A Study on Improving the Accuracy of Runoff Simulation in Paddy-Dominated Agricultural Watersheds

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SWAT
Soil & Water Assessment Tool
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swat.tamu.edu/conferences/2025-korea/

List

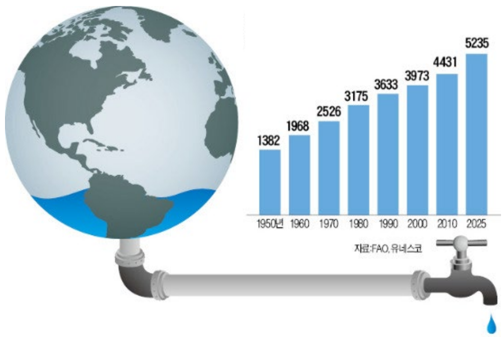
PART 1

Background and Rationale

I

THE NECESSITY OF AGRICULTURAL WATER MANAGEMENT

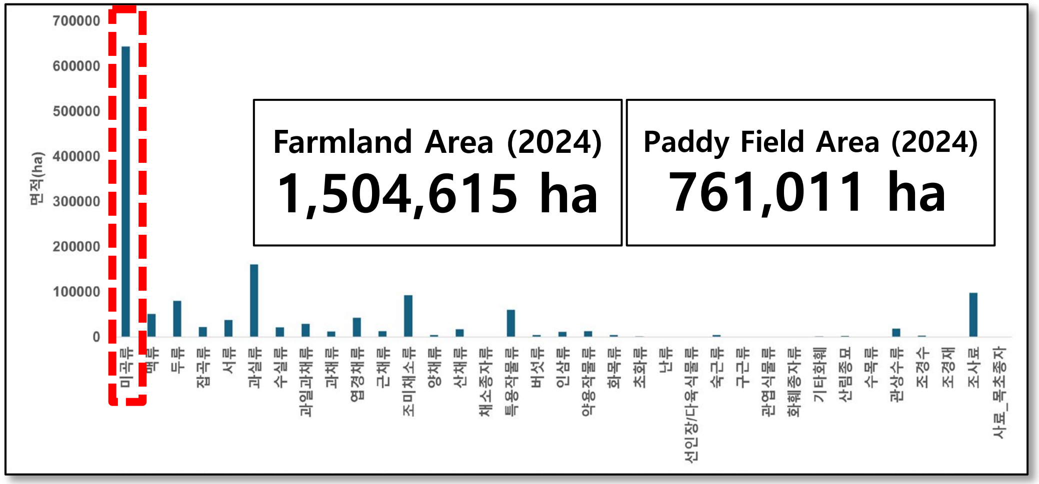
Background and Rationale



Soil & Water Assessment Tool | SWAT

- Due to climate change and increasing water demand, the efficient use of agricultural water is becoming increasingly important, highlighting the growing need for accurate hydrological modeling at the watershed scale.

LIMITATIONS OF WATER MANAGEMENT ACCORDING TO THE CHARACTERISTICS OF PADDY WATERSHEDS



National Agricultural and Food Statistics Service, Korean Statistical Information Service (KOSIS)

☑ Paddy fields account for more than 50% of the total farmland area

☑ Spatial structural characteristics such as mountainous terrain, distribution around slopes, small and fragmented land parcels, and dense irrigation canal networks.

☑ Paddy fields have a unique hydrological structure characterized by maintained ponding conditions, dependence on artificial irrigation, reduced surface runoff, increased infiltration, internal water storage capacity, and adjustable drainage conditions, where artificial water management is repeatedly carried out.

👉 It is difficult to accurately simulate actual runoff characteristics and the hydrological cycle using general hydrological models.

I

LIMITATIONS OF SWAT AND THE NEED FOR SPATIAL DISTRIBUTION REPRESENTATION

Conventional Hydrological Models

Soil & Water Assessment Tool SWAT

- SWAT (Soil and Water Assessment Tool) is a semi-distributed, long-term simulation-based watershed hydrology and water quality model developed by the United States Department of Agriculture – Agricultural Research Service (USDA-ARS).
  It quantitatively simulates runoff, erosion, nutrient transport, and agricultural non-point source pollution based on spatial information such as climate, topography, soil, and land use within a watershed.

Unable to reflect the ponding … ue to paddy fields

… e timing and operational … ion and drainage

… ent the structural … nd irrigation canals … y fields

Does not account for spatial distribution.

Improved Hydr…

Park, Y. S. (2013)

Irrigation and Drainage Schedule

Ponding Depth

Evapotranspiration

- … Assessment Tool for Paddy … (SWAT-PADDY) is an improved hydrological model developed to overcome the limitations of the traditional SWAT model.
  It enables more precise simulation of the hydrological cycle in watersheds dominated by inundated paddy fields.

It is not possible to consider each individual paddy and upland field

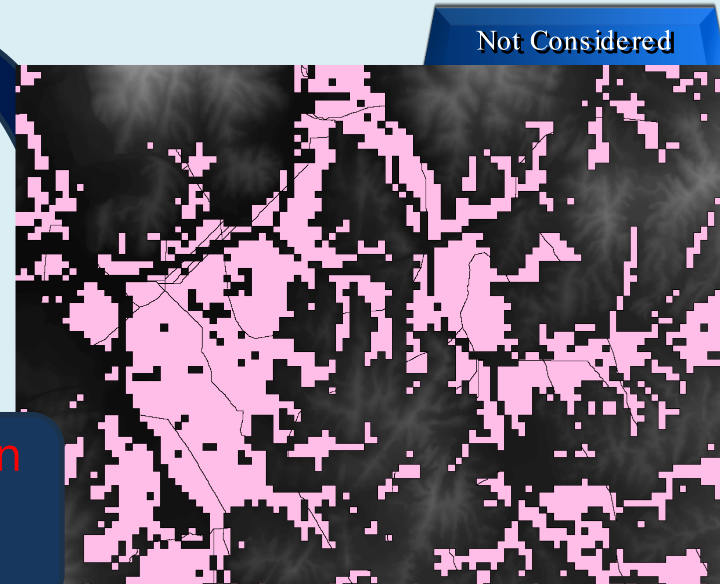
The model **may fail** to accurately represent actual water movement within the watershed

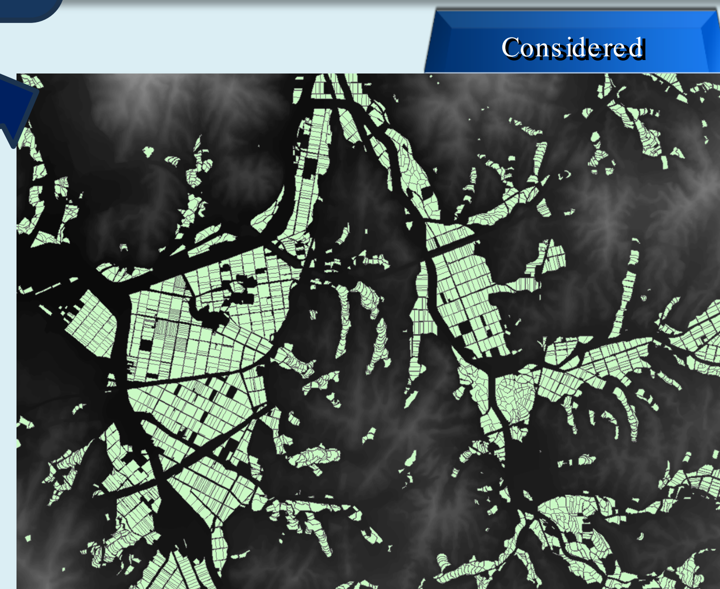
박윤식 외, "Development of SWAT SD-HRU Pre-processor Module...", ResearchGate, 2013.

RESEARCH OBJECTIVE

- To overcome the limitations of the SWAT model, which does not adequately reflect spatial distribution, an improved approach is considered.
- The model incorporates the actual spatial distribution of agricultural land to configure HRUs more realistically.
- Runoff volumes and flow duration curves (FDCs) will be analyzed and compared.

Consideration of Spatial Distribution



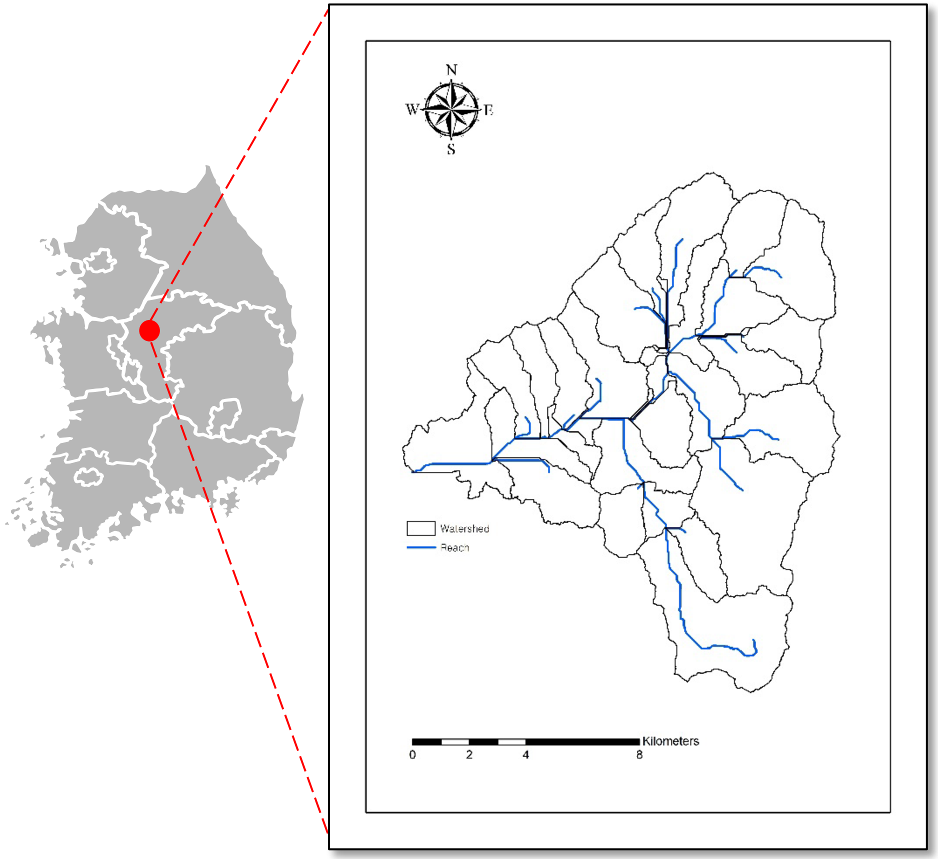


PART 2

Research Methodology

STUDY AREA

Bogangcheon Watershed



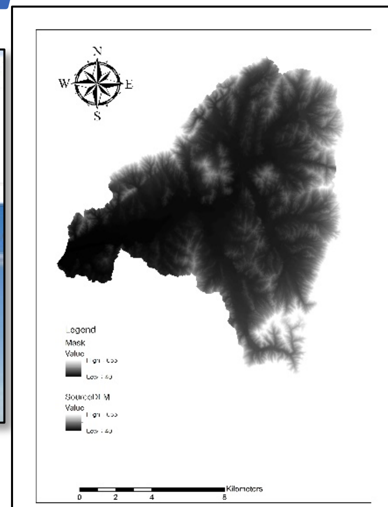
- The Bogangcheon Watershed is located across Goesan-gun, Jeungpyeong-gun, and Jincheon-gun in Chungcheongbuk-do, South Korea.
- An area of 149.22 square kilometers
- In the Bogangcheon Watershed, paddy fields account for 24% of the total land use.
- A region where irregular runoff patterns caused by irrigation and drainage in paddy fields interact with the complex hydraulic structures of small streams.

👉 By using a paddy-specific Hydrologic Response Unit (HRU) structure, the hydrological characteristics of paddy fields can be represented with greater accuracy.

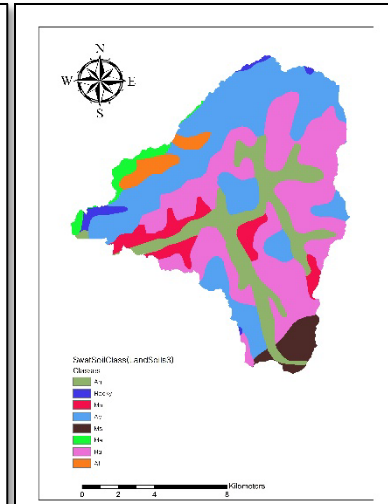
METHODOLOGY FOR CONSTRUCTING THE SWAT-PADDY MODEL

Simulation Period: 2018–2022

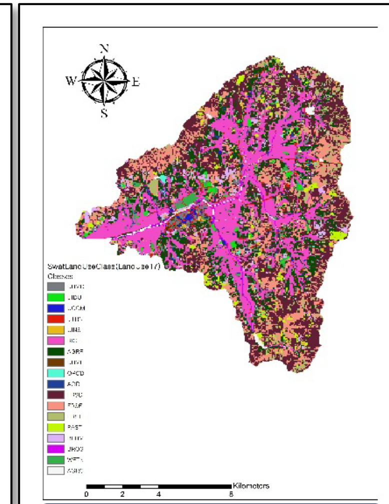
Weather Data



DEM



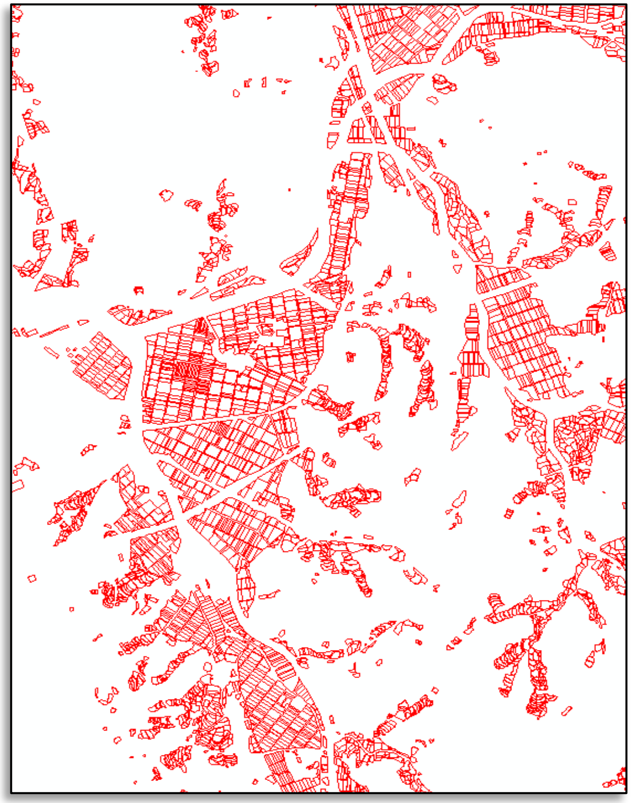
Soil Map



Land Use Map

- ✓ Weather data (daily precipitation, temperature, wind speed, solar radiation, and relative humidity) were collected from Cheongju, Eumseong, and Jeungpyeong weather stations.
- ✓ A 30 m × 30 m Digital Elevation Model (DEM) was generated using digital topographic maps from the National Geographic Information Institute
- ✓ Land use data (mid-level classification) were acquired from the Environmental Spatial Information Service.
- ✓ A detailed soil map was obtained from the Rural Development Administration (RDA), National Institute of Agricultural Sciences.

II MODIFIED SPATIALLY DISTRIBUTED-HRU (MSDH)



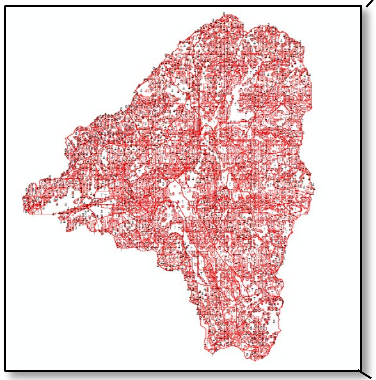
- ✓ Digitized actual agricultural field boundaries
- ✓ Assigning unique IDs to each agricultural field
- ✓ Applying land use and soil data to each field

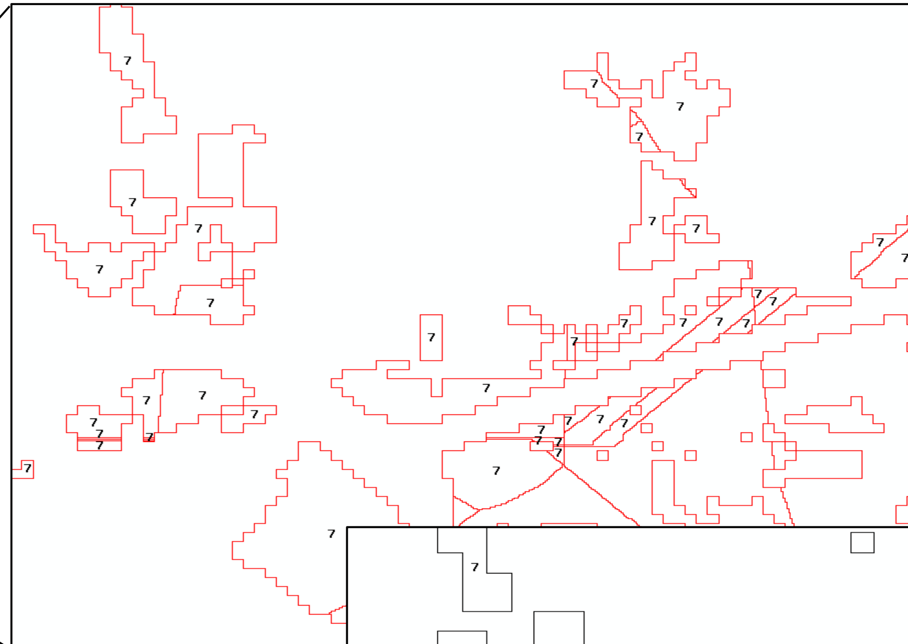
👉 HRU definition based on actual field boundaries and spatial location

- The integration of the MSDH preprocessing module into SWAT-PADDY enables the assignment of measured slope and slope length to each HRU, thereby considering spatial distribution.

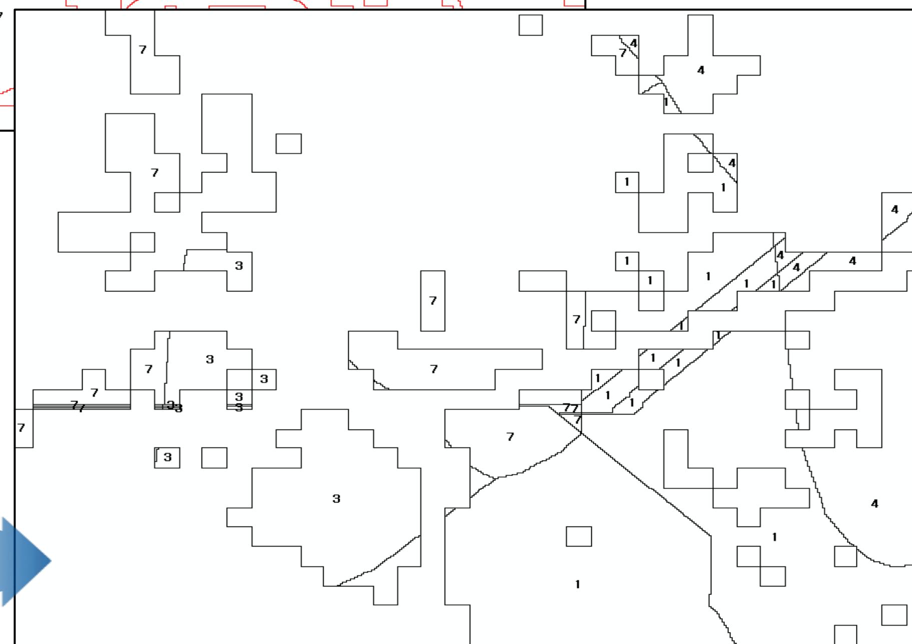
MODIFIED SPATIALLY DISTRIBUTED-HRU (MSDH)

Soil Map,
Land Use Map





Application of MSDH



✓ Conventional SWAT-PADDY defines identical land use and soil combinations as one HRU, regardless of location.

- Spatial Distribution Considered

PART 3

Research Results

RESULTS OF APPLYING MSDH: DIFFERENCES IN PADDY AREA

PADDY

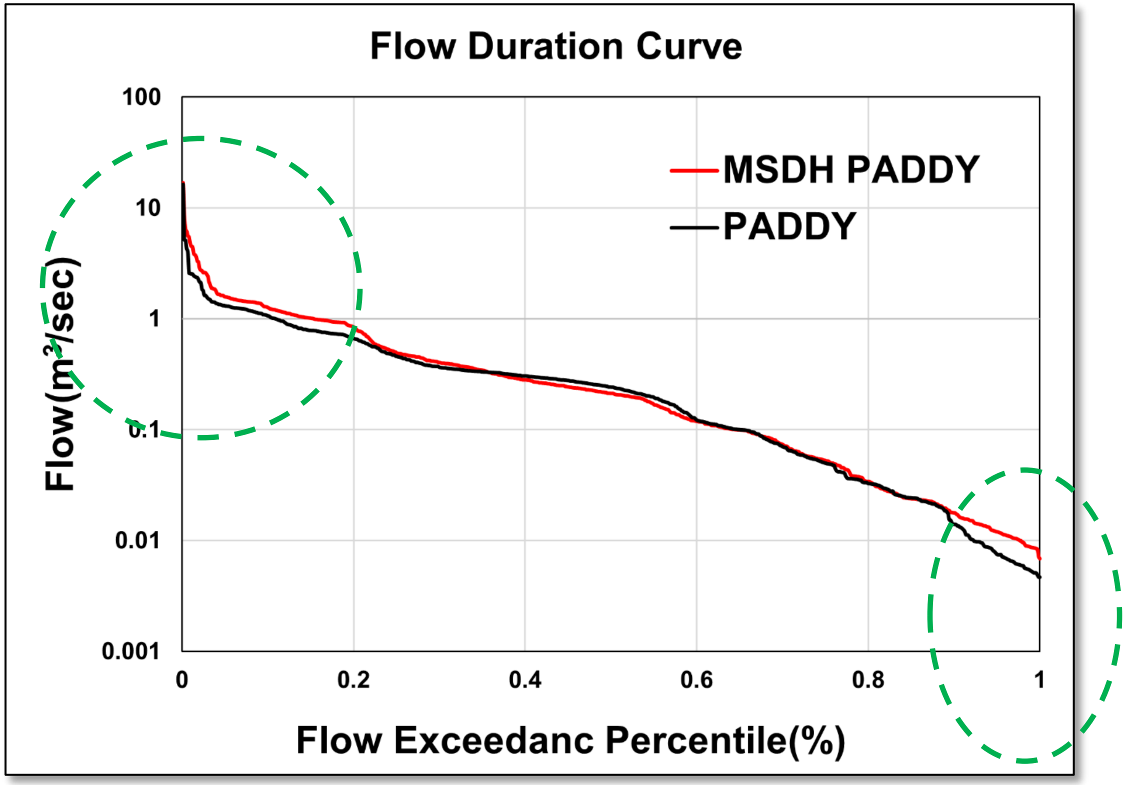
MSDH PADDY

Area Comparison

- PADDY: 0.217 km^2 / MSDH-PADDY: 0.240 km^2
- MSDH-PADDY shows a 0.023 km^2 increase in paddy area compared to the default model.

III

FLOW DURATION CURVE



FDC

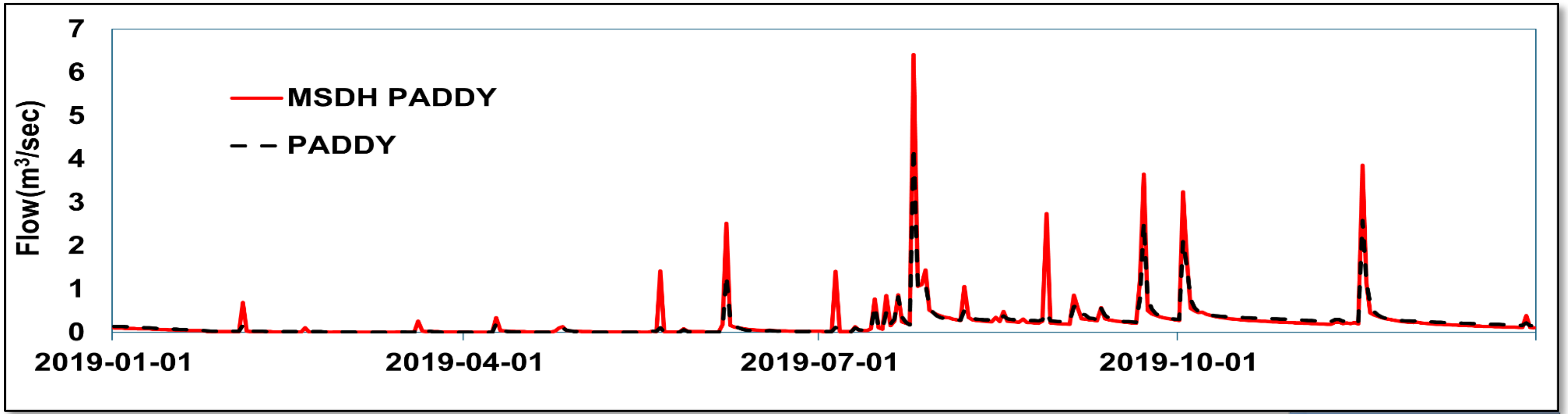
- An FDC (Flow Duration Curve) is a curve that represents the frequency, expressed as a percentage, at which specific flow rates are observed or simulated in a given river or watershed.
- When using the MSDH-PADDY model, both low and high flow rates were significantly estimated.
- Since HRUs are defined at the individual paddy field level, runoff contributions are independently calculated and reflected based on unique slope, length, spatial location, and soil characteristics, resulting in a more differentiated FDC.

- During the cultivation period, rainfall on paddy fields generates direct runoff, leading to an increase in high-flow values.
- Under ponded conditions, continuous infiltration contributes to baseflow generation, resulting in increased low-flow values.
- When MSDH is applied, the land cover is updated, which leads to increases in both high-flow and low-flow ranges.

III

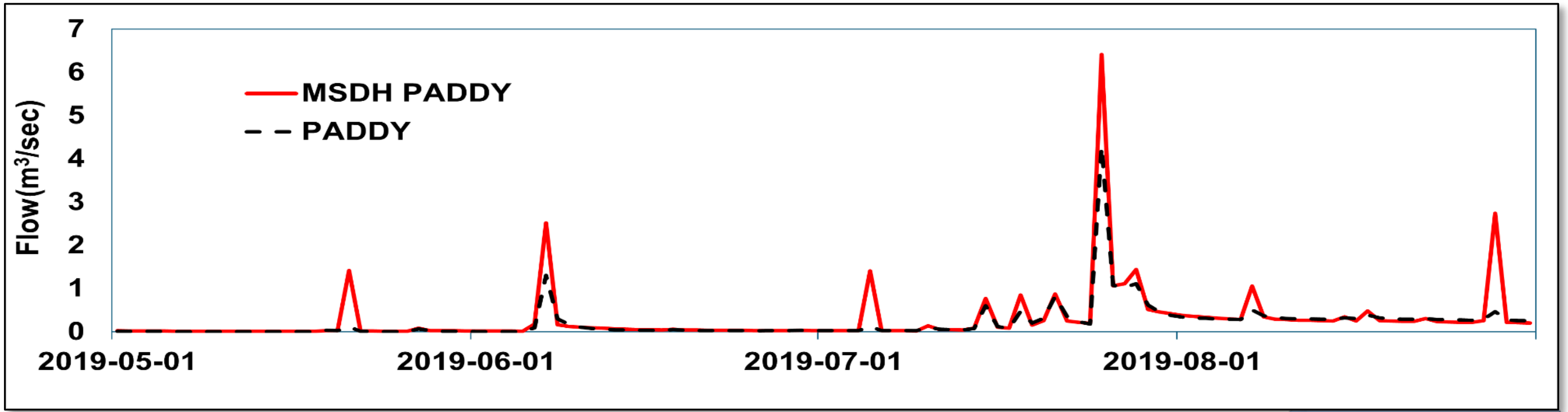
COMPARISON OF STREAMFLOW SIMULATION RESULTS

Research Results



2019

✓ The annual average streamflow in 2019 increased from 0.21 ㎥/sec (PADDY) to 0.24 ㎥/sec (MSDH- PADDY).

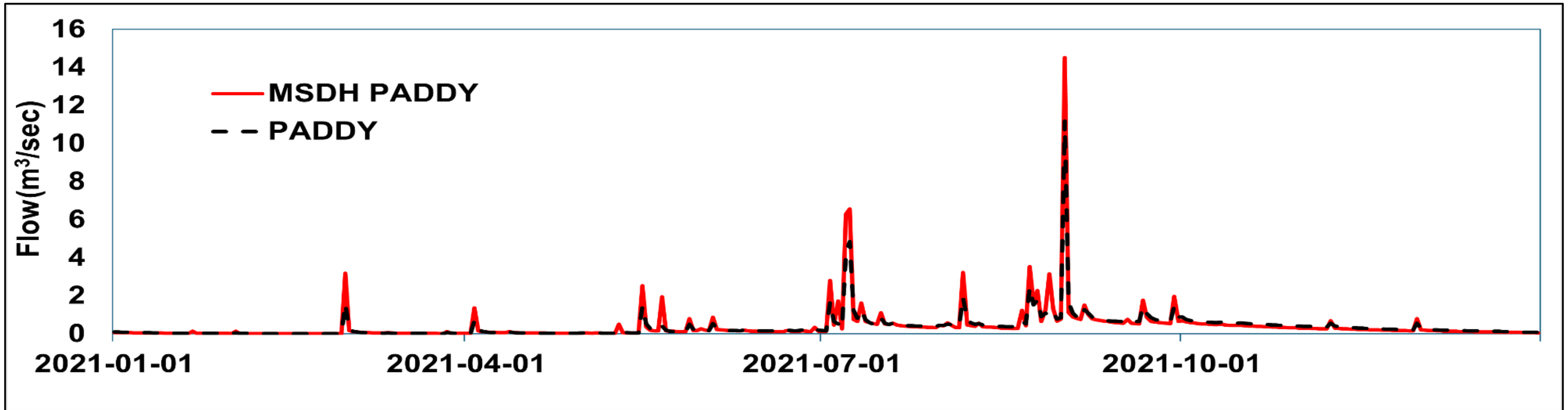


2019, 5~8

✓ In May–August 2019, streamflow increased from 0.21 ㎥/sec (PADDY) to 0.29 ㎥/sec (MSDH- PADDY).

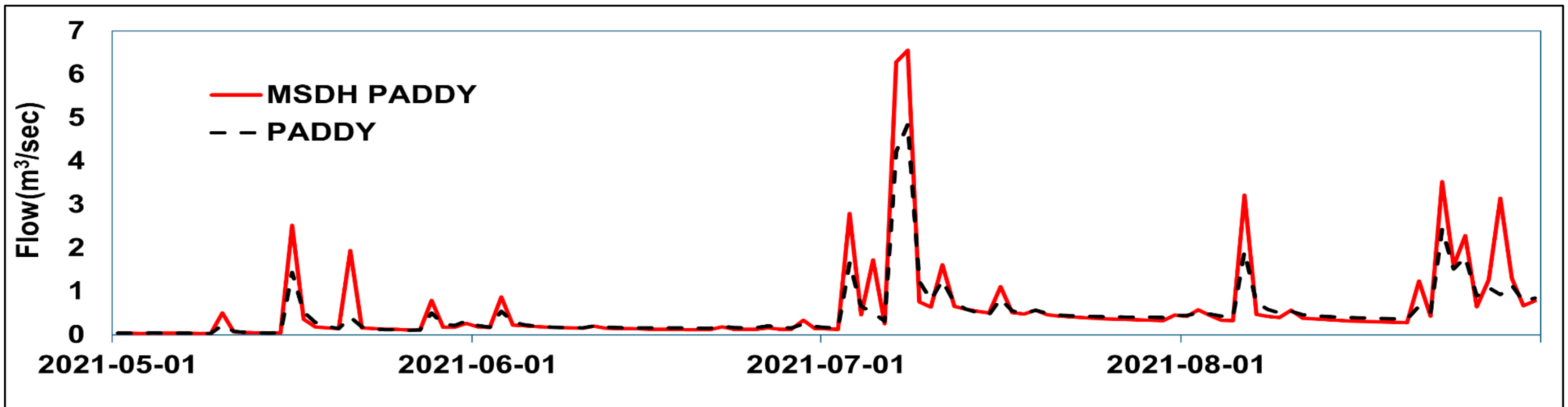
Ⅲ

COMPARISON OF STREAMFLOW SIMULATION RESULTS



2021

✓ The 2021 annual average streamflow increased from 0.37 ㎥/sec (PADDY) to 0.40 ㎥/sec (MSDH- PADDY).



2021, 5~8

✓ In May–August 2021 (cultivation period), streamflow increased from 0.49 ㎥/sec (PADDY) to 0.59 ㎥/sec (MSDH- PADDY).

PART 4

Research Conclusion

CONCLUSION AND LIMITATIONS

Conclusion

- ✓ In this study, the SWAT-PADDY and MSDH-SWAT-PADDY models were used to simulate ponded paddy fields in the Bogangcheon Watershed, which is a paddy-dominated agricultural basin.
- ✓ To evaluate the effect of applying MSDH, streamflow outputs from the default PADDY model and the MSDH-applied model were compared.
- ✓ The comparison revealed that applying MSDH resulted in noticeable differences in streamflow within ponded paddy areas, indicating that spatial representation significantly influences hydrological simulation.
- ✓ It is expected that applying MSDH to SWAT-PADDY in future simulations of paddy watersheds will improve the accuracy of flow estimation, making the model more effective for hydrological
- ✓ Additionally, this approach may contribute to integrated water management at the watershed level, including coordination between water sources and downstream irrigation reservoirs in paddy field regions.

CONCLUSION AND LIMITATIONS

Limitations

- ✓ Due to the lack of observed streamflow data in the study area, model calibration could not be performed.
- ✓ It is also expected that the update of the land cover map during the construction of the MSDH- PADDY model may have affected the streamflow and the FDC curve. In future studies, all input datasets for the model will be updated to the most recent versions.

Thank you for your attention

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