Water Environment Management Plan to Restore Nature

IWRM

Water Environment Management Plan to Restore Nature

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) 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 Envir onment Management (Ministry of Environment, 2017)

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

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

Contents

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, infiltration, 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 water, industrial water,** and **agricultural water**, has maintained its past framework without efficiently responding to changes in economic and industrial structure and changes in water demand 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 secured water resources is also insufficient**.
  • The government has made efforts to manage **water quality, quantity, and water ecosystems** from an **integrated water management** by changing the water management paradigm through many system improvements and collaboration.

- With the common goal of establishing an appropriate water circulation system, ministries should (1) institutionalize the supply of environmental ecological flows considering the water ecosystem, (2) establish an integrated surface water-ground water management system, (3) increase water storage and circulation across the country, and (4) strengthen water demand management.

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 l andmark 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 ac cess rivers and enjoy leisure in the aging era, and improves conditions so that the socially d isadvantaged, 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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8. Conclusions

- An appropriate water circulation system will be improved by securing alternative water res ources through integration of surface water and groundwater management, water reuse, an d 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.

Thank you very much

IWRM and Soil Management

IWRM

IWRM and Soil Management

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

Training Course

1 Soil

- Soil Health
- Soil Economic Value

2 Soil Ecosystem

- Soil Ecosystem
- Threat Factors in Soil Ecosystem

3 Soil Loss

- Soil Loss Process
- Soil Loss Measurement & Modeling

4 Soil Management

- Sustainable Soil Management

5 Perspectives on Soil

- Soil Security
- Soil & Carbon

Aims & Objectives

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

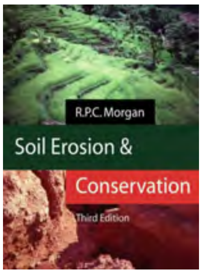
  Promote among trainees a good understanding of the watershed management for soil conservation and management

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

  (1) Various issues regarding soil – in particular, topsoil (surface soil)
  (2) Research trends related to soil loss measurement and modeling
  (3) Soil-related policies and future directions

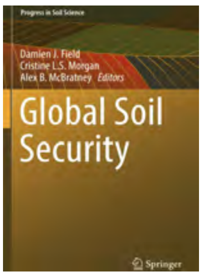
References

SSORii Report



Soil Erosion & Conservation

Principles of Soil Conservation and Management



Global Soil Security

Soil – Human Health Nexus

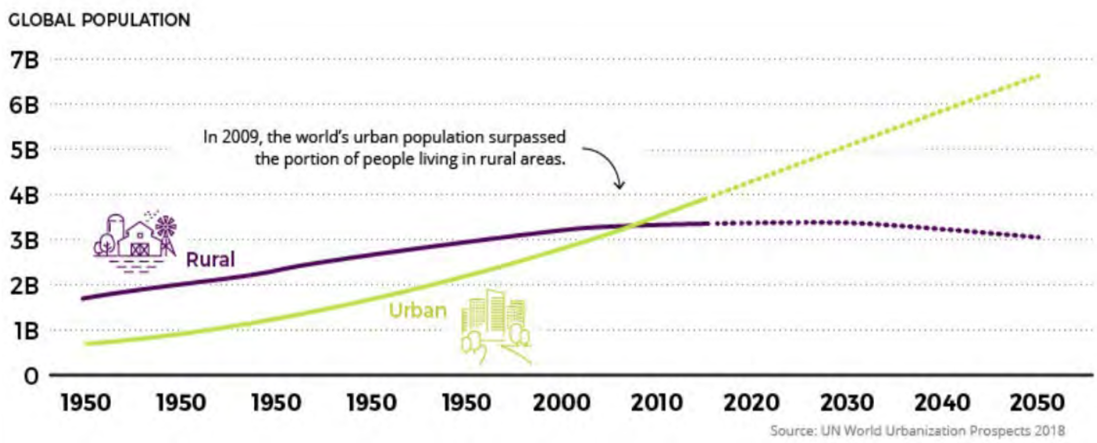
Contents

1. Understanding of soil

1.1 Soil & Urbanization
1.2 Soil Formation
1.3 Topsoil
1.4 Soil Functions

1.1 Soil & Urbanization

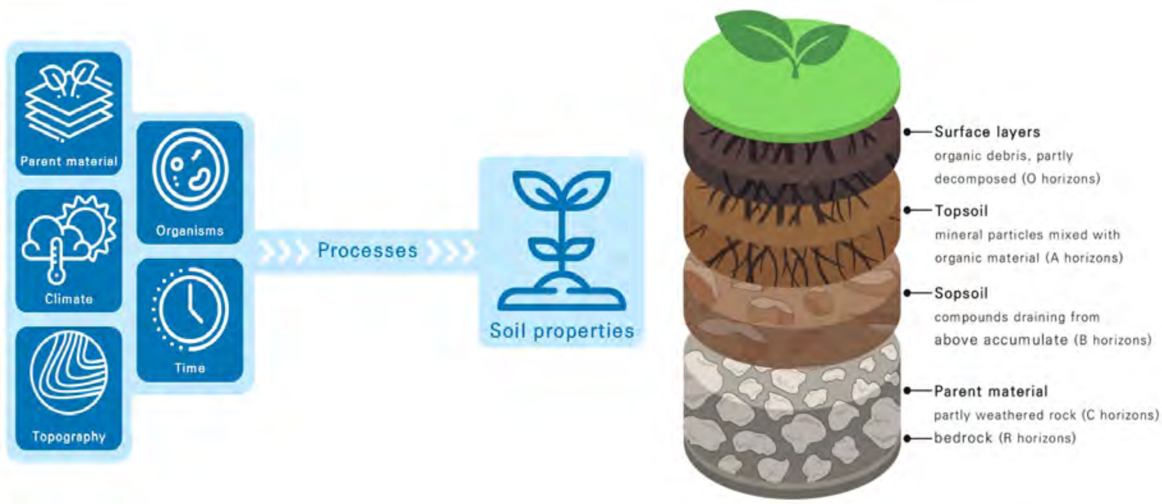
- **Today, around 68% of the world's population resides in urban areas.**
  - It is difficult to find large spaces with soil in urban areas except for some parks and landscaped areas.
  - Thus, most citizens are not very aware of soil, which is lower than the awareness regarding other environmental sources, such as water or air



Source: https://www.weforum.org/agenda/2019/09/mapped-the-dramatic-global-rise-of-urbanization-1950-2020/

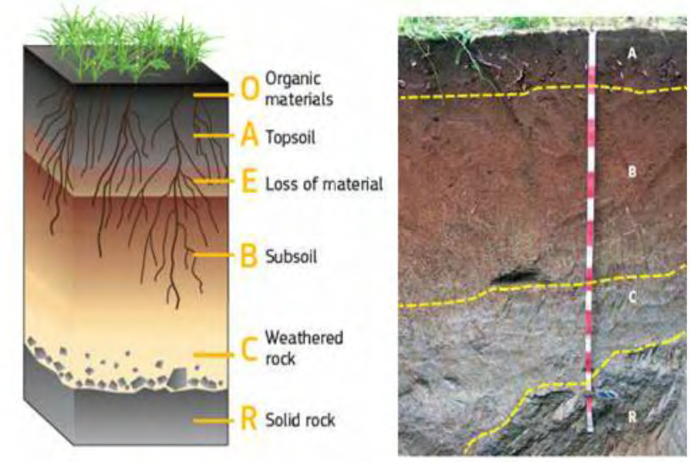
1.2 Soil Formation

- **There are five major factors that create different types of soils: parent material, climate, topography, organisms, and time.**
  - The soil cross-section shows many layers as it is affected by interactions between the five soil creation factors.
  - Among these, the topsoil layer is easily visible to touch and tread on.



1.3 Topsoil

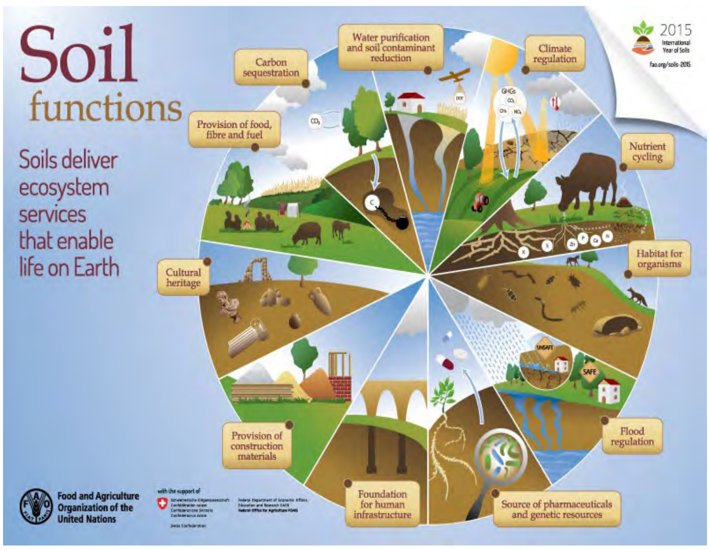
- **Topsoil is defined as the surface soil that is responsible for supplying nutrients and moisture to plants as it is rich in organic matter and microorganisms.**
  - Depending on the environmental characteristics, the depth of the topsoil layer can be more than 1 m or as low as several millimeters, but this layer is generally up to 30 cm deep.



Source: European Commission. 2016. Global Soil Biodiversity Atlas image credit: Lovell Johns Ltd.(left); E. Micheli, Joint Research Centre, Lovell Johns Ltd.(right)

1.4 Soil Functions

- **Soils deliver ecosystem services that enable life on earth.**
  - The main functions of soils mainly include climate regulation, food regulation, habitat for organisms, carbon sequestration, nutrient cycling, etc.



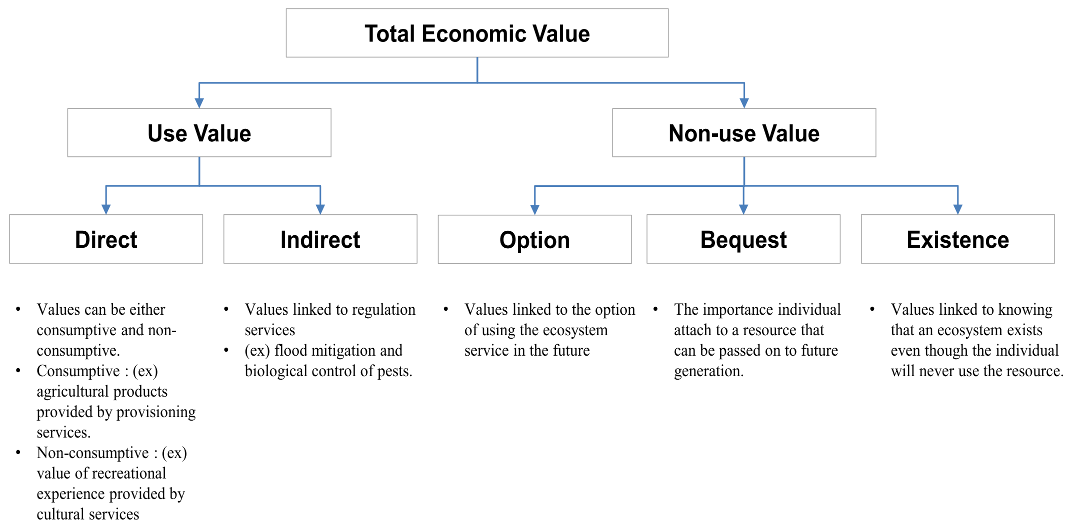
Source: https://www.fao.org/resources/infographics/infographics-details/en/c/284478/

2. Soil Economic Value

2.1 Soil Economic Value
2.2 Soil Ecosystem and Economic Valuation
2.3 Economic Costs for Soil Erosion in Korea

2.1 Soil Economic Value

- **To highlight the importance of soil and derive reasonable soil conservation policies, the economic value provided by soil to humans should be evaluated first.**
  - The economic value of environmental resources can be classified into the use value and non-use value.



2.2 Soil Ecosystem and Economic Valuation

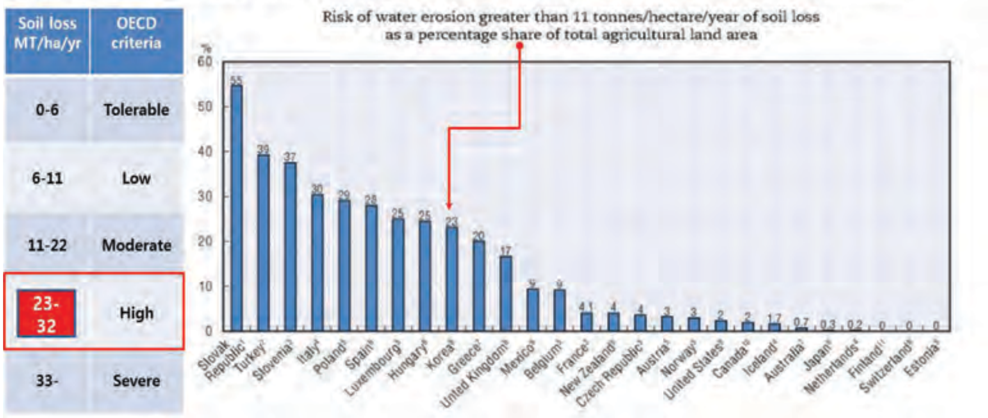
- In 2016, a research team in Iceland collected the **previous study results on the economic value of soils** (33 papers published from 1984 to 2014) and then estimated the economic value based on **soil services**.

Soil service category	Services/functions	Valuation method	International dollar (id$) 2012	id$ units
Support functions	Biodiversity pool	Various methods	2.1 trillion	id$/yr^{-1}
	Nutrient cycling	Replacement cost, market price, hedonic price	24–180	id$/ha^{-1}/yr^{-1}
	Soil formation	Market price	18–28	id$/ha^{-1}/yr^{-1}
	Water cycling	Market price	62–126	id$/ha^{-1}/yr^{-1}
Regulating services	Biological control of pests and diseases	Avoided cost, provision cost	59–268	id$/ha^{-1}/yr^{-1}
	Climate regulation	Choice experiments, market price, replacement cost	2–268	id$/ha^{-1}/yr^{-1}
	Hydrological control	Damage cost, hedonic cost, replacement cost, benefit transfer, defensive expenditure, provision cost, contingent valuation, choice modelling	30–1175	id$/ha^{-1}/yr^{-1}
	Recycling of wastes and detoxification	Provision cost	77–330	id$/ha^{-1}/yr^{-1}
	Filtering of nutrients and contaminants	Provision cost, defensive expenditure	544–6402	id$/ha^{-1}/yr^{-1}
Provisioning services	Biomass production	Market price, producers price	231–22,219	id$/ha^{-1}/yr^{-1}
	Clean water provision	Damage cost, net factor, hedonic cost	34–101	id$/ML
	Raw materials	Producers price	9–147	id$/t
	Physical environment	Defensive cost, replacement cost, provision cost	32–110	id$/ha^{-1}/yr^{-1}
Cultural services	Heritage	Net factor	ND	No data
	Recreation	Damage cost	571,720	id$/yr^{-1}
	Cognitive	No data	ND	No data

Source: Jónsson, J. Ö. G., Davíðsdóttir, B., 2016. Classification and valuation of soil ecosystem services. Agricultural Systems, 145:24-38.

2.3 Economic Costs for Soil Erosion in Korea

Agricultural land area having moderate to severe water erosion risk (1990-2010) (OECD, 2013)



- **Annual Average Soil Loss in Korea : 32 ton/ha/year**
- **Annual Average Total Soil Loss: 300*10^6 ton***
  (*Considering total land areas and surface soil weight)
- **Time to erode 30cm surface soils: 125 years (SSORii, 2017)**
- **300*10^6 ton x US$30/ton** = US$ 3.0*10^{12}**
  {**USDA NRCS US$28/ton}
- **Economic Loss from Arable Land: 60,800,000ton = 2.0*10^9 US$**

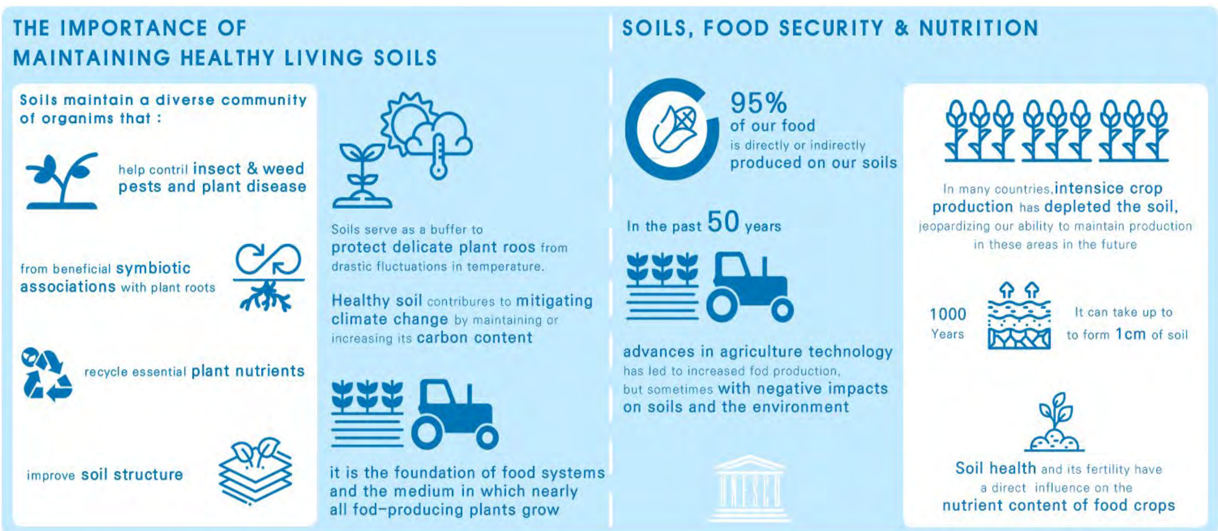
Source: J. Yang, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul

3. Soil Health

3.1 Soil Health
3.2 Soil Health Gap

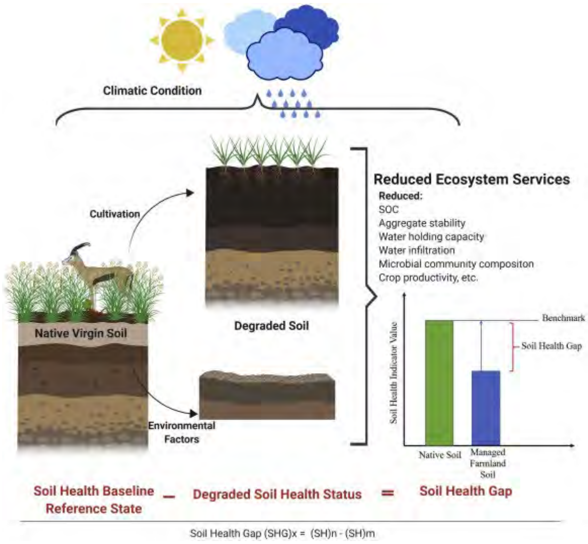
3.1 Soil Health

- **Soil health is defined as the soil capacity to function as a vital living system that sustains biological productivity, maintains environmental quality, and enhances the health of plants, animals, and humans.**
  - Soil quality is slightly different from soil health as it focuses on the soil functions, whereas soil health considers the soil as a finite non-renewable and dynamic living resource.



3.2 Soil Health Gap

- "**Soil Health Gap**" is defined as the difference between soil health in an undisturbed native soil and current soil health in a cropland in a given agroecosystem.
  - Soil Health Gap can be determined based on a general or specific soil property such as soil carbon.



Source: M. Bijesh et al., 2020, Soil health gap: A concept to establish a benchmark for soil health management, Global Ecology and Conservation

4. Soil Ecosystem

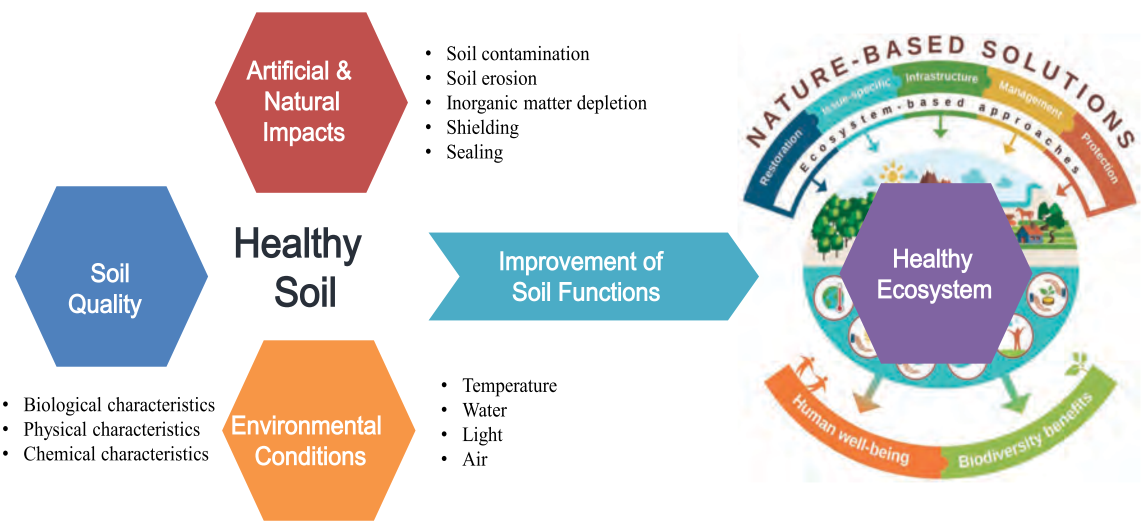
4.1 Ecosystem and Soil Ecosystem

- **The term "ecosystem" was coined by Tansley at the University of Oxford in the UK in 1935.**
  - Specifically, an ecosystem is defined as a physical or functional system that is steadily changing to maintain an equilibrium state while interacting between a community of living organisms and the inorganic (abiotic) components of the environment that the living organisms inhabit.

- **The soil ecosystem is defined as a system wherein dynamic interactions occur between the living organisms in soil and non-living organisms surround the living organisms, such as soil particles, organic and inorganic matter, water, and air.**
  - The soil should be recognized as a dynamic and vital resource where living organisms can thrive and perform various functions (producers, consumers, and decomposers) rather than as an abiotic environmental factor (a base in which plants can grow or a place of decomposition activities by living organisms).

4.2 Improvement of Soil Functions

- **Soil quality and health are closely related to the soil ecosystem; when the soil quality and health are maintained and conserved, healthy ecosystem functions can be achieved, thereby providing various ecosystem-related services to humans.**



4.3 Threat Factors in the Soil Ecosystem

- **The soil quality, health, and ecosystem are threatened by various factors globally.**
  - In particular, soil loss by erosion, organic matter loss, contamination and biodiversity loss, are known to be some of the major threats to the soil ecosystem.

EROSION

ORGANIC MATTER LOSS

CONTAMINATION

BIODIVERSITY LOSS

COMPACTION

SALINISATION

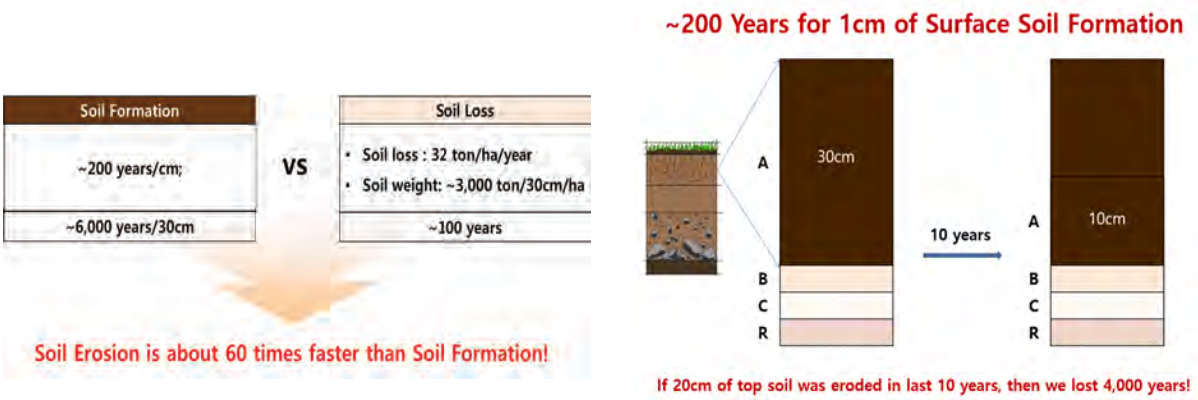
FLOODS-LANDSLIDES

SEALING

5. Soil Loss

5.1 Soil Loss Problems

- **Owing to population explosion, food shortage, and desertification as a result of global climate change, the conservation and continuous use of soil are very important.**
  - In particular, topsoil can be eroded easily by water and wind. Thus, massive property damages are being reported globally owing to topsoil erosion.
  - A duration of around 200 years is required to form 1 cm of topsoil.



Source: J. Yang, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul

5.1 Soil Loss Problems

- **Soil loss does not mean that the soil disappears and is physically lost but rather that the soil particles migrate and move elsewhere.**

- **Migration of the eroded soil particles causes two major problems.**
  - First, the movement of soil particles reduces the area of land that we live on or use and changes the land to an unusable state. (on-site impact)
    - If soil loss occur in farmlands, the area available for crop cultivation is reduced, and the surface layer (topsoil) containing relatively large amounts of nutrients is lost, which may inhibit crop growth.
    - Soil losses occurring in urban areas may threaten lives or properties from landslides.
  - Second, if the lost soil flows into rivers or streams, it may threaten the aquatic ecosystem and increase the river bed (off-site impact).
  - In addition the soil, flowing into reservoirs lead to failure of hydraulic structures, such as turbines in hydropower plants, which may limit leisure activities such as water sports (off-site impact).

5.2 Soil Erosion Types

- **Soil loss refers to the phenomenon where the soil is scattered or its surface is eroded by rain or wind or human activity.**

  - Soil losses are caused largely by natural, geological, and accelerated erosion.

    - Natural erosion refers to a condition wherein the surface is eroded by natural environmental causes without being affected by human activities.
    - Geological erosion is a type of natural erosion of the soil by wind or water flow caused by rain or snow over long periods of time.
    - Accelerated erosion refers to a phenomenon wherein the erosion is accelerated by various human activities by the development of human civilization.

Water Erosion

Wind Erosion

5.3 Water Erosion

- **Water erosion refers to the phenomenon of soil loss by rainfall and surface flow.**

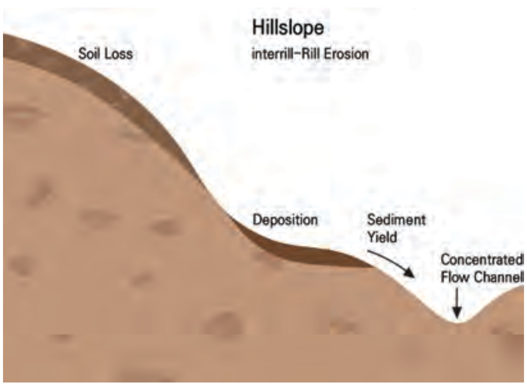
  - Water erosion and sedimentation include the processes of detachment , entrainment , transport and deposition of soil particles.

  - The major forces driving these processes are shear stresses generated by raindrop impact and surface runoff over the land surface.

  - Water erosion is a function of these forces applied to the soil by raindrop impact and surface runoff relative to the resistance of the soil to detachment.

- Once set in motion, soil particles are referred to as *sediment*.

- *Sediment delivery* is the amount of eroded material delivered to a particular location, such as from the eroding portions of a hillslope (*soil loss*) or the outlet of a watershed (*sediment yield*).



5.3 Water Erosion

- **Water erosion is mainly divided into [1] inter-rill erosion - splash erosion and sheet erosion, [2] rill erosion, [3] gully erosion.**

  - **Sheet erosion:** This type of soil degradation by water occurs when the rainfall intensity is greater than the soil infiltration ability and results in the loss of the finest soil particles that contain nutrients and organic matter.

  - **Rill erosion:** Rill erosion follows after, when the water concentrates deeper in the soil and starts forming faster-flowing channels. These channels can be up to 30cm deep and cause detachment and transportation of soil particles.

  - **Gully erosion:** This is an advanced stage of land damage by water when the surface channels are eroded to the extent when even tillage operations wouldn't be of any help. Apart from causing huge soil losses and destroying farmland, it also results in reduction of water quality by increasing the sediment load in streams.


Inter-rill Erosion


Rill Erosion

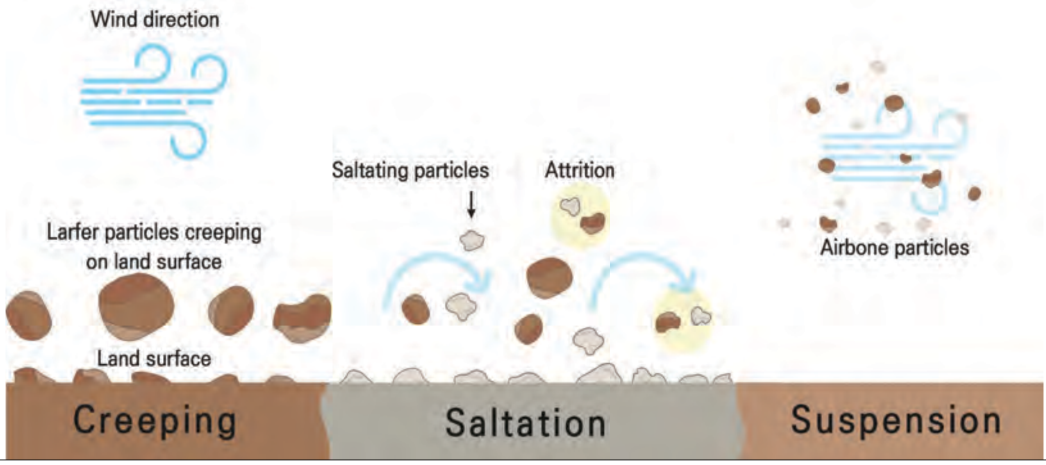

Gully Erosion

5.4 Wind Erosion

- **Wind erosion involves movement of sand or light weathering material and is likely to occur mainly in arid or semi-arid regions; it also occurs in temperate and humid climates.**

  - Wind erosion occurs when the forces applied to the soil by wind are greater than the resistance of the soil to these forces. The forces are directly a function of the environmental conditions (climate, soil, topography, and land use) at a particular location where wind erosion is occurring

  - Wind erodes soil particles by saltation , suspension, and creep along the soil surface.



5.5 Factors influencing Soil Erosion

- The factors influencing soil erosion are the **soil characteristics, topographical features, land cover, etc., including weather conditions** related to water and wind erosions.

Climate (rainfall)

- The greater the **intensity and duration** of a rainstorm, the higher the erosion potential.
- Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during **short-duration, high-intensity** thunderstorms.

Soil

- **Soil erodibility** is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil.
- **Texture** is the principal characteristic affecting erodibility, but **structure, organic matter and permeability** also contribute.

Topography

- The **steeper and longer the slope** of a field, the **higher the risk for erosion**.
- Soil erosion by water increases as **the slope length increases** due to the **greater accumulation of runoff**.

Landcover

- The potential for **soil erosion increases** if the soil has **no or very little vegetative cover** of plants and/or crop residues.
- **Plant and residue cover protects the soil from raindrop impact and splash**, tends to slow down the movement of runoff water and allows excess surface water to infiltrate.

6. Soil Loss Technology

6.1 Soil Loss Measurement
6.2 Soil Loss Modeling

6.1 Soil Loss Measurement - Plot

- **The soil loss measurements are based on field survey data on the amount of soil material removed by erosion.**

  - There are two main methods for field monitoring of soil erosion: open and closed plots.
    - In the open plot, a collector is installed in the survey area and used to monitor a small watershed.
    - In the closed plot, a plot with a boundary containing a certain area is used.

6.1 Soil Loss Measurement - Plot

- **There are several limitations of the ecosystem conditions for monitoring via plots.**

  - First, the time ranges of most monitoring programs using plots are limited to several years. Thus, the measured soil erosion does not represent long-term trends.

  - Second, as the eroded soil materials in the plot during the monitoring period are depleted, materials on the soil surface eroded by water are lost to some extent, and the remaining material is likely to be more resistant to erosion, such as gravel, such that that the amount of soil loss is reduced.

  - Third, closed plots have limitations with data interpretation because of the boundary that blocks data on soil loss from outside.

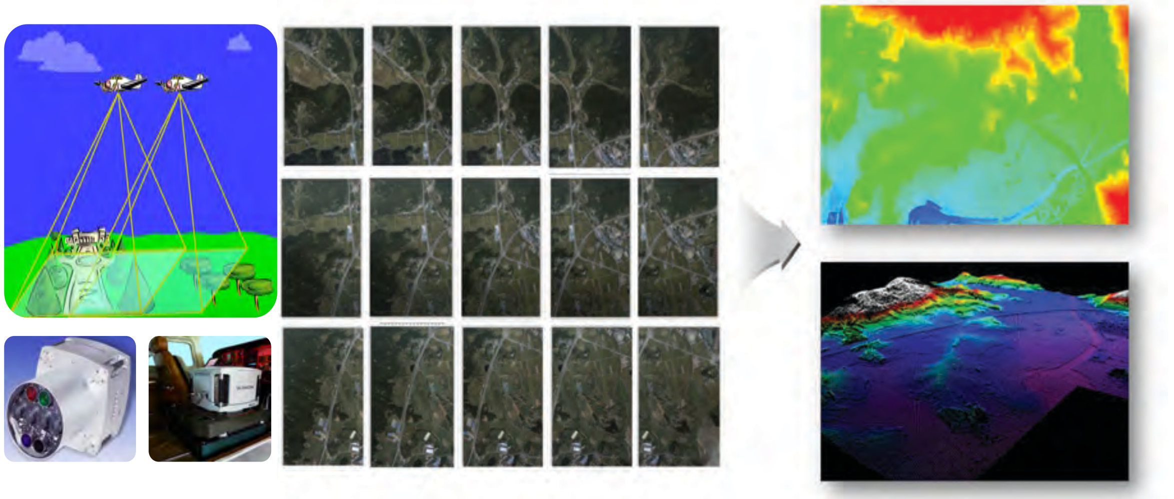
- **Note that the advantage of the closed plot monitoring is that it allows comparative analyses via several plots at the same scale.**

- **To overcome these limits, remote-sensing technologies can be used in combination with ^{137}Cs isotope measurements or the open plot can be used an alternative method.**

6.1 Soil Loss Measurement – Remote Sensing

- **Aerial photogrammetry and aerial laser surveys provide detailed spatial information over wide areas with very high spatial resolutions.**
  - The amount of soil loss can be calculated by comparing aerial photos with aerial laser data acquired in a time series.

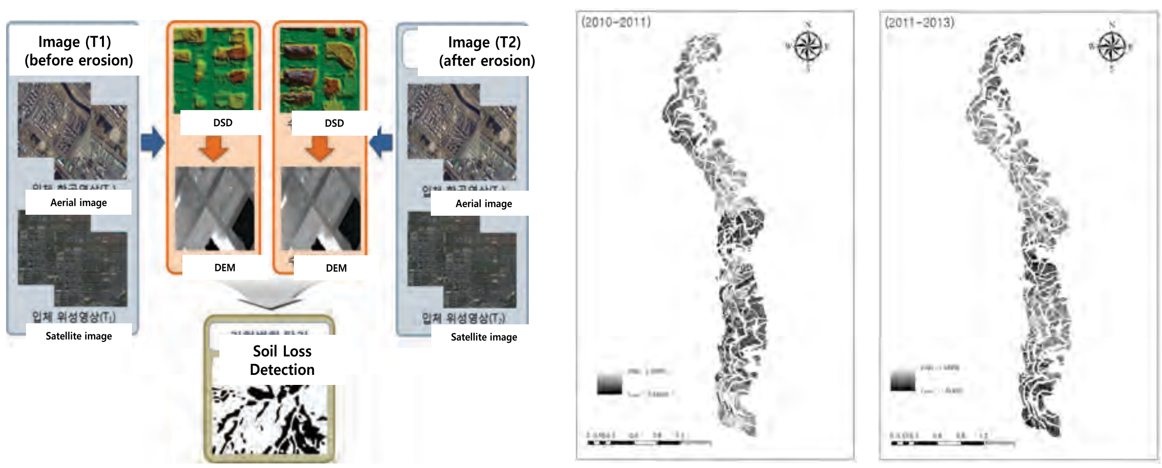
Source: J. Park, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul



Soil loss detection process using aerial photogrammetry and laser surveys

6.1 Soil Loss Measurement – Remote Sensing

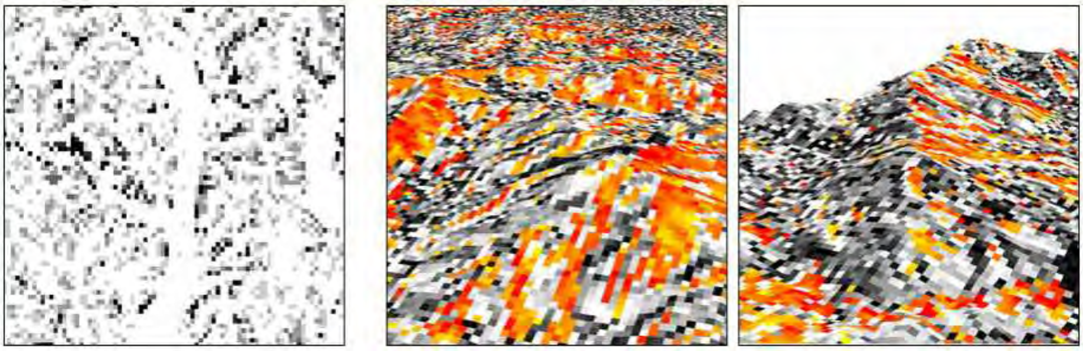
- **The amount of soil loss can be calculated by comparing aerial photos with aerial laser data acquired in a time series.**
  - Since the spatial resolutions of aerial photographs and aerial laser data are 12 to 24 cm (aerial photograph) and density of 3 to 5 points/m^2 (aerial laser), respectively.
  - It is possible to produce numerical elevation models with high spatial resolutions of within tens of centimeters to 1 m.



Source: J. Park, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul

6.1 Soil Loss Measurement – Remote Sensing

- Moreover, remote sensing techniques can be applied to **both natural and artificial soil loss detection** and have the **advantage of up-to-date maintenance** with periodically acquired images.
  - Since the slope and cover factors in the universal soil loss equation (USLE) are produced from aerial photographs or satellite images, they can quickly and accurately extract the topography for each pixel in the image data.

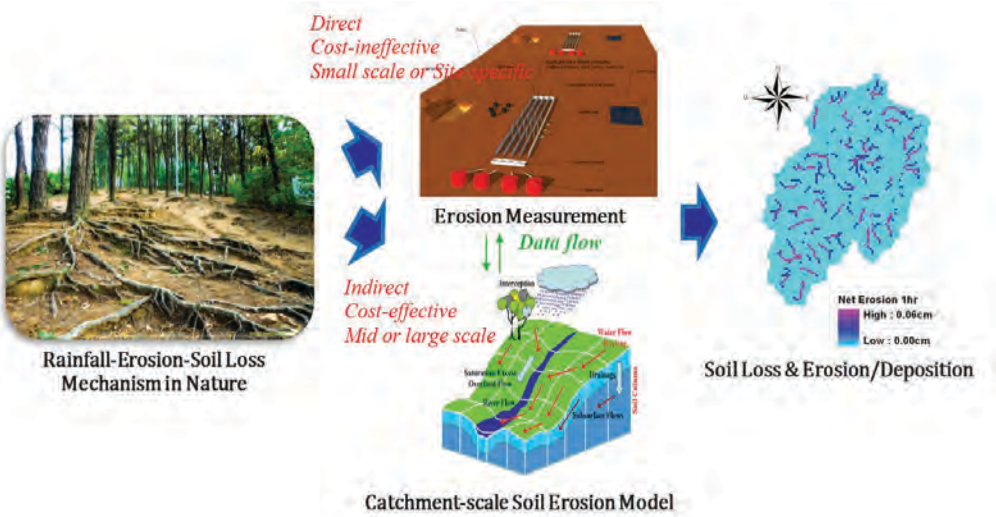


(a) USLE-based soil Loss (b) Aerial phots-based soil loss (Red cells: erosion, Black cells: deposition)

Source: J. Park, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul

6.2 Soil Loss Modeling – Need of Soil Erosion Model

- A **quantitative analysis of the amount of soil loss** from a watershed is fundamental to soil conservation and erosion-induced disaster mitigation.
- Soil erosion model is **a basic tool to serve information** such as sediment rate, spatiotemporal pattern of erosion and deposition.



6.2 Soil Loss Modeling – History of Models

- **Process-based (or physically-based) models currently integrate with GIS to take account of spatial heterogeneity in various hydrologic and geomorphologic variables.**
- **Thus, they predict where, when, and how much erosion or deposition is occurring.**

Emprical
- Field experiments
- Statistical techniques
- Lumped in time & space
- Unrealistic assumptions
- USLE, RUSLE, SEDNET, SPL, USPED, etc.

Conceptual
- Resflecting physical processes with emprical relationship
- Transfer mechanisms of sediment and runoff
- Parameter calibration
- AGNPS, HSPF, SWAT WATEM, etc.

Physically-based
- Mass, Momentum, Energy equations.
- Phusical parameters
- Distributed in time &space
- CREAMS, KINEROS2, EUROSEM, EPIC, WEPP, MIKE-11, etc.

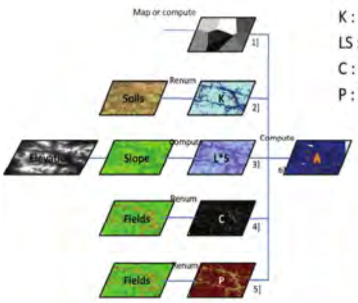
1970s 1980s 1990s 2000s

6.2 Soil Loss Modeling – USLE

- **To develop a soil loss formula at the national level, conferences were held by researchers and users at Purdue University in the USA in February and July of 1956.**
  - Whischmeier and Smith (1965) proposed the USLE (Universal Soil Loss Equation), and this equation was developed to provide convenience with respect to soil conservation.
    - Soil loss could be represented as a single number.
    - Each factor could be calculated from measurable data.
    - Each factor would be free of geographical constraints.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

where,
A : Yearly soil loss (MT ha^{-1} yr^{-1})
R : Rainfall erosivity (MJ mm ha^{-1} yr^{-1} hr^{-1})
K : Soil erodibility (=A/R, MT hr MJ^{-1} mm^{-1})
LS : Topographic factor (dimensionless)
C : Cover and management (dimensionless)
P : Support practices (dimensionless)



→ "pros" = 1) Only multiplying 2) Five input factors

→ "cons" = 1) Average annual approach 2) Empirical approach

Source: K. Jung, 2017, Surface Soil: Solutions for the Ecosystem Services and Environmental Problems, SSORii International Symposium, Seoul

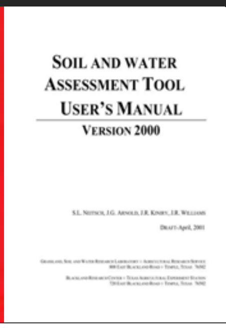
6.2 Soil Loss Modeling – USLE

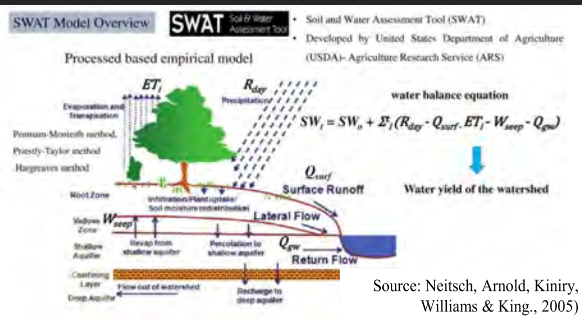
- **The USLE model has been upgraded to the revised USLE (RUSLE) and Modified USLE (MUSLE).**

  - Since the RUSLE model calculates the transport capacity by water, it can be partially used for sediment depositions at a dented area in a slope, densely vegetated area, and sedimentation basin.

  - Both the USLE and RUSLE mainly focus on predictions of the annual average soil losses, whereas the MUSLE aims to predict the amount of soil loss for a single rainfall event.

  - The Soil and Water Assessment Tool (SWAT) model, which simulates the suspended sediments in a watershed, can be used to predict the amount of soil loss by the MUSLE from the total runoff and peak flow calculations.

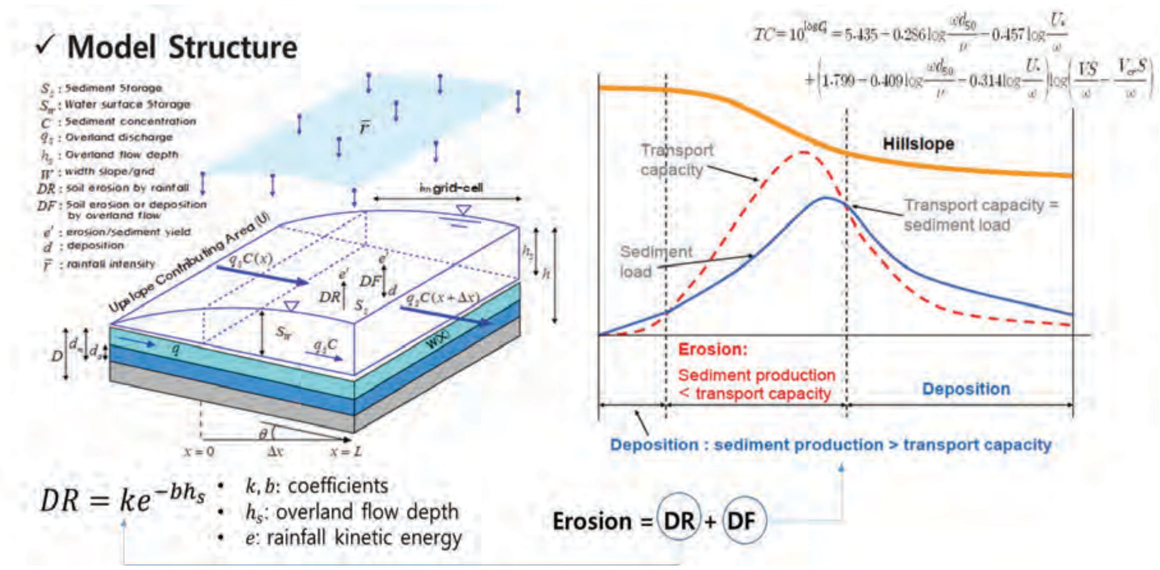




Source: Neitsch, Arnold, Kiniry, Williams & King., 2005)

6.2 Soil Loss Modeling – Physically-based Model

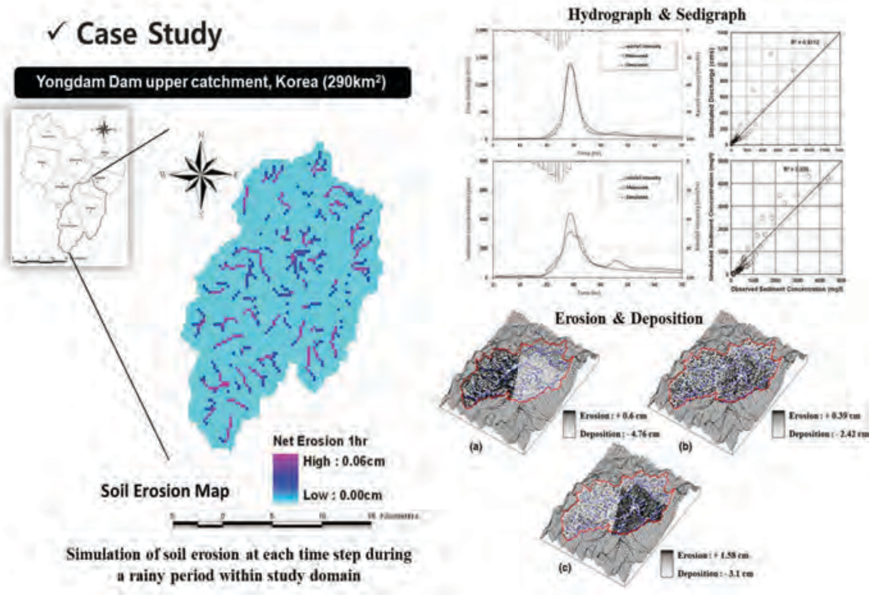
- **Physically-based models reflect the rainfall–runoff and erosion–soil loss mechanisms.**



Source: Surface Soil Erosion Model (SSEM), Lee et al., (2013)

6.2 Soil Loss Modeling – Physically-based Model

- Because physically-based models **divide a target watershed into cells** in the simulations, they can **analyze the spatiotemporal variations of erosion and deposition** and **simulate sediment yields** at the pre-determined outlets.



Source: Surface Soil Erosion Model (SSEM), Lee et al., (2013)

7. Sustainable Soil Management

7.1 Soil Management
7.2 Control Measures for Soil Loss Management

7.1 Soil Management – Need of a New Perspective

- Despite spatial movement characteristics of sediments, sediment-related problems are generally treated to prevent or alleviate disasters within the managed spaces by establishing or enforcing policies.

- New Perspective on Soil Management Strategy (multidisciplinary → transdisciplinary: Need of Understanding on Sediment Cycle in Basin)

7.1 Soil Management – Definition and Components

- Soil management is the application of operations, practices, and treatments to protect soil and enhance its performance.

7.2 Control Measures for Soil Loss Management

- **Measures to prevent soil Loss**

[1] Preservation of natural vegetation

- The best control method against soil erosion is preserving natural vegetation to the maximum extent possible.
- Maintaining natural vegetation is the most economical approach to controlling and preventing erosion, which is advantageous for application to wetlands, rivers, lakes, and surrounding steep slopes.

[2] Buffer zone

- A buffer zone is mainly installed in soil-disturbance and wetland areas as special zones and aim to provide natural vegetation or habitat, thus protecting the soil by controlling erosion and sediment runoff as well as stabilizing the riverbed.

[3] Seeding

- The use of vegetation cover is one of the best eco-friendly methods to prevent soil erosion.
- Vegetation seeding has the advantages of ensuring excellent stability and relatively economical installation, but it is limited by the time required to grow such vegetation.

7.2 Control Measures for Soil Loss Management

- **Measures to prevent soil loss**

[4] Mulching

- Vegetation roots suitable to the soil surface can be used as mulch to form a protective layer.
- Mulching can protect the soil from erosion immediately and requires constant fertilizer supply to maintain soil temperature and moisture consistently.

[5] Matting

- Various materials such as fibers and nets can be used for erosion control, which are collectively referred to as matting.
- The matting material is affected by the installation range, but various materials such as straw, jute, wood fiber, coconut fiber, plastic, and fiber matrix are used.

[6] Plastic sheeting

- Plastic sheets are used to immediately protect regions where plant roots cannot be used as mulch.
- Their installation is considerably quick and convenient, but they may rapidly decompose when exposed to UV light.

7.2 Control Measures for Soil Loss Management

- **Measures to control sediment runoff**

[1] Temporary slope drain

- The drain method uses pipes to drain sediments from a slope stably.
- Sediments occurring on steep slopes without erosion or deposition at the time of torrential rains can be stably discharged through pipes.

[2] Outlet protection

- Outlet protection is a method of reducing the flow rate of a concentrated stream by preventing scour at the outlet.
- It protects the outlet by dissipating energy and reduces the possibility of downstream erosion; it is constructed using riprap or concrete.

[3] Surface roughening

- By installing rough soil surfaces with horizontal grooves across the slope to ensure surface roughness, the runoff speed can be reduced.
- Surface roughness can be ensured using blades attached to the sides of a bulldozer or other agricultural equipment, such as spikes and cogs.

7.2 Control Measures for Soil Loss Management

- **Measures to control sediment runoff**

[4] Check dam

- A check dam is often built to reduce erosion from a wetland or channel and decrease flow rate due to a concentrated stream.
- It is a control method that prevents not only gully erosion but also significant amounts of sediment formation prior to vegetation installation.

[5] Sediment trap

- Sediment traps are temporary dry pond sediment containment detention systems used to capture sediment and settle suspended solids in runoff from disturbed soils
- A sediment trap is installed by building a weir by excavation and riprap weir or drilling vertical pipes at the outlets to create temporary pools.

[6] Sediment basin

- If sediment traps are not sufficient for stormwater and sediment control, the sediment basin method can be applied using its larger capacity.
- The installation of a temporary sediment basin consisting of one or more inlets and barriers can help diffuse flow.

8. Perspectives on Soil

5.1 Ecosystem and Soil Ecosystem
5.2 Improvement of Soil Functions
5.3 Threat Factors in the Soil Ecosystem

8.1 Soil Security

- **Currently, there are six primary environmental tasks for sustainable development of the Earth and mankind: food security, water security, energy security, climate change abatement, biodiversity protection, and ecosystem services.**
  - Soil plays a very important role in these environmental tasks. If soil resource losses continue, it could cause more serious impacts on the surrounding environments and humans than those at present.

Soil-Centric Nexus Framework

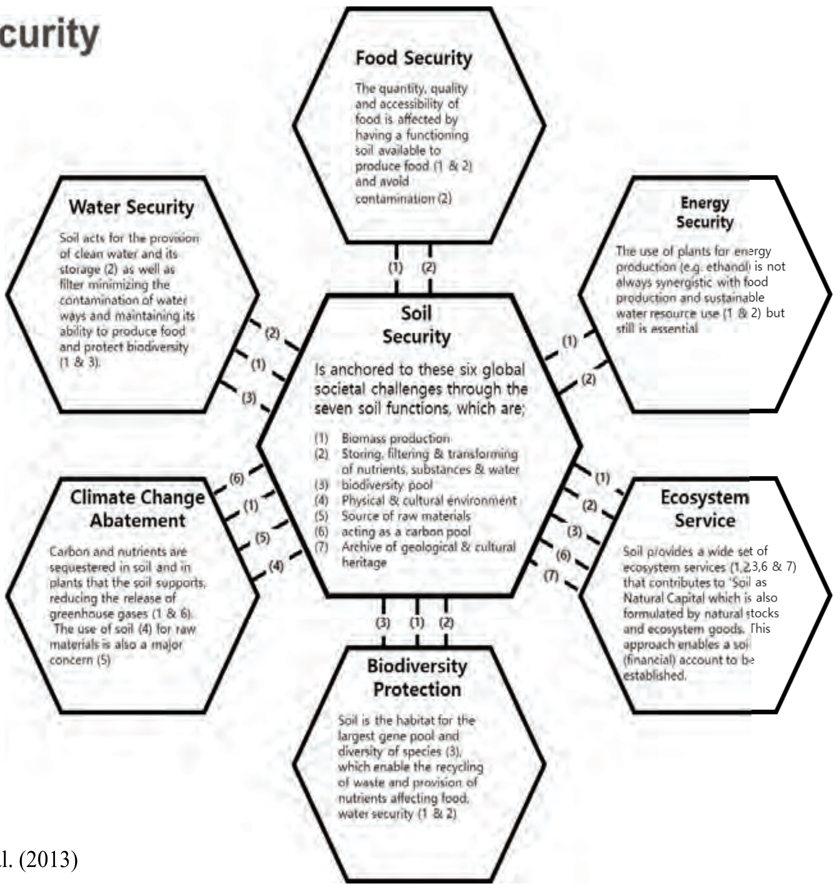
8.1 Soil Security

- **Soil security** is defined as the **maintenance and improvement of soil resources** for food, textile, energy and climate, biodiversity, as well as overall protection of the ecosystem.
  - To realize this concept, several dimensions need to be defined, and soil quantity, quality, and accessibility of food and water security must be considered.
- The **scope of soil security** can be categorized under **5Cs**: **capability, condition, capital, connectivity, and codification**.

Dimension	Threats to soil security
Capability	Erosion, landslides, sealing by infrastructure, source of raw materials
Condition	Contamination, loss of organic matter, compaction and other physical soil degradation, salinization, floods
Capital	Inadequate assessment of the value of the soil asset, *soil stock*, and the processes that: *support* (e.g. nutrient & water cycling, biological activity), *degrade* (e.g. acidification, salinization, loss of organic matter, compaction), and *regulate* (flood mitigation, erosion, control soil pests and disease, & greenhouse gas abatement) Indiscriminate treatment of soil as a renewable resource
Connectivity	Inadequate soil knowledge of land managers, lack of recognition of soil services and soil goods by society
Condification	Incomplete policy framework Inadequate or poorly designed legislation

Source: McBratney et al. (2013)

8.1 Soil Security



Source: McBratney et al. (2013)

8.2 Soil and Carbon

- **Owing to global greenhouse gas emissions, global warming and climate change issues have increased.**

  - The international community has continued its activities to reduce greenhouse gas emissions, such as establishing the Kyoto Protocol (1997) and Paris Agreement on Climate Change (2015).
  - In the Kyoto Protocol, six greenhouse gases[1] were selected for target emission reduction. Among them, CO_2 accounts for more than 80% of the total greenhouse gas.

1. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCS), perfluorocarbons (PFCS), and sulfur hexafluoride (SF_6)

1.1 Backgrounds

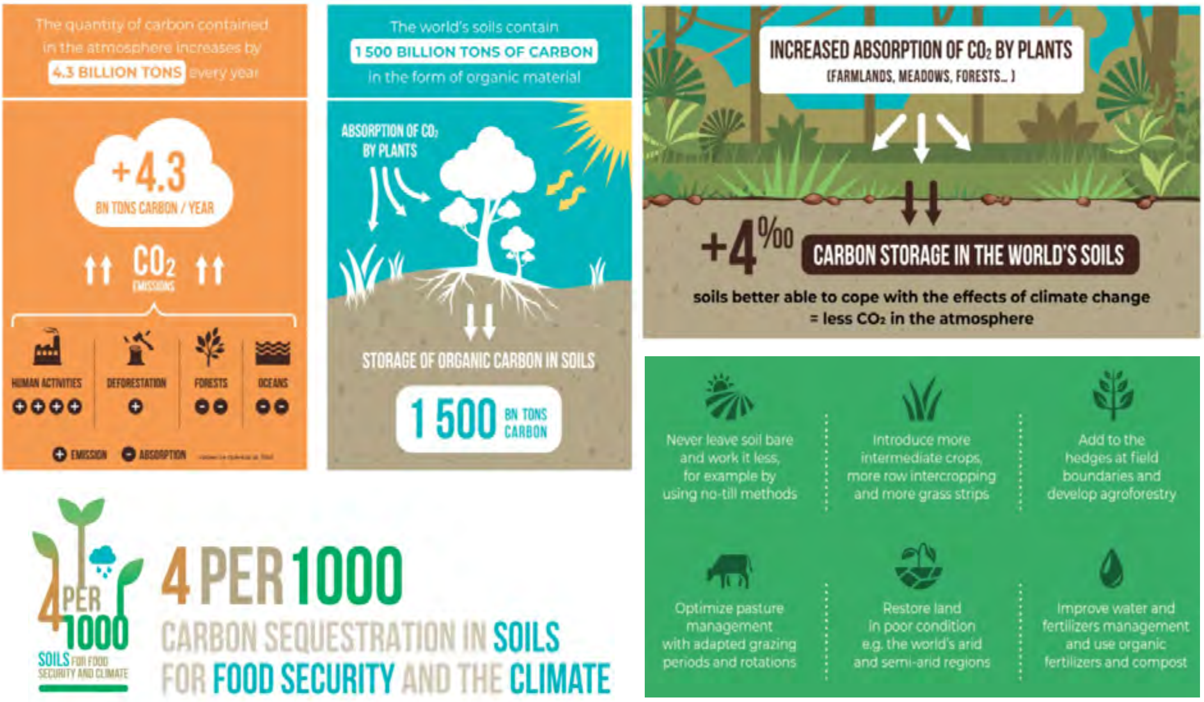
- **Sequestering carbon in Soil Organic Carbon is seen as one way to mitigate climate change by reducing atmospheric carbon dioxide.**

  - The argument is that small increases of SOC over very large areas in agricultural and pastoral lands will significantly reduce atmospheric carbon dioxide.
  - For the reduction to be long-lasting, organic matter would have to be in the more stable or resistant fractions.

- **The '4 per mile Soils for Food Security and Climate' agenda was proposed at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change in Paris in November 2015.**

  - This agenda noted that the use of fossil fuels emits about 8.9 Gt of carbon into the atmosphere each year, and because this emission is equivalent to 4‰ (0.4%) of the amount of carbon (2400 Gt) stored within 2 m of soil, it is possible to offset carbon emissions from fossil fuels by increasing the carbon stocks by 4‰ each year through soil conservation.

8.2 Soil and Carbon



Source: https://www.4p1000.org/

Thank you very much

River Maintenance and Management

IWRM

River Maintenance and Management

Contents

2

1. Introduction

1.1 Overview of river maintenance and management

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1.1 Overview of river maintenance and management`

▪ Definition of River

"A stream of water running along its water course from the ground surface of land. More specifically, it collectively refers to large rivers, small streams, and brooks."

The definition of a river specified in the River Act of KOREA is

1) The term 'river' means any water way which is formed by rainwater that has fallen on the water surface and flown together
2) A river in this sense should be designated as a national river or local river as they are closely related to public interests.

" an area within the riverside foreland and river facilities, which are closely related to public interest."

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1.1 Overview of river maintenance and management

▪ Why are rivers important?

<Water Supply>
Rivers carry water and nutrients to areas all around the earth. They play a very important part in the water cycle, acting as drainage channels for surface water. Rivers drain nearly 75% of the earth's land surface.

<Habitats>
Rivers provide excellent habitat and food for many of the earth's organisms.
Many plants and trees grow by rivers. Ducks, voles, otters and beavers make their homes on the riverbanks. Reeds and other plants like bulrushes grow along the riverbanks.

<Navigation>
Rivers provide travel routes for exploration, commerce and recreation.

<Farming>
River valleys and plains provide fertile soil. Farmers in dry regions irrigate their cropland using water carried by irrigation ditches from nearby river.

<Energy>
Rivers are an important energy source. During the early industrial era, mills, shops, and factories were built near fast-flowing rivers where water could be used to power machines. Today steep rivers are still used to power hydroelectric plants and their water turbines.

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1.1 Overview of river maintenance and management

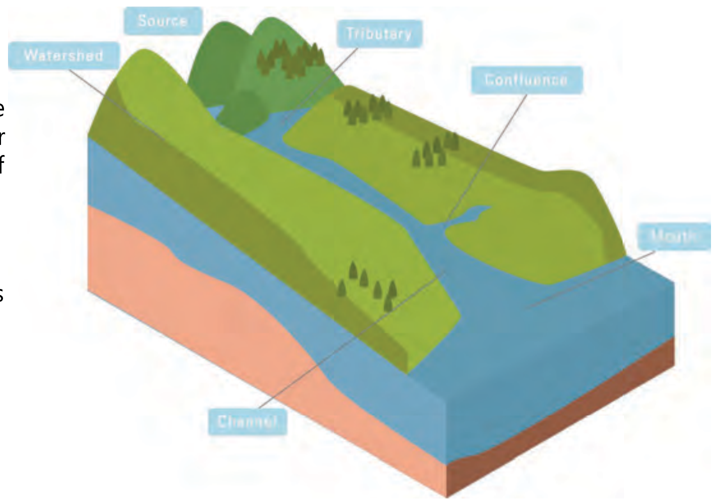
▪ Anatomy of a river

Tributaries
A tributary is a river or stream that feeds into another river, rather than ending in a lake, pond, or ocean

Channel
A river's channel is its unique signature, the course it carves across the landscape. The shape of a river channel depends on how long, over what kinds of soil, rock, and vegetation

Mouth/Delta
The end of a river is its mouth, or delta. At a river's delta, the land flattens out and the water loses speed, spreading into a fan shape

Riverbank
The land next to the river is called the riverbank, and the stream-side trees and other vegetation is sometimes called the "riparian zone."



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1.1 Overview of river maintenance and management

▪ Purpose of river maintenance and management

The purpose of **river maintenance and management** is "to manage rivers appropriately and contribute to the promotion of public welfare by providing for matters on the designation, management, use, conservation, etc. of rivers for the promotion of benefits from river use, the friendly environmental maintenance and conservation of rivers".<River Act of Korea>

However, the purpose of river management have changed according to the demands and necessity of the times and circumstances.

Therefore, it is required to develop and strengthen new function/ability of rivers such as connected development with nearby areas and vitalization of regional economy on top of the current of river management including water utilization, flood control, and river environment function.

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1.1 Definition and function of river

▪ Change in definition of rivers in the River Act of KOREA

	1961	1971	1999	2007
Public Understanding	Implicit expression	Implicit expression	Explicit expression -Preservation of national land/National economy	Explicit expression -Preservation of national land/National economy
Names and Sections	Each decree	Presidential Decree	Presidential Decree, Mayor/Provincial governor	Minister of MLTM, Mayor/Provincial governor
River area	Object for management	Object for management -Defined requirements for designation	Included in the river -Reinforced requirements for designation	Included in the river -Specified requirements for designation
River facilities	Object for management -Dealt as auxiliary facilities	Object for management -Dealt as auxiliary facilities -Consent from a river management authority is required.	Included in the river -Dealt as auxiliary facilities -Consent from a river management authority is required.	Included in the river -Dealt as river facilities -Classified according to installation purpose
River water	Object for preservation -Concept of running river water	Preservation/permission/ coordination - Concept of running river water	Preservation/permission/ coordination/manageme nt -Introduced the concept of flowing water quantity	Preservation/permission/ coordination/manageme nt -Added the concept of running river water

Source : Park(2013)

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2. Concept of River Maintenance and Management

1.1 Concept of river maintenance and management
1.2 Issues of river maintenance and management

2.1 Concept of river maintenance and management

▪ **Main problems in river systems and likely causes**

Problem	Possible Causes
Water Shortage	• Decreased rainfall • Unsustainable water demand • Decreased groundwater storage • Upstream measures
Flooding	• Increased rainfall • Changes in land use • Narrow bridges or other obstructions • People living on the floodplain
Erosion	• Natural erosion (e.g., effect of river meandering) • Infrastructure development • Increased discharge • Quarrying or mining

Source : A.D.B(2019)

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2.1 Concept of river maintenance and management

▪ Structure and major contents of river management task

	Small Categories	Detailed categories
Direct tasks	Establishment of plans	• Establishment and execution of basic plans for river management
	Surveys	• Inspection on floodgates, basin areas, and flood damages.
	Management of river facilities	• Management of river facilities
	Flood control	• Flood forecast, flood control, channel dredging works,
	Water utilization	• Water management in ordinary times and in drought
	River environment	• Water quality management, securing and operation of water for maintenance use, and landscape/ water friendly function/ river environment management, etc.
Indirect tasks	Inhibited activities	• Crackdown of inhibited works on river/river-planned land, and flood control area
	Technical work	• Standardization and informatization of materials on water gates • Research/development/support for river management Technology
	Administrative Work	• Personnel management : Appointment and operation of river management staff • Governmental authorization and permissions: Checking and taking actions on permission for use of river water, permission for occupation, etc. • Administrative disposition: Restoration to original state, penalties, measures for illegal actions, implementation of administrative actions, etc. • General administrative works Operation work
	Operation work	• Operation of various committees, dispute resolution, international cooperation, etc.

Source : Park(2013)

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2.2 Issues of river maintenance and management

▪ General characteristics of different river reaches

Reach	Hydrology	Morphology	Ecology
Upper Course (erosion zone)	- High flow velocities - Low discharge - Small streams - Intermittent wet and dry conditions	- Steep, V-shaped valleys - Rapids Waterfalls	- Coarse organic matter - Shredders*
Middle Course (transport zone)	- Medium flow velocities - Higher discharge	- Wider valleys - Meanders - Oxbow lakes	- Less dense vegetation - Sunlight for photosynthesis - Fine organic matter Grazers** and collectors***
Lower Course (deposition zone)	- Low flow velocities - Influence of the sea	- Wide, flat valleys - Floodplains - Deltas	- Opaque water column - Fine organic matter Collectors

* Shredders feed on coarse plant material and break this up into smaller pieces.
** Grazers feed on periphyton (a mix of algae, microbes, and bacteria dependent on light that accumulates on submerged surfaces such as stones, shells, and wood).
*** Collectors filter and catch finer organic matter

Source : Vannote et al. (1980)

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2.2 Issues of river maintenance and management

▪ Basic concepts and management issue of rivers

- **Hydrological Cycle** : Precipitation, Transpiration, Infiltration, Ground Water, Phreatic surface
- **Drainage Network** : Streaming ordering, Model of network growth, Minimum stream power theory
- **Sediments** : Sediment discharge, Sediment classification, Size distribution
- **Sediment Loads and Bed Forms** : Bed Load, Suspended Load, Bed Forms
- **River Patterns** : Meandering Rivers, Straight rivers
- **Morphological and Hydraulic Features** : Channel slope, Channel cross sections, Resistance and velocity)
- **Chemical Features** : pH, alkalinity, and acidity, DO, Sediment oxygen demand, Nutrients, Toxic chemicals
- **River Ecology** : Terrestrial ecosystems, Reptiles and amphibians

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3. Historic of Paradigm Shift in River Maintenance and Management

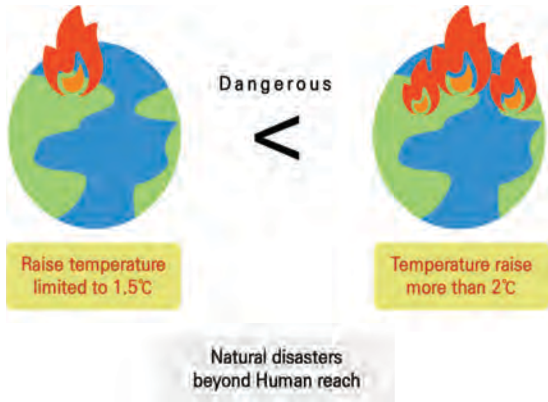
3.1 Diagnose river maintenance and management problems
3.2 Paradigm shift in river maintenance and management
3.3 Paradigm shift in KOREA

3.1 Diagnose river maintenance and management problems

▪ The increase in extreme rainfall events due to climate changes is a reality

- In 2021, floods across Western Europe, including Germany and Belgium, resulted in a total 242 deaths, with rainfall equivalent to the amount of precipitation per day for a normal month.

Altenahr, Germany flood(2021.07.16)



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3.1 Diagnose river maintenance and management problems

▪ Aspect of flood safety problem

<New Orleans levee failure by Katrina hurricane>

- As a dyke was built along the river, the sediments flow of the Mississippi river was blocked. Sediments were pushed and accumulated in the Gulf of Mexico in front of the city of New Orleans, causing the city to become lower than sea level
- Increased frequency of storm due to global warming
- Ground subsidence due to embankment construction and using groundwater
- Levees failed by the hurricane Katrina and it made huge catastrophe

✓ Even if the era of national development is over, the era of maintenance has not arrived yet.

✓ Now, almost 1/3 of the flood damage is due to the collapse of the levee or overflow, and the proportion is gradually increasing along with the aging of the facilities.

New Orleans levees failure

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3.1 Diagnose river maintenance and management problems

▪ Aspect of eco friendly river and environments

- Recently, the use of water-friendly spaces by citizens is increasing.
- In order to maximize the welfare of residents amidst the constraints of national finances, it is necessary to decide whether to maintain or improve performance or re-naturalize.
- There are also waterside parks that continue to repeat flood damage and restoration

Kolomenskoye riverside (Moskva)

Eco friendly river bank<Creative Nature>

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3.1 Diagnose river maintenance and management problems

▪ Difference between general SOC and river SOC

General SOC	River SOC
• Detailed and faithful design book with the quantity to be managed.	• The management extension is extensive and the design data is poor.
• Accidents can occur during normal or year-round.	• The need for a levee may not be felt for decades.
• A range of regular loads are applied .	• Sudden large hydraulic burden occurs only in case of large-scale flooding.
• Defects of facility function can be checked to some extent by physical or test operation.	• Difficult to understand internal condition because it is paved with vegetation or concrete.
• Catastrophic damage can occur limited to users.	• Spread of damage to people and property over a wide area.
• A specialized agency mainly handles maintenance work and responsible is clear.	• The state or local government is in charge of maintenance, and it is difficult to liability for compensation.

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3.2 Paradigm Shift in river maintenance and management

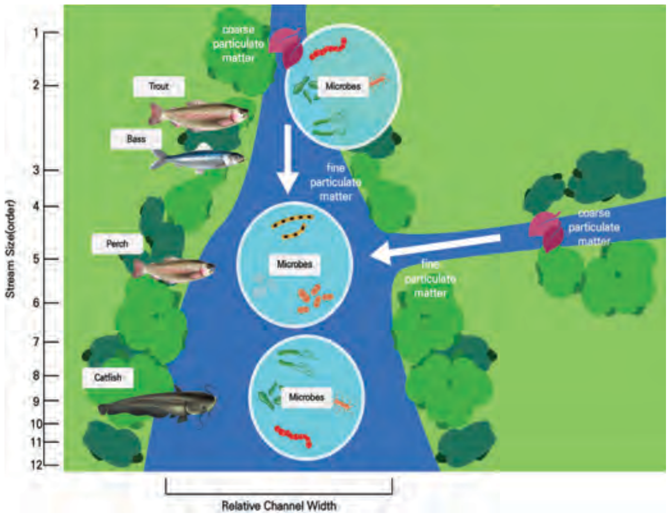
▪ Water Continuum Concept (WCC)

<River Continuum Concept>

Robin L. Vannote(1980)

-Physical parameters & Biological factors

-**LIMITATION**: NO Riverine Disturbances and Irregularities (e.g. Dam, Flood etc.)



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3.2 Paradigm Shift in river maintenance and management

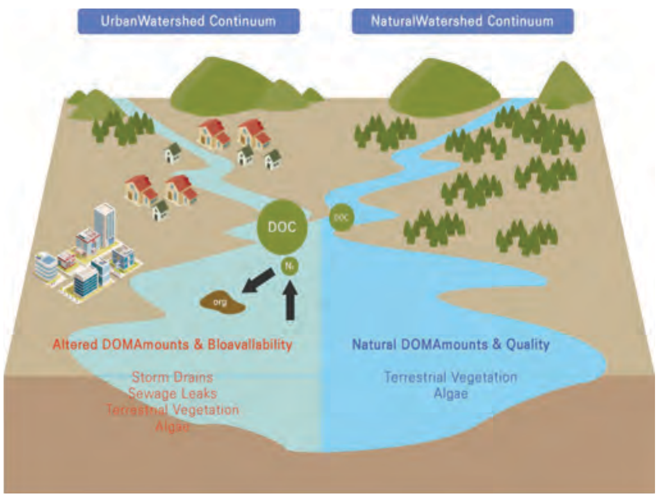
▪ Water Continuum Concept (WCC)

<Urban Watershed Concept>

S. Kaushal & Kenneth T. Belt* (2012)

- Natural River vs. Engineered River
- Transformer & Transport of materials and energy

*USDA Forest Service



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3.2 Paradigm Shift in river maintenance and management

▪ Water Continuum Concept (WCC)

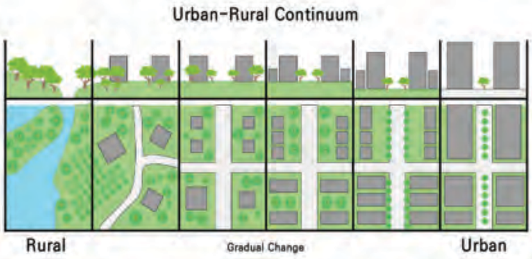
<Urban-Rural Continuum>

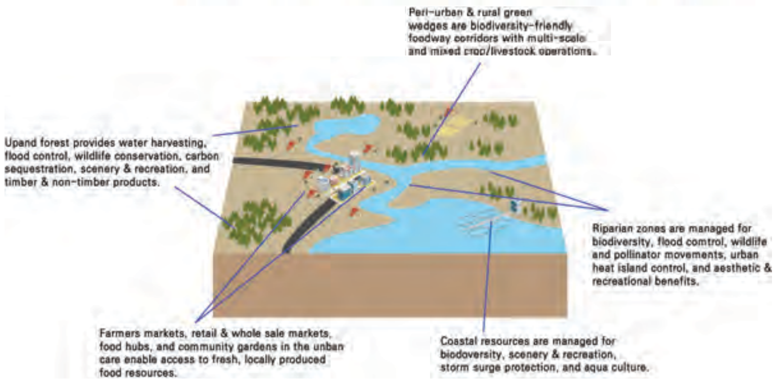
Urban, Peri-urban, Rural**

-Rural- Urban Continuum Codes(1974)***

**UN Habitat(2020) etc.

***USDA, Economic Research Service





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3.2 Paradigm Shift in river maintenance and management

▪ History of River Management

Hard and/ or gray infrastructure	built structures and mechanical equipment, such as embankments, reservoirs, groins, riprap, pipes, pumps, water treatment plants, and canals
Green infrastructure	strategically planned network of natural and seminatural areas that are consciously integrated into spatial planning and territorial development, and are designed and managed to deliver specific infrastructure services and to provide a range of co-benefits in both rural and urban settings(European Commission n.d.)
Nature-based solutions	"actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al. 2016)
Natural river management	iterative, science-based, and participatory water resources management focused on harnessing the functions and services of natural river systems while reducing hazard impact

SOURCE: Browder et al.(2019)

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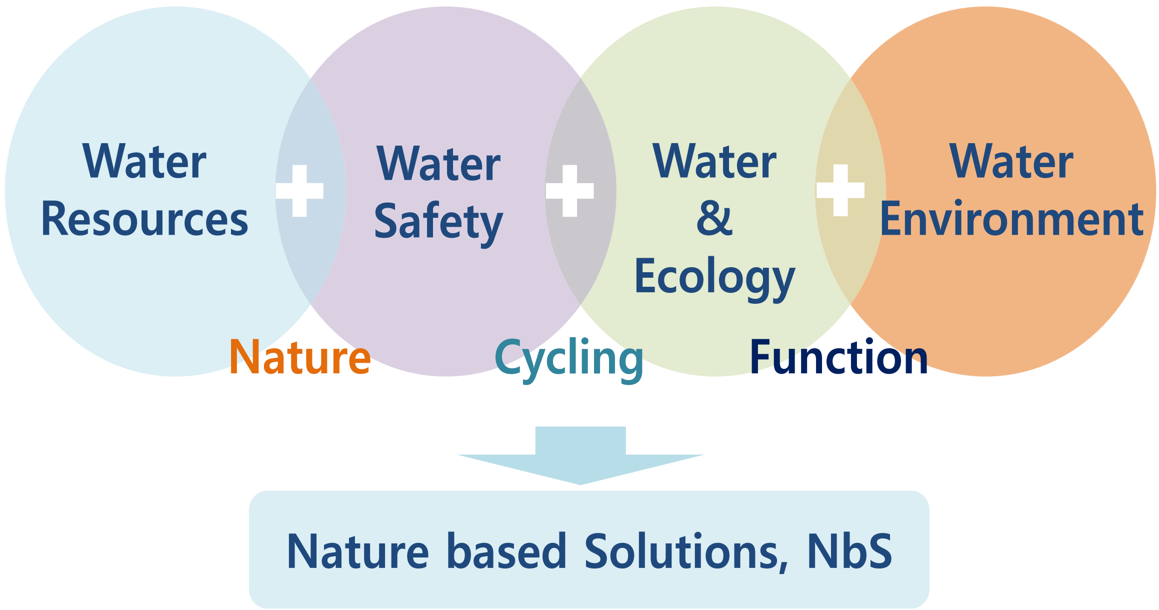
3.2 Paradigm Shift in river maintenance and management

▪ Nature based Solutions, NbS



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3.2 Paradigm Shift in river maintenance and management

▪ Nature based Solutions, NbS

Type	Basic concept	Targets (scope)	Notes
NbS	Solving socio-environmental issues using ecosystem	Socio-environmental issues	- Emerged from 2000 as an overarching concept of existing similar ones (utilization and mimicking of ecological functions) - Introduced to Korea since the late 2010s, its meaning and significance not established yet
EE	Integrated design of human society and ecosystem	Environmental issues	- Started in USA since 1960 as a new engineering discipline - A relevant academic society created in Korea, 2013
Eco-DRR	Reduction of disaster risk by protection and management of ecosystem	Disaster risk management	- Another type of NbS - May be called DRR-green infra for better understanding and dissemination
GI	(narrow meaning) Urban storm water management by mimicking nature (broad meaning) Solving socio-environmental issues by ecosystem management	- Urban stormwater management - Ecosystem management both in built and natural environments - Disaster risk management	- Started in USA, 1980s as broad meaning, but focused by USEPA water quality group on the quantitative and qualitative treatment of stormwater - The broad meaning is preferred in Europe as BGI - Extended to disaster risk reduction management in Europe and Japan (DRR-green infra) - Adopted to Korea since the late 2000s (MOE/Korea Univ. 2009) and used mixed with the concept of LID
LID	Maintaining hydrological condition at pre-development	Land development works	- Started in USA since 1990s as a BMP (now being gradually merged to GI) - In Korea, relevant national research projects started since 2010 (Technical guidelines published by EPA)
CRT	Use of natural material in river works and restoration of natural river morphology	River restoration works	- Utilized in German-speaking countries in Europe since the 18century as river work techniques (soil bioengineering) - Adopted in Korea in the mid-1990 by MOE/KICT and disseminated nationwide soon

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3.2 Paradigm Shift in river maintenance and management

▪ The natural river management concept

Item	Description
Definition	• Low-interference management of rivers to optimize river use and to reduce river-related risks, while respecting the nature dynamics and flow of freshwater, sediment, and nutrients, and peoples' dependence on these at the basin scale.
AIMS	• Facilitate sustainable social and economic development by advocating a short- as well as a long-term perspective on effects on the natural river system. • Define optimal management strategies and set of interventions for long-term sustainable river management. • Give guidance on optimizing the engineering process to arrive at a coherent set of interventions that constitutes the best investment option in the whole basin for achieving the desired objectives.

SOURCE: Browder et al.(2019)

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3.2 Paradigm Shift in river maintenance and management

▪ Opportunities presented by natural river management

Project Aspect	Opportunities
TECHNICAL	• More resilient infrastructure systems • Multifunctional • Simpler operation and maintenance options
SOCIAL	• Communities empowered through participation • Less water and air pollution • Lower health care costs • Social benefits, such as increased personal well-being
ECONOMIC	• Lower implementation costs • Multiple monetary and nonmarket benefits • Greater access to alternative financing resources
ENVIRONMENTAL	• Biodiversity protection • Ecosystem conservation and restoration

SOURCE: Browder et al.(2019)

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3.2 Paradigm Shift in river maintenance and management

▪ Opportunities presented by natural river management

- Natural river management provides river basin managers, policy makers, and funding agencies with a vision and a rationale for deciding where to spend available funds while optimizing the use of natural functions of rivers.
- Natural river management offers the flexibility to cope with future uncertainties associated with climate change and socioeconomic developments. This provides opportunities to learn by doing, to overcome technical complexity and the unpredictability of the river response to interventions.
- Natural river management provides the basis for starting a planning process that proactively chooses where to intervene, in accordance with a risk-based approach, and where to let the river follow its natural course.
- In practice, natural river management provides arguments based on natural river functioning to refrain from actions with adverse side effects on the upstream and downstream reaches, and to cease actions that will not be sustainable because of lack of long-term funding for operation and management.

SOURCE: Browder et al.(2019)

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3.2 Paradigm Shift in river maintenance and management

▪ Criteria to judge a Paradigm shift

Judgment factors	Criteria for judgment	Representative cases
Changes in scientific recognition and theories	- Development of river-related theories, research-related technology and methodologies, etc.	- Making scientific system and collecting information for nature-type river arrangement methodologies, river restoration methodologies, and river management
Changes in conventions, concepts, thoughts and sense of values	- Policy agendas - Social phenomena and demands, etc.	- River development for economic development and growth - Objections for dam construction, efforts for water quality preservation, water dispute, etc.
Possibilities to judge visible changes	- Sustainable related businesses - Planning, investigation, legislation and amendment of regulations, etc	- River improvement business(es), nature-type river arrangement methodologies, etc. - Investigation on river basin area, long-term comprehensive plan for water resources, dam development plan, legislation and amendment of the River Act and the Dam Act, etc.

SOURCE: Browder et al.(2019)

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3.2 Paradigm Shift in river maintenance and management

▪ Paradigm shift in water sectors

- **'Harmoni COP project',** stakeholders in diverse fields such as NGOs, local governments, policy makers, and water-related industries participate in the water management for river basin areas.

- **'NeWater project'** has the purpose to design clear and open social learning based on the interests of stakeholders, mutual cooperation, and trust.

- **'SWITCH project'** works to improve water management policies in 8 urban areas in Europe, Asia, Africa, and Latin America and it acknowledges interest in the circulation system and the institutional diversity of stakeholders

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3.2 Paradigm Shift in river maintenance and management

▪ Urban water management factors in the perspective of SWITCH

Current issues	Perspectives of SWITCH
Improper concept of the 19th century: Conventional urban water circulation system	Urban water paradigm shift for the 21st century.
Urban water quantity: flooding and drought	Heavy rainfall management
Inequality and discrepancy according to urbanization	Effective water supply and use
Reduction of wastewater and expansion of hygiene facilities against the ecological and public health damages	Effective use of water in consideration of hygiene and wastewater treatment
Development and operation of natural systems and the treatment process for effective urban water management.	Integration of urban water environment and planning process
Securing governance and a timeliness establishment of systems.	Governance in consideration of water value and changes in systems

SOURCE: SWITCH and the Paradigm Shift: First joint project ever between a UN organization and the European Commission, October 14, 2008

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3.2 Paradigm Shift in river maintenance and management

▪ Paradigm shift in water sectors

1970s	1980s	1990s	2000s
Recognition of water and environment	Taking actions against water problems by country	Setting international visions and goals for water management	Implementation of goals and international cooperation
- Recognized water problems as pan-global issues.	-Supply for clean water - Water supply and improvement of hygiene	- Sustainable development - Development and environmental preservation *1990 : Safe water and hygiene *1992 : Water and sustainable development, environment and development *1996 : Supply for clean water * 1998 : Water and sustainable development	- Reacting to climate change - Integrated water management * 2000 : Sustainable water resources management * 2003 : Integrated water resources management * 2006 : Strengthening practical capacity * 2009 : Water and disasters * 2012 : Actions for climate change
Water utilization/ water quality	Water utilization/ water quality	Water utilization/ environment (water quality)	Water utilization/flood control/ environment (water quality)

SOURCE: Park(2013)

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3.3 Paradigm Shift in KOREA

▪ River maintenance and management in Korea

- **River management system**

- The maintenance of national rivers is performed by the MOLIT<Ministry of Land, Infrastructure and Transport>, local governments and consigned operations.
- The MOLIT has 7 river management departments in the land management office to directly manage the levee reservoirs of the national rivers(Han River, Geum River, Yeongsan River, Seomjin River and Nakdong River)
- Local government manage independent rivers such as tributaries of national river and also responsible for the floodplain of national rivers.
- Korea Water Resources Corporation, a consigned operator, operates and maintains 16 multi-functional weirs, cultural centers, flood control areas, and facilities.

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3.3 Paradigm Shift in KOREA

▪ **River maintenance and management in Korea**

- **River facilities maintenance**

- It refers to the task managing the facility in a normal state from installation until dismantling
- It includes inspection, diagnosis, performance evaluation, maintenance, reinforcement work, and administrative work according to the type of facility in daily and regular management tasks.

- **Performance management**

- Rather than limiting to the function corresponding to the original installation purpose, it is a comprehensive and dynamic concept that includes utility and aesthetic value according to the use of facilities.

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3.3 Paradigm Shift in KOREA

▪ **River maintenance and management in Korea**

- **Expansion of recent concepts**

- Prevention of accidents due to damage or deterioration of facilities.
- Maintaining the lifespan of facilities and suppressing rapid cost.
- Prepare to ensure that the function is fully demonstrated even in the event of a special situation such as a disaster
- Compliance with legal obligations stipulated for the safety of citizens
- Provides user convenience, comfort and safety
- Maintain the aesthetics so that the facility is in harmony with the surrounding environment

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3.3 Paradigm Shift in KOREA

▪ National river maintenance and management Standard

- Set and announce minimum maintenance standard for each type to meet common standards

<Major component of the Standard>

- Management level designation
- Implement reinforcement
- Management history record
- Inspection, diagnosis, etc.
- Management group settings
- Establish of management measures

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3.3 Paradigm Shift in KOREA

▪ National river maintenance and management Standard

- Set up a management group of systematic maintenance

Critical flood Safety facilities	- River facilities designated as Class 1, Class 2, Class 3 facilities in accordance with Article 7 of the Facilities Safety Act. - Include gates, sluice gates, levee, multi-functional weirs, drainage pumps and flood control areas.
River use facilities	- River facilities installed to help the convenience and safety of river users and to enhance the use, attractiveness of rivers - Eco-friendly district, bicycle path, public relations hall, observatory and resting facilities, parks, sports facilities, trails, walking trails, camping sites, eco-learning facilities
Other management facilities	- Among other river facilities, it is necessary to systematically manage it to maintain the function of the river. - Channels, reservoirs,

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3.3 Paradigm Shift in KOREA

▪ Changes in maintenance policy according to time

I. 1960~1960
Mainly discussing maintenance responsibilities and roles

↓

II. 1995(after establishment of the 'facility safety Act')
Early response to public concern about flood safety

↓

III. 2007(after the full revision of the River Act)
Refinement of river maintenance concept and work method

↓

IV. 2012(after the national river maintenance project)
Establishment of the current maintenance system

↓

V. 2012(after the national river maintenance project)
Discussion on the introduction of performance-oriented strategic maintenance

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3.3 Paradigm Shift in KOREA

▪ Comparison of world trend of the times with Korea river polices

Section		1948~1951	1952~1960	1961~1977	1978~1988	1989~1998	1999~2006	2007~present	Future
Korea	River policy paradigm	1948~1951	1952~1960	1961~1995			1996~present		Future
		Passive administration of river affairs	Passive repair and maintenance of rivers	Active river development			Active river development		Creation of river values and expansion of river governance
	Characteristics by period	1948~1951	1952~1960	1961~1977	1978~1988	1989~1998	1999~2006	2007~present	Future
		Beginning stage of river policy	Restoration from Korean War and flood damages	Full-scale river development	Conflicts between river development and environment conservation	Conservation of water quality and mediation of water conflicts	Maintaining natural type rivers and providing basis for informatization	Restoration of river environment and multi-purpose use of rivers	Creation and vitalization of river culture
		Streamlined administration of river policies for river use	Restoration and repair from Korean war and flood damages	River development to support economic development	River development to support economic development	River development and resolving water conflicts	Active river improvement for nature conservation	Active river improvement for river restoration	Creative river management in consideration of regional characteristics
		Permission and authorization related to river-related works	Restoration of destructed rivers and tap water/ wastewater pipelines, securing electricity	Repair and maintenance of rivers and construction of large scale dams	Developing main stream of Top 4 Rivers of Korea, maintaining water quality	Developing middle-sized dams and improving natural type rivers	Management connected with dams, informatization for river management	Multi-purpose river management in consideration of river restoration	Characteristic river management through the utilization connected with surrounding regions

Source : Park(2013)

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3.3 Paradigm Shift in KOREA

▪ **Policy implication**

1) Relation between nature and human beings
2) The expansion of the purpose for river management and diversification
3) The scale that has been changed from large to small
4) Diversification of participants
5) The trend of cutting-edge techniques and globalization of river management
6) A paradigm change according to policies, social and technical circumstances of the times

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4. Prospect of river maintenance and management

4.1 Paradigm shift in river maintenance and management
4.2 Future of the river maintenance and management

4.1 Perspective of paradigm shift from existing polices

▪ Review of the perspective of paradigm shift

Perspective on comparison	Present	Future
Creation and vitalization of river culture	Uniformity and conformity	Creativity and diversity
Vitalization of sound river culture	Regulation and conservation	Safety and convenience
Environmental conservation of rivers and creation of new values	Functionality and environmental properties	Harmony and value
Vitalization of regional economics	Separation and management	Connection and utilization
Vitalization of regional governance	Leading role and responsibility	Voluntary participation and cooperation

Source : Park(2013)

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4.1 Perspective of paradigm shift from existing polices

▪ Prediction on a paradigm shift in water sectors

✓ **Prediction for a Paradigm Shift according to the Trend of the Times**

✓ **It is predicted that people try to understand the whole ecological system in an integrated way in consideration of "human beings, technologies and environment", which will be continuously expanded**

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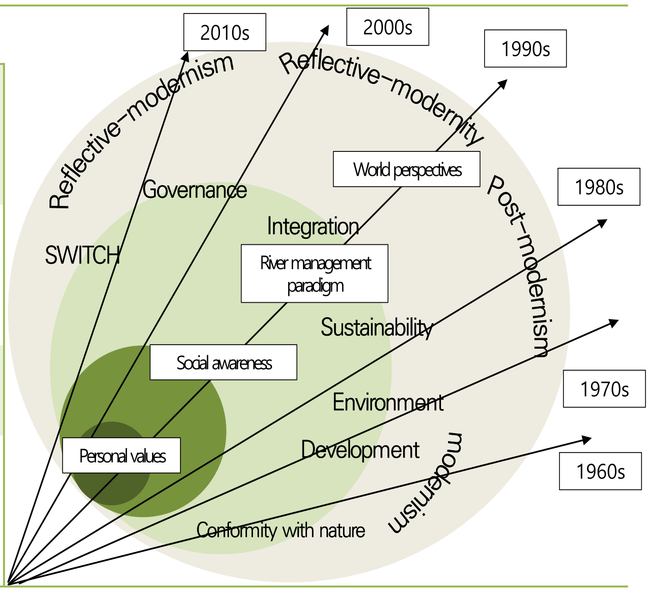
4.1 Perspective of paradigm shift from existing polices

▪ Prediction on paradigm shift in river maintenance and management

Spatial	Conceptional	Related factors
Global level	World view	Cooperation, information, support, exchange, coordination, conference
National level	Sectional paradigm	Experts, educators, researchers, believers, conference, media press
Regional level	Social recognition	Education, institution, environment
Personal level	Personal values	Phenomena, recognition, thoughts, values, experience, belief



Source : Park(2013)

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4.1 Perspective of paradigm shift from existing polices

▪ Prediction on a paradigm shift in water sectors

Section	Existing concepts	Future concepts
Purpose of river management	• To maintain existing river functions - To maintain water utilization, flood control, and river environmental functions • Ultimate purposes - To enhance public interests	• New river functions will be added. - Landscape/ecological/cultural functions will be added. - Ultimate purpose: Concepts of harmony with nature and coexistence will be added
Scope of river management	• Riverside foreland section - River area, river facilities, and river water	• Will be extended to nearby areas - Harmonious collaboration with nearby areas
Subject who conducts river management	• Top-down management led by Government - Advantageous in terms of conformity and securing sense of responsibility - Disadvantageous in terms of diversity by section and region	• Utilization of regional water governance concept will be added - Diversity and regional characteristics will be considered. - Clear motivation and voluntary participation are required.
River management method	• One-way management led by river Management according to unified standards and regulations - Insufficient consideration on river users and collecting their opinions	• Two-way management in consideration of river users - Quick communication and collecting opinions - Consideration on the socially weak class - Pursuit for diversity, creativity, safety, and convenience

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4.2 Future of the river maintenance and managament

▪ Policy Direction for future river management

Section	Description	
River management paradigm	Creation of new river values and expansion of governance for river management	
Theme of implementation	Humans' pursuit of happiness, creation of new river values, and coexistence with human beings	
Perspectives of implementation	<Purpose of implementation>	<Policy directions>
Humans' pursuit of happiness	Enhancing mental satisfaction	Creation and vitalization of river culture
	Enhancing behavioral satisfaction	Vitalization of sound utilization of river
New understanding on surrounding environment	Creation of new values of river environment	various functions of rivers
	Enhancement of vitalization of regional economy	Vitalization of regional economy through the collaboration with nearby regions
Basis for implementation	Vitalization of network among social members	Vitalization of regional governance

Source : Park(2013)

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4.2 Future of the river maintenance and managament

▪ Policy Direction for future river management

Section	Current	Future
World trend of the times	• Post modernism -Human-centered humanism -Ecology and environment-centered	• Reflexive modernism -Emphasis on multitudinous thinking and pluralistic values -Pursuing happiness and coexistence with environment
A paradigm in water sectors	• Sustainable water management in water sectors -Pursuing sustainable development and conservation	Expansion of integrated water management and water governance -Pursuing harmony among governance, human beings, and ecology.
A river management paradigm	• Restoration of river environment and multi-purpose utilization of rivers	• Creation of new river values and river management -Expansion of governance
- River environment	• Conservation and restoration of river environment	• Rediscovery of the values of rivers and surrounding environments
- River utilization	• Water-friendly, rest, and ecological function-centered	• Diversification to health, residence, arts, and culture
- Management methods	• One-way and top-down management led by the government	• Two-way and bottom-top management with regional governance
- Management technologies	• Development and introduction of cutting-edge technology and techniques	• Universalization and commercialization of cutting-edge technology and techniques

Source : Park(2013)

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5. Conclusion

5.1 Conclusion

5. Conclusion

▪ Conclusion

- Rivers are very valuable resources to people and environment. And river maintenance and managements are performed to manage rivers appropriately and contribute to the promotion of public welfare.
- Nowadays river maintenance and managements have changed according to the demands and necessity of times.
- Many countries are dealing with new paradigm shift of river maintenance and management by enacting new policy and system.
- Natural river management is most popular concept of river management. And it offers the flexibility to cope with future uncertainties associated with climate change and socioeconomic developments.
- Finally Ecologic, environment, people's usability, climate change, water use and flood safety , etc. are all considered to new river maintenance and managements.

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Thank you very much

River Infrastructures Maintenance and Management

IWRM

River Infrastructures Maintenance and Management

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United Nations Educational, Scientific and Cultural Organization | International Centre for Water Security and Sustainable Management

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2. Global situation of river infrastructures Maintenance and Management
3. Paradigm shift of river infrastructures Maintenance and Management
4. Conclusions

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1. Introduction

1.1 Overview of river infrastructure maintenance and management

1.2 What is river infrastructures

3

1.1 Overview of river infrastructure maintenance and management

▪ River infrastructures maintenance and management

- River infrastructures can be defined as **facilities** and **structures** that support all activities related to river.
- Many infrastructures that exist along river stream but few of them are listed and recognized as an important part in the river system.
- The condition of assets that support various river functions should be considered since it determines the sustainability of water supply system for many regions.
- Starting from upstream, **dam and reservoir** functioned as flood control that protect the downstream area from flood and inundation.
- Moreover, the water can be distributed to the downstream area for many requirements, such as **irrigation system, hydro power, industrial process**, etc.
- In alluvial river, there were erosions that occurs as river flow velocity could transported soft soil numerously.
- Hence, the **riverbank protections** were built in order to protect the nearby river infrastructures.
- Therefore, **river infrastructures recognition** as preliminary assessment to the river asset management needs to be conducted to maintain the whole river system.

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1.1 Overview of river infrastructure maintenance and management

▪ Maintenance and management?

- Preserving the function of the completed facility
- Enhance the convenience and safety of facility users
- Checked and maintained the facilities on a daily basis.
- Restore the damaged area to its original state.
- To engage in activities necessary for the improvement, repair, and reinforcement of facilities required according to elapsed time.

Maintenance: process of maintaining river functions or preserving the state of being maintained.
Management: process of dealing with or controlling river facilities and structures

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1.1 Overview of river infrastructure maintenance and management

▪ Objective of river infrastructures maintenance and management

✓ Improve socio-economic outcomes

✓ Improve environmental health

✓ Reduce water losses from evaporation

✓ Increase water access security for irrigation

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1.2 What is river infrastructures

▪ River line infrastructures <Water use>

- **<Dam>** It is designed to block river flow in certain area, thus the water will be accumulated in the reservoir as fresh water sources.
- **<Weir>** It is one of the most important infrastructures in irrigation systems as it requires water supply which taken from river and it is widely used to elevate river water level as irrigation system requirements.
- **<Reservoir>** It is linked to dam as a river barrier; thus the water can be accumulated at the upstream area.
- **<Irrigation Network>** It is designed to distribute water into cultivated land.




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1.2 What is river infrastructures

▪ River line infrastructures<Flood Safety>

- **<Levee>** It is one of infrastructure that be built along the river stream in order to protect nearby area from flood and inundation
- **<Flood Plain>** It is formed naturally based on the flood that occurs in the river
- **<Inspection Road>** It is required in order to maintain river infrastructures that may need some heavy equipment
- **<Bridge>** In order to connect the separate area due to river stream, the bridge is constructed by considering the span of the river




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1.2 What is river infrastructures

▪ River line infrastructures

- **Water gate**: It is a generic term for structures through which water flows in and out for the purpose of passing or controlling the flow rate.

<Management and maintenance>
① In the event of a flood, inspection and repair are carried out to maintain the same or higher stability than the levee.
② It is an important river structure that has the function of a levee by closing the gate during flooding, so it must be maintained in good condition to fulfill its function.

<Inspection>
- Inspect the damage to the sluice structure before, during, and after the flood period, and check the ground elevation and subsidence of the embankment around the sluice gate due to damage to the structure.

<Repair>
- Whether to repair, reinforce, or renovate a sluice gate is determined based on the evaluation results on the stability of the sluice gate and system, the scale of damage and frequency of occurrence, etc.

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1.2 What is river infrastructures

▪ River line infrastructures

- **Buried box culvert** : A structure consisting of conduits, battlements, wing walls, gutters, etc. with circular cross-section gates installed across the river levee for drainage

<Management and maintenance>
① In case of flooding, inspection and maintenance are carried out to maintain the same or higher stability same like levee
② Like the sluice gate, the culvert has functions as an levee by closing the gate during flood, so it must be maintained in good condition to fulfil its function.

<Inspection>
- Inspection of culvert is carried out within the range that can be visually inspected before and after the flood season and in accordance with detailed investigation.

<Repair>
- As for the repair of the culvert, it is decided whether to repair, reinforce, or replace according to the evaluation results on the stability of the culvert and the system, the scale of damage and the frequency of occurrence, etc.

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1.2 What is river infrastructures

▪ River line infrastructures

- Passage box: A facility to provide convenience for normal transportation and close it in case of a flood to prevent flood inflow into floodplain or backflow of high tide.

<Management and maintenance>

① In the event of a flood, inspection and repair are carried out to maintain the same or higher stability than the levee.

② It is an important river structure that has the function of a levee by closing the gate during flooding, so it must be maintained in good condition to fulfill its function.

<Inspection>

- In accordance with the water gate and special levee, inspected for cracks and damage to the structure, damage to the doorway joint and door frame, damage to the switchgear, etc .

<Repair>

- For the repair of the passage box, it is decided whether to repair, reinforce, or renovate them according to the evaluation results on the stability of the box and surrounding structures, the scale of damage, and the frequency of occurrence.

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1.2 What is river infrastructures

▪ River line infrastructures

- Drainage pump: A facility installed to forcibly drain water from drainage channels such as streams and spillways to the mainstream during heavy rains such as torrential rain and typhoons.

<Management and maintenance>

① In order to prevent flooding of major facilities such as houses and farmland, inspection, maintenance, and repair are carried out so that functions are preserved even in emergency situations such as lightning strikes and power outages.

② As a disaster countermeasure facility in preparation for flooding, it should always be maintained in good condition as it has a large impact on the local community in the event of loss of function, performance, or loss.

<Inspection>

- During flood and thawing seasons, damage such as ground subsidence, structural cracks and sedimentation, and normal operation of mechanical and electrical equipment should be checked.

<Repair>

- The maintenance of the drainage pumping station is judged through repair, reinforcement, or remodeling (replacement) according to the evaluation results of the stability of the drainage pumping station and the surrounding embankment, the scale of damage, and the frequency of occurrence.

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1.2 What is river infrastructures

▪ River line infrastructures

- Pumping district : It is a kind of water source facility for use as agricultural water by installing a pump and pumping water when natural irrigation is not possible because the water level of a river or lake is lower than that of an irrigated area.
- Intake pipeline: It is facilities refers to water pumps and protection facilities required to take in lakes, rivers, or groundwater

Management and maintenance

① In the short term, it aims to eliminate and repair the cause of failure in advance, and in the long term, to improve, update, and inspect safety facilities for poor facilities, and to implement security management appropriate to the site.
② In order to achieve the purpose of pump operation most efficiently by maximizing the facility's capabilities, it is important to maintain the function of each facility in a good condition and to conduct appropriate operation management in accordance with the performance characteristics and operating conditions of the manufacturing facility.
③ The facility is maintained through maintenance and operated over a long period of time, so when the limit is reached due to deterioration of reliability, increased frequency of maintenance, and increased maintenance cost, the time to review facility renewal is determined through diagnosis.
④ Appropriate operation management plan and maintenance/repair plan by reviewing the performance, characteristics, and operating conditions of all facilities in order to maintain each facility function normally and safely and economically manage the operation to achieve the operation purpose of the pump establish and manage

1.2 What is river infrastructures

▪ River line infrastructures

<Inspection>
- According to the inspection cycle, check whether damage caused to structures and pumping equipment, etc., and whether mechanical and electrical equipment are operating normally.

<Repair>
- It is a facility similar to a drainage pump station and a sluice gate consisting of a building, a pump and electrical equipment, and an intake gate, and is carried out using the maintenance method of the manual.

Division			Period	Inspection
Inspection	Regular Inspection	Daily Inspection	1 per day	Handling defect
		Monthly Inspection	1 per month	Cleaning, oiling
		Annual Inspection	1 per year	Conducted until 1 month before the flood season
		Rest check	After long term rest	maintenance operation
	Inspection on operation	Before operation	Ready for operation	Manipulation and operation
		On operation	Operation	monitoring and inspection
		After operation	After operation	Problem in device
	Emergency inspection		Flood, earthquake, thunder	malfunction and damage
Repair	Regular repair		1 per 5years	wear, gap measurement, parts, replacement
			1 per 10years	Condenser, Overhaul
	Temporary repair		Before regular maintenance	found through daily inspection

1.2 What is river infrastructures

▪ River line infrastructures

- Detention pond: Detention pond is a facility installed on the side of a river among facilities with the function of temporarily storing the amount of flooding in the river.

<Inspection>
- Inspection of damage to structures and embankments that occur before, after, and during the flood season.
- Considering overflow facility, discharge facility, river levee, common inspection.

<Repair>
- Repairs of detention pond are carried out using the method of repairing and reinforcing levee and water gates.
- Considering overflow facility, discharge facility, river levee, common repair.

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1.2 What is river infrastructures

▪ River line infrastructures

- Submerged groyne: A structure installed on the front part of a lakeshore or riverbank to protect the levee from erosion by running water by controlling the inspection flow direction and flow velocity.
- Bridge: In order to connect the separate area due to river stream, the bridge is constructed by considering the span of the river

<Repair>
- In the case of road bridges and railway bridges, since the vibration of the abutment is severe, gaps and voids may occur in the body, which causes the destruction of the embankment due to water leakage.
- During the pre-flood inspection, an external inspection is performed to identify cracks in the structure near the abutment, and, if necessary, a joint investigation is conducted.

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1.2 What is river infrastructures

▪ River line infrastructures

- **Water- friendly facilities: Refers to infrastructure, convenience, and entertainment facilities installed in rivers to perform the smooth functions of each space, such as plazas, resting areas, and green areas.**

❖ **Water-friendly facilities in the river space aims to maintain the facility under severe natural conditions such as immersion in water, sedimentation, and local scour of the river bed and to maintain the safety of users. Old and damage facilities should be replaced and maintained to improve the park landscape and provide convenience to the citizens.**

Division	Management details
Park facilities management	• Inspection and cleaning of various facilities (Pavement facilities, drainage facilities, bicycle paths and trails, auxiliary facilities and convenience facilities, sports facilities, lighting facilities, etc.) • Repair and maintenance of facilities • Parking lot management • Management of entry/exit space
Facility safety management	• Flood measures • Measures for river activity accidents • Management of hazardous areas

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2. Global situation of River Infrastructures Maintenance and Management

2.1 Necessity of developing river infrastructures maintenance and management
2.2 Korea river infrastructures
2.3 Global river infrastructures

2.1 Necessity of developing river infra maintenance and management

▪ Infrastructures management status

✓ **Change of demand → Rapid increase in demand for maintenance and performance improvement**.

- While infrastructure supply (investment) in OECD countries will be reduced, demand for maintenance and performance improvement is expected to increase rapidly (World Economic Forum, 14).

✓ **Changes in the management system → Transition from reactive management to preemptive management.**

- Developed countries shift the infrastructure management policy paradigm to preemptive management and promote innovation in maintenance systems for infrastructure life extension and efficient investment.

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2.1 Necessity of developing river infra maintenance and management

▪ Infrastructures management status

✓ **Changes in social and environmental conditions → Response to calamity and disasters and demand for life safety.**

- The demand for realizing a safe society in which people are actively guaranteed from welfare society and safety risks is a major trend

✓ **Diversification of infrastructure management methods → Introduction of smart maintenance methods.**

- It is necessary to change the management method of low cost and high efficiency and foster high value-added industries through the introduction of smart technology to infrastructure maintenance.

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2.1 Necessity of developing river infra maintenance and management

▪ Difference between common SOC and river SOC

Common SOC	River SOC
• Detailed and faithful design book with the quantity to be managed	• The management extension is extensive and the design data is poor
• Accidents can occur during normal or year-round	• The need for a levee may not be felt for decades
• A range of regular loads are applied	• Sudden large hydraulic burden occurs only in case of large-scale flooding
• Defects of facility function can be checked to some extent by physical or test operation	• Difficult to understand internal condition because it is paved with vegetation or concrete.
• Catastrophic damage can occur limited to users	• Spread of damage to people and property over a wide area
• A specialized agency mainly handles maintenance work and responsible is clear	• The state or local government is in charge of maintenance and it is difficult to liability for compensation

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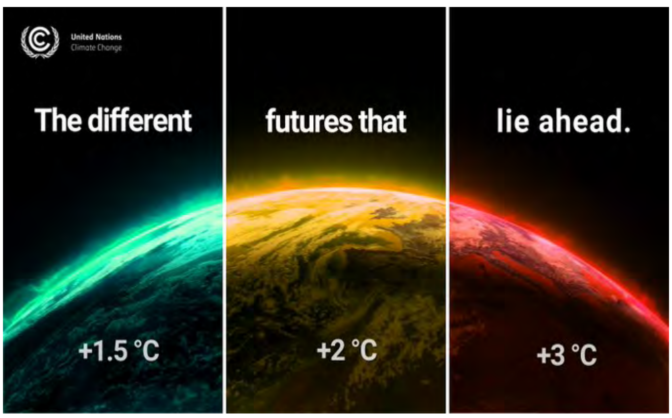
2.1 Necessity of developing river infra maintenance and management

▪ The reality of our climate

- ✓ As we all know, extreme weather due to climate change plays a huge role in the need to update and improve the bases of our community structure.
- ✓ Global warming has changed the whole game. As water temperatures rise, storms are growing stronger, and therefore cause greater and more expensive damage.
- ✓ Proactive movements to strengthen our infrastructure to protect our communities is now a must-have instead of a niceto-have.



Source :United Nation

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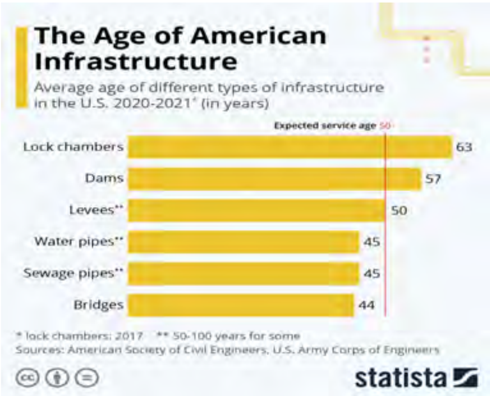
2.1 Necessity of developing river infra maintenance and management

▪ Aging problem of river infrastructures

- ✓ Aged infrastructure refers to a social overhead capital facility that has been constructed and needs to be processed, such as remuneration, after a certain period of use has elapsed.
- ✓ Improving the aging infrastructure has the effect of securing the safety of the people, who are direct/indirect consumers, and improving the quality of life.
- ✓ In terms of industry, markets such as inspection, diagnosis, repair, reinforcement, and reconstruction of social overhead capital facilities could be an alternative to the declining housing market in the construction industry.



Source :American Society of Civil Engineering, U.S. Army Corps of engineering

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2.2 Korea river infrastructures

▪ Korea river infrastructures

- Most Korean citizens today have access to water services, owing to the enormous investment made in water infrastructure.
- Recently, however, Korean society is facing issues concerning rapid deterioration and inappropriate management of urban water infrastructure.
- It has been determined that 72.3% of all water infrastructure will have deteriorated by 2035, which implies that the standard of water services then would be even lower than the current standard.
- Given the complex institutional system required for urban water infrastructure, the vagueness of management authority, limited maintenance budget, poor information management, and issues with maintenance methods are the high priority issues currently being faced

Source :Kang(2020)

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2.2 Korea river infrastructures

▪ Aging problem of river infrastructures in Korea

Deterioration rate of water infrastructures operating for more than 30 years

Infrastructure		In 2014		In 2025		In 2035	
		Rate	Average	Rate	Average	Rate	Average
Categories	Facility	(%)	(%)	(%)	(%)	(%)	(%)
Sewage	Pipe	14.1	10.5 27.8	38.1	45.3 50.4	51.5	67.6 72.3
arrangement	Sewage treatment equipment	6.8		52.5		83.6	
River facility	Riverbank	4.3	10.8	8.1	20.8	12.4	36.3
	Water gate	17.2		33.4		60.1	
Water supply	Pipe	9.6	20.6	35.9	50.3	65.4	84.1
	Filtration	18.8		50.0		93.8	
	Intake station	33.4		65.1		93.2	
Agricultural facility	Reservoir	95.9	70.0	97.7	80.7	99.2	94.0
	Pumping station	44.0		63.6		88.8	
Dam	Dam	34.4	34.4	59.4	59.4	75.0	75.0

Source :Kang(2020)

25

2.2 Korea river infrastructures

▪ Policy improvement direction to improve river infra maintenance system

< Past>

- River facilities focused on dimensions and completion rather than maintenance and longevity.
- The importance of facility maintenance was evaluated relatively low, so systematic maintenance was not managed under the plan.
- The amount of national river maintenance project budget is still only 74% of the appropriate amount.

< Revision>

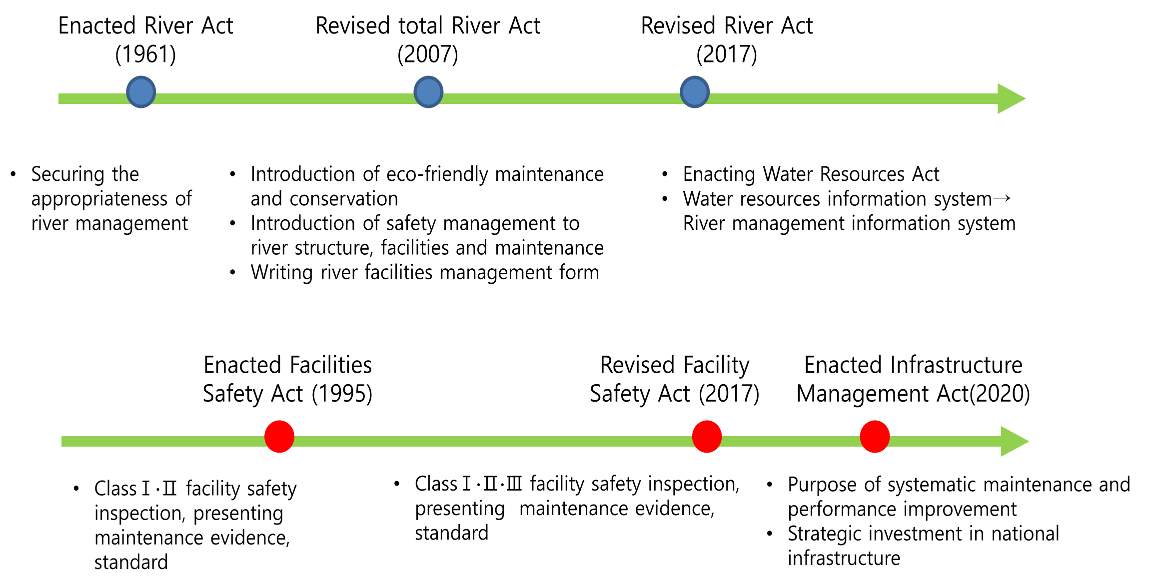
- Establish a cooperative and planned maintenance system.
- Improve maintenance performance in earnest.
- Expanding the foundation for smart maintenance technology.

Source :Kang(2020)

26

2.2 Korea river infrastructures

▪ Major changes in the「River Act」and the「Infrastructure Management Act」



Source :Lee(2021) revised

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2.2 Korea river infrastructures

▪ Act related to river infrastructures maintenance

Division	Terms	Definition
River Law	Maintenance	Activities such as inspection and maintenance to ensure that the function of the river can be maintained normally (Article 2, No. 6)
Infrastructure Management Act	Maintenance	In order to preserve the functions of the completed infrastructure and to increase the convenience and safety of users of the infrastructure, routine inspection and maintenance of the infrastructure, restoration of damaged parts, and maintenance and reinforcement of infrastructure required over time, etc. Conducting necessary activities (Article 2, Item 2)
	Performance Improvement	Activities to increase the value of infrastructure and extend its lifespan by repairing or changing the main structural part or external shape of the infrastructure (Article 2, 3)
Facility Safety Act	Maintenance	In order to preserve the functions of the completed facility and to increase the convenience and safety of facility users, routine inspection and maintenance of facilities, restoration of damaged parts, and activities necessary for the improvement, repair, and reinforcement of facilities required according to the elapsed time; (Article 2, No. 11)
	Safety Check	It refers to the act of inspecting risk factors inherent in a facility by a person with experience and technology by inspecting it with the naked eye or an inspection instrument, etc., and conducting regular safety inspections and Classified by precise safety inspection (Article 2, No. 5)

SOURCE: Lee(2021) revised Korea Ministry of Government Legislation.

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2.2 Korea river infrastructures

▪ Current status and performance of river infrastructures maintenance

Division	Management Status
National River	• Subdivided maintenance according to rivers and river facilities. • The national river main stream embankments and reservoirs are in charge of the land management office, and the flood plain are in charge of local governments (horizontal division).
Securing rate of river facilities safety	• Grade B or higher (Year 16: 93.5% → Year 17: 36.0% → Year 18: 96.3%)
Use of water-friendly district	• The waterfront districts created by the state within the main stream of the national river decreased significantly from 145.1 km² in 2015 to 52.4 km² in 2019, but the number of users per area is increasing every year.
Budget	• As a result of applying the maintenance budget calculation criteria after preparing the maintenance budget, the appropriate budget for maintenance and repair of the Ga River is around KRW 300 billion, but the appropriate budget for the existing work is estimated to be KRW 187.9 billion, so the actual secured amount for the project is only 74% of the appropriate amount.

Source :Kang(2020)

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2.2 Korea river infrastructures

▪ Policy improvement direction to improve river infra maintenance system

Asset Management Process	Country					
	Korea	Australia	USA	Canada	Japan	New Zealand
Asset Management Strategy	x	○	△	○	△	○
Check status of asset	△	○	○	○	○	○
Establish of service level considering cost	x	○	○	○	△	○
Asset valuation	x	○	○	○	△	○
Establish of long-term financing strategy	x	○	○	○	x	○

SOURCE: MOLIT of KOREA(2015)

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2.3 Global river infrastructures

▪ Netherlands

The Room for the River Program

- Netherlands has embraced climate realities and adapted their planning to create water management infrastructure that improves resiliency while decreasing water management cost.
- Indicated Issue : The river no longer has space to flow, causing erosion and floods
- Goal : Reduce flooding and erosion while creating extra benefits
- Solution: Create more space for the river to naturally flow
- Result : By creating more room for the river, water levels lowered and extra space was created for habitat and recreation

Room for the river in Netherlands

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2.3 Global river infrastructures

▪ USA

Expansion of investment for aging river Infrastructures.

- As the aging of infrastructure such as waterways progresses to a serious level, practical problems such as the collapse of bridges are encountered.

<Current Situation>

- In the United States, about 40,000 kilometers of waterways and 239 floodgates are in operation, and about 50% of ships have experienced congestion due to the aging hydrological system.

<Evaluation>

- As a result of the USCE infrastructure evaluation, the safety level due to aging of facilities is serious (grade D of waterway facilities (bad), as of 2017 years

<Improvement>

- The lifespan of the facility is lengthened, and repair and reinforcement are carried out quickly.

<Investment Plan>

- Adopting the improvement of old facilities as a " new deal policy" and inducing private cooperation to prepare an investment plan for public infrastructure and raise funds

SOURCE: KOREA MOLIT(2020) revised

32

2.3 Global river infrastructures

▪ Japan

Response through the establishment of a total plan and implementation system

- With the facilities aging more than 50 years increases since the construction of intensive river management infra in the 1970, 1980, resulting in a rapid increase in maintenance costs

<Current Situation>

- When it reaches 2030, 60% of river management facilities are expected to pass more than 50 years after construction (National Land Transportation Report, 2012).

<Improvement>

- Plans to prepare a "Japanese Revitalization Strategy for 13 years" and conduct safety inspections and repairs using new technologies such as sensors, robots, and non-destructive inspections on major facilities and all old facilities by 2030.

<Implement>

- In order to cope with the '2013 Great East Japan Earthquake' and frequent extreame rains, the Framework Act on the Reinforcement of National Land was enacted.

<Maintenance Plan>

- Effective maintenance by establishing a 'Basic Plan for Infrastructure Lifetime' to cope with the aging of infrastructure in 13 years

SOURCE: KOREA MOLIT(2020) revised

33

2.3 Global river infrastructures

▪ UK

Establishing long-term strategies and investment plans to prepare flood measures

- The flood management facility is in good condition at the "normal" level, but the investment plan for performance improvement is insufficient.

<Current Situation>

- As of 2014, flood management facility grade is evaluated as C-(normal) level

<Strategic Plan>

- In 2015, the National Infrastructure Commission was newly established to evaluate infrastructure and prepare long-term strategies

* Preparation of measures to strengthen the flood of national standards for all local communities (2050).

<Action Plan>

- Establish the 'National Infrastructure Construction Plan' by establishing the Infrastructure and Projects Authority in 2016.

SOURCE: KOREA MOLIT(2020) revised

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2.3 Global river infrastructures

▪ AUSTRALIA

Presenting business priorities through infrastructure planning.

- Recognition of the need to improve the performance of facilities to prevent flooding in preparation for future weather changes
- Maximize economic efficiency through project priority presentation and infrastructure maintenance manual through infrastructure planning.

<Current Situation>

- According to the 2010 Australian Institute of Engineering's evaluation report on infrastructure, Australia's overall infrastructure grade is evaluated as C+ (appropriate).
- Rather than improving water quality, we should focus on preventing flooding.

- Prepare the Australian Infrastructure Plan
- The Australian Institute of Public Civil Engineering regularly publishes the "International Infrastructure Management Manual" of public facilities.

SOURCE: KOREA MOLIT(2020) revised

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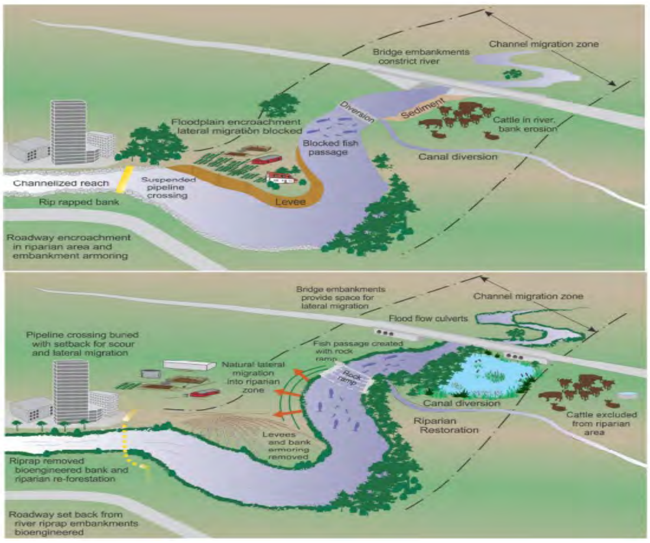
3. Prospect of river maintenance and management

3.1 Paradigm shift in river maintenance and management
3.2 Future of the river maintenance and management

3.1 Paradigm shift of river infrastructures

▪ Physical process associated with river line infra and potential consequences

- Illustrations of riverine infrastructure with greater impacts to physical stream processes and ecosystems and greater exposure to riverine hazards (top)
- More resilient and stream compatible infrastructure that permits a greater degree of channel movement supporting ecosystem processes(bottom)



SOURCE: Joel et al.(2017)

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3.1 Paradigm shift of river infrastructures

▪ Physical process associated with river line infra and potential consequences

Infrastructure Type	Physical Process	Result of Physical Process	Consequences to Infrastructure and Ecological Impact
Stream Crossing and Channel Infrastructure (dams, diversions, brid ges, channelization, culvert s, etc.)	Water impoundment	• Traps sediment, debris, nutrients, and organisms • Changes in water tempe rature upstream and d ownstream • Downstream scour • Changes to flow regime	• Trapped sediment can degrade habitat upstream • Stream environment converted to lake environment • Change in water temperature can impact aquatic species • Migratory fish passage limited or blocked • Channel movement and habitat maintenance from flow an d sediment reduced. • Downstream scour can undermine infrastructure
	Flow Acceleration Steeper slope	• Scours at inlet and outlet • Bed armoring	• Scour pools can compromise the integrity of infrastructure • Scour, break in slope, and fast flow may inhibit passage of fish. • Aquatic habitat impacted from scour and armoring Downstream deposition may impair infrastructure
	Channelization	• Limits or eliminates later al channel movement	• Limits natural migration channel processes that create and maintain complex aquatic and riparian habitat. • Can result in upstream migration of headcuts, underminin g upstream infrastructure

SOURCE: Joel et al.(2017) revised

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3.1 Paradigm shift of river infrastructures

▪ Physical process associated with river line infra and potential consequences

Infrastructure Type	Physical Process	Result of Physical Process	Consequences to Infrastructure and Ecological Impact
Streamside and Flood plain Infrastructure (levees, bank stabiliza tion, floodplain devel opment, roads, etc.)	Bank Armoring	• Limits natural lateral migr ation of channel • Encourages bed scour an d armoring	• May increase bed and bank erosion downstream • Limits natural migration channel processes that create and mai ntain complex aquatic and riparian habitat. • Reduce native species viability from lack of habitat
	Channel and Flo odplain Fill	• Narrows floodplain or ch annel • Scours existing channel • Limits natural channel mi gration • Hydrologic disconnection between channel and flo odplain	• Loss of flood storage and flood peak attenuation increases flo oding downstream • Increases bed erosion (incision) • Limits natural channel processes that create and maintain aqua tic and riparian habitat • Inhibits lateral connectivity between aquatic and riparian ecosy stems • Impacts to riparian vegetation that requires floodplain inundati on
	Riparian Vegetati on Removal	• Increases bank erosion ra tes • Reduces shading • Reduces large wood, org anic matter, and nutrient inputs to stream ecosyste m	• Increases in bank erosion can increase the rate of bank recessi on, encroaching on private land and compromising infrastruct ure • Habitat and water quality impacts via enhanced bank erosion and fine sediment inputs • Increases water temperatures and reduces nutrient and organi c matter inputs to channel • Less large wood in stream reduces habitat complexity compro mising aquatic species life cycles • Inhibits food web connectivity between aquatic and riparian ec osystems

SOURCE: Joel et al.(2017)

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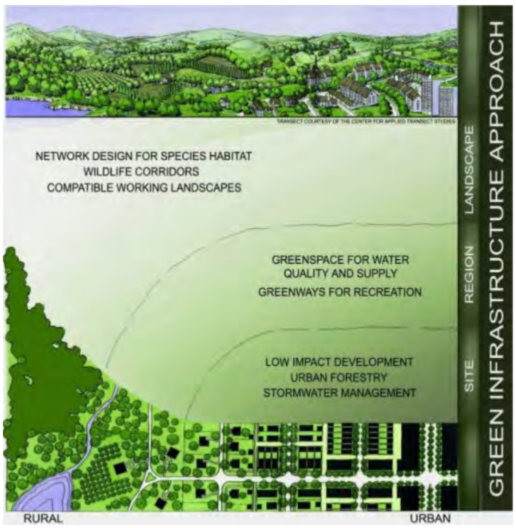
3.1 Paradigm shift of river infrastructures

▪ Green infrastructures

• Green infrastructure encompasses a variety of water management practices, such as vegetated rooftops, roadside plantings, absorbent gardens, and other measures that capture, filter, and reduce stormwater



SOURCE: modified from Reichert et al., (2011)

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3.1 Paradigm shift of river infrastructures

▪ Nature based Solutions, NbS

SOURCE: NbS as an umbrella term for ecosystem-related approach(IUCN 2016.)

LA river basin, USA linkage restoration project

A case of restoration of a watershed linkage ecological river of the Twin creek, USA

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3.1 Paradigm shift of river infrastructures

▪ Nature based Solution, NbS

Items designed to solve problems by NbS can be classified according to characteristic and purpose.

Retreat levee, restore floodplain
River walk

Vegetation mat
Stone net

Fish ladder
Eco-park
Nature friendly ford

Vegetative water
Downtown ditch
G-parking

Air tree
Greening slope
NbS-based landscape

→

Flood problem

Solving the turbidity problem

Ecosystem maintenance

Non-point source purification

Landscape

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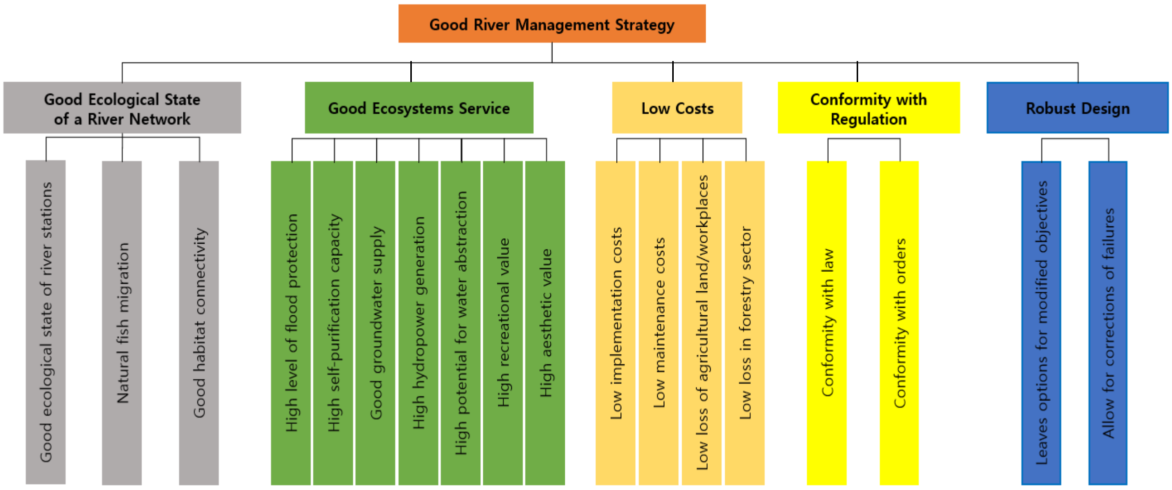
3.2 Future of river infrastructures

▪ Example of objective hierarchy for future river management



SOURCE: modified from Reichert et al.,(2011)

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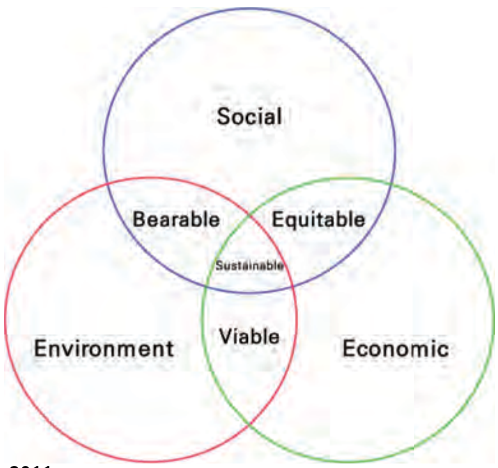
3.2 Future of river infrastructures

▪ New Paradigm : Integrated Resilient Management

- Integrate water and land management with resilience
- Close the loop on resource cycles : water, nutrients, carbon/energy, etc.
- Promote hydrological and ecological restoration through land application
- Achieve multiple watershed benefits



SOURCE: modified from Reichert et al., 2011

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4. Conclusion

4.1 Conclusion

4.1 Conclusion

▪ Conclusion

- ✓ River infrastructures can be defined as facilities and structures that support all activities related to river.
- ✓ Because of Climate Change and aging of infrastructures, the new paradigm shift of river infrastructures are important
- ✓ Therefore, the infrastructures recognition as preliminary assessment to the river asset management need to be done in order to maintain the river system.
- ✓ Green Infrastructures, economic evaluation, citizen usability, enhanced flood safety are needed to reflect in river infrastructures maintenance and management.
- ✓ Harmony of Flood Safety, Economy, Human usability, environment should be considered to paradigm shift of river infrastructures

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Thank you very much

Exploiting the Benefits of Global Water – Energy – Food Nexus

IWRM

Exploiting the Benefits of Global Water – Energy – Food Nexus

United Nations Educational, Scientific and Cultural Organization
International Centre for Water Security and Sustainable Management

Contents

1. Background

Population Growth

The world population has exceeded 7 billion. The total world population will be 8.1 billion in 2025 and 9.7 billion in 2050.
(UN,2019)

Energy Demand

From 2011 to 2030, the world's main energy consumption is increasing 1.6% every year. It is predicted to increase by 36% until 2030.

Water Demand

If the efficiency improvement is not realized under the current growing trend, it is forecasted that the water demand will increase from 4.5 trillion m^3 to 6.9 trillion m^3. *(UN water, 2019)*

Urbanization

Above 50% of world population live in cities *(UN,2018)* and urbanization acceleration leads to industrialization, which implies more water demand.

Food Demand & Changing Meals

The meat intake of world population is projected to increase by 14% by 2030 comparison to baseline 2018-2020. Under this situation, around huge proportion of grain production shall be converted to animal feeds.
(OECD-FAO,2021)

1. Background

- The ever-increasing demand for water, food and energy to support life by humans is sky-rocketing daily.
- The increasing demand and activities of population is creating pressure on water, food and energy systems.
- The Water-Energy-Food (WEF) Nexus explains the interactions among water, energy and food systems, indicating that actions in any can have effects on another or on both systems.

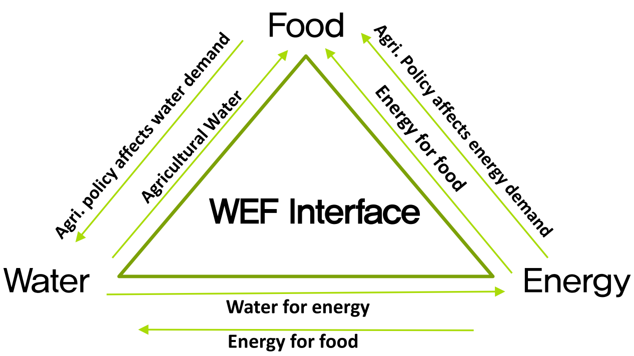


Fig : WEF Nexus

1. Background

Drivers of WEF Nexus

- Climate change
- Population growth
- Economic development
- International trade
- Urbanization
- Cultural lifestyles and technological changes

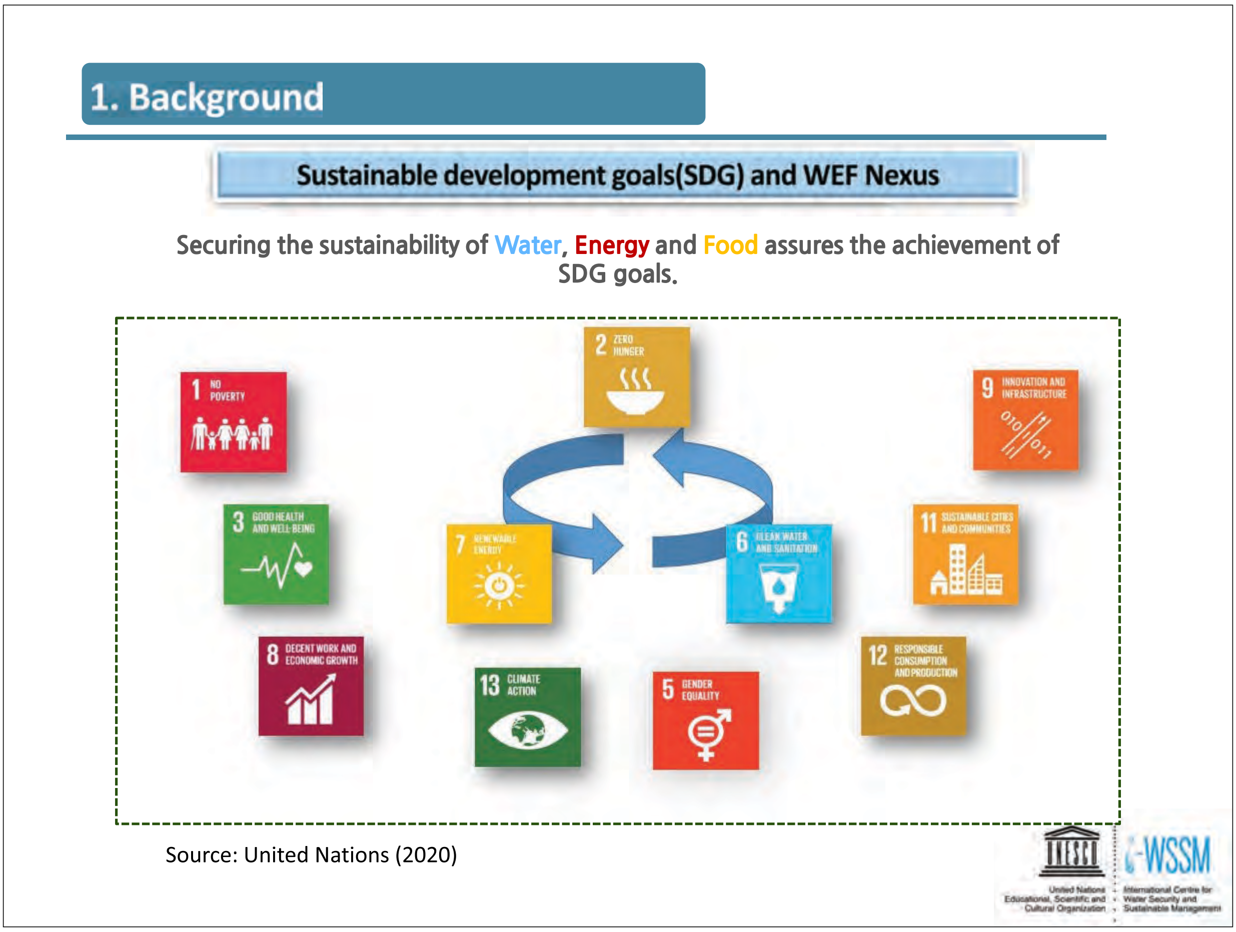
1. Background

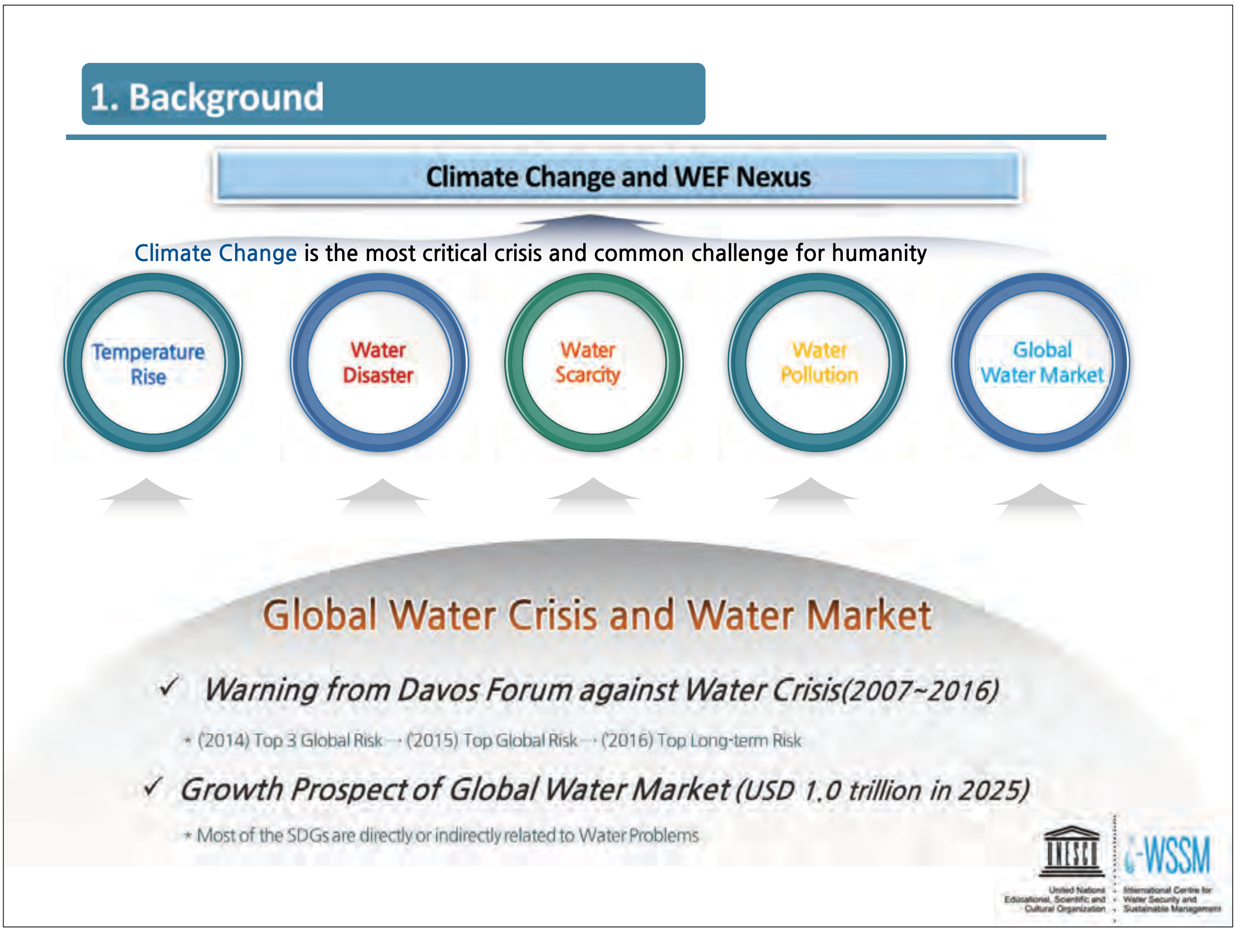
Global Statistics of WEF Nexus

- By 2050, global water demand will increase by 55% due to population increase and economic growth
- Irrigation is the largest volumetric producer of wastewater. *(UN water, 2019)*

- Just by **2035**, energy demand is projected to increase **by more than one-third**. Electricity demand will grow by **70%**. *(IEA, 2019)*
- About 90% of global power generation is water-intensive

- By 2050, global food production would need to increase by 60% to meet food requirements of a growing population *(OECD-FAO,2021)*
- 70% of global water usage:- agriculture
- 30% of global energy use: food production and supply


1. Background
Sustainable development goals(SDG) and WEF Nexus
Securing the sustainability of Water, Energy and Food assures the achievement of SDG goals.
1 NO POVERTY
2 ZERO HUNGER
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
3 GOOD HEALTH AND WELL-BEING
7 AFFORDABLE AND CLEAN ENERGY
6 CLEAN WATER AND SANITATION
11 SUSTAINABLE CITIES AND COMMUNITIES
8 DECENT WORK AND ECONOMIC GROWTH
13 CLIMATE ACTION
5 GENDER EQUALITY
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Source: United Nations (2020)
i-WSSM


1. Background
Climate Change and WEF Nexus
Climate Change is the most critical crisis and common challenge for humanity
Temperature Rise
Water Disaster
Water Scarcity
Water Pollution
Global Water Market
Global Water Crisis and Water Market
✓ Warning from Davos Forum against Water Crisis(2007~2016)
* (2014) Top 3 Global Risk → (2015) Top Global Risk → (2016) Top Long-term Risk
✓ Growth Prospect of Global Water Market (USD 1.0 trillion in 2025)
* Most of the SDGs are directly or indirectly related to Water Problems
i-WSSM

1. Background

Livelihoods and the Water-Energy-Food Nexus

i-WSSM International Centre for Water Security and Sustainable Management

United Nations Educational, Scientific and Cultural Organization

1. Background

Ecosystems and WEF Nexus

- **Ecosystem services: The benefits that human derive from ecosystems** *(MEA, 2005; TEEB,2010)*
- **Four major categories:**

1. PROVISIONING SERVICES
Products from ecosystem.
Food, timber, freshwater etc.

2. REGULATING SERVICES
Benefits from regulation of ecosystem processes.
Climate regulation, flood regulation etc.

3. CULTURAL SERVICES
Nonmaterial benefits from ecosystems.
Recreation, spiritual, aesthetic etc.

4. SUPPORTING SERVICES
Underpinning services that enable other services to function.
Soil formation, nutrient cycling.

- **Contributes to the provision and regulation of each component of the nexus.**
- **The exploitation of ecosystems was previously understood just as an unfortunate but necessary cost of development.**
- **But now, with nexus approach, ecosystem is recognized as an integral part of the solution to food, energy and water problems.** *(Bervoets et al., 2018)*

UNESCO United Nations Educational, Scientific and Cultural Organization

i-WSSM International Centre for Water Security and Sustainable Management

2. Concept of WEF Nexus

Bonn2011 Conference

A water-energy-food nexus approach can support a transition to sustainability by reducing trade-offs and generating additional benefits that outweigh the transaction costs associated with stronger integration across sectors. The nexus focus is on system efficiency, rather than on the productivity of isolated sectors.

UNESCAP, 2013

The nexus perspective focuses on the interdependence of water, food and energy by understanding the challenges and finding opportunities. Objectives are to: 1) improve energy, water and food security; 2) address externality across sectors and decision-making at the nexus and support transition to sustainability; 3) inter-connectedness of WEF across space and time.

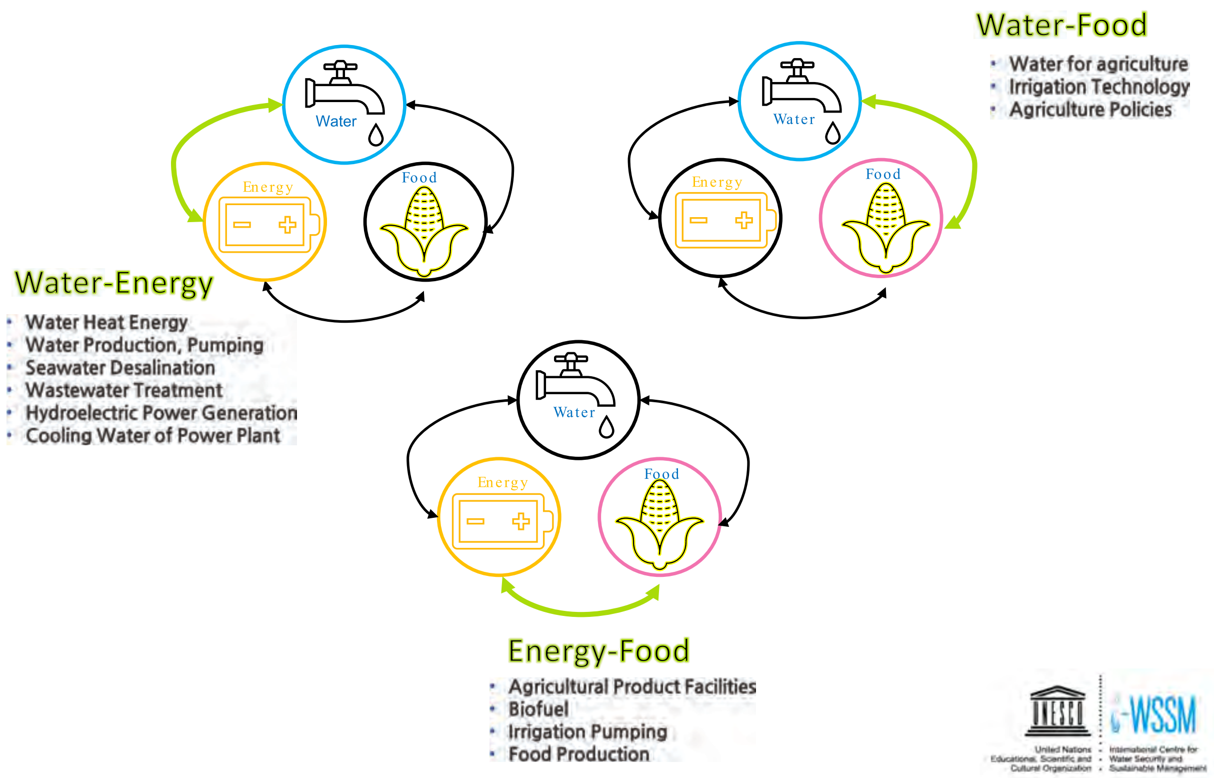
FAO, 2014

The basis of the Water-Energy-Food Nexus is an attempt to balance different uses of ecosystem resources (energy, water, land, soil and socio-economic factors). There are clear interactions between water, food and energy that may result in synergies or trade-offs between different sectors or interest groups.

World Water Assessment Programme, 2014

Competition over water highlights the difficult policy choices that are posed by the water-food-energy-nexus and the trade-offs involved in managing each sector, either separately or together. WEF, the three pillars of any functioning society are closely interlinked, and choices made in one area will inevitably impact the choices and hence resources available in the others.

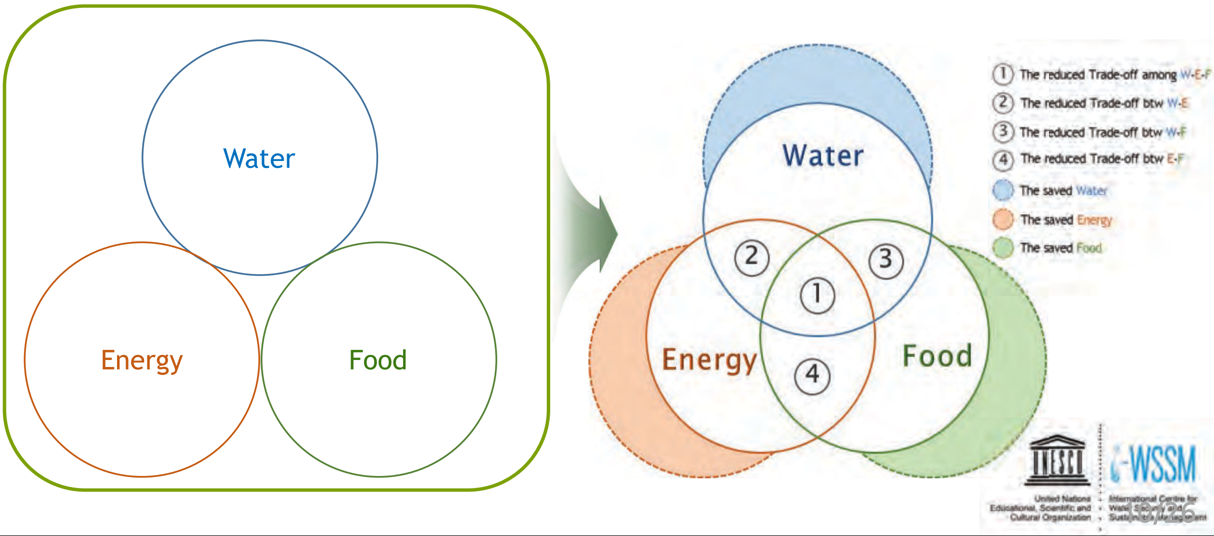
2. Concept of WEF Nexus



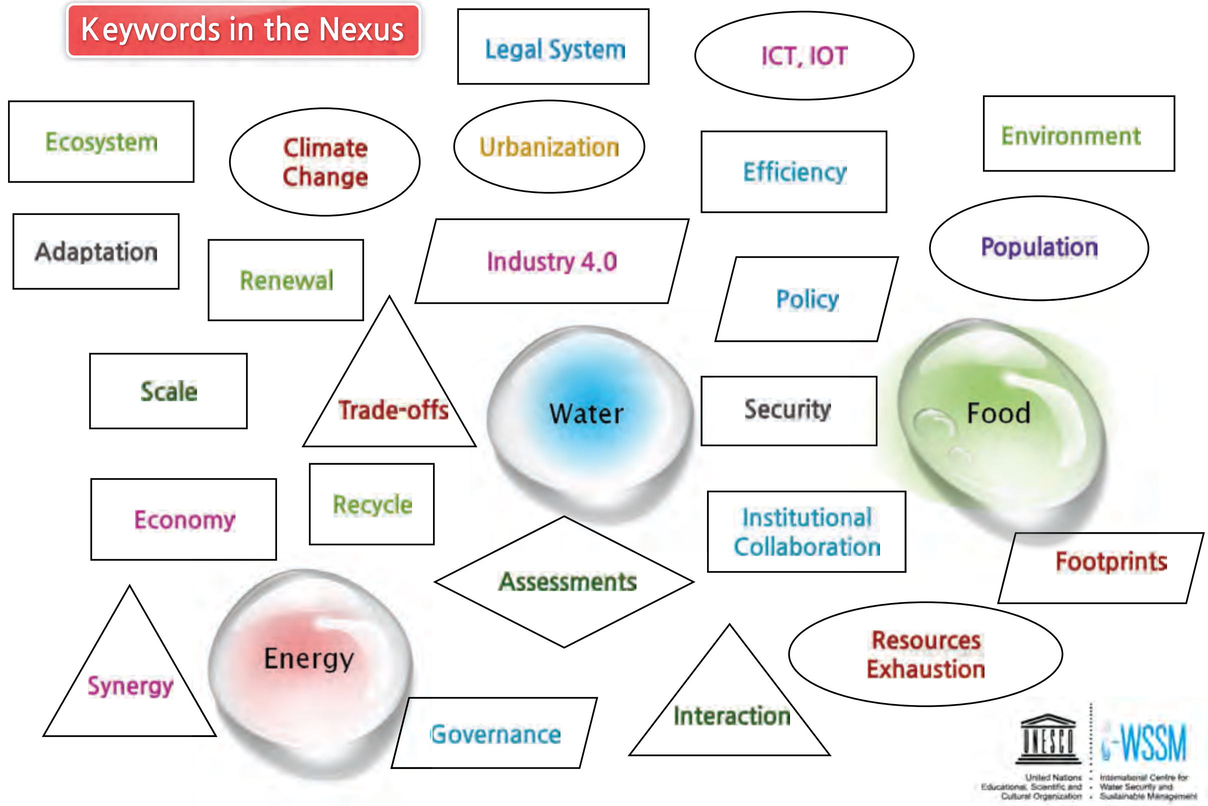
2. Concept of WEF Nexus

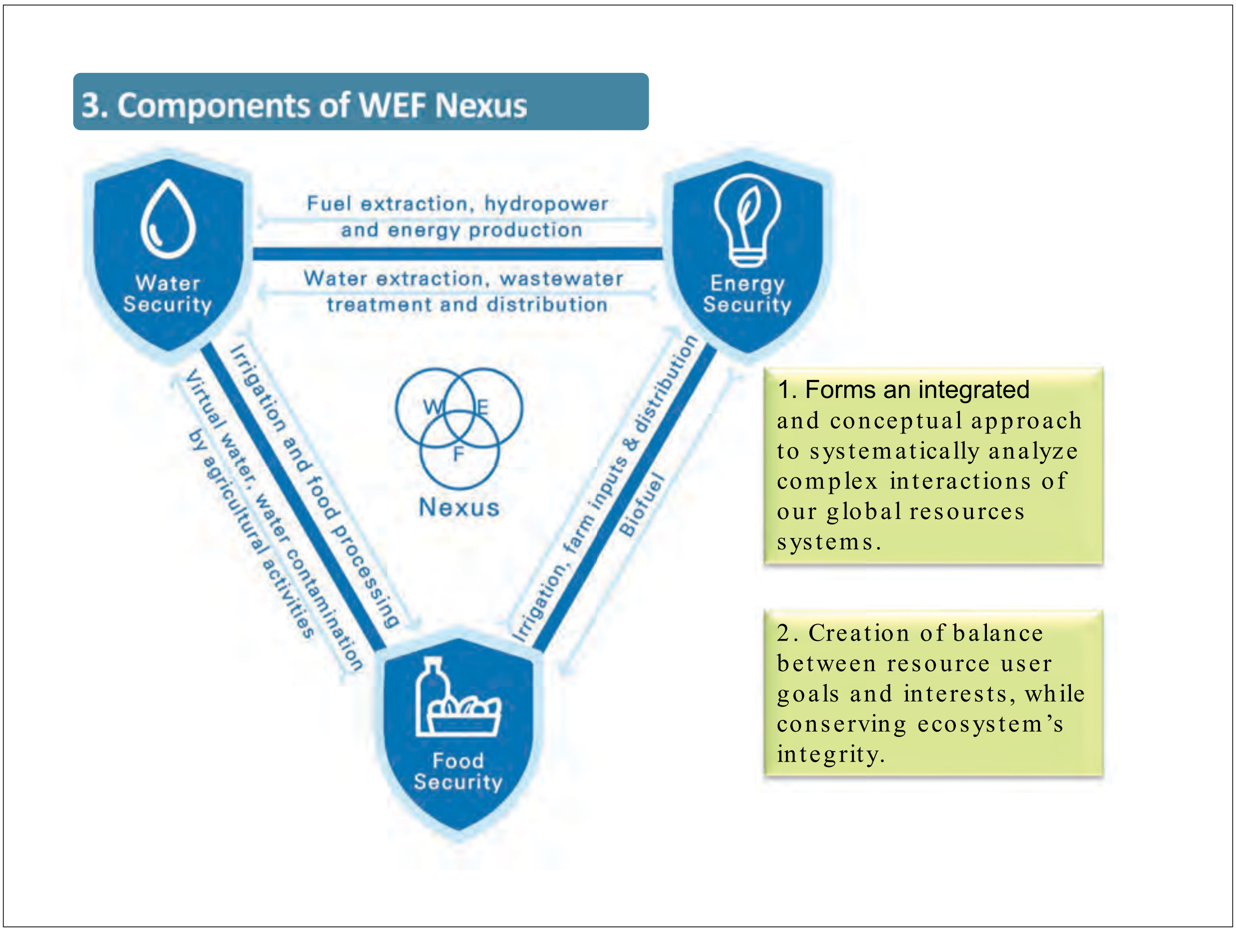
Aims

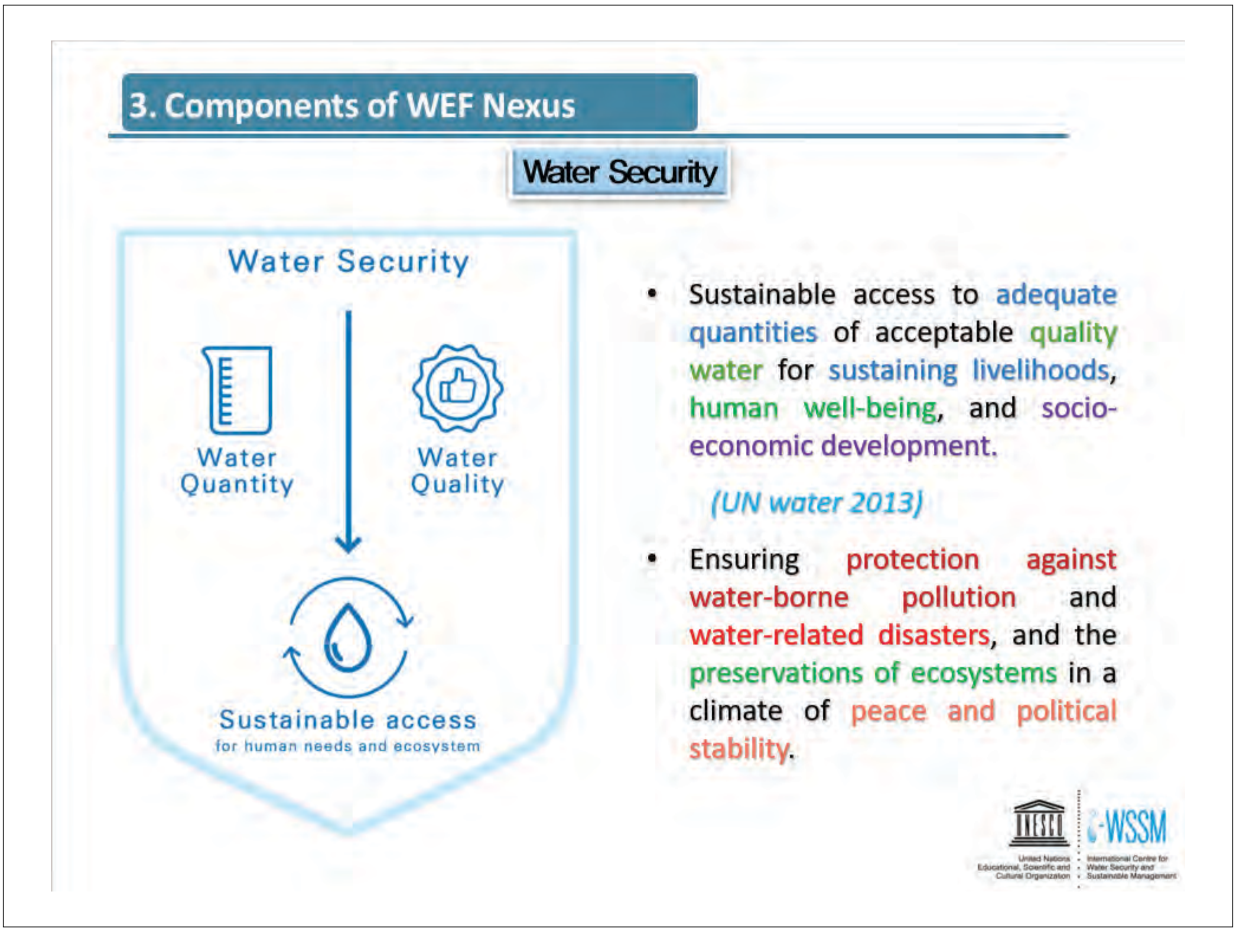
- ✓ Decrease trade-offs by using the interaction between resources which circulate in industrial eco-systems and concentrate on expanding production, supply and consumption efficiency for all connected resources through synergy expansion
- ✓ Increasing resource efficiency by incorporating multiple viewpoints, including technology, society, policy, laws, etc.,



2. Concept of WEF Nexus

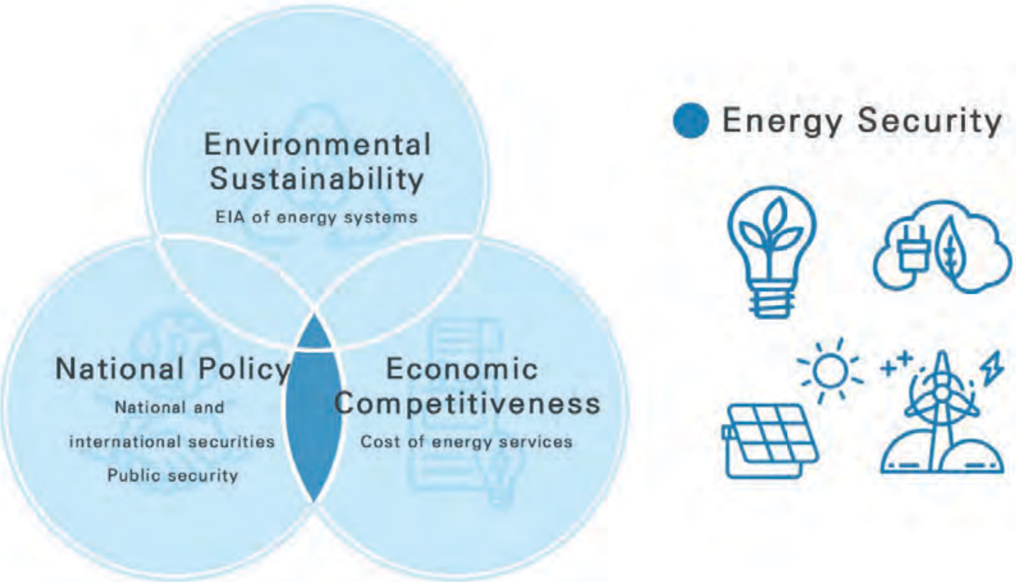



3. Components of WEF Nexus
Water Security
Energy Security
Food Security
Fuel extraction, hydropower and energy production
Water extraction, wastewater treatment and distribution
Irrigation and food processing
Virtual water, water contamination by agricultural activities
Irrigation, farm inputs & distribution
Biofuel
W E F
Nexus
1. Forms an integrated and conceptual approach to systematically analyze complex interactions of our global resources systems.
2. Creation of balance between resource user goals and interests, while conserving ecosystem's integrity.


3. Components of WEF Nexus
Water Security
Water Security
Water Quantity
Water Quality
Sustainable access
for human needs and ecosystem
• Sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development.
(UN water 2013)
• Ensuring protection against water-borne pollution and water-related disasters, and the preservations of ecosystems in a climate of peace and political stability.
i-WSSM

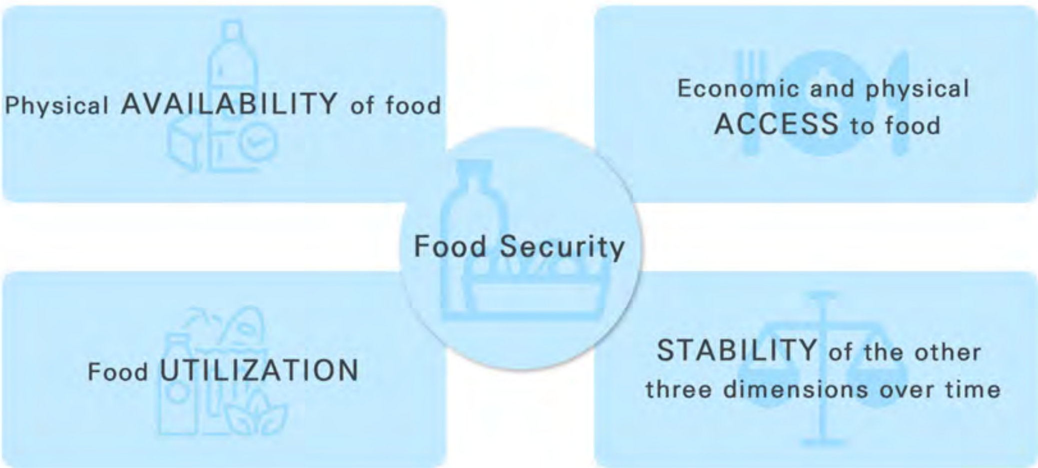
3. Components of WEF Nexus

Energy Security



UNESCO | i-WSSM

3. Components of WEF Nexus



"Food security is guaranteed when, at all times, all people benefit from economic, social and physical access to sufficient, safe and nutritious food to meet their nutrition needs and food preferences, so that they can lead an active and healthy life."

(*1996 World Food Summit*)

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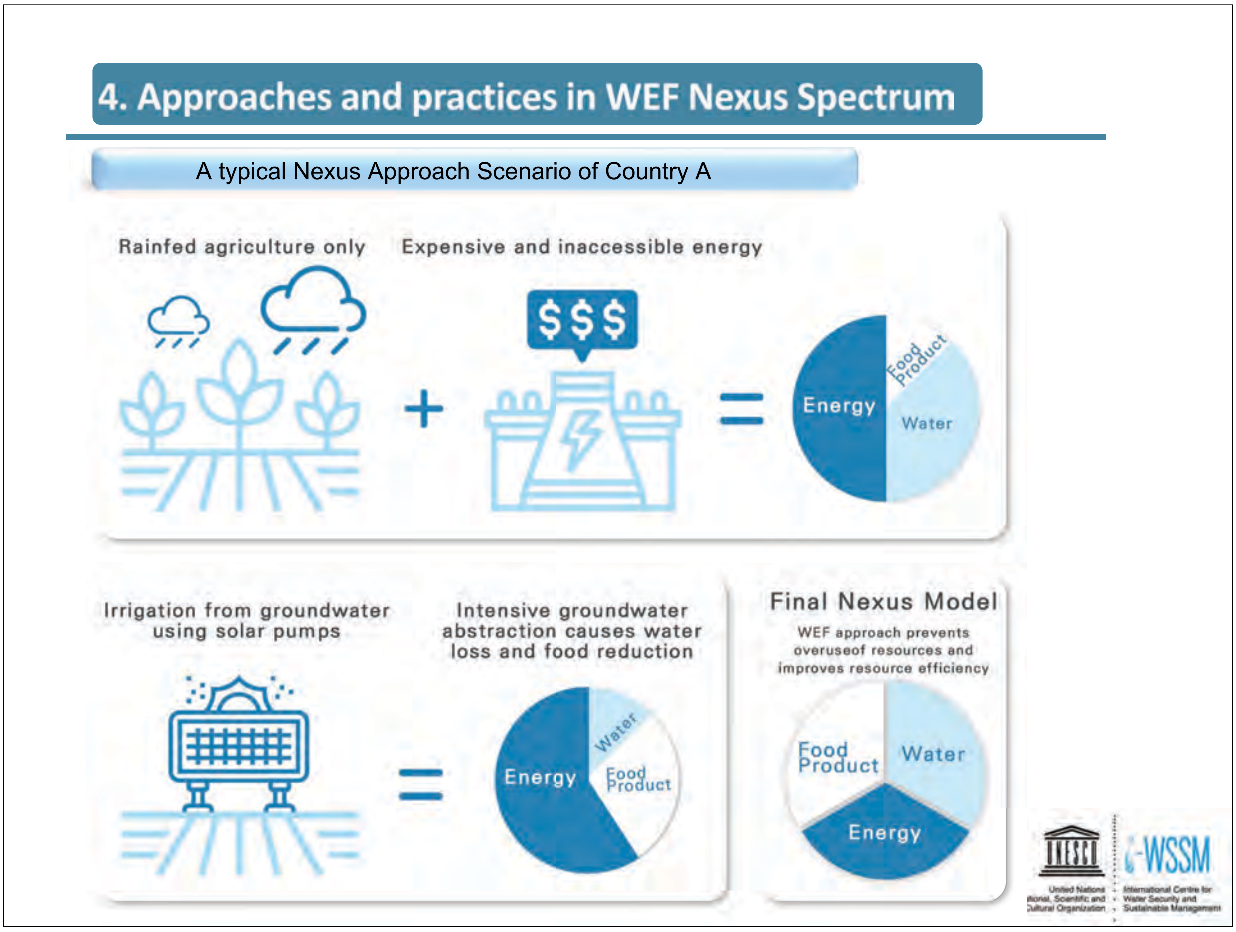
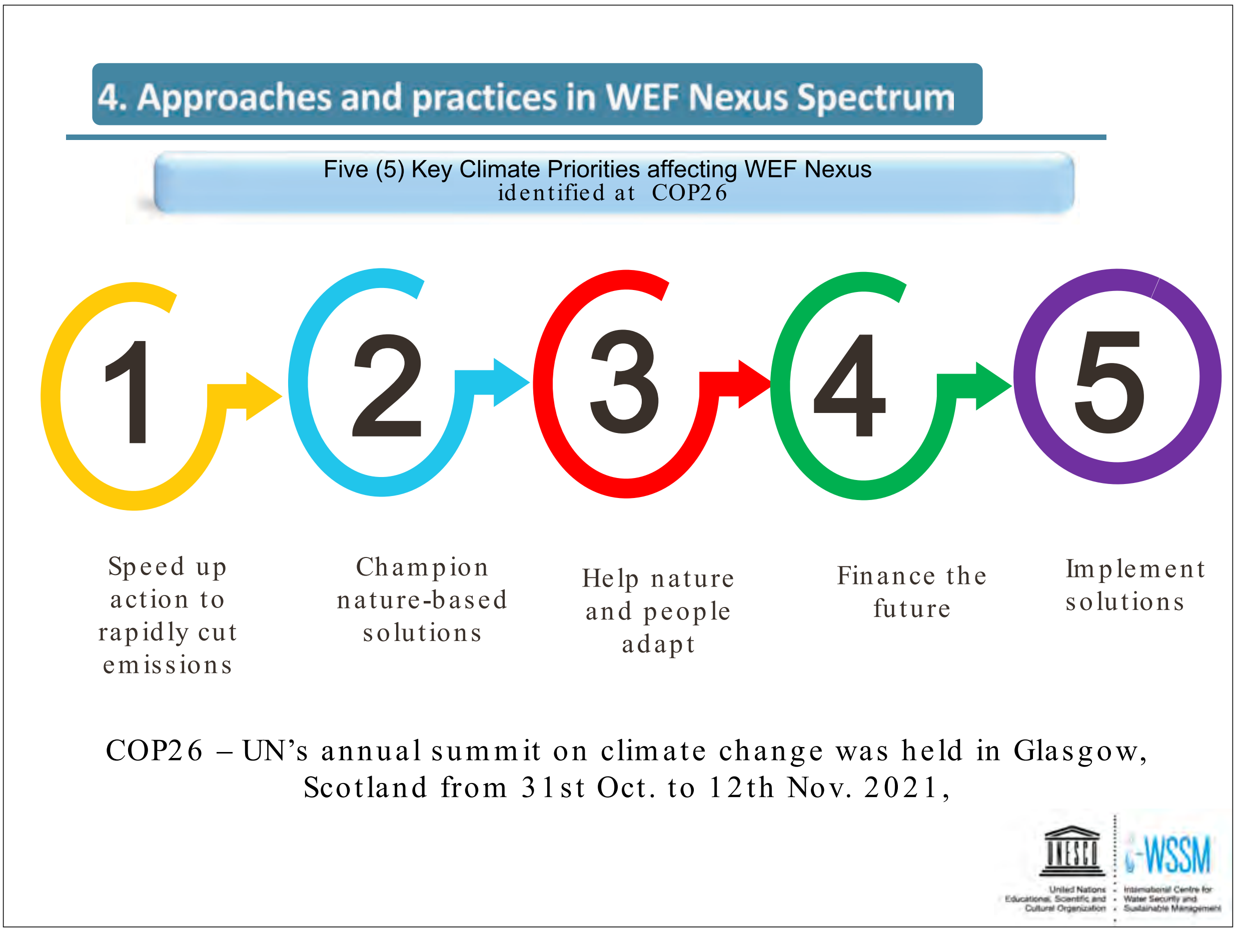

4. Approaches and practices in WEF Nexus Spectrum
A typical Nexus Approach Scenario of Country A
Rainfed agriculture only
Expensive and inaccessible energy
$$$
Energy
Food Product
Water
Irrigation from groundwater using solar pumps
Intensive groundwater abstraction causes water loss and food reduction
Energy
Water
Food Product
Final Nexus Model
WEF approach prevents overuseof resources and improves resource efficiency
Food Product
Water
Energy
i-WSSM


4. Approaches and practices in WEF Nexus Spectrum
Five (5) Key Climate Priorities affecting WEF Nexus identified at COP26
1
2
3
4
5
Speed up action to rapidly cut emissions
Champion nature-based solutions
Help nature and people adapt
Finance the future
Implement solutions
COP26 – UN's annual summit on climate change was held in Glasgow, Scotland from 31st Oct. to 12th Nov. 2021,
i-WSSM

4. Approaches and practices in WEF Nexus Spectrum

Workflow of WEF Nexus Approach

Data	Evidence	Scenario Development	Response Options

Data	Evidence	Scenario Development	Response Options
Data procurement (in-situ and satellite data) for resource manager use	Data processing. Linking with existing systems and supporting development of new systems use	Explore strategic questions, review policies, investment decisions, and create a 'common ground' for W-E-F & drivers	Planning and implementation of new policies, investments, regulations and services Achieved through evidence-based assessments and stakeholder dialogue

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

4. Approaches and practices in WEF Nexus Spectrum

Global implementations of Nexus in various sectors .

Electricity of France (Electricite de France)	• Signing a water saving agreement with major agricultural irrigation facility to compensate the money by water conservation • Water Consumption:Changed existing practice and management method (30% ↓), Efficient Water Usage Technology(70% ↓) • Efficient Water Usage for irrigation of water, generation quantity (325 mil. ㎥ → 235 mil. ㎥)
Veolia Water	• Operating a 100% Energy Self-Supported Waste-Water Facility • The concentration of waste-water is estimated and the heat produced during sludge treatment is used by wastewater facilities for energy supply (60%). Treated wastewater is utilized as agricultural water and fertilizer
Mutual Business Cooperation	• (Business cooperation with 3 companies in Texas) Austin Water Supply Company, Texas Water Service, Austin Energy • Developing multiple family energy and water efficient programmes → Resource-efficient house remodeling • Annually, 4.7 million kWh of electricity and 37.85 million liters of water saved
Mekong River Commission	• A comprehensive approach (Water resources, Hydropower, Food, etc.) is necessary in the Mekong river basin (China, Myanmar, Laos, Vietnam, Cambodia, Thailand) • Consultative group's approach (Sector based approach, Governance, Science- Policy Interface)

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4. Approaches and practices in WEF Nexus Spectrum

WEF Nexus in South Korea

Nexus for Water Management

✓WEF Nexus is a new global mega-trend for national resource management. Korea also actively participates in the trend and occupies this approach.

✓New technology using the interconnection in Water-Energy or Water-Food plans should be prepared to overcome the existing limitations of water resource technologies.

✓Integrated policy connected with energy and food categories are necessary to resolve main water issues including irrigation, flood control, and the rehabilitation of the hydrologic cycle.

Change in the Water Paradigm

4. Approaches and practices in WEF Nexus Spectrum

South Korea — Cooling-heating systems using ground source heat in horticultural greenhouses

- Korea's agricultural sector currently faces the challenge of procuring efficient substitutes for cooling/heating facilities in greenhouses.
- This is so because the conventional hot-air furnace or hot water boilers offer relatively cheaper investment costs than those that use ground source heating systems.
- In terms of total management cost of the horticulture sector, heating expenses account for 19~58% of the costs depending on type of cultivated crops.

  ※ About **92%** of the heating energy source used is fossil energy, specifically oil.
- (Initial investment cost recovery) Initial investment cost is recovered at 7 years (2,376㎡ plastic greenhouse) and 2 years (9,384m^2 glass greenhouse)

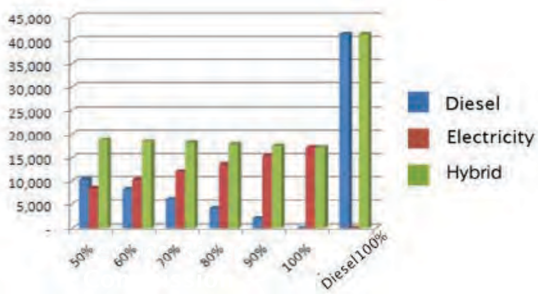

Fig: 2376 m^2 energy cost of plastic greenhouses

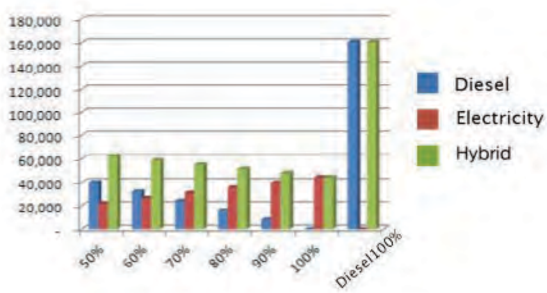

Fig: 9384 m^2 energy cost of glass greenhouses

4. Approaches and practices in WEF Nexus Spectrum

South Korea | System of Rice Intensification(SRI)

- SRI is a holistic approach to sustainable rice production, aimed at increasing rice production.
- Example in Korea (Ministry for Agriculture, Food and Rural Affairs, Korea Rural Community Corporation, 2011)

✓ Amount of irrigation water used : Compared to practice, 49.4% reduction in agricultural water usage

✓ Harvest amount : Compared to practice, increment of 109-120 % (white rice), 120-130 % (head rice)

✓ Greenhouse gases : Compared to practice, reduction in 71.8% of greenhouse gas

✓ If approx. 40% of agricultural water is reduced by applying the SRI method to all rice paddies, about **5.1 billion tons of water** can be secured.

Flooded Plantation

SRI(System of Rice Intensification)

4. Approaches and practices in WEF Nexus Spectrum

South Korea | Hydro -thermal energy facility – Lotte tower

- Lotte World Tower, 555.7 m, 123 storey skyscraper in Seoul, has the largest hydrothermal energy facility in Korea.
- Hydrothermal energy method of facility utilizes a temperature difference between water from the Han River and the atmosphere.
- Facility receives 50,000 tons of water a day and supplies 3000 RTs energy.
- Lowers energy consumption by 36% and cut out CO_2 emissions by 38% compared to other buildings in Korea.
- Does not require cooling tower on top of building making it economical project along with reduction in noise pollution and urban heat island phenomena.
- The energy efficiency of the building has helped it to receive a gold grade in the Leadership in Energy and Environmental Design (LEED) Certification from the U.S. Green Building Council (USGBC) in 2017.

Source: *BusinessKorea, 2021*

5. Covid-19 Implications on WEF Nexus

Energy

- More pressure on energy access has been reported during the pandemic in Sub-Saharan Africa due to inadequate energy generation, more dependence on firewood and local fuels, thereby, increasing environmental pollution *(Ogunbiyi, 2020)*
- Residential electricity demands skyrocketed while significant energy usage declines were recorded in both commercial and industrial sectors *(EIA, 2020)* as a result of the lockdown.
- As a result, use of fossil fuels and conventional energy sources has reduced significantly *(EIA, 2020)*
- Travel restrictions reduced emissions from use of vehicles and airlines. *(EIA, 2020)*
- Overall energy consumption during the 2nd quarter of the pandemic reduced drastically in several states in the United States *(EIA, 2020).*

5. Covid-19 Implications on WEF Nexus

Food and Food Wastes

- More food wastes generation was reported during the lockdown phase of COVID-19 by s ome countries, thereby creating more need for waste-to-energy technologies, landfilling, anaerobic digestion and a more efficient WEP nexus approach.
- *Zhao & You (2021)* optimized the food-water-energy-wastes scenario of New York during the pandemic and recorded:
    - a potential reduction of 38% food waste disposal amount;
    - Pareto-optimal solutions indicate a clear tradeoff between processed food wastes a nd unprocessed wastes in the anaerobic digesters used;
    - Minimum total cost of $27.1 million and optimal profit of $11.9 per ton of processed food wastes; and
    - Sensitivity analysis showed that biogas yield and electricity price are the most important factors for the economic objectives of the study.

6. Strategy for WEF Nexus sustainability

Past Hardware-oriented	• Water securement with the construction of infrastructure such as dams, weirs, etc. • Water securement to ensure the nation's economic foundation with nation-centered and industry-centered methods • Problem: Environment issues, deterioration, limitation of national land area
Present Software-oriented	• **Water securement by increasing water use efficiency** through the operation of dams and water supply networks • Operation of dams considering natural sluice effects (Safety securement)
Future Humanware-oriented ↑ (Nexus perspective)	• Water securement through demand management of the whole water supply process from source to consumer (e.g. Controlling water consumption required for the production of essential resources such as energy and food) Energy, food — Increasing water efficiency with the development of element technologies applied to production • **Positive effect of water securement and efficiency improvement for the securement of other resources and their efficiency** • **Increase of sustainability in water security by connecting the infrastructure with existing Hardware and Software and Industry 4.0 based technology**

6. Strategy for WEF Nexus sustainability

Natural Infrastructure

"Strategic use of networks of natural lands, working landscapes, and other open spaces to conserve ecosystem values and functions and provide associated benefits to human populations" (Allen, 2013).

Green Infrastructure	Gray Infrastructure	Benefit
• Forests and Wetlands	• Water filtration facilities	• Clean drinking water
• Forests (on slopes) upstream of hydroelectric facilities	• Periodic sediment dredging	• Reliable power and flood control
• Mangroves	• Sea walls	• Shoreline protection from storms
• Coral reefs	• Breakwaters and groins	• Reduced beach erosion
• Natural floodplains	• Dikes and canals	• Flood prevention
• Wetlands	• Tertiary water treatment facilities	• Clean effluent from municipal or industrial processes

6. Strategy for WEF Nexus sustainability

Resilience Climate Change Impact, Energy Economy/Management

- Sustainable Securement and suitable distribution of Water-Energy-Food and creation of new technologies

Efficiency Development, Investing in Facilities, Reutilization

- (Water-Food) Consumptive water use, irrigation efficiency, investing in facilities
- (Water-Energy) Operation of Smart Water Grid (SWG)
- (Food-Energy) High-efficiency of energy consumption in food production-processing-distribution

Value W-E-F Flow, Creating New Worth through Convergence

- (Water-Food) Virtual water, production distribution system, market forecasting
- (Water-Energy) Smart Water Grid (SWG) Management
- (Food-Energy) High-efficiency energy products

Service Technical, Social, Cultural, Global

- IT(Government Information), IoT(Public), W-E-F Cross-Sectoral and Governmental Departments
- (Water-Food) Government-Farmer (Precision Farming), Ecosystem services
- (Water-Energy) Building SWG Big Data Frame (Food-Energy) Storage, Distribution Services

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7.1 Case Scenarios of WEF Nexus and practice

WEF Approach for evaluating Sustainability of Water Availability in the Niger River Basin

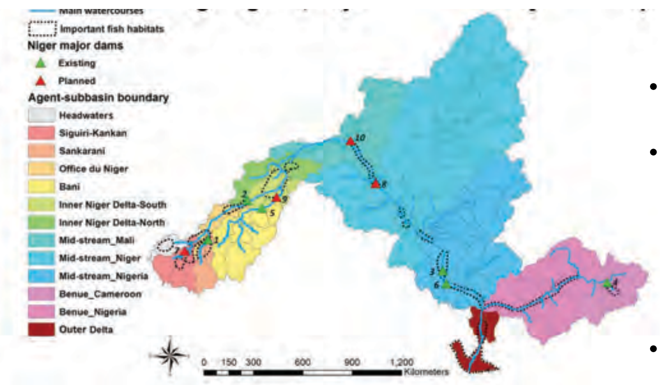


Fig: Niger River Basin
Source: *Yang et al. (2018)*

- The Niger River Basin in West Africa is the 9th largest catchment in the World, with a drainage area of 2,156,000 km^2 (Aich *et al.,* 2016)
- It runs through nine (9) countries.
- Headwaters are located in Guinea, flows in to Mali, to Niger, to Nigeria and combines with River Benue, then joins the Atlantic Ocean through the coastal Outer Niger Delta
- Necessity of Sustainability assessment of the Niger River Basin :

- For cross-sectoral comparisons of trade-offs.
- To evaluate the impacts of climate and anthropogenic changes on water, energy, ecosystem and food resources.

United Nations Educational, Scientific and Cultural Organization · International Centre for Water Security and Sustainable Management

7.1 Case Scenarios of WEF Nexus and practice

WEF Approach for evaluating Sustainability of Water Availability in the Niger River Basin

Climate Change Scenario

Downscaling of seven Regional Climate Models for Representative Concentration Pathways 4.5 and 8.5 to check for likelihood of future climate conditions

Water Infrastructure Development Scenario

Six existing dams (baseline) ; three proposed dams (Djenne , Touassa and Kandaji dams); and four proposed dams (Djenne, Touassa, Kandaji and Fomi dams) were selected

Generic metrics for sustainability assessment

Reliability
Resilience
Vulnerability

Sustainability Index (SI)

Annual hydropower energy calculated from daily streamflow
Average irrigated crop yields

Water available for irrigation
Hydropower generation
Riverine ecosystem health

7.1 Case Scenarios of WEF Nexus and practice

Results: WEF Approach for evaluating Sustainability of Water Availability in the Niger River Basin

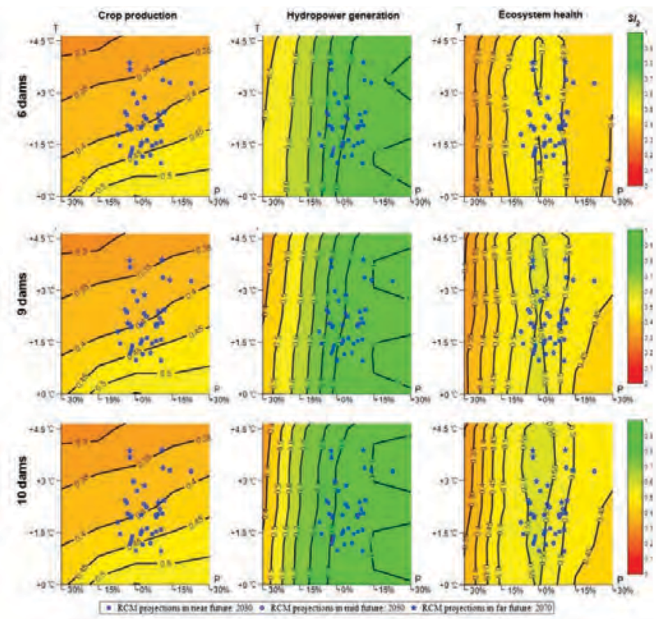


Fig: Climate stress test by Resilience on water availability
Source: Yang *et al.* (2018)

- Horizontal pattern of stress result shows that temperature is the dominant driver of irrigated crop production
- Vertical patterns show that precipitation is the main driver of ecosystem health and hydropower generation
- Blue dots indicate likely future climate domain with SI between 0.33 and 0.48
- Also, dam development doesn't prove to mitigate climate change impact

7.1 Case Scenarios of WEF Nexus and practice

Results: WEF Approach for evaluating Sustainability of Water Availability in the Niger River Basin

Economic trade-off implications

Since irrigated crop production and hydropower generation are directly related to a country's Gross Domestic Product (GDP), we can use it to analyze economic trade-offs

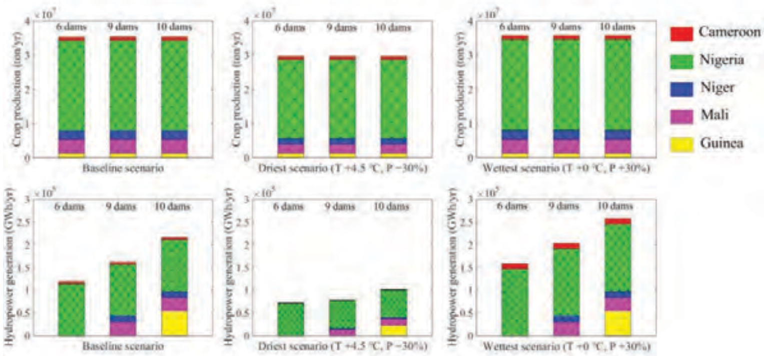


Fig: Effects of climate change and water infrastructure development on an nual irrigated crop production and hydropower generation based on available water
Source: Yang *et al.* (2018)

- Irrigated crop production will decrease by ~18% under the driest scenario but will increase slightly under wettest scenario.
- Increased precipitation improved hydropower generation during wettest scenario but under the driest scenario, streamflow decrease will negatively be affecting hydropower generation
- All countries in the basin, with or without new dams, will experience reduced hydropower generation.
- Maximum hydropower generation can be achieved with construction of ten dams

7.2 Case Scenarios of WEF Nexus and practice

WEF Approach for Reduction of Fossil Fuels and GHG Emission in Mauritius

Fig. 8 : Study Area (Mauritius)
Latitude:20° 15'6"S
Longitude: 57° 52'14"E
Source: Google map

The Republic of Mauritius:

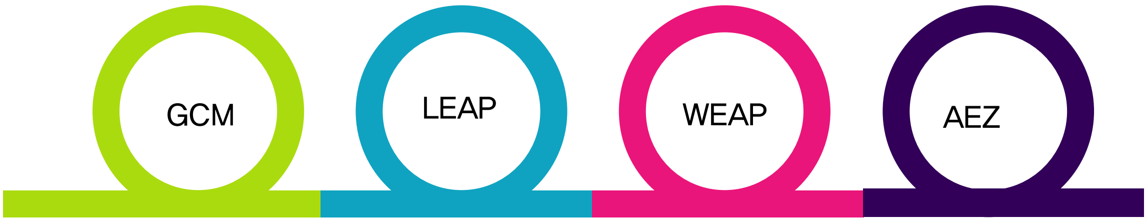
- An island nation in the Indian Ocean, with capital in Port Louis
- Land area: 2,040 sq. km
- Exclusive Economic Zone: 2.3 million sq. km
- It is 2000 km off the southeast coast of African c ontinent, east of Madagascar.
- With a GDP of USD29.187 billion in 2018, Mauritius relies mostly on petroleum products and renewable energy sources.
- **Project Goal**

Implement Mauritius-NEXUS modeling framework to assess energy, water and food systems through local energy generation (bioethanol from sugarcane) under different climate change scenarios

7.2 Case Scenarios of WEF Nexus and practice

WEF Approach for Reduction of Fossil Fuels and GHG Emission in Mauritius

The Integrated CLEWS Climate Models Approach



Climate Model (GCM)	Energy Model	Water Model	Food /Land Use Model
Rainfall reductions in climate change scenarios	Assessment of GHG emissions and energy demand	Water resources planning of 60 catchment areas of Mauritius rivers	Determination of production potential of farmland for ethanol production

Modified from Welsch *et al.* (2014)

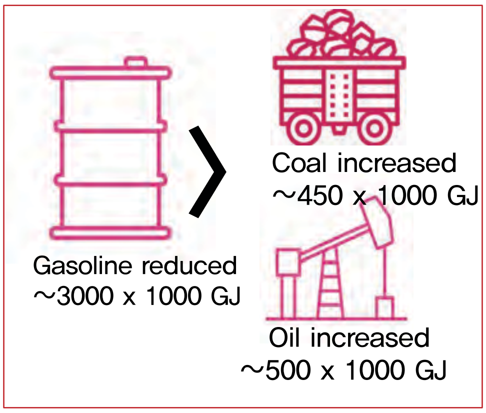
7.2 Case Scenarios of WEF Nexus and practice

WEF Approach for Reduction of Fossil Fuels and GHG Emission in Mauritius (contd.)

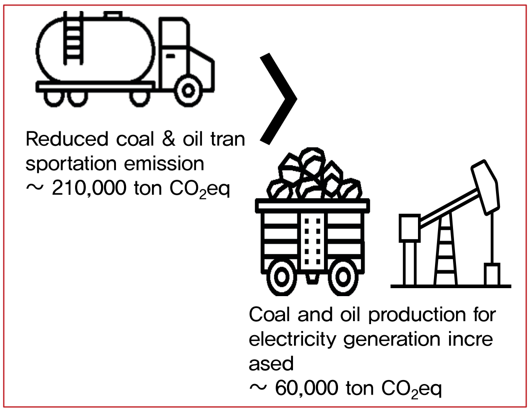
Results of transformation of two sugar processing plants to produce 2nd generation ethanol

Bioethanol was extracted from sugarcane bagasse at two sugar processing plants in Mauritius

Reduced fuel imports



Reduced GHG Emissions



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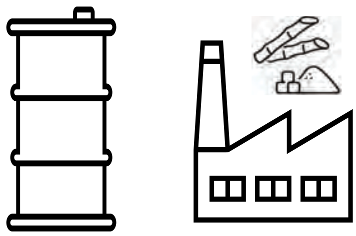
7.2 Case Scenarios of WEF Nexus and practice

WEF Approach for Reduction of Fossil Fuels and GHG Emission in Mauritius (contd.)

Results for Transformation of two sugar processing plants to produce 2nd generation ethanol

Bioethanol was extracted from sugarcane bagasse at two sugar processing plants in Mauritius

Reduced Expenditures



Gasoline imports and sugar refining costs reduced
~100,000 [1000 USD – Real 2005]

Sugar export earnings
~75,000 [1000 USD – Real 2005]

7.2 Case Scenarios of WEF Nexus and practice

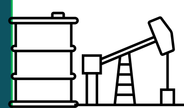
WEF Approach for Reduction of Fossil Fuels and GHG Emission in Mauritius (contd.)

- Based on the findings:
  - Future energy scenario for local biofuels under different climate scenarios was developed for Mauritius.
- Overall GHG balances showed that:

Climate change
- Decreased water availability

Water security
- Increased groundwater pumping
- More desalination needs

Food Security
- Reduced sugarcane and bagasse yield
- Lower ethanol production



Energy Security
- Higher dependence on gasoline and oil imports
- Unsustainable economy

7.3 Case Scenarios of WEF Nexus and practice

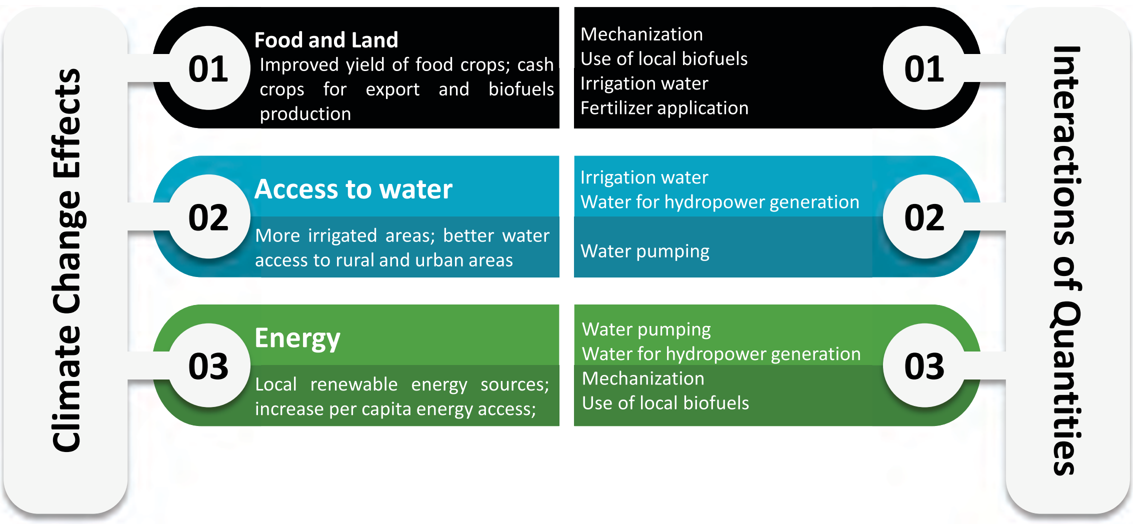
WEF Approach for Future Development Challenges under Climate Change Effects in Burkina Faso

Fig. 9 : Study Area (Burkina Faso)
Latitude:11° 54’20“N
Longitude: 1° 17’35"E
Source: Google map

- A landlocked country in West Africa.
- Land area: 274,200 sq. km
- Bordered by Niger in the northeast, Ivory Coast in southwest, Benin to the southeast and Mali to the northwest
- It has 41.4% of its population living below the poverty line, so, it’s ranked 181st out of 187 countries on the Human Development Index (World Bank, 2012)
- Future development challenges of resource scarcity, population growth and climate change are a great concern in Burkina Faso.
- A nexus approach is needed to analyze effects of future development on limited water, energy and land / food resources

7.3 Case Scenarios of WEF Nexus and practice

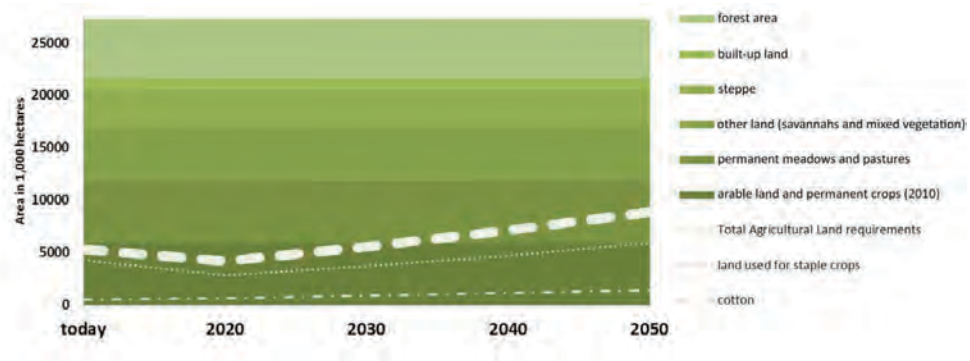
Resources and Interactions of Quantities for Burkina Faso’s Nexus Approach



Modified from *Hermann et al. (2012)*

7.3 Case Scenarios of WEF Nexus and practice

Energy and water inputs for agriculture are increased to a certain threshold to observe the interaction of climate change (driver) and other inputs (land / food).



Results showed that intensification of agricultural practices for increased food production requires heavy mechanization and more fossil fuel inputs, but results in higher yields for the booming Burkinabe population, while conserving agricultural areas.

7.4 Case Scenarios of WEF Nexus and practice

Water -Energy -Food Nexus for effective water management and governance in Nepal

- A landlocked country in South Asia, with capital city in Kathmandu.

- Land area: 147,516 sq. km
- Location: 28.3949° N, 84.1240° E
- Bordered by two big nation India (East-West-South) and China (North)

- Estimated water potential: 7000m3 per person/year (FAO 2016).
- Hydropower Potential: 80,000MW
- Water Security: Weakest in Asia and pacific (ADB, 2016), despite abundance of water resources.

- Sustainable water security requires not only understanding of water supply and demand but also proper understanding of linkages in WEF nexus.

7.4 Case Scenarios of WEF Nexus and practice

Water-Energy-Food Nexus for effective water management and governance in Nepal

Challenges to Water Security

Agricultural Water Security

1. Year-round irrigation coverage is low as most irrigation water comes from medium size rivers, which dries up in summer.
2. Pumping of groundwater is constrained due to insufficient energy. National Grid hasn't reached all rural areas.
3. Inappropriate crop selection.
4. Financial Constraints.
5. Reduction in optimum production.

Hydro Energy Security

1. Despite huge potential for a hydropower, infrastructure development and environment protection is crucial issue.
2. Main constrains are financial. Political and governance-related.
3. Depends on foreign investment, which is not always favorable for nation.
4. Market of surplus energy is another aspect which arises questions for various cross- border trade, as well as large political economy

Other Drivers of Water Insecurity

Climate Change, Disaster Risk, Population Growth, Competing water uses.

7.4. Case Scenarios of WEF Nexus and practice

Water-Energy-Food Nexus for effective water management and governance in Nepal

Addressing challenges in Water security through WEF Nexus

1. First step is acknowledging Nepal's large untapped reserve of renewable groundwater, especially in lower plains. This has high potential to meet irrigation demand of agriculture.

2. Reliable energy is main hindrance for optimum utilization of available water resources (pumping and supply) in irrigation practice. Production of affordable energy for water distribution can increase agricultural production all year round.

3. Nexus approach also highlight cautions such as proper environmental assessment for sustainable extraction of groundwater, preservation of water dependent-ecosystem along with hydropower development, biodiversity preservation, etc.

4. Incorporation of Nexus approach in water governance policy of nation plays a vital role for water security and holistic management of related resources.

8. Conclusion

- An elaborate overview of the concept and approaches of WEF nexus has been presented in this training manual.
- For the fulfillment of increasing demand of human population along with numerous stressors such as climate change impacts, rapid urbanizations, change in human lifestyle, etc, integration of Nexus approach in national policy is deemed as urgent to reduce tradeoffs and increase synergies.
- Case studies showed energy generation from agricultural bi-products can be better substitute of fossil fuel. This approach can be adopted globally with proper ground economic analysis.
- Incentives, fundings and technology innovation in the energy production can enhance irrigation capacity and ultimately food production/distribution.
- Developing nations, specially with high hydropotential should prioritize funding in energy.

8. Conclusion

- A WEF nexus approach will only be efficient if the socio-economic status of local people involved is considered. Nexus outcomes must be evaluated for the poor, who are greatly affected by the drivers of Nexus.
- As such, the Nexus approach must be implemented to harness the potentials in limited water, energy, food / land resources in an integrated and a holistic way, so as to create an eco-friendly, economic, and sustainable world.
- Nexus is the new gold!

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Thank you