A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

- Brief overview of historical development of irrigation and drainage in Japan
- Ishigaki-jima Irrigation and Drainage Project (Okinawa, Japan)
- Takasu-waju Irrigation and Drainage Project (Gifu, Japan)
- Summary and way forward

Historical development of irrigation & drainage systems

<table>
<thead>
<tr>
<th>Year</th>
<th>BC2000</th>
<th>BC1000</th>
<th>0</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
<th>1000</th>
<th>1100</th>
<th>1200</th>
<th>1300</th>
<th>1400</th>
<th>1500</th>
<th>1600</th>
<th>1700</th>
<th>1800</th>
<th>1900</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change over time in population and land area under cultivation (10,000ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water resources development (~1990s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New era</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before Industrial revolution

Mannou-ike reservoir

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan
Development of irrigation & drainage systems (source)

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

Concrete dams

Rock-fill dams
Earthen ponds

Weirs
1950s -1960s

Koorie headwork
1990s

Present

Development of irrigation & drainage systems (plot)

(a) Non-irrigated nature-based rice production system
(b) Conventional (plot-to-plot) irrigation & drainage system
(c) Modernized (independent) irrigation & drainage system
(d) Large-sized plot (independent) irrigation & drainage system

Head work

River

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan
Development of irrigation & drainage systems (pipeline)

Continuous water flow is needed in order to meet water demands by multiple farmers → This can be accounted as a loss

Conveyance loss can be minimized while meeting water demands by multiple farmers

Development of irrigation & drainage systems (land consolidation)

- Improving agricultural productivity and efficiency
  ✓ Replotting
  ✓ Land readjustment
  ✓ Irrigation & drainage facilities
  ✓ Farm road construction
  ✓ Soil dressing
  ✓ Underdrainage

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan
Construction/management of irrigation and drainage systems

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

Proportion of the cost for constructing an irrigation and drainage system (%)

<table>
<thead>
<tr>
<th>Main body</th>
<th>Project type</th>
<th>National Gov.</th>
<th>Guideline Prefectural Gov.</th>
<th>Local Gov.</th>
<th>Farmers (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Gov.</td>
<td>Irrigation</td>
<td>66.6</td>
<td>17.0</td>
<td>6.0</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>Disaster</td>
<td>66.6</td>
<td>30.0</td>
<td>3.4</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Land improvement</td>
<td>66.6</td>
<td>24.4</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Prefectural Gov.</td>
<td>Irrigation</td>
<td>50.0</td>
<td>25.0</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>Disaster¹</td>
<td>50.0</td>
<td>29.0</td>
<td>14.0</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Disaster²</td>
<td>50.0</td>
<td>37.0</td>
<td>13.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Land improvement</td>
<td>50.0</td>
<td>27.5</td>
<td>10.0</td>
<td>12.5</td>
</tr>
</tbody>
</table>

1: Irrigation reservoir, etc.
2: Flood prevention, etc.
Policy—Long-term Land Improvement Plan


<table>
<thead>
<tr>
<th>Year</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945-</td>
<td>- Postwar rehabilitation - Food production</td>
</tr>
<tr>
<td>1965-</td>
<td>- Selective farmland consolidation - Development of primary irrigation-drainage system</td>
</tr>
<tr>
<td>1973-</td>
<td>- Generalization of paddy field</td>
</tr>
<tr>
<td>1983-</td>
<td>- Expansion of rural infrastructure development - Quality control of irrigation water</td>
</tr>
<tr>
<td>1993-</td>
<td>- Accumulation of farmland to core farmers</td>
</tr>
<tr>
<td></td>
<td>- Improving community infrastructure</td>
</tr>
<tr>
<td>2003-</td>
<td>- Prioritizing farmland consolidation with plot enlargement &amp; farmers' capacity development - Conservation of rural landscape</td>
</tr>
<tr>
<td>2008-</td>
<td>- Quantitative assessment for better project management - Revising project period from 10 to 5 years</td>
</tr>
<tr>
<td>2012-</td>
<td>- Promoting stock management - Regional cooperative activities for maintenance works</td>
</tr>
<tr>
<td>2016-</td>
<td>- Enhancing food production - Rehabilitation from disaster / enhancement of disaster prevention / risk reduction - Revitalization of rural community</td>
</tr>
</tbody>
</table>

The main characteristics of the Act are described as follows:

1. **Not the land owner but the cultivator shall participate** in the land improvement projects as the beneficiary.
2. The prior conditions for starting the land improvement project are farmers’ application and agreement.
3. Construction and management works can be implemented with more than a certain amount of agreement, usually two-thirds. Although less than one third of the beneficiaries opposed to the project, they shall be involved in the project and shall shoulder the related costs regardless of their will.

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

Development of irrigation & drainage systems (Asset Management)

Map of existing assets of irrigation and drainage facilities in Japan (2014)

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan
A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

- Brief overview of historical development of irrigation and drainage in Japan
- Ishigaki-jima Irrigation and Drainage Project (Okinawa, Japan)
- Takasu-waju Irrigation and Drainage Project (Gifu, Japan)
- Summary and way forward

Case studies of pipeline systems in Japan

A pipeline system with a pump for water lifting
Two case studies of Japan

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

 Mountainous on northern and western side, mostly sloping regions with limited flat areas
 Most rivers are short with a small catchment (9 watersheds with 23 rivers/streams)
 Rainy in May-June and August-September (annual precipitation: 2106.8 mm)
Ishigaki-jima Irrigation and Drainage Project

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Irrigation improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneficiary area</td>
<td>4338 ha (Paddy: 265 ha; Crop fields: 4073 ha)</td>
</tr>
<tr>
<td>Year</td>
<td>2014</td>
</tr>
<tr>
<td>Cost</td>
<td>28.1 billion JPY (194 million USD) (price in 2012)</td>
</tr>
<tr>
<td>Dam</td>
<td>Sokobaru, Maezato, Ishigaki, Nagura, Oura</td>
</tr>
<tr>
<td>Headwork</td>
<td>Futamata, Hegin, Nagura</td>
</tr>
<tr>
<td>Pumping station</td>
<td>Hegina, Ishigaki, Banna, Miyara, Futamata, Nagura, Takada, Oura, Tohri</td>
</tr>
<tr>
<td>Farm pond</td>
<td>Hegina left-side, Hegina right-side 1–3, Futamata, Nagura, Takada, Oura 1-2&amp;5, Tohri</td>
</tr>
<tr>
<td>Pipeline</td>
<td>Hegina right-side bank, and 41 other pipelines (105 km-long new pipelines)</td>
</tr>
<tr>
<td>Control station</td>
<td>Central control station</td>
</tr>
<tr>
<td>Target crops</td>
<td>Rice, Sugarcane, Tabaco, Sweet potato, Okura, Pumpkin, Bitter gourd, Pineapple, etc.</td>
</tr>
</tbody>
</table>
Ishigaki-jima Irrigation and Drainage Project (pre-2\textsuperscript{nd})

- Oura river district was developed as a prefectural project
- Miyara river and Nagura river districts were developed as a national project
- Three districts are independent
- Maezato & Sokobaru dams are interconnected

National project:
Nagura river irrigation and drainage

Maezato
Sokobaru
Nagura

Rules of water conveyance from Sokobaru dam

✓ Use water of Sokobaru dam prior to water conveyance from Maezato dam
✓ Water is not conveyed if water level at Sokobaru dam is below 25\% level of its storage
✓ Water is conveyed from Sokobaru dam to Oura or Nagura dam if their water level is below 50\% level of its storage

Ishigaki-jima Irrigation and Drainage Project (2\textsuperscript{nd})

- Oura river district was developed as a prefectural project
- Miyara river and Nagura river districts were developed as a national project
- Maezato & Sokobaru dams will be interconnected with each of Nagura and Oura dams

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan
Underground dam for an island with limestone

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

- Brief overview of historical development of irrigation and drainage in Japan
- Ishigaki-jima Irrigation and Drainage Project (Okinawa, Japan)
- Takasu-waju Irrigation and Drainage Project (Gifu, Japan)
- Summary and way forward

http://www.ogb.go.jp/nousui/nns/c2/tikadamu_mizu
A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

There are 45 waju polders from Gifu city (45 km from river mouth) to Bay of Ise → Nobi Plain is wide flat low-lying area

- Flooding and drought events occur occasionally, resulting in severe damage in production
- Needs for mechanization in agriculture and for multiple uses of paddy fields increased with economic growth in the region
Takasu-waju polder (a little bit closer)

ICID+CID

1. Takasu-waju Irrigation & Drainage project
2. Nagara-gawa Irrigation & Drainage project

Before the project

- Objectives: Enhancement of drainage capacity (5 pumping stations) and land reclamation
- Beneficiary area: 3116.8 ha
- Additional project: Prefectural Irrigation and drainage project: primary open channel for irrigation

After the project

https://suido-ishizue.jp/kokuei/tokai/Prefectures/2104/2104.html
ICID-CHD

Nagara-gawa Irrigation and drainage project: overview

https://suido-ishizue.jp/kokuei/tokai/Prefectures/2103/2103.html

Nagara-gawa Irrigation and drainage project

Drainage improvement

Irrigation improvement

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Irrigation and drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneficiary area</td>
<td>3030 ha</td>
</tr>
<tr>
<td>Year</td>
<td>1980–1997</td>
</tr>
<tr>
<td>Cost</td>
<td>22.0 billion JPY (194 million USD) (price in 1997)</td>
</tr>
</tbody>
</table>
| Pumping station     | 2 pumps for irrigation  
                      | 2 pumps for drainage    |
| Irrigation channel  | 1 open channel and 5 pipelines (totaled 12 km long) |
| Related projects    | Prefectural I&D project: 1 district (A: 3030 ha; Cost: 6.3 billion JPY), 1980–1996  
                      | Primary drainage project: 11 districts (A: 1679 ha; Cost: 5.3 billion JPY), 1978–1991  
                      | Pref. land consolidation: 3 districts (A: 2937 ha; Cost: 24.7 billion JPY), 1980–1999 |

https://suido-ishizue.jp/kokuei/tokai/Prefectures/2103/2103.html
**Nagara-gawa Irrigation and drainage project**

- **Achievement**
  1. Establishment of highly productive agricultural district
     - Primary irrigation and drainage facilities for stable water supply and reduced risks of inundation
     - Land consolidation projects for enlargement of paddy fields, which enabled mechanization of agricultural production
     - Multiple uses of paddy fields for rice, wheat, soy bean, and greenhouse-grown vegetables such as tomatoes, cucumbers, and strawberries.
  2. Reduced operation and management costs
     - Central control of primary irrigation and drainage facilities reduced costs and time for O&M
     - Farm roads and farmland enlargement improved production efficiency
     - Some farmers shared agricultural machines to further reduce production costs
  3. Creation of comfortable rural landscapes
     - In addition to agricultural production, rural landscapes were improved
     - Reduced inundation risks and traveling time for works, schools, etc. improved local lives
     - Farmers’ market became a good place for consumers and farmers as a lively community

---

**A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan**

- **Brief overview of historical development of irrigation and drainage in Japan**
- **Ishigaki-jima Irrigation and Drainage Project (Okinawa, Japan)**
- **Takasu-waju Irrigation and Drainage Project (Gifu, Japan)**
- **Summary and way forward**
Summary and way forward

- Pomp-based pipeline systems can be useful for various landscapes including hilly and flat low-lying farmlands (Ishigaki-jima & Takasu-waju)
- A pipeline system can be useful for improving land drainage in a flat low-lying fields (Takasu-waju, Gifu)

- Toward sustainable irrigation and drainage
  ➔ Communities including both farmers and non-farmers need to be empowered for better planning, operation and management of the systems ➔ payment for multifunctionality enhancement

- One of the biggest challenges to meet spatiotemporally varying water demands in an irrigation system
  ➔ Information and communication technologies (ICT)-based irrigation and drainage systems have been constructed, but maintenance and/or renovation cost is extremely high

- Water-Energy-Food-Ecosystems nexus can be a key for sustainability

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

Special thanks to the Ministry of Agriculture, Forestry and Fisheries, Okinawa Prefectural Government, Ishigaki City Government, Okinawa General Bureau, Ishigaki-jima Land Improvement Districts, and the farmers in the region.
A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

Development of irrigation & drainage systems (plot)

- **Low Productivity/Efficiency**: High Impact on ecosystems
- **High Productivity/Efficiency**: Low Impact on ecosystems

(a) Non-irrigated nature-based rice production system
(b) Conventional (plot-to-plot) irrigation & drainage system
(c) Modernized (independent) irrigation & drainage system
(d) Large-sized plot (independent) irrigation & drainage system
**Water-saving irrigation approaches** *(Farmers’ efforts)*
mainly by Land Improvement District (LID)

1. Sequential water distribution: Water distribution management for the purpose of water conservation. Various methods are possible, such as:
   1. Segmenting the water use area and allotting water in sequence.
   2. Allotting water according to the rotation of farm fields and time set in advance.
   3. Withdrawal from water sources at intervals of several days.

2. Cyclic irrigation
   - Drainage water from fields: upstream is dammed, removed by pump, etc., and reused

3. Rotational irrigation

4. Sacrifice paddies
   - If there is an absolute shortage of water that cannot be covered by sequential or repeated use or by water replenishment, some paddy fields are sacrificed by withholding water in order to save the others.

5. Supplementary sources
   - If there is still a shortage of water after sequential and repeated use, emergency wells are dug and groundwater is used or bottom water from inactive dams or reservoirs is used or water is received from other users.

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan

---

**Multifunctionality of irrigation and drainage systems**

In Japan, irrigation water is not only for agriculture but also for domestic uses in the region.
Payment for multifunctionality enhancement

A) Farmland maintenance

- Weeding (levee)
- Dredging
- Weeding (bank)
- Farm road maintenance

B) Resource improvement

- Filling cracks
- Surface maintenance
- Planting
- Removing invasive species

<table>
<thead>
<tr>
<th>Price in JPY</th>
<th>Prefectures except Hokkaido</th>
<th>Hokkaido</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B (qual. Imp.)</td>
</tr>
<tr>
<td>Rice paddies</td>
<td>3,000</td>
<td>2,400</td>
</tr>
<tr>
<td>Upland/fruit</td>
<td>2,000</td>
<td>1,440</td>
</tr>
<tr>
<td>Grassland</td>
<td>250</td>
<td>400</td>
</tr>
</tbody>
</table>

A high-pressure pipeline system for irrigated agriculture in the Ishigaki Island, Japan