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Mak Sithirith * , Sao Sok , Sanjiv De Silva , Kong Heng , Kongkroy Chay , Thavrin Tim , Sarun Hy

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Water Governance in the Cambodian Mekong Delta: The Nexus of Farmer Water User Community (FWUC), Community Fisheries (CFis) and Community Fish Refuges (CFRs) in the Context of Climate Change

Mak Sithirith [1,*], Sok Sao [1], Sanjive de Silva [2], Heng Kong [3], Chay Kongkroy [3], Tim Thavrin [3] and Hy Sarun [3]

1 WorldFish
2 International Water Management Institute (IWMI), Sri Lanka
3 Inland Fishery Research and Development Institute (IFReDI)/Fishery Administration (FiA), Cambodia
* Correspondence: maksithirith@gmail.com

Abstract: Cambodia faces the challenge of managing excess water during the wet season and insufficient water during the dry season. This harms human life and endangers aquatic and natural resources, agricultural practices, and food security. In order to ensure the well-being of both people and food security, water governance is crucial. However, Cambodia's water governance is hindered by various obstacles, including sectoral and centralized influences, top-down and large-scale strategies, a lack of coordination among relevant agencies, and limited involvement of local communities. This study delves into water governance across different sectors, from centralized to community-based natural resources management to tackle these challenges. Through analyzing literature and case studies of farmer water user communities (FWUC), community fisheries (CFis), and community fish refuges (CFRs) in three Mekong Delta provinces in Cambodia, the study concludes that although water governance has improved, it has resulted in a decline in fishery resources from rivers and water bodies and an increase in water conflicts among farmers and sectors in the face of climate change. To enhance water governance in Cambodia, it is critical to integrate it at the district level. This will promote sustainable water use and management across the country and pave the way for a brighter future.

Keywords: water governance; rice farming; irrigation; community fisheries; community fish refuge; water conflict

1. Background

In Cambodia, there is an abundance of water during the wet season and a scarcity of it during the dry season. Unfortunately, the excess water can lead to devastating floods that damage infrastructure, properties, and crops. Conversely, the lack of water often leads to low agricultural yields, negatively impacting the livelihoods of farmers, fishermen, and the wider community [1]. These challenges have significantly impacted food production and consumption throughout the country. Experts agree that proper water management is essential for Cambodia's continued development [1–3].

It is widely believed that effective water management entails the development and management of irrigation systems to store water for rice farming. Despite the Ministry of Water Resources and Meteorology's (MOWRAM) efforts to support rice farming through large-scale irrigations, farmers continue to experience water scarcity issues and annual crop damage from floods. These challenges

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can be attributed to the centralization of water management through large-scale irrigation development [2–4].

In recent years, Cambodia has adopted a decentralized approach to water management through the introduction of the Farmer Water User Community (FWUC) system. This system entrusts farmers with the responsibility of managing irrigation systems through contributions in cash and kind [5]. However, studies have revealed that FWUCs tend to be weak and managed centrally, with minimal input from community members. Besides, other community organizations such as Community Fisheries (CFis) and Community Fish Refuges (CFRs) also compete for water resources to sustain their livelihoods [6–9]. While FWUCs utilize water for rice farming, CFis and CFRs rely on water resources for sustainable fishery productivity. Moreover, the situation is further complicated by climate change, which impacts water availability for all three communities [10,11]. This paper endeavors to examine water governance concerning FWUCs, CFis/CFRs, and rice farming in three Mekong Delta Provinces in Cambodia and evaluate how water resources are shared among these communities.

2. Conceptual framework

Water is an essential ingredient for the sustenance of life, the environment, and growth. It naturally flows and is stored in various forms such as rivers, streams, lakes, ponds, and underground reservoirs. These bodies of water provide habitat for aquatic animals, fish, and plants, while terrestrial plants rely on underground water for growth. The dry season can cause water stress in lakes, rivers, and streams due to evaporation [12].

In the past, water access was governed by the open access regime. However, the growing population and development pressures have increased the demand for water resources, resulting in technical and sectoral systems taking over. This has made water governance a significant challenge with multi-sectoral dimensions. The literature on water governance primarily discusses its effects on multiple sectors, including fishery and rice farming. A literature review highlights six dimensions of water governance related to fishery and rice production [13,14].

The management of water resources is intricately linked to the unique physical attributes of rivers, lakes, and floodplains, including their overall volume and quality. This issue primarily affects the communities residing upstream and downstream of these vital water sources during both wet and dry seasons [15]. In times of drought, for instance, upstream communities may consume a disproportionate amount of water, causing a scarcity of this resource for downstream farming and fishing communities. This can result in tensions and disagreements between the various groups. Similarly, during the flood season, the release of excess water by upstream communities can inundate the rice fields of downstream communities, exacerbating existing tensions [16,17].

Water governance is influenced by different sectors and actors. Some sectors are considered more economically important than others and, therefore, receive priority in terms of planning and investment aimed at extracting more water to generate income and benefits. Within each sector, actors with power and interests drive decision-making. In the Mekong River Basin, water has been prioritized for hydropower development over supporting the fishery sector, with the goal of securing energy and boosting industrial development in the Mekong countries [18]. Hydropower companies are actively involved in driving this development, supported by upstream states of the Mekong River. The industrial sector has also competed for water to support their own development, which has impacted the fishery, agriculture, natural resources, and food security during the production cycle [19,20].

Water usage, governance, and management across various sectors are guided by institutional frameworks and policies. These policies are formulated by institutions and governing bodies to provide a set of rules and regulations that help these sectors access and govern water resources for their benefit [21]. These policies are influenced by technical expertise and specialization within institutions, which in turn affect other institutions. The creation of policies is intrinsically linked with power and politics, where power sustains politics and policy, and politics involves the processes of achieving, exercising, and resisting power [22]. Politics operate within institutions and sectors, while power as a strategy involves controlling and organizing spaces and resources through forms of territoriality and the classification of precise geographic areas and boundaries. The organization of space is based on technical, scientific, economic, and political interests [23]. Henri Lefebvre [23] highlights that:

Specializations divide space among them and act upon its truncated parts, setting up mental barriers and practice-social frontiers. Thus, architects are assigned architectural space as their private property, economists come into possession of economic space, geographers get their own place in the sun, and so on. The ideologically dominant tendency divides space up into parts and parcels in accordance with the social division of labor [23, 1991: 89-90].

Furthermore, using, sharing, and controlling water for fishery, agriculture, industry, etc., involves decision-making by actors at different levels. Dore [24] in the deliberative water governance and Dore et al. [16] in a framework for analyzing transboundary water governance complexes in the Mekong Region suggest that water governance is a social process of dialogue, negotiation, and decision-making, in which many different actors are dealing with a variety of issues influenced by their individual and shared context—actors engage in multiple arenas, depending on the opportunity, necessity, and choice; drivers are what influence and motivate actors; actors employ drivers to establish and legitimize their positions, inform debate and influence negotiations; decisions emerge from the arenas, and the impacts of decisions result in fairness and sustainability of water allocation [16,21]. In addition, Ratner et al. [19] look at the governance of the aquatic agricultural system from three governance dimensions: (i) Stakeholder representation—which actors are represented in decision-making and how? (ii) Distribution of authority—how is formal and informal authority distributed concerning decisions over resource access, management, enforcement, dispute resolution, and benefit sharing, and (iii) Mechanisms of accountability—how are power-holders held accountable for their decisions, and to whom? These form the basis of governance of resources [20].

Access to water resources is crucial for the livelihoods of the rural poor. It also plays an essential role in ensuring the well-being of people, reducing crop failures during dry spells, and providing opportunities for farmers to grow two or three rice crops a year. However, treating water as a public good and assuming that it is accessible to all can create a few problems. Firstly, state institutions may be slow to respond to the needs of their citizens due to bureaucracy, rules, and regulations [25]. Secondly, treating water as a public good can lead to wasteful use, as it is free, and waste does not incur any cost [26,27]. On the other hand, when people have to pay to use water, they tend to use only enough water to satisfy their immediate needs. Also, markets can respond to people's needs faster than the state [25].

Water governance is intricately linked to the physical structures that are put in place to regulate, collect, store, move and distribute it. The design and operation of water infrastructure have a profound impact on the natural and social environments in which they exist. Furthermore, social systems and processes play a crucial role in shaping the physical infrastructure used for water management. To truly understand a water management system, it is essential to recognize the interdependence of social, technological, and ecological systems. This interconnectedness also highlights the continuous evolution of governance arrangements and processes. Ultimately, decision-making related to water management will involve a diverse group of stakeholders at different levels, utilizing a range of platforms and technologies [25,28].

3. Materials and Methods

The conceptual framework above has been utilized to analyze water governance in Cambodia's Mekong Delta and assess its impact on rice field fishery productivity, rice production, food security, and livelihoods. The framework was constructed through a combination of literature reviews, surveys, and fieldwork analysis, and it specifically examines the role of rice field fishery management, rice farming, irrigation development, and climate change in Cambodia's water governance landscape.

Empirical research was carried out in two of Cambodia's Mekong Delta Provinces, namely Prey Veng and Takeo, as well as in Kampong Thom- a province located in the Tonle Sap Lake (TSL) region.

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The study selected four sites across these three provinces: (1) Beung Sneh Lake (BSL) and (2) Beung Plang in Prey Veng Province, (3) Beung Ream in Kampong Thom Province, and (4) Ta Soung in Takeo Province.

BSL, a 3,924 ha freshwater lake in Prey Veng Province, is connected to the Mekong River and encompasses 44 villages across eight communes in 4 districts. Within BSL, you can find four CFis, two FWUCs, and a Community-based Eco-tourism (CBET). Our study examines the Chamcar Kouy Irrigation Scheme (CKIS) and the four CFis situated in BSL.

Beung Plang is a serene freshwater pond nestled in Ampil Krav Commune, Sithor Kandal District, Prey Veng Province. The pond is a beloved fixture in the area, surrounded by five vibrant villages and providing a home to 2,112 households. It is noteworthy that three of these villages have come together to establish the Community Fish Refuge (CFR), known as Beung Plang CFR (BPC). For our study, we directed our focus toward the CFR site and the Vaiko Irrigation Scheme (VIS) located in the Ampil Krav commune.

The Farmers Water User Community (FWUC) of the Ta Soung Irrigation Scheme (TSIS) serves nearly 1,000 farming households across 15 villages in Prey Kabbas District, Takeo Province. This community is linked to the Prek Ambel River (PAR), which feeds into the Bassac River. Additionally, the study delves into the connection between the TSIS and the four Community Fisheries (CFis) that were established to manage former fishing lot no.20 in PAR, Takeo Province.

Beung Ream is a pristine freshwater pond nestled in Kakoh Commune, Santuk District, Kampong Thom Province. It has been designated as Beung Ream CFR (BRC) and is linked to the Tang Krasaing Irrigation Scheme (TKIS), which has been established as FWUC. Nestled within TKIS, Kakoh Commune is home to approximately 3,309 households that are spread across 10 villages and organized into Sub-FWUC. This study explores the BRC and the Sub-FWUC of Kakoh Commune as a crucial component of TKIS.

The researchers utilized both qualitative and quantitative methods to gather primary and secondary data from the studied sites. The team, comprised of members from WorldFish, International Water Management Institute (IWMI), Inland Fishery Research and Development Institute (IFReDI), and Fishery Administration Cantonments (FiACs), conducted data collection between December 2022 and June 2023. Secondary data on various factors such as CFis, CFRs, FWUCs, irrigation schemes, rice production, fishery, pesticides and fertilizers, population, and farming lands were collected from the commune database (2021), CFi and CFR databases (2022), and the irrigation database of MOWRAM (2019). Primary data was obtained through key informant interviews (KIIs) and focus group discussions (FGDs). The KIIs were conducted with Provincial Departments of Water Resources and Meteorology (PDWRAMs), FiACs, District Officers in charge of Agriculture, Environment and Water Resources, Commune Chiefs, and NGOs in the respective sites. The FGDs were conducted with various groups such as CFis, CFRs, FWUCs, Identity of the Poor 1 & 2 (ID Poor 1&2), and non-ID Poor (Table 1).

During the inquiry, KIIs and FGDs were consulted regarding the performance of FWUCs, CFis, and CFRs. Specifically, the water usage of FWUCs during three rice farming seasons and its effects on CFis/CFRs were discussed, along with the competition between FWUCs and CFis/CFR for water resources. The roles of local governments in water governance were also examined, and recommendations were made for improving water governance for FWUCs, CFis/CFRs, rice farming, and fishing. Furthermore, FGDs were held with both ID Poor and non-poor participants to discuss the changes in water resources, fishery, agriculture, and food over the past 10-15 years. The impact of these changes on ID Poor 1, 2, and non-poor individuals was also explored. Finally, the group discussed the positive developments in water resources, rice farming, fishery, foods, and livelihoods that have resulted from the implementation of irrigation systems, FWUCs, CFis, and CFRs in the studied areas.

The information gathered from the FGDs, interviews, and secondary sources underwent analysis utilizing an Excel spreadsheet. The data was then transformed into percentages, figures, and tables, with qualitative data included to support the findings. This article delves into the subject of water governance, investigating the manner in which water is used by FWUCs, CFis, and CFRs, as

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well as its impact on water resources and sustainability. Additionally, it explores the ramifications of climate change on water usage, including its effects on rice farming seasons and the competition that arises between FWUCs and CFis/CFRs. The study concludes with recommendations for enhancing water governance to promote fishery, rice farming, and livelihood sustainability, and includes suggestions for improving water governance to aid in rice farming and fishery conservation efforts.

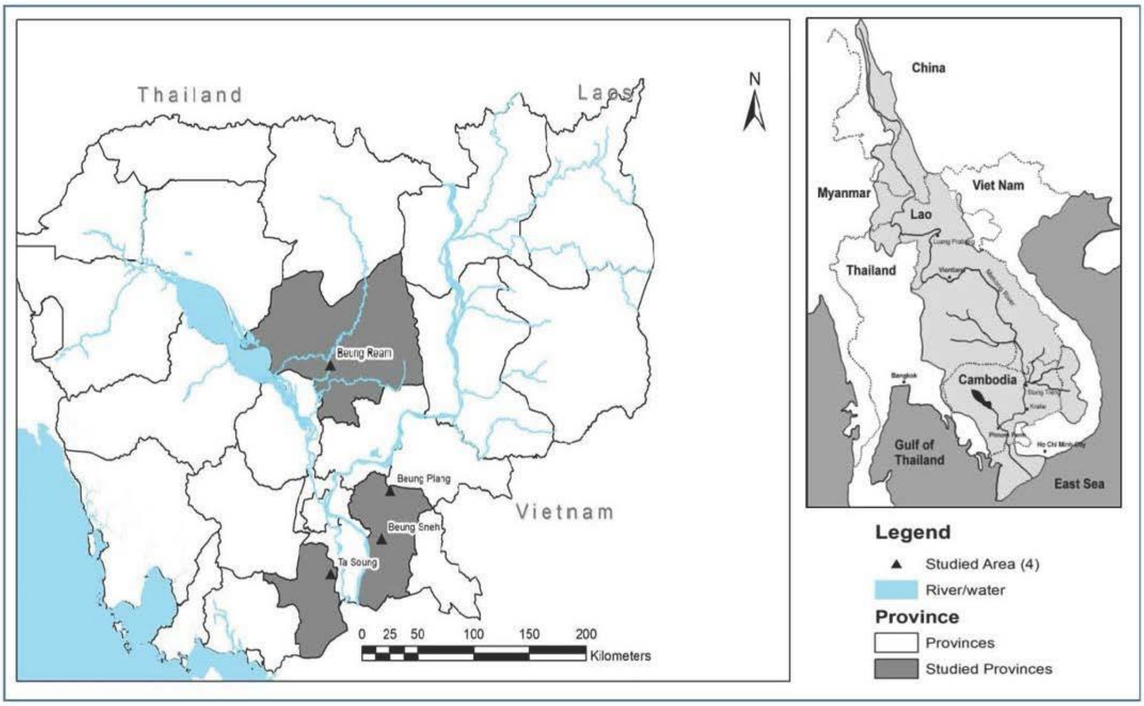

Figure 1. Map of the study provinces.

Table 1. The primary data collection using KIIs and FGDs.

Data Collection Methods/Sites	KIIs	FGDs with CFis/CFRs	FGDs with FWUCs	FGDs with ID Poor 1&2; and the Non-ID Poor
Beung Sneh	• Chief of PDWRAM and two staff, • FiAC Prey Veng, • Commune Chiefs of Prey Kandieng, Theay, Samrong & Damrei Poun Communes	4 FGDs with CFis: (1) Theay, (2) Samrong, (3) Damrei Poun; (4) Prey Kandieng	• 01 FGD with Chamcar Kyou FWUC • 01 FGD with Private FWUC in Toap Sday Village/Theay Commune	15 FGDS in 5 villages in five Communes around Beung Sneh: 1. Samrong, 2. Prey Khla, 3. Kok Trom, 4. Kampong Sleng, 5. Chamcar Kyou,
Beung Phlang		One FGDs with CFR	n/a	03 FGDs in Peanea Village
Beung Ream	• Deputy Chiefs of PDWRAM, • District of Officers in charge of FWUC, • Kakoh Commune Authority, • Chief of Kakoh's FWUC	02 FGDs	3 FGDs of FWUCs	15 GFDs in five villages in Kakoh Commune: (1) Chey Chomneas, (2) Kiriwone, (3) Samnak. (4) Santuk Krav, (5) Cheay Spai
Ta Soung	• District Officers in charge of irrigation, agriculture and fishery	03 FGDs with 3 CFis	One FGD with FWUC	15 FGDs in five villages three communes: (1) Sethey, (2) Prey Lvea Keut, (3) Pontong, (4) Kampomg Reab, (5) Prey Tapong

4. Results and Discussion

4.1. Water Resources in Cambodia

Cambodia is situated in the Lower Mekong Basin, spanning an area of 181,035 km^2. A substantial portion of Cambodian land, roughly 86% (156,000 km^2), is within the Mekong catchments. As a downstream and lowland nation, Cambodia is blessed with plentiful water resources. It boasts approximately 1216 km^3 of water within its borders, with an additional 355.5 km^3 flowing into the Mekong River from external sources. Cambodia's estimated annual total renewable water resources are around 476 km^3 [29] (Units of volume: 1 km^3 = 1 billion m^3 = 1000 million m3 = 10^9 m^3). The annual water usage amounts to around 2.18 cubic kilometers, with agriculture being the primary consumer at 94%. The withdrawal of irrigation water alone accounts for about 1.928 million cubic meters on a yearly basis, while the remaining water is allocated for domestic and industrial use. The estimated water withdrawal per individual ranges from 130-160 cubic meters per year [29].

With 39 river basins located in five sub-regions, Cambodia is home to a vast array of water resources. The Tonle Sap Lake alone is made up of 16 sub-river basins, while the Upper Mekong River basin contains five, the 3S basin has three, the Mekong Delta has eight, and the coastal river basin has eight sub-river basins. At Kratie, the Mekong River provides Cambodia with its primary external water resources, with an average discharge of 476 km^3 per year before it flows into the South China Sea [1].

4.2. Irrigation and Rice Farming

In Cambodia, there are 2,500 irrigation schemes across Cambodia, which could irrigate 2.32 million ha, among which 65% are located in the Mekong floodplains and Delta and 35% in the Tonle Sap floodplains. We studied three irrigation systems in Cambodia's Mekong Delta in Prey Veng and Takeo Provinces. Prey Veng province has 177 irrigation systems and Takeo of 136 irrigation schemes. In the Tonle Sap floodplain, the study focuses on Kampong Thom Province, with 258 irrigation schemes (CISIS Database, 2020; pers. communication, February 2023).

In Cambodia, there are 2,500 irrigation schemes that could irrigate 2.32 million hectares of land. Of these, 65% are found in the Mekong floodplains and Delta, while the remaining 35% are situated in the Tonle Sap floodplains. Our investigation specifically examined three irrigation systems in Cambodia's Mekong Delta, located in Prey Veng and Takeo Provinces. Prey Veng Province boasts 177 irrigation systems and Takeo has 136. Furthermore, we delved into Kampong Thom Province in the Tonle Sap floodplain, where there are 258 irrigation schemes. These statistics were procured from the CISIS Database in 2020 and were authenticated via personal communication in February 2023.

The analysis of four irrigation schemes has been chosen for the study, comprising of two in Prey Veng province (CKIS and VIS), one in Takeo Province (TSIS), and one in Kampong Thom Province (TKIS). The CKIS scheme is primarily supplied with water from BSL, which provides approximately 85 million cubic meters of water during the wet season and reduces to around 40 million m3 during the dry season. The TSIS scheme uses water from PAR, a tributary of the Bassac River, while the VIS scheme relies on the Mekong River. The TKIS scheme uses water from the Taing Krasaing and Stung Chinit Rivers. These irrigation schemes cover an area of approximately 63,895 hectares, which accounts for around 3% of the targeted national irrigated area of 2 million hectares by 2023 [30].

The Prey Kabbas District boasts the TSIS, an irrigation system that comprises of two main canals, ten secondary earth canals, and eight secondary concrete canals. The system is equipped with a pumping station that houses five pumping machines and irrigates 1,511 hectares of land owned by 970 farming households from 15 villages across four communes. Another notable irrigation scheme in Kampong Thom Province is the TKIS. TKIS in Kakoh Commune consists of a main canal, six secondary canals, and 16 tertiary canals, with two water gates that can cover a distance of 22km from the Stung Chinit River to the Beung Ream in Kakoh Commune, Santuk District. The TKIS in Kakoh Commune can irrigate up to 9,869 hectares of land across ten villages in Kakoh Commune (Table 2).

Surrounding the Beung Plang site in Prey Veng is the VIS, a water system consisting of two primary canals, six secondary canals, five water gates, and a pumping station. This system is responsible for irrigating five villages in Ampil Krav Commune and gets its water from Koh Sotin in the Mekong River located in Kampong Cham province. Flowing through Sithor Kandal District in Prey Veng and ending in Svay Rien Province, the VIS has a length of 78km and holds the potential to irrigate an impressive 153,400ha (Table 2). The CKIS, on the other hand, draws water from the BSL in Damrei Poun Commune. With one primary canal, this system is capable of irrigating 2,010ha in six villages within the commune. The BSL covers a vast area of 3,585ha and contains approximately 85 million m^3 of water during the wet season, reducing to around 40 million m^3 in the dry season.

Table 2. Irrigation schemes in the study sites.

Site	Irrigation Scheme	Length (km)	Water Sources	Irrigated Area (ha)	Province coverage	Total fund (million)	Donor	Year of construction	Year of Completion
Beung Phlang	Vaiko	78	Koh Sotin, Mekong River, Kampong Cham	153,400	Kampong Cham, Prey Veng & Svay Rieng	99.3	China	2012	2017
Ta Soung	Ta Soung Irrigation	50	Prek Ampil River	1,511	Prey Kabbas in Takeo	2	DFAT	2016	2017
Beung Ream	Taing Krasain	22	Stung Chinit	9,869	Taing Krasaing, Kampong Thom	40	ADB	2013	2015
Beung Sneh	Chamcar Kouy	9	BSL	2,010	Damreiu Poun Commune	10	ADB	2013	2019

4.3. Farmer Water User Community

The Royal Government of Cambodia (RGC) introduced the Water Law in 2005, which allows farmers who utilize the irrigation system to form FWUCs under Article 19 [11] (Ministry of Water Resources and Meteorology (MOWRAM). Sub-Decree on the Establishment and Dissolving of FWUC; Ministry of Water Resources and Meteorology: Phnom Penh, Cambodia, 2015). To better manage water resources, the RGC decentralized the implementation and maintenance of irrigation schemes to FWUCs via Prakas 306 in 2006. To date, 544 FWUCs have been established to manage irrigation schemes [30], but in Prey Veng Province, only 38 out of 177 irrigation systems have FWUCs. Meanwhile, Kampong Thom has 258 schemes and 30 FWUCs, but unfortunately, many FWUCs are inactive, with only 10% currently active.

Five of the identified FWUCs were examined in their respective study areas - two in BSL, and one each in Beung Phlang, Beung Ream, and TSIS. These FWUCs cover a total of 9,058 hectares of agricultural land and have 15,781 agricultural households as members. The largest of the studied areas is Damrei Puon's FWUC in BSL, followed by TSIS's FWUC in Takeo Province and Theay's FWUC in BSL (Table 3).

Table 3. FWUCs in the management of water.

Site/commune	No. of FWUCs	No. of Sub-FWUC	No. of villages in FWUC	Total areas (ha)	No. of members (HHs)	Year of establishment
Beung Phlang	1	0	3	107	93	n/a
Ampil Krau	1	0	3	107	93	0
Beung Sneh	2	0	10	2350	1660	0
Damrei Puon	1	0	6	1570	984	2018
Theay	1	0	4	780	676	2005
Boeung Ream	1	9	10	5099	13058	2018
Kakoh	1	9	10	5099	13058	2018
Ta Soung	1	15	15	1,511	970	2022
Grand Total	**5**	**24**	**38**	**9058**	**15781**	**0**

4.4. Fish and Fishery Resource Management

The areas under study are rich in fishery resources, with connections to a variety of water bodies including rivers, streams, and lakes. The TSIS was once a fishing lot numbered 20 in Takeo Province, and is now connected to PAR, a tributary of the Bassac River. Similarly, the BSL is linked to the Mekong River, which is home to a diverse array of fish that people from 44 villages depend on for their livelihoods. Beung Ream, located in the Tonle Sap Floodplain, serves as a migration route for fish between Tonle Sap Lake and Beung Ream during the rainy season. Despite this, only 24% of households in the studied areas rely on fishing, with Prey Kabbas District having the highest percentage of fishing households at 33%. Around 30% of households in Kampong Thom's Beung Ream still rely on fishing, while BSL in Prey Veng Province has a significantly lower percentage of fishing households at just 19%.

To promote the sustainable management of fishery resources, the Fishery Administration (FiA) has established eight Community Fisheries (CFis) and two Community Fishery Reserves (CFRs) in the studied areas. The CFR is linked to the rice fishery, which accounts for 30% of fish production in Cambodia [31]. According to the CFi Effectiveness Assessment 2018, CFis are responsible for 15% of the total inland fish production [32].

Table 4. The characteristics of the studied CFis and CFRs.

Studied Sites	CFis				CFRs			
	No	Area (ha)	No. of villages	Membership	No	Area (ha)	No. of Villages	Membership
Beung Phlang	-	-	-	-	1	27	3	4,981
Ta Soung	4	844,793	17	1016	-	-	-	-
Beung Ream	-	-	-	-	1	13	2	572
Beung Sneh	4	85,236	26	11,034	-	-	-	-
Total	8	930,029	43	12,050	2	40	5	5,553

4.5. Community Fishery

The studied CFis were established after 2000, following the release of commercial fishing areas for public open access to local communities. The prominent roles of CFis are to conserve and protect fishery resources within the CFi territories. All members could fish openly throughout the year using the fishing gear defined in the CFi by-laws. The by-laws allow CFi members to fish subsistent, not commercial, aiming at conserving fishery resources.

The CFis in BSL are connected to eight large irrigation systems that utilize water from the CFi areas to irrigate rice fields spanning over 22,899 hectares around the lake. These CFis are established at the commune level, with elected Committees from villages in the communes. Their primary objective is to protect and conserve the fishery resources by reserving approximately 40 hectares inside the lake and nine deep water areas in the BSL as CFi-protected zones. To achieve this, CFis maintain the water level in the lake at approximately 4-5 meters deep during the dry season, providing fish with shelter. However, their actions often contradict those of Farmer Water User Committees (FWUCs), where farmers need to pump water to irrigate their rice fields. This puts CFis under immense pressure as they lose water to rice cultivation, leading to a decrease in the lake's water level that impacts both the CFis and fisheries, and results in illegal fishing within the protected areas. Additionally, they also face the destruction of flooded forests around the lake and water pumping from the lake.

From 2000 to 2002, four Community Fishery institutions (CFis) were established in the Prey Kabbas District of Takeo Province, specifically in the areas of TSIS. These CFis boast a total of 1,016 members, with 550 of them being female. The leadership of the CFis consists of 36 Committee members, four of whom are female. The establishment of these CFis aimed to protect fishery resources and support the communities. Oxfam Australia partnered with these CFis from 2002 until 2015 to protect fishery resources to support communities. However, since Oxfam phased out of the area, CFis have become inactive due to financial and technical support, staffing, and budget constraints. In 2022 and 2023, the European Union provided a small grant of USD 1,000 per year to

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Kampong Reab, one of the CFis. However, this grant only addresses patrolling, conservation, and signboard for CFi awareness-raising and not the other pressing issues that CFis are facing.

CFis encounter several obstacles, including encroachment in their conservation zones, illegal fishing within CFi core areas, and limited participation from both members and non-members in the management of CFi areas. Moreover, the lack of support from FiA, FiAC, and local government in managing CFi areas, as well as limited financial and technical support from concerned agencies, hinders the protection of fishery resources. Addressing conflicts between CFis and Farmers Water User Committees (FWUCs) over water pumps from CFi areas to irrigate rice fields, overlapping areas between CFis and FWUCs, lack of fishery management within FWUC areas, and the use of pesticides and fertilizers in rice farming that results in the killing of aquatic animals and fish are crucial issues that require attention.

4.6. Community Fish Refuges

This study delves into two CFRs, namely the BRC in Kampong Thom and the BPC in Prey Veng Provinces. The BRC was established in 2021 by two villages in the Kakoh Commune, Santuk District, Kampong Thom Province. It covers a vast area of 13 hectares, with a 2-hectare core protected region and an average water depth of 2.5 meters during the dry spell. The CFR area is equipped with a water level monitoring system that triggers an alarm to prevent any further water extraction from the lake. It is marked with pillars, a security guard post, and a signboard that explicitly states the prohibition of illegal fishing within the BRC area.

Table 5. Framework for analyzing water governance in the studied areas.

Water User Community	No. of FWUCs	Source of Water--Upstream vs downstream	Policy	Institution	Water Conflict & cooperation—Power, politics, & position	Dialogue/ negotiation
FWUCs	• 01 FWUCs in TSIS • 01 FWUC in TKIS • 02 FWUCs in BSL—One is not active • 01 FWUC in Beung Phlang, not active.	• BSL, PAR in Takeo, • Taing Krasaing River, and • Mekong River (Vaiko Irrigation Scheme)	• The Constitution 1993-- Article 58 & 59. • Water policy (2004), • Water Law (2007). • Sub-decree for effective and sustainable management, protection, and development of surface water and groundwater in 39 river basins (July 2015). • FWUC Sub-decree (2015)	• MOWRAM was established in 1999, managing water & irrigation management--the operation of the irrigation system. • MAFF is responsible for rice farming and seems to have no roles in irrigated areas provided by MOWRAM. • Commune Authority plays in water management in their communes only when water conflicts occur. • The District Office of Agriculture, Environment, and Water coordinates activity concerning water uses, agriculture, and the environment	• Water is pumped from water sources through irrigation to irrigate three rice crops annually. Water shortages lead to competition and conflict among farmers between farming, fishing & domestic uses. • Irrigation is a weapon for fighting water shortage at the community level, and water pumping generators are weapons for fighting water shortage at the household level. • Competing between upstream and downstream communities: communities with and without irrigation schemes. • Rice farming and in-datedness and migration.	• At the regional level, there are regional dialogues on water sharing in the Mekong River Basin. • At the national level, Coordination between MOWRAM and MAFF remains challenging over water management and water uses for rice farming. • At the local level, there is a weak conflict between FWUCs and CFis over water use.
CFis	• 04 CFis in PAR	• BSL in Prey Veng.	• Fishery Law,	• FiA/FiAC, • The Fishery Sector has been decentralized, and	• CFis protect water at 3-4m deep to keep the fish habitat	• CFis and FWUCs are in the same villages and

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	• 04 CFis in BSL	• PAR in Takeo.	• Sub-decree on CFis. • Strategic Planning Framework for Fisheries. • Planning Framework	FiAC is not under FiA, but under the PDAFF. • FiA/FiACs organize the election to set up the CFi Committee to manage CFis. • CFis are weak and lack funding and technical support. Many CFis are not organizing re-elections and developments of the management plans. • Commune Administrations do not have a mandate in fishery management and CFis.	productive—below that will affect fish, increased fish catch, and encroach the wetlands in the lake to cultivate rice farming. • The irrigation scheme has blocked the river flow and fish migration, changing landscapes. The irrigation management has no fishery management system included. • The increased water pumping resulted in lower water, affecting the fishery. • The increased rice farming leads to the use of pesticides and fertilizers, affecting fishery and aquatic animals.	communes, but water conflicts remain unresolved. • Communes facilitate the CFis and FWUCs in the monthly commune meeting but cannot resolve the tensions between CFis and FWUC. • FiA has decentralized to FiACs, but FiACs have limited resources and capacity to resolve these conflicts at local levels. • CFis—no fishery officers at the district level. The fishery has not been integrated into the District Office of Agriculture, Environment, and Water.
CFRs	• 01 BRC • 01 BPC	• Taing Krasaing River, and • Mekong River (Vaiko Irrigation canals)	• Legal framework is being developed • Sub-decree on CFR is being drafted.	• FiA is the leading Institution. • The Department of Aquaculture Department (DAD) is mandated to manage CFRs. • FiA/DAD organized the election to set up the CFR Committee to manage CFRs. • Commune Administration has no knowledge and mandates in CFR management. • NGOs and Donors support CFRs financially.	• CFRs protect water sources to provide habitats to fishery and aquatic animals to seek refuge in the dry seasons in order for them to keep breeding so that in the wet season these fish and aquatic animals will migrate to rice fields and water bodies. • CFRs are often pumped by farmers, who are members of FWUCs and CFRs, to save their rice farming in the dry season when water is critically low in the CFRs and shortage.	• No mechanism in place to support the CFRs at the ground, only through donors/NGOs. • Commune Administration often facilitates CFRs and FWUCs in the monthly meetings of the Communes.

In the vicinity of BRC, three canals are present: O' Praing, Beung Karav, and irrigation canals constructed by MoWRAM. O' Praing underwent rehabilitation through a private company that utilized the soil to construct roads. Since then, it has ensured a year-long water supply to BRC. The Kakoh irrigation canal enters BRC via a water gate that regulates water supply to CFR areas. The Kakoh irrigation system is part of the TKIS. Farmers have been irrigating 995 hectares of rice fields surrounding BRC with water from the Kakoh irrigation canals and BRC, enabling them to cultivate 2-3 crops of rice. Approximately 572 households are actively involved in fishing and harvesting fish and OAAs from the floodplain area and rice fields surrounding BRC, which gets flooded during the rainy season. Besides, around 294 households fish within the BRC area for approximately five months a year. Fishing benefits approximately 716 families, of which 20 percent are impoverished

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households. The estimated annual fish catch per household is about 88kg, and the estimated annual catch of OAAs is about 48kg per household.

The BPC, situated in the Ampil Krau Commune, is home to 17,572 individuals from 2112 households across five villages. The majority of the population, approximately 85%, is engaged in farming, while about 20% are involved in fishing. Established in 2008 by Peanea, Kbal Beung, and Svay Teap villages, the BPC was created to protect land, fish, and biodiversity for the community's benefit. Covering an area of roughly 27 hectares, the BPC boasts a length of 1,800 meters and a width of 200 meters. It holds water all year round, with a depth of 6 meters in the wet season and 2 meters in the dry season. The core area, spanning 12 hectares, is managed as a conservation zone, with poles marking its boundaries. The release of indigenous fish fingerlings 2-3 times has resulted in an increase in fish stock. While villagers from these villages can fish within the CFR, they are not permitted to do so in the conservation areas. The VIS encircles the BPC and includes two primary canals, one pumping station, two vertical sub-canals, and four horizontal sub-canals. One vertical and one horizontal sub-canal link the BPC to the main canals. The canal system is observed to be shallow and poorly maintained, and villagers have not utilized much of the water. Nonetheless, the connectivity allows fish to move between the sub-canals and BPC to rice fields, with an estimated fish catch at about 25kg/ha.

4.7. Water Governance for Rice Farming, CFis, and CFRs

Water is a crucial component for both rice farming and fishery production. However, the extensive nature of commercial rice farming requires a larger amount of water for rice intensification, which leads to a rise in demand for irrigation development. Rice farming involves three crops each year: wet season rice farming from May to October, first dry season rice farming from November to January, and second dry season rice farming from February to April. Farmers extract more water from irrigation canals and, in some cases, from rivers, lakes, and ponds to irrigate dry season rice farming. This often causes conflicts among farmers and between upstream and downstream communities along rivers and around lakes. With the expansion of the rice farming industry, the use of pesticides, fertilizers, and other chemical inputs has increased to improve rice production. Unfortunately, the use of these inputs, pumping of water, water conflicts, climate change, and other factors have led to the degradation of aquatic resources, resulting in a decline in fishery resources. In this article, we will delve into the competition between rice farming and fishery management for water resources and the resulting consequences.

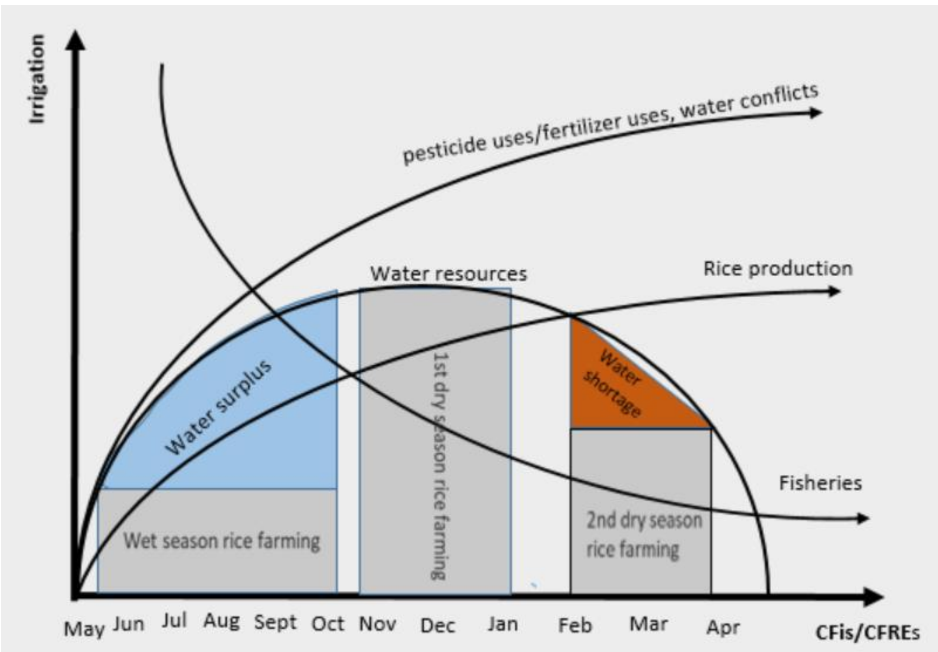

Figure 2. Water Governance.

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4.8. Changing Waterscapes and Upstream and Downstream Water Conflicts

In the last 20 years, changes to hydrological flows in the Mekong River, floodplains, and lakes have occurred due to several factors such as hydropower dams, infrastructure development, irrigation systems, and climate change [33–35]. These changes have significantly impacted the availability and distribution of water resources in the Lower Mekong River Basin. On average, approximately 13% of the annual discharge, which is equivalent to around 62 km^3 of water, has been withdrawn from the entire Lower MRB. The expansion of irrigation and croplands has played a role in altering water resources in the region. While irrigation systems have enabled an increase in rice farming, they have also caused a slight decrease in the annual flow of the Mekong River by 3%. This occurred between 2036 and 2065, compared to the period of 1971–2000 [37]. Climate change is another factor that has impacted the flow of the Mekong River. Experts predict that it will increase the river's annual flow by 15% over the period of 2036–2065, particularly during the wet season. Nevertheless, climate change is also expected to decrease the dry season flow by 2.18 percent. Frequent drought events also occur, offsetting the wet season flows, and resulting in frequent droughts in the lower MRB [38].

In Cambodia, multiple irrigation schemes, including VIS, TKIS, TSIS, and CKISs, have undergone rehabilitation to enhance agriculture, specifically rice farming. As a result, these communities have been transformed into thriving rice-producing industries. Over the past decade, the conversion of land and water into productive rice farming areas has led to a surge in rice production. At a national level, the total rice farming area is expected to reach 3.34 million hectares by 2023, with 82% dedicated to wet season rice farming and 18% to dry season rice farming. In the studied areas, the total rice farming area is 37,363.5 hectares, with 71% dedicated to wet season rice farming and 29% to dry season rice farming. Agricultural landholdings are relatively small, at approximately 1.3 hectares per household, and the increased rice production primarily relies on water and agricultural inputs.

In BSL, rice farming covers a vast area of 22,899 hectares. The majority of this land, 69%, is dedicated to wet season rice farming, while the remaining 31% is for dry season rice farming. The TSIS is the second-largest rice farming area, with 40% allocated to wet season rice farming and 60% to dry season rice farming. Although the Beung Ream and Beung Plang areas have constructed irrigation canals, farmers currently do not engage in dry-season rice farming. Nonetheless, many agricultural households in Beung Ream have been observed utilizing the TKIS and FWUC to manage water supply and transform wet season rice farming areas into dry season rice farming areas.

Based on recent research, over 30% of agricultural households in the country now have access to irrigation systems [39]. Within the studied areas, approximately 25% of agricultural households have irrigated rice fields. BSL boasts the highest percentage of households with irrigation access at 30%, followed by TSIS at 26% and Kakoh at 16% (Figure 4). The irrigation systems in the studied regions can pump an estimated 245.45 million m^3 of water annually through four primary pumping stations from the Mekong River's connected rivers and lakes. This water is utilized to irrigate dry-season rice farming areas that span at least 10,909 hectares (Figure 3). Nonetheless, the expansion of dry-season rice farming in the region results in the cultivation of more wetlands and the extraction of additional water for irrigation purposes.

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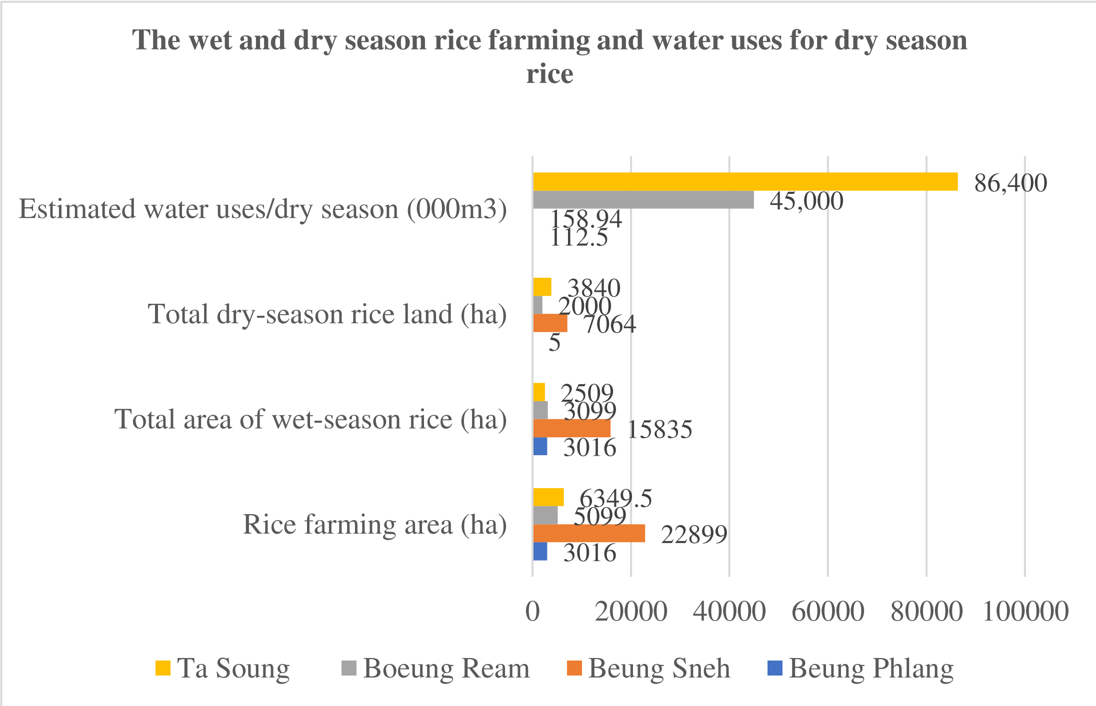

Figure 3. Indicates the total area of wet and dry seasonal rice in hectares by targeted communes.

Based on the efficiency of the irrigation system utilized in dry season rice farming, it takes one cubic meter of water to produce 0.11-0.242kg of paddy rice. In order to achieve an average rice production of 4 tons per hectare, 22,500m^3 of water from irrigation is needed. The rice farming communities located upstream and downstream of PAR, in Kandal and Takeo Provinces respectively, compete for water for both their fisheries and rice farming. TSIS has extracted a minimum of 86.4 million cubic meters (MCM) of water from the PAR to irrigate approximately 3,840 hectares of dry seasonal rice farming in four communes, namely Ban Kam, Kampong Reab, Pou Rumchak, and Prey Lvea, in Prey Kabbas District, Takeo Province. However, farmers in the Ta Soung Community cultivate three rice farming seasons per year, which means that the amount of water extracted from the PAR could be tripled. Additionally, the CFis in PAR, located in Prey Kabbas District, have reported the negative impact of TSIS's water pumping on fishery and fish conservation, mainly during the dry season when the water level in the PAR is low. This results in some areas along the river drying up. Rice farming communities downstream of the TSIS, particularly in Prey Kabbas Commune, have voiced their concerns about the shortage of water for their rice farming during the dry season.

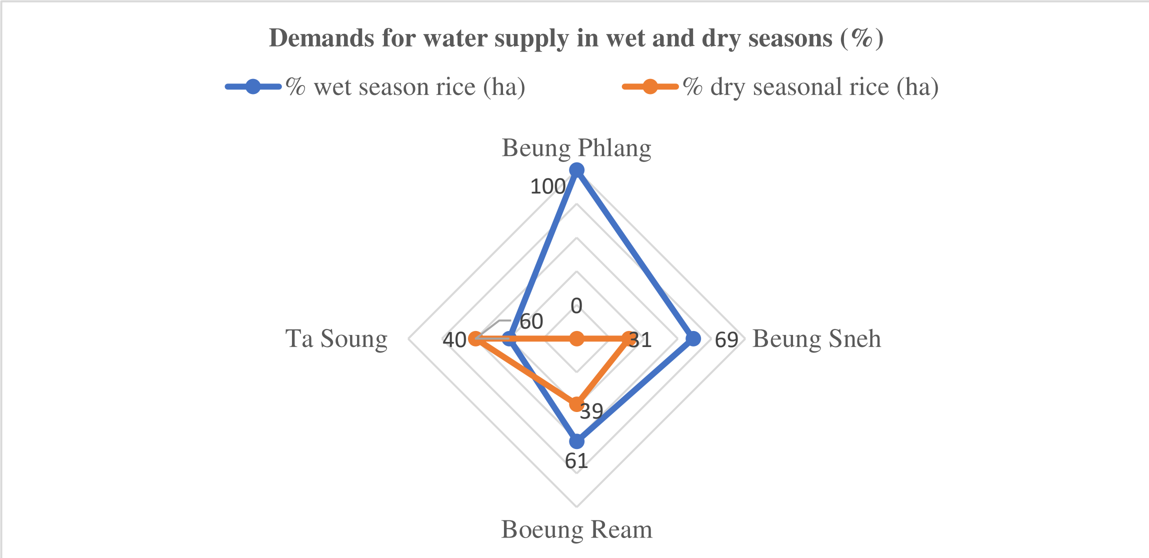

Figure 4. Indicates the demand in percentage of water supply in wet and dry seasons in the four targeted communes.

Competitions revolving around water usage for rice farming have been observed among farmers in the vicinity of BSL. In Damrei Puon Commune, a CKIS is responsible for extracting water for rice farming, which puts it in competition with other farmers from different communes. Despite this, the pumping station is capable of extracting a minimum of 4 MCM for dry season rice farming. Meanwhile, in Theay Commune, three irrigation schemes - Po Louk, Khse, and Top Sdach - are responsible for extracting approximately 23.35 MCM of water from BSL. In the Prey Kandieng Commune, three irrigation schemes - Phum Chan, Prey Kandieng, and Russei Muou Kom - use 32.82 MCM of water from BSL to irrigate 1,459 hectares of dry season rice. Similarly, in Ta Kao Commune, 2-3 irrigation canals that date back to the Khmer Rouge period have been revitalized by local communities using their own funds. The farmers in Ta Kao rely on these canals to extract 65.25 MCM of water from the BSL, competing with other communes to irrigate 2,900 hectares of dry season rice. At the village and household levels, each farmer possesses at least one pumping generator to extract water from the irrigation canals and irrigate their far-off rice fields. In total, around the lake, 158.94 MCM of water is extracted annually from the BSL to irrigate 7,064 hectares. Between 2022 and 2023, the demand for water to irrigate dry season rice farming caused the lake to reach dangerously low levels. Emergency measures were required due to the severity of the situation. The lack of water caused all irrigation canals to dry up, forcing nearby communities to resort to dredging the canals to extract the remaining water from the lake. In March, April, or early May of both years, farmers used water pumping generators to irrigate their rice fields, further exacerbating the already low levels of water in the lake and adversely affecting fishery and aquatic biodiversity.

The manipulation of floodplains and river channels through the construction of irrigation canals, dyke systems, and pumping stations has impacted the flooding patterns within the studied areas. Over the past 10-15 years, natural flooding around the BSL has been prevented due to the development of hydropower in the upper Mekong River and the construction of irrigational canals and dyke systems. Since 2011, the Mekong River has not caused any significant flooding in the region. Additionally, the VIS has played a role in limiting Mekong flooding from reaching rice fields in Sithor Kandal District, Prey Veng Province. Farmers in the TSIS area have reported no flood events in the past decade. Similarly, the natural Beung Ream Lake has not been affected by floods from the TSL for the last 15 years.

Based on reports from local communities, it appears that floods in the wet season are no longer 'tuk thom' (big floods) that occurred in the studied areas in the past 10-15 years. The frequent droughts make the wet and the dry seasons in the studied areas homogenous, with slight differences in terms of a short wet season with drought-pronged periods and a long dry season, particularly

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between 2014 and 2023. These have influenced the farming practices homogenously throughout the year, including using the same rice varieties (IR 504, IR5154) for different rice farming seasons—wet season rice farming, first dry season rice farming (November-January), and second dry season rice farming (February-April); three months cultivating periods, volumes same amounts of water quantity to irrigate the same plots of rice cultivating areas; using the same quantity of agriculture cultural inputs and get the similar rice yields per hectare (4-5 tons/ha) throughout the year. The wet season rice farming is also irrigated, as well as the first and second dry season rice farming, the only difference is when the irrigation canals run out of water, particularly during the first and second dry season rice farming, farmers compete for the remaining water from elsewhere using their extra pumping engines to pump water from river, lakes, and ponds nearby their rice fields.

Climate change has impacted the availability of water for rice farming, causing greater uncertainty and a homogenous seasonality in rice farming and its yield. Communities such as Kampong Reap and Pou Rumchak previously experienced frequent flooding from the Bassac River and PAR for half of the year, and waters receded the community areas in the dry season, leaving the community areas on the dry land for another six months of the year. However, now they rely on irrigation canals and embankments for protection. Similarly, Penea and Svay Rompea used to be inundated by Mekong floods during the wet season, but have not experienced such events since 2015 due to the completion of the VIS. These changes have resulted in a shift away from water-based communities to land-based communities reliant on human systems for water supply, such as irrigation systems, wells, and water supply and sanitation.

During the dry season of rice farming, the irrigation system serves as a water weapon for the community, playing a primary role in the fight for water. Additionally, the water pumping generator is a water weapon that households use to compete with other agricultural households in the same community for limited water resources. Farmers use water pumping generators to extract water from irrigation canals and distribute it to remote rice fields. There is also competition between farmers with rice fields near the canals and those with remote rice fields. Farmers collaborate at times to pump water from the canals, while other times, they work individually based on their financial resources.

4.9. Water for Rice Farming and Fisheries—Power, Politics, Policy and Position

Ensuring secure water sources is an essential component of both rice farming and the fishery production. To fulfill this requirement, irrigation systems are constructed to increase water availability for rice cultivation, while CFis/CFRs are established to support fishery management. The irrigation policy considers water as a valuable resource to be leveraged, utilized, controlled, and managed primarily for agricultural purposes. Agriculture, especially rice farming, relies on water as a key resource to support agricultural production. The irrigation system is designed to retain water and employ it for irrigating rice fields. On the other hand, the fishery sector views water as the natural habitat for fish and a source of production. Consequently, water governance plays a critical role in determining the fishery productivity and ecosystem services of the fishery domain, including rivers, lakes, and water bodies. Appropriate water management ensures sustainable fishery productivity and ecosystem services.

The impact of irrigation systems on fishery domains, including CFis, CFRs, and rice farming areas, is significant. These systems play a crucial role in controlling and regulating water flow between rivers, lakes, and rice fields. However, the physical infrastructure of these systems may hinder fish migration patterns, breeding, and feeding grounds between dry and wet seasonal refuges, affecting fishery and agriculture practices. The fishery domains and rice fields' segmentation into different sections can result in a lower fish population in rice fields, as reported by villages in the FGDs and KIIs, especially in the irrigation schemes. Additionally, the irrigation systems prioritize water for rice farming over fisheries, leading to the undermining of fisheries to some extent. For instance, irrigation canals are emptied to get water to rice fields, resulting in the destruction of fishery resources. Moreover, there is no management system for fishery in the irrigation canals.

In order to effectively manage fishery resources, CFis are established at various water sources and specific areas are designated as fishery conservation zones. The ultimate goal of these efforts is to safeguard rivers, lakes, and other bodies of water, creating a conducive environment for fish and their habitats, and ensuring their survival. However, irrigation schemes such as TSIS, TKIS, and CKISs extract water from the PAR, Taign Krasaing River, and the BSL, respectively, in areas where CFis and CFRs are present. To address this issue, FWUCs were established to decentralize water extraction for rice farming by agricultural households, particularly during the dry season. Without water, dry season rice farming would be compromised, resulting in lost income for farmers. Therefore, every effort is made to secure water for dry season rice farming, while also preserving the vital fishery resources.

The goals of CFis/CFRs and FWUCs/irrigation schemes can sometimes be at odds with each other. While CFis and CFRs aim to protect fishery sources to maintain productivity, FWUCs were established to extract water from sources to improve rice productivity. In dry seasons, these two organizations may compete for access to water resources, despite households being members of both. However, the extraction of water for rice farming can harm fisheries, leading to losses in productivity for sites such as BSL, PAR, and BRC. Farmers in the studied areas face a difficult decision, as prioritizing water for CFis and CFRs may lead to water shortages and a loss of dry season rice farming, while protecting rice farming is necessary to maintain yield and production.

Between 2020 and 2023, four community fisheries (CFis) in BSL have experienced low water levels during the dry season, posing a challenge for rice field irrigation. To address this issue, eleven irrigation schemes covering 22,899 hectares have been pumping water from BSL. In addition, 10,911 households in 44 villages have been utilizing the irrigation canals to irrigate their rice fields. The Prey Kabbas District's TSIS pumps water from the PAR to irrigate 1,511 hectares of rice fields in four communes, while farmers in the Beung Ream in TKIS have been pumping water from the BRC to the lowest water level during the dry season of 2023. Despite being from the same communities, these activities have led to tension between the CFis/CFRs and FWUCs.

Private individuals in the Torp Sdach village of Theay commune operate a private water pumping station (PWPS) under permits granted by the district authority. The PWPS operator has a four-year contract (2016-2024) to pump water from BSL and irrigate 305 hectares of land across five villages, charging water fees ranging from 270,000 to 300,000 riel per hectare per season. This enables farmers to cultivate 2-3 rice crops annually. Of the 305 hectares, 105 hectares of upland ricefield are not flooded by the rising water level in BSL, and farmers cultivate three rice crops per year. The remaining 200 hectares are located within BSL's floodplain, which floods during the wet season, permitting only one dry seasonal rice crop per year (typically from March to May). The PWPS serves approximately 250-300 households, 175 of which do dry seasonal rice farming and own at least one pumping generator per household. In addition, BSL has three water supply stations operated by private individuals who possess licenses from MOWRAM. These stations pump water from BSL, filter, clean, and sell it to villagers. Two stations are operational, while one is under construction. It is estimated that 50-60% of the population around Beung Sneh uses water from the water supply system, paying 1800-2000 riel per cubic meter. On average, a household uses around 10 cubic meters of water per month.

In the region of Beung Ream, the lowest part of the TSIS is known as the Kakoh. During the wet season, farmers from ten villages rely on the Kakoh's canals to cultivate rice, and thanks to the TKIS, they can now grow three crops per year. However, the farmers face challenges as upstream communities tend to use as much water as possible before releasing it downstream, causing delayed water release to the Kakoh's canals. The ten villages also compete for water, especially upstream and downstream ones. The Chey Chumnas, Kiriwon, and Samnak Villages, located at the lowest reach of the TKIS, have reported water shortages due to upstream villages tapping more water and releasing the leftovers downstream. As a result, the Kakoh Commune experiences water scarcity between January and April, and farmers resort to taking water from the BRC to irrigate their rice fields. Unfortunately, water conflicts have arisen between upstream and downstream villages, as well as between rice farming and CFR.

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4.10. Pesticides and Fertilizers Affecting Fishery

The rise in rice farming has led to an increase in the use of agro-chemical inputs to enhance rice yields. In the areas under study, fertilizers were commonly used by around 73% of households during both wet and dry farming seasons. Prey Veng Province saw the highest percentage of households using fertilizers, with 80% of them using it, compared to 67% in Takeo and 31% in Kampong Thom Provinces. In Prey Veng Province, farming households in Samraong, Tuek Thla, and Damrei Puong communes used fertilizers the most, accounting for 88%, 87%, and 85%, respectively. In Takeo Province, around 82% and 85% of farming households in Kan Kam and Pou Rumchak Communes applied fertilizers on their rice crops. Farmers usually used 5-7 bags (50kg/bag)/ha of fertilizers for a farming season, from the time they sowed the rice seeds until harvest. They used various types of fertilizers, including DAP, Urea, and others, which cost approximately 120,000 riel (USD30)/bag. The total cost of fertilizers per hectare ranged between USD150-210. These fertilizers were mainly imported from Vietnam and sold publicly. Based on the interviews conducted, farmers had limited knowledge about fertilizer indications and how to use them.

Pesticides are commonly used by farmers to protect their crops, but this practice can negatively impact rice yield. Research indicates that around 70% of agricultural households in the studied areas use pesticides during the rice farming season. Prey Veng Province has the highest percentage of pesticide use at 78%, followed by Takeo at 69%. Notably, the communes of Damrei Puon, Samraong, Ampil Krav, and Prey Kandieng located far from the BSL, which experiences water shortages during the rainy season, have the highest percentage of pesticide use at 90%, 83%, 81%, and 80%, respectively. In Takeo, Pou Rumchak and Ban Kam Communes have the highest percentages of pesticide use in rice farming, accounting for 83% and 80%, respectively.

Based on data provided by farmers, each hectare of land requires approximately nine containers of pesticides, each priced at 15,000 riels (USD3.75), resulting in a total pesticide cost of USD33.75. To ensure maximum effectiveness, farmers spray their crops with pesticides 3-4 times per hectare until harvest, at a cost of USD1.25 (5,000 riels) per spray. As a result, they spend around USD105-140 per hectare on pesticides alone. On top of this, farmers also use other chemical treatments to combat weeds and invasive species such as snails, which have been causing damage to their rice fields. Unfortunately, the use of pesticides can also have negative effects on aquatic life. The pesticide use kills aquatic animals, including fish, and thus, not many fish are reported by farmers in the rice fields. However, the percentage of households using organic pesticides and fertilizers is relatively low, 2% and 5% respectively. Farmers no longer use organic fertilizers and pesticides in some villages, such as in the Prey Kandieng Commune.

At the market, there was a diverse range of fertilizers offered by different importers and distributors. Urea and Muriate of Potash (KCl) were single-nutrient options, while di-ammonium phosphate (DAP) (18-46-0) and ammonium sulfate (16-20-0) were available as compound nitrogen-based fertilizers. Farmers could also find compound nitrogen, phosphorus, and potassium (NPK) products with ratios of 15-15-15, 16-16-8-(13S), and 20-20-15. Fertilizers could be purchased by the kilogram or in 50 kg bags. Most of the products were labeled in Khmer, with the exception of the 16-16-8-13 fertilizer from the Philippines and the urea from China and Vietnam, which had small Khmer stickers.

Table 7. The Uses of Chemical Inputs in rice farming.

Site	Commune	No. of HHs	HHs using chemical fertilizers		HHs using organic fertilizers		HHs using pesticides		HHs using organic pesticides (nature) to kill pests and grass	
			No	%	No	%	No	%	No	%
Beung Phlang	Ampil Krau	1981	1610	81	77	4	1606	81	71	4
Beung Sneh	Theay	2964	2240	76	186	6	2170	73	157	5
	Damrei Puon	2679	2284	85	32	1	2402	90	16	1
	Samraong	2482	2179	88	43	2	2060	83	25	1
	Tuek Thla	2820	2457	87	23	1	2107	75	15	1

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	Me Bon	2109	1531	73	67	3	1521	72	0	0
	Baray	1655	1256	76	27	2	1256	76	0	0
	Ta Kao	3739	2752	74	50	1	2754	74	4	0
	Prey Kandieng	2887	2308	80	60	2	2308	80	6	0
Sub-total	9	23316	18617	80	565	2	18184	78	294	1
Boeung Ream	Kakoh	3325	1023	31	536	16	609	18	81	2
Ta Soung	Ban Kam	1607	1320	82	111	7	1290	80	0	0
	Kampong Reab	532	220	41	100	19	220	41	100	19
	Pou Rumchak	778	662	85	25	3	648	83	55	7
	Prey Lvea	814	307	38	53	7	416	51	27	3
Sub-total	4	3731	2509	67	289	8	2574	69	182	5
Grant total	**14**	**30372**	**22149**	**73**	**1390**	**5**	**21367**	**70**	**557**	**2**

Source: Commune Database 2021

4.11. Level and Scale of Water Governance

Enhancing rice farming and fishery production requires improving water governance through the promotion and decentralization of integrated approaches to institutions and policies. In natural resource management, decentralization has been implemented through Community Fisheries (CFis) and Community Fisheries Resources (CFRs) to empower local communities to manage their own resources. Similarly, Local Water User Communities (FWUCs) enable local communities to decentralize water resources. However, centralized control of technical and financial resources presents challenges for sectoral decentralization. To address this, MOWRAM established two FWUCs while FiA/FiAC established four CFis in the BSL, and MoE established one Community-based Eco-tourism (CBET). Despite these efforts, decentralized practices remain unintegrated as each community organization is institutionalized by their respective line ministries, resulting in unintegrated CFis, CBET, and FWUCs. In TSIS, village communities are separated by CFis/CFRs or FWUCs, despite being from the same village. CFis are supervised by FiA and FiACs, while FWUCs are supervised by MOWRAM/PDOWRAM.

Furthermore, in BSL, different Communes tend to manage the BSL from the geographical locations of the Communes in the lake, not from the integrated approaches. Competitions between communes in the lake have led to the uncertainty of the lake in the future. In the TISIS, CFis and FWUCs are two different entities in the same Communes, but FWUC extracts water from the CFis to sustain rice farming and collect water fees from farmers. At the same time, CFis protect the water sources and do not charge any water fees to farmers or fishers to support their protection of the water sources. The lack of integration and connection between FWUCs and CFis leaves them uncertain about the system's future. Also, the Beung Ream and the Kakoh Irrigation Canal are connected in one integrated system, but they operate independently, one under the FiA and another under MOWRAM/PDOWRAM.

However, FWUCs in TKIS, TSIS, and CKIS are managed under the District Agriculture, Environment, and Water Resource Office (DAEW), in which District Officers in charge of water resources are responsible for managing FWUCs. Also, District Agriculture Officers are responsible for fishery management and agriculture. DAEW coordinates the agriculture, environment, and water management at the district level, and they report to District Governors and the Provincial Departments of Agriculture, Water Resources and Meteorology, and Environment.

Nonetheless, DAEW is still new and has limited capacity and resources to deal with the growing water, fishery, and agriculture issues. Given the limited capacity and staff, they still have not been given the full power to implement their roles and responsibilities. They need at large the capacity building and orientations to improve water governance, fishery management, and agricultural development. In the future, working with DAEW would address integrating water, fishery, and agriculture and decentralizing natural resource management.

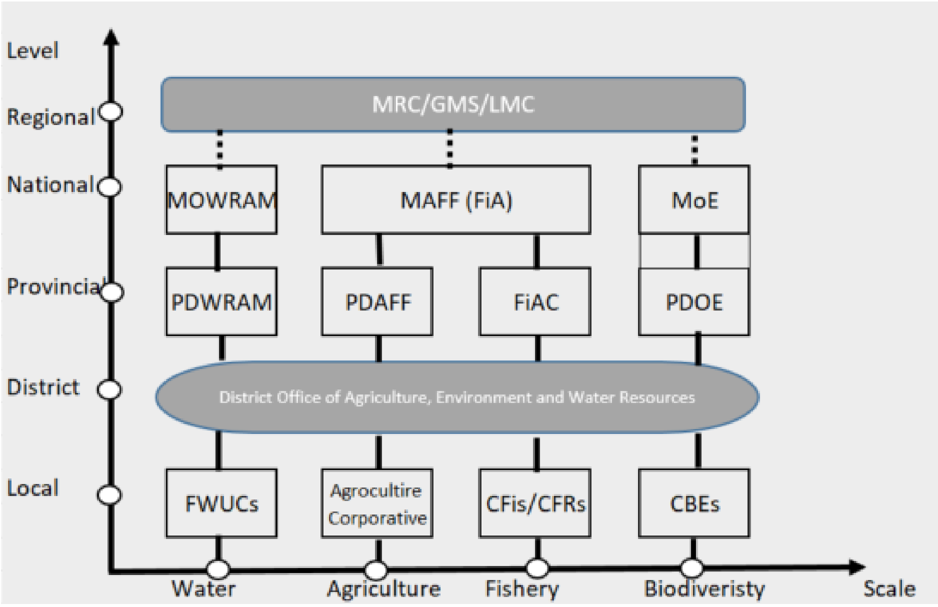

Figure 5. Level and scale of water governance.

5. Conclusions

Cambodia has abundant water resources in general, but it has little water in the dry season. Following the increased rice export policy in Cambodia in 2015 and the spill-over effects of the rice trade in Vietnam at present, the increased dry season rice farming in many provinces has led to high water demand for dry seasonal rice farming. These have led to water shortages and conflicts over water among farmers in many provinces in Cambodia and between sectors, for instance, fishery and rice farming.

Irrigation system development and improvement have improved water management and support for agricultural development and rice farming. Rice farming areas have been expanded to around 3.34 million ha in 2019, and from one to three rice crops a year, the rice yield has increased from 3 tons/ha to 4-5 tons per ha. At the same time, at the same time, rice production increased to 10.32 million tons in 2019, of which about 7 million tons were surplus for exports [41]. The increased rice production has occurred at the expense of the increased use of pesticides and fertilizers, mechanizations, indebtedness, and migration.

Furthermore, the irrigation system has imposed structures on the physical landscapes; first, it divides the land, wetlands, and water bodies into primary and sub-canals; and second, it blocks the water flows and migration pattern of fish in the floodplains and river systems in order to direct the irrigational flows to the rice fields. Further, it has broken the connectivity of fish migration pathways between the rivers, floodplains, lakes, and rice fields and vice versa. However, no tools and materials are in place to manage fisheries in the irrigation system. In contrast, fisheries management focuses more on central water bodies than rice field fisheries. The fishery is often ignored in irrigation management, as no expertise is involved in irrigation management. Thus, fishery productivity is low in the irrigation system and rice fields, where plenty of water exists. However, stock enhancement is needed to improve rice field fish stock.

The irrigation managements have been decentralized toward FWUCs, promoting the water fee system among members. To do so, FWUCs and irrigation schemes keep pumping water from river and lake systems, where CFis and CFRs are established to protect fisheries and water resources. These two systems are connected by water but are opposite in their approaches. The FWUC and CFis/CFRs often compete for water and conflict over water resources.

On the other hand, fishery and its productivity are undermined and affected by agricultural practices, particularly the uses of agricultural inputs such as pesticides, fertilizers, and chemical inputs to kill pests and herbs. These agricultural inputs are harmful to fishery and aquatic animals. Thus, even though there is water, there are few fish and aquatic animals in the rice fields.

Water governance remains sectoral, technical, and centralized, which has affected the productivity of water, fishery, and agriculture, and the cost of production and it also has induced conflicts between sectors and among farmers. Water governance can be done through improving coordination between sectors and agencies. It also needs an integration of different sectors and agencies and decentralization. Institutional integration should be strengthened to combine water, fishery, agriculture, and water resource management into one management system down at the ground. The district agriculture, water resources, and environment office should be strengthened to manage this integration.

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References

1. Sithirith M. Downstream state and water security in the Mekong region: a case of Cambodia between too much and too little water. *Water* **2021**, *13*, 6, 802.
2. Sithirith M. Water governance in Cambodia: From centralized water governance to farmer water user community. *Resources* **2017**, *6*,3, 44.
3. Sokhem P, Sunada K. The governance of the Tonle Sap Lake, Cambodia: integration of local, national and international levels. *International Journal of Water Resources Development* **2006**, 22, 3, 399-416.
4. Ojendal, J. *Sharing the Good: Modes of Managing Water Resources in the Lower Mekong River Basin*; Göteborg University Department of Peace and Development Research: Goteborg, Sweden, 2000.
5. Royal Government of Cambodia (RGC). *Sub-Decree on Farmer Water User Community*. RGC 2015, no. 73.
6. Center for Agriculture Development Study. *Inventory of Irrigation Schemes and Famer Water User Communities in Cambodia*; CEDAC and Water Program; CEDAC: Phnom Penh, Cambodia, 2009.
7. Cambodian Development Research Institute. *Hydrological Analysis in Support of Irrigation Management: A Case Study of Stung Chrey Bak Catchment, Cambodia*; CDRI Working Paper Series No. 59; CDRI: Phnom Penh, Cambodia, 2011; p. 55.
8. Nang, P.; Khiev, D.; Hirsch, P.; Whitehead, I. *Improving the Governance of Water Resources in Cambodia: A Stakeholder Analysis—Understanding Stakeholders' Roles, Perceptions and Constraints for Effective Irrigation and Catchment Management and Development*; Working Paper Series No. 54; Cambodia Development Research Institute: Phnom Penh, Cambodia, 2011.
9. Nang, P.; Ouch, C. *Gender and Water Governance: Women's Role in Irrigation Management and Development in the Context of Climate Change*; Working Paper Series No. 89; Cambodia Development Research Institute: Phnom Penh, Cambodia, 2014.
10. Ly, V. *The Baseline Assessment of the Effectiveness of Community Fisheries in Cambodia.* The Community Fisheries Development Department (CFDD), Fisheries Administration (FiA): Phnom Penh, Cambodia, 2018.
11. Royal Government of Cambodia (RGC). *Sub-decree on community fisheries*. No 25 OrNor Kror BorKor. Royal Government of Cambodia, 2005.
12. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*; Cambridge University: New York, NY, USA, 1990.
13. Rogers, P.; Alan, W.H. *Effective Water Governance*; TEC Background Papers No. 7; Global Water Partnership/Swedish International Development Agency: Stockholm, Sweden, 2003.
14. Tortajada, C. Water Governance: A Research Agenda. *Int. J. Water Resour. Dev.* **2010**, *26*, 309–316.
15. M. E. Arias, M.E., Piman, T., Lauri, H., Cochrane, T.A. and Kummu, M 2014. Dams on Mekong tributaries as significant contributors of hydrological alterations to the Tonle Sap Floodplain in Cambodia. *Hydrol. Earth Syst. Sci.*, **2014**, 18, 5303–5315. www.hydrol-earth-syst-sci.net/18/5303/2014/ doi:10.5194/hess-18-5303-2014.
16. Dore, J.; Lebel, L.; Molle, F. A framework for analysing transboundary water governance com-plexes, illustrated in the Mekong Region. *J. Hydrol.* **2012**, *466–467*, 23–36.

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17. Grundy-Warr C, Sithirith M, Li YM. Volumes, fluidity and flows: Rethinking the nature of political geography. *Political Geography* **2015**, 45, 93-5.
18. Öjendal J, Mathur V, Sithirith M. *Environmental governance in the Mekong. Hydropower site selection processes in the Se Son and Sre Pok basins*. Stockholm Environment Institute: Bangkok, Thailand, 2002.
19. Ratner, B.D.; Cohen, P.; Barman, B.; Mam, K.; Nagoli, J.; Allison, E.H. Governance of aquatic agricultural systems: Analyzing representation, power, and accountability. *Ecol. Soc.* **2013**, *18*, 59.
20. Savenije, H.H.G.; van der Zaag, P. Water as an economic good and demand management: Paradigms with pitfalls. *Water Int.* **2002**, *27*, 98–104.
21. Lebel, L.; Bastakoti, R.C.; Daniel, R. *CPWF Project Report: Enhancing Multi-Scale Mekong Water Governance*; Project Number PN50; CGIAR Challenge Program on Water and Food: Chiang Mai, Thailand, 2010.
22. Jones M, Jones R, Woods M, Whitehead M, Dixon D, Hannah M. *An introduction to political geography: space, place and politics.* Routledge, 2014.
23. Lefebvre H. *The social production of space*. Malden, MA, Blackwell Publishing, 1991.
24. Dore, J. An agenda for deliberative water governance arenas in the Mekong. *Water Policy* **2014**, *16*, 194–214.
25. Perry, C.; Rock, M.; Seckler, D. *Water as an Economic Good: A Solution, or a Problem?* International Water Management Institute: Colombo, Sri Lanka, 1997.
26. Asian Development Bank (ADB). *Proposed Revision of the Water Policy of the Asian Development Bank*; Asian Development Bank: Manila, Philippines, 2004.
27. Global Water Partnership. *GWP in Action*; Global Water Partnership: Stockholm, Sweden, 2002.
28. Rogers, P.; Alan, W.H. *Effective Water Governance*; TEC Background Papers No. 7; Global Water Partnership/Swedish International Development Agency: Stockholm, Sweden, 2003.
29. FAO. 2021. FAO Database. Available online: http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed on 12 October 202).
30. MOWRAM, *Water Strategic Development Plan, 2019-2023*. MOWRAM: Phnom Penh, Cambodia, 2019.
31. Bann C. and Sopha L. *Fish Counts: increasing the visibility of small-scale fisheries in Cambodia's national planning*. IIED Working Paper. http://pubs. iied. org; 2020.
32. Fisheries Administration. *Report on Status of Community Fisheries Assessment in 2018.* Community Fisheries Development Department (CFDD), Fisheries Administration (FiA): Phnom Penh, Cambodia, 2022.
33. Arias ME, Cochrane TA, Piman T, Kummu M, Caruso BS, Killeen TJ. Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *Journal of Environmental Management* **2012**, 112, 53-66.
34. Chen A, Liu J, Kummu M, Varis O, Tang Q, Mao G, Wang J, Chen D. Multidecadal variability of the Tonle Sap Lake flood pulse regime. *Hydrological Processes* **2021**, 35, 9, e14327.
35. Chua SD, Lu XX, Oeurng C, Sok T, Grundy-Warr C. Drastic decline of flood pulse in the Cambodian floodplains (Mekong River and Tonle Sap system). *Hydrology and Earth System Sciences* **2022,** 26, 3, 609-25.
36. Frenken K, editor. *Irrigation in Southern and Eastern Asia in figures*. Rome: Food and Agriculture Organization of the United Nations, 2011.
37. Liu J, Chen D, Mao G, Irannezhad M, Pokhrel Y. Past and future changes in climate and water resources in the lancang–mekong River Basin: Current understanding and future research directions. *Engineering* 2022, 13, 144-52.
38. Hoang LP, van Vliet MT, Kummu M, Lauri H, Koponen J, Supit I, Leemans R, Kabat P, Ludwig F. The Mekong's future flows under multiple drivers: How climate change, hydropower developments, and irrigation expansions drive hydrological changes. *Science of the Total Environment* **2019**, 649, 601-9.
39. National Institute of Statistics (NIS). *Cambodia Agriculture Survey (CAS) 2020.* Ministry of Planning: Phnom Penh, Cambodia, 2022.
40. Wokker C, Santos P, Bansok R. Irrigation water productivity in Cambodian rice systems. *Agricultural Economics* **2014**, 45, 4, 421-30.
41. Asian Development Bank (ADB). *Cambodia Agriculture, Natural Resources, and Rural Development Sector Assessment, Strategy, And Road Map.* Manila, Phillippines, 2021.