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Accelerating Sustainability by Hydropower Development in China: The Story of HydroLancang

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Abstract: Sustainable development is a shared responsibility. Accelerating sustainability of water–energy–people nexus and building a common awareness of issues pertaining to sustainable development are essential for any sort of success in this direction. Hydropower has been a useful sustainable energy for development, yet highly controversial. This paper reviews the overall situation of hydropower development and China's energy reforms and policies, accompanied with a case study of hydropower development the Lancang River by the HydroLancang, aiming to illustrate the two opposite sides of hydropower development—economy and environment. The paper concludes with a neutral view of hydropower as the necessary facilitator for development. Water is a shared responsibility. Hydropower might not be the optimum solution to eliminate the tension between human demand of energy and finite natural resource and the rising pressure of climate change worldwide, but it serves well as an "Electricity Bridge" before better alternatives become available. This is a more balanced view of hydropower rather than two extreme viewpoints that present themselves: on the one hand, exaggerated claims of the human power to tame the wild river, and, on the other hand, the idealistic fantasy of preserving nature by abandoning all human activity.

Keywords: sustainability; hydropower; electricity bridge, China, HydroLancang, Lancang River

1. Introduction

Sustainable development is a shared responsibility. Accelerating sustainability of water–energy–people nexus and building a common awareness of issues pertaining to sustainable development are essential for any sort of success in this direction [1,2] (the 'water–energy–people nexus' refers to building transformational pathways towards sustainability by integrating the ecological integrity—planetary boundary of water resource; social equality and security—social boundary of energy; and human rights and well-being—humanity boundary of people's well-being). Sustainability is developed upon the core concept of "sustainable development", which was described by the Brundtland Commission in 1987 as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. Sustainability, however, "far from being as mere doctrine of development science", "has emerged as a universal methodology of "futurity, equity, global environmentalism and biodiversity" (p. 118), for evaluating whether human options will yield social and environmental vitality" (p. 109, [4]). Human civilizations rely on people's constant interactions with the nature, socioeconomic activities, and dynamic development of technologies and science. There are many perspectives to study the construction of hydropower projects for harnessing river for development in China, especially along the Lancang-Mekong River [5,6]. This article takes the perspective of development studies, to focus on the conflict between welfare improvement of lagging developing regions and environmental/ecological concerns. The article adopts case study approach, which enables in-depth research into a complex eco-system of economics, politics and society, identifying the underlying issues and providing nuanced understanding of the complexities.

The employed empirical evidence on hydropower development along the Lancang River is interpreted by the analytical framework of Chinese governance—its effects and problems. This is not only theoretically important for scholarly inquiry into sustainable development, but also for informing public policy in China and perhaps in the world.

The comprehensive transition of our "overwhelmingly fossil-fueled civilization" will take a prolonged, multidecadal process [7]. Hydropower must act as an "Electricity Bridge" in this process. As "hydropower has played a prominent part in the electrification phase of the industrialization process" and being a clean, renewable, cheap source of electricity, it will undoubtedly "ease newcomers to the industrial world into functional electricity depending energy systems" in the future [8]. In addition to satisfying rising demands for electricity, hydropower projects fulfil other functions and reap long-term benefits, such as controlling floods. In a fundamentally changing political and economical global landscape, understanding China's transformative governance and vision is also important for the global acceleration of sustainability, and hydropower development is a crucial link for that transformation, as China's hydro capacity has ranked as the world's largest since 2014, and the hydropower accounts for about 20% of China's overall power generation (2016 data).

Hydropower has provided approximately a steady 20% of world's total electricity supply since the 1990s (from the World Water Assessment Programme). Hydropower is clean, renewable, reliable and affordable energy, and it is an important way of using water. Its power generation process is entirely mechanical. Greenhouse gas emission generated by hydropower is lower than other renewables. Hydropower produces neither solid waste nor wastewater. Well-proven technology and competitive advantage have enabled hydropower to act as an "electricity bridge" before better alternatives became available. The geological location, weather and volume of rainfall affect the hydropower capacity of specific rivers. However, pumped storage and cascade control could reduce natural disturbances and maintain a stable level of power generation. Although the cost of constructing a hydropower plant is huge, it has a long built life expectancy, so the unit cost is comparably low. It is almost 50% cheaper than nuclear power [9]. (The overnight cost (USD/kWe, median) of nuclear is 4896, while that of hydro is 2493 according to the report. Overnight cost includes pre-construction (owner's), construction (engineering, procurement and construction) and contingency costs, but not interest during construction (IDC).) Hence, despite the expensive initial input, hydropower still beats all currently available energies in terms of the unit cost of electricity produced in this way.

However, hydropower can generate negative environmental and social impacts by blocking rivers with dams. However, there is no comparison in the desirability of having a hydropower plant with no development whatsoever. There is considerably less power generated from water sources than from thermal coal in the world's massive power consumption. Other renewables using nuclear, wind and solar generated power are even less. Hydropower is the best option currently available, as argued by Rolf Sternberg [8].

China's hydropower development is necessarily vigorous considering the country's energy shortage and environmental pollution [10]. The strategically planned "13 hydropower bases" nationwide have expanded rapidly over recent years [11]. Integrated multi-cascade development along big rivers supported those hydropower bases, coordinating power generation, flood control, water supply, shipping, irrigation and ecological remedy within the catchment areas. Facilitated with power grid stability and pumped storage technology [12,13], China's hydropower could be more flexible to support other intermittent renewable energies such as wind and solar power. On the other hand, there are some problems in China's hydropower development, such as "insufficiency of scientific understanding by the public"; conflicts among all levels of government; overlapping project approval administration involving multiple ministries; "soring development cost", including high operation tax; "inconsistency on grid price" and "restrictions in transmission" caused by the lagging grid; and mostly discussed issues of environmental concerns and resettlement of people [14].

This paper discusses the governance of the Lancang hydropower development in serving the common good, together with the positive impact of the hydropower on powering the economy and fulfilling national social responsibilities; and its negative environmental and social impacts and their corresponding mitigation. Governance is a coordinating process in which there is constant interaction among all stakeholders, including the state, the market and society. Various stakeholders are involved in the Lancang hydropower development involving the commons of water and electricity. The common interest is multilayered due to different levels of stakeholders, generally three levels—a global common interest in socioeconomic and environmental sustainable development, a national common interest in development with balanced equality and efficiency for China and Chinese people, and a local common interest in poverty reduction and benefit sharing. The decision-making process on Lancang hydropower development needs to be understood within China's political system. For instance, as an energy enterprise, HydroLancang presents various political motivations and influences at both national and local levels, not to mention the competitive dynamics among the "big five" and with the grid companies. The vastly complex relationship of the "powershed politics" in Yunnan merits further explorations [15,16].

The exclusive developer, Huaneng HydroLancang, became a platform for demonstrating the typical Chinese governance logic on hydropower development. HydroLancang is supervised by one of big five national energy SOEs: the Huaneng Group. Local SOEs Yunnan Development and Investment Company and Yunnan Hongta Investment Company both held considerable shares in it, respectively, 31% and 13%. HydroLancang implements the national strategy and acts according to national developmental goals to serve the common interest. The story of HydroLancang demonstrates how China governs the hydro development, not perfectly but endeavouring to serve the common interest given the complicated conflicts of interest among stakeholders, and confrontations among power actors (the data were collected from author's intensive fieldwork of multiple visits to 14 power plants along the Lancang River, reorganized by the author). It also incorporates the local common interest of the poor ethnic-minority agricultural population of Yunnan and the larger river basin under different jurisdictions, such as Guangdong and Tibet. People do not necessarily share the same interest due to the differences of social status, power and pursuit, not to mention distinctive manifestations of individual self-interest. Governments are involved at all levels, together with multiple specialized agencies and governmental bodies (for instance, the National Energy Administration is responsible for managing the power system management, while the Yangtze River Administration Commission supervises water affairs as administrator of the river basin). NGOs (Non-governmental Organizations) and the media have their shifted focus to the Nujiang River and no longer concentrated on the Lancang River in recent years. The natural, economic and social disadvantages of the hydro-induced resettled villages were just as severe in non-resettled villages. However, NGOs chose those with more public media values, while "most mountain residents are tired of isolation, eager for development, and ready for change" [17].

HydroLancang operates commodities that have obvious features of the commons–electricity and water. It has to balance efficiency and equality with respect to the shortage and disparities of resources and energy, national and regional economic development, urbanization, industrialization and the pressure of the population explosion as the implementer of national strategy and policy. As a profitable business entity HydroLancang also faces (private) competition from the domestic and global market and from industrial chains. Further, it encounters considerable pressure due to the global trend of sustainable development in terms of environmental concerns and climate change because its parent company Huaneng Group still mainly operates on thermal power (about 77% of its total operating capacity). This is illustrated in its "three-colour" corporate culture as the HydroLancang stated: red represents public authority; green represents sustainable clean energy; and blue represents the nature of water to embrace all. As the most important stakeholder HydroLancang also coordinates with other stakeholders. There are various stakeholders involved in the Lancang hydropower development besides HydroLancang. International organizations such as UNESCO and World Bank participate in specialized fields. Regional institutions such as the Greater Mekong sub-region and the Mekong River Commission, and various countries in the Mekong stretch coordinate to solve conflicts and seek funds for development. International NGOs such as Oxfam, GNGOs such as the China Red Cross and local NGOs such as Green Watershed, and various media, both home and abroad, are active on hydropower developments. Universities and academic research institutions are also involved.

Energy policy and power system reform are closely embedded in the political system in China. Central control systems can mobilize large-scale resources effectively, but any subtle error such as underestimation or overestimation of a challenge could generate devastating results, thus amplifying the consequences. Therefore, "crossing river by feeling for rocks, taking one step at a time" is critical (this phrase has been mostly known as the symbolic words coined by Deng Xiaoping to show the pioneering strategy of China's opening-up and reform in 1980s. The phrase, originally from an old Chinese proverb, refers to that the strategy of wisdom to cross a river without bridge or boat is to walk into the river carefully with each step feeling for the stones underwater as the invisible obstacles. Since being firstly applied to China's incremental economic reforms by Chen Yun, with substantial supports from Deng Xiaoping, this phrase has become a core part of political philosophy of Chinese reforms and development strategy since the second generation of leadership [1976–1992]). As stated in the 13th Five Year Plan, China's energy revolution is at stake. Domestically, China faces potential energy crises over efficiency and security concerns. Internationally, China has grown into the world's largest energy producer and consumer. As the world's largest carbon emission country, China faces tremendous pressure from the international community over its contribution to climate change. Although China's coal production, hydropower capacity and wind power capacity all rank first across the world, its energy shortage persists. Energy-intensive industries face challenges of backward technologies and low efficiency. Although the Chinese government has nurtured substantially with preferential industrial policies on large "strategic" energy SOEs, their competitiveness in the global level playing field is still weak and open to challenge, "even in the oil sector that has achieved apparent success" [18]. Therefore, energy security is a big concern, as more than half of China's oil still depended on imports.

The power system reform in 2002 was considered a fundamental change of China's energy industrial framework. It was a huge step forward separating government administration from enterprise operation. The first key to the reform is the power grid, which is not only an electricity transmission carrier, but also a platform for the electricity market, and more importantly it is public service system. The most obvious problem is grid monopoly. That power grids constitute a natural monopoly and power generation an oligopoly is commonly acknowledged. However, a natural monopoly in an economic sense is different from administrative control of the monopoly. At present, the grid company gains interests from the administrative control of the price of the electricity, power market entry, exclusive trading rights and special permissions. The incomplete power system reform left an uncoordinated development between grid and power generator.

A distorted pricing system is another obvious problem. Both the feed-in tariff and the final sale tariff are set by government, which results in a high ratio between assets and liabilities ratio for generation companies. Moreover, the complicated power contest between central and local companies is also problematic. One striking conflict lies in the administrative measures to maintain the coordination of the price and supply of electricity. A fluctuating price and administrative power distribution system intimidated private and foreign investors.

Resettlement of people is also a contentious issue raised by hydropower development in the developing world. The resettlement process is complex and deeply controversial worldwide. At the very least in Yunnan it involved the resettled population, the power plant and the developer, the consulting company and institute, local governments, the local water affairs bureau and ethnic autonomous region governments, the institute of hydropower and hydraulics general planning. It involved many rounds of consultations, modifications to the plan, in-field investigations and government approval. The resettlement of people along the Lancang River shows the evolution of China's institutional approach to resettlement and compensation, under the rough transition from a planned economy. For instance, the Manwan project witnessed the whole transformation of government policy on resettlement and compensation from the period of a planned economy to a market economy, which had to carry out a second round of compensation and resettlement in 2003 due to the degradation of the living conditions of the resettled villagers. The resettled Tianba villagers relapse into poverty occurred for historical reasons, primarily being removed from the agricultural registry and placed on the non-agricultural one. Being listed in the non-agricultural household registry was attractive to many in the planned economy because urban residents could enjoy various government subsidies. However, the villagers became non-agricultural residents without farmland yet they could not find any other livelihood in the remote mountainous area, which was not an isolated case during the painful social transformation process in China, and it was not necessarily triggered entirely by hydropower development. As the "Chinese governance continues to undergo profound transformations, and lessons from historical transitions could provide guides for [dam-displacement compensation] policy making and reforms in the future" (p. 8, [19]). However, further discussion on resettlement is beyond this paper's scope.

2. The Story of HydroLancang

Understanding China's governance logic requires evidence-based study with the combination of explanation and interpretation. The explanation of the evidence is presented by the narratives emerging from the local realities as the storytelling. While the interpretation of such evidences is the underlying framework of the storytelling, such as mapping out key stakeholders, framing the system and dynamic of such governance, as well as the impacts toward a desired future through various actions. This article conceptualises sustainability of hydropower development through two strands of its impact. The two strands of impact are positive impact of electricity supply and economic development to China and to the Lancang valley; and negative impact of environmental and ecological concerns and remedies ranging from water system, environment, animals and plants, biodiversity to the multi-cascade effects. The research aims to shed light on understanding sustainability in an overall framework of development and applying it to present China's transformative governance logic of delivering positive impact and mitigating negative impact.

Two major aspects of hydropower development along the Lancang River will be discussed in this section. The contribution of *electricity supply* and *economic development* by hydropower is for the common good of the country and people, and it is also the "choice of no choice" because hydropower has to be the "electricity bridge" for China's giant appetite for power before any better alternatives become available. In respect to economic development, energy security and the power industrial chain, the Lancang hydropower development involves Yunnan and Tibet, Guangdong and indeed the whole of China. It is also associated with international projects situated downstream the Mekong at present and in the future. The discussion then goes on to the most familiar yet controversial aspect of hydropower development—natural resources, the environment and the ecosystem. The EIA and ECM of the Lancang River covered the water system, the environment, animals and plants, biodiversity and multi-cascade effects. It carefully analysed the negative impact of hydropower development on the environment and ecosystem, as well as the corresponding measures applied to mitigate such impacts.

2.1. Electricity and Economic Development

As a developing country China still prioritizes economic growth. The power industry is vital to economic development. During the 12th Five Year Plan, the power industry contributed 2.8 trillion Yuan per year to the economy and provided 2.7 million job opportunities per year [20,21] (all data in this section are quoted from the 12th Five Year Plan and the Yunnan Statistical Yearbook 2013, unless indicated otherwise). Hydropower as an "electricity bridge" is able to facilitate economic growth by providing affordable, reliable, clean and renewable electricity. By 2013 China's total hydropower generation capacity reached 280 GW, amounting to 22% of its total electricity generation capacity. Hydropower's substantial share has obvious impacts on carbon emission reduction. In 2012 hydropower replaced 2880 million tons of coal-powered electricity and reduced CO_2 emissions by 8600 million tons. Here, the following section describes the impact of Lancang hydropower on powering the economy at both the national and local level, and its role in integrating and competing in the industrial chain for socioeconomic and environmental sustainable development to serve common interest at all levels.

The power economy affects both the national and the local level. As a national energy strategy Lancang hydropower has had a profound impact on energy, the economy and development. These positive impacts are illustrated in their transformation of the industrial and economic structure, the energy framework and the power industry, together with the value added to the economy and the national overall development strategy of the GWDS and the WEET. The second section investigates its positive impacts on the local economy. Hydropower benefits Yunnan in several ways: by mitigating power shortages, by the value added to the economy and employment, by optimizing the industrial structure and by increasing fiscal contribution to local governments for improved public budgets, poverty reduction, rural electrification and rural–urban coordination. Therefore, Lancang hydropower serves the common interest by facilitating the overall development of the country, balancing regional disparity and scarcities, improving local development in various respects and balancing efficiency and equality while powering a sizeable economy.

Given the inferior economic situation in the Lancang-Mekong valley, hydropower offers tremendous development opportunities. The technically feasible hydropower potential of Lancang River has been estimated as 34,840 MW, with an annual average electricity generation of 169.03 billion kWh. Major hydropower potential is concentrated in the parent river. The Lancang River was one of the ten national hydropower development bases listed in 12th Five Year Plan, GWDS and WEET national strategies. HydroLancang planned to develop 23 multi-cascade power plants along the Lancang River in an integrated, coordinated fashion, to generate 141.15 billion kWh per year with a total capacity of 31,499 MW. Besides satisfying the local power demand, most of this hydroelectricity will supply power-thirsty Guangdong and Southeast Asia. After completion, these cascade plants could create an annual value of 42.34 billion Yuan. The downstream Mekong stretch is also under rapid construction and planning has been coordinated under the intergovernmental framework of the Mekong River Committee.

2.1.1. Macro-Economy

Lancang hydropower has facilitated China's overall development in various ways. Providing affordable, reliable, clean and renewable hydroelectricity for a gigantic economy has also reduced coal-fired electricity and CO_2 emissions. According to the International Energy Agency (IEA), hydropower as the largest single form of renewable energy, has contributed over 16% of the global electricity production at competitive prices in 2016. Given the size of China's economy, this contribution is also crucial to the world. According to China's 13th Five Year Plan, hydropower will supply 5600 billion kWh electricity between 2016 and 2020, which would reduce 1.68 billion tons of coal-fire energy portfolio, and hence reduce 3.5 billion tons of CO_2 emission. According to the UN Framework Convention on Climate Change (UNFCCC), hydropower generally has an evidently low emissions of 28 g CO_2 e/kWh, where the median value of other electricity generation ranges from 490 g CO_2 e/kWh for gas-fire generation up to 820 g CO_2 e/kWh for coal-fired generation. The national energy framework prioritized hydropower as the "electricity bridge" before better alternatives become available. Hydropower has also facilitated China's overall strategic development of regional coordination, using the GWDS, WEET and NHDB (National Hydropower Development Base) to mitigate regional disparities in economic development and resource endowment. Such national coordination represents the governance of the vertical dimension of public authority and horizontal dimension of sharing in common of the commons, working together to serve the common interest.

First, Lancang hydropower contributed to hydro-powering national economy and adjusting energy framework. Over the past three decades the main challenge of energy supply was the shortage of power. Thus, increasing the supply of power was the priority. Now China has developed into the world's largest energy producer and consumer. The installed capacity of power generation has reached 1250 GW and China has surpassed the USA to become the world's largest generator of power in 2013. After the 11th Five Year Plan, the national energy equilibrium was even, with a surplus electricity supply in several provinces. The "New rural area, new power and new service" project solved the electrification difficulties of 1.67 million rural households. Rural electrification rose to just under 100% by 2009. Meanwhile, the growing pace of energy consumption and oil imports decreased. Energy consumption grew by only 39% in 2013. This is because China's economic development slowed down. In addition, restructuring and improvements in energy efficiency mitigated electricity shortages. The safety, reliability and efficiency of the power system also improved. Hence, the current priority is no longer to increase supply, but to restructure the power industry, promoting technological innovation and new energies. During 2006–2009, 24% of the accumulated investment in the power system was used for renewable power generation. The 12th Five Year Plan was the crucial period for the transformation of the energy structure. The goal was to develop non-fossil energy to 11% of total energy share by 2015 (9% in 2012), mostly hydropower, amounting to 30% of the total capacity of non-fossil energy. The new energy framework prioritizes hydropower in selected whole river basins to facilitate the generation of cleaner coal-fired power with improved efficiency, and to substitute previous extensive power generation with greener alternatives. Power structure adjustment and efficiency improvement reduced the emission of CO_2 by about 969 million tons in 2013.

Powering the huge Chinese economy in a sustainable manner creates enormous positive externality to the world and is a major contributor to the common good of humanity. Although the Chinese economy has slowed down in recent years, its scale of development is still considerable, and so is the power it needs. Power is vital to achieving a well-off society by 2020, as by then estimated power consumption in China will be 8 trillion kWh, almost double the current total. From 2010 to 2020, energy consumption intensity will decrease due to the transformation to a new economic mode. Secondary industry (industrial and manufacture) share of power consumption in 2013 decreased by 0.34% compared to 2012. Steel, ferrous metal, the chemical industry and construction materials, which are major electricity consumers (about 25–30% of total power consumption), might become excess capacity. On the other hand, power consumption in the domestic and tertiary and service industry have increased due to urbanization and the availability of family appliances in rural areas. In 2013, power consumption n tertiary industries increased by 10%, while domestic power consumption increased by 9%. Although industrial power consumption grew at a slower pace, it still increased by 6% in 2013, while manufacture power consumption increased by 7%. This enormous power demand determines the position by hydropower as the "electricity bridge", and weighted among industries highlights the advantages of the low cost of hydropower. It is lower than thermal, nuclear and solar photovoltaic (PV) power. Although hydropower development in remote areas can be comparatively costly, its unit cost remains competitive. Therefore, hydropower is critical for China's revolutionary energy restructuring without sacrificing economic growth—balancing efficiency and equity in the common interest of sustainable development.

Second, the regional coordination of the power supply and economic development is in accordance with national common interest. The major power consumers are 16 provinces to the east and inland, such as Guangdong, Beijing, Tianjin and Shanghai. Their total power consumption amounted to 70% of the national total in 2009. The southwest has obtained 67% of its total hydropower potential while the rapidly developed industrial east was faced with severe power shortage. Southwest hydroelectricity is sold to the east and central regions to balance power supply, resource endowment and economic development. Coastal regions with larger power demands can afford to pay higher tariffs for power. Moreover, the coordination of large and small cascade plants can significantly enhance efficiency. It could avoid the negative externality of unsustainable competition in dispersed developments by different enterprises and also produce the large positive externality of comprehensive development and planning, as well as the bonus of a coordinated cascade operation. Therefore, 12th Five Year Plan selected 10 whole-river hydropower development bases. Lancang was one of them, with a planned total capacity of 20,350 MW by 2020. To reduce negative impacts on the environment and society, the development of large-scale plants was restricted and efficiency improved by coordinating multi-cascade plants.

Third, Lancang hydropower facilitated national development strategies. China's Southern Grid (CSG) is the main carrier of the WEET, covering Guangdong, Guangxi, Yunnan, Guizhou and Hainan and supplying electricity to 230 million people. A total of 42% of the CSG power was hydroelectricity from western provinces. A major power consumer of CSG is Guangdong. From 1986 to 2010 Yunnan sent 101.2 billion kWh of electricity to Guangdong. In 2012, with Xiaowan and Nuozhadu in operation, CSG sent 112.7 billion kWh of electricity to Guangdong in 2012 alone. The CSG also produced a large share of power for Hong Kong (25%) and Macau (93%) in 2013. After the Xiaowan project, power from Yunnan transmitted to the outside provinces and countries amounts to 30% of its total power supply. In 2010 Manwan, Dachaoshan, Jinghong and Xiaowan together sent 35 billion kWh electricity to the WEET. Those four plants alone provided a total substitution for 70.62 million tons of coal-fired power, and contributed to emission reductions of 48.02 million tons of CO_2 and 1.41 million tons of SO_2. Yunnan is a major contributor to the CSG in the WEET project. In 2013, the total WEET load from Yunnan was about 61.6 billion kWh. WEET could not function without Lancang hydropower. Coastal regions such as Guangdong would suffer from power shortages, while SEAs would face more severe electrification difficulties. From 1986 to 2010, the CSG transmitted 15 billion kWh electricity to Vietnam. In 2012 alone, CSG transmitted 1.98 billion kWh electricity to Vietnam and in 2013 it sent 3.2 billion kWh. The uneven distribution of resources made long-distance power transmission necessary. UHV made it feasible. The Yunnan–Guangdong 800 kV DC transmission channel greatly enhanced the grid capacity and power supply of the WEET project. The CSG also upgraded each province's power grid capacity to increase its transmission capability.

The developed east has a responsibility to help with western economic development. The GWDS was implemented to drive the western economy by power generation and the mining industry, so they could also benefit from growth and development. Lancang hydropower could narrow the gap between east and west in terms of economic development, infrastructural provision, improving people's quality of life and the overall financing and institutional environment. In 2013 the whole country's power consumption increased by 7%, and that of the western provinces in particular increased by 11%, indicating that the GWDS had started to drive the western economy.

2.1.2. The Local Economy

Lancang hydropower has contributed greatly to Yunnan's development and has served the common interest of local people. Apart from the direct value of power generation and increased local revenue, there are other benefits: it facilitated the restructuring of industry and the coordination of rural and urban development; generating job opportunities and nurturing new technologies.

The Lancang valley is mostly rural, and it is characterized by poverty, its remoteness and its ethnic population. Although it has abundant minerals, bio-resources and hydropower, inadequate transportation and infrastructure and power shortages have jeopardized its development. In the Lancang valley GDP per capita, the annual net income of farmers, fiscal expenditure per capita and infrastructural level are lower than the provincial average of Yunnan and even lower than the Tibetan average, not to mention the national average. Its economic inferiority and ecological fragility are exacerbated by the disadvantages of inefficient agricultural production and a poor ethnic population with a low level of education. In total, 70% of the population is concentrated in the middle range of Lancang, and only 30% live in the 70% drainage areas in the upper and down stretches. The carrying capacity of the area in terms of living standards, fertility rate and production level is generally low. Simao has high population pressure and a low growth rate so their Physical Carrying Capacity (PCC) approached the survival baseline. Only if Simao's GDP can grow by 9% by 2020 with a medium fertility level can the prefecture attain a well-off standard of living. In comparison, Xishuangbanna is much better off with higher growth and less population pressure. Thus, as long as its GDP grows at around 7%, despite different levels of fertility, it still may attain a well-off living standard by 2015

(p. 47, [22]). Therefore, the Lancang valley is trapped by extreme poverty, a fragile eco-environment, a lagging economy and remoteness.

First, hydropower has facilitated the growth of the local economy, particularly that of industrial development. The positive impacts of economic prosperity are clear in Yunnan and Tibet, although they have a different degree of impact on different individuals. Cascade hydropower development greatly alleviated local electricity shortages. After the building of all cascade plants, Changdu (Tibet) will have 29.57 billion kWh newly added electricity per year, while Yunnan will increase its total capacity of 24,145 MW. The on-going national development schemes of the GWDS have generated an accelerated growth in demand for power in the west. In 2011 Yunnan increased its power consumption by 20% compared to 2010 (faster than the national average of 12%). The major uptake was in the mining industries, such as ferrous metal. The GWDS prioritized a hydroelectricity-mining coordinating development model for Yunnan. This model aimed to mobilize mining and smelting industries by providing reliable and affordable hydroelectricity.

Developing green hydropower could facilitate the transformation of the traditional industrial framework and energy structure. The share of renewables amounts to 76% of Yunnan's total power generation because hydropower electricity has replaced 9.9 million tons of coal-fired electricity. Yunnan used to rely on coal to generate electricity for decades because of its model of extensive development and its endowment with adequate coal. Yunnan has the seventh largest reserves of coal in China and over 60% of its total energy production for years was based on coal. However, coalmining was mostly performed by dispersed and small-scale private developers; of which only 10% were considerable in scale. Thus, the average technological level was low and safety was a huge concern, together with the environmental pollution it caused. Under these circumstances, central government established a strategic plan to initiate a new coal-chemical industry for the future development of Yunnan, transforming the coal industry from one that was inefficient and high in pollutants to one that was less pollutant and where utilization was more efficient. However, this transformation could be realized only by turning to hydropower.

Cascade coordination of operations among various power plants along the river started to show its superiority in power generation. As at early 2013, six power plants, including two of the largest coordinating projects, were in operation along the Lancang. Manwan (1670 MW) was built in 1995, Dachaoshan (1350 MW) in 2003, Jinghong (1750 MW) in 2009, Xiaowan (4200 MW) in 2010, Gongguoqiao (900 MW) in 2011 and Nuozhadu (5850 MW of nine generator sets, partially operating with six generator sets now) in 2012. HydroLancang was operating with a total hydropower capacity of 14,283.9 MW by 2013. The largest regulating projects are Rumei, Xiaowan and Nuozhadu (with a total regulating capacity of 23 billion m^3 of water), and the latter two are already in operation. About 36% of the total power supply of the Yunnan Grid comes from HydroLancang, as the largest regional power generator (2012). Regulating the capacity of Xiaowan and Nuozhadu's large reservoirs could create a guaranteed extra 1690 MW power-generating capacity from cascade coordination. Another large planned regulating project (Rumei) would add 1510 MW to the generation of multi-cascade power.

The development of hydropower also motivated other industries to develop, such as those producing construction materials and agricultural products, as well as the transportation and service industry. The long period taken to construct a power plant could provide at least five years of stable demand for concrete. For instance, the construction of Xiaowan consumed about 85% of the supply of four nearby counties—Changning, Nanjian, Yunxian and Fengqing. The Nuozhadu project alone required at least 345,200 tons of rebar and 4.32 million m^3 of concrete. Moreover, the demands of developing new energy, the smart grid, new material, and information-sharing platforms greatly accelerated the development of new industries. Other important impacts were the improvement of land and water transportation routes to increase local accessibility and decrease their transportation costs; the diversion of funds, technology and human resources to the region to nurture a sub-regional market and upgrade industrial structure. Here are two concrete cases of irrigation and shipping.

Cascade hydropower development facilitated irrigation. Altogether 90% of the population of Lancang are farmers, who are mostly dependent on non-intensive and unmechanized primary agriculture for their living. However, 62% of the agricultural land along the Lancang River is dry rain-fed land. In eight counties more than 70% of the farmland in their total land reserve is arid. Reservoirs assist nearby areas through gravity-fed or mechanical irrigation. Because of the V shape of the land there is very little large-scale farmland along the parent river. Only the Lidi and Miaowei projects involved comparatively large farmland that requires diverted irrigation with a matching water supply system. There are 15,062 mu (one mu equals about 667 m^2) of paddy fields and 148,390 mu (one mu equals about 667 m^2) of farmland located downstream of the Lidi project. These farmlands are irrigated by two electricity-powered pump stations—Kangpu and Yezhi. The Lidi project was designed with 145 m^3/s run-off water flow speed, which was higher than the minimum requirement of both stations' water withdrawal level, to maintain an adequate supply of water for irrigating crops. There are also large areas of farmland below the Miaowei project. Although the Lancang River has abundant water, most nearby farmlands still relied on the seasonal variation flow of mountain brooks and rainwater collection. Irrigation is a challenge because of poor water supply facilities, for instance when water needs to be pumped to higher land than the river level. The Miaowei project was designed to guarantee the irrigation needs of 9884 mu (one mu equals about 667 m^2) of farmland in the neighbourhood and a drinking water supply for 6100 people and 12,000 livestock. It was estimated that the Miaowei project could supply 8.496 million m^3 of irrigation water per annum to adjacent farmland. Other hydropower projects also addressed the irrigation needs of nearby farms, but in an unsystematic and small-scale fashion. Besides irrigation, the large reservoirs also facilitated the domestic water supply for towns and cities. Jinghong City used to have two water utilities beside Lancang River. After the construction of the Jinghong hydropower plant its water was drawn directly from the reservoir at an average rate of 150,000 m^3/day. Water supply stabilized and the costs of water was much reduced. These improvements in irrigation and water supply are good examples of serving the local people's common interest, without which life cannot be sustained, as well as making development possible.

Another example is shipping. Shipping used to be difficult because of geological conditions. Cascade plants facilitated shipping by stabilizing river's fluctuating seasonal run-off water volume. The Nuozhadu project constructed a trans-shipment port. The Jinghong project facilitated a vertical ship elevator. The Ganlanba project was designed to regulate the volume of water released from the Jinghong reservoir to maintain stable volumes of water downstream for shipping on the Lancang-Mekong transnational river (Jinghong's daily regulating design would cause short-term water volume fluctuations downstream). The enormous regulating capacity of the Xiaowan and Nuozhadu reservoirs guaranteed a stable volume of water for shipping during the dry seasons. By 2014, the shipping channel between Simao port to the China–Myanmar No. 243 river boundary-tablet was renovated and is ready for the use of 300-ton ships in the high flow seasons (about 6 months/year) and 150-ton ships during the low flow seasons (the Chinese government also sponsored 242 km shipping lane improvements between the Nanla River outlet to Dong Peng). More than 200 ships operated between China, Laos, Myanmar and Thailand. In 2000, the governments of the four countries signed an agreement that shipping would be free of tax along an 818-km shipping channel between Simao and Luang Prabang port. The annual loads of ships importing agricultural products and timber, and exporting fruit, appliances and construction materials between China and Southeast Asia reached 300,000 and 60,000 tons, respectively, between Jinghong and Pu'er port. It is planned to build Jinghong port into a large transportation hub with a 1.5 million person/time passenger carrying capacity and a freight traffic volume of 1 million tons by 2020. Shipping can greatly facilitate Yunnan opening up as a gateway to South and Southeast Asia. Improved shipping conditions also offer trading opportunities in the large Chinese market to downstream countries. Expanding regional communication and trading are undoubtedly in the common interest of local people.

Second, hydropower helps in poverty reduction, local employment and the employability of the local population. A large rural population (83%) in Yunnan is still concentrated in the agricultural sector. Unlike in Sichuan, fewer migrant workers from Yunnan went to coastal cities to find work. There were 7.18 million migrant workers in 2012, 64% of whom were migrants within Yunnan. The service industry, the most likely sector to absorb the labour force, is unable to accommodate such a large migrant population. Tourism offers limited employment opportunities because of the limited carrying capacity of cities. Other service industries such as IT and finance were even less able to offer employment due to their lagging development. The secondary industrial sector employed only 14% of the labour force. A major reason for this uneven employment structure is the slower transformation of industries in Yunnan, compared to other provinces, and also to its lower urbanization rate (27%). Hydropower and related industries had a positive impact on employment. Besides offering direct employment, the advent of hydropower increased employment opportunities in mining, manufacturing, transportation, storage and food. The Nuozhadu construction team employed over 10,000 local people, who received free training to increase their future employability. The low education level of the labour force is a primary cause of their difficulties in finding employment, and increasing employment is the start to break the cycle of poverty. HydroLancang as a national SOE is devoted to improving education and vocational training in the area. Power plants also invested intensively in infrastructure, transportation and urbanization in river basin.

Third, hydropower has increased the revenue of the local governments. Since 2007, HydroLancang's investment in fixed assets exceeded 8% of the total in Yunnan. By 2012 the total investment along the Lancang River reached 110 billion Yuan, generating a huge fiscal contribution of 16.883 billion Yuan in taxation, 1.2 billion Yuan in water usage fees and 1 billion Yuan in funds for reservoir maintenance. From 2003 to 2010, Dachaoshan, Jinghong and Xiaowan projects all together paid 4.266 billion Yuan in taxes and other charges. Manwan alone contributed about two billion Yuan in taxes and 510 million Yuan in an infrastructure and education surtax since it began operating in 1993 (to 2006). Before the Xiaowan project was introduced to Nanjian and Fengqing, those two poverty-stricken counties had an annual fiscal revenue of only 40 million Yuan. After Xiaowan started construction, their fiscal revenue rapidly to about 100 million Yuan, of which annual taxes of 70 million Yuan were directly paid to the two counties. This huge fiscal contribution greatly improved the local capacity for public expenditure, and hence more public goods and infrastructure could be provided. Local governments in poorer areas face a larger fiscal deficit, as the central fiscal transfer payment is totally inadequate. Hydropower in Yunnan provided effective fiscal revenue for local governments, particularly county governments, who shouldered most of the burden of providing public goods. Therefore, the development of hydropower indirectly facilitated the provision of public goods in the area.

Finally, hydropower facilitated rural development and rural–urban coordination. The Coordination of rural–urban development included building power grid and improving electrification in rural areas. After 10th and 11th Five Year Plan, the rural–urban power grid has developed substantially. However, an increased supply of power and a better transmission grid are required because of rapid urbanization. Upgrading the rural power grid could greatly improve local irrigation via electric pumping systems, permit the building of green house units and the processing of tobacco and tea. In most rural areas, the main framework is built on a 110 kV grid with a limited central network of 220 kV lines, such as Changdu in Tibet. By 2015, power supply in the rural area has reached just under 100% of all households. Thus, rural grid upgrading became a developmental priority.

As for rural electrification, the specific transfer payment from central government targeting the rural power infrastructure is distributed from provincial to county government and then to villages. This is to the avoid misuse of capital arising from too much involvement by the multilevel local governments. Furthermore, medium and small scale hydropower copes well in the mountainous topography and dispersed rural population along the Lancang. Other renewables such as solar power and biomass may also improve the rural power supply. Unlike in the flat Lancang downstream area, while the Lancang upstream areas suffer mainly from landslides. Thus, promoting electricity as a substitute for firewood could encourage people to stop cutting trees, and thereby mitigate soil and water erosion. Currently, rural power is still mainly supported by straw, firewood and biogas (more than 20% of energy supply). Substituting straw and firewood fuel with hydropower, solar power and biogas is necessary to improve energy efficiency and reduce environmental damage. Competent rural governance is the key to China's success and that of the Lancang valley. Facilitating rural development addresses the common interest because of the large rural population and their inferior standard of living. Promoting a clean and green energy model for the rural population has a profound significance in the building of a sustainable future.

Hydropower plays an important role in China and Yunnan, serving the national common interest of efficient and equal development, local common interest of poverty alleviation and capability development, and also enhancing global common interest of reducing greenhouse emission and mitigating climate change. The Cascade hydropower development has governed the of water and electricity commons via efficient coordination. Conflict and competition would have exceeded cooperation and coordination if Lancang hydropower had been developed by different private competitors or large multinationals, because they do not embrace the overall situation of sustainability.

At the macro-level, hydropower facilitated the rapid improvement in the national economy within the challenging transitional development model. It also helped with adjustments to the energy structure according to new manifestations of supply and demand. The Chinese huge economy requires an enormous supply of power, and this has a fundamental influence on the global economy, the energy structure and climate change. Thus, as a national strategic energy plan served both the national and the global common interest. Due to China's vast territory and the great disparities among regions in their resource endowment and economic development, the regional coordination of power supply is in accordance with the national common interest. Moreover, Lancang hydropower also assisted the national development strategies of the WEET and the GWDS. It is not only a matter of electricity supply and economic development, but also one of efficiency and equality, and the overall situation.

Lancang hydropower also accelerated various aspects of local development. Cascade hydropower development reduced the local shortage of electricity and facilitated the local economy, particularly in terms of industrial development. The new hydropower-based industries in mining and smelting transformed the traditional industrial framework and energy structure. Cascade coordination showed its superiority over uncoordinated development. The development of hydropower also motivated other relevant local industries such as concrete and steel manufacturing, to release their excess capability. The cascade plants facilitated irrigation by providing a water supply system and electricity for pumping. Alongside hydropower development, Lancang-Mekong shipping developed and further facilitated local trading and economic integration with South and Southeast Asia. Moreover, hydropower helped in the reduction of local poverty and unemployment by increasing the employability and education of the local population. Hydropower developers constantly invested in the education and training of the local villagers, and in terms of fulfilling their mandate of their corporate social responsibility. Indirectly, hydropower contributed large fiscal revenue to the local governments, thus enhancing their public expenditure capability, which in turn improved the provision of education. In addition, as hydropower was mostly developed in the remote rural mountains, it contributed both infrastructure and power to rural development and accelerated urbanization and rural–urban coordination. Several cities such as Jinghong and Baoshan developed clusters of urbanized towns and small cities. Urbanization itself further facilitated the service industry by creating more job opportunities.

Development is not the question: the real question is how to develop in a sustainable manner. Lancang valley is populated by various ethnic groups with an inferior economic status and a poor standard of living, together with a lack of development opportunities. It is unrealistic to aim for the conservation of prosperity without growth. Development in the river basin is urgent and necessary. Hydropower development is an interesting case because it not only involves the governance of water but also of the energy supply, and is closely connected to the global commons in its capacity to mitigate climate change. Multilayered conflicts of interest among different stakeholders and within and among the generations made the seemingly simple common interest of sustainable development difficult to obtain. Nevertheless, hydropower continuously serves as the second-best choice for filling the power gap in China and reducing carbon emission, given its affordability, reliability, availability and sustainability. Anticipating a dramatic breakthrough that will lead to abandoning the use of traditional fossil fuel in the near future is unrealistic, while other clean energies are less promising than previously hoped.

2.2. Environment and the Ecosystem

One major concern over the development of hydropower is its negative environmental impact. The Lancang River 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 inevitably impact on nature. The crux is to minimize such impacts to a sustainable level for future generations, via sophisticated planning, coordination and remedies. The common interest should ensure inter-generational and intra-generational sustainability, but this also presents development needs. After all, the gigantic Chinese population does not justify depriving anyone of their right to survive and develop, and "the intrinsic worth of each Chinese person is equal to that of an American or European" [23]. Thus, serving the common interest needs to address the development needs of the local people and together with the requirements to attain the sustainable development of humans and nature.

The EIA carried out revealed the impacts of the project on the river system, while the ECM investigated the monitoring and management of the river system, as well as suggesting technical support for specific environmental and ecological remedies. The overall objective was to develop hydropower projects selectively, avoiding ecological problem areas and vulnerable zones to balance the river system and the biodiversity of river basin. However, it is extremely difficult to do, and it is almost impossible to incorporate economic consideration and ecological concerns, local benefits and the common interest as well as dynamic efficiency, and inter-generational and intra-generational equity into a development plan. More practical thinking to balance competing interests and settle for second best, seeks to minimize negative environmental impacts to an affordable level (carrying capacity) for in undertaking the necessary development and to apply remedies where possible.

2.2.1. Environmental Impact Assessment (EIA)

The EIA of the Lancang River's whole river hydropower development was accomplished by HydroChina. (HydroChina Corporation, formerly known as the Administration of Water Resources and Hydropower Planning and Design, acting as a government administrative agency responsible for engineering and construction of the water resources and hydropower projects nationwide, with a history of more than 50 years, was established in December 2002 with the approval of China's State Council (from its website). It is the only professional corporation throughout whole China that provides technical consultancy services for hydropower and wind power.) The study 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 analysing 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 project) until 2030 (estimated development completion).

Two major components of EIA study include the water system and the eco-environment. The water system study includes water quality, temperature, hydraulic studies, sedimentation and water usage. The Eco-environment study 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.

Long before the hydropower development the Lancang valley was known to have environmental problems. 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 fragile. The Hengduan 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, moisture 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. Lancang River is comparatively better off because it does not have many industries in the river basin and agriculture is dispersed along the banks of the river [20]. The Lancang catchment's mountainous geographical conditions determined that there are very few farmland and industries along the riverbanks. This is further hindered by the engineering difficulty of water supply both for drinking and irrigation, and the risks of seasonal floods. Therefore, most communities locate 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-village Enterprises) were falling behind, and agriculture was 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 in the upstream region is the centre 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. Yunnan has more industries than Tibet. 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 development 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 riverbank 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 (one mu equals about 667 m^2) of farmland in the river basin and the annual pesticides 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 about 541,600 ton of nitrogen/phosphorus pollutants. The Tibetan area is underpopulated so domestic pollution is insignificant. Yunnan, for its part, has more than 10 million people living in the river valley. However, 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 the years, wastewater discharge in the river basin has risen by an annual average increment of 5.9 million tons. The good news is 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. Although 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 enormous conflicts 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 the 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 favourable 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 for to develop similar unsustainable mass tourism since Yunnan became popular as a tourist destination.

Each project has distinctive conservation priorities. The Rumei project is located close to the Mangkang snub-nose monkey nature reserve, so its priority is to preserve the habitat of these beautiful creatures by keeping tourists at bay. The Jinghong and Ganlanba projects have prioritized the conservation of the tropical rainforest and the corresponding preservation of biodiversity. Altogether, 75 rare plant species are concentrated downstream of the Nuozhadu project and 78 precious animals live south of the Xiaowan project. Thus, their priorities differ accordingly.

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 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 release 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. Because dams slow down the flow of the river, the fish migrated either to the upper stretches of Lancang or to nearby tributaries. Their concentration made them more vulnerable to human activities, such as fishing and netting. Fish that live inside of the reservoir prospered but there was a tendency 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 and Xiaowan. Impacts on the terrestrial ecosystem were small.

From the EIA analysis, we can conclude that the *water system* and *aquaculture* are two of the areas mostly affected by the introduction of hydropower. There are also other impacts and pre-development environmental issues. The whole-river cascade development has limited large-scale projects to minimize their impact, and projects were selected to balance development 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.

2.2.2. Ecological Compensation Mechanism (ECM)

Hydropower development cannot avoid having negative impacts on the environment and eco-system. The ECM is intended to mitigate these negative impacts. The main components of ECM are water system remedy, aquatic and terrestrial ecosystem compensation, monitoring and information sharing, and whole river management. Those components are built up of many concrete measures.

For example, all power plants are built with an automatic system to monitor the ecological development of the river system. Both industrial wastewater and domestic sewage water from all power plants are reclaimed and processed for reuse, and solid waste is collected and transported to the landfill. The Nuozhadu reservoir built a selective water withdrawal structure. The non-economical Ganlanba project is designed to regulate water volume against the Jinghong reservoir. Most projects adopted wet processing to reduce dust and greening projects along roads to purify the air. The Gongguoqiao project planted 45,000 trees along the Huajiuzhou road in 2011. Labelling rare plants to protect them is also effective. The Nuozhadu project constructed a rare plant garden in 2008. Its wild animal rescue centre was built in 2009. A comprehensive centre to introduce knowledge about biodiversity, wild animals and plants was constructed. Some projects set up fish protection zones to forbid fishing and netting and to prevent alien fish species spreading in the river. The Gongguoqiao project built a fish breeding plant and hatchery in 2010. Nuozhadu's fish hatchery was introduced in the same year. Introducing clean energy facilities in resettled towns and living quarters of hydropower projects was a standard practice. The Dachaoshan project included a biogas unit and domestic solid waste collection in resettled towns.

All projects along the Lancang (constructed and planned) took into account the issue of fish migration. Remedial measures included building 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. Providing man-made flood peaks is one method of catering to the spawning needs of fish in the downstream of the reservoirs. The discharge of water in the cascade plants initiated by people may produce artificial flood peaks during fish spawning seasons, as in the Ganlanba project, for instance. Because 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 the fish were able to spawn. Additionally, Ganlanba is also able to create artificial flood peaks to meet the fish spawning needs. The Protection of the tributaries that have substantial fish populations is also important. For example, the Yongchun River is first-grade tributary of the Lancang River. Schizothorax species like to live in the Yongchun River because it has rapid torrents. All existing power plants across the Yongchun were therefore demolished to maintain the habitat for these fish. Projects such as Cege, Yuelong and Ganlanba were designed with passages for fish. Projects such as Rumei were supplied with a fish hoist because of their narrow river valleys. Projects such as Gushui and Dahuaqiao were built with fish transportation facilities. Seven fish reproduction stations have been planned with cascade projects. The Ganlanba fish reproduction station is a joint project undertaking in collaboration by HydroLancang and the Xishuangbanna aquaculture bureau. One major obstacle of ECM is the lack of professionalism and expertise. Reproduction of fish and artificial assistance to fish passing through the dams both require high-level expertise on each fish species. Any mistake might result in damage to the fish and hence threat the species.

In addition to protecting fish, the ECM performs other functions. Land and forest areas occupied during the construction of the dams paid compensation and restored. To restore the local ecology requires the careful nurturing of indigenous species, taking the complete local food chain into consideration. Thus, 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 is 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 reafforestation in situ. The downstream regions have the best natural conditions so the best choice here is to protect and replant trees on the site.

Controlling the invasion of alien species, both animal and plant is also crucial. Wildlife rescue is important. The wildlife rescue centre 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. The wild animal rescue centre is built within Baima snow mountain national park in the middle stretch. The downstream rescue centre is located in Xishuangbanna, aiming to protect the Asian elephant, the wild bull and other tropical animals. Other ecological compensation schemes include building a wildlife corridor connecting animals on both riverbanks and establishing an endangered plant garden.

Dynamic monitoring of flagship and endangered species is one way in which the regional eco-system is managed. Comprehensive coordination is important, and the ECM intends to set up a permanent eco-system monitoring and renewal institute along the whole Lancang-Mekong river basin, with a corresponding eco-system foundation jointly held by all stakeholders. Currently, the environmental monitoring system in China addresses ten different aspects: water temperature, water quality, TDG (total dissolved gas), water pollution, local climate, aquatic and terrestrial ecosystems, water soil maintenance, resettled communities and geological disasters. There are 16 hydraulic monitoring stations along the Lancang River that collect dynamic data on water temperature and quality. TDG is an important indicator in large dam projects, because water released from a large dam generates higher levels of TDG, which then cause gas bubble disease and sometimes even death, in fish. TDG monitoring is carried out every year between June to September (currently in five monitoring stations) to prevent oversaturation. Aquatic ecosystem monitoring takes place along the parent river and its tributaries to add to existing information on the fish and their habitats. Remote sensing monitoring technology is used for the terrestrial ecosystem and water soil conservation monitoring, combined with regular in-field investigations. Resettled communities are included in the monitoring system for the purpose of disease control and follow-up of human activities.

The current monitoring system is still under development, and in the future three sub-regional centres at Rumei, Xiaowan and Nuozhadu will be established to coordinate all the projects' monitoring stations (each project of which has an environment and ecosystem monitoring capability) and those of the professional institutes such as the hydraulic stations and the geological disaster monitoring bureau. The objective is to produce a digitalized online monitoring system to cover the whole Lancang basin. This system can also share information with downstream MRC countries. The "digital Lancang" concept has been proposed by HydroLancang to apply comprehensive, high-end technologies such as remote sensing, satellite surveillance, GIS, GPS, the Internet, and computerized modelling to monitor the Lancang valley and to build up an overall database for the environment and ecosystem. Digital Lancang phase-I was accomplished by June 2014. Upon completion of the project, Digital Lancang would be a sub-system of China Digital Hydropower, but still operates independently of it.

Manwan is a prime example of the effects of ecological compensation schemes, which it has been implementing for 20 years ever since the construction of the dam. According to the data from downstream hydrometric stations, the water run-off change but this was statistically insignificant, from -20 to 26 m^3/s. About 14% of sediment was held back by the reservoir. The water temperature change was insignificant (1.0–1.6 °C). No eutrophication was found in the water quality test but Cyanophyta (blue-green algae) significantly after the construction of the power plant. The 52 fish species discovered in 1984 pro-project are still all present, but their distribution pattern has changed greatly. The reservoir reduced rapids and fast-flowing water and nurtured a large amount of nutritious plankton, so more slow-water fish flourished and the rapid-water fish migrated upstream. The aboriginal coniferous forests flourished (increasing by about 140 km^2 until 2009) because the dispersed villages were removed from the site. The total had forest coverage increased by 9% after the ECM, mitigating water soil erosion. However, the newly reclaimed farmland for the resettled farmers contributed about 0.8% toward annual water soil erosion.

There are 11 rare reptile animal species living in the region, mainly snakes, and their living environment has not been disturbed. However, there have been impacts on birds, since the reservoir flooded parts of their habitat and the ECM could not provide as many habitats as there originally were so their habitats shrank.

Both before and after hydropower development natural disasters have been common in the Lancang valley. These are mostly landslides, floods and droughts. Because of uneven distribution of rainfall between upstream and downstream, 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 locating 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 flatland basin. Flood damage to upstream regions is further reduced because of the small population there.

Instead, the real threat comes from the frequent landslides and mudslides triggered by heavy rainstorms. Water soil erosion and subsequent landslides are major concerns. Deforestation in the surrounding mountains worsens the situation. Because of arable land shortage, local farmers have no choice but to reclaim mountain slopes and burn down forests to expand the available farmland. Landslides kill people, ruin farmland and block roads. Water soil erosion and landslides further damage land fertility and large amounts of soil enter the river, speeding up sedimentation (such as the Yellow River). The estimated water soil erosion area along Lancang River in Yunnan territory was 25,800 km^2, which amounts to 29% of the total catchment area, of which 320 km^2 was intensively eroded. Over the years, intensive ecological remedies have been applied to the region and a strict ban on logging was implemented in the river basin but the result was unsatisfactory. Compared to 1987, the water soil erosion area has decreased, but the intensity has actually increased. Therefore, the preservation of forests and the prevention of water soil erosion are still priorities. Furthermore, landslides have aggregated rocky desertification, which finally damaged water lifeline along with severe deforestation. Landslides became more frequent and destructive because of the unlimited and unplanned logging, mining, and the burning of vegetation for land reclamation. However, blaming the local people is not helpful, because most people still depend on primary agriculture due to the lack of other livelihood opportunities in the area.

To produce enough food, the local people have to reclaim the mountains and even the slopes for farming. However, irrigating this land is a huge challenge. It is ironic that there are water shortages in Yunnan because it is one of the most abundant regions for water in China. However, the shortage is not of water itself but of irrigation technology. A Mountainous topography results in higher land dominating the water source. This creates great difficulty in transporting water to the farmland, and it is uneconomic even if it is feasible. Furthermore, it is impossible to build a water supply network that covers all areas due to the sparsely distributed population and the high mountains in the region.

Another extreme natural disaster in the area is drought. Due to the climate change and other causes, there is an "increasing concurrent drought events" that occurred in China challenging China's water management and grand water diversion project [24]. Under such general context, both Yunnan and the other southwest provinces have already suffered from severe water shortage (engineering shortage) during normal regular times, not to mention the dry seasons. The Xiaowan reservoir alone released 840 million m^3 water during the severe drought of 2010, greatly easing the impact of the drought downstream. Facilitated by cascade regulation, downstream river run-off reached 504 m^3/s in Jinghong during the dry seasons in recent years, which was 49% higher than usual. In summary, as a result of its natural endowment of abundant water and rich rainfall frequent floods have occurred in downstream areas of Lancang, while the reclamation of forestlands has aggravated water soil erosion, repeatedly resulting in devastating landslides. The severe shortage of land and water has prompted the local people to engage in further deforestation, which has triggered even more severe droughts. Poverty and natural disasters repeated strike the region and people, and they reinforce and exacerbate each other. This leaves us with the contradictory picture in which farmers in extreme poverty struggle to live in a place with such superabundant 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.

ECM aims to remedy 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 grounds 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.

2.2.3. Effects of Multi-Cascade Plants

Lancang hydropower development aims at the development of the whole river via comprehensive planning and the use of cascade plants. Thus, a specific study was carried out by HydroChina to investigate the effects of the cascade plants. Hydraulic data and information were collected from Changdu, Liutongjiang, Jiuzhou, Gajiu and Yunjinghong national hydraulic monitoring stations (this research mainly studied the Rumei (Tibet, annual regulation), Guxue (Yunnan-Tibet junction, daily regulation), Gushui (Yunnan-Tibet junction, seasonal regulation), Gongguoqiao (Yunnan, daily regulation), Xiaowan (Yunnan, multi-year regulation), Nuozhadu (Yunnan, multi-year regulation), Ganlanba (Yunnan, counter-regulation) and Mengsong (close to the borderline, run-off-river) projects), covering the river course from Tibet to where it leaves Yunnan in the south. The study is mainly based on 2009 data, with information tracing back to 1972 and predictions to 2030, and comparisons of non-development natural conditions and the situation with respect to cascade plants in years of high, median and low flows, respectively.

After all the cascade plants have been built, the river basin water area will increase hugely, but the V shape valley pattern will remain. There will be another 675.2 km^2 of additional water area on top of the original 129.8 km^2 natural watercourses, as estimated (if the 23 cascade plants are all built). As the two largest reservoirs on the river Xiaowan and Nuozhadu contribute 67% of the new water area. Before the construction of the cascade plants, the loss of water surface are by evaporation decreased from as it flowed downstream in the natural watercourse. The river run-off increased rapidly along with the expansion of the water surface from June to October (high flow season) and concentrated in the downstream stretch during the low flow season (November–May). After the cascade plants begin operation, the expansion of water surface area will increase water evaporation, although the power plant and its operation do not themselves consume water. If all the proposed cascade projects are built, there will be an annual loss through evaporation of 358 million m^3 of water along the whole river, which is approximately 0.56% of total annual run-off of the Lancang River. Thus, the impact of these projects on river run-off is insignificant.

The biggest change is that the timing has changed because of the cascade regulation system. The Upstream plants with a smaller water flow will regulate a limited volume of water run-off, but the downstream plants will have a much larger impact because of the two largest regulating reservoirs (Xiaowan and Nuozhadu). Those two plants regulate water volume over the year, which means water run-off is controlled during years of high flow and released in years of low flow. Thus, the general impact of the cascade plants on river run-off is the regulation of the levels between high and low flow years. As estimated, after all cascade plants are in operation, water run-off will increase by 40–101% during the low flow season (dry season, November–May) and decrease by 10–29% during the high flow season (rainy season, June–October). In Nuozhadu, for instance, the change in water release (compared to the natural watercourse) in a high flow year is -119 m^3/s, in a median flow year (normal year) it is -6 m^3/s and in a low flow year is +209 m^3/s.

Additionally, river flow speed is another factor that will be greatly altered by cascade plants. The speed of flow of the river between the cascade plants will hardly change at all, compared with the natural watercourse, but the flow speed in the reservoirs will change greatly. For instance, large reservoirs such as Xiaowan and Nuozhadu have slowed down the river flow to an average speed of 0.02 m/s. However, other projects such as Ganlanba would still maintain average flow speed of 0.4 m/s in their reservoirs. This is because the dams block the river flow and thus slow down the flow speed, also because of the controlled regulation of water volume by the cascade plants.

The sedimentation of the Lancang River has the most positive correlation of the features measured with respect to water volume. Projects with large reservoirs have significant impact on holding sediment. The Rumei project could decrease sediment by 7.53 million tons, which amounts to 47% of the total sediment in the natural watercourse. Daily-regulated projects such as Gongguoqiao have a negligible influence over sedimentation. Upstream plants' sedimentation control will greatly decrease the sediment flowing into downstream plants. Sedimentation will also change if all cascade plants are functioning. The Annual sediment deposited in the natural watercourse was about 120.14 million tons up to where the Lancang River flows away from China and enters Laos and Myanmar, with a sediment concentration of 1.84 kg/m^3. After all cascade plants are in operation, the estimated annual sediment will be reduced to 17.51 million tons and the sediment concentration ratio will be reduced to 0.27 kg/m^3. Furthermore, the Lancang River located within the mountains, so its riverbed is mostly bedrock. Water erosion effects on the riverbed and riverbank are limited.

The cascade plants have an impact on aquaculture and the ecology. The power plants regulated daily will change the water volume and flow speed downstream, and thus influence fish spawning in those stretches. This is particularly true of the Gushui-Lidi stretch and Ganlanba stretch, where most concentrated fish spawning sites are located, so water control and release have to take its impact on fish spawning into consideration.

Moreover, blocking the river course will obstruct fish migration. Long-distance migratory fish species are rare in the Lancang River. There are still stretches of Natural river courses between the power plants that are a suitable habitat for short-distance migratory fish. However, the completion of all cascade plants will have a negative impact on fish biodiversity. Because the dams cut the river into sections, crossbreeding between different fish will be difficult, and as the time goes by, small groups might lose their genetic diversity.

Another concern is the blockage of fish migration from the Mekong River downstream. There are many more fish species downstream compared to upstream. There were only 186 fish species living in the upstream stretch (from the riverhead to near Lanping, but they migrate down to Manwan), but downstream the species exceed 600 (from Lanping to Mekong, but they migrate up to Gongguoqiao). The Ganlanba project will block the Mekong fish migrating upstream, and hence damage fish biodiversity. These projects are designed as run-off river plants to minimize impacts on fish migration. In general, two fish zones (the upstream cold water fish and the downstream warm water fish) will remain after the construction of the cascade plants because their zoning boundaries are distinctive. The biggest change will occur in the transition stretch between Xiaowan and Gongguoqiao, where the trend would for each zone to recede in opposite directions. Fish migration and crossbreeding within the zone will be maintained, but fish migration and habitat in the transition stretch might be influenced and thus would be moved to more suitable habitats in other stretches of the river. Most fish in the transition stretch are short-distance migratory fish so they may still accomplish their life cycle within a comparatively short stretch of the river. However, the shrinking of their spawning sites has a huge impact on fish and the cascade plants will flood a large part of their original spawning sites.

Although the extinction of any fish species is highly unlikely, the cascade projects will still greatly alter the distribution pattern and size of each fish species. Repeated investigations over the years have confirmed that this pattern of change is likely. Repeated EIAs on fish and other animal and plant species along the Lancang River and the impacts of cascade plants on the environment and biodiversity have been carried out by various scientific institutes, including the Yangtze River Fisheries Research Institute, Chinese Academy of Fishery sciences, the Kunming Institute of Zoology, Chinese Academy of Sciences, the Institute of Hydro-Ecology MWR & CAS, Huazhong Agricultural University, Yunnan University and the Yunnan Academy of Natural Sciences intensively in the 1990s and 2000s (from 1984 to the present). On-going fieldwork research is carried out almost every year to have time-based data on species biodiversity and environment changes. The fish species will not decrease but their distribution and habitat patterns will change significantly. On the other hand, the cascade plants provide a better environment for hatcheries and overwintering, with a wider and deeper water environment and a rich supply of plankton.

As for animals and plants, the most important natural reserves are the snub-nose monkey habitat near Rumei, three-parallel rivers region near Guishui, and tropical rainforests and Asian elephant habitat in Jinghong. There are 36 natural conservation zones in the Lancang valley, of which nine are national. Guxue, Bangduo, Baita, Xiaowan and Jinghong will flood a portion of the land belonging to the nature reserves. The largest influence may be that of the Guxue project, which will flood part of the core (0.29%) and buffer zones (0.03%) of the national snub-nose monkey nature reserve. The Xiaowan project has flooded part of the buffer zone (3%) of the Jinguang temple provincial nature reserve and 143 hm^2 of the buffer zone (13%) of the Weishan mountain provincial Qinghua Green Peacock nature reserve. The Jinghong project has flooded the largest area a nature reserve, 825.69 hm^2 (0.34%) of the Xishuangbanna national nature reserve (mostly, the buffer zone and part of the boundaries of the core zone). The bio-system of whole river basin is complicated, as it covers 13 latitudes, ranging from an altitude of 477 to 6740 m. From north to south, the river basin includes a plateau temperate zone, a north subtropical zone, a central subtropical zone, a south subtropical zone and a tropical north-fringe zone. As estimated, there are about 75 rare plant species, mostly in the area with 2000 and below altitude (river basin beyond of Huangdeng project). Rare animal species living in national nature reserves are scarcely affected by the cascade plants. Take the Asian elephant as an example. About 236 elephants live in Xishuangbanna, mainly in the Xishuangbanna nature reserve and in sub-regional reserves such as Mengyang, Shangyong and Mengla. The direct impact of cascade plants on the elephant population is the flooding of their habitat. The estimated flooded area of the rainforests and bamboo forests amounts to 4% of the total area. However, the rubber tree plantations in Xishuangbanna are a more serious threat. Many natural rainforests were reclaimed for rubber tree planting because of their high return. This has placed significant pressure on the Asian elephant habitat, as well as the environment and ecology. Rubber plantations were introduced into Xishuangbanna in 1948. The state promoted large-scale state-owned rubber plantations in 1950s and 1960s. The rubber plantations grew rapidly in the 1990s, particularly around 1998. Until 1998, rubber production amounts to 27% of Xishuangbanna's GDP. However, they eroded tropical rainforests and triggered water soil erosion. The natural forest coverage was reduced from 70% to 13% in the 1990s. The plantations threated the habitat of the Asian elephant, and because rubber trees consume large amounts of water, water soil erosion worsened in the region. The situation became so severe that the government started to realize that the development of rubber plantations was unsustainable and hence implemented a series of policies to restrict them.

The impact of the cascade plants on the downstream Mekong River is also a hotly debated topic. As a review study indicated, "the current literature and observational data suggest that" the damming of the mainstream Lancang-Mekong River has "only had small unfavorable effects on downstream environments and ecosystems outside of China" (p. 77, [5]). The Water supply to the Lancang River relies mainly on rainfall, replenished by melting snow and ice and underground water. The Mekong stretch is also mainly supplied by rainfall, supplemented by underground water. The annual mean run-off in upstream Changdu, Tibet is 482 m^3/s, rising to 2058 m^3/s along the China-Myanmar river boundary, and reaching up to 4397 m^3/s in Vientiane, Laos. When it flows into Kratie, Cambodia the annual mean run-off rises 14,000 m^3/s. Take Guanlei, located on China-Myanmar border as an example. The run-off of the natural watercourse was 3576 m^3/s in the high season and 974 m^3/s in the low flow season. After the cascade plants are in operation, the figures will change to 2639 m^3/s in the rainy season (−26%) and 1626 m^3/s in the dry season (+67%). The change in the volume of the annual average run-off is −0.49%. As the river flows downward, the impact decreases. The variation in run-off will be reduced to −12% in the high flow season and +34% in low flow season at the Vientiane hydraulic monitoring station, with an annual rate of change of −0.23%. The large reservoirs at Xiaowan and Nuozhadu will greatly reduce risks of floods between June and September for downstream countries. According to the data collected at Chiang Saen in Thailand, sedimentation will be greatly reduced after the operation of the cascade plants, amounting to an 80% reduction compared with the natural watercourse. However, the largest impact is upon the river stretches between Guanlei, China and Luang Prabang, Laos. This is because the downstream stretches beyond Luang Prabang have low levels of sedimentation compared with the upstream stretches (based on a comparison of the sediment composition of Guanlei and Luang Prabang). The downstream, long-distance migratory fish swim upward to Mengsong area in the rainy season, so their migration route extends far beyond the last cascade plant—Ganlanba. Therefore, the impact of the dam on those fish species is limited. However, because of the large run-off alteration in high flow seasons, downstream fish spawning will be influenced. However, correspondingly, when the run-off increases greatly in the dry seasons the fish downstream will have a larger and better overwintering water habitat. Nevertheless, the general impact is not significant because the total run-off of the Lancang River only contributes to 13% of the Mekong River's total run-off.

Cascade development brings multiplied benefits and also has chain impacts, as illustrated in aspects of hydraulic situation, sedimentation, fish, animal and plants, and the downstream stretches of the Mekong. The key to overcome those impacts is comprehensive management and cascade coordination, besides ECM.

Essential measures to reduce environmental impacts and maintain ecological balance are strict project control using EIAs, continuous and effective ECM and the overall coordinated management of the cascade plants. Some of the environmental problems described here are common in hydropower development, such as fish migration. We cannot deny there are negative impacts of hydropower development along the Lancang, which include those of the natural water situation, the fragmentation of the river course and fish migration. It is exceptionally important to take remedial ecological measures to mitigate these negative impacts.

As a transnational river the Lancang River has to develop within a framework of transnational coordination because of whole river development impacts on downstream countries. China has coordinated with GMS, ASEAN, MRC and each involved countries to negotiate potential conflicts. Transnational conflicts of interest plus the "threat" of China have led to some exaggerated condemnations of the Lancang hydropower development. Some have even ascribed all environmental and ecological changes in the river to the development of hydropower, while others are concerned that China's control over such a major watercourse might threaten the security of downstream countries. These claims have hindered transnational cooperation along the Lancang-Mekong and may not be helpful for serving the common interest of the people living in the region. Moreover, there are complex geopolitics at lager scale in the region, not only among Southeast Asian countries, but also between "China's new-found assertiveness" and the United States' regional security concern, which determined subtle relationship of energy and power along the Mekong [25]. The Mekong geopolitics reflects global geopolitical changes, and the logics to understand this shard river's development process continue to be geopolitical [26].

3. Conclusions

The hydropower debate presents the conflict between development and conservation. The ultimate goal of conservation is for future, sustainable development (according to the Brundtland Commission, "sustainable development" is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]), so it really is a conflict between present and future generations. Few people would argue for the extremes—complete conservation without any development or complete development without limits. The proper balance of the development-conservation spectrum is project-specific. Each project has different socioeconomic impacts and gives rise to different environmental concerns, so pre-project evaluation is crucial. Ignoring the negative impacts of development for a quick return is irresponsible. Ignoring their positive benefits is also reckless. It is a fantasy that humans can survive without influencing nature. Sustainable development entails the application of a people-oriented principle in human–nature relations. The ultimate goal of both the development and the conservation camp is to benefit people. The real conflict surrounds the question how. Development and conservation should not confront each other, but partners cooperating to achieve sustainable development for all.

Human development required the consumption of natural resources. Current consumption-oriented development is disturbing, because it leads to rising shortfalls in energy, urgent environmental concerns and climate change, together with an unsustainable model of industrialization and economic troubles. Modern industrialization is probably the most unsustainable form of development, based as it is on the exploitation of limited non-renewable resources. Thus, environmentalists have proposed that "less is more" together with the "relative decoupling" of ecological exploitation and economic growth to slow down the pace of resource utilization [27]. They believe that upgrading technology and improving resource governance is able to realize such "relative decoupling".

However, the notion of "prosperity without opulence" is a castle in the air. Jackson's bold proposal to decouple prosperity from economic growth is more of an ethical ideal than a feasible action to improve the lot of the poor. It is not a rational solution. This is particularly true of the "bottom billion" plan [28]. As controversial as the notion that "growth is good for the poor" is the idea that abandoning economic growth could help the poor to jump out of the "poverty trap" [29]. "Economic growth is and continues to be important, indeed, morally necessary if individuals and society care about improving the living standards of peoples around the world" [30].

Secondly, Jackson's proposal to change profoundly the social logic of the "iron cage" of consumerism is more appropriate for developed than undeveloped countries. The goal of poor people in developing world is to meet their basic needs for survival rather than greed and materialism. How can one expect people who live in extreme poverty to give up the goal of economic growth and consumption? However, developed countries could offer a sustainable role model of consumption and lifestyle to economies that are catching up.

Thirdly, humans have a tremendous capability to adjust to their environment. Innovation is the best tool for mitigating the conflict between people and nature, but it is not the only tool. Institutions and policies could be designed to modify lifestyles and social values to keep development from running off the rail. Achieving long-term goals via short or medium-term policies is difficult, so strategic planning is critical. *Laissez-faire* might be an effective tool for short-term growth but it is incapable of achieving long-term sustainability and prosperity.

Condemnations of rising energy consumption and environmental pressure concentrated on large emerging economies such as Brazil, India and China. Their fast-paced economic expansion, industrialization and urbanization are already worrying, not to mention their rapid population growth. Jackson says that it is the reckless developing countries that held back the process of "global resource intensities" decline and their economic growth is the reason that "resource efficiency is going in the wrong direction" [27]. The fact is that China has to feed 19% of the world's population (1.344 billion) with 20% of the world's total supply of primary energy, while the USA, for comparison, is home to 5% of world's population (312.04 million), but consumes 17% of the world's energy, with a total primary energy supply or population ratio that is $3\frac{1}{2}$ higher than China (2011 data) [31]. If China develops in the American way, their gigantic population would consume 80% of the world's energy.

Although the use of new technologies and policies could improve the situation, there is no evidence that they can entirely eliminate resource constraints. With their own cumulative processes of over-exploitation and pollution, developed countries should be more responsible. Environmental concerns were overlooked when high-income countries were developing, and their dominant advantages over colonies diminished their own need to restrict their consumption of energy. This development model, if applied to all countries, would be catastrophic. Thus, developed countries should shoulder more responsibility for environmental and climate disasters and cooperate with developing world towards a bright future, because "kicking away the ladder" [32] is no longer an option.

Ironically, the revenge of nature is disproportionately borne by the world's poorest and least developed countries. The fact is that, the less developed a country is, the more pollution it receives as a result of the unequal international division of labour in globalization. A "sustainable future" is much less likely to be found in the developing world. This is not only because the poorest and most vulnerable people shoulder a disproportionate share of the costs of environmental damage, but also because they cannot achieve sustainable development even if they change their lifestyles. Countries are in different phases of development with a different endowment of natural resources. Countries such as China, India and Russia could be blamed for compromising global "absolute decoupling" even if they completely give up their own economic development. Their huge populations require large amounts of resources to sustain them. For developing countries, it is time to reflect upon their model of growth and explore a new development path, because the world has changed profoundly and the neoliberal path that was used to facilitate growth in the developed economies is no longer feasible. Alongside the tides of globalization, cooperation beyond political boundaries has become exceptionally important. Nevertheless, "our global society will flourish or perish according to our ability to find common ground across the world on a set of shared objectives and on the practical means to achieve them" [29].

In this paper, two major aspects of the development of hydropower along the Lancang River in Yunnan were described: powering the economy at both macro and local levels; versus the environment and the ecosystem. It painted a holistic picture of water governance in the region. From its positive impacts on the macro-economy to local and regional development, from its negative impacts on the environment and their remedy, resettlement conflicts among local community, developer, government and NGOs to the overall social impacts, from HydroLancang's social positioning to concrete CSRs, all these facts and figures show how complicated and difficult it is to cooperate for sustainable common interest. There are many stakeholders involved in Lancang hydropower. The Chinese system of vertical control by the authorities and horizontal cooperation among different parties offers each agent a high degree of flexibility, while strict macro-level control is practiced over the whole. Such dynamic processes aim to serve the common interest via constant interaction, coordination, negotiation and compromise. However, the Lancang case also revealed some problems, such as SOEs corporate governance, special interest groups, and the rural governance of grassroots organizations. All of these problems damage trust and hinder communication between the state and the people, and hence compromise the realization of the common interest.

The mysterious and beautiful valley of Shangri-La described by James Hilton in Lost Horizon, is Yunnan. This tranquil wonderland is indeed covered with matchless natural beauty and exotic cultures. However, being isolated in the mountains and trapped in extreme poverty, Yunnan is far beyond its fictitious meaning of paradise. Conservation, to some extend reflects a form of hegemonic "governmentality" [33,34] and imperatives of colonial and postcolonial tendency to "protect" nature in such underdeveloped world [35]. There have been other studies on the Lancang River from different perspectives. For instance Brian Tilt applied a moral economy analysis of the power contests along the Lancang by illustrating the roles of different actors, including the government, the SOE, NGOs and the local people [6]. It is common for hydropower development in China to be viewed as a power confrontation between the authoritarian state and those who are to be 'developed', as James Scott phrases it—"the unjust and oppressive social orders with high-modernist social engineering" versus the "evolving mētis of the people" [36]. However, excessive emphasis on a top-down or bottom-up dichotomy does not really help to serve the common interest of the people, instead it rather makes the people and state relationship even more hostile and confrontational. In addition, to clearly position the state in Chinese society is difficult because the state is everywhere and the system covers all aspects of life, such as the HydroLancang or villagers' committee. The state is such a complex entity that its internal divisions and agencies are as much dynamic and impenetrable as the local communities, which have received far more attention. Treating the state as an endogenous factor rather than a discrete entity is more sensible under China's circumstances.

A fundamental difficulty of human cooperation is to identify the common interest. Not all stakeholders have a clear awareness of the common interest and their own respective interest. Communication is the key to help people obtain a better awareness of the common good. The communication between the state and its manifestations and the people should be positive and dynamic, especially on grand development projects such as hydropower to "create a good social atmosphere" [10]. The Lancang case offers the primary challenge of building a healthy communication platform among stakeholders, not only in China, but also across the world. Civil society is the carrier for communication (not necessarily superior and effective) in the West. In China, the state-local apparatus is a similar platform. However, trust between the state and the people is damaged by corruption scandals and rising social inequality. Problematic communication further erodes trust between the state and the people. Genuine anti-dam movements are not anti-development but an attempt to fight against inequality and injustice. The state stands in the teeth of the storm because people accuse it of empowering special interest groups, who not only block communication channels but also tarnish the good name of development projects. Special interest groups twisted roots and gnarled branches throughout the power structure. Today, special interest groups have replaced ideological disputes and become major obstacles to reform and development. Therefore, structural adjustment of vested interests is unavoidable.

Corruption in large SOEs is particularly destructive to development projects such as hydropower and infrastructure. SOEs manage public assets which belong to all the people, so the profits should be returned to the people and society. Recent corruption scandals involving CNPC, the three-gorge project and the CRC have eroded people's trust in the state. Complex affairs between government and SOEs provide room for eroding special interest groups. Additionally, convincing people to cooperate for the long-term common good is already difficult because of the complexity and scientific professionalism needed in large projects. Corruption scandals confused people even further and make it more difficult for them to accept those projects. People have no idea whether a project is truly beneficial to their common interest or whether they just are being deceived to give greedy managers opportunities to pursue their self-interest.

The Chinese government is determined to clear out those eroding forces. The Internet has played a tremendous role in the process. Information sharing and discussions over virtual platforms have helped to combat corruption. The determination of central government to combat corruption in recent high-profile cases has instilled confidence in people. More people chose to report corruption using their real names on a virtual platform provided by the Central Commission for Discipline Inspection of the CPC (the CCDI). The CCDI aims to expose corruption and defend the legitimacy of government and the governing party, thus earning the people's trust. However, it is difficult for local CDIs to work effectively because of their independence from the governmental system. Local CDI establishment have almost doubled recently to reinforce their power. However, the overlapping assignment of CDI and government posts sometime even leads to the use of fake corruption charges to attack political enemies. Thus, a central inspection group and a specific inspection group have been established to randomly check possible corruption to deter government officials and managers of SOEs. At a higher level, the CCDI also faced with various queries over dependency. However, it is more useful to understand government's determination rather than becoming entangled with questions of dependency, because no political institution is completely independent. Besides dependency, the source of the power and authority of CCDI needs to be clarified, particularly in high-profile cases. Additionally, SOE corruption is mostly hidden in sophisticated economic and financial frauds. Thus, anti-corruption projects also require a high level of expertise. Ongoing and future reforms of the transparency and accountability of CDI (Commission for Discipline Inspection) at all levels are important, as are general reforms of the political system and governance by law. Such a comprehensive task requires gradual institutional adjustments and great determination. However, it is the key to rebuilding people's trust, which then determines effective communication and eventually the common good of all.

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