Additional Groundwater Development for Climate Crisis

Groundwater

Additional Groundwater Development for Climate Crisis

United Nations Educational, Scientific and Cultural Organization

i-WSSM International Centre for Water Security and Sustainable Management

Aims & Objectives

- The aims of the course are to:

  (1) Study the types of artificial groundwater recharge
  (2) Study benefit of the surface dam installation and the reason for the need for artificial recharge

- The objectives are that trainees will understand:

  (1) Types of artificial recharge
  (2) Benefit of the surface dam installation
  (3) The needs for artificial recharge

Contents

1. Groundwater artificial recharge

1.1 Groundwater recharge

◆ Definition :

– A method that enables large-scale intake by increasing groundwater in the aquifer by withdrawing surface water from a river or lake, transporting it to an appropriate place, and forcibly infiltrating and cultivating the aquifer through various method

◆ Advantage : Reduction of environmental problems, evaporation loss, flooding, cost and improvement of water quality

◆ Disadvantage : Water quality problem and limit of soil texture

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1.1 Groundwater recharge

◆ Artificial recharge

– Use of aquifers as water storage sites

– Increase the amount of water source cultivated and stored as an aquifer through artificial methods

– Purpose

Groundwater level recovery, water quality improvement, control of underground pollutants, prevention of salinization of groundwater

Surface water-groundwater integrated water resource management

1.1 Groundwater recharge

◆ Type of artificial recharge

– Direct method:

- Aquifer Storage and Recovery: ASR
- Artificial recharge through wells or surface recharge fields

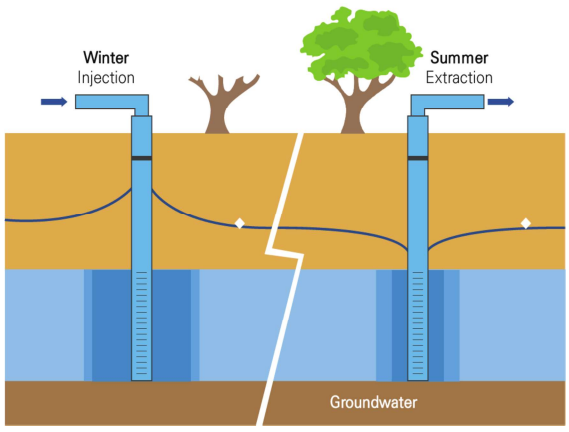
– Indirect method

- Riverbank filtration: RBF
- Groundwater dam

1.2 Type of groundwater recharge

(1) Aquifer storage and recovery(ASR)

- Treated water is directly injected into the aquifer through a well or recharge site to increase the groundwater storage,
- if necessary, the stored water is recovered and used
- Purified water can be stored for a long time in an aquifer
- Good water quality for injection water is required



1.2 Type of groundwater recharge

(1) Aquifer storage and recovery(ASR)

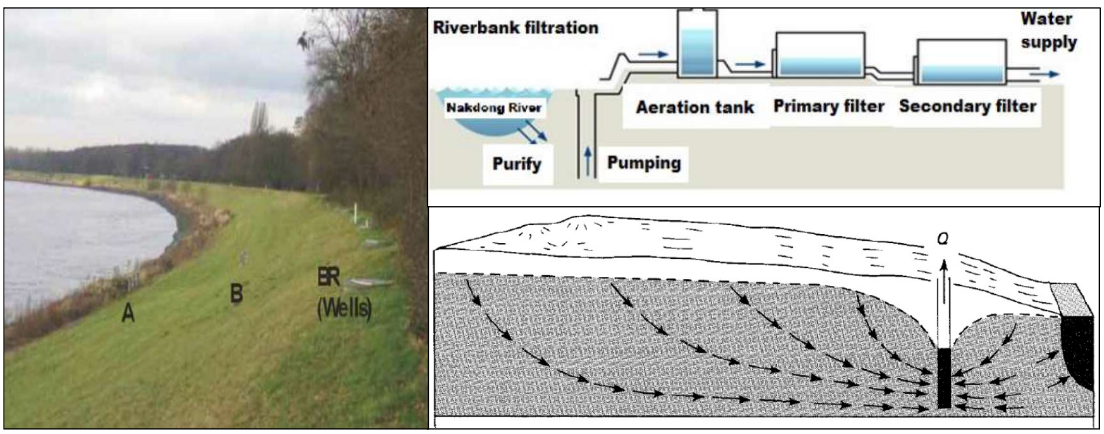
- ASR in Korea (Jeju)
  - short period of discharge time
  - water flows during rainy season
  - only 5–20 days per year
  - Artificial recharge using flood reduction reservoirs

Source) K-Water

1.2 Type of groundwater recharge

(2) Riverbank filtration (RBF)

- Collecting water filtered by pollutants while river water passes through the river bed sedimentary layer for a long period of time
- Started in the Rhine River in Germany from the 19th century

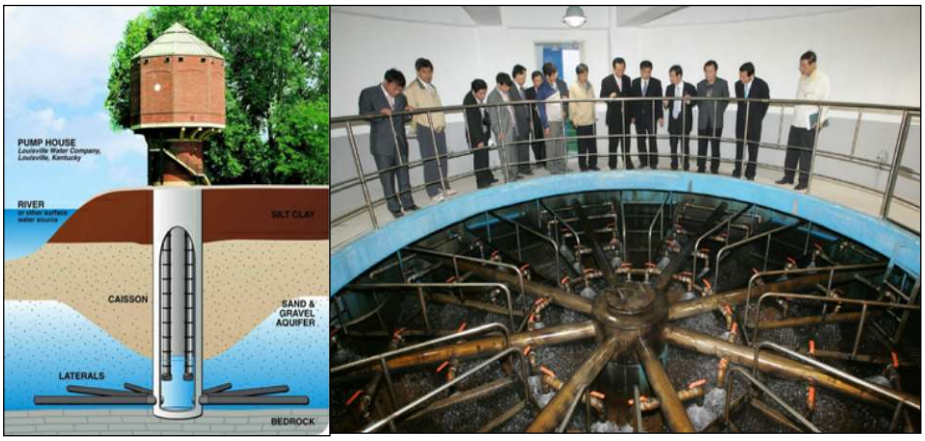


Source) K-Water

1.2 Type of groundwater recharge

(2) Riverbank filtration (RBF)

- Feasibility study was started in 1995 by K-water
- 60,000 ton Riverbank site was constructed during 2000 to 2005

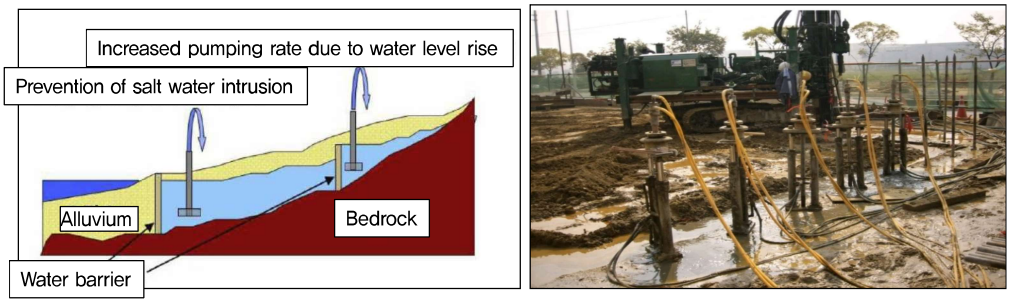


Source) K-Water

1.2 Type of groundwater recharge

(3) Groundwater dam

- By constructing a water barrier in the basement, groundwater is stored, and pumped
- Advantage
  - No loss due to evaporation, no submerged area on the surface
  - Low risk of water pollution and relatively low construction cost
- Disadvantage
  - Pumping facility required for pumping, maintenance cost
  - Difficult to evaluate the amount of groundwater storage



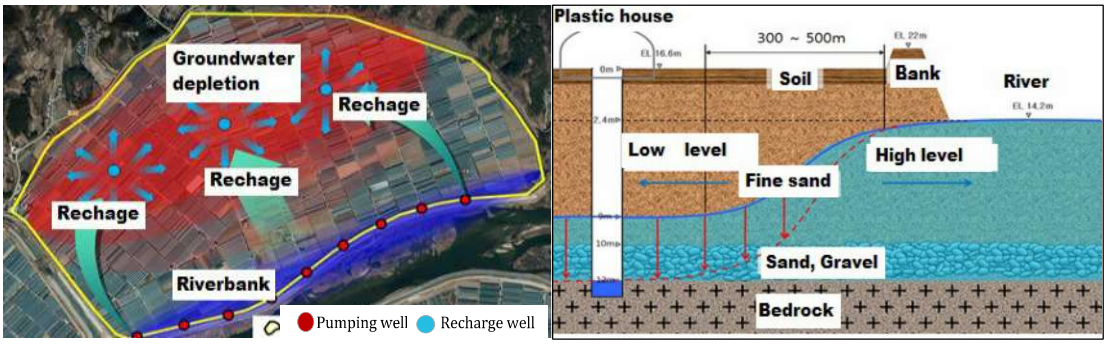
Source) Korea Rural Community Corporation

2. Case study of artificial recharge in Korea

2.1 Overview of the artificial recharge
2.2 Artificial recharge site investigation
2.3 Recharge plan at test site

2.1 Overview of the artificial recharge

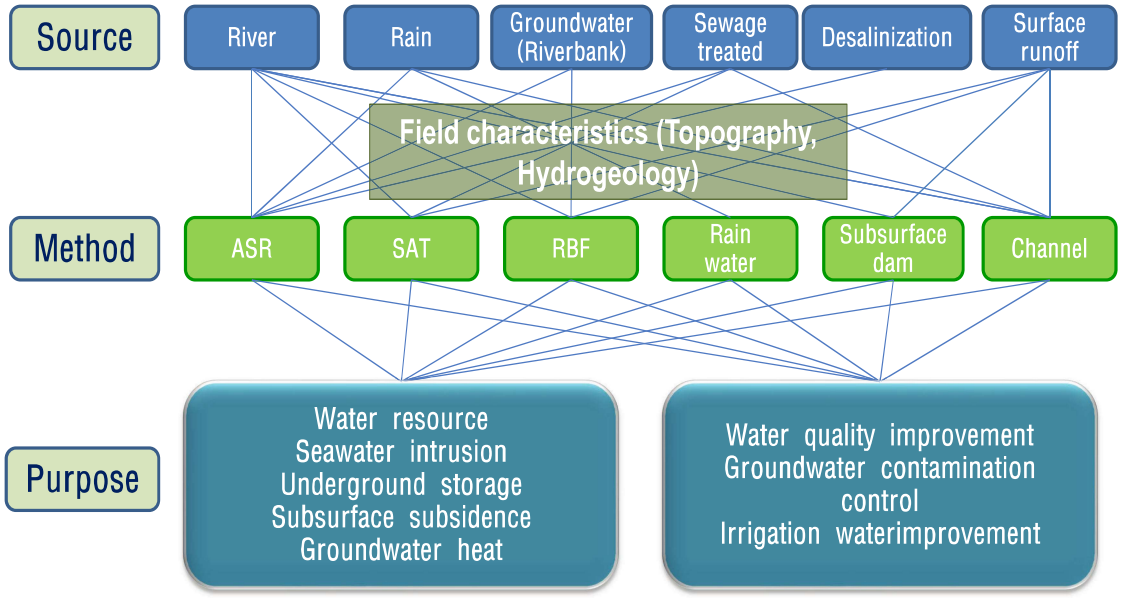
- Location of test site : Southern part of Korea
- Cause of water shortage : Excessive water use in collective facility cultivation complex
- Purpose of recharge : Supply of water through groundwater recharge to areas suffering from water agricultural water shortage



Source) Korea Rural Community Corporation

2.1 Overview of the artificial recharge

◆ Classification of artificial recharge

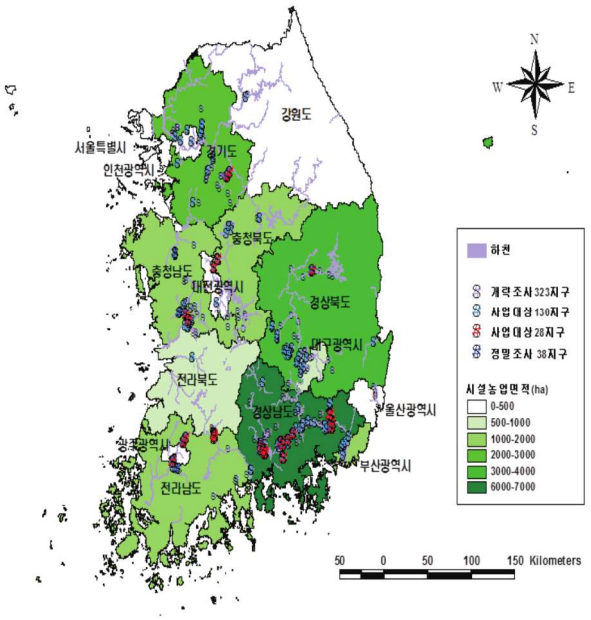


2.2 Artificial recharge site investigation

◆ Feasibility study for groundwater recharge project

- Facility agriculturel complex
- 323 site(more than 10 ha)
- Area : 18,936ha

- Water shortage occurred at 219 site out of 323 site (68%)
- 98 site is more than 50ha



Source) Feasibility report for artificially recharge groundwater in a facility agricultural complex, KRC 2015

2.2 Artificial recharge site investigation

◆ Investigation results

◆ Basic status of site •Facility area : 250ha •Greenhouse : 2,058ea •Groundwater well : 972ea	◆ Greenhouse crop (2,058 ea) •Main crop : Pumpkin(45.7%), paprijka(18.7%), pepper(13.8%), strawberry(10.2%), pimento(7.1%), etc(4.5%)
◆ Groudwater well (972ea) •Water for growing : 439ea, 45.2% •Water for energy : 189ea, 19.4% •Water usage at each grounhouse : 64.18(㎥/day) •Combined use : 334 ea, 35.4%	

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Source) Korea Rural Community Corporation

2.2 Artificial recharge site investigation

◆ Investigation results

〈 Test well location for soil texture 32ea 〉

〈 Location of groundwater well 972ea 〉

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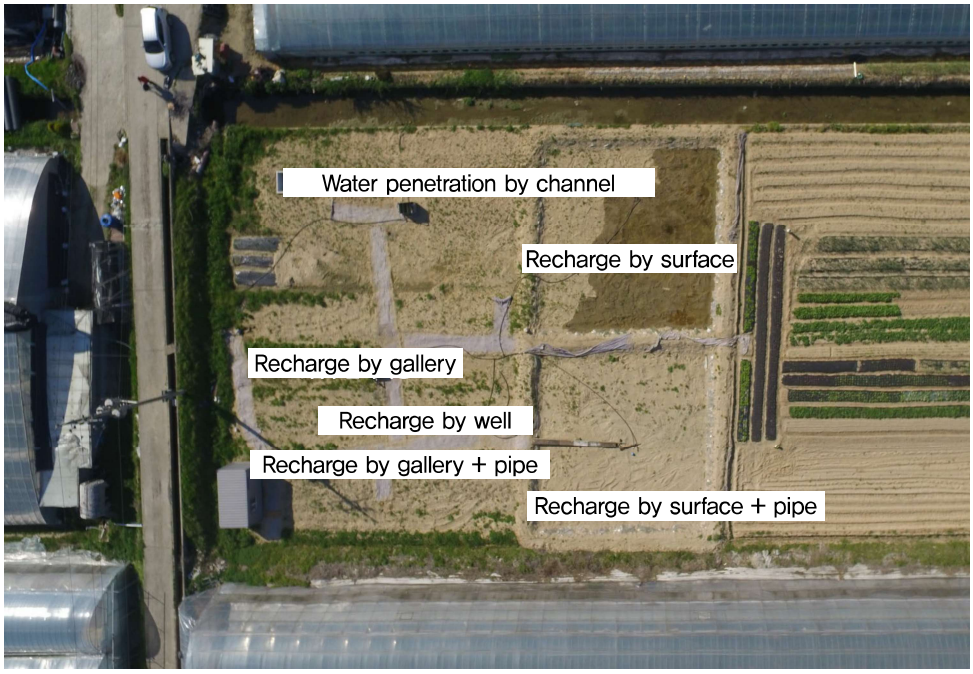
Source) Korea Rural Community Corporation

2.2 Artificial recharge site investigation

◆ Investigation results for recharge rate



Source) Korea Rural Community Corporation

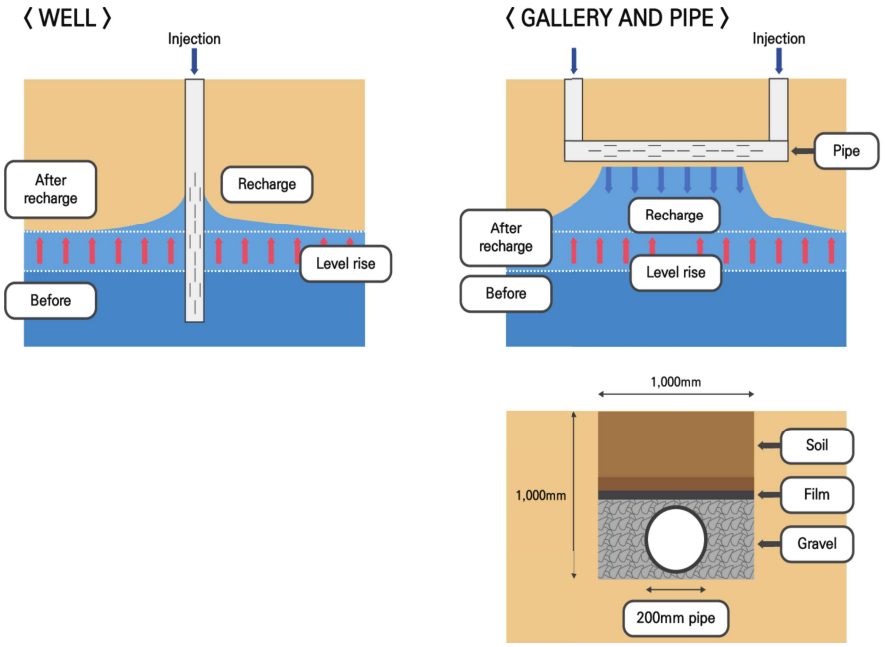
2.2 Artificial recharge site investigation

◆ Investigation results for recharge rate

Source) Korea Rural Community Corporation

2.3 Recharge plan at the site

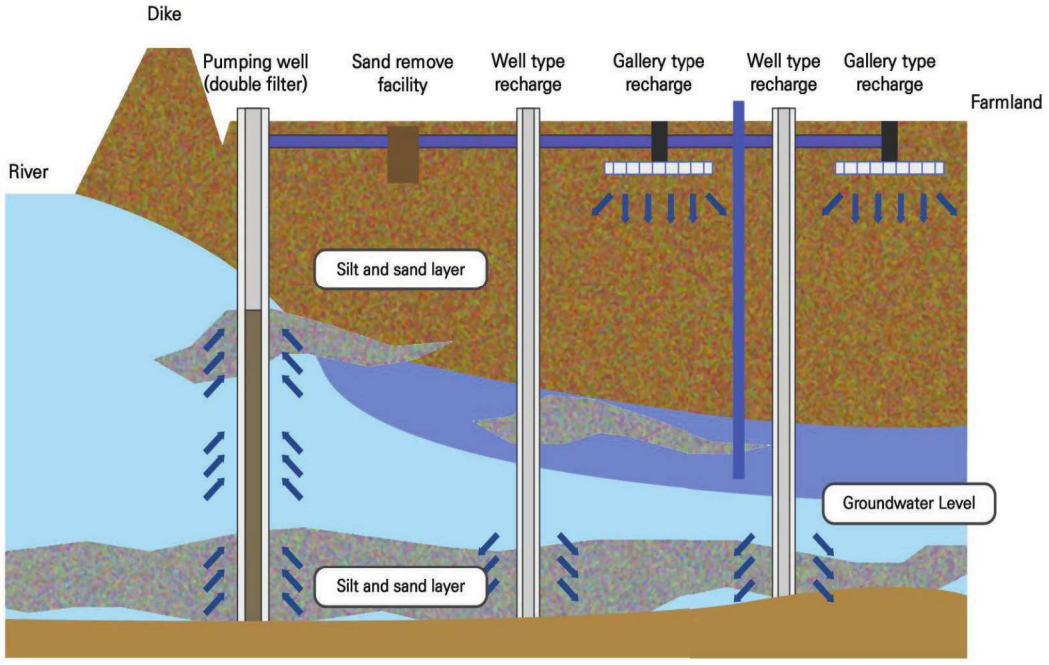
◆ Recharge plan



Source) Korea Rural Community Corporation

2.3 Recharge plan at test site

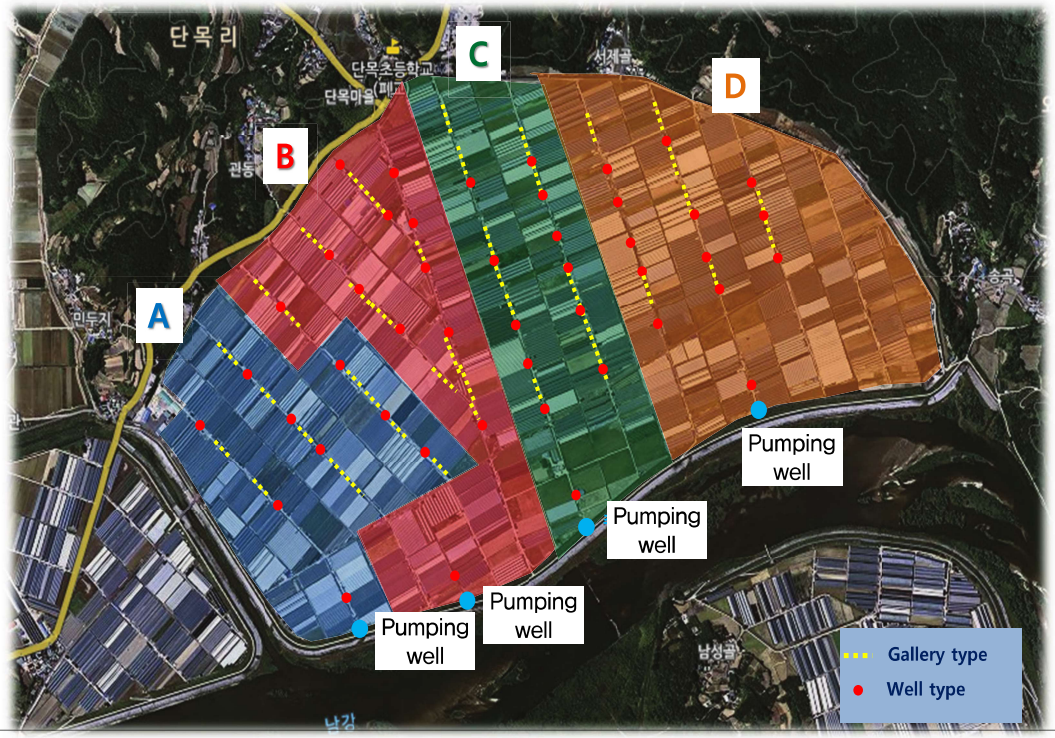
◆ Recharge plan



Source) Korea Rural Community Corporation

2.3 Recharge plan at test site

◆ **Recharge plan**



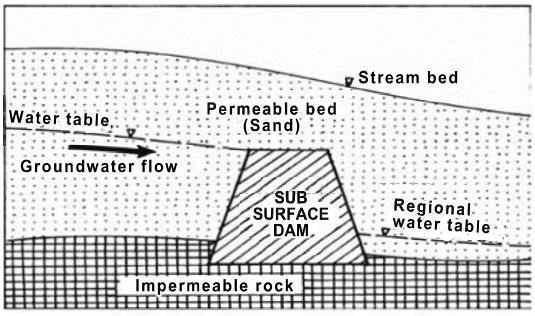
Source) Korea Rural Community Corporation

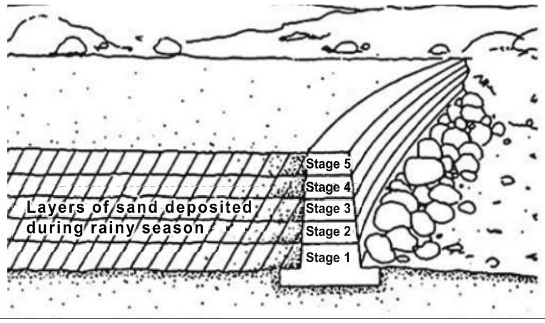
3. Case study of subsurface dam in Korea

3.1 Description of groundwater dam
3.2 Subsurface dam in Korea
3.3 Characteristics of irrigation by subsurface dam

3.1 Description of Groundwater dam

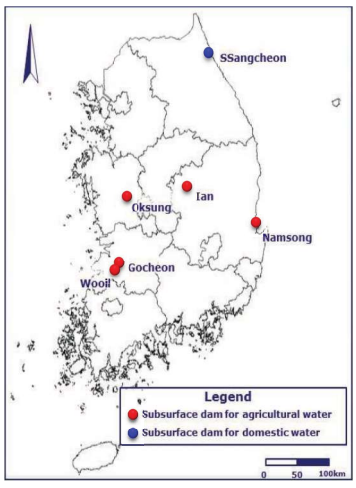
- Groundwater dam is classified into ***subsurface dam*** and sand storage dam.
- Subsurface dam is constructed ***to secure additional groundwater resources and to prevent seawater intrusion*** in coastal aquifer. (i.e. S. Korea, China, Japan)
- Sand storage dam is constructed to secure additional sand deposits (or aquifer). (i.e. Kenya, Ethiopia)





3.2 Subsurface dam in Korea

◆ Location and specification

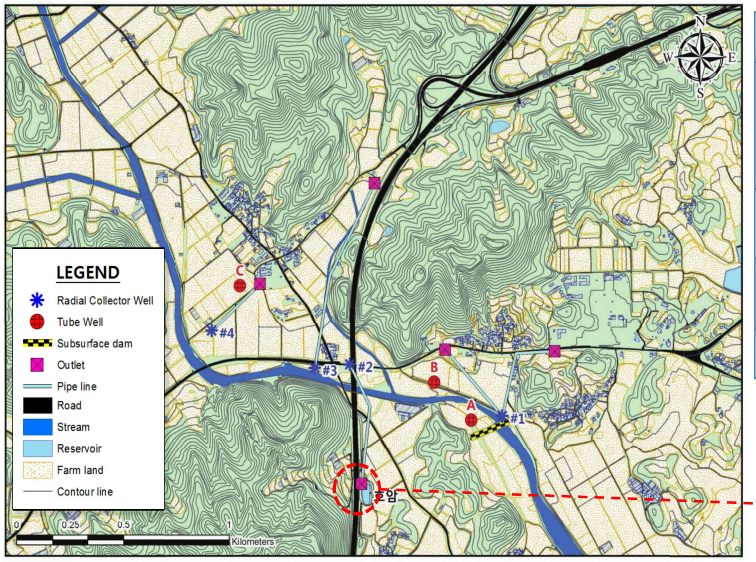


Name	Constructed year	Length (m)	Height (m)	Storage (×10³㎥)	Pumping rate (㎥/day)	Type
Ian	1984	230	4.0	4,143	24,000	Surface water–groundwater interaction type
Gocheon	1986	192	7.5	1,543	25,110	
Wooil	1986	778	6.7	2,457	16,200	
Oksung	1986	482	9.2	2,850	27,900	Linkage type to irrigation canal
Namsong	1986	89	18.8	4,017	27,000	Seawater intrusion prevention type
Ssangcheon	1998	840	27.0	7,300	41,000	

Source) Rural Research Institute

3.2 Subsurface dam in Korea

◆lan dam : surface water–groundwater interaction type

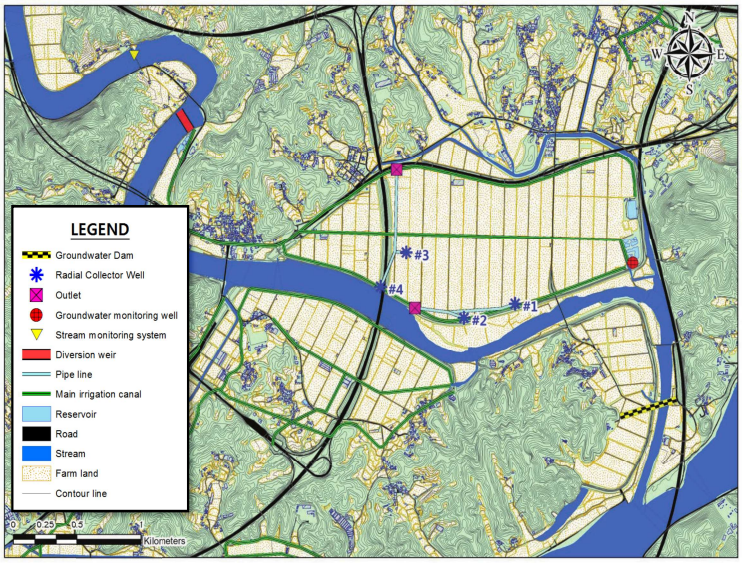


Role	Main source
Construction type	Stage grouting + Concrete Displacement
Benefited area	134ha
Catchment area	2,700ha
Pumping rate	24,000㎥/day

Source) Rural Research Institute

3.2 Subsurface dam in Korea

◆Oksung dam : linkage type to irrigation canal



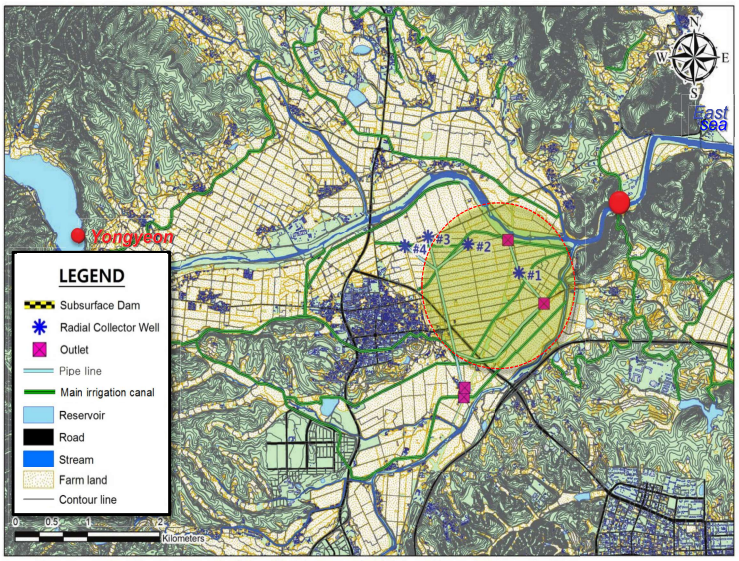
Role	Secondary source
Construction type	Stage grouting
Benefited area	146ha
Catchment area	27,500ha
Pumping rate	27,900㎥/day

- Subsidiary of Dongcheon diversion weir
- Water supply increases during drought periods

Source) Rural Research Institute

3.2 Subsurface dam in Korea

◆ Namsong : Seawater intrusion prevention type



Role	Secondary source
Construction type	Grouting
Benefited area	155ha
Catchment area	15,300ha
Pumping rate	27,000㎥/day

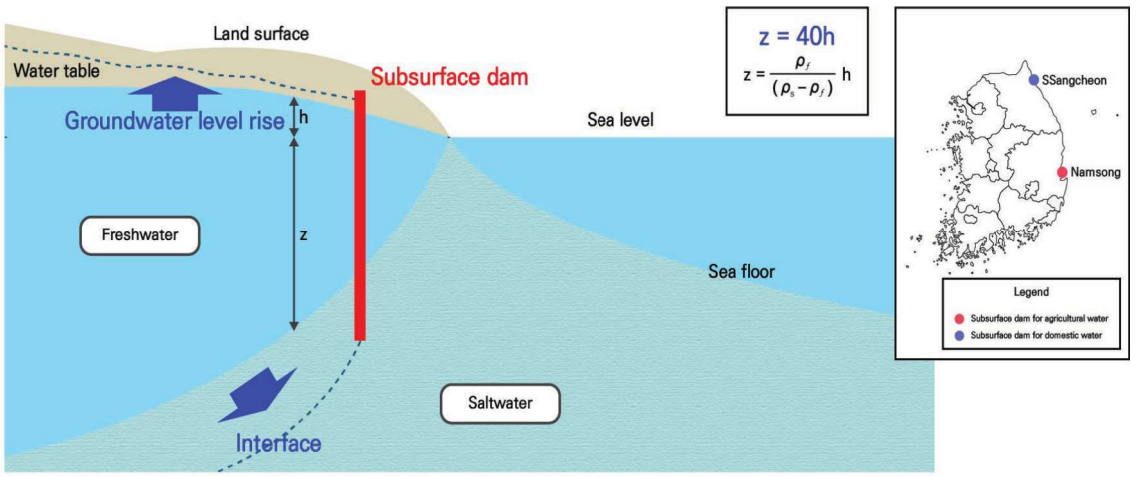
▪ To prevent seawater intrusion

Source) Rural Research Institute

3.2 Subsurface dam in Korea

◆ Prevention of seawater intrusion

Seawater intrusion can be prevented by subsurface dam.

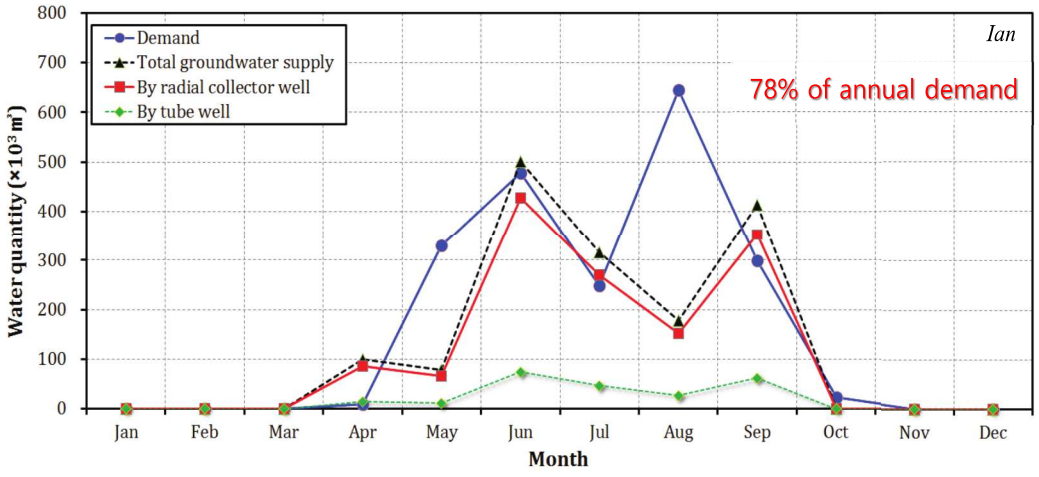


The interface is regressed into saltwater zone

Source) Rural Research Institute

3.3 Characteristics of irrigation by subsurface dam

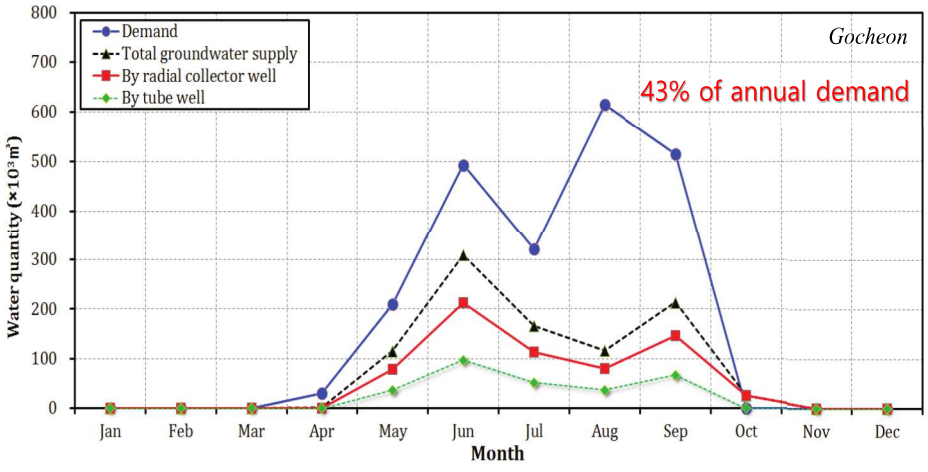
- *Monthly supply of each subsurface dam in 2015 at Ian dam*



Source) Rural Research Institute

3.3 Characteristics of irrigation by subsurface dam

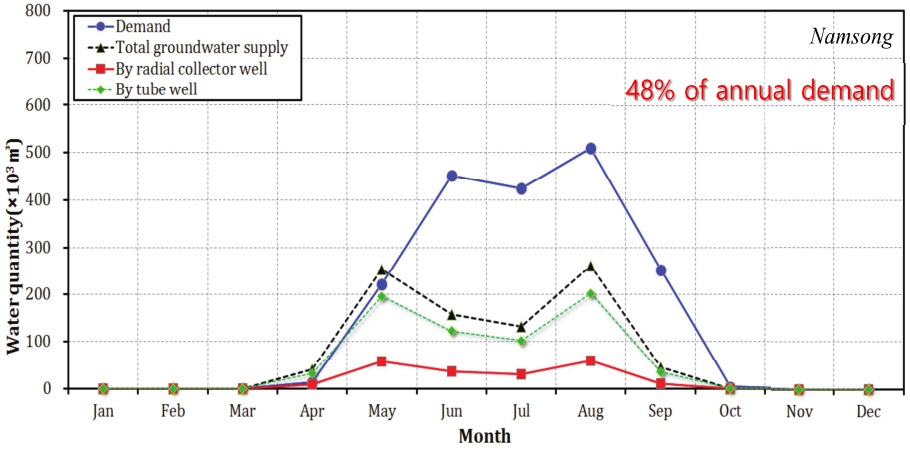
- *Monthly supply of each subsurface dam in 2015 at Gocheon dam*



Source) Rural Research Institute

3.3 Characteristics of irrigation by subsurface dam

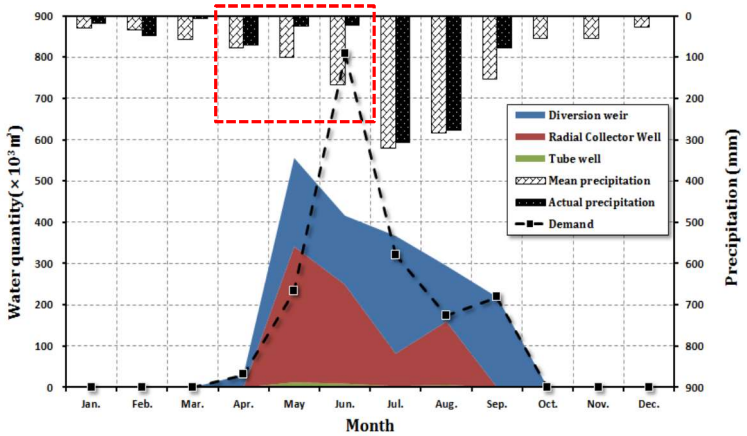
- *Monthly supply of each subsurface dam in 2015 at Namsong dam*



Source) Rural Research Institute

3.3 Characteristics of irrigation by subsurface dam

- *Monthly demand and water supply in Oksung area (2017)*



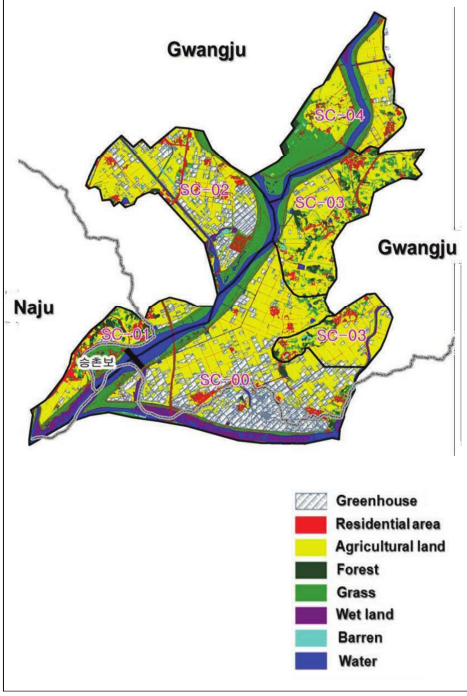
Time	Demand	Total Supply	Diversion weir (Surface water)	Subsurface dam (Groundwater)
Annual	1,787.7	1,883.4(105.4%)	1,051.8(58.8%)	831.6(46.5%)
April to June (drought)	1,072.5	1,002.8(93.5%)	412.6(38.5%)	***590.2(55.0%)***
				Unit : ×10³㎥

Source) Rural Research Institute


Thank you very much

4.2 Calculation of irrigation water requirement

(Example) Area of crop cultivation in the watershed



(unit : ha)

Greenhouse	Total	SC-00	SC-01	SC-02	SC-03	SC-04
Area	695	446	20	183	35	11
Ratio(%)	100	64.2	2.8	26.3	5.1	1.6

Area of SC-02~SC04	Single cropping	Double cropping	Total(㎡)	Ratio
Total	1,297,453	991,523	2,288,975	100.0%
Dropwort	200,944	470,373	661,749	28.9%
Tomato	354,340	119,774	477,726	20.9%
Young radish	349,118	44,680	395,509	17.3%
Chili(pepper)	91,765	120,832	215,650	9.4%
Water melon	103,071	-	104,886	4.6%
Eggplant	35,552	62,707	98,450	4.3%
Cucumber	55,158	16,649	72,302	3.2%
Leek	30,014	8,242	38,820	1.7%
Sesame	19,006	-	19,326	0.8%
Potato	10,416	2,938	13,458	0.6%
Strawberry	6,085	3,045	9,206	0.4%
Buckwheat	7,059	-	7,099	0.3%
The rest	34,927	142,283	174,793	7.6%

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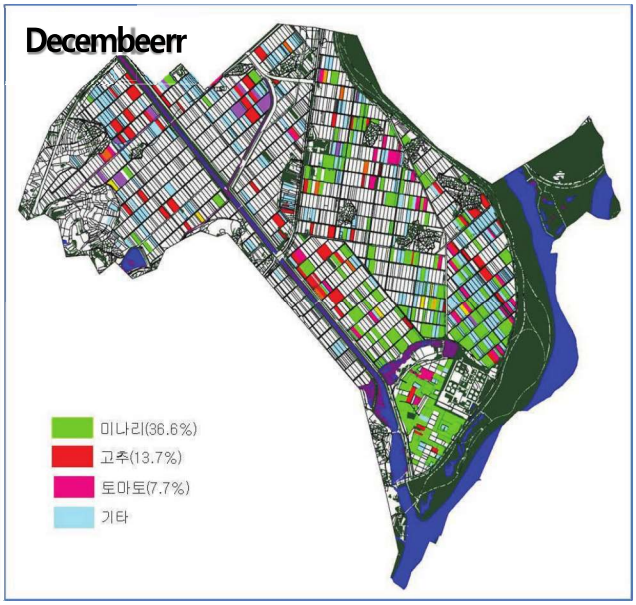
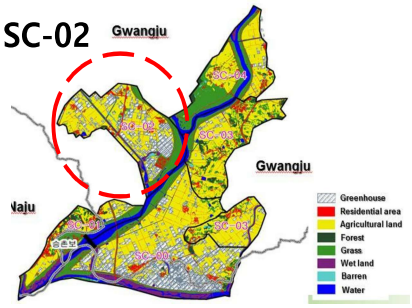
[References] Song (2019)

4.2 Calculation of irrigation water requirement

(Example) Crop cultivation status by month and land (lot)



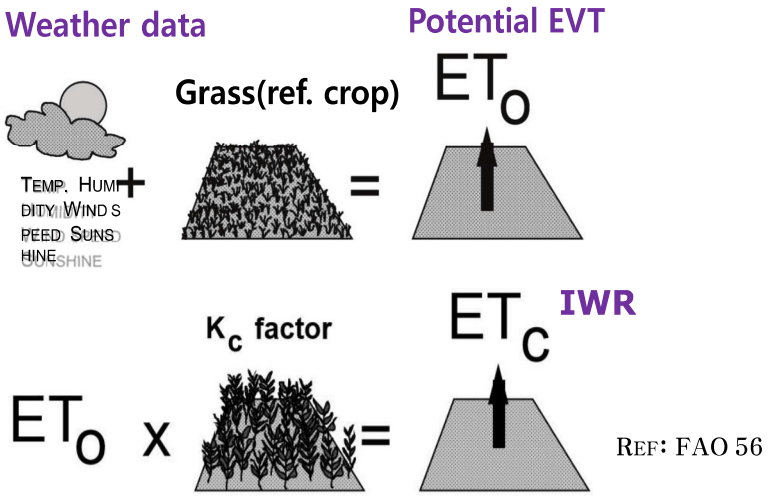


[References] Song (2019)

4.2 Calculation of irrigation water requirement

(Example) Calculation of irrigation water requirement

Irrigation water requirements (mm/day) = Potential EVT × Crop coefficient (Kc)



4.2 Calculation of irrigation water requirement

(Example) Calculation of potential evapotranspiration (PET)

$$ET_0 = \frac{0.408\Delta(R_n - G) + r\frac{900}{T+273}U_2(es - ea)}{\Delta + r(1 + 0.34u_2)}$$

(unit : mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	PET
2010	25.9	34.7	58.1	83.1	113.7	116.3	106.5	108.5	92.0	65.6	40.3	28.8	**873.57**
2011	24.7	34.6	0.0	89.9	113.3	114.7	113.7	97.3	97.2	65.8	38.4	27.8	**817.49**
2012	28.8	34.2	0.0	94.4	127.4	125.3	122.2	130.1	92.3	71.5	41.8	23.8	**891.81**
2013	26.1	37.3	0.0	90.2	123.9	120.9	133.3	148.4	99.4	73.0	37.3	26.7	**916.50**
2014	31.1	41.4	0.0	93.8	139.2	125.6	124.7	100.3	96.8	71.6	37.4	23.8	**885.80**
2015	27.1	36.2	0.0	86.1	132.0	115.0	113.0	112.6	94.7	67.5	29.0	23.8	**837.08**
2016	25.0	37.6	0.0	90.6	124.6	103.8	125.7	132.4	80.0	53.4	37.9	25.3	**836.25**
2017	27.2	36.4	0.0	100.6	126.6	125.9	106.4	117.4	89.4	62.3	37.5	24.5	**854.07**
2018	24.2	35.6	0.0	91.5	105.4	121.2	143.7	136.0	82.2	59.6	34.3	27.9	**861.64**

[References] Song (2019)

4.2 Calculation of irrigation water requirement

(Example) Calculation of crop coefficient

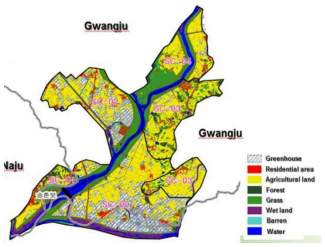
Month	Tomato	Young radish	Chili (pepper)	Water melon	Eggplant	Cucumber	Leek	Sesame	Potato	Strawberry	The rest
Jan	0.90	1.20	0.82	-	0.90	0.75	1.28	0.35	0.82	0.40	0.70
Feb	0.90	1.11	-	-	0.90	-	1.28	1.10	-	0.85	1.05
Mar	0.90	0.58	-	-	0.90	-	0.64	0.25	-	0.75	0.95
Apr	0.90	1.20	-	0.50	0.60	0.60	1.08	0.35	0.50	0.40	0.70
May	0.50	1.11	0.53	0.80	0.60	0.60	1.28	1.10	0.77	0.85	1.05
Jun	0.80	0.58	0.96	0.98	1.05	1.00	1.28	0.25	1.11	0.75	0.95
Jul	1.20	1.20	1.06	0.88	1.05	1.00	1.28	0.35	0.82	-	0.70
Aug	0.90	1.11	1.06	-	1.05	0.75	1.28	1.10	-	-	1.05
Sep	0.90	0.58	0.82	-	0.90	0.60	1.28	0.25	-	0.40	0.95
Oct	0.90	1.20	0.53	-	0.90	0.60	1.28	0.35	0.50	0.85	0.70
Nov	0.90	1.11	0.96	-	0.90	1.00	1.28	1.10	0.77	0.75	1.05
Dec	0.90	0.58	1.06	-	0.90	1.00	1.28	0.25	1.11	-	0.95

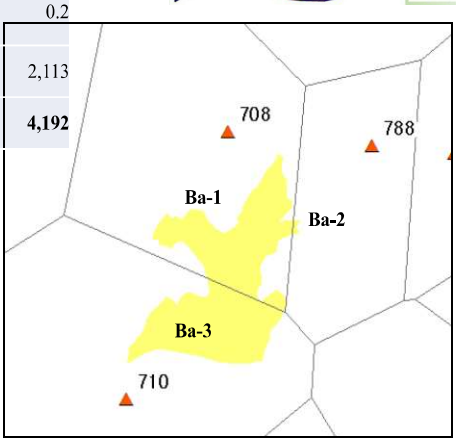
REF: RDA,RRI, FAO 56

4.2 Calculation of irrigation water requirement

(Example) Calculation of groundwater recharge

Watershed	Area (㎢)	Areal rainfall (mm)	Total amount of water (x10³ ㎥)	Recharge rate	Recharge (x 10³ ㎥)
Ba-1	20,775,865	676	14,044	0.148	2,079
Ba-2	189,084	6	1.12	0.148	0.2
Ba-3	21,538,129	663	14,280	0.148	2,113
총 계	42,503,078	1,345	28,325		**4,192**





4.2 Calculation of irrigation water requirement

(Example) Estimation of potential water supply compared to IWR

Water budget = potential water supply – irrigation water requirements

(unit : 10^3 m³/year)

		Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Potential water supply		54,847	1,106	1,856	2,844	4,387	3,203	4,165	11,091	12,707	5,454	3,674	2,681	1,680
IWR	Total	43,312	3,058	9,944	2,941	365	1,819	1,831	2,045	1,963	4,351	1,962	3,112	9,920
	Crops from upland	3,862	104	133	184	346	403	496	759	626	299	244	158	109
	Dropwort	37,335	2,954	9,811	2,757	0	1,402	678	678	678	3,893	1,718	2,954	9,811
Water budget		13,649	-1,952	-8,088	-97	4,041	1,398	2,992	9,653	11,403	1,261	1,711	-431	-8,241

5. Conclusions

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- **Understanding of the impact the climate crisis on the groundwater system is essential to stably supplying irrigation water and securing groundwater during the event of a drought.**

- **Understanding groundwater system**
  - Hydrologic cycle
  - Subsurface distribution of water
  - Aquifer formation
  - Sustainable groundwater development
- **Climate crisis environment**
  - Climate crisis
  - Climate change impact on agriculture
- **Effect of drought on groundwater system**
  - Standardized precipitation index (SPI)/ Standardized groundwater level index (SGI)
  - Evaluation of drought for groundwater system
  - Determination of limit value of groundwater level
- **Irrigation water requirement**
  - Irrigation water requirement (IWR)
  - Calculation of irrigation water requirement

Thank you very much