# Integrated Water Resources Management (IWRM)

United Nations Educational, Scientific and Cultural Organization

i-WSSM
International Centre for Water Security and Sustainable Management

# IWRM


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# IWRM and Korean Case Study

IWRM

# IWRM and Korean Case Study

## Aims & Objectives

- The aims of the course are to:

  (1) Understand the basic principles of IWRM and learn the IWRM implementation process for efficient water management at the basin level.
  (2) Learn the concepts of integrated flood management and integrated drought management to which the concept of IWRM is applied.
  (3) Understand the concept of water security and learn how to connect within the IWRM framework.

- The objectives are that trainees will understand:

  (1) Key components and basic principles of IWRM;
  (2) IWRM process and achievements in Korea;
  (3) Advantages of IWRM

## References


Integrated Water Management of Korea, MOE (2020)

Regional Review of National Water Plans and/or Strategies(SWIM, 2013)


Water Resources Management in the Republic of Korea, IDB (2018)


2020/21 KSP with MRC Interim Report Workshop (2021)

Collaboration and integrated water resources management: (2019)

Global Water Partnership
Towards a water secure world

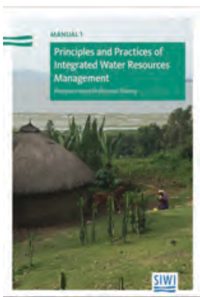
Global Water Partnership

## References

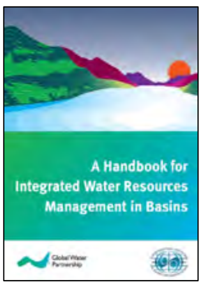

Nexus for Water Security
2020 수자원학회 학술발표회 (2013)


Water Issues in the Mekong and Role of International Development, (2021)

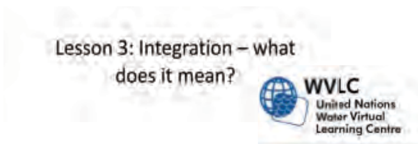
UN-Water (2013)




Principles and Practices of Integrated Water Resources Management, Manual 1 (SIWI)




A Handbook for IWRM in Basin (GWP)




Lesson 3 : Integration –
What does it mean?  WVLC

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1. Introduction of IWRM
2. IWRM Principles and Water Security
3. IWRM Case Study: Korean Case
4. Integrated Flood and Drought Management
5. Assessment of IWRM Implementation


# 1. Introduction of IWRM

## 1.1 Defining IWRM

## 1.2 Integration Category

## 1.3 The Benefits of IWRM

## 1.1 Defining IWRM

▪ **Integrated Water Resources Management (IWRM)**

- 'A (political) process which promotes the coordinated development and management of water, land and related resources, in order *to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems* (GWP 2000)'

▪ **Integration : what does this mean?**

- The need of integration : dealing with regular interactions of interdependent groups of items forming a uniform whole
- Integration → *the art and science* of blending the right proportions of these items into a whole
  - Integration does not necessarily guarantee development of optimal strategies, plans, and management schemes
  - Necessary to avoid 'mechanical amalgamation or merger' without consideration of benefits and trade-offs simultaneously → geared towards creation of synergistic effects

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## 1.1 Defining IWRM

▪ **Integrated Water Resources Management (IWRM)**

- 'A (political) process which promotes the coordinated development and management of water, land and related resources, in order *to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems* (GWP 2000)'

▪ **IWRM : political process**

- Allocation of water, financial resources and implementation of environmental goals
- Political willingness crucial
- Important to institutionalize this concept

▪ **Integrating What?**

- Natural systems : critical importance for resource availability and quality
- Human systems : determining the resource use, waste production, pollution of the resource & deciding the development priorities

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## 1.1 Defining IWRM

▪ **IWRM and its Relations to Sub-sectors**

Whilst elaborating on the different change areas with a clear focus on issues of governance, maintaining a crosssectoral approach is of paramount importance, given the interdependencies and reciprocal impacts between water resources and other sectors


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## 1.1 Defining IWRM

▪ **Important Elements of IWRM**

- The enabling environment: the general framework of national policies, legislation & regulations & information for water resources management stakeholders

- The institutional roles: functions of the various administrative levels and stakeholders

- The management instruments: operational instruments for effective regulation, monitoring & enforcement that enable the decision-makers to make informed choices between alternative actions

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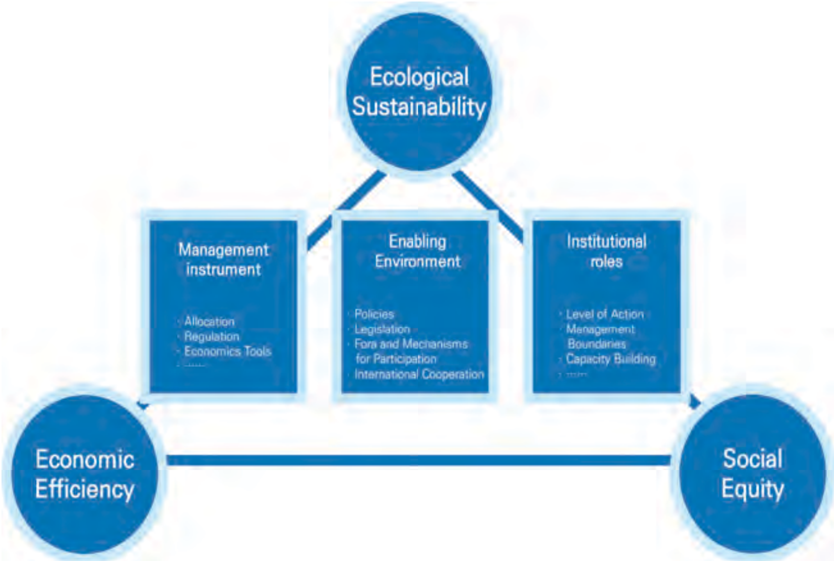
## 1.1 Defining IWRM

### ▪ Three Basic Pillars of IWRM

An IWRM approach focuses on three basic pillars and explicitly aims at avoiding a fragmented approach of water resources management by considering the following aspects, also with due reference to the 3Es of sustainable development (social-Equity, Environmental sustainability and economic Efficiency)

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## 1.1 Defining IWRM

### ▪ 13 Key IWRM Change Area

**The enabling environment**

1. Policies – setting goals for water use, protection and conservation.
2. Legislative framework – the rules to follow to achieve policies and goals.
3. Financing and incentive structures – allocating financial resources to meet water needs.

**Institutional framework**

4. Creating an organizational framework – forms and functions.
5. Institutional capacity building – developing human resources.

**Management instruments**

6. Water resources assessment – understanding resources and needs.
7. Plans for IWRM – combining development options, resource use and human interaction.
8. Demand management – using water more efficiently.
9. Social change instruments – encouraging a water-oriented civil society.
10. Conflict resolution – managing disputes, ensuring sharing of water.
11. Regulatory instruments – allocation and water use limits.
12. Economic instruments – using value and prices for efficiency and equity.
13. Information management and exchange– improving knowledge for better water management.

Source: Regional Review of National Water Plans and/or Strategies(SWIM, 2013)

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## 1.1 Defining IWRM

- **Overriding Criteria**

- Economic efficiency in water use : increasing scarcity of water & financial resources
  - The finite & vulnerable nature of water as a resource & the increasing demands, water use with maximum possible efficiency

- Social Equity : the basic right for all people to have access to water of adequate quantity and quality for human well-being, universally recognized

- Ecological sustainability : resource use managed in a way that does not undermine the life-support system & compromise use by future generations of the same resource

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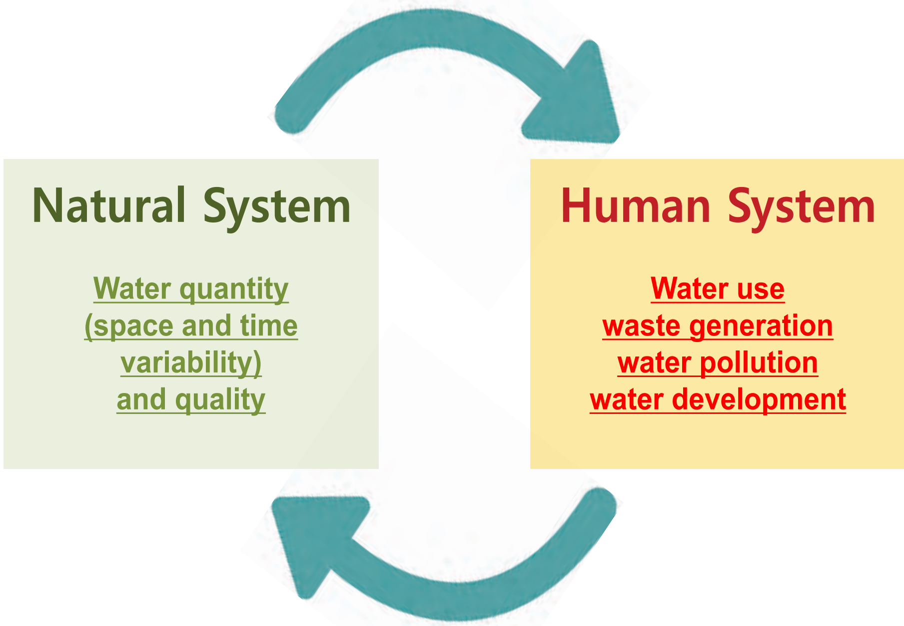
## 1.2 Integration Categories

- **Natural System & Human System**

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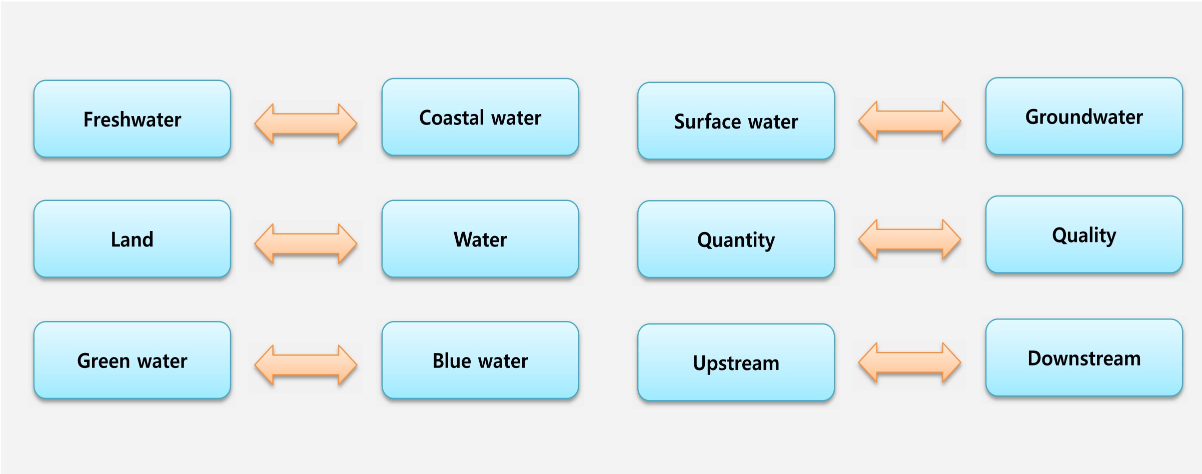
## 1.2 Integration Categories

- **Natural System Integration**

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## 1.2 Integration Categories

- **Natural System Integration**

| Natural System | Description |
|---|---|
| Freshwater & coastal zone | • Reflecting the continuum of freshwater and coastal waters<br>• Freshwater systems, important determinants of conditions in the coastal zone |
| Land & water resources | • Reflecting the hydrological cycle between the compartments air, soil, vegetation, surface and groundwater sources<br>• Land use developments and vegetation cover, influencing the physical distribution and quality of water<br>• Water, a key determinant of the character and health of all ecosystems<br>• Catchment and basin level management, imperative in managing the relationships between quantity and quality and between upstream and downstream water interests |
| Surface & ground water | • Surface water recharging groundwater<br>• A number of people rely on groundwater for water supply<br>• The use of agro-chemicals and pollution from other Non-Point Sources (NPS), threats to groundwater quality |
| Quality & quantity | • Adequate water supply with appropriate water quality<br>• Deterioration of water quality in upstream, a negative impact on downstream users |
| Upstream & downstream | • An identification of conflicts of interests between upstream and downstream users<br>• Water volume, pollution loads, flood control measures carefully considered<br>• Recognition of downstream vulnerability to upstream activities |

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## 1.2 Integration Categories

▪ **Human System Integration**

- Sectoral Integration in WR Planning, development and management
- Integration of water policy in national economic and social policy and development plans
- Integration of all stakeholders in planning and decision making process
- Integration of water and wastewater management
- Integration of policy, legal and institutions for water development
- Integration of donors

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## 1.2 Integration Categories

▪ **Human System Integration**

| Human System | Description |
|---|---|
| All policies considering impacts on water | • Governmental policies, financial priorities and planning (physical, economic & social)<br>• Encouraging the private sector players to opt for technological, production & consumption choices based on eco-efficiency<br>• Facilitating stakeholder participation in water resource allocation decisions, conflict resolution and trade-off issues |
| Integrated with economic, food, energy policies | • Integration between water policy and national economic, food, energy policies<br>• Cross-sectoral information exchange and coordination procedures & techniques for the evaluation of individual projects regarding their implications for the water resources and society included in water policy |
| Stakeholder participation in policy planning & decision process | • A key element in achievement of a balanced and sustainable utilization of water<br>• Being useful for conflict management and resolution as well as for the evaluation of trade-offs between different objectives, plans and actions |
| Water & wastewater services | • Wastewater, a useful addition to resource flows or water supply<br>• No coordinated management, reducing effective supplies by impairing water quality & increasing future costs of water supply |
| Public-private partnerships | • A lack of advanced technology, management skills, and financial resources in the public sector<br>• Contribution from the private sector, beneficial for enhancement of water supply & sanitation services<br>• Adequate sets of regulatory framework for private operators, prerequisites for the partnership |

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## 1.3 The Benefits of IWRM

- **Water Uses: Interlinked and Interrelated**
  - IWRM for better integrating environment, equity and efficiency to water use

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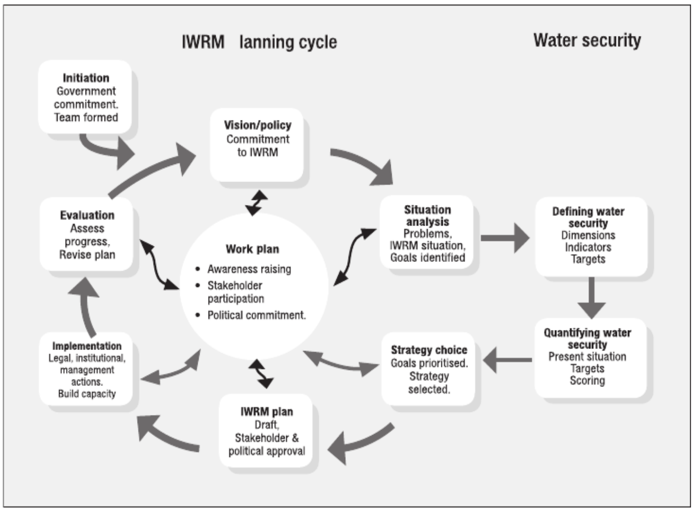
## 1.3 The Benefits of IWRM

- **IWRM planning Cycle**

Collaboration, as a part of the stakeholder engagement, could be presented at various phases of the IWRM planning cycle, including initial stages, development, implementation, and evaluation




Source: Galvez, V. & Rojas, R. (2019) Collaboration & IWRM: a literature review. World Water Policy

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## 1.3 The Benefits of IWRM

▪ **The IWRM Approach Provides Multiple Benefits**

| Type of Benefit | Aspects |
|---|---|
| Ecological | • Allocation of water resource to ecosystems to sustain terrestrial and aquatic biodiversity<br>• Maintenance of the flow of the natural water cycle and other natural nutrient cycles<br>• Role of ecosystems in erosion regulation<br>• Role of ecosystems in recharge of underground and surface water resources<br>• Role of ecosystems in water purification and pollution regulation (ecosystem cleansing, of polluted water, carbon sequestration, etc.)<br>• Role of ecosystems in flood regulation<br>• Role of ecosystems in climate regulation<br>• Role of ecosystems in air quality regulation |
| Economic | • Efficient and equitable supply of water for industry and agriculture<br>• Water recycling reuse and waste reduction<br>• Sustainable sanitation (minimization of pollution and waste reduction)<br>• Efficient irrigation systems<br>• Fishing and other natural resources for economic activities |
| Social | • Provision of quality water for human consumption, health and sanitation needs<br>• Transportation of waste by water |
| Cultural | • Natural and cultural heritage : water resources and ecosystems for recreation, tourism and sports |
| Spiritual | • Conservation of sacred sites and rare species |
| Political | • Democratic processes to ensure equitable participation and distribution of water rights and responsibilities<br>• Inclusion of women in water resources planning and decision-making<br>• Stakeholder cooperation and collaboration in water resource development, use and management |

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# 2. IWRM Principles and Water Security

## 2.1 IWRM Principles

## 2.2 What is Water Security?

## 2.3 Water Security Assessment

## 2.1 IWRM Principles

### ▪ Principle 1: Water as a Finite and Vulnerable Resource

- A holistic approach
- Resource yield has natural limit
- Effects of human activities
- Upstream-downstream user relation
- A holistic institutional approach



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## 2.1 IWRM Principles

### ▪ Principle 2: Participatory Approach

- Real participation
- Participation is more than consultation
- Achieving consensus
- Creating participatory mechanism and capacity
- The lowest appropriate level



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## 2.1 IWRM Principles

### ▪ Principle 3: The Important Role of Women

- Involvement of women in decision-making
- Women as water users
- IWRM requires gender awareness


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## 2.1 IWRM Principles

### ▪ Principle 4: Water as an Economic Good

- Water has a value as an economic good
- Useful water value and cost concepts
- The goal of full cost recovery
- Managing demand through economic instruments
- Financial self-sufficiency versus water as a social good



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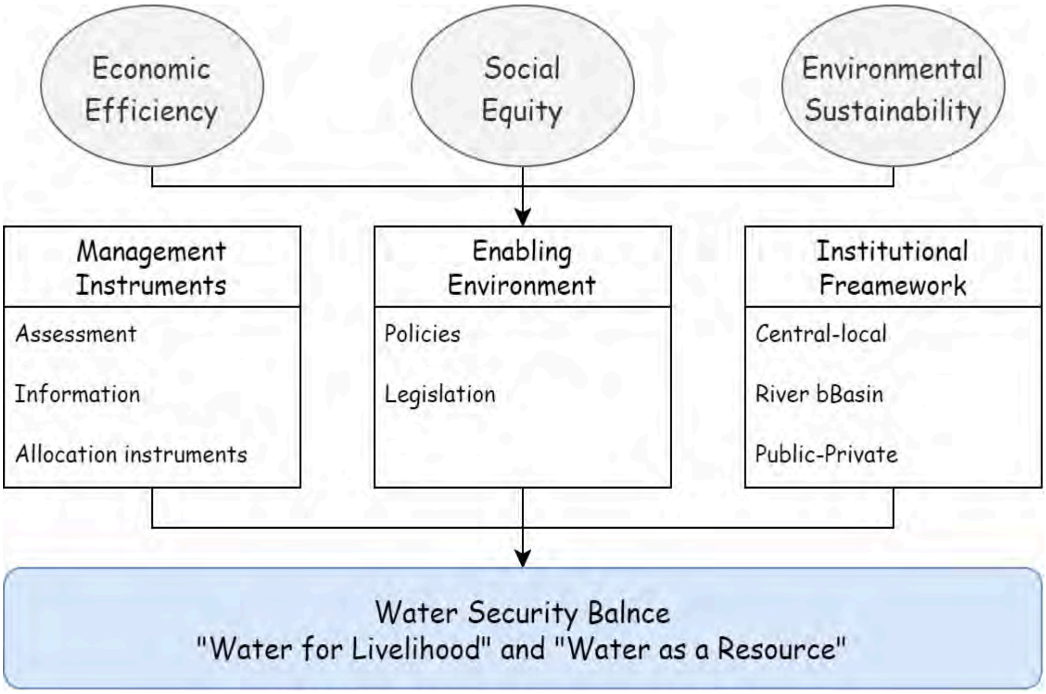
## 2.2 What is Water Security?

▪ **IWRM for Water Security**

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## 2.2 What is Water Security?


Assessing key gaps and needs to improve global Water Security require a clear understanding of the drivers, trends and patterns of collective action, and of the newer dimensions of the Water Security Nexus.

Source: UN-Water (2013), www.watercooperation2013.org

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## 2.3 Water Security Assessment

- **Water Security Assessment Framework**


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## 2.3 Water Security Assessment

- **Indicators for Water Security Assessment**

| Water Security Core area | Indicators | Temporal Scales | Definition of Indicators | Resource |
|---|---|---|---|---|
| Core are 1. **Social equity** | Improved drinking water supply rate | 2017 | Total population with access to improved drinking-water source(JMP) | WHO / UNICEF(JMP) |
| | Renewable water resources per person | 2012 | Total internal renewable water resources(IRWR)/Total population | AQUASTAT |
| | Sewerage rate | 2015 | Improved sanitation facilities (% of population with access) | INDEX MUNDI |
| | Diarrheal diseases | 2017 | Diarrheal diseases death rates in children under 5 | Our World in Data |
| Core area 2. **Economic efficiency** | Value of industrial water consumption | 2000:2017 | Industrial production/ Industrial water withdrawal | OECD / AQUASTAT |
| | Value of agricultural water consumption | 2000:2017 | Value of Agricultural Production/Agricultural water withdrawal | FAO / AQUASTAT |
| | GDP(Gross Domestic Product) | 2015 | GDP per capita | World Bank |
| Core area 3. **Resilience to water-related disasters** | Drought frequency | 1979:2018 | SPI(Standardized Precipitation Index)<-1 or less occurrence frequency | NOAA |
| | Areas of vulnerable to drought | 2013:2017 | % of Total country area cultivated | AQUASTAT |
| | Flood frequency | 1969:2018 | Flood occurrence(WRI) | AQUASTAT |
| | Areas of vulnerable to flood | 2017 | Urban population/Total population | AQUASTAT |
| | Irrigation area ratio | 2012 | Area equipped for irrigation: total (1000 ha) | AQUASTAT |
| | Flood control ability | 1950:2018 | Reservoir Capacity/Total Area | ICOLD / AQUASTAT |

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## 2.3 Water Security Assessment

▪ **Indicators for Water Security Assessment**

| Water Security Core area | Indicators | Temporal Scales | Definition of Indicators | Resource |
|---|---|---|---|---|
| Core area 4. **Environmental sustainability** | River Health Index | 2010 | Biodiversity Threat | RIVERS IN CRISIS |
| | | | Human Water Security Threat | |
| Core area 5. **Government Competency** | Government Capacity | 2018 | Voice and Accountability | World Bank |
| | | | Political Stability and Absence of Violence | |
| | | | Government Effectiveness | |
| | | | Regulatory Quality | |
| | | | Rule of Law | |
| | | | Control of Corruption | |

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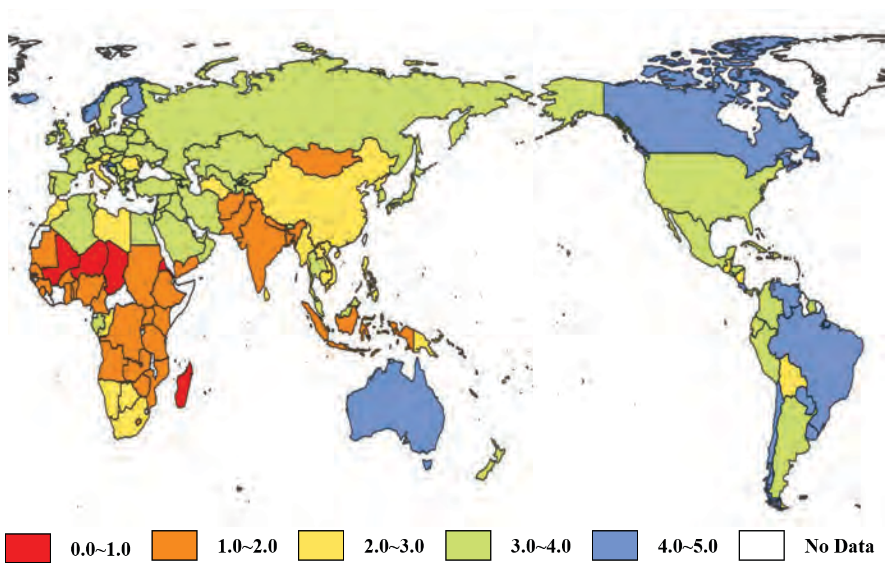
## 2.3 Water Security Assessment

▪ **Core area 1. Social Equity**

| Indicators |
|---|
| Improved drinking water supply rate |
| Renewable water resources per person |
| Sewerage rate |
| Diarrheal diseases |

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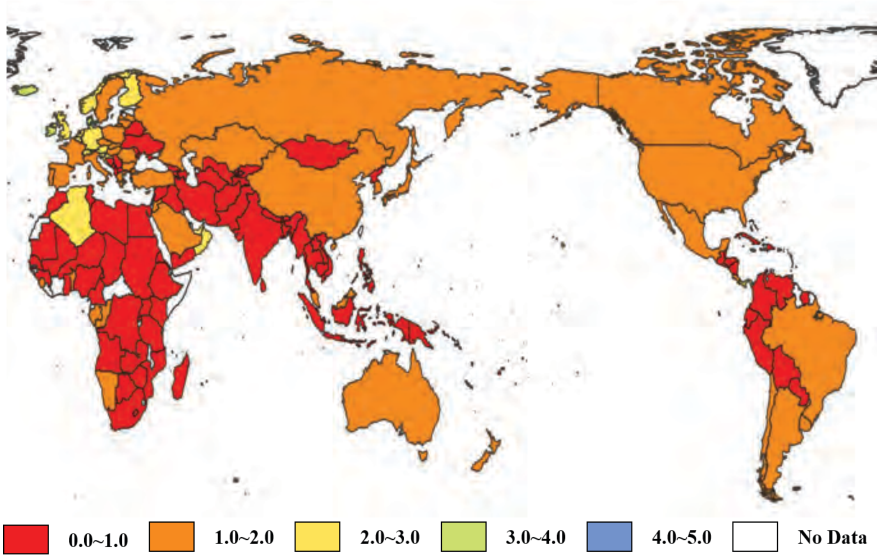
## 2.3 Water Security Assessment

▪ Core area 2. Economic Efficiency

| Indicators |
|---|
| Value of industrial water consumption |
| Value of agricultural water consumption |
| GDP (Gross Domestic Product) |

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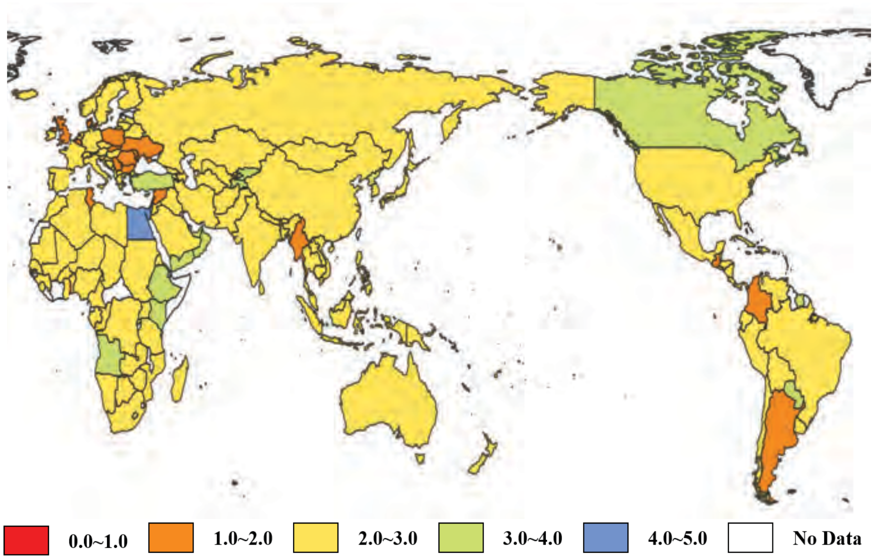
## 2.3 Water Security Assessment

▪ Core area 3. Resilience to Water-Related Disaster

| Indicators |
|---|
| Drought frequency |
| Areas of vulnerable to drought |
| Flood frequency |
| Areas of vulnerable to flood |
| Irrigation area ratio |
| Flood control ability |

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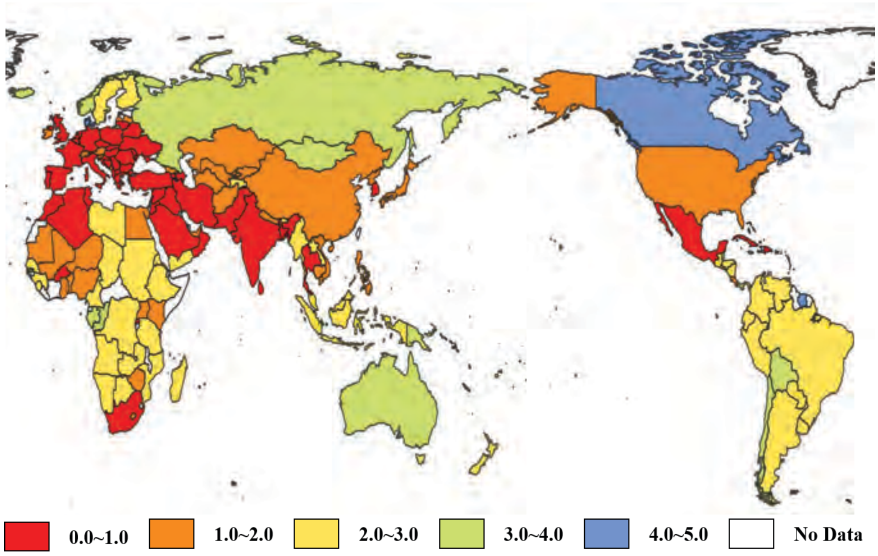
## 2.3 Water Security Assessment

- **Core area 4. Environmental sustainability**

| Indicators |
| --- |
| Biodiversity Threat |
| Human Water Security Threat |

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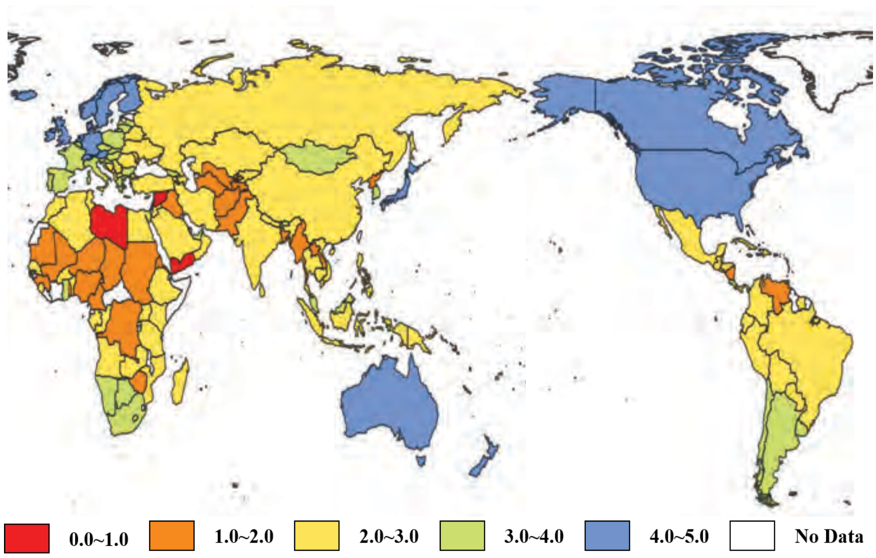
## 2.3 Water Security Assessment

- **Core area 5. Government Competency**

| Indicators |
| --- |
| Voice and Accountability |
| Political Stability and Absence of Violence |
| Government Effectiveness |
| Regulatory Quality |
| Rule of Law |
| Control of Corruption |

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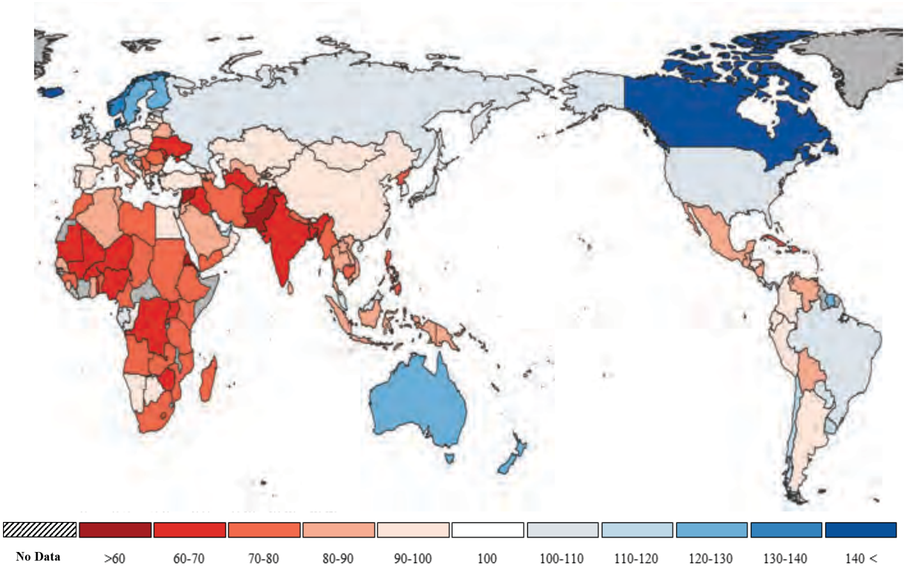
## 2.3 Water Security Assessment

▪ **Water Security of Global South**

- Based on the results of the global water security evaluation

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## 2.3 Water Security Assessment

▪ **Water Security of Global South**

- The results of Mekong's water security evaluation and international cooperation plan based on Korea

| Country | Core Area 1<br>Social Equity | Core Area 2<br>Economic Efficiency | Core Area 3<br>Water Disaster | Core Area 4.<br>Environmental Sustainability | Core Area 5.<br>Government Competency | Water Security |
|---|---|---|---|---|---|---|
| **Cambodia** | **2.25** | 1.00 | 2.83 | 2.00 | 2.17 | **2.05** |
| **Laos** | 2.50 | 1.00 | **3.00** | **3.00** | **2.00** | 2.30 |
| **Thailand** | 3.50 | 1.00 | 2.67 | 1.00 | 2.67 | 2.17 |
| **Vietnam** | 2.50 | **0.67** | 3.00 | 2.00 | 2.83 | 2.20 |
| **Myanmar** | 2.75 | **0.67** | **2.00** | **3.00** | **2.00** | 2.08 |
| **Republic of Korea** | **4.00** | **1.67** | 2.83 | **1.00** | **4.00** | **2.70** |

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# 3. IWRM Case Study : Republic of Korea

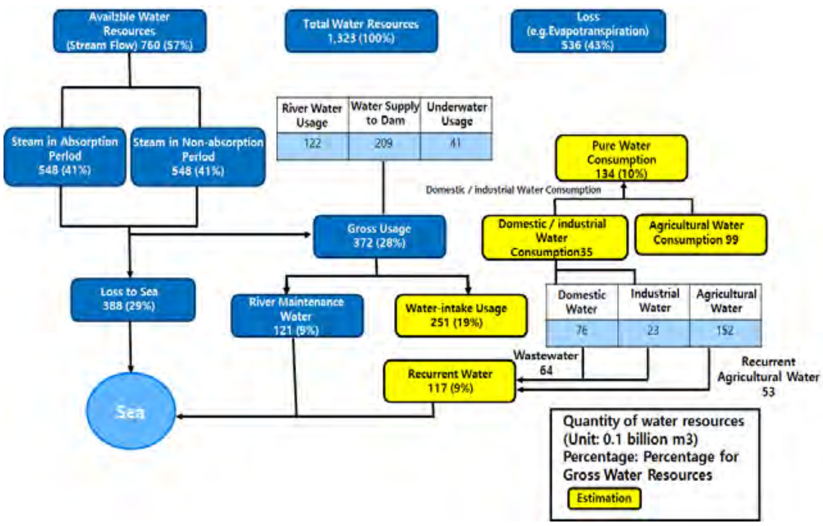
3.1 Water Resource Management Framework

3.2 IWRM Process

3.3 Achievements of IWRM

## 3.1 Water Resources Management Framework

- Annual renewable water resources in South Korea total 76 billion m3, or 57% of the total amount of water resources (132 billion m3).
- The remainder is lost by evapotranspiration or other causes. Total water use consists of river maintenance water (12.1 billion m3), domestic water (7.6 billion m3), industrial water (2.3 billion m3), and agricultural water (15.2 billion m3), which is equal to 61% of water intake usage.

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## 3.1 Water Resources Management Framework

- **IWRM through Water Resources Management Unification (2018)**

| Water Related Functional Ministry | **Before** the unification of water management ( ~2018 ) | | **After** the unification ( 2019 ~ ) |
|---|---|---|---|
| | Water resource management | Water resource development | |
| Ministry of Land, Infrastructure and Transport (MOLIT) | • National river management<br>• Flood and drought management<br>• Wide-area water supply management<br>• Hydrological observation<br>• Multi-purpose dam management<br>• Groundwater management<br>Quantity Management | • Construction of a multipurpose dam<br>• Construction of wide-area water supply system<br>• Construction of canals<br>Supply Infra Structure | Unified into the **Ministry of Environment** |
| Ministry of Environment (MOE) | • Water quality observation and regulation<br>• River naturalization project<br>• Drinking water quality standard management<br>• Local water supply and sewage maintenance<br>• Sewage and wastewater treatment facility management<br>• Meteorological observation services<br>Quality Management | • Environmental impact assessment<br>• Construction of urban sewage treatment facilities<br>• Construction of wastewater treatment facility<br>Treatment Infra | |
| Ministry of Interior and Safety (MOIS) | • Local river management<br>• Establishment of measures to reduce natural disasters | • Natural disaster impact assessment | Keep status quo an d continue to prom ote unified water m anagement |
| Ministry of Food, Agriculture, Forestry and Fisheries | • Agricultural dam management<br>• Estuary bank management | • Construction of agricultural dams<br>• Groundwater development (for agriculture) | |

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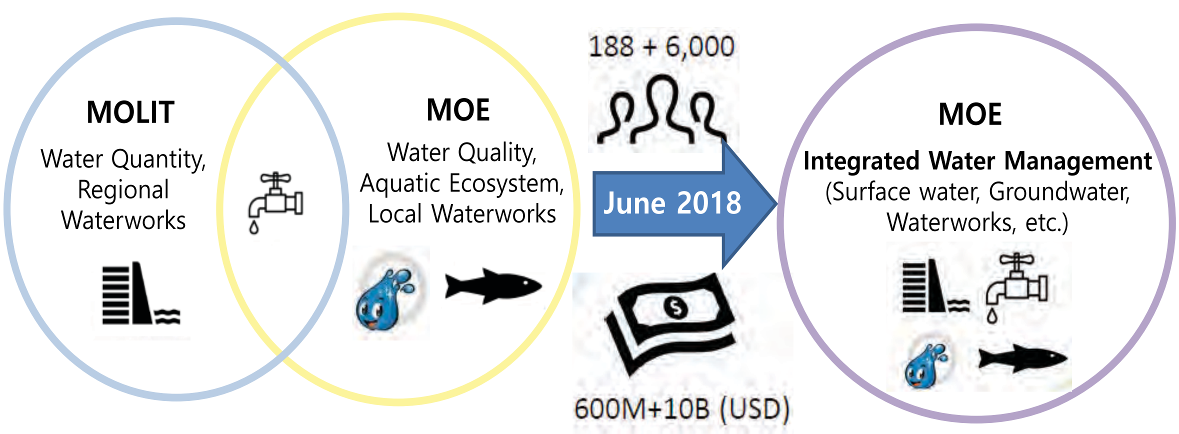
## 3.2 IWRM Process

- **Policy Reform for Integrated Water Management of Korea**

- "1st Governmental Reorganization in Water Sector since 1994"

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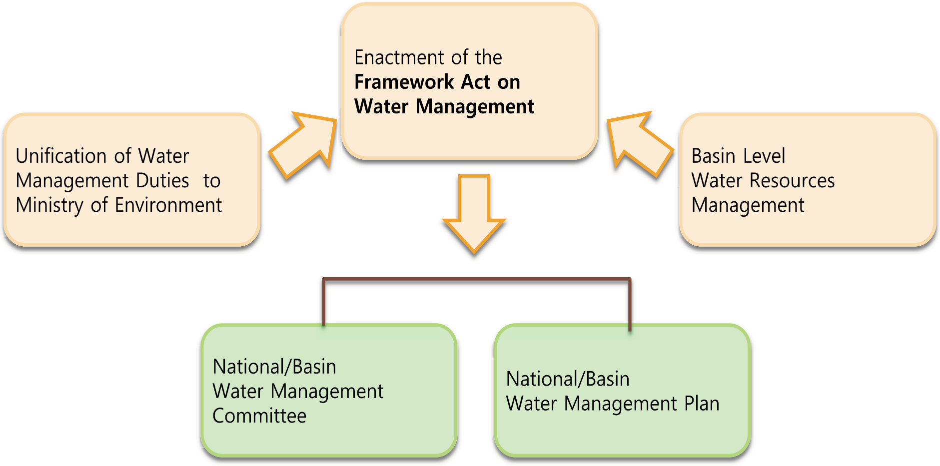
## 3.2 IWRM Process

- **Strategy for IWRM of Korea**

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## 3.2 IWRM Process

- **[Mission 1] The Framework Act on Water Management** (enforced in June 2019)

  - "The State shall have the responsibilities to **establish a sustainable water management system in accordance with the basic ideology for water management** and to **formulate and implement a comprehensive plan** necessary for improving the quality of life of the people. (Article 5)"

**Basic Ideology / Principles**

- Public nature of water (Article 8)
- Sound water cycle (9)
- Conservation of aquatic ecosystems (10)
- Management by basin (11)
- Integrated water management (12)
- Cooperation and coordinated management (13)
- Distribution of water (14)
- Management, etc. of water demand (15)
- Permission, etc. to use water (16)
- Cost bearing (17)
- Response to climate change (18)
- Participation in water management policies (19)

**National / Basin Plans**

- Items included in the National Plans (27)
  - ✓Basic objectives and implementation direction of water management policies
  - ✓Mid to long term prospect on water supply and demand
  - ✓Mid to long term future investment of water management budget
  - ✓Boosting the growth and strengthening t he competency of the water industry
  - ✓Annual assessment on implementation p rogress of the Master Plans, etc.
- Holding of public hearing (31)

**Water Committees**

- Establishment, etc. of the National/Basin Water Committees (20)
- Composition, etc. (21, 23)
- Functions (22, 24)
- Term of Office, etc. of Members (25)
- Meetings, etc. (26)

Source: Ministry of Environment of Korea

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## 3.2 IWRM Process

### ▪ [Mission 1] The Framework Act on Water Management

| | Water Environment | Water Supply and Sewerage | Water Resources | Disaster Prevention | Other |
|---|---|---|---|---|---|
| Ministry of Environment | Water Environment Conservation Act | Water Supply and Waterworks Installation Act | Water Supply and Waterworks Installation Act | | |
| | Act on the Management and Use of Livestock Excreta | Sewerage Act | Groundwater Act | | |
| | Act on the Improvement of Water Quality and Usage of the Four Major River Basin | Drinking Water Management Act | Act on the Construction of Dams and Assistance, etc. to Their Environs | | |
| | | Act on Promotion and Support of Water Reuse | Special Act on the Utilization of Waterfronts | | |
| Other ministries | | | River Act (Ministry of Land, Infrastructure and Transport) | | Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy (Ministry of Trade, Industry and Energy) |
| | | | Agricultural and Fishing Villages Improvement Act (Ministry of Agriculture, Food and Rural Affairs) | Small River Maintenance Act (Ministry of the Interior and Safety) | |
| | | | Development and Management of Deep Sea Water Act (Ministry of Oceans and Fisheries) | Reservoir and Dam Safety Control and Disaster Prevention Act (Ministry of the Interior and Safety) | |

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## 3.2 IWRM Process

### ▪ [Mission 2] Presidential/Basin Water Management Commissions

- 「Framework Act on Water Management」 Article 20
  - **"The National Water Management Committee..., and Basin Water Management Committees by each basin shall be established...to deliberate and decide on important matters concerning water management."**

**Functions of the National Water Management Committee (Article 22)**

- **Formulating and amending the "Master Plans for National Water Management"**
- Whether the "Comprehensive Basin Water Management Plans" complies with the "Master Plan for National Water Management"
- Designating the scope of basins by water system
- Water movement among basins for appropriate water distribution
- Whether plans related to water management submitted by related administrative agencies comply with the relevant plans for national or basin water management
- **Mediation of any of the following water disputes**
  - ✓ A water dispute to which a central administrative agency or metropolitan government is a party
  - ✓ A water dispute over at least two basins
  - ✓ Any other water dispute prescribed by Presidential Decree
- **Evaluating the implementation of the "Master Plan for National Water Management" as well as overall water management;**
- Matters brought to the Committees by the Chairpersons, regarding national or basin water management, etc.

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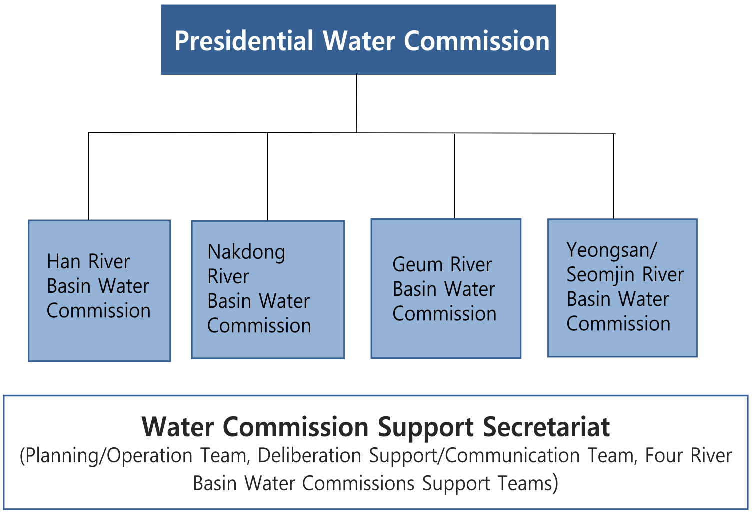
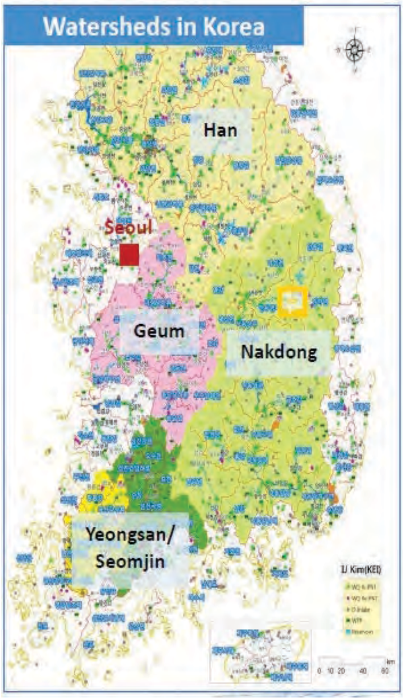
## 3.2 IWRM Process

- **[Mission 2] Presidential/Basin Water Management Commissions**

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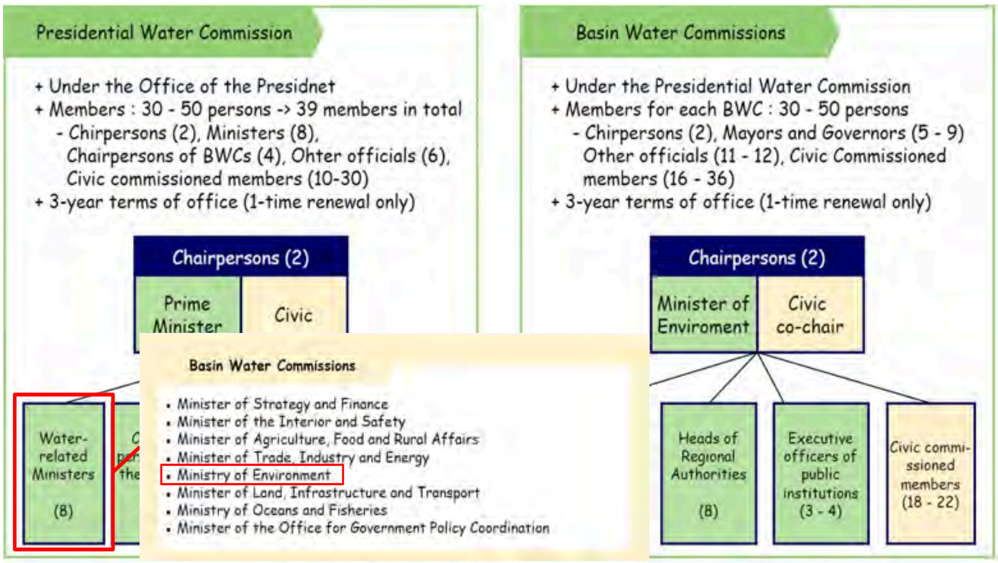
## 3.2 IWRM Process

- **[Mission 2] Presidential/Basin Water Management Commissions**




**By law, the number of the civil members should be GREATER than the ex-officio members.**

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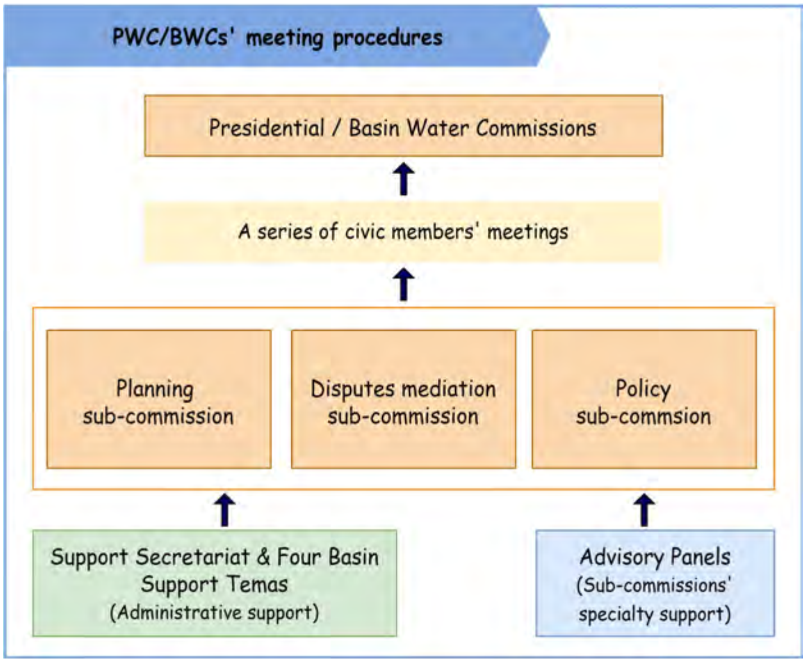
## 3.2 IWRM Process

- **[Mission 2] Presidential/Basin Water Management Commissions**
  - A number of discussions led by civil committee members

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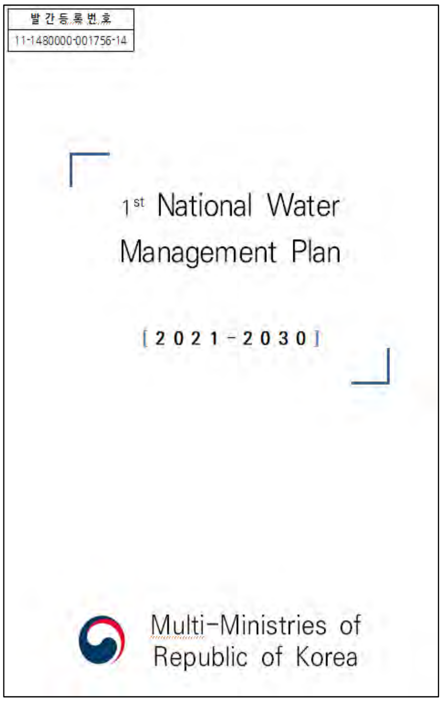
## 3.2 IWRM Process

- **[Mission 3] National/Basin Water Management Plan**

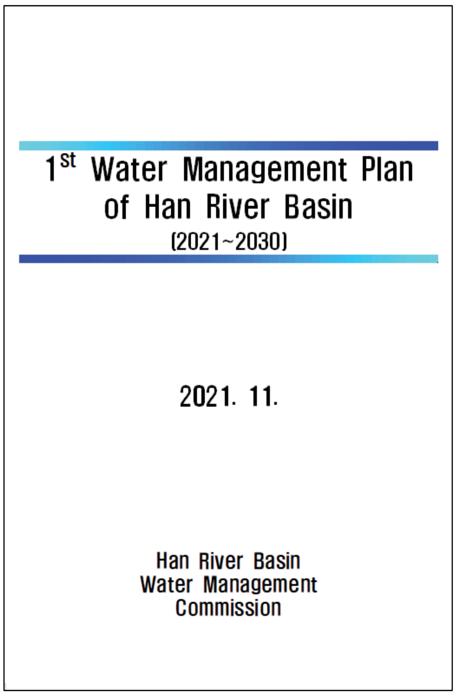


발간등록번호
11-1480000-001756-14

1st National Water Management Plan

[2021-2030]

Multi-Ministries of Republic of Korea



1st Water Management Plan of Han River Basin
(2021~2030)

2021. 11.

Han River Basin Water Management Commission

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## 3.3 Achievements of IWRM

- **(IWRM strategy 1) To establish a groundwork for IWRM system**
  - To establish the basic principles of water management
  - The solve local water-related problems through governance

- **Established the basic principles of water management.**
  - Derived core values and targets for water management from the operation of the IWRM Vision Forum.
  - They will be reviewed then implemented to the establishment of the National Basic Plan for Water Management (in 2020).
    - (Core values) Publicity, sustainability, safety, equity, efficiency, democracy, and accountability
    - (Targets) To ensure sound water cycles, to integrate water supply and demand, to implement basin-level IWRM, to establish the required governance, and to establish a sustainable administrative and financial system

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## 3.3 Achievements of IWRM

- **(IWRM strategy 2) To establish a swift response system to ensure water security**
  - To improve water quality through the integrated management of water quantity and quality
  - To respond to algal bloom through the utilization of the water for environmental improvement
  - To overcome droughts through the establishment of a stable industrial and agricultural water supply system
  - To strengthen inter-organizational cooperation for flood response

- **(A case of the Han River) Detection of a compound (2-MIB) deteriorating the taste and smell of tap water at Paldang Dam (November 2018, maximum 162ppt)**
  - A swift increase of water release from Soyanggang Dam was carried out (November 28th to 29th, 2018, 150 million tons in total)
  - The amount of the compound in the Han River was decreased to below the standard for drinking water (2-MIB, 20 ppt)

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## 3.3 Achievements of IWRM

- **(A case of the Nakdong River) Occurrence an algae alert in Changnyeonghaman stank (August 2018, up to 350,000 cells of blue-green algae)**
  - A swift increase of water release from Andong Dam, Hapcheon Dam and Imha Dam was carried out. (August 14th, 2018, 40 million tons)
  - The amount of algal bloom in Changnyeonghaman stank was reduced (350,000 cells → 150,000 cells after the water release)

- **Secured 10 billion tons of water by the end of the flooding period (September 2019) through accurate predictions of weather and the water storage of dams.**
  - Steady supply of industrial and agricultural water (140% water storage of multi-purpose dams compared to last year, 1.39 million people in the west of Chungnam Province and other areas avoided limited water supply)

- **Stable flood management in 2018, including effective national wide operations of multi-purpose dams**
  - Minimization of flood damage

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## 3.3 Achievements of IWRM

- **(IWRM strategy 3) To provide clean drinking water**
  - To advance the management of pollution sources
  - To strengthen the credibility of tap water

- **Launch the new policies to advance the management of pollution sources.**
  - Started a pilot project of zero liquid discharge in Daegu and Gumi, which aimed to block the inflow of waste water into the water system by re-using processed waste water as industrial water. (March 2019)
  - Started the operation of the Waegwan Water Quality Monitoring Station to reinforce the management of micropollutants from February 2019, and introduced environmental forensic techniques using analysis of isotopes (Env-Forensic, a collaboration between Environmental Offices, National Institute of Environmental Research, and K-water).
  - To strengthen the management of a large scale non-biodegradable organic materials' emission from industrial complexes, we created a solution that converts the index for the management of organic materials applied to waste water emitting facilities from Chemical Oxygen Demand) (COD) to Total Organic Carbon (TOC).

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## 3.3 Achievements of IWRM

- **(IWRM strategy 4) To create new values of water**
  - To create eco-friendly water cycle cities
  - To promote water-related industries and jobs

- **To create eco-friendly water cycle cities.**
  - Create the basic design (July 2018) and the comprehensive plan (December 2018) for the pilot project to build the Eco-Delta City in Busan, a national smart city. Based on the plan, we will make the city a Korean style water-specialized city.
  - Introduced high-precision small-sized rainfall radars, smart water purification facilities, water reuse system and the first-ever hydrothermal energy system in Korea using river water for every step of urban water circulation (rainfall-stream-purification-sewage-reuse)
  - In order to solve urban water-related problems, we are continuously working on water cycle city projects (Daejeon, Gwangju, Ulsan, Gimhae and Andong), and participating in the national project to build a hydrothermal energy convergence cluster (Chuncheon).
  - We laid a groundwork to promote water-related industries and jobs.

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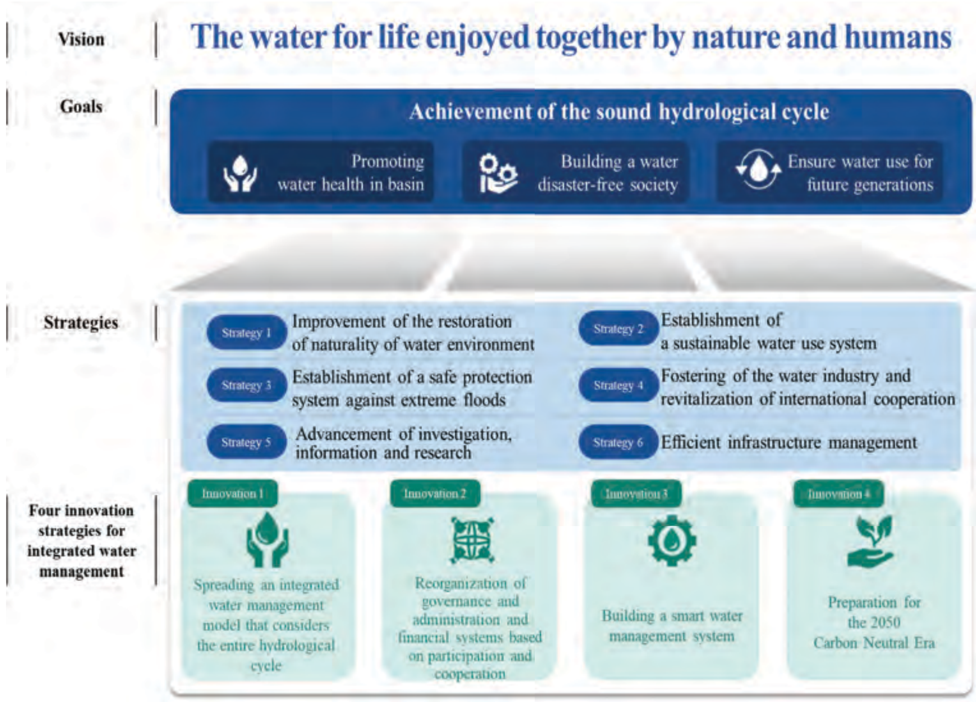
## 3.3 Achievements of IWRM

- **1st National Water Management Plan of Korea (2021-2030)**

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# 4. Integrated Flood and Drought Management

4.1 Concept of IFM and IDM

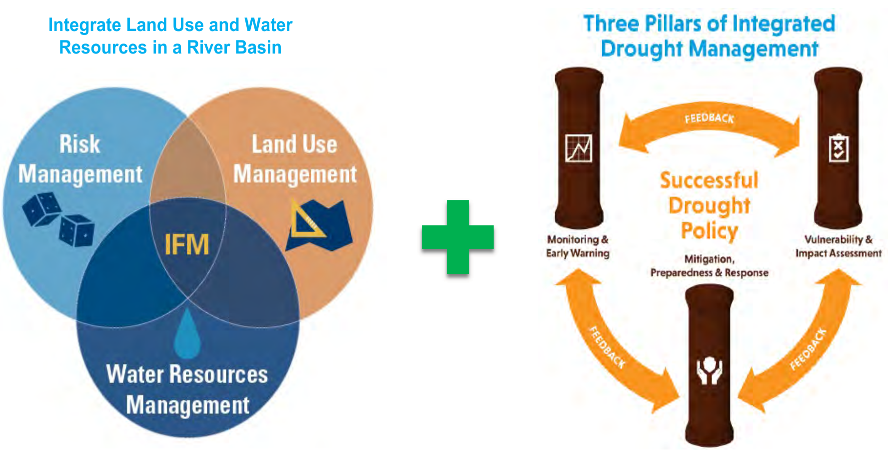
4.2 National Strategy for Flood & Drought Management

4.3 Adaptive Actions for Integrated Flood & Drought Management

## 4.1 Concept of IFM and IDM

- **Benefits of Integrated Flood and Drought Management**

1. Develop capacity and established frameworks at the local, national and regional levels to ensure risk informed decision-making
2. Develop concrete adaptation and environmentally-friendly actions using an integrated approach
3. Strengthen policy and institutional capacity for integrated flood and drought management at the local, national and trans-boundary levels.

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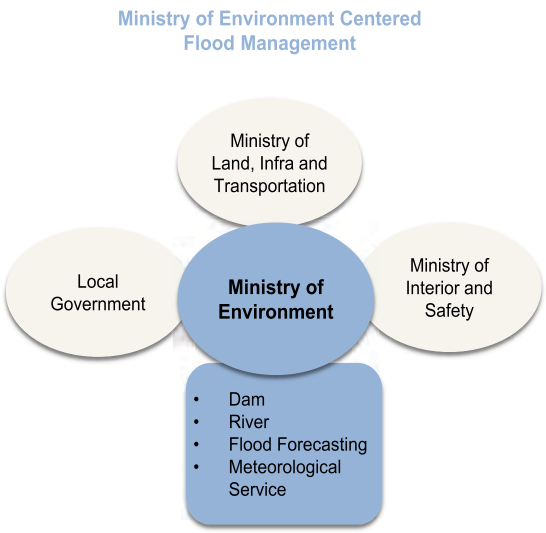
## 4.1 Concept of IFM and IDM

- **Integrated Flood and Drought Management Framework of Korea**

- The ultimate meaning of IWRM is not the integration of water-related government organizations.
- It is more important to see how well coordination and cooperation are made between ministries rather than which department leads the flood and drought management.





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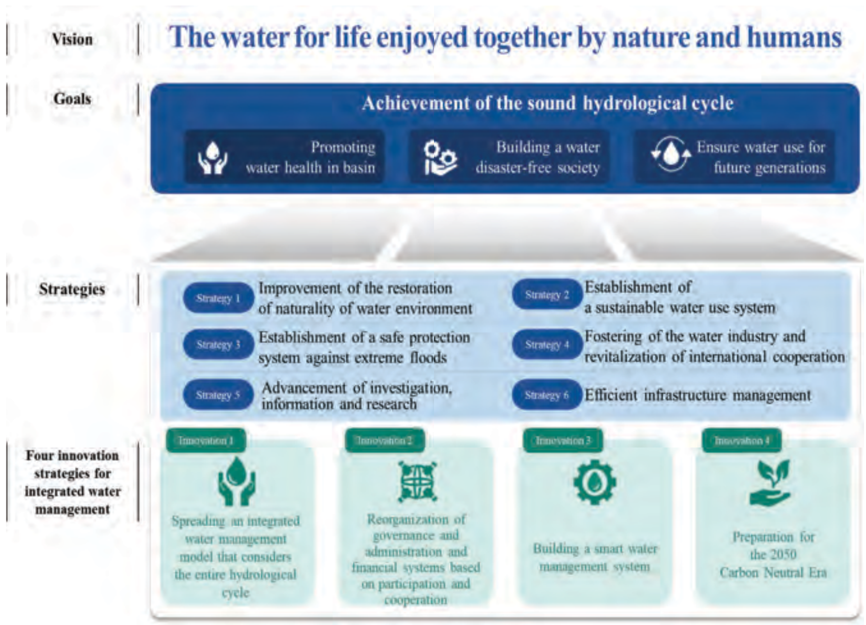
## 4.2 National Strategy for Flood & Drought Management

- **National Water Management Plan of Korea (2021-2030)**

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# 4.2 National Strategy for Flood & Drought Management

## ▪ National Strategy for Drought Management of Korea

| | |
|---|---|
| Strategy ❶ | Building a response system for extreme floods in response to climate change |
| Initiatives | 1-1 Increase in flood protection standards in response to the climate crisis<br>1-2 Improvement of flood protection targets for major national infrastructures<br>1-3 Establishment of a basin-level flood management system |
| Strategy ❷ | Reinforcement of flood response and expansion of preventive investments in connection with dams and rivers |
| Initiatives | 2-1 Expansion of flood control capacity for multipurpose dams<br>2-2 Relief of flood control constraints in the downstream area of the dam<br>2-3 Enhancement of decision-making for dam operation and establishment of a resident-participating flood management system<br>2-4 Reinforcement of river facility safety standards<br>2-5 Expansion of preventive investment in river facilities<br>2-6 Enhancement of reservoir capacity to respond to the flood crisis |
| Strategy ❸ | Reinforcement of the urban flood management system |
| Initiatives | 3-1 Reinforcement of urban flood protection standards<br>3-2 Expansion of urban inundation response projects<br>3-3 Reinforcement of the maintenance of disaster prevention facilities<br>3-4 Establishment of evacuation system for flood-risk areas |
| Strategy ❹ | Advancement of the flood forecast system |
| Initiatives | 4-1 Expansion of flood forecast points and improvement of forecast accuracy<br>4-2 Enhancement of predictability for localized flash floods through expansion of rainfall radars, etc.<br>4-3 Reinforcement of the cooperation system with forecasting agencies and establishment of a comprehensive control system for flood forecasting and dam operation |

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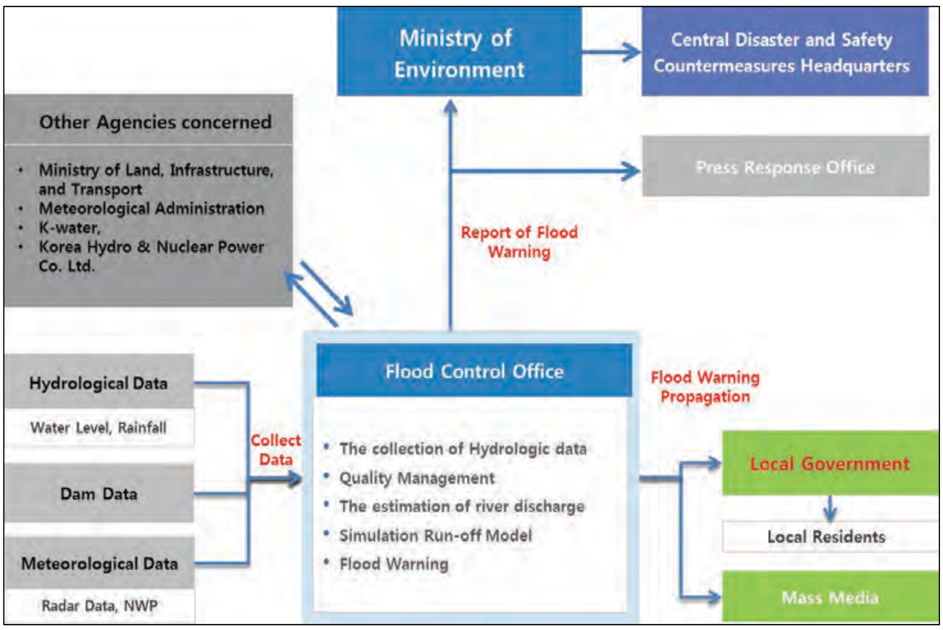
# 4.2 National Strategy for Flood & Drought Management

## ▪ Flood Forecasting & Warning Framework of Korea

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## 4.2 National Strategy for Flood & Drought Management

▪ National Strategy for Drought Management of Korea

| | |
|---|---|
| Strategy ❶ | **Establishment of a foundation for strengthening demand management to prepare for future water shortages** |
| Initiatives | 1-1 Establishment of a demand management strategy that links water use and carbon emissions<br>1-2 Improvement of management system for efficient use of agricultural water<br>1-3 Reinforcement of regulations on the use of groundwater<br>1-4 Establishment of water demand management system |
| Strategy ❷ | **Securing water resources through efficient water supply facilities and diversification of water sources** |
| Initiatives | 2-1 Improvement of water supply capacity for existing dams and reservoirs<br>2-2 Improvement of the efficiency of water supply through a water supply linkage system<br>2-3 Securing new water resources customized for each region considering the water self-sufficiency rate<br>2-4 Reinforcement of management of groundwater run-off in downtown areas<br>2-5 Development of alternative water resources and activation of water reuse |
| Strategy ❸ | **Establishment of a rational water distribution plan through mutual consent** |
| Initiatives | 3-1 Establishment of the foundation for the advanced river water management system<br>3-2 Establishment of standards to redistribute the previously secured quantity of dams, reservoirs, rivers, etc.<br>3-3 Establishment of principles and standards for rational cost-sharing for the use of water resources<br>3-4 Establishment of the principle of water dispute mediation, and reinforcement of the effective water dispute mediation system |
| Strategy ❹ | **Establishment of a water supply system trusted by the people** |
| Initiatives | 4-1 Reinforcement of sanitation standards for water supply facilities in consideration of the public's expectation<br>4-2 Facility reinforcement to prevent water supply accidents such as the occurrence of red water and inflow of larvae<br>4-3 Improvement of the efficiency of tap water management through the introduction of new technologies and ICT equipment<br>4-4 Improvement of an operating system by reinforcing management manpower and operators' expertise<br>4-5 Establishment of a tap water management system in which citizens directly participate and communicate |
| Strategy ❺ | **Guaranteed Water Right in areas with vulnerable water welfare** |
| Initiatives | 5-1 Improvement of the water supply rate in rural areas<br>5-2 Reinforcement of safety management of small-scale water supply facilities<br>5-3 Efficiency of the operating system through linkage of local and regional water supply systems |
| Strategy ❻ | **Advancement of the drought management system and establishment of the extreme drought response system** |
| Initiatives | 6-1 Establishment of national drought monitoring, forecasting, response, and comprehensive management system<br>6-2 Reinforcement of the capacity of local governments to respond to drought customized to the region<br>6-3 Establishment of a response system for extreme droughts (megadroughts) that have not been experienced |

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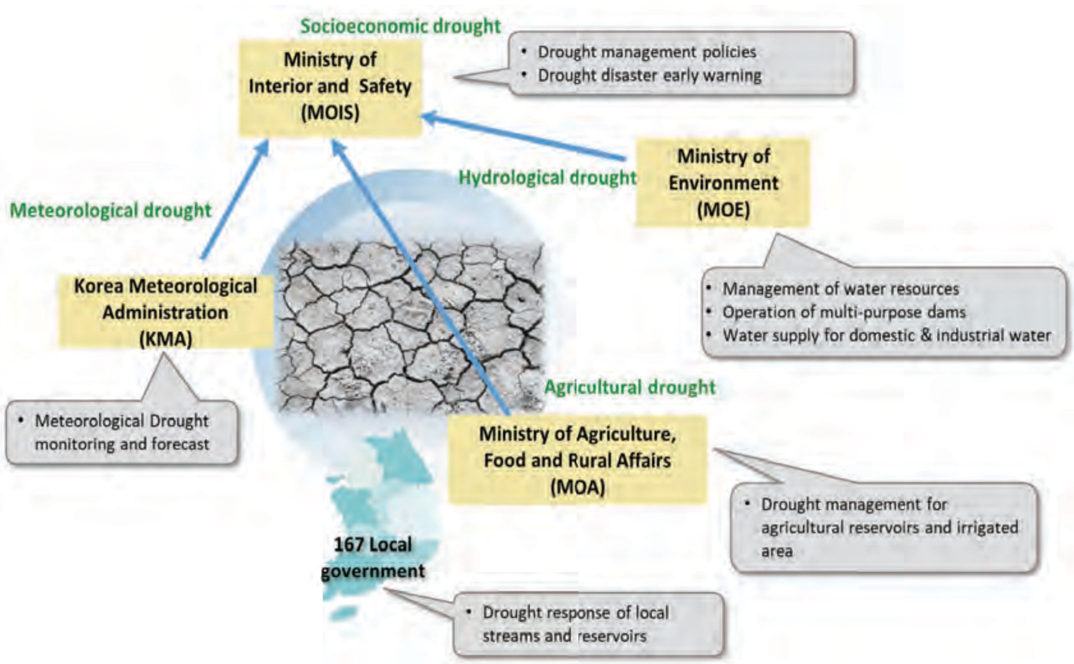
## 4.2 National Strategy for Flood & Drought Management

▪ Multi-ministries' Drought Management Framework and Coordination of Korea

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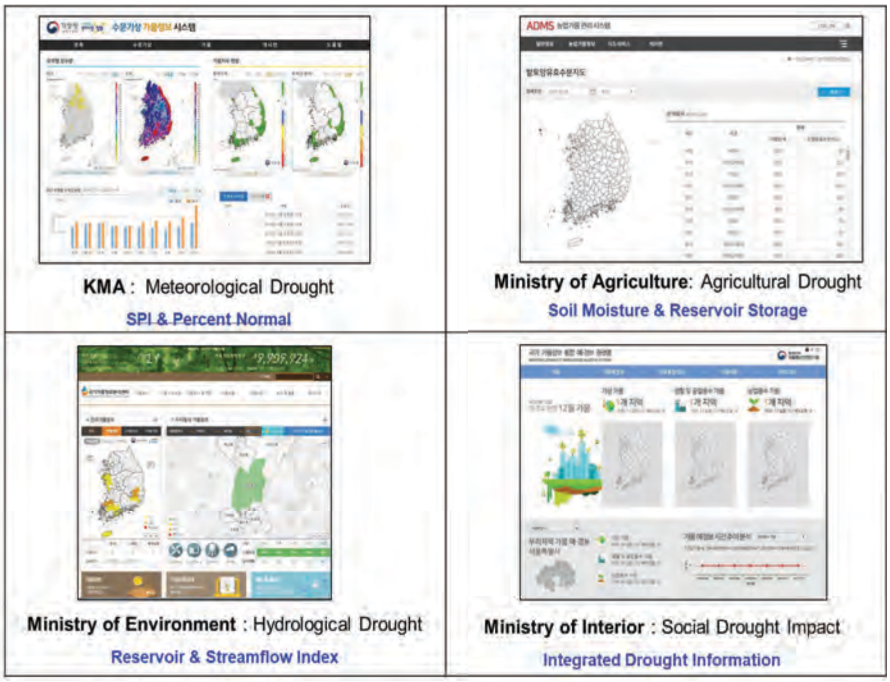
## 4.2 National Strategy for Flood & Drought Management

▪ Multi-ministries' Drought Monitoring System

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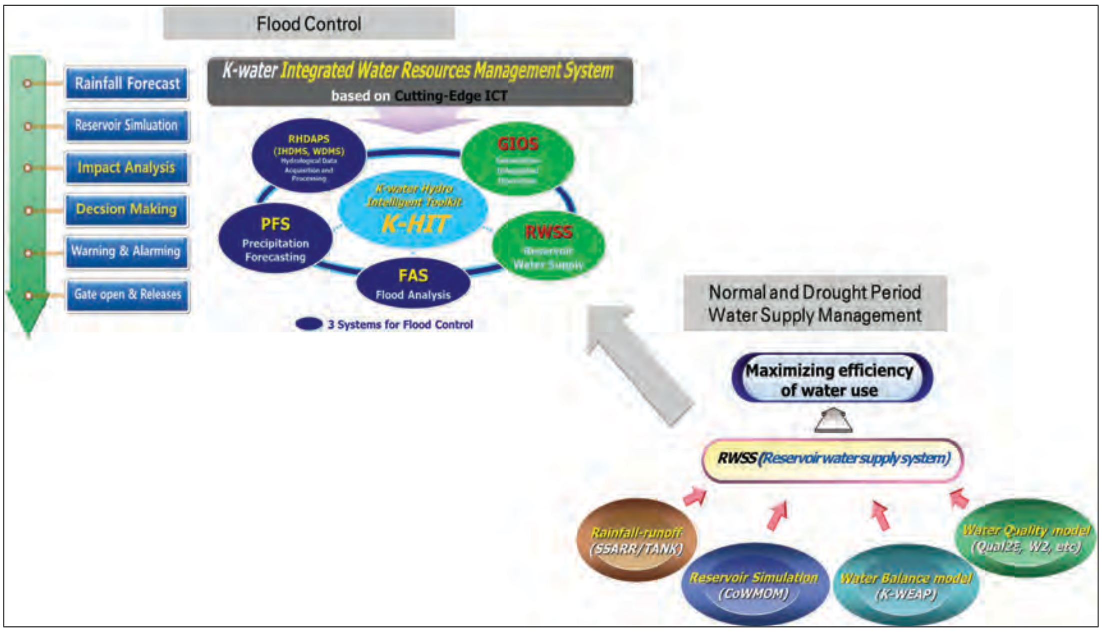
## 4.3 Adaptive Actions for Integrated Flood & Drought Management

▪ Integrated Reservoir Operation for Flood & Drought Management by K-water

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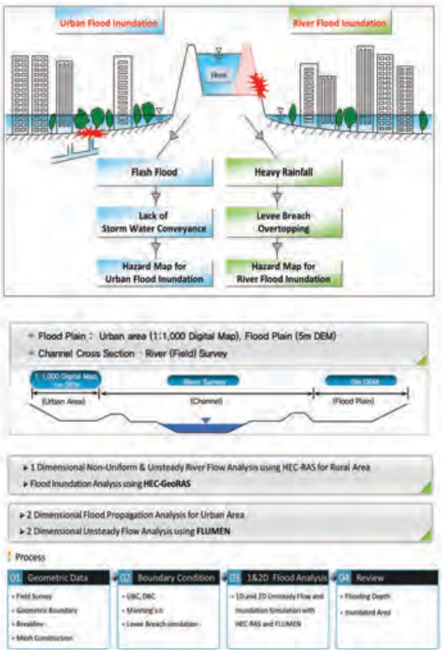
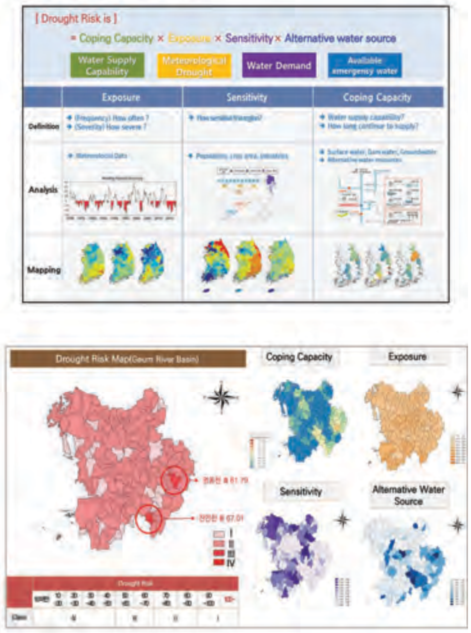
## 4.3 Adaptive Actions for Integrated Flood & Drought Management

- Disaster Risk Map for Flood and Drought

❖ Flood Risk Map




❖ Drought Risk Map

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# 5. Assessment of IWRM Implementation

5.1 Successful Implementation

5.2 Unsuccessful Implementation

5.3 Assessment of IWRM Implementation

## 5.1 Successful Implementation

### ▪ Indicators of successful implementation of IWRM

| Aspect | Indicators |
|---|---|
| **Policy, laws and regulations** | • Development of appropriate policy and legislative framework for IWRM at national and sub-national (regional) levels |
| **Participation** | • Stakeholder consultation and participation in IWRM planning and implementation<br>• Establishment of a multi-sectoral water basin management body<br>• Establishing a multi-level management framework<br>• Decision-making decentralized to the lowest appropriate level (community level)<br>• Enabling information flow and transparency<br>• Education and public awareness on IWRM<br>• Training and capacity-building on IWRM processes and practices |
| **Efficient water use** | • Clear legal status of water entitlements and/or water rights<br>• Establishment of water demand management tools for water pricing and cost recovery to support sustainable water allocation<br>• Funding, development and maintenance of water resource infrastructure |
| **Environmental (ecosystem) sustainability** | • Recognition of ecosystems as drivers of the water cycle and their protection<br>• Protection of aquatic and terrestrial (watershed/riverine) biodiversity<br>• Allocation of adequate water resources to water basin ecosystems to sustain their natural functioning and the services they provide<br>• Rehabilitation and restoration of natural ecosystems<br>• Water pollution monitoring, control and reduction |

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## 5.1 Successful Implementation

### ▪ Mekong River Commission, Asia (Source: Principles and Practices of IWRM, SIWI, 2015)

- The Council of Ministers of the Mekong River Commission sits at the top of the hierarchy for integrated management of the Mekong basin and brings together ministers from the four countries of the Lower Mekong (Cambodia, Lao People's Democratic Republic, Thailand and Vietnam), as well as high-level representatives of dialogue partners China and Myanmar.

- Adopting a formal IWRM-based Basin Development Strategy to guide the Basin Development Plan for joint development efforts in the basin.
  The Basin Development Plan is supported by and articulated with IWRM strategies and plans at lower levels, i.e. the national level, basins and tributaries at provincial level, and at sub-basin and district levels.

- Implementation actions take place through national, provincial and district authorities, including regulation and infrastructure development at basin and sub-basin levels, or in thousands of small watersheds, such as water quality regulation, flood protection measures, local water supplies, small scale hydropower and irrigation dams.

- The institutional arrangements in the Mekong basin hence cater for both vertical and horizontal integration.

- Basin and sub-basin committees draw members from the public sector (including across sectors between key ministries), the private sector and civil society.

- Mostly being planned, built and operated by private developers, with a focus on stakeholder dialogues and increasingly bringing the private sector to the table

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## 5.2 Unsuccessful Implementation

Unsuccessful IWRM occurs when aspects of integration, stakeholder participation and ecosystem sustainability are poorly implemented. However, it is difficult, if not inappropriate, to label an IWRM process as unsuccessful since IWRM is an ongoing process that is subject to changes and improvements.

**Assessment questions:**

1. What are the strengths and weakness of the target river basin IWRM plan against the indicators?
2. Who are the missing stakeholders in this case study?
3. Suggest how the IWRM process for the target river basin can be improved.

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## 5.3 Assessment of IWRM Implementation

- **Indicators of successful implementation of IWRM**

| Goals (17) | Targets (8/169) | Indicators (11/241) |
|---|---|---|
| 6 CLEAN WATER AND SANITATION | 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all | 6.1.1 Proportion of population using safely managed drinking water services |
| | 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations | 6.2.1 Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water |
| | 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally | 6.3.1 Proportion of wastewater safely treated<br>6.3.2 Proportion of bodies of water with good ambient water quality |
| | 6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity | 6.4.1 Change in water-use efficiency over time<br>6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources |
| | 6.5 **By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate** | 6.5.1 Degree of integrated water resources management implementation (0-100)<br>6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation |
| | 6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes | 6.6.1 Change in the extent of water-related ecosystems over time |
| | 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies | 6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan |
| | 6.b Support and strengthen the participation of local communities in improving water and sanitation management | 6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management |

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# 5.3 Assessment of IWRM Implementation

## ▪ Assessment Items of 6.5.1

| 1. Enabling Environment | |
|---|---|
| 1.1 What is the status of **policies, laws and plans** to support IWRM **at the national level?** | a. National water resources **policy**, or similar |
| | b. National water resources **law(s)** |
| | c. National IWRM **plans**, or similar |
| 1.2 What is the status of **policies, laws and plans** to support IWRM **at other levels?** | a. **Sub-national** water resources **policies** or similar |
| | b. **Basin/aquifer management plans** or similar, based on IWRM |
| | c. **Arrangements for transboundary water management** |
| | d. Sub-national water resources **regulations** (laws, decrees, ordinance or similar) |
| **2. Institutions and Participation** | |
| 2.1 What is the status of **institutions** for IWRM implementation **at the national level?** | a. National **government authorities** for leading IWRM implementation |
| | b. **Coordination between** national government authorities representing **different sectors** on water resources, policy, planning and management |
| | c. **Public participation** in water resources, policy, planning and management at national level |
| | d. **Private sector participation** in water resources development, management and use |
| | e. **Developing IWRM capacity** |
| 2.2 What is the status of **institutions** for IWRM implementation **at other levels?** | a. **Basin/aquifer level organizations** for leading implementation of IWRM |
| | b. **Public participation** in water resources, policy, planning and management at the **local level** |
| | c. **Participation of vulnerable groups** in water resources planning and management |
| | d. **Gender included in laws/plans or similar** within water resources management |
| | e. **Organizational framework for transboundary water management** |
| | f. **Sub-national authorities** for leading IWRM implementation |



# 5.3 Assessment of IWRM Implementation

## ▪ SDG 6 Targets and Indicators

| 3. Management Instruments | |
|---|---|
| 3.1 What is the status of **management instruments** to support IWRM implementation **at the national level?** | a. **National monitoring of water availability** (includes surface and/or groundwater, as relevant to the country) |
| | b. **Sustainable and efficient water use management** from the national level (includes surface and/or groundwater, as relevant to the country) |
| | c. **Pollution control** from the national level |
| | d. **Management of water-related ecosystems** from the national level |
| | e. **Management instruments to reduce impacts of water-related disasters** from the national level |
| 3.2 What is the status of **management instruments** to support IWRM implementation **at other levels?** | a. **Basin Management instruments** |
| | b. **Aquifer management instruments** |
| | c. **Data and information sharing <u>within</u> countries** at all levels |
| | **d. Transboundary data and information sharing <u>between</u> countries** |
| **4. Financing** | |
| 4.1 What is the status of **financing** for water resources development and management **at the national level?** | a. **National budget** for water resources **infrastructure** (investment and recurrent costs) |
| | b. **National budget** for **IWRM elements** (investments and recurrent costs) |
| 4.2 What is the status of **financing** for water resources development and management **at other levels?** | a. **Sub-national or basin budgets** for water resources **infrastructure** (investment and recurrent costs) |
| | b. **Revenues** raised for IWRM elements |
| | c. **Financing for transboundary cooperation** |
| | d. **Sub-national or basin budgets for IWRM elements** (investment and recurrent costs) |

# 5.3 Assessment of IWRM Implementation

▪ **Final Score of Korea's IWRM Implementation**

| Section | Average Scores |
|---|---|
| 1. Enabling Environment | **71** |
| 2. Institutions and Participation | **87** |
| 3. Management Instruments | **83** |
| 4. Financing | **63** |
| **Indicator 6.5.1 Score (= Degree of IWRM implementation (0-100))** | **76** |

Source: Integrated Water Management of Korea, MOE (2020)

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# 5.3 Assessment of IWRM Implementation

▪ **SDG-PSS(Policy Support System)**

The SDG-PSS is designed to enable government actors and stakeholders to collaborate and create an agreed, authoritative national-level evidence around SDG 6. In the language of the 2030 Agenda, strengthening and re-aligning enabling environments to drive successful implementation of SDGs will become a critical step for many countries.


https://sdgpss.net/en/

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## 5.3 Assessment of IWRM Implementation

- **Six critical components of SDG-PSS**

There are six critical components of SDG-PSS designed around an Evidence Framework. Each critical component presents a perspective of related priorities, needs and gaps to assist policy makers on decision making:

1. Capacity Assessment
2. Finance Assessment
3. Policy and Institutional Assessment
4. Gender Mainstreaming
5. Disaster Risk Reduction (DRR)/Resilience Mainstreaming
6. Integrity

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## 5.3 Assessment of IWRM Implementation

- **6.5.1 Degree of IWRM Implementation: Republic of Korea**


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## 5.3 Assessment of IWRM Implementation

- **SDG-PSS Summary View: Republic of Korea**



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# Thank you very much

# Flood Management Plan in Response to Climate Change

IWRM

# Flood Management Plan in Response to Climate Change

UNESCO
United Nations Educational, Scientific and Cultural Organization
i-WSSM
International Centre for Water Security and Sustainable Management

## Aims & Objectives

- **The aims of the course are to:**

  (1) Understand the phenomenon of frequent flood disasters caused by climate change;
  (2) Classify the types of floods according to the cause of the floods;
  (3) Understand the problems of existing flood prevention measures;
  (4) Study the flood prevention plan, reinforcement of resilience.

- **The objectives are that trainees will understand:**

  (1) Causes of climate change and patterns of flooding;
  (2) Problems with exiting flood prevention measures;
  (3) Flood prevention plan;
  (4) Reinforcement of resilience due to increased risk of flood damage;
  (5) Legislative and policy improvement measures.

## References

Countermeasures against urban flooding in response to climate change
(NARS, 2020)


River Design Standard Commentary
(KSWR, 2019)

A Study on the Water Security Crisis Management Policy against Climate Change
(KEI, 2012)

The Countermeasure for Extreme Flood-Resilience in the Urban Area Considering the Climate Change
(KDPA, 2011)

## Contents

1. Introduction
2. Climate change
3. Problems with flood prevention measures
4. Flood prevention plan
5. Reinforcement of resilience due to increased risk of flood damage
6. Legislative and policy improvement measures
7. Conclusions

# 1. Introduction

## 1. Introduction

- **Damage from storm and flood caused by climate change**

  - **Water-related disaster damage** is increasing rapidly around the world due to climate change.

    - In 2019, about **72% of disasters** around the world were **floods** and **typhoons.**
    - The number of casualties by cause of natural disasters is high in the order of **typhoons (35%), floods (33%),** and **droughts (31%),** and 99% of all casualties are caused by water-related disasters.

- **In the case of Korea, the impact of climate change is leading to flood damage due to the increase in torrential rain.**

  - The frequency and intensity of torrential rains have increased since the mid-1990s.

    - The frequency of strong rainfall with a **daily precipitation of 80 mm or more clearly increased**.

  - Due to the seasonal characteristics of **most precipitation concentrated** in a short period of **summer**, the occurrence of abnormal rainfall exceeding the ability of water resource facilities to control floods (e.g., dams, levees, estuary barrages, and detention reservoirs) increases.

## 1. Introduction

- **In the case of Korea, the impact of climate change is leading to flood damage due to the increase in torrential rain.**

  - In the **summer of June-August, 638.7 mm of rainfall** occurs for an average of 29.1 days, accounting for **more than half (51.6%) of the annual average precipitation** of 1237.4 mm.

  - In order to reduce the damage caused by repeated **spring drought** due to seasonal variations in precipitation, **the risk of flooding increases as the maximum amount of storage** is secured using **dams and reservoirs** during summer.

  - **Flood damage** continues every year, especially in **cities with many impermeable surfaces**.

  - Much of the city is covered with buildings and roads made of asphalt and cement, **preventing precipitation from infiltrating the ground**.
  - **Direct runoff along the surface** is causing **flood damage** to various underground and low-lying facilities (e.g., semi-basement houses, shopping malls, tunnels, and parking lots).

  - Since most of Korea's population lives in urban areas, **urban floods** lead to **massive casualties and property damage.**

  - **Legislative and policy improvement** measures should be proposed to protect life and property from increasing floods due to climate change.

## 1. Introduction

- **Definition of flood**

  - **Flood**

  - An **overflow of water that submerges land** that is usually dry.
  - The phenomenon of **inundation** due to the increase in water in the river

  - **Urban flood**

  - Floods occurring in urban areas due to the runoff of stormwater along with river inundation

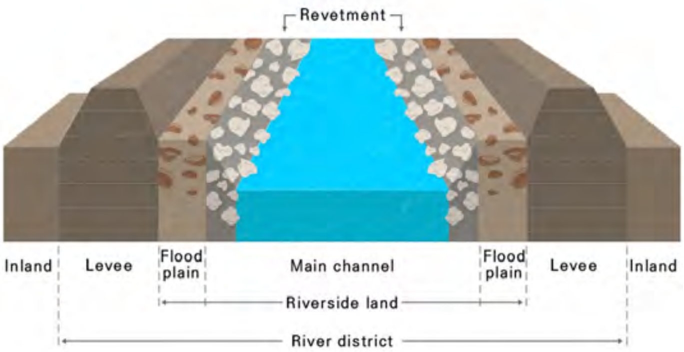
  - The **causes of flood** are largely divided into **rising water levels in rivers** due to torrential rains such as typhoons and rainy seasons and **excessive direct runoff of stormwater**.

  - The River Act stipulates the **occurrence of floods** based on the **flow rate** and **water level of rivers.**

## 1. Introduction

### ▪ River space

- **Main channel:** part where the water flows from the low flow rate in the river
- **Floodplain**: area of land adjacent to a river which stretches from the banks of its channel to the base of the enclosing valley walls, and which experiences flooding during periods of high discharge
- **Revetment:** sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water
- **Inland**: land that is located in the levees and protected by the levees
- **Riverside land**: land by the river outside the levees
- **River district**: Land to which rivers and river accessories (e.g., levee, revetment) belong




**[Conceptual diagram of river space]**

## 1. Introduction

### ▪ Classification of floods

- **River inundation:** it occurs as the **water level of the river** flowing adjacent to or through the city **rises** and crosses the levee or collapses the levee, and the **river water flows into the inland**.

- **Inland flooding:** It refers to water **flowing back from the river to the inland** due to torrential rains and floods that usually **occur in low-lying areas** or **lack of sewage capacity in the absence of river inundation from rivers.**

**[River inundation]**


**[Inland flooding]**

# 2. Climate change

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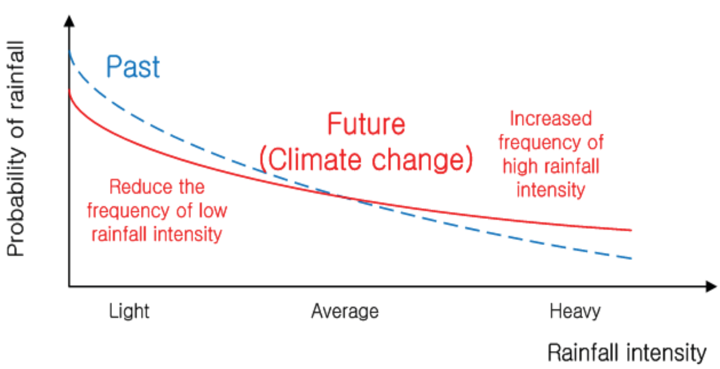
## 2. Climate change

- **Nonstationary patterns of climate change**

  - Water management variables such as **flood flow rates often deviate from the confidence interval of stationary frequency analysis** (Milly et al., 2008).

  - The frequency of low rainfall intensity decreases due to climate change, but the frequency of **high rainfall intensity** is expected to **increase** (USCCSP, 2008).

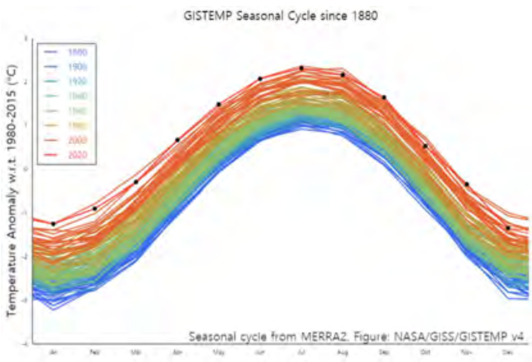



**[Changes in rainfall patterns due to climate change]**

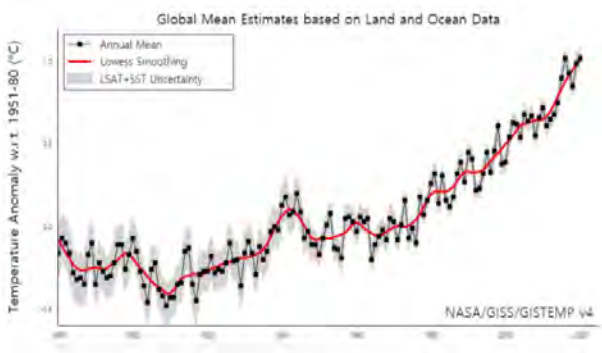
## 2. Climate change

### ▪ Nonstationary patterns of climate change

- In designing the overall water management, such as water supply, demand, and crisis management, **stationary as in the past can no longer be used** as a basic assumption.
- From 1880 to 2020, the Earth's surface **temperature rose by about 2** ℃.
- The average monthly temperature increased significantly from the Earth's monthly average temperature in 1880 (blue line) to 2020 (red line).
- The Earth's average **surface temperature** was the lowest around 1910 but **continued to rise significantly since the 1940s.**




Source: NASA




Source: NASA

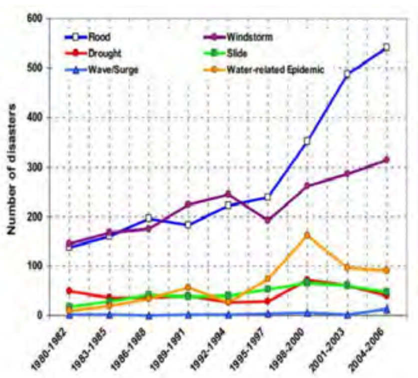
**[Changes in the average temperature of the Earth's surface (1880-2020)]**

## 2. Climate change

### ▪ Frequency of flood occurrence and trend of flood damage

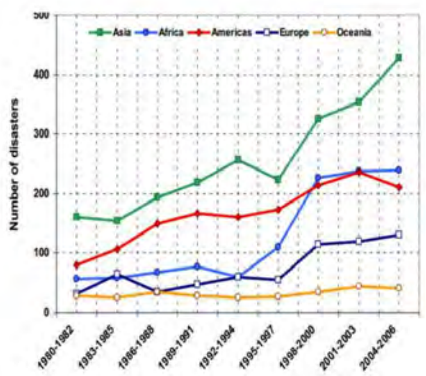
- In the world disaster statistics, **the number of floods** and **storms** is **increasing** (UNESCO, 2009).

- The **number of floods in Asia** increased more than **3 times** from other regions.
- Asia and the Americas, the most drought occurred in 1998 and 2000.
- The number of casualties caused by flood disasters is decreasing, but **economic losses are on the rise.**




Source: UNESCO, 2009

**[Trends of occurrence by disasters]**




Source: UNESCO, 2009

**[Trends in disasters by region]**

## 2. Climate change

### ▪ Climate change scenarios based on Representative Concentration Pathways (RCP)

- The 12.5 km resolution **climate change scenario** derived through **RCP, a greenhouse gas scenario used in the 2013 IPCC 5th Evaluation Report**, is used.
- Reflecting the **trend of increasing greenhouse gases** until 2005, **changes in land use** caused by human activities such as cities, ice, and grasslands are considered, **enabling a practical future outlook.**
- Compared to the SRES (Special Report on Emission) scenario, the **RCP scenario is 9 times more detailed** than the spatial resolution of the global data from 400 km to 135 km.

**[Types of RCP scenarios]**

| RCP scenario | Explanation |
|---|---|
| RCP 8.5 | Scenario in which greenhouse gases are emitted without reducing greenhouse gases due to the current trend |
| RCP 6.0 | Scenario where the reduction of greenhouse gases is realized to some extent |
| RCP 4.5 | Scenario where greenhouse gas reduction is realized significantly |
| RCP 2.6 | Scenario in which the Earth itself can recover from the effects of human activity |

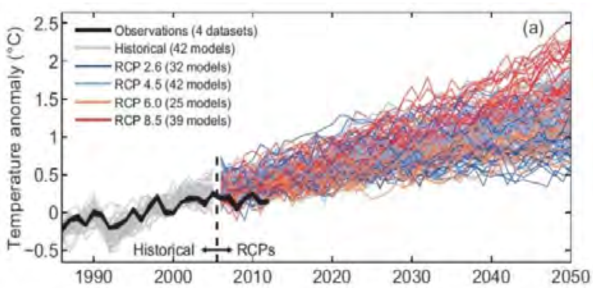
- RCP scenario consists of four types:

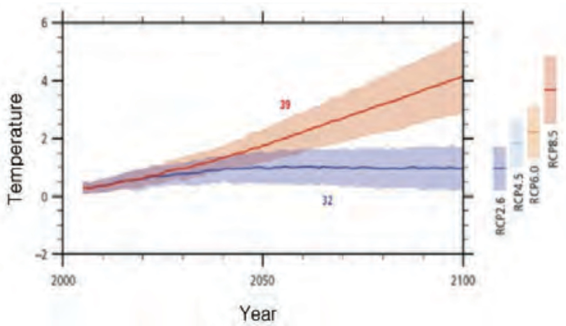
(1) RCP 8.5: current trend
(2) **RCP 4.5 and 6.0**: cases where **greenhouse gas reduction policies** are realized **to some extent**
(3) RCP 2.6: the maximum limit for the Earth to have resilience

## 2. Climate change

### ▪ Climate change scenarios based on Representative Concentration Pathways (RCP)

- In RCP 2.6 scenarios, the average temperature of the current surface is maintained in 2100 as well.
- In RCP 8.5 scenarios with the highest carbon emissions, the temperature rise in 2100 is expected to rise by 2 degrees.
- In **RCP 4.5 and RCP 6.0 scenarios**, even if carbon emissions are reduced, the average surface **temperature in 2100** is expected to **rise by about 1** ℃.




Source: IPCC 5th Assessment Report, 2007

**[Changes in the average temperature of the surface by RCP scenario]**

## 2. Climate change

- **Prospect of extreme index changes due to climate change**

**[Extreme index (STARDEX, 2005)]**

| Index | | Explanation |
|---|---|---|
| Rainfall | Limit of torrential rain | 90% of the rainfall date (mm/day) |
| | Ratio of rainfall above the limit of torrential rain | Percentage of total rainfall in the event that occurred > 90% for a long time |
| | Frequency of occurrence above the limit of torrential rain | Number of days of rainfall > 90% of the number of days of rainfall for a long time |
| | Maximum precipitation for 5 days | Total rainfall for 5 days (mm) |
| | Rainfall intensity on wet days | Single rainfall intensity (rain intensity on the day of rainfall) |
| | Maximum duration of dryness | Maximum number of days of consecutive no rain |
| Temperature | Hot-day limitations | 10% of the hottest day of the season |
| | Cold-day limitations | 10% of the coldest nights in each season |
| | Freeze days | Lowest freezing temperature |
| | The maximum hot weather period | Hot weather period with a value above a certain standard temperature |

- **The rainfall intensity in wet summer** tends to **increase** into the future.
- The ratio of **rainfall above the limit of torrential rain increase** significantly in the future summer.
- The maximum dry duration increases in spring but decreases slightly in winter.

## 2. Climate change

- **Prospect of extreme precipitation in the future**

- If the magnitude of the precipitation occurs **more than once in an average $T$ year**, it has a **return period** (**recurrence interval**) $T$.
- The reciprocal of the return period $T$ is the **probability of occurrence equal to or greater than the rainfall in a certain year**: **exceedance probability**

$$T = \frac{1}{1-P}$$

where, $P$ = non-exceedance probability.

- **Extreme precipitation** is calculated using a non-excessive probability of **General Extreme Value (GEV) distribution**

• GEV distribution is **suitable for expressing extreme precipitation** due to its thick upper tail.

## 2. Climate change

- **Prospect of extreme precipitation in the future**

  - **Cumulative Distribution Function (CDF)** that calculates the non-excess probability of the GEV distribution

$$F(x) = \exp\left[-\left(1-\kappa\frac{x-\xi}{\alpha}\right)^{1/k}\right], \qquad \kappa \neq 0$$

$$= \exp\left[-\exp\left(-\frac{x-\xi}{\alpha}\right)\right], \qquad \kappa = 0$$

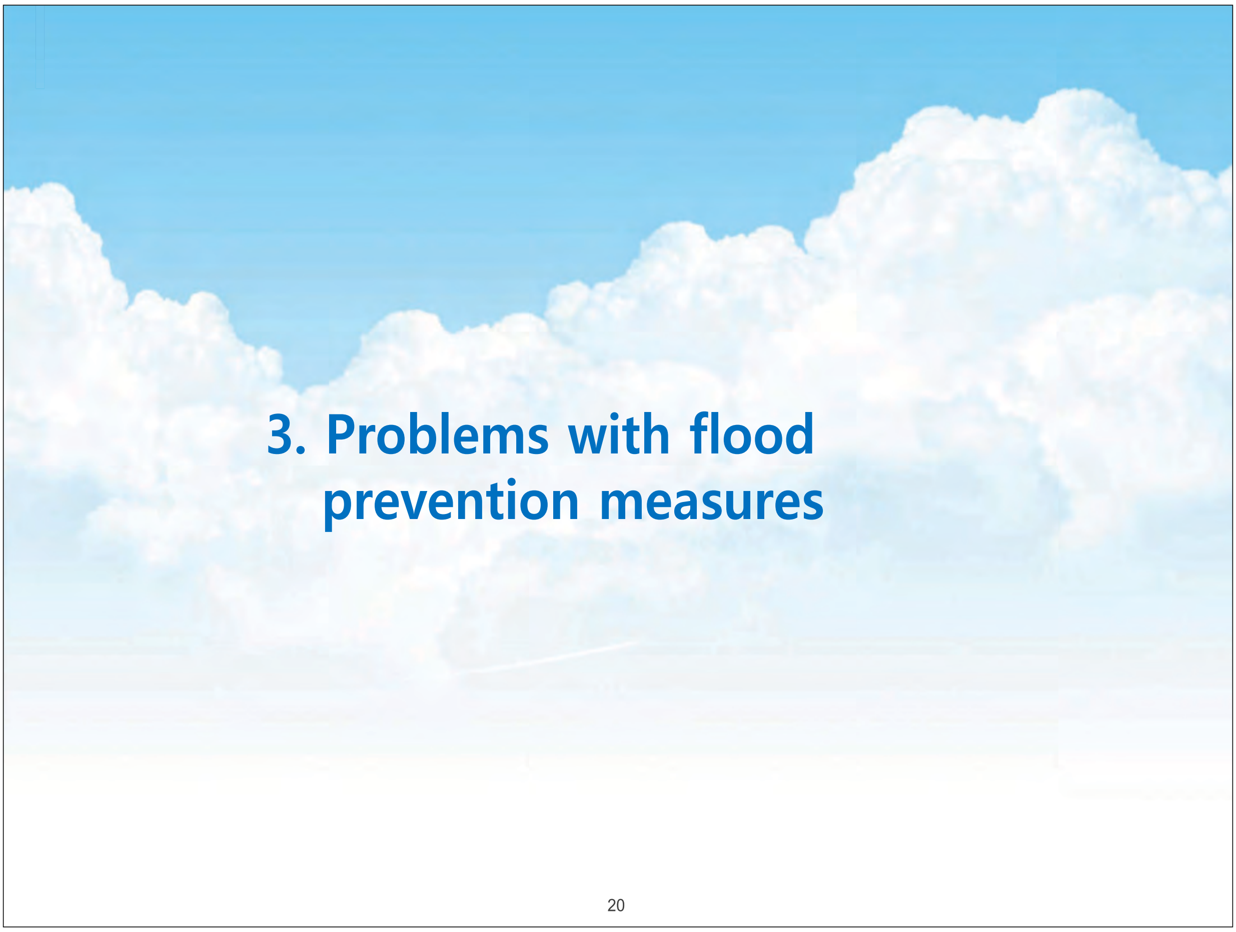
where, $x$ = precipitation, and $\xi$, $\alpha$, $\kappa$ = parameters of location, scale, and shape.

$$x = \xi - \alpha\log[-\log(P)], \qquad \kappa = 0$$

$$= \xi + \frac{\alpha}{\kappa}\{1-[-\log(P)]^{\kappa}\}, \qquad \kappa \neq 0$$

  - As the **nonstationary of precipitation due to climate change increase**, the location parameter $\xi$ and scale parameter $\alpha$ of the probability distribution type increase and the shape parameter $\kappa$ decrease as the future goes on:

(1) **Increasing the location parameter**: increasing the average size of the extreme precipitation
(2) **Increasing the scale parameter**: increasing the fluctuation of extreme precipitation
(3) **Decreasing the shape parameter**: Increasing the probability of occurrence of extreme precipitation



## 3. Problems with flood prevention measures

### ▪ Frequency of flood occurrence and trend of flood damage

- **River inundation**

• When the **design Flood Water Level (FWL) is higher than the elevation of the levee occurs** by overflowing the levee and flowing river water into the levee.

• A typical flood case occurs because the **levee height is lower than the FWL**.

- **Inland flooding**

• Inland flooding occurs due to **lack of water conveyance** (e.g., **backflow of sewage pipes**, and **blockage of drainage pipes)**.

• Heavy rains occurred that **exceeded the design standards of sewage pipes**.

• The maximum rainfalls intensity are recorded, exceeding the hourly drainage capacity, which is the design standard for sewage pipes.

## 3. Problems with flood prevention measures

### ▪ Frequency of flood occurrence and trend of flood damage

- Due to **climate change** in the 2000s, the **frequency of flooding** and drought tends to increase at the same time as the **flood cycle decreases from the past 4-6 years to 1-2 years** and the drought from the past 5-7 years to 2-3 years.

- In Korea, most of the damage caused by **natural disasters** is caused by **water-related disasters** (e.g., heavy rain, heavy snow, and typhoons).

- In the past 10 years (2009-2018), the **total amount of damage** caused by natural disasters was KRW 3.6281 trillion, of which **KRW 3.438 trillion (94.8%) was caused by water-related disasters**.

**[In the last 10 years (2009-2018), casualties by cause of natural disasters]**

| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Total sum (person) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Torrential rain | 13 | 7 | 77 | 2 | 4 | 2 | - | 1 | 7 | 2 | 115 |
| Typhoon | - | 7 | 1 | 14 | - | - | - | 6 | - | 3 | 31 |
| Others | - | - | - | - | - | - | - | - | - | 48 | 48 |
| Total sum | 13 | 14 | 78 | 16 | 4 | 2 | - | 7 | 7 | 53 | 194 |

**Source: Disaster Report, 2018**

## 3. Problems with flood prevention measures

- **Lack of linkage of flood defense measures by government ministries**

  - While enacting the water resources act, a legal basis for **establishing integrated measures for urban flooding** should be established.

  - For stream basins flowing **through or adjacent to two or more local governments**, the **watershed flood prevention plan** shall be established and implemented to prevent and minimize flood damage.

  - Some master plans related to flooding prevention, which were distributed by ministries, can be integrated and established, but implementation plans and actual projects for each **local government** are still being **carried out individually**.

- **Lack of utility of flood prevention facilities**

  - In the case of various flood prevention facilities installed and operated according to flood prevention measures by government ministries, there is a limit to efficiently responding to **climate change due to differences in the frequency of planned design in river design standard (KDS 51 00 00)** that determine the size of **hydraulic structures**.

## 3. Problems with flood prevention measures

- **Increase in impermeable surfaces due to urban area development**

  - Due to **rapid urbanization**, the **water circulation system** in urban areas is greatly **distorted**, acting as a cause of urban flooding.

    • **In the past**, river inundation caused due to **lack of water conveyance, levees, and floodgates** was the main cause of urban flooding, but **recently,** flooding due to **distortion of the water circulation system** has been pointed out as the main cause of flooding.

  - As the population is concentrated in **urban areas**, green spaces in urban areas decrease and **impermeable areas increase** significantly for the construction of infrastructures (e.g., houses, shopping malls, and roads).

    • As rainfall in urban areas **cannot infiltrate underground and flow along the impermeable surface** and the runoff increases, flooding occurs in urban facilities such as semi-basement houses, underground roads, tunnels, subways, and parking lots, leading to human and property damage.

## 3. Problems with flood prevention measures

▪ **Lack of effectiveness of flood prevention facilities**

- There is a limit to efficiently responding to **climate change due to differences** in the **frequency** of planned design in river design standard (KDS 51 00 00) that determine the **size of hydraulic structures**.

• In the case of river levees to prevent river inundation, **national rivers** are designed with a frequency design discharge of **100-200 year**, **local rivers** with a frequency design discharge of **50-200 year**, and **small streams** with a frequency design discharge of **50-100 year.**

• In the case of discharging a **flow rate of 200 year from a dam**, **local rivers and small rivers** with the flow rates of less than 200 year are likely to cause flood damage that **overflows the levees**.

• In the case of sewage pipes to discharge rainwater, **urban main sewage pipes** are designed at a **30-year of frequency design rainfall**, but **branch sewage pipes** are designed at a **10-year of frequency design rainfall**, so **inland flooding** may occur due to insufficient capacity of branch sewage pipes in the city.

• In most cases, it is **simply designed and operated** according to the **hydraulic structures** and importance of the facility, so the effectiveness of urban flood prevention facilities is poor.

## 3. Problems with flood prevention measures

▪ **Lack and underdevelopment of flood prevention system**

- **Disaster prevention facilities** such as multi-purpose dams, flood control reservoirs, and levees are built around the national river, and **large-scale dredging need** to be conducted to establish measures to prevent flood damage.

- Most of the flood damage occurred in **local rivers and small streams** that were relatively **poorly managed** compared to national rivers.

- Considering the characteristics of urban floods with large-scale flooding in a short period of time, the flood warning system through observation of urban rivers is very important, but observation data for implementing **flood warning systems for local rivers or small streams in urban areas are insufficient**.

- Most **observation stations of water level and flow rate** are installed around national rivers, but hydrological information such as water level and flow rate in urban areas located near **local rivers or small streams cannot be provided in real time.**

## 3. Problems with flood prevention measures

- **Lack and underdevelopment of flood prevention system**

  - There is a **lack of systematic establishment** and utilization of **Flood Risk Map** to establish habitual flooding areas and flood damage expected areas:

  - **Flood risk map** is one of the major data for establishing urban flood countermeasures, such as designation and maintenance of natural disaster risk improvement zones, **integrated natural disaster reduction plans**, and establishment of **rainfall-runoff reduction measures**.

  - **In the past**, the **Inundation Trace Map**, which creates flood damage, was created by excluding damage from houses and shopping malls due to complaints from residents concerned about falling housing prices, and **flood risk maps are limited to the general public, so their utilization is low.**

## 3. Problems with flood prevention measures

- **Implications for establishing flood countermeasures against climate change**

  - It is necessary to establish an **effective water circulation system** across urban and river watersheds.

  - It is mandatory to prepare and **utilize inundation trace maps** for past floods and **flood risk maps** expected in the future.

  - It is necessary to systematically establish a **flood warning system** and an **evacuation system** for storm and flood disasters.

# 4. Flood prevention plan

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## 4. Flood prevention plan

- **Flood prevention plan**
  - The **flood prevention plan** is established in line with the **integrated watershed master plan** so that the **flood control and prevention plan** designed based on the **design flood** and the installed river facilities can be consistently, technically and economically harmonized throughout the watershed.
  - When establishing a **flood prevention plan**, all functions of the river (e.g, **flood control, water supply,** and **river environment**) should be comprehensively considered, and at the same time, it should be determined in consideration of the **possibility of flooding exceeding the planned scale (excess flood).**
- **Flood prevention and control methods**
  - Appropriate **measures** shall be selected for upstream, midstream, and downstream of the river by reviewing possible means to **prevent and control floods**, but possible means shall be appropriately combined according to the **flood, topography,** and **socio-economic characteristics of the watershed** to achieve flood prevention objectives.

## 4. Flood prevention plan

### ▪ Flood prevention and control methods

- For the **selection of flood prevention and control methods**, the **optimal method** is selected and used among various selectable methods (e.g., structural measures and non-structural measures)

• **Structural measures:** dredging, reservoir, levee, dam for flood control, and floodplain maintenance
• **Non-structural measures:** operating system of dam and reservoirs, flood warning, floodplain management, flood insurance, flood prevention, basin management and land use adjustment, and evacuation

### ▪ Optimal flood prevention and control measures

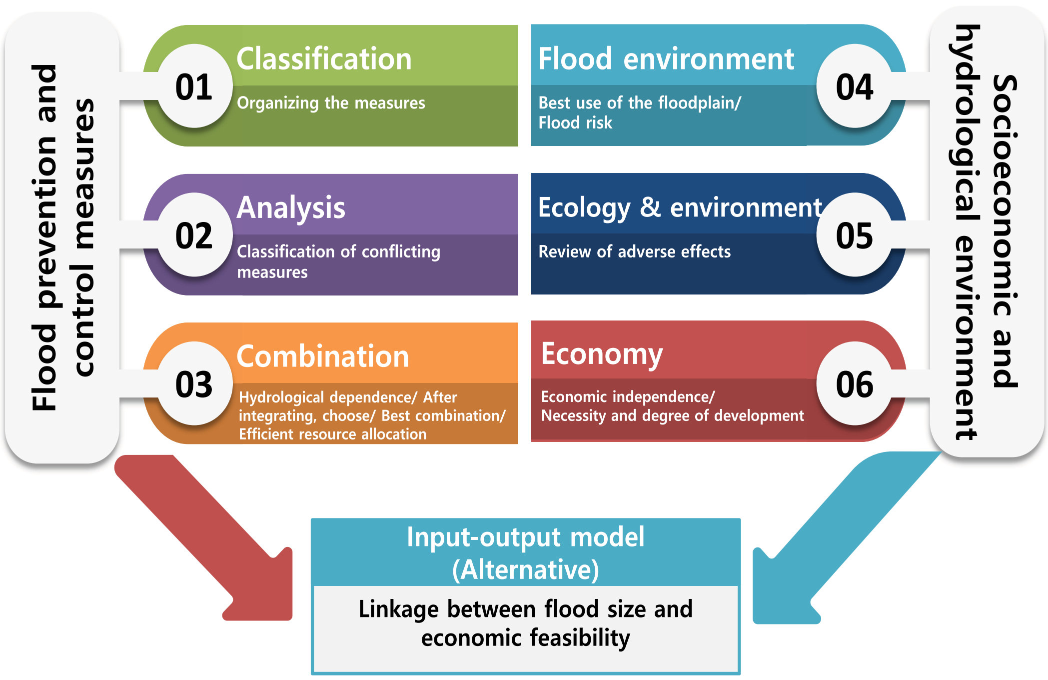
- The flood prevention and control plan must be carried out in a long and step-by-step manner.

- When determining the **optimal method of flood prevention plan**, it is basic to investigate and determine **engineering feasibility** and **economic feasibility**.

- Flood prevention and control plans are determined by comprehensively analyzing **topographic and hydrological factors, meteorological factors, socioeconomic factors**, and **flood prevention factors**.

## 4. Flood prevention plan

### ▪ Optimal flood prevention and control measures



# 4. Flood prevention plan

## ▪ Integrated flood control measures

- When establishing an **integrated flood control measure**, a **basic survey project** is conducted to investigate and review all conditions surrounding the river.
- **Hydraulic structures designed** in connection with integrated flood control measures or other plans in the watershed or structures for flood control measures shall **comply with river design standard.**
- Integrated flood control measures should promote (1) **maintenance of flood control facilities** in the watershed, (2) smoothly **transport flood discharges and sediment discharges** from watershed development, and (3) **minimize flood damage** caused **by inundation risk areas and debris risk watershed**.

# 4. Flood prevention plan

## ▪ Integrated flood control measures

- The **plan for the number of hydraulic structures or the design frequency of river** shall be determined according to the **importance of river**, but if necessary, it may be determined by referring to the **flood prevention grade** according to the **use of inland**, and the characteristics and conveyance of the downstream area **(River Design Standard KDS 51 14 15, 2018)**.

**[Importance of river according to the importance of river]**

| Importance of river | Design frequency of river (Return period) | Applied river |
|---|---|---|
| Grade A | More than 200 year | National river |
| Grade B | 100 – 200 year | National river and local river |
| Grade C | 50 – 200 year | Local river |

**[Flood prevention grade of river according to the use of inland]**

| Flood prevention grade | Design frequency of river (Return period) | Use of inland |
|---|---|---|
| Grade A | 200 – 500 year | Population-intensive areas, asset-intensive areas, industrial complexes, major national infrastructure |
| Grade B | 100 – 200 year | Commercial facilities, industrial facilities, public facilities |
| Grade C | 50 – 80 year | Agricultural land |
| Grade D | Less than 50 year | Wetland, bare ground |

## 4. Flood prevention plan

### ▪ Flood prevention and control methods

| Flood prevention and control methods |
|---|
| **Structural measures** |
| • Dredging: expansion and excavation of channel<br>• Reservoir: detention reservoir, retention reservoir, drainage facility<br>• Levee: parapet, super levee, spur<br>• Dam for flood control: multipurpose dam<br>• Flood channel maintenance: sluiceway, new channel |
| **Nonstructural measures** |
| • Multi-reservoirs operation<br>• Flood warning system<br>• Floodplain management: flood risk map<br>• Flood insurance<br>• Flood prevention: drainage facility<br>• Watershed management and land use adjustment: development coordination, securing a permeable area, Low Impact Development (LID) techniques, preventing basin erosion, adjusting cultivation methods, preserving soil<br>• Flood warning and evacuation |

## 4. Flood prevention plan

### ▪ Structural measures of flood prevention and control methods

- **River maintenance**

- The river maintenance plan is made through the selection of alternatives in the river channel plan for flood prevention.
- The **selection of alternatives in the river channel design plan** is decided by reviewing the **construction or enhancement of levees**, measures to **increase the water conveyance capacity**, and the **construction of sluiceway**.

- **Decisions on alternatives to the river channel design plan** is made through the process of basic initiatives for flood reduction, selection and supplementation of possible alternatives, **flood reduction scale** and method determination, and **optimal design plan determination**.

- **Rainfall-runoff reduction facilities**

- The rainfall-runoff reduction facility plan is established through the establishment of measures to **suppress rainwater runoff** and the **retention reservoir and detention reservoir plan** for flood prevention.

- The rainfall-runoff reduction facilities can be divided into **storage and infiltration types**, and they can greatly contribute to the use of limited water resources and maintenance of natural ecology, so they must be reviewed when establishing flood prevention plans or direct runoff of stormwater.

## 4. Flood prevention plan

- **Structural measures of flood prevention and control methods**

  - **Rainfall-runoff reduction facilities**

  - When planning a **retention reservoir** as part of the flood prevention plan, the retention reservoir shall **gradually discharge or forcibly drain a part of the flood amount** in the middle and downstream of the river to **reduce the peak flow rate of the river water level or downstream.**
  - If it is not possible to install a retention reservoir on the ground, it is desirable to consider introducing **rainwater storage facility** in areas where flood damage is highly feared, such as **underground parking lots** by installing rainwater storage facility in underground spaces and **using water stored in the non-flood season**.

  - **Detention reservoir for flood control**

  - The detention reservoir plan determines the **flood control method** and the **design flood** amount to determine the flood size, and is established by comprehensively considering the **environments** (e.g., water supply, power generation, and securing instream flow).
  - In order to determine what to do with the flood control method by considering the topography and river arrangement characteristics of the watershed, consider **flood control facilities that can be installed in the detention reservoirs** (e.g., retention reservoir and detention reservoir).

## 4. Flood prevention plan

- **Structural measures of flood prevention and control methods**

  - **Detention reservoir for flood control**

  - When considering the **water supply and demand** of the watershed, a **multi-purpose reservoir** or **dam** is placed.

  - Whether flood control is controlled by a **single reservoir with a large control capacity** or by a **reservoir group** consisting of several reservoirs shall be determined by comprehensively determining flood control capacity, topography, combination of water supply and river environmental purposes, and economic feasibility.

  - The **design flood of detention reservoirs or dams** is reasonably determined by reviewing the planned flood at the relevant point, **peak flood discharge** of reservoirs or dams, **flood control capacity**, and the **maximum possible flood discharge**.

  - **Other structural measures**

  - It shall be established through the development of **groundwater recharge**, planning facilities to **prevent the sediment and waste**, installation of **infiltrating public facilities**, and supplementation of **water storage facilities**.

## 4. Flood prevention plan

### ▪ Structural measures of flood prevention and control methods

- **Other structural measures**

• It is desirable to actively introduce **roads and parking lots** as they increase the **infiltration** amount of rainwater, reducing floods and increasing the use of groundwater.

• The increase in **impermeable road pavement and public facilities** increases the surface runoff during rainfall, so it is necessary to consider supplementing and **expanding rainfall-runoff reduction facilities** (e.g., reservoirs and infiltration facilities).

## 4. Flood prevention plan

### ▪ Nonstructural measures of flood prevention and control methods

- **Optimal reservoir operating system**

• The optimal reservoir operating system is one of the non-structural measures and can bring about a flood control effect through **improvement of reservoir operating methods and optimal analysis techniques.**

- **Flood warning system**

• As one of the non-structural measures, the flood forecasting and warning system can be expected to have a flood control effect by **improving the flood forecasting method and flood forecasting process**.

- **Watershed management**

• Watershed management is to **control the conveyance of floods and sediment** by properly managing the watershed so that the **draining water, and water storage functions** can be maintained and increased

- **Flood insurance**

## 4. Flood prevention plan

- **Nonstructural measures of flood prevention and control methods**

  - **Floodplain management**

    - The floodplain management includes the designation of **flood risk zones, flood prevention, land use, construction laws,** and **inundation lines** to reduce flood damage while having sufficient flood control capabilities.
    - When establishing a flood prevention plan, the **possibility of inundatio**n must be evaluated and a **flood inundation risk map** must be prepared.
    - It is very important in floodplain management to **derive flood risk information** by collecting past flood data and analyzing **land-use changes** in watershed and floodplain, and **natural and artificial changes** in streams and watershed.

  - **Other nonstructural measures**

    - Establishment of an **appropriate water circulation system** in the basin by actively utilizing structural flood measures (e.g., **LID techniques**)

## 5. Reinforcement of resilience due to increased risk of flood damage

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## 5. Reinforcement of resilience due to increased risk of flood damage

- **Climate change is rapidly progressing, and direct and indirect damage due to climate change flood disasters is expected, especially in densely populated urban areas.**
  - According to the RCP climate change scenario, climate change is expected to proceed rapidly, especially increasing the risk of flood disasters due to increased rainfall.
  - Urban areas are very likely to deteriorate into natural disaster triggered technological disaster in the event of a flood disaster due to the concentration of population and industry along with the development of disaster-vulnerable areas and the increase in impermeable areas.
- **Introduction of the concept of resilience to respond to disasters in the field of disaster prevention**
  - **Resilience**: ability to withstand, absorb, and adapt to the shock necessary for recovery in a changing environment
  - There are studies in various disaster prevention fields to **utilize the concept of resilience**
    - To **minimize damage by mitigating impact** through durability, robustness, and diversity before a disaster occurs
    - To **emphasize recovery capacity** considering rapid disaster response and prevention through resource nonexistence.

## 5. Reinforcement of resilience due to increased risk of flood damage

- **Establishment of a policy to strengthen resilience and the recent introduction of the concept of resilience in urban disaster prevention policies**
  - UN-ISDR (United Nations - International Strategy for Disaster Reduction)'s Making **Cities Resilient Campaign**, Rockefeller Foundation's **Asian Climate Change Resilience Network**, and 100 Resilience Cities emphasized the need to strengthen resilience.
  - In the United States, the Federal Disaster Management Agency (FEMA) and the Ministry of Housing and Urban Development (HUD) have **established anti-disaster measures that introduce the concept of resilience, including a national disaster response system, a pre-recovery plan**, a $1 billion prize money contest, and reconstruction by design.
  - In Korea, urban disaster prevention policies using urban planning factors such as disaster vulnerability analysis and **disaster prevention urban planning** were introduced in 2011 due to the landslide in Umyeonsan Mountain, and the **concept of resilience** was recently introduced in urban planning-related guidelines.

## 5. Reinforcement of resilience due to increased risk of flood damage

- **Need to realize a city with resilience by strengthening damage reduction and damage recovery capabilities**

  - Focusing on international organizations, the **concept of a resilient city** that strengthens the **sustainability of the city** by mitigating and adapting to disaster shocks is being proposed.

  - Considering the characteristics of resilience in the disaster prevention field, it is necessary to **implement a resilience city** by improving policies related to damage reduction and damage recovery capabilities.

## 6. Legislative and policy improvement measures

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## 6. Legislative and policy improvement measures

- **Maintenance of watershed flood control master plan**

  - In order to prepare comprehensive measures to preemptively prevent floods, it is necessary to **improve the deficiencies of the watershed flood control master plan** established.

  (1) The purpose of establishing the river basin master plan should be clarified by **revising the scope of the river basin** that is the subject of the river basin flood control master plan.

  - The river basin was defined as an area flowing through or adjacent to two or more cities, counties, and autonomous districts.

  - Since most of the river basins do not conform to the purpose of establishing the watershed master plan established for urban rivers, it is necessary to clearly define them as river basins that require integrated flood damage prevention measures due to urbanization.

  (2) The establishment of a **watershed flood control master plan** should be **regularly managed and mandated**, and after the river construction project is completed, its maintenance should be carried out, such as evaluating its effectiveness.

  - As the frequency and scale of torrential rains, abnormal rainfall, and typhoons are expected to continue to increase due to climate change, it is mandatory to regularly investigate areas where flood damage occurs and establish a watershed master plan for rivers that have the city as a watershed.

## 6. Legislative and policy improvement measures

- **Maintenance of watershed flood control master plan**

  - After projects such as installation of flood control storage facilities and maintenance of rivers and sewage are completed according to the watershed flood control master plan, maintenance management is required, such as evaluating the effect of urban flooding in the basin, establishing supplementary measures, or establishing linkage operations between facilities.

  (3) Based on the watershed flood control master plan, it is necessary to strengthen the linkage between flood-related plans for each ministry.

- **Improvement of the water circulation system in the watershed**

  - In order to establish an **appropriate water circulation system** for the entire watershed, it is necessary to combine existing structure-oriented flood measures and nonstructural measures using **LID techniques**.

  - LID technique aims to restore and maintain the water circulation system distorted by development activities such as urbanization as similar as possible to the state before urban development.

  - Through the creation of rooftop gardens, parks, artificial wetlands, tree planting, and water-permeable packaging materials in urban areas, the infiltration of rainwater is activated, and water reuse facilities such as rainwater facilities are installed to efficiently use water resources.

## 6. Legislative and policy improvement measures

### ▪ Improvement of the water circulation system in the watershed

- In order to establish an **appropriate water circulation system** in urban areas, when implementing development projects of a certain size or larger, it seems necessary to stipulate that the **relevant laws establish a plan** in consideration of **LID techniques.**

- A systematic mid- to long-term project plan should be established and promoted by analyzing and evaluating the current flood prevention capabilities, **reflecting various LID techniques** (e.g., **urban green space creation, water reuse facilities, and natural river maintenance** and **restoration**).

## 6. Legislative and policy improvement measures

### ▪ Establishment of flood prevention capacities

- As torrential rains occur frequently due to climate change, it seems necessary to prepare measures to sufficiently respond to possible floods in the future.

(1) Depending on the **size and importance of hydraulic facilities**, the **design standards of flood prevention facilities should be re-established** to respond appropriately to climate change by comprehensively considering rainfall types and topographic conditions..

• Rather than uniformly applying the **design standards for each water resource facility** to all regions, it is necessary to improve the relevant guidelines so that the design standards for each facility can be raised and adjusted according to the flood defense plan **considering the current status of land use by regions** (e.g., **urban, rural, and fishing regions**).

(2) The **Water Resources Act** may consider a plan to **periodically review** whether the design standards of water resource facilities are appropriate to cope with **climate change**.

• Facilities requiring monitoring of facilities are defined centering on urban areas, and details such as design standards, materials, and monitoring cycles of target facilities should be stipulated in each individual law.

## 6. Legislative and policy improvement measures

### ▪ Establishment of flood prevention capacities

- As torrential rains occur frequently due to climate change, it seems necessary to prepare measures to sufficiently respond to possible floods in the future.

(3) Breaking away from the existing national river-centered flood management policy, it is necessary to **maintain local rivers and small rivers** where flood damage mainly occurs.

- It is necessary to preferentially carry out river maintenance projects to reduce flood damage, such as **increasing levees, dredging**, and **constructing flood control reservoirs** for **local rivers and small rivers**, which were relatively neglected compared to national rivers.
- Mid- to long-term measures should be established to fundamentally solve the cause of flood damage, and to **investigate habitual flooding areas** where disaster recovery and support costs have been continuously invested.

## 6. Legislative and policy improvement measures

### ▪ Advancement of flood response systems

- The flood warning system for flood occurrence needs to be improved.

(1) Real-time river hydrological and hydraulic information throughout urban rivers, such as upstream, boundaries, and major points of the basin, should be provided.

- It is necessary to construct an optimal observation network and continuously install and expand observation stations to prepare water level and flow data so that **real-time observation data can be established** not only in national rivers but also in adjacent **local rivers and small rivers.**

(2) If water levels and flow rates above the limit are observed due to flooding, a **flood warning system** should be established to minimize flood damage **based on real-time river information.**

- Local governments and related agencies should establish decision-making standards to promptly determine whether to implement emergency measures such as evacuation of local residents within a limited time.

## 6. Legislative and policy improvement measures

### ▪ Advancement of flood response systems

- The flood warning system for flood occurrence needs to be improved.

(3) In the event of torrential rain, a **systematic flood response system** must be established to **quickly restrict or control the access and use of facilities** installed in habitual flooding areas and expected flooding areas, and operate flood prevention facilities such as rainwater drainage pumps.

• If flooding is expected, disaster prevention facilities such as drainage channels installed in facilities such as lowlands, underground roads, tunnels, shopping malls, and parking lots will be inspected in advance.

• Temporary restrictions on access and use of dangerous areas or facilities located in the area shall be made promptly in the event of torrential rains of a certain size or an increase in the water level or flow rate of urban rivers.

• There is a need to improve the flood warning system to automatically restrict the use of facilities by **utilizing Information and Communications Technology (ICT).**

## 6. Legislative and policy improvement measures

### ▪ Advancement of flood response systems

- The flood warning system for flood occurrence needs to be improved.

(4) It is necessary to **systematically establish flood risk maps** (e.g., flood trace maps and flood risk maps), a **rapid evacuation system** should be established in which all local governments, related agencies, and residents in flood risk areas can participate.

• According to the established **evacuation system**, local residents should evacuate to shelters quickly, and local governments and related organizations should regularly conduct **education** and training to understand a series of processes to reduce urban flood damage, such as distributing relief supplies, flood prevention, and rescue.

# 7. Conclusions

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## 7. Conclusions

- **Due to the recent climate change, the occurrence of torrential rains exceeding the flood prevention capability of water resource facilities is increasing.**
  - Due to the rainy season, typhoons, and torrential rains, great flood damage is being caused, such as being declared as a disaster area caused by flood damage.
- **In the process of economic development, flood damage is increasing in cities where a large number of populations and major facilities are concentrated.**
  - In cities, most of the surface is paved with impermeable surfaces such as asphalt and cement, so most of the precipitation does not infiltrate, and flood damage occurs in various facilities located in low and underground areas.
- **Flood-related laws and prevention policies should be improved to prevent increasing floods due to climate change and minimize their damage.**

## 7. Conclusions

- **Problems with flood prevention measures and flood response systems**

  - Even after the introduction and implementation of the river basin flood control master plan, which is a comprehensive measure for flooding, projects by ministries are being promoted individually, so the efficiency of policy promotion is low and problems such as budget waste remain.

  - Excessive development of urban areas caused by urbanization and industrialization distorts the water circulation system, and the effectiveness of linkage operations between various flood prevention facilities decreases, making it difficult to cope with urban floods.

  - Data such as real-time water level and flow observation data of urban rivers and flood inundation risk maps are insufficient, and systematic management of many urban facilities and publicity and education for local residents are insufficient.

## 7. Conclusions

- **Measures to improve flood-related legislation and policies to cope with climate change**

  - Improvement and maintenance of the river basin flood control master plan.

  - Establishment of a river basin flood control master plan is regularized and mandatory, and after the construction project is completed, the effect is evaluated, and additional measures are prepared. If necessary, maintenance management is implemented.
  - Before establishing a river basin flood control master plan, it is necessary to strengthen the linkage between flood-related plans for each ministry by having consultations with the heads of related organizations in advance.

  - Establishment of  an appropriate water circulation system in the basin by actively utilizing structural flood measures (e.g. LID techniques)

  - In the case of implementing development projects larger than a certain size in urban areas, a plan to stipulate that the relevant laws consider LID techniques may be considered.
  - Cities that have been developed should implement mid- to long-term measures to restore the water circulation system by reflecting various LID techniques in the river basin flood control master plan.

## 7. Conclusions

- **Measures to improve flood-related legislation and policies to cope with climate change**

  - Establishment of flood prevention capabilities considering the impact of climate change

    • Design standards for flood prevention facilities should be re-established in consideration of the size and importance of hydrological and hydraulic facilities and the climate and topography of the basin.
    • The design standards of water resource facilities are periodically reviewed for adequacy to respond flexibly to climate change.
    • Breaking away from the existing national river-centered flood management policy, it is necessary to expand the maintenance of local rivers and small streams where flood damage mainly occurs.

  - Systematic establishment of a flood response system to minimize flood damage

    • Basic data should be prepared by expanding the water level and flow rate observation stations for local rivers and small rivers, and systematically establishing flooding traces and flood risk maps.
    • It is necessary to strengthen the management of multi-use facilities in urban areas in advance and after urban floods, and establish a rapid evacuation system in which local governments, related agencies, and residents in flood-risk areas can all participate.

# Drought Monitoring and Forecasting for Drought Preparedness and Management

IWRM

# Drought Monitoring and Forecasting for Drought Preparedness and Management

United Nations Educational, Scientific and Cultural Organization

International Centre for Water Security and Sustainable Management

## Aims & Objectives

- **The aims of the course are to:**

  (1) Learning the basic theory of drought;
  (2) Understanding Drought Monitoring and Prediction Methods;
  (3) Understanding drought management methods

- **The objectives are that trainees will understand:**

  (1) Types of drought and types of drought impact;
  (2) Drought monitoring method based on remote sensing;
  (3) Global situation and response to mega drought

## References


Crausbay, S. D., et al., (2017), BAMS

AghaKouchak, A. et al., (2015) Reviews of Geophysics

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Van Dijk, A. I., et al., (2013), Water Resources Research

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## Contents

1. Understanding Drought

2. Drought Monitoring

3. Remote sensing for Drought Monitoring

4. Drought Forecasting

5. Drought Management and Preparedness

6. Paleo-Climate & Mega Drought

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# 1. Understanding Drought

1.1 Definition of Drought
1.2 Types of Drought
1.3 Drought Impact
1.4 Drought and Water Shortage
1.5 Drought Index

## 1.1 Definition of Drought

- Drought is a recurrent feature of the climate. It occurs in virtually all climatic zones, and its characteristics vary significantly among regions. Drought differs from aridity in that drought is temporary; aridity is a permanent characteristic of regions with low rainfall.
- Drought is an insidious hazard of nature. It is related to a deficiency of precipitation over an extended period of time, usually for a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector.

### Conceptual Definition

- Conceptual definitions help understand the meaning of drought and its effects.
- For example, drought is a protracted period of deficient precipitation which causes extensive damage to crops, resulting in loss of yield.

### Operational Definition

- Operational definitions help identify the drought's beginning, end, and severity.
- To determine the beginning of drought, operational definitions specify the degree of departure from the precipitation average over some time period.

Source: http://ponce.sdsu.edu/droughtdatasheet.html

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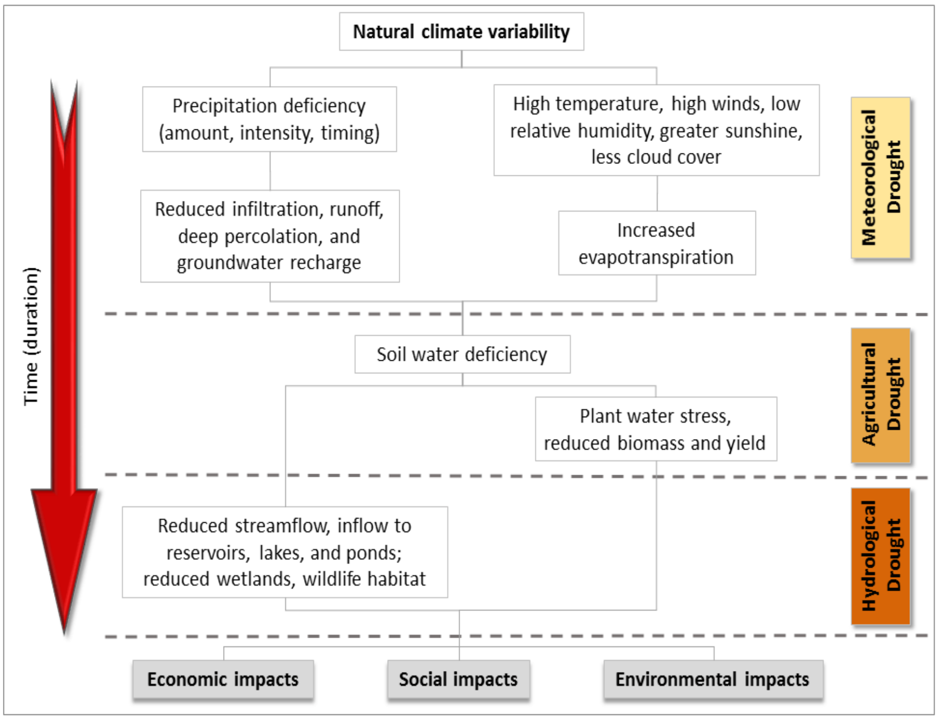
# 1.1 Definition of Drought




*NDMC - National Drought Mitigation Center (2003)*

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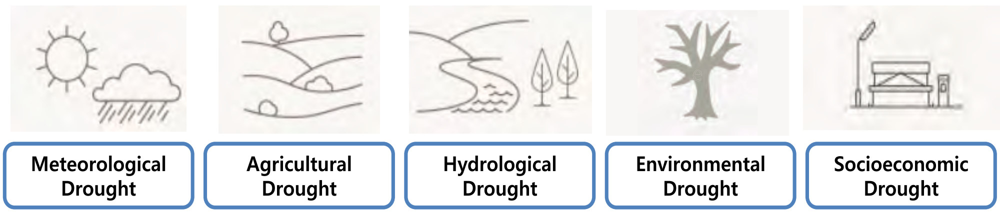
# 1.2 Types of Drought




- **Meteorological Drought**
  - It is defined based on the degree of dryness and duration compared to the normal or average concept.
  - The definition differs locally depending on the change in weather conditions.
    - Meteorological office : If the number of days without precipitation is more than 15 days, If the daily precipitation is less than 5mm for 10 consecutive days, If precipitation of less than 5 mm persists for 15 days,
    - The United States (1942) : Southwest portion of the United States averages less than 3 inches (7.6 centimeters) of precipitation per year
    - The United Kingdom (1936) : If the day when the daily rainfall is less than 2.5mm is 15 days in a row,
      India (1960) : If the actual seasonal rainfall is less than twice the average deviation

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## 1.2 Types of Drought

- **Agricultural Drought**
  - Agricultural drought connects various characteristics of meteorological or hydrological drought to agricultural effects, focusing on the lack of rainfall, differences between actual and latent evaporation, lack of soil moisture, and a decrease in groundwater in reservoirs.
  - The correct definition of agricultural drought should be able to fully consider the various sensitivity of grain to water during various stages of grain development from sprout to growth.

- **Hydrological Drought**
  - Hydrological drought is related to the effect of rainfall (including snowfall) shortage period
    on the supply of surface or water (stream outflow, Seo-si or lake level, groundwater).
  - Hydrological droughts generally have periods and delays in meteorological and agricultural droughts. It takes more time for rainfall shortages to appear from elements of hydrological systems such as soil moisture, river runoff, groundwater and reservoir water levels.

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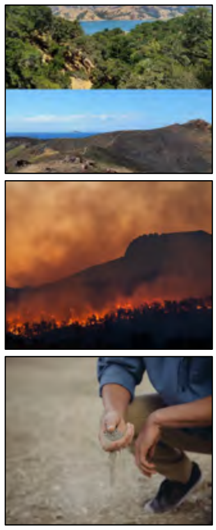
## 1.2 Types of Drought



- **Environmental/Ecological Drought**
  - "Environmental-ecological drought" refers to a situation in which the supply of water available naturally is insufficient due to a long-term lack of precipitation, exceeding the limitations of water resource vulnerabilities generally required by environmental ecosystems such as water ecosystems, water quality, and vegetation.
  - In particular, the "environmental-ecological drought" has a very wide range of water quality problems caused by drought, aquatic damage, soil pollution, forest fires, damage to animal and plant habitats, and damage to aquatic organisms.

- **Socioeconomic Drought**
  - The socioeconomic definition of drought relates the demand and supply of economic goods (water) to meteorological,
    hydrological, and agricultural drought factors, which occur when demand for economic goods exceeds supply due to lack of weather-related water supply.
  - Demand for economic goods is increasing due to an increase in population and per capita water consumption, and supply can also be increased by the construction of reservoirs that increase improved production efficiency, technology, or surface water storage capacity.

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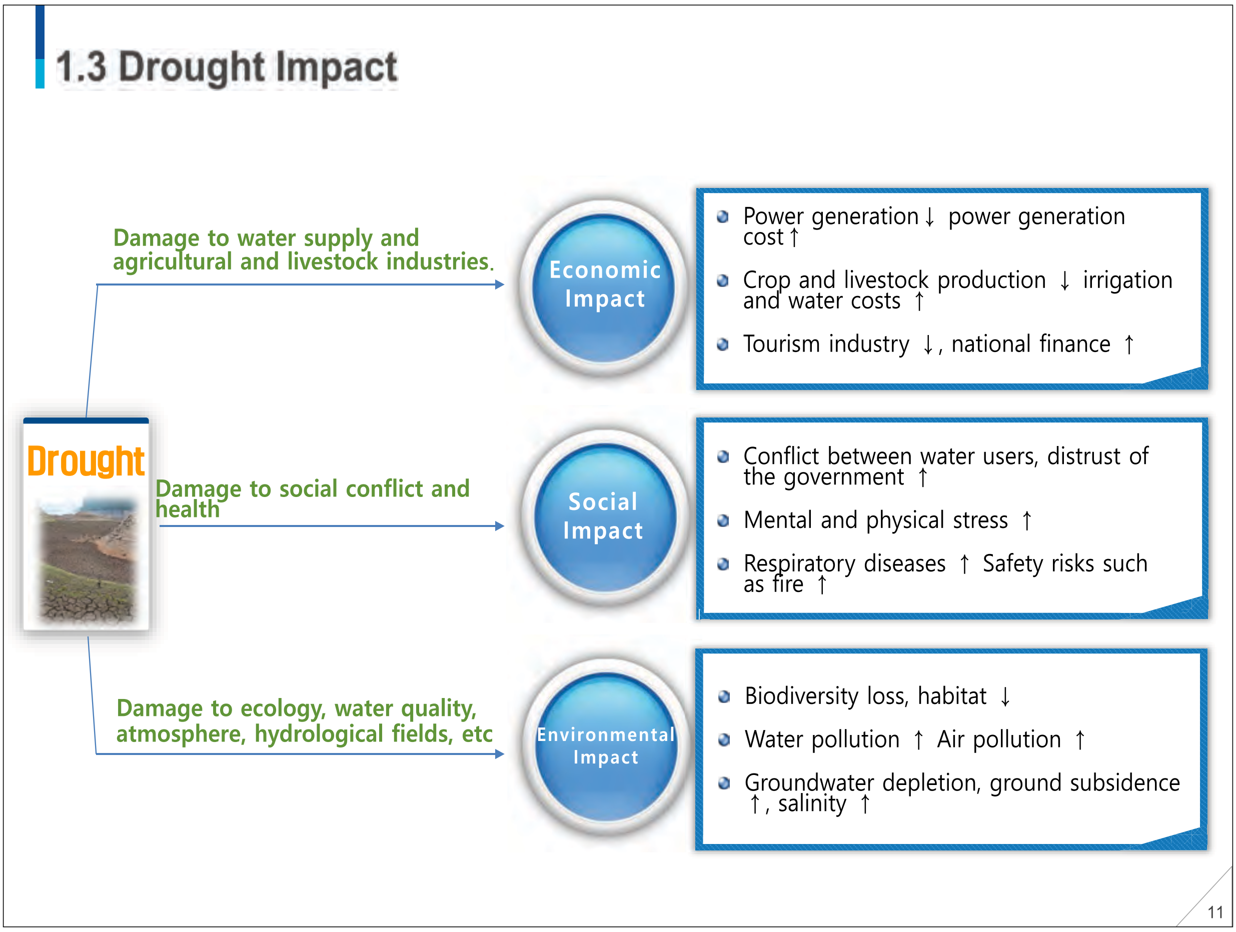
1.3 Drought Impact
Drought
Damage to water supply and agricultural and livestock industries.
Economic Impact
Power generation ↓ power generation cost ↑
Crop and livestock production ↓ irrigation and water costs ↑
Tourism industry ↓, national finance ↑
Damage to social conflict and health
Social Impact
Conflict between water users, distrust of the government ↑
Mental and physical stress ↑
Respiratory diseases ↑ Safety risks such as fire ↑
Damage to ecology, water quality, atmosphere, hydrological fields, etc
Environmental Impact
Biodiversity loss, habitat ↓
Water pollution ↑ Air pollution ↑
Groundwater depletion, ground subsidence ↑, salinity ↑
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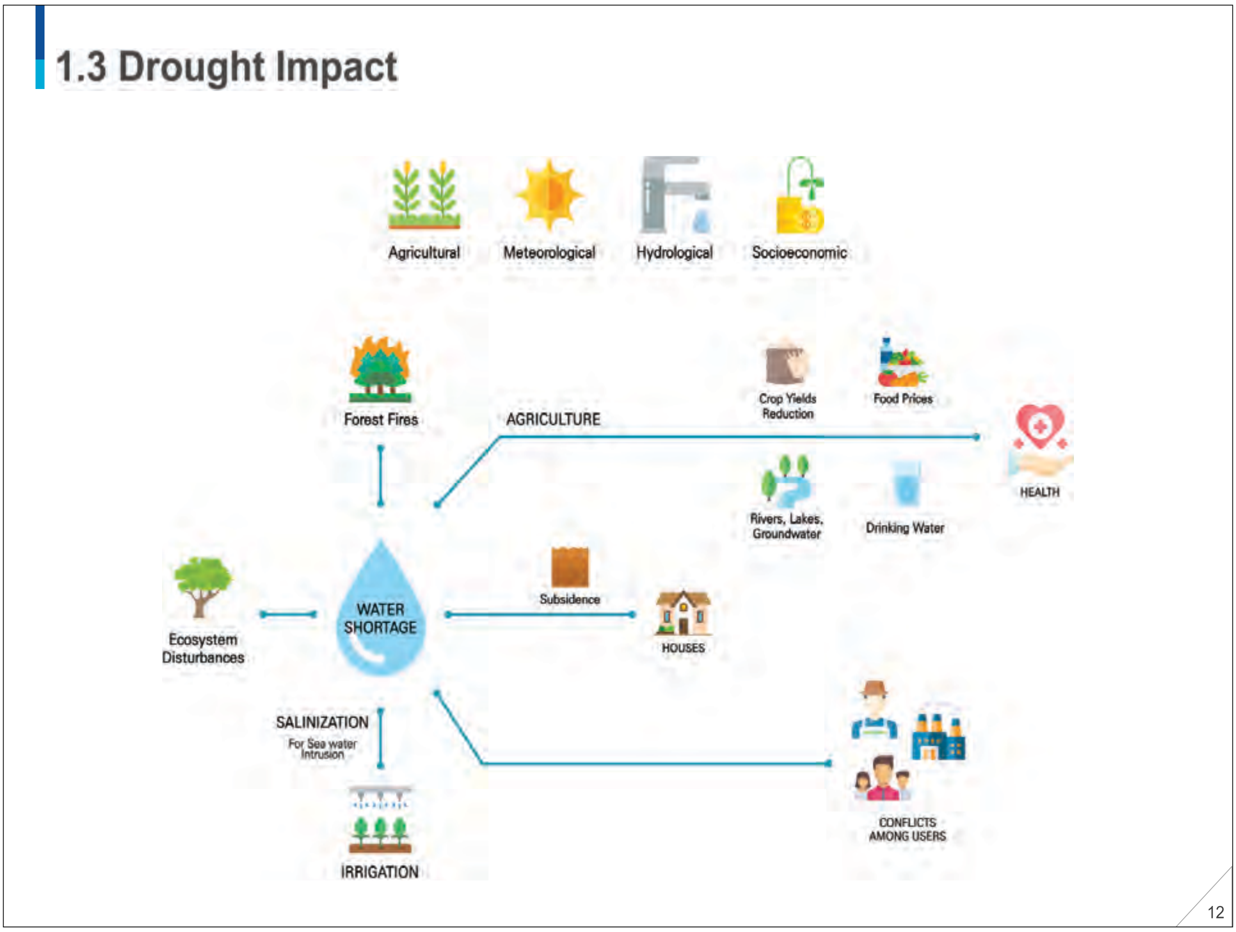
1.3 Drought Impact
Agricultural
Meteorological
Hydrological
Socioeconomic
Forest Fires
AGRICULTURE
Crop Yields Reduction
Food Prices
HEALTH
Rivers, Lakes, Groundwater
Drinking Water
Ecosystem Disturbances
WATER SHORTAGE
Subsidence
HOUSES
SALINIZATION
For Sea water Intrusion
IRRIGATION
CONFLICTS AMONG USERS
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## 1.3 Drought Impact

- **Environmental Drought - What should we monitor?**

**[Vegetation stress and die-off]**

**[Degraded Wildlife Habitat]**

**[Wildfires]**

**[Degraded Water Quality]**

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## 1.3 Drought Impact

- **Environmental Impacts of Drought**

| Examples of Environment Impacts of Drought | |
|---|---|
| Fish and Animals | • Reduction and degradation of fish and wildlife habitat.<br>• Lack of drinking water for livestock and wildlife. |
| Water Sources | • Lower water levels in reservoirs, lakes, and ponds.<br>• Reduced streamflow. |
| Land | • Reduced soil quality<br>• Increased quantity of dust. |
| Plant Communities | • Reduced soil quality<br>• Death of vegetation and trees. |

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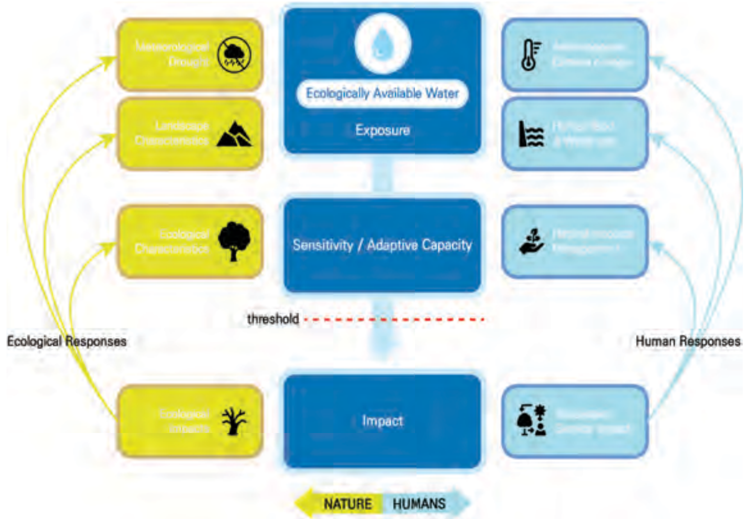
## 1.3 Drought Impact

- **Impact Assessment vs Vulnerability Assessment**

- The term **ecological drought** as an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and /or human systems.




**Vulnerability = exposure + sensitivity + adaptive capacity**

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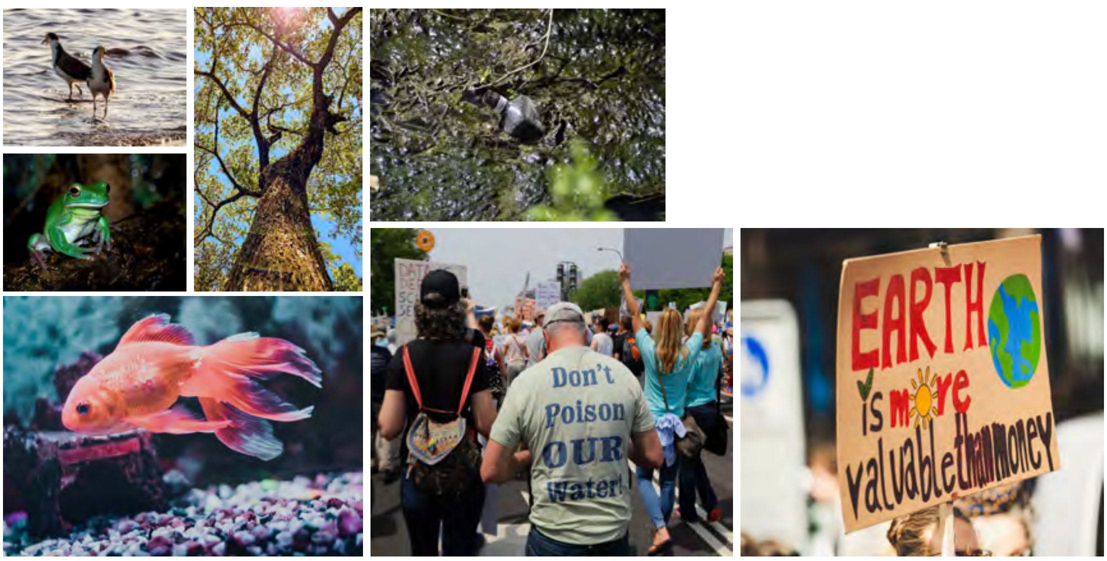
## 1.3 Drought Impact

- **Who's the Owner of the Insufficient Water?**
  - Necessity of concerning whose the water is responsible for in order to monitor environmental/ecological droughts.

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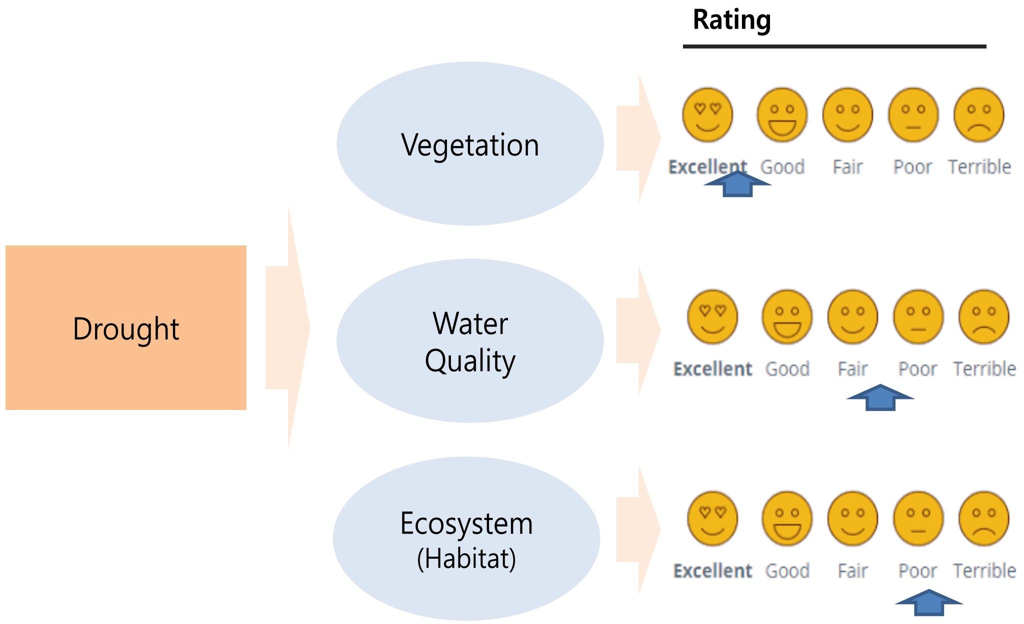
## 1.3 Drought Impact

- **Assessment of Environmental Drought Impact**

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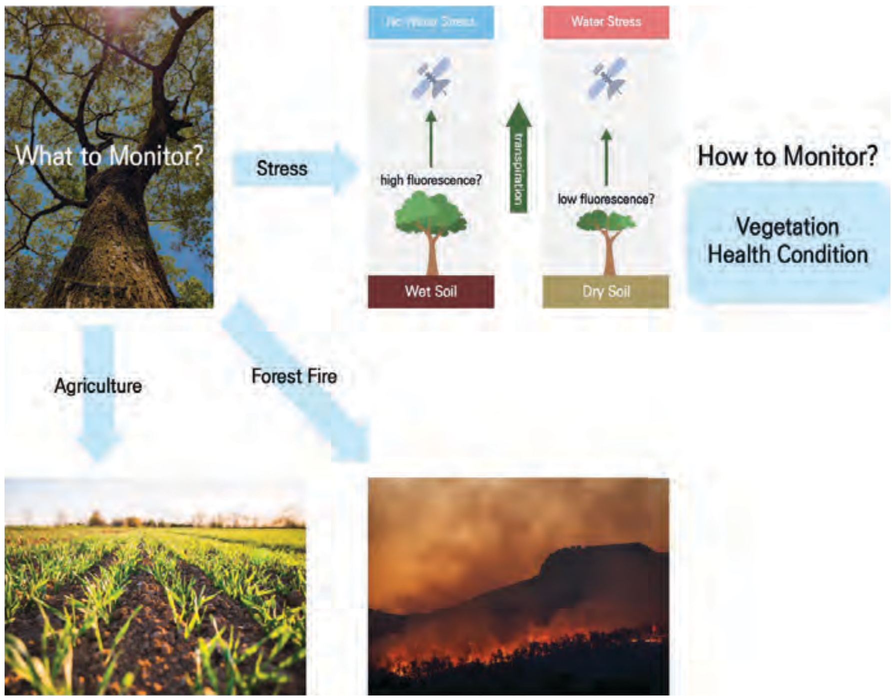
## 1.3 Drought Impact

- **Vegetation Impacts by Drought**

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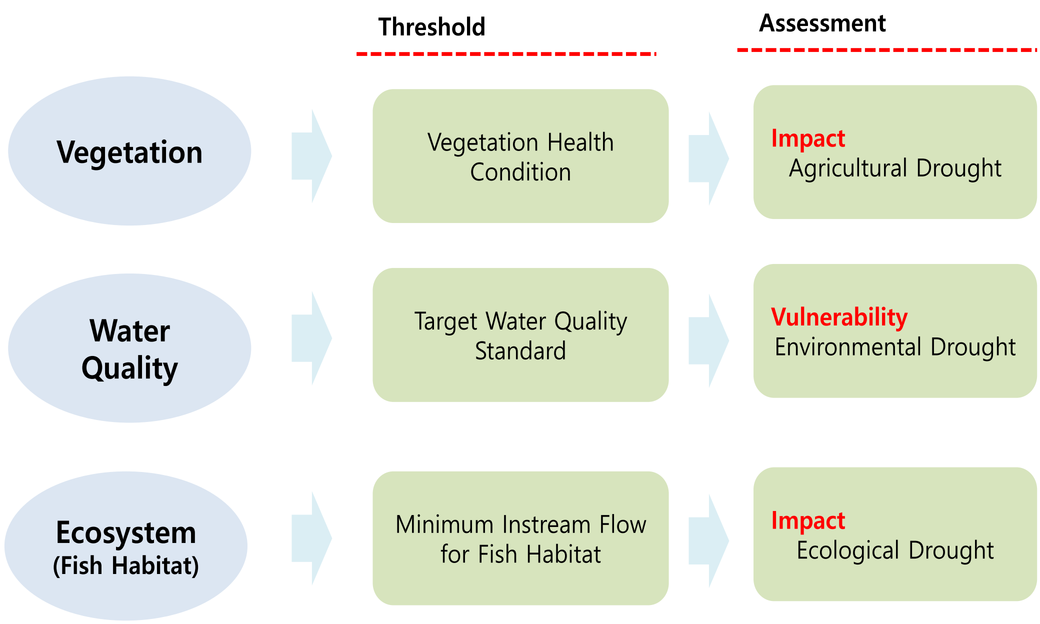
## 1.3 Drought Impact

- **The first step in developing an environmental drought index**
  - How to set up Thresholds & How to Assess (monitor)

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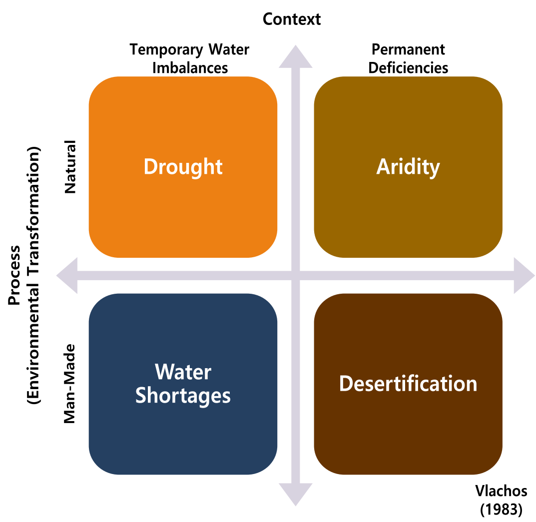
## 1.4 Drought and Water Shortage

- Humans beings, like other ecosystems, know how to live without disasters if they have enough water in their local climate. Therefore, if a water shortage causes a disaster, it will cause a disaster only when it is less than the seasonal average of the area.

**Drought should be assessed based on the shortfall of the climatic averages in the region**




- The lack of water in the desert region is the average nature of the area, not a disaster. Therefore, there should be no drought in the desert.
- Drought refers to the occurrence of an unusual water shortage. If there is no disaster caused by water shortage, it is not necessary to define it as drought.

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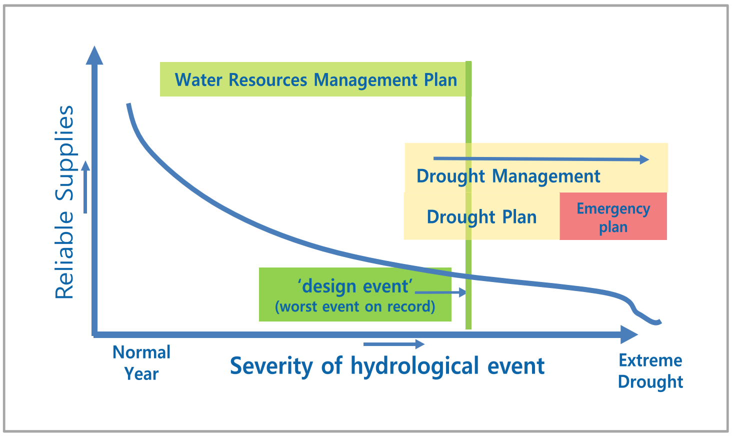
## 1.4 Drought and Water Shortage

- Drought (a natural-scientific phenomenon) and water shortage (an anthropogenic phenomenon) are not the same.
- Water management is a large part, but not all, of drought management.
- There is a difference between drought management measures and water shortage measures
- The cause of drought requires a natural-scientific analysis, and the cause of water shortage requires engineering and socioeconomic analysis

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## 1.5 Drought Index

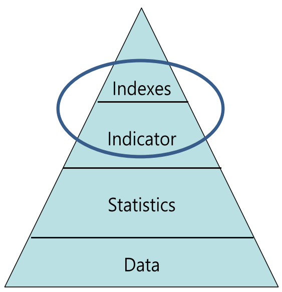
| Meteorological drought index | Agricultural drought index | Hydrological drought index |
| --- | --- | --- |
| • Precipitation<br>• Temperature<br>• **Driving Force** | • Soil moisture<br>• The storage level of agricultural reservoirs<br>• **State** | • River water, underground water level<br>• Multipurpose dam storage<br>• **State** |

It is calculated as an index by combining and processing simple indicators currently being monitored by each institution

| Environmental drought index (Space consideration) | | Environmental drought index (Target to monitor) |
| --- | --- | --- |
| • Aquatic environment<br>• Swamp and lake environment<br>• Basin environment | Impact | • Water quality/tide<br>• the country water supply<br>• Habitat/Ecology |

**DPSIR (PSR or DSR)** is a causal framework for describing the interactions between society and the environment.
This framework has been adopted by the European Environment Agency.

The components of this model are:
- **D**riving forces
- **P**ressures
- **S**tates
- **I**mpacts
- **R**esponses

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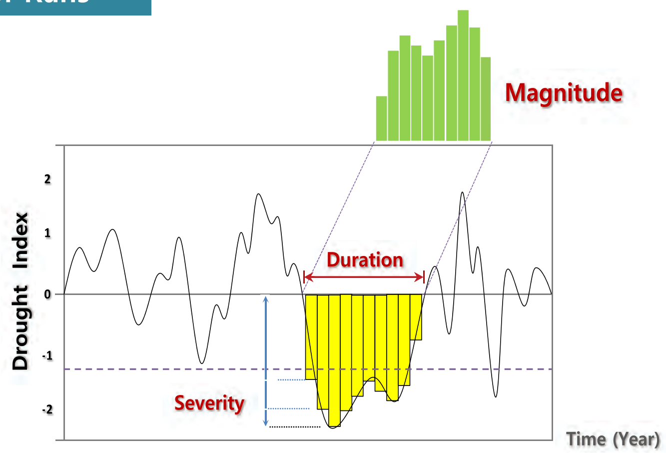
# 1.5 Drought Index

- **Theory of Runs**

$$\text{Severity} = \frac{\text{Magnitude}}{\text{Duration (Month)}}$$

Magnitude : Integrated area of drought duration and severity
Duration : length of drought period
Severity : Intensity of drought

**Theory of Runs**

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# 1.5 Drought Index

| Drought Index | Input Data | Strength | Weakness |
|---|---|---|---|
| **PNP** (Percent of Normal Precipitation) | • Precipitation | • effective for comparing one region or seasons | • Shows impact of extreme precipitation<br>• Doesn't assure normal distribution |
| **SPI** (Standardized Runoff Index) | • Precipitation | • can be calculated by various<br>• more simple | • Only considers precipitation(input data)<br>• Index calculated in the past can vary |
| **PDSI** (Palmer Drought Severity Index) | • Precipitation<br>• Temperature<br>• Available Soil Moisture | • considers region meteorological difference<br>• considers meteorological water balance | • Appearance of drought can be delayed<br>• Mountainous regions or regions with frequent extreme meteorological conditions has low accuracy |
| **SWSI** (Surface Water Supply Index) | • Precipitation<br>• Snowmelt<br>• Water Discharge<br>• Reservoir Storage | • reflects different water supplies of each region<br>• relatively simple calculation and reflects surface water supply capacity | • Different observing point or water supply structure requires new calculation method<br>• Limited comparison between regions |
| **RDI** (Reclamation Drought Index) | • Precipitation<br>• Snowmelt<br>• Run Off<br>• Reservoir Water Level<br>• Temperature | • Includes temperature factors (considering evapotranspiration) | • Limited comparison between regions |
| **SMI** (Soil Moisture Index) | • Precipitation<br>• Temperature<br>• Humidity<br>• Soil Data | • Daily simulation available<br>• Shows natural condition of drought<br>• Effective for short term drought assessment<br>• Sensitive about sufficient precipitation induced drought solution | • Difficult to reflect non-vegetation drought |

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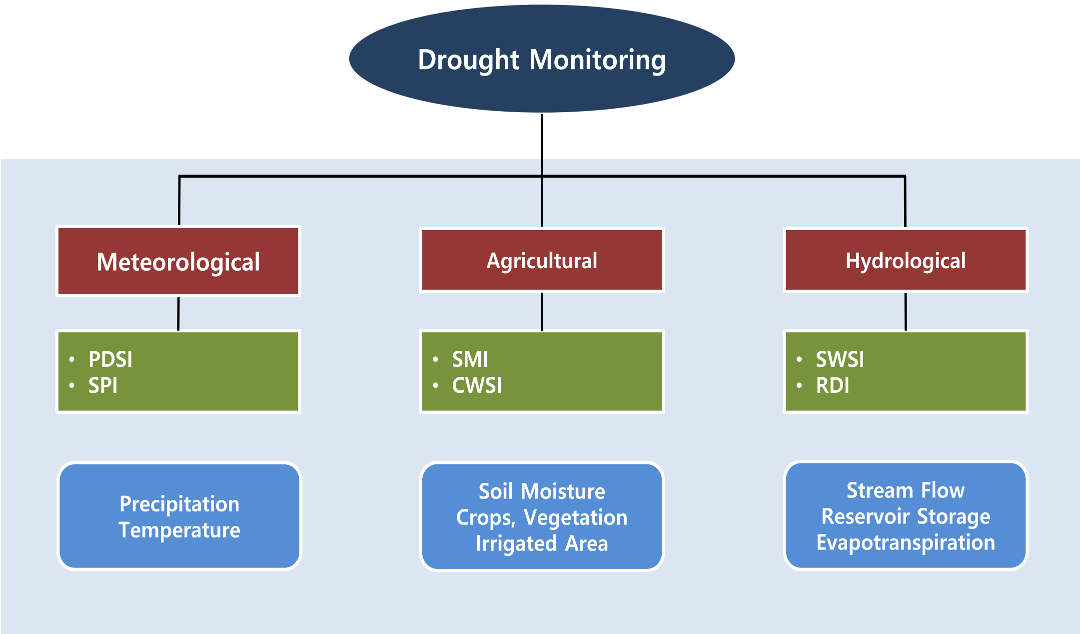
# 2. Drought Monitoring

2.1 Drought Monitoring Concept
2.2 Drought Monitoring : Korea
2.3 Drought Monitoring : US
2.4 Drought Condition Classification

## 2.1 Drought Monitoring Concepts

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## 2.1 Drought Monitoring Concepts

**SPI**

| Range | Condition | Range | Condition |
|---|---|---|---|
| More than 2.00 | Extremely Wet | -1.00 ~ -1.49 | Moderately Dry |
| 1.50 ~ 1.99 | Very Wet | -1.5 ~ -1.99 | Severely Dry |
| 1.00 ~ 1.49 | Moderately Wet | Less than -2.00 | Extremely Dry |
| -0.99 ~ 0.99 | Near Normal | | |

**PDSI**

| Dry Condition | Class | Wet Condition | Class |
|---|---|---|---|
| -0.5 ~ 0.5 | Near normal | X ≥ 4.0 | Extremely Wet |
| -1.0 ~ -1.5 | Incipient drought | 3.0 ~ 4.0 | Very Wet |
| -2.0 ~ -1.0 | Mild drought | 2.0 ~ 3.0 | Moderately Wet |
| -3.0 ~ -2.0 | Moderate drought | 1.0 ~ 2.0 | Slightly Wet |
| -4.0 ~ -3.0 | Severe drought | 0.5 ~ 1.0 | Incipient Wet |
| -4.0 ≥ X | Extreme drought | -0.5 ~ 0.5 | Near normal |

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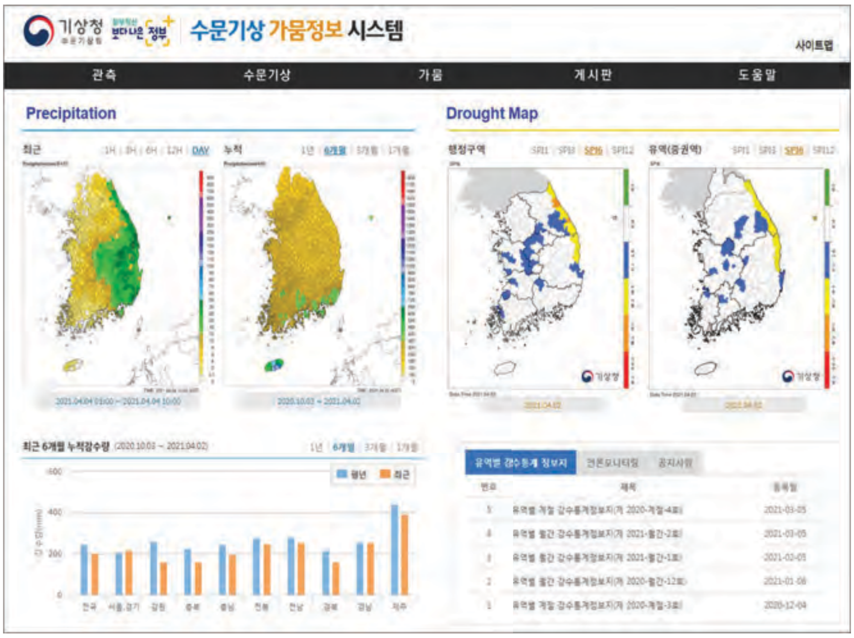
## 2.2 Drought Monitoring : Korea

- **Meteorological Drought**




| Drought Index |
|---|
| SPI (Standardized Precipitation Index) |
| EDI (Effective Drought Index) |
| SPEI (Standardized Evaporation-Precipitation Index) |
| PN (Percent Normal) |

Source: https://hydro.kma.go.kr/front/intro.do

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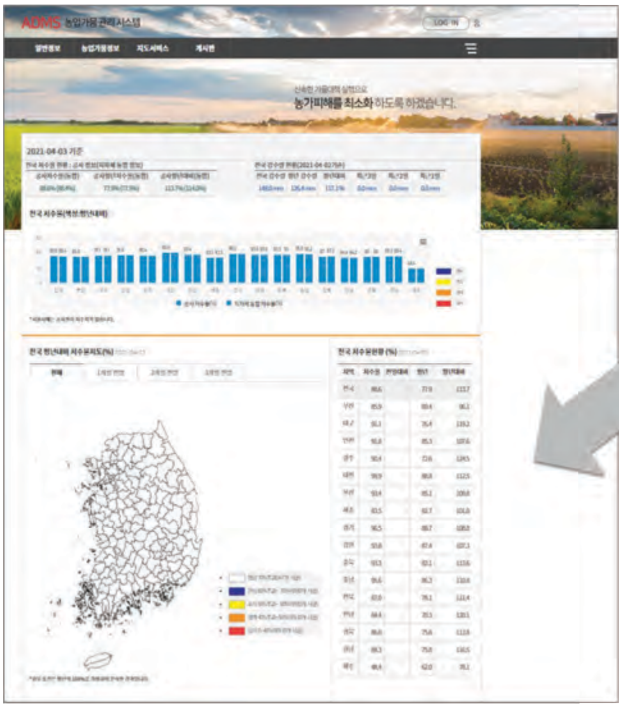
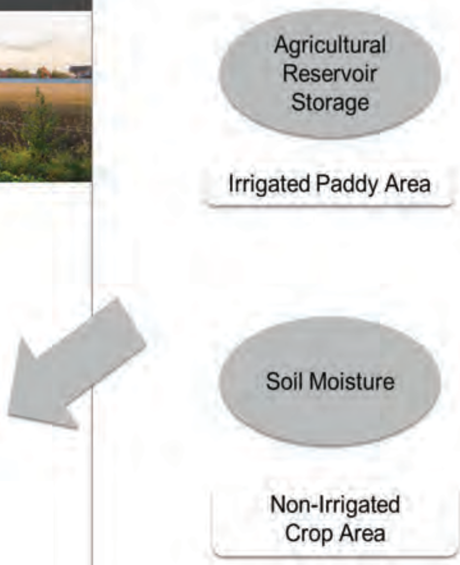
## 2.2 Drought Monitoring : Korea

- **Agricultural Drought**



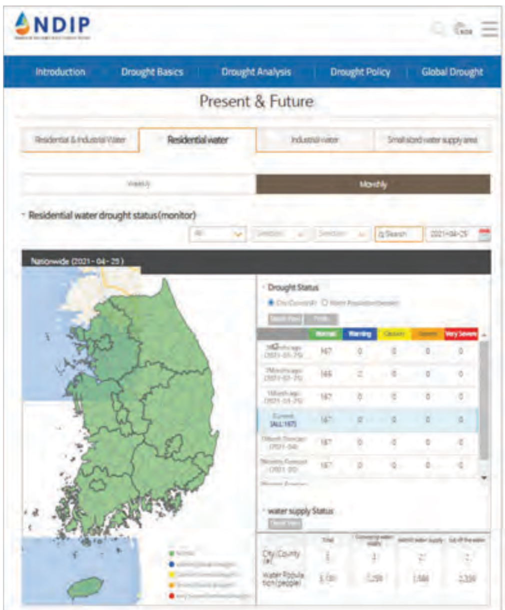




Source: http://adms.ekr.or.kr/main/main.do

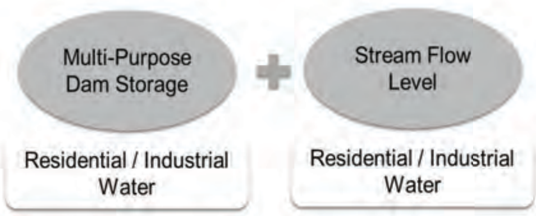
29

## 2.2 Drought Monitoring : Korea

- **Hydrological Drought**








Source: http://www.drought.go.kr/main.do

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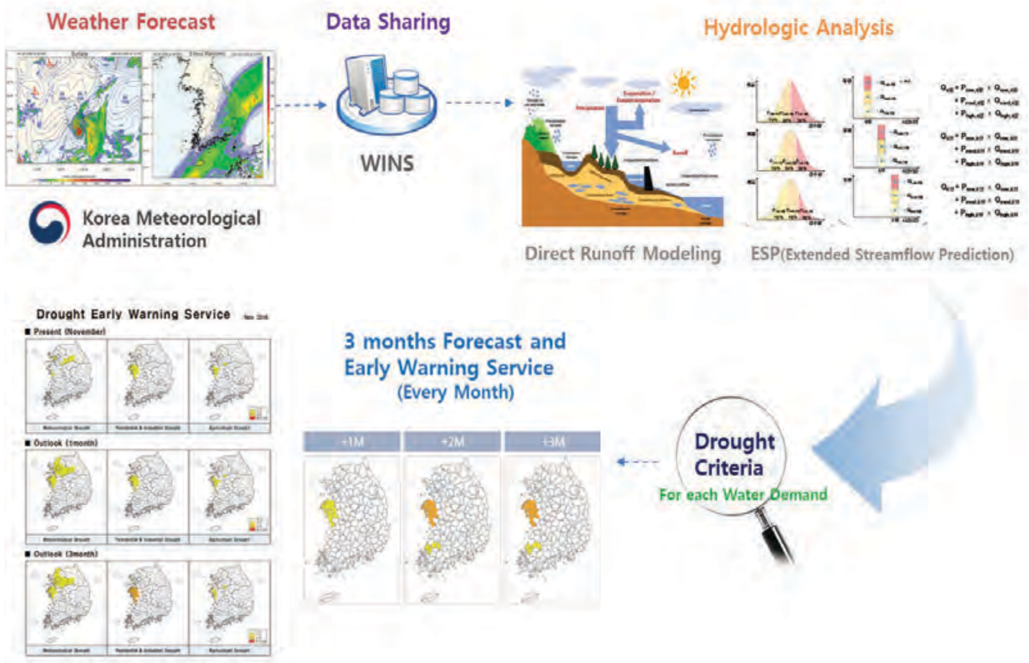
## 2.2 Drought Monitoring : Korea

▪ **Hydrological Drought Monitoring Process**

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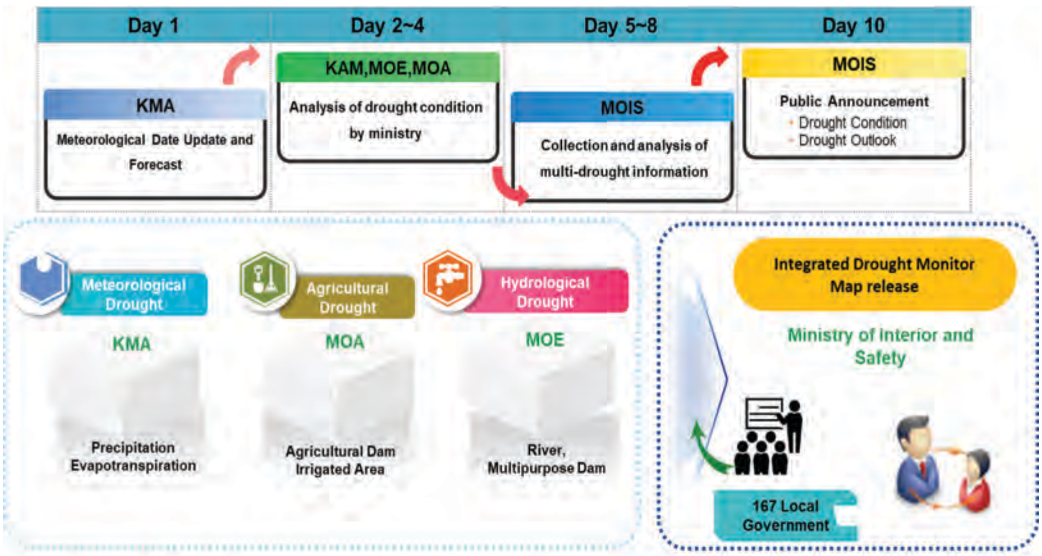
## 2.2 Drought Monitoring : Korea

▪ **Drought Early Warning Process by Multi Agencies**




**[Released by] MOIS** (by Multi-ministries)
**[Map Release]** Day 10, Every Month
**[Spatial Unit]** 167 Local Government

**[Map Information]** Current Drought Condition
**[Drought Outlook]** 1month ~ 3 months forecast
**[Drought Class]** D1~D4

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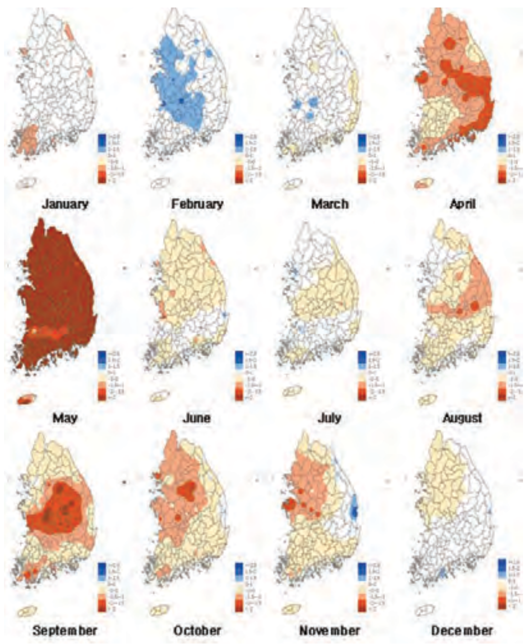
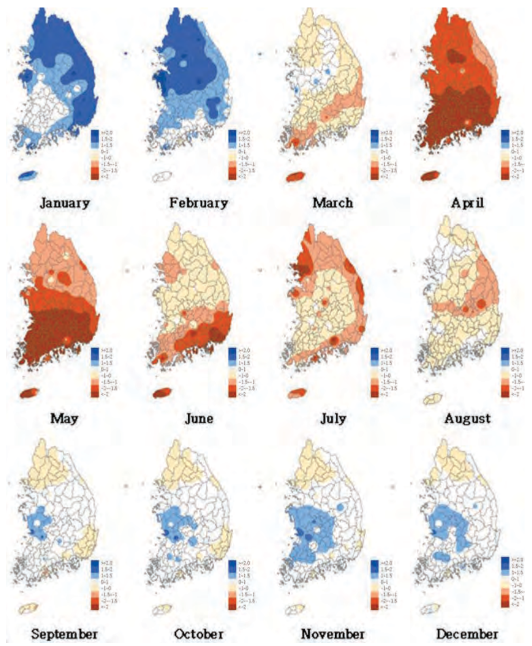
## 2.2 Drought Monitoring : Korea

**2001 SPI(3)**




**2001 SPI(6)**

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## 2.3 Drought Monitoring : US

▪ **US Drought Portal**


Source: https://www.drought.gov/

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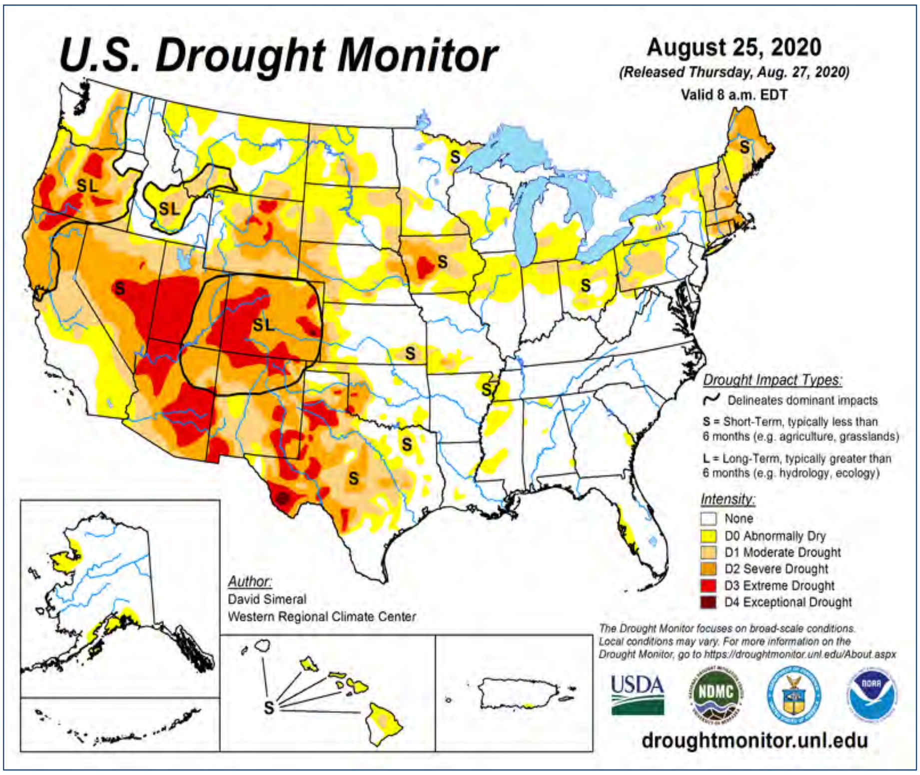
## 2.3 Drought Monitoring : US

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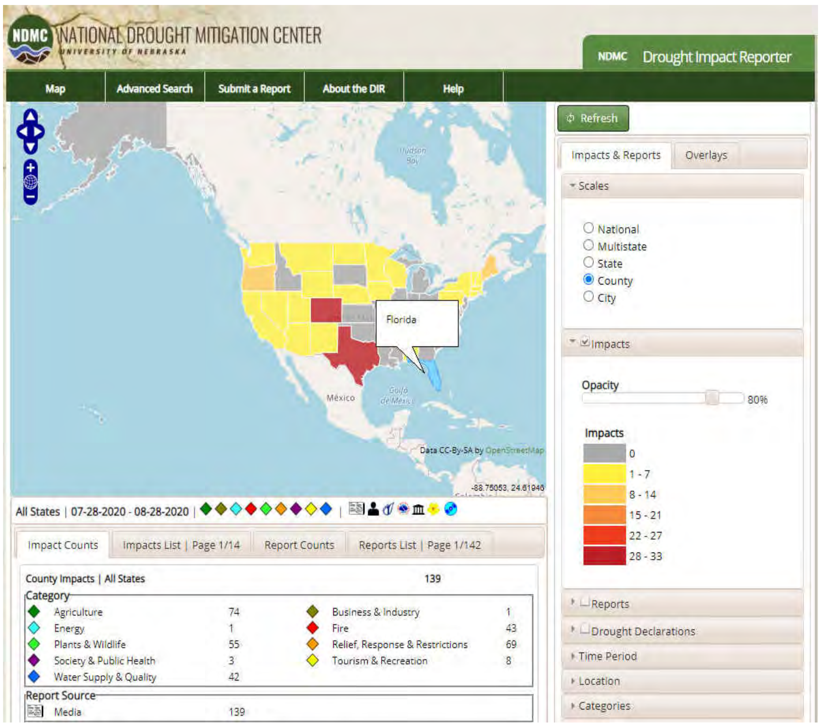
## 2.3 Drought Monitoring : US

- **Drought Impact Reporter**

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# 2.4 Drought Condition Classification

## ▪ Drought Early Warning Criteria of Korea

| Drought Class | Drought Early Warning Criteria |
|---|---|
| **Attention**<br>(Mild drought) | **Meteorological Drought**<br>It is assumed that the weather drought is expected to continue to be below the standard precipitation index of -1.0 or less (about 65% of the normal year) using the accumulated 6-month precipitation, but it may reflect regional precipitation characteristics.<br>**Agricultural Drought**<br>[Rice field] Agricultural reservoir storage level less than 70% of average.<br>[Field] Less than 60% effective water content of soil<br>**Hydrological Drought**<br>The water level of rivers and water facilities is lower than normal, so that the drought needs to be managed, such as managing the amount of living and industrial water in order to supply normal water. |
| **Caution**<br>(Normal drought) | **Meteorological Drought**<br>It is assumed that the weather drought is expected to continue to be below the standard precipitation index of -1.5 or less (about 55% of the normal year) using the accumulated 6-month precipitation, but it may reflect the regional precipitation characteristics.<br>**Agricultural Drought**<br>[Rice field] Agricultural reservoir storage level less than 60% of average<br>[Field] Less than 45% effective water content of soil for crop cultivation<br>**Hydrological Drought**<br>The water level of rivers and water facilities is low, so that the flow rate of stream maintenance is limited or the supply of river maintenance water is required in dams and reservoirs. |
| **Warning**<br>(Severe drought) | **Meteorological Drought**<br>It is assumed that the meteorological drought will last for less than the standard precipitation index of -2.0 or less (about 45% of the normal year) using the accumulated 6-month cumulative rainfall<br>**Agricultural Drought**<br>[Rice field] Agricultural reservoir storage level less than 50% of average<br>[Field] Soil Effective Moisture Content Less than 30%<br>**Hydrological Drought**<br>If there is a shortage of living or industrial water in rivers and water facilities and there is a concern about the occurrence, there is a need to limit the supply of river water and agricultural water |
| **Very Severe**<br>(Extreme drought) | **Meteorological Drought**<br>The standard precipitation index of less than -2.0 (45% compared with the normal year) using the cumulative precipitation in the last 6 months is considered to be the case where the drought is expected to continue for 20 days or more and the drought damage is expected nationwide<br>**Agricultural Drought**<br>[Rice field] Agricultural reservoir storage level less than 40%<br>[Field] Soil Effective Moisture Content Less than 15%<br>**Hydrological Drought**<br>If living and industrial water shortage in rivers and water facilities has increased, and there are restrictions on the supply of Residential and industrial water in rivers, dams, reservoirs, etc. |

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# 2.4 Drought Condition Classification

## ▪ US – NDMC (National Drought Mitigation Center)

| | | | Ranges | | | | |
|---|---|---|---|---|---|---|---|
| **Category** | **Description** | **Possible Impacts** | **Palmer Drought Severity Index (PDSI)** | **CPC Soil Moisture Model (Percentiles)** | **USGS Weekly Streamflow (Percentiles)** | **Standardized Precipitation Index (SPI)** | **Objective Drought Indicator Blends (Percentiles)** |
| **D0** | Abnormally Dry | Going into drought:<br>▪ short-term dryness slowing planting, growth of crops or pastures<br>Coming out of drought:<br>▪ some lingering water deficits<br>▪ pastures or crops not fully recovered | -1.0 to -1.9 | 21 to 30 | 21 to 30 | -0.5 to -0.7 | 21 to 30 |
| **D1** | Moderate Drought | ▪ Some damage to crops, pastures<br>▪ Streams, reservoirs, or wells low, some water shortages developing or imminent<br>▪ Voluntary water-use restrictions requested | -2.0 to -2.9 | 11 to 20 | 11 to 20 | -0.8 to -1.2 | 11 to 20 |
| **D2** | Severe Drought | ▪ Crop or pasture losses likely<br>▪ Water shortages common<br>▪ Water restrictions imposed | -3.0 to -3.9 | 6 to 10 | 6 to 10 | -1.3 to -1.5 | 6 to 10 |
| **D3** | Extreme Drought | ▪ Major crop/pasture losses<br>▪ Widespread water shortages or restrictions | -4.0 to -4.9 | 3 to 5 | 3 to 5 | -1.6 to -1.9 | 3 to 5 |
| **D4** | Exceptional Drought | ▪ Exceptional and widespread crop/pasture losses<br>▪ Shortages of water in reservoirs, streams, and wells creating water emergencies | -5.0 or less | 0 to 2 | 0 to 2 | -2.0 or less | 0 to 2 |

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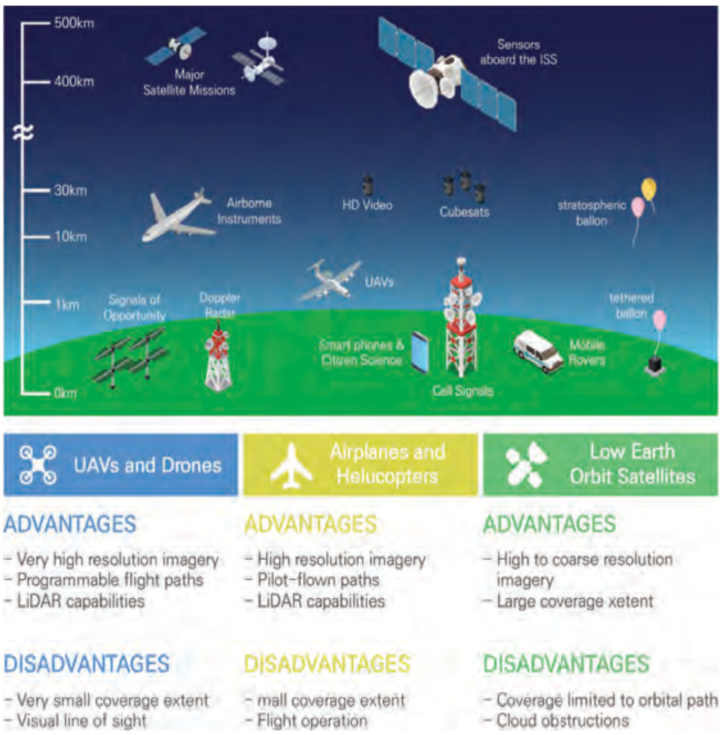
# 3. Remote Sensing for Drought Monitoring

3.1 Remote Sensing
3.2 Drought Monitoring

## 3.1 Remote Sensing

▪ **Types of Remote Sensing**

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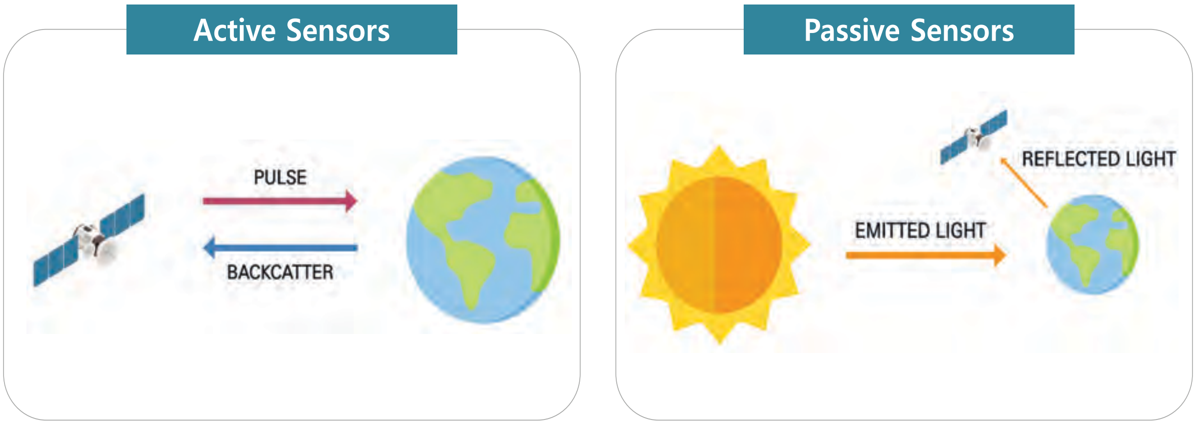
## 3.1 Remote Sensing

- **Types of Remote Sensing**
  - **Passive remote sensing** measures reflected energy emitted from the sun.
  - Where as **active remote sensing** illuminates its target and measures its backscatter.

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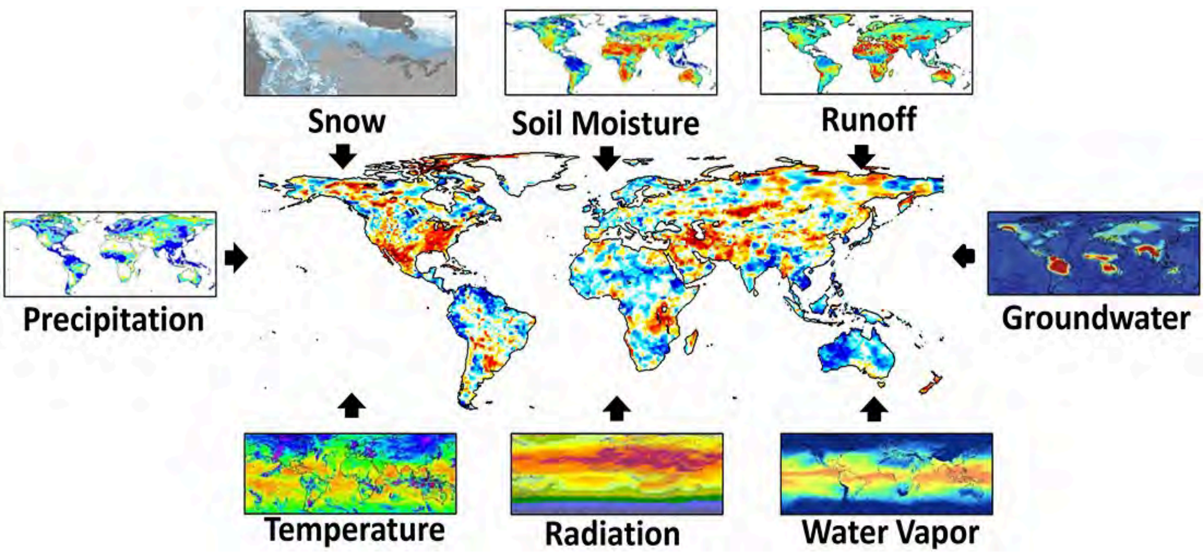
## 3.1 Remote Sensing

- **Hydro-Meteorological Variables from Remote Sensing**




Source: AghaKouchak et al. (2015), Remote sensing of drought: Progress, challenges and opportunities(2015), Reviews of Geophysics

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## 3.1 Remote Sensing

- **Limitations of Current Drought Monitoring**
  - Traditional drought monitoring is mostly based on meteorological data derived from weather station which is not adequate for characterization of drought conditions at regional scale, especially where current networks of weather stations are sparse
  - Limited to topographic condition, it is not possible to set up an intensive weather monitoring network at complex terrain.
  - Using interpolation to estimate meteorological variables often produce some uncertainties
  - Drought information provided by drought map is at coarse level of spatial detail which limits drought study at finer scale

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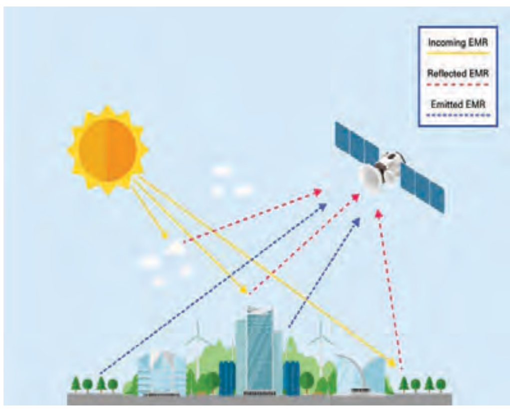
## 3.1 Remote Sensing

- **Drought Monitoring with Remote Sensing**
  - Remote sensing provide cost effective, near real time drought monitoring over large area.
  - The satellite constantly monitor various environmental components which potentially affected by agricultural drought (vegetation , ET, LST...).
  - Compared to traditional drought monitoring methods, remote sensing technique can detect drought onset, duration and severity, providing farmers and scientists with timely drought information at continuous spatial coverage.

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## 3.1 Remote Sensing

▪ **Drought Monitoring with Remote Sensing**

- **Advantages**

  - Cost-effective and rapid method of acquiring up-to-date information over a large geographical area.
  - An practical way to obtain data from inaccessible or isolated areas.
  - High repetition rate and continuous coverage.

- **Limitations**

  - Indirect measurements of the phenomenon.
  - Interference from cloud cover and atmospheric particles
  - Geometric issues
  - Sensor calibration issues

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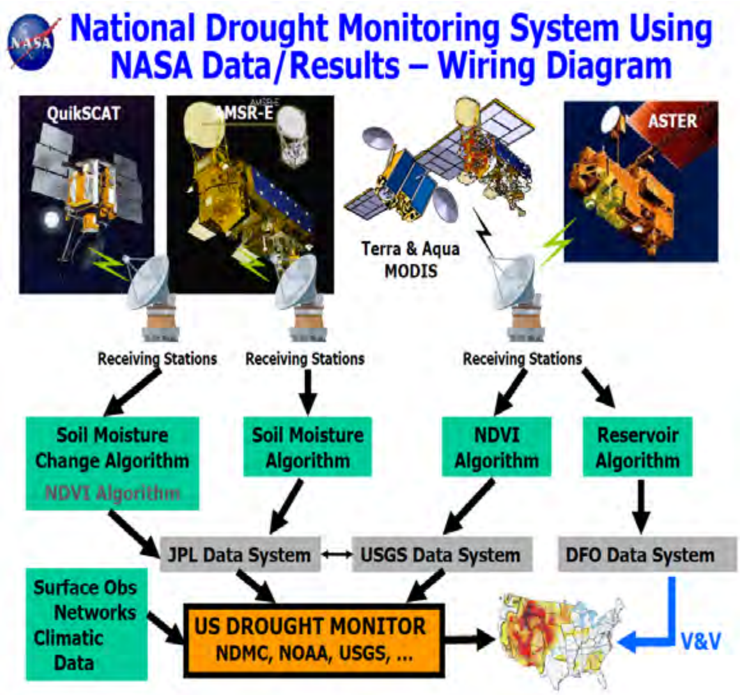
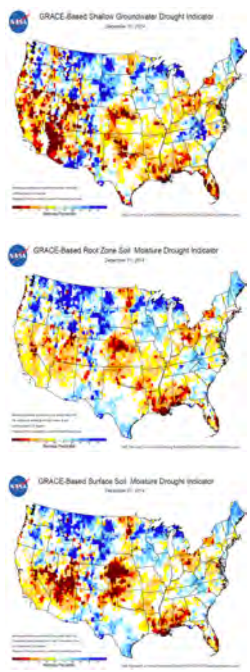
## 3.1 Remote Sensing

▪ **US Drought Monitoring with NASA**




NDMC GRACE Satellite based on drought monitoring.



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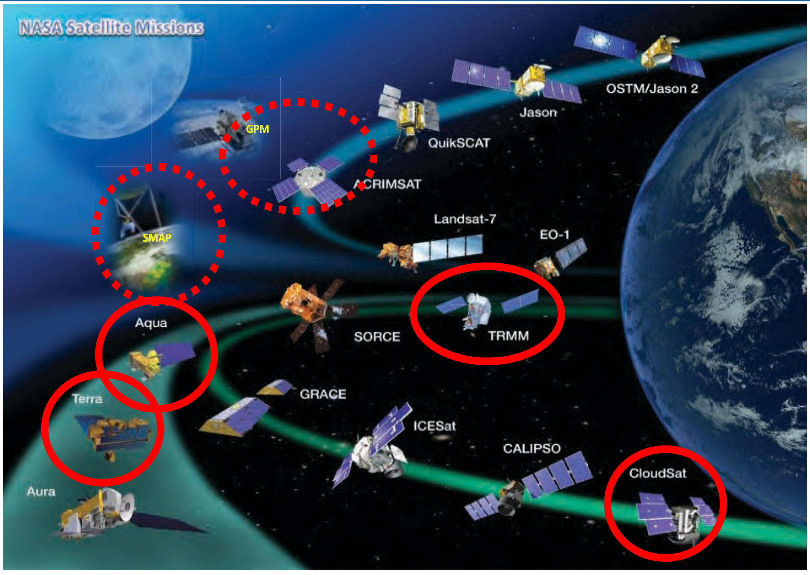
## 3.1 Remote Sensing

- **NASA's Earth Observing System (EOS)**

NASA's Earth Observing System (EOS) is a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. The EOS Project Science Office (EOSPSO) is committed to bringing program information and resources to the Earth science research community and the general public alike.

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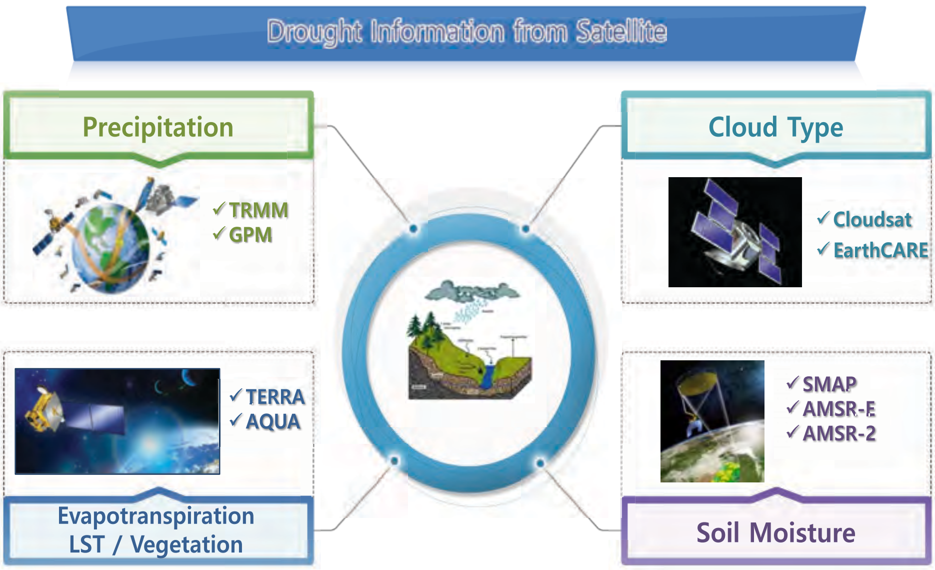
## 3.1 Remote Sensing

- **Drought related variables from Multi Sensor-Satellites**

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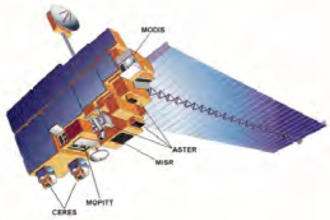
## 3.1 Remote Sensing

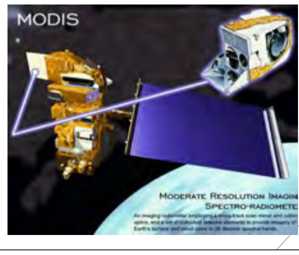
- **Terra : 1999 - present**

- Terra explores the connections between Earth's atmosphere, land, snow and ice, ocean, and energy balance to understand Earth's climate and climate change and to map the impact of human activity and natural disasters on communities and ecosystems.
- Terra is in a circular sun-synchronous polar orbit that takes it from north to south (on the daylight side of the Earth) every 99 minutes.

- Terra Instrument
  - MODIS (Moderate-resolution Imaging spectroradiometer)
  - MOPITT (Measurements of Pollution in the Troposphere)
  - MISR (Multi-angle Imaging Spectro Radiometer)
  - CERES (Clouds and Earth's Radiant Energy System)
  - ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer)



- MODIS Characteristics
  - Product : Vegetation Indices (NDVI, EVI), Land Surface Temperature, Evapotranspiration
  - Pixel Size : 500 ~ 1000m
  - Temporal Granularity : daily, 8 day, 16 day, Monthly

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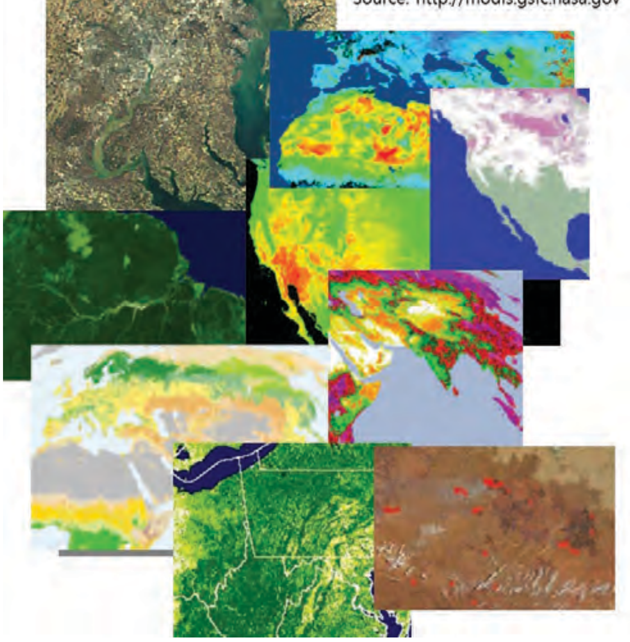
## 3.1 Remote Sensing

- **Terra : 1999 - present**
- MODIS Land Products
  - Energy Balance Product Suite
    - ✓ Surface Reflectance
    - ✓ Land Surface Temperature, Emissivity
    - ✓ BRDF/Abledo
    - ✓ Snow/Sea-ice Cover
  - Vegetation Parameters Suite
    - ✓ Vegetation Indices
    - ✓ LAI/FPAR
    - ✓ GPP/NPP
  - Land Cover/Land Use Suite
    - ✓ Land Cover/Vegetation Dynamics
    - ✓ Vegetation Continuous Fields
    - ✓ Fire and Burned Area



Source: http://modis.gsfc.nasa.gov

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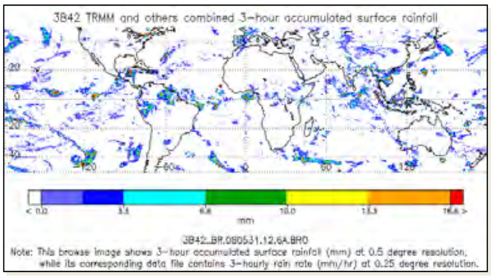
## 3.1 Remote Sensing

### ▪ TRMM (Tropical Rainfall Measuring Mission) : 1997-2015

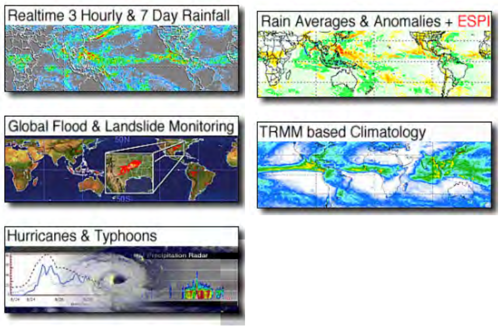
#### - TRMM Instrument

- TRMM Microwave Imager(TMI)
- Precipitation Radar(PR)
- Visible and Infrared Scanner(VIRS)
- Cloud and Earth's Radiant Energy System(CERES)
- Lightning Imaging Sensor(LIS)




#### - Products and Applications

- Realtime 3 Hourly & 7 Day Rainfall
- Global Flood & Landslide Monitoring
- Hurricanes & Typhoons
- Rain Averages & Anomalies + ESPI
- TRMM based Climatology

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## 3.1 Remote Sensing

### ▪ GPM (Global Precipitation Measurement) : 2014 – present

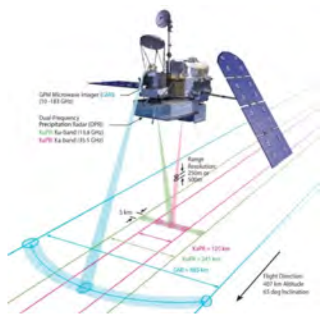
#### - GPM Characteristics

- International network of satellite that provide
  the next-generation global observations of rain and snow
- GPM core and cooperation satellites are updated with 10-km resolution precipitation data every 30 minutes.


#### - IMERG Output Data

| Data Type | Production Time | Object |
|---|---|---|
| Early | Production 4 hours after start of observation | Flood prevention and Short-term |
| Late | Production 12 hours after start of observation | Forecast of crop |
| Final | Production 3 month after start of observation | Research |

File Format : HDF5



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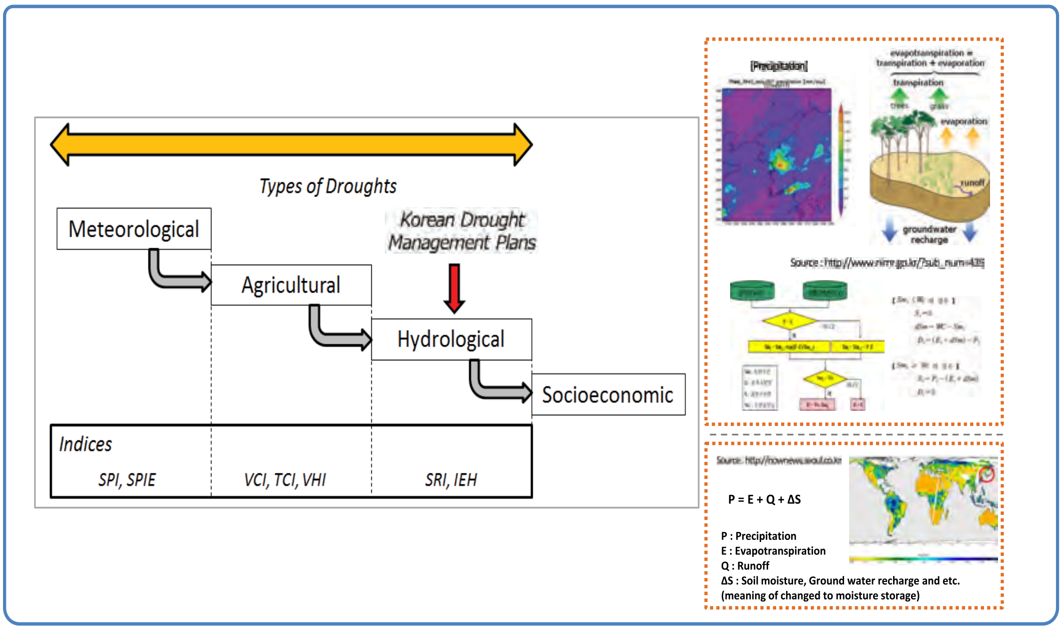
## 3.2 Drought Monitoring

▪ **Drought indices based Multi Drought Impact Monitoring**

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## 3.2 Drought Monitoring

▪ **Drought indices based on Multi Sensor-Satellite Images**

- **Meteorological Drought Index**
  - **SPI**
    - ✓ Precipitation

- **Agricultural Drought Index**
  - **VHI(Vegetaion Health Index)**
    - ✓ $VHI = 0.5(VCI + TCI)$
  - VSIA(Vegetation Stress Index Anomaly)
    - ✓ $VSIA_{month} = EVI_{month} - \overline{EVI}_{monthlyaverage}$
  - SDCI(Scaled Drought Condition Index)
    - ✓ $SDCI = 0.5(VHI) + 0.5(PCI)$
  - MIDI(Microwave Integrated Drought Index)
    - ✓ $MIDI = 0.3(SMSI) + 0.2\,(TCI) + 0.5(PCI)$

- **Hydrological Drought Index**
  - ESI(Evaporative Stress Index)
    - ✓ $fPET = AET/PET, \; - \; ESI = z(fPET)$
  - **WBDI(Water Budget-based Drought Index)**
    - ✓ $WBDI = z(MA(P - E))$
  - **EWDI(Energy-based Water Deficit Index)**
    - ✓ $EWDI = z(MA(ESI + z(SMSI)))$

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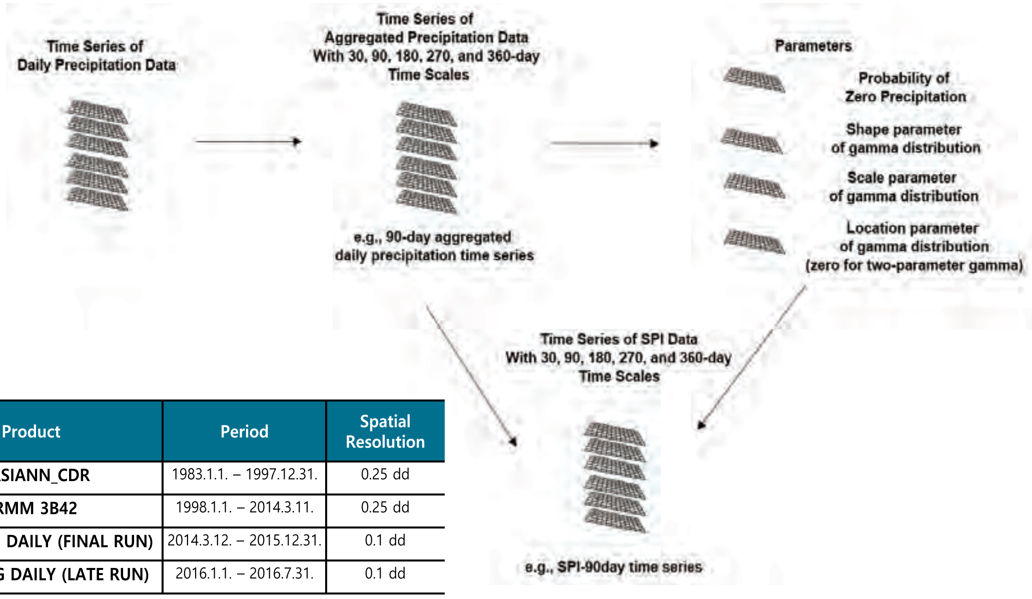
# 3.2 Drought Monitoring

- **Meteorological Drought Monitoring**
  - SPI using satellite precipitation(PERSIANN, TRMM, GPM IMERG)




| Product | Period | Spatial Resolution |
|---|---|---|
| PERSIANN_CDR | 1983.1.1. – 1997.12.31. | 0.25 dd |
| TRMM 3B42 | 1998.1.1. – 2014.3.11. | 0.25 dd |
| GPM IMERG DAILY (FINAL RUN) | 2014.3.12. – 2015.12.31. | 0.1 dd |
| GPM IMERG DAILY (LATE RUN) | 2016.1.1. – 2016.7.31. | 0.1 dd |

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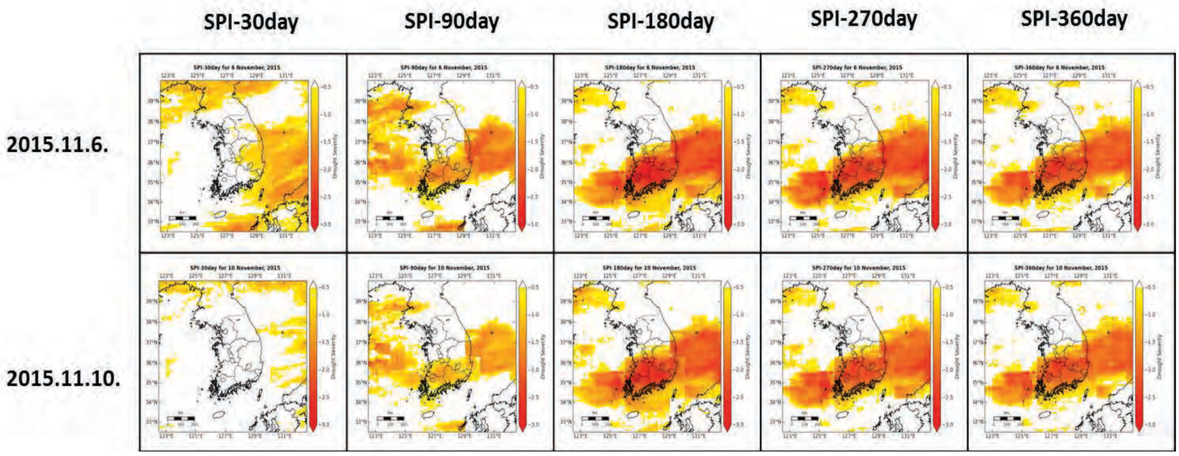
# 3.2 Drought Monitoring

- **Meteorological Drought Monitoring**
  - SPI using satellite precipitation(PERSIANN, TRMM, GPM IMERG)

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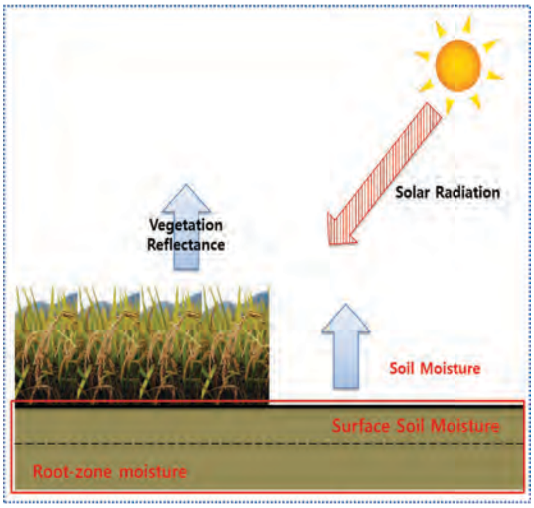
## 3.2 Drought Monitoring

- **Agricultural Drought Monitoring**
  - Main Concept Agricultural Drought Monitoring




VHI = 0.5 (VCI + TCI)

Soil Moisture Index

ADCI = 0.4(VHI) + 0.6 SMSI

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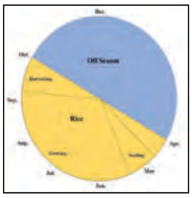
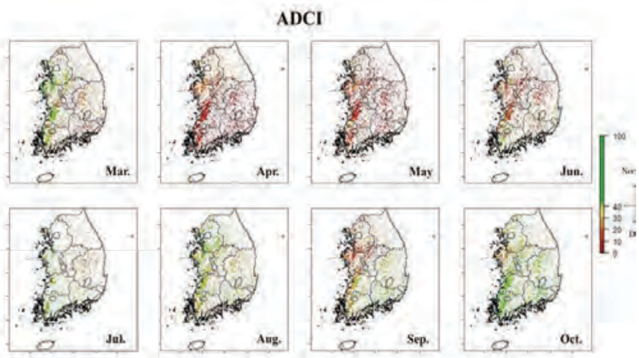
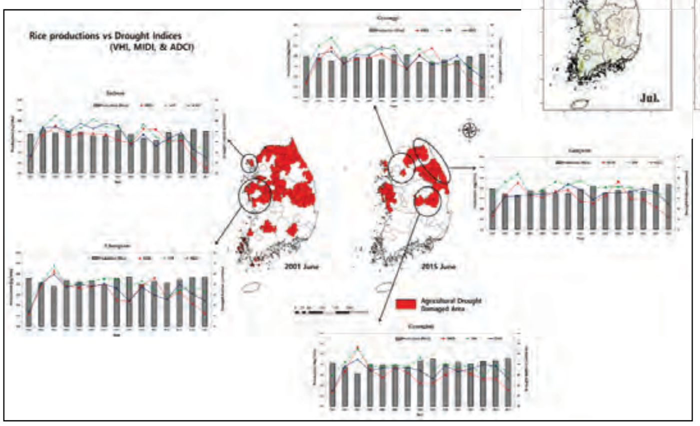
## 3.2 Drought Monitoring

- **Agricultural Drought Monitoring**
  - Agricultural drought index verification (crop production)



✓ Crop growth calendar

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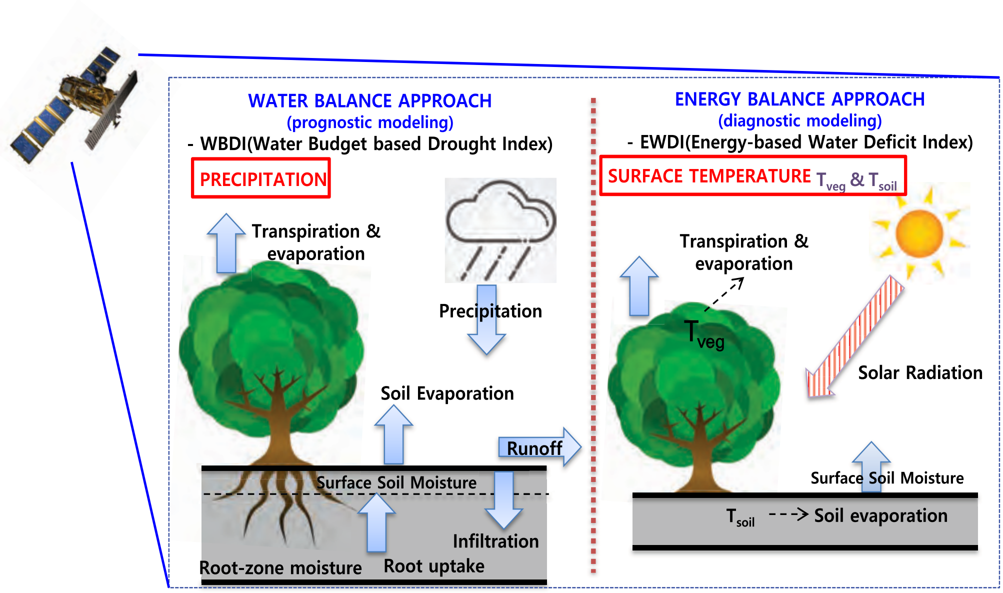
## 3.2 Drought Monitoring

- **Hydrological Drought Monitoring**
  - Main Concept for Hydrological Drought Monitoring




Runoff+$\Delta s = MA3(Z(P - AET))$

WBDI = MA3(Z(P-AET))

EWDI = MA3(Z(ESI+Z(SMSI))

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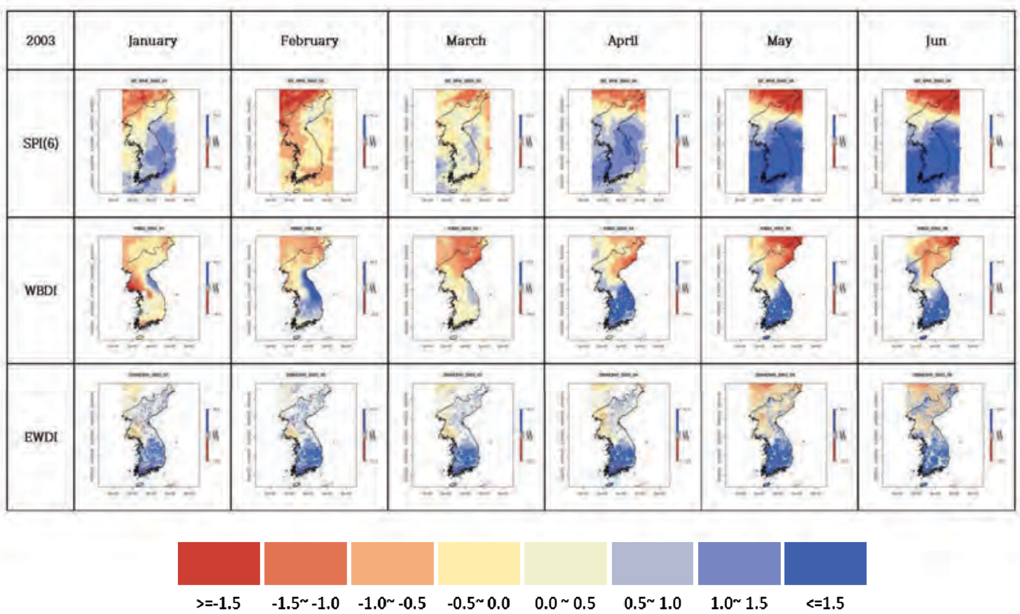
## 3.2 Drought Monitoring

- **Hydrological Drought Monitoring**
  - Flood Monitoring in 2003 (Flood Year) - (1)

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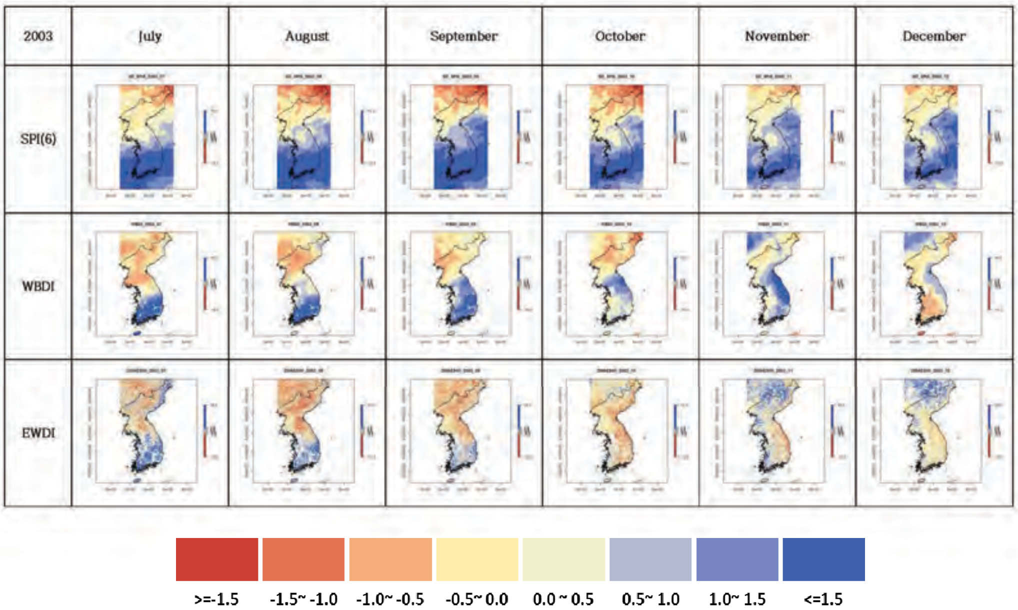
## 3.2 Drought Monitoring

- **Hydrological Drought Monitoring**
  - Flood Monitoring in 2003 (Flood Year) - (2)

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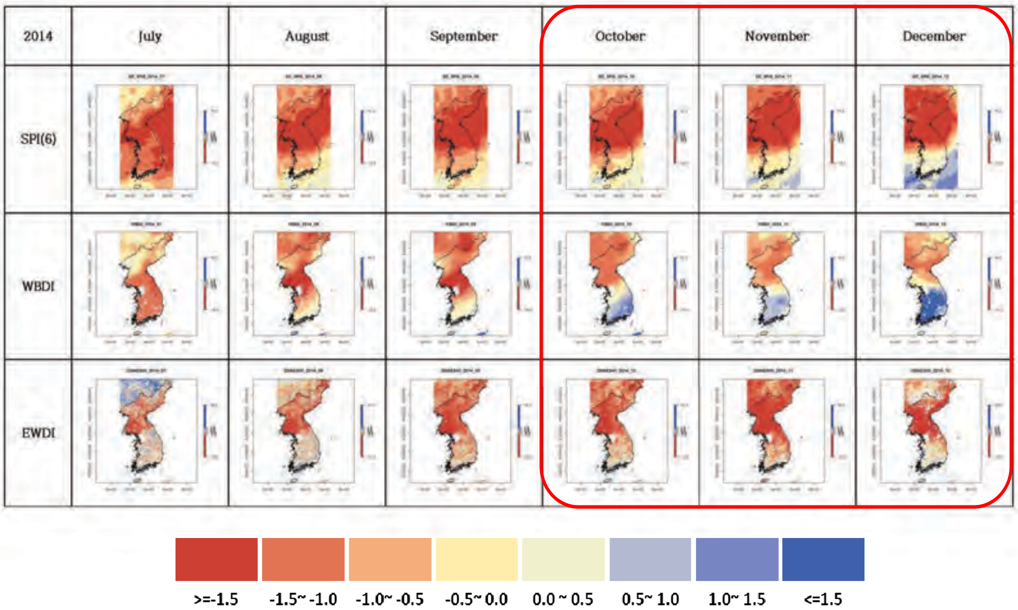
## 3.2 Drought Monitoring

- **Hydrological Drought Monitoring**
  - Hydrological Drought Monitoring in 2014 (Severest Drought Year-Han River Basin)

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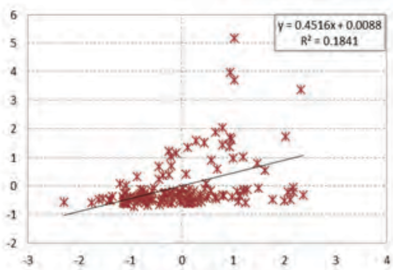
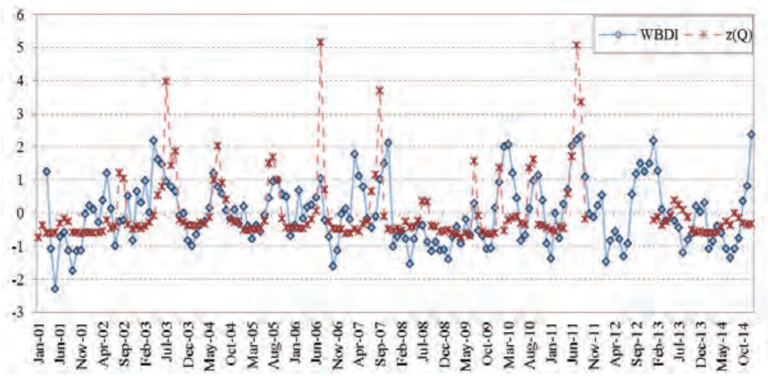
## 3.2 Drought Monitoring

- **Hydrological Drought Monitoring**
  - Accuracy of Hydrological Drought Monitoring (2001-2014)

**[Correlation (WBDI – Runoff)]**




**[Error matrix (WBDI – Q)]**

| DI < 0 , Low quantile | | Streamflow | | SUM | Drought Accuracy | Overall Accuracy |
|---|---|---|---|---|---|---|
| | | Drought | No drought | | | |
| WBDI | Drought | 27 | 11 | 38 | 71.1 % | 55.6 % |
| | No Drought | 56 | 57 | 113 | | |
| | SUM | 83 | 68 | 151 | | |

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# 4. Drought Forecasting

4.1 Drought Forecasting Concept
4.2 How to Predict Drought
4.3 Statistical Drought Forecasting
4.4 Drought Forecasting using Bayesian network

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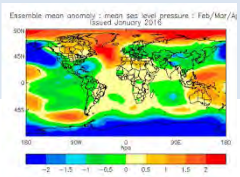
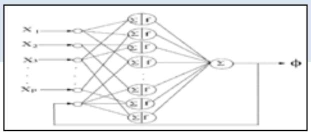
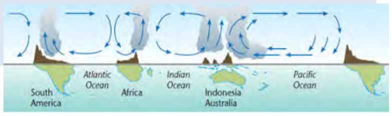
## 4.1 Drought Forecasting Concept

**Drought Forecasting**

- **Numerical Model**
  - Short Term Forecast (1-3 months)
    - GloSea 5
    - LSM
    - WRF
- **Statistical Method**
  - Mid/Long Term Forecast (4-6 months)
    - Bayesian Network
    - ANN
    - Fuzzy
    - ARIMA
- **Atmospheric Science**
  - Long Term Forecast (Seasonal)
    - Teleconnection
    - El Niño & La Niña
    - Climate Patterns





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## 4.2 How to Predict Drought

| Short-Term Forecasting | | Long-Term Projection |
|---|---|---|
| Numerical | Statistical | Climate Change |
| Based on the calculation of Numerical Model | Based on the Statistical Approach (ANN, Bayesian, Fuzzy, Machine Learning) | • Hybrid<br>• Long-term Forecasting<br>• Reflect Regional Climate Variability & Non-Stationarity |
| Physical equations used for describing the connections between variables | easy to calculate (no need of the "complicated" physical models) | |
| Chaotic behaviour of the climate systems produce uncertainty for long range forecasts | historical correlation between global variables and regional climate is stationary (Climate changing | • Scenario Based<br>• Uncertainties |

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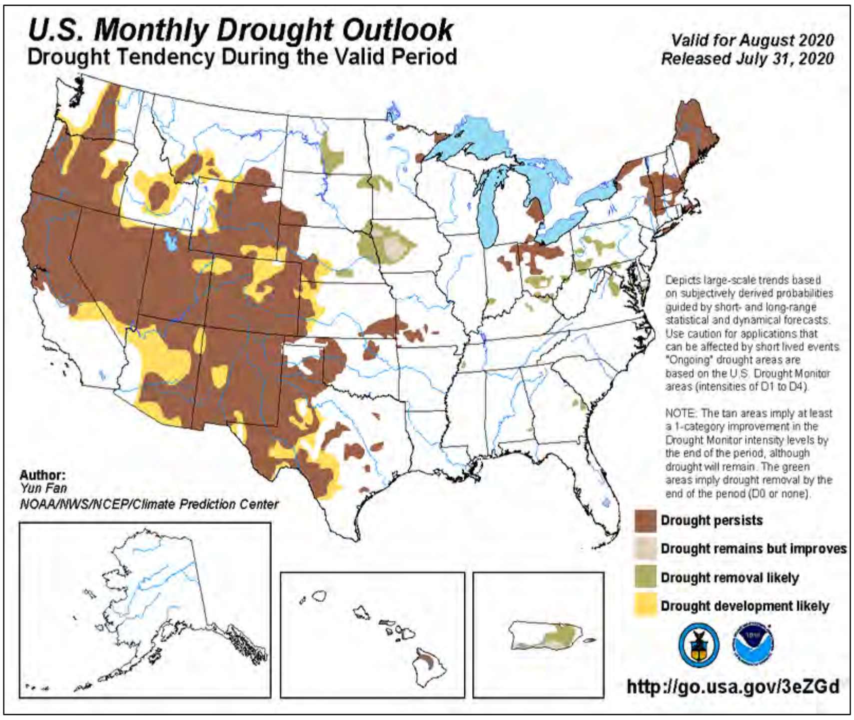
## 4.2 How to Predict Drought

- **Drought Outlook**

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## 4.3 Statistical Drought Forecasting

| | |
|---|---|
| Autoregressive Integrated Moving Average Model **(ARIMA)** | • Mishra and Desai (2005), Durdu (2010)<br>• Only able to forecast 1- month ahead SPI values<br>• Not able to forecast longer lead time due to seasonality |
| Seasonal Autoregressive Integrated Moving Average Model **(SARIMA)** | • Good results up to 2 month ahead drought forecasts<br>• Better for higher time scale SPI series<br>• SPI based forecasting model by removing seasonality |
| Markov Chain Model | • Paulo and Pereira, 2007; Liu *et al., 2009*<br>• Able to forecast transitions of drought severity 3 months ahead<br>• Performance decreased greatly as severity increased |
| Log Linear Model | • Moreira *et al. (2008) used 3-dimensional loglinear* model<br>• Good for short-term drought forecast 2 month ahead<br>• Not good for forecasts of more than 2 months (parameter) |
| Artificial Neural Network Model **(ANN)** | • Rainfall, Storage, NAO, SOI as predictors variables<br>• SPI, PDSI , EDI, PHDI<br>• Able to forecast up to 6 months ahead with high accuracy |
| Adaptive Neuro-Fuzzy Inference System Model | • Bacanli *et al. (2008)*<br>• forecast 1-month ahead drought with different time scale<br>• Higher time scale SPI (SPI 9 or 12 months) show good results |

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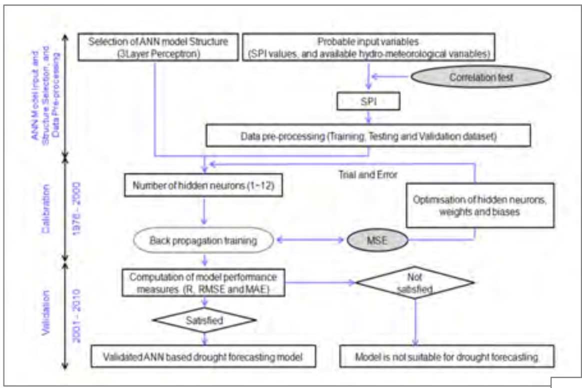
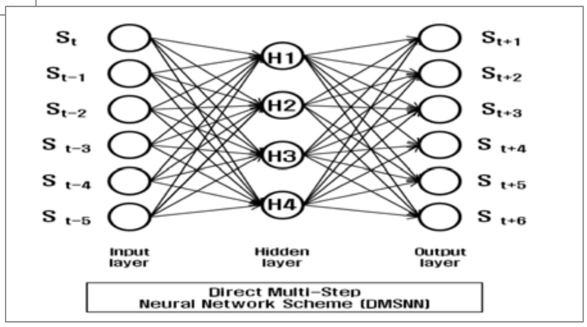
## 4.3 Statistical Drought Forecasting

- **ANN-based 6-month drought outlook**

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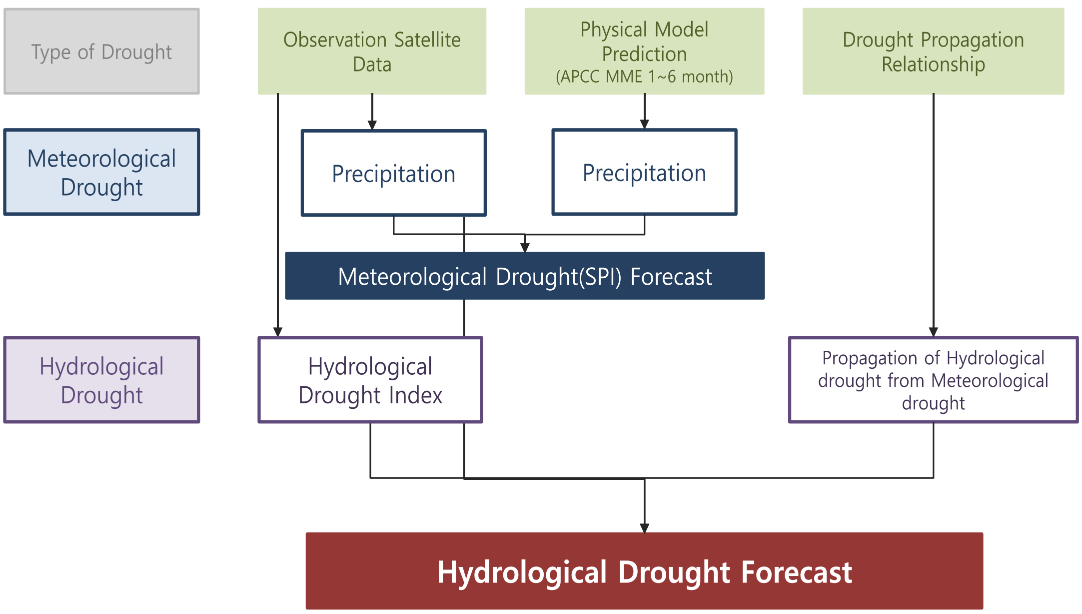
## 4.4 Drought Forecasting using Bayesian network

- **Hydrological Drought Outlook Procedure**

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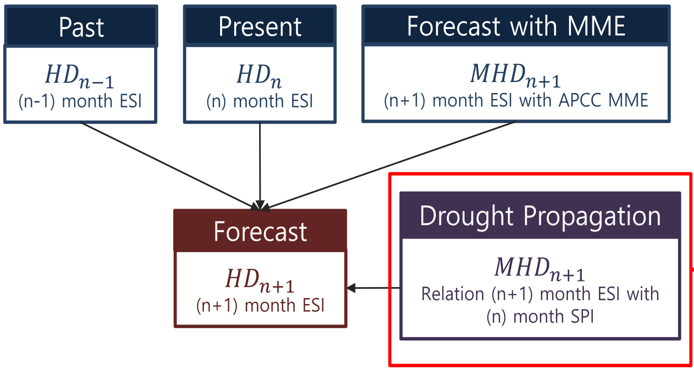
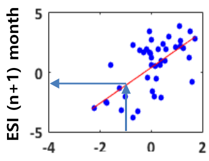
## 4.4 Drought Forecasting using Bayesian network

- **Bayesian Network based Hydrological Drought Prediction Model**
  - Hydrological drought prediction model considering drought propagation based on Bayesian network
    - Bayesian network is a statistical model of probabilistic prediction that reflects uncertainty.
    - Based on the causal relationship between variables, it is possible to predict a drought considering drought propagation relation that can easily add or eliminate factors needed for prediction.

**< 1 month forecast >**



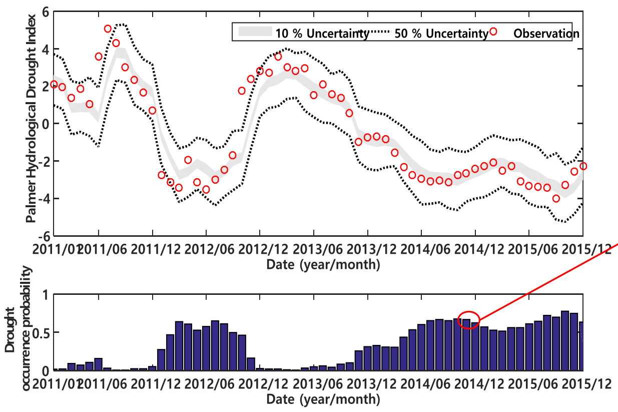




The relationship between the (n) month SPI and the (n+1) month ESI is established, and **the (n+1) month ESI estimated by the (n) month SPI information** is used as the value of the drought propagation node



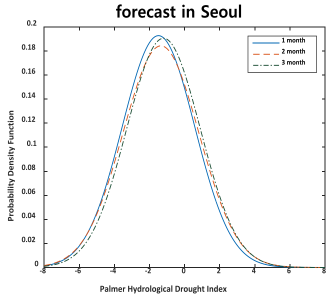
## 4.4 Drought Forecasting using Bayesian network

- **Hydrological Drought Prediction Result**
  - Example for drought forecasting result (using PHDI instead of ESI)




▲ Time series of 1 month hydrological drought forecast in Seoul

▼ 1~3 month hydrological drought forecast in Seoul




1~3 month drought forecasting results generated by **probability distribution model**

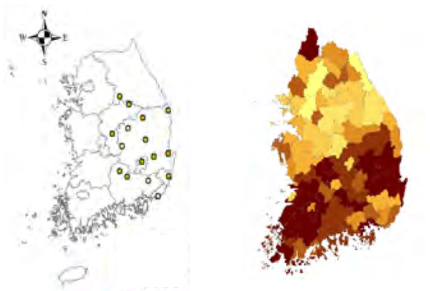
- When the probability of drought occurrence (P (PHDI <-2.0)) was calculated from the 1 month drought forecast probability distribution, the drought index was actually observed to be low during periods of high drought occurrence probability.

## 4.4 Drought Forecasting using Bayesian network

- **Hydrological Drought Outlook information based on Satellite Drought Index**
  - Drought outlook information presentation
    - Period of outlook : 1, 3, 6 month
    - Outlook index : Meteorological drought(SPI), Hydrological drought(WBDI)
    - Outlook information : Derive the drought outlook data comparing the current drought stage with the future drought stage.

| Criteria (Drought stage) | Outlook information |
|---|---|
| Present = Future | **Drought persist** |
| Present > Future | **Drought improve / Drought development likely** |
| Present < Future | **Drought removal likely / Drought termination** |

**Expected results**



<Drought outlook (Point)>    <Drought outlook (Mid Watershed)>

- The drought outlook provide information through expert decision-making integrating weather, climate forecasting and monitoring information

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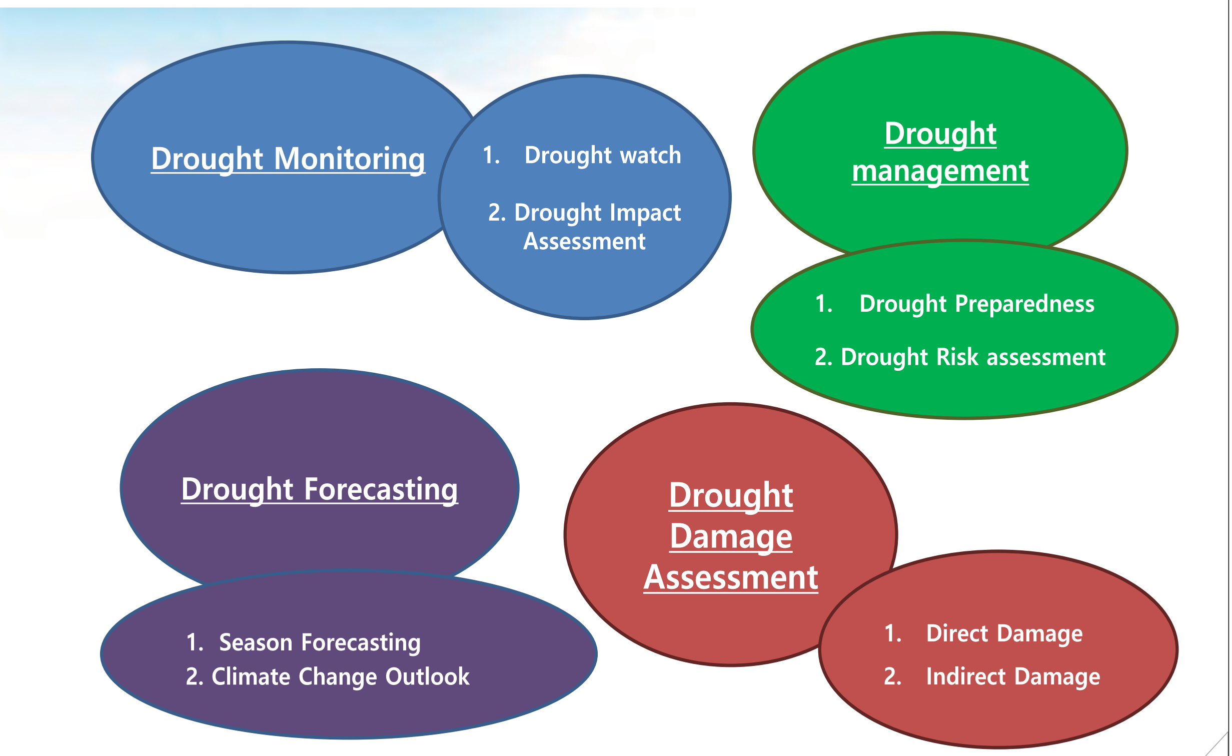
# 5. Drought Management and Preparedness

5.1 Drought Management Framework
5.2 Alternate Water Resources
5.3 From Crisis Management to Risk Management

## 5.1 Drought Management Framework

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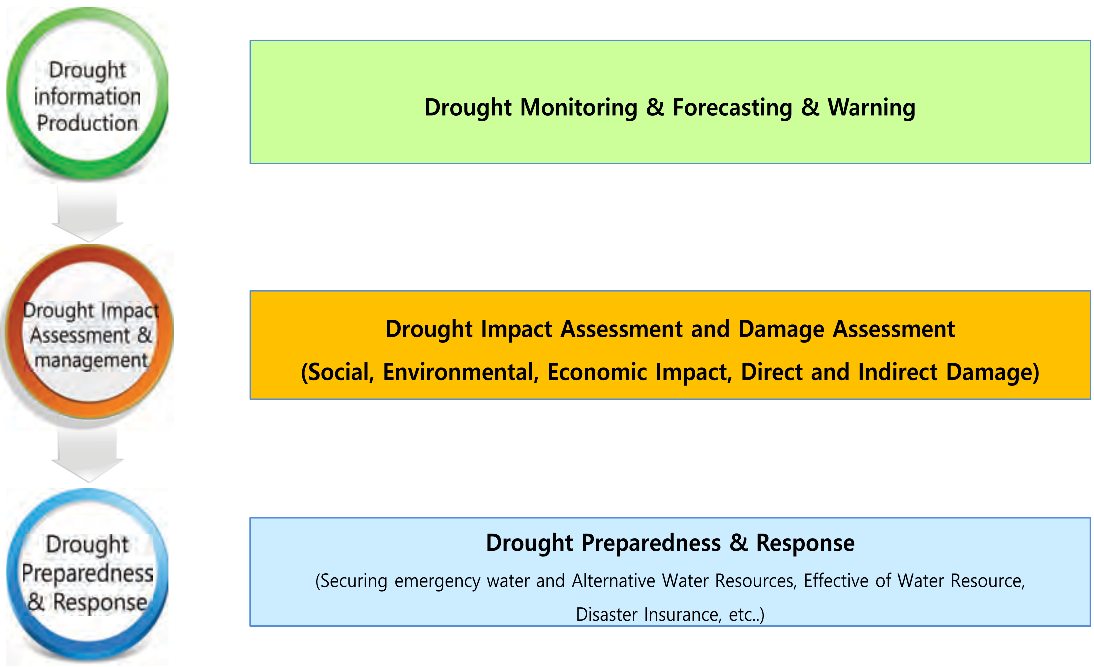
## 5.1 Drought Management Framework

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## 5.1 Drought Management Framework

- **US National Drought Policy Commission (NDPC)**

  - **Need better preparedness**
  - **Need better coordination**
  - **Need adequate climate information**
  - **Need to improved crop insurance**
  - **Need to streamlined emergency procedures**
  - **Need additional scientific research**
  - **Need a coordinated National Drought Policy**

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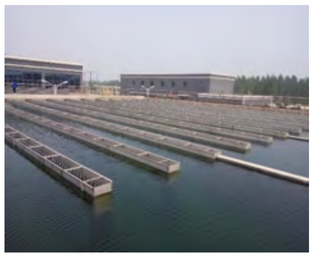
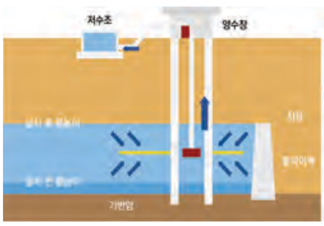
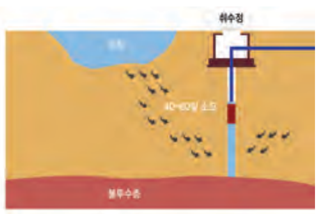
## 5.2 Alternate Water Resources

- Water resources newly secured by other artificial methods (rainwater, seawater desalination, groundwater artificial recharge, etc.) rather than securing traditional water resources through dam, river and groundwater, etc.

① Rainwater utilization
② Recycling of Wastewater
Reclamation and Reusing System, Wastewater, Hot waste Water
③ Seawater desalination
④ River bank filtration
⑤ Groundwater reservoir
⑥ Artificial recharge groundwater







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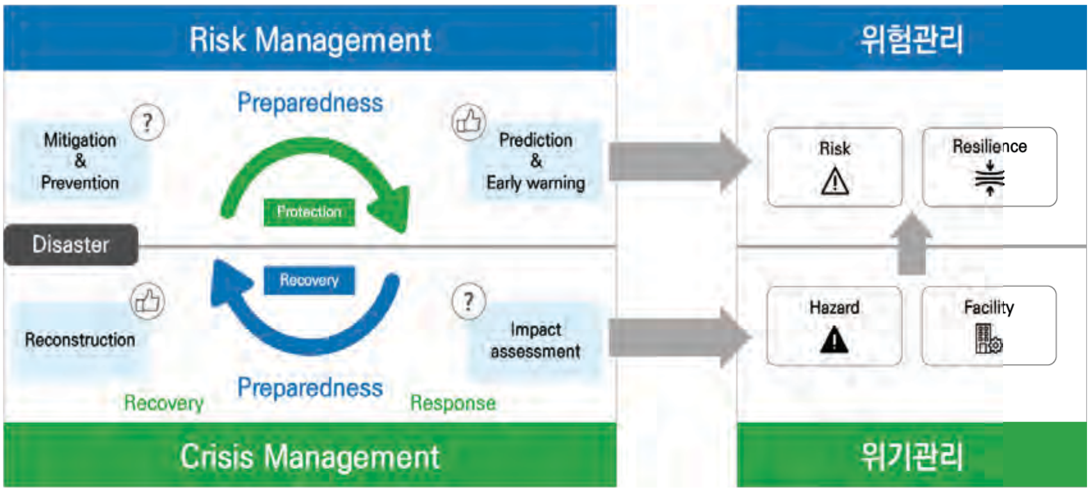
## 5.3 From Crisis Management to Risk Management

- It is necessary to switch from crisis management to risk management.
  - Natural disasters don't exist, but natural hazards do

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# 6. Paleo-Climate & Mega Drought

6.1 Definition of Mega Drought
6.2 Mega Drought Damage
6.3 What happen in Korea now

## 6.1 Definition of Mega Drought

- A prolonged drought ng two decades or longer. (Wikipedia) Past megadroughts have been associated with persistent multiyear La Niña conditions (cooler than normal water temperatures in the tropical eastern Pacific Ocean)
- Mega-drought is used to describe the length of a drought, and not its acute intensity.
- Scientifically, the term is used to describe decades-long droughts or multi-decadal droughts **(NOAA)**.
- Multiyear droughts of less than a decade, such as the Dust Bowl drought of the 1930s, are generally not described as mega-droughts even though of a long duration.


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## 6.1 Definition of Mega Drought

- **A World Suffering from Drought**


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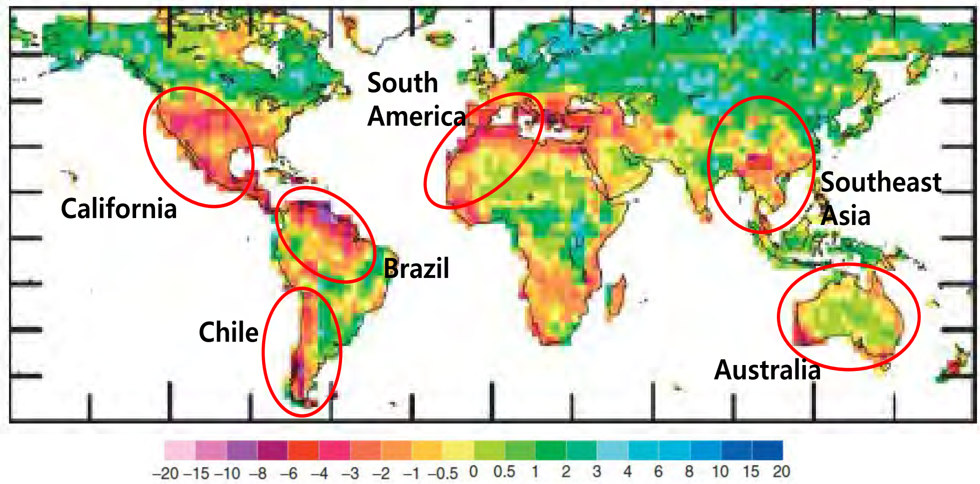
## 6.2 Mega Drought Damage

### ▪ Mega Drought Occurrence Condition of the World

- The above figure represents the **average drought severity** using SC-PDSI from **2000 to 2009**
- There are many areas around the world that are subject to Extreme drought that lasts more than five years.
- California, Chile and Brazil, West Africa, Southeast Asia, Australia, etc., are currently suffering from Extreme mega drought.

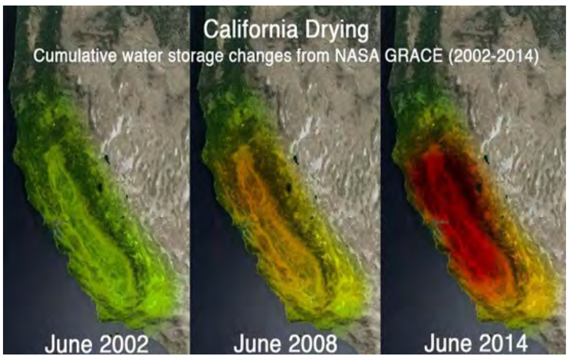
Source : Dai (2010)





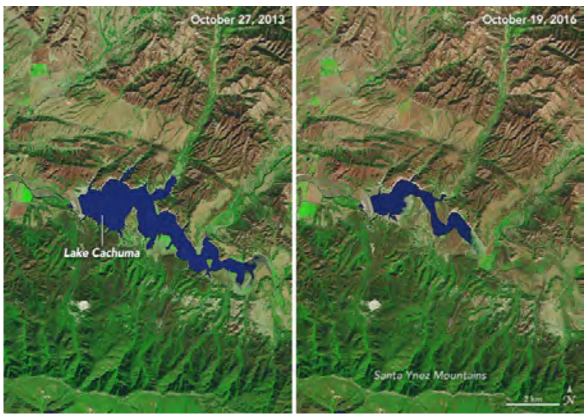

## 6.2 Mega Drought Damage

### ▪ Mega Drought in California




- **Drought condition continues from 2006 to present**
  - Decrease of 17,000 jobs
  - 25% decrease in crop area
  - 23 forest fire

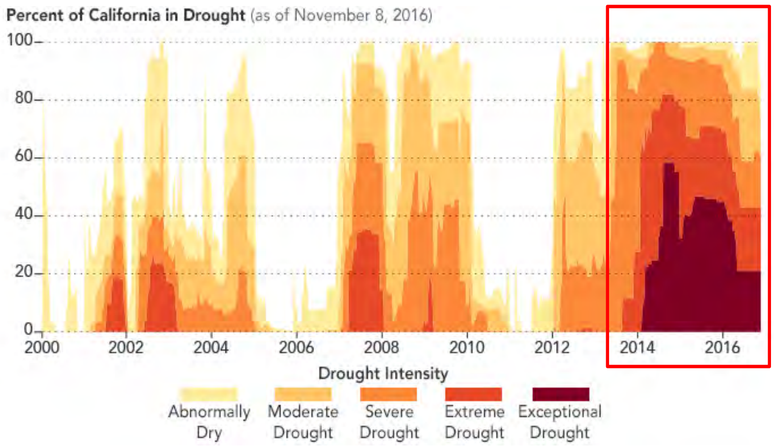
- **The cause of La Lina condition**
  - Changes of east surface of the sea of tropics pacific
  - Extreme drought damage for 5years

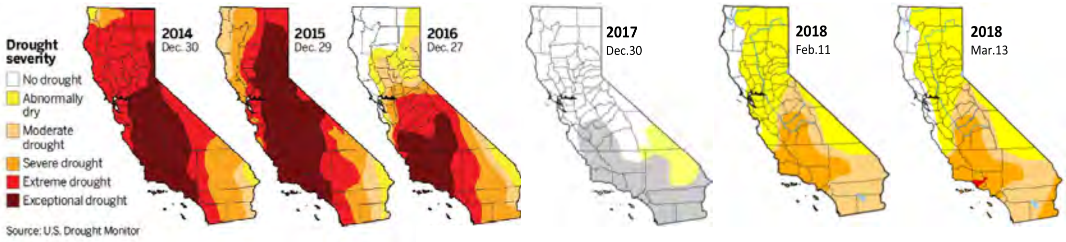



**Source: http://earthsky.org/**

# 6.2 Mega Drought Damage

▪ **Mega Drought in California**

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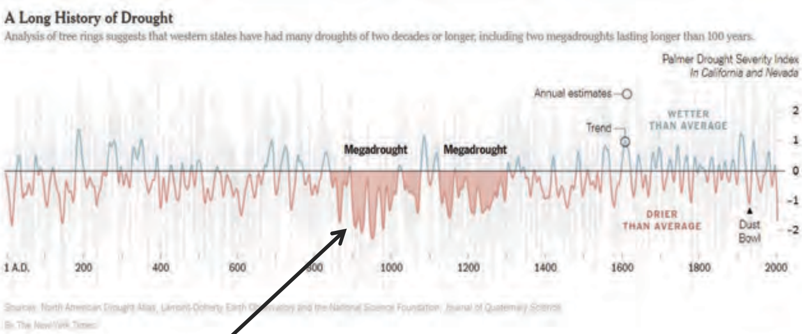
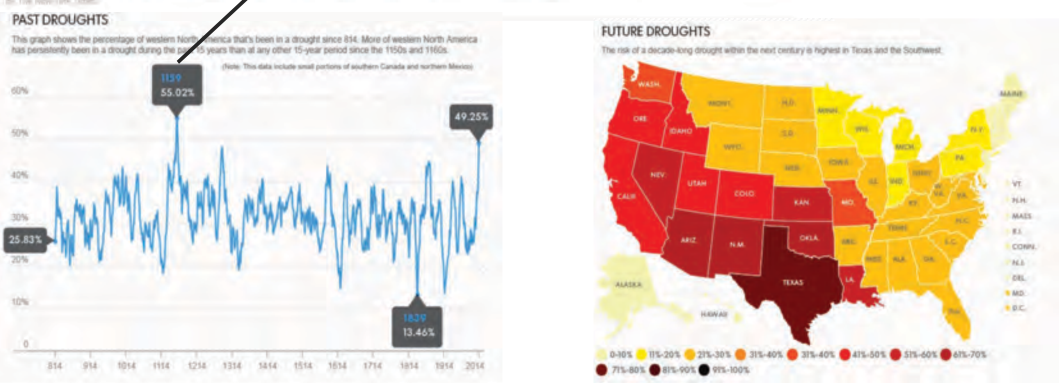
# 6.2 Mega Drought Damage

▪ **Multi year drought & mega drought in California**




**Multi Drought Year**

- 1917–21
- 1922–26
- 1928–37
- 1943–51
- 1959–62
- 1976–77
- 1987–92
- 2006–10
- 2012–17

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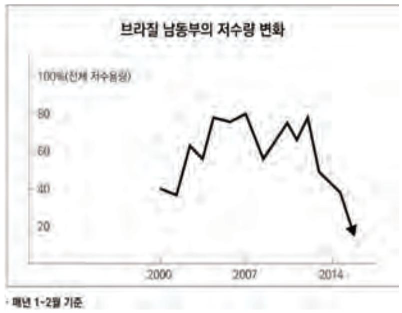
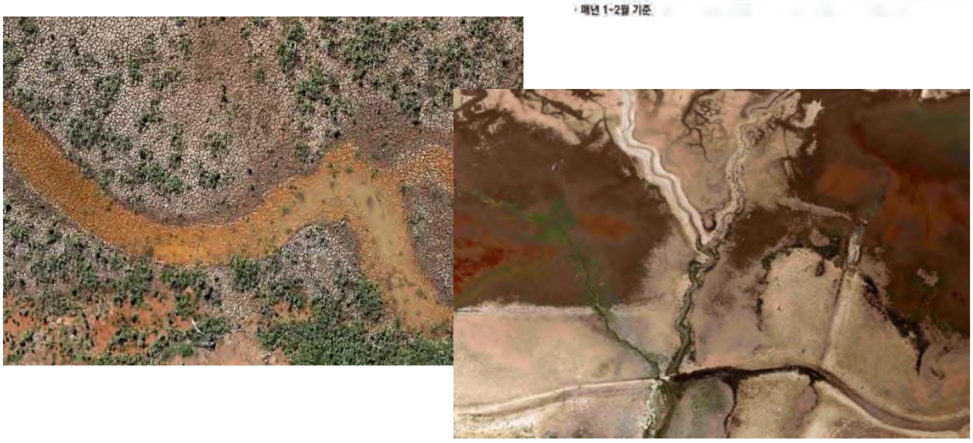
## 6.2 Mega Drought Damage

- **Mega Drought in Brazil**
  - **Extreme drought from 2014 to present**
    - The worst drought in 80years
  - **25% precipitation in a normal year in 2016**
    - 15% decrease of water supply, coffee production



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## 6.2 Mega Drought Damage

- **Mega Drought in Chile**

Report to the Nation

*The 2010-2015 mega-drought: A lesson for the future*

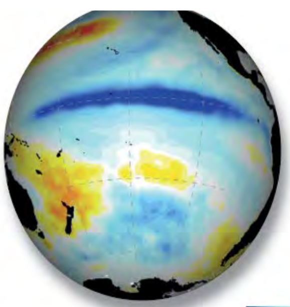
Center for Climate and Resilience Research (CR)2

November 2015

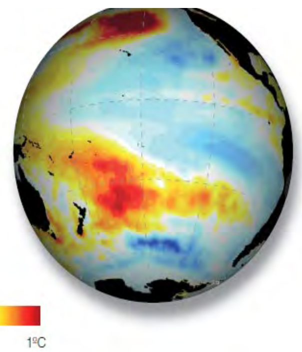
- Although droughts lasting one or two years have been relatively frequent historical phenomena in the climate of Central Chile, the last six years are longest and most spatially extensive dry spell since the early twentieth century

▣ Four multi-year events:
- 1945 ~ 1947
- 1988 ~ 1990
- ☆ 1967 ~ 1969
- ☆ 2010 ~ 2015

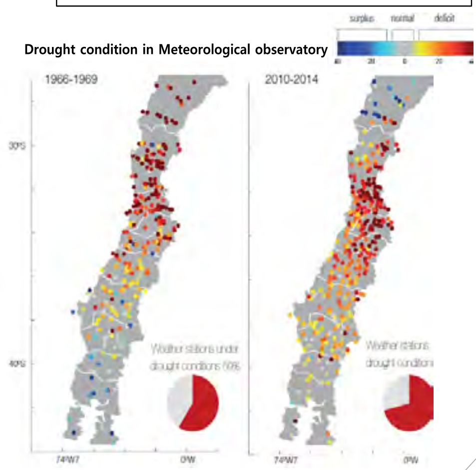
**Average temperature of sea surface during La Niña** (1974, 1975, 1985, 1988, 1998, 1999, 2000)



**Average temperature of sea surface during mega drought** (2010 ~ 2015)




**Drought condition in Meteorological observatory**

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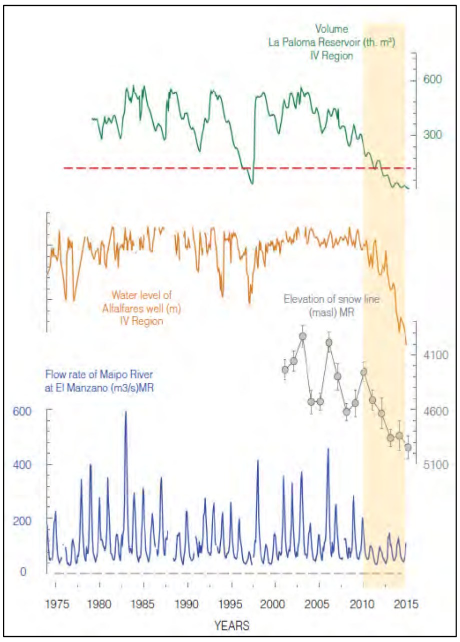
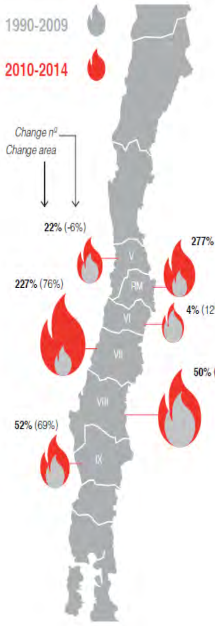
## 6.2 Mega Drought Damage

- **Impact from mega drought in chile (2010 ~ 2014)**

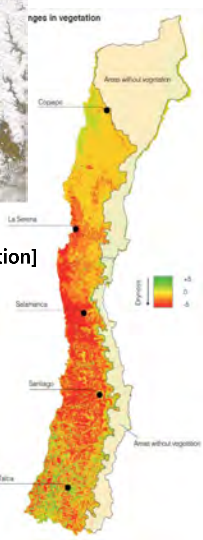
**[Water resource]**




**[Forest Fire]**




**[Coastal Resource]**



**[Vegetation]**

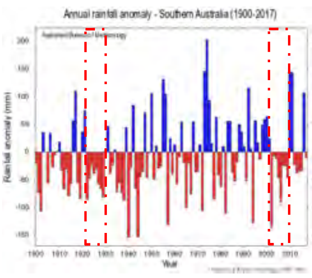


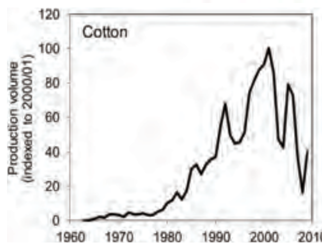
## 6.2 Mega Drought Damage

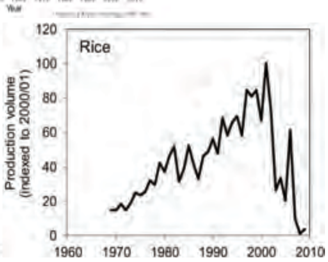
- **Australian Millennium Drought**
  - **The Millennium Drought in southeast Australia (2001~2009)**

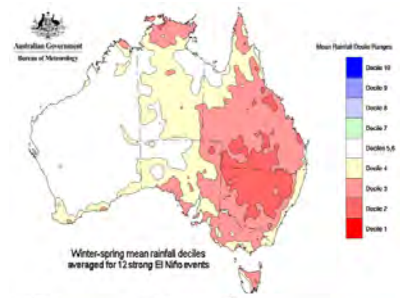
**The Millennium Drought in southeast Australia (2001–2009): Natural and human causes and implications for water resources, ecosystems, economy, and society**

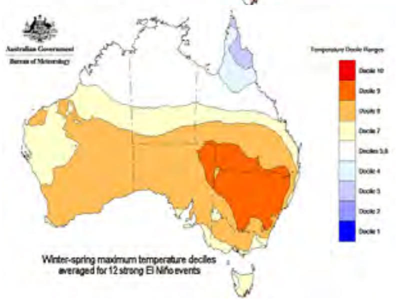
Albert I. J. M. van Dijk,[1,2] Hylke E. Beck,[3] Russell S. Crosbie,[4] Richard A. M. de Jeu,[3] Yi Y. Liu,[2,5] Geoff M. Podger,[2] Bertrand Timbal,[6] and Neil R. Viney[2]




- Big financial loss
- 16% fall in agricultural production value

## 6.2 Mega Drought Damage

- **African Drought**
  - Super El Nino in 2014
    - Impact on most African region
  - Decrease precipitation and extreme drought damage in north Africa
    - the worst drought in Ethiopia in 10 years
  - Similar condition in south africa
    - South Africa : 1/3 decrease of corn production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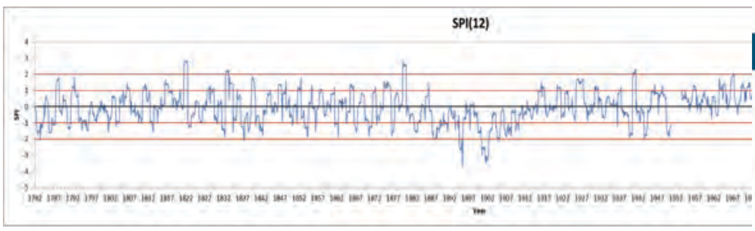
## 6.3 What happen in Korea now

- **Mega Drought Evidence?**

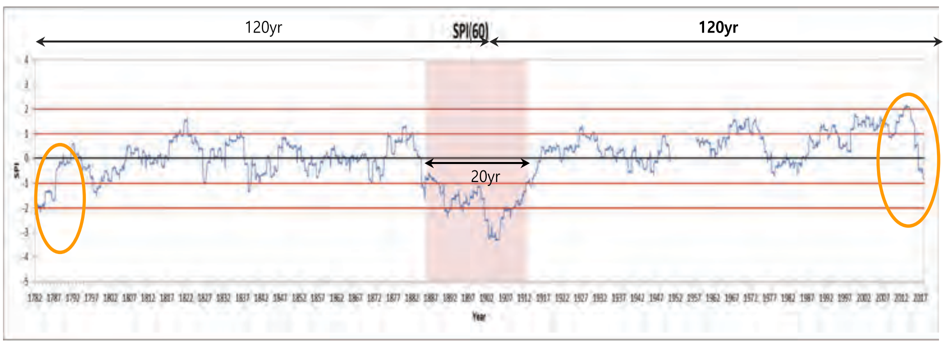




AGU100

Geophysical Research Letters

The unusual 2013–2015 drought in South Korea in the context of a multicentury precipitation record: Inferences from a nonstationary, multivariate, Bayesian copula model




| Year | Annual Precp. (mm) | Percent Normal (%) |
|---|---|---|
| 2014 | 808 | 60.7 |
| 2015 | 711 | 53.1 |
| 2016 | 995 | 74.4 |
| 2017 | 1100 | 82.3 |
| 1887~1907 | 806 | 63.4 |
| 1899~1907 | 702 | 51.3 |

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# Thank you very much

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# Water Environment Management Plan to Restore Nature

IWRM

# Water Environment Management Plan to Restore Nature

## Aims & Objectives

- The aims of the course are to:

  (1) Recognize the need for water environment management and present specific methods and strategies for water environment management plans to trainees;
  (2) Introduce specific strategies and methods for water environment management for natural recovery.

- The objectives are that trainees will understand:

  (1) Establishment of a proper water circulation system;
  (2) Securing clean water by applying integrated watershed management;
  (3) Ecosystem service by improving the aquatic ecosystem;
  (4) Creating a foundation for a safe water environment;
  (5) Creating economic and cultural values of the water environment;
  (6) Establish the foundation for water environment management.

## References


2nd Basic Plan for Water Environment Management (Ministry of Environment, 2017)


A Study on the Derivation of a Policy for Restoration of River Nature through a Deliberate Approach (KEI, 2019)


Management and utilization of water drainage channels to improve the water environment of small and medium-sized rivers (KEI, 2018)

## Contents

1. Introduction
2. Establishment of a proper water circulation system
3. Securing clean water by applying integrated water management
4. Ecosystem service by improving the aquatic ecosystem
5. Creating a foundation for a safe water environment
6. Creating economic and culture values of water environment
7. Establishing the foundation for water environment management
8. Conclusions

# 1. Introduction

## 1. Introduction

- **Water environment**

  - **Water**: constantly circulating around the Earth and interacting closely with the natural environment and living environment

  - **Water environment**: Earth, surface, and underground environments where water cycles are taking place, and living things that survive there.

  - **Management of the water environment**: essential requirement for human survival, prosperity, and sustainable development of society.

  - **Water environment policy**: various interest groups participate, resulting in high degree of value intervention, and conflicts between value standards that are at odds with each other such as stability and growth, development and conservation, efficiency and equity

  - It is necessary to establish a clear system of policy value in order to establish and promote water environment policies while coordinating conflicts and conflicts of interest.

## 1. Introduction

- **Keys of water environment management policy**

(1) Coexistence of nature and humans

- The master plan for environmental management includes "humans" and "including ecosystems (e.g., animals and plants and their habitat environment)."
- The approach to protection is not for the individual existence of humans and aquatic ecosystems, but for "coexistence of nature and humans together."
- It pursues the value of ecocentrism in the concept of sustainable growth of nature.

(2) Virtuous cycle of environment and economy

- According to economic growth, environmental pollution conflicts with environmental conser vation, and the water environment problem is evaluated as an essential problem to be solve d for sustainable economic development.

(3) Definition of environment

- Substantial definition: in terms of environmental conservation, the water environment policy has made improving water pollution and protecting the water ecosystem a top priority ma nagement goal.
- Distributive definition: everyone actively participates in water environment decisions, and the benefits and responsibilities of the water environment are distributed fairly to all members.

## 2. Establishment of a proper water circulation system

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## 2. Establishment of a proper water circulation system

### ▪ Background

- **Water** is one of the resources that are constantly being reused on Earth, and water, which is essential for the survival of life, is supplied through **water circulation** (e.g., precipitation, inf iltration, runoff, evaporation, transpiration).
- **The global climate change** phenomenon is a major threat to a healthy water circulation system.
  - Concerns coexist over the possibility of flood damage caused by torrential rain and the unstable water supply problem caused by heavy droughts.
  - Water quality and water ecosystems are gradually deteriorating due to overlapping hydrological changes caused by climate change and the increase in pollutants.
- Through the rapid **urbanization** and industrialization process, the **impermeable area increased sharply**.
  - The increase of the impermeable area reduces infiltration and baseflow, deepening the depletion of stream water during the dry season and **distorting the appropriate water circulation system**.
  - It is a major cause of deteriorating water quality by **increasing the inflow of non-point pollutants** due to the increase in surface runoff.

## 2. Establishment of a proper water circulation system

### ▪ Background

- The existing **water management system** is not very efficient in order to establish an appropriate water circulation system.
  - Currently, Korea's water quantity management system, which is divided into **residential wat er, industrial water,** and **agricultural water**, has maintained its past framework without effi ciently responding to changes in economic and industrial structure and changes in water de mand and usage patterns.
  - Not only does it not meet the increased needs of the people for the preservation of water quality and aquatic ecosystems, but the **efficient and balanced allocation of already sec ured water resources is also insufficient**.
  - The government has made efforts to manage **water quality, quantity, and water ecosyst ems** from an **integrated water management** by changing the water management paradi gm through many system improvements and collaboration.
- With the common goal of establishing an appropriate water circulation system, ministries sh ould (1) institutionalize the supply of environmental ecological flows considering the water e cosystem, (2) establish an integrated surface water-ground water management system, (3) in crease water storage and circulation across the country, and (4) strengthen water demand m anagement.

## 2. Establishment of a proper water circulation system

### ▪ Institutionalization to secure environmental and ecological flow

- **Environmental and ecological flow**: flow rates to maintain the health of the aquatic ecosy stem excluding human water use and to continuously secure the services provided by the a quatic ecosystem
- **Instream flow** ($Q_{IN}$)
- Minimum flow rate required by the river ecosystem as the drought flow in the river
- Maximum value between drought flow ($Q_{355}$) and fish flow ($Q_F$) depending on seasonal variation at a particular reach of river

$$Q_{IN} = \max(Q_F, Q_{355})$$

- **Current flow management status**

- While the current water resource management focuses on **off-stream use** in public waters s uch as **(1) residential water, (2) industrial water**, and **(3) agricultural water**, there is a lack of interest in **in-stream use** related to **(1) aquatic ecology, (2) waterfront, (3) fishing,** and **(4) landscape**.
- The instream flows are calculated around the national river, and it is more difficult to secure the flow rate of ecologically important local rivers or small rivers where endangered species live.
- Human water uses (e.g., residential water, agricultural water, and power generation water), a re prioritized, and consideration for the preservation of water quality and water ecosystem i s greatly insufficient.

## 2. Establishment of a proper water circulation system

### ▪ Institutionalization to secure environmental and ecological flow

- **Limitations of how to respond to drought**

- In the event of a drought, consideration of the ecosystem is also excluded from water resource management.
- In order to stock up on water in the event of a drought, the supply of instream flow will be reduced by 100% at the "caution" stage, the second of the total four stages of drought (e.g., attention, caution, warning, and serious stages).

- **Institutionalization for calculating and securing environmental and ecological flow**

- The environmental and ecological flow is legislated to manage the flow rate in consideration of ecological functions.
- By institutionalizing measures to calculate and secure environmental and ecological flow for national rivers or ecologically important tributary streams, water resources are allocated to the ecosystem and the function of the river ecosystem is maintained.
- The environmental and ecological flow is also reflected in the operation plan of the available water in dams, weirs, and reservoirs, so that the water use of the ecosystem is considered t he same as that of humans such as agricultural and living water.

## 2. Establishment of a proper water circulation system

- **Institutionalization to secure environmental and ecological flow**

  - **Development and introduction of environmental drought index**

  - The environmental drought index, an indicator of drought vulnerability by size and basin cha racteristics of rivers and lakes, is developed and reflected in the calculation of environmental and ecological flow to secure the flow rate necessary to maintain the function of the river ec osystem.
  - **Short-term measures** such as strengthening monitoring of water quality, water ecosystem, and water quantity, strengthening water quality standards for basin discharge water, and in specting emission sources, as well as **mid- to long-term measures** including re-use of gr oundwater and sewage discharge water.

## 2. Establishment of a proper water circulation system

- **Integrated management of surface water and ground water**

  - **Importance of baseflow**

  - **Baseflow**: during the water circulation process, rainwater infiltrating into the ground through the water permeable surface flows back into the river in the form of groundwater.
  - During the dry season, the baseflow accounts for a significant portion of the river flow, and the water quality has **a great influence on not only the water quantity of public waters but also the water quality.**
  - In the event of the worst drought, **systematic management of baseflow** is necessary to maintain the environmental and ecological sustainability of the river.

  - **Integrated management of surface water and ground water**

  - **Coefficient Flow Fluctuation (CFF)**: ratio of annual maximum flow rate and annual minimum flow rate
  - When the river level difference is severe by season due to the large CFF, it is important to efficiently manage the groundwater and groundwater by the integrated management.
  - It is necessary to establish an integrated groundwater and groundwater management plan by establishing point and non-point pollution source management measures suitable.
  - Due to the nature of groundwater, the baseflow, which accounts for a large portion of the river flow, takes a lot of time to recover once contaminated, so thorough groundwater m anagement is required.

## 2. Establishment of a proper water circulation system

- **Improving the water storage function of the soil**

  - **Improving the water storage function of the soil**

  - In order to enhance the water storage function, the application of **Low Impact Deve lopment (LID)** and **Green Stormwater Infrastructure (GSI)** technologies will be expa nded to urban areas covered with impermeable layers such as asphalt.

**(1)LID**: method of simultaneously improving water circulation and reducing pollution by r educing the surface runoff of rainwater and increasing the soil infiltration of rainwater by reducing the impermeable surface

**(2) GSI**: facilities that reduce rainwater runoff by increasing infiltration, evaporation, and reuse of water through the expansion of green and ecological spaces in urban areas

  - **Implementation of sewage charge**

  - The rainwater charge system is introduced to reduce impermeable areas by collecting costs for rainwater runoff, as well as charge for projects that cause additional costs such as expa nsion of sewage pipes.

## 2. Establishment of a proper water circulation system

- **Improving the water storage function of the soil**

  - **Expanding the permeable area**

  - Since land development projects due to urbanization and industrialization lead to an inc rease in the impermeable surface, the environmental impact assessment at the project pl anning stage is strengthened to secure the permeable surface.
  - In order to increase the water storage function, the installation of stormwater storage tanks will be expanded and green spaces will be created.
  - LID technique is applied to the new city construction project.

  - **Preparation of water circulation standards and guidelines**

  - Guidelines for designing LID in new towns
  - LID maintenance manual
  - The desirable ratio of the area of water permeation by city size
  - Standards for creating a green space for water circulation
  - Guidelines for storage functions and installation of water storage facilities

## 2. Establishment of a proper water circulation system

- **Securing alternative water resources through water reuse**

  - **Water reuse**

    - The **discharged water treated in the sewage treatment plant** can be used as a very stable alternative water resource in terms of water quality and quantity.
    - Securing sewage treatment water as an alternative water resource has the effect of reducing the cost of society as a whole by reducing water use and demand for dam construction.

  - **Rainwater reuse**

    - Rainwater storage facilities are expanded and installed in cities, and rainwater storage and utilization systems are applied to spaces or facilities with a large catchment area such as public institutions, public parking lots, and schools.
    - It is used as a means to protect the water ecosystem and create a water-friendly space during dry season by expanding rainwater management facilities.

## 2. Establishment of a proper water circulation system

- **Water demand management**

  - **Introduction of incentives to water demand management**

    - The introduction of the **Up-down System**, which adjusts the rate of water use charges, will be considered.
    - **Water Footprints** (total amount of water required for the production of goods and services) are calculated to support products or services with low water footprints as eco-friendly pro ducts under the Water Quality Act.

- **Strengthen collaboration with ministries**

  - **Diversified water management system**

    - It integrates and manages groundwater water quality and baseflow, including water circul ation and non-point pollutant management applying water and water supply linkage mea sures and LID technique.

  - **Integrated water management**

    - In order to use a sustainable water environment, water management and service efficiency should be maximized by considering quantity, water quality, ecology, and regional develo pment in an integrated manner.

# 3. Securing clean water by applying integrated water management

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## 3. Securing clean water by applying integrated watershed management

▪ **Background**

- River water quality has improved dramatically with the construction of river environmental facilities and sewage treatment plants.
- In many rivers, non-decomposable organic materials are still on the rise, and the water quality of some water sources is below grade I.
- Livestock management and agricultural non-point pollution management are still insufficient.
- Due to the improvement of living standards and awareness of the water environment, the demand for clean water and the national demand to enjoy the benefits are increasing

## 3. Securing clean water by applying integrated watershed management

- **Integrated Water Management (IWM)**
  - **IWM**: management that comprehensively considers all human activities that affect or are affected by the water environment within a limited range of watersheds, stakeholders in volved in the activities, and the environment affected by the actions
  - For IWM, **feasible and sustainable integration targets and directions** are determined.
  - IWM will be promoted in consideration of the **link between land use and water envir onment** (water quantity and water quality, and tributaries and main streams in the wate rshed).
- **Achieving grade 1 of water quality in major water sources and establishing the watershed management plan**
  - The water quality goals of the main stream, tributary, and stream should be determined differently depending on the water environment conditions, such as the purpose of water use, the status of the watershed, and the characteristics of the natural environment.
  - A large watershed plan and a key investment plan reflecting the characteristics of the watershed are established to devise a means of achieving the target water quality.

## 3. Securing clean water by applying integrated watershed management

- **Achieving grade 1 of water quality in major water sources and establishing the watershed management plan**
  - The plan for small and medium-sized watersheds will be selectively established for practical water quality improvement in the future to improve the system so that water quality impro vement capabilities can be concentrated in necessary areas.
  - **Watershed governance** must be activated in order to sufficiently reflect **water problems** an d **current water disputes** occurring in the watershed when establishing and implementing a watershed plan.
- **Introduction of the Total Maximum Daily Loads (TMDL) to improve water quality of water sources**
  - TMDL should be an important policy implementation means to **achieve the target water quality of the water environment management**.
  - **The target water quality evaluation method** of the pollution total amount system introduc es evaluation methods by **Load Duration Curves (LDC)** in consideration of the good water q uality during the low and dry season.

## 3. Securing clean water by applying integrated watershed management

- **Introduction of the Total Maximum Daily Loads (TMDL) to improve water quality of water sources**
  - TMDL should be an important policy implementation means to **achieve the target water quality of the water environment management**.
  - **The target water quality evaluation method** of the pollution total amount system introduces evaluation methods by **Load Duration Curves (LDC)** in consideration of the good water quali ty during the low and dry season.
  - The target water quality of TMDL is gradually raised in consideration of local conditions to a level that can **achieve the water quality goals**.
  - **By matching the operating point of the national measurement network and the operating point of TMDL**, the target water quality according to the IWM plan and the target water qual ity by TMDL are organically linked.
  - **TMDL in tributary** is introduced for pollutants that need to be improved urgently by tributary.
  - If there is an effect of **improving water quality in connection with the unstructural manage ment measures of non-point pollutants and TMDL**, a method and analysis technique for calc ulating the **pollution load reduction should be developed and utilized**.

## 3. Securing clean water by applying integrated watershed management

- **Strengthen water quality improvement in tributaries and streams**
  - In order to improve rivers with severe water pollution in a short period of time, the governm ent will expand **integrated and intensive pollution river improvement projects** that intensive ly support possible means such as strengthening **sewage treatment, reducing non- point p ollution,** and **restoring ecological rivers**.
- **Management of pollutants in the agricultural and livestock industries**
  - In order to solve the problem of over-injection of nutrients in farmland, a **nutrient management system** should be implemented for each local government.
  - In order to treat livestock manure, which is a major cause of non-point pollution, the **manag ement of livestock manure discharged water** by livestock farms will be strengthened step b y step

## 3. Securing clean water by applying integrated watershed management

### ▪ Setting and managing water quality targets for each reservoir

- The target water quality for each reservoir (e.g., **multipurpose dam, agricultural reservoir, power generation dam, estuary barrier**) is determined in consideration of environmental changes.
- Considering the purpose of each reservoir, the target water quality is set to achieve a good **(Ib) grade or higher for water source reservoirs**, a little good **(II) grade or higher for re sident-friendly reservoirs**, and a normal **(III) grade for agricultural reservoirs**.
- In order to improve the water quality of the lake, local governments operate **separated sew er system for sewage and rainwater** and improve the water quality of discharged water as an **advanced wastewater treatment plant**.

### ▪ Collaboration of relevant ministries for estuary management

- In order to manage the water quality and aquatic ecosystem of the estuary, a **cooperative system of related ministries** should be established to investigate the water quality and a quatic ecosystem environment, establish improvement measures, and restore ecology.

## 3. Securing clean water by applying integrated watershed management

### ▪ Collaboration of relevant ministries for estuary management

- For estuaries, **comprehensive measures for estuaries ecological restoration**, including water quality improvement, habitat protection, saltwater damage prevention, and restoration of est uaries wetlands and marshlands, will be established.
- Since the **water quality of artificial freshwater reservoir created at estuaries exceeds the IV grade**, which is an agricultural water standard, improvement measures should be establi shed in cooperation with related ministries in water quality management.

# 4. Ecosystem service by improving the aquatic ecosystem

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## 4. Ecosystem service by improving the aquatic ecosystem

- **Background**

  - **Changes in the habitat environment of aquatic organisms** are expected, such as a decrease in dissolved oxygen (DO) in rivers and lakes due to an increase in water temperature **due to climate change**.
  - A biodiversity conservation strategy is needed to cope with climate change.

  - It is a **damage to the continuity of the aquatic ecosystem** due to hydraulic structures (e.g., dam, weir, reservoir)
  - Problems such as disconnection of ecological passages and deterioration of water quality are occurring in hydraulic structures where **fishways** are not installed.

  - The goal of **restoring the aquatic ecosystem** is determined, and projects are promoted to ensure the survival of the aquatic ecosystem, which has been marginalized for human water use in **conservation and restoration of ecological rivers**.
  - In response to climate change and changes in river environment, biodiversity is preserved and ecosystem connectivity is restored to create a water environment where various species can interact with surrounding ecosystems and inhabit abundantly.

## 4. Ecosystem service by improving the aquatic ecosystem

- **Establishing a stream health assessment for aquatic ecosystems and achieving goals for good grades**
  - In order to improve the health of the aquatic ecosystem, a consistent and systematic evalu ation criteria system is established, and the health of the aquatic ecosystem is divided into five stages (A to E).
  - The goal is to maintain and restore the **health of the river aquatic ecosystem above the good (B) grade.**
  - It is mandatory to evaluate whether or not the ecosystem health goal is achieved, and appropriate **river restoration** is performed for the damaged river environment.
- **Identification of the cause of the river whose health has been damaged and restoration of the river**
  - In order to evaluate whether the target standards for aquatic ecosystem health are achieved, a survey and evaluation technique that considers the characteristics of each watershed by cl assifying rivers, reservoirs, main streams, and tributaries is applied.

## 4. Ecosystem service by improving the aquatic ecosystem

- **Identification of the cause of the river whose health has been damaged and restoration of the river**
  - As a result of the stream health assessment, a **stream diagnosis system** is prepared for rivers with low grades, and **major causes of damage to the health of the aquatic ecosystem** (e.g., water pollution, lack of environmental ecological flow, change in water temperature, and lack of longitudinal and transverse connectivity of streams).
  - The stream diagnosis system establishes management strategies for water pollutants and ecological flow management, water temperature management, and stream restoration.
  - In order to **restore the health of the aquatic ecosystem**, it is mandatory to implement an **ecological stream restoration project** for damaged rivers.
  - In order to establish the **management direction of aquatic ecosystem health**, rivers with relatively well-maintained primitivity of aquatic ecosystems are designated and used as **re ference streams**.

## 4. Ecosystem service by improving the aquatic ecosystem

- **Improving the longitudinal and transverse connectivity of aquatic ecosystems**

  - The health of the aquatic ecosystem should be **continuously connected to the longitudinal stream** through the installation of **fishways** so that migratory fish can move from the down stream to the upstream of the river.
  - The **fishway design guideline** that comprehensively reflects the **connectivity of the aquatic ecosystem**, the characteristics of fish, and the maintenance of rivers will be prepared.
  - **Levees were built** to defend against floods, and floodplains and wetlands disappeared, resulting in **loss of the transverse connection of rivers**.
  - The ecological transverse connection between the main streams and tributaries will be strengthened by **promoting abandoned channel restoration**.

## 4. Ecosystem service by improving the aquatic ecosystem

- **Management of aquatic ecosystems vulnerable to climate change and conservation of biodiversity**

  - The impact of climate change on water quality and aquatic ecosystems should be identified, and **climate change water environment indicators** (e.g., changes in hydrological data, water quality, and aquatic ecosystem environment) should be developed.
  - Designate and manage ecosystems vulnerable to floods and droughts, and establish measures to **protect and restore habitats in case of floods or extreme droughts**.

- **Measuring the value of aquatic ecosystem services and utilizing policies**

  - **Ecosystem services**: the benefits that humans get from the ecosystem

(1)recognize the value provided by the ecosystem to humans as the **concept of ecosystem s ervice.**
(2) preserve the ecosystem for human happiness and sustainable use of the ecosystem.
(3) calculate the contribution to human life.

## 4. Ecosystem service by improving the aquatic ecosystem

- **Measuring the value of aquatic ecosystem services and utilizing policies**

  - The aquatic ecosystem provides various services to humans such as **energy production, water purification, habitat provision, recreation, and landscape**, and enhances human welfare.
  - The preservation and sustainable use of the ecosystem, biodiversity, and the **economic value of ecosystem services** can contribute to converting the value of ecosystem protection into **actual cash flows** and **changes in human behavior.**
  - It **quantitatively evaluates the value of various goods and services** provided by humans from the aquatic ecosystem and returns them to policies to **raise awareness of the impo rtance of the aquatic ecosystem of the people and policymakers**.

## 5. Creating a foundation for a safe water environment

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## 5. Creating a foundation for a safe water environment

- **Background**

  - In the Water Quality Act, 28 out of a total of 53 types of **water pollutants** are designated as **specific water hazards** and **strictly managed**.
  - As living standards improve and industrial technology develops, the generation and emission of various pollutants are increasing, and public **interest in pathogenic microorganisms, hor mones, and radioactive substances** is increasing.
  - In a situation where awareness of the importance of the aquatic ecosystem is increasing, the **cause of water quality accidents** such as **fish death** should be identified and countermeas ures should be established.
  - Due to **climate change**, water temperature and insolation increase, and the characteristics of watersheds change, so the **possibility of green algae occurrence** exists, and **green algae m anagement** should be strengthened.

## 5. Creating a foundation for a safe water environment

- **Introducing hazardous monitoring substances and strengthening the designation and management of water pollutants**

  - By systematically classifying the **management scope of water pollutants in rivers** into **(1) water pollutants, (2) specific water hazardous substances,** and **(3) monitoring substances**, measures will be taken to increase the sustainability and predictability of the **hazardous sub stances management system** felt by the public and to ensure **reasonable regulations**.
  - If unreasonably regulated **compounds of water pollutants** (e.g., phenols, bromine compounds, and chlorine compounds), **separation regulations** should be considered.
  - Considering the changes in the level of pollutant discharge in wastewater discharge facilities and public sewage treatment facilities, the appropriateness of the existing **water pollutant discharge standards is regularly reviewed (e.g., every 5 years)**.

- **Reinforcement of organic material management centered on Total Organic Carbon (TOC)**

  - The **introduction of TOC standards** can eliminate the problem of organic material managem ent in rivers by managing total organic materials including non-decomposable organic mater ials, **away from BOD and COD-centered organic material management** in the past.

## 5. Creating a foundation for a safe water environment

- **Management of wastewater discharge facilities considering the characteristics of the industry**
  - The types of hazardous substances and the amount of pollutant generated load reflect the characteristics of each industry and discharge various water pollutants.
  - **Wastewater discharge facility management system** by industry should be introduced.
  - In the **integrated environmental management system**, the **maximum emission standard f or hazardous substances** is set in accordance with the **Best Available Techniques (BAT)** thr ough discussions with the industry, and the license discharge standard for each workplace is determined during the licensee's review.
- **Consignment companies are selected and operating standards are prepared in consideratio n of the characteristics of operating institutions such as companies or corporate councils for public wastewater treatment facilities.**
- **In addition to the toxicity management of emission facilities, the ecological risk of public streams around the industrial complex will be evaluated and graded, and the scope of ec otoxicity management will be expanded to public streams by introducing an ecotoxicity m anagement system.**

## 5. Creating a foundation for a safe water environment

- **Establishment of the foundation for self-management of water pollution at workplaces**
  - The obligation to self-measure according to the priorities of each workplace is redefined to establish a reasonable foundation for industrial wastewater management policy by grasping the emission status of the workplace and compliance with related regulations.
  - A virtuous cycle of facility improvement and pollutant reduction is established by reasonably **adjusting the amount imposed according to the pollutant discharge responsibility** and **r educing the amount of facility investment in pollution prevention**.
- **Strengthen the ability to respond to water pollution accidents**
  - The **intensive water quality measurement center** strengthens monitoring of water pollution accidents in areas vulnerable to water pollution accidents.
  - It will also organize and operate the **Crime Scene Investigation (CSI) to analyze the causes of fish death**, such as water pollution accidents and lack of dissolved oxygen, and to prepare maintenance measures and measures to prevent recurrence.
  - **Buffer storage facilities** will be installed in areas where water pollution accidents are expected or in water supply areas.

## 5. Creating a foundation for a safe water environment

- **Strengthen the ability to respond to water pollution accidents**
  - The **nationwide water quality automatic measurement network** is installed and operated to monitor water pollution, such as rapid response to water pollution accidents and monitoring of water quality, but efficient operation is required as it **simultaneously monitors and mana ges water quality**.
  - **Water pollution warning standards** are improved and water quality observation stations for mainstream and tributaries are expanded so that related agencies can respond quickly.
- **Strengthen green algae management**
  - For proactive **green algae management**, a plan to manage watershed pollutants that **block nutrients (e.g., nitrogen, phosphorus) flowing into the stream** is promoted.
  - **Water pollution warning standards** are improved and water quality observation stations for mainstream and tributaries are expanded so that related agencies can respond quickly.
  - **Retention basin** is installed downstream of the tributary to reprocess sewage and wastewater, and to **reduce non-point pollution sources** in the agricultural and livestock industries.

## 5. Creating a foundation for a safe water environment

- **Strengthen green algae management**
  - A **water-friendly green algae warning system** is operated to ensure the safety of water-friendly activities from the occurrence of green algae.
  - The **target water quality of streams or basins** used as water sources is set and managed.
- **Climate change vulnerable facilities management**
  - As subsidiary facilities such as pipelines, pump stations, and sludge treatment are aging due to poor maintenance, it is required to **prepare a proactive response system for environme ntal basic facility accidents** considering the **impact of climate change**.
  - In preparation for climate change, **vulnerability assessment maps** are prepared by cond ucting vulnerability assessments due to disasters such as floods and droughts, and a **clim ate change response management manual for each facility**.

# 6. Creating economic and culture values of water environment

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## 6. Creating economic and cultural values of the water environment

- **Background**

  - While the world's population doubled in the 20th century, water consumption increased 6 times, but an **increase in water demand has rapidly expanded** the global water industry market.
  - It is necessary to **manage the water environment** so that it can increase the value of water by expanding the existing perspective on drinking water or water use and become water that you see, touch, and feel.
  - Creating the **cultural value of water** through leisure use, ecotourism, experience, and edu cation in waterfront spaces contributes to the realization of national **water welfare** and im proves the **value of the region.**
  - In the process of **maximizing the cultural value of water**, consumption and investment can be promoted and the **effect of revitalizing the local economy** can be expected.

## 6. Creating economic and cultural values of the water environment

- **Create a water industry by specializing in water environment management**
  - In order to improve the **technology of water companies** and enter overseas markets, it is necessary to foster global water companies while promoting research and development and commercialization of high-end technologies.
  - It is necessary to establish an information and communication technology (ICT)-based **water industry R&D infrastructure** and **water industry cluster** to enable advanced convergence and complex R&D considering future technology demands such as smart water supply and intelligent pipe networks are possible.
  - For the continuous growth of the water industry, it **fosters experts in the water industry** linked to industry, academia, and research.
  - The main field of the water industry will shift from improving water treatment methods to **developing equipment and facilities in the water industry**.
  - It is necessary to focus on **investing in R&D in the water industry** to foster the water industry.
  - It continues to promote **exchanges with foreign governments** to foster the water industry.

## 6. Creating economic and cultural values of the water environment

- **Introduction of the asset management system for environmental facilities**
  - As the water environment infrastructure has been rapidly installed and operated in the past, **problems of aging and deteriorating functions of existing facilities** are emerging, so an **environmental facility asset management system** should be introduced in preparation for the time when facilities exceed their useful life.
  - Based on **asset management** for the current environmental facilities, a service-level goal is set, and priority is determined according to risk to establish operational management and **optimization measures for facility investment**.
- **Ensuring safety and improving comfort during waterfront activities**
  - A system that can safely manage water used for waterfront activities to ensure water quality and secure stability in  water will be prepared and the existing system will be reorganized.
  - A **database** is established by investigating information related to waterfront activities, and a **water quality information system** is established in which water quality information for  wat erfront activities is disclosed.

## 6. Creating economic and cultural values of the water environment

- **Create a water culture experience space**
  - It will **create an eco-city river** that combines humanities, arts, and ecology as a local landmark and push for a pilot project that provides programs to provide ecotourism to waterside **ecological belts** and **waterfront cities**.
  - Develop and distribute **water culture programs** that can inherit and create local water culture, and operate hands-on programs.
  - **Educational programs** are promoted to **reduce water consumption** and recognize the **ecological value of water**.
  - It improves **access to urban rivers and waterfront spaces** so that the elderly can easily access rivers and enjoy leisure in the aging era, and improves conditions so that the socially disadvantaged, such as the disabled, can access the waterfront spaces of rivers.

## 7. Establishing the foundation for water environment management

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## 7. Establishing the foundation for water environment management

▪ **Master plan for water environment**

- Objective

• A society where all members of society are happy with clean water everywhere in the country

- Strategy

(1) Establishment of a proper water circulation system
(2) Securing clean water through watershed integrated water management
(3) Improvement of ecosystem services through restoration of aquatic ecosystems
(4) Creating a foundation for a safe water environment
(5) Creating economic and cultural values of the water environment

- Activation strategy

(1) Revitalization of Water Environment Governance
(2) Advancement of science and technology
(3) Efficiency of financial management

## 7. Establishing the foundation for water environment management

▪ **Revitalization of Water Environment Governance**

- In order to resolve the inconsistency between the basin scope and administrative jurisdiction of rivers, it is necessary to improve and supplement the **current watershed management co mmittee for each watershed**, and establish a **watershed governance system** for upstream a nd downstream areas.

- In order for the **watershed management committee** to become the **center of governance in the upstream and downstream watersheds**, roles and organizations of the watershed mana gement committee need to be improved.

- Focusing on the **regional environment center**, specific action measures such as **managing non-point pollutants and TMDL** that require the participation of local residents will be p repared.

- Establish **e-governance** based on ICT.

- Reinforce the **pollutant burden principle** and **user burden principle**, and establish an efficient imposition system for environmental services.

## 7. Establishing the foundation for water environment management

- **Revitalization of Water Environment Governance**

  - Improve regional equity in water environment services to strengthen water environment c onflict mediation and **expand stakeholders' participation in decision-making** to resolve **water conflict and water dispute** between regions.
  - **Water Management Act** is enacted and the legal and institutional system of water governa nce is established as a legal basis for clarifying and coordinating the responsibilities and rol es of each ministry and institution in charge of water-related policies.
  - Promote **international cooperation projects** on environmental concerns such as ecological stream restoration, environmental technology and industrial exchange, and rural environme ntal protection.

## 7. Establishing the foundation for water environment management

- **Advancement of science and technology**

  - As a representative factor for evaluating whether or not the target standard is achieved in the river's environmental standards, it is **replaced by the Total Organic Carbon (TOC) standard** i n order to expand from the current Biological Oxygen Demand (BOD) to non-decomposable organic materials.
  - The existing water quality measurement network should be operated in consideration of **mutual connectivity** to the newly introduced **non-point pollutant measurement network**.
  - **Automation of the water quality measurement network** to which automatic measurement technology is applied is performed.
  - The measurement network for **non-point pollutant measurement** and **sediment management** is expanded, and **radioactive material irradiation** is conducted.

- **Establishment of an integrated water environment decision-making system**

  - It will improve the reliability of national pollution source surveys using **ICT-based decision-making systems** and establish an **information system for industrial wastewater**.

## 7. Establishing the foundation for water environment management

- **Efficiency of financial management**

  - Develop performance indicators and measurement methods for each project to regularly evaluate the project performance and establish a system that links the results to future budgeting.
  - The financial allocation system reflects **future water environment conditions and changes in policy priorities** accordingly.
  - Establish basic principles such as the **principle of burden of cause** and the **principle of burden of user** in financing for water environment management.

## 8. Conclusions

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- An appropriate water circulation system will be improved by securing alternative water resources through integration of surface water and groundwater management, water reuse, and water demand management.
- TMDL can be introduced using the IWM method to maintain the water quality of the mainstream and tributaries as the first grade.
- Through river health assessment for the aquatic ecosystem, damaged river restoration is promoted to improve the connectivity of the aquatic ecosystem to secure biodiversity and enable ecosystem service through improvement of the aquatic ecosystem.
- It is possible to create a safe water environment by strengthening the management of organic substances centered on TOC, managing wastewater discharge facilities, and managing green algae in consideration of the characteristics of each industry.
- With the introduction of the water environment facility asset management system, aging river facilities can be improved to ensure water quality during waterfront activities and create economic and cultural values of the water environment by providing a water culture experience space.
- Through science and technology and financial management, water environment governance can be activated to effectively establish a foundation for water environment management.