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China's ECM Model in Sustainable Management of Rivers: Drawing Lessons for the Zambezi River Basin from the Case of Mekong River

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Abstract

With China's successfully implemented Ecological Compensation Mechanism (ECM) in its management of the Mekong River Basin, one will assume that in the face of enormous cross-sector infrastructural development projects along Africa's Zambezi River Basin which was implemented through partnerships between riparian states and China, some practical lessons could be drawn to manage the Zambezi River Basin. However, no study has embarked on addressing this nexus. This study therefore comprehensively examines China's ECM model on a comparative basis to draw practical lessons from the Mekong River Basin for the management of the Zambezi River Basin. In terms of methodology, the study adopts secondary data sources to analyze the socio-economic, environmental, ecological and geopolitical benefits of rivers as a natural resource and some accompanying weaknesses of Chinese-implemented dam projects in riparian states and Africa as a whole. In conclusion with a suggested recommendation, a relationship of intertwined futures and equal target to meet key tests at the very least where Africa will not only dwell on grants but draw on lessons from its Chinese counterpart and implement them to attain a brighter Africa for the next generation is underscored.

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Keywords: *China-Africa relations, river management, Mekong River Basin, Zambezi River Basin*

1. Introduction

Globally, water security is often understood as the capacity of a population to safeguard access to water resources in sufficient quantity and quality to sustain livelihoods and socioeconomic development. According to UNESCO 2012, the concept embraces issues of health and sanitation, food security, natural disasters, and economic development. It is difficult to overstate the importance of water. Agriculture accounts for 70% of water withdrawals worldwide while some 1.5 billion people work in water-related sectors including agriculture, energy and environmental protection, among others (UNESCO, 2016), yet a large part of the world's population lacks adequate measures to sustainable water resource management.

One of the most diverse and valuable natural ocean resources in Asia is undoubtedly the Mekong River. The Mekong River, known as the Lancang (瀾滄) in China, is the heart and soul of mainland Southeast Asia. While countries in the lower stretch of the river have yet to complete a dam on the mainstream Mekong, China had already built six dams on the Lancang by the year 2013 with at least 14 more dams in the pipeline yet to be completed by the year 2023. The Mekong is the eighth largest river in the world, with a basin covering 800,000 square kilometers of mainland East Asia. In addition to meeting the basic needs of some 80 million people consisting of about 90% of the riparian population and sustaining a rich and diverse natural environment, the river plays a central role in the economies of China and six Southeast Asian countries including Laos, Thailand, Myanmar, Cambodia and Vietnam. It provides important environmental goods and services to the region and is essential to regional socio-economic development, food security and hydropower production among others.

Shared water resources epitomize the dilemmas surrounding common pool resources, whose use by one party diminishes the potential benefits to others. Rivers are particularly subject to these conflicts in terms of upper or mid-stream pollution, abstraction or impoundment, which may reduce the quality and quantity of water available to downstream users. Furthermore, in the case of an international river like the Mekong, the incongruence between hydro-ecological and political boundaries leads to conflicts between the principle of sovereignty as opposed to common resource issues of ownership, allocation, security and environmental degradation.

Extreme rainfall events, an increase in intensity and frequency of floods and droughts, and a continued deterioration of water quality are all expected to occur. Uncertainty over the length and severity of floods and droughts will likely have severe impacts on regional economic activities and may lead to China storing more water upstream for its own use. All of these factors could spell disaster for downstream countries that depend on the river's water and sediment flow for agriculture, navigation, fish migrations and other critical ecosystem services.

To mitigate these negative effects likely to affect the Mekong River and its beneficiaries, China administered a mechanism to counteract forecasted damages to the river.

The first aspiration on the agenda of African Union Agenda 63 is first, for Africa to become a prosperous continent on the basis of inclusive growth and sustainable development given factors such as the improvement in blue or ocean (marine resources and energy) economy for accelerated economic growth. Second is for Africa to have environmentally sustainable resilient economies and communities with emphasis on water security, biodiversity, conservation and sustainable natural resource management, climate resilience and natural disasters preparedness and prevention in a bid to improve living standards among communities and economies on the continent. Furthermore, given the critical threat posed to development of water management insecurity, the UN has incorporated sustainable water and sanitation into its Sustainable Development Goals to improve and mitigate the threat-related outcome. This AU agenda amidst UN Sustainable Development Goals in line with the adoption and application of China's ECM for ocean management heightens the novelty of the extant study.

Based on the preceding developments, this study will analyze the ecological environment of a river basin property (ECM), consider the location and pollution concentrations, and draw relevant lessons and policy implication for the Zambezi River Basin using Mekong River Basin as a case study. This work can provide practical analytical guidance for the application of watershed ecological compensation standards from Chinese perspective to the Southern African context.

Major Energy Projects by China in Africa

In a bid to further strengthen and improve on friendship ties between China and Africa, Chinese firms have successfully built or are in the process of building many hydro-power plants across the continent. These energy projects, located in many African countries including Côte d'Ivoire, Uganda, Zimbabwe, Angola and the Democratic Republic of the Congo (DR Congo), are intended and expected to create nearly 3,700 MW of electricity for the continent amidst creation of jobs for locals. With all these projects, there is a high need for strategic management mechanisms in place to see to its sustainability, development and maintenance.

Table 1 is a list of six Chinese-constructed hydro-power plants, some of which are already commissioned, or almost near completion by the year 2017.

Table 1 Hydro Projects by Chinese in Africa

Project Description	Country	Installed Capacity on Completion (MW)
Soubre Hydroelectric Power Station	Côte d'Ivoire	275
Kariba South Expansion Project	Zimbabwe	300
Isimba Power Plant Project	Uganda	183
Karuma Hydro Power Project	Uganda	600
Zongo II Hydro Power Project	DR Congo	150
Caculo Cabaca Hydropower Project	Angola	2,172
Garissa Power Plant	Kenya	50

Source: Author's own construction using data from Xinhua, 2017.

2. Research Materials and Methods

This study adopts a qualitative research (comparative case study) approach as methodology in addressing water management system in the southern African region, specifically the Zambezi River. In this regard, China's ECM model was used as a gauge to measure and draw lessons for restructuring the water management system adopted recently by the Zambezi River Basin located in southern Africa. While elaborating on the historical trends of the Mekong River, thus the case under study, this study analyses the various projects constructed by the Chinese counterpart in the African region and accounts for management systems of which basis practical lessons are drawn to effectively sustain and manage the Zambezi River Basin.

2.1. History and Trends of Mekong River

Perhaps more than any other region in the world, the Mekong River Basin (MRB) provides a case study of the importance of striking a balance between water, food and energy consumption. The Mekong basin is fed by a unique bounty of fresh water capable of supporting energy and food production that has become integral to the regional and global economies.

The Mekong River Basin (MRB) is a region of vast and potentially lucrative water resources. It cradles the Mekong River for almost 5,000 km and is home to more than 70 million people across six countries consisting of Cambodia, China, Laos, Myanmar, Thailand and Vietnam. In the study of Fasman (2016), it was highlighted that the basin's rich biodiversity includes 20,000 plant and 2,500 animal species, making it a natural endowment matched only by the Amazon and Congo River basins. Despite the long-standing economic challenges faced by these countries, the MRB is an intensely productive region. Its agriculture and fisheries not only support its own population, but also contribute to supporting that of the world. The Lower Mekong Basin produces 15% of the world's rice and one-quarter of its freshwater fish. The fisheries alone have an estimated annual value of US$17 billion (Mekong River Commission, 2016). In recent decades, the Mekong river's massive, untapped hydropower potential has also drawn increased attention and attracted dozens of new dam proposals, amounting to hundreds of gigawatts of installed hydroelectric capacity, that some in the basin view as a pathway to future economic growth. Despite the MRB's natural wealth, governments within the basin face a number of resource-related challenges that threaten the prosperity of the region. Some of these such as climate change have been foisted on them, while others are the result of unilateral decisions by particular countries about how best to pursue their individual economic interests. For instance, new hydropower construction threatens to impact agriculture and fisheries in the basin's downstream countries. Agricultural run-off in the form of pesticides and fertilizer also represents a threat to water quality in some areas, and in coming decade's urbanization and new development could lead to greater industrial pollution. At the same time, vulnerability to natural disasters and food insecurity is already high in some areas, and climate change is a major threat as changes in temperature and rainfall exacerbate drought and flooding. By 2100 rising sea levels could inundate one quarter of the Mekong delta, displacing millions of people and jeopardizing agriculture productivity in Vietnam. Even amid the wealth of water resources in the Mekong basin, the failure to address these problems in a collaborative way that takes into account the transboundary impacts of water use could result in heavy costs for countries in the region.

In the Upper Mekong, which is called the Lancang River, China has been developing hydropower projects as a cascade of dozens of mega dams; more than six of those have been completed in recent years and more than twelve others are under construction or planned for the near-term future (Magee, 2011). In time past, the upper Mekong dams have caused large-scale and trans-boundary impacts throughout the basin and the Lower Mekong dams are expected to largely compound these impacts by causing abrupt changes in water levels, altering sediment transport, and blocking fish migration (Stone, 2011). Since there is still great untapped potential in the Lower Mekong, downstream countries have also been accelerating dam construction. The study of Magee (2011) further explains that while some large dam projects have recently been completed, others are under construction, and hundreds of others are planned. Among these planned dam projects are 16 dams in the main stem (11 in the LMRB) and over 100 in the tributaries, most of which are expected to be completed by 2030 (Ziv *et al.*, 2012; Winemiller *et al.*, 2016; Grumbine, 1997; Lauri *et al.*, 2012; Stone, 2011; Keskinen *et al.*, 2012; Kummu *et al.*, 2010). While Xayaburi dam has been built to fulfill the growing regional energy needs (its installed capacity will be 1,285 MW), experts believe that the energy supply will come with unprecedented and devastating costs to the environment and livelihoods of tens of millions of people in the region (Stone, 2011; Stone, 2016; International Rivers, 2011). The dam will likely cause irreversible and permanent ecological change to the Mekong by altering the natural flow regime and adversely affecting fisheries and other aquatic resources; it will also affect flood-recession ecosystems in the lowlands and impede sediment delivery to the Mekong delta region (International Rivers, 2011; Kummu *et al.*, 2010; Nguyen Van Manh *et al.*, 2015; Darby *et al.*, 2016; Kummu and Varis, 2007). Growing transportation networks, especially the mountain roads in headwater catchments, some of which are linked with the construction of new dams, are causing significant changes in sediment production and deposition in river channels (Sidle and Ziegler, 2012). The dam will likely cause basin-wide changes, but the impacts are expected to be felt the most in the regions surrounding and downstream of the dams where serious threats to food security through loss of fisheries and agriculture are likely (Ziv *et al.*, 2012). The Don Sahong (260 MW) and Pak Beng (912 MW) are the second and third largest dams, respectively, among the 11 mainstream cascade dams planned in the LMRB. Construction of these two dams has been approved despite significant controversies due to the complaints about their environmental impacts and long-term implications for ecological well-being and regional food security (Stone, 2016). Similar to the Xayaburi dam, these two dams could irreversibly alter fish migration throughout the LMRB, with potentially devastating consequences for the river's richest ecosystems and the livelihoods of hundreds of thousands of people (International Rivers, 2015).

2.2. History of Zambezi River Basin

Similar to the Mekong River Basin is the Zambezi River Basin. The Zambezi River Basin (ZRB) is one of the most diverse and valuable natural resources in Africa. Its waters are critical to sustainable economic growth and poverty reduction in the region. In addition to meeting the basic needs of about 30 million people and sustaining a rich and diverse natural environment, the river plays a central role in the economies of the eight riparian countries, viz. Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. It provides important environmental goods and services to the region and is essential to regional food security and hydropower production. Because the Zambezi River Basin is characterized by extreme climatic variability, the River and its tributaries are subject to a cycle of floods and droughts that have devastating effects on the people and economies of the region, especially the poorest members of the population.

The Zambezi River lies within the fourth-largest basin in Africa after the Congo, Nile, and Niger River basins. Covering 1.37 million km^2, the Zambezi River has its source in Zambia, 1,450 meters above sea level. The main stem then flows southwest into Angola, turns south, enters Zambia again, and passes through the Eastern Caprivi Strip in Namibia and northern Botswana. The Zambezi River then flows through Mosi-oa-Tunya (Victoria Falls), shared by Zambia and Zimbabwe, before entering Lake Kariba, which masses behind Kariba Dam, built in 1958. A short distance downstream from Kariba Dam, the Zambezi River is joined by the Kafue River, a major tributary, which rises in northern Zambia. The Kafue River flows through the Copper belt of Zambia into the reservoir behind the Itezhi Tezhi Dam (ITT), built in 1976. From there, the Kafue River enters the Kafue Flats and then flows through a series of steep gorges, the site of the Kafue Gorge Upper (KGU) hydroelectric scheme, commissioned in 1979. Below the Kafue River confluence, the Zambezi River pools behind Cahora Bassa Dam in Mozambique, built in 1974. Some distance downstream, the Zambezi River is joined by the Shire River, which flows out of Lake Malawi/Niassa/Nyasa to the north. Lake Malawi/Niassa/Nyasa, which covers an area of 28,000 km^2, is the third-largest freshwater lake in Africa. From the confluence, the Zambezi River travels some 150 km, part of which is the Zambezi Delta, before entering the Indian Ocean. The basin of the Zambezi River is generally described in terms of 13 sub-basins representing major tributaries and segments.

3. The ECM and EIA Model

Ecological compensation is an important economic means to protect ecosystem services and regulate market failure for the protection and sustainable use of the ecosystem (Herzog *et al.*, 2005; Yin and Zhao, 2012). Ecological compensation takes economic means as the main way of adjusting the institutional arrangement of stakeholder interests (Yin and Zhao, 2012). Specifically, ecological compensation consists basically of four main aspects being (1) the cost to protect the ecosystem itself; (2) externality of economic benefits should be internalized by economic means; (3) economic compensation to individuals or regional protection of ecosystems and environments for the loss of development opportunities; and (4) protective actions undertaken for regions or objects with great ecological value (Wunder, 2005).

In the late 1990s, China initiated the ecological compensation mechanism (ECM) with a focus on forest ecological benefits. Since then, many ECM pilot projects have been implemented with notable success through tremendous efforts from central and local governments. Even though there have been some identified challenges such as the allocation and unequal distribution of environmental and economic benefits between various stakeholders amidst various factors including legislative system, financial system, administrative system, the overall benefits have been tremendous.

As a large and densely populated country, China faces major challenges to properly conserve and manage its river basins. It stands to be an undeniable fact that China's rapid urbanization and economic growth have placed severe demands on available water supplies for both surface water and groundwater (Xie *et al.*, 2009). Major sectors of the Chinese economy including agriculture, industry, and municipal users all compete for increasingly scarce, and often polluted, water supplies. As the availability of water is becoming a major constraint to economic growth, China has adopted mechanisms to better protect and manage existing water supplies and the watersheds that produce them. Ecosystems in upper reaches, especially forests and wetlands, are an important source of clean water that flows down rivers and provides a source of water for households, communities, and other users, including natural ecosystems, in the lower reaches. In this regard, ecological compensation mechanisms have become an increasing means of protecting water resources, which in turn promotes the economic growth of poor rural areas during ecological protection. With increasing demand for water resources from ecological compensation systems, the topic of water ecological compensation began to appear as an object of study (Qiu and Zhai, 2014; Zhang *et al.*, 2007; Chen *et al.*, 2006). Recently, foreign experts and scholars in the field of watershed ecological compensation standards say that such standards are generally based on ecological environment construction and protection costs, values of ecosystem services or willingness to pay the values of ecological services and other aspects of measurement. In the study of Pagiola *et al.* (2005), the author interpreted the basic idea of the theoretical framework of ecological compensation and proposed the idea of ecological compensation quota calculation based on the ecological value equivalent from the perspective of geographic scale correlation and scale conversion. In another insightful study, Pimentel *et al.* (1997) used the ecosystem value equivalent method to estimate the service value of natural capital and calculated the benefits directly or indirectly obtained from the ecosystem. Following the variant of Pagiola *et al.* (2005), Pimentel *et al.* (1997) and Kong *et al.* (2014) adopted the methodology of willingness to pay (WTP) value evaluation method, taking the Poyang (鄱陽) Lake wetland as a case study, and determined watershed ecological service values and the corresponding ecological compensation standard. However, the definition of the ecological environmental property rights of these studies is vague, and the cost and income of the damaged party or beneficiary party are often not considered. Several times, it was found difficult for the determinant of ecological compensation standards to consider the interests of all parties.

Likewise, the ecological compensation is not sufficiently humane and the amount of compensation is infinitesimal. Single compensation standards often lead to the phenomena of excessive compensation and insufficient compensation, which lead to difficulty in implementing compensation policy (Qin and Kang, 2007; Yu *et al.*, 2017). In China, water resources mainly belong to the state and are of collective ownership; therefore, water resources and ecosystem services are not implemented by market transactions but through financial transfer payments for ecosystem services provider compensation by the central or local government (Chen *et al.*, 2015). The upper reaches of major rivers in China are mostly in the western parts of the country. Due to a semi-arid climate, extreme weather, and generally low soil productivity, the upper reach regions are ecologically fragile and susceptible to degradation. These same regions, however, have a long history of settlement. Most of the communities are poor, with an economy dependent on agriculture or animal husbandry. Unsustainable land use practices including steep slope cultivation, overgrazing, poor conservation techniques and the thirst for economic development have put sky-high pressure on ecological conservation. Nationwide, it is estimated that 40 percent of the country's land area is affected by some form of degradation (wind and water erosion, overgrazing, deforestation), mostly in the upper reaches of river basins. The causes of the degradation include abnormally heavy rainfall, deforestation, and soil erosion in upper reaches. Another significant factor is human encroachment on flood-prone plains and the conversion of flood-prone lands. For instance, a major flood took place in the Yangtze River in 1998. The floods caused major loss of life and extensive property damage. With this, economic losses were estimated at over RMB 200 billion. In the aftermath of this disaster, the Chinese government was determined to take action to protect the ecosystems in upper reaches of major river basins and prevent similar disasters in the future.

Currently, finding a sound and effective mechanism has been explicitly put forward in many official and guiding documents and reports, such as the state council on implementing the advanced scientific view of development and strengthening environmental protection in 2005 (State Council, PRC, 2005); the outline of the 11th Five-year Plan of national economic and social development, to fully implement the concept of scientific development and to speed up the construction of environment-friendly society in 2006 (Wen Jiabao, 2006); some opinions concerning the implementation of ecological compensations pilot work and report in the 17th National Congress of the Communist Party of China, and the 11th Five-year Plan for national environmental protection in 2007; the outline of the 12th Five-year Plan of national economic and social development and the 12th Five-year Plan for national environmental protection in 2011; and report on the 18th National Congress of the Communist Party of China in 2012 (SEPA, PRC, 2007). Under the context of political and social needs, the Ordinance of Ecological Compensation was initiated for drafting in April 2010 to cover several key fields, including forest, grassland, wetland, resource exploitation, marine, watershed and ecological functional zones, which represents a major achievement of ECM legislative system. For now, through the determined framework of the Ordinance of Ecological Compensation, the principles, the applicable areas, the objectives, the standards, the measurement, and the capital sources of ecological compensation have been clearly defined. Also, the implementing regulations of ECM for watershed, forest, grassland, wetlands, and mineral resources will be further refined. Once officially promulgated in the near future, the Ordinance of Ecological Compensation will be the first law in the world to solely concentrate on ecological compensation.

Presently, four major areas of ECM implementation exist including watershed, resource exploitation, ecosystem services and nature reserves. However, the payment for ecological services has not been widely deployed. During the ECM implementation, the Central Government plays a leading and vital role in the establishment of ECM programs through financial transfer payments, special funds, resource taxation systems, regional policies, major ecological engineering projects, etc. (Chang *et al.*, 2014; Li and Imura, 2007). Also, ecological engineering projects has been the key factor to improve the environmental quality and provide various compensation packages, such as capital, resources and technology, to residents living in project areas.

3.1. Chinese Application of a Two-in-One Model to the Mekong River Basin

Human civilizations over time have seen to be reliant on people's constant interactions with the nature, socioeconomic activities, and dynamic development of technologies and science. China has taken to many dimensions to study the construction of as well as the management of predicted threats of hydropower projects for harnessing river for development in China, especially along the Lancang-Mekong River (Fan *et al.*, 2015).

One major concern over the development of hydropower is its negative environmental impact. The Mekong River (called Lancang River in China) Basin is managed and developed on a whole-river basis. Therefore, environmental impact assessments (EIAs), the corresponding ecological compensation mechanism (ECM) and the cumulative environmental impacts of the cascade development are all based on the whole river basin. Human survival and development obviously do have anticipated impact on nature. The bottom line is to minimize such impacts to a sustainable level for future generations, through practical and applicable sophisticated planning, coordination and remedies. The common interest should ensure both inter-generational and intra-generational sustainability; however, this is also accompanied by developmental needs. Thus, serving the common interest needs to address the development needs of the inhabitants, together with the requirements to attain the development of humans and nature. To manage efficiently the Lancang River, China adopted the application of EIA. This mechanism implemented reveals the impacts of projects on the river system, while the ECM investigates the monitoring and management of the river system, as well as suggests technical support for specific environmental and ecological remedies. The overall objective was to develop hydropower projects – in other words, to manage effectively, avoiding ecological problem areas and vulnerable zones to balance the river system and the biodiversity of river basin. It is worth taking note that it is extremely difficult and near impossible to integrate economic consideration and ecological concerns, local benefits and the common interest as well as dynamic efficiency, inter-generational and intra-generational equity into a development plan. More practical thinking is needed to balance competing interests and in settling for what will seem the best outcome to minimize negative environmental impacts to the barest minimal level (carrying capacity) in undertaking the necessary development and in applying remedies where possible.

3.1.1. Environmental Impact Assessment (EIA)

The EIA of the Lancang River's whole river hydropower development was accomplished by HydroChina. In China, HydroChina is the sole professional corporation that provides technical consultancy services for hydropower and wind power. The study of EIA was incorporated into the whole process right from the initial proposal, and implementation to the completion and operation of the power plant. It is a parallel system corresponding to hydropower development planning. In Lancang's case, the EIA acted simultaneously with the initial investigations of the river's hydropower potential. The EIA aims to set up clear goals for environmental and eco-system maintenance by analyzing general conditions and special features of the river system and the surrounding environment. Its suggestions for avoiding ecological problems and vulnerable zones were sent to a parallel hydropower development planning group at an early stage, so that the project engineers could incorporate their considerations. After project development plans were formulated, the EIA group would start assessing each plan and propose suggestions based on environmental considerations. Once the final development plan was selected, the EIA group had to study the selected plan in-depth and recommend corresponding criteria to be used in their assessments, matching control measures and monitoring schemes. There was also a feedback assessment upon the completion of the project. The EIA for the whole river basin development also suggests the development pace and order of each project to maintain coordination among all cascade projects. Lancang EIA also included an integral downstream Mekong stretch in its assessment. Hence, it covered 4880 km of the Lancang-Mekong River system from 1984 (first proposal of Manwan (漫灣) project) until 2030 (estimated development completion).

The study of EIA consists of two major components, i.e. the water system and the eco-environment. The water system study includes water quality, temperature, hydraulic studies, sedimentation and general water usage. The eco-environment study on the other hand includes the local climate, eco-diversity and the integrity of the river basin, ecological problem areas and vulnerable zones, aquatic organisms and bio-systems, terrestrial organisms and river basin eco-systems, and water soil erosion. Assessment indicators for each sub-section of those components are elaborated, such as the level of organic pollutants, carrying capacity and remedy capacity of the local bio-system, a study of fish species, and the extent of water soil erosion. The following paragraphs discuss several of these aspects: biodiversity and threats from alien species, water pollution, water soil maintenance, specific concerns for selected individual projects and a comparison between the present conditions and those before the development started in 1984.

For decades the Lancang valley was known to have environmental challenges. These included the frequent natural disasters of landslides, droughts and floods, engineering shortage of reticulated water supply, the fragile ecological environment of upstream regions and the general deterioration of the ecology in the whole river basin, together with the human impacts on the fish and transnational river issues. These are mostly the result of harsh natural phenomena, unsustainable development and unplanned deforestation to sustain a fragile agriculture. Thus, development, though not hydropower, has existed in Lancang valley for as long as humans have lived there.

Biodiversity is critical yet extremely delicate. The Hengduan (橫斷) mountain ranges in Tibet, Yunnan and Sichuan are endowed with great biodiversity and rare animal and plant species. The Lancang River and its catchment areas are treasures of biodiversity. More than 114 phytoplankton species, 239 zooplankton species and 80 benthonic animals are found in the river valley, as well as 186 fish species. Plant biodiversity is also abundant. Along the river there are 174 plant communities spreading from the cold, dry highland to the hot, moist tropical zone. Among the 692 terrestrial animal species are 78 species that are classed as endangered at a national level, mostly living in downstream regions of Lancang. One negative impact of the hydropower development was the introduction of alien species that might destroy local biodiversity. Fish, for instance, are under threat by the flourishing of alien species, the blockage of water by the dams and changes in river run-off patterns after the cascade plants came into operation. The topic of fish is always contentious in a hydropower development. A total of 186 fish species live in the Lancang River (from Changdu to Xishuangbanna), including 23 alien species; of these 90% are cypriniformes and siluriformes. The cascade river blockage had had negative impacts on the migration of fish. Subtle temperature changes in the water released from the reservoirs have an obvious impact on fish spawning seasons. Fortunately, very few of the fish in this system are long-distance migrating species, and the short-distance migrating fish are less influenced by blocking the river. Water pollution is the major concern for all river systems in China. The Lancang catchment's mountainous geographical conditions determined that there are very few farmland and industries along the river banks there. Also, there is further hindrance by way of the difficulty in engineering water supply both for drinking and irrigation, and the risks of seasonal floods. Therefore, most communities are located in highland further away from the river. This is particularly typical in the upstream valley where the arable land ratio is as low as 10%. There is no large industrial development upstream of Lancang, even TVEs (Township and Village Enterprises) are falling behind, and agriculture is also underdeveloped, so water pollution is not serious in those areas. However, there is still some water pollution generated by the small-scale industries, together with agriculture and the discharge of domestic wastewater. Changdu (昌都, Chamdo/Qamdo) in the upstream region is the center of small-scale industries in the Tibetan region, including a concrete factory, a printing factory and a leather manufacturer. However, these factories are too small to have a significant impact on the Lancang River. Comparatively, the downstream area of Lancang is at a more developed phase, where mining and smelting have become the main source of water pollution.

There are 33 large and medium industrial companies along the Lancang River in Yunnan, mostly concentrated in Dali, Baoshan, Lincang, Pu'er and Xishuangbanna. For instance, Dali City's industrial companies discharge about 7.45 million tons of industrial wastewater (2002 data). Other prefectures such as Nujiang are less developed industrially, and hence they discharge a limited amount of industrial wastewater. Overall, agricultural water pollution in the Lancang River is not significant because farmland along the river bank is limited. It is estimated that 541,600 tons of nitrogen and phosphorus pollutants are discharged into the river each year via pesticides and fertilizer residue. There are about 22.66 million *mu* (畝 , one *mu* equals about 667 m^2) of farmland in the river basin and the annual pesticide usage is calculated according to the proportion of the Yunnan provincial average level, which is about 23.9 kg/*mu*, and the pesticide pollutant discharge rate is around 20%, therefore it is estimated that the whole river basin's agriculture discharges are about 541,600 ton of nitrogen/phosphorus pollutants. The Tibetan area is under-populated, so domestic pollution is insignificant. There are about 10 million people living in the river valley in Yunnan. Nevertheless, the medium and large towns and cities are mostly located far away from the river. The only big city along the Lancang is Jinghong City (downstream in Xishuangbanna). In general, domestic wastewater discharge is about 23% of the industrial wastewater discharge along the Lancang parent river. However, the tributaries are intensively populated, and the domestic wastewater pollution there is correspondingly greater. This also explains why the quality of the mainstream water is much better than that in the tributaries. Over time, wastewater discharge into the river basin has risen by an annual average increment of 5.9 million tons. It is such a relief to note that the main pollutant, COD (Chemical Oxygen Demand), has decreased since 2006 (after fluctuating between 2001 and 2006). However, the discharge of polluted water from the tributaries to the parent river has become a rising problem. Water soil conservation is the priority for the region due to deforestation. The loss of soil by water run-off has made the river valley vulnerable to landslides and mudslides.

Forest conservation is the priority for both upstream and downstream areas of the entire river. Even though the population is small in upstream areas in Tibet, population density is still comparatively high due to the limited land carrying capacity in this area. There are conflicting issues between development and conservation in these regions because extreme poverty converges with a rich biodiversity. Arable land is limited, the supply of water for both drinking and irrigation is inadequate, and the high altitude and severe weather condition greatly compromise the existing poor transportation access to the region. Sustainable substitutions for production, living, energy supply and development are essential to solving these conflicts.

Deforestation is severe in downstream areas of Lancang, where the precious tropical rainforests are mainly concentrated. The illegal hunting and trading of wild animals prevail in these areas. Because of favorable climate conditions, agriculture develops much better in the downstream region of Lancang. However, some ethnic groups still practice slash-and-burn agriculture, which damages large swathes of forestland. The development of mass tourism has become a huge threat to both regions in recent years, where quantity has been prioritized over quality. Many tourist resorts along the Lancang River exhibit the same tendency to develop similar unsustainable mass tourism since Yunnan became popular as a tourist destination.

At present, six cascade hydropower plants are operating and more are under planning and construction.

In the EIA environmental changes between present conditions and the 1984 pre-development conditions were compared, with the following results. The first impact was the change of hydraulic condition and sedimentation. The largest three regulating projects, Rumei, Xiaowan and Nuozhadu, have altered water run-off patterns throughout the year. While the total water volume has not changed its seasonal distribution has greatly changed, so the volume of water stored is now more even throughout the year. The variations between the rainy season and dry season of the lower reaches have decreased. When the water temperature was monitored no significant changes were found after the development of hydropower. The water quality of the parent river remains at grade III, with no eutrophication. In the Lancang River the volume of sedimentation increases with the volume of water. Thus, near Changdu the river carries 22 million tons of sediment annually while in Xishuangbanna it rises to 139 million tons per year. The annual average sedimentation rate is about 0.6–1.8 kg/m^3. Cascade plants help to hold back sedimentation, but each plant is also facilitated with sediment flushing device to release sediment going down the river to reduce the sedimentation pressure of the plant. The second impact is on the aquatic ecosystem. One obvious impact of cascade plants is their segmentation of the holistic eco-system of the river basin. The most obvious impact is on fish including reducing the size of the fish, the significant spatial relocation of the fish and the invasion of alien species. A sophisticated river system was divided into sections of simpler reservoir bio-systems, and the distribution pattern of fish species changed accordingly. Although the change in the numbers of fish species was insignificant, the relocation of fish whose habitats is running water was significant in the new reservoirs, mostly in downstream stretches of Lancang. The slowing down of the river flows also influenced the aquatic ecosystem. The population of slow-flow fish greatly increased but numbers of torrent-inhabited fish shrank dramatically. Their concentration made them more vulnerable to human activities, such as fishing and netting. Fish that live inside of the reservoir survived but there was an affinity for them to get smaller. The introduction of alien species also increased the risks to indigenous species. Seven fish spawning sites in the parent river will be flooded after all cascade plants have been constructed. These widely dispersed spawning sites were sticky sinking spawning sites with smaller scales. Instead, the cascade reservoirs provide large feeding grounds with abundant food sources for fish. Fish communities (from the riverhead to Gongguoqiao) and downstream fish communities (from Xiaowan to the Mekong) maintain their habitat, but the biggest change has occurred on transitional stretch between Gongguoqiao (功果橋) and Xiaowan (小灣). Impacts on the terrestrial ecosystem were small.

The above EIA analyses on China's Lancang (MRB) provide evidence to the fact that the water system and aquaculture are two of the areas mostly affected by the introduction of hydropower and the construction of dams. It must however be noted that there are other impacts and pre-development environmental issues as well. The whole-river cascade development has limited large-scale projects to minimize their impact, and projects were selected to balance developmental advantages and environmental disadvantages. Such a dynamic system is devoted to bringing negative impacts to the possible minimum, because to completely avoid influences is unrealistic as long as humans live in Lancang valley, even without hydropower development. It seems, overall, that planned and coordinated development can better serve the common interest of sustainability than dispersed uncoordinated development.

3.1.2. Ecological Compensation Mechanism (ECM)

Undoubtedly, water resource and hydropower development cannot be totally devoid of its accompanying negative effects on the environment and eco-system. ECM mechanisms, primarily consisting of water system remedy, aquatic and terrestrial ecosystem compensation, wildlife rescue, resettling management, monitoring and information sharing, as well as whole-river management ECM is strategically implemented to moderate these adverse effects.

China has been in the limelight following through on the successful application of the ECM model. First, in terms of water system remedy, China built all power plans with an automated system in a bid to critically monitor the river basin in terms of ecological development. To this effect, industrial and domestic launderers from all power plants are treated for recycling while hazardous wastes are also transported to landfill. Construction of a selective water supply was built in the Nuozhadu (糯扎渡). Also, the Ganlanba (橄欖壩) non-economic project is developed to regulate the volumes of the water in the Jinghong (景洪) reservoir. Majority of these projects have undergone a sophisticated treatment for environmental protection projects like the planting of trees along the roads to reduce air pollution. In view of protecting rare plant species, the Gongguoqiao project in 2011 planted 45,000 trees along the Huajiuzhou road while the Nuozhadu project in 2008 built a rare plant garden. In addition, a complete center was established to enlighten the inhabitants about the essence of wildlife and plants among related others.

Following the provision of a water system remedy, China again implemented an aquatic and terrestrial ecosystem compensation mechanism. This saw to it the launching of Nuozhadu's fish hatchery and the building of a fish breeding plant and hatchery in 2010 by the

Gongguoqiao project all introduced in the same year. In effect all projects along the Lancang (constructed and planned) considered the issue of fish migration and reliable measures to mediate possible effects. Some of these remedial measures included the building of passage channels for fish, establishing fish habitats and reproduction bases on nearby tributaries, and building fish breeding and nurturing stations as an integral part of the power plant. HydroLancang's provision of man-made flood peaks for instance is one method of catering to the spawning needs of fish in the downstream of the reservoirs. In view of the fact that there are fish spawning sites downstream from the Ganlanba plant, the project was designed to stabilize the fluctuations from the Jinghong project to mitigate changes in the water level, flow speed and run-off volume so that the fish were able to spawn. However, the discharge of water in the cascade plants brought about by the people is most likely to produce artificial flood peaks during fish spawning seasons. To offset this adverse effect, Ganlanba created artificial flood peaks to meet the fish spawning needs. This takes into account the protection of tributaries that have substantial fish populations. In another example, the Yongchun River has been home to the Schizothorax species due to its rapid torrents. Serving as the first-grade tributary of the Lancang River, all existing power plants across the Yongchun were therefore demolished to maintain the habitat for these rare fish. Projects such as Cege, Yuelong and Ganlanba were designed with passages for fish. Furthermore, projects such as Rumei were supplied with a fish hoist because of their narrow river valleys while projects such as Gushui and Dahuaqiao were built with fish transportation amenities.

Another major variable in the ECM model is the management of resettlements. In the case of Lancang projects, land and forest areas occupied during the construction of the dams were paid compensation and restored. To restore the local ecology requires the careful nurturing of indigenous species, taking the complete local food chain into consideration. Subsequently, ECM is a complicated and long-term process. For instance, to restore a river valley plantation one has to choose among different options according to the specific local conditions. The Lancang upstream highland has an extremely harsh climate, so the best option for China is the adaptation of artificial plantations using indigenous soil and seedlings, which are then replanted in the wild when they are sufficiently sturdy. In the middle stretch of Lancang closed mountainsides facilitate reforestation in situ. The downstream regions have the best natural conditions, so the best choice here is to protect and replant trees on the site.

The fourth variable in the consideration of the ECM model is wildlife rescue, i.e. controlling the raiding of alien species in both animal and plant. The wildlife rescue center upstream is in the Tibetan Mangkang snub-nose monkey national park, specifically aiming to protect snub-nose monkeys, clouded leopards, forest musk deer and other endangered animals. Supplementary ecological compensation schemes include building a wildlife corridor connecting animals on both riverbanks and establishing an endangered plant garden.

It is indicative to note that pre- and post-dam construction and hydropower development often come with recorded natural disasters of which the Lancang valley has not been an exception. These are mostly landslides, floods and droughts. Because of uneven distribution of rainfall between upstream and downstream, there are more frequent floods in the downstream reaches of the river than the top. Flood control facilities in downstream areas are inadequate. For instance, Jinghong City, the largest city along the river, has the ability to cope with a five-year peak flood discharge only, which places the whole city at huge risk of flooding. At present, Nuozhadu located on the upper river from Jinghong City has shouldered the task of flood control for the Jinghong residents. The flood-control reservoir capacity of Nuozhadu was therefore designed to be large and cope with 2 billion m^3. This has greatly increased the flood resistance capability of Jinghong and its surrounding areas. Lancang River flows in a V shape through Yunnan, which makes it difficult to flow over the riverbanks in a flood. In addition, the river basin is in mostly mountainous areas or semi-mountainous areas, and farmland is too sparsely distributed to suffer from huge flood damage, unlike the Chengdu (成都) flat land basin. Flood damage to upstream regions is further reduced because of the small population there. The Lancang project was also faced with natural disaster in the area, i.e. extreme drought. Due to the climate change and other causes, according to Liu *et al.* (2015), there are increasing concurrent drought events that occurred in China challenging China's water management and grand water diversion project. To this effect, provinces like Yunnan and the other southwest provinces have already suffered from severe water shortage (engineering shortage) during normal regular times, and even worse during the dry seasons. To mediate the challenge of extreme drought, the Xiaowan reservoir for instance released 840 million m^3 of water during the severe drought in 2010 which greatly eased the impact of the drought downstream.

Overall, as a result of its natural endowment of abundant water and rich rainfall, frequent floods have occurred in downstream areas of Lancang, while the recuperation of forestlands has aggravated water soil erosion, repeatedly resulting in overwhelming landslides. The unadorned shortage of land and water has impelled the local people to engage in further deforestation, which has triggered even more severe droughts. Poverty and natural disasters constantly strike the region and people, and they reinforce and aggravate each other. This results in the situation where farmers in extreme poverty struggle to live in a place with such super abundant resources. Yunnan has thus become one of the typical regions exhibiting poverty with abundant natural resources, which are common in southwest and northwest of China.

Given all the negative impacts discussed above, the ECM is intended to offset the negative impacts from hydropower development and also pre-development problems and natural disasters to maintain environmental and ecological sustainability. Dynamic monitoring is crucial in achieving ECM, and is the ground of possible cooperation along whole Lancang-Mekong river basin. Manwan's long-term ECM proved its effectiveness and also demonstrated its shortcomings. The ECM is the key to sustaining the common good, so introducing more effective measures and dynamic monitoring are equally important for the future.

4. Assessment of Chinese Dam Projects in Africa

Chinese hydropower companies over the years have explored new hydropower markets given that Africa has huge hydropower potential that is yet to be developed. Africa has rich water resources. The total hydropower potential in Africa is estimated to be 35,000 TWh but only about 5% of Africa's hydropower potential, estimated to be 1750 TWh, has been exploited (UNIDO, 2009). A number of dam projects have been implemented by African countries in partnership with China. These dam projects include projects such as the Merowe Dam in Sudan, Song'oro Dam in Kenya, Imboulou Dam in the Democratic Republic of Congo (DRC), Kariba South Dam Expansion Project in Zimbabwe, Dam Project in Botswana, Tekeze Dam in Ethiopia, Caculo Cabaca Dam in Angola, Batoka Gorge Dam Project in Zambia, Mamve'ele Dam Project in Cameroon, Soubre Dam Project in Côte d'Ivoire, Poubara Dam Project in Gabon, Mambila Dam Project in Nigeria, Isimba Power Plant Project in Uganda, and Grand Renaissance Dam in Ethiopia, among other several projects across Africa (Anning and Vhumbunu, 2018). All these dams in spite of the merits have also drawn some negative consequences.

Standing as one of the dam projects developed in recent years in Africa, financed and constructed by China Exim Bank (CEB) and Sinohydro respectively, is the famous Ghana's Bui Dam. Bui Dam's history began in 1925 when its location was first deemed to be promising for a dam. In 1978, negotiations on the construction of the dam had evolved to the planning stage, with the involvement of the World Bank and Australia. After some failed attempts to get the dam working, China's low-interest loans got the Bui Dam project into becoming a reality (International Rivers, 2015). Anane's (2015) report further highlights this fact when the World Bank refrained from the decision to fund the project in the early 2000s particularly due to "the amount of campaign against the dam" on the environmental impacts of the project (*see* Anning and Vhumbunu, 2018). Secondly, the 1250 MW Merowe Dam on the fourth cataract of the Nile is Sudan's biggest hydropower project. The project was funded by Chinese and Arab financiers, and built by Chinese, German and French companies. Zambia's Lower Kafue Gorge Dam is also contracted with Sinohydro. The Lower Kafue Gorge Dam is situated on the Kafue River – a tributary of the Zambezi. In Ethiopia, Chinese contractors built the 300 MW Tekeze hydroelectric dam. China National Water Resources and Hydropower Engineering Corporation (CWHEC) built the main concrete dam for Tekeze which, at 185 meters high, is one of Africa's tallest dams. In the Republic of Congo, again, China Exim Bank bankrolled the construction of the 120 MW Imboulou Dam on the Lefini River, a tributary of the Congo River. China's Sinohydro was also involved in the construction of Zongo II. Lastly in Gabon, Chinese companies were involved in the construction of the Koungou Falls Dam.

4.1. Geopolitical and Ecological Effects of Chinese Dams in Africa

Water is being taken for granted by many. It rarely comes to mind that water has economic value which, in today's circumstances, is overwhelming its social value. It is even less common to think of water as a political issue. In Africa, 60 percent of the continent is covered by trans-boundary river basins. However, about one third of the population (300 million people) lives under a situation of water scarcity. It is projected that by 2025 half of African countries will experience water stress and the sharing of water will play a significant role in inter-state relations amidst a combination of population growth and recurrent drought and famine in some parts of the continent.

Even though water politics have historically been a central feature of geopolitics in the African region, they have grown particularly tense over the last decade due to the pressures of population growth, industrialization, and climate change. For instance, when Ethiopia diverted the first stretch of the Nile in May 2013 in anticipation of a dam's construction, tensions reached unprecedented heights and led Egyptian politicians to publicly threaten military action. Egypt and Ethiopia have long struggled for control of the Nile. In an effort to reach a common understanding and develop a mutually beneficial framework, the Nile Basin Initiative was launched in 1999 by all riparian states, viz. Egypt, Sudan, Ethiopia, Kenya, Uganda, Rwanda, Tanzania, Burundi, and the Democratic Republic of Congo (DRC), as well as Eritrea as an observer. The old divides have nonetheless yet to be overcome while nearly all downstream states (Ethiopia, Kenya, Uganda, Rwanda, and Tanzania) signed a May 2010 Cooperative Framework Agreement, which replaced previous colonial-era treaties based on the principle of equitable use; Sudan and Egypt opposed it and claimed that it infringed upon their historical rights. The international law of transnational watercourses is ambiguous and, as this dispute illustrates, it contains principles that are somewhat contradictory. One principle emphasizes the sovereign rights of states to utilize any resources within their territories, while the other requires that such actions do not cause significant harm to other states that share the resource. Consequently, although all parties cite international law in defense of their hydro-political claims, it has had marginal practical and political consequences. The ensuing diplomatic drama in recent years have led many to question whether or not the millennia-long rivalry over the Nile will finally culminate in an armed confrontation between these two regional giants. In this case as in others, water-politics (i.e. the influence of hydrology on politics) and geopolitics (i.e. the influence of geography on politics) go hand in hand. This discovery does not only pertain to the twenty-first century globalizing world but had been so even in the past. It is needless to cite some of the great river civilizations such as Ancient Egypt on the Nile, Mesopotamia with Tigris and Euphrates, the Senegal, the Niger, the Zambezi river basins among special others. Chinese aqueducts are still objects of admiration as technological achievements with regard to the ecological, environmental, social and geopolitical management of rivers. The rise of nations goes hand in hand with their ability to master water. Conversely, their decline is also accompanied by the loss of their ability to do so. In the case of Ghana for instance, although the Black Volta River originates in Burkina Faso and forms the border between Ghana and Côte d'lvoire, these countries are upstream of the Bui area of influence at a full supply level of 183 million or less. Downstream of Bui, the Black Volta and Volta Rivers remain within the borders of Ghana. Consequently, impacts on Côte d'Ivoire or Burkina Faso are not anticipated and efforts to investigate the possible threats to neighboring countries as well as to lay practical policies to see to the peaceful sharing of water have not yet been made.

4.2. Weaknesses of Chinese-implemented Dam Projects in Africa

Since 2006, investment from China has rapidly increased in Africa. According to a World Bank report in 2008, most of the Chinese investment goes to the infrastructure sector, mostly hydropower, railroad, and telecommunications. In the light of these projects, dam projects are widely blamed for negative impacts on local community and natural environment amidst ecological and geopolitical harsh effects.

First, the Bui dam project in Ghana has seen forced resettlement of eight communities with some yet to be resettled. There have been several conservation groups both international and local who advocated against the dam project. The challenges and errors in planning the Bui resettlement have therefore marred its successful implementation, resulting in adverse impacts on the affected people. These people have not been duly consulted and given the platform to effectively participate in order to influence the decisions made. They have been relegated to the background and positioned at the receiving end instead of being key participants in an issue which is about their lives. None of the three major livelihood activities of the affected people being farming, fishing and trading as well as their corresponding assets of fertile farmlands and fishing grounds have been restored after years of resettlement. Concurrently, income support given to the people (a daily wage which was less than USD 0.50 per person) has ended. Furthermore, the lands offered to affected persons eligible for land compensation have been identified to be of poor quality indicating a poorly structured ecological compensation mechanism. In addition, trade is on hold and picking forest products will not be possible since the portions of the Bui forest reserves the people could access will be inundated. New farmland preparation assistance was insufficient and some farmers have not received crop compensation yet.

The Merowe Dam in Northern Sudan has become one of the world's most destructive hydropower projects. Even though, with a capacity of 1,250 megawatts, the project doubled Sudan's electricity generation, the adverse catastrophes have been massive. In the face of displacing more than 50,000 people from the fertile Nile Valley to arid desert locations, thousands of people who refused to leave their homes were flushed out by the rising waters of the reservoir. No proper environmental impact assessment for the Merowe Dam was ever carried out. Project construction was started without approval by Sudan's environmental ministry, which violates the country's laws. The project also submerged immeasurable archeological treasures in its reservoir. The people affected by the Merowe Dam strenuously resisted their displacement from the Nile valley, and proposed to be resettled along the banks of the new reservoir. The government completely ignored their views, and brutally suppressed any protests. Several people were killed and many more were injured in crack-downs by the security forces.

In Ethiopia, the 185-meter Tekeze Dam (which is ten meters higher than the Three Gorges Dam), built on a tributary of the Nile, promises to bring the kinds of serious environmental and social problems that Three Gorges planners are only now beginning to recognize. In addition to the familiar environmental problems associated with large dams, such as altered hydrology and threatened fisheries, Tekeze will also completely change the face of one of Africa's deepest canyons. The deepness of the canyon walls will likely contribute to major sedimentation at the dam site once the region is flooded. To this effect, the situation will most likely reduce the capacity and lifespan of the dam, leading to reductions in irrigation and economic growth. The rural poor will not benefit from the dam project either, since the power generated will go mainly to large cities or sold to neighboring countries with more developed industries.

Similar undesirable effects are recorded with Chinese dams in various African countries like Cameroon's Lom Pangar dam, Congo's Imboulou Dam and Amerti-Neshe dam in Ethiopia.

5. China's ECM Model in the Sustainable Management of HydroLancang: Drawing Lessons for the Zambezi River Basin

In spite of the regional importance of the ZRB, few improvements have been made in the management of its water resources over the past 30 years. Differences in post-independence development strategies and in the political economy of the riparian countries, as well as the diverse physical characteristics of the Basin, have led to approaches to water resources development that have remained primarily unilateral. There is no doubt that better management and cooperative development of the Basin's water resources could significantly increase agricultural yields, hydropower outputs, and economic opportunities. Collaboration has the prospect of increasing the efficiency of water use, strengthening environmental sustainability, improving regulation of the demands made on natural resources, and enabling greater mitigation of the impact of droughts and floods. Seen in this light, cooperative river basin development and management provide not only a mechanism for increasing the productivity and sustainability of the river system, but also a potential platform for accelerated regional economic growth, cooperation, and stability within the wider Southern African Development Community (SADC) (SEDAC, 2008).

Sino-African relations is witnessing the consolidation of trends such as China's enthusiastic building of dams without regard to their ecological or geopolitical impacts; a pervasive tendency to relegate Africa's own labor from Chinese-funded energy projects and other projects; and forward-looking agenda such as on sustainable energy featuring too scantily on the agenda of the China-Africa partnership. Neither China's enthusiastic burnishing of its own Africa credential nor a Western-inspired attempt to vilify it for its role in Africa presents the whole picture. Nowhere is the need for Chinese help more apparent than in Africa's strategic power sector where current levels of investment significantly lag fast-growing needs.

Even then, a closer reading of the sector exposes how China instrumentally tailors its investments to further narrow advantages whilst ignoring the inconvenient truths about sustainability and the environment. Deconstructing the Chinese-Africa "partnership" on energy (hydropower sustainability) by way of adopting China's ECM on the MRB in the context of ZRB offers a much-needed corrective to the distorted lens that Beijing employs to view its role in Africa.

In the light of the above discussion, some relevant lessons to be drawn from EIA and ECM adoption practice to the sustainable management and development of the MRB are as follows.

First, governments in riparian countries along the ZRB should take a leading role in investing up-front in generating and organizing the information that the system will require. As was accomplished in China, a detailed ecosystem database for ZRB accompanied with a scientifically robust selection methodology would help ZRB choose priority compensation sites that are compatible with the national biodiversity conservation plans for riparian countries involved. Spatially explicit, best estimates of restoration and conservation costs could also be included in the database and selection algorithm. Developers could then more easily include compensation costs into overall project feasibility assessments.

Second, the governments of respective countries should facilitate participation by a wide range of third-party compensation providers, including public protected areas, private reserves and indigenous communities. In the short term, ZRB could adopt to partially using public protected areas as a ready supply of offset sites with clear property rights and known conservation gaps while establishing in the longer term the institutions, intermediaries, and mechanisms necessary to facilitate transactions between developers and private offset sellers.

Third, a consistent metric or standard should also be developed for indirect impact estimation as well. In this vein, option for a predictive model based on spatial analyses of historical land-use change by policy-makers could simplify the methodology further by establishing a standardized set of offset multipliers based on the specific type of infrastructure development and a very limited set of biophysical factors that determine indirect impacts (i.e., flat terrain vs. mountains).

Additionally, there is a sky-high possibility that the systems elaborated above could include a habitat banking or financial program, which fits into existing compensation framework (Bovarnick *et al.*, 2010). A fee-based system could allow developers to pay into an ecological compensation fund managed by a third party rather than undertake or contract for offset actions themselves. It is suggested that the fee must be appropriately scaled to the cumulative direct and indirect impact of the development project and funds must be directed toward ecologically equivalent offsets. As in the case of China, where compensations are paid mainly through financial transfer payments for ecosystem services provider compensation by the central or local government, in the case of ZRB, the respective governments can utilize effectively these funds.

6. Final Consideration and Recommendations

Large development projects commonly cause damage to ecosystems, even after some measures have been taken to avoid and reduce the impacts on site. Governments are increasingly seeking to offset losses through ecological compensation programs to maintain overall levels of biodiversity and ecosystem services, with the key to successful programs being criteria that reduce uncertainty and transaction costs while enhancing ecological equivalency.

Even though Zambezi River Basin has existing methods for establishing ecological equivalence, it still has yet to develop mechanisms and institutions necessary to reduce transaction costs. These experiences suggest a trade-off between rules that rigorously compensate losses with ecologically equivalent areas, and simpler approaches that have low transaction costs but may fail to ensure specific biodiversity goals. Again, the success of ZRB's sustainability and management system will depend on being practical enough to implement at scale and rigorous enough to deliver environmental benefits. In all of these, ecological compensation as well as EIA is still an embryonic effort in the Southern African perspective and policy adjustments will be necessary as better information on success and failure becomes available.

In all recorded dams identified in this study, rural land-users experience and grapple with new social, political and ecological conditions wrought by development processes and uneven power dynamics operating across sites. Rural people's lived experiences contradict neoliberal and nation-building discourses circulated by politicians and development expert officials. For instance, in Ghana, State elites justified Bui Dam with historical understandings of dams as vehicles for modernization while simultaneously framing rural people as responsible for accessing dam-related "benefits". Yet, the dam's socio-ecological outcomes undermined people's ability to "fit into the system".

Farming and fishing livelihoods have been radically transformed, resulting in food insecurity, diminished household incomes, and psychological stress. Yet, some respondents reproduced nationalistic discourses of hydro-electric power, articulating the harmful outcomes of various dams with a shared, imagined future of modern economies.

These Chinese dams in Africa show how local socio-ecological as well as geopolitical systems are affected by the globalization of the hydropower industry in the face of management of river basins through the emergence of China as a key source of finance and technical capacity in dam constructions. Local communities therefore face a particularly difficult situation in which the interests of the national government, multinational corporations, and emerging economies are linked. This produces a situation in which communities do not only face their governments but also transnationally operating actors that are not accountable, meaning that there are no formal processes through which local communities could hold transnationally operating companies to account.

Furthermore, a robust environmental policy within Sinohydro and China Exim Bank could have improved the impact the dam has on local communities. One of the ethics of Exim Bank who stands acute in most of the dams constructed by Chinese in Africa is reviewing the quality of the environmental and social impact process during the dam planning process before approving the credit facility. Therefore, an improvement of environmental policies and credit approval procedures on the Chinese side should result in less harmful projects even in projects where Chinese actors are not involved in the resettlement process, as was the case for the Bui dam.

A relationship of intertwined futures and equal partnership – of the type that China trumpets – must meet these key tests at the very least where Africa will not only dwell on grants but draw lessons from its

Chinese counterpart and implement them to attain a brighter Africa for the next generation.

The incorporation of many of these lessons drawn in ecological compensation policy and EIA requires a wider landscape-level perspective on development and balance activities, timing of offset generation, measurement of biodiversity and ecosystem services, consistent accounting procedures and rules for calculating losses and gains, transparent institutions and intermediaries, forecasting of future changes to natural habitats, and approaches to managing risk (Gardner *et al.*, 2013). The enterprise of ecological compensation is still relatively new. Consequently, many ecological compensation programs including those in China will require periodic monitoring and evaluation in order to refine and improve policy design. I am with high hope that these lessons drawn can contribute to the elaboration of appropriate ecological compensation rules in the ZRB leading to the effective internalization of environmental costs, stronger protection for species and habitats, and more socially beneficial development choices on the whole. If this process is successful, it could benefit other forested countries globally as they look for models for their own conservation goals, and the regulations and institutions necessary to achieve them.

Note

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