Current status and perspectives for smart agriculture in Japan

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Topics

- World and Japan food problems
- Cross-Ministerial Strategic Innovation Promotion Program (SIP)
- Ag-robot developments in Vehicle Robotics Laboratory (VeBots)
- Quasi-zenith satellite system (QZSS) application to smart agriculture
World food problems

- Population growth ↑
- Protein consumption ↑
- Global warming ↑
- Energy crops ↑
- Food prices ↑
- Land & soil quality ↓
- Available land & water ↓
- % Rural population ↓

9 Billion by 2050
Labor shortage of agriculture in Japan

(2010 Japanese Census of Agriculture)

Average age of farmers:
- 1991: 59.1
- 1996: 61.1
- 2001: 63.2
- 2006: 65.8
- 2011: 66.4
- 2016: 66.4

Number of farmers:
- 1991: 482
- 1996: 414
- 2001: 389
- 2006: 335
- 2011: 260
- 2016: 215
Topics

- World and Japan food problems
- Cross-Ministerial Strategic Innovation Promotion Program (SIP) “Technologies for Creating Next-Generation Agriculture, Forestry and Fisheries”
- Ag-robot developments in Vehicle Robotics Laboratory
- Quasi-zenith satellite system (QZSS) application to smart agriculture
Headquarter for Science and Technology to foster innovation  
- Council for Science, Technology and Innovation (CSTI) -

- **Promoting effective measures across ministries to create innovation beyond the borders of disciplines, ministries and sectors**

### Three Arrows of Reinforcement of the HQ

<table>
<thead>
<tr>
<th>Improvement of the process for policy-making</th>
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<tr>
<td>“S&amp;T Budgeting Strategy Committee” and “Action Plans for S&amp;T Priority Measures”</td>
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<tr>
<td>➢ Prioritized area: “Energy”, “Next-generation infrastructures”, “Local resources”, “Health &amp; Medical”</td>
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<td>➢ Budget for FY2014: ¥335bil</td>
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**SIP (Cross-Ministerial Strategic Innovation Promotion Program)**

- **Budget for FY2017:** ¥50bil
  *Of this amount, 35 percent (¥17.5 billion) was allocated to medical fields*

**ImPACT (Impulsing PAradigm Change through disruptive Technologies)**

- **Budget for FY2014-2018:** ¥55bil
# 11 Themes of SIP

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<tr>
<th>Priority policy issues</th>
<th>Themes</th>
<th>Objective</th>
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<td><strong>Energy</strong></td>
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<tr>
<td>Innovative Combustion Technology</td>
<td>Improving fuel efficiency of automobile engines</td>
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<td>Next-Generation Power Electronics</td>
<td>Integrating new semiconductor materials into highly efficient power electronics system</td>
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<tr>
<td>Structural Materials for Innovation (SM⁴I)</td>
<td>Developing ultra-strong and lightweight materials such as magnesium-, titanium-alloys and carbon fibers</td>
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<td>Energy Carriers</td>
<td>Promoting R&amp;D to contribute to the efficient and cost-effective technologies for utilizing hydrogen</td>
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<td>Next-Generation Technology for Ocean Resources Exploration</td>
<td>Establishing technologies for efficiently exploring submarine hydrothermal polymetallic ore</td>
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<td><strong>Next-generation infrastructures</strong></td>
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<td>Automated Driving System</td>
<td>Developing new transportation system including technologies for avoidance accidents and alleviating congestion</td>
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<td>Infrastructure Maintenance, Renovation and Management</td>
<td>Developing low-cost operation &amp; maintenance system and long life materials for infrastructures</td>
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<tr>
<td>Enhancement of Societal Resiliency against Natural Disasters</td>
<td>Developing technologies for observation, forecast and prediction of natural disasters</td>
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<td>Cyber-Security for Critical Infrastructures</td>
<td>Development of technologies that monitor, analyze, and defend control and communication system as well as confirm integrity and authenticity of system components to protect critical infrastructures against cyber threats.</td>
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<td><strong>Local resources</strong></td>
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<tr>
<td>Technologies for Creating Next-Generation Agriculture, Forestry and Fisheries</td>
<td>Realizing evolutionary high-yield and high-profit models by utilization of advanced IT etc</td>
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<tr>
<td>Innovative Design/Manufacturing Technologies</td>
<td>Establishing new styles of innovations arising from regions using new technologies such as Additive Manufacturing</td>
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1. Summary of the project plan

Current situation of agriculture, forestry and fisheries in Japan

- Decrease of core persons mainly engaged in farming (1.75 million, 15% decrease in 5 yrs)
- Aging of core persons mainly engaged in farming (65 yrs-old or older accounts for 65%)
- Rapid increase of large-scale farm (100ha or larger increased by 30% in 5 yrs)

Science and technology innovation aimed by SIP (2 goals)

1. To develop a highly productive and labor-saving smart agriculture model by innovative technologies such as robotics, IT, and NBT <Smart agriculture>
2. To add high value to agricultural and forest products by focusing on functionality of foods and developing new materials from unutilized resources <Enhancing value>

Future vision of agriculture, forestry and fisheries in Japan

- Strong production agriculture competitive with foreign countries
- Market expansion of agri-food industry and regional development by enhancing the value of products
Goal 1: Development of smart agriculture models

Develop an ultra-laborsaving and highly productive smart agriculture model using innovative technologies such as robotics, ICT, and NBT.

1-1) Paddy rice farming

- Smart fertilization system
- Labor-saving water management
- Multi-robot tractors
- Remote sensing

Reduce rice production cost by 40% by improving cultivation techniques by automation and intelligentization.

1-2) Greenhouse horticulture

- Japanese genome-editing techniques
- Epoch-making varieties
- Develop competitive Japan-made genome-editing techniques which produce high-yield and high-quality varieties.

Establish an optimum cultivation condition of tomato that can balance high-yield and high-quality using omics data. Reduce disease and pest damage substantially using new pesticide-free technologies.

Utilization of omics data

Technologies for disease and pest prevention
Goal 2: Enhancing the value of agricultural and forestry products

Promote enhancing values of agricultural and forest products. For example, development of high-quality or **functional healthy foods** and **new materials from unutilized resources**

**2-1) Development of functional health foods**

- Functional healthy foods
- Improvement of brain function
- Cultivation of DHA-rich algae
- Aquaculture feed
- DHA-rich seafood

**2-2) Creation of new local industry by developing new materials**

- Take out forest residues
- Modified lignin production plant
- Electronic substrate
- Heat-resistant gasket
- Slow-release fertilizer

Obtain evidences about new functions of foods such as **better cognition and locomotion** and **commercialize more than 15 foods** by cooperating with food companies and agricultural cooperatives.

Extract **modified lignin** from forest residues safely at lower cost, and develop a comprehensive processing technology to obtain **high value-added industrial applications**, then **create a new market**.
Overall goal of smart farming system

GOAL: Smart farming system realize “Society 5.0” in agricultural sector
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Introduction

Vehicle Robotics Laboratory
Research Faculty of Agriculture
Hokkaido University

ICT & Robotics for Agriculture

April, 2016
Vehicle Robotics Laboratory (VeBots)

- Unmanned Ground Vehicle
- Unmanned Surface Vehicle
- Unmanned Aerial Vehicle
- Satellite Vehicle
Prime Mister Shinzo Abe directed to get robots working in Japanese agriculture by 2020 in “Public-private dialogue towards future” held in March 4.2016.

Aging of core persons mainly engaged in farming
(65 yrs-old or older accounts for 65%)

Decrease of core persons mainly engaged in farming
(1.75 million, 15% decrease in 5 yrs)

Now

Auto steering

Robot tractor associating with human-drive tractor

Robot tractor under human observation

- Robot system by remote observation
- Multi-robot

2018

By 2020
The purpose of the guideline is to ensure safe operation of an autonomous agricultural vehicle incorporating with a robot technology. The guideline also indicates a basic concept of the safety security including the enforcement of the risk assessment and the role of the person concerned.

Effective date: March, 2017
Robot system by remote observation

Robot management system

Task planner

GIS map

Real-time monitoring & Automated documentation

Multi-GNSS

Tillage

Weeding

Spraying

Seeding

Harvesting
Tillage

Start working

Puddling

May-19-2013 Soil puddling at the same place

Soil preparation

Planting
Agri. robot demonstrations

Start working

Tillage

Transfer from barn to field

Chemical application

Harvesting
Safety sensors: laser scanners

Detection angle: 270°
Angular resolution: 0.25°
Max distance: 30m

Scanning direction

Front laser scanner

Back laser scanner
Demonstration of safety sensor
Timeline of launching Agri-robots into Japan agriculture

**Auto steering**

**Robot tractor associating with human-drive tractor**

**Robot tractor under human observation**

- Robot system by remote observation
  - **Multi-robot**

2018

By 2020

**GOAL**: Create new type of agricultural meccanization using robots, and put the technology on global markets such as US, EU and Australia.
Current trend for mechanisation to get bigger

Advantages
- Current system very effective
- Reduced labour cost/ha
- High work rates/hour
- Good for large farms & fields
- Economies of scale

Disadvantages
- High cost of operator
- High capital expense
- Reduced flexibility
- Subsoil compaction?
- Cannot be used on wet soil
Soil compaction!

Soil pan

Professor Simon Blackmore, Harper Adams University, UK
Current system: Compaction

• Up to 90% of the energy going in to cultivation is there to repair the damage caused by large machines
• Up to 96% of the field area compacted by tyres in “random traffic” systems
• If we do not damage the soil in the first place, we do not need to repair it
• Move towards light machines
Climate change!
Cooperative work by two robot tractors

Tillage

Puddling
Cooperative work by two robot tractors with human

Daytime

Night

Observation is human’s job

(This system is enable aged people, women, non-skilled people to operate perfectly)
Multi-robot tractor

Multiple small farm lands

Large farm land

Small size machines are good for both safety and soil compaction

Benefit

Farmers borrow a small robot tractor each other, and make a flexible and efficient work.
Multi-robot tractor (continued)

Multiple small lands

Large land

Multi robot system can be used from small farm land to large farm land.
FOUR multi-robot tractor demonstration
Remarks By Prime Minister Abe at 14th Annual Meeting of the STS Forum
(October 1, 2017, Kyoto, Japan)
Robot combine harvester for four rows (67PS and 70PS) M2M commutation is installed for safety.
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QZSS utilization for enhancing precise positioning

Current GNSS cannot be used in any time and any places

- Low reliability due to limited number of SVs
- Acquisition of correction signal for RTK-GPS has problems
QZSS for enhancing precise positioning

QZSS enhances GPS services in the following ways:

- **Availability enhancement** (improving the availability of GPS signals)
- **Performance enhancement** (increasing the accuracy and reliability of GPS signals)
Rice harvesting by robot combine harvester using QZSS (Sep. 12-13, 2013)
Current GNSS cannot be used in any time and any places

- Low reliability due to limited number of SVs.
- Acquisition of correction signal for RTK-GPS has problems.

- QZSS (Michibiki) will be started in Nov. 2018 to develop a satellite positioning service that can be used in a stable way in all locations at all times. This system is compatible with GPS satellites and can be utilized with them in an integrated fashion. In this way, the satellite positioning service environment will be advanced dramatically.

- QZSS can be used even in the Asia-Oceania regions with longitudes close to Japan, so its usage will be expanded to other countries in these regions as well.
Demonstrations of “Michibiki”

- Cassava farm in Thailand
- Homebush cane farm in Australia

- 90% sugar from QLD
- 2nd largest export crop
Cassava Planting Experiments
Demonstration of a robot tractor in Mackay
Remote sensing of sugarcane using a drone

Feasibility study for acquiring NDVI and crop height

Flight altitude: 100 m
Flight speed: 5 m/s
Ground resolution: 4.5 cm;
Area of test field: 550m * 300m
Generating height map from lidar data by using natural neighborhood interpolation method, to integrate with 2D NDVI map for mapping biomass’s spatial variation.

Flight speed: 5 m/s
Lidar Output: 5 Hz

To extract NDVI value and multiply with corresponding height data.
Video clip of measuring sugarcane height

Flight altitude: 30 m   Flight speed: 5 m/s
Harvesting robot for heavy crops

A harvesting robot and two transporting robots

- Harvesting heavy crop is very laborious for farmers.
- The harvesting robot is able to perform "Selective Harvesting" without giving damage.
- Target crops are pumpkin, watermelon, and cabbage, etc.
Smart farm robot

Crop status
Weather
Pest & disease

IoT

Bigdata/AI

Variable rate
Spot application of herbicides

Internet

UAV

GIS/Database

Earth observation satellite
Telematics
Multi-GNSS

Weather station

Smart robot tractor

Smart equipment
Summary

✓ Many countries including Japan are interested in robot agriculture to solve current problems of production agriculture.

✓ Performed ICT agriculture demonstration using QZSS and robot technologies in Australia and Thailand.

✓ Smart agriculture is important for next generation's production agriculture

Thank you for listening!!!