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FINAL REPORT

Strengthening Food Security via Strategic Agricultural Water Management: A Case Study on Assessing Water Demand from High-Resolution SAR Remote Sensing for Enhanced Operational Plans in Water Works Systems of Vietnam and Cambodia

CRRP2024-09SY-Ngo

2025

BỘ NÔNG NGHIỆP VÀ MÔI TRƯỜNG
IMHEN
VIỆN KHOA HỌC KHÍ TƯỢNG THỦY VĂN VÀ BIẾN ĐỔI KHÍ HẬU

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1. Summary

The Southeast Asia (SEA) region, especially Vietnam and Cambodia, has encountered uncertainties/challenges in sustaining the production system of its food and water systems due to climate fluctuations. Despite investments in both structural and non-structural solutions, the lack of advanced methods and techniques to monitor and forecast drought, as well as assess water demand for operationalising the water and food system, is deemed critical from both policy and social perspectives. The utilisation of big Earth data has demonstrated significant potential for application in observing food and water systems. By integrating big Earth data, essential operational parameters can be derived for agriculture, providing valuable insights for policymakers and water resource managers.

The project creates a tool supporting agricultural water management using the water-demand index (WDI) derived from influencing first-order variables, namely soil moisture (SM), vegetative growth (NDVI), and heat factor (growing degree day, GDD). Within the APN Seed grant project, the WDI maps in different periods of a critical drought event (2020) were conducted at weekly and monthly time scales over the two piloting regions of Vietnam and Cambodia. The WDI zoning maps were verified using the ground survey and collected data in Ninh Thuan province and Kampong Thom province to assess their suitability to integrate with irrigation system operations, and inform policy development for regions facing water stress.

Evaluation of farmers and water resources managers' questionnaire results indicates that the WDI maps are reasonably reliable and applicable for irrigation planning and identifying crop water-stressed areas. This finding highlights the value of WDI as a strategic tool for irrigation officers and local authorities, particularly useful for coordinating water allocation during severe drought periods, in line with stakeholders' priorities for integrated water resource management. The information contained in the WDI maps was highly appreciated by the local meteorological department as it reflects the crop water status, hence it will be more useful once they can integrate such maps within their regular bulletins for local citizens and public organisations.

However, the application of WDI remains limited due to its recent introduction in the practice; thus, the WDI products have not had much record of usage by farmers and water managers for their technical application. Additionally, the index currently has a lag time due to the availability of the remote sensing products and overpasses. Therefore, it reduces the capability of the tool and product to capture the timing and severity of drought events, reducing its effectiveness for early warning and crop transition planning.

To enhance the role of WDI, it is necessary to release the maps earlier in the season as a crop water management scenarios development technique, integrating additional hydrological data, and linking the tool with localised farming guidance. Beyond its technical function, WDI also serves as a governance instrument that contributes to improved water allocation and climate-resilient agricultural planning at the local level. Therefore, the implementation of the project in the next phase is essential to scale up and enhance the applicability of the WDI maps in strengthening water and food security in Viet Nam and Cambodia.

2. Objectives

The overarching goal of the seed grant project is to evaluate the ability of water demand assessment applying big data from very high-resolution Synthetic Aperture Radar (SAR) observations to inform and integrate in operational irrigation management, addressing food security-related Sustainable Development Goals (SDGs) in the agriculturally dominated provinces of Vietnam and Cambodia. The achievement of this overarching goal will be pursued through the following objectives:

- Objective 1: Developing a Water Demand Index (WDI) in the agricultural regions of Vietnam and Cambodia using SAR data.
- Objective 2: Preliminary evaluation and validation of the WDI application with stakeholders in Ninh Thuan province (Vietnam) and Kampong Thom province (Cambodia).

3. Outputs, Outcomes and Impacts

Based on the above objectives, the project is undertaken to achieve the following outputs to address some aspects of SDGs related to food and water security.

Outputs	Outcomes	Impacts
Zoning maps of Water Demand Index (WDI) at a 1 km* resolution for the entire regions of Vietnam and Cambodia.	● Provide a rapid and visual tool for assessing water demand and water stress at the commune level. ● Support managers and agricultural officers in decision-making for irrigation regulation and rational water allocation. ● Enhance technical capacity in using SAR, MODIS, and SMAP data for drought and water demand monitoring.	● Improve water use efficiency in agriculture. ● Reduce the risk of water shortages during the dry season and under climate change conditions. ● Contribute to strengthening national water and food security (SDG 2, SDG 6, SDG 13). ●
Survey data and a report on the evaluation and validation of the WDI operation in Ninh Thuan province (Vietnam) and Kampong Thom (Cambodia)	● Validate the reliability of WDI maps through consultation and field verification. ● Strengthen the capacity of local stakeholders in collecting, managing, and utilising agricultural water data. ● Improve coordination between central and local agencies in monitoring drought and water demand.	● Enhance the national system for water and drought monitoring to support evidence-based policies for managing water resources. ● Promote data-driven decision-making in agricultural management and climate change adaptation. ●

Outputs	Outcomes	Impacts
Outlook for the application and scaling up of the method and future uptake	● Identify the feasibility and enabling conditions for scaling up the WDI tool. ● Provide a scientific basis for integrating the WDI into national programs on drought management, water resources and crops planning, and climate adaptation. ● Foster regional cooperation in data sharing and experience exchange.	● Contribute to the Indochina regional water resource management framework based on science and digital technology. ● Support the development of cross-border climate adaptation policies, promoting cooperation among Viet Nam, Cambodia, and the Southeast Asian region.

** In the seed grant phase, the WDI maps are implemented at 1 km resolution.*

4. Key facts/figures

- The project developed monthly and weekly zoning maps indicating the Water Demand Index (WDI) of agricultural land in Ninh Thuan (Vietnam) and Kampong Thom (Cambodia) provinces during the severe drought event of 2020. Six monthly WDI maps (from March to August 2020) and corresponding weekly WDI maps were produced for Ninh Thuan Province. Five monthly WDI maps (from January to May 2020) and weekly WDI maps were generated for Kampong Thom Province.
- A field survey was conducted to evaluate the accuracy and impacts of the WDI maps on farming and irrigation practices at selected sites of Ninh Thuan and Kampong Thom. Two sets of questionnaires were directly distributed to 22 Vietnamese and 29 Cambodian respondents to collect feedback.
- Four group meetings were organised, both in-person and virtually, to discuss technical issues.
- A consultative workshop was held at the Viet Nam Institute of Meteorology, Hydrology, and Climate Change (IMHEN) to gather feedback from professional and local experts on the WDI maps.
- A scientific paper was published in a domestic journal in Vietnam.

5. Publications

Ngo Thi Thuy, Luong Tuan Trung, Vu Thi Thuy, Duong Hong Nhung, Narendra N. Das (2025). Remote sensing-based water demand index mapping: Insights from Khanh Hoa province, Vietnam. Journal of Climate Change Science, No. 35, Sep 2025. doi: 10.55659/2525-2496/35.120222.

6. Media reports, videos and other digital content

Featured on the title “Consultative Workshop on Developing Agricultural Water Demand Index Maps Using Satellite Data” (in Vietnamese)
https://imh.ac.vn/hoi-thao-tham-van-xay-dung-ban-do-chi-so-nhu-cau-nuoc-nong-nghiep-dua-tren-du-lieu-ve-tinh/

7. Pull quotes

“The project has been a wonderful opportunity for me to collaborate and connect with international scientists in applying remote sensing technology to assess water demand and promote efficient water use in drought-prone areas. Its outcomes lay the foundation for us, as young scientists, to contribute to the shared goals of ensuring food and water security in Viet Nam and Cambodia.” – Dr. Ngo Thi Thuy, Project Leader, The Vietnam Institute of Meteorology, Hydrology and Climate Change.

“This study contributes to advancing scientific understanding of agricultural water demand and accelerating the application of advanced science and technology in water resource management. Through the integration of SAR remote sensing and field validation, IMHEN has enhanced its expertise in water demand assessment, and data-driven decision support” – Assoc. Prof. Dr. Pham Thi Thanh Nga, Director General, The Viet Nam Institute of Meteorology, Hydrology and Climate Change

“We are excited to be part of this applied scientific project focused on hydrology and agriculture, the core sectors driving Cambodia’s development. Agriculture remains vital to our economy yet highly vulnerable to climate change, especially in rainfed rice-growing areas. This project brings real opportunities to strengthen productivity and resilience by improving water management. Its outcomes will help both decision-makers and farmers use resources more efficiently, enhance their livelihoods, and support food security both locally and across the region.” – Mr. Sovann Chansopheaktra, Royal University of Phnom Penh, Cambodia.

"The WDI project holds great potential for guiding decision-makers and policy planners. The maps are expected to provide a solid foundation for developing effective water management strategies, ensuring resources are allocated where they are needed most," said an agriculture and irrigation official in Kampong Thom province.

"With the proposed WDI project, we anticipate significant improvements in our farming practices. The maps will help us better plan, respond to water needs, and make timely requests. This project could be crucial for protecting crops, boosting productivity, and strengthening food security in our region," said a farmer and a commune official in Kampong Thom province.

8. Acknowledgments

The project team wishes to express its deepest gratitude to the Asia-Pacific Network for Global Change Research (APN) for providing financial support to this seed project. We sincerely hope that the project's findings and outcomes will be further expanded and applied in future initiatives.

Our heartfelt appreciation is also extended to the Vietnam Institute of Meteorology, Hydrology and Climate Change, the host institution, for its continuous guidance, encouragement, and facilitation throughout the implementation of the project. We are equally grateful to the APN Secretariat for their kind assistance and timely support in addressing administrative and technical matters during both the contracting and implementation phases.

This project could not have been successfully completed without the enthusiastic collaboration and support of local managers and experts in Ninh Thuan (now Khanh Hoa Province, Viet Nam) and Kampong Thom (Cambodia). We sincerely thank them for their valuable time, efforts, and commitment during the entire project period.

9. Appendices

APPENDIX 1. WDI MAPS

1. Conceptual framework

Agricultural water demand in Vietnam and Cambodia was assessed using the Water Demand Index (WDI) developed by [8]. Unlike traditional drought indicators that primarily emphasize precipitation deficits, such as the (Mckee et al., 1993), the Palmer Drought Severity Index (PDSI) (Palmer, 1965), or the Crop Moisture Index (CMI) (Palmer, 1968), the WDI defined agricultural drought as a deficiency resulting from the imbalance between available soil moisture and crop water requirements. This framework integrates three variables, including soil moisture (SM), vegetative growth (NDVI), and heat units (GDD), which together capture the interaction between soil water availability, crop development, and temperature-driven evapotranspiration.

The framework is based on three variables:

- Soil Moisture (SM): representing available water in the root zone;
- Normalized Difference Vegetation Index (NDVI): representing vegetation growth and canopy condition, both of which influence evapotranspiration;
- Growing Degree Days (GDD): representing accumulated heat units that regulate crop development and water demand.

The relationship among these components can be illustrated in Figure 1.

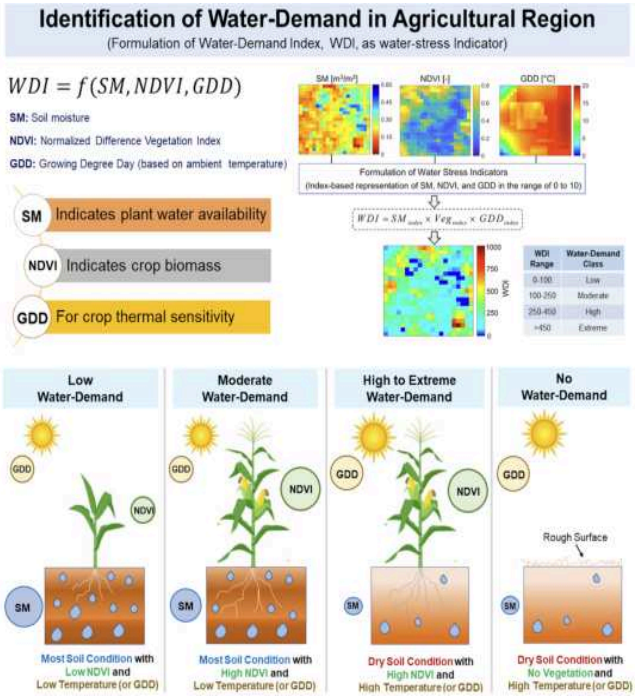

Figure 1: The conceptual diagram of water demand index (WDI)

By integrating these variables, WDI enables a spatial assessment of crop water stress and irrigation needs, providing a physical framework for monitoring agricultural drought and supporting climate adaptation planning in water-scarce regions.

2. *Data and preprocessing*

All indices required for calculating the Water Demand Index (WDI) were derived from satellite images with spatial resolutions ranging from 0.1° to 1 km. To ensure spatial consistency, all datasets were reprojected onto the Equal-Area Scalable Earth Grid 2.0 (EASE2) coordinate system and resampled to a 1 km grid by the linear scattered data interpolation method (Amidror, 2002). This preprocessing ensured uniform spatial alignment across soil moisture, vegetation, and temperature datasets prior to temporal aggregation. Details of the datasets are described in the following in Table 1.

Table 1: Description of datasets used in this study

Variable	Dataset	Resolution	Temporal Scale	Source	Data Period	Purpose
Soil Moisture	SMAP/Sentinel -1 L2_SM_SP	1 km	5 days	NASA NSIDC	Mar–Aug 2020	Estimate surface soil moisture
NDVI	MOD13A2 V6	1 km	16 days	NASA LP DAAC	Mar–Aug 2020	Represent vegetation growth and canopy condition to calculate WDI
					2016-2020	Calculate $NDVI_{max}$
Temperature	ERA5-Land (ECMWF Reanalysis v5)	0.1° (~9–10 km)	Daily	ECMWF	Mar–Aug 2020	Derive daily ambient temperature
Land Cover	MOD13A2 V6	1 km	Static	NASA LP DAAC	2020	Identify agricultural land areas
Soil Bulk Density	SoilGrids250m	250 m	Static	ISRIC	No temporal variation	Compute SM_{max} for SM normalisation

All datasets corresponded to the March–August 2020 period, consistent with the agricultural growing season across the study area.

3. *Normalisation of input* variables *and computation of WDI*

Since the three input variables differ in their physical units and dynamic ranges, each was normalised to a dimensionless scale (0–10) before computing the WDI. Each index was computed for every 1 km grid cell (i,j) and day t as follows:

a. Soil Moisture Index (SM_{index}):

$$SM_{index}(t) = \left(1 - \frac{SM(t)}{SM_{max}}\right) \times 10 \qquad (1)$$

where $SM(t)$ is the soil moisture of grid cell (i,j) for day t, and SM_{max} is the saturated water content (soil porosity) of the grid cell (i,j). Soil porosity was estimated as:

$$SM_{max} = 1 - \frac{\rho_{bulk}}{\rho_{particle}} \qquad (2)$$

with ρ_{bulk} representing soil bulk density, which were extracted from the dataset of Hengl (2018) (Hengl, 2018)and $\rho_{particle}$ the particle density, assumed to be 2.65 g/cm³ (Singh & Das, 2022).

b. Vegetation Index (Vegindex)

The Vegetation Index (Veg_{index}) was computed as:

$$Veg_{index}(t) = \left(\frac{NDVI(t)}{NDVI_{max}}\right) \times 10 \quad (3)$$

where $NDVI(t)$ is the NDVI value of grid cell (i,j) for day t, and $NDVI_{max}$ is the maximum NDVI observed for that grid cell.

c. GDD Index (GDD_{index}):

The GDD_{Index} was then derived as:

$$GDD_{index}(t) = \left(\frac{GDD(t)}{Temperature\ growth\ range}\right) \times 10 \quad (4)$$

Where GDD(t) is the growing degree days of grid cell (i,j) on day t, and the temperature growth range was defined as $T_{base\_upper} - T_{base}$. For each day, the average temperature is calculated as the mean of the daily maximum and minimum air temperatures, and the GDD(t) is then expressed as:

$$GDD(t) = \frac{Tmax+Tmin}{2} - T_{base} \quad (5)$$

T_{base} and T_{base_upper} were used as 10°C and 30°C, respectively, represented for all types of crops and seasons (Anandhi, 2016)(Fjell et al., 2010)(McMaster & Wilhelm, 1997). To minimize the influence of extreme temperature values on GDD calculation, several constraints were applied. When $T_{min} < T_{base}$, it was adjusted and set equal to T_{base}. Similarly, when $T_{max} > T_{base\_upper}$, it was replaced by T_{base_upper}. In cases where both conditions occurred on the same day, the two adjustments were applied simultaneously.

All computations were implemented in MATLAB. Following spatial resampling, the time series of each parameter was compiled on a weekly timescale to ensure consistent temporal resolution. The temporal aggregation method varied among variables:

- GDD_{index}: averaged from daily temperature data;
- SM_{index}: represented by the available SMAP–Sentinel observation within the week.
- Veg_{index}: reconstructed from 16-day MODIS composites using Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) interpolation (Fritsch & Carlson, 2006) to fill temporal gaps and align with weekly intervals.

Wednesday was selected as the midpoint reference of each week to synchronize temporal alignment among all datasets.

Finally, for each grid cell, the weekly WDI was computed as:

$$\mathbf{WDI(t)= SM_{index}(t) \times Veg_{index}(t) \times GDD_{index}(t)} \quad (6)$$

Higher WDI values indicate greater crop water stress and irrigation demand. Weekly WDI layers were compiled into a continuous spatiotemporal dataset.

4. Mapping and Classification of WDI

After computing the weekly WDI layers, each raster map was classified according to the scheme proposed by (Singh & Das, 2022) into four categories:

- Low (0–100): Minimal water stress
- Moderate (100–250): Emerging irrigation demand
- High (250–450): Severe water stress
- Extreme (>450): Critical water deficit

The classified maps were processed and visualized using ArcGIS 10.1.

5. WDI Zoning maps

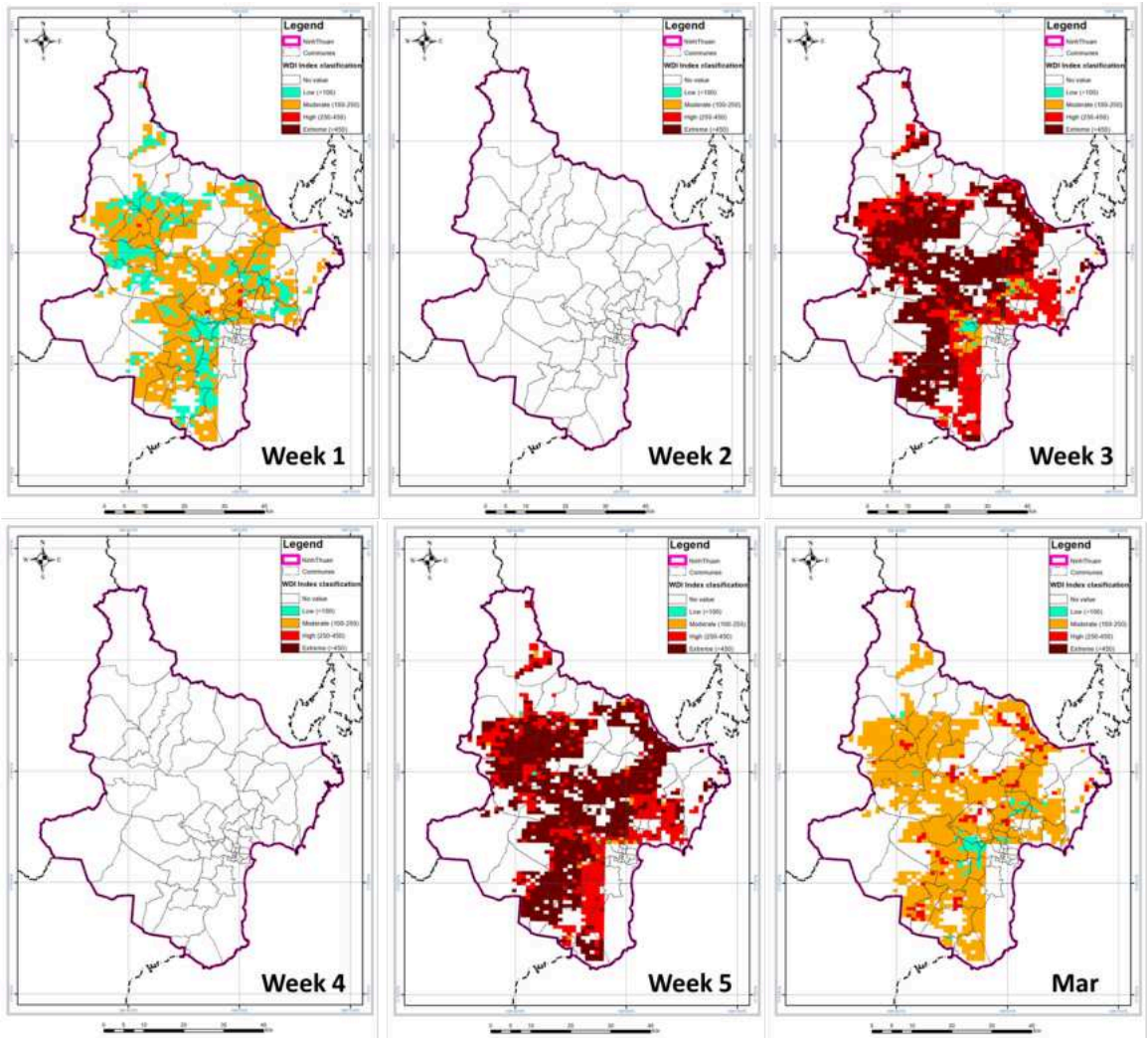

Figure A1.1. WDI map for agricultural area in March 2020 (Ninh Thuan, Vietnam).
Note: The blank maps present no SM data for this period

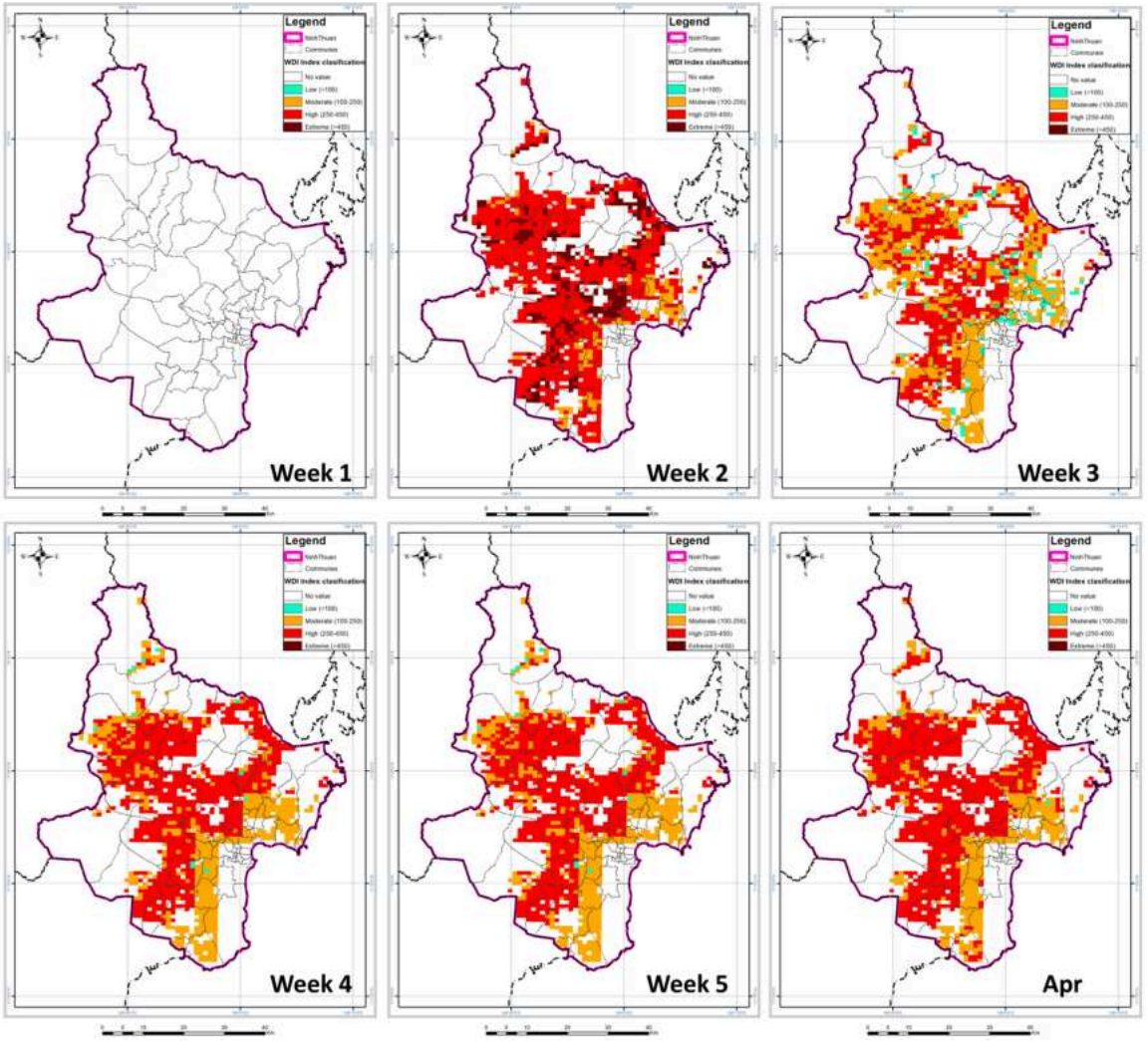

Figure A1.2. WDI map for agricultural area in April 2020 (Ninh Thuan, Vietnam)
Note: The blank maps present no SM data for this period

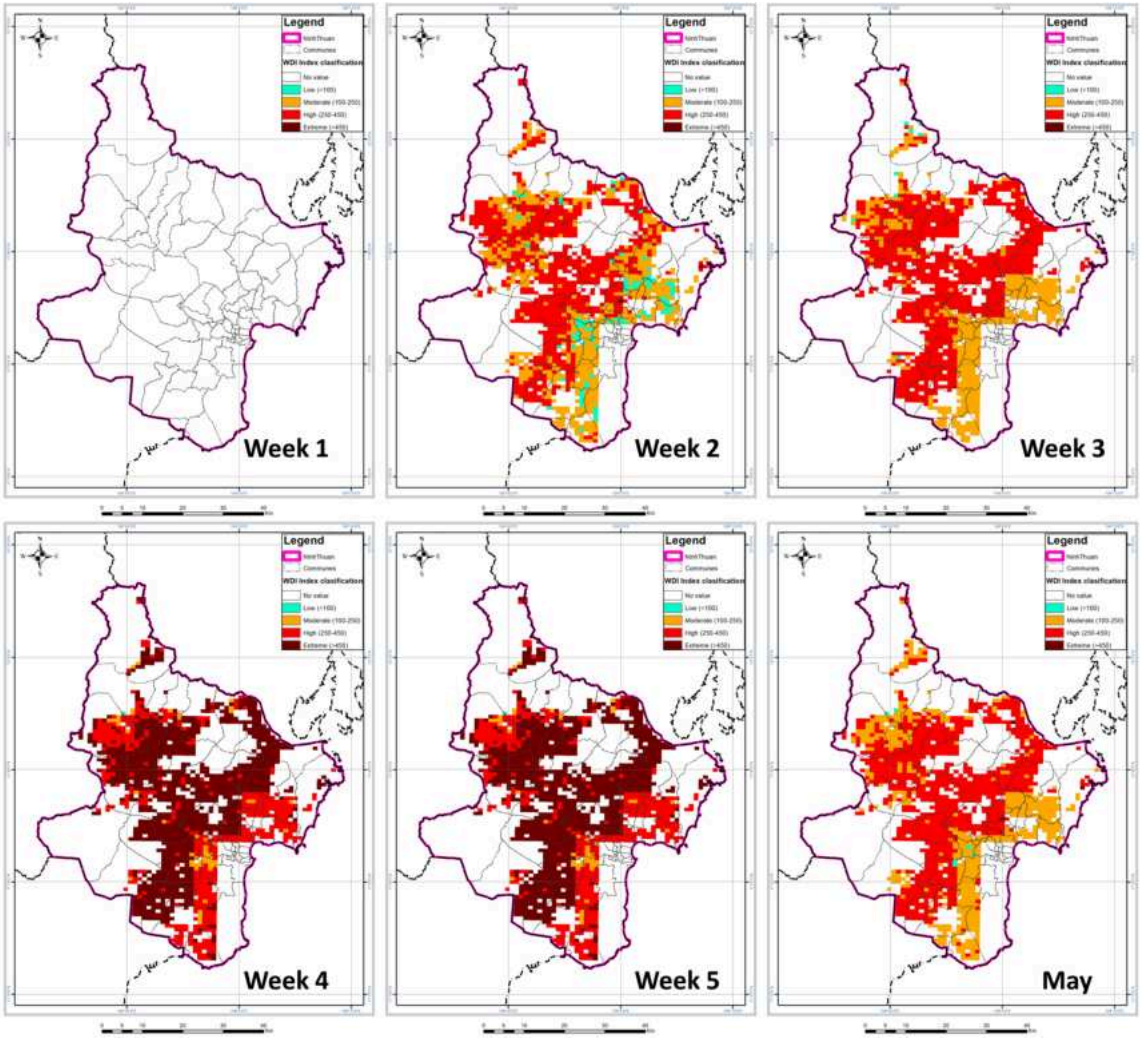

Figure A1.3. WDI map for agricultural area in May 2020 (Ninh Thuan, Vietnam)
Note: The blank maps present no SM data for this period

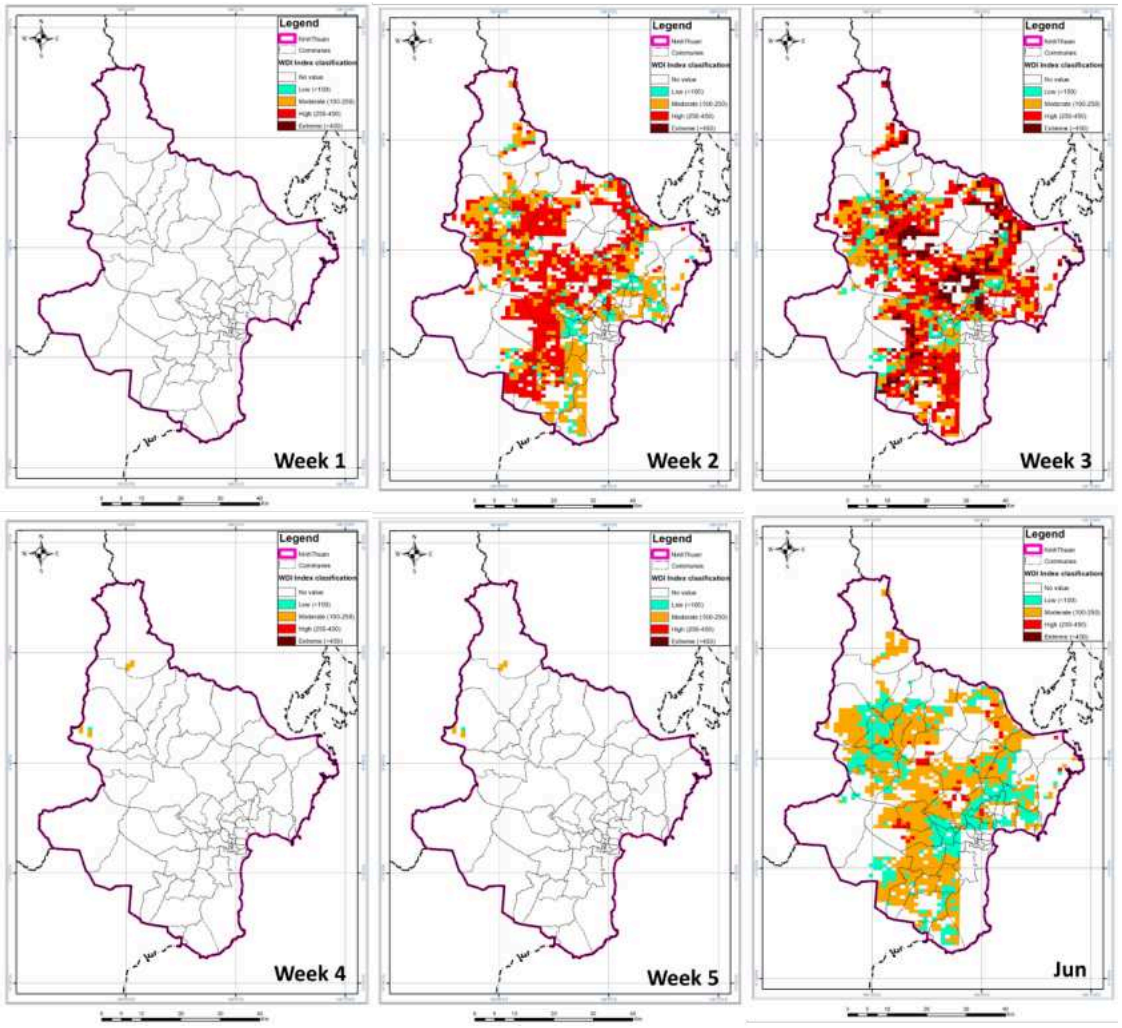

Figure A1.4. WDI map for agricultural area in June 2020 (Ninh Thuan, Vietnam)
Note: The blank maps present no SM data for this period

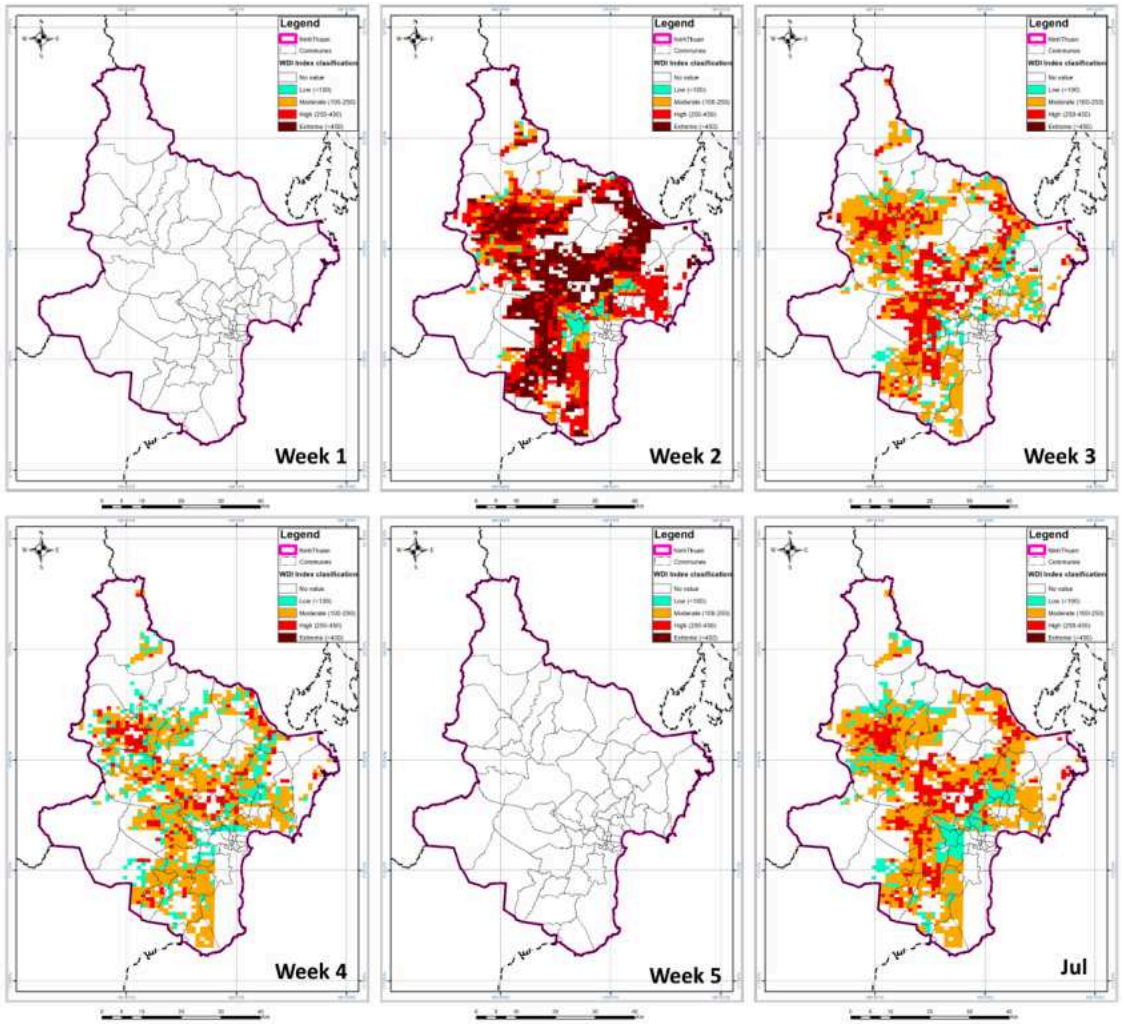

Figure A1.5. WDI map for agricultural area in July 2020 (Ninh Thuan, Vietnam)
Note: The blank maps present no SM data for this period

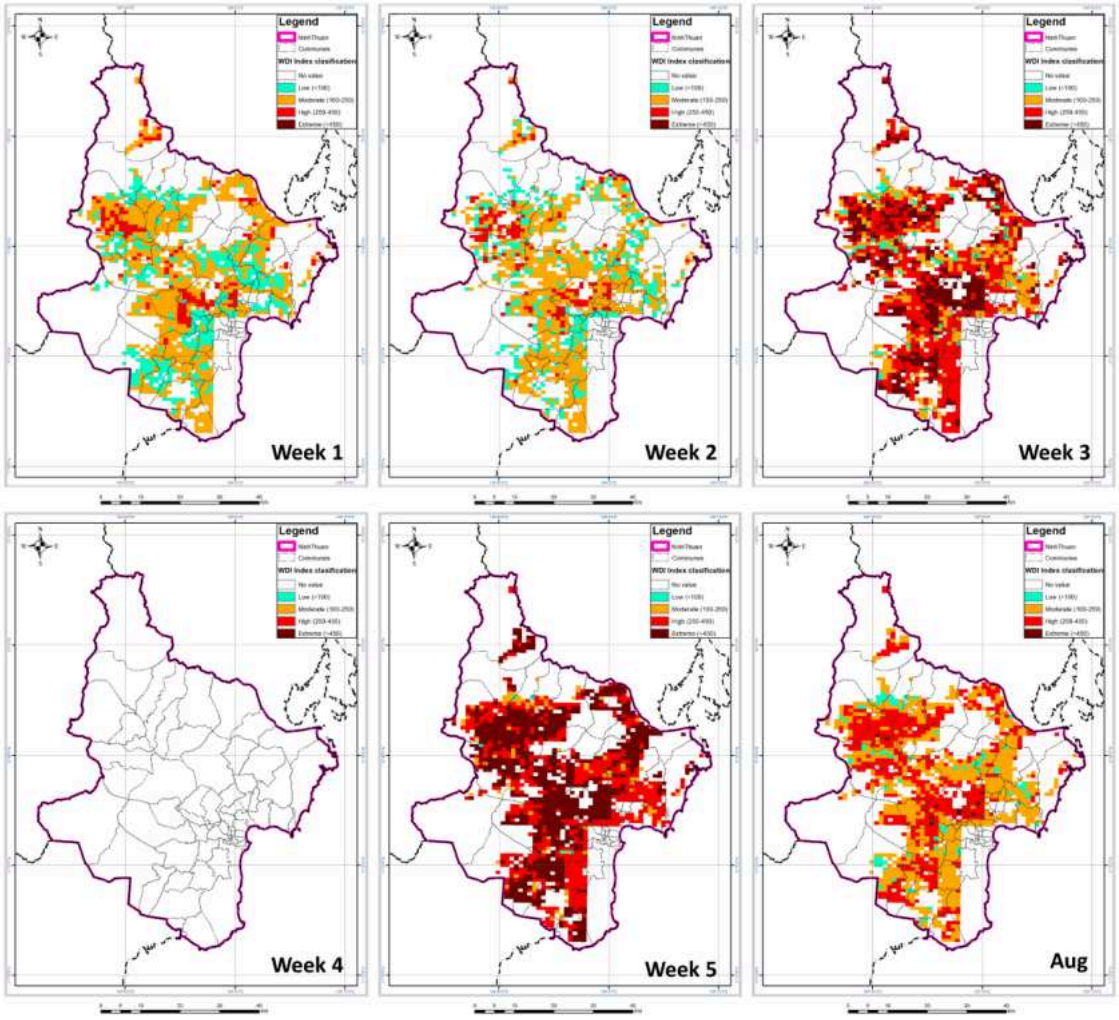

Figure A1.6. WDI map for agricultural area in August 2020 (Ninh Thuan, Vietnam)
Note: The blank maps present no SM data for this period

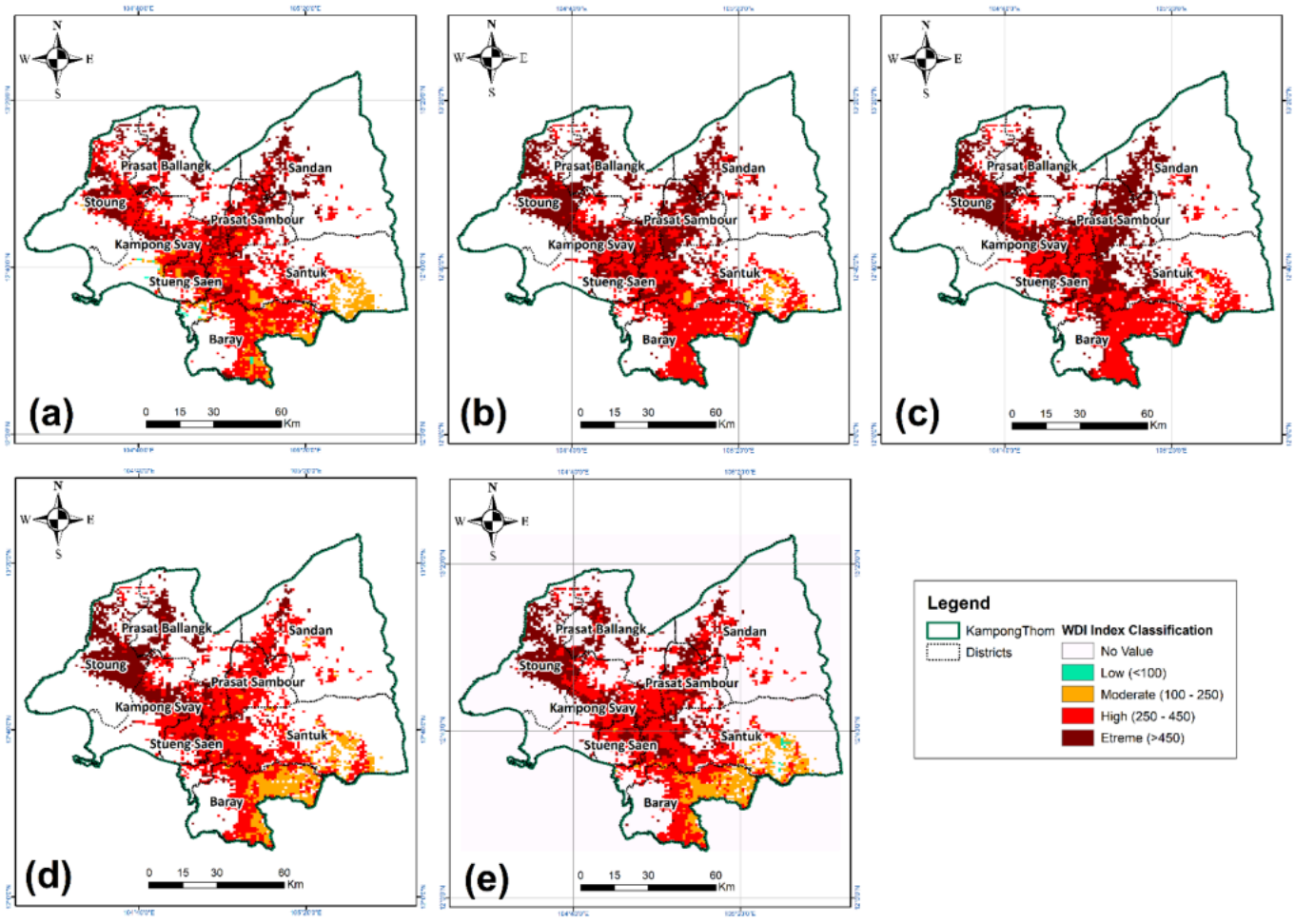

Figure A1.7. Monthly WDI map for the agricultural area from January to May 2020 (Kampong Thom, Cambodia)

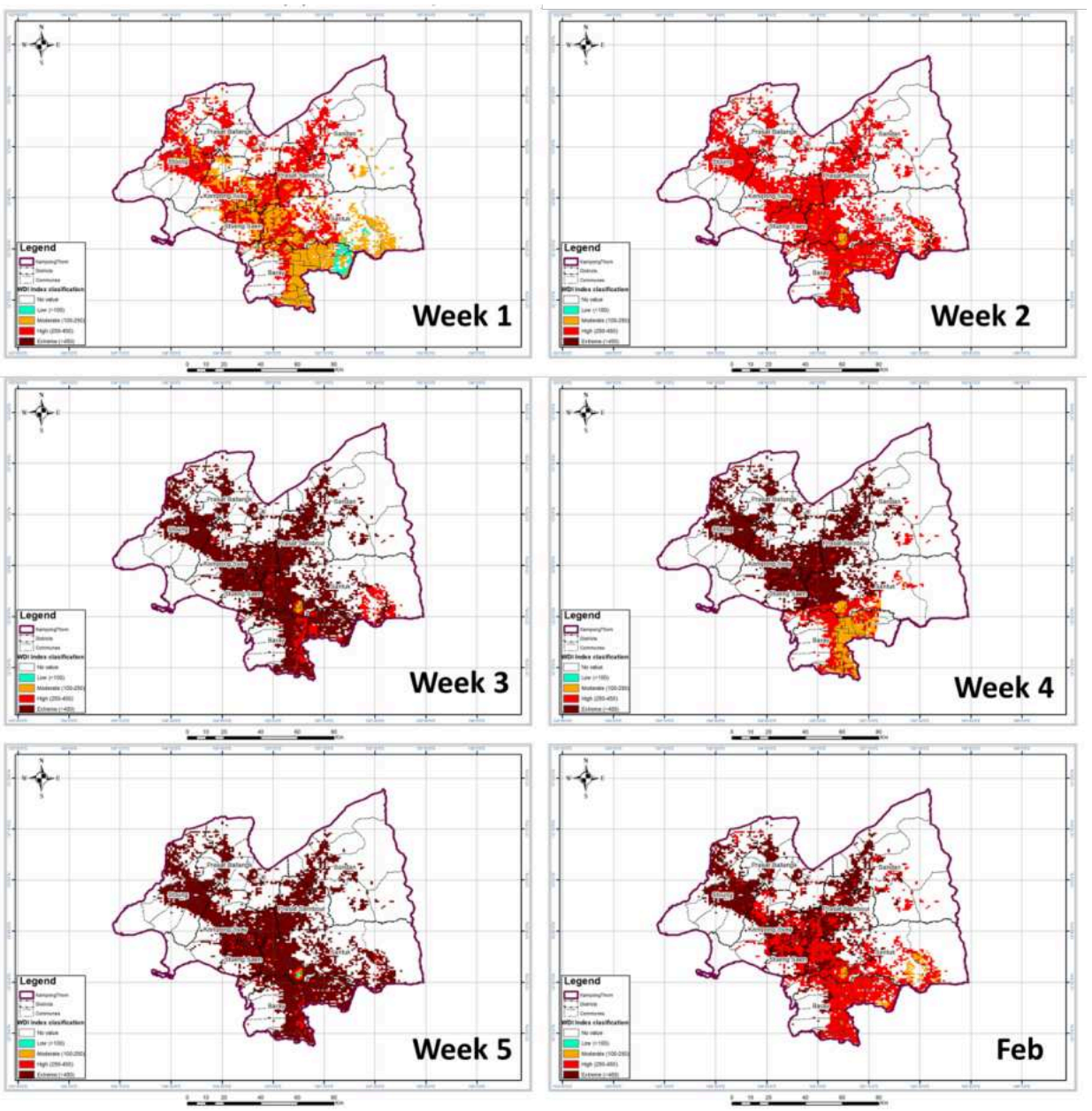

Figure A1.7. Monthly WDI map for the agricultural area in February 2020 (Kampong Thom, Cambodia)

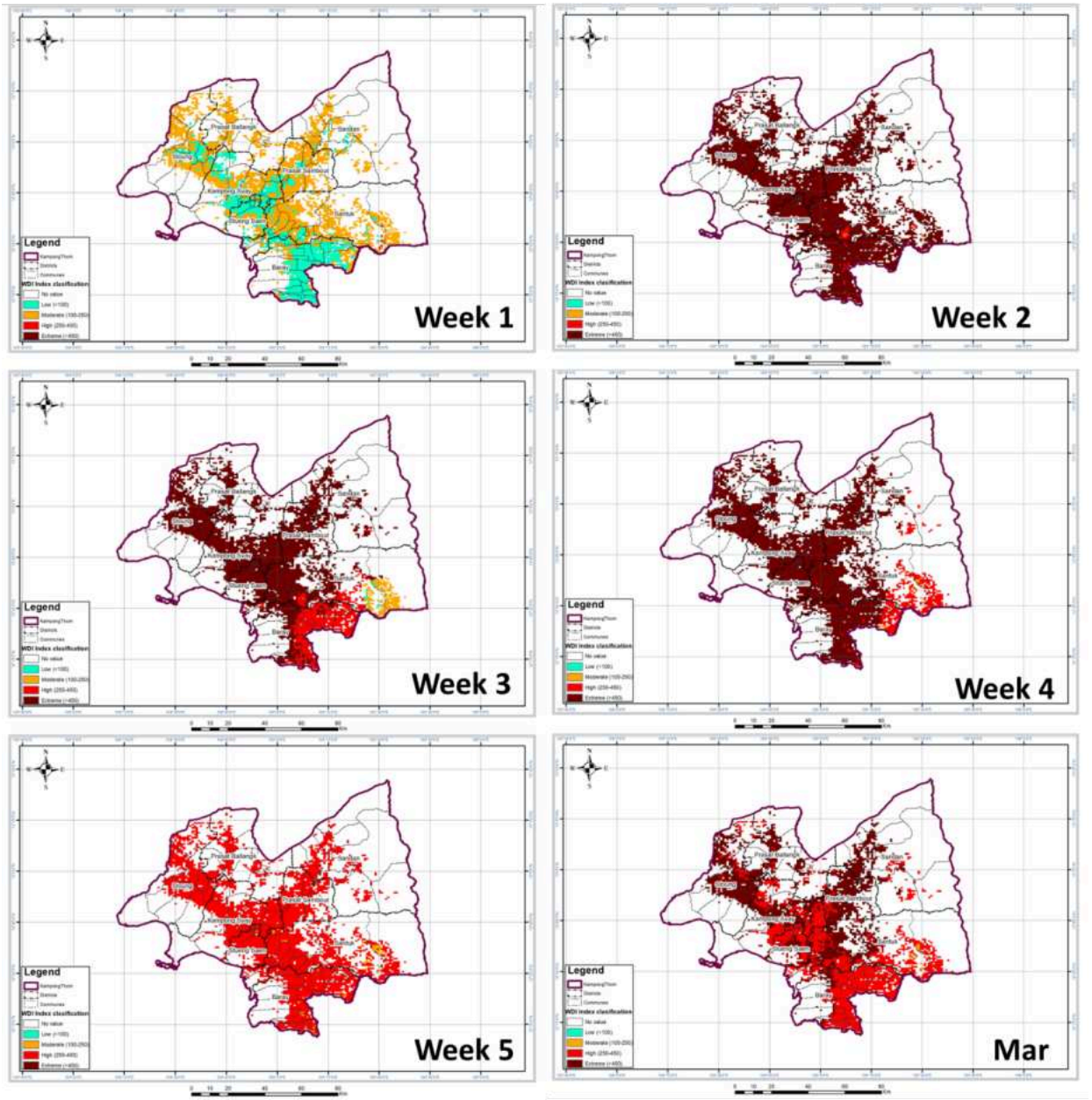

Figure A1.8. Monthly WDI map for the agricultural area in March 2020 (Kampong Thom, Cambodia)

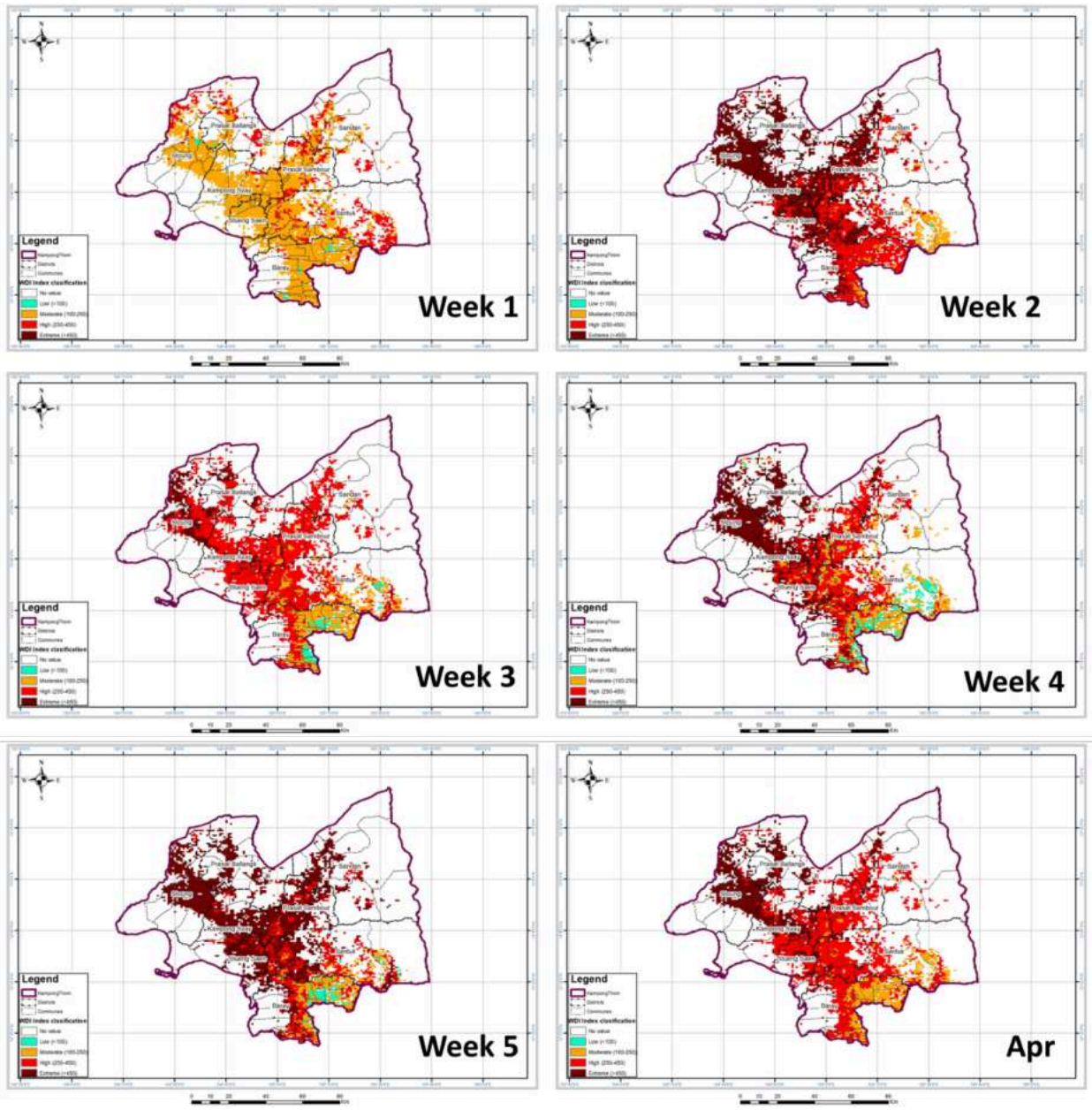

Figure A1.9. Monthly WDI map for the agricultural area in April 2020 (Kampong Thom, Cambodia)

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APPENDIX 2. SURVEY DATA AND REPORT

A2.1. Objectives

The fieldwork conducted in Ninh Thuan province (Vietnam) and Kampong Thom province (Cambodia) aims to achieve the overarching objective of evaluating the suitability and effectiveness of the Water Demand Index (WDI) maps for water resource management in the province. To support this goal, the specific objectives are as follows:

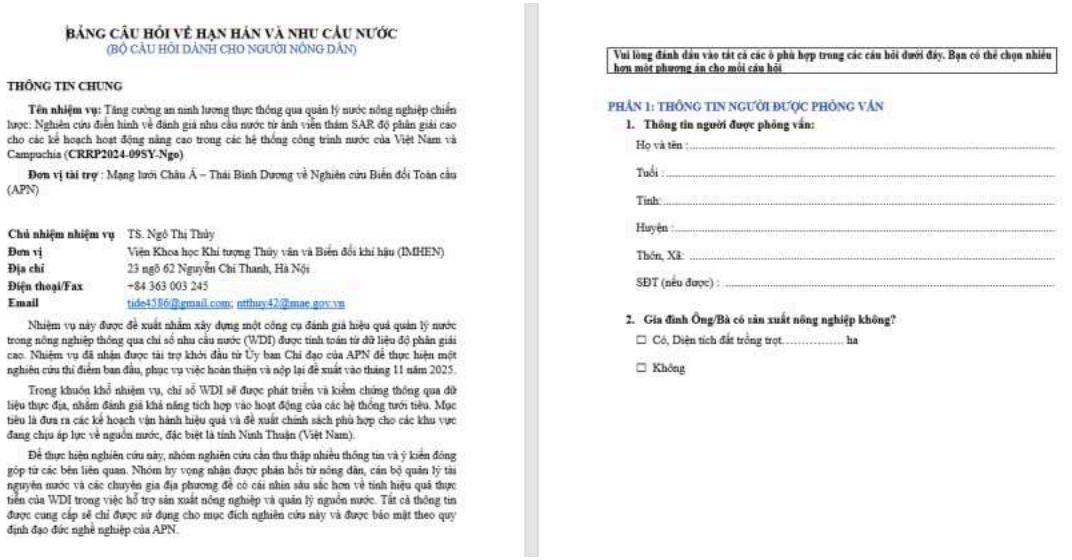
- To assess the current status of water demand, water use, and water scarcity in agricultural crop production in Ninh Thuan province (Vietnam) and Kampong Thom province (Cambodia).
- To evaluate the effectiveness of the 2020 WDI map set in reflecting the spatial and temporal patterns of agricultural water demand in the province

A2.2. Questionnaire for Manager and Farmer

The questionnaires used in this project were developed separately for managers and farmers, and were translated into Vietnamese and Khmer to ensure clear communication with local respondents in Vietnam and Cambodia. Two structured questionnaires, which were specifically designed to assess perceptions of drought, irrigation practices, and the practical use of the Water Demand Index (WDI) maps, were employed to collect both quantitative and qualitative data. Each questionnaire consists of five main sections, covering respondent information, crop characteristics, drought and water shortage conditions, irrigation system operations, and evaluation of the 2020 WDI map, so that comparisons between the two groups could be made. Each form included about 18–20 questions in mixed formats combining multiple-choice, rating-scale, and open-ended items in order to collect both measurable responses and contextual insights. This structure ensured consistency in analysis while reflecting the distinct roles and experiences of managers and farmers in agricultural water management.

Question part	For Manager	For Farmer
Part 1 – Respondent Information	Collects personal details, position, organisation, and management area	Collects basic information such as name, age, location, and cultivated land area.
Part 2 – Crop Characteristics	Identifies main crops grown in the managed area and their growing seasons.	Identifies key crops grown by the household and the cultivation calendar.
Part 3 – Drought and Water Shortage Conditions	Assesses drought severity, duration, and the most affected areas; records water shortage status in 2020.	Gathers information on drought impacts, crop damage, and the level of water shortage in 2020.
Part 4 – Irrigation System Operations	Examines irrigation management practices, monitoring frequency, and data sources (e.g., weather forecasts, water levels, local reports).	Identifies main water sources, types of irrigation systems, water sufficiency, and decision-making criteria for irrigation.

Part 5 – Evaluation of the WDI Map (2020)	Evaluates map readability, accuracy, and usefulness for water allocation, irrigation planning, and drought warnings.	Evaluates map readability, accuracy, and usefulness for farming decisions, crop adjustment, and drought loss reduction.



BẢNG CÂU HỎI VỀ HẠN HÁN VÀ NHU CẦU NƯỚC
(BỘ CÂU HỎI DÀNH CHO NGƯỜI NÔNG DÂN)

THÔNG TIN CHUNG

Tên nhiệm vụ: Tăng cường an ninh lương thực thông qua quản lý nước nông nghiệp chiến lược: Nghiên cứu điển hình về đánh giá nhu cầu nước từ ảnh viễn thám SAR độ phân giải cao cho các kế hoạch hoạt động nâng cao trong các hệ thống công trình nước của Việt Nam và Campuchia (**CRRP2024-09SY-Ngo**)

Đơn vị tài trợ: Mạng lưới Châu Á – Thái Bình Dương về Nghiên cứu Biến đổi Toàn cầu (APN)

Chủ nhiệm nhiệm vụ	TS. Ngô Thị Thúy
Đơn vị	Viện Khoa học Khí tượng Thủy văn và Biến đổi khí hậu (IMHEN)
Địa chỉ	23 ngõ 62 Nguyễn Chí Thanh, Hà Nội
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Nhiệm vụ này được đề xuất nhằm xây dựng một công cụ đánh giá hiệu quả quản lý nước trong nông nghiệp thông qua chỉ số nhu cầu nước (WDI) được tính toán từ dữ liệu độ phân giải cao. Nhiệm vụ đã nhận được tài trợ khởi đầu từ Ủy ban Chỉ đạo của APN để thực hiện một nghiên cứu thí điểm ban đầu, phục vụ việc hoàn thiện và nộp lại đề xuất vào tháng 11 năm 2025.

Trong khuôn khổ nhiệm vụ, chỉ số WDI sẽ được phát triển và kiểm chứng thông qua dữ liệu thực địa, nhằm đánh giá khả năng tích hợp vào hoạt động của các hệ thống tưới tiêu. Mục tiêu là đưa ra các kế hoạch vận hành hiệu quả và đề xuất chính sách phù hợp cho các khu vực đang chịu áp lực về nguồn nước, đặc biệt là tỉnh Ninh Thuận (Việt Nam).

Để thực hiện nghiên cứu này, nhóm nghiên cứu cần thu thập nhiều thông tin và ý kiến đóng góp từ các bên liên quan. Nhóm hy vọng nhận được phản hồi từ nông dân, cán bộ quản lý tài nguyên nước và các chuyên gia địa phương để có cái nhìn sâu sắc hơn về tính hiệu quả thực tiễn của WDI trong việc hỗ trợ sản xuất nông nghiệp và quản lý nguồn nước. Tất cả thông tin được cung cấp sẽ chỉ được sử dụng cho mục đích nghiên cứu này và được bảo mật theo quy định đạo đức nghề nghiệp của APN.

Vui lòng đánh dấu vào tất cả các ô phù hợp trong các câu hỏi dưới đây. Bạn có thể chọn nhiều hơn một phương án cho mỗi câu hỏi

PHẦN 1: THÔNG TIN NGƯỜI ĐƯỢC PHỎNG VẤN

1. **Thông tin người được phỏng vấn:**

Họ và tên : .....

Tuổi : .....

Tỉnh: .....

Huyện : .....

Thôn, Xã: .....

SĐT (nếu được) : .....

2. **Gia đình Ông/Bà có sản xuất nông nghiệp không?**

☐ Có, Diện tích đất trồng trọt..... ha

☐ Không

Figure A2. 1. Questionnaires for farmers (in Vietnamese)

ផ្នែកទី៤៖ ប្រតិបត្តិការប្រព័ន្ធជលសាស្ត្រ៖ សម្រាប់អ្នកគ្រប់គ្រង / PART 4: IRRIGATION SYSTEM OPERATIONS – FOR MANAGERS

7. **ស្ថាប័ន / Organization:**

☐ ស្ថានីយជលសាស្ត្រ / Irrigation station ☐ ភ្នាក់ងារសហប្រតិបត្តិការ / Cooperative ☐ គណៈកម្មាធិការឃុំ / Commune People's Committee

☐ ការិយាល័យប្រតិបត្តិកសិកម្មស្រុក / District Agriculture Office ☐ ផ្សេងៗ / Other: .....

8. **តើអ្នកបានធ្វើការគ្រប់គ្រង និងត្រួតពិនិត្យប្រព័ន្ធជលសាស្ត្រញឹកញាប់ដែរឬទេ? Do you regularly monitor and manage irrigation systems?**

☐ បាទ/ចាស ទៀងទាត់ Yes, regularly ☐ បាទ/ចាស ប៉ុន្តែមិនស្ថិរទៀងទាត់ទេ Yes, but not consistently

☐ ទេ No

9. **តើនៅក្នុងតំបន់របស់អ្នកធ្លាប់ជួបប្រទះនឹងការខ្វះខាតទឹកនៅក្នុងប្រព័ន្ធជលសាស្ត្រដែរឬទេ នៅឆ្នាំ២០២០? Did your area experience irrigation water shortage in 2020?**

☐ ទេ មិនខ្វះខាតទេ No shortage ☐ បាទ ចាស តិចតួច Yes – mild ☐ បាទ ចាស មធ្យម Yes – moderate ☐ បាទ ចាស ធ្ងន់ធ្ងរ Yes – severe

10. **តើទីតាំងណាខ្លះដែលងាយរងផលប៉ះពាល់ខ្លាំងជាងគេ និងញឹកញាប់បំផុតដោយគ្រោះកំងួតស្ងួត? Which locations are most severely and frequently affected by drought?**
(សូមបញ្ជាក់ឈ្មោះឃុំ ឬភូមិ / Please list commune or village names)

.....

.....

.....

11. **តើជាធម្មតាអ្នកពឹងផ្អែកលើអ្វី ដើម្បីគ្រប់គ្រងប្រព័ន្ធជលសាស្ត្រ? What do you usually rely on to manage irrigation?** *(រុញជំរើសចម្លើយបានច្រើនបំផុត ០២ ឬតិចជាង ២ / Select up to 2 options)*

☐ កម្រិតទឹកនៅក្នុងអាងស្តុកទឹក / ប្រឡាយក្បាល Water level in reservoirs/head canals

☐ ការព្យាករណ៍ធាតុនិយម / Meteorological forecasts

☐ សំណូមពរពីប្រជាពលរដ្ឋក្នុងតំបន់ / Requests from local people

☐ បទពិសោធន៍ពីឆ្នាំមុន / Experience from previous years

☐ ទិន្នន័យពីស្ថានីយ៍ត្រួតពិនិត្យ / Data from monitoring stations

☐ ផ្សេងៗ / Other: _____

4

ផ្នែកទី៥៖ ការវាយតម្លៃតាមរយៈផែនទីសន្ទស្សន៍នៃតម្រូវការទឹក (WDI) សម្រាប់ស្ថានភាពគ្រោះកំងួតក្នុងឆ្នាំ២០២០ / PART 5: EVALUATION OF THE WDI MAP FOR A TYPICAL DROUGHT YEAR (2020)

(សូមផ្តល់សន្លឹកផែនទី ឬជាប្រភាពឌីជីថល នៃ WDI ដល់អ្នកឆ្លើយដើម្បីអ្នកឆ្លើយថ្នាក់ / Provide printed or digital WDI map for the respondent to view)

12. **តើផែនទីសន្ទស្សន៍នៃតម្រូវការទឹកនេះងាយស្រួលមើល និងងាយយល់ដែរឬទេ? Is the WDI map easy to read and understand?**

☐ ងាយស្រួលខ្លាំងណាស់ / Very easy ☐ ងាយស្រួល / Quite easy ☐ ធម្មតា / Average ☐ តិចាក / Difficult ☐ តិចាកនឹងងាយយល់ / Very difficult

13. **តើផែនទី WDI នេះបានឆ្លុះបញ្ចាំងពីកម្រិតកង្វះទឹកនៅក្នុងតំបន់កសិកម្មរបស់អ្នកដែរឬទេ នៅក្នុងឆ្នាំ២០២០? Does the WDI map accurately reflect the water shortage level in your farming area for 2020?**

☐ តិចជាឆ្លុះបញ្ចាំងបានល្អឥតខ្ចោះ / Very accurate ☐ តិចជាឆ្លុះបញ្ចាំងបានល្អណាស់ / Quite accurate ☐ មិនប្រាកដ / Not sure ☐ មិនឆ្លុះបញ្ចាំងទេ / Inaccurate ☐ មិនឆ្លុះបញ្ចាំងទាល់តែសោះ / Completely inaccurate

14. **បើធ្វើការប្រៀបធៀបទៅនឹងលក្ខខណ្ឌជាក់ស្តែង ថាតើទិដ្ឋភាពនានានៃគ្រោះកំងួតស្ងួត ត្រូវបានឆ្លុះបញ្ចាំងយ៉ាងត្រឹមត្រូវ ដែរឬទេ នៅក្នុងផែនទី WDI នេះ? Compared to actual conditions, what aspects of the drought did the WDI map reflect correctly?**

☐ ពេលវេលាគ្រោះកំងួតស្ងួត / Timing of drought ☐ កម្រិតនៃភាពធ្ងន់ធ្ងរ / Severity level ☐ ទីតាំងនៃការខ្វះខាតទឹក / Location of water shortage ☐ មិនមាន / None

15. **តើវាមានភាពខុសគ្នាអ្វីខ្លះ (ប្រសិនបើមាន) ដែលអ្នកបានធ្វើការកត់សម្គាល់រវាងផែនទី WDI និងលក្ខខណ្ឌជាក់ស្តែង? What differences (if any) did you notice between the WDI map and actual conditions?**

☐ ផែនទីបង្ហាញពីកង្វះខាត ប៉ុន្តែមានទឹកគ្រប់គ្រាន់នៅក្នុងតំបន់ / Map indicated shortage, but there was enough water, in the area .....

☐ ផែនទីបង្ហាញទឹកគ្រប់គ្រាន់ ប៉ុន្តែគ្រោះកំងួតស្ងួតបានកើតឡើងនៅក្នុងតំបន់ / Map showed sufficient water, but drought occurred, in the area .....

☐ ភាពខុសគ្នាតិចតួច មិនសំខាន់ / Minor discrepancies, not significant

☐ គ្មានយោបល់ទេ / No opinion

5

Figure A2. 2. Questionnaires for manager (in English and Khmer)

A2.3. Field trip results in Ninh Thuan province (now belongs to Khanh Hoa province)– Vietnam

Within the framework of the project, a research team from the Institute of Meteorology, Hydrology and Climate Change conducted a field trip to Ninh Thuan Province to evaluate the suitability and effectiveness of the Water Demand Index (WDI) map, as well as the feasibility of applying this index in local water resource management.

The team conducted surveys to collect information and data through interviews and questionnaires targeting two main groups: (1) management staff at specialized agencies (Department of Agriculture and Environment, Hydrometeorological Station, District People's Committee), and (2) local farmers. Overall, the WDI maps were found to effectively reflect the spatial and temporal status and trends of water demand. However, adjustments are needed in areas where irrigation water is supplied by irrigation systems rather than rain-fed sources. The WDI maps were also considered user-friendly and potentially suitable for further development and integration into tools supporting provincial water resource management.

A2.3.1. Scope and methodology

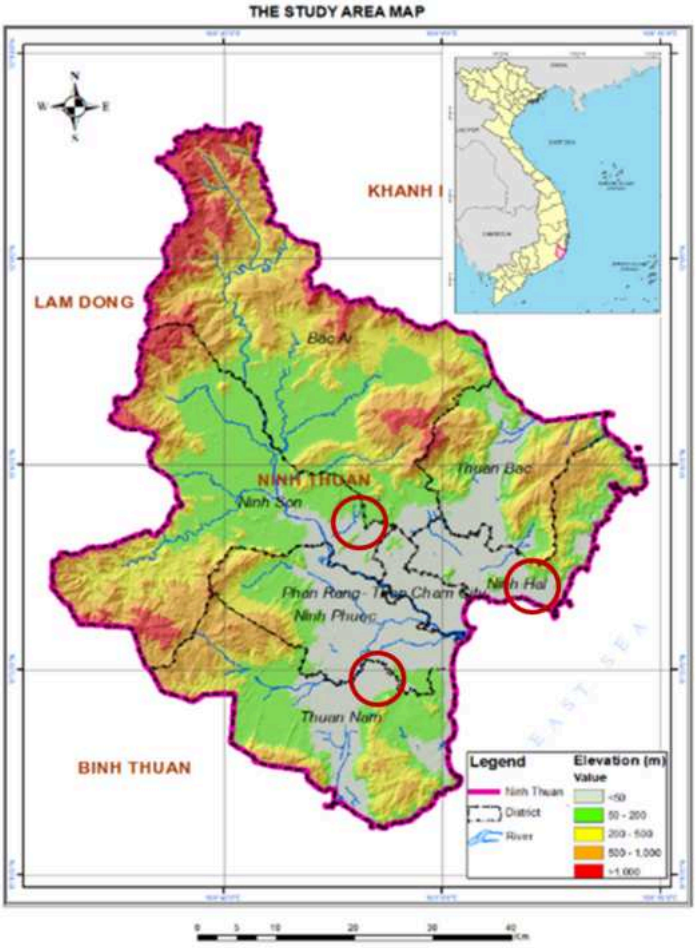


Figure A2. 3. Selected fields for survey in Ninh Thuan (Vietnam)

- Location: Ninh Son, Thuan Nam and Ninh Hai districts, Ninh Thuan Province (now belongs to Khanh Hoa province) -
- Period: 11/6 – 13/6/2025
- Field team members:
    - Trinh Duc Tran - RMIT University Vietnam
    - Thuy Thi Vu – The Vietnam Institute of Meteorology, Hydrolog,y and Climate Change
    - Trung Tuan Luong - The Vietnam Institute of Meteorology, Hydrolog,y and Climate Change
- Materials:
    - WDI maps at 1km resolution were established for Ninh Thuan province in 2020.
    - Questionnaires for managers and farmers.

A2.3.2. Plans of field survey

Date	**Activities**	**Location**	Respondent
11/6/2025	Interview staff of Hydo-meteorological Station of Ninh Thuan	Hydo- meteorological Station of Ninh Thuan	Bui Van Tho – Deputy Director
	Interview staffs of Water resources management division – Department of Agriculture and Environment	Department of Agriculture and Environment	Tran Ngoc Vu – Specialist
	Interview staffs of Irrigation Management One Member Limited Liability Company	Irrigation Management One Member Limited Liability Company (IMC)	Luu Anh Tuan – Director
12/6/2025	Do a field survey in My Son commune (Ninh Son district)	My Son Commune People's Committee	Pham Duc Hanh – Irrigation Officer; Nguyen Thi Hien – Farmer
	Do a field survey in Nhon Son commune (Ninh Son district)	Nhon Son Commune People's Committee	Nguyen Thi Loan – Farmer; Nguyen Dinh Chi – Farmer
	Do a field survey in Phuoc Nam commune (Thuan Nam district)	Thuan Nam Irrigation Station	Dong Sy Thai – Irrigation Officer
	Do field survey in Phuoc Ninh commune (Thuan Nam district)	Vu Bon Hamlet, Phuoc Ninh Commune, Thuan Nam District	Thien Ngoc Phung – Agricultural Officer
13/6/2025	Do field survey in Nhon Hai commune (Ninh Hai district)	My Son Commune People's Committee, Ninh Son District	Le Van Phi – Irrigation Officer

A2.3.3. Field survey results

- Number of interview questionnaires:
    - From manager: 07
    - From famers: 15

- The ease of understanding and reading of the map: the majority of interviewees said that the map is easily understand

Answer	Number of answers		Note
	Manager	Farmer	
Very easy	0	0	
Easy	4	2	
Moderate	3	3	
Difficult	0	4	
Very difficult	0	3	
No idea	0	3	

- Accuracy of the WDI for the drought 2020:

Answer	Number of answers		Note
	Manager	Farmer	
Very accurate	0		
Quite accurate	4	5	
Not sure	0	7	Because they cannot define where they are in the maps
Inaccurate	0	0	
Completely inaccurate	0	0	
No idea	3	0	

- The aspects WDI present the actual situation:

Answer	Number of answers		Note
	Manager	Farmer	
Timing of drought	4	6	
Severity level	0	3	
Location of water shortage	2	1	
None	0	0	
No idea	1	5	

- Differences between the WDI map and actual conditions

Answer	Number of answers		Note
	Manager	Farmer	
The map indicated shortage, but there was enough water	2	6	Thuan Nam District The area having an irrigation system (IMC)
The map showed sufficient water, but drought occurred	0	0	
Minor discrepancies, not significant	2	4	

No idea	3	5	

- Improvement if WDI is available in 2020:

Answer	Number of answers		Note
	Manager	Farmer	
Irrigation planning	2	5	
Timely crop switching	0	1	
Drought warnings	2	4	Hydrometeorological Station, My Son Commune, Ninh Son District
Water allocation	1	0	Water Resources Management Division – Department of Natural Resources and Environment
Crop loss reduction	1	2	
Not sure	1	1	
No idea	0	2	

Based on the interview results, it can be seen that the majority of respondents believe that the WDI maps are quite easy to understand and read. The WDI maps reflect the water shortage situation quite closely. In particular, the maps reflect the time and area where water shortage occurs. However, there are still some differences compared to reality: there are some areas that the map assesses as lacking water, but in reality, there is enough water because it is concentrated in areas irrigated by irrigation systems. Regarding the impact of the WDI index: it can support drought work and irrigation planning, crop conversion.

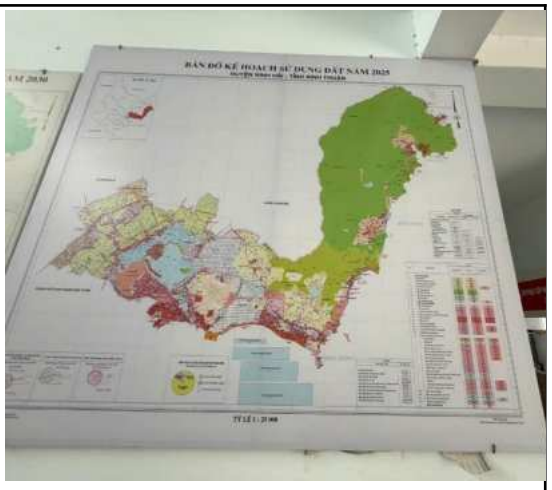
Some photos from the field survey process:

At Ninh Thuan Meteohydrological Station

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td colspan="2">Irrigation Management One Member Limited Liability Company</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Officer interview - My Son Commune People’s Committee</td><td>Farmer interview - My Son Commune</td></tr>
</table>


Farmer interview - Nhon Son Commune


Thuan Nam irrigation station



Nhon Hai Commune People's Committee- Nhon Hai District

Rice field in My Son Commune, Ninh Son District

Rice field in Phuoc Nam Commune, Thuan Nam District

A2.4. Field trip results in Kampong Thom province (Cambodia)

The selected field trip of the Chong Dong Commune, Baray District, Kompong Thom province, Cambodia, took five days, from August 1 to 5, 2025. During that time, all significant and necessary data and information were collected based on the WDI map in 2020. The semi-structured questionnaire serves as a tool for both key stakeholder levels, including managers and farmers, to observe various trends and behaviours within the study area. The results were analysed to draw important conclusions and inform future projects.

A2.4.1. Scope and methodology

Location: Baray District, Kampong Thom Province, Cambodia

Period: 1-5 August 2025

Field Team Member:

- KHEM Sothea - Advisor of the Ministry of Water Resources and Meteorology
- SOVANN Chansopheaktra - Royal University of Phnom Penh
- KAO Chanbora - Ministry of Water Resources and Meteorology

Materials:

- WDI maps at a 1 km resolution were established for Kampong Thom province in 2020.
- Questionnaires for managers and farmers.

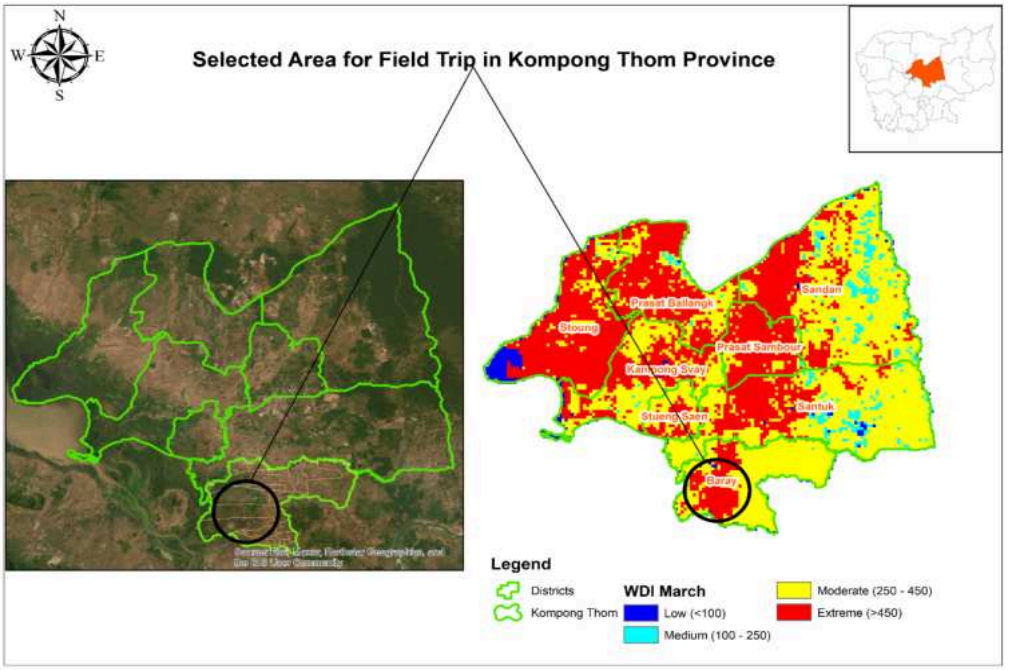


Figure A2. 4. Selected fields for survey in the Kampong Thom (Cambodia)

A2.4.2. Plans of field survey

Date	Activities	Location	Respondent
01/08/25	Interview Chief of Agriculture and Irrigation office	PDORAM	Mr. Yan Vanny
	Interview with the Vice of Agriculture and Irrigation office	PDORAM	Mr. Hong Sivheang
02/08/25	Interview with the Vice of Agriculture and Irrigation office	PDORAM	Mr. Chan Sopharoth
	Interview with a Representative of Yakumo E&C Co., Ltd.	Rice field demonstration site in Baray District	Mr. Rum Pheara
	Interview with Commune Council	Chong Dong Commune Hall	Mr. Sek Chamroeun
	Interview with Commune Council	Chong Dong Commune Hall	Mr. Yim Sareth
03/08/25	Interview Commune Clerk	Chong Dong Commune Hall	Mr. Teav Vy
	Interview Deputy head of Kou village	Chong Dong Commune Hall	Mr. Hanh Soeun

	Interview Samrong Village Head	Chong Dong Commune Hall	Mrs. Mao Phach
	Interview Chong Dong Village Head	Chong Dong Commune Hall	Mrs. San Heang
04/08/25	Interview Kshach La'et Village Head	Chong Dong Commune Hall	Mrs. Phum Phorn
	Interview with the Tuol Damnak village head	Chong Dong Commune Hall	Mr. Seu Nhor
	Interview Head of Norng San FWUG	Chong Dong Commune Hall	Mr. Khin Hin
	Interview Deputy Head of Chong Dong Village	Chong Dong village	Mr. Pech Chin
05/08/25	Interview with a Village Member of Tuol Damnak village	Tuol Damnak Village	Mr. Suos Kean
	Interview with the Tuol Damnak village head	Tuol Damnak Village *(The village head asked to observe his village)*	Mr. Seu Nhor
	Conducted FGD with Farmers in Chong Dong Village	Chong Dong village	14 farmers in Chong Dong village

A2.4.3. Field survey results

T**otal interview questionnaires:** 29
Managers: 15 (M: 12, F: 3)
Farmers (FGD): 14 (M: 8, F: 6)

Location: 80% respondents from Baray (mainly Chong Dong commune – drought-prone area)
Private sector: 7% of respondents
Rice monoculture: 73% practice single rice cropping with fixed seasonal schedules (Oct–Nov planting, drought Feb–Mar), showing limited diversification and high vulnerability.
Severe droughts: 90% reported frequent droughts (peak: Feb–Mar) affecting rice's late growth stage.

WDI 2020 evaluation: Most participants found the map easy to read and understand.

Answer	Number of Answer		Notes
	Manager	Farmer	
Very easy	0	0	
Quite easy	15	5	
Average	0	9	

Difficult	0	0	
Very difficult	0	0	

Accuracy of the WDI for the 2020 drought:

Answer	**Number of answers**		**Note**
	Manager	Farmer	
Very accurate	0	0	
Quite accurate	15	3	
Not sure	0	10	
Inaccurate	0	0	
Completely inaccurate	0	0	
No idea	0	1	

The aspects of WDI present the actual situation:

Answer	Number of answers		Note
	Manager	Farmer	
Timing of drought	1	0	
Severity level	5	6	
Location of water shortage	9	8	
None	0	0	
No idea	0	0	

Differences between the WDI map and actual conditions

Answer	Number of answers		Note
	Manager	Farmer	
Map indicated shortage, but there was enough water	0	0	
Map showed sufficient water, but drought occurred	0	0	
Minor discrepancies, not significant	15	5	
No idea	0	9	

Improvement if WDI is available in 2020:

Answer	Number of answers		Note
	Manager	Farmer	
Irrigation planning	0	0	
Timely crop switching	3	0	
Drought warnings	3	5	
Water allocation	8	6	
Crop loss reduction	1	3	
Not sure	0	0	
No idea	0	0	

According to the table above, the evaluation of the WDI in 2020 indicates that while managers generally found the tool accurate and user-friendly, many farmers expressed lower confidence and had limited awareness, particularly struggling with map interpretation. The WDI effectively identified locations of water shortages but was less successful in indicating drought timing and severity. Despite these limitations, the tool demonstrated reliability, with the system only having minor discrepancies and was recognised as highly beneficial for guiding water allocation, issuing drought warnings, and minimising crop losses. To enhance its effectiveness, simplified communication and farmer training are recommended.

WDI Map Utilisation: Water Demand Index (WDI) maps are a reliable but not very accurate tool for drought management, but they have a major actionability gap. 47% of respondents wanted more detailed information about water shortages in villages or fields, indicating a bias toward crisis management. Maps are useful for big-picture planning, but cannot help with tasks like drilling wells or moving crops. Stakeholders use maps to decide who receives water when it's scarce, but they don't want to switch crops very much (27%). Crop switching needs more than just access to maps; it's of low importance (27% of all issues). Allocating water (87% of the time) supports current power structures, while crop switching affords farmers more freedom. The produced WDI maps demonstrate their usability, with acceptable information and straightforward for most respondents. They are more useful for water management purposes, especially for the operation and planning of irrigation systems, especially as a reference driving the measurement and adaptation strategy for the heavily water-shortage period, February and March, before the harvesting period to ensure the possibility and productivity of crops.

The Water and Drought Index (WDI) application is used by 100% of irrigation officers for infrastructure planning, but only 58% of local authorities use it for planning purposes. 33% seek guidance on crop-switching. The maps are primarily used by hydraulic engineers, not farmers. The lack of agronomic guidance renders them irrelevant for 42% of local authorities. Proposed enhancements include overlaying crop-specific drought risk zones and collaborating with agro-dealers to connect map alerts to seed access.

Process of Decision Making: The pilot area's water decision-making process is characterised by a hybrid knowledge ecosystem, with 93% relying on reservoir/head canal levels and only 20% using meteorological forecasts. This reactive approach leaves communities vulnerable to predictable shortages. Local requests are highly incorporated, demonstrating effective social infrastructure. This methodology blends experiential knowledge with technical monitoring to create adaptive local solutions. However, meteorological data offers no lead time for prevention. Communities trust visible water levels over invisible forecasts, which may be inaccessible or irrelevant. To improve water management, forecasts should be translated into actionable village-level alerts and integrated into provincial water planning.

Yet, the drought calendar highlights the misalignment between current responses and climate change realities, leading to farmers rationing water after significant plant investments. The Water Demand Index (WDI) maps provide crucial information but arrive too late to guide informed crop choices. To address this, a timeline is proposed: release WDI maps with planting-risk ratings, activate crop-switching subsidies in high-risk zones, and enforce water allocation according to the maps. In September, the release of WDI maps triggered the deployment of district agronomists to high-risk villages; by January, these maps facilitated access to drought adaptation vouchers.

The WDI tool was found to be reliable and easy to use by managers, but less familiar to farmers. It effectively identified water shortage areas but was weaker on drought timing and severity. Used mainly by irrigation officers (100%) and local authorities (58%), the maps support water allocation (87%) more than crop switching (27%). Most users requested an earlier release and clearer guidance for local adaptation.

Strategic Road Map: The final phase of a strategic roadmap aims to address drought concerns in Kampong Thom by implementing a staged strategy roadmap. This involves implementing WDI maps, which provide essential drought forecasts, before planting decisions in October and November. This will help farmers make informed decisions, potentially ensuring entire harvests. The Provincial Government will require the publication of these maps before September, and consultant teams will collaborate with commune councils to develop hyper-local zoning for drought risk. By January, these maps will enable access to drought adaptation vouchers for high-risk communities.

Unasked feedback from stakeholders reveals three requirements for transforming WDI maps from informational tools into drivers for systemic resilience. The requirement to "produce maps on time for 2026" (Irrigation Officer) clearly indicates that late data increases people's vulnerability. Since planting choices can't be changed after October or November, getting maps in September is more of a necessity than an option. This shows that timeliness is a matter of justice: farmers who aren't allowed to receive or be informed of WDI early take on risks that could have been avoided. Requests from the business sector to "add hydrological data" show a serious lack of knowledge about groundwater. The maps we have now only show surface water (reservoirs and canals), not aquifers that keep towns alive during droughts. By adding well-level data to maps, they would go from showing where resources are scarce to showing where they are running out, which would allow for focused actions like recharging aquifers. The statement that "the local authority needs this map" (Commune Council) changes the way we think about WDI maps as tools for running the government. Maps aren't just data products; they're also tools that give authority, legitimacy and make it clear how water is distributed during emergencies. Their absence forces people to make impromptu, often unfair, decisions. All of these requests show a big change in what people expect to get out of life.

Some photos from the field survey process:




The discussion with PDMRAM (irrigation and agriculture office) prolongs 3 sessions.


The discussion with representative of Yakumo E&C Co., Ltd.

	
Commune council	Commune council
	
Commune council	Commune clerk
	
Kou Village head	Samrong Village head

	
Chong Dong village head	Kshach Laet village head
	
Tuol Damnak village head	Norng San FWUG Head
	
Deputy head of chong dong village	Tuol Damnak village member

	
Tuol Damnak_site visit with Village head	Chong Dong FGD
	
Ricefield_pilot site	Ricefield_pilot site
	
Rice field_pilot site	Rice field_pilot site

Road to the Rice field

APPENDIX 3 GROUP MEETINGS

1. Kick-off meeting

Time: 6th December 2024

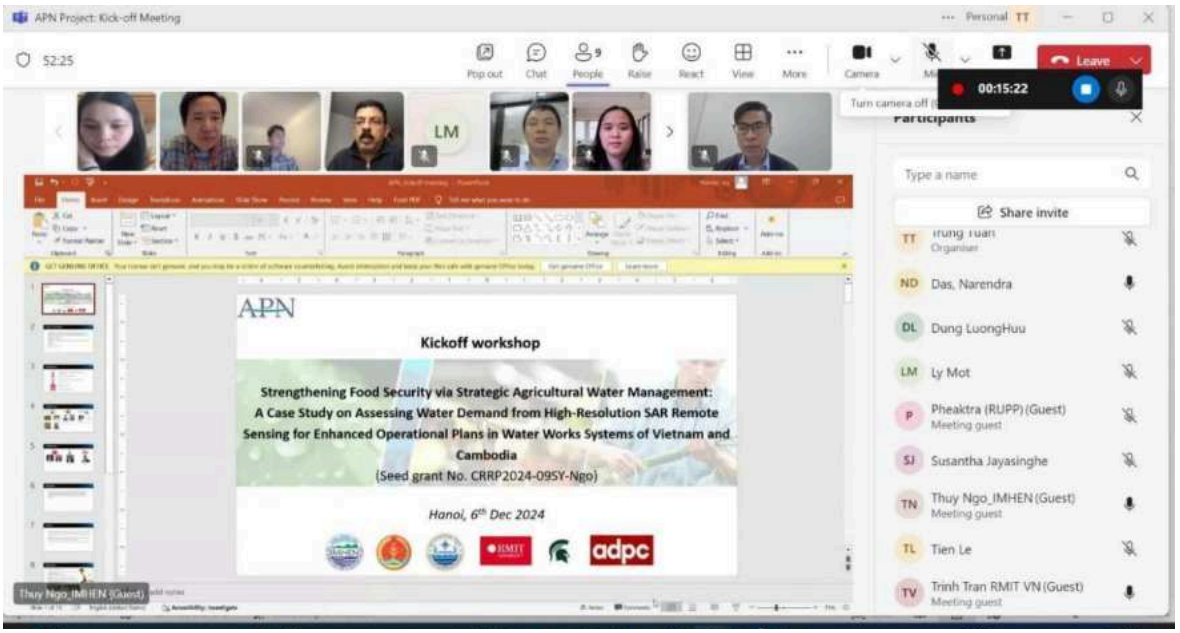
Place: Online via Google meet

Objectives: Launch the project, introduce project members and orient upcoming activities

Participants:

Institutions	Name	Role
IMHEN (The Vietnam Institute of Meteorology, Hydrology and Climate Change)	**Thuy Thi Ngo**	Proponent
	Dung Huu Luong	Collaborators
	Trung Tuan Luong	Collaborators
	Thuy Thi Vu	Collaborators
RUPP (Royal University of Phnom Penh)	Sovann Chansopheaktra	Collaborators
	Mot Ly	Collaborators
MOWRAM (Ministry of Water Resources and Meteorology)	Sothea Khem	Collaborators
	Kao Chanbora	Collaborators
RMIT (RMIT University)	Trinh Duc Tran	Collaborators
	Tien Le	Collaborators
MSU (Michigan State University)	Narendra N. Das	Collaborators
ADPC (Asian Disaster Preparedness Center)	Susantha Jayasinghe	Collaborators

Photos




APN Project: Kick-off Meeting
Personal TT
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Chat
People
Raise
React
View
More
Camera
Leave
00:03:43
Trung Tuan
Thuy Ngo_IMHEN (Guest)
Das, Narendra
LM
ly Mot
TV
Trinh Tran RMIT VN (Guest)
Pheaktra (RUPP) (Guest)
DL
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Tien Le
22°C
Mostly cloudy
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ENG
US
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06/12/2024

2. 1st Technical meeting

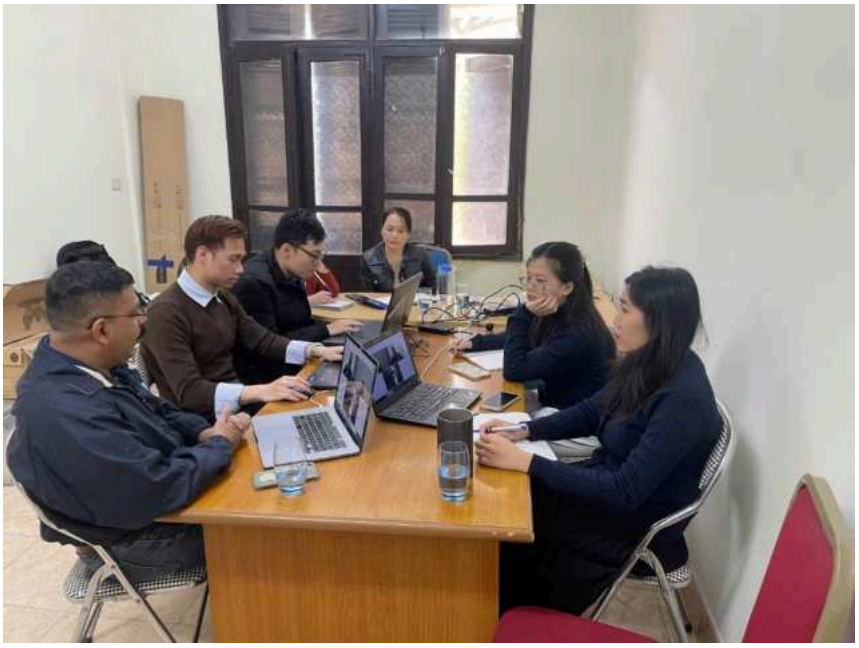
Time: 20th December 2024

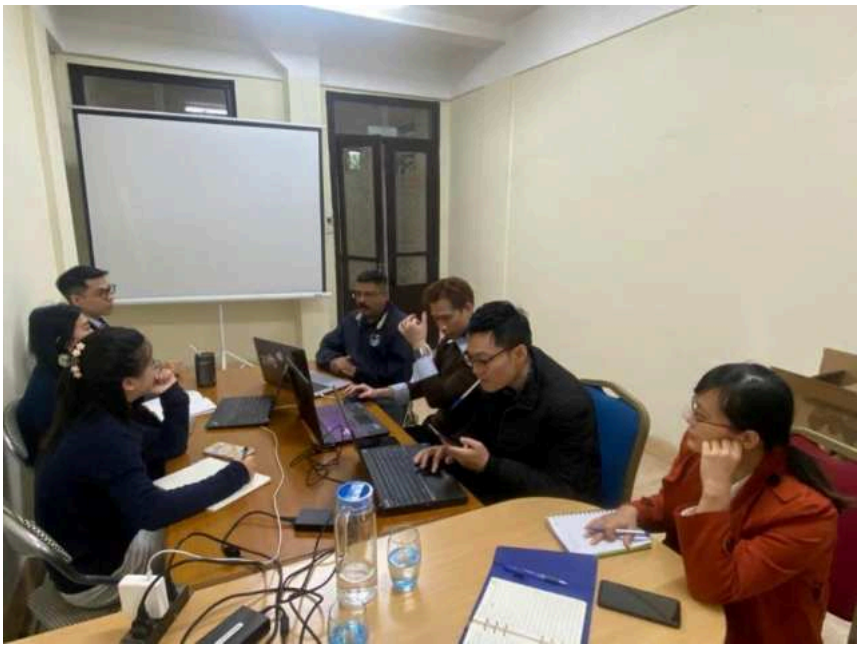
Place: at IMHEN and online

Objectives: Introduce the WDI and calculation methods and mapping

Participants: Dr. Das, IMHEN and RUPP members

Photos





3. 2nd Technical meeting

Time: 12th May 2025

Place: at IMHEN and online

Objectives:

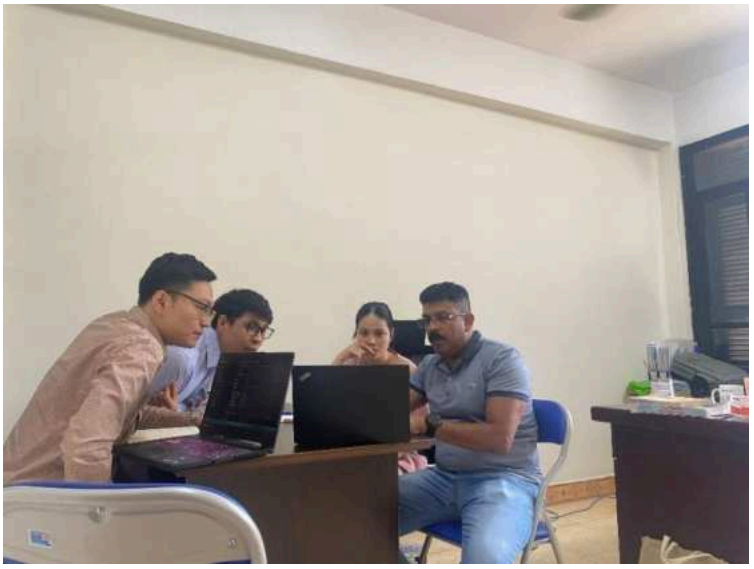
- Decide the download link of data

- Understand the WDI codes

- Discuss how to run the Matlab code to conduct WDI maps for case studies and for a month (loops)

Participants: Dr. Das and IMHEN members

Photos



4. **3rd Technical meeting**

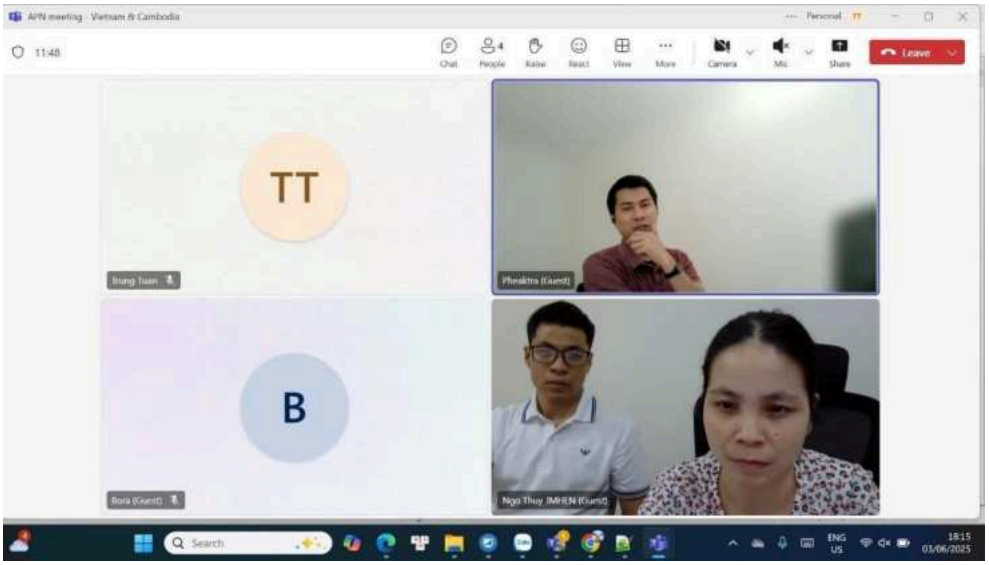
Time: 3rd June 2025

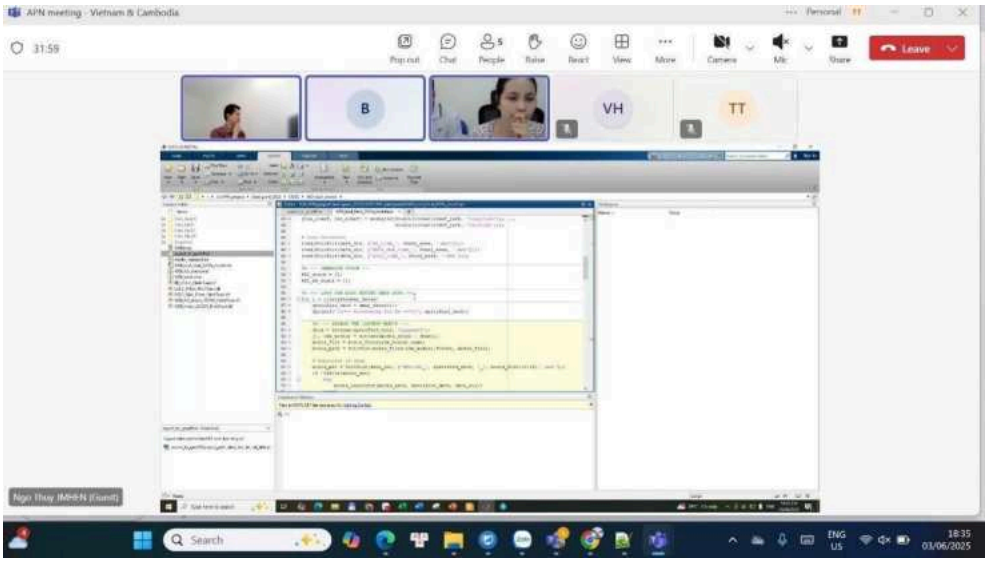
Place: Online

Objectives: Smoothly running the WDI codes and solve technical issues

Participants: IMHEN and RUPP members

Photos:





5.

APPENDIX 4 FINAL WORKSHOP

Date and time: 12th September 2025

Venue: The Vietnam Institute of Meteorology, Hydrology and Climate Change, 23 Lane 62 Nguyen Chi Thanh street, Hanoi

Objectives: To collect feedback on the water demand index (WDI) maps at pilot cases to assess its ability to integrate with irrigation system operations, ultimately yielding valuable operational plans and policy recommendations for regions facing with water stress, particularly in Ninh Thuan (Vietnam) and Kampong Thom (Cambodia).

Participants:

- All members of the CRRP2024-09SY-Ngo project (online and offline)
- Interested researchers from Vietnamese institutions (offline):
  - The Vietnam Institute of Meteorology Hydrology and Climate change
  - Vietnam Institute of Water Resources
  - Vietnam National Center for Hydro-meteorological Forecasting
- Representatives from Khanh Hoa province (online):
  - Mr. Lê Xuân Thái, Director of the Sub-Department of Irrigation, Khanh Hoa Province
  - Ms. Trương Thị Thanh Vân, Director of the Center for Clean Water, Department of Agriculture and Environment
  - Mr. Đặng Thanh Bình, Deputy Director of the Hydro-Meteorological Station of Khanh Hoa Province

Agenda

Time	Content	Speaker
08:30 - 09:00	Registration	The Vietnam Institute of Meteorology, Hydrology and Climate Change (IMHEN)
09:00 - 09:05	Introducing participants	The Vietnam Institute of Meteorology, Hydrology and Climate Change
09:05 - 09:10	Welcoming and Forewords	The Vietnam Institute of Meteorology, Hydrology and Climate Change
09:10 - 09:30	Introduction on Project the project CRRP2024-09SY-Ngo	Dr. Ngo Thi Thuy, IMHEN
09:30 - 10:00	Development of the water demand index maps and validation process, case study for Ninh Thuan area (Vietnam)	Mr. Luong Tuan Trung, IMHEN
10:00 – 10:10	Coffee break	All participants
10:10–10:40	Development of the water demand index maps and validation process, case study for Kampong Thom province (Cambodia)	Mr. Kao Chanbora, Ministry of Water Resources and Meteorology (MOWRAM)
10:40 – 11:15	Discussion	- Mr. Le Xuan Thai - Ms. Truong Thi Thanh Van - Mr. Dang Thanh Binh - Ms. Tien Le

Time	Content	Speaker
11:15 – 11:30	Remarks and Conclusion	
11:30 – 12:30	Lunch	All participant

Workshop materials:

https://drive.google.com/drive/folders/17ZI3DLcZNCB7JZb16inRJtTajtyj3lS-?usp=sharing

Photos

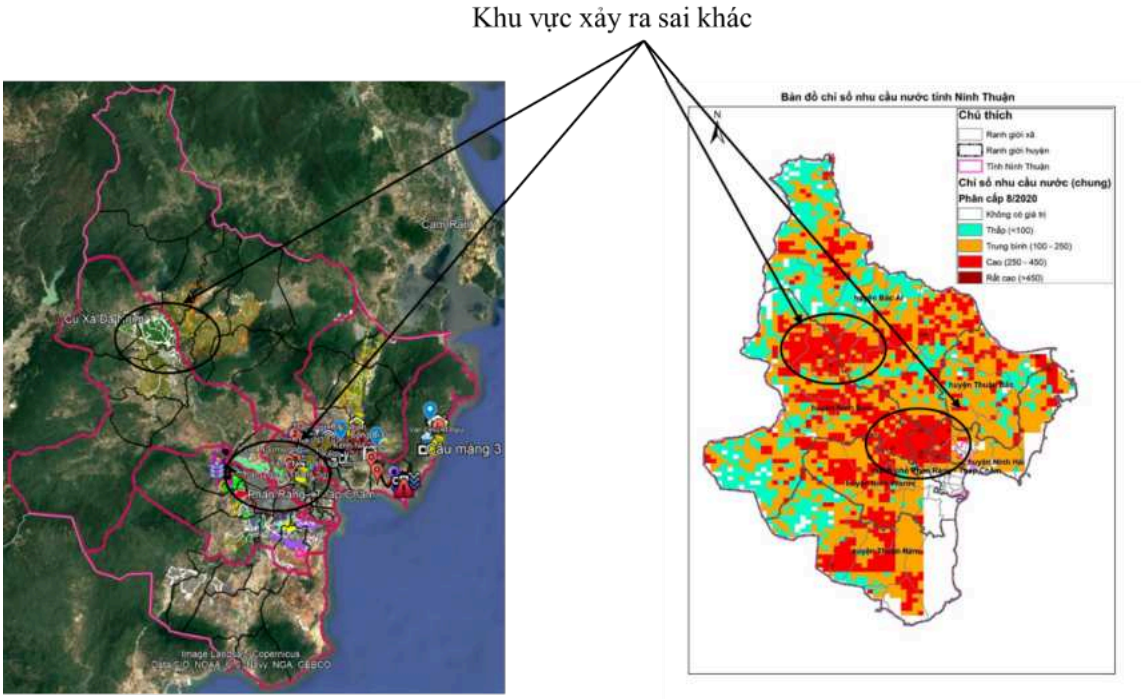
APPENDIX 5 ASSESSING APPLICABILITY AND FUTURE RESEARCH

A5.1. Discussion

Ninh Thuan pilot

- Drought is one of the persistent serious problems in Ninh Thuan province. Especially in recent years, there have been severe droughts such as 2015, 2016, and 2020, causing the demand for water in these years to increase. The water shortage period usually occurs during the dry season from December to August of the following year, with the peak water shortage occurring in March, April and May.
- Areas with severe water shortages: Phuoc Trung and Phuoc Thanh communes - Bac Ai district, Phuoc Ha, Nhi Ha, Phuoc Nam and Phuoc Ninh communes - Thuan Nam district, Ma Noi, Hoa Son and My Son communes - Ninh Son district.
- When drought occurs or is forecasted to occur, surface water sources will be prioritised for domestic use, industry and livestock, proactively cutting down on crops to ensure water demand is at a minimum level.
- In recent years, especially after the irrigation system from Tan My lake was put into use (2021), the water shortage in the province has significantly decreased. The project includes the Song Cai reservoir cluster with a capacity of 219 million m^3, ensuring irrigation water for 1,969.43 hectares in the communes of Tan Son, My Son, Nhon Son (Ninh Son), Phuoc Hoa, and Phuoc Trung (Bac Ai).
- Hydrometeorological Station: responsible for issuing drought warning bulletins with a period of 10 days, 1 month and detailed seasonal information to the commune level to provide to the Department of Agriculture and Environment, IMC to plan crop development. However, the forecast only stops at comments on rainfall and temperature trends, without assessments of available water and crop status (details of the bulletin in the appendix). The WDI map can partly overcome these limitations. In addition, based on the distribution of the WDI index, the hydrometeorological station can incorporate the appropriate assessment of the water stress situation in the bulletin: raise warnings in areas at risk and reduce warnings in other areas. It will be particularly helpful for the coordinated action of the local authorities and farmers to spatially allocate water efficiently in the relevant water scheme and catchment.
- Department of Agriculture and Environment: Currently, drought forecasting only depends on the water storage status in reservoirs from the previous season, combined with weather forecasts to provide directions for crop structure. Therefore, the WDI map can be used as a reference tool to delineate areas at risk and adjust crop acreage. However, the crop structure in the province has changed a lot, so it is necessary to pay attention to updating land cover data. This is the additional required update for the WDI index for the inclusion of crop classification and assessment, and detailing the water deficit accordingly.
- IMC: IMC is the unit responsible for planning the crop season for areas covered by the irrigation system, based on the actual water available in the reservoir and irrigation rates for crops, as well as weather forecasts from the beginning of the season (about 1 month in advance). This plan is made at the beginning of the season and is almost unchanged throughout the season because it is calculated in the safest scenario. Therefore, the WDI

map is difficult to use in the operation of the irrigation system. In addition, there are parts of the 2020 WDI map that do not clearly reflect the ground situation, such as areas covered by the irrigation system, when the WDI maps present severe water stress, but this is handled by irrigation. Therefore, it is necessary to review the model input data, especially humidity, or to review the way the values are divided on the map.



The area with differences between the WDI map (severe water requirement) and the actual water shortage situation.

Kampong Thom pilot

The findings highlight both strengths and gaps in the WDI's application. On the positive side, managers relied on WDI maps for planning and considered them reliable for identifying water shortages. This demonstrates WDI's utility as a strategic planning tool, particularly for irrigation officers and local authorities. The tool also showed strong potential to guide water allocation during critical drought periods, aligning with stakeholder priorities for resource distribution.

However, the study also revealed significant challenges. Farmers exhibited lower confidence in the maps and limited familiarity with their use, which reflects both a technical knowledge gap and weak dissemination of information to local communities. The WDI was less effective in capturing drought timing and severity, limiting its usefulness for early warning and crop-switching decisions. This weakness was compounded by the reactive nature of local water governance, which relies heavily on visible water levels rather than predictive forecasts.

The role of WDI in bridging this gap is clear: maps must be made more timely, user-friendly, and localised. Respondents' requests to integrate hydrological data, produce maps before planting decisions, and link drought alerts to agronomic guidance underscore the importance of aligning WDI with farmers' decision-making timeframe. In this sense, the WDI can be further

elevated as a governance tool that influences the negotiation of water distribution and agricultural planning at local levels.

A5.2. Recommendation

To enhance the applicability and reliability of the Water Demand Index (WDI) maps in supporting agricultural water management, several key recommendations are proposed:

1. **Differentiate irrigation types:** Future WDI maps should clearly distinguish between areas actively irrigated by formal irrigation systems and those dependent primarily on rainfall. This classification will improve interpretation and enable more targeted irrigation planning.

2. **Improve spatial and administrative resolution:** The map resolution should be refined to capture local-scale variations in crop water demand. Additional administrative layers down to the commune and irrigation-system levels are required to facilitate decision-making by local authorities and water user groups.

3. **Integrate forecast and real-time data:** Current WDI maps mainly reflect existing conditions. Integrating hydrometeorological forecasts will allow for predictive mapping, thereby supporting proactive drought management and more effective seasonal planning. This recommendation aligns with feedback from the National Centre for Hydro-Meteorological Forecasting (NCHMF) and the Irrigation Management Company (IMC).

4. **Enhance data verification and parameter calibration:** A systematic approach should be established to verify the reliability of soil moisture datasets and recalibrate WDI thresholds for different agro-ecological zones. Localised calibration will ensure that WDI values more accurately reflect actual drought intensity and crop stress.

5. **Leveraging big earth and ground data for climate-smart agriculture system and an open-access web portal:** The wealth of open-access data on earth observation for climate and crop management is making the desire for the climate-smart agriculture system closer for every farmer and provincial officer. The leveraging of the data from the hydrological network and big earth data will be the next suitable direction to inform smart agriculture decisions at the regional and commune levels. Additionally, a dedicated web-based platform should be developed to provide open access to the latest WDI maps and datasets. This portal would allow users from provincial and commune levels to visualise, download, and analyse data each time the WDI maps are updated, enhancing transparency and usability.

   By implementing these improvements, the WDI will become a more robust, user-centred tool capable of supporting drought preparedness, irrigation scheduling, and adaptive agricultural planning at both national and local scales in Viet Nam and Cambodia.