CTU Journal of Innovation and Sustainable Development
ISSN 2588-1418 | e-ISSN 2815-6412

DOI:10.22144/ctujoisd.2025.072

"Serious Game" dialogue tool for groundwater extraction in Ben Tre and Soc Trang provinces

Nguyen Luyen Phuong Doan[1*], Van Pham Dang Tri[1], Niels Mulder[2], Dinh Phuong Trang[2], and Gregor Van Essen[3]

[1]*The Research Institute for Climate Change (DRAGON-Mekong), Can Tho University, Viet Nam*

[2]*Deltares Institute, Unit of Groundwater and Subsurface Systems, the Netherlands*

[3]*The Water Agency, Vietnam Water Hub, the Netherlands*

**Corresponding author (nguyendoan041297@gmail.com)*

Article info.

Received 19 Dec 2024
Revised 22 Feb 2025
Accepted 18 May 2025

Keywords

Groundwater management, Raise awareness, "Serious Game", Vietnamese Mekong Delta

ABSTRACT

Groundwater resource in the Vietnamese Mekong Delta (VMD) face over-exploitation activities, which leads to subsidence and salinity intrusion. Several efforts to limit groundwater exploitation have been made, existing limitations. Therefore, groundwater stakeholders' meetings are conducted to discuss deeply management and usage problems at the local level in a general forum. The "Serious Game" discussion tool simulates scenarios addressing groundwater issues and facilitates active participation and dialogue among diverse stakeholders, including policymakers, water supply units, and water users. Through rounds of "Serious Game", participants directly observed the effects of over-exploitation of groundwater, such as subsidence and salinity intrusion, to decide on choosing irrigation-used water. The main approach is to assess participants' consideration of groundwater management strategies for their farming activities. Research results showed that the amount of water demand in Soc Trang and Ben Tre provinces had a downward trend, which indicates changes in insights into groundwater sustainable usage. They learned how to negotiate water demands among different zones to reduce water units. Feedback from players and stakeholders contributes to the completion of the "Serious Game". This tool is recommended for use in public awareness campaigns and community events to raise awareness of groundwater issues for local water users.

1. INTRODUCTION

Groundwater in the VMD supplies almost all domestic and production activities (Van Tuan et al., 2024). However, unsustainable groundwater use caused a drop in its available level (Minderhoud et al., 2017; Duy et al., 2021; Van Tuan et al., 2024); this leads to land subsidence and salinity intrusion in the VMD (Ha et al., 2024). Notably, land subsidence has appeared in many locations, with the main recorded reason being excessive groundwater exploitation (Erban et al., 2014; Anh et al., 2016; Minderhoud et al., 2017; Loc et al., 2021). Regarding the relationship between over-extraction of groundwater and land subsidence, the 3D hydrogeological groundwater model results showed that some locations in the VMD experienced a land subsidence rate from 25 cm to 35 cm between 1991 and 2015 (Minderhoud et al., 2017). Negative impacts of excessive groundwater exploitation are a critical factor in developing sustainable

groundwater use management policies, with Decree No. 167/2018/NĐ-CP implemented on December 26, 2018, to reduce over-extraction of groundwater.

After that, the extension of relevant groundwater regulations is inefficient, and understanding available fresh groundwater limitations and raising awareness on sustainable groundwater use are likely not to be considered in communities (Van Tuan et al., 2024). Therefore, stakeholder engagement through consultant meetings positively enhances discussion efficiency in groundwater management and usage at the local level. The discussion tool depends on the idea of a simulation game, "Serious Game", which combines and reveals knowledge behind participants. At the consultant meetings, "Serious Game" has a proviral role to play in effectively assessing stakeholder decisions and their understanding under different conditions; specifically, the "Serious Game" supplies an environment to observe how stakeholders respond (Morgan et al., 2024). Thanks to stakeholder analysis, their behavior, interests, and understanding are used to assess the feasibility of policy implementation and develop strategies for groundwater management and use for stakeholders in the future.

The research explores the "Serious Game" concept to promote sustainable groundwater management in the VMD by fostering learning and dialogue between government officials, water users (such as farmers, industry, and water supply companies), and other stakeholders. In this research, the "Serious Game" discussion tool provides policy and scientific aspects being combined directly into farming activities, such as knowledge from Decree No. 167, groundwater-used zones, environmental impacts from using groundwater, and suggesting potential technology solutions. In addition, stakeholders, such as policymakers, water users, and scientists, quickly understand the relationships between the over-extraction of groundwater and land subsidence and salinity intrusion, affecting the region's salinity intrusion and land subsidence levels. The "Serious Game" emphasizes that the overextraction of groundwater affects the environment and brings negative economic impacts. As an example, high levels of salinity intrusion and land subsidence in farming areas decrease crop productivity and increase the investment costs of technological solutions. This research provides a roadmap for integrating "Serious Games" into raising stakeholders' awareness of sustainable groundwater use.

2. MATERIALS AND METHOD

The Vietnamese Mekong Delta (VMD), located in the South of Viet Nam, is vulnerable to climate change impacts, such as rising sea levels. Besides surface water being contaminated is not good to use for agricultural and domestic purposes; therefore, groundwater becomes the primary water resource (Smajgl et al., 2015; Eslami et al., 2021; Ha et al., 2024). However, the over-extraction of groundwater activities causes salinity and land subsidence (Toan, 2014; Ha et al., 2023), and this consequence brings about the interregional influence of the VMD. To research these issues and toward sustainable development strategy, stakeholders, including policymakers, water managers, water users, and scientists, pointed out feasible causes of groundwater depletion, how to develop innovative tools, and effectively integrated models related to water resources management in the delta.

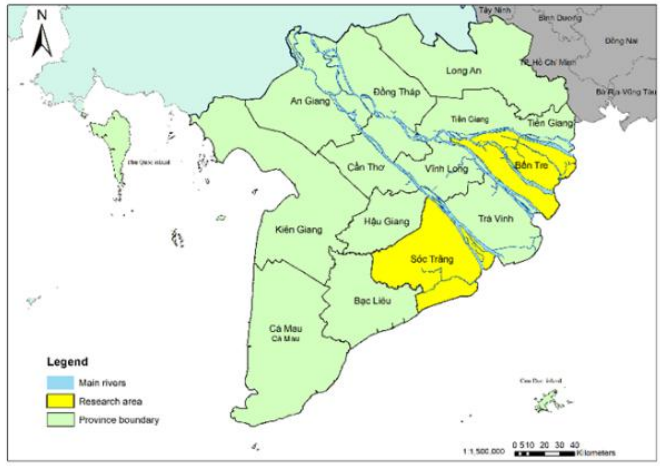

Figure 1. Location of research area

In the VMD, Ben Tre and Soc Trang provinces (Figure 1) are selected to research the current situations of groundwater exploitation, management policies, and stakeholders' awareness assessment. Current years have seen the proliferation of surface water pollution, leading to poor quality (Ha et al., 2024) groundwater resources have become the primary supply source for most production and domestic activities. Thus, raising awareness of the importance of sustainable groundwater use among stakeholders is urgent. Meetings with local consultants will focus on implementing Decree No. 167's process for restricting groundwater extraction, the current status of groundwater management and use, and practical solutions for sustainable groundwater resource use.

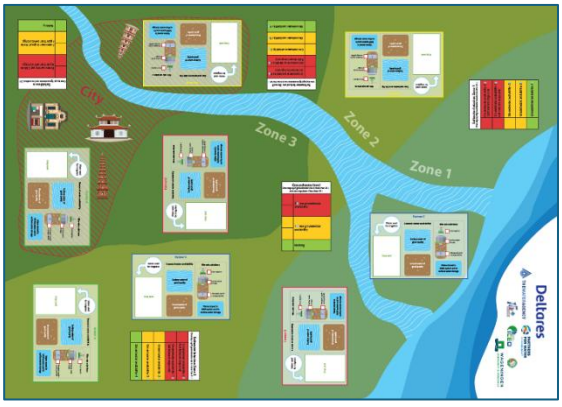

Figure 2. "Serious Game" discussion tool (designed by Deltares Institute)

Regarding groundwater policies in two provinces, water users, such as industries and farmers, are still not accessing the implemented groundwater regulations and Decree 167. With regard to Ben Tre province, groundwater is used for domestic purposes and added to shrimp farming in some places. In Soc Trang province, groundwater is used mainly due to its good quality, stable quantity all year round, and easy exploitation. Salinity intrusion and land subsidence, however, negatively impact groundwater resources in both Ben Tre and Soc Trang provinces. The most applied solutions at the local level to access alternative water sources are rainwater harvesting, drought-resistant crops, and stopping groundwater exploitation licenses.

The research aims to assess stakeholders' awareness of sustainable groundwater use and management using questionnaire surveys and "Serious Game". A set of questions concerns water use status, knowledge about groundwater policy and Decree 167, and driving factors and solutions for reducing groundwater use, expectations, and recommendations. "Serious Game" has been used to research decision-making and collect data by assessing changes in behavior and observing how participants behave (Morgan et al., 2024; Vermillion et al., 2017). This discussion tool is applied to test the efficiency of sustainable policies (Czaika & Selin, 2017) and determine how participants respond to increased awareness (Merrill et al., 2019). The "Serious game" discussion tool is a simulation game to create a common forum for stakeholders, including policymakers, policy implementers, scientists, water supply units, and water users (water supply units, enterprises, and farmers), which directly involves in groundwater exploitation and management situations, particularly in Ben Tre and Soc Trang provinces. In Figure 2, the "Serious Game" is designed as a board map with eight farmlands located in three zones, and five indicators of salinity intrusion and land subsidence showing several levels presenting the health of the VMD.

The "Serious Game" includes actual scenarios of groundwater management and usage in the agricultural aspect to efficiently encourage stakeholders to direct dialogues, learn sustainable groundwater usage strategies by making farming decisions on each farming step, and contribute to transferring policy implementation smoothly. Stakeholders play a farmer role in different rounds to recognize that excessive groundwater use affects not only environmental issues but also economic risks for the following crops and the representing levels of land subsidence and salinity intrusion in the delta. The results from experiencing "Serious Game" can be combined using the data methodology that permits participants to freely discuss three blocks of questions, including water use status, knowledge of groundwater policies and Decree 167, and driving factors and solutions for reducing excessive groundwater extraction activities.

Different types of stakeholders, such as policymakers, water supply units, and water users, took the role of farmers to understand easily tasks and challenges in farming activities. The map (shown in Figure 2) has three different zones, such as four farmers (A, B, C, and D) owning two plots of farms. Each region will have its characteristics in terms of indicators such as groundwater volume and salinity intrusion level. For example, Zone 1, which has eight units of groundwater and a salinity intrusion index at level four (meaning when the

groundwater use of the area exceeds four units, the salinity intrusion index of the area will increase by one level), represents the downstream delta. Similarly, Zones 2 and 3 signify the midstream and upstream delta; all have total groundwater units 12, and the salinity intrusion index is at levels 6 and 8, respectively. The total 3 Zone salinity intrusion index will be 15 units of groundwater use. If it exceeds fifteen units, the whole area will be affected, and the total index will increase by one level.

Each farmer has two farms in two different areas. For example, farmer A will have one farm in Zone 2 and another in Zone 3. Then, the moderator will set the surface water available for each round, and the farmer will select the plant for the crop. After watering the plant, the farmer will harvest their crop and earn the next round's income. The moderator will count the amount of groundwater the water unit uses in each area and calculate the total for the entire region. In fact, groundwater distribution depends on topography and geography in each region. Next, farmers must pay tax of one money unit (revenue from buying agricultural products) per crop. In addition, two farms in the urban area are subject to paying taxes if the groundwater index of this area exceeds the permitted threshold, as stated above. In fact, taxes are understood as the repair costs for infrastructure when urban subsidence happens. During each round, special events occur after the round, such as price increases or decreases for crops, plant disease, and extreme weather conditions (floods, droughts). The moderator will decide these events based on the game situations. In the Serious Game, win-win solutions were introduced to participants, such as drip irrigation, surface water storage, and groundwater storage, to remain available water sources for irrigation purposes in case of water-irrigated shortage. Choosing solutions for farms was not required for participants.

3. RESULTS AND DISCUSSION

3.1. Water demand in Ben Tre province

In Ben Tre province, we divided the participants into three groups. In this case, stakeholders with representatives from government and various water user groups, such as farmers, industry and water supply, experienced as the same role of a farmer. In terms of policy markers, they understood the farming process and the water demand at the household level when they suggested management policies in the local. Whereas, farmers witnessed risks of salinity intrusion and land subsidence from over-exploitation of groundwater. In group A, water usage trends showed that groundwater levels rose once but later stabilized across zones, with minor fluctuations in zone 3. Notably, subsidence increased by one level. Regarding the economic impact, Zone 1 struggled financially, needing price adjustments to remain viable. Overall water and financial usage varied per farmer. The income among farmers was 29 for farmers A, 35, 20, and 20 for farmers B, C, and D, respectively. Participants highlighted concerns over fairness in groundwater use, calling for taxes on high water users to balance impacts. Investment largely focused on drip irrigation, with limited funds for surface water storage. There was a discussion about improving the monitoring of groundwater extraction for better regulation. Overall, farmers generally aimed to sustain resources rather than maximize profit. The simulation mirrored real-world issues, such as the need for coordinated water management policies to prevent conflicts.

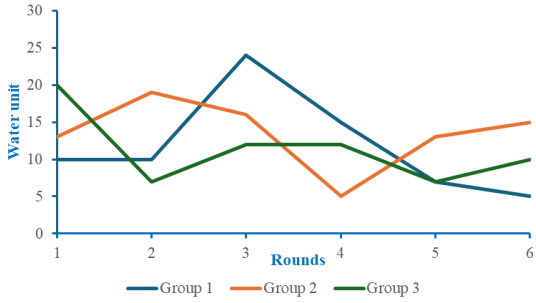

Figure 3. Water demands in Ben Tre province

In contrast, group B showed the spirit to stabilize groundwater during the rounds. The groundwater level increased twice but then showed a decreasing trend. Zone-specific observations indicate increases in Zones 1 and 2 but stability in Zone 3. Subsidence rose by two levels, suggesting a potential consequence of increased groundwater extraction. As a result, Zone B used the most water with 30 units, followed by Zone C (28 units), Zone A (24 units), and Zone D (27 units). Zone B generated the highest income (45), followed by Zone D (100, possibly an error as it stands out), Zone A (34), and Zone C (30), described in Figure 3. Urban area farmers feel disadvantaged due to higher taxes linked to subsidence, while farmland productivity remains similar. This is prompting some to abandon land or seek alternative land uses. In addition, farmers are increasingly considering groundwater levels across different areas to determine the optimal water use. Farmers found the provided

support solutions beneficial. They indicated a willingness to adopt similar measures in real-life scenarios to improve water use and farm sustainability.

In group C, groundwater levels initially increased in the first round but showed a decrease subsequently. Levels in all zones (1, 2, and 3) remained stable throughout the later rounds. The subsidence increased by one level, gradually impacting land stability due to groundwater extraction. Participants in Group C suggested a higher initial investment and requested banking support for capital and investment in sustainable solutions. Next, farmers mainly used drip irrigation but avoided expensive solutions like surface water storage and underground water storage. In the agricultural sector, cassava was preferred due to profitability and low water requirements, while coconut was avoided because of its high initial investment costs and low profit. Farmer C had the highest income of 36, while others had below 30. Farmers preferred cost-effective, low-water crops and asked for financial support mechanisms for sustainable practices.

3.2. Water demand in Soc Trang province

In Soc Trang province, we separated participants into three groups to convey the message of groundwater usage and conduct water policies to stop exceeding groundwater extraction. Group A showed the groundwater level increased initially across Zones 2 and 3, but later adjusted due to restrictions and special events. Specific rounds included interventions such as price subsidies for drip irrigation, and surface water storage solutions. Additionally, the price for coconut and banana was purchased because this kind of crop has less water demand. Compared to the reality, the productivity of each crop depends on farming area, soil type, and climate region. These price subsidies aimed to promote sustainable practices and reduce reliance on groundwater when the amount of used water was decreased. Also, subsidence rose twice during the rounds, indicating a gradual depletion of groundwater resources. Zone 1 consistently showed moderate groundwater usage, with farmers in urban areas facing economic strain and requesting price support by Round 4. Zones 2 and 3 exhibited higher groundwater usage, increasing groundwater indicators and subsidence, suggesting a significant reliance on these resources. Farm C accrued the highest expenditure (39) by the end, indicating high investment or inefficient management. Meanwhile, Farms A and B had balanced expenses.

Group B indicated the groundwater levels increased once but showed a downward trend afterward, with subsidence levels rising by one level. Zone-specific analysis revealed stability in Zones 1 and 3, while Zone 2 saw a slight increase in groundwater levels. Farm C had the highest groundwater usage (21 units), while farm A used the least of 13. Farm D earned the most income (80), followed by Farm B (44), shown in Figure 4. Especially in round 5, most farmers adopted specific solutions, focusing on water-saving crop varieties. Participants understood that crop choices affect groundwater levels, salinity, and subsidence. They also valued the solution and desired more comprehensive water use data to improve collective decision-making.

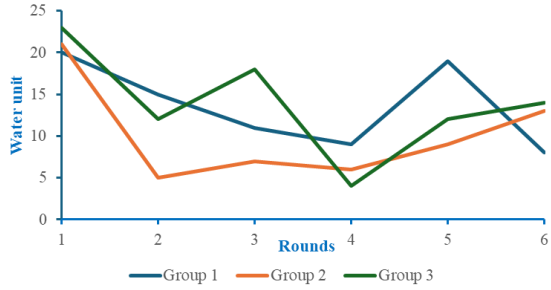

Figure 4. Water demands in Soc Trang province

Group C showed across all zones that the overall groundwater level showed an initial increase in the first round but declined in the following rounds. Specifically, Zone 2 saw an increase of one level, contrasting with Zones 1 and 3, which maintained stable groundwater levels throughout the simulation. There was an increase in subsidence of one level, indicating land settlement likely due to groundwater extraction. Farm C used the highest amount of groundwater at 26 units, and Farm D made the most income at 59. The initial lack of interaction among farmers evolved into a cooperative approach, resulting in sustainable water use and reduced environmental impact. Ultimately, all participants deemed the solutions valuable, indicating their practicality and potential for real-world application.

4. CONCLUSION

In general, participants demonstrated their actions and thinking, and balanced economic benefits with sustainable practices through rounds of “Serious Game”. Compared to water demand in the two provinces, the average of water demand from round 1 to round 6 in Soc Trang province was higher than

that in Ben Tre. In round 1, the average water demand in Soc Trang was highest at 21 water units. Moving to the next round, water demand in Soc Trang remarkably decreased to 10 water units, and that in Ben Tre dropped from 14 to 12 water units. When special events happened, such as less available irrigation sources, weather conditions, or crop buying price subsidy, almost all participants considered crop choice with less used water for irrigation. The assumption of special events depends on actual situations, which makes participants easily close to their farming activities. In the next rounds, the average water demand in both provinces sharply decreased. This means that they had considered the water demand for their farms. In addition, participants still pay more attention to discussing with neighbors the amount of water used in the same region and the whole area.

The assumption of paying taxes on groundwater usage helps participants to have better economic and environmental considerations in farming activities and is easily compared with their actual situations. Participants agreed that not all farms should be taxed. Most participants aimed to cooperate effectively to keep groundwater use below sustainable limits. This approach led to a successful decrease in groundwater levels after two cycles of the game. The farmers grasped the game's goals and emphasized long-term sustainability over short-term profit. Their primary focus was on adopting drip irrigation systems rather than relying on surface water storage, demonstrating a shift toward responsible water management.

Furthermore, participants can afford to receive insightful messages about the serious game. They learned the critical relationship between groundwater use, land subsidence, and saltwater intrusion. Excessive groundwater extraction was identified as a primary cause of land subsidence and increased salinity intrusion, highlighting the need for the conjunctive management of surface water and groundwater and balanced water use. Moreover, farmers realized the dual impact of groundwater overuse: environmental degradation and economic damage. They understood that excessive groundwater use increases repair costs and taxes and lower agricultural productivity. Evidently, the water use demand experienced a downward trend, which means that dwellers' awareness has improved. Moreover, they understood that using too much groundwater without refilling it, even if initially it seemed to be beneficial for their production in the farms, eventually would translate to effects at a larger scale in the delta (groundwater level decline, salinization, and subsidence), and eventually would also affect their business. This aspect mirrors real-world scenarios where collective action is crucial for sustainable resource management.

The common problem discussed was that most groundwater exploitation at the household scale is not monitored, so it's impossible to charge fees and taxes based on usage volume. They devised installing monitoring devices at household wells to measure extracted groundwater volumes. The government should enforce this through legal requirements. The first solution was the impact of new regulations, which is essential. Reactions will vary if the government requires groundwater monitoring for tax or fee purposes. While most people will probably comply and install monitoring devices, shrimp farmers may object out of concern for penalties for unforeseen circumstances like severe weather or water shortages. The second solution was related to the water shortage. Make sensible use of water, use replenishing techniques, and call public gatherings to explore and identify solutions for balanced water usage.

With regard to management policies, Decree 167 on restriction on groundwater extraction expires in June 2024, and the required aspects of groundwater management, exploitation, and sustainable-remaining solutions are included in the Law of Water No.28/2023/QH15 dated July 2024 by the National Assembly of Viet Nam. The "Serious Game" partly contributes to transmitting the message of groundwater management policies, promotes stakeholder access to alternative water sources, and raises awareness for stakeholders, such as policymakers, water supply units, and water users. Similarly, the "Serious Game" application is essential to apply continuously in the remaining provinces in the VMD. Moreover, this positive effect motivates stakeholders to strengthen their awareness of maintaining a healthy delta as a foundation for sustainable development.

ACKNOWLEDGMENT

The authors would like to acknowledge the "Negotiating Groundwater Extraction" project, fully funded by Partners of Waters Program, The Kingdom of the Netherlands.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Anh, N. T., Tin, N. H., Tien, M. V., & Hien, N. T. M. (2021). *Assess the impact of salinity intrusion on commune groups in the coastal areas in the Vietnamese Mekong Delta and proposal to complete the social security policy* (GIZ Report). https://colasa.edu.vn/wp-content/uploads/2021/11/3.-Bao-cao-danh-gia-tac-dong-cua-xam-ngap-man_Eng.pdf

Czaika, E., & Selin, N. E. (2017). Model use in sustainability policy making: An experimental study. *Environmental Modelling & Software*, *98*, 54-62.

Duy, N. L., Nguyen, T. V. K., Nguyen, D. V., Tran, A. T., Nguyen, H. T., Heidbüchel, I., Merz, B., & Apel, H. (2021). Groundwater dynamics in the Vietnamese Mekong Delta: Trends, memory effects, and response times. *Journal of Hydrology: Regional Studies*, *33*. https://doi.org/10.1016/j.ejrh.2020.100746

Erban, L. E., Gorelick, S. M., & Zebker, H. A. (2014). Groundwater extraction, land subsidence, and sea-level rise in the Mekong Delta, Vietnam. *Environmental Research Letters*, *9*(8), 084010.

Eslami, S., Hoekstra, P., Minderhoud, P. S., Trung, N. N., Hoch, J. M., Sutanudjaja, E. H., Dung, D. D., Tho, T. Q., Voepel, H. E., & Woillez, M.-N. (2021). Projections of salt intrusion in a mega-delta under climatic and anthropogenic stressors. *Communications Earth & Environment*, *2*(1), 142.

Ha, Q. K., Dang, V. T., Vo, L. P., & Dang, D. H. (2023). Integrated approaches to track saline intrusion for fresh groundwater resource protection in the Mekong Delta. *Groundwater for Sustainable Development*, *23*. https://doi.org/10.1016/j.gsd.2023.101046

Ha, Q. K., Phung, T. H., Phan, N. L., Minderhoud, P. S., Le Vo, P., & Essink, G. O. (2024). Groundwater resource challenges and abstraction-induced land subsidence in the Vietnamese Mekong Delta. *The Mekong River Basin*, 421-451.

Loc, H. H., Low Lixian, M., Park, E., Dung, T. D., Shrestha, S., & Yoon, Y. J. (2021). How the saline water intrusion has reshaped the agricultural landscape of the Vietnamese Mekong Delta, a review. *Sci. Total Environ., 794*, 148651. https://doi.org/10.1016/j.scitotenv.2021.148651

Merrill, S. C., Moegenburg, S., Koliba, C. J., Zia, A., Trinity, L., Clark, E., Bucini, G., Wiltshire, S., Sellnow, T., & Sellnow, D. (2019). Willingness to comply with biosecurity in livestock facilities: Evidence from experimental simulations. *Frontiers in Veterinary Science*, *6*, 156.

Minderhoud, P. S., Erkens, G., Pham, V., Bui, V. T., Erban, L., Kooi, H., & Stouthamer, E. (2017). Impacts of 25 years of groundwater extraction on subsidence in the Mekong delta, Vietnam. *Environmental Research Letters*, *12*(6), 064006.

Morgan, C. B., Merrill, S. C., Clark, E. M., Wolfson, J. A., & Trubek, A. B. (2024). A serious games methodology to test solutions for regional food systems inequities. *Journal of Rural Studies*, *110*, 103366.

Smajgl, A., Toan, T. Q., Nhan, D. K., Ward, J., Trung, N. H., Tri, L., Tri, V., & Vu, P. (2015). Responding to rising sea levels in the Mekong Delta. *Nature Climate Change*, *5*(2), 167-174.

Toan, T. Q. (2014). Climate change and sea level rise in the Mekong Delta: flood, tidal inundation, salinity intrusion, and irrigation adaptation methods. In Coastal disasters and climate change in Vietnam, *Elsevier*, 199-218.

Van Tuan, P., Jiang, Y., Stigter, T., & Zhou, Y. (2024). Understanding groundwater use and vulnerability of rural communities in the Mekong Delta: The case of Tra Vinh province, Vietnam. *Groundwater for Sustainable Development*, 25. https://doi.org/10.1016/j.gsd.2024.101095

Vermillion, S. D., Malak, R. J., Smallman, R., Becker, B., Sferra, M., & Fields, S. (2017). An investigation on using serious gaming to study human decision-making in engineering contexts. *Design Science*, *3*, 15.