Journal of the Korean Society of
Agricultural Engineers, Vol. 42, 1~8
June 2000

Investigation of Irrigation Water Use in Sumjin River Basin

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Abstract □ To examine the irrigation water uses in Sumjin river basin, existing status and operation records of headworks facilities including reservoirs, pumping stations, tube wells, and diversion dams were surveyed and analyzed for the period of 1994~1998. Daily irrigation demand and water use were estimated for the irrigated paddy field using Penman equation, Tank model, reservoir water balance model and daily pumping rate of pumping stations. Irrigation water use from multi-purpose dams in the basin was not included in this study.

Keywords □ irrigation water use, Sumjin-river basin, headworks, irrigated paddy field

I. Introduction

Since irrigation water use is major water use of a river basin, it is very important to get hold of actual amount of the water use for the effective management of the river systems and planning of the national water resources development. Surveying of basin scale irrigation water use has been initiated in Nakdong river basin (RDC, 1997). The estimation of irrigation water use of the river basin was based on the relationship between measured irrigation amounts from selected reservoirs and those of pumping stations. Thereafter, the surveying on Han river basin was performed systematically to figure out the actual irrigation water use (SNU, 1998).

Sumjin river is the 4th largest river in Korea, which located at mid-western area of southern part of Korean peninsula, and runs through Chollabuk-do, Chollanam-do, and Kyongsangnam-do providing agricultural water, living and industrial water to these provincial areas. The irrigation water in Sumjin river basin was supplied by stream water intake from main and tributary streams, surface water

from reservoirs, and groundwater. But, there was no survey report about the irrigation water use in Sumjin river basin, only except for the data like storage rate of reservoirs collected from Farmland Improvement Association (FIA) or data from administrative districts such as Si-gun (city and county) during drought period for the drought mitigation measures.

The objective of this study is to investigate irrigation water use from water supply facilities in Sumjin river basin based on operation records. The inventory of existing irrigation facilities such as reservoirs, pumping stations, tube wells, diversion dams within the basin was made and classified for further analysis. Operational records for those facilities were also obtained and analyzed for the estimation of daily water use of irrigated paddy fields in Sumjin river basin. Reservoir water balance model, Tank model, and pumping rate were used for this study. irrigation water use from multipurpose dams such as Sumjingang dam, Boseonggang dam, and Jooam dam were not considered here.

Ⅱ. Materials and Methods

1. Sumjin river basin

Total area of Sumjin river basin is 4,896.5km^2, and the length of main river is 212.3km. Chollabuk-do, Chollanam-do and Kyongsangnam-do covers 44%, 47% and 9% of the basin area, respectively. The location map of Sumjin river basin is shown in Fig 1, which shows 10 subbasins divided for this study.

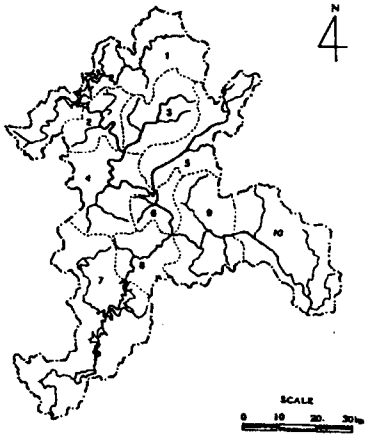

Fig. 1. Map of Sumjin river basin.

The land use of Sumjin river basin is summarized in Table 1. In Sumjin river basin, cultivated land is 924.85km^2 in 1998 that is equivalent to 19% of total basin area. Land use shows that paddy field, upland, forest, and others consist 12.8%, 6.1%, 71.8%, and 9.3% of basin area, respectively. The paddy field can be classified as irrigated and partially irrigated paddy field, and the area of irrigated paddy field is 45,632ha as 72% of the whole paddy field and that of partially irrigated paddy field is 17,556ha as 28% of total paddy field area.

Table 1. Land use in Sumjin river basin.(1998)

Province	Area (km^2)	Land use			
		Paddy	Upland	Forest	Others
Chollabuk-do	2,133.13	283.09	141.27	1,485.99	222.78
Chollanam-do	2,304.25	294.92	136.48	1,679.19	193.66
Kyongsangnam-do	459.12	49.47	19.62	348.26	41.77
Total	4,896.50	627.48	297.37	3,513.44	458.21

2. Survey of irrigation facilities

Head works for irrigation water supply are

classified into irrigation reservoirs, pumping stations, tube wells, and diversion dams. Basic informations of each irrigation facilities such as size, location, irrigation capacity, irrigated area, and operation record were obtained by visiting each FIA office and compared with the data of the Agricultural Water Resources Database. Irrigation reservoirs, pumping stations, tube wells, and diversion dams were clustered based on managerial organization such as FIA, Si-gun (city and county) and subbasin. Irrigated area by clustered headworks were checked by consulting the data of Yearbook of Agricultural Land and water Development Statistics (Ministry of Agriculture and Forestry, 1998).

The number of headworks in Sumjin river basin are summarized as Table 2.

Table 2. Headworks in Sumjin river basin (1998)

Facility	Number		Irrigated area	
	No.	%	ha	%
Reservoir	1,177	35.1	28,297.8	62.0
Pumping station	242	7.2	5,668.6	12.4
Tube well	1,071	31.9	3,007.5	6.6
Diversion dam	864	25.8	8,667.4	19.0
Total	3,354	100.0	45,641.3	100.0

3. Estimation of irrigation water use

Thiessen network was constructed for the basin and weather stations were selected for the reference weather station of each subbasin. Daily climate data of sele ted weather stations in Sumjin river basin during 1994-1998 were collected and used for simulation of runoff and potential evapotranspiration of watersheds in subbasin. Monthly precipitation observed at Namwon station in 5 years from 1994 to 1998 was shown in Table 3 as an example of the collected data. Rainfall amounts varied during study period and severe drought occurred in the year 1994 and 1995.

Table 3. Precipitation at Namwon station

Month	Precipitation(mm)					
	1994	1995	1996	1997	1998	Mean
1	27.4	40.1	27.2	26.2	29.2	30.0
2	16.4	26.5	7.7	46.8	34.8	26.4
3	27.3	28.5	111.5	67.0	61.1	59.1
4	35.5	100.0	40.5	68.0	133.0	75.4
5	79.0	60.0	51.0	143.5	94.0	85.5
6	81.5	50.0	330.0	236.0	309.5	201.4
7	1.0	126.0	135.0	428.5	231.5	184.4
8	139.5	314.0	201.5	409.5	633.0	339.5
9	24.5	93.0	35.0	48.0	203.5	80.8
10	89.5	20.5	60.0	7.0	59.8	47.4
11	29.0	32.8	102.7	139.5	32.8	67.4
12	14.5	13.9	22.4	58.9	6.5	23.2
Total	565.1	905.3	1,124.5	1,678.9	1,828.7	1,220.5

(1) Reservoirs

Estimation of irrigation water use from irrigation reservoirs was performed using the daily or ten days storage rate data during 199 4~1998 and reservoir water balance model, DIROM (Daily Irrigation Reservoir Operation Model) developed by Kim(1988). The model was used for surveying of reservoir irrigation water use of Han river basin and proved to be adequate for estimating irrigation reservoir water use by comparing results of simulation and observed data of several reservoirs (1998). The continuity equation in the reservoir water balance model can be represented as equation (1).

$$S_t = S_{t-1} + I_t + P_t - (R_t + O_t + E_t) \quad (1)$$

Table 4. Crop coefficients for modified Penman equation

District	May			June			July			August			September		
	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Southern	0.56	0.56	0.56	0.75	0.95	1.06	1.09	1.17	1.39	1.53	1.58	1.47	1.42	1.32	-

(Note) Ministry of Agriculture and Forestry, Rural Development Corporation (1997), Design Criteria of Agricultural Land and Water Development Planning (Irrigation).

where, S_t and S_{t-1}, = Storage, I_t = Inflow from watershed, P_t = Precipitation on reservoir, R_t = Release for irrigation use, O_t = Overflow by spillway, E_t = Evaporation from reservoir.

The amount of precipitation onto and evaporation from reservoir water surface can be neglected and the equation can be simplified as equation (2).

$$S_t = S_{t-1} + I_t - R_t - O_t \quad (2)$$

In this study, water balance components estimated by following methods.

① Inflow (I) was determined by modified-Tank model imbedded in DIROM model. Parameters of modified-Tank model were determined from suggested relationship between land use pattern of a watershed and runoff parameters by Kim (1988).

② Release for irrigation use (R) from reservoir can be determined as equation (3).

$$R_t = 10\,(REQ_t + TS_t) \cdot A \,/\, (1 - L/100) \quad (3)$$

where, TS = transplanting water use (140mm used in this study), REQ_t = water requirement of day t (mm/day), A = irrigated area(ha), L = channel loss plus management loss(%) (15% was used in this study).

Daily water requirement for paddy, REQ_t can be defined as equation (4).

$$REQ_t = ETP_t \times K_c + F_t - Re_t \quad (4)$$

where, ETP_t = potential evapotranspiration(mm) by modified Penman method, Kc = crop coefficient of paddy (Crop coefficient used for this is shown in Table 4.), F_t = infiltration(mm, and Re_t = effective rainfall(mm)

The simulated daily irrigation amount was adjusted until simulated storage rate fit to the recorded storage rate of each reservoir. Then, daily release water obtained from the simulated result of the reservoir was determined as daily irrigation water use by each reservoir. Observed and simulated storage rate of Joongpyong reservoir was shown in Fig. 2 as an example of 1995.

To estimate daily irrigation amount of reservoirs having no operation records, annual water use was estimated first and daily amount was determined. Annual water use of a reservoir was estimated using relationship between irrigated area and annual water use, which was derived from simulated data of reservoirs having operation data within same FIA or subbasin. To estimate the daily water use from the reservoir without operation

records, the estimated annual irrigation amount was distributed by average daily water supply pattern which was derived from the simulated daily irrigation data of other reservoirs within same FIA or subbasin.

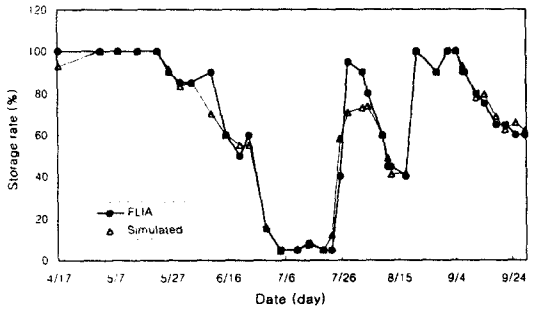

Fig. 2. Observed and simulated storage rate of Joongpyong reservoir(1995)

(2) Pumping stations

To investigate the water use from pumping stations, the past records such as electric power use, operation time, amount of pumping water were collected from FIA. If the record of pumping amount did not exist, water use was calculated using the relationship between electric power use or operation time and the amount of pumping water. If there are no related data, annual water use of a pumping station was estimated using relationship between irrigated area and annual water use, which was derived from recorded data of pumping stations having the data within same FIA or subbasin. Fig. 3 shows the relationship between irrigated area and annual irrigation water supply by pumping stations in Namwon Farmland Improvement Association in 1995. To estimate the daily water use from the pumping station without operation records, the estimated annual pumping amount was distributed by average daily pumping rate which were derived from the daily pumping data of other pumping

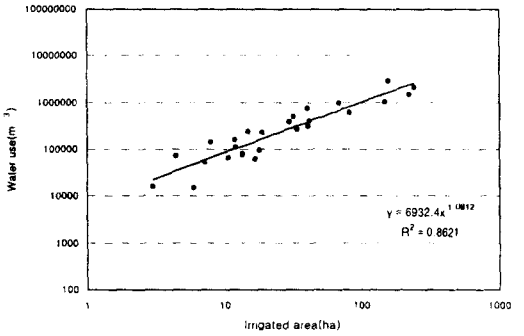

Fig. 3. Relationship between irrigated area and water use in Namwon FIA(1995)

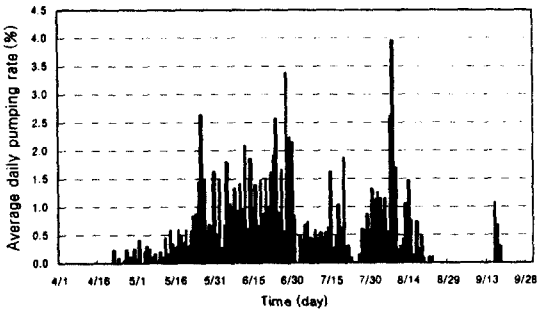

Fig. 4. Average daily pumping rate in Namwon FIA(1995)

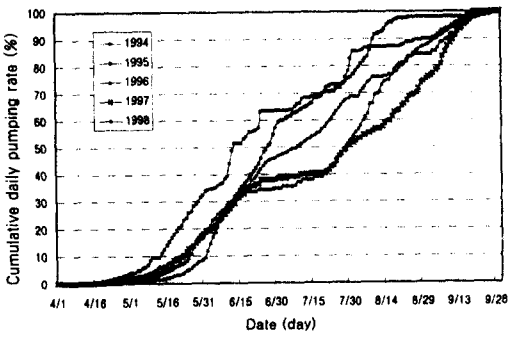

Fig. 5. Cumulative curves of daily pumping rate in Namwon FIA district

stations within same FIA or subbasin. Fig. 4 shows a typical daily pumping rate during the growing period within Namwon Farmland Improvement Association in 1995, while Fig. 5 shows the cumulative daily pumping rate curves during 5 years.

(3) Tube wells

The amount of daily water pumped from tube wells was estimated assuming fulfilling crop water demand while following pumping rate considering pumping capacity. If pumping capacity was less than daily crop water requirement, irrigated amount was assumed to be limited to the pumping capacity.

(4) Diversion dams

The daily water use from diversion dams was investigated considering crop water demand, stream discharge simulated by TANK model, and design intake capacity of diversion dam. Simulated stream discharge was compared with design intake capacity and crop water requirement. If simulated stream discharge was less than both crop water requirement and design intake capacity, intake amount was determined as simulated stream discharge. Intake water amount from a diversion was adopted for design capacity when daily crop water requirement was less than simulated stream discharge but greater than design intake capacity.

Ⅲ. Results and Discussion

1. Irrigation water use by reservoirs

Irrigation water use for the irrigated paddy field supplied from reservoirs, pumping stations, tube wells, and diversion dams in Sumjin river basin during 1994~1998 was estimated as Table 5. The minimum water use was 190.7 million m^3 in 1995, and the maximum use was 248.8 million m^3 in 1998. An average annual water use from reservoirs during 5 year period was 226.9 million m^3 which is equivalent to 802 mm per unit area, and 64.6% of total water use for irrigated paddy field. It was found that portion of irrigated water from reservoirs was larger than that of other irrigation facilities in the year with comparatively high rainfall. The amount of water use in 1995 was less than that of 1994. The reason was considered that the capability to supply irrigation water was ralatively low due to the severe drought in 1994 and continued less rainfall in 1995.

Table 5. Irrigation water use from various irrigation facilitiesl

Facilities	Number	Irrigated area(ha)	Irrigation water use ($10^6 m^3$)					
			1994	1995	1996	1997	1998	Average(%)
Reservoir	1,177	28,297.8	214.7	190.7	237.9	242.1	248.8	226.9(64.6)
Pumping station	242	5,668.6	76.0	57.1	66.5	63.1	58.3	64.2(18.3)
Tube well	1,071	3,007.5	33.0	25.1	21.9	15.4	17.4	22.6(6.4)
Diversion dam	864	8,667.4	41.6	37.8	36.7	40.7	30.8	37.5(10.7)
Total	3,354	45,641.3	365.3	310.8	363.0	361.4	355.4	351.2(100)

2. Irrigation water use by pumping stations

In Sumjin river basin, annual average of irrigation water use from pumping stations during 5 years was 64.2 million m^3 which is equivalent to 18.3% of total irrigated water for paddy fields. And, it was found that minimum annual use was 57.1 million m^3 in 1995, while maximum use was 76.0 million m^3 in 1994 due to the severe drought.

3. Irrigation water use by tube wells

Investigation results of the annual irrigation water use from tube wells during 1994~1998 showed minimum of 15.4 million m^3 in 1997, maximum of 33.0 million m^3 in 1994, and average use of 22.6 million m^3 which is equivalent to 6.4% of total irrigated water in the basin.

The irrigation water use in each ten days period during the growing season from tube wells showed a wide variations because of the different water demand in each growing stages according to weather cond' ions. The maximum water use in ten days was 4.12 million m^3 in late May, which was equivalent to 18.3% of total irrigated amount by tube wells. The maximum monthly water use by tube well was 5.82 million m^3 in May, which consists of 25.8% of total irrigated water by tube wells.

4. Irrigation water use by diversion dams

Intake water from diversion dams is mainly restricted owing to the availability of stream discharge. As shown in Table 5, the minimum use of annual irrigation water use from intake diversion dams was 30.8 million m^3 in 1998, while maximum use was 41.6 million m^3 in 1994, and average annual water use was 37.5 million m^3, which is equivalent to 10.7% of total irrigated water use. Ten days maximum irrigation water use by diversion dam was 6.5 million m^3 in the late May which is considered as rice nursery and transplanting stage in the basin.

Ⅳ. Conclusion

To investigate the irrigation water uses in Sumjin river basin during 1994~1998, inventory and operation records of water supply facilities including reservoirs, pumping stations, tube wells, diversion dams were made and analyzed. And daily irrigated water amount from irrigation facilities was estimated based on operation records. Irrigation water use from multi-purpose dams in the basin was not included in this study.

Reservoir water balance model was used to simulate irrigation amount of reservoir based on observed storage rates. Pumping rates were developed with pumping discharge, electric power use, and operation time records. Irrigation water uses from tube wells were determined by crop water demand and pumping rate. Water use from diversion dams was estimated by simulating the stream flow conditions at diversion dams.

Investigation results show that average annual irrigation water uses from headworks in Sumjin river basin were 226.9 million m^3 from reservoirs, 64.2 million m^3 from pumping stations, 22.6 million m^3 from tube wells, and

37.5 million m^3 from diversion dams during 1994~1998 period, respectively.

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