IWMI
International Water Management Institute

Innovation Brief

Framework for advancing water resource sustainability and climate resilience through local-scale hydrological modeling in the Mekong Delta

The Mekong Delta is a vast region that is crucial for providing food to millions of people. However, climate change and human activities are causing water scarcity, floods and soil salinization, which are a threat to food security and livelihoods. To tackle these issues, the CGIAR Initiative on Asian Mega-Deltas (AMD) is working towards creating more resilient, inclusive and productive deltas that can adapt to climate change and other challenges. As part of the AMD initiative's activities, the International Water Management Institute (IWMI) is conducting local-scale hydrological modeling in two delta regions, namely Ganges and Mekong.

This innovation brief outlines the methodology that will be used to develop satellite-based crop water use estimates for targeted irrigation schemes in the Mekong Delta. Through local partnerships, the AMD initiative hopes to generate site-specific knowledge that can be used to understand water use patterns, optimize water management at scales, increase agricultural productivity and ensure the long-term sustainability of this important deltaic system.

Fisherman in a boat in the Mekong Delta (*photo*: IRRI).

Background

Asian mega-deltas are vast, ecologically vital regions that support millions of livelihoods and critical food baskets but face growing challenges such as water scarcity, flood risks and ecological degradation (Syvitski et al. 2009; Nicholls et al. 2020; Loc et al. 2021a). The sustainability of the Asian mega-deltas is critical for regional and global food security as they impact livelihood and food security, both within and beyond their borders. The landscapes of the Asian mega-deltas are far more vulnerable to the ever-increasing surge in climate extremes, severe cyclones, sea-level rise, increased freshwater salinization, soil salinization and land subsidence (Tuan et al. 2007; Nicholls et al. 2020; Loc et al. 2021b). In addition, climate change accelerates the threats posed by these challenges and inflicts severe social and economic consequences. These impending climatic trends, if left unaddressed, will place additional pressure on the already vulnerable communities residing in these deltas, aggravating food insecurity, deepening poverty and intensifying hunger. The foreseeable outcome is a grim cycle of diminishing food security and a relentless increase in destitution and malnutrition, which further underscores the urgency of proactive interventions to safeguard the future of these vital regions.

The AMD initiative aims to create resilient, inclusive and productive deltas that maintain socio-ecological integrity, adapt to climatic and other stressors, and support human prosperity and well-being by removing systemic barriers to the scaling of transformative technologies and practices in the community, national and regional levels. As part of the AMD initiative, IWMI is undertaking a series of activities that aim to develop local-scale hydrological models in two deltas (the Ganges and the Mekong) to aid informed decision-making for enhancing water resilience in deltaic regions.

The Mekong Delta

The Mekong Delta faces complex water management challenges ranging from large seasonal fluctuations in water availability, large dam infrastructure altering monsoon and dry season flows into the delta and sediments accumulated, and aging and inefficient irrigation infrastructure contributing to salinization (Biggs et al. 2009; Renaud and Kuenzer 2012; Smajgl et al. 2015; Lacombe and McCartney 2016). While irrigation schemes form a vital part of the Mekong Delta, the landscape is dominated by intensely irrigated agricultural production systems with substantial groundwater use. Understanding spatial and temporal patterns of crop water use is critical for adopting sustainable water management practices and investing in infrastructure. The last large-scale evapotranspiration and water productivity assessments were conducted by Mainuddin and Kirby (2009). Most of the recent studies related to crop water use in the Mekong Basin focus on the utilization of globally available moderate to coarse resolution evapotranspiration products, which may not be suitable for addressing water use dynamics at the local scale. Considering the large spatial extent of the Mekong Delta and the need for sufficiently high-resolution data, IWMI has conducted a number of internal (AMD and other CGIAR initiatives) and external discussions to understand the ongoing activities in the Mekong Delta and how hydrological modeling can inform sustainable crop water management. Based on the outcomes of these discussions, the following objective was developed.

Objective

Develop satellite-based crop water use estimates (actual evapotranspiration – monthly and seasonal) of specific irrigation schemes in the Vietnam Mekong Delta to support water productivity improvements in intensively irrigated systems.

Researcher observing a rice field in the Mekong Delta (*photo*: IRRI).

Innovation

Development of crop water use metrics in the Vietnam Mekong Delta: This innovation involves developing precise metrics for actual evapotranspiration on a monthly and seasonal basis for specific irrigation schemes in the Vietnam Mekong Delta. The goal is to enhance water productivity in intensively irrigated systems. By accurately measuring and managing crop water use, this activity will provide the data-driven foundation for water management strategies in the region while supporting improvements in the efficiency of the irrigated systems in one of Southeast Asia's most vital agricultural regions.

Methodological framework

- IWMI will utilize the Python version of the Surface Energy Balance Algorithm for Land (PySEBAL) for estimating crop water use (Pareeth and Karimi 2023).
- Through activities of the AMD initiative, IWMI will update the cloud-based version of the PySEBAL model named Google Earth Engine SEBAL (geeSEBAL) to estimate crop water use, yield and water productivity (WP) in the targeted investigation areas, as shown in Figure 1 (Laipelt et al. 2021).
- The model will primarily use Landsat 8 and 9 satellite data, in addition to weather and soil hydraulic properties.
- If there are local weather datasets available for the baseline period, they will be used in the geeSEBAL model. In the absence of hourly and daily weather datasets, publicly available global reanalysis datasets (ERA5-Land/Global Land Data Assimilation System [GLDAS]/Modern-Era Retrospective Analysis for Research and Applications [MERRA-2]) will be used instead.
- The model will provide estimates of land and water productivity indicators for every 30 x 30 meter land area on days when Landsat satellite data are available. These estimates will be aggregated on a seasonal scale to provide summary estimates of water use, biomass and WP. The data will be further disaggregated to selected irrigation schemes in the Mekong Delta region.

River flow in the Vietnamese Mekong Delta (*photo*: Phan Ky Trung/Can Tho University).

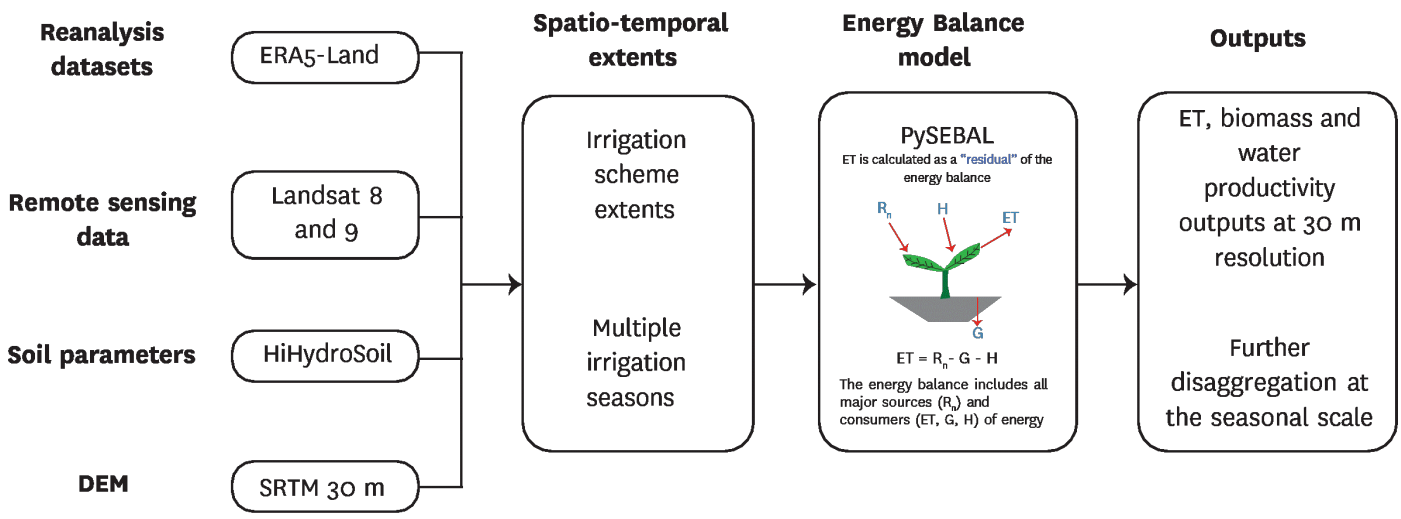

Figure 1. Framework to develop crop water use and productivity analytics.

Notes: DEM- Digital Elevation Model; SRTM- Shuttle Radar Topography Mission; ET- Evapotranspiration

Irrigated rice fields and canals in the Mekong Delta (*photo*: WorldFish).

Technical outputs by the end of 2024

- Monthly crop water use dataset for the entire Mekong Delta (Cambodia and Vietnam).
- Crop water use, salinity and productivity analytics for two selected irrigation schemes in the area of focus of the AMD initiative.
- A journal article on the review of the socio-hydrology of Asian mega-deltas.
- An integrated assessment report on crop water use and salinity in the two selected irrigation schemes in the Mekong Delta.

Innovation beneficiaries

The primary beneficiaries of this innovation include:

- **Government agencies**: Implement data-driven, evidence-based policies for water resources management and climate resilience of the irrigation infrastructure system in the Mekong Delta.
- **Local water authorities**: Enhance decision-making capabilities by integrating high-resolution land and water productivity indicators' data into water resource planning and allocation strategies for specific irrigation. Additionally, assess and benchmark the performance of irrigation schemes in the Mekong Delta against their design objectives.
- **Researchers and academia**: Utilize the crop water use and biomass production (yield) data of critical crops for in-depth studies, contributing to scientific understanding and innovation in sustainable agriculture and the overall sustainability of the Mekong Delta.

Farmer at work in the aquaculture ponds of the Mekong Delta (*photo*: WorldFish).

References

Biggs, D.; Miller, F.; Hoanh, C.T.; Molle, F. 2009. The delta machine: Water management in the Vietnamese Mekong Delta in historical and contemporary perspectives. In: Molle, F.; Foran, T.; Kakonen, M. (eds.) *Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance*. London, UK: Earthscan. pp.203–225.

Lacombe, G.; McCartney, M. 2016. *Evaluating the flow regulating effects of ecosystems in the Mekong and Volta river basins*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Research Report 166). https://doi.org/10.5337/2016.202

Laipelt, L.; Kayser, R.H.B; Fleischmann, A.S.; Ruhoff, A.; Bastiaanssen, W.; Erickson, T.A.; Melton, F. 2021. Long-term monitoring of evapotranspiration using the SEBAL algorithm and Google Earth Engine cloud computing. *ISPRS Journal of Photogrammetry and Remote Sensing* 178: 81–96. https://doi.org/10.1016/j.isprsjprs.2021.05.018

Loc, H.H.; Lixian, M.L.; Park, E.; Dung, T.D.; Shrestha, S.; Yoon, Y-J. 2021a. How the saline water intrusion has reshaped the agricultural landscape of the Vietnamese Mekong Delta, a review. *Science of The Total Environment* 794: 148651. https://doi.org/10.1016/j.scitotenv.2021.148651

Loc, H.H.; Van Binh, D.; Park, E.; Shrestha, S.; Dung, T.D.; Son, V.H.; Truc, N.H.T.; Mai, N.P.; Seijger, C. 2021b. Intensifying saline water intrusion and drought in the Mekong Delta: From physical evidence to policy outlooks. *Science of The Total Environment* 757: 143919. https://doi.org/10.1016/j.scitotenv.2020.143919

Mainuddin, M.; Kirby, M. 2009. Spatial and temporal trends of water productivity in the lower Mekong River Basin. *Agricultural Water Management* 96(11): 1567–1578. https://doi.org/10.1016/j.agwat.2009.06.013

Nicholls, R.J.; Adger, W.N.; Hutton, C.W.; Hanson, S.E. (Eds.) 2020. *Deltas in the Anthropocene*. Cham, Switzerland: Springer Nature Switzerland AG. 282p. https://doi.org/10.1007/978-3-030-23517-8

Pareeth, S.; Karimi, P. 2023. Evapotranspiration estimation using Surface Energy Balance Model and medium resolution satellite data: An operational approach for continuous monitoring. *Scientific Reports* 13: 12026. https://doi.org/10.1038/s41598-023-38563-2

Renaud, F.G.; Kuenzer, C. (Eds.) 2012. *The Mekong Delta system: Interdisciplinary analyses of a river delta*. Dordrecht, The Netherlands: Springer Dordrecht. 480p. https://doi.org/10.1007/978-94-007-3962-8

Smajgl, A.; Toan, T.Q.; Nhan, D.K.; Ward, J.; Trung, N.H.; Tri, L.Q.; Tri, V.P.D.; Vu, P.T. 2015. Responding to rising sea levels in the Mekong Delta. *Nature Climate Change* 5: 167–174. https://doi.org/10.1038/nclimate2469

Syvitski, J.P.M.; Kettner, A.J.; Overeem, I.; Hutton, E.W.H.; Hannon, M.T.; Brakenridge, G.R.; Day, J.; Vörösmarty, C.; Saito, Y.; Giosan, L.; Nicholls, R.J. 2009. Sinking deltas due to human activities. *Nature Geoscience* 2: 681–686. https://doi.org/10.1038/ngeo629

Tuan, L.A.; Hoanh, C.T.; Miller, F.; Sinh, B.T. 2007. Flood and salinity management in the Mekong Delta, Vietnam. In: Be, T. T.; Sinh, B. T.; Miller, F. (eds.) *Challenges to sustainable development in the Mekong Delta: Regional and national policy issues and research needs: Literature analysis*. Bangkok, Thailand: The Sustainable Mekong Research Network (Sumernet). pp.15–68.

Female farmer in the irrigated fields of the Mekong Delta (*photo*: IRRI).

Rice planting in flood irrigated fields of the Mekong Delta (*photo*: IRRI).

Local public transport via ferry in the Mekong Delta (*photo*: IRRI).

Authors

Karthikeyan Matheswaran, International Water Management Institute (IWMI), Colombo, Sri Lanka (k.matheswaran@cgiar.org)

Mahesh Jampani, International Water Management Institute (IWMI), Colombo, Sri Lanka (m.jampani@cgiar.org)

Dipaka Ranjan Sena, International Water Management Institute (IWMI), New Delhi, India (d.sena@cgiar.org)

Acknowledgements

This work was carried out under the CGIAR Initiative on Asian Mega-Deltas, which is grateful for the support of CGIAR Trust Fund contributors (www.cgiar.org/funders).

CGIAR Initiative on Asian Mega-Deltas

The CGIAR Initiative on Asian Mega-Deltas aims to create resilient, inclusive, and productive deltas that maintain socio-ecological integrity, adapt to climatic and other stressors, and support human prosperity and wellbeing by removing systemic barriers to the scaling of transformative technologies and practices in the community, national and regional levels.
https://www.cgiar.org/initiative/asian-mega-deltas/

Citation

Matheswaran, K.; Jampani, M.; Sena, D. R. 2023. *Framework for advancing water resource sustainability and climate resilience through local-scale hydrological modeling in the Mekong Delta*. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Asian Mega-Deltas. 8p.

Disclaimer

This publication has been prepared as an output of the CGIAR Initiative on Asian Mega-Deltas and has been internally peer reviewed. Responsibility for the opinions expressed and any possible errors lies with the authors and not the institutions involved.

IWMI
International Water Management Institute
CGIAR
IWMI is a CGIAR Research Center

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 15 countries and a global network of scientists operating in more than 55 countries.

International Water Management Institute (IWMI)

Headquarters
127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka

Mailing address:
P. O. Box 2075, Colombo, Sri Lanka
Tel: +94 11 2880000
Fax: +94 11 2786854
Email: iwmi@cgiar.org
www.iwmi.org