WATER GOVERNANCE FOR SUSTAINABLE DEVELOPMENT IN MEKONG RIVER BASIN

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

IRRIGATION WATER MANAGEMENT

by

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JUNE, 2019

CANDIDATE'S DECLARATION

I hereby declare that the work being presented in this final thesis report titled "**Water Governance for Sustainable Development in Mekong River Basin**" is presented on behalf of partial fulfillment of the requirement for the award of the degree of **Master of Technology** with specialization in **Irrigation Water Management** and submitted to the **Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology Roorkee, India.** This is an authentic record work carried out under the supervision and guidance of **Dr. M.L. Kansal**, Professor and Head, WRD&M, IIT Roorkee (India).

The matter presented in this thesis report has not been submitted by me for the award of any other degree.

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ACKNOWLEDGEMENT

On the submission of my final thesis report, I would like to extend my deep sense of gratitude and sincere thanks to my guide **Dr. M.L. Kansal**, Professor & Head Department of Water Resources Development and Management, IIT Roorkee, for his constant encouragement and valuable guidance throughout the course of present work, without which I could not have successfully completed this work.

I would like to thank the following Professors of Department of Water Resources Development and Management; Dr. S.K. Mishra, Dr. Deepak Khare, Dr. Ashish Pandey, Dr. T.R. Chelliah, Dr. R.D Singh, for their useful materials and Lectures.

I would also like to thank Dr. Venkataramana Sridhar, Associate Professor, Department of Biological Systems Engineering, Virginia Tech for providing the data related to this work. The data received from him really helped me for the smooth completion of this work.

Furthermore, I am greatly indebted to the Ministry for Foreign Affairs Government of India through ITEC/SCAAP Program and the Government of United Republic of Tanzania which made the necessary assistance for the course of study at IIT Roorkee.

I would also like to thank my Late Mother, Aimbora Paulo Kimaro, my father, Mr. Erasto Kilonge Mwanga, my wife, Odilia Juma, my son Elvis Elibariki Mwanga, my brothers, my friends and staffs for their inspiration and encouragement in bringing out this final thesis report.

Date……………… **(ELIBARIKI E. MWANGA)**

ABSTRACT

Water governance for sustainable development in transboundary river basins is complex due to each riparian state to have different levels of social, political and economic. That means each country differ in levels of wealth, job opportunities, climate change, deforestation, decreased wetland, environmental degradation, business regulation, law enforcement and political freedom, etc. The Mekong River, which flows through countries of China, Myanmar, Laos, Thailand, Cambodia and Vietnam have challenges related to its stream flows from upstream to downstream. Keep in mind that the increasing water demand which results from increasing population and human economic activities calls for the development and management of waters of transboundary. Therefore, there is a need to develop and manage the water resources by adopting and implementing Integrated Water Resources Management & Development Plans (IWRMD). The plans will ensure the assessments of water resources and water demand, reviews of the institutional and legal framework, and implementation of strategy and/or action plans. The present of economic activities support organizations like Mekong River Commission (MRC), ASEAN and Greater Mekong Sub-Region Program (GMS) is a good indicator of achieving sustainable development in Mekong Basin (MB). However, this study applied the use of Water Evaluation and Allocation Program (WEAP) in analysing of water supply and demand in Mekong Basin (MB). The use of the WEAP model ensured equal allocation of water for different demand such as domestic water demand, industry water demand, agriculture water demand, and allowing minimum environment flow requirement. Furthermore, WEAP enable the authorities to decide on current and future water uses and the requirements by various sectors; help to resolve myriad conflicts amongst countries. The results obtained from the WEAP model in this study shows there is an increase of requirement of water in the near future for all simulated scenarios of water demand in the Mekong basin. Generally, the study observed a few things which need to be done in the basin to ensure sustainable development. Firstly, the Mekong River Commission needs to be reformed and re-constructed by including China and Myanmar as members of the MRC. Secondly, strengthen the cooperation and exchange of information among riparian states. Finally, hydropower development projects and its consequences should be assessed under involvement of all Mekong Basin riparian states and consultant agencies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1. INTRODUCTION

Chapter overview

This chapter briefly about the background of the study, identified research gap, causes of changing flow pattern in Mekong River and importance to conduct scenarios analysis of supply and demand. Furthermore, it enlists the study objectives such as to understand the hydropolitics international river basins. At the end of the chapter, there is a short description of the report structure.

1.1 Background of the Study

Water governance relates to the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society (Rogers and Hall 2003).

Water within a basin serves human needs such as drinking, cooking, washing and sanitation; allows arid land to become productive through irrigation; provides a habitat for plants, fish, and wildlife; supplies urban and industrial uses; generates electricity through hydropower; and supports many recreational uses (Loucks et al., 2005).

Since the setup of civilization, mankind has faced problems associated with the river and freshwater sharing. To add on to the precarious situation most of the freshwater rivers are transboundary Rivers i.e they cross at least one political border, either a border within a nation or an international boundary. According to the Transboundary Freshwater Dispute Database (TFDD), the World consists of 263 international transboundary river basins which cover more than 45 percent of the land surface on the Earth (Loucks et al. 2005)

There are 263 Transboundary Lake and river basins which cover nearly half of the earth's land surface. These basins expurgate through 145 nations contributing to their socio-economic and regional development. There are 13 basins worldwide that are shared between 5 and 8 riparian nations. The river that flows through the most nations is the Danube in Europe, which travels within the territory of 18 nations (UN "Water for Life" 2011).

Transboundary water resources often create borders between states e.g. the Mekong between Cambodia and Vietnam, the Yalu between North Korea and China, the Indus between Bangladesh and India. The water resource sharing requires trust and cooperation among riparian states. The Aral Sea shows a case where transboundary water resource management can cause conflicts and end with severe environmental degradation. The problems of managing trans-boundary water resources include scarcity, maldistribution, sharing, overutilization and misuse (Kliot et al., 2001).

The Mekong River is 12^{th} largest River in the World with the largest River basin in Southeast Asia. The River flows millions of years ago and plays a vital role in moving the economy of the riparian state. The river encompasses six riparian countries: China, Myanmar, Vietnam, Cambodia, Lao PDR and Thailand. Among these six riparian states, China and Myanmar are in the upper reaches and the remain riparian states are in lower reaches.

The present study makes an attempt to highlight the complexities of water governance in the Mekong River Basin. It highlights the geography, understands the regional, political, economic and environmental setting in the basin. It further highlights the issues of sustainable development and briefly describes the opportunities to better utilize the available resources with an underlying philosophy of mutual co-operation, goodwill and friendship.

1.2 Research Gap

1. The world has about 286 number of transboundary rivers and water sharing in these rivers has resulted in complex social, economic and environmental situations and hence the hydro-politics.

2. To date, no scenarios analysis of water resources (supply) and demand conducted using WEAP model to future use planning for the waters of transboundary rivers such as the Mekong

3. The flow pattern in Mekong River is changing due to rapid and unrestricted development of large hydropower dams in Mekong River Basin.

4. This has resulted in conflicts related to water allocation, water uses, quality, social and environmental issues among China, Myanmar, Thailand, Lao PDR, Cambodia & Vietnam.

1.3 Problem Statement

Mekong River is a trans-boundary river which plays a vital role to the development of riparian states: the People's Republic of China, the union of Myanmar, democratic republic of Laos, the kingdom of Thailand, Cambodia and the social republic of Viet Nam that are within Mekong River Basin. The water of the river is used for food, energy and environmental nexus. Also, the water of the river is used for other uses such as irrigation to sustain livelihoods.

There are constructed, under-construction and planned water resource projects such as dams, river diversions, inter-basin transfers, thirsty cities and irrigation expansion in the basin. Some of these projects are of benefits while others are subject to disputes and protests.

The Mekong River basin is currently undergoing extensive hydropower development. The underlying drivers of the hydropower development are linked to the demographics, human development, water and food security, economic integration and climate change in the region. Hydropower development will also have adverse impacts on the region's ecosystems, social systems and livelihoods. The devastating developments within Mekong River such as rapid and unrestricted development of large hydropower dams are changing the flow pattern to downstream. The changing flow pattern in Mekong River has resulted in reshaping the societies and has added further pressure on natural resources on a regional basis, this will lead to conflict between riparian States, civil unrest within riparian States, and violence within communities of Burma, Cambodia, Laos, Thailand, Vietnam and Tibet. Due to the above-mentioned problems, there is a need to conduct a study analysis on water resources to enable basin authorizes to better water use planning to the river waters in Mekong Basin.

Due to the above-mentioned problems, there is an importance to conduct a study of scenarios analysis of water resources (supply) and demands so as to evaluate past trends in stream-flows and simulate different scenarios for current demand, this will help the riparian states/basin authorities in planning for future water use and avoid conflicts in the Mekong basin.

1.4 Objectives of the Study

1. To know about various transboundary river systems.
2. To understand the hydropolitics of a few international river basins.
3. To understand the various doctrines for water conflict resolution.
4. To create and analyzing scenarios of water supply and demand using Water Evaluation and Planning model (WEAP)

The study will provide a rational basis for evaluation of various options with a minimum scope of subjectivity and can be practically applied to a real river basin. Moreover, the use of the WEAP model provides the outputs of the unmet demands in the basin. Furthermore, the study will underlie the philosophy of mutual co-operation, goodwill, friendship and reduce conflicts within the Mekong River Basin.

1.5 Organization of the Dissertation

This Study is organized into seven chapters as stated below;

- Chapter One covers the overview of the study, water governance issues, problem statement, objectives of the study and the research gap.
- Chapter Two discusses the literature review which includes philosophy of various trans-boundary water treaties, hydropolitics of the international river basin of the World, theoretical framework model formulation for water sharing in order to resolve conflicts.
- Chapter Three describe in detail the study area. It shows the various salient features of the Mekong River Basin.
- Chapter Four deals with the Methodology and Model Formulation.
- Chapter Five highlights Results of the water sharing model and allowing the Discussions.
- Chapter Six Cover Conclusions and Recommendations.
- Chapter Seven enlist all References.

CHAPTER TWO

2. LITERATURE REVIEW

Chapter overview

This chapter defines the hydropolitics of few transboundary river basins, reviews the principles applied to the uses and allocation of the waters of international rivers. Further, discuss the principals of some trans-boundary water treaties and thereafter governance issues of Mekong Basin. Finally, the literature review in this chapter summarizes published papers, journals and books that highlighting the geography, political, economic, environment, and sustainable development in river basins.

2.1 Register of Transboundary River Basins in the World

From 1978 to 2016, the Transboundary River Basins (TRB) has been updated from 214 to 286 respectively. This information is according to several sources as; 214 transboundary basins recognized by UNDESA (1978), 261 recognized by Oregon State University (1999), 276 recognized by OSU (2012). The new register has two hundred and eighty-six (286) TRB. Ten (10) river basins were explained in Table 2.1a, and other basins were given as an appendix (Table 2.1b).

Table 2.1a: *Description of Ten Trans-Boundary River Basins*
(Source: UN (2011); A.T Wolf et al. (1999); Ntem, B. and Melvin, L. (2016))

No.	Basin Name	Area of the Basin (sq.km)	Continent	Number of Countries within the River Basin
1.	Danube	779,500	Europe	Austria, Czech, Bulgaria, Albania, Bosnia and Herzegovina, Switzerland, Italy, Germany, Moldova, Croatia, Hungary, Yugoslav, Montenegro, Serbia, Poland, Ukraine, Romania, Slovenia and Slovakia
2.	Alsek	8,300	N. America	USA and Canada

No.	Basin Name	Area of the Basin (sq.km)	Continent	Number of Countries within the River Basin
3.	Rhine	195,000	Europe	Germany, Belgium, Switzerland, Austria, France, Liechtenstein, Italy, Luxembourg and Netherlands
4.	Mississippi	3,226,300	S. America	USA and Canada
5.	Congo/Zaire	3,699,100	Africa	Burundi, Cameroon, Angola, Central African Republic, Gabon, Rwanda, Congo, South Sudan, Tanzania, Malawi, Sudan, Uganda, Zambia and DR Congo
6.	Nile	3,038,100	Africa	Central Africa, Burundi, Egypt, Eritrea, South Sudan, Ethiopia, Hala'ib triangle, Kenya, Sudan, Abyei, Rwanda, Tanzania, DR Congo and Uganda
7.	Zambezi	1,388,200	Africa	Angola, Mozambique, Malawi, Botswana, Namibia, Zambia, Tanzania, DR Congo and Zimbabwe
8.	Indus	1,086,000	Asia	China, India, Afghanistan, Aksai Chin, Pakistan, Nepal, Jammu and Kashmir
9.	Mekong	795,000	Asia	China, Myanmar, Laos, Thailand, Cambodia, and Viet Nam
10.	Ob	2,734,800	Asia	China, Kazakhstan, Mongolia, Russian Federation

2.2 Principles of Transboundary Water Sharing

Generally, the principles which are the major legal instruments for the uses and allocation of the Waters of International Rivers developed under the support of the United Nations. The principles obtained from the three most known documents namely; Helsinki Rules on the Uses of the Water of International Rivers as adopted by the International Law Association in 1966, Helsinki Convention on the protection, use of transboundary watercourses and International Lakes as prepared in 1992 and UN Convention on the law of the non navigational uses of international watercourses as putted in writing in 1997.The principles are discussed below:

2.2.1 The principle of International Waters

The UN Convention on the Law defined some terms to describe the concepts of international water. Examples, "watercourse" means a system of surface and groundwater constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus. "International watercourse" means a watercourse, parts of which are situated in different States. "Watercourse State" means a state party to the present Convention in whose territory part of an international watercourse is situated or a Party that is a regional economic integration organization, in the territory of one or more of whose Member States part of an international watercourse is situated. "Regional economic integration organization" means an organization constituted by sovereign States of a given region, to which its member States have transferred competence in respect of matters governed by this Convention and which has been duly authorized in accordance with its internal procedures, to sign, ratify, accept, approve or accede to it.

2.2.2 The principle of Reasonable and Equitable Utilization

The principle gives a mandate to all watercourse states regarding their territories utilize an international watercourse in an equitable and reasonable mode. According to the Helsinki Rules and UN Convention, an international watercourse shall be used and developed by watercourse States in a manner to achieve optimal and sustainable utilization of these water resources. The principle has no limit to require riparian states to share equally in the uses and benefits of an international watercourse system. All riparian states shall participate in the use, development, and protection of an international watercourse in an equitable and reasonable manner. Such participation includes both the right to utilize the watercourse and the duty to cooperate in the protection and development thereof, as provided in the present Convention. Examples of river basins or treaties which adopted this principle are such as Mekong River Basin (as indicated in Mekong document in articles 5 to 8 and 26), Indus Water Treaty, etc.

2.2.3 The Obligation not to Cause Significant Harm

The UN Convention and general interpretation of customary international water law require riparian states to take all appropriate measures to prevent the causing of significant harm to other watercourse states. This Harm may occur due to several factors or actions such as impounding water that is already utilized downstream, water pollution, increasing flood peaks and interfering with the stability of the aquatic ecosystem. When occurred that the harm being caused by any state, the state that caused the harm will be responsible to take all appropriate measures, as stated under the provisions of articles 5 and 6, in consultation with the affected state, to eliminate or mitigate such harm and if possible to discuss the matter of compensation. A good example of the adaptation of this principle is seen at Mekong Water Treaty.

2.2.4 The principle of Notification and Negotiations on Planned Measure

Many treaties contain provisions for the creation of implementing organizations. Example, the Mekong River Commission adopting rules of intercourse that directly or indirectly call for an outline to declare the differences among the riparian states. The UN Convention has procedural which can assist watercourse states in maintaining an equitable balance between their respective uses of an international watercourse by helping to avoid disputes and providing a context for negotiations if harmful effects are inevitable. Some procedures are weak for planned projects in one state which may affect other watercourse states. Watercourse states have a responsibility to provide each other with information concerning the possible effects of planned measures.

2.2.5 Duty to Cooperate

According to the UN Convention, the establishment of joint management mechanisms among the riparian states is not required though in another hand it can be established under some circumstance and get encouraged by the UN. International river basins cooperate in many ways and several treaties have been created to support various organizational mechanisms. Also, the UN Convention requires the exchange of available data such as hydrological, meteorological, hydrogeological, ecological nature and forecasts. The exchange of data will facilitate mutual co-operation, goodwill, and friendship. Example, it is the same international normal and treaty law that the Lower Mekong riparian made negotiation and started the process of drafting a new Mekong agreement in February 1992, and successes to form Mekong Agreement in 1995. Also, the principle of duty to cooperate was adopted by the Indus Water Treaty.

2.3 Principals of Trans-boundary Water Treaties

2.3.1 Indus Waters Treaty (IWT)

The IWT is the treaty between two countries namely India and Pakistan signed in Karachi on 1960 by then Prime Minister of India Pandit Jawaharlal Nehru and then President of Pakistan Ayub Khan. This occurred after a long time of about 8 years of mediating the contentious Indus basin dispute made by the World Bank. The drainage area of Indus River is 966,000 km^2 and a length of 2,900 km (Qureshi 2011). According to Qureshi (2011) publication paper, soon after the IWT, Pakistan was allowed exclusive use of 3 western rivers (Indus, Jhelum, and Chenab), and India was entitled to 3 eastern rivers (Ravi, Sutlej, and Beas). During the water allocation among these two countries, the mean flow of the “eastern” river and “western” river was 33 MAF and 136 MAF respectively. According to Silas (2018) the Pakistan’s rivers receive more water flow from India, thus the treaty limited uses of western rivers by India in several uses such as for Irrigation, and unrestricted for power generation, domestic, industrial and non-consumptive uses (navigation, floating of property, fish culture, etc.), also the treaty lay down precise regulations for India to build projects. To avoid India cut off the water inflows of the Indus basin rivers which in turn could create droughts and famines in Pakistan, the treaty considers the declaration that gave out the objectives that recognizing rights and obligations of each country in settlement of water use from the Indus river system with an underlying philosophy of mutual co-operation, goodwill, and friendship. Furthermore, in cooperation, the treaty adopted 3 international watercourse principles which are equitable utilization, duty to cooperate, and watercourse joint management. IWT is one of the most successful water sharing treaty in the world, it requires some updating in certain technical specifications, to expand the scope of document by adding the issues of climate change, provisions in the treaty can provide India and Pakistan to use the water carried by the Indus rivers system by 20% and 80% respectively (Silas 2018).

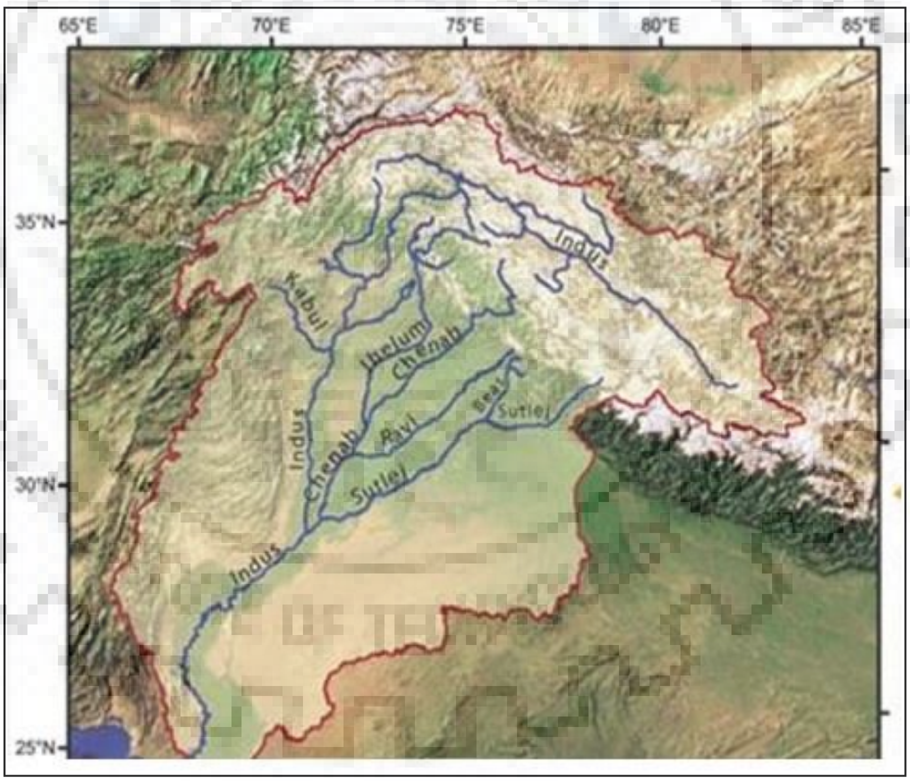

Figure 2.1: *Map of the Indus River Basin.*

Source: Bahadur et al. (2011)

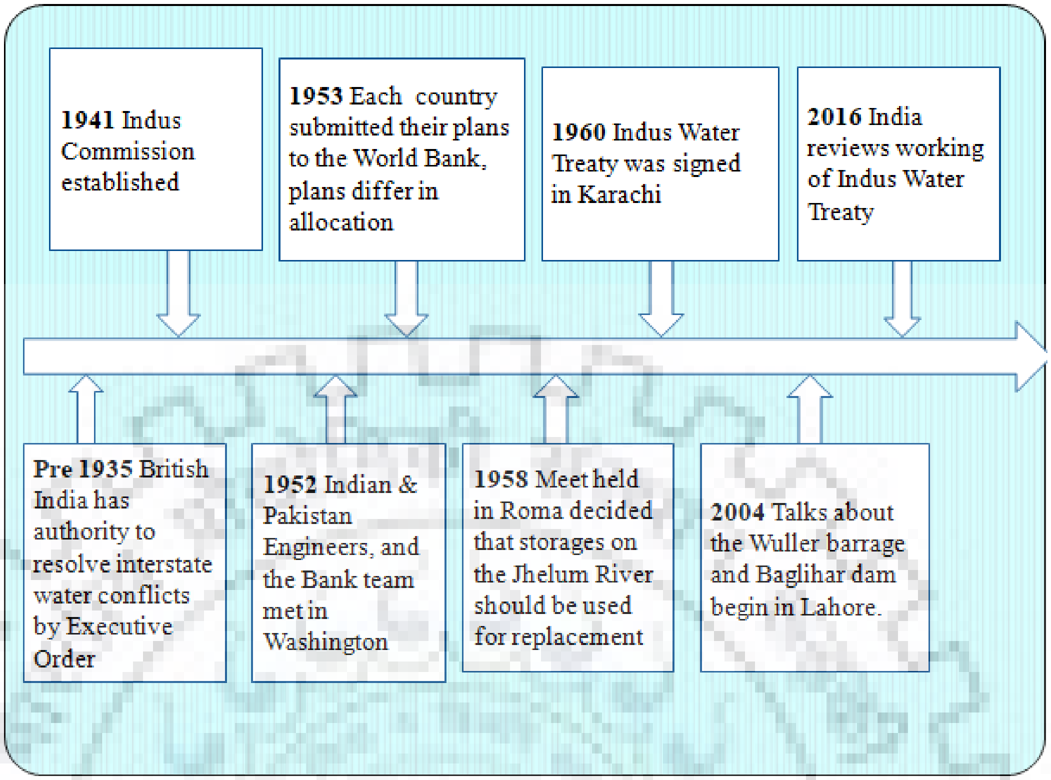

Figure 2.2: *Historical Timeline of IWT.*

(Source: Biswas et al. (1992), Wolf and Newton (2004))

2.3.2 Nile Water Treaty

The Nile Basin is divided into sub-basins having two known major tributaries which are White Nile and the Blue Nile. The total area of the basin is approximately to be 3,112,000 km^2, the number of 10 countries (Sudan, Ethiopia, Egypt, Uganda, Tanzania, Kenya, Eritrea, DR Congo, Rwanda and Burundi) have their territories within the basin (McKinney 2011). According to 2016 revised register of river basins system, there is additional of 4 countries that shared the Nile river (total shared countries to be 14) that are Abyei, South Sudan, Central African Republic, and Hala'ib. The development of the Nile River has a long history centuries back. During the period of the early 20th Century, the development of the river in upstream areas came to threaten the downstream water resources system and this development touched Egypt state direct and Sudan on the other hand. Both Egypt and Sudan states dominate the Nile River resources for decades over other riparian states.

2.3.2.1 The Treaties on the Nile Basin

Anglo-Italian Protocal (1891)

Two parties namely Great Britain and Italy signed the treaty. Apart from other articles, article III of this treaty refers to the Nile water: "the Italian government engages not to construct on the Atbara River, in view of irrigation, any work which might sensibly modify its flow into the Nile" (McKinney 2011). The Atbara River has important meaning to Britain because it flows through Sudan and Egypt (Zewdie 1976).

Great Britain and Ethiopia (1902)

The treaty was all about the establishment of the border between Ethiopia and Sudan. The issues of Nile waters was considered in article III of this treaty. The different authors tried to show how the King of Ethiopia involved in the protection of the Nile. The King not constructed or allowed any construction of the work across the Blue Nile, Lake Tana, or the Sobat that feared to arrest the flow of their waters, any construction issues should focus on agreement with His Britannic Majesty's government and the government of Sudan (McKinney 2011; Okidi 1994; Tilahun 1979).

Tripartite Treaty (1906)

This treaty was entered by Britain, France and Italy. Blue Nile waters were discussed in article 4 of this treaty. The treaty denied Ethiopia state over Nile water resource (Zewdie, 1976).

Nile Waters Agreement between Egypt and Sudan (1959)

The mentioned treaty "Nile Waters Agreement" signed due to the historical background of Egypt to planning construction of Aswan High Dam. The desire of Egypt to construct this dam started in the 1950s. Soon after the military takeover in Sudan in 1958, the door of negotiations with Egypt opened. The signed treaty takes consideration of Aswan High Dam, that assuming the annual mean flow of this dam to be 84 billion m^3. This resulted in the allocation of Nile flow water where the allocation to Egypt was 55.5 billion m^3 and that of Sudan was 18.5 billion m^3. This allocation can be taken as a percentage, that is to say, Sudan awarded 22% while Egypt got 66% of the total river flow

Figure 2.3: *Map of the Nile River Basin.*

Source: (Nile and Issue 2017).

On the other hand, if there will be any claim from any riparian state (s) within the Nile river systems, the Sudan and Egypt will sit together and view that claims. Moreover, if there will be a possibility of allocating a Nile waters the two Republics (Sudan and Egypt) will share an equal amount by deducting from their existing shares to get the claimed amount.

Tecconile (later NBI) 1992-2001

The Technical Cooperation Committee for the Promotion of Development and Environment Protection of the Nile Basin is known as ***Tecconile.*** This Technical Cooperation Committee started with only six member states namely Sudan, Egypt, Rwanda, Uganda, Tanzania and Zaire. Als, there were observer states which were Ethiopia, Kenya, Eritrea and Burundi. Waterbury (2002) said that the Nile Basin Initiative (NBI) replaced the Tecconile in1999.

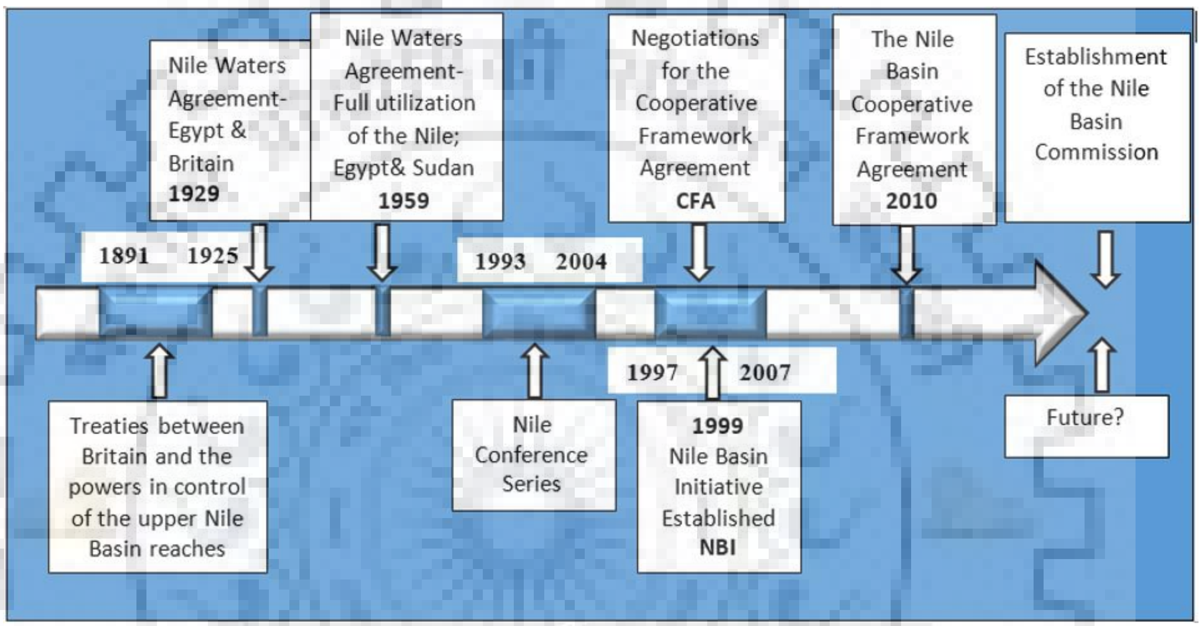

Figure 2.4: *Historical Timeline of Nile Basin Treaties.*

Source: Kansal and Silas (2018).

2.3.3 Danube River Case Study

The Danube River which is Europe's second longest river with a length of 2,845 km rises in the Black Forest in Germany and empties into the Black Sea in Romania and Ukraine (Silas 2018; Rai 2014). The river shared by twenty countries which are Albania, Austria, Bulgaria, Bosnia and Herzegovina Switzerland, Czech Republic, Germany, Croatia, Hungary, Italy, Moldova, Republic of the former Yugoslav, Republic of Macedonia, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia and Ukraine. According to McKinney (2011), the river used for transportation of commerce and military operations for about 2,000 years. The historical agreements and treaties emphasise on flood control, hydropower, and protection of river quality with the aided of an integrated, basin-wide framework (Rai, 2014). The river is of importance for hydropower generation, drinking water, provide habitat for wildlife and recreational activities.

In most cases, the Cold War and the advent of authoritarian regimes in Europe during a period of the the 1930s weakened the liberal interpretation of the principle of freedom of navigation. The practice of the 1948 Convention Regarding the Regime of Navigation on the Danube restricted the freedom of navigation to those vessels that navigated on the river while carrying the flags of the riparian states of Eastern Europe. On the other hand, after the Cold War ended, those restrictions also came to the end, thus recognized the right to navigate and benefit all ships of the riparian states (Silas 2018).

Figure 2.5: *Danube River.*

Source: Wikipedia (2019).

2.3.4 The Cauvery River Dispute

The dispute of Cauvery River has a long history; it involves two states of Karnataka (previous known as the Princely State of Mysore) and Tamil Nadu (previous known as Madras Presidency). The basin states had a task of secure water for control flooding and irrigating agricultural farms in the Cauvery river basin. Several measures were applied to resolve the conflicts emerging in the basin focuses on us of Cauvery River due to increasing the water demand for Irrigation. Furthermore, on reducing of water tension two dams were constructed on the Cauvery river, one dam in Mysore (Krishnarajasaga dam) and another dam in Madras Presidency (Mettur dam). Additionally, small dams were constructed on Cauvery river tributaries for the same reason of supply water to fulfil the demand in the basin. The short description of the Cauvery river dispute timeline is given in Table 2.2 of this study.

Table 2.2: *Cauvery River Dispute Timeline*
(Source: Silas (2018); Sood (2012))

<table>
<tr><th>Karnataka Basin State</th><th>Tamil Nadu Basin State</th><th>Kerala Basin State</th><th>Puducherry Basin State</th></tr>
<tr><td colspan="4">➢ The sharing of waters of the Cauvery River has been the source of a serious conflict between the two states of Tamil Nadu and Karnataka.
➢ The genesis of this conflict rests in two agreements in 1892 and 1924 between the erstwhile Madras Presidency and Kingdom of Mysore.
➢ The total length of the Cauvery River is 802 km (498 mi).</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Basin Area=32,000 km^2</td><td>Basin Area=44,000 km^2</td><td></td><td></td></tr>
<tr><td>Inflow (From)=425 tmcft</td><td>Inflow (From)=252 tmcft</td><td></td><td></td></tr>
<tr><td></td><td>Agriculture Area used = 3,000,000 acres (12,000 km^2)</td><td></td><td></td></tr>
<tr><td colspan="4">UN Conversion Principles used:

1. Watercourse agreements (Article 3) of the UN Conversion used by Supreme Court (SP) to rejected Karnataka’s plea on Cauvery Waters Disputes Tribunal of 2007 and declared the colonial agreements signed between Karnataka and Tamil Nadu in 1892 and 1924 are valid.
2. Equitable and reasonable utilization and participation principle (Article 5) of the UN Conversion used by SP to allocated the Cauvery water.</td></tr>
<tr><td colspan="4">In 1972, the Centre agreed to appoint a committee to collect statistics from each of the states that had the river basin — Kerala, Tamil Nadu and Karnataka.</td></tr>
<tr><td>177 tmcft of water used</td><td>566 tmcft of water used</td><td></td><td></td></tr>
</table>

Karnataka Basin State	Tamil Nadu Basin State	Kerala Basin State	Puducherry Basin State
Cauvery Waters Disputes Tribunal of 2007			
270 tmcft of water allocated annually	419 tmcft of water allocated annually	30 tmcft of water allocated annually	7 tmcft of water allocated annually
16 February 2018 Verdict (Binding for 15 years) -States refused to accept the tribunal verdict			
284.75 tmcft of water allocated annually	404.25 tmcft of water allocated annually	30 tmcft of water allocated annually	7 tmcft of water allocated annually

NB. TMC or tmcft= thousand million cubic feet

2.4 Mekong River Basin Governance Issues

Most transboundary river systems lack effective organizations and institutions to develop and manage water resources. The Mekong Basin has a vast land favourable to agriculture and water resources and has huge forest areas which can change the lives of people living within and outside the basin. The Mekong basin countries have different basin management plans due to complex challenges ranging from economic, social, cultural, environmental and political. Campbell (2016) defined clearly the dimensions of the new MRC indicator framework as the dimensions of the economic, social, environment, climate change and cooperation. Some of these issues are discussed as follows:

Economic Issues

Several activities such as agricultural, fishing, and hydropower generation are being conducted in the Mekong Basin. These activities increase the income of individual people and also raise the entire economy of all countries. MRC (2010) gave out how the production of rice from the basin feed up around 300 million people per year by irrigating only 12,500 schemes. More than 70% of people in the basin depend on agriculture that makes them earn more money by exporting their crops, improving livelihoods and raising standards of living (FAO 2011). The cultivated land in the Mekong Basin is used to produce both commercial and domestic crops. In Lower Mekong Basin about 10 million hectares are already used for rice plantation, and the common commercial crops are rice, coffee, cassava, soybean, sugarcane and maize (MRC 2014).

According to its hydropower status report, IHA (2015) gave out an estimated data that there is the hydropower potential of 53 GW found in Mekong Basin River, where the Upper Mekong Basin (China) and Lower Mekong Basin has a hydropower potential of 23 GW and 30 GW respectively. Among the Mekong Basin riparian countries, China has the most powerful economy. This is because China has good foreign trade and investment, the good environment of the private sector to grow, good development of stock markets, has an open modern banking system, foreign trade and good industrial policy. According to the World Fact-book, the China economy is growing at a rate of 7% per year (CIA 2016). The China policy to constructing large hydropower dams in the Mekong River, example, the constructed dams of Manwan, Dachaoshan, Xiaowan, Jinghong, Gongguoqiao, Nuozhadu, and Mengsong total up 16,000 MW made China earn more money by selling the electricity around the areas for industrial and other uses. On a measured of purchasing power parity (PPP), Figure 2.6 indicates that China has GDP per capita (PPP) of 16806 US dollars. Cambodia has a low economy which estimated as GDP per capita (PPP) of 4001 US dollars in 2017. In Lower Mekong Basin, though Thailand being the most economically developed country still has a high energy demand due to industrialization.

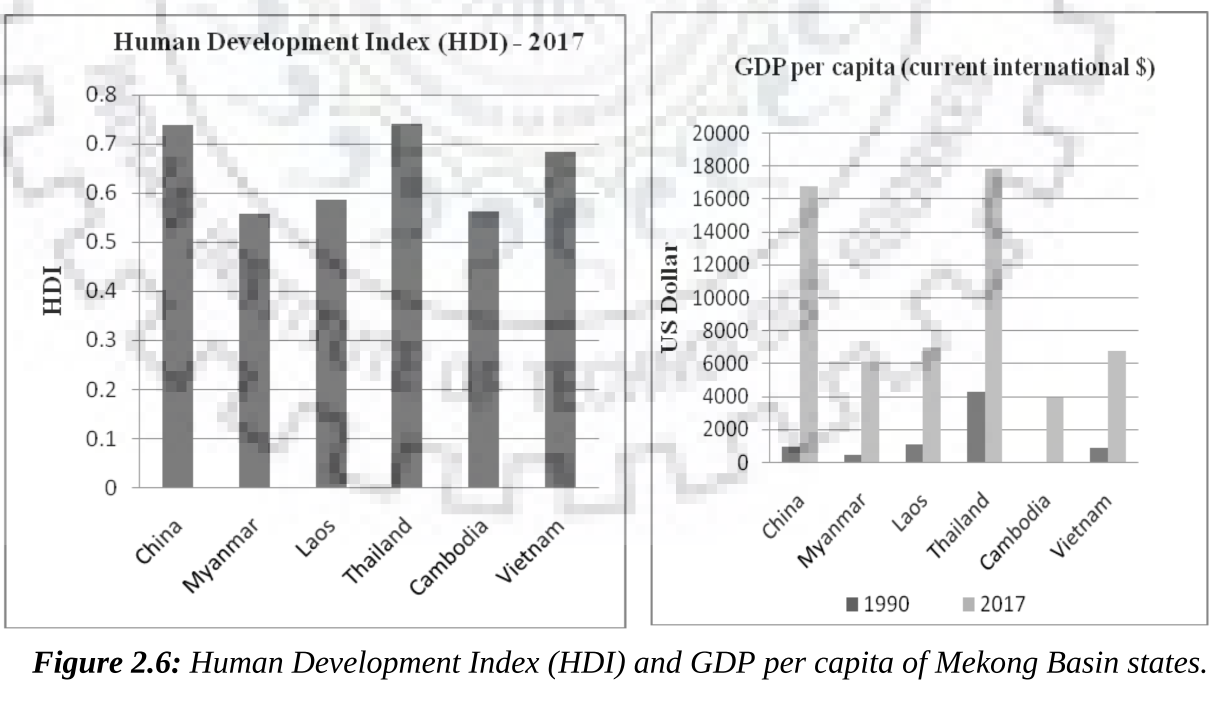

Figure 2.6: *Human Development Index (HDI) and GDP per capita of Mekong Basin states.*

Source: World Bank (2017).

On other hand, other countries such as Myanmar, Laos, Cambodia and Vietnam have a lower energy investment, while China has a huge energy investment; this together calls for regional cooperation for power trade which will lead to earning foreign currency among riparian countries. Also, several dams are being built by these lower Mekong Basin countries to generate hydropower for their own uses and selling outside of their boundaries. ICEM (2010) stated that the projection of Thailand will increase by the annual average of 2,600 MW/year between 2010 and 2025 while that of Vietnam will have the annual increase of 4,600 MW/year. The existence of several development programs under the Mekong River Commission (MRC) and some organizations such as the Greater Mekong Sub-Region Program (GMS) and ASEAN boost the economic growth in the Mekong River Basin.

- *Greater Mekong Sub-Region Program* (GMS): This development program was launched in 1992 by the Asian Development Bank (ADB) and it brought together the six riparian states of Mekong river basin. The GMS Program plays a major role in identifying and implements urgently sub-regional projects in an extensive field of agriculture, energy, environment, health, communication technology, tourism, transport, trade facilitation, and urban development.
- *Association of Southeast Asian Nations* (ASEAN): This Mekong Basin Development Cooperation was established in 1996 and plays a role to advocate economic amalgamation amongst the ASEAN member states and Mekong riparian states by developing means of communications, transportations and improving their people's living standards.

Social Issues

The social life of any community can be achieved at a high level only if the economy is growing well. We all know that the daily population increase leads to a demand for more resources to sustain life. In Mekong Basin most of their population are living in poverty, the communities differ in the living standards. According to the website report, CIA (2016) gave out the details data on people and society in the world and for the countries in the Mekong Basin the details data are as follows; in 2018 an estimated population growth rate was 0.29% in Thailand and 1.48% in Cambodia, life expectancy at birth is 65 years at Laos and 75 years at China, in 2014 an estimated health expenditure was only 1.9% of GDP in Laos and 7.1% of GDP in Vietnam, in 2015 an estimation of improved sanitation facility access was 42.4% of the population in Cambodia and 93% of the population in Thailand, also the problem of unemployment to youth ages of 15-24 was high of about 7.2% in Vietnam as per estimated data in 2016, there is no unemployment data for Myanmar in 2016 but it's the problem of unemployment was only 1.6% to youth ages of 15-24 as per estimated data in 2015.

By considering Figure 2.7, the riparian countries differ in their access to get potable water. Some countries such as China, Thailand and Vietnam are getting good access to potable water in both urban and rural areas. Myanmar has good water access in urban but low access in rural. As population growth, the need to increase the facilities to get access to potable water is very important to all Mekong Basin countries.

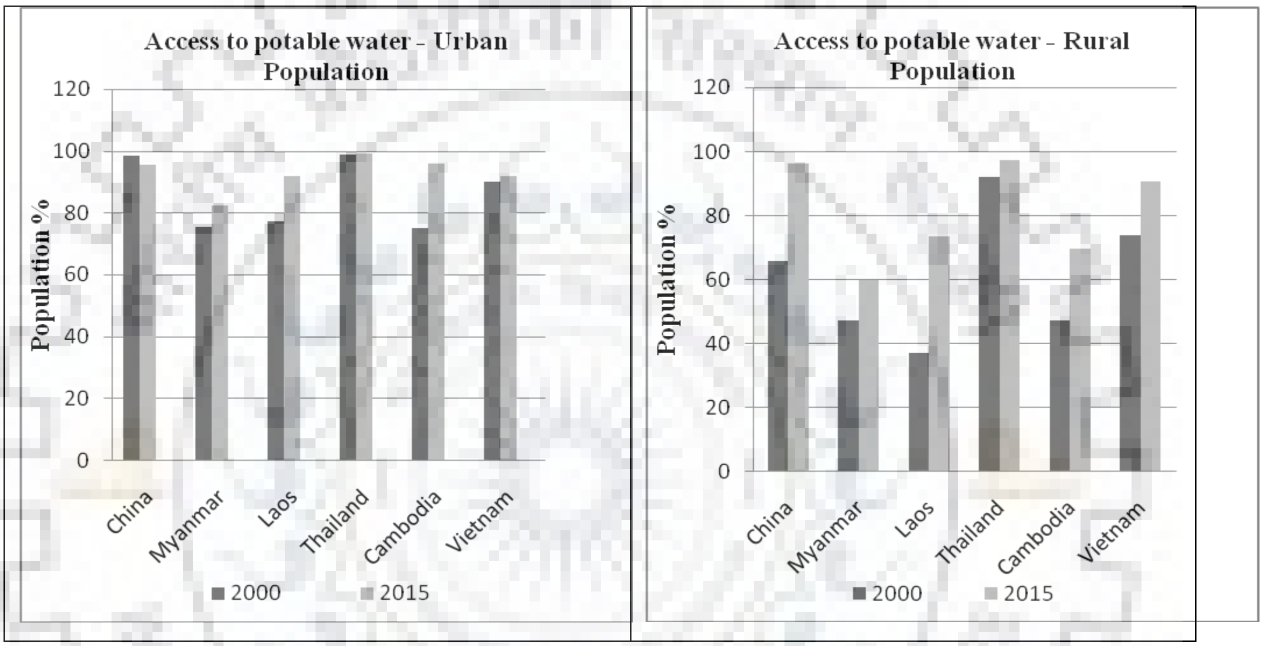

Figure 2.7: *Access to Potable Water in the Mekong Basin states.*

Source: World Bank (2017)

The observed status Mekong Basin countries to getting access to electricity and energy are shown in Table 2. All countries have a good rank in accessing electricity for those populations living in urban areas. Except for Myanmar and Cambodia who are getting electricity even below the rate of 50% for people living in rural areas, the remaining countries have also a good rate of access to the electricity for their population living in rural areas.

Table 2.3: *Access to Electricity and Energy installed in the Mekong Basin*
(Source: World Bank (2017), IHA (2017), CIA (2016))

	Percentage of population with Electricity in 2016		Total Energy Generated in 2016 (Million kW)	Hydropower (MW)	
Country	**Rural**	**Urban**		**Potential**	**Installed (2017)**
China	100%	100%	1653	600, 000	341,190
Myanmar	39.8%	89.5%	5.205	100, 000	3,140
Laos	80.3%	97.4%	6.94	26500	4,984
Thailand	100%	99.9%	44.89	15150	4,510
Cambodia	36.5%	100%	1.697	10,000	1,367
Vietnam	100%	100%	40.77	35,000	16,679

Environmental Issues

The Mekong Basin has a large ecosystem diversity which needs to be protected. It has a wide range of flora and fauna and land of rich forests and wetlands. It is feared that construction of large storages and various anthropogenic activities are bringing the various species to endanger categories and affecting the overall environment of the basin. The fish production in terms of quantity and type will get affected in the time to come. Further, the forests are being cut for various reasons such as the need for timber and change of land use etc., which in turn is one of the main reasons for environmental degradation. Le and Wyseure (2014) describes the Mekong Delta (MD) that has 3.9 million ha, 2.4 million ha used for aquaculture and agriculture, 0.4 million ha for forest, and its water environmental affected by; salinity intrusion in which affected area of 2.1 million ha is hindering crop production, acid sulfate soils which covers about 1.6 million ha, polluted water as a result of the agricultural, industrial chemicals, and domestic untreated wastewater, fresh water shortages which causes the 1.5 million ha not to be irrigated during dry season, floods where Mekong River discharge up to averages of 39,000 m^3/sec during wet season thus affect area of about 1.2 to 1.9 million ha, in turn, causes deaths, properties damage etc. Apart from MD, according to Global Climate Risk report of 2016, Myanmar was the most affected among the member countries by the extreme weather events (Development et al. 2017).

If good water governance systems will be implemented and adopted by all riparian states in Mekong basin then there will be a creation of abundant opportunities such as benefit-sharing, energy security, food security, quality and enough water for communities, cooperative trading, improved livelihoods of people and sharing of data to the public.

2.4.1 Historical Timeline of Mekong Basin Major Events.

In the year 1949 soon after the conclusion of Second World War (WWII) the United Nation (UN) began to involve in Mekong River Basin by established the regional bodies including Economic Commission for Asia and the Far East (ECAFE). This regional body under the Bureau of Flood Control investigates the potential for integrated development in the Lower Mekong Basin. The first report on the potential development of Lower Mekong Basin was completed by the ECAPE in 1952 and the report recognized the Mekong as an international watercourse.

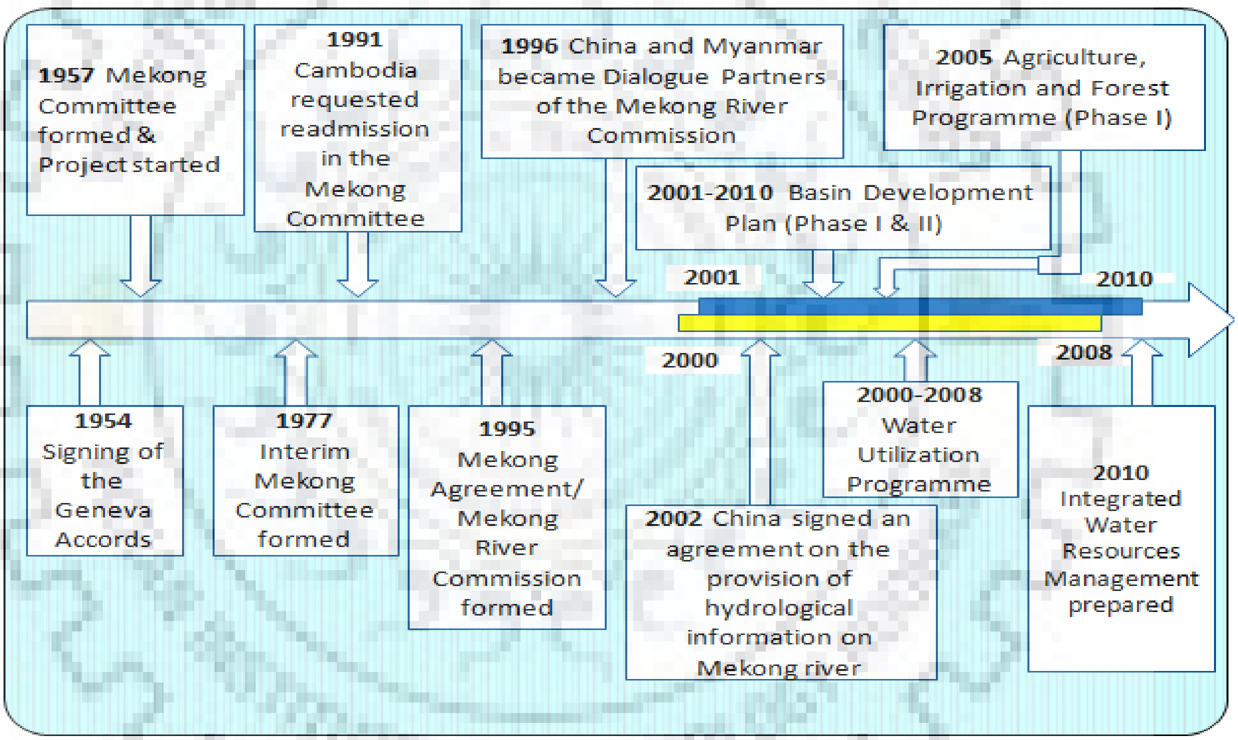

Figure 2.8: *Historical Timeline of MRC.*

In 1954 the Cooperation in the Mekong River Basin begins with the formal signing of the Geneva Accords. The area passed through a period of Cold War and politics for its development. It is also in this period where the Basin got aids of Technical and Science from UN and International involvement that enabled to continue developing and cooperating.

In 1957, four lower countries namely Cambodia, Laos, Thailand, and Vietnam adopted the “Statute of the Committee for Coordination of Investigations of the Lower Mekong Basin”. During this period the Mekong Project was launched which was undertaken by the United Nations. The Mekong Committee conducted a number of surveys and studies using professionals that used boats, on foot, elephants; to map, measure, sample and catalog entire water resources mainstream and tributaries (MRB, 2010).

Also, between 1958 to 1975, a number of attempts were made to expand the functions of the Mekong Committee by including the construction of development projects. In 1965 the name of the Committee changed to be "Committee for Coordination of Comprehensive Development of the Lower Mekong Basin" instead of the name of 1957. The joint Declaration of Principles for Utilization of the water of the Lower Mekong Basin was formed by members of the Mekong Committee.

The Mekong River Commission

The Mekong River Commission (MRC) was established in 1995. This was a result of the Mekong Agreement in the same year between the governments of Cambodia, Lao, Thailand, and Vietnam on the Cooperation for the Sustainable Development of the Mekong River Basin (MRC 1995). The Mekong River Commission emphasis on joint development, ecological protection and a dynamic process of water allocation. During a discussion on the MekongAgreement, five general principles of customary international water law were used(Radosevich and Olson,2009). In governing the Mekong river and also in negotiating other integrated river basin management policies, the mentioned Agreement played an important role.

The Mekong River Commission composed of three permanent bodies:

Council: The body has Chairman who rotates each year by following the alphabetical listing of the four countries. It composed of one member from each state at Ministerial or Cabinet-level who meets once a year and their functions are to make policy decisions on behalf of their government, provide necessary guidance to implement the 1995 Agreement and has overall governance of the Mekong River Commission.

Joint Committee: The body has Chairman who rotates each year by following the reverse alphabetical listing of the four countries. It composed of one member from each state with a qualification of no less than the head of the department level. It ensures the implementation of the policies and various decisions of the council and supervises the activities of the Mekong River Commission Secretariat. Also, the body functions as a board of management.

Secretariat: The body is headed by CEO from outside the riparian states who recommended by the Joint Committee and approved by the Council for the period of 3 years. He is responsible for daily operations of approximately 155 professional and general support staff. The CEO is assisted by an Assistant CEO who comes from the Mekong River Commission Secretariat staff and who has the nationality of the Chairman of Joint Committee for that year. It provides technical and administrative services to the Joint Committee and the Council.

China and Myanmar became Dialogue Partners of the Mekong River Commission in 1996. It took some years up to 2002 when China signed an agreement to provided hydrological information on the Mekong River. Currently, China provided water level data in the flood season from its two stations located in Upper Mekong River. By doing so, this enables all riparian countries now to work closely together (MRC, 2010).

Other Organizations in Mekong River Basin

Greater Mekong Sub-Region Program (GMS): This development program was launched in 1992 by the Asian Development Bank (ADB) and it brought together the six riparian states of Mekong river basin. The GMS Program plays a major role in identifying and implements urgently sub-regional projects in an extensive field of agriculture, energy, environment, health, communication technology, tourism, transport, trade facilitation, and urban development.

ASEAN-Mekong Basin Development Cooperation: This was established in 1996 and plays a role to promote economic integration among the ASEAN member states and Mekong riparian states by developing infrastructure and human capital in the sub-region. It has also led to the international recognition of the sub-region as a growth area.

2.4.2 Challenges in Mekong River Basin Governance

Below are the numbers of challenges in the Mekong basin;

Population Pressure on Water Resources

The growing population in the Mekong River demands clean and sufficient water, food and energy security. The supplied water can support sustainable development in the basin by better utilize the available resources; minimize environmental damage and ecological system. The population of

Mekong Basin has estimated 63 million in 1995 and grew up to 72 million in 2005. Also by use of constantly changing of population growth rate method the estimation of Mekong Basin population will be 115.2 million in 2050 (Pech and Sunada, 2008).

Deforestation

Deforestation affects the ecosystem, river flow, social groups, and entire watershed. The activities like use of land for agricultural, human settlements, development of infrastructure, heavy fuelwood use, excessive and inefficient commercial logging are some causes of deforestation in Mekong river basin (MRB, 2009).

Environment degradation, pollution and water quality

The Mekong river basin contains substantial forests and wetlands which reserved the biological diversity. The ongoing environmental degradation within the basin threatens the diversity of more than 2,000 species of fish and more population will get a shortage of fish whereby the river provide around 2 million tons of fish per year to these population.

Climate change

Regional impacts of climate change are expected to affect river flow, decreasing overall water availability, decreasing food production capacity (Mainuddin et al., 2010) and rising sea level in the Mekong Delta (Cruz et al. 2007). Also, climate change will add further stress to the region's ecosystems in the near future, increase the temperature in the headwaters of the Mekong river which in turn will altering the seasonality of stream flows and affect agricultural productivity (Pokhrel et al. 2018).

Hydropower projects

The Mekong River is under atrocious development pressure. Many water resource projects such as dams have been completed, under construction, or are being planned in both upstream and downstream of the river. These projects not only alter ecosystems and human livelihoods but also are subject to disputes and protests. For some years back to-date hydropower development has begun to change the hydrology of the Mekong River (ICEM, 2010). The hydropower projects constructed on the upper and lower basin mainstream and its tributaries are altering water flows, affecting sediment transport and flooding.

2.5 Hydropower Development

Hydropower development in Mekong River is a big threatens to downstream users (as explained early in this study in section 2.5.2). China is a dominant country in the Mekong Basin (MB) with higher extensive hydropower development projects. A number of hydropower projects constructed, are under construction and planned as indicated in Tables 2.4, Table 2.5 and Table 2.6 below;

Table 2.4: *Constructed Hydropower Projects*

No.	Project	Country	River	Longitude	Latitude	Installed Capacity(MW)	Commissioned Year
1	Dachaoshan	China	Mekong	100.3703°E	24.024947°N	6x225=1350	2003
2	Gongguoqiao	China	Mekong	99.335567°E	25.585917°N	4x225=900	2012
3	Nuozhadu	China	Mekong	100.436336°E	22.642128°N	9x650=5850	2014
4	Jinghong	China	Mekong	100.766478°E	22.053206°N	5x350=1750	2009
5	Manwan	China	Mekong	100.448544°E	24.622086°N	5x300=1500	1992
6	Xiaowan	China	Mekong	100.091255°E	24.7042226°N	6x700=4200	2010
7	Miaowei	China	Mekong	99.163155°E	25.854121°N	4x350=1400	2016
8	Jinfeng	China	Nan La He	101.225135°E	21.592026°N	16	1998
9	Jinhe	China	Jin He	97.332926°E	30.806181°N	60	2004
10	Guoduo	China	Mekong	97.191279°E	31.529089°N	160	2015
11	Laoyinyan	China	Shun Dian He	99.81754°E	24.469128°N	16	1997
12	Nanhe 1	China	Luo Zha He	100.012183°E	24.342442°N	40	2009
13	Nanhe 2	China	Luo Zha He	100.050098°E	24.377086°N	25	
14	Xi'er He 1	China	Xi'er He	100.202419°E	25.578801°N	105	1979
15	Xi'er He 2	China	Xi'er He	100.131191°E	25.561991°N	50	1987
16	Xi'er He 3	China	Xi'er He	100.107878°E	25.558584°N	50	1988
17	Xi'er He 4	China	Xi'er He	100.065574°E	25.576262°N	-	1971
18	XunCun	China	Hei Hui Jiang	99.993301°E	25.421835°N	78	1999
19	Houay Ho	Laos	Houayho/Xe kong	106.764377°E	15.059464°N	2x75=150 1x2.1=2.1	1999
20	Houay Lamphan	Laos	Xekong	106.501106°E	15.356153°N	88	2015

No.	Project	Country	River	Longitude	Latitude	Installed Capacity(MW)	Commissioned Year
21	Nam Beng	Laos	Nam Beng	101.237563°E	19.946436°N	36	2014
22	Nam Khan 2	Laos	Nam Khan	102.369791°E	19.685364°N	2x65=130	2015
23	Nam Khan 3	Laos	Nam Khan	102.222793°E	19.747016°N	88	2016
24	Nam Leuk	Laos	Nam Leuk/Nam Ngum	102.94675°E	18.437406°N	2x30=60	2000
25	Nam Lik 1-2	Laos	Nam Lik	102.116714°E	18.793782°N	100	2010
26	Nam Mang 1	Laos	Nam Mang	103.196286°E	18.53423°N	64	2016
27	Nam Mang 3	Laos	Nam Gnogn	102.765244°E	18.349383°N	2x20=40	2004
28	Nam Ngiep 2	Laos	Nam Ngiep	103.352263°E	19.299877°N	3x60=180	2015
29	Nam Ngiep 3A	Laos	Nam Ngiep	103.283913°E	19.243546°N	44	2014
30	Nam Ngum 1	Laos	Nam Ngum	102.547577°E	18.531068°N	2x17.5=35 3x40=120	1971
31	Nam Ngum 2	Laos	Nam Ngum	102.776476°E	18.755374°N	615	2011
32	Nam Ngum 5	Laos	Nam Ngum	102.621196°E	19.356095°N	120	2012
33	Nam Theun 2	Laos	Nam Theun/Xe Bangfai	104.952306°E	17.997353°N	2x37.5=75 4x250=100	2010
34	Nam Ou 2	Laos	Nam Ou	102.472817°E	20.411698°N	3x40=120	2016
35	Nam Ou 5	Laos	Nam Ou	102.344263°E	21.411349°N	3x80=240	2016
36	Nam Ou 6	Laos	Nam Ou	102.344263°E	21.411349°N	3x60=180	2016

No.	Project	Country	River	Longitude	Latitude	Installed Capacity(MW)	Commissioned Year
37	Theun-Hinboun	Laos	Nam Theun	104.562525°E	18.261005°N	220	1998
38	Theun-Hinboun Expansion Project	Laos	Nam Gnouang	104.636171°E	18.297248°N	222	2013
39	Xe Kaman 3	Laos	Xe Kaman	107.362611°E	15.425194°N	250	2014
40	Xeset 1	Laos	Xeset	106.27867°E	15.49200°N	3x13=39 2x3=6	1994
41	Xeset 2	Laos	Xeset	106.280332°E	15.403775°N	2x38=76	2009
42	A Luoi	Vietnam	A Sap	107.161897°E	16.197619°N	170	2012
43	Buon Kuop	Vietnam	Sre Pok	107.925762°E	12.52504°N	2x140=280	2009
44	Buon Tua Sra	Vietnam	Se San/Krong Po Ko	108.041299°E	12.282116°N	2x43=86	2009
45	Dray Hlinh 2	Vietnam	Sre Pok	107.903978°E	12.6757°N	16	2007
46	Plei Krong	Vietnam	Se San/Krong Po Ko	107.862991°E	14.408227°N	2x50=100	2008
47	Sesan 3	Vietnam	Sesan	107.722061°E	14.215816°N	2x130=260	2006
48	Sesan 3A	Vietnam	Sesan	107.722264°E	14.215314°N	2x54=108	2007
49	Sesan 4	Vietnam	Sesan	107.6578°E	14.106394°N	3x120=360	2009
50	Sre Pok 3	Vietnam	Sre Pok	107.8762°E	12.750772°N	2x110=220	2009
51	Yali Falls	Vietnam	Sesan	107.829597°E	14.227481°N	4x180=720	2001
52	Chulabhorn	Thailand	Nam Phrom	101.650036°E	16.536267°N	2x20=40	1972
53	Pak Mun	Thailand	Mun	105.468058°E	15.2818942°N	4x34=136	1994
54	Sirindhorn	Thailand	Lam Dom	105.429156°E	15.206339°N	3x12=36	1971

No.	Project	Country	River	Longitude	Latitude	Installed Capacity(MW)	Commissioned Year
			Noi				
55	Ubol Ratana	Thailand	Nam Pong	102.618325°E	16.775394°N	3x8.4=25.2	1966
56	Lam Ta Khong	Thailand	Lam Ta Khong	101.560303°E	14.865175°N	2x250=500	1974

Table 2.5: *Under Construction Hydropower Projects*

No.	Project Name	Country	River	Longitude	Latitude	Installed Capacity(MW)	Construction began year
1	Dahuaqiao	China	Mekong	99.139288°E	26.308096°N	4x225=900	2010
2	Gushui	China	Mekong	98.746133°E	28.608683°N	2600	
3	Huangdeng	China	Mekong	99.112669°E	26.548199°N	4x475=1900	2010
4	Lidi	China	Mekong	99.030555°E	27.848016°N	3x127=381	-
5	Luozhahe 1	China	Luo Zha He	100.451749°E	24.505207°N	30	-
6	Luozhahe 2	China	Luo Zha He	100.402128°E	24.486867°N	50	-
7	Wunonglong	China	Mekong	98.9333°E	27.932554°N	3x330=990	2010
8	Don Sahong	Laos	Mekong	105.964247°E	13.956223°N	4x65=260	2016
9	Houay Por	Laos	Houay Pore	106.256763°E	15.545605°N	15	2017
10	Nam Bi 1	Laos	Nam Bi	107.515959°E	15.23565°N	50	2017
11	Nam Bi 2	Laos	Nam Bi	107.540761°	15.212256°N	68	2017

No.	Project Name	Country	River	Longitude	Latitude	Installed Capacity(MW)	Construction began year
				E			
12	Nam Chian 1	Laos	Nam Ngiep	103.557259° E	19.145395°N	104	2014
13	Nam Kong 2	Laos	Nam Kong	106.856669° E	14.494672°N	66	
14	Nam Kong 3	Laos	Nam Kong	106.912551° E	14.566338°N	45	
15	Nam Ngiep 1	Laos	Nam Ngiep	103.5516582 °E	18.6458578°N	272	2014
16	Nam Ngiep 2C	Laos	Nam Ngiep	103.357806° E	19.21347°N	45	
17	Nam Ngiep (Downstream)	Laos	Nam Ngiep	103.516607° E	18.64747°N	18	2015
18	Nam Ngum 1 Extension	Laos	Nam Ngum	102.530765° E	18.527772°N	120	2014
19	Nam Ou 1	Laos	Nam Ou	102.265379° E	20.0883°N	160	2016
20	Nam Ou 3	Laos	Nam Ou	102.665404° E	20.695251°N	150	2016
21	Nam Ou 4	Laos	Nam Ou	102.494173° E	21.120153°N	116	2016
22	Nam Ou 7	Laos	Nam Ou	102.264436° E	22.07779°N	190	2016
23	Nam Pha Gnai	Laos	Nam Pha Gnai	102.264436° E	19.013318°N	19.2	2014
24	Nam San 3A	Laos	Nam San	103.663052° E	19.129054°N	69	
25	Nam Tha 1	Laos	Nam Tha	100.892433° E	20.249467°N	168	2014
26	Xayaburi	Laos	Mekong	101.813699° E	19.254006°N	1285	2010

No.	Project Name	Country	River	Longitude	Latitude	Installed Capacity(MW)	Construction began year
27	Xekaman-Sanxay	Laos	Xe Kaman	107.119451°E	14.890823°N	2x16=32	2011
28	Xepian-Xenamnoy	Laos	Xepian/Xenamnoy	106.627369°E	14.946382°N	410	2013
29	Xeset 3	Laos	Xe Don	106.31115°E	15.342113°N	23	2014
30	Lower Sesan 2	Cambodia	Sesan	106.263841°E	13.551408°N	5x80=400	2014
31	Battambang 1	Cambodia	Sangker	102.912094°E	12.804805°N	24	2013

Table 2.6: *Planned Hydropower projects*

No.	Project Name	Country	Longitude	Latitude	Installed Capacity(MW)	Expected Commissioning Year
1	Ban Kum	China	105.587364°E	15.417881°N	1872	2030
2	Dongzhong	China	96.99°E	31.872777°N	108	-
3	Ganlanba	China	100.937917°E	21.843867°N	31x5=155	-
4	Guxue	China	98.6067°E	29.18295°N	1700	-
5	Lin Chang	China	97.1852°E	31.1804°N	72	-
12	Ru Mei	China	98.3477°E	29.649933°N	2100	-
6	Yue Long	China	97.347124°E	30.868008°N	129	-
7	Kagong	China	97.444417°E	30.622567°N	240	-
8	Latsua	Laos	105.582803°E	15.33146°N	800	2023
9	Luangprabang	Laos	102.192339°E	20.06663°N	1200	2030
10	Pak Beng	Laos	101.016502°E	19.843927°N	912	2022
11	Pak Lay	Laos	101.530575°E	18.327581°N	1320	2030
13	Sanakham	Laos	101.556969°E	17.829183°N	700	2024
14	Santhong-Pakchom	Laos	102.050588°E	18.201038°N	1079	-

No.	Project Name	Country	Longitude	Latitude	Installed Capacity(MW)	Expected Commissioning Year
15	Sambor	Cambodia	105.938582°E	12.786849°N	2600	2020
16	Stung Treng	Cambodia	105.245516°E	13.302404°N	980	-

2.6 Sustainable Development

The term sustainable development can be defined as the kind of development that ensure the satisfaction of the present needs and also the satisfaction for the future living organisms will be met. This means the available resources should be used in a good manner under consideration of future generations to use the same resources. The Sustainable Development Goals entrust subscribing the countries with targeted new ways that focused on achieving the sustainable use of water, use of energy and practices in the agricultural sector, as well as advancing economic development (UN, 2014). The concepts of sustainable development (SD) approaches and sustainable livelihood (SL) approaches can be assumed to be the same in this study though there is a slight difference between them. The 1992 United Nation Conference on Environment and Development placed the term sustainable livelihoods (SL) as a means of connecting socio-economic and environmental concerns (Brocklesby and Fisher, 2003). Integration of SD and SL are important to patterning the international agenda on problems related to environmental towards a centre of awareness on people and their livelihood activities, and introducing these agenda within a policy structure for development (Biggs et al., 2014). Sustainable livelihood approaches have advanced from a change in perspectives on poverty, participation and sustainable development (Chambers and Conway, 1992) Generally, approaches to sustainable development (SD) have a propensity to evaluate progress at different levels such as national, regional and global scales. Furthermore, the SD carries two concepts; the need concept which gives priority to poor communities, and the idea of the limitation on the ability of people to meet their present needs as well as future needs.

This study explains the term SD in Sustainable Use of Water focused on four pillars of sustainability, that are Economic Efficiency, Social Equity, Environmental sustainability and Water Governance (Figure 2.9).

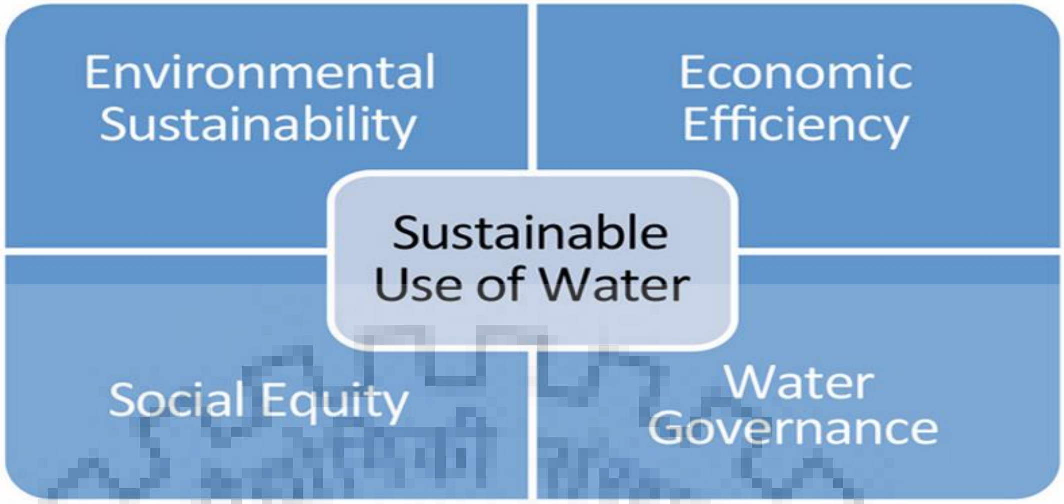

Figure 2.9: *Sustainable Development.*

Environmental sustainability (ES): Carried through performing various tasks to conserve and protects the environment such as protecting living organisms living within the environment (biological diversity), sustainable use of natural resources, preventing environmental degradation, and establishing friendly ecological projects. The ES activities in the aspect of livelihood have a wide chance to contribute to deforestation, soil erosion, desertification, salinisation, and water tables declining (Chambers and Conway 1992). There is a benefit in conserving environments through well-matched activities which also consideration climate change such as reforestation and agro-biodiversity (Tompkins et al., 2013).

Social Equity (SE): Sustainable use of water should ensure that the water is being allocated equally among the communities, there should be equal distribution of water projects in the river basins, the conflicts of water wherever arise diplomatic measures regarding water laws should be used to resolve the conflicts, human rights should be promoted, enhancing the low-class communities by aiding them through water projects.

Economic Efficiency (EE): In developing countries, the EE is rarely to be achieved due to the failure of implementing projects at high levels to sustain development. The overall economic development in Lower Mekong Basin (LMB) countries is low and differs to each member states. There is an existing gap of implementation in most development projects due to lack of funds to secure the design projects, lack of technical personnel, and lack of technological equipment. While demand for sustainable development there are some factors that hindered progress such as population increase. In most cases, the economic in this region is being affected by higher population growth. There is a substantial growth in population in the lower basin compare with the sustainable use of water resources to build the economy. Currently, in April 2019 Vietnam has approximately 97 million with an annual growth rate of 0.97%, Laos has 7 million with a growth rate of 1.48%, Cambodia has 16 million with a growth rate of 1.6% and Thailand has 69 million with a growth rate of 0.18%. is the least state with a population of 5.2 million. Other challenges threaten the efficiency of a growth economy is environmental degradation as discussed in most parts of this study.

Water Governance: According to MRC (1995) the only organization which acts on behalf of lower basin riparian countries of Vietnam, Cambodia, Lao and Thailand is the Agreement of 1995 as being discussed in previous section 2.5.1 about the historical timeline of Mekong basin major events. This agreement is all about the cooperation of riparian states for the "Sustainable Development of the Mekong River Basin". The cooperation will increase benefits and reduce the harmful effects. The basin authority itself has already integrated various policies that help to guide several operations. This will support the management of Mekong river basin in most areas. There is good progress in improving the water governance especially at the lower basin and as discussed in previous chapter two also the effort of MRC to invite China and Myanmar to join the coming will increase more power in transboundary governance in future. To ensure strong leadership over the Mekong, the MRC summit was inaugurated in April 2010 which brought together the Lower basin riparian states prime ministers with China and Myanmar representatives of high level. Furthermore, MRC supports the discussion on the issue of the Xayaburi dam, which located in Lao. The discussions ended successfully regardless of external pressure among Lower countries and the important data from MRC members were shared to MRC to supporting the preparation of the better advisory report (MRC 2011).

Generally, there is a close link between those water demands for projects conducted within the basin. The water is consumed for water, food, energy and nature. In any economic activity, there is key water-related that can support the growth in the Mekong basin (Figure 2.10).

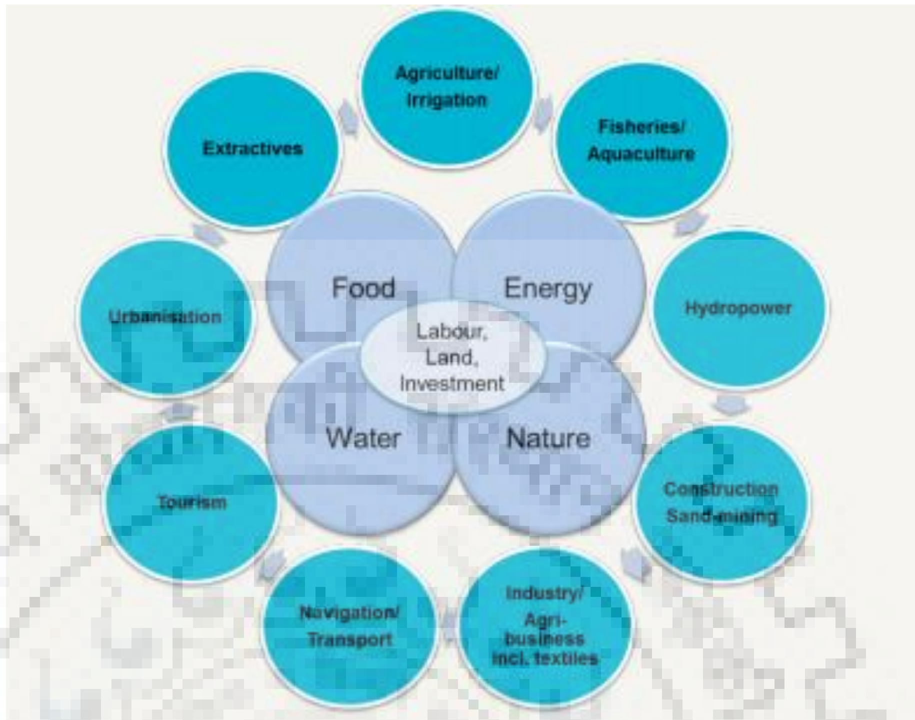

Figure 2.10: *Key economic drivers of change in the MRB*

Source: World Wide Fund for Wildlife (2016)

The combination framework should be formed to call for water – energy – food-nature nexus. Through a combination of elements required for sustainable use of water with those nexuses mentioned above. There is a near relationship to each sector in the figure above, the main requirement resources are labour, land and capital (investment) which in turn driving the economy in the basin. The meta-drivers (Food, Water, Energy & Nature) are depending on other functioning sectors in the basin. There is good inter-link of these sectors (Tourism, Urbanization, Extractives, Agriculture/Irrigation, Fisheries/Aquaculture, Hydropower, Construction Sand-mining, Industry/Agri-business, & Navigation/Transport). This linking has a healthy and positive indication in the Mekong river basin system. The MRB should be capable of maintaining and use this driver to enable the sustainability of the whole basin to a higher extent.

Finally, the water resources management and development can be achieved by observing on principles of sustainable development as that of integrating water resource management (IWRM); that is to improve economic of people as already discussed. Addition to that, to improve the people economic without compromising the equity of society and sustainability of environment (Mehtonen, 2008)

2.7 Integrated Water Resources Management Concept

The term Integrated Water Resources Management (IWRM) is defined in broader sense as a coordination development and its management of water, land, and other related water resources for the purposes of maximizing economy and social welfare with no interfere ecosystem and environment sustainability (Global Water Partnership 2010). The concept of IWRM was applied based on the integration of science, technology and society.

IWRM use the Dublin principles which emphasizing to use water inequitable ways, efficient management, and in sustainable ways. The Dublin principles (1992) can be underlined as follows;

- **Water is a finite and vulnerable resource**: The appreciation of water as natural occurrence has no doubt, the existing of hydrological cycle and all its process which is evidence that the fresh water is a finite, home to living organisms, facilitate crop production, industrial uses, domestic uses, drinking uses, nature uses, water is a vulnerable resource, sustain life, support all kind of development, made beauty environment, etc.
- **Participatory approach**: IWRM should involve several groups and media in its development and management such as Local actors, universities, public awareness, administration, stakeholder links, communication and workshops.
- **Role of women**
  Women play a central part in the provision, management and safeguarding of water
- **The social and economic value of water**
  Water is a public good and has a social and economic value in all its competing uses

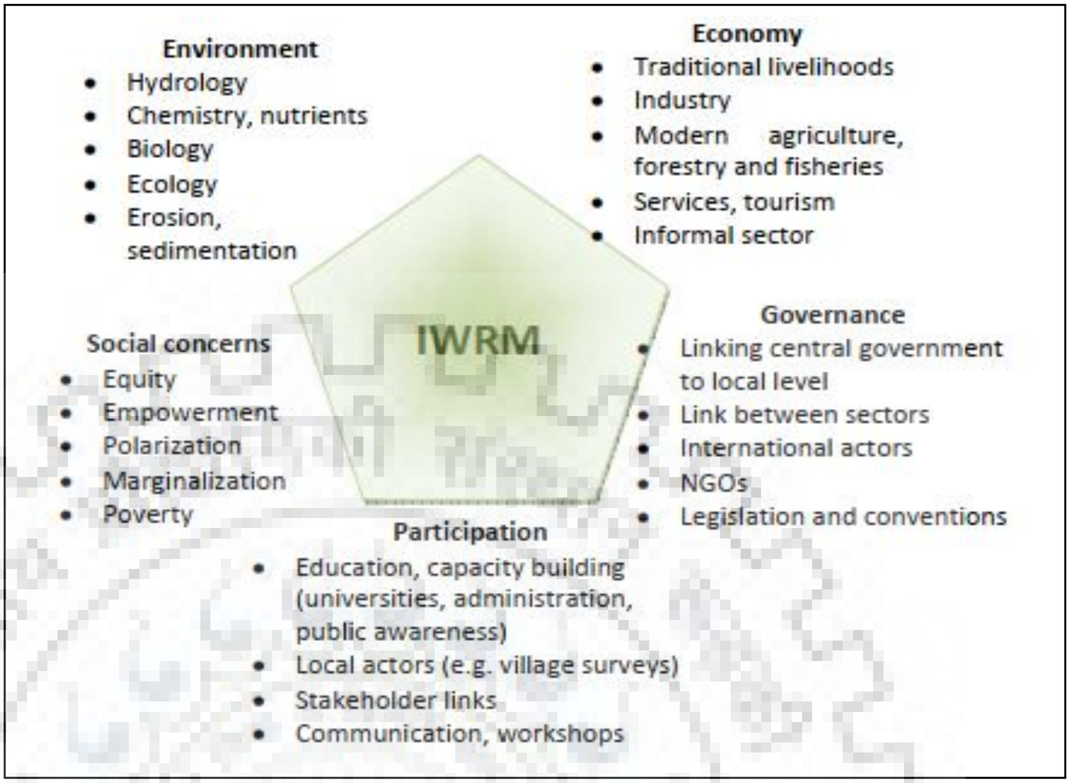

Figure 2.11: *The concept of social-ecological systems (SES) in IWRM.*

Source: Varis (2006).

The better understanding of IWRM can be observed in Figure 2.11 above, which list down the five aspects of IWRM (economy, environment, governance, participation and social concerns) as being explained by Varis (2006).

The use of IWRM system can promote food production within the basin as the surface water and groundwater can be integrated for efficiently used together and also consider land/soil management. The advantages of using IWRM are many, for example; traders, food consumers, and workers generate more income from food production. The application of new technology in using water resources such a "concept of the social-ecological system" (Figure 2.11) which considers water storages in the soil and also the primary plant production will enable water to be used efficiently in the basin.

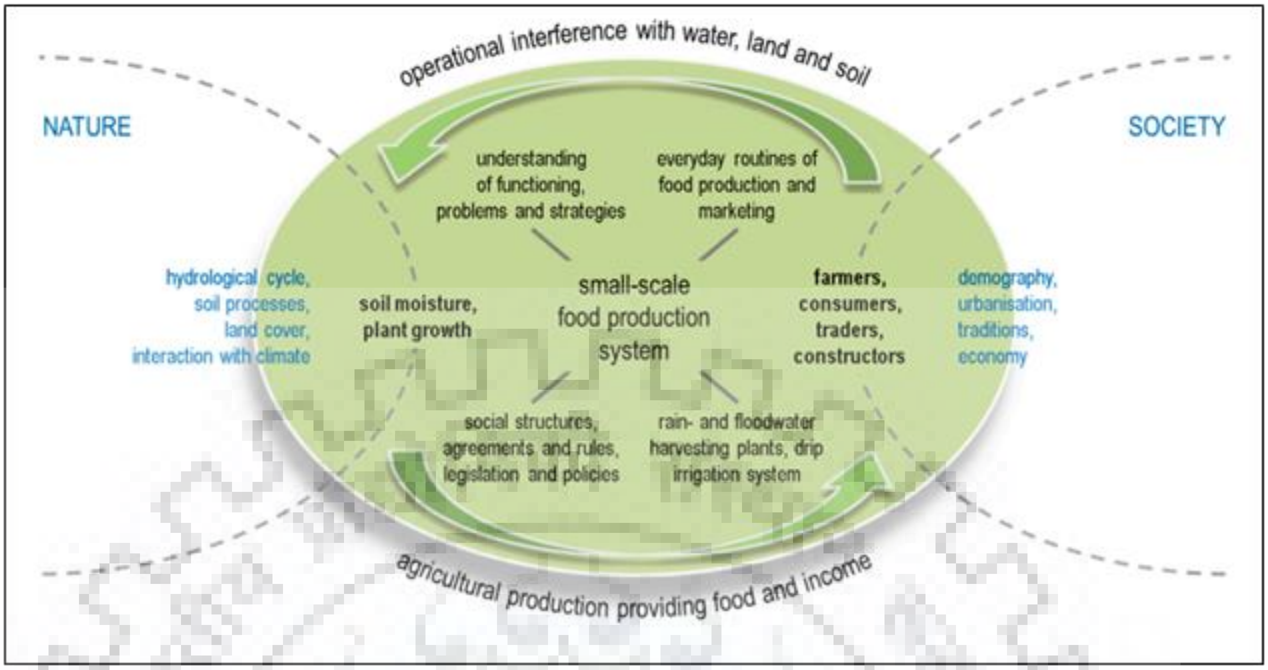

Figure 2.12: *The concept of social-ecological systems (SES) in IWRM.*

Source: Biggs et al. (2015).

The SES is a feedback loop system, interlinked by depending on several processes to regulate the nutrient and water fluxes and also determine biomass in its production. Land management and water influence the functions of the ecosystem and produces agricultural products (ecosystem service). The system management costs are those results from changes in the hydrological cycle such as water buffering, soil processes (nutrient and moisture distribution) and land cover (cultivation of crops).

3. DESCRIPTION OF THE MEKONG RIVER BASIN

Chapter overview

This chapter describes the Mekong basin and its several salient features including its river profile from headwaters to mouth. Furthermore, it gives an overview of the availability of water resources in the basin. Moreover, it highlights activities conducted within the basin, export crops from the basin area to foreign countries.

3.1 Salient features of Mekong River Basin

The Mekong River extends from the Tibetan Plateau in China to the Mekong Delta in Vietnam. The Mekong River Basin (MRB) is the land area that includes the streams and rivers that run into the Mekong River (Figure 3.1).

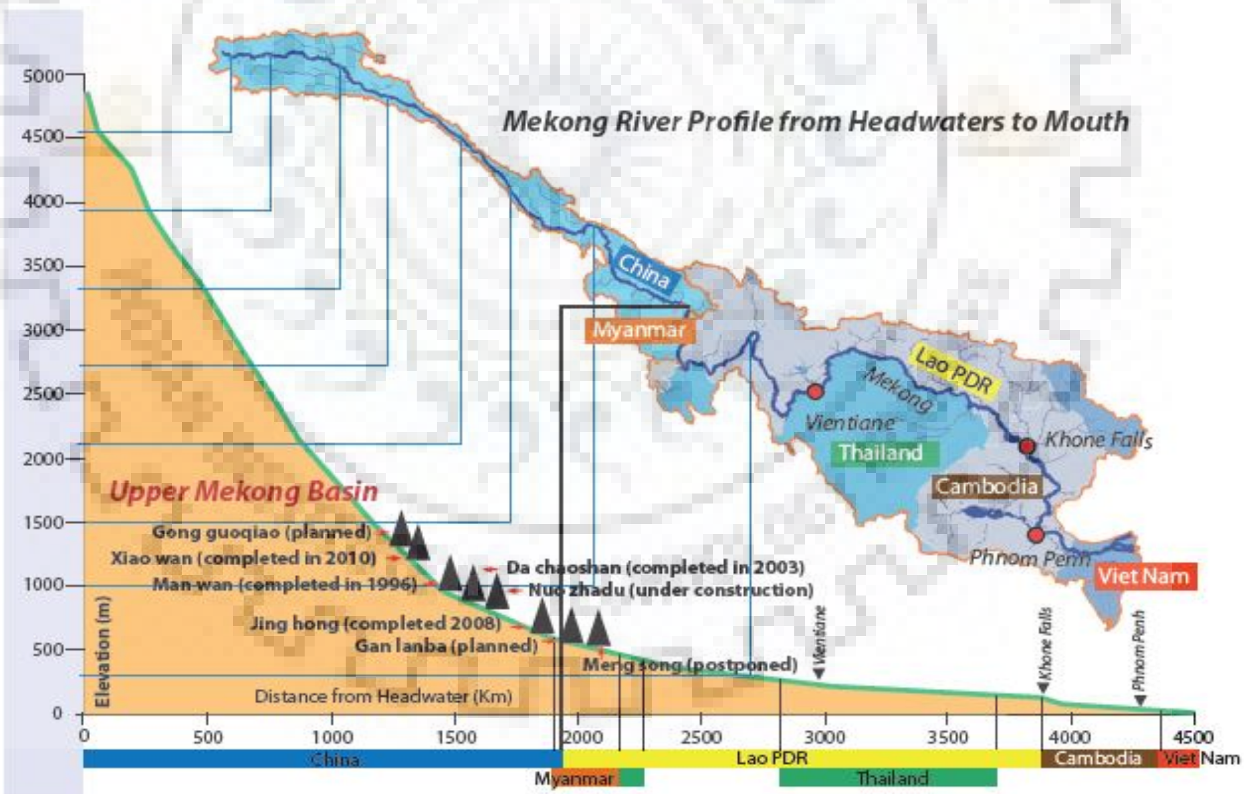

Figure 13: *The Mekong River Profile.*

Source: World Wide Fund for Wildlife (2016).

The river basin is located between latitudes 8^o N to 34^o N and the longitude of 94^o E to 110^o E (Figure 3.2).

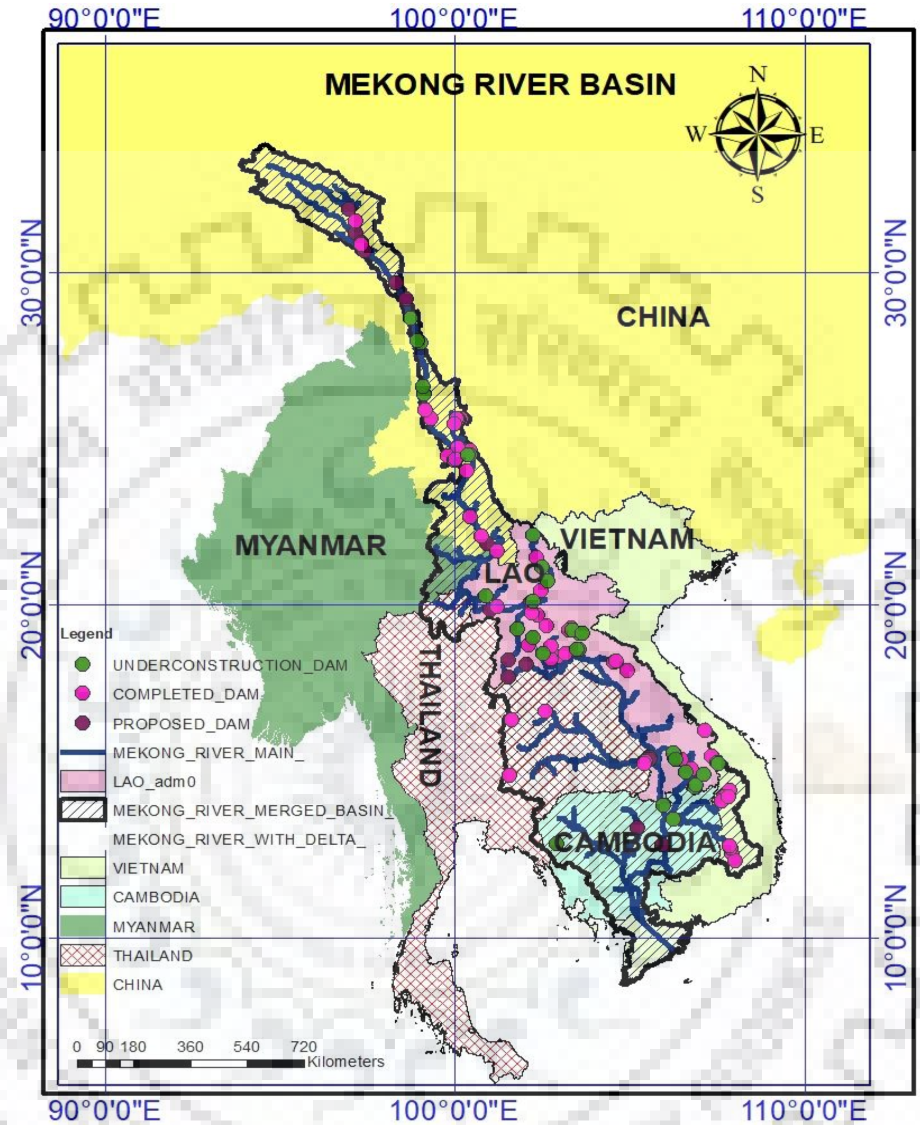

Figure 14: *The Mekong Basin in Asia*

The total catchment area of the MRB is 795,000 km^2 and produces approximately 475,000 million m^3 of runoff during the rainy season (MRC,1997). The entire length of the Mekong River is 4,800 km long and is the tenth largest river in the world on the basis of mean annual flow at the river mouth. The LMRB has a total basin area of 629,520 km^2 with a river length of 2,200 km. The source of the Mekong River is located in China, from where it flows across the Chinese Province of Yunnan, then forms the border between Myanmar and Lao PDR (Laos), and continues on forming most of the border between Lao PDR and Thailand. Once the Mekong exits Thailand, it flows next across Cambodia, passes through a delta in southern Vietnam, and ultimately empties into the South China Sea. Only 3% of the Mekong river basin lies within Myanmar territory (Table 3.1).

***Table 3.1**: Mekong River Basin countries including area and portion of the country in the MRB (MRC, 2005).*

S/N	Nations	Area (km^2)	Area of the country in the basin (km^2)	The areas % of the total area of the basin	The area as % of total country Area
1.	China	9,597,000	165,000	21	2
2.	Myanmar (Burma)	678,030	24,000	3	4
3.	Lao	236,725	202,000	25	85
4.	Thailand	513,115	184,000	23	36
5.	Cambodia	181,100	155,000	20	86
6.	Viet nam	331,700	65,000	8	20

Myanmar is mainly concerned with construction the hydropower stations and play a part in the navigation project but some factors such as the geography of the Mekong River, lack of infrastructure and political instability makes difficulty for Myanmar to utilize the river compared to the other riparian states. Thailand apart from being the most powerful state in the lower part of Mekong basin is a foremost electricity consumer in Southeast Asia, played a crucial role in the economics, politics and hydropolitics of the region. It's a desire to developing hydropower will also develop the northeast part of the country by diverting the Mekong river. Vietnam comprises about 20% of the Mekong River Basin, the state made the Mekong delta an essential part in the rice production, irrigation, forestry and fishery. The Delta is the home to approximately 16 million people and accounts for roughly 50 to 65% of the GDP production. Saltwater intrusion in the river delta and acidic soils are big distress for the rice cultivation. Apart from having a desire to develop the delta to attain two to three rice crops a year, also they have the ambition to construct hydropower dams in the northern part of the country. Yali Falls Dam found in Vietnam state, Se San River, a tributary of Mekong River has a capacity of 720MW was constructed and commissioned in 2001. The Dam is the second biggest dam in Vietnam and it has a direct impact on the downstream Cambodian villages' livelihood (Hirsch and Wyatt, 2004). Laos state controls over

85% of the Mekong River Basin that enables to provides the water for irrigation though affected by the mountain, fishery, hydropower generation and transport. Cambodia, another country in the lower basin has been underdeveloped due to the Vietnam War and much successive civil wars involved on the Mekong river for its rice agricultural, irrigation and fishery production from Tonle Sap lake. Tonle Sap is a major source of protein and income for Cambodians and ecologically extremely valuable for Cambodia's ecosystem (Sokhem and Sunada, 2006). Like other countries in the region, Cambodia has the desire to construct a dam for hydropower generation.

3.2 The basin climate

Generally, according to the Mekong River Commission, the climate of the lower part of Mekong Basin is conquered by the Southwest Monsoon (Table 3.2).

Table 3.2: *Mekong River Basin Climate Seasons (MRC, 2005).*

Cool / Cold		Hot / Dry		Wet						Cool / Cold	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Monsoon		Transition		SW Monsoon						NE Monsoon	

The southwest monsoon generates a wet and dry season which varies in length and its season lasts from May until late September or early October. The most of the areas within the basin receives a distribution of heavy rainfall of more than 5mm which lasting in time of one or two days. Also in a year, subsequently in the season, there is tropical cyclone which occurs in most regions that make August, September and October (delta area) be wettest months. There is a lower temperature in the Northeast Monsoon (NE Monsoon) which occurred on October as indicated in the table above. During NE months there is rainfall in Vietnam than other rest parts of Lower Mekong basin. In case of Upper Mekong Basin especially in Yunnan province, there is a similar NE monsoon climate though slightly variation from tropical and subtropical monsoons to temperate monsoons are found in the south and north of Yunnan respectively. The summaries about rainfall and temperatures within the basin can be discussed as follows;

- **Rainfall**

  The distribution of rainfall within the basin varies in most of the areas within MRB. In Cambodia and areas of Mekong Delta, the average annual rainfall is less than 1500 mm. Mekong Delta (MD) receives average annual rainfall which varies from 1,400 mm to 2,200 mm and most of its rainfall (about 90%) falls from May to October. Moreover, areas of Lao (central highlands) and Pakse (at main-stream valley) the rainfall is over 3000 mm. Furthermore, in Thailand, the rainfall is highest in July, August and September. The existing of tropical storms and cyclones affects the basin climate with evidence of rising of the peak during rainfall seasons in most of the region. As discussed early the Yunnan province (China) has a monsoon climate which varies with its local topography, also its rainfall distribution is determined by global monsoon systems (GMS). The upper part ascends between elevations of 2500 m to 4000 m above mean sea level. Additionally, in seasonally wise the upper basin experience the same rainfall distribution to the lower basin but there is a decrease of annual rainfall up to 600 mm. Finally, there is significant snow flowing from higher altitudes which support supply during the dry season.

- **Temperature**

  The temperature in MRB varies in summer and winter seasons. Some of the lowlands and in river valleys experience a little mean temperature difference. During the summer period, some areas such as Phnom Penh (Cambodia), north of Laos, and Chiang Rai (Thailand) gets similar mean temperatures. Few areas such as upper San sub-basin (Vietnam) and Pleiku differ in their mean summer temperatures by 2 ^{o}C to 3 ^{o}C lower than most of the lowlands. During winter there is a decrease in mean temperatures from south to north, by the difference of 1 ^{o}C (from 26 to 27 ^{o}C) in Phnom Penh & by the difference of 2 ^{o}C (from 21 to 23 ^{o}C) in Chiang Rai. The average summer temperatures at Jinghong lower by 2 to 3 ^{o}C and average winter temperatures lower by 5 to 6 ^{o}f at Chiang Rai

3.3 The availability of water resource

3.3.1 Surface Water

According to Botkosal (2009), the Mekong River (MR) which is the main surface water in Mekong River Basin (MRB) has a mean annual discharge of 475 km^3 and empties its water into the South China Sea. During the rainy season, the MR carries the floodwater draining from the upstream areas to downstream areas such as Mekong Delta. This results in the destruction of properties and human life if the floods are high. It is approximate that during the wet season the MR discharge averages of 39,000 m^3/sec. The MR starts flowing from China where China itself contributes 13% and the annual flow from three countries of China, Myanmar and Lao is 73.63 km^3. Myanmar itself contributes an annual flow of 17.6 km^3 where Thailand contributes an annual flow of 51.9 km^3. Moreover, Cambodia receives the annual flow of 324.45 km^3 and releases the annual flow of 470 km^3 to Vietnam. According, to MRC (2005) the MRB formed by a huge network of tributaries (mainly in Lower Basin) which in-turn forms many sub-basins. In MD (at Phnom) the river divided into two main distributaries namely the Bassac and the Mekong. The Bassac divides into 3 channels and Mekong into 6 main channels, in order to form the 9 dragons, that outer delta in Vietnam. The flowing water flooded the Delta areas every year and this makes the floodplain to be the productive inland fishery in the world. This supports the economy as well as the health of Cambodia and the surrounding peoples. Finally, the Mekong River supports flowing water for several activities in the basin such as agricultural industrial and domestic activities. These activities, in turn, polluted downstream flowing water through entering chemicals and untreated wastewater and distort the quality of this river.

3.3.2 Groundwater

The groundwater is another sources of water that also support several activities in the basin. Some areas have recharge aquifers and others have very slow recharge water to their aquifers. Some areas such as mountainous areas of Lao and Vietnam highland has good freshwater aquifers. Most of the groundwater in both Lao and Vietnam are used for irrigating crops like coffee. On another hand, there is over-pumping of groundwater resources in Vietnam which makes water tables to decline day by day and also recharge of water go slowly. In Thailand, most aquifers have saline groundwater but also there is lower available freshwater though it makes difficult to use it to irrigate the farms. Furthermore, areas such as Tonle Sap and areas around Bassac have being found groundwater for shallow reserves though not sufficient for large-scale irrigation.

Other important areas in the Mekong basin which has aquifers up to six is Delta areas. Its aquifers range in a depth of 15 to 75 m and also from the depth of 275 to 400m. The Delta has more groundwater reserves but the problems are how to makes good exploration and to drill safely because the areas have many salts. The intrusion of saline to these delta groundwater resources is because most water tables undergo over pumping whereas water levels decline by 1.0 m. This led to oxidizing of the pyrite horizon into sulfate acid due to deep cracks formed in the soil.

3.4 The activities conducted within the basin

- ❖ Agriculture: For a long time, the Lower Mekong countries engaged mostly in the production of crops for household uses but nowadays they put more efforts to produces the crops for commercial and export to other foreign countries. They adopt advanced technology in their agricultural production. In Delta, there was an increase of 20% in land cultivation for crops plantation between 1976 and 1990. They produce varieties of crops such as rice, cassava, sugar cane, natural rubber, coffee, soybean and maize. A total of 109 million tons of paddy rice was being produced by Lower Mekong states in 2017. This lower Mekong country has a good rank of producing paddy rice in the world. The Vietnam, Thailand, and Myanmar ranked as 5th, 6th and 7th among the largest world paddy rise producers. Though the high extent of rice is being consumed within local markets, a part of the produced rice is export to foreign countries. The main exporters of rice are Thailand, Vietnam and Cambodia.

❖ **Fishing:** The Mekong river system apart of being named the world largest inland fishery is famous for a huge number of biodiversity after the Amazon river system. To showed how this diversity is important; about more than 75% of protein supplied to people living around the Mekong basin comes from fish products, fisheries, and aquaculture also estimated to provide about 4.4 million tons in 2015. These activities of fishing support the life of many people by providing food and also as a source of income by raising the GDP of riparian countries. Most people are living along river banks, and it's rich so as to get food (fish) for their survival. For example, the Delta area supports more than 60% of fish production in Vietnam.

3.5 The Crops Exported to Foreign countries

The lists of cash crops that exported from Lower Mekong Countries (LMC) to foreign countries are as follows:

❖ **Rice**: More areas have been cultivated, for example, in Delta, there was annually increased cultivated land of 100,000 ha during the period of 1995 -1999. The fields of paddy rice serve several functions such as; source of subsistence food, flood mitigation, soil erosion control and fishery production. In 2015, the export of rice generated USD millions to the Mekong countries as follows; Cambodia (326), Lao (29.1), Vietnam (2,300) and Thailand (4,390).

❖ **Natural rubber:** Thailand, Vietnam, Laos, and Cambodia are the main producers of natural rubber in MRB. There is an existence of big companies from Vietnam and China engaged in buying the produced natural rubber. The Vietnamese companies invest mostly in Cambodia and southern Laos while Chinese companies invest in northern Laos. In 2015 the commodity generated the incomes of USD millions for LMC as follows; Thailand (5160), Vietnam (1,097), Cambodia (142) and Lao (108).

❖ **Coffee**: Two countries namely Vietnam & Laos in the Mekong basin are well known all over the world for coffee production. In the period of 2011 - 2015 Vietnam exported coffee with an increased of more than 9% compared to previous years and it's ranked the second country for coffee export worldwide. Also, Laos is ranked the 5th country worldwide for exporting coffee. In 2015 both countries Lao and Vietnam generated USD millions 87.7 and 2,600 respectively for export of this commodity.

- ❖ Sugar cane: In 2015, the export commodity earned USD millions to the Mekong countries as follows; Cambodia (22.1), Lao (27.3), and Thailand (2,660).
- ❖ Soybean, Maize and Cassava

4. METHODOLOGY AND MODEL FORMULATION

Chapter overview

Chapter four explaining about the use of the WEAP model that observe the current situation of water resources by evaluates the previous streamflows and simulate the present demand scenarios. The different demands such as domestic, agriculture, industrial have been created for the current demands of the year 2016 and forecasted to the future scenarios (2017 – 2050). This kind of analysis which predicts the future use demands can enable the riparian states authorities to have good planning on water resources.

4.1 Scenario Analysis of Water Resources (Supply) and Demand Using WEAP Model

4.1.1 WEAP Model

There are several models used by river basin authorities for planning issues, support water allocation, water supply-demand analysis, water quality assessment, sedimentation transport and river flow routing (Mugatsia 2010). Some of this models are such as MODSIM, River Basin Simulation Model (RIBASIM), MIKE Basin, Water Balance Model (WBalMo), Multi-Sectoral, Integrated and Operational Decision Support System (MULINO-DSS) and Water Evaluation and Planning System (WEAP).

The WEAP model was developed by the Stockholm Environment Institute (SEI). The WEAP model can be applied to systems such as municipal and agricultural, and also addressed to wide range of issues such as demand analyses, water conservation, water rights and allocation priorities, groundwater and stream-flow simulations, reservoir operations, hydropower generation, pollution tracking, ecosystem requirements, vulnerability assessments, and project benefit-cost analyses (SEI 2005). According to Amisigo et al. (2015), they used WEAP to evaluate water availability and allocated various water demand in a given water basin system. WEAP model has two primary functions (Sieber et al. 2005; Amadou 2014; Arranz and McCartney 2007):

- Simulation of natural hydrological processes (e.g. evapotranspiration, runoff and infiltration) to enable assessment of the availability of water within a catchment.

- Simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (i.e. consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

There is a characterization of elements of water demand and supply in the WEAP system so as the simulation of water allocation to take place. The system under given catchment is represented by considering the various water sources such as surface water, groundwater, desalinization and water reuse elements; withdrawal, transmission, reservoirs, and wastewater treatment facilities, and water demands such as user-defined sectors but typically comprising industry, mines, irrigation, domestic supply, etc. According to SEI (2005), the WEAP system consists of 5 main views namely; Schematic, Data, Results, Overviews and Notes. This data structures and the level of detail can be combining demand sites to correspond to the requirements of a particular analysis and constraints imposed by limited data. A graphical interface facilitates visualization of the physical features of the system and their layout within the catchment (Sieber et al., 2005). Without a graphical interface, the constructing, modifying and viewing the whole system and the available data in the system will be impossible. This is because interactive screen structure, for example, assists to perform various duties such as to load data, calculate and reviewed the results. The WEAP system can accommodate and develop the needs of the users in a flexible manner. The output results are produced with quality information; satisfy the policy demand for future water use, supporting several requirements in management planning. WEAP model helps to balance water flows from upstream to downstream of the river basin system. It gives a room to abstract flowing water for created demands and allows also the minimum flow requirement for the environment. In the case of the simulation process, the software divides the river into reaches. Furthermore, there is a determination of reach boundaries in the river in areas of flow changes due to the confluence with river tributary, abstraction, return flow and in areas having structures like a dam or flow gauging. Finally, WEAP used to simulate different scenarios using “what if” to analyses the impact of developing and managing options, example the impact of analysis of water supply and demand it gives wide chance for authority to discuss on unmated water demand. A number of priorities which varies between 1 and 99 are assigned to demand sites. The assigned number 1 indicates the highest priority and the number 99 indicates the lowest priority. WEAP has being recognized as a comprehensive, easy-to-use, straight forward and endeavors to support.

4.1.1 WEAP Model Process

The WEAP process is always done by better assistance from the Main Screen. The Main Screen has the View Bar located on the left of the screen. Also, it has the Main Menu at the top of the screen which enabled to access all functions of the WEAP program. The modeling of any catchment or watershed or basin using the WEAP model consists of the below steps:

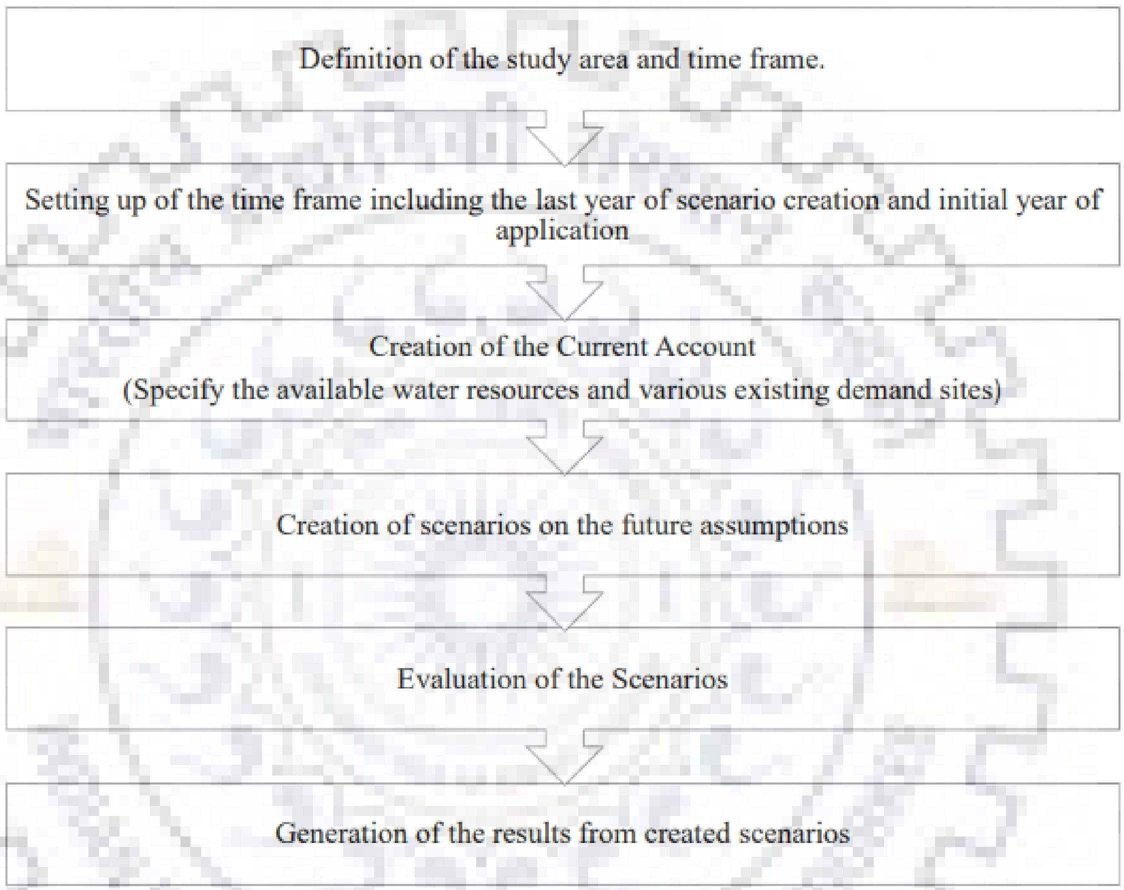

Figure 15: *Modeling process of WEAP.*

Source: Sunny (2016).

4.1.2 WEAP model for the Mekong Basin

In this study, the WEAP schematic that representing the Mekong basin was established by creating nodes to both water supply and demand. The study did not include the currently existing local irrigation, infrastructure of water supply and local dams in the study area. The required data was inputted and running the model. The data input on the side of demand differ and demand used here are agriculture water demand, industrial water demand and domestic water demand. The input on the supply data are those average monthly streamflows in Mekong River. The monthly streamflows data was available from 1990 – 2016. This data divided into two groups to calibrate and validate the model. The datasets (1990 – 1995) and (2010 – 2015) were used for calibration and validation of the WEAP model respectively. The year 2016 was used as a start-up year of the model, and the model forecasting the future water demand for a period of 2017 – 2050. The model gives an equal priority to meet the demands for created water demands mentioned above. As stated in study gaps, there is an altering of flow pattern and declining of down-stream flows in the Mekong River. This declining of stream flows requires scenarios analysis of water supply and demand for the basin, also simulating current demand scenarios for forecasting future use. This study used the monthly stream flows data for selected gauge station (Jinfeng) in the main river for the period of 1990 – 2016. The simulation took place to assess water resources (supply) and demand in the basin for the period of 2017 – 2050. All demand sites created within the basin is shown in Figure 4.2.

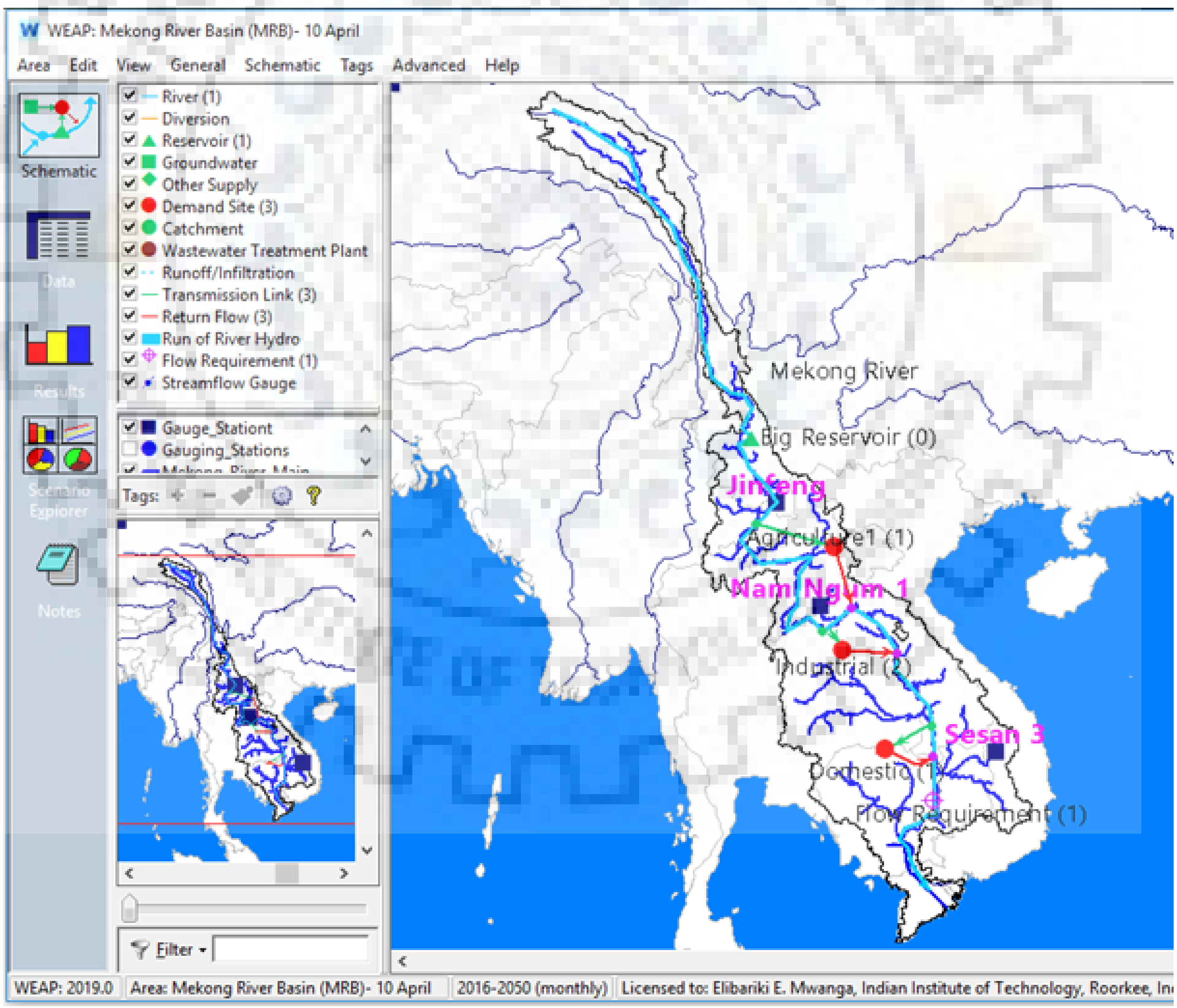

Figure 16: *Schematic View of Demand sites in Mekong River Basin*

4.1.3 Material and Methods

Data used in this analysis were obtained from various sources such as different reports, published papers, assumption where possible etc. The categories of the data are listed below;

- Population data
- Streamflow data (5 gauge stations)
- Domestic water demand
- Per capita water demand
- The agricultural demand
- The industrial demand
- Any other significant demand
- Rainfall distribution over the MRB
- Environmental flow requirement

4.1.3.1 Flow diagram of simulation methodology

The WEAP model system will consist of the following steps: Initial stage (start), collection of the necessary information, simulation of stream-flows data, define of demand scenarios, run WEAP model, obtain results and demand analysis.

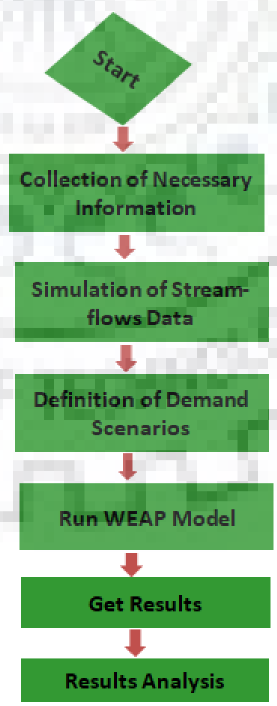

Figure 17: *The Schematic flow of the simulation methodology*

4.1.3.2 Water Supply

The WEAP model in this study used only the Mekong River as a source of supply. More details on this river were given in section 3.2 under the salient features of Mekong River Basin. However, worldwide the river ranked 12^{th} for its length and scored 8^{th} number in its water discharge (Dan et al., 2018). Because of the limitation of getting data for stream-flows from gauge stations along Mekong main river branches and its tributaries, the study decided to use only available data of one station (Jinfeng). These stream-flows data (1990 – 2016) were computed using excel to monthly mean flow as shown in Table 3.2.

Table 4.1: *Monthly data (year 2016) for simulation start up- current account scenario*

Month	**Flow (CMS)**
January	714.6
February	571.7
March	450.7
April	400
May	667.2
June	1055.5
July	2438.6
August	3229.2
September	2882
October	2133.5
November	1355.3
December	924.5

4.1.3.3 Water Demand

The ambitions to meet water demands for various sectors within the Mekong River Basin are influenced by population growth. According to FAO (2010), many of the countries in Southeast Asia are experiencing high population growth and increases in food demand. These analyses of water demand observe three water use sectors within MRB that were agriculture, domestic and industrial. The WEAP model was used to create the mentioned demands and modeling it, hence the obtained results were analyzed. Also, the issue of environmental flow requirement was observed in order to allow a certain amount of water to flow downstream of the Mekong basin for other living organisms. Water demand data for the sectors used in this model were obtained from different published papers, websites and books. The basin requires more water to meet the demand for estimation of more than 60 million people l, living in MRB. However, the study considers only a demand of 500,000 people who uses water for domestic demand at the water-use rate assumed to be 320 cubic meters per person annually. Apart from using this water-use rate the system required to use a domestic variation (unit less) as a key assumption on the basis of monthly time series throughout the year. The values of domestic variation used with their respective months varied from month to month. The model uses the Key Assumption "*Domestic Water Use = Domestic Water Variation *100 /12*" by entering the domestic variation for each month as follows; January (0.9), February (0.85), March (0.9), April (0.95), May (0.95), June (1.00), July (1.15), August (1.0), September (1.05), October (1.10), November (1.15) and December (1.00). Water demand for agriculture was estimated to irrigate 6,600,000 ha (Annual Activity Level) and application rate of water use in a year was 3,600 cubic meter per hectares (Annual Water Use rate). The extension of agriculture land for growing varieties crops requires more water. Example, an explanation from Hoanh et al. (2003) indicated the increased of 20% cultivation of areas for agriculture in Delta from 1976 to 1990 which also doubled production. Furthermore, Tuan et al. (2004a) said there was an increase in rice production from 1995 to 1999 whereby 100,000 hectares were cultivated in Delta. The WEAP model used monthly variation in the water use rate and in this study the monthly variation was as follows: For Months of January, February, November, December there were no variation, March (3%), April (13%), May (6%), June (5%), July (19%), August (28%), September (23%) and October (3%). The overall consumption of water for agriculture was 87 percentages. Furthermore, the study made consideration of industrial water demand by made its Annual Activity Level to be 30000 CMS. In addition to that, Annual Water Use Rate of the industry was made 30 cubic meters per second, consumption on current account for the industry is 20 per cent.

4.1.3.4 Population Growth

The overall population of the whole basin was estimated to be 60 million (MRB 2009). In the WEAP model analysis, the study used only a portion of the mentioned population to show the trends of water demand. The estimated population for domestic demand was 500,000 people and the growth rate was 2%. So the period of set up of this population in modeling was 2016 and for running scenarios the duration forecasted between 2017 – 2050. The mean annual growth rate in percentage was given during the creation of different scenarios.

4.1.4 WEAP Scenarios Description

The scenario is a conceivable description developed to predict and used to judge the future use of the systems. In WEAP model analysis of water supply and demands, the use of various scenarios helps to forecast the water demand for future use. Scenarios itself are neither predictions nor forecasts (Arranz et al. 2007). There are different types of scenarios based on the approach of their development, merits, and demerits (Kumar G., 2018). In most case, the researchers and modelers can use some categories such as strategic, exploratory and anticipatory as indicated by Mahmoud (2008). Strategic scenarios aimed to recognize the inconsistent behavior of a complex system regarding different disciplines and approaches where explicit assumptions, patterns, and data selected by the disciplines are emphasized (Mahmoud, 2008; Kumar, G., 2018). Furthermore, exploratory scenarios depict the future through courses of change and past observation predictions (McCarthy et al., 2001; Kumar, G., 2018).

In this study, a Reference scenario (2017 – 2050) was established from the current account (2016) to simulated evolution of the WEAP system without intervention. The WEAP model has an option on how to create a scenario by manage scenario and add a new scenario together with its percentage (population growth rate). Before the creation of different scenarios, in this study, "Additional Key Assumption" was created and its population growth rate on current accounts is taken as 1%. The percentage of one (1%) is chosen after closely observed and averaged the current growth rate of all six riparian countries that have difference growth rate as shown in the brackets as follows; Vietnam (0.97%), Laos (1.48%), Cambodia (1.6%), Thailand (0.18%), China (0.35%) and Myanmar (0.89%).

For domestic demand, the study observed the water demand needed by changing the growth rates. The scenarios were namely SC1, SC2, SC3, etc by changing the percentage of growth as from 1% to 1.2%, from 1% to 1.35%, from 1% to 1.5% respectively. The water demand scenarios thus considered as Lower Population Growth (SC1), Medium Population Growth (SC2) and Higher Population Growth (SC3) depends upon the growth rate of population applied in the reference scenario.

In irrigated agriculture demand, the scenarios focused on improving irrigation technology. Before creation and run scenarios in agriculture sector the data were entered to made changes in Unit Irrigation Water Use (an existing Key Assumption) to the annual pattern for a duration of 2016 – 2050 after 2016 (Current Accounts year). The data are being "interpolated" using a function together with “Yearly Time-Series Wizard” that helps to construct the time series by adding data. The study categorized the data in10 year interval and the following data were added to the time series as follows: values were 3600, 3400, 3350, and 3300 in (m^3) with respective years 2016, 2026, 2036 and 2046.

4.1.4.1 Water Efficiency Improvement Scenarios

In this section, two types of management scenarios were discussed based on Reference Scenarios (2017 – 2050). The scenarios were SC4- industry and SC5- urban and tourism. The stated scenarios required inputs data in WEAP data management so as to forecast the demand available for industry and another sector such as Urban and Tourism.

For industry scenario (SC4), the data management input was 42%. This percentage was a water target efficiency achieved for the whole industrial consumers. The improved water use efficiency acquired by use of new heating & cooling systems, new processing method, water reuse & recycling, water saving devices, and rainwater harvesting. The input data simulated and the results discussed in the next section 5.4.4.

For urban and tourism scenario (SC5), the data management input was 27%. The input percentage is a reduction percentage in total monthly demand after practice the management programs for improving efficiency in water use. The improved water use efficiency acquired by the installation of new pipes, Leakage reduction program, rainwater harvesting, and water saving devices. Finally, the input data simulated and the results discussed in the next section 5.4.5.

4.1.5 Reservoir and Flow Requirements Creation

The modeling of the Reservoir and adding Flow Requirements are important aspects in enabling the supply refinement in WEAP system. Also, the process of refining the supply is done by changing priorities in supply water resources for a given demand. More details are explained in section 4.2.3.4 and section 4.2.3.4.

4.1.3.4 Reservoir Creation

The new scenario named “Reservoir” was created on the reference account. Moreover, the reservoir object named “Big Reservoir” was added on the Mekong River above Agriculture demand object. Furthermore, the data of reservoir storage capacity was added by right click on the Big Reservoir and entering the required data. The data entered in this reservoir as a storage capacity was 60 Mm^3. Finally, the model was run and results were evaluated.

4.1.3.4 Flow Requirement Creation

The Flow Requirement object was created along the Mekong River, downstream of the Domestic demand object. The data was entered after the selection on the "Edit Data/Minimal Flow Requirement". A Minimal Flow Requirement of 7 CMS was entered and then the model was run and results evaluated.

5. RESULTS AND DISCUSSIONS

Chapter overview

This chapter gives out all discussion of the results from various developed scenarios. The outcome of the simulated WEAP model and its analysis summarized herein. Finally, the conclusions and recommendations, and thereafter references of the dissertation are presented in chapters six and seven respectively.

5.1 General

The study analyzed the outputs of the WEAP model for the Mekong River Basin. Moreover, it analyzed the results of different scenarios that simulated. The scenario results presented indicate how much water is needed to meet different demand for agriculture, domestic, industrial and allowing for minimal environment flow for the period of 2017 - 2050. Those analyze outputs from scenarios were the degree of satisfaction of the water demands in the dissimilar sectors. Furthermore, the analysis considered the changes of water supplied to the demand by the construction of a big reservoir (storage) and by allowing the minimal flow for the environment. The comparison of various results obtained from different scenarios was made with the aims of assessing the impact of water demands increase.

5.2 Current Account Scenario

This section explains the scenario under the gauge station located upstream namely Jinfeng (China). The stream-flows across this station considered in the study as a flow of Mekong River (MR) and it is given as average monthly stream flows in Million Cubic Meter. The results under the Current Account Scenario for this station covered the forecast period between 2017 and 2050. The monthly flow data were used to simulate the results in Current Account Scenarios using the average monthly stream-flows in CMS by given the required month and its value of flows in brackets as follow: January (714.6), February (571.7), March (450.7), April (400), May (667.2), June (1055.5), July (2438.6), August (3229.2), September (2882), October (2133.5), November (1355.3) and December (924.5). The flow observed in three categories on a monthly basis as high flow months, low flow months and normal/moderate monthly flows. The monthly highest flows occurred in August followed by the month of September. The moderate flows occurred in months of is June, July, October, November, and sometimes December. The lowest flows occurred in April. Other low flow months include January, February, March, and May. The inflow to the Mekong area can be observed in figure 5.1 below as it shows the stream-flows for the scenario developed in Jinfeng Gauge Station.

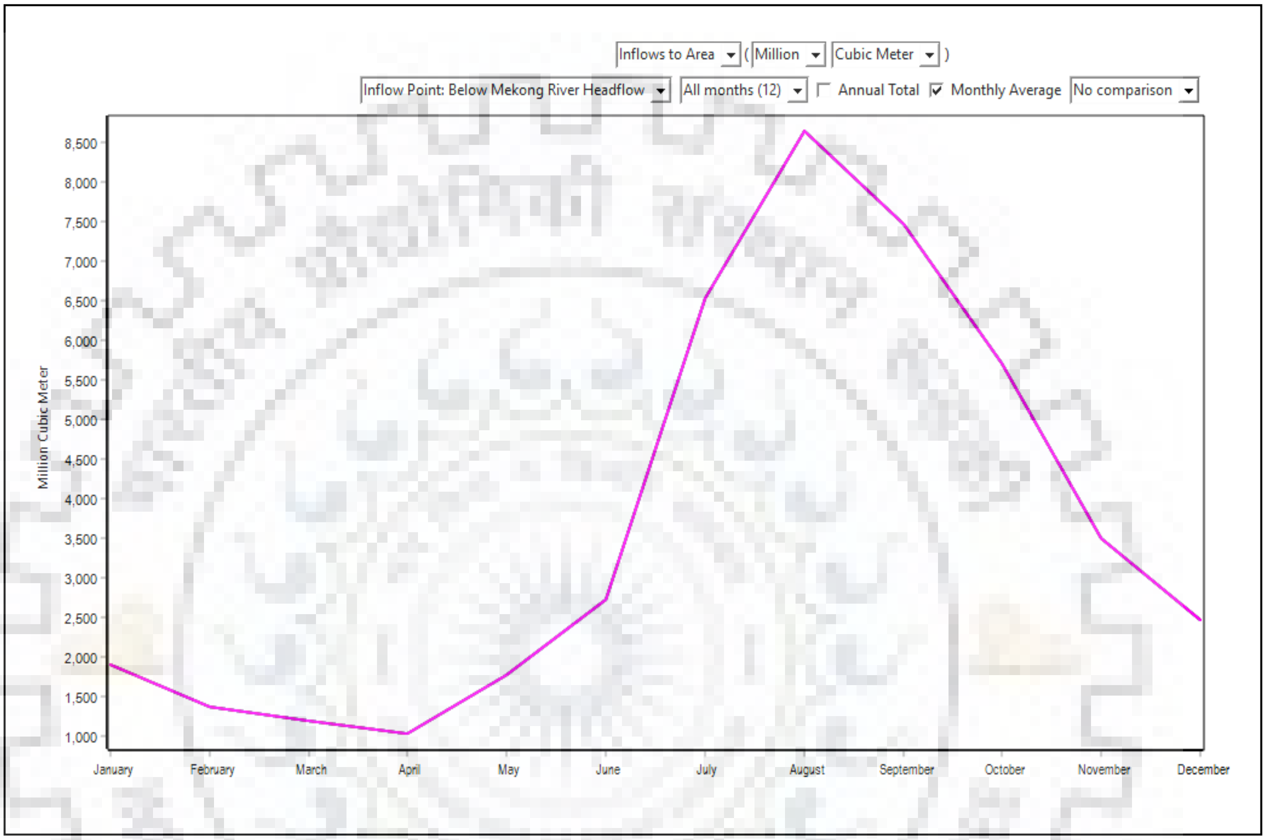

Figure 5.1: *The Stream-flows under current scenario (Jinfeng Gauge Station)*

The evolution of the various water demand scenarios was best illustrated in figure 5.2 as shown below. The demand for water increases as the population growth increase. The demand for the current year 2016 was estimated to be 23.92 Billion Cubic Meter before the simulation of scenarios

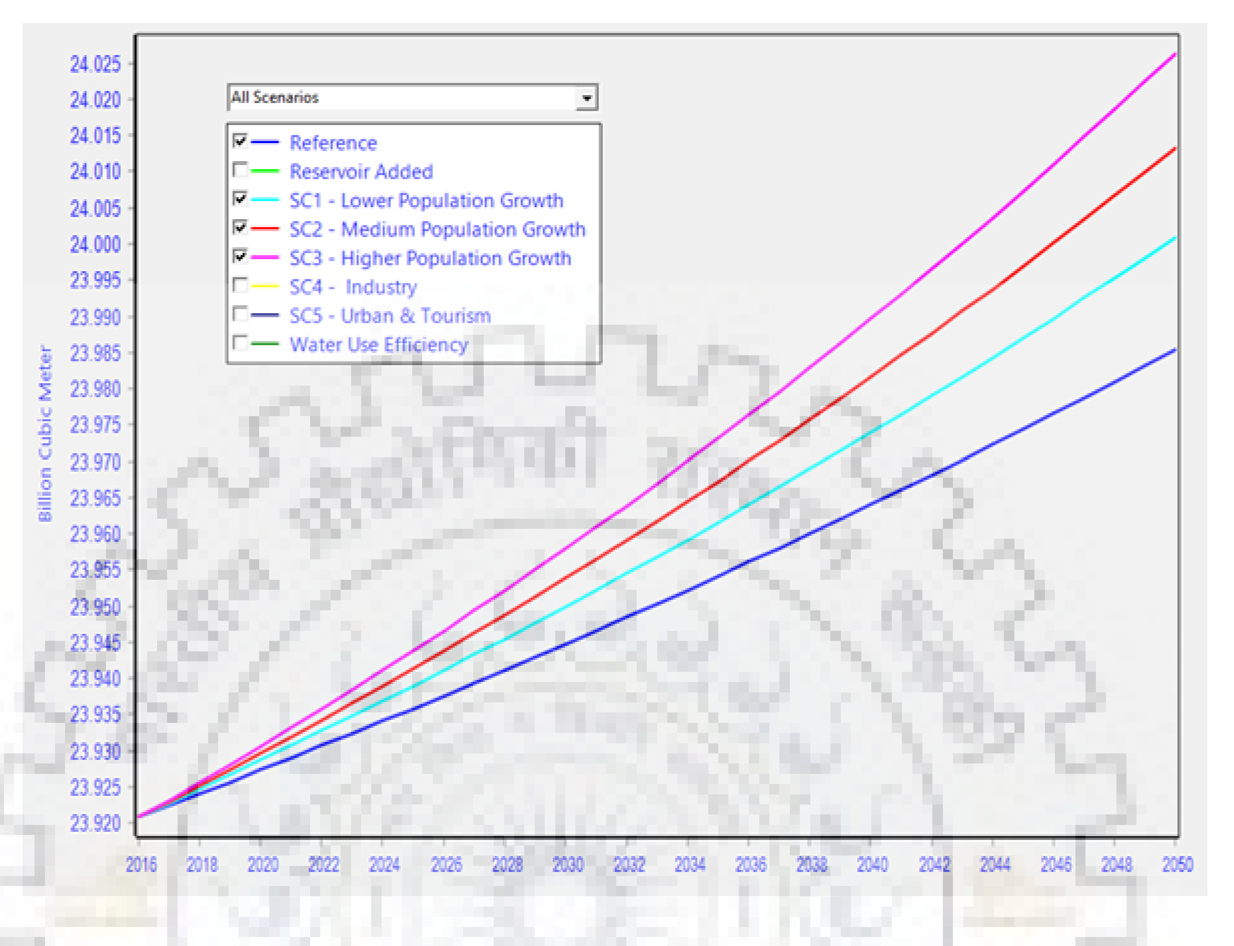

Figure 18: *The Water Demand Scenarios in Mekong River Basin.*

The summaries of the total water demand from the year 2016 to 2050 for the given scenarios in figure 5.2 were as follows: The Lower Population Growth (SC1) raised the total demand of water to be 838.54 Billion Cubic Meter, where scenario used the only annual growth rate of 1.2%. Moreover, the Medium Population Growth (SC2) and Higher Population Growth (SC3) raised the water demand to be 838.73 and 838.93 Billion Cubic Meter by using annual growth rates of 1.35% and 1.5% respectively.

5.3 Reference Scenario

The various scenarios were simulated under the reference scenario (2017 – 2050). In most cases the set of scenarios postulate What-if there would be certain factors like; "What if" there would be High Population Growth but improving the abstraction or improving the storages", etc. Three major scenarios were discussed in section 5.4.1 "SC1 – Lower Population Growth", in section 5.4.2 "SC2

– Medium Population Growth” & in section 5.4.3 “SC3 – Higher Population Growth”, and their monthly demand were shown in Table 5.1.

Table 5.1: *Monthly Average Water Demand Data (2017 - 2050) for Mentioned Scenarios*

	Monthly Average Water Demand (not including loss, reuse and DSM) in Million Cubic Meter											
Scenarios	Jan.	Feb.	Mach.	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
SC1	16	15	729	3105	1442	1204	4531	6669	5481	729	16	16
SC2	17	15	730	3105	1442	1204	4531	6670	5481	730	16	17
SC3	17	16	730	3106	1443	1205	4532	6670	5482	730	17	17
SC4	13	12	726	3102	1439	1201	4528	6666	5478	726	13	13
SC5	13	12	726	3102	1439	1201	4528	6666	5478	726	13	13

5.3.1 SC1 – Lower Population Growth (1.2%)

In this scenario, the simulation results indicated that there was an increase of water demand. The water demand in the year 2017 was 23.92 Billion Cubic Meter (BCM) and the water demand in the year 2050 was 24.0 Billion Cubic Meter. The total water demand as predicted in reference scenario (2017 – 2050) was 814.62 BCM. The trends of increasing water demand shown in Figure 5.3.

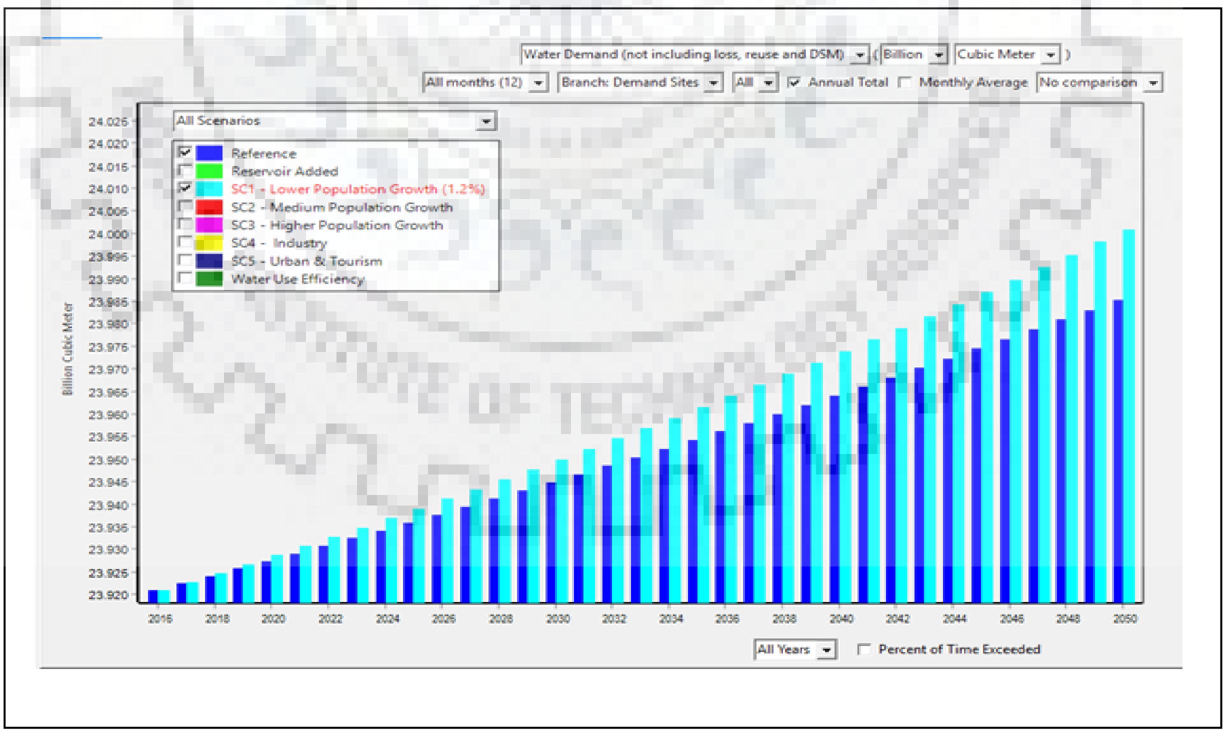

Figure 19: *Water Demand Simulation Trends for Lower Population Growth Scenario*

5.3.2 SC2 – Medium Population Growth (1.35%).

Simulation results of the mentioned SC2 showed that there was an increase in water demand as the time moved on. The water demand was observed to be 23.92 and 24.01 BCM in the year 2017 and 2050 respectively. Generally, the trends of water demand can be observed in below in Figure 5.4.

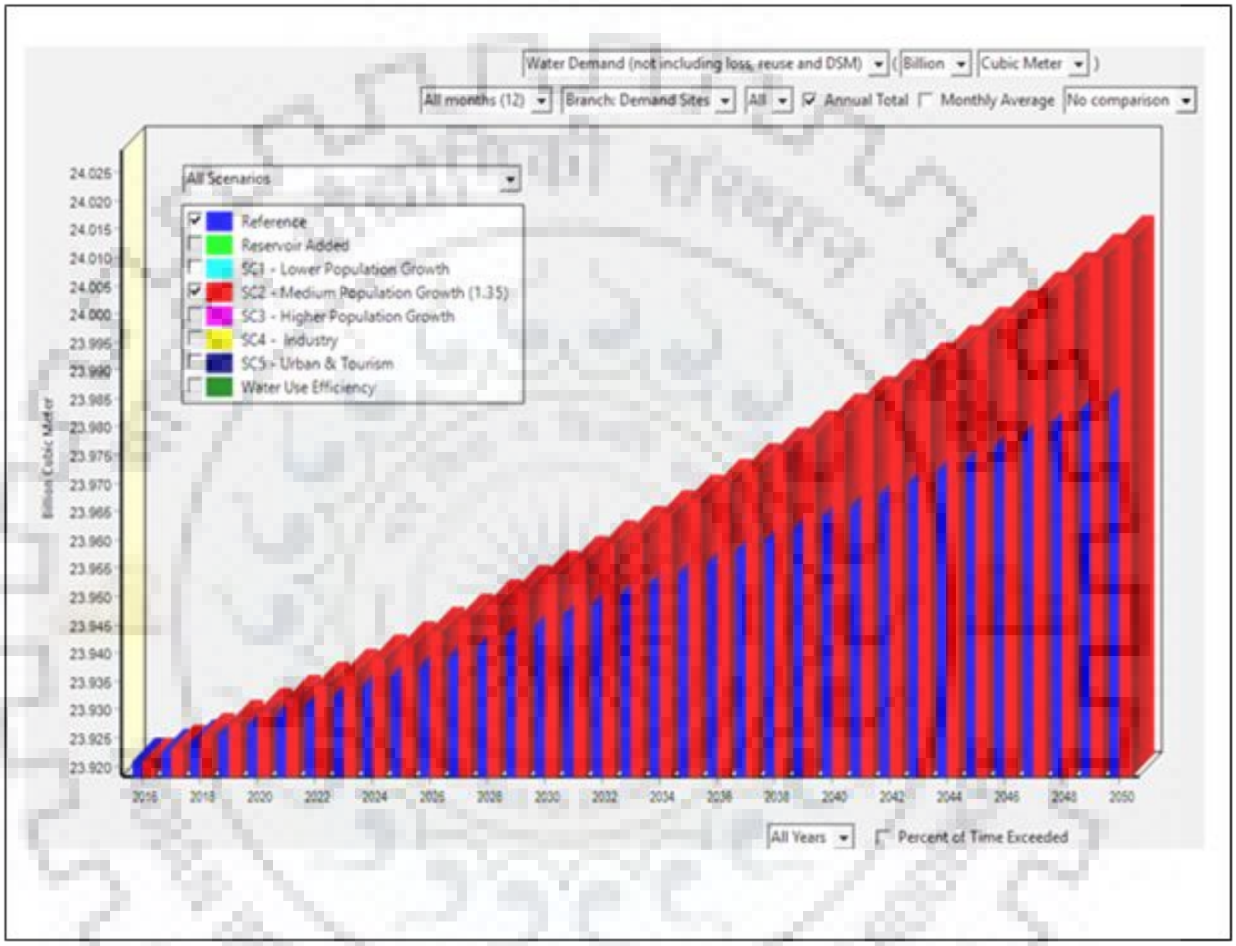

Figure 20: *Water Demand Simulation Trends for Medium Population Growth Scenario*

5.3.3 SC3 – Higher Population Growth (1.5%)

In this scenario, the simulation results indicated that the water demand in the year 2017 was 23.92 BCM while that of the year 2050 was 24.03 BCM. The trends of water demand simulation can be observed below in Figure 5.5.

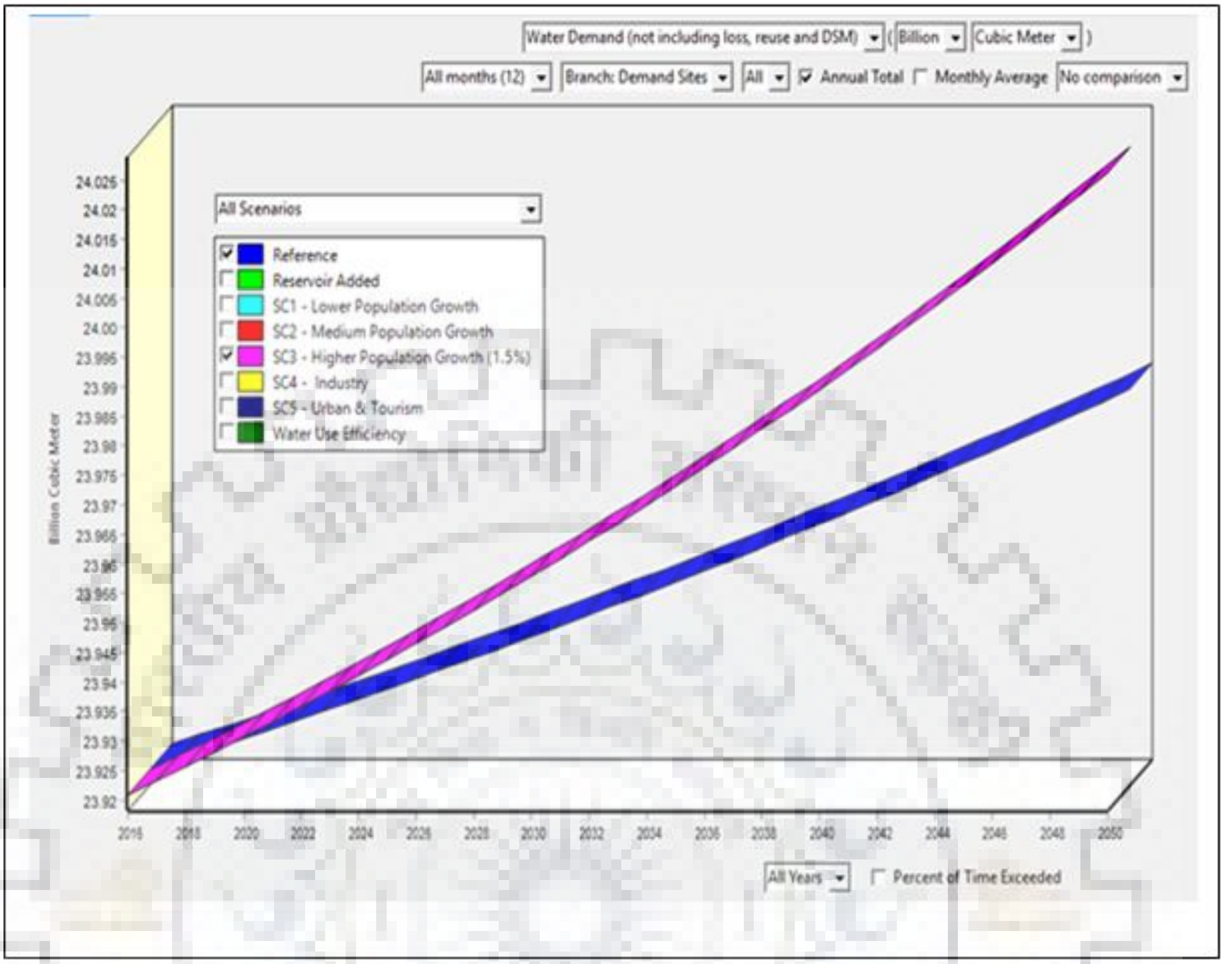

Figure 21: *Water Demand Simulation Trends for High Population Growth Scenario*

6. SUMMARY AND CONCLUSION

The Mekong River, a well-known river in Southeast Asia, is a very important river for serving the life of many species of fish, animals, plants, and providing food, water and other financial opportunities for the population living in Mekong Basin. There is a need for sustainable development in the Mekong River Basin in order to have a good balance in the use of water resources. In addition to this, sustainable development will ensure water, food and energy security. This study focus on water governance and the use of the WEAP model to analyzed water supply and demands in the Mekong River Basin.

The WEAP model was used to simulate various water demands. The main target of simulating that water demand was to observe the possible water demand of the created domestic water demand, agriculture water demand, industrial water demand, and allowing water for environmental flow requirements. The model used scenarios of water demand to forecast the future water demand (reference demand) for a period of 33 years from 2017 to 2050.

The WEAP model used the Mekong River as a source of water supply. The input data on the river was monthly stream-flows data. Also, the level of priorities for the supply was considered to be equal. For demand sides, input data were; the estimated population for domestic water use, per capita water use, monthly percentage variation on irrigation water use, the allowable amount for environment flow, etc. Moreover, some assumptions were made where possible to meet the model requirements in the modeling Mekong Basin.

This study provides some general conclusions related to the theoretical part, methodology and model formulation as follows;

1. The Mekong River Basin problems and challenges were identified; this is a big step in achieving sustainable development within the basin. This should go parallel with the cooperation of all riparian countries so as to handle all issues of transboundary together. The cooperation here can be in forms of mutual co-operation, friendship and goodwill. Furthermore, good cooperation and coordination will improve the use of water resources in effectiveness ways, expand social and economic development, improve the environment, raise international trade, etc.

2. The MRC must endure with efforts to facilitate riparian states to negotiate on issues of water resources through a joint examination of specific development scenarios to enumerate uncertainties. Also, should emphasize and strengthen water governance so as to improve decision making and trans-boundary cooperation.

3. The Integration of Water Resources Development and Management concept is highly needed for the healthy development of the Mekong basin through local engagement to a higher level.

4. The impending development of some projects like the construction of the dams along the Mekong River should be observed carefully to avoid any potential loss of economy as well as the ecological, social and cultural values in the basin

5. The water demand increases as the population increases; this is clearly seen for the water scenarios generated in different growth rate.

The use of the WEAP model for the analysis of water resources (supply) and the demand needs more and realistic data rather than more assuming data. In case of future studies in Mekong River Basin, the riparian state authorities can use WEAP model for decision making in their water resources planning and allocation. This study may give only ideals on how to use the WEAP model in the basin for analysis and more studies are needed to come on with a realistic solution on governing Mekong river basin for sustainable development.

Appendix. Trans-boundary River Basins and Shared Countries

Table 2.1b: *Trans-boundary River Basins and Shared Countries*
(Source: UN (2011); A.T Wolf et al. (1999); Ntem, B. and Melvin, L. (2016))

No.	Basin Name	Shared Countries
1.	Lotagipi Swamp	Kenya, Uganda, Ethiopia, Ilemi triangle and South Sudan
2.	Akpa	Nigeria and Cameroon.
3.	Awash	Ethiopia, Djibouti, Somalia and Eritrea
4.	Amacuro	Venezuela and Guyana
5.	Amazon	Colombia, Bolivia, Brazil, Ecuador, French, Guyana, Suriname, Peru Guiana, and Venezuela
6.	Amur	Korea, China, , Russian Federation, Mongolia
7.	An Nahr Al Kabir	Syrian Arab Republic, and Lebanon
8.	Aral Sea	China, Afghanistan, Kashmir and Jammu, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan
9.	Artibonite	Dominican and Haiti
10.	Asi/Orontes	Syrian, Turkey and Lebanon

No.	Basin Name	Shared Countries
11.	Astara-Chay	Azerbaijan, and Iran
12.	Atrak	Turkmenistan and Iran
13	Atui	Mauritania and Western Sahara
14.	Aviles	Argentina, Chile
15.	Aysen	Argentina and Chile
16.	Zarumilla	Peru and Ecuador
17.	Ma	Vietnam and Laos
18.	Mana-Morro	Liberia, Guinea, and Sierra Leone
19.	Maputo	Mozambique, Swaziland, South Africa
20.	Maritsa	Greece, Bulgaria, and Turkey
21.	Maro	Papua New Guinea, and Indonesia
22.	Maroni	Brazil, Suriname, and French Guiana
23.	Massacre	Haiti and Dominican
24.	Mataje	Ecuador and Colombia
25.	Mbe	Equatorial Guinea and Gabon
26.	Medjerda	Tunisia and Algeria
27.	Ca/Song-Koi	Vietnam and Laos
28.	Mino	Spain, Portugal
29.	Mira	Ecuador and Colombia
30.	Mius	Federation of Russian, and Ukraine
31.	Rudkhanehe/ BahuKalat	Iran and Pakistan
32.	Baker	Argentina and Chile
33.	Bangau	Malaysia, and Brunei Darussalam
34.	Bann	United Kingdom and Ireland
35.	Baraka	Sudan and Eritrea
36.	Barima	Venezuela and Guyana
37.	Barta	Latvia and Lithuania
38.	His/Bei Jiang	Viet Nam and China
39.	Beilun	Vietnam and China
40.	Belize	Belize and Guatemala
41.	Ntem/Benito	Cameroon, Equatorial Guinea and Gabon
42.	Bia	Ghana and Côte d'Ivoire
43.	Bidasoa	France and Spain
44.	Buzi	Mozambique and Zimbabwe
45.	Cancoso/Lau ca	Bolivia, Chile
46.	Candelaria	Mexico and Guatemala
47.	Carmen Silva-Chico	Argentina and Chile
48.	Castletown	United Kingdom (UK) of Great Britain and Ireland
49.	Moa	Sierra Leone, Guinea, and Liberia
50.	Moho	Belize, and Guatemala
51.	Mono	Togo and Benin
52.	Motaqua	Honduras, and Guatemala
53.	Muhui	Bangladesh and India
54.	Murgab	Turkmenistan and Afghanistan.
55.	Nahr El Kebir	Turkey and Syrian
56.	Narva	Estonia, Russian Federation, Belarus, and Latvia
57.	Negro	Nicaragua and Honduras
58.	Nelson-Saskatchewa n	Canada, United States of America
59.	Neman	Lithuania, Poland, Belarus, Latvia and Russian Federation
60.	Neretva	Croatia, Bosnia and Herzegovina
61.	Nestos	Greece and Bulgaria
62.	Niger	Burkina Faso, Algeria, Benin, ,Côte d'Ivoire, Cameroon, Mauritania, Guinea, Niger, Mali,

No.	Basin Name	Shared Countries
		Nigeria, Chad and Sierra Leone
63.	Nyanga	Gabon and Congo,
64.	Naatamo	Norway and Finland
65.	Pungwe	Mozambique and Zimbabwe
66.	Oder/Odra	Czech Republic, Germany, Poland, Slovakia
67.	Catatumbo	Colombia, Venezuela
68.	Cavally	Liberia, Côte d'Ivoire, and Guinea
69.	Cestos	Liberia, Côte d'Ivoire, and Guinea
70.	Chamelecon	Honduras and Guatemala
71.	Changuinola	Panama and Costa Rica
72.	Chilkat	USA and Canada
73.	Chiloango	DR Congo and Angola
74.	Chira	Peru and Ecuador
75.	Chiriqui	Panama and Costa Rica
76.	Choluteca	Nicaragua and Honduras
77.	Chuy	Brazil and Uruguay
78.	Coatan Achute	Mexico and Guatemala
79.	Segovia/ Coco	Nicaragua and Honduras
80.	Colorado	USA and Mexico
81.	Columbia	USA and Canada
82.	Comau	Argentina and Chile
83.	Conventillos	Nicaragua and Costa Rica
84.	Corantijn/ Courantyne	Brazil, Suriname and Guyana
85.	Corredor es/ Colorad o	Panama and Costa Rica
86.	Corubal	Guinea and Guinea-Bissau
87.	Coruh	Turkey and Georgia
88.	Cross	Nigeria and Cameroon
89.	Ogooue	Cameroon, Congo, Gabon, Equatorial

No.	Basin Name	Shared Countries
		Guinea
90.	Oyupock/ Oiapoque	Brazil and French
91.	Okavango	Zimbabwe, Angola, Namibia and Botswana
92.	Olanga	Russian Federation and Finland
93.	Ural/Oral	Kazakhstan and Russian Federation
94.	Orange	Lesotho, South Africa, Botswana and Namibia
95.	Orinoco	Colombia, Brazil, Venezuela and Guyana
96.	Oued Bon Naima	Morocco and Algeria
97.	Oueme	Nigeria, Benin and Togo
98.	Oulu	Russian and Finland
99.	Pakchan	Thailand and Myanmar
100.	Palena	Argentina and Chile
101.	Pandaruan	Malaysia and Brunei Darussalam
102.	Pangani	Tanzania and Kenya
103.	Parnu	Latvia and Estonia
104.	Pascua	Chile and Argentina
105.	Patia	Colombia and Ecuador
106.	Paz	El Salvador and Guatemala
107.	Pedernales	Haiti and Dominica
108.	Po	Switzerland, Italy and France
109.	Prohladnaja	Russian and Poland
110	Psou	Russian and Georgia
111.	Cullen	Argentina and Chile
112.	Cuvelai/Etos ha	Namibia and Angola
113.	Daoura	Morocco and Algeria
114.	Dasht	Pakistan and Iran
115.	Daugava	Belarus, Estonia, Lithuania, Latvia, Russian Federation
116.	Digul	Papua New Guinea and

No.	Basin Name	Shared Countries
		Indonesia,
117.	Dnieper	Ukraine, Belarus and Russian
118.	Dniester	Ukraine, Moldova and Poland
119.	Don	Ukraine and Russian
120.	Douro/Duero	Portugal and Spain
121.	Dra	Morocco and Algeria
122.	Dragonja	Croatia and Slovenia
123.	Drin	Montenegro, Albania, Yugoslav and Serbia
124.	Ebro	Andorra, Spain, France, Austria, Czech, Germany and Poland
125.	El Naranjo	Nicaragua and Costa Rica
126.	Elancik	Ukraine and Russia
127.	Elbe	Germany, Austria, Poland and Czech
128.	Erne	United Kingdom (UK) of Great Britain and Ireland
129.	Pu Lun T'o	Mongolia and China
130.	Puelo	Argentina and Chile
131.	Red/Song Hong	China, Lao People's Democratic Republic, Vietnam
132.	Rezvaya	Bulgaria, Turkey
133.	Pasvik	Norway, Russian and Finland
134.	Rhone	Switzerland, France and Italy
135.	Rio Grande (N. America)	Mexico, United States of America
136.	Rio Grande (S. America)	Argentina and Chile
137.	Roia	Italy and France
138.	Ruvuma	Tanzania, Mozambique and Malawi
139.	Sabi	Mozambique and

No.	Basin Name	Shared Countries
		Zimbabwe
140.	Saigon	Cambodia, Vietnam
141.	Salaca	Latvia and Estonia
142.	Salween	Myanmar, Thailand and China
143.	Samur	Azerbaijan and Russia
144.	San Juan	Nicaragua and Costa Rica
145.	San Martin	Argentina and Chile
146.	Sanaga	Cameroon, Central African and Nigeria
147.	Essequibo	Guyana, Brazil and Venezuela
148.	Fane	United Kingdom and Ireland
149.	Fenney	India and Bangladesh
150.	Firth	USA and Canada
151.	Flurry	United Kingdom, and Ireland
152.	Fly	Papua New Guinea and Indonesia
153.	Foyle	United Kingdom, and Ireland
154.	Fraser	USA and Canada
155.	Gallegos/Chi co	Argentina and Chile
156.	Gambia	Gambia, Guinea and Senegal
157.	Ganges-Brahmaputra -Meghna	Bhutan, Arunachal Pradesh, Bangladesh, Myanmar, China, India and Nepal
158.	Garonne	France, Andorra and Spain
159.	Gash	Sudan, Eritrea and Ethiopia
160.	Gauja	Latvia and Estonia
161.	Geba	Senegal, Guinea and Guinea-Bissau
162.	Glama	Sweden and Norway

No.	Basin Name	Shared Countries
163.	Goascoran	El Salvador and Honduras
164.	Golok	Thailand and Malaysia
165.	Sarata	Ukraine and Moldova
166.	Sarstun	Belize, and Guatemala
167.	Sassandra	Guinea and Côte d'Ivoire,
168.	Schelde	France, Belgium and Netherlands
169.	Sebuku	Malaysia, and Indonesia
170.	Seine	France and Belgium
171.	Sembakung	Indonesia, and Malaysia
172.	Senegal	Mali, Guinea, Mauritania and Senegal
173.	Seno Union/ Serrano	Argentina and Chile
174.	Sepik	Papua New Guinea and Indonesia
175.	Chu/Shu	Kazakhstan and Kyrgyzstan
176.	Sixaola	Panama and Costa Rica
177.	Skagit	USA and Canada
178.	Song Vam Co Dong	Vietnam and Cambodia
179.	St. Croix	USA and Canada
180.	St. John (Africa)	Liberia, Côte d'Ivoire and Guinea
181.	St. John (North America)	USA and Canada
182.	St. Lawrence	USA and Canada
183.	Great Scarcies	Sierra Leone and Guinea
184.	Grijalva	Belize, Guatemala and Mexico
185.	Guadiana	Portugal and Spain
186.	Guir	Algeria and Morocco

No.	Basin Name	Shared Countries
187.	Hamun-i-Mashkel/ Rakshan	Afghanistan, Iran and Pakistan
188.	Han	Democratic People's Republic of Korea, and the Republic of Korea
189.	Har Us Nur	Mongolia, China and Russia
190.	Harirud/Hari	Afghanistan, Turkmenistan and Iran
191.	Helmand	Afghanistan, Iran and Pakistan
192.	Hondo	Belize,Guatemala and Mexico
193.	Kunes He/ Ili	China, Kazakhstan and Kyrgyzstan
194.	Incomati	Mozambique, Swaziland and South Africa
195.	Little Scarcies	Sierra Leone and Guinea
196.	Irrawaddy	China, Arunachal Pradesh, India and Myanmar
197.	Isonzo	Italy and Slovenia
198.	Jacobs	Norway and Russia
199.	Jayapura	Papua New Guinea and Indonesia
200.	Yenisey/ Jenisej	Mongolia and Russia
201.	St. Paul	Liberia and Guinea
202.	Stikine	USA and Canada
203.	Struma	Greece,Bulgaria, Yugoslav and Serbia
204.	Suchiate	Guatemala and Mexico
205.	Sujfun	Russia and China
206.	Sulak	Azerbaijan, Georgia and Russia
207.	Tafna	Algeria and Morocco
208.	Tagus/Tejo	Portugal and Spain

No.	Basin Name	Shared Countries
209.	Taku	USA and Canada
210.	Talas	Kazakhstan, Kyrgyzstan and Uzbekistan
211.	Tami	Papua New Guinea and Indonesia
212.	Tana	Finland and Norway
213.	Tano	Côte d'Ivoire and Ghana
214.	Tarim	China, Tajikistan Aksai Chin, Afghanistan, Jammu and Kashmir, Kazakhstan, and Kyrgyzstan
215.	Temash	Belize and Guatemala
216.	Terek	Russia and Georgia
217.	Thukela	South Africa and Lesotho
218.	Shatt al Arab /Tigris-Euphrates	Iran, Iraq, Saudi Arabia, Turkey, Jordan and Syria
219.	Jordan	Israel, Lebanon, Egypt, West Bank, Jordan and Syrian
220.	Juba-Shibeli	Somalia, Ethiopia and Kenya
221.	Jurado	Panama and Colombia
222.	Kaladan	Bangladesh, India and Myanmar
223.	Karnaphuli	India, Myanmar and Bangladesh
224.	Kemi	Russia, Finland and Norway
225.	Klaralven	Sweden and Norway
226.	Kogilnik	Ukraine and Moldova
227.	Komoe	Ghana, Burkina Faso, Mali and Côte d'Ivoire
228.	Kowl E Namaksar	Iran and Afghanistan
229.	Krka	Croatia, Bosnia and Herzegovina
230.	Kunene	Namibia and Angola
231.	Kura-Araks	Azerbaijan, Armenia, Georgia, Russia, Iran and Turkey
232.	La Plata	Argentina, Bolivia, Brazil, Paraguay and Uruguay
233.	Lagoon Mirim	Brazil and Uruguay
234.	Lake Chad	Chad ,Cameroon, Libya, Central African, Algeria, Niger, Sudan and Nigeria
235.	Lake Fagnano	Argentina and Chile
236.	Tijuana	USA and Mexico
237.	Tjeroaka-Wanggoe	Indonesia and Papua New Guinea
238.	Torne/ Tornealven	Sweden, Finland and Norway
239.	Tuloma	Russia and Finland
240.	Tumbes	Peru and Ecuador
241.	Tumen	Korea , China, Russia
242.	Umba	Tanzania and Kenya
243.	Umbeluzi	Mozambique, Swaziland and South Africa
244.	Utamboni	Equatorial Guinea and Gabon
245.	Valdivia	Argentina and Chile
246.	Vanimo-Green	Papua New Guinea and Indonesia
247.	Vardar	Greece, Bulgaria , Yugoslav and Serbia
248	Velaka	Turkey and Bulgaria
249.	Venta	Latvia and Lithuania
250.	Vijose	Greece and Albania
251.	Wista/Vistul a	Belarus, Czech Republic, Poland, Slovakia and Ukraine

No.	Basin Name	Shared Countries
252.	Volga	Kazakhstan and Russia
253.	Lake Natron	Kenya, Tanzania, Greece, Yugoslav and Albania
254.	Lake Prespa	Greece, Yugoslav and Albania
255.	Lake Titicaca-Poopo System	Bolivia, Peru and Chile
256.	Lake Turkana	Kenya, Uganda, Ethiopia, South Sudan and Ilemi triangle
257.	Lake Ubsa-Nur	Russia and Mongolia
258.	Pregel/Lava	Lithuania, Russia and Poland
259.	Lempa	El Salvador, Guatemala and Honduras
260.	Lielupe	Latvia and Lithuania
261.	Lima	Portugal and Spain
262.	Limpopo	South Africa, Botswana, Zimbabwe and Mozambique

No.	Basin Name	Shared Countries
263.	Loes	Timor-Leste and Indonesia
264.	Loffa	Liberia and Guinea
265.	Volta	Côte d'Ivoire, Benin, Ghana, Burkina Faso, Mali and Togo
266.	Vuoksa	Russia, Belarus and Finland
267.	Wadi Al Izziyah	Lebanon and Israel
268.	Whiting	USA and Canada
269.	Wiedau	Denmark and Germany
270.	Yalu	Korea and China
271.	Yaqui	USA and Mexico
272.	Yelcho	Argentina and Chile
273.	Yser	France and Belgium
274.	Yukon	USA and Canada
275.	Zapaleri	Argentina ,Bolivia and Chile
276.	Lough Melvin	United Kingdom (UK) of Great Britain and Ireland

CHAPTER SEVEN

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