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Community, Enterprise, and State in Groundwater Governance: The Case of the Long Xuyen Quadrangle-Vietnam

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ABSTRACT
Groundwater is a critical resource for water security, agriculture, and livelihoods in the Long Xuyen Quadrangle (LXQ) of the Mekong Delta. However, the region faces mounting challenges including over-extraction, declining quality, weak monitoring, and limited institutional capacity. This study examines groundwater use and management through surveys of 162 households, 20 enterprises, and 20 government officials in An Giang and Kien Giang provinces. Results show that more than 80% of users remain heavily dependent on groundwater, while unlicensed extraction is widespread (≈80% of households and 50% of enterprises) and water quality monitoring is largely absent. Signs of degradation such as iron contamination, salinity intrusion, and discoloration were commonly reported. Despite recognizing over-extraction, local authorities rely mainly on manual management tools and face shortages of staff and financial resources, creating a significant gap between regulations and actual practices. The findings highlight a "knowledge–action" paradox in groundwater governance. To ensure long-term sustainability, the study proposes an integrated framework that strengthens licensing, expands clean water infrastructure, adopts digital monitoring systems, and enhances inter-provincial coordination. Raising community awareness and participation is essential to secure sustainable groundwater use and water security in the LXQ.
Keywords: *Groundwater management; Water governance; Over-extraction; Community participation; Long Xuyen Quadrangle; An Giang, Kien Giang.*

INTRODUCTION

The Long Xuyen Quadrangle (LXQ), located in the Mekong Delta (MD), plays a strategic role in agriculture, aquaculture, and water security. However, the heavy reliance on groundwater, combined with the impacts of climate change, saltwater intrusion, and over-extraction, has posed significant challenges to sustainable development (Minderhoud et al., 2017; Erban et al., 2014).

In Vietnam, many studies have primarily focused on the hydrogeological and hydrological aspects of groundwater exploitation. Minderhoud et al. (2017) revealed that 25 years of groundwater extraction have caused an average land subsidence of 18 cm in the MD, equivalent to 1.1 cm per year. Le et al. (2023) estimated groundwater recharge in the LXQ ranging from 95.7–150.4 mm/year, accounting for only 5.3–7.5% of total rainfall, which highlights the aquifer's vulnerability. In addition, Nguyen and Tran (2022) applied the MIKE 11 model to simulate surface water quality in the irrigation system of LXQ, showing degradation in aquaculture zones.

By contrast, the social dimensions, particularly community perceptions and behaviors—have been less explored. In the MD, Pham et al. (2021), through household surveys, found that despite the availability of rainwater and piped water, residents continued to rely on groundwater due to its reliability and accessibility. Vo et al. (2024), in Tra Vinh, confirmed that groundwater remains a strategic livelihood resource for poor coastal households, even though this resource is declining. Vo and Nguyen (2020), by applying the OECD principles of groundwater governance in Bac Lieu, highlighted limitations in community participation and inter-sectoral coordination.

International research has provided additional perspectives. Foster and Chilton (2003) emphasized that groundwater is an "invisible resource" often overexploited due to lack of monitoring. Gleeson et al. (2012) evaluated global groundwater extraction and warned that 20% of the world's major acquirers are already in an unsustainable state. From a socio-institutional perspective, Theesfeld (2010) demonstrated in Eastern Europe that institutional frameworks and community involvement are key determinants of groundwater governance effectiveness. In India, Shah (2009), based on farmer interviews, showed that groundwater extraction is driven more by economic motives than by environmental concerns. In Latin

America, Homestayer and Wester (2015) demonstrated that community participation and co-management mechanisms can reduce overexploitation and improve equity in water distribution.
This overview indicates that most Vietnamese studies are still oriented towards technical–hydrogeological aspects, while international research has underlined the importance of integrating technical management with social factors. Consequently, an academic gap remains: the lack of systematic analyses on community perceptions, usage behaviors, and institutional governance of groundwater in the LXQ context. This paper seeks to address this gap by conducting interviews with households, businesses, and government officials in An Giang and Kien Giang. The analysis focuses on: (i) the degree of dependence on groundwater; (ii) water quality and degradation risks; (iii) licensing and legal compliance; (iv) state management capacity; and (v) proposing a suitable groundwater management framework that bridges science, policy, and community participation.

METHODS

The study was conducted using a sociological survey combined with semi-structured interviews targeting three main groups: households (162 questionnaires), enterprises (20 questionnaires), and government officials (20 questionnaires). The survey was carried out in seven districts, with households selected from official lists of groundwater users; the sample size was determined based on Slovin's formula (1984):

$$n = \frac{N}{1 + N * e^2}$$

where n is the required sample size, N is the total population, and e is the acceptable margin of error."
The interviews focused on the history and current status of groundwater extraction, purposes and water demand, changes in groundwater quality over time, alternatives available when wells run dry, and household-level water treatment practices.
For enterprises (including ice production, noodle processing, mineral extraction, aquaculture and seafood processing, and water supply plants), interviews were designed to collect information on water demand, costs and efficiency of groundwater use, compliance with licensing requirements, and challenges in accessing alternative water sources. At the same time, district- and provincial-level government officials were interviewed to assess licensing procedures, monitoring and enforcement practices, as well as management capacity and cross-sectoral coordination in groundwater protection. Integrating data from these diverse actors enabled cross-validation of perceptions, behaviors, and governance mechanisms, thereby providing a comprehensive basis for developing a suitable groundwater management framework in the Long Xuyen Quadrangle.

Figure 1: Interview with an enterprise

Figure 2: Interview with a management official

Figure 3: Farmer household interview

Study area

The Long Xuyen Quadrangle (LXQ) is a sub-region of the Mekong Delta, located between An Giang and Kien Giang provinces, covering an area of approximately ... km². It is bordered by the Hau River to the east and the Gulf of Thailand to the west. The area is characterized by low-lying terrain, with elevations ranging from 0.4 to 1.2 meters above sea level and is strongly influenced by the Mekong flood regime as well as seawater intrusion from the coast. The average annual rainfall ranges from 1,600 to 2,200 mm, concentrated mainly in the rainy season (May–November). Socio-economically, LXQ is a key agricultural and aquaculture production zone, while also experiencing increasing industrial activities and urbanization. Groundwater plays a particularly important role in domestic water supply, agricultural production, and aquaculture, but is facing growing pressure from over-extraction, declining quality, and land subsidence.

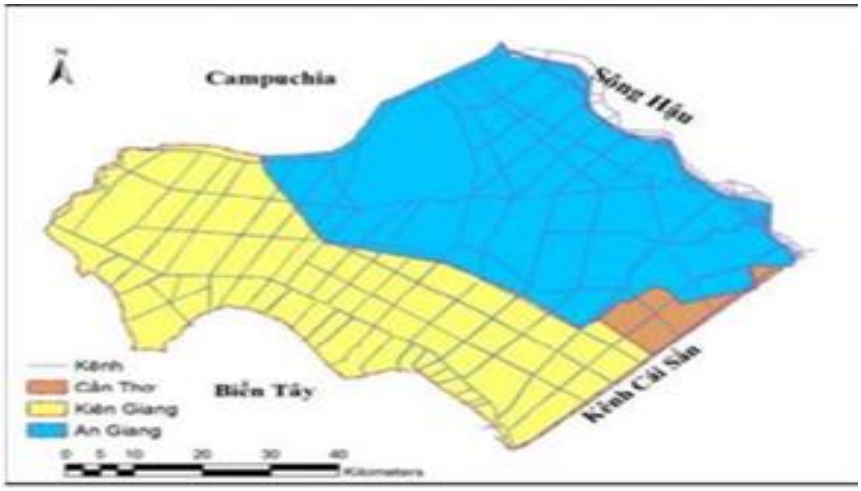

Figure 4: Map of the Long Xuyen Quadrangle

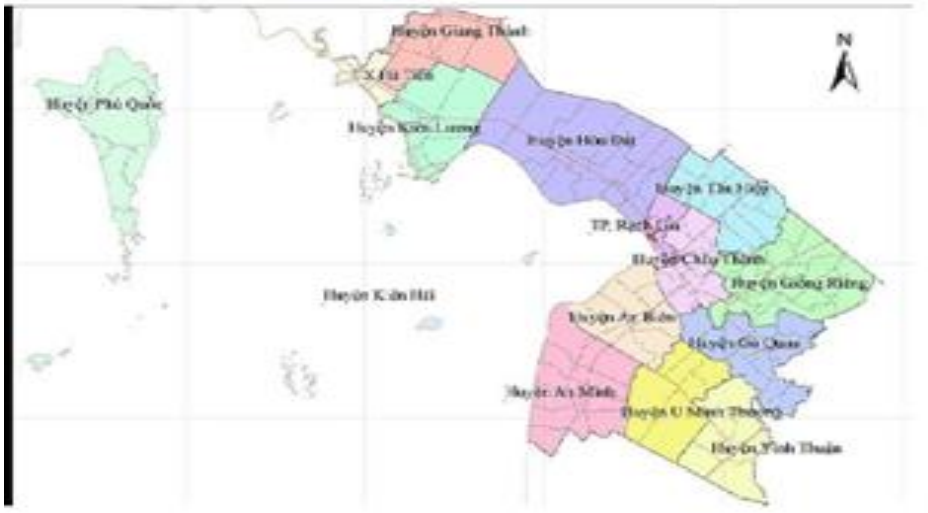

Figure 5: Map of Kien Giang Province
Source: Kien Giang Provincial E-Portal

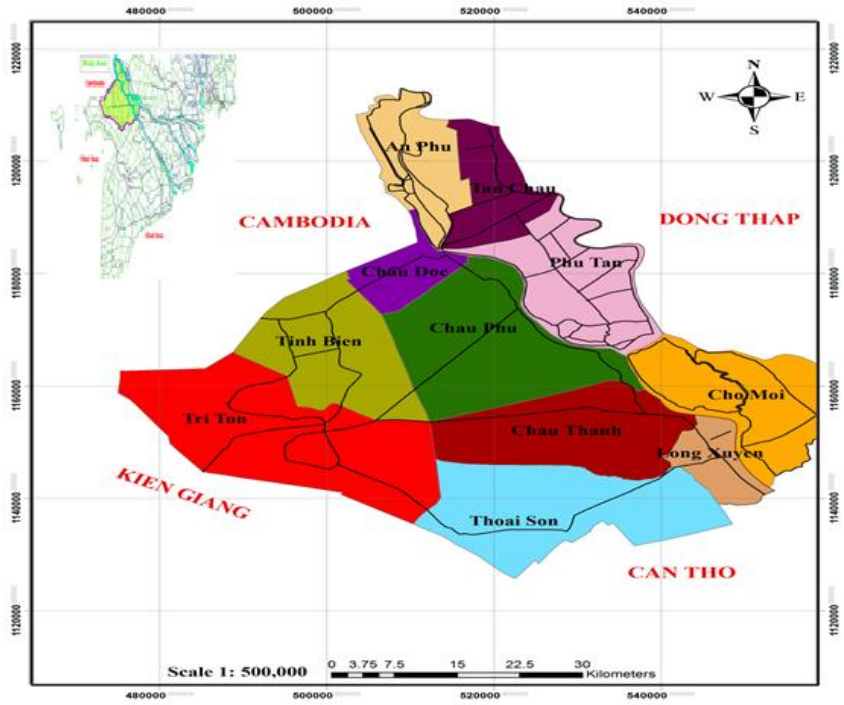

Figure 6: Map of An Giang Province

RESULTS

Households

In both Thoai Son and Tri Ton districts (An Giang Province) as well as in Kien Giang Province, survey results reveal a strong and long-term dependence of households on groundwater. More than 80% of households in Thoai Son and Tri Ton have relied on wells for over five years, while in Kien Giang, as many as 50% have extracted groundwater continuously for over ten years. This highlights the essential role of groundwater in daily life, with 83–90% of households using it primarily for domestic purposes. At the same time, a considerable proportion (10–17%) exploit it for agricultural production, particularly in specialized farming zones, reflecting increasing extraction pressures beyond household consumption.

In terms of quality, nearly half of households in both provinces reported noticeable deterioration, with common signs including iron contamination, salinization, discoloration, or odor; in Kien Giang, 29.7% of respondents indicated clear evidence of pollution. This problem is not unique to the Long Xuyen Quadrangle but has also been well documented in previous studies. For instance, Renaud and Kuenzer (2012) found that long-term groundwater exploitation in the Mekong Delta leads to declining water levels, deteriorating quality, and increased risks of salinity intrusion. Globally, Famiglietti (2014) also warned that groundwater over-extraction beyond recharge capacity has degraded water quality in many major aquifers worldwide.

Another striking issue is the extremely low rate of extraction permits only 20% of households in Thoai Son, 16.7% in Tri Ton, and 21% in Kien Giang reported having licenses, meaning roughly 80% of groundwater use in the region is unlicensed. This demonstrates a wide gap between regulatory frameworks and actual practices at the local level, consistent with Wagner et al. (2013), who argued that groundwater legislation in many developing countries is often weakly enforced. Even more concerning, over 90% of households had never conducted water quality testing, reflecting a disconnect between health risk awareness and protective actions. Previous studies (such as Hoque et al., 2006 in Bangladesh and Erban et al., 2013 in Vietnam) have shown that inadequate monitoring and lack of testing can increase exposure to contaminants such as arsenic, iron, or salinity.

Overall, the findings indicate that long-term dependence, declining quality, widespread unlicensed extraction, and weak monitoring represent severe challenges for groundwater security in the Long Xuyen Quadrangle. These results reinforce global warnings about the groundwater crisis and underscore the urgent need for integrated management strategies, combining community awareness, stronger enforcement, and stricter licensing, to ensure long-term sustainability.

Enterprises

Among enterprises, survey results reveal a very high dependence on groundwater for production, with 80% in An Giang and 81.8% in Kien Giang directly exploiting it for industrial activities, food processing, and aquaculture. However, the legal compliance of groundwater use remains limited: only 50% of enterprises in An Giang and 45.5% in Kien Giang possess permits, with a considerable proportion already expired. This situation reflects weak governance and poor enforcement of regulations, consistent with the findings of Fontenelle et al. (2019), who highlighted the prevalence of unlicensed groundwater extraction in agro-industrial regions of Southeast Asia.

Moreover, groundwater monitoring practices are largely neglected, as more than 60% of enterprises do not conduct regular assessments. The lack of monitoring data not only hampers regulatory oversight but also limits enterprises' ability to evaluate production risks. While most enterprises acknowledge that overexploitation and saltwater intrusion are the primary drivers of groundwater degradation, about 36–40% have not developed any specific strategies to safeguard or substitute their water sources. This is consistent with the findings of Wada et al. (2010) and Sefelnasr & Sherif (2014), which emphasize that environmental risk awareness is often insufficient to translate into concrete protective actions.

Such conditions not only intensify the pressure on already declining groundwater reserves but also pose major challenges for implementing sustainable management policies. Particularly, when compared with households—where the rate of unlicensed extraction also reaches nearly 80%—it becomes evident that the widespread pattern of "unregulated exploitation" reflects both gaps in user awareness and weaknesses in regulatory enforcement.

Local Authorities

Interview results indicate that the majority of local officials in both An Giang and Kien Giang (80–90%) acknowledge signs of groundwater extraction exceeding natural recharge capacity. However, management tools remain relatively basic, relying primarily on Excel spreadsheets or manual records, while only 14–20% of respondents reported using specialized software or digital mapping. This situation reflects the limited degree of digitalization in groundwater governance, consistent with Foster et al. (2013), who observed that many developing countries still rely on manual methods and incomplete databases.

With respect to compliance, officials reported that the proportion of licensed and lawful extraction is still modest: only 20% in An Giang and 42.9% in Kien Giang were considered to be at a "good" level of compliance. This finding aligns with Villholth (2013), who noted that unlicensed groundwater abstraction remains a widespread challenge in many developing regions.

Local officials also highlighted several barriers to effective groundwater management, including a shortage of technical personnel (40–57%), limited financial resources (20–43%), and the need for clearer and more specific legal frameworks (40–43%). Similar challenges have been documented internationally (Shah, 2007; Pavelic et al., 2012), underscoring that groundwater governance is inherently complex and requires coordinated investment in human capacity, financial resources, and institutional frameworks. Overall, while there have been notable efforts in the Long Xuyen Quadrangle, substantial room remains for improvement, particularly in terms of modernizing management tools and strengthening institutional capacity.

Comparison of Groundwater Use and Management between An Giang and Kien Giang

The survey results reveal that both An Giang and Kien Giang share several common features. Groundwater dependence is consistently high, with more than 80% of households relying on wells for many years. Unlicensed extraction remains widespread (around 80%), while concrete protective actions such as regular water testing or switching to centralized clean water systems remain limited. From the management perspective, both provinces face similar challenges, including a lack of modern tools, insufficient technical staff, and limited financial resources for monitoring.

Despite these similarities, important differences exist. In Kien Giang, surface water serves as the main supply (93.1% of households), yet small-scale, unlicensed groundwater extraction persists. In contrast, An Giang relies heavily on wells, with many households extracting at relatively high volumes (>500 liters/day). For enterprises, legal awareness is generally higher in Kien Giang, though groundwater monitoring practices remain inadequate in both provinces. These contrasts are largely shaped by natural and socioeconomic conditions: Kien Giang benefits from a dense network of rivers, canals, and lakes, while An Giang's higher terrain and seasonal scarcity of stable surface water foster greater dependence on wells.

Socioeconomic structures further influence compliance. In Kien Giang—particularly in coastal urban centers such as Rach Gia—enterprises are subject to stricter oversight, resulting in stronger legal awareness. Conversely, in An Giang, where agriculture and small-scale processing dominate, regulatory compliance in groundwater extraction has received less attention. Nonetheless, in both cases, monitoring systems

remain insufficient, leaving groundwater resources vulnerable to overexploitation and degradation.
These findings suggest two levels of management priorities. At the regional level, a unified groundwater governance framework for the Long Xuyen Quadrangle is needed, emphasizing stricter licensing, enhanced monitoring through digital tools (GIS, shared inter-provincial databases), and community education on the risks of overexploitation. At the local level, An Giang should focus on controlling household extraction volumes and expanding rural clean-water supply systems, while Kien Giang should strengthen oversight of small-scale unlicensed abstraction alongside investments in safe and sustainable surface-water systems. For enterprises, although legal awareness is relatively stronger, mandatory monitoring and reporting remain critical to ensure accountability.
In sum, groundwater management in the Long Xuyen Quadrangle cannot be confined to individual provinces. The transboundary nature of aquifers and extraction impacts highlights the need for inter-provincial and cross-sectoral cooperation, which is key to achieving sustainable use and long-term water security for the entire region.

DISCUSSION

The research results indicate that the Long Xuyen Quadrangle is facing a dual paradox in groundwater management and exploitation. First, the demand for groundwater extraction from households and enterprises is increasing, while centralized clean water supply systems remain insufficient, particularly in rural areas and intensive agricultural production zones (Foster & MacDonald, 2014; Mukherjee et al., 2015). Second, although the legal awareness and understanding of groundwater degradation risks among managers and enterprises are relatively high, actual implementation is constrained by the lack of technical tools (monitoring software, digital databases), specialized human resources, and financial capacity. This creates a gap between "knowledge" and "action," weakening the effectiveness of groundwater protection policies (Shah, 2014; Villholth, 2020).
Another critical issue is the deterioration of groundwater quality. Signs of acid sulfate contamination, salinity intrusion, and changes in physical–chemical properties not only directly threaten public health but also increase treatment costs, thereby exerting pressure on household livelihoods and industrial–service production. In parallel, prolonged over-extraction is undermining the stability of aquifers, leading to declining groundwater levels, land subsidence, and salinity intrusion—risks that have been widely highlighted in international studies (Wada et al., 2010; Sefelnasr & Sherif, 2014; Gleeson et al., 2020).
In particular, the fact that around 80% of households extract groundwater without permits reflects a major gap in the current legal and licensing framework. Although regulations exist, enforcement tools and sanctions remain insufficient to ensure compliance. This situation of "uncontrolled extraction" illustrates how groundwater management at the local level remains largely formalistic, failing to establish substantive accountability between users and regulators. Similar challenges have also been documented in many developing countries, where legal frameworks coexist with weak enforcement practices (Fontenelle et al., 2019; Shah, 2014; Villholth, 2020).
From the cases of An Giang and Kien Giang, it is evident that groundwater exploitation and management in the Long Xuyen Quadrangle have reached an alarming stage: unlicensed extraction is widespread, water quality is declining, and management tools remain outdated. The greatest challenge for the region thus lies not only in extraction pressures and pollution risks but also in the disconnect between the legal framework, management capacity, and water-use behavior of households and enterprises. To ensure water security and sustainable development, a comprehensive strategy is required from the community to the regional level, focusing on reforming licensing mechanisms, strengthening clean water infrastructure, enhancing monitoring and supervision capacity, and, most importantly, establishing cross-sectoral and interprovincial coordination mechanisms for sustainable and effective groundwater management (Gleeson et al., 2020; Villholth, 2020).

CONCLUSION

The study highlights that groundwater exploitation and management in the Long Xuyen Quadrangle are facing critical challenges. Widespread unlicensed extraction, deteriorating water quality, and outdated management tools have placed the region at a tipping point. While household and enterprise dependence on groundwater remains high, centralized clean water supply systems are still insufficient, especially in rural and agricultural areas. At the same time, although awareness of legal regulations and resource degradation risks is relatively strong among managers and enterprises, implementation is hampered by limited technical tools, financial resources, and human capacity.

To ensure long-term water security and sustainable development, it is essential to adopt an integrated strategy that spans from community to regional levels. Key priorities include strengthening the licensing framework, expanding clean water infrastructure, improving monitoring and supervision through modern tools, and fostering public–private cooperation in water management. In particular, interprovincial and cross-sectoral coordination is crucial, since groundwater systems extend beyond administrative boundaries. Only with such comprehensive and collaborative efforts can the Long Xuyen Quadrangle achieve sustainable groundwater use while safeguarding the livelihoods, ecosystems, and socio-economic stability of the region.

RECOMMENDATIONS

To address the challenges in groundwater management and exploitation in the Long Xuyen Quadrangle, a set of integrated solutions is required. First, the licensing system should be reformed by simplifying procedures, introducing fast-track permits for small-scale wells, and digitizing all licensing data to build a centralized and transparent management platform. At the same time, investment in clean water infrastructure must be prioritized, particularly in densely populated areas, to reduce reliance on groundwater and ensure safe water access for communities. For local households, communication campaigns are essential to raise awareness of health risks and the long-term economic benefits of clean water, supported by policies to subsidize connection costs. Strengthening management capacity is also crucial, including training human resources, mobilizing financial support from sustainable development projects, and adopting modern data management software. Finally, to ensure regional coherence and effectiveness, a Long Xuyen Quadrangle Water Resources Management Board should be established, with the participation of An Giang and Kien Giang provinces as well as relevant departments and sectors, thereby creating a mechanism for cross-sectoral and inter-provincial coordination in groundwater governance and protection.

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