Assessment of Irrigation Water Quality under Cyclic Irrigation Scheme in Imbanuma Irrigation Area, Chiba, Japan

千葉県印旛沼灌漑地域における循環灌漑地区の灌漑用水の水質の評価

〇Ilham Putra ADIYAKSA*　Fumi OKURA**　Tasuku KATO*

イルハム プトラ アディヤクサ*　大倉芙美**　加藤亮*

I. Introduction

Water quality issues in lakes remain a critical concern. They are exacerbated by non-point source pollution, especially from agricultural activities. As the main crop in Japan, rice production contributes to nutrient runoff into water bodies, which makes 30% of lakes in Japan eutrophic (Kishimoto & Ichise, 2013). One specific area affected is Imbanuma Lake, where rice production is quite intensive. Additionally, to conserve the water environment of Imbanuma Lake, a cyclic irrigation system has been developed. This study aims to assess the irrigation water quality in the Imbanuma irrigation area based on its physicochemical characteristics, which contribute to the water conservation of Imbanuma Lake.

II. Material and Method

The study area is located in the Imbanuma irrigation area, Chiba, and consists of a northern block (Shiroyama) and a southern block (Jinbee). The cyclic block area covers 260.4 ha in Shiroyama and 263.5 ha in Jinbee. Fig 1 shows the sampling points for the irrigation water quality assessment. Temperature and electrical conductivity (EC) were measured in the field, while total nitrogen (T-N) and total phosphorus (T-P) were analyzed in the laboratory. The measurement and analysis were done monthly during the non-planting period and biweekly during the planting period. Statistical methods were used to analyze the data, including the Welch's T-test and Mann-Whitney U test. The Pollutant Index (PI) was calculated to assess water quality, and a Principal Component Analysis (PCA) was conducted to determine the key influencing factors on water quality.

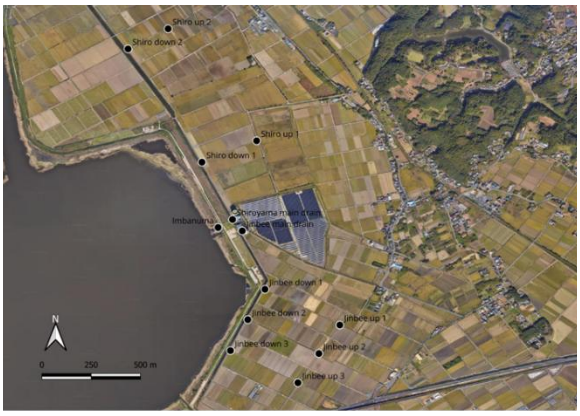

Fig 1. Sampling points in the study area

所属　*東京農工大，*Tokyo University of Agriculture and Technology, **国際農林水産業研究センター，**Japan International Research Center for Agricultural Sciences.
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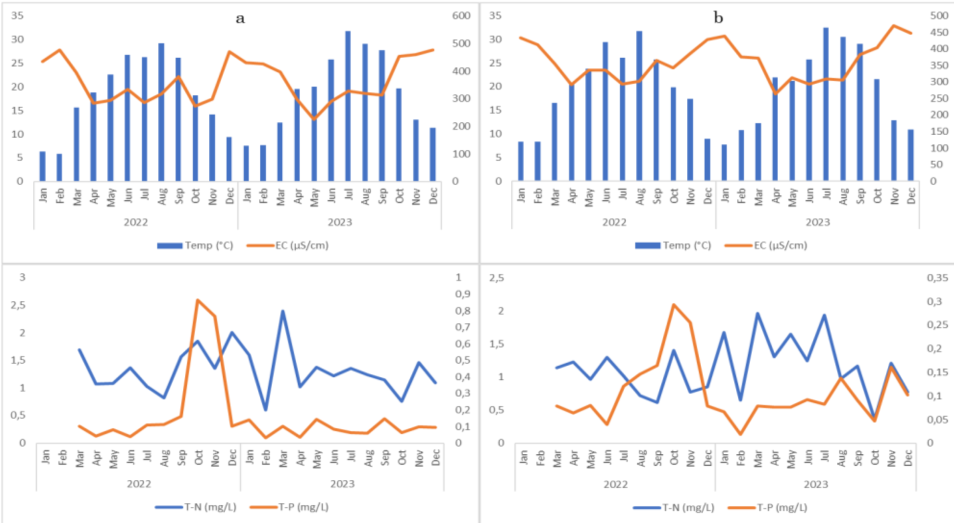
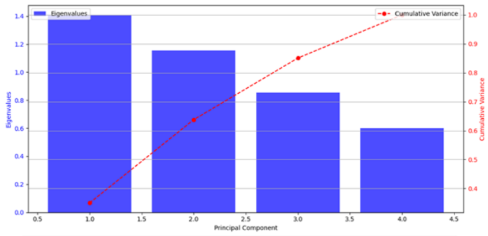


Fig 2. Physicochemical characteristics of water in the main drainages of a) Shiroyama and b) Jinbee

Table 1. Comparison of PI value in Shiroyama and Jinbee during 2022 and 2023

	2022			2023		
	Shiroyama	**Jinbee**	**Stat**	**Shiroyama**	**Jinbee**	**Stat**
Ave	1.96	1.60	***	1.80	1.57	***
Max	4.54	4.23	γ	4.94	4.75	γ
Min	0.53	0.65		0.48	0.66	
SD	1.04	0.81		0.81	0.66	

Note: For Welch's t-test, *** represents significance at the 90 percent level ($p < 0.10$). For the Mann-Whitney U test, γ represents significance at the 90 percent level ($p < 0.10$).



	Temp	EC	T-N	T-P
PC-1	**-0.645043**	**0.694034**	0.173547	-0.268546
PC-2	0.124116	0.167482	**0.754502**	**0.622312**
PC-3	-0.486359	-0.050405	-0.498957	0.715511
PC-4	0.576168	0.698374	-0.389423	0.169278

Fig 3. Secree plot and table of variable contributions of PCA

III. Results

The physicochemical characteristics of water did not change significantly from 2022 to 2023 in both Shiroyama and Jinbee (Fig. 2). However, the average of T-P showed a decreasing trend. EC during the planting period (April to August) decreased significantly.

From the PCA analysis (Fig. 3), PC-1 is the most important component, which has the highest eigenvalue and explains the most variance. EC has the largest variable contribution of 0.69, which makes it the key influencing factor. PC-2, mainly driven by T-N (0.75) and T-P (0.62), demonstrates nutrient influence.

IV. Discussion and Conclusion

The slight improvement in water quality from 2022 to 2023, given the decrease of PI (Table 1), appears to be a result of the cyclic irrigation system. The better condition in Jinbee aligns with previous research indicating that water use efficiency in Jinbee is higher than in Shiroyama (Okura et al., 2025). However, a more detailed analysis shows that the physicochemical concentration between inflow and outflow is not balanced, which may suggest the influence of lateral flow. To enhance water conservation, further research on optimized irrigation strategies considering EC as the main influencing factor is needed for more effective irrigation water management in the study area.