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Hydro-dam – A nature-based solution or an ecological problem: The fate of the Tonlé Sap Lake

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ABSTRACT

Recent proliferation of hydro-dams was one of the nature-based solutions to meet the increasing demand for energy and food in the Lower Mekong River Basin (LMRB). While construction of these hydro-dams generated some hydropower and facilitated expansion of irrigated lands, it also significantly altered the basin-wide hydrology and subsequently impacted wetland ecosystems. Unintended adverse consequences of ecosystem services from lakes and wetlands offset the intended gains in hydroelectricity and irrigated agriculture. The trade-offs between gains in energy and food production and losses in aquatic ecosystem services were perceived to be significant but knowledge of the magnitude, spatial extent, and type of ecosystem services change is lacking and, therefore, the question whether the hydro-dam is an optimized solution or a potential ecological problem remains unanswered. In this study, as the first step to answer this question and using the Tonlé Sap Lake as an example, we quantified one of the impacts of hydro-dams on lake ecosystem's phenology in terms of open water area, a critical ecological characteristic that affects lake systems' fish production, biodiversity, and livelihoods of the local communities. We used the MODIS-NDVI time series, forecast function and the Mann-Kendall trend test method to first quantify the open water area, analyzed its changes over time, and then performed correlation analysis with climate variables to disentangle dam impacts. The results showed reduced hydro-periods, diminishing lake seasonality and a declining trend in Tonlé Sap Lake open water area over the past 15 years. These changes were insignificantly related to climatic influence during the same period. It is concluded that basin-wide hydro-dam construction and associated agricultural irrigation were deemed to be the primary cause of these ecological changes. Further analyses of changes in the lake's ecosystem services, including provision and cultural services, need to be carried out in order to have a holistic understanding of the trade-offs brought by the hydro-dam proliferation as a solution to the emerging energy and food demand in the LMRB.

1. Introduction

For thousands of years, food production in the LMRB has relied on timely rainfall and the seasonal flows of the rivers and streams of the Mekong River. Fisheries in rivers, lakes, and wetlands benefitted from abundant freshwater and nutrients supplied by seasonal flood surges, while crops were grown on rich soils timed with plentiful seasonal rainfall; together these ecosystem services supported livelihoods in the region for generations. However, this is changing: the rhythm and intensity of the Asian monsoon have noticeably changed, with more frequent floods and intense droughts devastating crops and dramatically altering aquatic ecosystems, and thus deeply disrupting rural livelihoods (Adamson, 2006; Fredén, 2011; Parr et al., 2013; MRC, 2010b, 2011b, 2015).

In response to these negative consequences of climate variability, both mitigation and adaptation solutions were sought from different aspects, ranging from management improvements to engineering solutions. One of the largest-scale regional solutions is the proliferation of hydro-dams in the LMRB with an intention to 1) mitigate extreme climate events such as floods and droughts, 2) increase freshwater captures for irrigated agriculture, and 3) generate hydropower to mitigate demand increases in energy. As a result, there are currently over 300 hydro-dams in the entire basin, with more being planned or under construction (Fig. 1).

Such hydro-dam engineering solution to climate variability may have achieved the intended goals but likely ignored two important aspects that could lead to regional instability and ecological disasters: geographic disparity of water resources and loss of other important ecological habitats that are critical to local communities. The geographic disparity refers to the fact that hydro-dam construction is a

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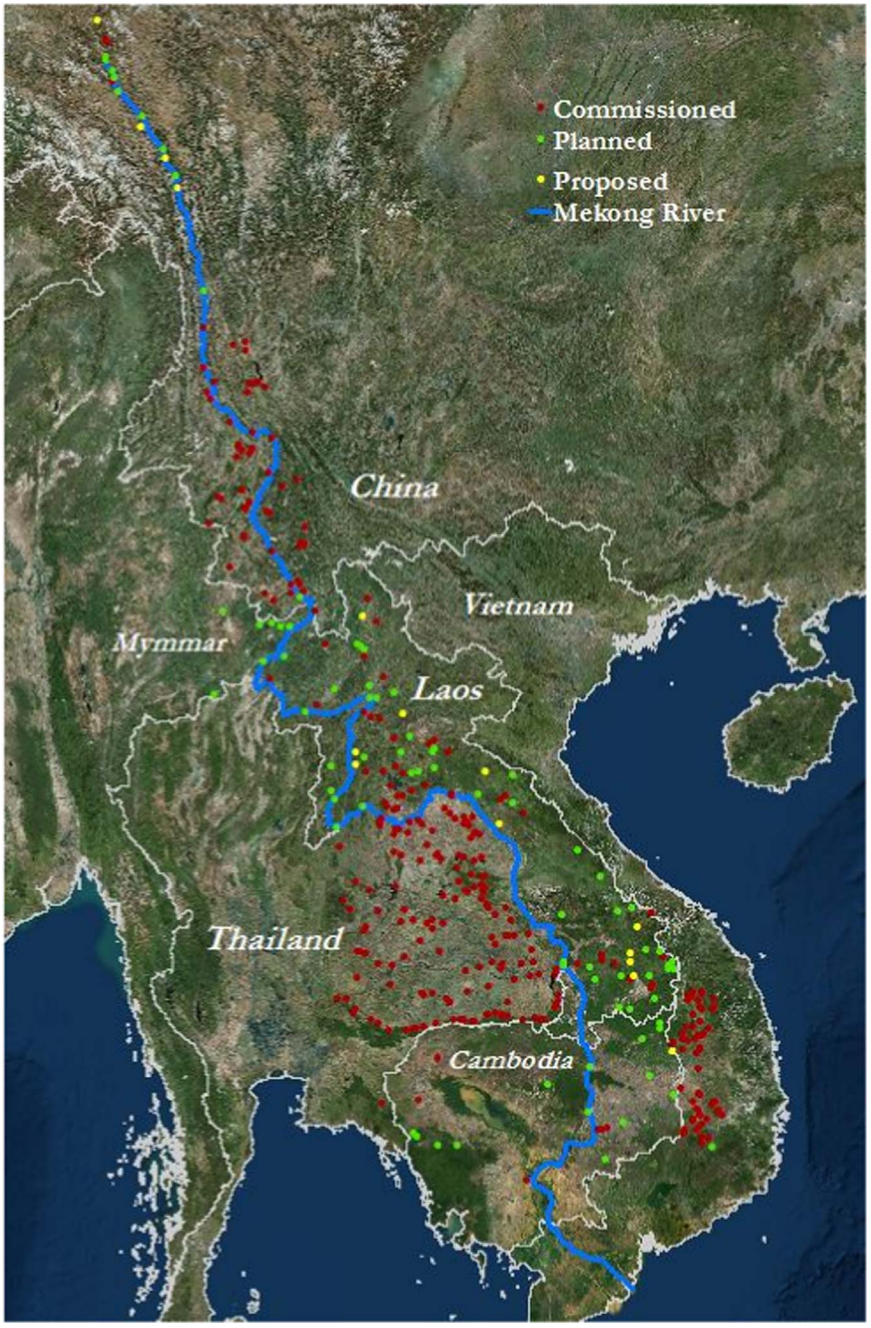

Fig. 1. Distribution of hydro-dams in the entire Mekong River Basin (updated to 2016, data source from the Greater Mekong CGIAR Research Program on Water, Land and Ecosystems (WLE)).

human intervention of hydrological processes to spatially re-distribute water resources. As water, like any other natural resources, is limited in space and time, re-distributing water is bounded to create competitions in access and right to use, requiring a close coordination among communities across administrative boundaries and international borders. A failure to coordinate flow regulations of these hydro-dams to balance trade-offs among all communities, near or far from the hydro-dams, would result in regional conflicts.

Loss of other important ecological habitats has been a major unintended consequence of hydro-dam constructions. Regulated dam flows have shown to disrupt the naturally formed aquatic ecosystems such as lakes and wetlands, adversely affecting the delivery of associated ecosystem services (ADB, 2008; Dugan et al., 2010; MRC, 2010a; Peterson and Middleton, 2010; Grumbine and Xu, 2011; McCartney et al., 2015), including fish recruitment, biogeochemical processes, nutrition retention, net primary productivity and wildlife refuge (Lamberts, 2006; Sarkkula et al., 2008; Keskinen et al., 2013). Constructions of additional hydro-dams will likely result in expansions of rainfed ecosystems and diminishments of seasonally inundated habitats according to recent simulations of floodplain landscape change (Arias et al., 2012, 2014a, 2014b).

Sound solutions must be developed in order to safeguard these valuable but threatened ecosystem services for the livelihoods of millions of people in the LMRB. These solutions should not only be nature-based, but also more importantly be science-based, in order to achieve a balanced trade-off among different sectors and communities. This study focuses on scientific evidences of dam construction impact on key ecological attributes that are critical in maintaining associated ecosystem services. The primary objective of this study is to assess impact of hydro-dam construction on phenological properties of aquatic ecosystems that are critical to some provisional services (Suepa et al., 2016). A secondary objective is to discern the contribution of hydro-dam construction from climate impact.