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Evaporation and Percolation Control in Small Farm Ponds in Thailand

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Abstract

In savanna and tropical monsoon areas where the dry and rainy seasons can be clearly distinguished, it is important for farmers to secure as much irrigation water as possible in the dry season in order to produce fruits and vegetables. Though the Department of Land Development, Ministry of Agriculture and Cooperatives, Thailand recommends that farmers excavate small farm ponds for the purpose mentioned above, the irrigation water stored in the farm ponds in the rainy season is not effectively used in the dry season because of evaporation from the surface of water and percolation from the bottom and lateral parts of the ponds. Therefore, the authors developed methods to control the evaporation and percolation in small farm ponds. They selected 4 methods mentioned below, based on the results of experiments carried out in the eastern region of Thailand by Kobayashi. They developed low cost and sustainable methods which farmers can apply themselves as follows: (1) Covering the surface of water with floating materials. (2) Management of irrigation water using several ponds. (3) Changes in the pond shape. (4) Compaction of the bottom of the pond after crushing. The authors confirmed the effectiveness of the 4 methods through field experiments and model calculations.

Discipline: Irrigation, drainage and reclamation
Additional key words: floating materials

Introduction

The climate of Thailand can generally be classified into 2 main types, savanna and tropical monsoon. For example, the major part of the eastern region in Thailand has a savanna climate where the dry and rainy seasons can be clearly distinguished by the amount of rainfall. Consequently, rainfall in the eastern region of Thailand is concentrated during the rainy season from May to October and the amount is very small during the dry season, especially from December to March.

Presently the authorities concerned have attempted to promote crop diversification including the development of orchards in order to improve the standard of living of the farmers. To achieve this objective, the farmers must secure water resources for the dry season. For example, since some of the tropical fruits in the eastern region of Thailand pollinate from January to February, irrigation water must be preserved at least until February through the utilization of farm ponds, groundwater, etc. However, water resources in this region are mainly derived from surface water with some supply from groundwater.

Construction of farm ponds is one of the measures to alleviate these shortcomings. However, valuable irrigation water in farm ponds gradually evaporates and percolates under the strong sun in the dry season. Therefore, it is important for the authorities concerned to implement sustainable measures to preserve farm pond irrigation water as much as possible.

The authors studied and conducted some experiments related to the development of methods to control evaporation and percolation in small farm ponds for 2 years (1995–1996), based on experiments carried out by Kobayashi in 1994[2]. In the current report, the results of this study are described.

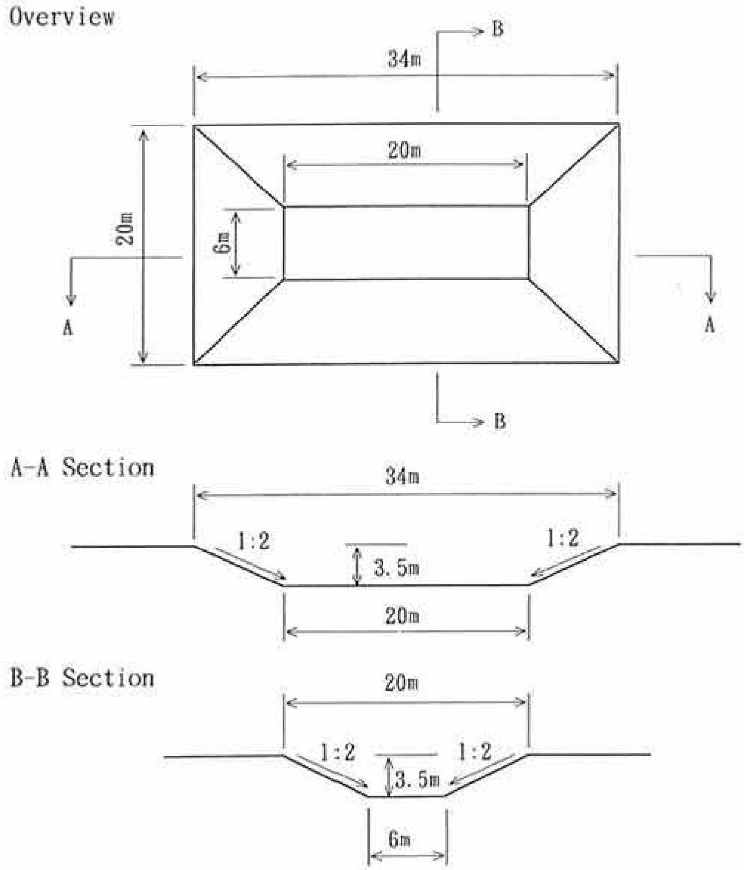


Fig. 1. DLD standard-type small farm pond (excavated type)

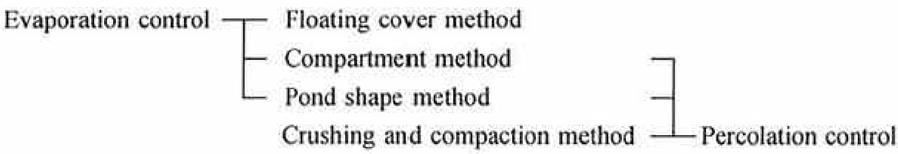


Fig. 2. Selected measures

Selected measures

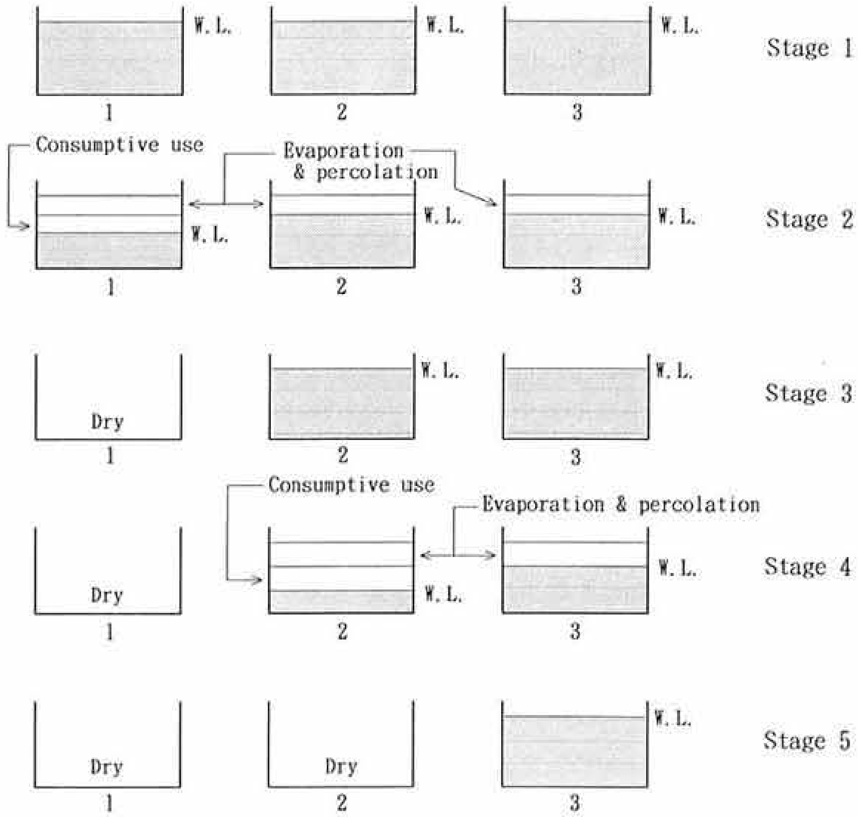
In this study the authors aimed at implementing water conservation measures in small farm ponds, especially in standard-type small farm ponds (Fig. 1) recommended by the Department of Land Development (DLD), Ministry of Agriculture and Cooperatives, Thailand. Moreover, the authors aimed at implementing practical water conservation measures which farmers can apply themselves.

The following 4 methods were selected: (1) Covering the surface water with floating materials (hereafter referred to as Floating cover method). (2) Use of several ponds (hereafter referred to as Compartment method). (3) Changes in pond shape (hereafter referred to as Pond shape method). (4) Crushing and compaction of the bottom of the pond (hereafter referred to as Crushing and compaction method) (Fig. 2).

1) Floating cover method

The authors carried out 2 experiments in the 1995 and 1996 dry seasons. The results of these experiments are shown in Table 1.

Based on the 1995 experiment, though the results showed that polystyrene foam was most effective in reducing evaporation from farm ponds, the authors selected duckweed (a kind of floating weed) as the most suitable and sustainable floating material in



Stage 1 ; End of rainy season
Stage 2 ; Just before 1st pumping
Stage 3 ; Just after 1st pumping, surface area reduced by 33%
Stage 4 ; Just before 2nd pumping
Stage 5 ; Just after 2nd pumping, surface area reduced by 67%

Fig. 3. Schematic cross-section diagram of 3-compartment ponds
Water levels at various stages in the annual cycle of operation are indicated.

Table 1. Floating cover experiments

Method	1995 Experiment			1996 Experiment		
	77-day-cumulative evaporation total (mm)	Daily average evaporation (mm/day)	Evaporation reduction rate (%)	77-day-cumulative evaporation total (mm)	Daily average evaporation (mm/day)	Evaporation reduction rate (%)
Control	494.57	6.42 (100%)[a)	–	433.02	4.98 (100%)[a)	–
Polystyrene foam	304.85	3.96 (62%)	38	–	–	–
Bamboo	370.64	4.81 (75%)	25	–	–	–
Drinking water bottles	331.97	4.31 (67%)	33	–	–	–
Duckweed	450.00	5.84 (91%)	9	359.75	4.13 (83%)	17

a): Rate taking "Control" as 100%

taking account of the cost and load on the environment.

In the 1996 experiment, the authors confirmed again the effectiveness of duckweed for evaporation control. Based on these experiments, the authors observed that duckweed used as floating cover reduced the evaporation by about 10%.

2) Compartment method

(1) Method[1)]

A schematic diagram illustrating the method is shown in Fig. 3. The ponds were operated as follows:

① They were full of water at the end of the rainy season (Stage 1).

② Water for consumptive use was pumped from pond 1 until the evaporation and percolation losses from pond 2 and pond 3 were equal to the amount of water remaining in pond 1 (Stage 2).

③ A pump was used to transfer the water remaining in pond 1 to fill the unused capacity of pond 2 and pond 3 (Stage 3), which eliminated further evaporation and percolation losses from pond 1.

④ Water was withdrawn as needed for consumptive use from pond 2 until the amount of water remaining in pond 2 was equal to the unused capacity in pond 3 (Stage 4).

⑤ A pump was used again to transfer the remaining water from pond 2 into pond 3 (Stage 5). At this stage, pond 3 was filled and pond 1 and pond 2 were empty, which eliminated further evaporation and percolation from pond 2.

Table 2. Calculation of water reduction in the Compartment method

Case	Number of ponds	Storage capacity of each pond (m^3)	Water reduction (m^3)				Water availability (days)
			Consumption	Evaporation	Percolation	Total	
Case-A	1	1,285.7 (5.0 m^3)a)	691.7	285.0	308.9	1,285.7	138
Case-B1	2	664.1 (5.0 m^3)	704.6	277.5	306.1	1,288.2	141
Case-B2	3	430.3 (5.0 m^3)	681.7	288.3	321.2	1,291.0	136
Case-B3	4	321.8 (5.0 m^3)	666.0	293.5	327.7	1,287.2	133
Case-C1	2	1,285.7 (10.0 m^3)	1,480.9	521.7	568.7	2,571.4	148
Case-C2	3	1,285.7 (15.0 m^3)	2,276.5	755.3	825.2	3,857.2	152
Case-C3	4	1,285.7 (20.0 m^3)	3,072.7	988.8	1,081.4	5,142.9	154

a): Daily water consumption in each case.

Table 3. Effectiveness based on the number of ponds in Case-C series

Case	Number of ponds	Evaporation + percolation (m^3)	Evaporation + percolation per pond (m^3)	Reduction of evaporation + percolation per pond [A] (m^3)	Water movement by pump			Effectiveness [A]/[B] × 100 (%)
					Frequency	Total volume (m^3)	Volume per pond [B] (m^3)	
Case-A	1	593.9	593.9	–	–	–	–	–
Case-C1	2	1,090.4	545.2	48.7	1	376.6	188.3	25.9
Case-C2	3	1,580.5	562.8	67.1	2	807.0	269.0	24.9
Case-C3	4	2,070.2	517.6	76.3	3	1,270.9	317.7	24.0

(2) Results

Based on a computer calculation, it was observed that this method was effective for the control of evaporation and percolation.

When the method is applied to DLD standard-type small farm ponds, it is considered that there are 2 systems. In one, a pond is divided into various compartments, and in the other some standard-type small farm ponds are used with water consumption corresponding to the number of ponds. Therefore, the authors examined 7 cases as shown in Table 2. Case-A corresponded to the DLD standard-type small farm pond. In Case-B1 to Case-B3 the former system was used and in Case-C1 to Case-C3 the latter system was employed.

The assumptions for the calculations were as follows: evaporation amounted to 5.0 mm/day, percolation to 5.0 mm/day, there was no rain and the daily water consumption per standard-type pond was 5.0 m^3 /day.

The results of calculation are shown in Tables 2, 3 and Fig. 4. The conclusions were as follows:

- In the Case-C series, consisting of some DLD standard-type small farm ponds which were used with water consumption corresponding to the number of ponds, evaporation and percolation control of farm ponds was effective.
- The more farm ponds were used in Case-C series, the greater the effectiveness.
- Using the figures listed above in the calculation, farmers could reduce evaporation and percolation from ponds by 13% and secure irrigation water for 16 days more in Case-C3 (use of 4 ponds) than in Case-A (DLD standard-type small farm pond).
- The effectiveness based on the number of ponds was almost the same in all 3 cases of the Case-C series. Since the reduction of evaporation and percolation per pond in Case-C3 was about 1.6 times greater than in Case-C1, 4 ponds should be used in the Case-C series.

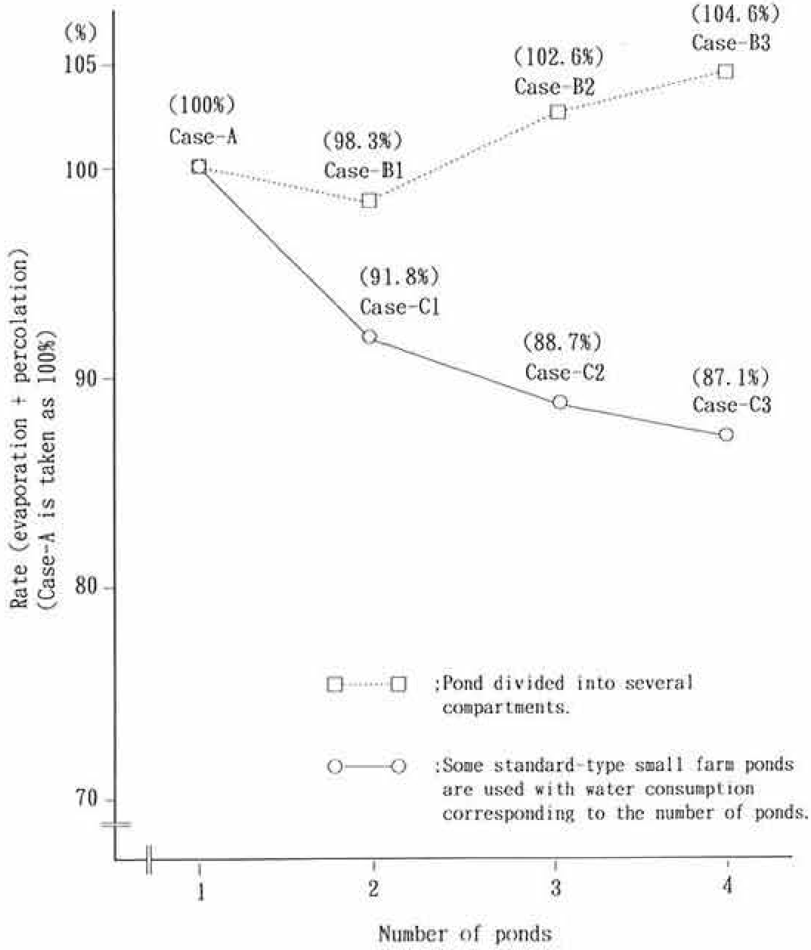


Fig. 4. Effectiveness of Compartment method in reducing evaporation and percolation

3) Pond shape method

Based on the computer calculation, it was observed that the steeper the slope, the greater the effectiveness for evaporation and percolation control. Furthermore, round farm ponds were more effective for evaporation and percolation control than rectangular farm ponds, based on the same calculation method.

Sixteen cases were analyzed as shown in Table 4. In Case-A to Case-L the rectangular ponds were used and in Case-M to Case-T round ponds were used. Four patterns of slopes were examined = 1:2.0, 1:1.5, 1:1.2 and 1:1.0.

The assumptions for the calculations were as follows: evaporation rate was 5.0 mm/day, percolation rate was 5.0 mm/day, there was no rain and the daily water consumption per pond was 5.0 m^3/day.

The results of the calculations are shown in Table 4 and Fig. 5. The conclusions were as follows:

- The steeper the slope, the greater the effectiveness for evaporation and percolation control.
- Round ponds were more effective for evaporation and percolation control than rectangular farm ponds.
- Steeper slopes and round shape resulted in greater effectiveness when the Compartment method was applied than when it was not applied.
- Using the figures mentioned above in the calculation, farmers could reduce evaporation and percolation from ponds by 23% and secure irrigation water for 28 days more in Case-P (slope 1:1.0, round shape, application of the Compartment method using 4 ponds) than in Case-A (DLD standard-type small farm pond).

4) Crushing and compaction method

The authors carried out a percolation control experiment in December 1996 using a simulated farm pond. The results of the experiment are shown in Table 5. The soil of the bottom of the simulated farm pond consisted of gravelly sandy loam soil.

Based on the results of the experiment, the Crushing and compaction method was effective in reducing percolation from farm ponds. At the bottom of the simulated pond where the Crushing and compaction method was used, the percolation rate decreased to about 20% compared with the rate in the unimproved area.

Though we observed that the Crushing and

Table 4. Calculation of water reduction in the ponds (Pond shape method)

Case				Water reduction (m^3)				Water availability (days)
Name	Shape	Slope	No. of ponds	Consumption	Evaporation	Percolation	Total	
Case-A	Rect.	1:2.0	1	691.7	285.0	308.9	1,285.7	138
Case-C3	Rect.	1:2.0	4	3,072.7	988.8	1,081.4	5,142.9	154
Case-G	Rect.	1:1.0	1	710.0	267.3	307.8	1,285.1	142
Case-H	Rect.	1:1.0	4	3,266.5	852.9	1,021.0	5,140.4	163
Case-I	Rect.	1:1.2	1	710.0	270.5	306.3	1,286.8	142
Case-J	Rect.	1:1.2	4	3,239.6	880.5	1,027.1	5,147.2	162
Case-K	Rect.	1:1.5	1	705.1	275.9	306.1	1,287.1	141
Case-L	Rect.	1:1.5	4	3,182.0	922.6	1,043.9	5,148.4	159
Case-M	Round	1:2.0	1	705.3	281.1	301.0	1,287.4	141
Case-N	Round	1:2.0	4	3,159.0	955.7	1,034.9	5,149.6	158
Case-O	Round	1:1.0	1	715.1	268.1	303.4	1,286.6	143
Case-P	Round	1:1.0	4	3,316.2	840.9	989.2	5,146.4	166
Case-Q	Round	1:1.2	1	715.0	270.4	301.4	1,286.8	143
Case-R	Round	1:1.2	4	3,287.3	865.8	994.2	5,147.2	164
Case-S	Round	1:1.5	1	713.1	273.3	299.0	1,285.4	143
Case-T	Round	1:1.5	4	3,240.0	898.3	1,003.5	5,141.6	162

compaction method was able to cut the percolation rate by 80% on gravelly sandy loam soil, we could not determine whether the same phenomenon occurred on clay soil which is suitable for the bottom of the ponds. Therefore, similar experiments should be conducted on clay soil, at the bottom of several actual farm ponds, especially, to confirm the effectiveness of the method.

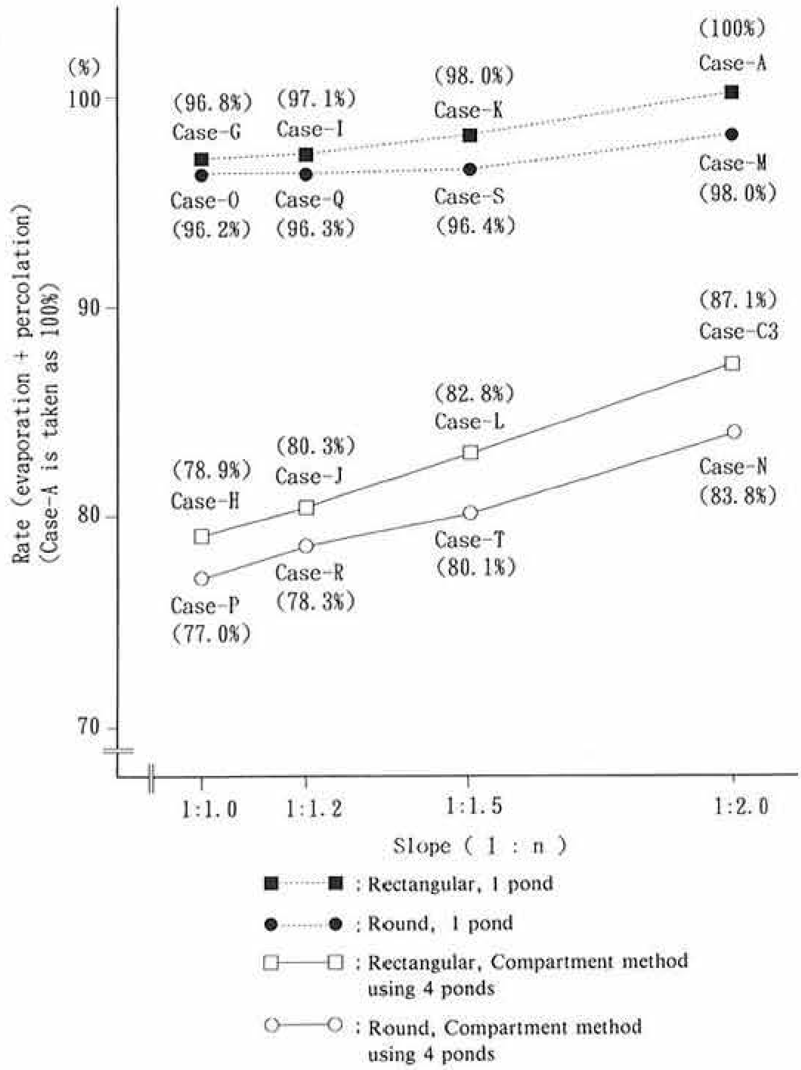


Fig. 5. Role of pond shape in reducing evaporation and percolation

Table 5. Percolation control experiment

Case	Percolation rate (cm/s)						
	1st trial	2nd trial	3rd trial	4th trial	5th trial	6th trial	Average of 1st to 4th trials
Unimproved [A]	5.7×10^{-2}	5.7×10^{-2}	4.9×10^{-2}	5.1×10^{-2}	3.7×10^{-2}	3.1×10^{-2}	5.3×10^{-2}
Crushing and compaction [B]	1.5×10^{-2}	1.0×10^{-2}	8.9×10^{-2}	7.4×10^{-2}	-	-	9.8×10^{-2}
Ratio of [B] to [A]	26.3%	17.5%	18.2%	14.5%	-	-	18.5%

Integrated application of the 4 methods

The authors studied the effectiveness in each case where all or some of the 4 methods described above (Floating cover method, Compartment method, Pond shape method and Crushing and compaction method) were integrated, based on the computer calculations. Table 6 shows the 16 calculation cases. In Case-a, none of the methods listed above were used. In Case-b to Case-e we used only one method, in Case-f to Case-k we combined 2 methods, in Case-l to Case-o we used 3 methods together and in Case-p we integrated all of the 4 methods.

The assumptions for the calculations were as follows:

- Evaporation was assumed to be 5.0 mm/day.
- Evaporation was assumed to be 4.5 mm/day when the floating cover method was employed because the experiments showed that this method reduced evaporation by about 10%.
- Percolation was assumed to be 5.0 mm/day.
- Percolation was assumed to be 2.0 mm/day at the bottom of the farm ponds when the Crushing and compaction method was applied because the experiments showed that the method was effective in reducing percolation and the reduction rate was about 80% in the case of gravelly sandy loam soil.
- There was no rain.
- The daily water consumption per pond was assumed to be 5.0 m^3/day.

The results of the calculations are shown in Tables 6, 7 and 8. The conclusions were as follows:

- When only one method was applied, the Compartment method was the most effective in reducing evaporation and percolation, followed by the Crushing and compaction method and the Pond shape method, while the Floating cover method (duckweed) was the least effective.
- The more methods we applied, the greater the effectiveness, except for Case-c and Case-i where the Compartment method was employed.
- We could expect greater effectiveness by applying the Pond shape method together with the Compartment method and/or the Crushing and

Table 6. Calculation of water reduction in the ponds (integration of methods)

Case	Method				Water reduction (m^3)				Water availability (days)
	Floating cover method (duckweed)	Compartment method (using 4 ponds)	Pond shape method (round, slope 1:1.2)	Crushing and compaction method	Consumption	Evaporation	Percolation	Total	
Case-a					691.7	285.0	308.9	1,285.7	138
Case-b	○				706.7	263.0	316.0	1,285.7	142
Case-c		○			3,072.7	988.8	1,081.4	5,142.8	154
Case-d			○		715.0	270.4	301.4	1,286.8	143
Case-e				○	721.2	295.4	269.1	1,285.7	145
Case-f	○	○			3,120.2	913.2	1,109.4	5,142.8	156
Case-g	○		○		730.1	248.7	308.0	1,286.8	146
Case-h	○			○	737.0	273.0	275.8	1,285.7	147
Case-i		○	○		3,287.3	865.8	994.2	5,147.2	164
Case-j		○		○	3,138.7	1,017.8	986.4	5,142.8	157
Case-k			○	○	777.0	292.8	216.9	1,286.8	155
Case-l	○	○	○		3,338.4	794.7	1,014.1	5,147.2	167
Case-m	○	○		○	3,195.1	938.0	1,009.7	5,142.8	160
Case-n	○		○	○	795.0	269.6	222.2	1,286.8	159
Case-o		○	○	○	3,454.6	918.1	774.6	5,147.2	173
Case-p	○	○	○	○	3,511.7	844.4	791.1	5,147.2	176

Table 7. Degree of effectiveness

Order	Case	Method				Rate when Case-a is taken as 100% (%)		Water availability (days)
		Floating cover method (duck-weed)	Compart-ment method (using 4 ponds)	Pond shape method (round, slope 1:1.2)	Crushing and compact-tion method	Total (= Evaporation + percolation)	Difference between this case and Case-a	
1	Case-p	○	○	○	○	68.8	-31.2	176
2	Case-o		○	○	○	71.3	-28.7	173
3	Case-l	○	○	○		76.1	-23.9	167
4	Case-i		○	○		78.3	-21.7	164
5	Case-m	○	○		○	82.0	-18.0	160
6	Case-n	○		○	○	82.8	-17.2	159
7	Case-j		○		○	84.4	-15.6	157
8	Case-f	○	○			85.1	-14.8	156
9	Case-k			○	○	85.8	-14.2	155
10	Case-c		○			87.1	-12.9	154
11	Case-h	○			○	92.4	-7.6	147
12	Case-g	○		○		93.7	-6.3	146
13	Case-e				○	95.0	-5.0	145
14	Case-d			○		96.3	-3.7	143
15	Case-b	○				97.5	-2.5	142
16	Case-a					100.0	-	138

Table 8. Effectiveness of Pond shape method when combined with another method

(Unit: %)

Case	Trend	Floating cover method (2.5)	Compart-ment method (12.9)	Pond shape method (3.7)	Crushing and compaction method (5.0)	Total
Case-p (31.2)	>	○	○	○	○	(24.1)
Case-o (28.7)			○	○	○	(21.6)
Case-l (23.9)		○	○	○		(19.1)
Case-n (17.2)		○		○	○	(11.2)
Case-i (21.7)			○	○		(16.6)
Case-k (14.2)				○	○	(8.7)
Case-h (7.6)	=	○			○	(7.5)
Case-g (6.3)		○		○		(6.2)
Case-m (18.0)	<	○	○		○	(20.4)
Case-j (15.6)			○		○	(17.9)
Case-f (14.8)		○	○			(15.4)

( ) indicates the reduction rate of "evaporation + percolation".

compaction method. For example, in Case-i, the reduction rate of "evaporation + percolation" (21.7%) was higher than the total (16.6%) of the rate when the Compartment method was applied (12.9%) and the rate when the Pond shape method was applied (3.7%).

- Using the figures mentioned above in the calculation, farmers could reduce evaporation and percolation from ponds by 31% and secure irrigation water for 38 days more in Case-p (the 4 methods were integrated) than in Case-a (DLD standard-type small farm pond).

Conclusion

Though the experiments on the Floating cover method and the Crushing and compaction method should be continued, and the degree of effectiveness of these methods in reducing evaporation and percolation should be confirmed, the conclusions from this study were as follows:

- Considerable reduction of evaporation and percolation could be expected by employing only the Floating cover method (duckweed) and the Crushing and compaction method. These methods should be disseminated among farmers because they are cheap and easy to apply by farmers under the support of the government.
- When new ponds are excavated, the shape of the ponds should be round. Furthermore, the lateral parts of the ponds should be as steep as possible.
- The use of several ponds (Compartment method) was very effective for evaporation and percolation control. Therefore, the DLD should ask the farmers to form small groups, excavate several farm ponds and let them manage water use by employing the Compartment method.

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