society.



Absorption of the vast amounts of CO_2 emitted into the atmosphere can only be done by photosynthesis.
Excerpted from IPCC Climate Change 2021

The amount of CO_2 emitted by humans annually is estimated to be 11.0 billion carbon tons equivalent. As for the amount of CO_2 fixed by photosynthesis on land, this is estimated to be 113.0 billion carbon tons in nature, and 29.0 billion carbon tons by agriculture, forestry and other human activities. Most of this amount ends up being released again as CO_2 by such activities as breathing and combustion, leaving an estimated 1.9 billion carbon tons fixed in the natural world and 3.4 billion carbon tons by agriculture, forestry and the like. While various technologies have been proposed for absorption of CO_2 in the atmosphere, photosynthesis remains the only means for absorbing the huge amount emitted.

Approach to achieving carbon negativity and position of each target



Carbon fixed by photosynthesis in rice, trees and algae will be used as materials and fuel. Unused biomass will be processed into fertilizer, and excess carbon will be stored. Measures will be devised for gaining public acceptance of this cycle and implementing it. Since achieving this cycle will require social implementation at each stage, various companies will participate in the implementation processes.

Research Projects

The amount of CO_2 captured (fixed) in agriculture and forestry will be increased and CO_2 emissions from fossil resources will be reduced by energy saving and the usage of natural energy and also fuel from biomass, while CO_2 emissions originating from biomass will be reduced by conversion to materials and carbon storage. The Hub will challenge the limits of carbon negativity by means of carbon cultivation, making maximum use of the potential of photosynthesis.
Specific examples of social implementation:

- Create new biomass industries in the agriculture, forestry and fisheries industries and replace fossil resources-dependent industry
- Suppress methane generation in rice farming, promote CO_2 fixation, and revitalize regional economies (Increasing rice production will also contribute to food security.)
- In the forestry industry, increase the amount of stored carbon by carbon cultivation using fast-growing trees
- Create regional biomass industry clusters to produce replacements for plastic from fossil resources (Healthy forests lead to disaster prevention/mitigation.)
- In the fisheries industry, make use of idle fishing port facilities to build large-scale plants for culturing marine microalgae
- Promote carbon storage and alternative fuel production

Five targets have been set to realize this vision.

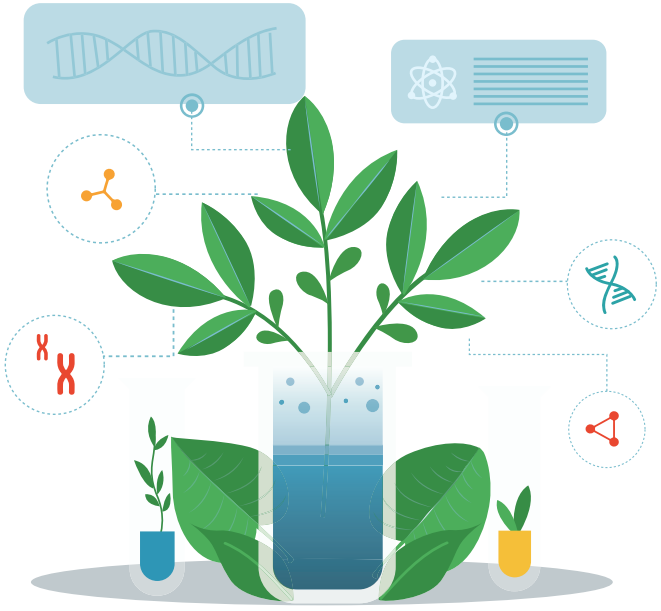
○Establishing carbon cultivation agriculture and forestry industries ○Establishing technologies for developing materials based on carbon cultivation ○Establishing technologies for producing fuel based on carbon cultivation ○Establishing technologies for reducing greenhouse gases and treating wastes generated in carbon cultivation ○Realizing a society that accepts carbon cultivation

Based on these targets, five research projects and goals have been set.

Project 1

Development of Sustainable Carbon Cultivation Technology

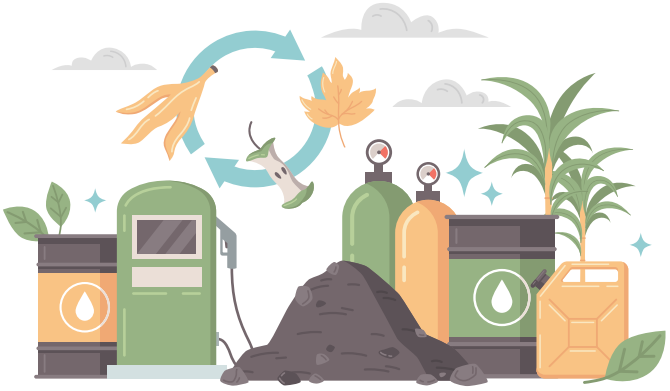
We aim for efficient biomass utilization contributing to carbon neutrality, with rice and trees as targets for land-based green carbon, and microalgae as targets for ocean-based blue carbon. Although these targets each have high CO_2-fixation and storage capacity, practices such as cascading use of biomass, use of biomass plastic and other biomass resources, use in animal feed and fertilizer use by resource recycling have not sufficiently progressed, while issues for trees include the depletion of natural forests and illegal logging in regions such as Southeast Asia. In this research project, we will undertake the development of sustainable biomass materials cultivation systems, from the biomass production for land-based green carbon and ocean-based blue carbon to the cascade utilization and the establishment of an overall resource cycle.



Project 2

Development of Carbon Cultivation-Based Materials Development Technology

Biomass has enormous potential for replacing fossil resources.
In this research project, we will undertake development of various materials, with biomass as their raw material, to replace materials made from fossil resources. A particular aim is to design biomass materials with high environmental friendliness and develop chemicals. We will develop conversion technologies for cellulose, hemicellulose, and lignin, which are the main constituents of the plant biomass, such as rice and woody materials, at which this research is directed, to useful substances. We will also seek to develop conversion technologies for vegetable oils and fats extracted from biomass, directed at oil palms abundant in Southeast Asia as well as at algae biomass. With a view to the social implementation of these green products, we will accelerate research and development through industry-academia collaboration, and increase cooperation with emerging countries (especially ASEAN) having abundant unutilized resources that are targets of this research.



Project 3

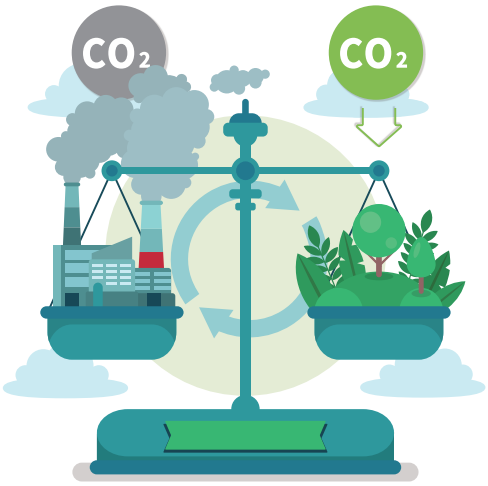
Development of Carbon Cultivation-Based Technologies for Producing Fuel

Hydrogen is expected to be the ultimate clean energy, since it produces only water during combustion; it can be produced, stored, and transported from diverse energy sources, including renewable energy; and it can be used for decarbonization in all kinds of sectors, including power, transportation, and heat and industrial processes. Currently, however, major hydrogen production technologies use fossil fuels, and the resulting CO_2 emissions are a critical challenge. For its social implementation, it will therefore be necessary to greatly reduce the cost of producing CO_2-free hydrogen.
A medium- to long-term theme in carrying out the R&D for this research project will be to develop CO_2-free hydrogen production processes with biomass as raw material, while a short- to medium-term theme will be to develop liquid fuel production processes making use of the same basic technologies as the long-term theme.

Project 4

Development of Technologies for Reducing Greenhouse Gases and Treating Wastes Generated in Carbon Cultivation

A key issue in biomass cultivation from the standpoints of sustainability and environmental protection is the proper recycling of wastes generated in each of the technological processes. An aim of this research project will be to develop a co-fermentation technology that mixes difficult-to-recycle wastes from Projects 1, 2, and 3 with livestock industry wastes, and to establish an efficient methane recovery technology. We will further seek to develop technology that carbonizes methane fermentation residues, converting them to slow-release fertilizer, and to assess the effectiveness of this technology. Combining these underlying technologies, we will aim to develop sustainable systems based on the livestock industry and agriculture that are instrumental in accelerating the establishment of a “regional circular and ecological sphere”.



Project 5

Development of Evaluation Methods for Social Acceptability

In biomass production, processing, and use, resources circulate over a broad scope from rural to urban areas, and from inside to outside the nation. While some of these can be stockpiled, others cannot, which complicates the social processes. A further issue is that in some cases, the processes involved in cascading use of biomass may lack economic rationality. On the basis of this background, the project will seek to devise methods to evaluate the social acceptability of the developed technologies, by back casting “carbon cultivation society” in regard to local sustainability. Furthermore, in spreading Japanese technology to Asian countries with abundant biomass resources and creating a wide-area circular sphere that includes Japan, we will seek to clarify the issues faced by local communities in Asian countries, and to devise logics pertaining to the inevitability of the carbon cycle (cycle of food, energy, and people) in Asia. Based on these logics, we will build a regional circular sphere framework that leads to creation of new value.

Social implementation and contribution of TUAT Hub activities

Through carbon cultivation techniques that maximize the potential of photosynthesis, particularly in rice cultivation, the TUAT Hub project aims to suppress methane production, contribute to CO2 fixation, energize the local economy, and promote sustainable development.
The focus area for this activity is Iriomote Island, which is a World Natural Heritage Site and therefore subject to a number of environmental restrictions. The project aims to apply the hub's technologies in a variety of dimensions on the island: resource circulation and value creation in agriculture, livestock farming, fisheries, distribution and sales, and even tourism, an important industry. Underlying factors shaping the activity include the facts that:

(1) Rice is the most widely cultivated crop in Southeast Asia.

(2) Reducing the use of chemical fertilizers and pesticides is an important issue.

(3) Rice paddies face the issue of emissions of greenhouse gases such as methane and nitrous oxide.

Specific issues for Iriomote Island agriculture

(1)Local production and consumption

Creating a system where the island's agricultural, forestry, and fishery products can be consumed locally

(2)Resource circulation

Creating a system to produce fertilizer, such as compost from cow dung and food waste, and use it to grow crops
The problem of piled-up cow dung, the impact of chemical fertilizers on coral, and the impact of pesticides on biodiversity
Making food waste–processing activities work effectively

(3)Organic farming

Reducing the use of pesticides and chemical fertilizers, preserving biodiversity and coral reefs, and creating value
Difficulties in obtaining compost to use, a lack of technology and knowledge regarding non-pesticide production, and a lack of necessary machinery

How the project can help find solutions to the issues

(1)Developing rice varieties and cultivation technologies suitable for carbon cultivation
(2)Developing an island-type recycling agriculture system that effectively utilizes agricultural and livestock waste
(3)Supplying omega fatty acids for farmed fish feed using marine microalgae
(4)Restoring seagrass beds
(5)Exploring the creation of new value in a carbon cultivation society

In particular, the plan for item (5) aims to improve and stabilize rice yields on Iriomote Island, produce alcohol (Awamori) for local consumption, and create a society in which distribution efforts communicate the value of these products more fully and broadly.

Activities aimed at solving problems in island regions through carbon cultivation

- Iriomote Project -

Discussions focusing on the challenges of rice cultivation on the island identified issues in circulation (including livestock farming and the marine environment) and corresponding local needs. Based on these insights, we envision expanding into new research themes.

Solving issues with a focus on rice cultivation⇒

Cooperating on rice cultivation-related technologies → Involving researchers in the project → Clarifying other related issues

The issues facing remote islands are a microcosm of the issues facing the entire country, which means that solutions can serve as models for other regions.

New themes that focus on issues facing the entire local community

Circular Economy

- The collapse of the local production and consumption economy
- Dependence on external sources of feed and fertilizer
- Dependence on external assistance for waste disposal

Carbon Neutral

- Optimization of regional logistics
- Utilization of renewable energy
- Methane gas emissions from livestock manure
- Reduction of blue carbon

Nature Positive

- Ecosystem destruction due to the increase of certain species
- Phosphorus discharge into the ocean and disappearance of seaweed beds
- Disruption caused by overtourism
- Land degradation due to the neglect of primary industries


Strengthening collaboration between regional leaders and researchers to address local issues


Creating a circular economy based on rice cultivation


Research of plant activity for the restoration of seaweed beds


Researching ways of reducing the livestock industry's environmental impact


Solving issues through collaboration with distributors

Specific activities

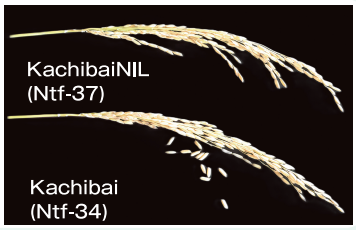
Breeding research

Breeding for rice cultivation on Iriomote Island

TUAT has registered "Sakura Fukuhime" as a rice variety resistant to typhoons and high temperatures and is cultivating it on Iriomote Island.

Improving Kachibai

Karchibai (introduced from an Indian variety) has been selected as a variety resistant to high temperatures and typhoons, and is being worked to improve its shedding properties.



Improving the shedding properties of Kachibai

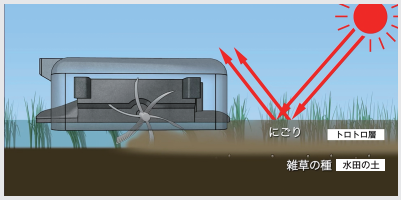
Aigamo Robot

The TUAT hub, in collaboration with NEWGREEN Co., Ltd., is developing rice-cultivation technology using the Aigamo Robot ("duck" robot) and conducting demonstrations on Iriomote Island.

What is the Aigamo Robot?

Powered by solar energy and equipped with GPS, the Aigamo Robot moves around rice paddies automatically and agitates the water with a screw, suppressing weed growth.
It also minimizes damage to rice caused by apple snails, a problem in paddies in warm regions.
Demonstration experiments have confirmed that methane gas emissions can be halved.


The Aigamo Robot operating in a rice paddy



Key points for weed control

Muddying the water to inhibit weed photosynthesis

The screws churn the soil to make the rice paddy cloudy, thereby blocking sunlight, and creating an environment that makes it difficult for weeds to photosynthesize.

Forming a layer of soft soil

The churned soil accumulates and forms a layer of soft soil, burying weed seeds and preventing them from sprouting.

Manufacture and sale of Awamori using ingredients from Iriomote Island

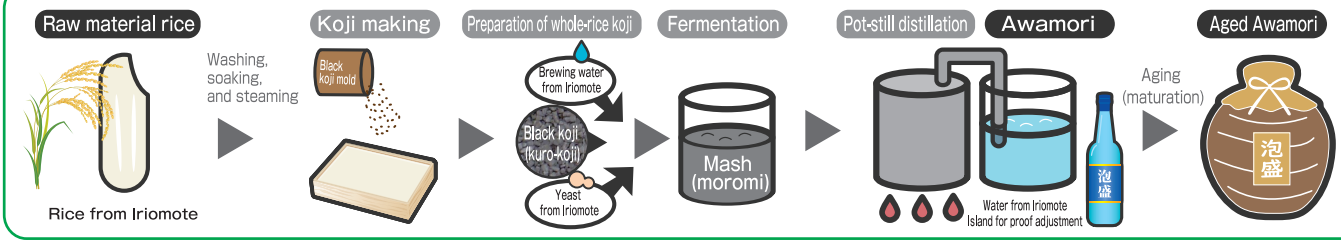
The project creates value by producing Awamori using exclusively Iriomote-sourced ingredients, including rice, water, and yeast.

The value of using materials from Iriomote Island

Exploring and resolving issues related to the natural environment and circulation, finding value in those solutions, and linking the results to social understanding

▶ **Cultivating products that resonate with society and lead to expanded sales**

The Awamori manufacturing process



Livestock waste processing

Methane emission-suppression technology

The goal of this research is to reduce greenhouse gases produced by carbon cultivation and establish waste disposal technologies.
Specifically, we will take the following steps to develop sustainable systems based on livestock farming and agriculture:

- ○Reduce GHG emissions in rice cultivation by incorporating water management with fermentation residue and charcoal application
- ○Develop high-efficiency biogas-recovery technology from mixed waste, such as biomass utilization residues and livestock waste
- ○Use carbonized methane fermentation residue as an adsorbent
- ○Establish upcycling technology using methane, nitrogen, and phosphorus
- ○Develop a material circulation model that takes GHG and nutrients into account

The system technology to be developed will help solve issues related to resource circulation and the realization of organic farming on Iriomote Island.

Creating value beyond biodiversity

Achieving major social change hinges on identifying local issues. It is essential to design a cumulative cycle on the local level.

Satoyama-style circulation design rooted in the local community

Developing products that serve as a model for the virtuous cycle of local resources

Generating feedback on consumer needs through test sales

Efforts to help consumers understand the story behind circulation can produce value. In doing so, cooperation and coordination among production, manufacturing, distribution, and consumption is key.

Creation of BtoC value that supports circulation

Researching methods to help consumers understand local resource circulation

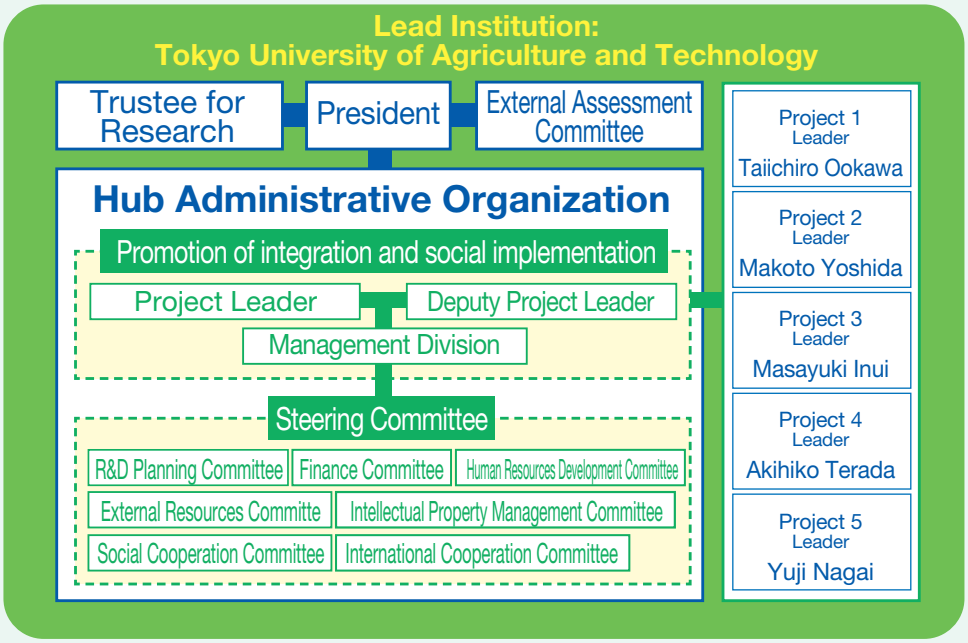
Developing value-creating advertising methods

Demonstrations at World Heritage sites and UNESCO Biosphere Reserves can be effective as precedent cases for creating frameworks (OECM) throughout Japan.

From consumer lifestyles to local nature positivity

Developing a logic model that connects customer value and global environmental

Organizational Structure for Hub Administration



Participating Institutions Research Institutions	Hirosaki University/Nagaoka University of Technology/Waseda University/Institute of Science Tokyo/Ritsumeikan University/University of the Ryukyus/Ehime University/National Agriculture and Food Research Organization (NARO)/ Research Institute for Humanity and Nature/Tokyo Kasei Gakuin University/Engineering Academy of Japan/National Institute of Advanced Industrial Science and Technology (AIST)/Research Institute of Innovative Technology for the Earth/Forestry and Forest Products Research Institute/Japan Agency for Marine-Earth Science and Technology
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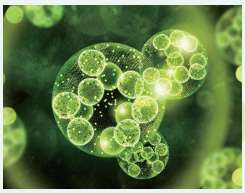
Municipalities	Hirono Town, Futaba District, Fukushima Prefecture/Tsugaru City, Aomori Prefecture/Taketomi Town, Yaeyama District, Okinawa Prefecture/Hirosaki City, Aomori Prefecture
Cooperating Organizations	Asahi Agria/Idemitsu Kosan/Yanmar Holdings/Electric Power Development (J-Power)/Astena Holdings/Chiyoda Corporation/Seibu Shinkin Bank/The America-Japan Society of Tama Tokyo/JA Fukushima Sakura/SONY GROUP CORPORATION Fuchu City (Tokyo), 6 partner corporations/Toshiba/NEC/Suntory Spirits/Kewpie/ Tokyo Metropolitan Government/Nihonmatsu City, Fukushima Prefecture/Tomioka Town, Futaba District, Fukushima Prefecture/Study Group on Energy Crops in Nagawa Town



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