Community water access, availability and management survey in the Tonle Sap Region, Cambodia

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COMMUNITY WATER ACCESS, AVAILABILITY AND MANAGEMENT SURVEY IN THE TONLE SAP REGION, CAMBODIA

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This synthesis report is part of a set of study reports that includes three case studies:

- Joffre O. 2014. Community survey on water access, availability and management, Tonle Sap Region, Cambodia: Focus group discussions survey report.
- Joffre O. 2014. Community survey on water access, availability and management, Tonle Sap Region, Cambodia: Households survey report.
- de Silva S. 2014. Institutional profiles from the Tonle Sap Lake Region: Findings from informant interviews. Penang, Malaysia: CGIAR Research Program on Aquatic Agricultural Systems. Program Report: AAS-2014-44.

As such, some sections draw heavily on one or more of the above contributing reports. This is especially the case with Section on governance of aquatic agricultural systems, which is a summary of information presented in the last of the reports listed above.

CONTENTS

PREFACE

The Tonle Sap of Cambodia is a vast lake and wetland that includes both the Tonle Sap Lake and the Tonle Sap River, which connects hydrologically to the Mekong River. Tonle Sap Lake is a tropical shallow and seasonally inundated floodplain lake system. Its geomorphology is very transient, depending on the hydrological phases—the water level oscillates from less than 1 meter (m) to about 10 m in depth annually, and the lake surface expands and contracts from about 2700 square kilometers (km^2) to 16,000 km^2. Much of the Tonle Sap is open water, but there are also large expanses of flooded forest and shrubland, along with deep-water rice fields and other forms of cultivation.

The Tonle Sap region supports a huge population through its enormous fisheries productivity and water supply and provides the last refuge for some of Asia's most globally significant biodiversity. Human population and development pressures, however, are increasing year to year.

The ancient Khmer civilization, exemplified by the Angkorian temple complex, was based on the shores of the Tonle Sap, and the two products that formed the basis of this civilization are still produced in abundance: rice and fish. The Tonle Sap is of great significance to Cambodians and is described as forming the heart of the country's culture and economy.

The Royal Government of Cambodia, under the leadership of Samdech Hun Sen, Prime Minister of the Kingdom of Cambodia, clearly recognized the need to enhance the effectiveness and efficiency of the region's governance by the establishment of the Tonle Sap Authority in 2009. It is one of the most significant steps, politically, ever taken by the Royal Government of Cambodia.

The Tonle Sap Authority was established with the mandate of coordinating management, conservation and development of the Tonle Sap Lake region.

The evaluation of the Tonle Sap Lake ecosystem made by the Tonle Sap Authority since 2010 has focused on the main human activities in relation to natural resources, such as hydrology, flooded forest, agriculture, fishery, degradation of water quality in the dry season and livelihoods in floating villages.

The memorandum of agreement between WorldFish and the Tonle Sap Authority was signed in August 2013 for the CGIAR Research Program on Aquatic Agricultural Systems (AAS) scoping in the Tonle Sap region, which focused on improving the well-being of people dependent on aquatic agricultural systems by undertaking a community survey on water access, availability and management.

The conclusion of this phase of study is the need to help, learn, and share information and experiences between the different types of communities. Therefore, AAS and the Tonle Sap Authority convened what is termed a "best practice" committee meeting with representatives from the main government agencies. The results of this synthesis report highlight the distinctions between communities, with access to drinking water, water quality, lack of water storage, and irrigation systems as the first priorities to address. Other potential interventions could address livelihoods of local communities, such as improving income via fish processing and diversifying livelihoods with floating gardens.

Professor Lim Puy
Vice chair of the Tonle Sap Authority

INTRODUCTION AND OBJECTIVES

The Consultative Group on International Agricultural Research (CGIAR) has created a new generation of global agricultural research programs. The CGIAR Research Program on Aquatic Agricultural Systems (AAS) seeks to reduce poverty and improve food security for the millions of small-scale fishers and farmers who depend on the world's floodplains, deltas and coasts. AAS combines more conventional approaches for introducing and scaling technical innovations, such as applied research and training, with approaches that foster innovation and promote institutional and policy change. Specifically, AAS utilizes participatory action research with communities to identify technology and policy solutions that best meet community long-term needs. Participatory research empowers communities and strengthens their capacities, provides access to new knowledge, and links them effectively with other stakeholders. AAS is implemented by WorldFish, the International Water Management Institute (IWMI) and Bioversity and engages a wide range of local, national, global and regional organizations that legitimize the integration of social and ecological systems through the engagement of partners and communities in the research process.

AAS research is designed to meet the goal of improving the well-being of aquatic agricultural systems-dependent people and is achieved through six research themes:

- Theme 1: Sustainable increases in productivity
- Theme 2: Improved nutrition
- Theme 3: Gender equality
- Theme 4: Equitable access to markets
- Theme 5: Resilience and adaptive capacity
- Theme 6: Empowering policies and institutions
- Theme 7: Effective knowledge sharing, learning and innovation

During the rollout of AAS in Tonle Sap in 2013, water management was highlighted as one of the key development challenges. With limited capacity to regulate water, the situation oscillates between too much water in the wet season and too little water in the dry season. Access to and availability of water were seen by local communities as major limitations for aquatic and agricultural production, impacting on functions that include the lake fishery, intensive (dry season) rice crops, recession rice, rainfed rice and floating rice by the lakeside. For both fish and rice production, water and water management are determined principally by the natural flooding of the Tonle Sap Lake.

During the stakeholder consultation for AAS development, the Tonle Sap region was characterized as having a diverse aquatic agricultural system whose productivity is determined by the flood pulses of the lake and the various (both traditional and modern) land and water management practices. The opportunity for development was articulated as follows: *making more effective use of the knowledge networks and practices for improving water access, availability and management that can optimize productivity from the flood pulses and result in diversified livelihoods, better food and nutrition, and a healthy ecosystem.*

The community survey on water access, availability and management was conceived out of the AAS consultation process and was developed to help identify existing practices in water use and management, as well as best practices where lessons can be learned and promising activities scaled out to other communities. The survey forms part of an ongoing program of research in development, which is a community-driven participatory action research process that aims to improve production and incomes of households and farmers in the Tonle Sap through better water management.

The research questions developed for the community survey on water access, availability and management were the following:

- What are the key issues with regard to water availability, access and management in the Tonle Sap for communities and households in the selected AAS communities?

- What is already being done in relation to these issues in each of the villages?
- What are the priority actions to improve access and management of water for people living in the Tonle Sap?

The community survey on water access, availability and management was designed to understand the issues and opportunities of different communities living around the Tonle Sap Lake. Communities living in this ecosystem face alternate flood and drought periods that create both opportunities and constraints for access to and availability of water for domestic uses and livelihood activities (Johnstone et al. 2013). Management of water for access to fishing grounds or irrigation was also identified as a key constraint for livelihoods of the resource-poor.

The community survey on water access, availability and management aims to understand, identify and analyze constraints and opportunities related to water, and includes a gender perspective to better understand the role of women in water management and use. The survey includes three components:

1. a household-level survey that investigates access to and use of water at the household level, providing some quantitative and qualitative facts in the different communities surveyed
2. focus group discussions with local authorities, farmers, fishers and women to understand rules, constraints and opportunities related to water uses and access in each community
3. key informant interviews in selected communities and at the district and provincial levels to enlarge our scope of understanding of water-related institutional issues through in-depth dialogues.

The three components of the survey present each community's perspective on water access, availability and management. A community is defined as those people whose livelihoods are dependent on aquatic agricultural systems and where the various water management regimes and practices determine access to and availability of water for domestic and productive use. In this study, we consider the following:

- **access** as the right of the community to make use of water for domestic and productive functions;
- **availability** as the extent to which water is easily obtainable for domestic and productive functions;
- **management** as the activity of planning, developing, distributing and managing water resources for domestic and productive functions.

In this report, we present a summary of findings from the three survey components, highlighting differences in water access, availability and management across three different types of communities to identify potential key areas for intervention. The three types of communities are located in different agro-ecological zones around the Tonle Sap Lake:

- **land based**, where villagers are engaged principally in farming and less in fishing;
- **water based**, where fishing is a primary occupation for residents of floating villages;
- **land and water based**, where villages are physically located in water for six months and on land for six months. (These villages are located in the ecological zone most affected by seasonal water-level variations.)

The outputs of the community survey on water access, availability and management will be used to support pilot interventions in the 12 target AAS communities. These interventions will be integrated into the community action planning process. The aim of the pilot interventions is to promote better knowledge sharing and learning within and between households and producers through the demonstration of best practices. A best practice committee has been set up with the support of the Tonle Sap Authority to oversee the pilot interventions and to support scaling of innovations in water access, availability and management to the broader community of the Tonle Sap region.

METHODOLOGY

Twelve selected villages (Figure 1) are distributed among the three agro-ecological zones—land based, land and water based, and water based—with three villages in each province and three to five villages in each agro-ecological zone. The agro-ecological zones are differentiated by the duration of floods from the Tonle Sap Lake, with a limited flood area and duration in land-based communities and a longer and higher flood amplitude in land-and-water-based communities (Sithirith 2011). The village domain of land-and-water-based communities alternates between flooded land in the rainy season and exposed land in the dry season. Some of these villages are found at the edge of the Tonle Sap Lake with houses built on stilts. Finally, water-based communities are found on the Tonle Sap Lake; they are floating villages without access (or with little access) to land for cultivation. In this last agro-ecological zone, households are highly dependent on fishery resources. A detailed definition of this classification based on elevation and thus on the influence of flood pulses is found in Sithirith (2011).

Our survey sample includes land-based, land-and-water-based, and water-based villages in Siem Reap, Battambang, Pursat, Kampong Thom and Kampong Chhnang provinces. For the household survey (component 1), we interviewed 12 households per village, for a total of 144 households. We stratified the sample by resource-poor, medium-wealth and better-off households, based on the wealth ranking assigned by local authorities. For the focus group discussion (component 2), we held focus group discussions around issues related to domestic and productive uses of water. We held separate focus group discussions with each participating group, including (i) local authorities and community-based organizations; (ii) farmers and fishers; and (iii) women. Different focus groups were necessary to triangulate information pertinent to each user group and to enable in-depth discussion on specific topics that were of particular importance for each group. For the last component of the survey, key informant interviews, 6 villages were chosen as a representative sample of the 12 villages covered by the study. These six villages covered all five provinces and the three different agro-ecosystems. Key informant interviews were also conducted with members of the relevant commune councils, the Provincial Department of Water Resources and Meteorology, the provincial

Figure 1. Location of the 12 communities surveyed for the AAS community survey on water access, availability and management.

Fisheries Administration, and the police, as well as with the Tonle Sap Authority (in Phnom Penh) to provide some understanding of the vertical institutional structure (national to local). Attempts to interview key officers at the Ministry of Environment in Phnom Penh were unsuccessful. However, given time constraints, the key informant interviews focused mostly on the village level.[1]

The combination of survey instruments provided a holistic view of water access and availability for communities. However, the household sample was small and not statistically representative of the population in the different agro-ecological zones. Similarly, the focus group discussions and key informant interviews were held in 12 and 6 villages respectively, which is limited considering the high level of diversity in the sampled region.

Characteristics of villages and population

- Village size ranges from 695 to 3700 inhabitants (185 to 725 households).
- Forty percent of the population is under 20 years old.
- Water-based villages have lower levels of education compared to villages in other agro-ecological zones.
- In land-based and land-and-water-based communities, 11%–30% of households are landless, and 90%–100% of households in water-based communities are landless.
- In several communities in all agro-ecological zones, the percentage of resource-poor and very resource-poor households is above 20% (up to 65%).
- Resource-poor households and female-headed households represent the highest proportion of households without access to land for rice culture.
- Both young and adult males are more involved in fisheries activities than women.
- Fishing is the primary occupation in water-based communities for 52% of the adults; fewer adults are involved in fishing in land-and-water-based (25%) and land-based communities (6%).

The participatory process of data collection.

Within each agro-ecological zone, population size and levels of educational attainment and wealth suggest both high diversity and some common characteristics. Overall, this rural population is involved in rice farming, other types of agriculture, fisheries and aquaculture, some wage labor, and petty trade.

There is an inverse gradient between fishing and rice farming activity for villages. Villages closer to the lake show a decrease in households involved in farming and an increase in households involved in fishing. The increase in fishing activities is correlated with poverty levels in land-based and land-and-water-based communities, with the most resource-poor more involved in fishing.

In all agro-ecological zones, agricultural land is seasonally flooded, but the duration of the floods varies. Of the water-based communities with access to land, the land exposure is limited to 6 months. The exposure of land for growing rice increases in land-and-water-based communities (8.6 months) and land-based communities (9.6 months). Pond aquaculture is not commonly found in land-based and land-and-water-based ecosystems, with only about 4% of the households interviewed engaged in aquaculture. Cage aquaculture is more common in water-based communities.

Water and diversity of water sources

Water sources are numerous and vary by agro-ecological zone and community. Availability of water from these sources is not always perennial, and the quality, particularly for domestic uses, changes during the year. Table 1 presents a summary of water sources, management rules and water quality by ecosystem.

Water source	Uses	Access and availability	Quality	Land based	Land and water based	Water based
River, Tonle Sap Lake	Domestic, irrigation, fisheries, (livestock)	Open access, community based Low water level in dry season	Low in dry season	●	●	●
Ponds	Domestic, irrigation, (livestock, fisheries)	Private, community Shortage of water in dry season	Low in dry season	●	●	●
Irrigation scheme	Irrigation	Open, community Shortage at end of the cropping season	Good	●	●	⊘
Motorized well	Domestic	Community, fee based All year	Good	⊘	●	⊘
Manual well	Domestic (livestock)	Open, community, (private) Shortage in dry season	Low in dry season	●	●	●
Community filter	Domestic	Community managed All year with limited supply in dry season Variable fees	Good	⊘	⊘ (●)	●
Rainwater harvesting	Domestic	Private Rainy season (mainly)	Good	●	●	●

Frequency of presence and uses in each community: ● low, ● medium, ● high, ⊘ absent

Table 1. Uses of, access to and availability of water resources and importance in different ecosystems.

We did not find many groundwater sources, even in land-based and land-and-water-based villages, where this type of water source is typically found. In general, groundwater is not affected by quality issues and is available all year long, but in one community it was found that the shallow well delivers water only in the rainy season.

Ponds, natural or man-made, are common in land-based and land-and-water-based communities. All land-based and land-and-water-based villages have access to ponds. Water can be available for as short as 6 months. Ponds are prone to droughts, triggering water quality issues and conflicts between different types of users; thus, they are not a reliable source of water in several cases. Ponds can be privately owned and are mainly used for irrigation and capture fisheries. Some villages have a large number of small-scale ponds.

Only three communities in land-based and land-and-water-based areas have small- or medium-scale irrigation schemes linked to water bodies, such as reservoirs or ponds, with shortages of water often occurring in the dry season. Rainwater harvesting is privately managed, and access to the resource is open and seasonal, with uses limited to the rainy season; this source is found mainly in land-based villages and in land-and-water-based communities.

Water-based communities have access to community filters, which can be categorized as surface water. The filters are privately or community managed, selling clean water at a fixed and affordable price to community members throughout the year. In almost all the communities surveyed, water sellers—whether from the community or outsiders—were also identified. The sellers deliver water directly to households or are hired to pump from rivers and ponds into private water storage units such as large clay jars.

Typology of community water resources

Villages can be classified according to their water resources, availability and uses. Water sources in land-based and land-and-water-based communities are similar, with overlapping characteristics regarding the natural environment, infrastructure and flood duration. By contrast, water-based communities have a more unique relationship to water and floods.

Land-based and land-and-water-based communities

Communities with access to surface water and that do not irrigate crops have the lowest level of diversity and are the most vulnerable to water shortages. Ponds can dry up at the end of the dry season, making households dependent on water sellers. Vulnerability to drought is a critical issue, as there is no access to community filters[2] or groundwater sources.

Some communities have access to surface water (river and ponds) and irrigation. Both groundwater and privately operated irrigation (pumping from river or ponds) were found. Rivers, ponds and—in a few cases—shallow wells can face water shortages and/or water quality issues during the dry season, increasing the vulnerability of water for domestic use and irrigation for recession rice.

Other communities have a higher number of water sources (groundwater, ponds and rainwater harvesting systems) and have access to collectively managed small- or medium-scale irrigation schemes. Here villagers irrigate their home gardens. This last type of community is more resilient to drought, as they have access to several types of water sources.

Water-based communities

These communities have access to water from community filters and surface irrigation (ponds, rivers and the lake). The main difference is in access to (i) groundwater and irrigated agriculture, (ii) irrigated agricultural pumping from a lake or river, or (iii) only surface water and community filters. In all cases, rivers and ponds face shortages of water and degradation of water quality in the dry season, making communities vulnerable in the absence of community filters. The most resource-poor households, who cannot afford to purchase water, are extremely vulnerable.

Domestic water use

Domestic uses, availability, access and sources of water were specifically investigated with women's groups who were identified during the study's preliminary phase as key informants within the households in terms of domestic water management.

Water sources

Purchasing water is common in water-based villages with access to community filters and the presence of an active water market with local or mobile water sellers. Groundwater and rainwater collection are the most common water sources in land-based communities, while river water and groundwater are dominant in land-and-water-based communities. Access to community filters and clean water in water-based communities is now common and has significantly impacted livelihoods of local households. However, water supply can be limited in the dry season and filters can face technical difficulties. Households need to purchase water from water sellers or find alternative water sources.

Rivers are the main source of drinking water in the rainy season, especially for resource-poor and very resource-poor households in all communities. In the rainy season, rainwater harvesting is used to partially replace the purchase of water. Harvesting rainwater is the second most important source of drinking water in land-based and land-and-water-based communities, while it is not commonly used in water-based communities. There is not a consistent age or gender pattern for collecting water across communities. It is most often a joint activity, with both men and women involved.

Water quality and water treatments

Seventy-three percent of the households have water quality issues, with a higher percentage in land-and-water-based and water-based communities using rivers and ponds. Groundwater from manual wells can show signs of lower quality in the dry season, but this does not apply to all communities.

For surface water, a common seasonal pattern regarding water quality was found across agro-ecological zones, starting with turbid water early in the rainy season caused by first rains and sediment runoff. During peak floods, surface water is considered of good quality, with low turbidity and no contaminants. The quality of drinking water is lower in the dry season. Surface water during this period of the year is shallow and has a high concentration of pollutants and organic matter. Water-based communities who depend exclusively on surface water are the most vulnerable to this seasonal water variation.

Land-based communities treat water more often than other communities by boiling it or using private filters or sedimentation jars. Perhaps this is due to lower water quality and absence of community filters. Boiling water and residue sedimentation in jars are common especially among resource-poor households.

Villages' water consumption

- Water consumption is homogeneous across wealth groups, seasons and agro-ecological zones. Average yearly water consumption is between 164 and 170 liters per day and per household.
- In the dry season, 8% of total water consumption is allocated for drinking, while in the rainy season, 7% is allocated for drinking.

Land-based communities have access to groundwater, rainwater harvesting and surface water for their domestic uses. The use of a rainwater harvesting system is widespread in both seasons by households, including resource-poor ones, with good storage capacity across the communities. In the rainy season, rainwater harvesting is a major source of drinking water. Transportation means for water vary (walking, cart motorbike or bicycle). Pumping from the river is also common. These communities treat their water more often than other communities, using traditional chemical treatments, boiling or filtering.

AVAILABILITY OF WATER: DOMESTIC AND PRODUCTIVE USES

Better-off households frequently use additional private filters or traditional chemical treatments to precipitate sediments.

Water sellers and the water market

Water sellers commonly pump water from rivers or purchase it in cities or from community filters before reselling it to households. Alternatively, residents purchase water directly from the community filters.

The price of water is extremely variable, from less than USD 0.1 per 30 liters to USD 0.6 per 30 liters. Vendors are private water sellers or community filters. Water prices across the different ecosystems depend on the type of management (community based or private) and distances to households, with an increase in prices in the case of home delivery. In Raing Til, a filter can process 4000 liters a day and supply water to all the households in the flood season, but in the dry season the production of clean water is limited and the supply meets the needs of only about 80 households.

Purchases are usually triggered by lower water quality in the dry season. Female-headed households were found to purchase more water than male-headed households and to use the delivery system more often. Purchasing water is sometimes not possible for the most resource-poor households, who are forced to depend on other sources of water or drink water of lower quality. Resource-poor and very resource-poor households purchase water less often and for shorter periods during the year, especially in water-based communities, where the difference across wealth groups is even more significant. An estimation of the yearly cost of water per household in water-based communities varies from USD 65 for resource-poor households to USD 303 for better-off households.

Water storage

Water storing occurs all year long, although storing of rainwater takes place only from May to October or November. On average, 95% of the households surveyed store water for a period of between 3 and 23 days, depending on their capacity. Water-storing capacity is significantly lower in water-based communities (0.11 cubic meters [m^3] per household) compared to other agro-ecological zones (30 m^3 and 43 m^3 in land-and-water-based and land-based communities respectively) due to lack of space. Water-based communities are also less equipped with water harvesting capabilities. This structural characteristic does not affect water consumption during normal circumstances but makes water-based communities more vulnerable to drought and economic shock and more dependent on water sellers.

Water storage capacity is different among wealth groups, with resource-poor households having a shorter time period to store water, averaging 7 days; the average period is 8.4 days for female-headed households and 16 days for better-off households. Resource-poor and very resource-poor households are more vulnerable to drought, due to limited water storage capacities.

Climate hazards and coping strategies for domestic water

Drought periods can trigger a shift in the source of water. Groundwater is important for land-based communities, while rivers and ponds become less important and have less water available for land-and-water-based communities. Manual wells suffer from lower water quality and sometimes dry up during droughts. Rivers are still the most important source of water for water-based communities.

In **land-and-water-based communities,** domestic water is sourced from surface water in the rainy season (river and rainwater harvesting), while in the dry season the sources are groundwater, ponds and rivers. Daily water consumption is slightly lower than in land-based communities, but households face more water quality issues (turbidity, bad smell and taste, and organic matter load) when using more surface water. Resource-poor and very resource-poor households do not have access to private groundwater for domestic uses and rely on public or open sources of water. Water storage capacity is lower for the resource-poor than for other wealth groups.

Water-based communities are the most vulnerable regarding access to drinking water, with high dependency on water sellers and community filters. Access to clean water requires either purchasing from a water seller or using a boat to access selling points, sometimes located more than 30 minutes away. Most of the better-off and medium-wealth households can afford to purchase water all year long, but resource-poor households cannot. The river is an alternate source of water for drinking but at the cost of water quality. Water storage capacity is limited compared to other communities, and the use of rainwater harvesting systems is not common. Water-based communities face water-quality issues more frequently than communities in other agro-ecological zones, with water turbidity and organic matter content during the dry season. During droughts, households lacking water limit their water consumption and use lower-quality water, relying on the lake or river for drinking water. In water-based communities, households also have limited storage capacity, which increases their vulnerability to drought.

The main impact of drought on surface water is the deterioration of water quality, as the water requires treatment (boiling, sedimentation or filtering) before consumption. Rules about access to groundwater are usually not modified during drought periods. Only land-and-water-based Tramper village limited the volume collected per household. Collective ponds have more restricted access, with no livestock or water sellers allowed to use the water.

Water consumption during droughts is reduced due to (i) lower water quality, (ii) increased pumping cost or (iii) change in ponds' access rules. This reduction of water consumption is mostly found in land-based and land-and-water-based communities without access to community filters. In these cases, the reduction in volume of the water collected is estimated to be between 40% and 50%. Nonpoor households purchase more drinking water, and some households increase their water storage capacity. In water-based ecosystems, households tend to purchase water, reduce water consumption and/or drink lower-quality water.

Severe floods affect all agro-ecological zones in terms of frequency, with two severe floods—in 2011 and 2013—recorded in the last 10 years. Floods affect the quality of drinking water mostly in land-and-water-based communities, where ponds and rivers are the main household sources of drinking water. Surface water, ponds and manual wells are not accessible. Rivers are more accessible, with lower costs. For land-based and land-and-water-based communities, treating the water (boiling or sedimentation) is necessary. Rainwater harvesting is an important source of water in these communities, as it provides clean water during floods.

The main coping strategy for better-off and medium-wealth households is to purchase water and invest in rainwater storage capacities. Resource-poor households use surface water, which requires treatment (boiling, precipitating sediments, etc.).

Land-and-water-based communities are the most vulnerable during floods, with no access to groundwater, deteriorating water quality, and difficulty in accessing roads to obtain other sources of water or to buy water from water sellers.

Past experiences, lessons learned and areas of intervention for domestic water uses

Rainwater harvesting is well developed in land-based communities. Other communities apply this technique less frequently. Individual rainwater harvesting could be developed to increase water storage capacity and reduce the cost of purchasing water.

Water treatment methods are limited. In communities where resource-poor and very resource-poor households use surface water as drinking water, individual filters could be used to improve water quality and reduce waterborne diseases. We found that the distribution of individual water filters in the surveyed communities is effective when educational training is provided and when the most vulnerable households are targeted. Making the filters available on the local market allows nondirect program beneficiaries to individually invest in the technology. This technology was also found to be efficient in water-based communities, where resource-poor households can treat the water from the Tonle Sap Lake or rivers, which are easily available water sources.

Groundwater access is more developed in certain land-based communities than in land-and-water-based communities. An assessment of groundwater availability and the cost of developing community-based wells should be explored to improve water access and quality. An example is Kampong Kor village. Here the community manages a motorized deep well, which provides access to drinking water with no fee for the most resource-poor households in the village and with low prices for the rest of the villagers. This type of regulation acknowledges wealth differences within the population and allows resource-poor households to benefit from—while facilitating the success of—the intervention.

Free access was also found to be an important criterion guaranteeing the success of groundwater-related interventions. Manually operated wells do not require operational costs, allow households to complement other water sources in the dry season and reduce vulnerability to drought. The location of the wells within the village is important, as all households, even those located remotely, should have access to water. However, the maintenance of the wells (in case of damage) is potentially problematic without specific funds allocated for this.

Community filters represent an intervention with a very high direct impact on households' access to water and indirect impact on community health. The price of the water is fixed by communities to cover the maintenance cost of the filter. The communities themselves usually manage the community filters. However, management of the oldest community filter in the sample (in Chnok Tru village) was transferred to the private sector to limit conflicts within the management committee. A private operator now pays a rental fee to use the community filter, while the local authorities still monitor the price of the water. This transfer of responsibility was found to be easily manageable and maintains the station.

Training and capacity building of community staff was an important criterion for sustainability of the technology, as was long-term backup from NGOs or donors to provide technical support in case of technical issues. This technology generates opportunities for livelihood diversification with the creation of employment opportunities and enables the presence of water sellers within the community.

In all agro-ecological zones, water sellers have an important role, while water markets, governance along the water value chain and quality of water provided are increasingly areas of interest within the establishment of this sector.

Successful interventions are contingent upon accessibility to the largest number of households, access to knowledge, and capacity building of communities to handle management and maintenance of new technologies. In a case where community-based management of a community filter was not successful, transfer to the private sector under the control of local authorities was found to be successful. Education programs for water, complementing the technology transfer, were also found to be successful.

Productive uses of water

Irrigation

Within ecosystems there are differences in access to irrigation between villages; some villages only practice rainfed agriculture (Santey and Prey Chas villages in land-based and land-and-water-based ecosystems), while other villages within the same agro-ecological zone have access to irrigation.

Expanding irrigation

Dry season irrigation increased in all agro-ecological zones in the last 10 years. In land-based communities, the development of individual and collective pumping, collective irrigation from reservoirs, and irrigation schemes (Rohal Suong and Santey villages) increased the irrigated area per household from 0 to 0.2 hectares (ha) per household in the last 10 years. These communities have a larger irrigated area, but irrigated agriculture is not found in every village of this agro-ecological zone. Households with access to irrigation are found more frequently in land-based communities but with smaller irrigated areas than in land-and-water-based areas. Individual pumping from rivers and ponds and small-scale irrigation schemes are common, and the average irrigated area per household increased

from 0.02 ha in 2003 to 0.7 ha in 2013. Irrigated homestead gardens are not common and are found mostly in land-based villages, using groundwater or water from ponds, with a large presence of these gardens in resource-poor and very resource-poor households.

Water-based communities have limited to no access to land, and are often located near or within conservation areas. Access to irrigation is found in the dry season in less than 10% of the households in two water-based villages, Chnok Tru and Phat Sanday. Chnok Tru village has a large irrigated area, but the land is rented out and cultivated by noncommunity members. In water-based communities, when access to land is possible, irrigation is limited to short-cycle crops such as vegetables in the dry season. Moreover, the cultivated areas are small and only involve a few households.

Irrigation schemes are not common, with only three land-based and land-and-water-based villages owning small- and medium-scale ones, ranging from 50 ha to 500 ha. The schemes require maintenance and some, such as those in Tramper village, are damaged and nonfunctional. Irrigation from other water surfaces, such as rivers or individual and collective ponds, are more common. When averaged, about 10% of the households in land-based communities have access to irrigation in the dry season compared to 26% in land-and-water-based communities.

The nature of irrigation changes according to the community, with individual pumping and irrigation schemes in land-based and land-and-water-based communities. Access to irrigation allows recession rice to grow from November to February following the flooding season or allows both early wet season rice (June–July) and recession rice, when access to water early in the wet season is possible. Thus, by enabling rice culture before and/or after the peak flood, access to irrigation prevents the risk of damage by flooding. In addition, access to irrigation during the rainy season (called supplementary irrigation) secures crops in the case of dry spells.

Lack of a secure water supply

Water sources for irrigation are not necessarily perennial during the dry season, when water demand is high and irrigation is critical; water is not always available or irrigation faces technical issues.

Individual pumping from the river is quite common, but distance to the river limits the irrigated area. This affects lower-income households more, since their land tends to be located further away from water sources. Low water levels in the dry season increase pumping costs and require larger investments in pumping equipment. Water sellers for irrigation services are available, but are not common across villages. Low water levels and shortages are also commonly reported in the case of ponds used for irrigation purposes. Irrigating from this water source entails similar issues of distance and water shortages, which in the case of collective ponds leads to conflicts between different water uses and users, especially farmers and fishers.

Seasonal water bodies and their associated irrigation infrastructure involve a high risk for agriculture, with a lack of water often reported at the end of the crop cycle in February and March. In general, irrigation infrastructure is poor, limited and does not allow for efficient management of the resource. Without clearly defined institutional entities to manage them, water bodies (ponds and canals) used for irrigation require the commune council to mitigate conflicts regarding access to the water resource.

Land-based communities are farming communities, using supplementary irrigation. Early wet season rice is the main irrigated crop, avoiding the flood later in the rainy season. These communities are not really engaged in either fish culture or fishing. Only resource-poor and very resource-poor households fish. Droughts and dry spells affect late recession rice crops and early wet season rice, while floods affect both agriculture and livestock, which requires migration to higher ground.

Vulnerability of rice culture and livestock to drought and floods

Long drought events are usually recorded 1 to 1.75 times per decade, for a duration of 4 to 6 weeks each, due to the delay of the rainy season or because of an early retreat of the monsoon. Dry season and early wet season rice are highly vulnerable to drought in land-and-water-based communities in the absence of secure water storage, while recession rice is more vulnerable in land-based communities. Seasonal water bodies like ponds (mostly small and shallow) were found to be insecure for rice irrigation purposes, not providing enough water. Risks are especially high in the late dry season from February to April.

Coping strategies for drought, when water is sourced from reservoirs and ponds, are limited. Communities can receive support from the provincial or district agriculture office to increase water storage or from the Provincial Department of Water Resources and Meteorology to pump water from other sources. However, we only recorded a few of this type of intervention in the villages. In the case of dry spells during early wet season rice, investment in pumping equipment by farmers to respond to this threat was observed and plots located near water bodies were less affected. This response to threats is not common and limited to farmers with sufficient investment capacity. Farmer extension services are consistently absent, especially in the view of smallholders, who also appear not to be aware of other coping options, such as alternate varieties and water-soil management methods.

Besides its impact on agriculture, drought can affect forage access and increase disease outbreaks in livestock, which leads to livestock migration when farmers have the financial capacity, or selling livestock at very low prices when migration is not possible. Similar impacts were described in the case of floods.

Severe floods are more frequent in land-and-water-based communities than in other agro-ecological zones located in higher elevations (land based) or living with a flood (water based). Rainfed rice crops can be affected by abnormal floods, and an early flood can affect the harvest period of early wet season rice. For example, in 2011 and 2013, severe floods affected Rohal Suong rice culture and destroyed 85% of early wet season rice.

Flood patterns can have an indirect impact on recession rice culture. In 2013, a delay in flood recession postponed the recession rice crop, increasing water demand during the last stage of plant development in the dry season. It led to higher risks of drought and conflicts over access to water. Damages due to flooding resulted in income shocks, with households in need of financial support to sustain livelihoods in the absence of harvest or requiring additional funds to cover the cost of re-planting. Main coping strategies of households were to contract loans or migrate to seek wage labor.

To cope with floods in water-based communities, where the duration of land exposure is limited, farmers shift from rice to short-duration crops such as maize and soya that can be harvested after three months and provide reasonable returns.

The recently increased frequency of climate hazards has reduced farmers' capacity to invest in irrigated crops and their willingness to take risks by investing in irrigation or early

In **land-and-water-based communities**, recession rice and dry season rice are common crops and require irrigation. These crops are vulnerable to drought when water is sourced from seasonal ponds or rivers.

Less than 50% of the households have access to irrigation, and rainfed culture is threatened by recurrent flood events in late September. Floods also affect large livestock, requiring migration. Aquaculture ponds face flood damage and require protection with nets, while cage culture faces water-quality issues in the dry season that require either harvesting crops or migration to deeper parts of the lake or river. Fishing is common in rivers and in the Tonle Sap Lake in the dry season and in the flooded forest and rice fields in the rainy season. However, fishing is mostly for household consumption or as a secondary livelihood activity in the household.

wet season or rainfed rice crops. Farmers prefer not to cultivate or shift to other crops in the absence of available water sources for irrigation. These impacts are more prevalent for smallholders who—as is the case in Tramper village—are situated closer to the Tonle Sap Lake and hence bear the brunt of seasonal inundation.

Aquaculture

Climate threats and coping strategies in aquaculture

Aquaculture is mostly found in water-based and land-and-water-based communities, for both pond and cage culture. Resource-poor and very resource-poor households have access to aquaculture, but with a significantly lower cage culture volume compared to better-off households. In the dry season and during droughts, cage culture on the lake faces low water levels. Coping strategies vary according to wealth group. Resource-poor households tend to harvest the crop to mitigate losses, while better-off households migrate to deeper zones in the river or to Tonle Sap Lake. Floods also affect cage culture and require reinforcing cages. In Prek Toal and Peam Ta Uor villages, the 2010 drought affected aquaculture activities (including crocodile farming), with an increase in disease occurrence and higher mortality of the animals. This required the fish farmers to either harvest and sell the product or move the cages into deeper areas of the Tonle Sap Lake where fishers usually fish.

In early rainy season, abundant water runoff carrying pesticides and other pollutants can affect aquaculture production, increasing disease occurrence and fish mortality. Floods also impact cage aquaculture by causing damages to assets, requiring additional maintenance and increasing the cost of aquaculture.

Pond culture is not widespread and is found mostly in land-and-water-based communities. Ponds can become flooded, requiring protection to avoid losing the product, while most of the ponds are seasonal and aquaculture is limited to a certain number of months during the year. When available, homestead ponds can be used as sources of water for other livelihood activities.

For various reasons, including low water quality and limited water depth, aquaculture was found to be a risky activity, requiring technical support and access to knowledge. Lack of access to external assistance was identified as a constraint to aquaculture development, with little support from extension services or the private sector. In addition, knowledge sharing and cooperation regarding aquaculture within the community are limited, which aggravates the lack of external support. This has resulted in a history of high levels of fish mortality. Other factors suppressing a wider adoption of aquaculture include high startup and input costs and poor market access, in addition to the lack of technical knowledge linked to a failure of extension service delivery.

Aquaculture in Cambodia can be productive and profitable for small-scale farmers to medium-scale enterprises (Joffre et al. 2010; WorldFish 2011). The relatively low aquaculture production observed in the various survey sites suggests a significant untapped potential.

In **water-based communities**, fishing is the main livelihood activity, and fish catch is significantly higher than in other communities in both dry and rainy seasons. Fishing occurs in the Tonle Sap Lake in the dry season and the flooded forest in the rainy season. The lake and flooded forest are more important ecosystems for communities' livelihoods than water for irrigation. Cage aquaculture is common, using small-sized fish catch to feed aquaculture fish. Aquaculture can face drought, leading to deterioration of water quality and high mortality rates. Agriculture is limited to the dry season, but access to land is scarce. Village territories can be within or adjacent to conservation areas. Resource-poor households rely entirely on fisheries, as other livelihood opportunities are limited. In addition, their aquaculture cages hold significantly lower volumes than those of households from other wealth classes. Fisheries recently faced declines due to overfishing and a lack of capacity of the community fisheries to control fishing activities within their territory. While fisheries are declining, households have limited or no other livelihood opportunities.

Aquaculture development can help offset the economic and nutritional losses faced by households in floating and seasonally flooded villages that rely heavily on a declining fishery. Another important aspect of aquaculture development is its suitability for women and the elderly, who may be restricted to the house either by gendered social norms or the physical inability to fish or farm. The fact that aquaculture cages can be connected to the house partially eliminates the need for mobility, although inputs and the sale of produce still require mobility unless these services come to the houses in the form of middlemen.

Fisheries

When and where people fish

Fishing grounds vary with seasons and between communities. Land-based and land-and-water-based communities have access to flooded rice fields, ponds, irrigation schemes and rivers. Water-based communities, on the other hand, focus on the Tonle Sap Lake and the flooded forest. Communities located further away from the Tonle Sap Lake only fish in the lake during the peak season while fishing more often in seasonal and multipurpose water bodies like ponds or flooded rice fields.

Average fish catch is linked to habitat. Ponds, flooded rice fields and irrigation schemes are less productive than flooded forests and the Tonle Sap Lake, where in the peak season the fish catch can be higher than 50 or 100 kilograms (kg) per day. Fish catch in land-based and land-and-water-based communities is limited (10 kg per outing) and reflects more subsistence fishing, while fish catch in water-based communities is higher and generates a significant part of households' income.

Drought and floods do not significantly affect fishing activities, but drought does modify fisheries in small-scale water bodies, like ponds and/or fish sanctuaries that are found in land-based and land-and-water-based communities, by lowering water levels. Fish refuges require a governance mechanism for the water bodies to sustain a minimum water level during the dry season. In Rohal Suong village, the fish refuge is managed by the community and allows or forbids the pumping of water from the pond based on its water level. This type of management was made effective only by hiring a guard paid USD 20 per month by the community fisheries savings group to safeguard against infringement and illegal pumping. However, the creation of the community fish refuge and its water management regulation created conflict and tension with farmers wanting to irrigate their rice fields.

Importance for livelihoods across ecosystems

In water-based and land-and-water-based communities, 90% of resource-poor and very resource-poor households fish. Fishing is an important activity for local livelihoods in water-based ecosystems, as these communities have little or no access to land. In land-based and land-and-water-based communities, fisheries are significant for household food security for the most resource-poor, while wealthier households fish less and mostly for their own consumption. Women's engagement in fisheries differs across communities, with more women in water-based communities engaged in fishing than in other types of communities, especially in the dry season when risks are lower. This difference might be explained by the lack of other livelihood activities, especially access to land in this agro-ecological zone. Otherwise, males—especially young adult males—are more engaged in fisheries and aquaculture than women are.

Past interventions in agriculture, aquaculture and fisheries

Farmers using seasonal water bodies to irrigate their crops are the most vulnerable to drought, especially in cases where the water resources are not managed or regulated and when rice fields are located away from water sources, involving higher costs for water transport.

Intervention in this context is complex, difficult and often not successful. There are examples of communities where new or existing canals were developed to support irrigation for recession and dry season rice. However, this led to conflicts between upstream and downstream water users when water resources were scarce and institutional arrangements were either weak or absent. The development of community-based organizations (not necessarily farmer water user committees) can mitigate these conflicts, like in the case of Rohal Suong village. In this community, one group of farmers using a nearby canal reached an agreement on an

Photo Credit: Sanjiv de Silva/WWF

Adaptations to flooding: Houses are built on stilts while the flood water and flooded forests provide a range of ecosystem services such as fish and fuel wood, Muk Wat village.

irrigation fee that acknowledged distance to the water source and cost of pumping. In other communities, when conflict occurred between water users and no community-based organization operated locally, the intervention of local authorities was necessary.

Dry spells and drought can trigger collective action for access to irrigation, such as in the case of the Rohal Suong community. Farmers invested in water pipes to pump water from ponds located further away so that water could flow from one plot to the other. Farmers shared the cost of fuel in case they could not afford the investment alone. Irrigation usually requires pumping equipment, which is a barrier to entry for the resource-poor. As the presence of water sellers or service providers was rarely mentioned, we deduced that it doesn't bring significant economic benefit to farmers.

When well connected with the district and provincial Department of Water Resources and Meteorology, communities can ask for financial and technical support to increase water-holding capacities of ponds and pumping from rivers. These types of interventions are limited in number and are exceptional, usually occurring in the case of extreme drought.

No groundwater irrigation interventions were recorded, but potential might exist, since groundwater use for irrigation was found in Siem Reap, Kampong Chhnang and Battambang provinces (Johnston et al. 2013).

Moreover, no specific interventions were associated with flood protection or mitigation. The number of interventions regarding aquaculture or fisheries was also extremely low. Two communities (Santey and Tramper villages) recently developed a community refuge pond to enhance rice field fisheries.

In water-based and land-and-water-based communities, women are involved in fisheries and are traditionally in charge of fish processing for fish paste and smoked fish. Providing new technology for fish processing and/or new approaches for marketing can improve income and fishery revenue, which is a significant part of the livelihoods of resource-poor and very resource-poor households.

Small-scale cage aquaculture is well known for low-use efficiency of feed resources. Providing simple stocking and feeding technologies to aquaculture farmers can help to increase production and reduce feed cost.

This section presents information on institutions covered by this study. It is, however, not meant to be an exhaustive assessment of all the actors and processes that influence aquatic agricultural systems in the Tonle Sap region. The broader range of actors is depicted in Annex II, where those covered by this study are represented in red boxes.

Institutions related to water management at provincial and national scales

Tonle Sap Authority

Inaugurated in 2009, the Tonle Sap Authority represents a relatively new institution in the lake's governance structure. It gives expression to the government's desire for an institutional layer with a mandate to coordinate the multiple sectoral interests operating at the basin level of the Tonle Sap. The Tonle Sap Authority reports directly to the prime minister, suggesting an ability to garner the necessary political support to discharge its functions, as well as a mechanism for political agendas to be manifested more directly in the lake's management.

In practice, however, no formal coordination mechanism exists between the various ministries and departments engaged in the management of the lake, and there is no common vision or action plan for the lake's management. The Tonle Sap Authority's management activities appear focused mainly on the national parks established by the Ministry of Environment. Its other activities consist of monitoring and delivering status reports to the prime minister's office on the condition of fish stocks, illegal fishing activities and the status of flooded forests (zoning and fish species inventorying). While the Tonle Sap Authority is meant to protect flooded forests as fish breeding spaces, the dispersed nature of these ecosystems and continued forest loss highlights the challenges faced by the Tonle Sap Authority in exercising control. A fundamental constraint is that the Tonle Sap Authority is not authorized to enforce laws against illegal flooded forest clearance or illegal fishing. Nor is there any formal institutional mechanism for coordinating enforcement activities among other sector agencies, although bilateral links with the Fisheries Administration exist.

Provincial Fisheries Administration

Functions of provincial Fisheries Administration offices include the enforcement of fisheries laws, training fishers in how to use legal fishing gear properly, and promoting aquaculture. Feedback from Fisheries Administration officers confirmed the views of interviewed fishers that there is an overall decline in the fishery, although one positive change after closing the fishing lots has been the return of some fish species that were not seen in 2009 and are now being caught. From an enforcement standpoint, fishing activities have been much harder to control since the abolition of the fishing lots, which resulted in more dispersed fishing activities and more actors entering the industry. Consequently, the enforcement burden is now much higher, while government fund allocations for law enforcement have not yet matched this increase. Therefore, illegal fishing has also increased, carried out by both locals and people from other provinces. The impact is significant, considering that illegal fish traps can catch 60 kg in two days, while legal fishnets can catch only 30 kg over one and a half days. Moreover, the equipment for illegal fishing is easy to make and takes only two to three hours, which makes confiscation of equipment less effective, while the investment needed for monitoring (boats, fuel and workforce) is high.

The Fisheries Administration also leads the creation of community fisheries. It meets with the commune council and village head to include specific villages in a community fishery. The Fisheries Administration also assists community fisheries with developing their own management plans to protect the area they are to manage, with a focus on stopping illegal fishing and the cutting of flooded forests. It also facilitates the making of regulations by community fisheries, which are documented by the Fisheries Administration. The community fisheries are expected to provide reports mainly on illegal activities. The main requests received from community fisheries are for cooperation


Photo Credit: Senjiv de Silva/IWMI

Rice fields under water during seasonal floods, Rohal Suong village.

and fuel. The Fisheries Administration officer from the provincial office is expected to visit each community fishery to check its status, especially with respect to illegal activities. The local Fisheries Administration officers are expected to do this more often. However, there are not enough funds for this to occur regularly, and there are no regular meetings with the community fishery unless there is a specific problem.

Provincial Department of Water Resources and Meteorology

The Ministry of Water Resources and Meteorology became an independent state entity in 2000, and was part of the Ministry of Agriculture, Forestry and Fisheries before that. Its primary functions are surface and groundwater management and research, as well as building irrigation systems. This also includes the establishment of farmer water user committees and interventions in water management during droughts. Irrigation schemes are classified into small (25–500 ha), medium (500–5000 ha) and large (>5000 ha) schemes. There are many informal farmer organizations in the floodplains (about 50–60 in Battambang Province alone), and the Provincial Department of Water Resources and Meteorology is working with some of these already. It was clarified that there is no need for large irrigation infrastructure to form a farmer water user committee. These committees are expected to control and maintain the secondary and tertiary canals and to ensure the equitable distribution of water. The Provincial Department of Water Resources and Meteorology does not play a role in the election of farmer water user committee members. It does, however, train the farmer water user committees on rules and responsibilities. At the beginning of the wet and dry seasons, the Provincial Department of Water Resources and Meteorology meets with the farmer water user committees to discuss water supply. How much will be irrigated depends on water availability, though it was claimed by the Provincial Department of Water Resources and Meteorology in Battambang that farmers don't often listen to advice on water availability when planning for dry season cultivation. The Provincial Department of Water Resources and Meteorology in Battambang Province is not involved in resolving conflicts over use of resources.

While stating that the aquifers are too deep and too small to support rice cultivation in Battambang, the Provincial Department of Water Resources and Meteorology is also aware that groundwater use has become prevalent since 2011. Although farmers traditionally did not cultivate dry season rice in Battambang, people from the floodplains have begun to do so on leased land. The significant income from

this has created a demand for groundwater among others who wish to follow suit, and this demand may increase due to changes in rainfall. While the same amount of rain has been falling (1200 millimeters per year), it has been characterized by more intense but less frequent occurrences. There has also been a change in timing, causing uncertainty, as well as increased flooding. Another reason to expect that demand for groundwater irrigation may increase is the lack of funds and human capacity for increasing surface irrigation, though the entry of China and South Korea as financiers of such schemes in Cambodia may change this scenario. The Battambang Provincial Department of Water Resources and Meteorology has only four staff members to cover four districts, and they all operate from the provincial office, which means there are no officers at more local levels.

Management of fisheries and irrigation

Governance issues in fisheries

Fisheries in these communities are crucial sources of livelihoods, especially for the most resource-poor households. A consensus among researchers and development agencies exists on this statement. Another consensus was found among the communities visited during this study regarding the overall decline of the fish catch in the last few years and the inability of fishers to adequately support households' developmental needs. Fish catch has declined despite an intensification of fishing effort at the household level, which also means added time, financial and energy expenditure, and opportunity costs. According to communities, the decline in fish catch can be attributable to several factors, including the use of illegal fishing methods, lack of control of fishing gear and of access to fishing grounds, an increase in the number of fishers, and deterioration of fish habitat. The recent replacement of fishing lots by conservation areas had not yet yielded any increase in fish catch, and local fishers perceive this development as detrimental given the "dilution" of fish stocks into larger areas.

Increased fishing pressure results from a lack of other livelihood opportunities for the local population. The increase in the number of fishers is also due to migrant fishers or fishers from other communities, districts or provinces fishing within the same fishing grounds. Outsiders, who only see the forest as a source of timber rather than for its ecological significance for fisheries, are also blamed for the decline in flooded forests.

With the increase in the number of fishers, controlling fisheries has become much harder despite the establishment of community fisheries organizations. Community fisheries

Photo Credit: Sanjiva de Silva/IWMI

Preparing fish for sale at local markets, Muk Wat village.

lack resources to patrol and control their territory, which is often large. In several cases, like in Muk Wat, fishers do not see any benefit in taking an active role in the community fishery. A fundamental weakness is the community fisheries' inability to generate revenue to support enforcement activities. Community fisheries' ability to enforce rules against illegal fishing is also hampered by the interference of kinship networks within the local communities.

Irrigation management, institutions and conflicts

A major restriction to agriculture has been the declaration of conservation areas following the cessation of the fishing lots. Several land-and-water-based and water-based villages are located near or within conservation areas. This means that agriculture is either restricted to a small area of land, as in Raing Til village, or not possible at all in the dry season.

Pumping costs and limited returns on crops restrict access to irrigation. The cost of pumping increases with distance. Water sellers are found in several communities, either transporting water in tanks, like in Muk Wat, or providing irrigation services, like in Kampong Kor. Farmers with limited investment capacity rent pumps, but in general irrigation is individualistic and hiring water sellers is not common.

Water scarcity in seasonal ponds and reservoirs leads to upstream versus downstream conflicts in the absence of management bodies. Several land-based and land-and-water-based villages recorded conflicts within communities or with upstream or downstream farming communities, requiring mitigation by the respective commune councils. Farmers with plots located near water sources benefit from the situation and may not be in favor of changes in management regimes or rules for sharing. Large landowners located near water sources benefit from the status quo for water management, where water can be appropriated by those with the equipment and funds for fuel.

In response to water scarcity and/or irrigation costs, a few communities have developed collective irrigation to share pumping costs. In Rohal Suong, a collective action partially rehabilitated an irrigation canal, facilitating access to water. A community-based organization has been formed to manage water use and canal maintenance, with a management committee organized into three subcommittees: pump management, technical and water resources, and finance. Water users have to pay a fee.

Interestingly, in this community another old irrigation canal needing rehabilitation could not provide sufficient water in the dry season. This example illustrates a lack of cooperation or collective action in the irrigation sector at the community level where individualistic and opportunistic behaviors concerning irrigation are dominant. In spite of the shared challenges brought on by water scarcity, farmers' behavior remains surprisingly individualistic. In another block of farmland in Rohal Suong, for instance, each farmer pumps for himself or herself, which undermines opportunities for optimizing dry season water use. The issue appears to be a lack of willingness to cooperate in pumping water from the river to the canal from which all the farmers can then irrigate their respective plots. Instead, whenever a farmer pumps water from the river to the stream, other farmers pump water to their streams as well, exposing a free-rider mentality. This leaves the system open to abuses, especially when a farmer closer to the river can pump at the expense of farmers further down the canal, and the farmers closer to the river have fewer incentives to cooperate in establishing a shared irrigation system.

The contrasting situations regarding water access of the two blocks of farmers in Rohal Suong village leads to notably different production options and hence economic gains. Farmers with secure access to water are able to grow dry and rainy season rice crops intended for the export market, achieving a high yield and a high market price. Farmers without secure access to water are limited to a single crop of rice of a different variety sold in the national market and thus a lower market price. The existence, or lack thereof, of farmer groups organizing to collectively access irrigation thus determines not only the cropping calendar, but also rice varieties and market strategies.

Development planning at village and commune levels

Recognizing that the governance of the aquatic agricultural systems in the Tonle Sap

Women with fuel wood, Phat Sanday village.

is part of broader governance frameworks and processes, this section considers two key elements of this broader framework, which impacts village development as a whole, including water and land management. These elements are the village development plans and the attendant planning process, and the commune councils and their roles in supporting village development, including natural resource management planning and associated conflict resolution.

Village development plans represent the starting point of the bottom-up development planning process introduced through the government's decentralization and deconcentration program, intended to give local communities greater control over selecting rural development priorities. The process involves each village developing a development plan according to its respective priorities. These are grouped into commune development plans that reflect priorities at the commune level. The commune development plans are then grouped at the district level to form a district development plan, which is presented at an integration workshop held at the district level for donors, NGOs and government agencies to select activities they will fund in a given year, even though there is no guarantee that all activities will be funded.

In theory, the commune council head, along with the head of each village, is to develop the village priorities in consultation with the villagers. However, interviews conducted with smaller-scale farmers in particular and fishers in general suggest that they have benefited very little through this process. Thus they exhibited little appreciation for the process and often perceived the process to be dominated by elite groups and individuals. Even with respect to the villages overall, the village development plan process appears not to have had a significant impact in virtually any of the sampled villages.

Commune councils represent a group of villages, and as such, they are lowest level of collective administration in Cambodia's administrative system. They are meant to provide a more locally accountable platform for supporting development activities at village scale. As such, their mandate is extensive, including most aspects of village life, from dealing with domestic violence to helping resolve conflicts over natural resources such as illegal fishing or conflicts for water between fishers and farmers. In addition to facilitating village development planning, commune councils can also fund village priorities through the commune fund allocated annually to each commune's council by the General Department of National Treasury. Interviews

with commune councilors, however, indicate that these funds often fall far short of what is necessary to meet the development needs of a commune. This financial scarcity triggers an additional prioritization of already identified village priorities by the commune councils, which sometimes means that only one village receives funds in a specific year. In general, the commune council selects the most common priorities across the village development plans, focusing on the first priority in each village development plan. However, given the paucity of funds, some villages will not receive any funds even if they share the most common priority among all the villages.

The information generated on the village development plan's process and commune fund's operations suggests that the priorities of the more resource-poor and marginalized groups within these aquatic agricultural systems are likely to be underrepresented. In the first instance, this is due to dominance of village development plans that prioritize elite interests, likely placing those of the resource-poor low on the list. This also becomes a disadvantage when a commune council seeks to match its limited budget with village development needs by focusing on the top priorities of the village development plans.

Moreover, what is funded through the commune fund is heavily biased towards the construction of infrastructure. Soft activities such as training for farmers, fishers and others are suspended until an NGO can take on the task. The commune council does not see these activities as valuable compared to hardware investments, thereby losing opportunities to enhance the productivity of available land and water resources. This bias is also noted with respect to the content of village development plans, even though smaller and less costly investments in soft skills linked to capacity development may be more viable and generate their own livelihood impacts by potentially supporting productivity gains and livelihoods diversification.

Another factor that should be kept in mind is the political economy influencing commune councils' decisions in relation to the well-being of the villages, households and individuals. While commune councils are elected by their constituent villagers and are meant to represent multiple political interests, they are far from being politically neutral. This arises from the rules pertaining to voting by members, which requires half of the candidates to be drawn from the ruling party, causing a built-in weightage in favor of this party. Thus, while commune councils are meant to represent a component of political and administrative reform in favor of locally driven and representative governance, the current structure of the commune councils suggests a strong element of political capture of this process whereby the very institutions meant to broaden political participation have become instruments for consolidating the existing power structure.

The governance of aquatic agricultural systems in the Tonle Sap is thus closely associated with and influenced by the local administrative framework, not only in terms of its mandate to promote local development, but also through the power structures and politics these arrangements bring to the management of these resources.

Women and leadership

Very few women hold leadership positions such as village leader, commune council member or director of a community-based organization such as a community fishery. Respondents indicated that village life remains male-centric, and that women's leadership is neither encouraged nor welcomed. One female commune councilor and former village leader in fact remarked that her friends considered her unwise for taking on such a position. The women consider male dominance a self-enforcing system whereby men's authority prevails and that of women is undermined, making it harder and thus more daunting for a woman to assume leadership positions. It was also pointed out that many of the key livelihood and other activities are still dominated by men, and decisions relating to village affairs are closely linked to male-centric informal social networks and activities such as when they gather in the evenings to drink alcohol.

The only exception to this scenario is the requirement by commune councils that there be at least one female member, though this is a result of a prescription to engage women.

CONCLUSIONS

Access to and availability of water resources vary greatly between communities. Within land-based and land-and-water-based communities there is a situational gradient, with some communities accessing only a limited number of water sources and often suffering water scarcity in the dry season, while other communities have access to irrigation and groundwater and face only limited constraints in access to and availability of water. Several variations were found between and within communities, with spatial dimensions being an important criterion.

Constraints are multiple, with seasonal variations and strong biophysical factors influencing access to and availability of water. Lack of local institutions to regulate the use of and access to water resources also increases the vulnerability of the most resource-poor households. Governance and collective action for management of water or water-related resources, like fisheries and irrigation, are limited, and this was identified as an area for improvement. Better and collective management of these resources is needed, in order for benefits to also reach resource-poor and vulnerable households that are dependent on common-pool resources such as fisheries and water for drinking. Successful examples of collective management of irrigation schemes or collective ponds were identified during this study and can be looked to as examples of good community practice where lessons learned can be used for scaling.

With increasing pressure on water resources and the development of a market economy, a vibrant water market has been established and is now expanding, with a diverse pool of private sector and community-based stakeholders supplying water. Little is known about this water market, the institutional arrangements between stakeholders or the quality of the water marketed.

To help learn and share information and experiences between the different types of communities, AAS and the Tonle Sap Authority convened a best practice committee meeting with representatives from the main government agencies,[3] who were invited to assess the outputs of the community survey on water access, availability and management and to discuss and prioritize potential interventions regarding water resource management in pilot communities. Results of this workshop highlighted distinctions between communities in land-based ecosystems according to access to drinking water, water quality, and lack of water storage and irrigation systems. For land-and-water-based communities, identified priorities focused on access to drinking water and irrigation, and in both community types, the investigation identified potential availability of groundwater resources as a key priority. In water-based communities, improving water quality for domestic uses is the first priority. Other potential interventions could address livelihoods of local communities, such as by improving income via fish processing and diversifying livelihoods with floating gardens.

These interventions embrace the diversity of constraints and the need to support water access and water-related livelihood activities, which may not be directly linked to water resources, thus acknowledging the complex relationships that exist between local livelihoods and water resources.

NOTES

[1] A total of 55 key informant interviews were conducted. A summary of villages and survey instruments used is provided in Annex I.

[2] Filtering station managed by the community.

[3] Ministry of Water Resources and Meteorology, Fisheries Administration, Inland Fisheries Research and Development Institute, Ministry of Woman Affairs, and Royal University of Agriculture.

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ANNEX I

List of villages and survey instruments

Agro-ecological zone	Village	Province	Household surveys and focus group discussions	Key informant interviews
Land	Santey	Siem Reap	X	
	Rohal Suong	Battambang	X	X
	Bakou	Pursat	X	
Land and water				
	Muk Wat	Siem Reap	X	X
	Prey Chas	Battambang	X	
	Tramper	Pursat	X	X
	Kampong Kor	Kampong Thom	X	
Water	Peam Ta Uor	Siem Reap	X	
	Prek Toal	Battambang	X	
	Raing Til	Pursat	X	X
	Phat Sanday	Kampong Thom	X	X
	Chhnoc Trou	Kampong Chhnang	X	X

Key informant interviews at national level

Organization	Designation	Location
Tonle Sap Authority	Director, National Reserves and Biodiversity (focus on Flooded Forests)	Phnom Penh
Tonle Sap Authority	Director of National Reserves and Biodiversity (focus on Fish Biology)	Phnom Penh

Key informant interviews at provincial level

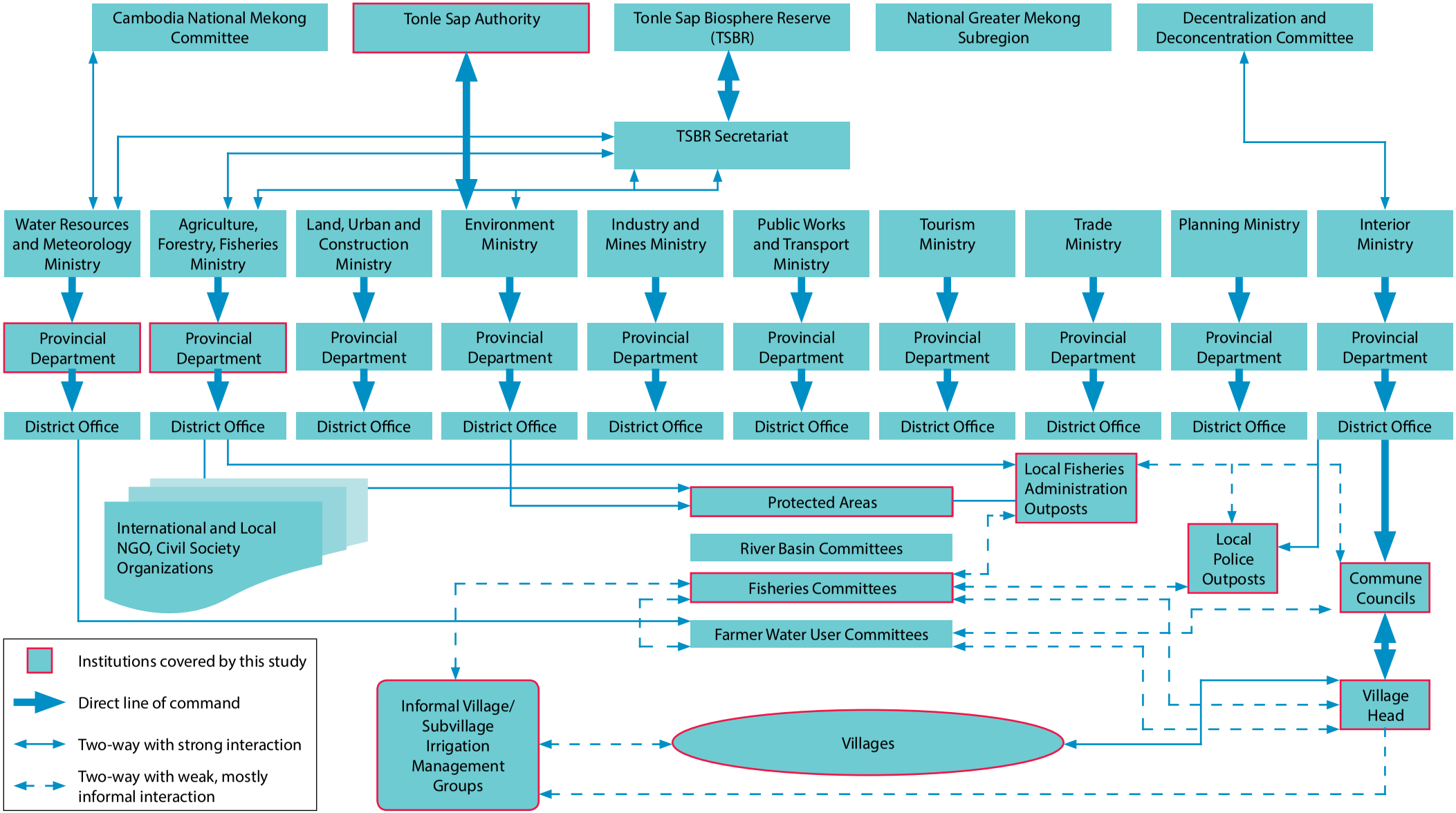
Organization	Designation	Location
Ministry of Environment	Sub-Deputy of Biodiversity, Kampong Chhnang Province	Chnok Tru village
Fisheries Administration Provincial Office	Fisheries Officer	Pursat Province
Fisheries Administration Provincial Office	Fisheries Officer	Pursat Province
Provincial Department of Water Resources and Meteorology	Deputy Director	Pursat Province
Fisheries Administration Provincial Office	Fisheries Officer	Battambang Province
Provincial Department of Water Resources and Meteorology	Deputy Director	Battambang Province
Provincial Department of Water Resources and Meteorology	Deputy Director	Siem Reap Province

ANNEX I

Survey instrument outline

Survey instrument	Topic/data collection
Household survey	• Household characteristics and assets • Domestic use of water: water sources, storage, purchase and water collection, and consumption and water quality • Response to climate events • Agriculture and water: water sources, response to climate events • Livestock and water sources, response to climate events • Aquaculture and fisheries: seasonality, production and fish catch, response to climate events
Focus group discussions with local authorities and community-based organizations	• Water resources mapping: access, availability, uses, regulation and constraints • Irrigation trends • Institutional arrangements associated with water use • Timeline of climate-related events • Past and current interventions in the village
Focus group discussions with farmers and fishers	• Water resources mapping: access, availability, uses, regulation, and constraints for agriculture and fisheries • Seasonal calendar: vulnerability to climate events • Timeline of climate-related events and coping strategies
Focus group discussions with women	• Water sources for domestic uses: access, availability, uses, regulation and constraints • Purchase of water and water market • Response to climate hazards • Past and current interventions in the village
Key informant interviews	• Case studies on water management for irrigation and fisheries, including how these two water uses relate to each other • Case studies on how broader institutional structures operating at commune to national levels influence village-level water and land management

ANNEX II


Cambodia National Mekong Committee
Tonle Sap Authority
Tonle Sap Biosphere Reserve (TSBR)
National Greater Mekong Subregion
Decentralization and Deconcentration Committee
TSBR Secretariat
Water Resources and Meteorology Ministry
Agriculture, Forestry, Fisheries Ministry
Land, Urban and Construction Ministry
Environment Ministry
Industry and Mines Ministry
Public Works and Transport Ministry
Tourism Ministry
Trade Ministry
Planning Ministry
Interior Ministry
Provincial Department
District Office
International and Local NGO, Civil Society Organizations
Local Fisheries Administration Outposts
Protected Areas
River Basin Committees
Fisheries Committees
Farmer Water User Committees
Local Police Outposts
Commune Councils
Village Head
Informal Village/ Subvillage Irrigation Management Groups
Villages
Institutions covered by this study
Direct line of command
Two-way with strong interaction
Two-way with weak, mostly informal interaction

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About the CGIAR Research Program on Aquatic Agricultural Systems
Approximately 500 million people in Africa, Asia and the Pacific depend on aquatic agricultural systems for their livelihoods; 138 million of these people live in poverty. Occurring along the world's floodplains, deltas and coasts, these systems provide multiple opportunities for growing food and generating income. However, factors like population growth, environmental degradation and climate change are affecting these systems, threatening the livelihoods and well-being of millions of people.

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