SUSTAINABLE WATER MANAGEMENT AT COMMUNITY LEVEL: A CASE OF PAHANG, MALAYSIA

by Mohammad Reza
MIT-UTM Malaysia Sustainable Cities Program
Massachusetts Institute of Technology

Abstract

Fresh water is essential for life—among other things, a key contributor to food security, and a prerequisite for human and economic development. Water security—referring to the availability of fresh water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environment and economies—is therefore receiving considerable attention in discussions of national and regional development. It is expected that many regions, and particularly many in Southeast Asia, will face more pressure on water resources; and by extension on food security, biodiversity, human health, and livelihoods. This study examines loopholes in water management at the community scale, using a case in the state of Pahang, Malaysia. The study first quantified two key physical parameters—rainfall patterns and land use changes—over the past several decades, and then applied a qualitative methodology to evaluate the community perceptions of and degree of engagement in ensuring their water security. The main findings include: i) water security and food security are interlinked; ii) land use and water management policies should be harmonized to ensure that development upstream has minimal negative impact downstream; and iii) stakeholder participation is important for river basin planning, as it can show and relate how water management affects different stakeholder groups differently. In light of these findings, it is important to reconstruct the decision-making and implementation processes whereby community participation will be incorporated and increased. The paper suggests a set of workable recommendations for a more effective and systematic process to ensure food and water security in Malaysia.

© Mohammad Reza & Massachusetts Institute of Technology 2017

Introduction

Fresh water is essential for life, a key to food security, and a prerequisite for human and economic development. Water security refers to the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environment, and economies (Grey & Sadoff, 2007; Bakker, 2012), and is receiving considerable attention in national and regional development. However, as global environmental change and anthropogenic activities hamper natural flow regimes, worries about fresh water availability are increasing, particularly in the rapidly developing Southeast Asia region (Cook & Bakker, 2012). Many regional and international river basins are likely to experience low water security over the coming decades (Gain et al., 2016). It is evident that these regions will face more strains on water resources, and that these strains will put increasing pressure on food security (Rockstrom et al., 2009), biodiversity, and human health and livelihoods (Braadbaart & Braadbaart, 1997; Vorosmarty et al., 2010).

Currently, many parts of Malaysia are experiencing water crises due to population increases and increased demand for water in the industrial sector (Chan, 2009). The crisis has been severe in the Klang Valley, which comprises Malaysia's capital Kuala Lumpur and the state of Selangor—the country's most developed area, and home to almost half of Malaysia's population. The Klang Valley has a significant deficit of water availability of 152.6 and 182.6 mm rainfall per year in 2010 and 2020, respectively (MNRE, 2011). As annual rainfall amounts—approximately 3000 mm—are relatively high, many attribute the crisis of water to poor water management (Saimy & Yusof 2013; Chan, 2012). Nevetheless, under current circumstances, Klang Valley must augment its water supply from other sources to meet growing demand.

In 2004, to address the mounting crisis of water, the federal government planned to build the Pahang-Selangor Raw Water Transfer Project, which was designed to transfer raw water to the Klang Valley from the Semantan River in Pahang. However, this initiative exacerbates conflicting demands for water in the Pahang region versus the Klang Valley. Conflicting views and positions between the federal government and the state of Selangor have been evident as the project is being established ("New Straits Times" 2014, 2016). Moreover, residents, civil society groups, and NGOs (WWF, 2000; Furuoka, 2011) have criticized the initiative on the grounds that it may cause environmental degradation and leave the communities in the Semantan River basin water insecure ("The Malay Mail," 2010).

© Mohammad Reza & Massachusetts Institute of Technology 2017

Taking the above issues into consideration, this study will examine possible approaches for sustainable water management, and will suggest a scale that is better suited for effective management. The study will identify the gaps in implementation of the integrated approach for sustainable water management to ensure food and water security at the community level.

Semantan River basin

The Semantan River basin is an important sub-river basin of the Pahang River Basin. About 40,000 people live in 63 villages within this sub-river basin area. Approximately 54 percent of the total land use of this sub-river basin consists of agriculture (mostly oil palm and rubber), 33 percent is forest and developed areas cover 6 percent. Two interstate highways and the East-West Expressway pass within this sub-river basin. Many new commercial ventures and industries have been built in this area in recent years. The majority of the population lives on farming and fishing.

The Semantan River starts from the confluence of river Kelau and river Bentung at the Karak of the Bentong District. It ends where it drains into the Pahang River by the city of Temerloh. A number of tributaries originate from Titiwangsa Mountain and finally meet river Kelau and Bentung to become the Semantan River. River Kelau flows through extensive agricultural landscapes, while river Bentung traverses comparatively natural landscapes (Figure 1). Temerloh, on the Semantan River, is the second largest city in the Malaysian state of Pahang.

© Mohammad Reza & Massachusetts Institute of Technology 2017

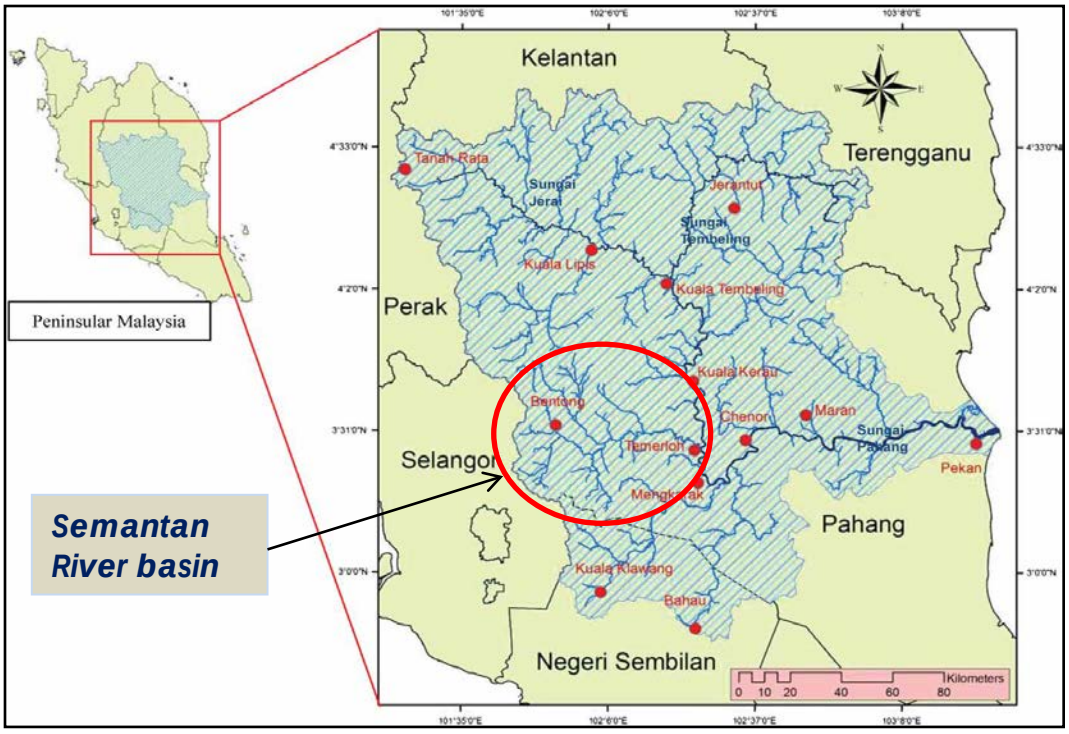

Figure 1: Semantan River basin, Pahang, Malaysia[1]

Pahang's climate is classified as tropical. The average annual temperature in Pahang is 26.8 °C and the rainfall is significant, with precipitation even during the dry season. The average annual rainfall in Pahang is 2,470 mm, and surface runoff is 1,100 mm. It is estimated that about 70 percent of the runoff flows to the sea. About 15 percent is available for use by all sectors, hence considered as "effective rainfall". This is used as an index that indicates the availability of unregulated flow—in other words, without dams, that could otherwise capture part of the high flow. The useable proportion of the runoff for various sectors in Pahang is 165 mm rainfall per year.

The water demand for the various sectors of potable water, irrigation, animal husbandry, and fisheries is displayed in Figure 2, presented as mm rainfall per year (MNRE, 2011). As there is significant effective rainfall, the scarcity of water may be due to poor water management and wasteful exploitation of water, rather than a lack of rainfall.

© Mohammad Reza & Massachusetts Institute of Technology 2017

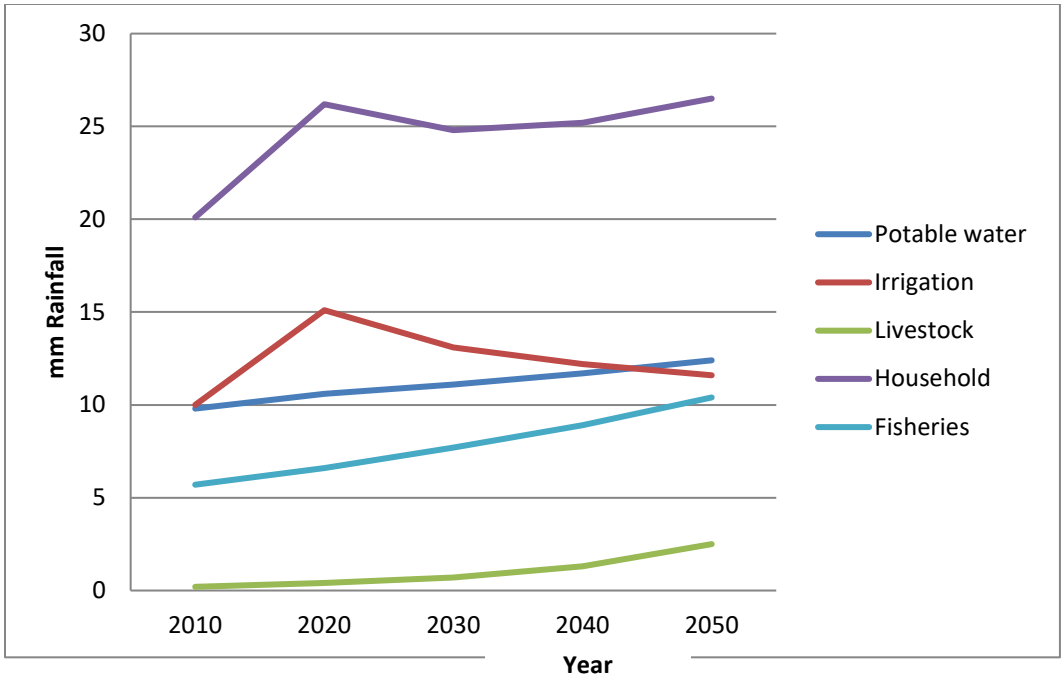

Figure 2: Per capita water demand for various sectors in Pahang, Malaysia[2]

The Semantan River is highly significant to the local economy, where many residents fish for a living. Rivers, including Semantan River in Temerloh district, are home to the silver catfish (*Pangasianodon hypophthalmus*), locally known as "Ikan Patin." Fish from the Semantan River is highly desired for its taste, which is dependent on the quality of water in the Semantan River. However, the quality of the river water has been declining over the past few years due to residential development, extensive commercial agriculture, and waste from industries. Fish stocks in the river are declining, and the fishing communities are among the hardest hit by degradation of water quality.

In 2017, the federal government of Malaysia completed a 44.56 km long raw water transfer tunnel mega-project—begun in 2010—at a cost of RM 9 billion. The scheme aims to transfer 1,890 million litres per day from Semantan River to the Hulu Langat water treatment plant in Selangor, to meet the water demand of the urban dwellers of the Klang Valley near Kuala Lumpur. Despite the Selangor state government's lack of interest ("Malaysiakini," 2010) and objections from many—including newspaper reports and features, social enterprises and NGOs including WWF (WWF, 2000; Furuoka, 2011)—the federal government and the Ministry of Energy, Green Technology and Water (KeTTHA) are enthusiastic about the raw water transfer from the Semantan River to the Klang Valley in Selangor. The water transfer has been interrupted several times since

© Mohammad Reza & Massachusetts Institute of Technology 2017

2016, however, due to poor quality and odor of the Semantan River water ("New Straits Times," 2016; "The Sun Daily," 2016).

The Semantan River became so badly polluted that in October 2016, two local water treatment plants had to be shut down, leaving locals without clean water ("Clean Malaysia," 2016; "New Straits Times," 2016).[3] Three factories were reportedly dumping toxic waste into the river, and media reports indicate that official negligence has allowed such behavior to persist. Solid and liquid waste released from urban areas, as well as soil erosion from development activities and farming, also contribute the pollution of the Semantan River. In a recent study, Marcel et al. (2013) reported that the water quality of Semantan River was found to be above the recommended limits of ammonia, sulphide, iron, and nitrite-nitrogen levels.

Methodology

This study uses mixed methods. First, a quantitative approach has been employed to identify the causes of water scarcity and deteriorating water quality in the Semantan River basin. The following measures were taken:

Rainfall time series data analysis: Rainfall data of last 30 years have been analyzed to understand whether water insecurity is due to declining rainfall in this region. The data are in the monthly format with total and average rainfall data collected from the Meteorological Department of Malaysia.

Spatio-temporal pattern analysis: Spatio-temporal data was analyzed to understand whether changes in land use have significantly affected water quality. ArcGIS 10 was used in spatial analyses. Land use maps of 2000 and 2010 were collected from the Department of Agriculture, Malaysia, and the land use map of 2014 from the Institute for Environment and Development, Universiti Kebangsaan Malaysia. The changes in land use over the years have been delineated, reclassified, and developed from the land use maps of the Semantan River basin. Data were extracted from the map's attribute tables, and then analyzed to produce comparative features of land use changes over time.

Next, using the inductive method, the study employed a qualitative approach (Burnard et al., 2008). A rigorous literature review of publications, journal articles, government reports, and newspaper accounts helped frame the research problem and identify the primary group of interviewees.

Objectives of semi-structured interviews: Interviews were conducted to (i) identify the different stakeholder groups in the Semantan River basin and in Temerloh (the administrative center of this river basin);

© Mohammad Reza & Massachusetts Institute of Technology 2017

(ii) determine how changes in water quality/quantity affect them; and (iii) summarize their concerns and suggest more localized and effective recommendations for addressing water insecurity.

Field survey involving interviews with stakeholders: 35 in-depth interviews were conducted (see Table A1 in the appendix). Interviews were with local villagers, fishermen, farmers, leaders of villages and *mukim* (the smallest administrative sub-division of districts in Malaysia), relevant agency representatives in the district level, a Land and District Office of Temerloh representative, and a federal-level policy maker. At first, representatives of the affected population (i.e., fishermen, farmers and household members) were randomly selected from the population who use water from the Semantan River. Subsequently, relevant local leadership were interviewed, and finally, the first and second round selected interviewees helped to identify the next group of interviewees. These interviews were conducted between September 2017 and January 2018.

Results/findings

This study found that there is a decrease in water security and food security for the villages of Pahang due to decreased quantity and quality of water in the Semantan River. The following section will share these findings, along with perceptions of local villagers, leaders, farmers, and fishermen to explore possible causes.

Decrease in water security due to a decrease in quantity and quality

An initial observation: *reduction in water quantity is not related to amounts of rainfall.* Total annual rainfall data between 1985 and 2014 was analyzed. The total and mean rainfall patterns do not show much significant difference in rainfall patterns, which might otherwise explain the causes of declining in water quantity over the last three decades (Figure 3). Also, it is not evident that climatic factors are responsible for declining water quantity, particularly when 2014 drought and flood events are compared.

© Mohammad Reza & Massachusetts Institute of Technology 2017

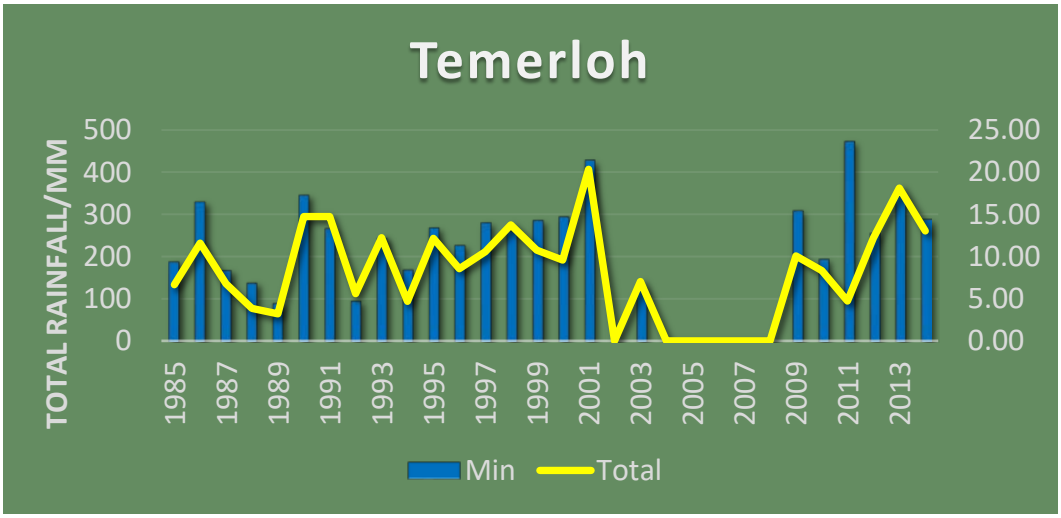

Figure 3: Rainfall in Temerloh, Malaysia: 1985−2014 [data are missing between 2004 and 2008][4]

Additionally, World Weather Online data shows a fairly regular and sufficient rainfall pattern and rainy days between 2009 and 2018 (see Figure A2 in the appendix). True, the total number of rainy days in 2014 was much lower than in other years, but the overall rainfall pattern and total number of rainy days implies that climatic factors, including less rain, are not responsible for the most recent water stress in the Semantan River basin area.

Water quantity decreased due to overuse and poor land use and water planning. It is evident from the field survey and responses from the villagers, farmers, fishermen, and local leaders that water quality has decreased significantly over the past few years (see Table 1 for detail). A fisherman who lives upstream, Mahmud Bin Sami, reported that the flow of river water has become very slow due to the construction of the dam for the water transfer project.[5] He used to catch all types of fish, but noticed that after 2010, the quality of fish and size of catch decreased. Fishermen downstream from the dam have noticed even more change in water quality due to the increased turbidity.[6] They can remember that in their youth, they could use river water for drinking and for all their household work. Once the water level went down, they couldn't use river water anymore. Moreover, they objected that during periods of heavy rain, the Kelau dam releases water that causes flooding downstream.

Stakeholders (Number)	Quantity/Quality Issues	Perceived cause of problem	Adaptations

© Mohammad Reza & Massachusetts Institute of Technology 2017

Fishermen	Overall, the river has reduced flow and an odor. Water quality is better upstream of the dam than downstream. The Semantan dam/intake prevents fish from spawning, which has led to decreased diversity and number of fish.	Land use changes (increased sand mining, increased industries along river, reduced forest and wetlands, and increased agriculture) have led to riverbank erosion and overall reduced quality of river water.	Looking for earnings from other sources, reducing living standard, seeking loans
Farmers and other villagers[7]	Piped water (from Semantan River) is interrupted (sometimes no water for 2 to 3 days) and water has odor. River quality and quantity downstream of dams have degraded and noticeable decrease in fish stocks. River water quality decreases even more after rain.	Blame interruptions in piped water supply on lack of maintenance and poor management. Also pointed to land use changes as a reason for decreased water quality.	Rain water harvesting, pond, reserving water, reducing living standard
Village leaders		Pointed to land use changes as a reason for decreased water quality but also highlighted the raw water transport project (to the Klang Valley).	Inspiring villagers to share water within their neighbors
District and Agency officials[8]	Recognize interruptions in piped water from Semantan River). Reduced quality of river water.	Piped water is interrupted due to high turbidity of river water. Emphasized a need to stop sand mining to improve river quality.	Pahang Water Management Co. (PAIP)rationing on water supply, collecting water from other river (i.e., Pahang River)

© Mohammad Reza & Massachusetts Institute of Technology 2017

Table 1: Matrix showing diversity of stakeholder perspectives on water quality/quantity issues and remedies ***

Water quality has decreased

Increased turbidity. It is reported that the turbidity of river water has increased significantly. Local villagers, fishermen, and community leaders think that over the past decade this situation reached an extreme.[9] A village leader, Mrs. Ida, noticed the situation becomes very bad after heavy rainfall, and the water supply managers experience greater problems at that time as well. Even a water processing plant has been damaged by mud infiltration.[10] ***

Mix of sand. Local people experience sand mixed with the supply water and sometimes their pipes become clogged due to sand. Village restaurant owners complaint they have been experiencing this problem at regular intervals over the last five years.[11] A Pahang Water Supply Authority (PAIP) Senior Operational Officer confirmed that due to high turbidity and muddy water, a water treatment plant had become inoperable, and the water supply had been interrupted. He said that, due to this, water quality cannot be well maintained, and the water supply network has become inoperable in many regions.

Increased sediment. Many local villagers, fishermen, and farmers [5,12,13] responded that that have observed that over the last few years, water from the Semantan River carries increased sedimentation.[12] They claim that river bank erosion as well as excessive agriculture accelerate the process.

Pollution. According to Mr. Mohammad Petah and many others, sometimes they find chemicals in the river water, especially in the rainy season. "When we usually go for fishing in the rainy season," he added, "we feel itchiness after coming back. This is because industries in upstream areas directly release chemicals into the Semantan River."

Palm oil and rubber plantations along the Semantan River also dispose waste directly into the river. Sand mining also causes pollution, as diesel used for machinery is dumped in the river.

Decrease in food security

The above findings show a significant decrease in quality and quantity of water in the Semantan River. The following section explains how food security has decreased over time, due to those changes.

Fish stocks have decreased. Recently, local residents have noticed that a number of types of fish have diminished. The villagers and fishermen who live upstream and downstream from the Semantan intake have a similar opinion.[13] They remember that, as recently as a decade and

© Mohammad Reza & Massachusetts Institute of Technology 2017

a half ago, when there was no significant development in this area, even a seven-month-old fish would be large enough to sell. Now, the growth rate of fish is reduced due to the poor quality of water, which means it takes longer for fish to grow large enough for fishermen to sell. The taste of the fish has also changed significantly, as well. Finally, fishermen's incomes in this area have decreased significantly as a result of declining fish populations. The district's fishery department records confirm that fish stocks in the river have declined significantly.

There are other negative indicators, as well. Many types of fish, including tilapia and *ikan patin,* are dying in their cages on commercial fish farms. Farmers believe that higher water temperature due to climate change—as well as turbid water and chemical pollutants released from the industries in upstream areas—are among the main causes of these fish dying in the cages. Commercial fish production in 2017 in the Temerloh district has reduced significantly, and the Temerloh District fishery officer thinks that the production loss is due to the deteriorating quality and quantity of Semantan River water.[14]

Diversity of fish has decreased. Several interviewees mentioned that the diversity of fish has decreased significantly in the past few years. It's now hard to find *ikan patin buah* (silver catfish), *temoleh* (Jullien's golden carp), and *jelawat* (Haven's carp) in the Semantan River. In 1976, the price of *jelawat* was only RM3 per kg; today, it is RM300 per kg. They are more profitable—but it is far harder to catch them.

Drivers of changes

This study also investigated the main drivers of the changes that affected the quality and quantity of water, and thereby affected the overall functions and services of the water resources in the Semantan River basin area over time. The following section presents the nature and processes of those drivers.

Sand mining. The Pahang state government is in charge of land use. District officials are responsible for enforcing regulation of sand mining, but do not have the ability to properly enforce good sand mining practices. Excessive sand mining has been observed in several places in the downstream Semantan River. Villagers and fishermen and a PAIP officer claimed that this practice is among the main causes of deteriorating water quantity and quality. Although many district officials recognize that a problem exists, they don't believe that they have the ability to enforce regulations.

Dam construction. The Kelau dam and Semantan intake dam—built in the Semantan River basin for the water transfer project that will transfer water to Klang Valley—have caused multiple problems. According to

© Mohammad Reza & Massachusetts Institute of Technology 2017

villagers, these dams are decreasing water quality and quantity; impeding movement of fish from downstream to their breeding area upstream, and thereby decreasing fish diversity and abundance; and creating other environmental problems. Some village leaders complain that government representatives haven't visited their village to hear their opinions on the dam and water transfer project. In many cases, those opinions are strong: they fear water transport will seriously affect their communities. They are frustrated that policy makers didn't take local people and leaders' opinions into account when undertaking this project.

Table 1 represents the diversity of perceptions and mindsets of the various stakeholders on different issues regarding the project. These perceptions and viewpoints are significantly related to the stakeholder's status and location, and how and where they are using the water.

Poor maintenance of water supply. One elderly villager, Mr. Mohammad Akik, explained that villagers often have to go to great lengths to get access to clean water, which he believes is due to poor maintenance of the water supply system. Many others complain that old and broken pipes are among the common supply system faults.[15] The villagers have made formal complaints to the Water Supply Authority (PAIP), but they are not satisfied by the authority's response. For his part, the relevant PAIP officer believes that village residents have been suffering due to the degraded water quality in the Semantan River, rather than the condition of the supply system. He disclosed that PAIP is currently looking to implement new technology and a new system for water treatment.

Rapid land use change due to deforestation and illegal conversion of wetlands into agricultural land. In Temerloh, forest land use decreased from 58 percent in 2000 to 46 percent in 2014, whereas agricultural land use increased from about 39 percent in 2000 to 47 percent in 2014. Built up areas also increased from 1.3 percent to 2.5 percent. These changes suggest that the regional land use policy is not capable of protecting the environment and natural resources like ecosystems and water.[16] The trends in land use change are even more drastic in the Semantan River basin, which has experienced rapid change over the past three decades. Land use changes in the years 2000, 2010, and 2014 are shown in Figure 4, which illustrates how human-dominated areas have increased over time. There have been significant reductions in forest cover between 2010 and 2014, which may explain why local people have recognized a significant decrease in water quality over the last five years. At the same time, agricultural and built-up areas have been increased to a significant degree (Figure 5).

© Mohammad Reza & Massachusetts Institute of Technology 2017

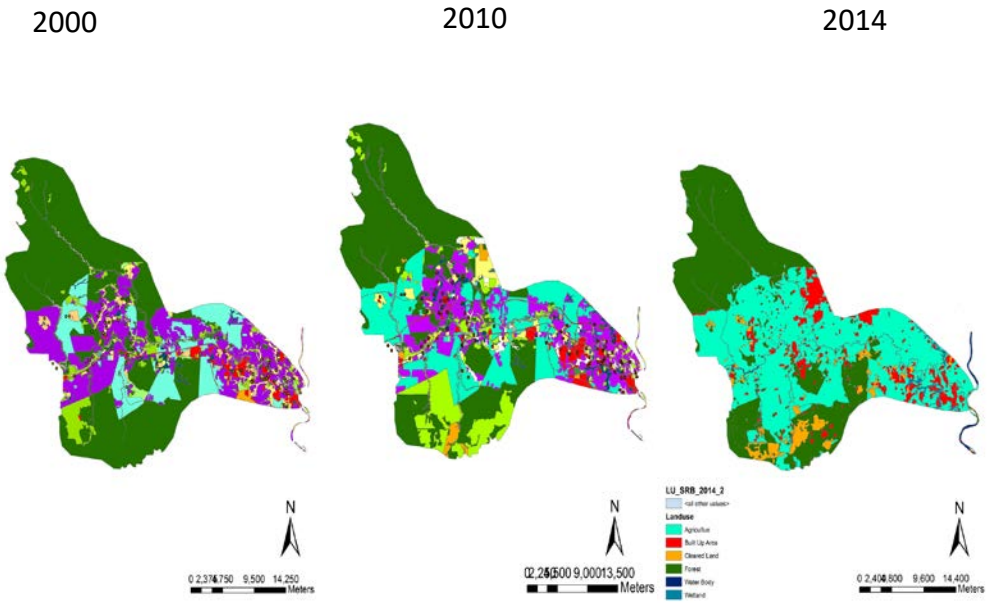

Figure 4: Land use change in the Semantan River basin in 2000, 2010, and 2014[17]

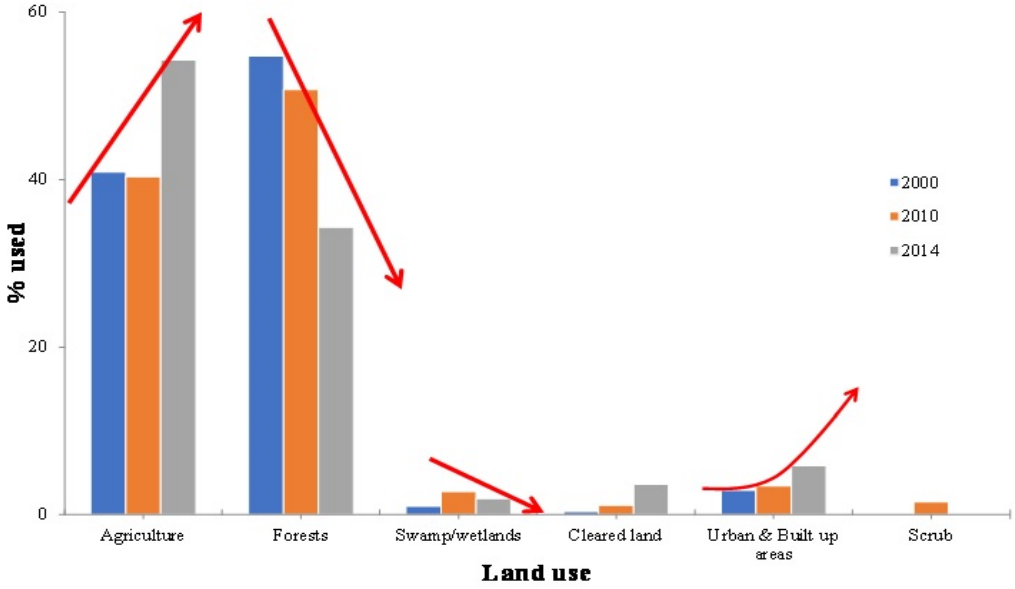

Figure 5. Land use changes in 2000, 2010, and 2014 in the Semantan River basin

© Mohammad Reza & Massachusetts Institute of Technology 2017

Poor environmental awareness and enforcement of environmental standards. The field survey and interviews indicated that some communities are draining wetlands and clearing forestland for oil palm cultivation. Toward that end, communities form cooperative societies to raise funds that are invested in the wetland conversion process, thereby building a social enterprise that enhances their livelihood. It is evident, though, that there is a very low level of understanding of the value of the natural systems that provide safeguards to their water security. The wetlands drying process may take 5 to 6 years.

Communities have undertaken wetland conversion in part because of the National Policy on Wetlands—comprising more than 60 federal and state laws for wetlands protection—which does not allow any sort of development in the wetlands (Ibrahim et al., 2012). By all accounts, however, this policy has not been implemented effectively. Land matters are conferred to the state government to manage, and the forests and wetlands fall under state jurisdiction. Responsibility for the enforcement of the National Policy on Wetlands therefore falls to the state law enforcement authority—and by extension, local officials. Unfortunately, these officials are sometimes corruptible, enabling local people to drain wetlands.

A Temerloh District officer said that by and large, industry is not concerned about how it disposes of its byproducts, even though excessive sand mining has a very detrimental impact on the river.[18] She thinks that if these conditions continue, the Semantan River will become unusable, which will significantly affect the economy, given how many people depend on the river. To remedy this situation, she suggested that a committee with strong enforcement powers for water management at the river basin level be created.

Certainly, federal policy makers are aware of the degradation in river water quality and the consequent suffering of local households, fishermen, and other affected groups. However, those policy makers argue that local problems must be solved by the relevant local authorities. A key official of the Ministry of Energy, Green Technology and Water (KeTTHA) who serves as a federal policy advisor observed, "National or regional policy may not always entertain all local issues like fish stock declining, or production loss of any agro product, due to a big project that has national or regional interest."

He also argued that "despite the fact that Pahang-Selangor water transfer project may cause some environmental problems, it will start full operation to ensure water security of a million city dwellers in Klang Valley."

© Mohammad Reza & Massachusetts Institute of Technology 2017

In response to the concerns of locals and fishermen communities regarding the project, he stated, "There may be some problems, but this is not our Ministry's area to focus. We ensure water supply. Water environment is a subject for another department. We will construct water reservoirs upstream, and will go for more structural establishments to hold more water."

He also commented on stakeholders' participation, or lack of participation, in policy-making: "I have no idea—do they have any role in such high-level planning and initiative? I don't know. And we cannot listen to what a community or fishermen group, for example, are thinking or suffering. A regional level policy cannot listen to all."

To summarize the results presented above:

i) Reduction in water quantity is not related to rainfall;
ii) Reduction in water quality and quantity, as well as hydraulic infrastructure (i.e., dams) has led to a reduction in fish stock diversity and quantity;
iii) There are differences in water quality upstream and downstream from the Semantan intake/dam;
iv) Water quality has degraded over the past ten years, and significantly so over the past five years;
v) Changes in land use (i.e. increased sand mining, increased industrial activity along the river, reduced forest and wetlands, and increased agriculture) have led to riverbank erosion and reduced quality of river water.

Overall, these processes disrupt the riverine ecological processes. They reduce water quantity and quality to an extent that harms aquatic biodiversity and ecosystem integrity.

Discussion

As is evident from the above findings, the state of Pahang experiences multiple problems that challenge communities' food and water security, and—at the same time—threaten sustainable water management practices. It is evident that, in general, Malaysia receives a good amount of rainfall. However, lack of environmental awareness, poor water and land management policies, and lax enforcement of laws are among the causes of an artificial scarcity of water within the communities living in the river basin. The following section describes, in more detail, the various aspects of these causes, and compares similar contexts using examples of other regions.

© Mohammad Reza & Massachusetts Institute of Technology 2017

Disconnect between federal, state and district policies and enforcement

The water transfer tunnel is the responsibility of the Ministry of Energy, Green Technology and Water (KeTTHA), a federal government agency. As noted, the effects of the tunnel include reduced water quantity and a negative impact on the river ecosystem, which are local impacts. In this case, federal, state, and local-level perceptions regarding how water should be managed differ significantly. Their existing approaches, however, mainly involve policy makers and practitioners (Bakker, 2012), and don't involve communities, which means that they largely ignore social and institutional capacities (Saimy & Yusof, 2013). But because upstream water withdrawal, deterioration of water quality, and the shortage of social infrastructure limit the availability of water resources (Oki et al., 2001), a more holistic approach and an environmental boundary unit (i.e., river-basin scale) may be a better approach for sustainable water resources management.

Poor land use and water management policy

This study revealed that in the ecosystem under examination, land use change is not integrated into water management. Spatial analyses show that poor land use policy has allowed parties to alter natural landscapes into artificial ones, such as extensive agriculture, townships, and transportation networks. They reveal, too, that declining forests and wetlands have significant negative impacts on water quality and quantity over time. It is also evident that the destruction of riparian (river bank) ecosystems and forests has made the land susceptible to erosion, thus allowing soil to drain into the river system. Due to this, the turbidity of the river water increased and the color and transparency of the water changed. In addition, as noted, industrial factories and rubber and oil palm farmers release solid and chemical pollutants in the water, which directly affects the river's ecosystems and biodiversity (DOE, 2005). Such effects include declining fish stocks, which threatens fishermen communities.

In summary, rapid development activities, unsustainable consumption, extensive agriculture, poor regional and structural planning, and increasing extreme weather events are exerting increasing pressure on the region's freshwater resources (Chan, 2012).

Poor enforcement of environmental protection laws

© Mohammad Reza & Massachusetts Institute of Technology 2017

Although Malaysia's Environmental Quality Act of 1974 prescribes a fine of up to RM100,000 and/or a jail term of up to five years for polluting rivers, its enforcement is rare ("Clean Malaysia," 2016). One reason is a general lack of environmental awareness, and a failure to underscore the importance of keeping rivers free of pollutants. Meanwhile, policies that are made at one level (federal) are meant to be enforced at another (state). But sometimes, federal and state government represent different political parties, and thus have competing interests. Actual jurisdictions may be unclear, or changeable. For example, sometimes state governments seek more control over federal initiatives ("New Straits Times," 2014). Finally, many blame corrupt officials for not enforcing laws, especially at the local level. As a result, factories have been allowed to operate directly on river banks, causing untreated waste and other effluents are to flow directly into rivers (or at least leach into them) ("Clean Malaysia," 2016).

Stakeholders' experiences are different based on their status

Stakeholders are affected differently, based on where they are located along the river and how they use the river. These differences are important to understand when developing policies or constructing hydraulic infrastructure like dams or water transfer tunnels. It is evident from this case study that the placement of the dam has interrupted fish spawning, causing a decrease in the overall diversity and number of fish in the river. This has disproportionately affected the fishermen who depend on the river for their livelihood.

Lack of sustainable water management practices

Establishing a dam, reservoir, or water transfer tunnel may solve a water-related problem for a particular area—in this case, the Klang Valley. However, at the same time, such structures may well create problems for downstream communities' water availability, reducing fish stocks and causing environmental harm in the long run. While these initiatives may relieve the water stress in a particular region or set of communities, they may not be sustainable, and may create long-term environmental problems if they do not reliably consider the relevant environmental and ecological aspects of the initiatives (Pahl-Wostl et al., 2013). Therefore, recent global initiatives suggest linking food and energy security with national or regional water security approaches (Sastry et al., 2015).

This study similarly shows how water and food security are interlinked. In practice, however, policies that deal with the hydrological,

© Mohammad Reza & Massachusetts Institute of Technology 2017

ecological, and socioeconomic aspects of water separately ignore this inherent interdependency, and thereby undercut long term sustainability (Engle et al., 2011). At the same time, the importance of community culture, economy, and choice may not be addressed in national or regional initiatives. It is therefore important to consider different aspects of the environment and different interests of stakeholders, when planning a regional initiative for water management. Stakeholders must put forward their issues and priority areas to discuss, evaluate, and delineate how different issues will be addressed in a regional initiative for water management. When environmental and ecological aspects are taken into account concurrently with stakeholder participation, an effective and workable strategy may emerge to ensure long-term sustainable water management initiatives.

Malaysia has federal and state government systems which someimtes overlap, including in the realm of water management (Chan 2009, 2012), and sometimes compete—for example, in the governance of water infrastructure projects ("New Straits Times," 2014). As noted, water management in Malaysia has become fragmented due to implementation of policies and laws at different levels of government (Saimy & Yusof, 2013). Although many important water management laws and policies have been introduced in Malaysia ,(e.g. the Water Act 1920 (Revised in 1989), the Environmental Quality Act 1974, and the National Water Services Commission Act 2005), implementation has been hindered due to lack of support from stakeholders and lack of integration among the agencies involved in water management (Khalid et al., 2013). Many localized issues and needs are ignored when policymakers are framing the national water security policies.

Scale of water management

The spatial extent of scale of water management is an important factor in effective management (Bakker & Morinville, 2013). A basin-wide scale has been successfully used to balance user needs for water resources, protection from water-related hazards, public participation in decision making, effective monitoring, and resources mobilization (Loubet et al., 2013). A policy and legislative framework is required to ensure the effectiveness of the river basin organization (Global Water Partnership, 2004). In this case, a river basin scale is important for ensuring water and food security, as well as for sustainable water management.

Looking at the example of the Semantan River, it is evident that upstream land use and other anthropogenic activities are helping to determine downstream water quality and quantity. Eventually, an

© Mohammad Reza & Massachusetts Institute of Technology 2017

integrated approach and laws that require proper monitoring may provide the necessary support to the river basin for effective water planning, maintenance of sustainable management of water quality and quantity, environmental integrity, and conflict management (Lee & Dinar, 1996). Vital ecological processes—such as life cycles of aquatic organisms like fish, or sediment transport and deposition, are often complex, and tend to require careful consideration of both spatial and temporal scales and levels (Dore & Lebel, 2010). As the issues of this case are considered, "polycentric river basin management"—emphasizing local, collective ownership and promoting locally-agreed ownership that is institutionally, organizationally, and geographically more decentralised—may be effective for sustainable water management (Lankford & Hepworth, 2010).

Whatever scales are set for the community's common resources to be managed, a "tragedy of the commons" may be inevitable. On this basis, recent studies show that sustainable common pool resource (CPR) use is possible, and the common resource can be managed in a sustainable manner (Ostrom 1990, 2010). Therefore, a community-based resource management approach can be successful in maintaining natural resources in a sustainable manner if the communities follow certain common norms and conditions (Agrawal & Chhatre, 2006; Pailler et al., 2015).

Recommendations

As described in this paper, it is important to prioritize needs in order to design a strategy for implementing sustainable water management in Malaysia. Some recommendations are listed below, for both short-term and long-term implementation.

Short term (immediate measures):

- Increase environmental awareness to reduce conversion of wetlands into agricultural land by villagers.
- All form of plantations at the banks of the river must be stopped. Reforestation and afforestation should be implemented to revive the destroyed riparian ecosystem and reduce riverbank erosion.
- Pollution generated from industrial and agro-based commercial activity and households should be stopped immediately; proper enforcement of existing laws is needed to ensure that pollution does not continue.

© Mohammad Reza & Massachusetts Institute of Technology 2017

- Indiscriminate sand mining should be stopped to control high levels of turbidity that are harmful for aquatic flora and fauna, particularly fish.
- It is important to identify fishermen groups that have been severely affected by poor water management practices, and to provide them with the necessary support to revive their affected fisheries.

Policy changes:

- Better enforcement of land use planning and environmental law should be enacted. Table A4 in the appendix shows various agencies and departments involved at multiple administrative levels, from the federal to district level, in water management. Figure A5 shows the existing executive committee deal development activities at the state level. However, effective co-ordination among different agencies is not satisfactorily practiced. At present, there is no specific committee for water management at the state and local government levels (see Figure A5); therefore, many water-related issues remain hidden or unaddressed. This study suggests a management authority based at the river basin level: the River Basin Council (see Figure A6 in the appendix), which may provide better water management. It is suggested to include the following agencies for sustainable water planning and management:
    - Department of Fisheries (DOF)
    - Department of Wildlife and National Parks (DWNP)
    - National Disaster Management Agency (NADMA)
    - Pengurusan Air Pahang Berhad (Pahang Water Management Company, or PAIP)

- The River Basin Council may be led and governed by the National Disaster Management Agency (NADMA), which falls under the National Security Council of the Prime Minister's Office. In Malaysia, NADMA governs and manages disasters like floods and draughts. They have organizational bodies in place extending down to the district level. All the related agencies that have been suggested here for water management have been working with NADMA for disaster management. As this integrated approach may reduce hydro-meteorological disasters and may implement

© Mohammad Reza & Massachusetts Institute of Technology 2017

long-term initiatives for disaster risk reduction in the region, it is rational to involve NADMA in the proposed River Basin Council.

- It is important to integrate land use and water management planning bodies to make land and water planning sustainable.
- Any development in the river basin area must be passed through the proposed River Basin Council. The Environmental Impact Assessments (EIA) should be carried out by the National Water Research Centre, or by the academics attached to the council.
- Sand mining from the river must be properly certified by the River Basin Council, and must be kept within designated limits to reduce the negative impacts of sand mining.
- A buffer zone must be created to maintain more space between agricultural land and the river, so that fertilizers and agricultural waste aren't carried as easily into the river. This will also contribute to reducing river bank erosion.
- There is a need to increase wetlands and conserve forests. The Semantan River basin is naturally rich with diverse wetlands and riparian and forest ecosystems. Many of them have been converted to other anthropogenic landscapes, predominantly agriculture. It is important to stop such conversions immediately, and to take initiatives to revive wetlands and forests through various activities. The Forestry department should launch initiatives—such as social forestry and engaging school and college students in reforestation and afforestation programs—that can help to build awareness about the importance of these valuable ecosystems.
- Increase stakeholder participation to identify ways to mitigate potential negative impacts. For example, local communities and the local government should identify practices that affect river water quality, e.g., waste disposal and pollution. They should develop environmental awareness programs for local people and other stakeholders, and identify issues that may affect communities due to dams or the water transfer project.
- It is important to reliably conduct EIAs with utmost transparency and accountability before advancing infrastructure projects, including dams, reservoirs, or water tunnels. EIAs should be conducted by professional agencies

© Mohammad Reza & Massachusetts Institute of Technology 2017

that have been provided with enough independence and freedom to carry them out. Recommendations from the EIAs must be followed while building infrastructure. Political will, and a commitment to sustainability and the protection of natural resources, is very important.

Conclusion

As is apparent from the Semantan River basin case, the scarcity of water in Malaysia and in the Southeast Asian tropical region is not due to climatic or hydro-meteorological factors. Malaysia receives an average annual rainfall of 2,940 mm, which is considered to be adequate. However, rapid development activities, population growth, and extensive commercial agriculture have increased demand for water in various parts of the country (Abidin, 2004). These increasing water uses have also led to deteriorating water quality and quantity, and increased water pollution ("The Star," 2016). Existing approaches towards management have been largely sectoral and supply-driven. Unjustified usage of water by dominating sectors (e.g., agriculture, industry, and water transfer projects), inadequate attention to maintain the ecosystems that can continue to supply water in a sustainable way, and poor and fragmented land use policies that result in destruction of forests and wetlands for oil palm plantations, urbanization, and excessive sand mining are directly or indirectly affecting the quantity, quality, and sustainability of the water environment ("The Star," 2016). These practices cause deterioration of water quality and quantity in many Malaysian rivers—including the Semantan River—that lead to decreases in fish stocks ("The Star," 2016; "New Straits Times," 2017) and decreasing river ecosystem integrity. As a consequence, sustainable management of water resources has become a contemporary challenge across Malaysia.

Overall, the availability of water, and quality and quantity of water in Malaysia is largely affected due to anthropogenic activities and poor water management practices. The major lessons identified through this case are:

i) Water security and food security are interlinked,
ii) Land use and water management policies should be harmonized to ensure that development upstream has minimal negative impact downstream, and
iii) Stakeholder participation is important for river basin planning, so planners must see and relate how water

© Mohammad Reza & Massachusetts Institute of Technology 2017

management affects different stakeholder groups differently.

Sustainable water management in the broader Southeast Asian region should take these lessons into account both for short-term and long-term planning.

The case of Pahang, Malaysia, also shows how anthropogenic activities that degrade water quality and quantity in a river may affect the livelihoods and food security of communities. In this case, the fish stock and its diversity are significantly affected, and subsequently the economy, culture, and food security of the communities are affected. Extensive agriculture, widespread logging, sand mining and destructions of wetlands are frequently practiced in the river basin, particularly in the upstream areas, and these activities are destroying the ecological and environmental integrity of the water system. These processes are leading to a decrease in the amount of flow in the surface run-off, resulting in lowered water levels in the river. Additionally, widespread pollution and high turbidity are causing a decrease in fish stocks.

Based on the above findings, this study gives specific recommendations for sustainable water management at the river basin scale. The findings and recommendations in this study can be of potential use for sustainable water management and improved water and food security for communities in throughout Malaysia and the Southeast Asian region.

© Mohammad Reza & Massachusetts Institute of Technology 2017

Acknowledgments

Thanks are given to the interviewees, villagers, village leaders, and local leaders of the study area for providing valuable information and for their heartfelt support. Thanks to Yasmin Zaerpoor and Lawrence Susskind for their scholarly insights and comments throughout the study, and to Selmah Goldberg for editorial input and excellent support throughout.

References

1. Abidin, R.Z. 2004. Water resources management in Malaysia: the way forward. In: Asia Water 2004, held between 30 March and 02 April, 2004 in Kuala Lumpur, Malaysia
2. Agrawal, A., and Chhatre, A. 2006. “Explaining success on the commons: community forest governance in the Indian Himalaya.” *World Development* 34 (1):149-166
3. Bakker, K. 2012.”Water security: research challenges and opportunities.” *Science,* 337, 914–5. doi: 10.1126/science.1226337
4. Bakker, K. and Morinville, C. 2013. "The governance dimensions of water security: a review.” *Philosophical Transactions in Royal Society A* 371: 20130116
5. Bernama, 2016. DoE conducts through probe on Sungai Semantan water pollution, 10.10.16
6. Braadbaart, O. and Braadbaart, F. 1997. "Policing the Urban Pumping Race: Industrial Groundwater Overexploitation in Indonesia." *World Development,* 25(2), 199-210
7. Burnard, P., Gill, P., Stewart, K., Treasure, E. and Chadwick, B. 2008. "Analyzing and presenting qualitative data." *British Dental Journal* 204 (8), 429-432
8. Chan, N.W. 2009. "Issues and challenges in water governance in Malaysia." *Iranian Journal of Environmental Health, Science and Engineering* 6 (3), 143-152
9. Chan, N.W. 2012. "Managing urban rivers and water quality in Malaysia for sustainable water resources." *Water Resources Development,* 28 (2), 343-354
10. Clean Malaysia, 2016. Cases of water pollution highlight lack of effective law enforcement, 10.18.16. http://cleanmalaysia.com/2016/10/18/cases-water-pollution-

© Mohammad Reza & Massachusetts Institute of Technology 2017

highlight-lack-effective-law-enforcement/ [accessed on January 12, 2018]
11. Cook, C. and Bakker, K. 2012. "Water security: debating an emerging paradigm." *Global Environmental Change*, 22, 94-102.
12. DOE, 2005. Annual Report, 2004, Department of Environment, Pahang, Malaysia
13. Dore, J., and Lebel, L. 2010. Deliberation and scale in Mekong region water governance. Environmental Management, 46, 60-80
14. Engle, N.L., Johns, O.R., Lemos, M.C. and Nelson, D.R. 2011. "Integrated and adaptive management of water resources: Tensions, legacies, and the next best things." *Ecology and Society* 16(1): 19
15. Furuoka, F. 2011. "Japanese aid to the Pahang-Selangor Water Transfer Project in Malaysia: Aid guidlines and decision making." *New Zealand Journal of Asian Studies*, 13 (1): 31-45
16. Gain, A.K., Giupponi, C. and Wada, Y. 2016. "Measuring global water security towards sustainable development goals." *Environment Research Letters*, 11, 124015. doi:10.1088/1748-9326/11/12/124015
17. Global Water Partnership, 2004. Catalyzing change: A handbook for developing integrated water resources management (IWRM) and water efficiency strategies. Rep., 1-56 pp, Global Water Partnership (GWP), Stockholm, Netherlands
18. Greay, D. and Sandoff, C. W. 2007. "Sink or swim? Water security for growth and development." *Water Policy,* 9, 545-571
19. Ibrahim, I., Aziz, N.A. and Hanifah, N.A. 2012. "The laws of Wetness: the legislative framework in Malaysia regarding wetlands conservation." *Procedia - Social and Behavioral Sciences*, 50, 574-581
20. Khalid, R.M., Rahman, S.A, and Mokhtar, M.B. 2013. "Legal perspective on development policies for sustainability of water in Malaysia." *Sustainable Development,* 21, 144-151
21. Lankford, B. and Hepworth, N. 2010. "The cathedral and the bazaar: Monocentric and polycentric river basin management." *Water Alternatives*, 3(1), 82-101

© Mohammad Reza & Massachusetts Institute of Technology 2017

22. Lee, D. J., and Dinar, A. 1996. "Integrated models of river basin planning, development, and management." *Water International,* 21(4), 213-222
23. Light, S., Medema, W. and Adamowski, J. 2013. "Exploring collaborative adaptive management of water resources." *Journal of Sustainable Development*, 6 (3)
24. Loubet, P., Roux, P., Nunez, M., Belaud, G. and Bellon-Maurel, V. 2013. "Assessing water deprivation at the sub-river basin scale in LCA integrating downstream cascade effects." *Environmental Science and Technology* 47, 14242-14249
25. Malaysiakini, 2010. Water transfer project: "What's the rush, DMP?" 07.20.10.
26. Marcel, G., Sabri, M.Y., Siti-Zahrah, A. and Emikpe, B.O. 2013. "Water condition and identification of potential pathogenic bacteria from red tilapia reared in cage-cultured system in two different water bodies in Malaysia." *African Journal of Microbial Research,* 7, 5330-5337
27. MNRE, 2011. *Review of the National Water Resources (2000-2050) and Formulation of National Water Resources Policy,* Volume 12, Pahang, Final Report, August 2011, Kuala Lumpur, Malaysia: Ministry of Natural Resources and Environment, Malaysia
28. New Straits Times, 2014. Selangor wants executive role in Langat 2 project, Oct 16, 2014
29. New Straits Times, 2016. Too much politicking over water, 12.19.16
30. New Straits Times, 2017. "Ikan Patin" at risk of becoming endangered, 11.12.17
31. Oki, T. Agata, Y. Kanae, S. Saruhashi, T. Yang, D. and Musiake, K. 2001. "Global Assessment of Current Water Resources using the Total Runoff Integrating Pathways." *Hydrological Sciences Journal,* 46, 983-996
32. Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK: Cambridge University Press
33. Ostrom, E. 2000. "Polycentric systems for coping with collective action and global environmental change." *Global Environmental Change*, 20, 550-557
34. Pahl-Wostl, C, Palmer, M. and Richards, K. 2013. "Enhancing water security for the benefits of humans and

© Mohammad Reza & Massachusetts Institute of Technology 2017

nature - the role of governance." *Current Opinion in Environmental Sustainability,* 5(6), 676-684
35. Pailler, S., Naidoo, R., Burgess, N.D., Freeman, O.E. and Fisher, B. 2015. "Impacts of community-based natural resource management on wealth, food security and child health in Tanzania." *PLoS ONE*, 10(7), e0133252. https://doi.org/10.1371/journal.pone.0133252
36. Rockstrom, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. and Gerten, D. 2009. "Future water availability for global food production: The potential of green water for increasing resilience to global change." *Water Resources Research,* 45, W00A12, doi:10.1029/2007WR006767
37. Saimy, I. S. and Yusof, N. A. M. 2013. "The need for better water policy and governance in Malaysia." *Procedia- Social and Behavioral Sciences,* 81, 371-375
38. The Malay Mail, 2010. Kelau Dam project: Need to look for other options. 09.15.10.
39. The Star, 2016. Stop Contamination of Malaysian Rivers, Editorial Notes, 10.12.16
40. The Sun Daily, 2016. Sg Semantan pollution: Pahang DOE prepared to meet Selangor government. 10.12.16
41. Varady, R. G., Zuniga-Teran, A., Garfin, G. M., Martin, F. and Vicuna, S. 2016. "Adaptive management and water security in a global context: definitions, concepts and examples." *Current Opinion in Environmental Sustainability,* 21, 70-77
42. Vorosmarty C J, McIntyre, P. B. Gessner, M. O. Dudgeon, D. Prusevich, A. Green, P. Glidden, S. Bunn, S. E. Sullivan, C. A. Reidy Liermann, C. and P. M. Davies, 2010. "Global threats to human water security and river biodiversity." *Nature*, 467, 555–61
43. Wallace J.S., Acreman M.C. and Sullivan C.A. 2003. "The sharing of water between society and ecosystems: from advocacy to catchment based co-management." *Philos Trans R Soc Lond B Biol Dec* 2003, pp 513–528
44. WWF, 2000. Comments to the Department of Environment on the Detailed EIA for the Pahang to Selangor Water Transfer Project. World Wide Fund, Malaysia, November, 2000
45. Yaseen, Z.M., Ebtehaj, I., Bonakdari, H., Deo, R.C., Mehr, A.D., Mohtar, W., Diop, L., El-shafie, A. and Singh, V.P. 2017. "Novel approach for streamflow forecasting using a

© Mohammad Reza & Massachusetts Institute of Technology 2017

hybrid ANFIS-FFA model." *Journal of Hydrology*, 554, 263-276

© Mohammad Reza & Massachusetts Institute of Technology 2017

Notes

[1] Modified from Yaseen et al. (2017)
[2] MNRE, 2011 (Review of the National Water Resources 2000−2050)
[3] On October 10, 2016, Selangor State's two water treatment plants had to be temporarily shut down at 8.30 p.m. and 10 p.m., respectively, due to odor pollution suspected to have originated from the Semantan River in Pahang ("Bernama," 2016). The Straits Times reported both the Selangor and Pahang rivers had been contaminated by the factories' waste that was released into the water ("New Straits Times," 2016).
[4] Based on data from Meteorological Department of Malaysia
[5] Author interview on 10.16.17 in Kampong Kengkong with Muhammad Bin Abdullah Sami (fisherman, age 60). I will cite each of my local interviewees once, for simplicity's sake, but I draw on their relevant observations throughout this section. See Table A1 in the appendix for a more detailed description of interviews.
[6] Author interviews on 10.18.17 in Kampong Lorong with Mohammad Petah (fisherman, age 60), Razzak Bin Ishak (cage fisherman, age 50; and Nor Almi Bin Hashim (fisherman, age 47, Kampong Lorong
[7] Author interview on 10.05.17 in Kampong Raantau Panjang with Mohammad Bin Akik (villager, age 76
[8] Author interview on 10.16.17 in Kampong Mempateh with Ida Rayani Abu Bakar (Secretary, Village Development and Security Committee, age 37)
[9] Author interviews on 10.06.17 in Kampong Sungai Buluh with Roz Bin Adi (farmer, age 69); and with Mohammad Yahia (village leader, age 56, Kampong Teris) on 10.05.17
[10] Author interview on 10.19.17 in Temerloh with Mohammad. Daud Bin Musa (PAIP Officer, age 42)
[11] Author interviews on 10.17.17 in Kampong Cempaka Kiri with Nor Farini Nazlin (restaurant owner, age 30, and Piah (restaurant owner, age 60)
[12] Author interviews on 10.17.17 with, among others, Rosnani Binti Din (villager, age 52, Kampong Cempaka Kiri); Haji (community leader and vegetable farm owner, age 57, Kampong Lanchang); and Akeong (farmer, age 31, Kampong Lanchang)
[13] Author interviews with Haji Abdullah Bin Jusoh (community leader, age 81, Kampong Lorong, 10.18.17); and Nor Azhar Bin Matludin (fisherman, age 50, Kampong Lengkong, 10.16.17)
[14] Author interview on 10.19.17 in Temerloh with Mohammad Shahidan Bin Rushan (Fishery Officer, Fishery Department, age 39)
[15] Author interview on 10.19.17 in Kampong Jergoh with Alias (farmer, age 57, Kampong Jergoh)
[16] Author interview on 10.17.17 at Kampong Bukit Lakum with Abd Rahman Bin Ismail (Federal Land Development Authority Manager, age 56)
[17] Analyzed and modified from regional land use maps of 2000 and 2010 obtained from the Department of Agriculture, Malaysia; and land use map of 2014 from the Institute for Environment and Development, Universiti Kebangsaan Malaysia
[18] Author interview on 10.19.17 at Temerloh with Nur Hidayah binti Che Omar (Assistant District Officer, Temerloh Land and District Office, age 37)

© Mohammad Reza & Massachusetts Institute of Technology 2017