Quantitative Analysis of the Paddy Irrigation Effects on Groundwater Recharge

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1.Introduction

Groundwater usage:

Drinking

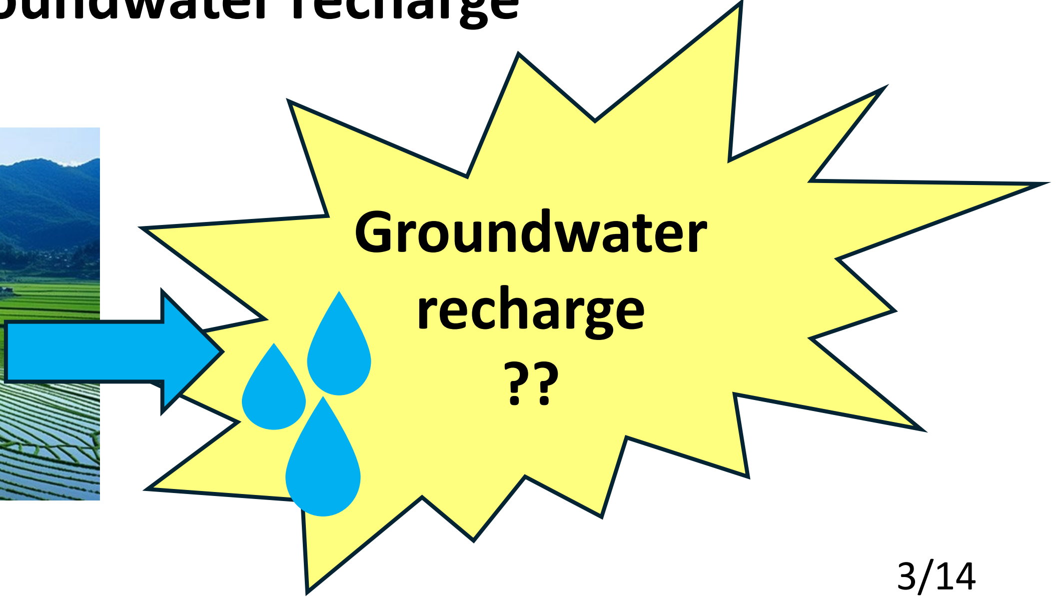
Agricultural purposes like paddy cultivation

Picture Source:Copilot

Snowmelt management

◆Paddy irrigation practice and its contribution on groundwater recharge

Mitsuno et al., (1982), Anan et al., (2007), Tanaka et al., (2010) have simulated significant effects of irrigation on groundwater; however, groundwater recharge estimation through observed data during the irrigation season is still unclear.

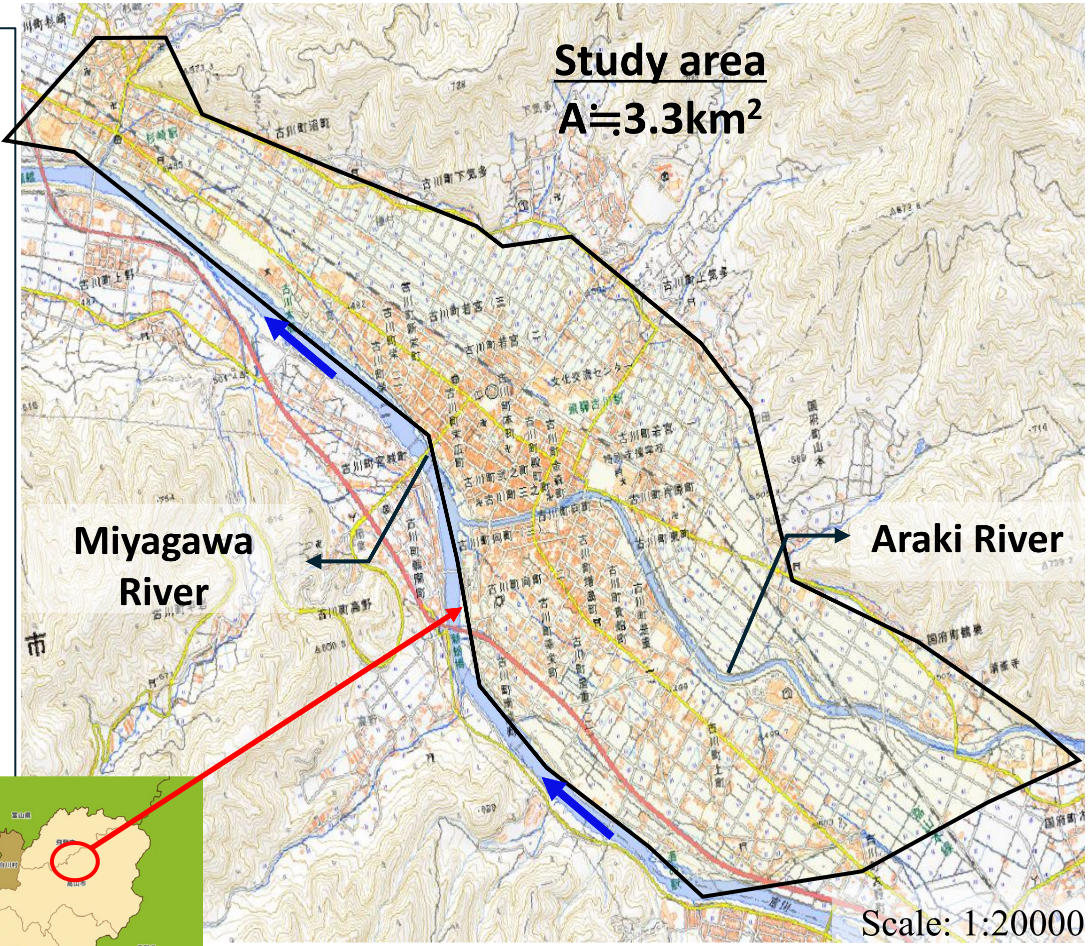


2. Study Area

Study Area

- Furukawa Kokufu basin, Hida city, Northern Gifu Prefecture
- Analysis domain area: 3.3km^2
- Paddy field area: 1.3km^2 (Fude polygon, MAFF) 39% of total land area
- Snow period: November to April
- Irrigation period: Mid-April to Mid-September
- Average annual precipitation: 1,780 mm (Japan Meteorological Agency(JMA))

Relies on groundwater for daily necessities like drinking water and for snow melting



Gifu Prefecture Map (Map-It)

Figure 1: Study Area-
Hida Furukawa Kokufu Basin

3. Methods

(1) Observation

1. Flow rate observation

From September 8,2023 to November 25,2024 (20 times) except for winter months

2. Groundwater level observation

GNSS positioning

Water Pressure Sensor
HOBO-U20-001-0, Onset

Constant observation (every 10 minutes)

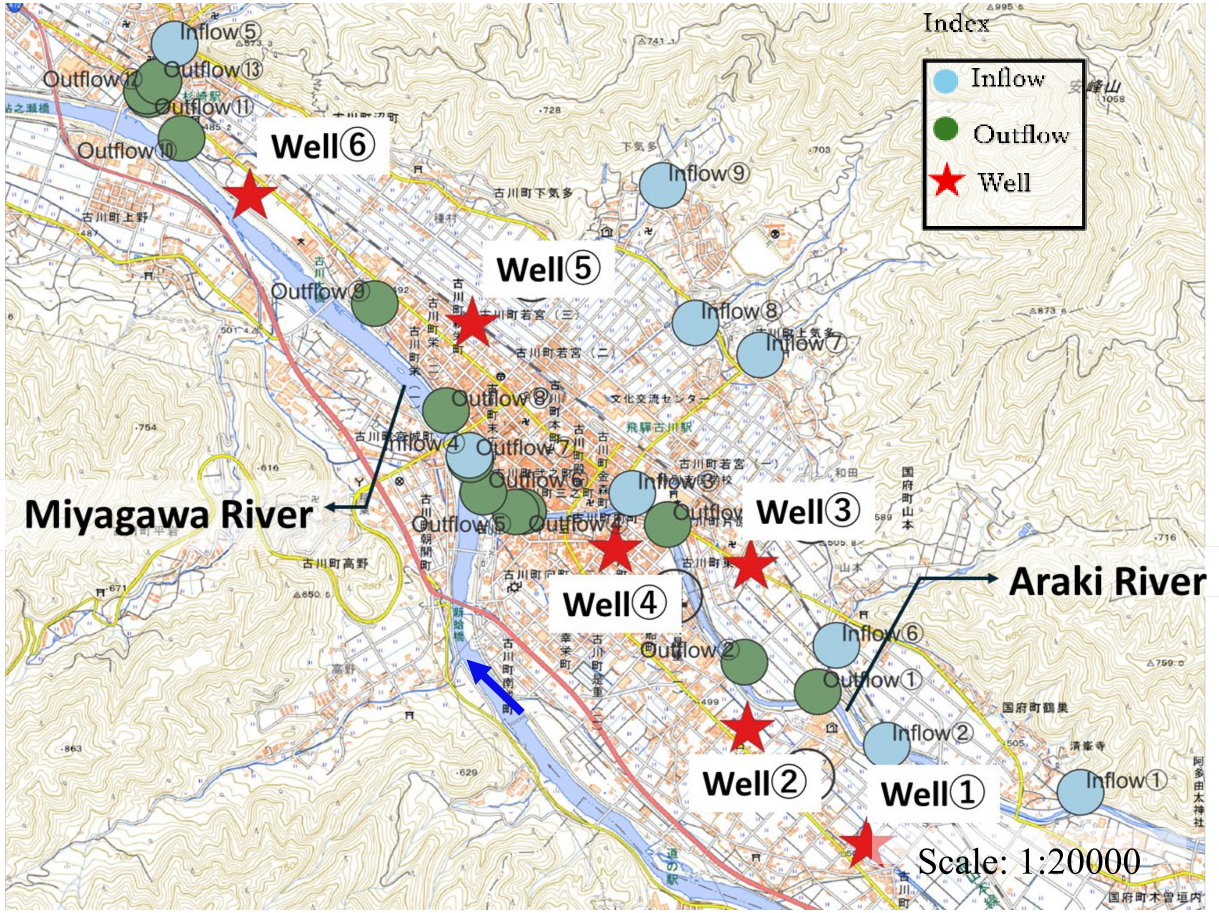


Figure 2: Observation points

9 inflow points
(near headwater and mountain streams)
13 Outflow points (agricultural drainage channel)
6 Wells

3. Methods

(2) Data Analysis

1. Surface water budget estimation

◆ Groundwater recharge:

During no rainfall period,

$$I_{deep} = Q_{in} - Q_{out} - ET$$

Where,
I_{deep}: groundwater recharge rate (mm/d)
Q_{in} : surface inflow (mm/d)
Q_{out}: surface outflow (mm/d)
ET: evapotranspiration rate from paddy fields (mm/d)

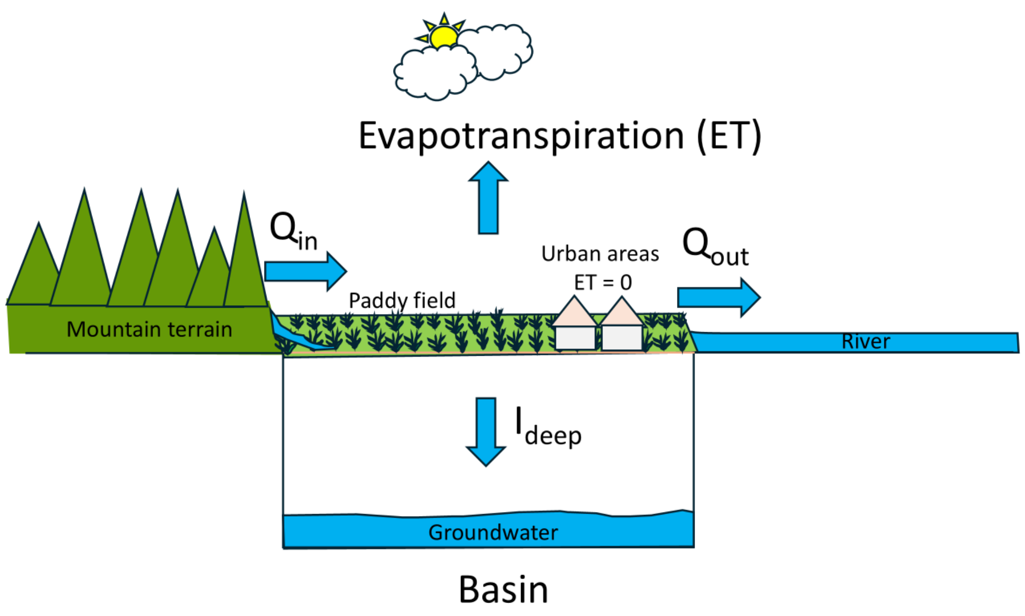


Figure 3: Schematic Diagram of Surface Water Budget

◆ Evapotranspiration (ET):

Penman Equation

Climate data from Takayama weather station of Japan Meteorological Agency (JMA)

$$ET=\frac{\Delta}{\Delta+\gamma} \cdot \frac{S}{l} + \frac{\gamma}{\Delta+\gamma} \cdot f(u_2)(e_{s\alpha} - e_{\alpha})$$

Where,
S : Net radiation at the crop surface(MJ/m²/day), l=Latent heat of vaporization of water(MJ/kg),
$f(u_2)(e_{s\alpha} - e_{\alpha})$ = Dalton`s Law of evaporation (mm/day), u_2 = Wind speed at 2m height,
esα: Saturation vapor pressure at temperature t,
e_{α} =Water vapor pressure of air,
Δ = Slope of the saturation vapor pressure curve (kPa/°C)
γ = Psychrometric constant (kPa/°C)

3. Methods

2. Groundwater level analysis:

- Observed groundwater data (10 minutes) converted into 10 days moving average of non-rainfall days

Paddy field area

- Delineated within 100m radius from each well
- Fude polygon data retrieved from Ministry of Agriculture, Forestry and Fisheries (MAFF)

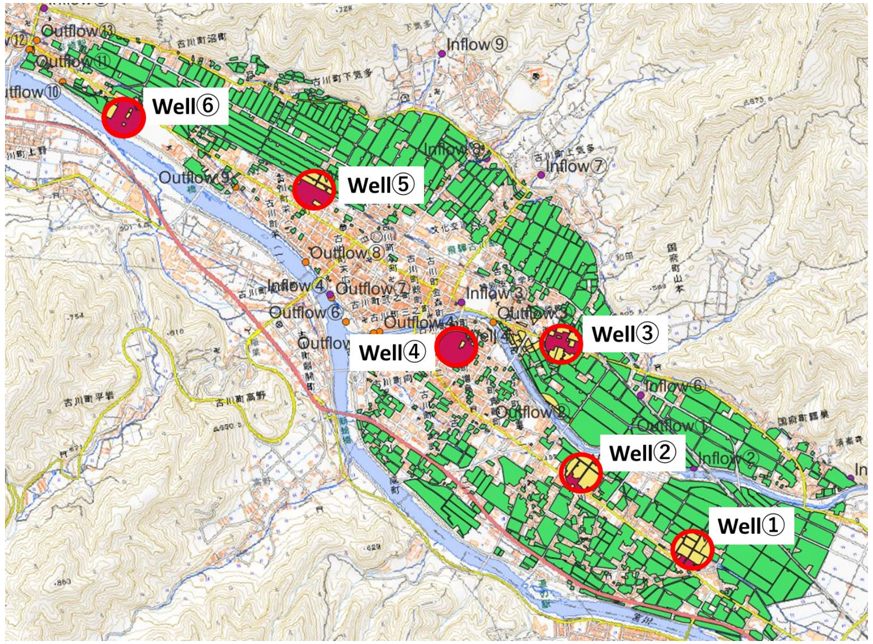


Figure 4: Fude polygon of paddy field (MAFF)

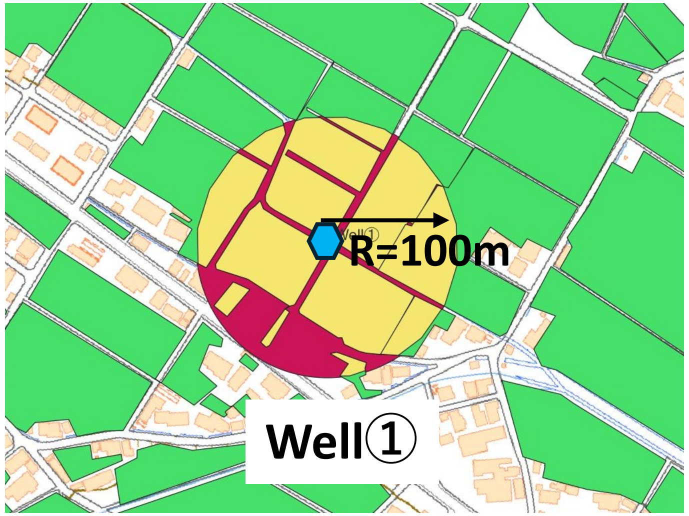


Figure 5 : Paddy field area delineated within 100m radius around each well

4. Results

1. Surface water budget

◆ Observed Inflow and Outflow:

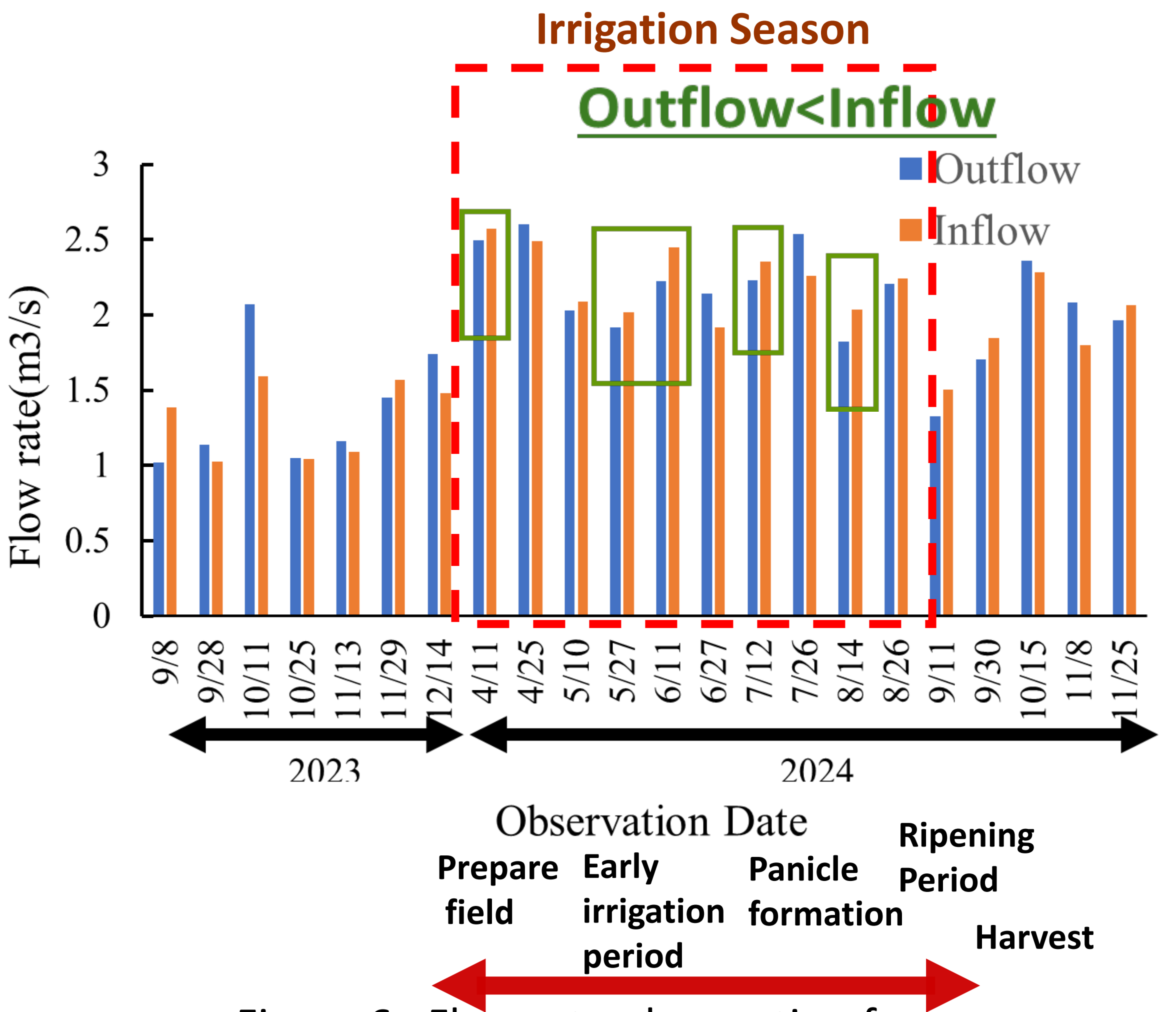


Figure 6 : Flow rate observation from 2023/09/08 to 2024/11/25

◆ Groundwater recharge

$$I_{deep} = Q_{in} - Q_{out} - ET$$

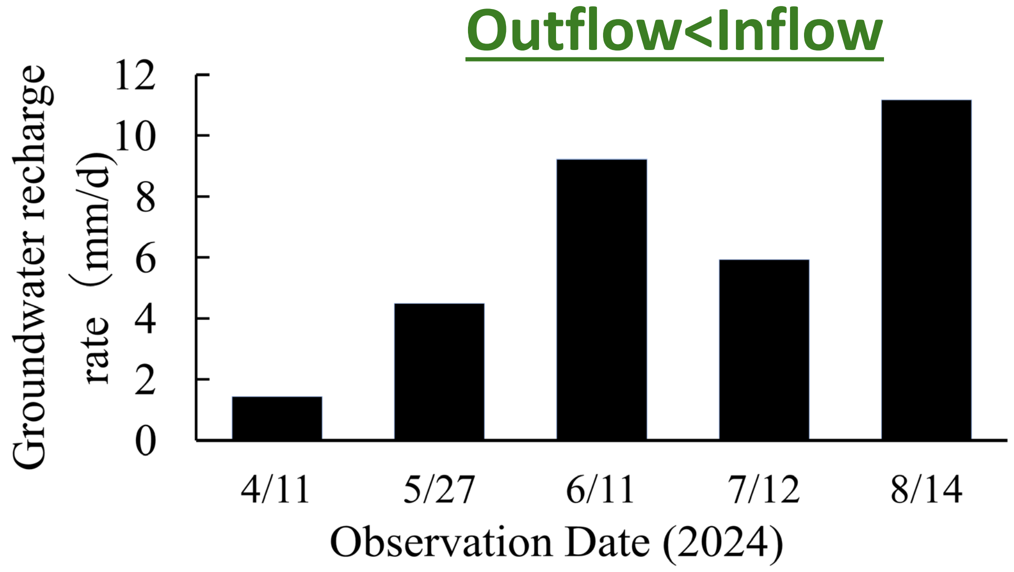


Figure 7 : Groundwater recharge rate through Surface water budget estimation

4. Results

2. Groundwater level

◆ Observed groundwater level at each well

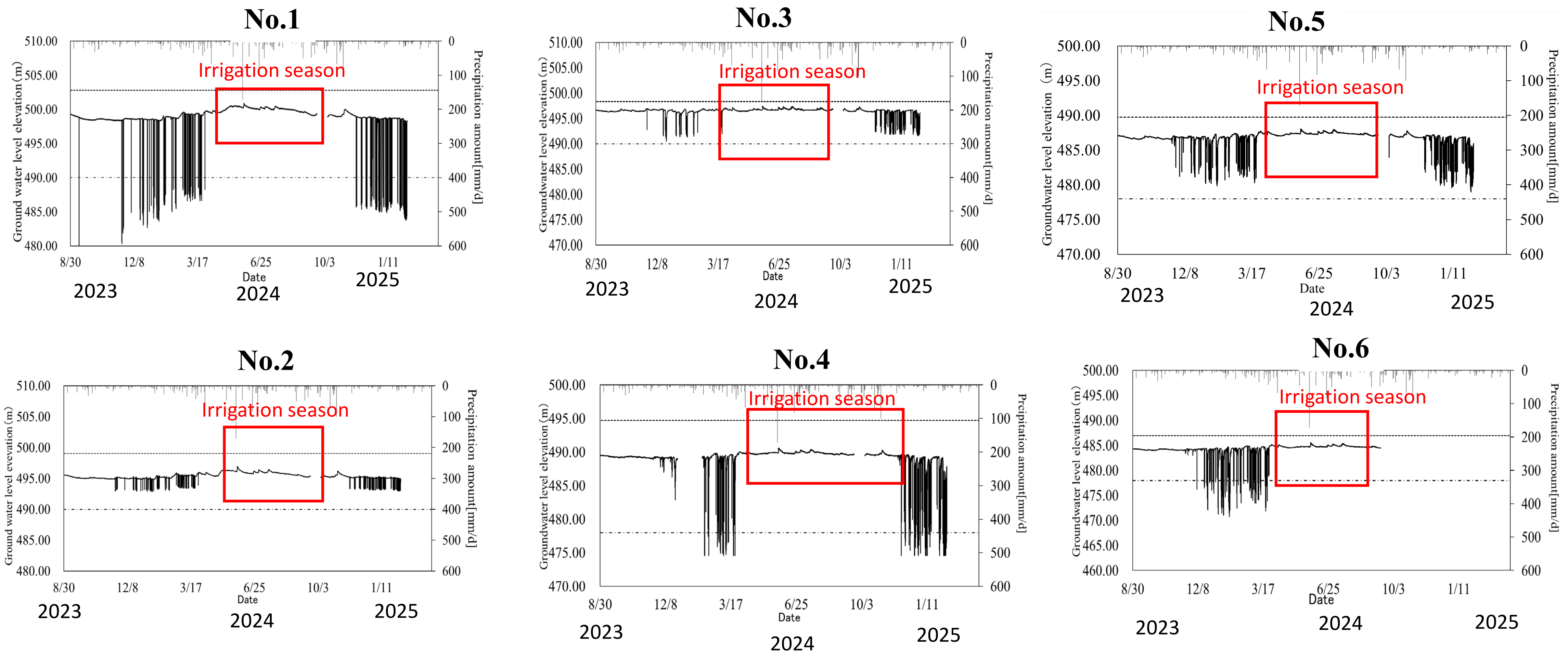


Figure 8: Observed Ground water level elevation at 6 wells measured at every 10 minutes and precipitation from 2023/8/17 to 2025/2/ 10

4. Results

◆ Irrigation season groundwater level

(10 days moving average of non-rainfall days)

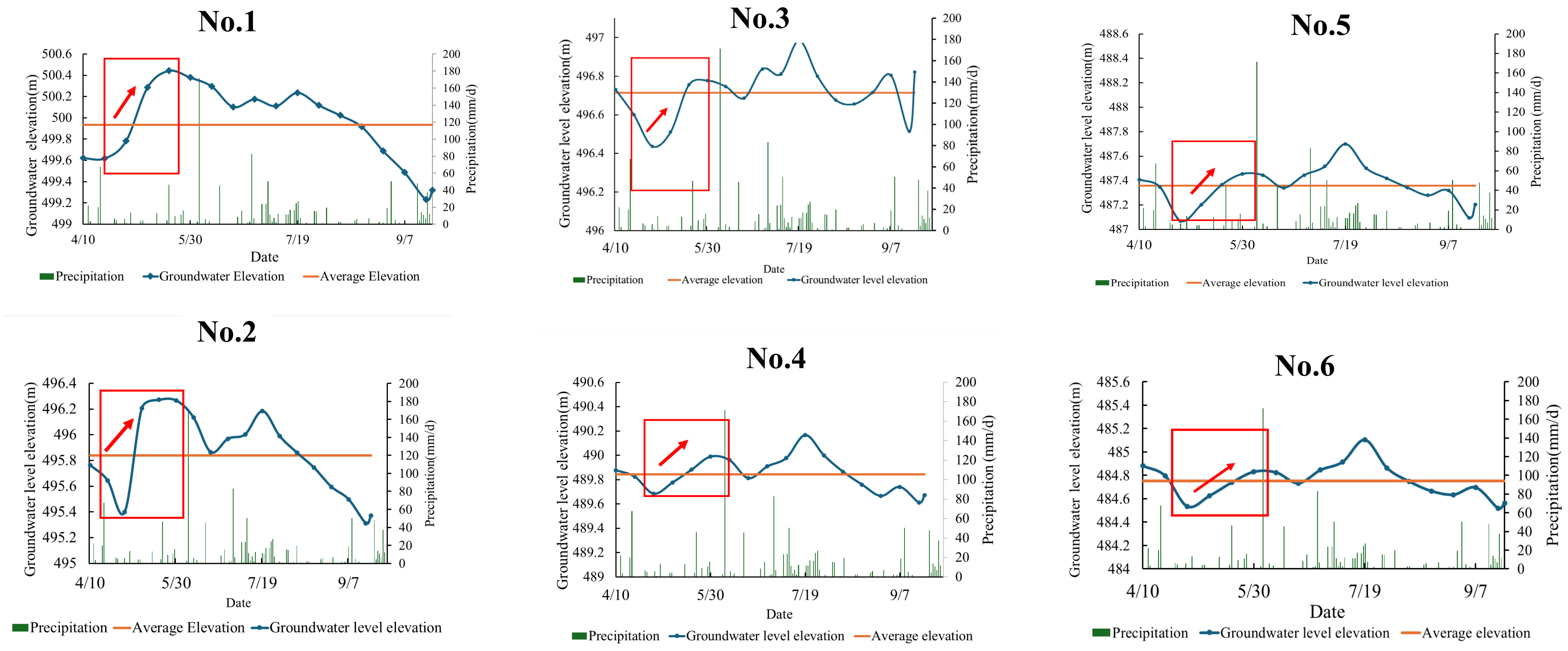


Figure 9: Groundwater level change during Irrigation season

4. Results

◆Paddy Cultivation phases

Well No.①

Paddy cultivation Phases

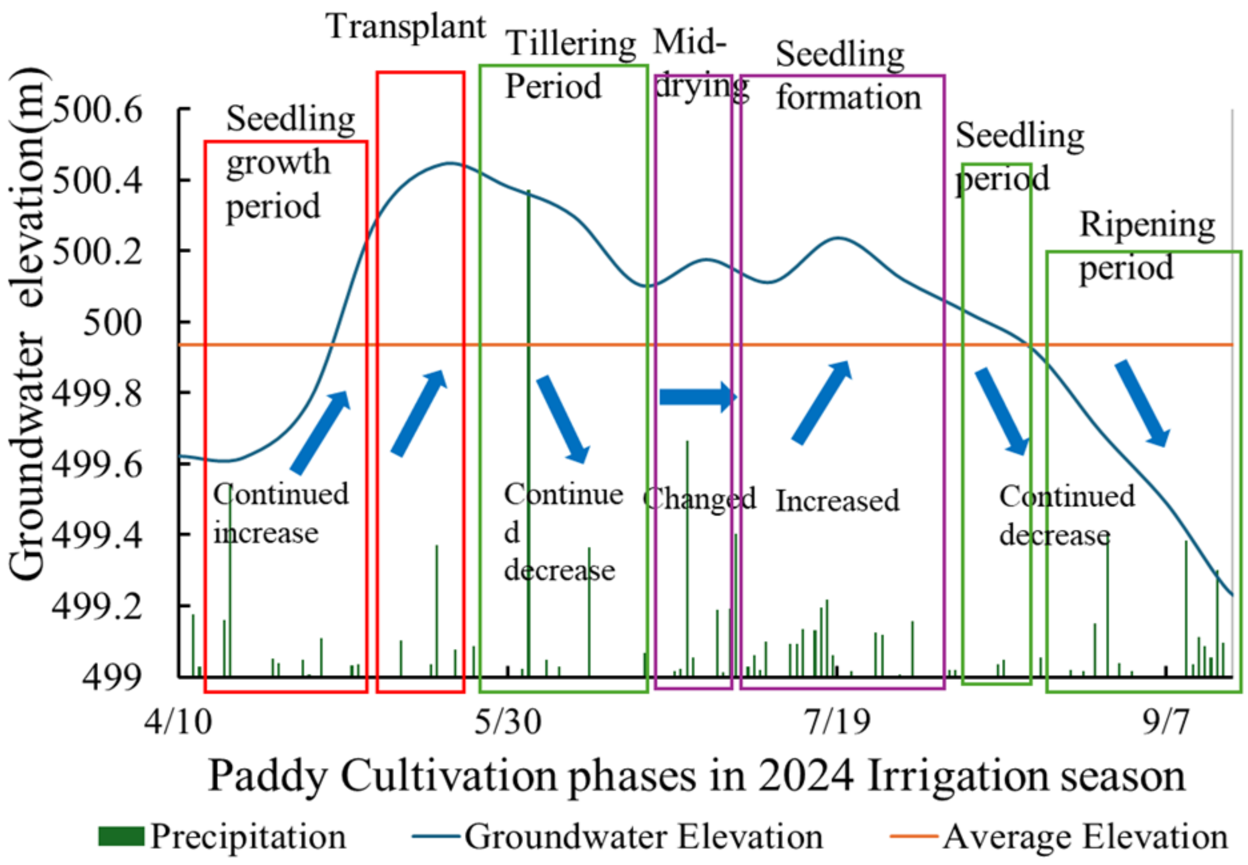


Figure 10: Paddy cultivation phases and groundwater level

4. Results

Paddy field area:

Delineated within 100m radius from each well using Fude Polygon (MAFF)

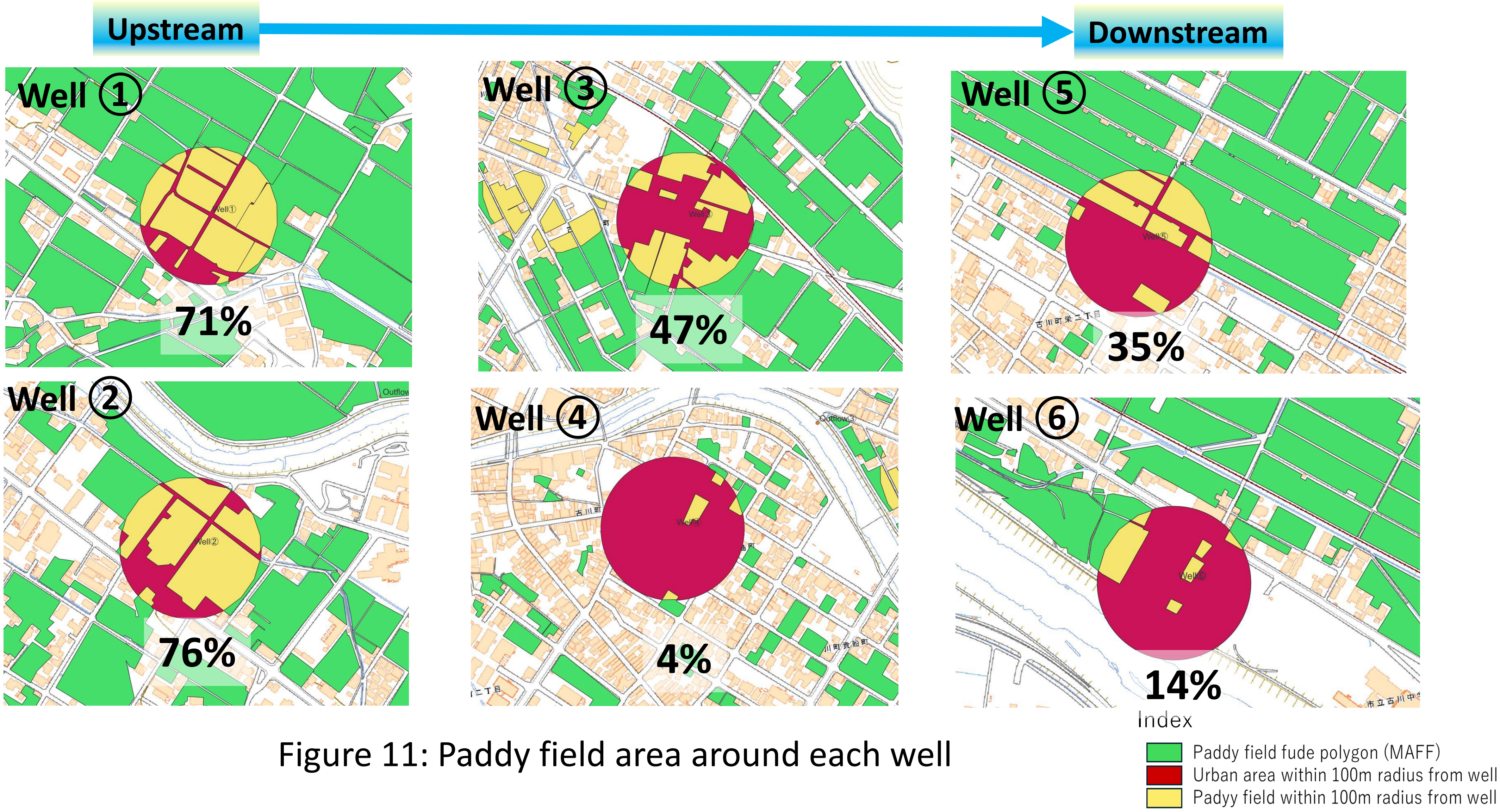


Figure 11: Paddy field area around each well

4. Results

◆Ground water recharge and paddy field area during initial irrigation period:

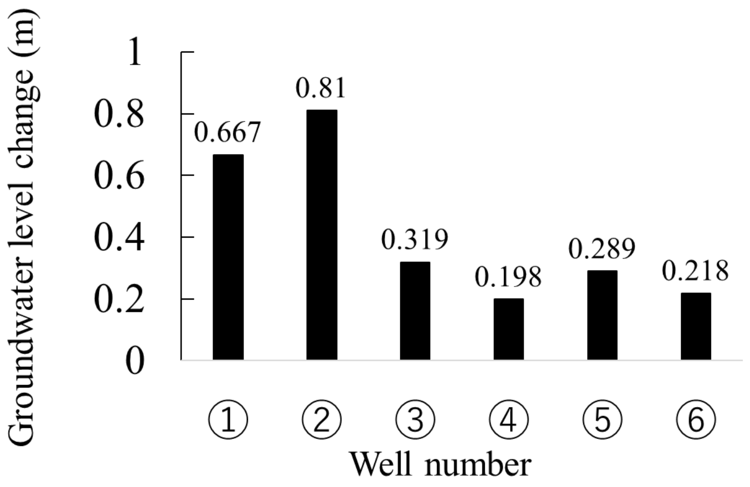


Figure 12: Groundwater level change at each well

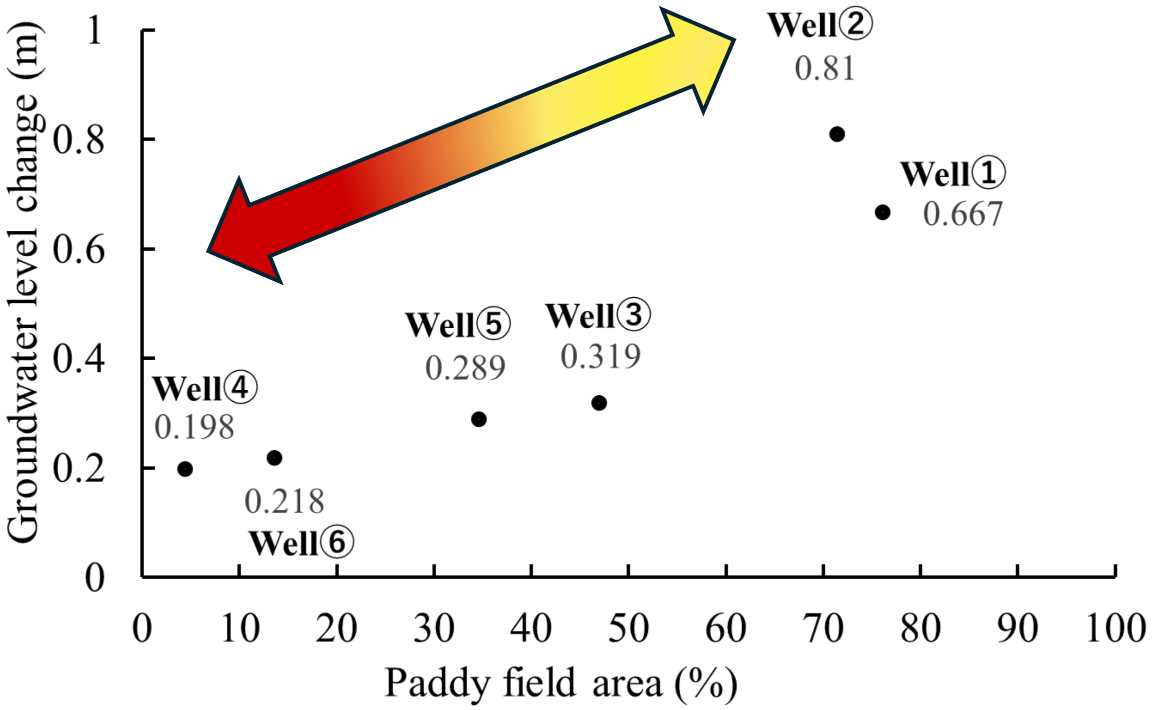


Figure 13: Paddy field and Groundwater level change

Groundwater level change:
0.198m in Well ④ to 0.81m in Well②.

Wells surrounded by larger paddy field area showed higher ground water level and vice versa

5. Conclusions

- Analysis reveals a positive correlation between paddy field area and groundwater recharge
- Highlights the role of paddy fields in groundwater recharge during the irrigation season.

◆ **Further Step**

- Currently, only the initial irrigation period has been evaluated, and the evaluation of other phases of irrigation is still lacking.
- Moreover, the effect of precipitation on groundwater recharge is not yet clarified.
- As a future plan, we expect to develop a groundwater flow model by assigning the groundwater recharge rate obtained in this study as the boundary conditions and by calibrating the data with the measured groundwater level.

Thank you for your attention.

ありがとうございました。

Questions:

1. Is the height of the ground level considered while doing groundwater survey?

(Question from Noda Sensei)

Find: Influence of rainfall days to groundwater elevation increase

Senge Sensei