water

MDPI

Article

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

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

1 WorldFish, Phnom Penh P.O. Box 1135, Cambodia; soksao1987@yahoo.com
2 International Water Management Institute (IWMI), Battaramulla 10120, Sri Lanka; s.s.desilva@cgiar.org
3 Inland Fishery Research and Development Institute (IFReDI), Fishery Administration (FiA), Phnom Penh 120101, Cambodia; heng.kongspidermans@gmail.com (H.K.)
* Correspondence: maksithirith@gmail.com or m.sithirith@cgiar.org

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. Water governance is crucial to ensure the well-being of both people and their food security. However, Cambodia's water governance is hindered by various obstacles, including sectoral and centralized influences, top-down and large-scale strategies, weak coordination among relevant agencies, and limited involvement of local communities. This study examines water governance across different sectors, from centralized to community-based natural resources management, and explores the opportunities that can be done to improve water governance. This study undertakes the literature and case studies of farmer water user communities (FWUCs), community fisheries (CFis), and community fish refuges (CFRs) in three Mekong Delta provinces in Cambodia. This study concludes that water governance has been challenged by FWUCs competing for water resources to intensify rice production at the expense of increased pesticides and fertilizer uses, which undermine the fishery productivity, degrade the natural resources in rivers and water bodies, and increase 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

check for updates

Citation: Sithirith, M.; Sao, S.; de Silva, S.; Kong, H.; Kongkroy, C.; Thavrin, T.; Sarun, H. Water Governance in the Cambodian Mekong Delta: The Nexus of Farmer Water User Communities (FWUCs), Community Fisheries (CFis), and Community Fish Refuges (CFRs) in the Context of Climate Change. *Water* **2024**, *16*, 242. https://doi.org/10.3390/w16020242

Academic Editors: Lianqing Xue and Guang Yang

Received: 22 October 2023
Revised: 12 December 2023
Accepted: 26 December 2023
Published: 10 January 2024

1. Background

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 [1]. Water governance is crucial to ensure the well-being of both people and their food security. However, Cambodia's water governance is hindered by various obstacles, including sectoral and centralized influences, top-down and large-scale strategies, weak coordination among relevant agencies, and limited involvement of local communities. This study examines water governance across different sectors, from centralized to community-based natural resources management, and explores the opportunities that can be done to improve water governance [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 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 by introducing the Farmer Water User Community (FWUC) system. This system entrusts farmers responsible for managing irrigation systems through contributions in cash and kind [5]. However, the study has revealed that FWUCs tend to be weak and managed centrally, with limited financial and technical support, minimal input and poor ownership from community members, and unclear benefit-sharing mechanisms, contributing to the weak performance of FWUCs. In addition, 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. Furthermore, the decentralized water governance is complicated by a centralized system whereby FWUC management and performance are influenced by the decisions and direction of the Ministry of Water Resources and Meteorology (MOWRAM), while CFis/CFRs are influenced by the Fishery Administration (FiA) and the Ministry of Agriculture, Forestry, and Fishery (MAFF). While water is viewed as part of the fishery sector and its management, MOWRAM considers water management as its mandate, and to do so, it is done through irrigation management and development [10]. Nevertheless, MAFF has a role to play when it comes to rice production, and so, water has been strategically planned as part of rice farming planning and programs. These different dimensions and approaches have made the coordination and integration between sectors challenging, implicating decentralized water governance [8,9]. Moreover, the situation is further complicated by climate change, which impacts water availability for all three communities [11,12].

This study examines water governance in FWUCs, CFis/CFRs, and rice farming in three Mekong Delta Provinces in Cambodia and evaluates how water resources are shared among these communities. First, this article reviews the literature concerning water governance and constructs the framework that analyzes water governance in the study sites. Second, this article delves into the subject of water governance, investigating the manner in which water is used by FWUCs, CFis, and CFRs, as well as its impact on water resources. Third, 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. This study concludes with recommendations for enhancing water governance to promote fishery, rice farming, and livelihood.

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 a 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 [13]. These are relevant to the Mekong River and Tonle Sap Lake, where Cambodia is part of these river systems, and it experiences heavy floods in the wet season and severe drought in the dry season, raising the need for water governance [3,4]. Water governance is key to the development of Cambodia. In the past, water governance was governed by the open access regime, for instance, Tonle Sap Lake (TSL) and Cambodia's Mekong Delta (CMD) play a critical role in terms of providing natural and cultural capital for numerous communities living around the Lake and the Delta. Hitherto, there have always been relatively plentiful supplies of fish that provide a 'safety net' against famine. Thus, many Cambodians rely on the river and Lake's resources for their living, and they consider these water bodies as a 'social safety net' [14]. However, the growing population and development pressures have increased the demand for water resources, resulting in technical and sectoral systems taking over, including increasing irrigation development, commercial fishing, and industrial uses. These have made water governance significant challenges with multi-sectoral dimensions.

Thus, water governance in Cambodia has evolved and changed over time. 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 [15,16].

First, water governance is influenced by different sectors and actors at different levels. 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 [17,18]. 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 its own development, which has impacted the fishery, agriculture, natural resources, and food security during the production cycle [19–21].

In Cambodia, water governance is characterized by top-down, sectoral, and large-scale approaches, emphasizing the role of the irrigation system as a key sector in managing water resources. As such, it requires a high technical capacity, high costs, and state-driven interventions, which are highly complex, administratively and politically challenging, and have limited capacity of local authorities [22,23]. Consequently, farmers still face water scarcity, affecting agricultural productivity and low yields. In 2000, concerted efforts were made to decentralize water governance by establishing Farmer Water User Communities (FWUCs) to manage water resources at local levels for rice cultivation. FWUCs were formed in accordance with the Water Law (2007) and a subsequent sub-decree, comprising the regulations on water use and fee collection, controlling, and monitoring [10]. However, water governance via FWUCs has been challenged by the lack of focus on roles and responsibilities, particularly with regard to distributing water equitably, effectively, and efficiently to members of FWUCs. There has been little communication and mediation between farmers and the Provincial Department of Water Resources and Meteorology (PDOWRAM) in administrative processes to comply with IWRM procedures and frameworks and even less financial support [24]. At the same time, another form of decentralization of related water governance is the establishment of the community fisheries (CFis) and the community fish refuges (CFRs) to manage fishery resources under the Fishery Administration (FiA), as well as oversight by the Ministry of Agriculture, Forestry, and Fishery (MAFF) [25]. While CFis/CFRs protect water resources and water bodies to improve fishery productivity and fish production, FWUCs extract water to irrigate rice cultivation in the wet and dry seasons. Thus, while decentralized water governance has been constrained by the weak FWUCs, it has also been challenged by competing sectoral interests and weak coordination between sectors at local levels [9,26].

Second, the management of water resources is intricately linked to the unique physical attributes of the Mekong River, 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, which are the cases in the study areas, where some communities are located upstream of the rivers, lakes, and canals, while others are in the downstream [9,18]. In times of drought in the context of climate change, 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 [17,19,20,24].

Third, 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 [2,3,27]. 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 [28]. Politics operates 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 and management of water resources are based on technical, scientific, economic, and political interests [29]. Henri Lefebvre [29] highlights the following:

> Specializations divide space [water resources] 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 ([29], 1991: 89–90).

In Cambodia, the Ministry of Water Resources and Meteorology (MOWRAM) has developed and managed the irrigation systems to manage water resources, but very few have enough water for rice farming in the dry season, while rice farming is under the responsibility of MAFF, which is not managing water [10]. Meanwhile, fisheries and water are closely linked, but each management has been separated by sectoral policies and interests; for instance, the irrigation system may be beneficial for the national output of rice, but tensions and conflict over land and water use often arise between local user groups and large-scale commercial actors in the irrigated and intensively cultivated land. Also, the segmentation of traditional rice-field fisheries, which are unaccounted-for trade-offs with inland capture fisheries, remains a critical issue. In the fisheries sector, unregulated fisheries tend to exclude household fisheries, impacting food security and household income.

Fourth, using, sharing, and controlling water for fishery, agriculture, industry, etc., involves decision-making by actors from different sectors at different levels. Dore [30] 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 from different sectors are dealing with a variety of issues influenced by their individual and shared context: actors from different sectors engage in multiple arenas, depending on the opportunity, necessity, and choice; drivers are what influence and motivate actors in different sectors; 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 water allocation [19,27]. The same happens in Cambodia. Along this line, Ratner et al. [21] look at the governance of the aquatic agricultural system in TSL from three governance dimensions: (i) Stakeholder representation—which actors are represented in decision-making and how? (ii) Distribution of authority—how are formal and informal authority distributed concerning decisions over resource access, management, enforcement, dispute resolution, and benefit sharing? (iii) Mechanisms of accountability—how are power-holders held accountable for their decisions and to whom? These form the basis of governance of water, where decision-making by actors from different sectors and levels, is always challenging and dominated by powerful sectors, in this case, the irrigation development more than the fishery sector [31].

Fifth, access to water resources is crucial for the livelihoods of the farmers, fishers, and the rural population. 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 in the study areas. However, treating water as a public good and assuming that it is accessible to all can create a few problems. Firstly, powerful farmers with resources and equipment would maximize the extraction of water for their rice farming at the expense of other farmers, leading to potential water conflicts and shortages, which state institutions may be unable to address fairly due to limited financial resources, capacities, rules, and regulations [32]. Secondly, treating water as a public good can lead to wasteful use, as it is free, and wasting it does not incur any cost [33,34]. On the other hand, when people have to pay to use water, such as a member of FWUCs, they tend to use only enough water to satisfy their immediate needs; however, poor farmers may be unable to do so due to small farmlands and low yield with the uncertainty of climate change. Thus, this article examines these dilemmas in the study areas in a great deal [32].

Sixth, 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 biophysical 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 [15,32]. There has been a variety of infrastructural interventions affecting the natural environmental regime [35]. Chief amongst these are hydropower dams, which have a high disruptive potential, altering flow, quantity, temperature, and flooding patterns, sometimes in combination with large-scale irrigation schemes. Finally, the effects of global climate change are increasingly being felt. Southeast Asia in general, and particularly Cambodia and its water regime, are hypothesized to be one of the most vulnerable areas in the world [36].

3. Materials and Methods

The conceptual framework above has been utilized to analyze water governance in Cambodia's Mekong Delta (CMD) and assess its impact on rice field fishery productivity, rice production, food security, and livelihoods. The CMD is a rice-producing region in Cambodia; it is rich in fishery resources and agricultural products, which produce foods to support millions of people with water at the center of food production. The increased population, the development pressures from the upstream and around the CMD, and climate change underline the capacity of the CMD to produce foods, affecting many people. Thus, the above framework is employed to analyze water governance in the FWUCs, CFis, and CFRs in the CMD under the above changing dynamics aiming at increasing rice farming and fishery management for food production to feed its population.

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 (Figure 1). This study selected four sites across three provinces: (1) Beung Sneh Lake (Beung Sneh) and (2) Beung Plang in Prey Veng Province, (3) Beung Ream in Kampong Thom Province, and (4) Ta Soung in Takeo Province (Table 1). Beung Sneh, a 3924 ha freshwater lake in Prey Veng Province, is connected to the Mekong River and surrounded by 44 villages located in 8 communes in 4 districts. Hundreds of thousands of people living in these villages are dependent on Beung Sneh for water for both domestic uses and agriculture, fish, and biodiversity. Within Beung Sneh, 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 Beung Sneh. 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 2112 households. It is noteworthy that three of these villages have come together to establish the community fish refuge (CFR), known as a Beung Plang CFR, to protect the last remaining fish refuge areas and link the CFR to rice fields, aiming at increasing fish and rice production for food security. For our study, we directed our focus toward the CFR site and the Vaiko Irrigation Scheme (VIS) located in the Ampil Krav commune.

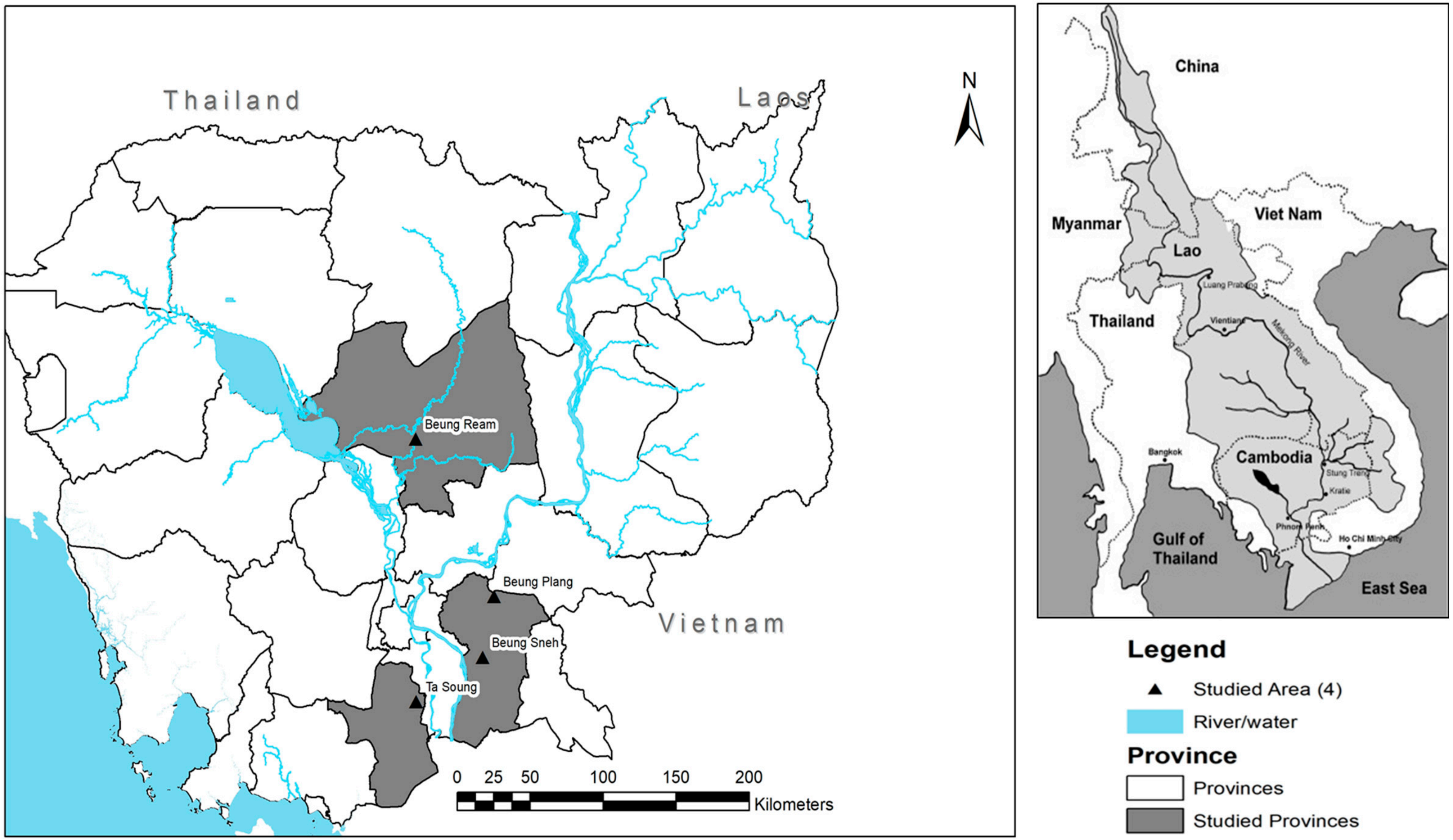

Figure 1. Map of the study provinces.

Table 1. Characteristics of the study sites, FWUCs, CFis, and CFRs.

Studied Sites	FWUC					CFis				CFRs			
	Irrigation System	Irrigation Canal (km)	Irrigated Area (ha)	No. of Villages	Membership (HHs)	No	Areas	No. Villages	Membership	No	Area	No. of Village	Membership
Beung Phlang	Vaiko (no FWUC)	78	153,400	3	93	-	-	-		1	27	3	4981
Ta Soung	Ta Soung Irrigation	50	1511	15	970	4	844,793	15	1016	-	-	-	
Beung Ream	Taing Krasain	22	9869	10	13,058	-	-	-		1	13	2	572
Beung Sneh	Chamcar Kouy	9	2010	6	984	4	85,236	6	11,034	-	-	-	
Total	4	159	166,790	31	15,105	8	930,029	21	12,050	2	40	5	5553

Note: Source: authors.

The Farmers Water User Community (FWUC) of the Ta Soung Irrigation Scheme (TSIS) serves nearly 1000 farming households across 15 villages in Prey Kabbas District, Takeo Province. This community is linked to the Prek Ambel River, which feeds into the Bassac River. It is a rice-producing region where farmers cultivate three rice crops a year using water from the Bassac River, and it has a former fishing lot area, where rice and fish are produced for food consumption and trade. Additionally, this study delves into the connection between the Ta Soung Irrigation Scheme and the four community fisheries (CFis) that were established to manage former fishing lot no. 20 in the Prek Ambel River, 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 and is linked to the Tang Krasaing Irrigation Scheme, which has been established as FWUC. Nestled within Tang Krasaing Irrigation Scheme, Kakoh Commune is home to approximately 3309 households that are spread across 10 villages and organized into Sub-FWUC. This study explores the Beung Ream CFR and the Sub-FWUC of Kakoh Commune as a crucial component of Tang Krasaing Irrigation Scheme.

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), and data collection was conducted 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 were 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 to obtain their knowledge on sectors, the policy and legal frameworks, the institutional arrangements, roles, responsibilities, activities, challenges and opportunities in carrying out their works. The FGDs were conducted with various groups such as CFis, CFRs, FWUCs, Identity of the Poor 1 and 2 (ID Poor 1 and 2), and non-ID Poor (Table 2). The KIIs and FGDs were conducted concerning 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 people 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 and 2 and non-Poor individuals was also explored. The ID Poor is a government system under the Ministry of Planning to classify poor households into four categories to which households can be assigned: Poor 1 (very poor); Poor 2 (poor); at-risk; and non-Poor, which were promulgated by sub-decree no. 291 issued in December 2011 [37]. 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 were then transformed into percentages, figures, and tables, with qualitative data included to support the findings. This article is descriptive and based on the data and analysis, and it is structured into first, the introduction; second, the analytical frameworks; third, the results and discussions; and fourth, the conclusion.

Table 2. 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 and 2; and the Non-ID Poor
Beung Sneh	• Chief of PDOWRAM and two staff, • FiAC Prey Veng Province, • Commune Chiefs of Prey Kandieng, Theay, Samrong and Damrei Poun Communes	4 FGDs with CFis: (1) Theay, (2) Samrong, (3) Damrei Poun; (4) Prey Kandieng	• 01 FGD with Chamcar Kyou's 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	• PDWRAM of Prey Veng Provinve, • District of Officers Santuk District 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

Note: Source: authors.

4. Results and Discussion

4.1. Results

4.1.1. 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 [38] (units of volume: 1 km^3 = 1 billion m^3 = 1000 million m^3 = 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 to 160 cubic meters per year [38].

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 sixteen 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].

4.1.2. Water Management through Irrigation Development

Irrigation Development

There are 2500 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 the Prey Veng and Takeo Provinces. Prey Veng province has 177 irrigation systems and Takeo has 136 irrigation schemes. In the Tonle Sap floodplain, this study focuses on Kampong Thom Province, with 258 irrigation schemes [39].

In Cambodia, there are 2500 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, which are 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 [39].

An analysis of four irrigation schemes has been chosen for this study, comprising two in Prey Veng Province (Chamcar KKouy Irrigation Scheme and Vaiko Irrigation Scheme), one in Takeo Province (Ta Soung Irrigation Scheme), and one in Kampong Thom Province (Taing Krasaing Irrigation Scheme). The Chamcar Kouy Irrigation Scheme is primarily supplied with water from Beung Sneh, which provides approximately 85 million cubic meters of water during the wet season and reduces to around 40 million m^3 during the dry season. The Ta Soung Irrigation Scheme uses water from the Prek Ambel River, a tributary of the Bassac River, while the VIS scheme relies on the Mekong River. The Taing Krasaing Irrigation 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 [40].

The Prey Kabbas District boasts the Ta Soung Irrigation Scheme, which is an irrigation system that comprises 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 1511 hectares of land owned by 970 farming households from 15 villages across four communes. Another notable irrigation scheme in Kampong Thom Province is the Taing Krasaing Irrigation Scheme. The Taing Krasaing Irrigation Schem in Kakoh Commune consists of a main canal, six secondary canals, and sixteen tertiary canals, with two water gates that can cover a distance of 22 km from the Stung Chinit River to the Beung Ream in Kakoh Commune, Santuk District. Part of the Taing Krasaing Irrigation Scheme located in Kakoh Commune can irrigate up to 9869 hectares of land across ten villages in Kakoh Commune (Table 1).

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 [12]. To better manage water resources, 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 [41], 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 Beung Sneh and one each in Beung Phlang, Beung Ream, and the Soung Irrigation Scheme. These FWUCs cover a total of 9067 hectares of agricultural land and have 15,781 agricultural households as members. The largest of the studied areas is Damrei Puon's FWUC in Beung Sneh, followed by the FWUC in Ta Soung Irrigation Scheme in Takeo Province and Theay's FWUC in Beung Sneh (Table 3).

Table 3. The selected FWUCs for the studies of water governance.

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
Beung Sneh (Damrei Puon and Theay)	2	0	10	2350	1660	(2018, 2005)
Boeung Ream (Kakoh)	1	9	10	5099	13,058	2018
Ta Soung	1	15	15	1511	970	2022
Grand Total	5	24	38	9067	15,781	0

Note: Source: authors.

4.1.3. 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 Soung Irrigation Scheme was a former fishing lot n. 20 in Takeo Province, and it is connected to Prek Ambel River, a tributary of the Bassac River. Similarly, the Beung Sneh is linked to the Mekong River, which is a habitat for 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 Beung Sneh in Prey Veng Province has a significantly lower percentage of fishing households at just 19%.

Community Fisheries (CFis)

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 with subsistence and not commercial, aiming at conserving fishery resources.

The CFis in Beung Sneh 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 Beung Sneh as CFi-protected zones (Table 1). To achieve this, CFis maintain the water level in the lake at approximately 4–5 m deep during the dry season, providing fish with shelter. However, their actions often contradict those of Farmer Water User Committees (FWUCs), as 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, which 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 1016 members, with 550 of them being female (Table 1). The leadership of the CFis consists of 36 committee members, 4 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 1000 per year to 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.

Community Fish Refuges (CFRs)

This study delves into two CFRs, namely the Beung Ream CFR in Kampong Thom Province and the Beung Phlang CFR in Prey Veng Province. The Beung Ream CFR 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 m during the dry spell (Table 1). 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 Beung Ream CFR area.

In the vicinity of Beung Ream CFR, 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 Beung Ream CFR. The Kakoh irrigation canal enters Beung Ream CFR via a water gate that regulates water supply to CFR areas. The Kakoh irrigation system is part of the Taing Krasaing Irrigation Scheme. Farmers have been irrigating 995 hectares of rice fields surrounding Beung Ream CFR with water from the Kakoh irrigation canals and Beung Ream CFR, enabling them to cultivate 2–3 crops of rice. Approximately 572 households are actively involved in fishing and harvesting fish and other aquatic animals from the floodplain area and rice fields surrounding Beung Ream CFR, which gets flooded during the rainy season. In addition, around 294 households fish within the Beung Ream CFR area for approximately five months a year. Fishing benefits approximately 716 families of which 20 percent are impoverished households. The estimated annual fish catch per household is about 88 kg, and the estimated annual catch of other aquatic animals is about 48 kg per household.

The Beung Phlang CFR, 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 Beung Phlang CFR was created to protect land, fish, and biodiversity for the community's benefit. Covering an area of roughly 27 hectares, the Beung Phlang CFR boasts a length of 1800 m and a width of 200 m. It holds water all year round, with a depth of 6 m in the wet season and 2 m 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 Vaiko Irrigation Scheme encircles the Beung Phlang CFR 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 Beung Phlang CFR 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 the Beung Phlang CFR to rice fields, with an estimated fish catch at about 25 kg/ha.

4.2. Discussion

4.2.1. Rice Export Policy, Irrigation Development, and Fishery Management

Water is a crucial component for both rice farming and fishery production. With abundant water resources, Cambodia is rich in fishery, standing no. 5 globally after China, India, Bangladesh, and Myanmar in inland fishery production. The Tonle Sap Lake and Mekong Rivers are well known for fishery production. However, between 2000 and 2012, RGC removed the fishing lot systems, a hundred-year-old system, and turned the fishing lot areas into CFis/CFRs, fishery conservations and open access areas. The fishery sector has gradually and economically become inactive [41,42]. In 2015, RGC developed a rice export policy to promote the paddy rice export for one million tons a year. These have led to mushrooming of rice production and the development of irrigation systems to manage water to irrigate rice farming [43].

To promote rice intensification and fulfill the rice export policy, investments are poured into irrigation development and rehabilitation to increase water availability for rice cultivation. MOWRAM has developed the National Irrigation and Water Resources Management Investment Program (NIWRMIP) 2019–2033 to develop and rehabilitate irrigation schemes at a total cost of USD 2.64 billion. FWUCs have been established under the MOWRAM, as a local arm, which is in line with the above policy to promote community participation in water management and uses for rice farming [44,45].

Nevertheless, agriculture is managed under the Ministry of Agriculture, Forestry, and Fishery (MAFF), including rice farming, agricultural extension, agricultural land management, and so on. At the same time, fishery policy supports the establishment of CFis/CFRs to manage the changing fishery management system. The fishery views water as part of the fishery and water bodies as natural habitats for fish and fishery production [46]. However, MOWRAM treats water as a separate sector, which is managed as part of the irrigation system. Thus, the irrigation policy considers water as a valuable resource to be leveraged, utilized, controlled, and managed primarily for agricultural purposes. The irrigation system is designed to retain water and employ it for irrigating rice fields [47,48]. The rice intensification for commercial rice exports requires a larger amount of water. 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.

In the name of economic development, policy, actors, power, and interest drive these changes. Even with a common policy for promoting rice production and export, some sectors (agriculture, irrigation) gain momentum, while others (e.g., fishery sector, etc.) are vulnerable in terms of their contribution to the economy and the country's development. Instead, dominant and powerful sectors get leveraged, which to some extent undermines the credibility of other sectors, in this case, the fishery sector (Table 4) [27,28,30].

Table 4. 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 and Cooperation—Power, Politics, and Position	Dialogue/ Negotiation
FWUCs	• 01 FWUCs in TSIS • 01 FWUC in Taing Krasaing Irrigation Scheme • 02 FWUCs in Beung Sneh—One is not active • 01 FWUC in Beung Phlang, not active.	• Beung Sneh, • Prek Ambel River in Takeo, • Taing Krasaing River, and • Mekong River (Vaiko Irrigation Scheme)	• The Constitution 1993—Article 58 and 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 and irrigation management—the operation of the irrigation system. • MAFF is responsible for rice farming and seems to have no role in irrigated areas provided by MOWRAM. • The community authority plays a role 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, and 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 Prek Ambel River • 04 CFis in Beung Sneh	• Beung Sneh in Prey Veng. • Prek Ambel River in Takeo.	• Fishery Law • Sub-decree on CFis. • Strategic Planning Framework for Fisheries. • Planning Framework	• FiA/FiAC, • The Fishery Sector has been decentralized, and FiAC is not under the 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.	• CFis protect water to keep it at 3–4 m deep to keep the fish habitat productive—anything below that will affect fish—increased fish catch, and encroachment of 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.	• CFis and FWUCs are in the same villages and 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 FWUCs. • 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.

Table 4. *Cont.*

Water User Community	No. of FWUCs	Source of Water—Upstream vs. Downstream	Policy	Institution	Water Conflict and Cooperation—Power, Politics, and Position	Dialogue/ Negotiation
CFRs	• 01 Beung Ream CFR • 01 Beung Phlang CFR	• 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 the is a shortage.	• No mechanism is 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.

The rice export policy has triggered the expansion of agricultural land. At a national level, the total rice farming area has expanded to reach 3.34 million hectares by 2023, with 82% dedicated to wet-season rice farming and 18% to dry-season rice farming. Multiple irrigation schemes, including the Vaiko, Taing Krasaing, Ta Soung, and Chamcar Kouy Irrigation Schemes, have undergone rehabilitation to enhance agriculture, specifically rice farming.

In the study 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 1.95 hectares per household, and the increased rice production primarily relies on water and agricultural inputs. In Beung Sneh, 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 Ta Soung Irrigation Scheme 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 to utilize the Taing Krasaing Irrigation Scheme and the FWUC to manage water supply and transform wet-season rice farming areas into dry-season rice farming areas.

Under the rice export policy and improved irrigation system, farming households have intensified the rice farming industry. They have graduated from one rice crop a year to 2–3 rice crops a year, moving away from rainfed farming to irrigated agriculture, from labor-intensive to mechanization, from farming for subsistence to farming for trading, and from low yield to high yield. Farmers cultivate both wet- and dry-season rice at present. These happen following the increased water availability, irrigation systems, and access to water bodies.

On the other hand, the rice market is influenced by rice traders from Vietnam who buy rice from Cambodian farmers to sell in Vietnam. The Vietnamese rice traders have to introduce the Vietnamese rice varieties to Cambodian farmers if they intend to trade their types of rice with Vietnamese rice traders. For these reasons, Cambodian farmers in the study areas cultivate a high-yield rice variety, including IR 504, IR 5154, and others imported from Vietnam.

About 98% of Cambodian agricultural households own farmlands, of which 99.3% are in Takeo Province, 99.1% in Prey Veng Province, and 98.3% in Kampong Thom Province. Furthermore, about 5% of agricultural households in Cambodia rent farmlands from others for agriculture; perhaps they are landless. In Prey Veng Province, about 4% of agricultural households rent their farmlands or are landless, followed by 3.4% in Kampong Thom Province and 2% in Takeo Province [49]. In the study areas, about 57% of all agricultural households are engaged in agricultural production [50]. The average household landholding is 1.95 ha. About 12.5% of farming households own less than one hectare of farmland, and 10.3% of households are landless. About 24% of the total population is in fishing. In Prey Kabbas District, the fishing population constitutes 33% of the total population. In Beung Ream in Kampong Thom, about 30% of its population is still engaged in fishing. However, the fishing population in Prey Veng, generally, and in Beug Sneh constitute 19%, which is low compared with other provinces.

Cultivating three rice crops per year requires much water. The irrigated command area is about 1.2 million hectares, which represents only 22% of all arable land [51]. In the study area, about 19% of farming households have their farmlands irrigated, of which 26% of farming households are located in the Ta Suong Irrigation Scheme, 18% of farming households around the Beung Sneh in Prey Veng, and 17% of farming households in Kah Koh Commune/Beung Ream. However, 42% of the total dry-season farmlands are irrigated, while 24% of the wet rice farming areas are irrigated in the wet season.

This study found that most farming households cultivate 2–3 rice crops per year. The first rice farming season starts in May and harvests in October, which is called 'wet-season rice farming'; it is when rainfalls and river water flood the floodplains, and when farmers cultivate the wet-season rice in the upper rice fields or 'sreleu' that are not flooded. Farmers cultivate the local varieties, namely, 'neang minh, senkra oup, malis, and others, which yield between 4 and 5 tons/ha. Farmers cultivate the 'wet-season rice' mostly for household consumption and the rice surplus is sold to those in need. However, given the increased rice trades, farmers gradually changed to cultivate the high-yield rice varieties from Vietnam for sale, and some farming households buy local rice production with local varieties for household consumption.

The second rice farming season starts from November to January, which is called the first dry-season rice farming, which is when the flood water recedes the floodplains and farmers start cultivating the recession rice, namely, the 'first dry-season rice farming'. During this period, farmers cultivate high-yield rice varieties, including rice varieties from Vietnam, such as IR 504 and IR 5154 in the middle rice fields, or 'srekandal'. These varieties consume so much chemical agricultural inputs and water, which could yield 5–6 tons/ha for three three-month periods. With the increased rice farming during the first dry-season rice farming, farmers experience water shortage to some degree but in many cases manage to secure water for their rice farming. The rice production during this period is mostly sold to rice traders who trade them to Vietnam (Figure 2).

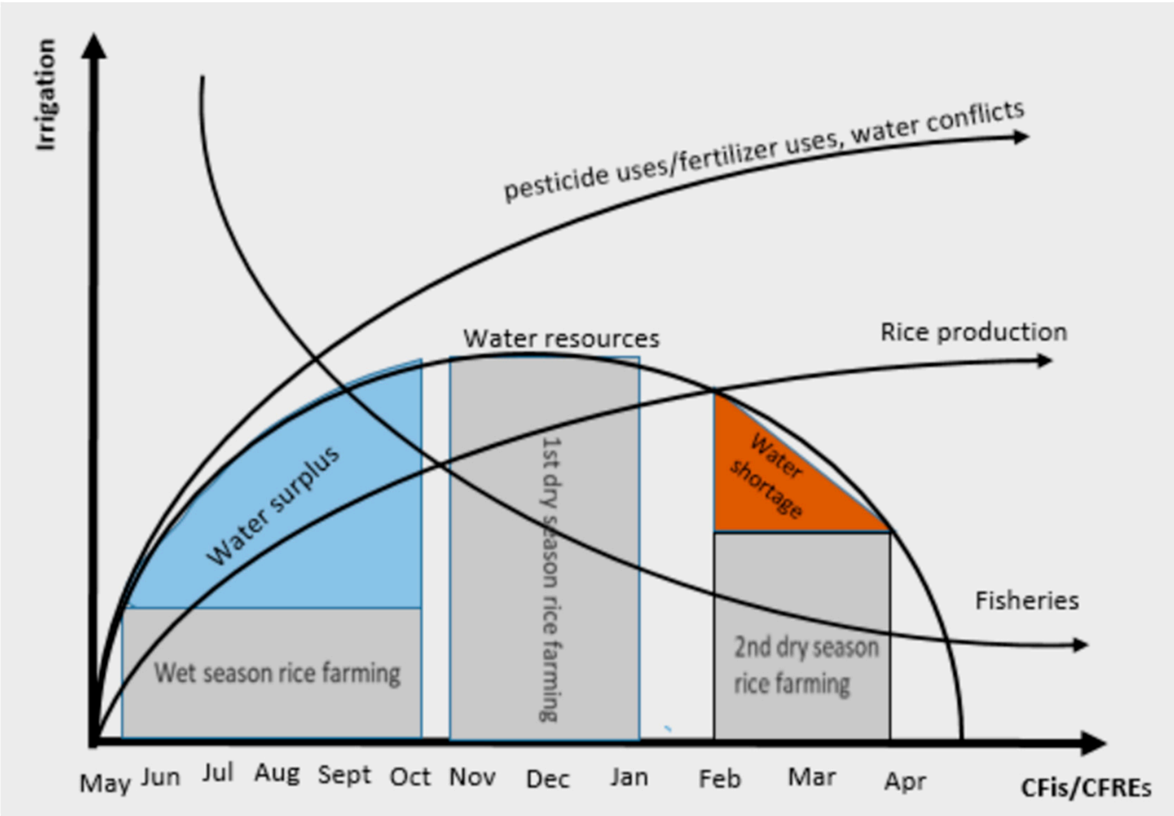

Figure 2. Water governance challenges (source: authors).

Some farmers cultivate the second dry-season rice farming, from February to April, but are at risk of water shortage, which could harm rice farming and increase the cost of production. Due to water shortage, farming households cultivate the second dry-season rice farming in the lower rice fields or 'srekrom' located adjacent to water bodies (lakes, rivers, and streams), where farmers could pump out water to irrigate the rice farming. The second dry-season rice farming is mainly for rice trades to Vietnam, and so, farmers cultivate the high-yield rice varieties from Vietnam, but it may not have a high yield, approximately 4–5 tons/ha, as they could be spoiled due to shortages of water or severe droughts. Water competition during this period is relatively high between farmers and between 'sreleu, srekandal, and srekrom'. Water competition sometimes could lead to water conflicts, which could increase the cost of rice production (Figure 2).

4.2.2. Changing Hydrological Regime and Climate Change

In the last 20 years, changes to hydrological flows in the Mekong River, floodplains, and lakes have occurred. The hydrological flows of the Mekong River to the Tonle Sap Lake and the Mekong Delta have dropped, affecting rice farming, fishery production, food security, and the livelihoods of millions of people downstream. Many scholars blame this on the developments of hydropower, particularly the Chinese hydropower dams [52–56], while others in favor of Chinese dams deny the accusations but claim climate change to be the cause [57,58]. Nevertheless, a third group of scholars came out and asserted neither Chinese dams nor climate change caused the declines in the Mekong flow downstream to Tonle Sap Lake and the Mekong Delta but argued that it was due to local developments, particularly the irrigation developments [59,60]. It is estimated that, 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, of which Vietnam, Thailand, China, Laos, Cambodia, and Myanmar account for approximately 52%, 29%, 9%, 5%, 3%, and 2%, respectively. The expansion of irrigation and croplands will play a role in decreasing the annual streamflow by 3% over the period of 2036–2065 compared with the period of 1971–2000 [61]. Furthermore, another study has confirmed that hydropower and other infrastructure developments could reduce the water discharge in the Mekong River by 21% at Kratie, 5% at the Kampong Cham, and 8% at Prek Kdam and Chak Tomuk. They also confirm that rainfall in the Cambodian floodplains has remained roughly constant from 1960–2019 and conclude that local anthropogenic factors are likely causing the flow reduction [59].

In the study areas, particularly the Mekong Delta, over the past 10–20 years, the natural flooding events have been altered due to the development of hydropower in the upper Mekong River and the construction of irrigational canals and dyke systems. In the Mekong River at Neak Luong, which is in the Mekong Delta Region in Cambodia, the annual wet season discharge dropped by 10% between 2010 and 2020 [59]. Local villagers reported that the Mekong River has not caused any significant flooding since 2011. Furthermore, the Vaiko Irrigation Scheme has played a role in reducing the Mekong flooding from reaching rice fields in Sithor Kandal District, Prey Veng Province. Farmers in the Ta Soung Irrigation Scheme area have reported no flood events in the past decade. Similarly, the natural Beung Ream Lake has not been affected by floods from the Tonle Sap Lake for the last 15 years.

Climate change has impacted the availability of water for rice farming, causing greater uncertainty of rainfalls. In the Mekong River Basin (MRB), climate change may increase the annual streamflow by 15% over the period of 2036–2065 compared with the period of 1971–2000 [61]. 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 [62]. In the study areas, local communities report that '*tuk thom*' (the big floods) in the wet season have never occurred in the study areas in the past 10 years. Instead, farmers experience frequent droughts, which cause damage to agriculture and rice farming. It is observed that the frequent droughts make the wet and the dry seasons homogenous, with slight differences in terms of a short wet season with drought-pronged periods and a long dry season duration, particularly between 2014 and 2023 [63]. These have created the farming practices homogenously throughout the year, including using the same rice varieties (IR 504, IR5154) for different rice farming seasons, three-month cultivating periods for rice cultivations, using the same amounts of water quantity to irrigate the same plots of rice cultivating areas, and using the same quantity of agriculture cultural inputs and obtaining the similar rice yields per hectare (4–5 tons/ha) throughout the year. The wet-season rice farming is also irrigated, as is the first and second dry-season rice farming; the only difference is that 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 generators to pump water from rivers, lakes, and ponds near their rice fields (Table 4).

Communities such as Kampong Reap and Pou Rumchak in the Ta Soung Irrigation Scheme previously experienced frequent flooding from the Bassac and Prek Ambel Rivers for half of the year, and waters receded 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 Vaiko Irrigation Scheme. 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 first and second dry-season rice farming periods, the irrigation system serves as a water weapon [64] for the communities, playing a primary role in the fight for water between different communities either upstream or downstream of the Beung Sneh Lake, the Vaiko Irrigation Scheme, the Prek Ambel River, and the Taing Krasaing Irrigation Scheme. Additionally, at the household level, each farming household owns at least one or two water pumping generators, which are considered a water weapon that households use to compete with other agricultural households in the same community to fight for limited water resources during severe droughts [65]. Farmers use water pumping generators to pump water from irrigation canals, rivers, and lakes and distribute it to remote rice fields. There is also competition among farmers with rice fields near the canals, rivers, and lakes and those with remote rice fields. Farmers collaborate at one time to pump water from the canals but compete at other times to pump water to irrigate their rice farming.

Four community fisheries (CFis) in Beung Sneh have experienced low water levels during the dry season between 2020 and 2023, posing a challenge for rice field irrigation. To address this issue, eleven irrigation schemes covering 22,899 hectares have been pumping water from Beung Sneh. In addition, 10,911 households in 44 villages have been utilizing the irrigation canals to irrigate their rice fields. In the Prey Kabbas District, the Ta Soung Irrigation System pumps water from the Prek Ambel River to irrigate 1511 hectares in four communes, while farmers in the Beung Ream in the Taing Krasaing Irrigation Scheme pump water from the Beung Ream CFR 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 [10].

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 Beung Sneh and irrigate 305 hectares of land across five villages, charging water fees ranging from KHR 270,000 to KHR 300,000 per hectare per season. This enables farmers to cultivate 2–3 rice crops annually. Of the 305 hectares, 105 hectares of upland rice fields are not flooded by the rising water level in Beung Sneh, and farmers cultivate three rice crops per year. The remaining 200 hectares are located within Beung Sneh'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, Beung Sneh has three water supply stations operated by private individuals who possess licenses from MOWRAM. These stations pump water from Beung Sneh Lake, 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 KHR 1800–2000 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 Taing Krasain Irrigation Scheme 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 Taing Krasain Irrigation Scheme, 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 the upstream and downstream ones. The Chey Chumnas, Kiriwon, and Samnak Villages, located at the lowest reach of the Taing Krasain Irrigation Scheme, 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 Beung Ream CFR to irrigate their rice fields. Unfortunately, water conflicts have arisen between upstream and downstream villages, as well as between rice farming and CFR.

4.2.3. Water Resources, Water Fees, and Water Conflict

Every year, water resources are limited, as shown in Figure 2, and they have been used throughout for rice farming; they are abundant in the wet-season rice farming, moderate but with a slight shortfall in the first dry-season rice farming, and have a severe shortage in the second dry-season rice farming. Based on the efficiency of the irrigation system utilized in dry-season rice farming, it takes one cubic meter of water to produce 0.11–0.242 kg of paddy rice [66]. 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.

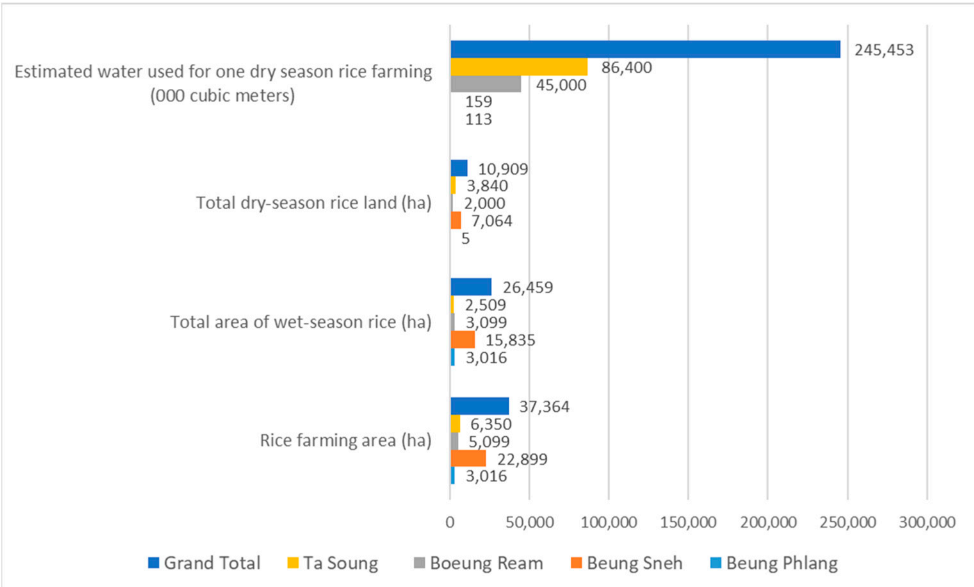

Figure 3. The total area of wet and dry seasonal rice in hectares by targeted communes (source: authors).

The rice farming communities located upstream and downstream of the Prek Ambel River, in Kandal Province and Takeo Province, respectively, compete for water for both their fisheries and rice farming. The Ta Soung Irrigation Scheme has extracted a minimum of 86.4 million cubic meters (MCM) of water from the Prek Ambel River to irrigate approximately 3840 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 Prek Ambel River could be tripled. Additionally, the CFis in the Prek Ambel River, located in Prey Kabbas District, have reported a negative impact of the Ta Soung Irrigation Scheme's water pumping on fishery and fish conservation; this mainly during the dry season when the water level in the Prek Ambel River is low. This results in some areas along the river drying up. Rice farming communities downstream of the Ta Soung Irrigation Scheme, particularly in the Prey Kabbas Commune, have voiced their concerns about the shortage of water for their rice farming during the dry season.

Competitions revolving around water usage for rice farming have been observed among farmers in the vicinity of Beung Sneh. In Damrei Puon Commune, the Chamcar Kouy Irrigation Scheme 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 the Theay Commune, three irrigation schemes—Po Louk, Khse, and Top Sdach—are responsible for extracting approximately 23.35 MCM of water from Beung Sneh. In the Prey Kandieng Commune, three irrigation schemes—Phum Chan, Prey Kandieng, and Russei Muou Kom—use 32.82 MCM of water from the Beung Sneh to irrigate 1459 hectares of dry-season rice. Similarly, in the 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 Beung Sneh, competing with other communes to irrigate 2900 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 Beung Sneh to irrigate 7064 hectares. Between 2022 and 2023, the demand for water to irrigate dry-season rice farming areas 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.

Given the increased rice farming, farming households in the study areas experience increasing water shortages during the late first dry-season rice farming and the second dry-season rice farming. In response, FWUCs put the prices for water uses for its members to increase efficiency and effectiveness in water governance [9,25]. The fees for water use from the irrigation schemes per farming season range between 270,000 and 300,000 KHR/ha (USD 67–75). The water fee by gravity is around 250,000 KHR/ha and 300,000–350,000 KHR/ha by pumping. In the Ta Sung, FWCU collects water fees based on the costs of electricity usage to pump the water from the Prek Ambil River into the irrigation system, ranging between 200,000 and 250,000 KHR/ha. In Beung Sneh and Beung Ream, farmers pay water fees only for the first dry-season rice farming, which is between November and January, as they receive enough water to irrigate their rice fields, but they do not pay water fees for the wet-season rice farming between May and October, as they cultivate with rainfalls. The dry-season rice farming is between February and April, as there is not enough water to irrigate the dry-season rice farming. Also, about 50% of water users pay water fees. However, due to intensive three rice crops yearly, water use has reached critical levels. In addition, farmers have pumped from nearby water sources to irrigate the dry-season rice farming. Each household owns a water pumping machine/generator. There is competition among farmers over the uses of water from Beung Sneh areas. The water used for rice farming has affected the fisheries [10].

4.2.4. Pesticide and Fertilizer Utilization for Rice Farming

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 them, 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 to their rice crops. Farmers usually used 5–7 bags (50 kg/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 KHR 120,000 (USD 30)/bag. The total cost of fertilizers per hectare ranged between USD 150 and 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 (Table 5).

Table 5. 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
	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	Sub-total	23,316	18,617	80	565	2	18,184	78	294	1
Boeung Ream	Kakoh (Sub-total)	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	Sub-total	3731	2509	67	289	8	2574	69	182	5
Grant total	Grant Total	30,372	22,149	73	1390	5	21,367	70	557	2

Note: Source: commune database 2021.

Based on data provided by farmers, each hectare of land requires approximately nine containers of pesticides, each priced at KHR 15,000 (USD 3.75), resulting in a total pesticide cost of USD 33.75. To ensure maximum effectiveness, farmers spray their crops with pesticides 3–4 times per hectare until harvest, at a cost of USD 1.25 (KHR 5000) per spray. As a result, they spend around USD 105–140 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 [67]. 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 (Table 5).

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 [68].

4.2.5. Impacts on Fishery Resources

The irrigation systems play a crucial role in controlling and regulating water flow between rivers, lakes, and rice fields. It is a type of structure that was built to improve water efficiency for rice farming, which may hinder fish migration patterns, breeding, and feeding grounds between dry and wet seasonal refuges, affecting fishery and agriculture practices [69]. 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 [70]. For instance, irrigation canals are emptied to get water to rice fields, resulting in the destruction of fishery resources in the canals. Moreover, there is no management system for fisheries in the irrigation systems, so fisheries are being harvested without any restrictions.

CFis and CFRs are established at various water sources, and some specific areas are designated as fishery conservation zones 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 Ta Soung, Tang Krasing, and Chamcar Kouy Irrigation Schemes extract water from the Prek Ambel River, Taign Krasaing River, and Beung Sneh Lake, respectively, in areas where CFis and CFRs are present. Also, FWUCs were established overlapping CFi and CFR areas to decentralize water extraction for rice farming, particularly during the dry season, by agricultural households. Without water, dry-season rice farming would be compromised, resulting in lost income for farmers [25].

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 Beung Sneh, Prek Ambel River, and Beung Ream CFR. 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.

Rice fields are treated as food stocks for rural households in the study areas, including paddy rice, aquatic plants, aquatic animals, and fish. The use of pesticides and fertilizers for rice intensification has harmed and killed the aquatic animals and fisheries, undermined the aquatic plants, and also polluted the water in the canals, lakes, and rivers. Farming households in the study areas have reported a decline in fisheries in the rice fields and water bodies. Also, households indicate that they buy fish from the market to make food for their family members. These issues have affected the food items of rural households.

4.3. 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. Improving water governance involves multi-stakeholders at different levels and scales [19,29,30]. In natural resource management, decentralization has been implemented through community fisheries (CFis) and community fisheries refuges (CFRs) to empower local communities to manage their own resources [42,46]. Similarly, farmer water user communities (FWUCs) enable local communities to decentralize water resources. However, centralized control of technical and financial resources presents challenges for sectoral decentralization [5]. To address this, MOWRAM established two FWUCs, while FiA/FiAC established four CFis in Beung Sneh, 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, CBETs, and FWUCs. In the Ta Soung Irrigation Scheme, 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 (Figure 4).

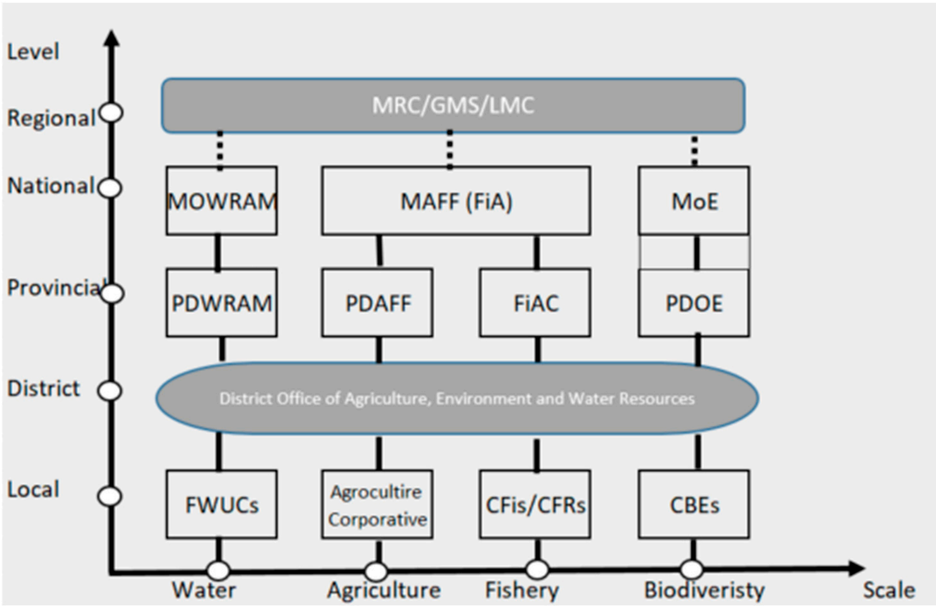

Figure 4. Level and scale of water governance (source: authors).

Furthermore, in Beung Sneh, different communes tend to manage the Beung Sneh from the geographical locations of the communes in the lake and not from integrated approaches. Competitions between communes in the lake have led to the uncertainty of the lake in the future. In the Ta Soung Irrigation Scheme, CFis and FWUCs are two different entities in the same communes, but the 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 CFR 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 Taing Krasaing, Ta Soung, and Chamcar Kouy Irrigation Schemes 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. Nevertheless, CFis/CFRs are not managed under the DAEW due to the fact that the fishery sector is not decentralized to DAEW, and so, its management remains with the FiACs. Thus, there is an urgent need to integrate fisheries into DAEW, so that district agriculture officers are responsible for fishery management and agriculture. This new approach would enable DAEW to coordinate the agriculture, environment, and water management at the district level, and they could 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. Above all, they need 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.

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 increased water availability, which improves 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. Rice production increased to 10.32 million tons in 2019, of which about 7 million tons were surplus for exports [7]. 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 patterns 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, fisheries and their productivity are undermined and affected by agricultural practices, particularly the use 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, as well as the cost of production, and it also has induced conflicts between sectors and among farmers. Decentralized water governance has been embedded into the policy, planning, and implementation through FWUCs, Cfis, and CFRs, but they are still sectoral and centralized to some extent, with limited financial and human resources and a lack of capacity.

Water governance can be improved through improving coordination between sectors and agencies at different levels and scales. 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 and promote decentralized water governance.

Author Contributions: Conceptualization, M.S., S.d.S. and H.K.; Methodology, M.S., H.K. and H.S.; Formal analysis, M.S.; Investigation, M.S., S.S., S.d.S., H.K., T.T. and H.S.; Resources, S.d.S.; Data curation, S.S., C.K., T.T. and H.S.; Writing—original draft, M.S., S.S., S.d.S. and H.K.; Writing—review & editing, M.S., S.d.S. and H.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding support from CGIAR through the Asian Mega Delta Project.

Data Availability Statement: Materials are available on request from the corresponding author.

Acknowledgments: The authors thank the teams from WorldFish, IWMI, and IFReDI for their support in conducting this research. Special thanks are extended to Sean Vichet for his time in developing the map for the study.

Conflicts of Interest: The authors declare no conflicts of interest.

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*, 802. [CrossRef]
2. Sithirith, M. Analysing transboundary water governance: A global-regional-national water governance framework of Tonle Sap Lake. *Lakes Reserv. Res. Manag.* **2022**, *27*, e12396. [CrossRef]
3. Sokhem, P.; Sunada, K. The governance of the Tonle Sap Lake, Cambodia: Integration of local, national and international levels. *Int. J. Water Resour. Dev.* **2006**, *22*, 399–416. [CrossRef]
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: Phnom Penh, Cambodia, 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.
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. Sithirith, M. Water governance in Cambodia: From centralized water governance to farmer water user community. *Resources* **2017**, *6*, 44. [CrossRef]
11. 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.
12. Royal Government of Cambodia (RGC). *Sub-Decree on Community Fisheries*; No 25 OrNor Kror BorKor; Royal Government of Cambodia: Phnom Penh, Cambodia, 2005.
13. Ostrom, E. *Governing the Commons: The Evolution of Institutions for Collective Action*; Cambridge University: New York, NY, USA, 1990.
14. Sithirith, M. Political Geographies of the Tonle Sap: Power, Space and Resources. Ph.D. Dissertation, National University of Singapore, Singapore, 2011.
15. Rogers, P.; Alan, W.H. *Effective Water Governance*; TEC Background Papers No. 7; Global Water Partnership/Swedish International Development Agency: Stockholm, Sweden, 2003.
16. Tortajada, C. Water Governance: A Research Agenda. *Int. J. Water Resour. Dev.* **2010**, *26*, 309–316. [CrossRef]
17. 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.
18. Arias, M.E.; Piman, T.; Lauri, H.; Cochrane, T.A.; Kummu, M. 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. [CrossRef]
19. Dore, J.; Lebel, L.; Molle, F. A framework for analysing transboundary water governance complexes, illustrated in the Mekong Region. *J. Hydrol.* **2012**, *466–467*, 23–36. [CrossRef]
20. Grundy-Warr, C.; Sithirith, M.; Li, Y.M. Volumes, fluidity and flows: Rethinking the nature of political geography. *Political Geogr.* **2015**, *45*, 93–95. [CrossRef]
21. 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. [CrossRef]

22. Sreymom, S.; Sokhem, P.; Channimol, K. Governance for Water Security and Climate Resilience in the Tonle Sap Basin. In *Climate Change and Water Governance in Cambodia: Challenge and Perspectives for Water Security and Climate Change in Selected Catchments, Cambodia*; CDRI: Phnom Penh, Cambodia, 2015; pp. 124–153.
23. Seng, S.; Keartha, C.; Phyrom, S.; Sokhem, P. *Institutional Arrangements: Policies and Administrative Mechanisms on Water Governance in the Kingdom of Cambodia*; CPWF Mekong, M-Power, Asian Institute of Technology, CENTDOR, ewarec.: Phnom Penh, Cambodia, 2013.
24. Chea, C.; Nang, P.; Whitehead, I.; Hirsch, P.; Thompson, A. *Decentralised Governance of Irrigation Water in Cambodia: Matching Principles to Local Realities*; CDRI: Phnom Penh, Cambodia, 2011.
25. Fisheries Administration. *Report on Status of Community Fisheries Assessment in 2018*; Community Fisheries Development Department (CFDD), Fisheries Administration (FiA): Phnom Penh, Cambodia, 2022.
26. Chap, S.; Touch, P.; Diepart, J.X. *Fisheries Reforms and Right-Based Fisheries: Insights from Community Fisheries across Cambodia*; The Learning Institute: Phnom Penh, Cambodia, 2016.
27. 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.
28. Jones, M.; Jones, R.; Woods, M.; Whitehead, M.; Dixon, D.; Hannah, M. *An Introduction to Political Geography: Space, Place and Politics*; Routledge: London, UK, 2014.
29. Lefebvre, H. *The Social Production of Space*; Blackwell Publishing: Malden, MA, USA, 1991.
30. Dore, J. An agenda for deliberative water governance arenas in the Mekong. *Water Policy* **2014**, *16*, 194–214. [CrossRef]
31. 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. [CrossRef]
32. Perry, C.; Rock, M.; Seckler, D. *Water as an Economic Good: A Solution, or a Problem?* International Water Management Institute: Colombo, Sri Lanka, 1997.
33. Asian Development Bank (ADB). *Proposed Revision of the Water Policy of the Asian Development Bank*; Asian Development Bank: Manila, Philippines, 2004.
34. Global Water Partnership. *GWP in Action*; Global Water Partnership: Stockholm, Sweden, 2002.
35. Ratner, B.D.; So, S.; Mam, K.; Oeur, I.; Kim, S. Conflict and Collective Action in Tonle Sap Fisheries: Adapting Governance to Support Community Livelihoods. *Nat. Resour. Forum* **2017**, *41*, 71–82. [CrossRef]
36. Meynell, P.J.; Kong, K.; Sorn, P.; Lou, V. *Climate Change Vulnerability Assessment Boueng Chhmar Ramsar Site, Cambodia*; IUCN: Bangkok, Thailand, 2019.
37. Royal Government of Cambodia (RGC). *Sub-Decree on Identification of Poor Households*; Ministry of Planning: Phnom Penh, Cambodia, 2011.
38. FAO. FAO Database. 2021. Available online: http://www.fao.org/nr/water/aquastat/data/query/results.html (accessed on 12 October 2022).
39. MOWRAM. *Databased on Cambodian Information System on Irrigation Schemes (CISIS)*; MOWRAM: Phnom Penh, Cambodia, 2017.
40. MOWRAM. *Water Strategic Development Plan, 2019–2023*; MOWRAM: Phnom Penh, Cambodia, 2019.
41. Fishery Administration (FiA). *The Strategic Planning Framework for Fisheries: Update for 2015–2024*; Ministry of Agriculture, Forestry and Fishery (MAFF): Phnom Penh, Cambodia, 2015.
42. Royal Government of Cambodia (RGC). *Law on Fisheries Management*; Fishery Administration: Phnom Penh, Cambodia, 2006.
43. World Bank. *Cambodia Rice Sector Review: Turning Cambodian Rice into White Gold*; Technical Working Paper; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA, 2015.
44. Ministry of Water Resources and Meteorology (MOWRAM). *The National Irrigation and Water Resources Management Investment Program (NIWRMIP) 2019–2033*; MOWRAM: Phnom Penh, Cambodia, 2020.
45. Royal Government of Cambodia (RGC). *National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019–2033*; MOWRAM: Phnom Penh, Cambodia, 2019.
46. Royal Government of Cambodia (RGC). *Sub-Decree on Community Fishery Management*; Fishery Administration: Phnom Penh, Cambodia, 2005.
47. MOWRAM. *Water Law*; MOWRAM: Phnom Penh, Cambodia, 2007.
48. MOWRAM. *Water Policy*; MOWRAM: Phnom Penh, Cambodia, 2005.
49. National Institute of Statistics (NIS). *Cambodia Agriculture Survey (CAS) 2020*; Ministry of Planning: Phnom Penh, Cambodia, 2022.
50. Ministry of Interior. *Commune Database*; Royal Government: Phnom Penh, Cambodia, 2021.
51. Sagara, J. *Surface Water Resources Assessment of the Tonle Sap and Mekong Delta River Basin Groups: Improving Climate Resilience, Productivity, and Sustainability*; Asian Development Bank: Manila, Philippines, 2021.
52. Arias, M.E.; Cochrane, T.A.; Piman, T.; Kummu, M.; Caruso, B.S.; Killeen, T.J. Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin. *J. Environ. Manag.* **2012**, *112*, 53–66. [CrossRef] [PubMed]
53. 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. *Hydrol. Process.* **2021**, *35*, e14327. [CrossRef]
54. Kallio, M.; Kummu, M. Comment on 'Changes of inundation area and water turbidity of Tonle Sap Lake: Responses to climate changes or upstream dam construction?'. *Environ. Res. Lett.* **2021**, *16*, 058001. [CrossRef]

55. Green, W.N.; Baird, I.G. The contentious politics of hydropower dam development in the Mekong River basin. *Political Geogr.* **2020**, *83*, 102272. [CrossRef]
56. Grumbine, R.E.; Dore, J.; Xu, J. Mekong hydropower Drivers of change and governance challenges. *Front. Ecol. Environ.* **2012**, *10*, 91–98. [CrossRef]
57. Wang, Y.; Feng, L.; Liu, J.; Hou, X.; Chen, D. Changes of inundation area and water turbidity of Tonle Sap Lake: Responses to climate changes or upstream dam construction? *Environ. Res. Lett.* **2020**, *15*, 0940a1. [CrossRef]
58. Frappart, F.; Biancamaria, S.; Normandin, C.; Blarel, F.; Bourrel, L.; Aumont, M.; Azemar, P.; Vu, P.L.; Le Toan, T.; Lubac, B.; et al. Influence of recent climatic events on the surface water storage of the Tonle Sap Lake. *Sci. Total Environ.* **2018**, *636*, 1520–1533. [CrossRef]
59. Chua, S.D.; Lu, X.X.; Oeurng, C.; Sok, T.; Grundy-Warr, C. Drastic decline of flood pulse in the Cambodian floodplains (Mekong River and Tonle Sap system). *Hydrol. Earth Syst. Sci.* **2022**, *26*, 609–625. [CrossRef]
60. Frenken, K. (Ed.) *Irrigation in Southern and Eastern Asia in Figures*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011.
61. 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*, 144–152. [CrossRef]
62. Hoang, L.P.; van Vliet, M.T.; 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. *Sci. Total Environ.* **2019**, *649*, 601–609. [CrossRef] [PubMed]
63. NGO Forum on Cambodia (NGOF). *Impacts of a Low Flow of Water from the Mekong River to Tonle Sap Lake on the Livelihoods of Different Communities and Natural Environments*; NGOF: Phnom Penh, Cambodia, 2023.
64. Zawahri, N. International rivers and national security: The Euphrates, Ganges-Brahmaputra, Indus, Tigris, and Yarmouk rivers. *Nat. Resour. Forum* **2008**, *32*, 280–289. [CrossRef]
65. Sithirith, M. Dams and state security: Damming the 3S rivers as a threat to Cambodian state security. *Asia Pac. Viewp.* **2016**, *57*, 60–75. [CrossRef]
66. Mainuddin, M.; Kirby, M. Agricultural productivity in the lower Mekong basin: Trends and future prospects for food security. *Food Secur.* **2009**, *1*, 71–82. [CrossRef]
67. Sokcheng, S.; Socheat, K.; Sarom, M. *Pesticide Use Practices in Cambodia's Vegetable Farming*; CDRI, Cambodia Development Resource Institute: Phnom Penh, Cambodia, 2021.
68. Vuthy, T. The Supply of Fertilizer for Rice Farming in Takeo. In *White Gold: The Commercialisation of Rice Farming in the Lower Mekong Basin*; Springer: Singapore, 2020; pp. 291–308.
69. Baran, E.; Starr, P.; Kura, Y. *Influence of Built Structures on Tonle Sap Fisheries*; Cambodia National Mekong Committee and the WorldFish Center: Phnom Penh, Cambodia, 2007.
70. Khoa, S.N.; Lorenzen, K.A.I.; Garaway, C.; Chamsinhg, B.; Siebert, D.; Randone, M. Impacts of irrigation on fisheries in rain-fed rice-farming landscapes. *J. Appl. Ecol.* **2005**, *42*, 892–900. [CrossRef]