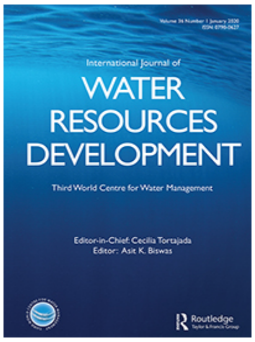

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The rationality of groundwater governance in the Vietnamese Mekong Delta's coastal zone

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ABSTRACT
This article assesses the rationality of the governance of the Vietnamese coastal zone's water system. We first specify five assessment criteria, which we apply to a case study. Based on document analysis, stakeholder surveys and in-depth interviews, we found an average score on the criterion that relevant water system knowledge must be available. The scores on the criteria that water usage is systematically monitored, that the legal framework is complied with, that long-term human and wider ecological interests are addressed, and that governance is decentralized appeared to be low. The article concludes with some recommendations to change the governance system.

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Groundwater; rational governance; stakeholder participation; groundwater depletion; Vietnamese Mekong Delta

Introduction

In recent decades, water availability per capita has declined sharply in many developing countries, 'a trend that is expected to worsen with an ever-increasing population and economic growth' (Grafton et al., 2013). With an exponential rise on the demand side of groundwater resources, due to increasing population and expanding agriculture, and an approximately constant supply side, the demand–supply imbalance is also rising exponentially (Mahendra, 2013). This is particularly the case in coastal areas of large delta systems, in which fresh surface water resources are limited. In these areas, groundwater remains the ultimate freshwater resource, offering reliability in ways that irrigation canals can hardly match (Siebert et al., 2010). However, coastal water resources are becoming increasingly saline due to excessive groundwater extraction (Ferguson & Gleeson, 2012).

The Vietnamese Mekong Delta (VMD), with an average elevation of 2 metres above mean sea level, is one of such deltas at risk (Allison, Nittrouer, Ogston, Mullarney, & Nguyen, 2017; Minderhoud et al., 2017; MONRE, 2016). In the VMD, the exploitation of groundwater for domestic, agricultural (including aquaculture) and industrial needs has rapidly increased to a vast but as yet unclear number (Danh, 2008; Smajgl et al., 2015; Wagner, Tran, & Renaud, 2012). This upward trend in groundwater exploitation will

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continue, especially since the availability of fresh surface water in the delta is at risk due to a (predicted) upstream reduction in river discharge from the Mekong, rising sea level and ever-increasing demand. Agricultural water demand in 2100 is expected to be two to three times that in 2000 (Smyle & Cooke, 2014). Increasing groundwater extraction has resulted in declining hydraulic heads in the aquifers (Pham, van Geer, Tran, Dubelaar, & Oude Essink, 2019; Wagner et al., 2012) and large-scale land subsidence (Minderhoud et al., 2017). Projections show that this subsidence will bring large parts of the delta below sea level by 2050 (Ingebritsen & Galloway, 2014). The 5th Assessment Report of the IPCC claimed that global sea levels rose about 3.2 mm/y in 1993–2010, and it was projected that the rise would reach 10 mm/y or more by 2100 (Church et al., 2013). As a result, large parts of the VMD will be subject to flooding (Dang, Cochrane, Arias, & Tri, 2018) and saltwater intrusion (Smajgl et al., 2015), leading to a loss of arable land (Smyle & Cooke, 2014) and jeopardizing food security (Ericson, Vorosmarty, Dingman, Ward, & Meybeck, 2006).

Rational governance mechanisms that promote equitable groundwater access and sustainable extraction are therefore needed (Dore, Lebel, & Molle, 2012; Hoogesteger & Wester, 2015). Institutional structures, processes, mechanisms and policy tools for the harmonization of resource users' interests, the wider societal interests and the interests of future generations are essential. Several researchers have investigated water governance issues in the Mekong Basin (Grumbine, 2017; Hissen, 2016; Urban, Siciliano, & Nordensvard, 2017) or Delta (Ha, Dieperink, Tri, Otter, & Hoekstra, 2018; Sok & Yu, 2015; Tran, Pittock, & Tuan, 2019), but so far no paper has taken rational governance as its point of departure. This article addresses this knowledge gap, as it aims to assess whether current groundwater governance in the VMD can be considered rational. The article is structured as follows. First, we elaborate on the concept of rational groundwater governance by reviewing the literature and developing an assessment framework. Next, we clarify how we have applied this assessment framework in empirical research. Following this methods section, we present our results by confronting the empirical evidence with the criteria of our framework. We conclude with a discussion of our results and some suggestions for future governance.

Rational groundwater governance: an assessment framework

Since ready-to-use frameworks for assessing groundwater governance from a rationality perspective do not seem to exist, we looked for inspiration and common ground in other water governance assessment frameworks. These are the Integrated Water Resources Management (IWRM) approach, the Sustainability Wheel, the Ten Building Blocks approach, the OECD Multi-level Governance Framework, the Management and Transition Framework, and the Water, People and Sustainability approach.

The Global Water Partnership (GWP, 2000) defines IWRM as 'a process which promotes the coordinated development and management of water, land and related resources, to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems'. Action and adaptation should take place, taking account of pro-environmental and stakeholder-friendly stakes (GWP, 2000; Karthe, Heldt, Houdret, & Borchardt, 2014; Mukhtarov, 2007). This approach acknowledges that the environment itself is a legitimate user of water

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resources as well (Miranda, Hordijk, & Torres Molina, 2011). The Sustainability Wheel (Schneider et al., 2015) is based on the principle that current and future generations should be able to meet their development goals with ample water availability. Surface- and groundwater quality and quantity should support these same development goals while maintaining ecological and hydrological integrity. Moreover, social equity (and justice) should concern current and future generations. Adaptive capacity also should allow for flexible response and adaptation to changing supply and demand, taking into account the variability, change and impacts on the state of the system.

Van Rijswick, Edelenbos, Hellegers, Kok, and Kuks (2014) argue that 10 building blocks are required to address water shortage, water quality and flood risks. These building blocks deal with knowledge (of the water system, values, principles, and policy discourses), organization (stakeholder involvement, trade-offs between social objectives, the attribution of responsibilities, regulations, agreements and financial arrangements and implementation (engineering and monitoring, enforcement, and conflict resolution).

The OECD Multi-level Governance Framework (OECD, 2015) stresses that effective governance contributes to the definition and implementation of clear sustainable water policy goals and targets, including implementation. Moreover, it defines the efficiency of the governance contributions in terms of the maximization of sustainable water management and welfare at the lowest societal costs. Governance should furthermore be legitimate and fair by building public confidence and stakeholder inclusiveness. The Management and Transition Framework (Pahl-Wostl, Holtz, Kastens, & Knieper, 2010) aims to improve interdisciplinary scientific understanding of system properties, embracing complexities and the wealth of resource governance interactions. This approach emphasizes the relevance of adaptive capacities and learning processes. The Water, People and Sustainability approach (Wiek & Larson, 2012) was introduced to overcome water governance failure by focusing on what people use their water resources for, why they do it and what the impacts are. The approach stresses the importance of comprehensive perspectives on water systems, and analyzes how social actors fit in the water system in terms of their actions, needs, intentions and norms. This approach also aims to account for perspectives on water sustainability, equally recognizing long-term depletion, justice and livelihood issues.

Multidisciplinary and multi-actor governance are common features in these six frameworks. The frameworks also emphasize knowledge of the water system, social equity and objectives, stakeholder inclusiveness and the maximization of sustainable management and welfare at the lowest societal costs and based on a long-term perspective. Therefore, we argue that rational water governance ideally accounts for all different aspects of the water system, including resource users, uncertainties as to environmental change, and political factors.

We conducted an additional Scopus search to further specify what rationality may imply for the contents, processes and institutional setting of groundwater governance. In terms of contents, we argue that rational groundwater governance is ideally based on uncontested evidence about the quality (and quantity) of available resources. This implies that water system knowledge is up to date and that water usage is clear and monitored (Jones, Dennis, Owen, & van Hees, 2003; Lemos & Agrawal, 2006). Open stakeholder processes are needed to match scientific evidence to governmental and stakeholder perceptions. These processes must be embedded in a clear and fair legal

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framework with full compliance (Fung, 2006), which is adapted to specific financial, technological and institutional capabilities, appropriate to geography and environment, customs, cultures, political systems and prevailing practices (Mechlem, 2016). Responsibilities must be clearly defined, and instruments must be available at the appropriate levels of governance. A balance must be found between central and decentralized activities. Ideally, local stakeholders must be able to influence local policy making and implementation (Fung, 2006). All this is synthesized in the assessment framework shown in Table 1.

Materials and methods

To assess the rationality of groundwater governance in the coastal part of the VMD, we developed a scoring system based on the reviewed literature and our expert knowledge (Table 1). This scoring system is applied in an assessment of the groundwater governance in Vinh Chau District, Soc Trang Province (Figure 1). Soc Trang, located in the Bassac estuary, is one of 13 provinces in the VMD. It has an area of about 3310 km^2 and a total population over 1.3 million (as of 2015) (General Statistics Office of Vietnam, 2017). In Soc Trang Province, three agro-ecological zones can be discerned: a fresh (surface) water zone; a seasonally saline (surface) water zone; and the permanently saline (surface) water zone. Vinh Chau District (Figure 1b) is in the saline zone (Linh, Be, Tri, Duyen, & Ha, 2014). The population of the district was about 166,000 (in 2015), of which 56% lived in rural areas (Vinh Chau District, 2016). The average household size was 4.4 individuals (Hoang, Dinh, Nguyen, & Tacoli, 2008). At about one metre above mean sea level, this district is a predominantly low-lying area (Tuan, Hoanh, Miller, & Sinh, 2007), and saline intrusion along the river network in the study area is expected to increase due to sea level rise (Mekong Delta Plan, 2013).

In Vinh Chau, groundwater is a vital resource for social and economic development that has been exploited and used intensively for agricultural and aquaculture activities (Hang, Trang, An, & Tri, 2018; Trang, Hang, Diep, An, & Tri, 2018). Since 2012, local residents have experienced the degradation (in both quality and quantity) of groundwater resources in the area. Many pumps were left unused, as there was no water to be pumped, while many others could hardly be used due to the sinking groundwater levels (Tri, Dieperink, & Otter, 2016).

Various data sources were used to confront the situation in the study area with our assessment criteria. First, the available literature (in both English and Vietnamese) related to the (geo)hydrology of the VMD, Soc Trang Province, Vinh Chau District, (ground)water governance, regulations and the institutional framework was reviewed. Relevant scientific publications were found in the Scopus, Web of Science and Google Scholar databases using (combinations of) search terms like 'groundwater', 'governance', and 'management'. Next, we analyzed relevant policy documents (Circular No. 27/2014/TT-BTNMT; Decision 09/2011/QD-TTg; Decision No. 01/2012/QĐ-TTg; Decision No. 11/2008/QĐ-UBND; Decision No. 87/QĐ-UBND; Decision No. 90/QĐ-TTg; Decision No. 357/NN-QLN/QĐ; Decree No. 21/2013/NĐ-CP; Decree No. 167/2018/ND-CP; Decree No. 199/2013/ND-CP; Law On Water Resources No. 17/2012/QH13; Order No. 15/2012/L-CTN; Resolution 120/NQ-CP) and labelled elements of the text as relevant for one of our criteria (Bowen, 2009).

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Table 1. Five criteria for assessing the rationality of groundwater governance.

	Good	Average	Low	Literature
Water system knowledge is available and knowledge gaps are addressed.	Both micro- and macro-scale water system knowledge is available to the largest extent. Knowledge gaps and/or misconceptions are fully addressed by research efforts.	Only macro-scale water system knowledge is available to the largest extent. Knowledge gaps and/or misconceptions are incompletely addressed by research efforts.	Water system knowledge is barely or not available. Knowledge gaps and/or misconceptions are not addressed by research efforts.	van Rijswick et al., 2014; Pahl-Wostl et al., 2010; Schneider et al., 2015; Wiek & Larson, 2012
Water resource usage is clear and systematically monitored.	Water resource usage is clear on both the micro- and the macro-scale, and thorough monitoring takes place.	Water resource usage is only clear on the macro-scale, and/or only average monitoring takes place.	Water resource usage is barely or not clear, and/or monitoring takes place only in part or not at all.	van Rijswick et al., 2014; Pahl-Wostl et al., 2010
The legal framework is clear, equitable and fully complied with.	The legal framework is equitable, with full compliance and involvement.	The legal framework is equitable, although with limited legitimacy, compliance, or involvement.	The legal framework is not equitable or legitimate, and lacks compliance and/or involvement.	van Rijswick et al., 2014; OECD, 2015
Groundwater governance addresses direct human interests and wider ecological interests in both the short term and the long term.	Action and adaptation lead to a full appreciation of all social-ecological stakes. There is a clear, equitable and sustainable long-term vision for development regarding groundwater resources, without knowledge gaps or uncertainties.	Action and adaptation are mainly based on social and economic stakes. There is a clear, equitable, or sustainable long-term vision for development regarding groundwater resources, with some knowledge gaps or uncertainties.	Action and adaptation are lacking. There is not a clear, equitable or sustainable long-term vision for development regarding groundwater resources, and focus is on the short term.	Pahl-Wostl et al., 2010; Mechlem, 2016; Karthe et al., 2014; GWP, 2000; Mukhtarov, 2007; Miranda et al., 2011; Wiek & Larson, 2012
Groundwater governance is decentralized, allowing local stakeholders to influence policy making and implementation.	There is ample opportunity for local stakeholders to influence local policy making, implementation and natural resource use cooperation.	There is some opportunity for local stakeholders to influence local policy making, implementation and/or natural resource use cooperation.	There is limited or no opportunity for local stakeholders to influence local policy making, implementation, and/or natural resource use cooperation.	Karthe et al., 2014; GWP, 2000; Mukhtarov, 2007, Miranda et al., 2011; van Rijswick et al., 2014; OECD, 2015

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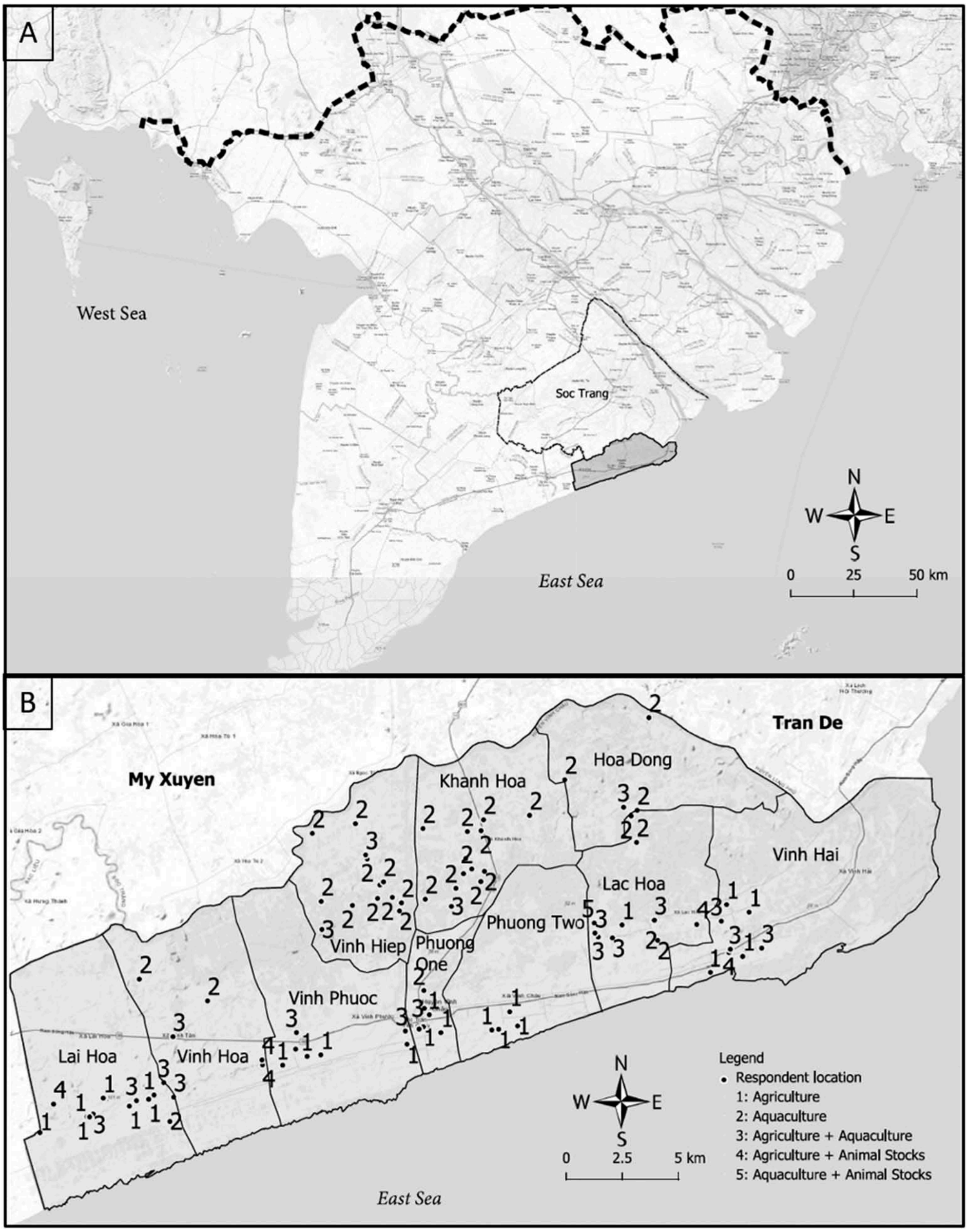

Figure 1. (A) The Mekong Delta. (B) Vinh Chau District, and spatial distribution of survey respondents.

Apart from this, semi-structured, qualitative, in-depth interviews were held with 15 researchers at Can Tho University (CTU), the hub of scientific knowledge in the VMD, and 12 policy makers. Both groups of interviewees were asked about their opinions on groundwater governance and more specifically the elements addressed in our assessment criteria. The policy experts were selected based on an institutional overview

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carried out by CTU and Deltares (2011) and included high-ranking officials of the provincial and district offices of the Department of Agriculture and Rural Development (DARD) and the Department of Natural Resources and Environment (DONRE) in Soc Trang. Ten respondents were in Soc Trang City (Soc Trang Province's capital), seven at the DARD and three at the DONRE, in water and agriculture-related divisions, respectively. The other two interviewees work in Vinh Chau in the district offices of the DARD and the DONRE. In the results section, the abbreviations SE and PM refer to interviews with scientific experts and policy makers, respectively. The contacted organizations selected the persons to be interviewed, which is a common practice in Vietnam. The interviews were held in English or in Vietnamese and were subsequently transcribed.

The perceptions of local agricultural households were collected by conducting a survey in the summer of 2016. The survey addresses topics related to the criteria and provides insights into the way water resources are used locally (number and depths of wells, frequency and duration of irrigation), livelihood (farm type and size), experienced environmental changes (variations in soil moisture) and farmers' experiences with governance. Our questionnaire was translated into Vietnamese, and farmers were approached by the first author and a Vietnamese translator, and were requested to fill it out. We tried to have representative samples of households, in terms of both geographical location and the population size of each commune. Based on Cochran's (1977) sample size (correction) formula, 90 agricultural households were surveyed. All the contacted households were willing to participate (a 100% response rate). The survey data were analyzed using SPSS.

We cross-checked the data from the different sources and compared our findings with the scoring categories mentioned in the assessment framework. But our results may be a little biased since we focus on just a small part of the coastal VMD.

Results

Table 2 summarizes the results of our assessment. Governance in Soc Trang scores low on all but one criterion. On the first criterion it scores average, as water system knowledge is available and some knowledge gaps are addressed. Governance scores low on the second and third criterion, since water resource usage is neither clear nor systematically monitored, and the legal framework lacks clarity and equity and is not fully complied with. Also on the fourth criterion, our study area scores low, since short-term visions dominate. The score on the final criterion is also low, which is due to a lack of

Table 2. Assessment of the rationality of water governance in Soc Trang.

Criteria	Score
Water system knowledge is available and knowledge gaps are addressed.	Average
Water resource usage is clear and systematically monitored.	Low
The legal framework is clear, equitable and fully complied with.	Low
Groundwater governance addresses direct human interests and wider ecological interests in both the short term and the long term.	Low
Groundwater governance is decentralized, allowing local stakeholders to influence policy making and implementation.	Low

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decentralization and a lack of stakeholder participation in policy making and implementation. We further clarify these findings in the sections below.

Availability and development of water system knowledge

Table 2 shows that our first criterion has been met in part. Several studies of the water system in Soc Trang Province or in the wider delta are available. They show that groundwater exploitation for mainly agricultural needs has increased from a limited number of wells before the 1960s to a vast though ambiguous amount at present (Danh, 2008; Wagner et al., 2012). They also show that the VMD faces a paradox of water availability, with water scarcity in the dry season and an abundance of water in the wet season, the latter contributing 80–85% of annual rainfall. This abundance is caused by precipitation (van Leeuwen, Dan, & Dieperink, 2015) and upstream discharge. It is argued that groundwater extraction in itself has a strong relationship with further environmental degradation, e.g. land subsidence and soil degradation, although data and studies are limited (Danh & Khai, 2015; Erban, Gorelick, & Zebker, 2014; Mekong Delta Plan, 2013; Minderhoud et al., 2017). As a result of land subsidence, large parts of the delta will be below sea level by 2050 (Ingebritsen & Galloway, 2014). The VMD could see much of its area subjected to both tidal and upstream-induced floods and to saltwater intrusion, threatening even more arable land (Smyle & Cooke, 2014). Consequently, food security will be at high risk (de Araujo Barbosa et al., 2016; Ericson et al., 2006).

Knowledge of groundwater, however, is only available to a limited extent in the region. The natural recharge of groundwater from Cambodia, the potential storage per aquifer layer (SE10), groundwater availability, groundwater age and origins, groundwater inflow, and groundwater quality (SE4) are other unknowns. Knowledge of the drivers of land subsidence is limited (SE4, SE10). As one our interviewees (SE12) put it, 'It is not really clear whether there is subsidence or whether it is the sea level that is rising. However, in Can Tho City, roads are broken open, and rocks point out of them, damaging cars and motorcycles.' According to another interviewee (PM2), 'More knowledge is needed to address the problem of subsidence, because that is the basis for further research. Because of a lack of information, it is difficult to study problems related to subsidence. One reason for subsidence would appear to be the exploitation of groundwater.' There is a need for a deep aquifer survey (SE4, SE6). New data are needed to address knowledge gaps (SE6) such as hydraulic conductivity, storage coefficient and groundwater drilling levels. Moreover, further data are needed on boundary conditions (e.g. head boundary and groundwater level boundary) for groundwater modelling. The interviewees also argued that there is a need for more recent data on outflow (water extraction) and inflow (infiltration), since the available data are outdated given the changes in land use and environmental problems in the VMD (SE3, SE6).

The transparency of available government data on the environment (such as monitoring data) appeared to be an issue. Mechanisms for sharing information between government departments or between the government and interested individuals are lacking (SE13), and data are not shared, or only to a limited extent (SE1). Next to that, public environmental authorities lack a good database management system, while data or other forms of information are fragmented among government offices and

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individuals (SE13). For instance, the exchange of information between the MONRE and the MARD is limited. Both ministries only use data from their own departments (SE2). According to an interviewee (SE2), 'They choose their own data over external data, and outsiders are not believed.'

Also, the transfer of monitoring data on water levels and reserves from the DONRE's provincial level to its district level seems to be a concern. Data remain primarily at the provincial level, and there is no information at the local levels of the DONRE on the actions taken by the central government on water resources (PM3).

Concerning laymen's knowledge, our survey respondents reported that they perceive their soil to be a lot drier (61%) or a bit drier (32%), compared to the dry season a decade ago. No decadal change was reported regarding the wet season. In general, farms were negatively affected by environmental changes (e.g. saltwater intrusion and drought). The respondents reported being significantly (37%), generally (38%), or somewhat (9%) negatively affected by environmental changes. But 14% said they were not affected by this at all. The aquaculture farms seem to be most severely affected by environmental changes (47%), followed by the agriculture and aquaculture combination farms (35%) and the agricultural farms (22%).

In conclusion, we argue that there seems to be enough basic knowledge on the water system, although there is still a need for more detailed information. There is not enough knowledge to conduct more advanced environmental analyses (for modelling purposes, for example), but general information on the drivers and pressures and especially the state of the groundwater seems to be available. However, research related to agriculture and the environment is hampered by constraints on information sharing, both between the scientific community and the government and between different government departments and levels. Moreover, there seems to be a gap in scientific and governmental understanding of groundwater resources degradation. Overall, governance in the VMD scores average on the first criterion.

Clear monitoring of water resource usage

Following the second criterion, water resource usage must be clear on both the macro and micro scales, and monitoring should take place thoroughly. We found that information on water resource usage is available to some extent, but monitoring efforts are limited. This accounts for the low score of Soc Trang Province (Table 2).

Water resource usage in the VMD is linked to agriculture and aquaculture. The survey respondents are active in aquaculture (40%), concentrating on shrimp farming, and agriculture (30%), in which 37% cultivate unions and 32% cultivate spices. The combination of aquaculture and agriculture is also common (22%), while the combination of either one of those with animal stock farming is rare. The farms differ in size. On average, the largest farms are the aquaculture and agriculture combination farms (19,437 m^2), followed by aquaculture (14,547 m^2) and agriculture (3841 m^2). Farmers of Kinh ethnicity (36%) are mainly aquaculture farmers (75%) and own an average of 10,811 m^2 of land. The farmers of the Khmer ethnic group (45%) primarily own agriculture (51%) and agriculture and aquaculture farms (27%), with an average farm size of 5123 m^2. The smaller group of farmers of Chinese ethnicity (19%) are more diverse, with agriculture

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(24%), aquaculture (41%) and combinations thereof (35%). The latter group has an average of 15,618 m^2 of land.

The respondents mentioned using groundwater (50%), rainwater (31%), surface water (13%) or seawater (6%). Crops are watered twice daily (63%) or twice or thrice (19%) in the dry season. In the wet season, irrigation is less than daily (37%), or once per day (30%) or every two days (22%). For this water resource usage, groundwater is extracted from the lower Pleistocene layer (123–158 m) by 57% of the farmers, while 30% extract groundwater from the middle Pleistocene layer (65.7–117.8 m). Groundwater extraction is done by pumps with an average discharge capacity of 19 m^3/s (71%) or 24 m^3/s (18%). Most farms have either one well (69%), two wells (23%), or no wells (4%). Back in 2005, 18% had no wells, 65% had one well and 15% had two wells, so these numbers have gone up. The numbers of wells differ per type of farm. The agriculture farmers use either one well (27%) or two wells (48%). The aquaculture farmers use either one well (42%) or two wells (24%). The agriculture and aquaculture combination farms use one well (19%) or two wells (29%). Groundwater pumping occurs mainly in the dry season for durations of 1–3 hours a day (37%) or 5–7 hours a day (30%). In the wet season, 37% of the respondents do not use groundwater at all. Those who do pump groundwater in the wet season do so for less than one hour a day (30%) or 1–3 hours a day (22%). All these figures are from our survey. They are not from a long-lasting, systematic monitoring programme.

Scholars argue that groundwater exploitation may increase two to threefold by 2100, compared to the demand in the year 2000 (Smyle & Cooke, 2014). However, detailed historical data on groundwater extraction are lacking. Minh et al. (2014) found that most of the province's groundwater extraction takes place in Vinh Chau District. In that study, households reported the extraction of groundwater mainly for domestic usage (>95%) in the dry and wet seasons, for agriculture (>40%) in the dry season, and for aquaculture with rice farming (>6%) in the wet season. Our survey indicates that on average farmers use around 100 m^3 per household per year in Vinh Chau for both agricultural and domestic purposes. Groundwater use varies from 74 to 122 m^3 per household per year (Hamer, 2016). This is similar to groundwater usage by rural households around Can Tho City and in Hau Giang Province, where rural households extract 104 m^3 per household per year from private tube wells (Danh, 2008). Sometimes, however, groundwater is not available, and according to one of the interviewees (PM4), 'It occasionally happens that people have to wake up in the night to pump water.'

The Vietnamese government acknowledges that more monitoring is needed. Regulations concerning a monitoring network for natural resources and the environment are set in Decision No. 90/QĐ-TTg, which was issued by the prime minister in 2016. This decision aims to increase the number of Vietnamese groundwater resource monitoring stations and wells to 71 and 1557, respectively, by 2030. In addition, 56 surface water monitoring stations are planned nationwide. For hydrologic monitoring, 354 existing monitoring stations will be upgraded, and in 2030 the total number foreseen will be 640. In Soc Trang Province, the DONRE collects samples at 16 locations bi-annually. These samples are analyzed at their Centre for Environmental Monitoring. Monitoring of groundwater levels and quality is also carried out through international projects. But the continuation of these monitoring activities is hampered by a lack of provincial government funds and the incompatibility of the collected data with the

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currently available data processing systems (Tri et al., 2016). In Vinh Chau District, one monitoring station is operational, while three more are planned (PM3), which could help address several knowledge gaps regarding the water system (SE3).

Clear and equitable legal framework and compliance

The VMD scores low (Table 2) on this criterion. The legal framework is not clear and equitable, since local governments do not operate uniformly and there is a lack of compliance by the farmers. Moreover, limited coordination between government authorities results in insufficient harmonization of legal documents and secondary regulations. Subsectors are targeted separately without consideration of water-related problem complexities, and water resource management remains an exclusive task for technical experts, implemented under state patronage.

Figure 2 shows the overall institutional arrangements of groundwater management in Vietnam. Both the MONRE and the MARD play an important role in the overall management of environmental resources and agriculture. Their responsibilities and obligations are established by Decree No. 21/2013/ND-CP and Decree No. 199/2013/ND-CP, respectively (Tri et al., 2016; Waibel et al., 2012). In 2002, the MONRE was established and charged with water resource allocation, the regulation and management of surface water and groundwater quality, and water resource assessments (Tri et al., 2016; Waibel et al., 2012). The MONRE is the most relevant authority for groundwater management. Its 2006 National Water Resources Strategy towards the Year 2020 was the first in the country to lay out the IWRM principles, objectives, missions and implementation measures to protect against water-related adverse impacts. Nonetheless, in practice a technical water engineering approach to flood prevention and freshwater provision dominates. Limited attention is paid to the protection of (ground)water resources (Waibel et al., 2012). Since 1995, the MARD has been responsible for the management of irrigation for agricultural and aquacultural purposes, and based on this responsibility it has to develop rural water supply programmes. Their key focus is on surface and groundwater-related engineering. Until 2002, Decision No. 357/NN-QLN/QĐ of the MARD regulated the investigation, extraction and management of groundwater resources, which was implemented in Soc Trang in 1998 with Decision No. 87/QĐ-UBND. According to Decree No. 199/2013/ND-CP, the MARD's scope of functions and responsibilities are defined as the management of irrigation for agriculture and aquaculture and rural water supply programmes (Tri et al., 2016).

Both the MONRE and the MARD have departments involved in groundwater management at provincial and district levels: the DONRE and the DARD. The DONRE works directly under the MONRE and the Provincial People's Committee. The DONRE's Water and Mineral Resources Division and Meteorology Division, and the DONRE in each district, are the most involved in groundwater management. At the district level, the DONRE operates under the authority of the People's Committee in each district. At the community level, water resources are managed by a staff member of the People's Committee (Tri et al., 2016). Alongside their administrative and professional departments, the ministries also have research and planning institutes. The National Water Resources Council and the River Basin Office are agencies that have been set up to incorporate different perspectives and concerns relating to specific legislation, for

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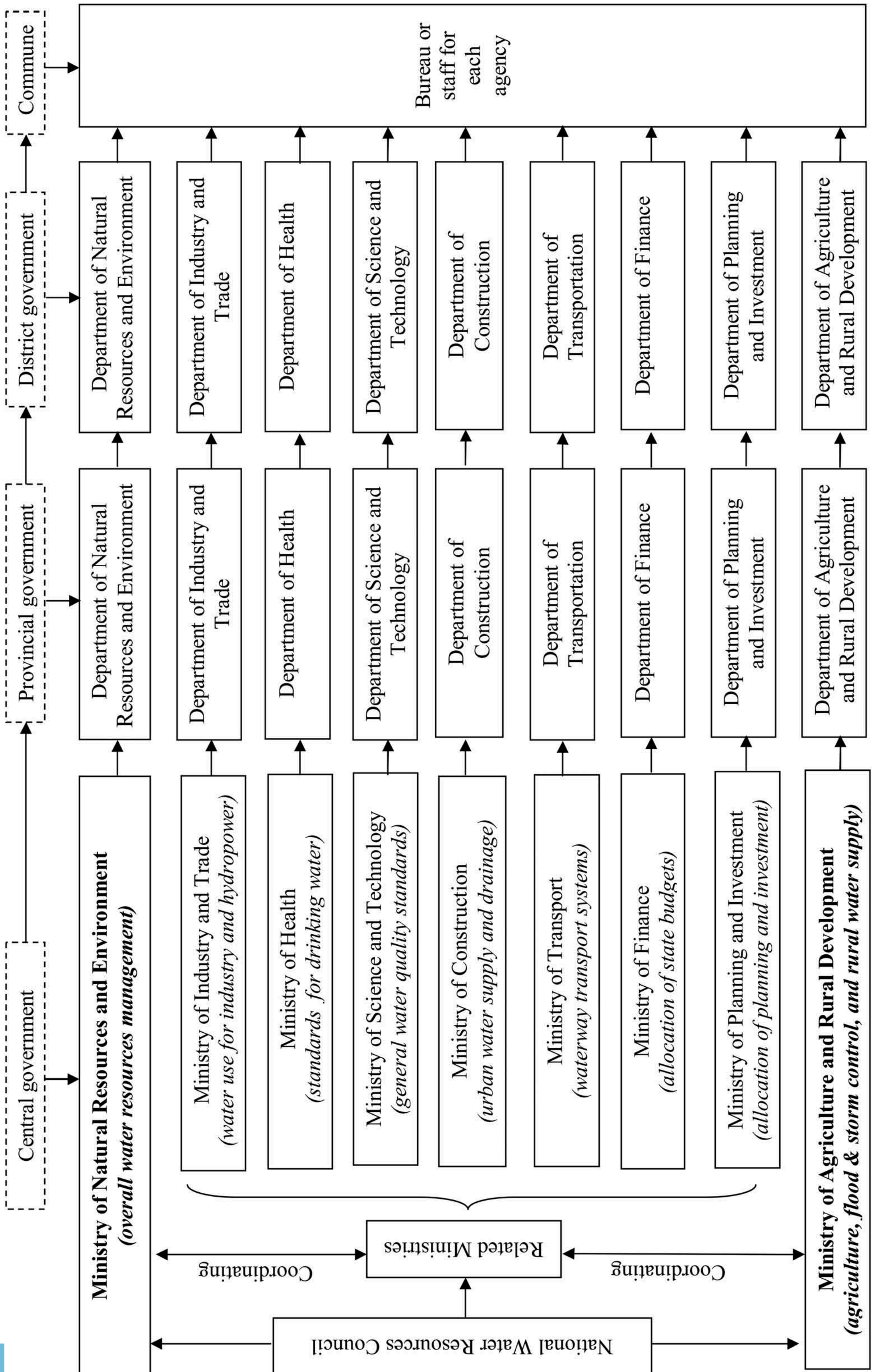

Figure 2. The formal institutional structure of groundwater management at different levels in Vietnam (Can Tho University & Deltares, 2011).

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instance on environmental policy, natural disaster prevention, hydropower development, rural clean water and sanitation, or the management of dikes, wetlands and coastal zones, but neither has more than an advisory role (Waibel et al., 2012).

Overall, the legal structure seems clear. In practice, however, ineffective coordination occurs between different government agencies and levels, which hampers successful groundwater management. This is due to a lack of periodic monitoring of water resource exploitation with local citizen feedback (Trung, Hang, Diem, & Tri, 2015). IWRM has not been transformed into practice, as is empirically revealed by Waibel et al. (2012). Coordination between provinces is lacking, due to an insufficient mutual orientation, a dominant top-down orientation focusing on the implementation of national agreements at the ministry level, and insufficient focus on taking responsibility from a bottom-up perspective (Kuks, Bressers, de Boer, Vinke-de Kruijf, & Ozerol, 2012). Also, the division of responsibility between the district and provincial authorities differs from province to province, even though this distinction is not in line with national standards. Local governments do not operate in a uniform way (Waibel et al., 2012), which results in the unsuccessful translation of national policies into local practice by local authorities, leading to a lack of enforcement of regulations relating to groundwater management.

We found that compliance is limited, as regulations often repeat or contradict each other, state different hierarchies, or cause confusion. Provincial regulations are limited, and officially issued DONRE guidelines are absent. According to Circular No. 27/2014/TT-BTNMT of the MONRE, farmers need a permit to extract groundwater in coastal areas. According to Decision No. 11/2008/QĐ-UBND, issued by the Soc Trang Provincial People's Committee, registration is required when groundwater exploitation exceeds 20 m^3 per day (PM4). The DONRE, however, fails to identify zones where groundwater extraction is allowable. As a result, older regulations are still maintained (Tri et al., 2016).

Our survey and in-depth interviews indicate several instances of a lack of enforcement of various regulations. According to the interviews, farmers never register new wells, even though it is required by Decision No. 11/2008/QĐ-UBND, and the government does not inspect for it (SE4). However, the survey states otherwise. Since 2008, 39% of the farmers in our survey had drilled new groundwater wells, of which 26% immediately registered their wells, 6% registered them later, and 68% did not register them. In Vinh Chau District, farmers report that they manage their water needs independently. Governments are hardly involved. Farmers report that they did not ask the (local) government (68%) or any other organization (81%) for assistance related to environmental problems and management (Table 3).

As a result, farmers have wells drilled at any spot convenient for them, leading to situations where local governments have very limited insight into or influence on actual groundwater resource usage. Furthermore, abandoned wells are common. They function as pathways for insecticides and pesticides to pollute groundwater. Rule enforcement is also lacking in this case, and penalties for violations are as low as VND 1 million (about

Table 3. Agricultural households generally do not ask for help.

	Did you ask help from any organization (e.g. NGO)?	Did you ask help from the (local) government?
Yes	2%	27%
No	81%	68%
I do not know	16%	5%

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USD 45) (SE4). As mentioned above, most farmers received no support from the government. Those who did (26%) got support in the form of information (26%), or funds and subsidies (43%).

Addressing human interests and wider ecological interests in both the short term and the long term

Ideally, both a short-term and a long-term vision of the importance of groundwater is manifest in regulations and policy documents. Farmers are aware of the issues and try to mitigate them by using water-saving techniques. However, our data show that in Soc Trang Province this ideal situation is not present at the moment.

Several long-term visions of the development of the VMD have been developed. The Mekong Delta Plan (2013) was developed in cooperation with Dutch scientists. It proposes a vision towards the year 2100. The plan's intention is to contribute to the realization and maintenance of the VMD as a prosperous delta in a social, economic and environmental sense. Climate change and changes in the availability of water resources are taken into account, and uncertainties concerning groundwater depletion are spelled out. Other long-term visions (towards 2100) are to be found in the Resolution 120, signed by the prime minister on 17 November 2017, on the sustainable and climate-resilient development of the VMD. However, this vision hardly addresses groundwater depletion.

In Soc Trang Province, land use has to comply with regulations from the DONRE. Those on groundwater use, however, are not enforced (PM4). Policies do support agriculture and aquaculture (e.g. Decision no. 01/2012/QĐ-TTg dated January 9, 2012 by the Prime Minister, Hanoi, Vietnam,). In Soc Trang Province, more than 80% of the agriculture sector consists of small aquaculture households (PM5). However, the choice of aquaculture as a development strategy may lower the quality of groundwater resources. These consequences arise since farmers dilute saline water in the aquaculture ponds using (ever increasingly saline) groundwater to create optimal living conditions for their shrimp stocks (SE1, SE11, SE12). This is especially common in the dry season, during which increased evaporation causes increased salinity due to the reduction of the ratio of water to the concentration of dissolved salts in the ponds (SE12, SE2). This food–water nexus (Gephart et al., 2017) results in a downward spiral leading to increased salinity of the groundwater resources. However, one of the interviewees involved in policymaking (PM5) argued that 'Salinization causes difficulties, but it is also an opportunity, depending on each region in the planning of aquaculture. In addition to the challenges caused by the high temperatures, high salinity is also an opportunity for shrimp farms.' Decree No. 167/2018/ND-CP identified four zones in Vietnam where groundwater use should be limited to reduce land subsidence, water pollution and groundwater level drawdown.

In our survey, we saw some awareness among agriculture and aquaculture farmers of the negative consequences of intensive groundwater exploitation. In both these groups, 37% and 36% of the respondents, respectively, assume that the intensive exploitation of groundwater resources results in a systematic lowering of the water table. But only a limited number of farmers have adapted their farming practices (Table 4). Some have invested in water-saving techniques, while others have changed the crops they produce.

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Table 4. Agricultural households adapt their farming practices to environmental changes to a limited extent.

Did you change crops in the last 10 years, forced by environmental changes?				
Yes, I changed my crops completely	Yes, partially	Yes, but only to a minor extent	No	I do not know
9%	30%	9%	46%	7%
Did you change your farming system in the last 10 years, forced by environmental changes?				
Yes	No	I do not know		
6%	91%	3%		
Do you use improved agricultural farming techniques (such as drip irrigation, for example)?				
Yes	No	I do not know		
14%	84%	1%		

In general, farmers reported that they have not adapted to environmental change over the last 10 years. Crop shifts (e.g. from onions to red peppers) or product shifts (e.g. from shrimp to catfish) in response to environmental change occurred not at all (46%), very limitedly (9%), or only partially (30%). Only 9% of the respondents mentioned that they had completely shifted their crop or product because of this. Neither did changes to their farming system (e.g. from agriculture to aquaculture) occur (91%). Additionally, 84% of the farmers stated that they did not use improved water-saving techniques. Most of the farmers (69%) using these techniques believe that there is a causal relation between groundwater extraction and the lowering of the water table. But among these latter, 74% did not use improved agricultural water-saving techniques.

Farmers may be aware of the importance of freshwater resources, but most of them are too poor to change their farming practices or to use alternative freshwater resources. Most farmers in our sample are near-poor (41%), earning less than USD 270 per person per year, or poor (22%), earning less than USD 210 per person per year. For addressing groundwater issues, some farmers see a role for the (local) government in providing information (19%), providing funds or subsidies (16%), developing engineering solutions (13%), or providing general (unspecified) help (21%).

Our expert interviews confirm the above. In coastal areas, farmers are forced to use groundwater due to the lack of other water sources (PM4, SE7.2, SE12; SE7). Over-exploitation has severely reduced the availability of fresh groundwater resources (PM4, PM6). According to the local policy experts, local and state authorities do recommend restricting the use of groundwater to prevent subsidence (PM1). However, farmers mainly care about their short-term benefits (SE12), and due to their limited economic means they must pump water for irrigation to generate their income (PM4).

Decentralization of groundwater governance and local stakeholder involvement

Both our survey and our interview data reveal that this criterion is not met in Soc Trang. Governance is centralized and top-down. Local stakeholders have hardly any voice in the making and implementation of policies concerning the utilization of natural resources.

The central government develops legislation regarding water resources and environmental degradation. They focus mainly on saltwater intrusion problems and coping with climate change (PM5) and have a sector-specific focus on engineering and water (SE13). Although subsidence also occurs in Hanoi, knowledge of subsidence at the central-government level is considered insufficient (SE3, SE8, SE9, SE11, SE13). According to the

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Law on Water Resources of 2012, the provinces have to issue documents related to water resources (e.g. provincial water resource master plans), but this has not been done, which causes difficulties for the implementation of policies for the DONRE at the district level in Vinh Chau District (PM3). Moreover, financial issues occur, since often not all the money budgeted at the national level arrives in the VMD (SE4, SE11). Sometimes only 80% of the funding arrives, leaving 20% in Hanoi (SE4). Also, plans of substantive scale made by the central government are often too big to manage for the local government at the district level (SE11). Our in-depth interviews, however, suggested a difference in perspective between scientists and policy makers. Interviewee SE15 said, 'There is not much concern from Hanoi for the VMD', while interviewee PM4 said, 'The Ministry of Agriculture and Rural Development is very interested in policies related to land subsidence. The prime minister and the deputy prime minister were here in person to measure salinity. Soc Trang Province is an agricultural province, and subsidence is a matter of survival.'

Stakeholder involvement is limited. Most of the surveyed farmers (57%) stated that they find it necessary for the government to include farmers' thoughts and concerns before promulgating a legal document on groundwater resources. But this never happens. Policies are not considered to require the consultation of non-governmental organizations, and there is no regulation in place to gather the farmers' opinions (PM2). Moreover, government staff involved in local authorities indicated that local residents should not be involved, since they have no technical knowledge, and could only raise their opinions when new projects are planned. However, local citizens have not received government consultancy at any governmental level, which reflects their minor role in water-related policies (Tri et al., 2016). As a result, according to an interviewee involved in policymaking (PM3), 'There is a knowledge gap as to the views and opinions of some civilians on environmental degradation.'

Discussion

Triangulating our data and confronting them with our criteria, we find that most of the criteria are not met. We do admit that we have focused only on a limited part of the coastal zone of the VMD. But we believe that many of the shortcomings in water governance described in this article are not location-specific but have a more general character, as our results are confirmed by recent publications. Bui, Nguyen, Bui, Le & Le (2017) argue that a comprehensive database of national water resources is currently under development and will provide a resource for basic investigational data, monitoring data and water resource prediction data. They also state that improving the legal framework and legal enforcement for the management and protection of water resources are among the highest priorities to address the VMD's environmental issues. Moreover, they put forward the importance of water resource planning, including the allocation and protection of water resources and the prevention of water-related damage. They also state that public education and awareness of sustainable water usage must be improved and that the consolidation of water institutions and the improvement of institutional capacities is under consideration.

Our results are also in line with the findings of Gilfillan, Nguyen, and Pham (2017), who argue that health-sector adaptation to climate change in the VMD is hampered

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by a lack of collaboration between government ministries and departments, on issues that span mandates. Formal mechanisms for interprovincial collaboration are lacking. Although decentralization efforts have sought to devolve authority and decision making to lower levels, state-centred, top-down policy making continues, and this limits collaborative coordination across scales. These coordination issues are recognized by the Vietnamese government, but to date there has been little success in addressing them.

Still, a study by Seijger, Hoang, van Halsema, Douven, and Wyatt (2019) on the implementation of the 2015 Mekong Development Plan shows that some seeds of change are present in the VMD. They find that officials of the DONRE realize the importance of reducing groundwater use and have written at least six proposals for projects to harvest and store rain and floodwater during the wet season. They also find that thoughts about rice production and interregional cooperation have changed at various levels of the Vietnamese planning system.

Tran et al. (2019) suggest increased recognition by the Vietnamese state of the relevance of public participation in flood control schemes and irrigation development. This recognition would enable more formal and informal collaborative learning practices between farming households and local government agencies. We expect that in the years to come the relevance of more participation will also be recognized in the domain of groundwater governance.

Conclusion and recommendations

We conclude that it is hard to classify current groundwater governance in the VMD as rational. Water system knowledge is only available to a limited extent, and data are often not sufficient or reliable enough for more advanced (model-based) analysis. Knowledge gaps are not addressed by research efforts, and limited monitoring occurs. The legal framework is not equitable or legitimate, and lacks compliance and involvement. Action and adaptation are lacking. Neither is there a clear, equitable, or sustainable long-term vision for development regarding groundwater resources; the focus is only on the short term. There is little or no opportunity for local stakeholders to influence local policy making, implementation or natural resource use cooperation.

Although some elements of rational groundwater governance are in place, achieving more rationality in groundwater governance will require a more thorough and open debate between all sectors of Vietnamese society to develop tailor-made solutions. Political and legal structures need to be adapted to better facilitate these debates and to implement the resulting policy measures. More specifically, we suggest the following improvements. First, a proper and easily accessible database system must be set up to enable more modelling studies on the interactions within the water system. Such studies could result in serious gaming tools, which could facilitate scenario development and decision-making processes. However, as a second element, governmental actors must acknowledge the importance of both scientific and lay knowledge in policy making. This requires wider stakeholder involvement and participation. Third, regulations should be adjusted to make them appropriate for environmental protection, e.g. by avoiding deliberate non-compliance for economic reasons. More specifically, we suggest incorporating enforcement mechanisms in

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groundwater-related regulations, such as Decision No. 11/2008/QĐ-UBND. Local authorities must inspect wells and groundwater usage at the household level. Moreover, the higher levels of governance must harmonize the implementation of policies at the lower levels. This can be done by reviewing current practices and clarifying uncertainties that result from a lack of provincial master plans and contradictory legislation. Such a review implies more involvement of local authorities and other stakeholders in policy making. These more open debates could also discuss measures like water saving, artificial groundwater recharge and the planting of climate-resilient crops.

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