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THE STATE OF THE GLOBAL WATER RESOURCES: HOW SUSTAINABLY DO WE USE THEM?

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ABSTRACT

The presentation will overview the current global perspective on freshwater with a view identify major likely future challenges along with an outline of potential opportunities for solutions. Given the projected demands for water, and the likely impact of climate variability and change, the present water uses, including those in/of rivers and lakes, are clearly not sustainable. Finally, the political recognition is born that freshwater is a major global issue. The presentation will attempt to identify the technical, social and ecological challenges that need to be addressed to establish sustainable river development and management practices for the future in the context of lake management. It will look into the catchment scale hydrological impacts of various global change drivers. All these changes imply strong non-stationarity. It will be argued that the design methodologies, such as the concept of design floods, developed under the hypothesis of stationary hydrological processes, need to be revisited and updated. Potential impacts of climate change will also be outlined along with the likely increase in the occurrence of extreme events such as floods and droughts. Mitigation and adaptation measures will shortly be outlined. Of the later structural and non-structural measures will be shortly examined. The presentation will argue that the re-examination of some of the structural measures, such as the need for more water storage, the need for more intensive hydropower development and the need to further develop inland navigation, respectively, is a timely task. These measures will pose new social and ecological challenges but also offer new opportunities. Various hypotheses will be entertained as to the relative importance of the various global drivers at catchment scale. The big question is: are we really dealing with the most important issues? What is indeed the major driver that will determine how rivers and lakes will be managed two generations from now? In case of transboundary water bodies, where nearly half of humanity leaves, who calls the shots? How effective international cooperation is? Why do we need that, to start with? Is sustainable water management an ethical and cultural issue or simple a matter of engineering by more structures? Isn't water just a matter of quick technical fixes by applying more technology? Is water a source of conflict or that of cooperation? Some of the potential responses to these questions will be outlined along with an assessment of emerging research needs.

TS2-2

日本における流域の水循環・水資源管理の展開と課題

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キーワード：流域水循環，水資源開発，水資源管理，リスク管理型

抄録

水資源の適切な開発管理は，流域における生活や生産の基本であり，そのためには流域の水循環の健全な保全管理が求められる。これは，流域における湖沼水資源の持続的利用はもちろんのこと，流域や関連するする地域や海域の環境保全の基本的な要件である。

日本では，流域における健全な水循環を維持・回復させ，経済社会や国民生活の一層の発展・安定を図るために，地下水を含む水循環に関する施策を総合的・一体的に推進する「水循環基本法」が 2014 年に施行された。また，主要水系においては，水資源の需給の逼迫度の低減，気候変動や災害対応の必要度の増大などを背景に，「リスク管理型」向けての水資源開発基本計画の改訂が 2017 年より順次進められている。

本報告では，日本におけるこれら水循環や水資源の開発管理に関わる基本的な考え方や法制度等の枠組みの近年の整備状況を整理し，湖沼を含む淡水資源の，今後の一層の持続的な利用に向けての課題を検討する。

1.　はじめに

流域の水資源の適切な開発・管理は，生活や生産の基本であり，そのためには流域の水循環の健全な保全と管理が求められる。これは，流域における湖沼水資源の持続的利用はもちろんのこと，流域や関連するする地域や海域の環境保全の基本的な要件である。日本では，洪水災害の防止や軽減とともに，安定した水供給のための制度が整えられ，さまざまな施設整備事業が進められてきた。また，水質や生態系を含め流域水環境の保全も取り組まれてきた。

近年，これらの整備の進展や水供給の安定化を踏まえ，また経済成長動向や人口動態の変化を背景に，新たに制度や仕組みの整備がなされ，その実施の具体化が進められている。本報告では，日本におけるこれら水循環や水資源の開発・管理の展開を整理し，水資源の今後の一層の持続的な利用に向けての課題を検討する。

2.　日本における治水と利水の展開の概要

日本はモンスーン地域に位置し，夏季の豪雨・洪水と干ばつ・渇水は，古来国土管理の中心的な課題であった。水資源の開発・管理に関しては，水田稲作のための用水確保が古代からの継続した課題で，近世に入っての進展と新田開発は，その後の人口増加と社会システムの基盤を形成した。近代に入っても，この基本は継続し，とくに第二次世界大戦以降は，土木技術の発展や経済成長に伴う都市用水の需要増大などを背景に，流域の水循環を管理し，水資源を開発する事業はより大規模に展開されてきた。

その結果として，洪水等の水害で死亡する人の数は大きく減少した。また，大規模な水資源開発によって，増大した需要にほぼ対応した用水供給が実現し，各地で頻発していた「水不足」も，限られた地域や期間に限られるようになったといえる。

一方で，高度経済成長や人口増加と集中に対応した水資源開発や管理は，一部で流域の水循環や水環境に影響を与え，その健全性の確保が課題として顕在化した。これに対しては様々な対応がなされてきているが，法制度としては，1997 年の河川法の改正がその象徴的なものであり，その目的に，河川環境の整備と保全が加えられた。これにより，具体的には，コンクリート主体の護岸工事の修正，河川生態系や植生の保護・育成などが進められることとなった。

3.　近年における流域の水循環・水資源の管理の展開

(1)健全な水循環系の構築

継続的に展開されてきた流域の水循環の改変や水資源の開発・管理に関わる様々な制度の整備や事業の展開を踏まえ，「健全な水循環」の構築が基本的な課題として認識されるようになり，1998 年に水に関係する6省庁は「健全な水循環系構築に関する関係省庁連絡会議」を設置し，1999 年にはその共通認識等を中間的にとりまとめている。その後の，これを目的とする基本法の策定必要性の議論を踏まえ，2014 年に「水循環基本法」が施行されることなった。

水循環基本法は，「水循環に関する施策を総合的かつ一体的に推進し、もって健全な水循環を維持し、又は回復させ、我が国の経済社会の健全な発展及び国民生活の安定向上に寄与すること」が目的とされている。この法律では，「水循環」は「水が、蒸発、降下、流下又は浸透により、海域等に至る過程で、地表水又は地下水として河川の流域を中心に循環すること」をいい，「健全な水循環」は「人の活動及び環境保全に果たす水の機能が適切に保たれた状態での水循環」をいう。

この法律は基本法であって，具体的な事業等は従来通り関連する個々の事業法等で対応することになるが，水循環を経済社会や国民生活との関係で明確に位置付け，「流域として総合的かつ一体的に管理されなければならない」ことを明確にしたことは重要な点である。政府は，施策の総合的かつ計画的な推進を図るために「水循環基本計画」を定め，水循環政策本部を設けて推進することとなった。今後，いくつかの流域で流域水循環協議会を立ち上げ，流域水循環計画を作成するなどの具体的な展開が進むことになっている。

(2)水資源開発基本計画のリスク管理型への転換

国土交通省は，2017 年，国土審議会からの「リスク管理型の水の安定供給に向けた水資源開発基本計画のあり方について」の答申[1]を受け，新たな水資源開発基本計画の策定を行うこととした。

「水資源開発基本計画（通称：フルプラン）」は，水資源開発促進法（1961 年）によって，指定された水資源開発水系において決定されるもので，1)水の用途別の需要の見通し及び供給の目標，2)供給の目標を達成するため必要な施設の建設に関する基本的な事項，3)その他水資源の総合的な開発及び利用の合理化に関する重要事項，を記載することになっている。これまで，指定された，利根川，荒川，豊川，木曽川，淀川，吉野川，筑後川の7つの水系について，総合的な水資源の開発と利用の合理化を図るために，水資源開発基本計画が定められてきた。

上記の答申では，新たな水資源開発基本計画の策定にあたって，需要主導型の水資源開発の促進を目指してきたこれまでの計画から，「リスク管理型」の水の安定供給を目指す計画への転換を図ることが提言されていて，現在これに沿った計画変更の検討が始まっている。これは，従来の需要の見通しとそれを賄う供給の目標，さらにそれに対応した施設建設という基本に対して，過去の需要の見通しと実績との乖離，用水需給逼迫の解消傾向，経済成長動向や人口動態による用水需要増加の抑制傾向，整備施設と老朽化の拡大，地震等への大規模災害への対応の必要性，気候変動に伴う用水需給量の変化とその見込みの不確定性など，様々な情況や要因の変化を鑑み，多様性や不確定性に対応した水資源開発に転換することを提唱したもので，それを「リスク管理型」という語で表現したと理解する。

その「リスク管理型」の計画のあり方は以下の4点にまとめられている。

1)水供給を巡るリスクへの対応：地震等の大規模災害，施設の老朽化に伴う大規模な事故，危機的な渇水等発生頻度は低いものの水供給に影響が大きいリスクにも対応。

2)水供給の安全度を総合的に確保：需要と供給の両面に存在する不確定要素を考慮して，水需給バランスを総合的に評価。地域の実情に即した取組を着実に推進。

3)既存施設の徹底活用：長寿命化対策を計画的に進め，大規模災害等の危機時も含めて水の安定供給を確保するため，既存施設を徹底活用。

4)ハード・ソフト施策の連携による全体システムの機能確保：様々なリスクや不確実性に対し，柔軟性をもって包括的に対応してシステム全体の機能を確保するため，ハード対策とソフト対策を一体的に推進。

4. 流域の水循環・水資源の管理の課題

最近の，日本における水循環管理と水資源の開発・管理に関わる制度等の整備の状況を概観した。そこでは，単に，法や制度の整備だけではなく，その背景となる実態や考え方の展開，そして具体的な計画や事業の実施を含めて今後の課題が，現れている。

水循環の管理については，既述した基本法と関係事業法との具体的実務的連携などの課題とは別に，これを契機に，改めて進展が求められる2つの課題を整理しておきたい[2]。まず一つは，法にもある「総合的かつ一体的」な施策の推進のためには，「水循環管理手法」（マネジメント・インストルメント）の整備が求められるという技術的課題である。総合的な管理には，法的枠組みだけでなく管理評価手法を用意することが必要であるが，その開発は案外進んでいない。水循環の健全性を評価し，改善の方策を提案できる具体的な指標や方法など，関係者が共有・活用できる情報を整える手立てが必要である。

もう一つは，理念に基づき関係者に求められる具体的な「協働」の仕立てである。健全な水循環の保全には，基盤となる基盤施設と規則制度だけでなく，それらの主体となるべき関係者の「共同」を仕立て直す必要があると考える。法にある「連携と協力」には，地域の住民や関係団体の協働に託す部分を計画的に配置すべきである。

水資源開発と管理については，指定水域を対象とする「水資源開発基本計画」の「リスク管理型」への展開を紹介した。この「リスク管理型」への転換の考え方は，指定水系に限らず，基本的には全国の水系にも展開すべきものであると考える。その内容は，これまでの計画の中心にあった，水資源利用における用水の需要と供給を，一定の条件において量的にバランスさせることを超えたものとなっていると理解できる。「水資源開発促進法」は，「水を必要とする地域に対する水の供給を確保するため」のものであり，目的にある「水源の保全かん養と相まって，河川の水系における水資源の総合的な開発及び利用の合理化の促進」を図るには，新たに策定された水循環基本法の理念とさらに整合性を高めた仕組みに転換させる議論が必要であろう。

なお、「水資源開発基本計画」を「リスク管理型」で策定する場合，様々な要因や対象に対する関係者や専門家の「主体的な判断」が求められる局面が多くなることが考えられる。計画の客観性やプロセスの透明性・公開性を向上させる視点から，ここでも，流域の水文現象や水利の状況を表現し，対応の選択肢の影響を客観的に表現する「水循環管理手法」（マネジメント・インストルメント）の整備が求められる。

5. おわりに

本報告では，日本における水循環管理と水資源の開発・管理の展開と課題を，近年の「水循環基本法」の制定と「水資源開発基本計画」の「リスク管理型」への展開を主な材料として検討した。これらは，広く統合的水資源管理の展開に向けてのプロセスとして位置付けることができるようになることが期待される。統合的水資源管理のための基本的な条件として，法的枠組み，協働と合意形成，管理手法の3つが一般に挙げられるが，日本においては，法的枠組みの整備が一定程度進んだとすれば，関係者の連携と合意形成のための枠組みの整備，そして具体的な管理ツールの開発・整備の展開が求められることになる。こうした日本の状況は，他の条件の異なる国や地域の流域における水資源管理の整備の視点からの検証も必要で，また，日本の経験が，他の国の流域における課題の解決につながるものとなることが望まれる。

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TS2-2

Recent Development and Challenges in the Management of Water Cycle and Water Resources of a Basin in Japan

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Keywords: basin water cycle, water resources development, water resources management, risk-management approach

ABSTRACT

Appropriate development and management of water resources is the basis of life and production in a basin, and for that purpose sound conservation and management of hydrological cycle is required. This is a fundamental requirement for environmental conservation in a basin and related areas and coasts as well as sustainable use of lake water resources in the basin.

In Japan, the "Basic Act on Water Cycle" was promulgated in 2014, which is a comprehensive and integrated promotion of measures concerning water circulation, including groundwater, in order to maintain and restore sound water circulation in the basin, further develop and stabilize economy and society and people's lives. In the main river systems, the "risk management type" basic plan for water resource development has been advanced from 2017, based on the reduction in tightness of demand and supply of water resources, and the increase in the necessity of measures against climate change and disaster, etc.

In this report, the basic thinking on water circulation and water resource development and management in Japan and the recent improvement situation of the framework of legal system are reviewed, and the further necessary challenges for further improvement of the sustainable use of freshwater resources including lakes.

1. INTRODUCTION

Appropriate development and management of water resources is the basis of life and production in a basin, and for that purpose sound conservation and management of hydrological cycle is required. This is a fundamental requirement for environmental conservation in a basin and related areas and coasts as well as sustainable use of lake water resources in the basin. In Japan, together with prevention and reduction of flood disasters, systems for stable water supply have been prepared, and various infrastructure development have been implemented. Conservation of basin water environment including water quality and ecosystems has also been tackled.

In recent years, based on the development of these improvements and the stabilization of water supply, and according to the economic growth trends and demographic dynamics, the establishment of new systems and mechanisms has been made and actual implementation of relevant projects are being advanced. In this report, the recent history on management of water cycle and water resources of Japan is summarized and the issues for further sustainable use of water resources are discussed.

2. OUTLINE OF THE DEVELOPMENT OF FLOOD AND DROUGHT MANAGEMENT IN JAPAN

Japan is located in the monsoon area, and floods with heavy rains and drought with dry spell during the summer season have been the central issue of land management from ancient times. Regarding the development and management of water resources, securing water supply for rice cultivation is a continuing task from the ancient, and its progress and further paddy field reclamation in the 16-17 C modern founded the base for the subsequent population increase and the social system. Even when entering the modern era, this basic principle continues, especially after the World War II, with the background of civil engineering development and demand for urban water accompanying economic growth, etc., the project to control water cycle and develop water resource of the basins has been advanced on a larger scale.

As a result, the number of people who die due to water related hazards including floods has decreased drastically. In addition, due to the development of large-scale water resources development, water supply has become almost corresponding to the increased demand, and "water shortage" which frequently occurred in various places was limited to some specific areas and periods.

Meanwhile, development and management of water resources in response to the higher economic growth and the population increase and concentration, in part, affected water cycle and environment in basins, consequently ensuring “sound water cycle” became manifest as a subject. While various measures have been taken against this issue, as a legal system, the amendment of the River Law in 1997 is a symbolic one, with the objective of improving river environment and conservation. As a result, exact actions have been promoted, such as revision of concrete-based bank strengthening works, protection and improvement of river ecosystems and vegetation, etc.

3. RECENT DEVELOPMENT OF MANAGEMENT OF WATER CYCLE AND WATER RESOURCES IN BASINS OF JAPAN

(1) Construction of sound water cycle system

Based on the continuous modification of the water cycle and the improvement of various systems in the basins and implementation of relevant actual project related to the development and management of water resources, the establishment of "sound water cycle" was recognized as a fundamental issue. In 1998, the six ministries concerned with water established the "Liaison Committee on Relevant Ministries and Agencies concerning the Establishment of a Sound Water Cycle System", and in 1999 they drafted the common recognition on it. Based on the discussion of the necessity of formulating the basic law aiming at "sound water cycle", finally the "Basic Act on Water Cycle" was enforced in 2014.

The "Basic Act on Water Cycle" is "to promote comprehensive and integrated measures on water cycle, conserve or restore sound water cycle, and contribute to the sound development of the economy and society and stability improvement of the people's lives". In this Act, "water cycle" means "circulation of water around a river basin in the course to the sea area, as surface water or groundwater, by evaporation, falling, runoff or infiltration", and "sound water cycle" means "water cycle functioning appropriately to human activities and the environmental conservation".

While this law is a basic law and then the actual programs or projects are to be operated by the related business laws, it is importantly to be noted that water cycle is clearly recognized in relation to the socio-economy and people's lives there, and that it is prescribed as “must be managed in a comprehensive and integrated manner". According to the Act, the government should establish a "water cycle basic plan" to promote comprehensive and systematic measures, and to establish the headquarters for it. In the near future, concrete development such as to set up basin water cycle council in several basins and to prepare basin water cycle plan will be advanced.

(2) Conversion to the risk management-type basic plan for water resource development

In 2017, the Ministry of Land, Infrastructure and Transportation received a report from the Land Council [1] on "Basic Plan for Water Resources Development for Risk Management-type Stable Water Supply", and the Ministry decided to formulate the new approach to water resources development planning.

"Water Resource Development Basic Plan (so-called "Full Plan)" is draw up for the designated river systems according to the Water Resources Development Promotion Act (1961). In the Plan, the following items are to be described, including 1) water demand forecast for each water use sector and supply goals, 2) basic matters concerning the construction of necessary facilities to achieve supply goals, and 3) other important matters concerning comprehensive water resources development and rationalization of water use. So far, the basic plan has been established for the seven designated river systems, including the Tone, Arakawa, Toyo, Kiso, Yodo, Yoshino, and Chikugo Rivers.

In the above Council report, in planning a new water resource development basic plan, converting from the past style that has aimed to promote demand-driven water resource development, it is recommended to introduce "risk management type" for stable water supply, and the research of plan changes is now under way according to these recommendation and decision. This policy change is to be organized corresponding to actual changes in the various circumstances and factors, including the followings: the disparity between the forecast and actual performance of water demand, the tendency to eliminate the tightness in the balance of water supply and demand, the trend of suppression of increase in water demand due to actual economic growth and demographics, the increase of needs for maintenance and lifetime expansion of aged facilities, the need to respond to large-scale disasters such as earthquakes, and the uncertainty of changes in the water supply and demand due to the climate change. These approach is expressed as the term of "risk management type".

The core idea of the "risk management type" plan is summarized in the following four points.

1) Response to risks related to water supply: Responding to risks that have a large influence on water supply although their frequency of occurrence are low, such as large-scale disasters like earthquakes, big accident caused by aged facilities, and critical crisis of droughts.
2) Secure comprehensive safety of water supply: Assessing comprehensively the water demand-supply balance considering uncertain factors in both demand and supply.

Promoting steadily the initiatives consistent with local circumstances.

3) Full utilization of existing facilities: Planning progressively the countermeasures to prolong the lifetime of the existing facilities, and utilizing thoroughly them to ensure stable water supply including crises such as large-scale disasters.

4) Securing the function of the overall system through collaboration of hardware and software measures: Ensuring the function of the whole system, adapting to various risks and uncertainties flexibly and comprehensively, with combination of the hard-measures and soft-measures.

4. ISSUES ON MANAGEMENT OF WATER CYCLE AND RESOURCES IN A BASIN

Recent situation of the development of systems related to water cycle management and water resource development and in Japan was summarized. There, not only the re-tailoring of the laws and institutions, but also the actual situation and ideas that constitute the background, and the future issues including the implementation of actual plans and projects are addressed.

Regarding the management of water cycle, apart from issues such as practical cooperation between the basic law and related business laws as described above, two issues are to be discussed [2]. Firstly, in order to promote the "comprehensive and integrated" measures found in the law, as a technical issue, the development of exact "water cycle management method (management instrument)" is required. For the integrated water resources management, it is necessary to prepare not only a legal framework but also a method for evaluation of management performance, while its development has not progressed unexpectedly. It is necessary to establish a system for information that is to be shared and used by the all stakeholders, including quantitative indicators and methods for evaluation of the soundness of water cycle and for suggestion of improvement measures.

The other is a tailoring of concrete "collaboration" required by stakeholders. The conservation of the sound water cycle requires not only the basic infrastructures and institutions, but also "cooperation" of the stakeholders. To realize the real "collaboration and cooperation" described in the law, some parts or issues are to be entrusted to the local residents or their related organizations in the management plan in a systematic manner.

Regarding the water resources development and management, the idea of conversion to "risk management type" water is not limited to the designated river systems, basically it should also be developed in other river systems of the country. It can be understood that the contents are beyond quantitatively balancing the supply and demand of water for water resource utilization under a certain condition, which was the core of the plan to date. The "Water Resources Development Promotion Act" is for "to ensure the supply of water to the areas requiring water", and to realize its objective "to promote integrated water resources development and rationalization of water use in river system, with conservation and recharge of water resources", further discussion about the idea and process for establishing the advanced system in much deeper consistency with the newly formulated "Basic Act on Water Cycle Water".

When formulating the basic plan for water resource development with risk management type, many aspects might require "subjective judgment" by stakeholders and experts on various factors and subjects. From the viewpoint of improving the objectivity of the plan and the transparency and openness of the process, here also, "water cycle management method (management instrument)" is awaited, which can simulate the hydrological regime of the basin and the situation of water use and assess objectively the influence of the possible options.

5. CONCLUSION

In this report, the development and management of water cycle management and water resource development and management in Japan are discussed, reviewing the recent establishment of the "Basic Act on Water Cycle" and the introduction of the "Risk Management Type" of the "Water Resources Development Basic Plan". These are expected to be recognized in the future as a process for the integrated water resources management. While three basic conditions for integrated water resources management are the legal framework, collaboration and consensus formation, and management methods in general, and in Japan the legal framework has advanced a certain degree, it is to be required to develop a framework for collaboration and consensus building among stakeholders, and to develop an effective and serviceable management method or instrument. Such situations in Japan need to be reviewed from the viewpoint of water resource management in basins of other countries and regions with different conditions, and those Japan's experiences are desired to lead to the resolution of issues in basins in other countries and regions.

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O2-1

Water purification for portable water using Bio-fence around Nyanza Gulf of Lake Victoria
- Results in LAVICORD project -

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Keywords: Lake Victoria, water pollution, toxic cyanobacteria, microcystin

ABSTRACT

Kenya has been struggling with various water problems such as shortage of water, contamination of water sources and deterioration of water environment. Of course, although the problems have been addressed not only in Kenya but also in other countries so far, many problems remain yet. If a practical solution for such problem will be obtained, the solution can be spread to other countries in the world from Kenya. Hence, in LAVICORD (The Lake Victoria Comprehensive Research for Development) project, we focused on the development of several appropriate technologies for safe water. The studies were performed at Nyanza Gulf of Lake Victoria. At several beaches in Nyanza Gulf of Lake Victoria, we found cyanobacteria blooms. Therefore, first of all, we solved the cyanotoxin microcystin contamination problem, because we elucidated the remarkable microcystin contamination in drinking water collected from beach of Nyanza Gulf. Thus we installed Bio-fence system at Ogal beach, where highest contamination of microcystin was found, to produce safe portable water. The installed bio-fence using charcoal could effectively remove microcystin from lake water. However, it was significantly affected by the water level fluctuation of Lake Victoria. We should improve the system design of Bio-fence for practical use, because the strength of water level fluctuation recently became larger.

1. Introduction

Ogal Beach like many rural beaches along Lake Victoria is faced with the challenge of deteriorating water quality; evident in cyanobacterial blooms on and off-shore. The Inhabitants at shores of Nyanza Gulf face a risk of consuming cyanotoxin microcystin[1]. Many of them drink the lake water without adequate treatment to reduce cyanotoxin microcystin and boiling of water alone doesn't decompose microcystin. The lake water quality situation at the beach may not improve in the near future considering the introduction of cage fish culture in the area; hence, there is need to provide a practical and appropriate technology to improve the water quality for domestic use.

2. METHOD

The bio-fence is a simple mechanism of obtaining clean water by using crushed charcoal as a filtration medium as shown in Figure 1. The crashed charcoal forms a good habitat for predators of toxic cyanobacterial cells and degradation bacteria of microcystin. The frame of the structure was made of timbers s and a rubber sheet to seal the bottom. The both width and length of the bio-fence was 1m. Effective depth was changed by the lake water level. The minimum depth of the bio-fence was 30cm and the maximum depth was around 1m. The residence time of water flow thorough the bio-fence was around from 8 hr to 12 hr. Chl-a, TSS and microcystin were mainly measured as water quality parameters.

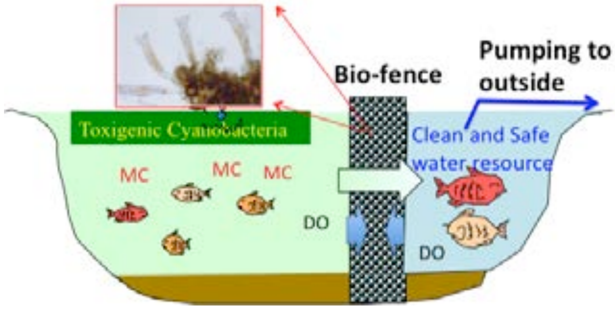

Fig. 1 Concept of Bio-fence

Fig. 2 Bio-fence Experiment at Ogal Beach

3. RESULTS

The typical results are shown in Figure 2. The transparent clean water in the water bottle was treated water from the cyanobacterial bloom water by the bio-fence. Water with green color showed the cyanobacterial contaminated water of Nyanza Gulf. The cyanobacterial bloom at Ogal Beach was mainly consisted with *Microcystis* sp.

Under optimal conditions, the biofence was effective in removing up to 94% of the harmful Microcysits from the lake water. It also removed 97% and 93% of Chlorophyll a and TSS respectively. The lowest values recorded for MC in the biofence treated water was 0.92 μg/l which is below the WHO guidelines [2] of 1 μg/l of MC in drinking water.

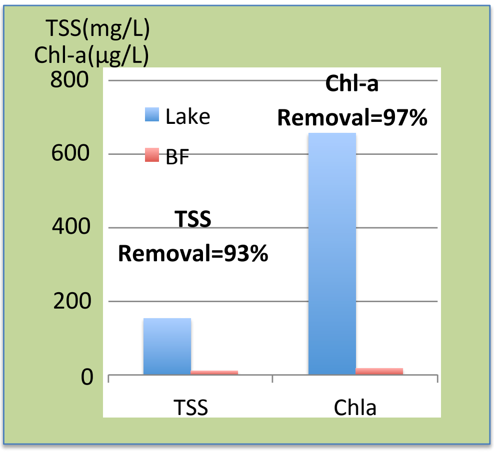

Fig. 3 TSS and Chl-a in Bio-fence treatment water and Lake water

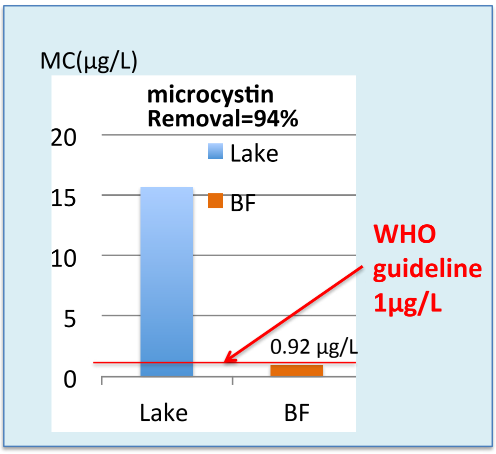

Fig. 4 Microcystin in Bio-fence treatment water and Lake water

These results showed that the water quality was drastically improved by the bio-fence system from the viewpoint of cyanotoxin contamination. However, after this good results, the water level of Ogal Beach was increased over the top surface of the bio-fence. The bio-fence couldn't purify the water. Then it didn't work well when water level was decreased until the depth of bio-fence of 30 cm.

4. DISCUSSION

The results showed the good treatment performance because it may be suitable media for the habitat of microbes which degrade cyanobacterial cells and cyanotoxin microcystin. In the previous study in Japan [3], we found the several metazoan whuch can degrade and remove toxic cyanobacterial cells in a bioreactor system for pond water treatment. Similar species could be acted on charcoal media effectively. However, the use of wood charcoal may affect the wood resource problem in Africa. Thus we will use maze charcoal (Bio-char) as media in future.

Then we have to improve the system regarding with the fluctuation of water level. A floating type bio-fence is one idea. It was succeeded in the experiment of a fishpond in Thailand. But it can be affected by the strong wave of Lake Victoria. Thus the other new idea have to be created.

5. CONCLUSION

This results showed that the biofence technology can be used a cost effective, efficient easy to operate technology for treatment of drinking water around Lake Victoria. However have to improve the bio-fence system for practical use in Lake Victoria, because we clarified several demerit of this system.

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O2-2

桜川及び千波湖における霞ヶ浦導水事業による水質改善

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キーワード：水質汚濁，アオコ，水管理，富栄養化，水資源の利用・開発

抄録

水戸市を流れる桜川では、千波湖及び支川流域も含め、都市化の進展と共に生活排水の流入等による水質悪化が進み、夏季には千波湖や桜川下流においてアオコによる水面景観の悪化や悪臭が発生するなど水環境の悪化が著しく、様々な対策を講じている現状においても目標値を満足出来ない状況にあり、さらなる水質の改善が急務となっている。このような状況に対処するため、霞ヶ浦導水事業は第二期水環境改善緊急行動計画　桜川清流ルネッサンスⅡの施策の 1 つとして、桜川及び千波湖の水質浄化を図るものである。霞ヶ浦導水事業は、那珂川、霞ヶ浦及び利根川の 3 つの水域を地下トンネルで結び、それぞれの河川の水を相互に融通する流況調整河川として、霞ヶ浦及び桜川・千波湖の水質浄化、那珂川下流部及び利根川下流部の渇水時の既得用水の補給及び新たな都市用水の確保を図ることを目的とした事業であり、昭和 59 年度に工事に着手し、現在鋭意事業を進めている。

1.　はじめに

那珂川、霞ヶ浦及び利根川は、茨城県をはじめ周辺地域の水資源の安定的かつ広域的な供給等に重要な役割を果たし、流域の産業・経済の発展に寄与してきた。一方、流域の産業発展や都市化の進展によって、霞ヶ浦や水戸市を流れる桜川・千波湖では水質汚濁が進み、また那珂川・利根川では渇水時における取水制限など、様々な課題が発生するようになり、その対策として種々の取り組みがなされて、一定の効果は上げているものの、まだまだ課題解決には至っていない。

霞ヶ浦導水事業は、上流ダム群、中下流域の貯水池、湖沼開発、河口堰等とあわせ、限られた水資源を有効活用するため、流況調整河川として、流況の異なる那珂川・霞ヶ浦・利根川を地下水路で結び水のネットワークを形成するものであり、時期に応じて相互の導送水を行うことにより、河川及び湖沼の水質改善を図るとともに、それぞれの河川の流況を改善し、更に新規に都市用水を開発することを目的としている。

図 1　霞ヶ浦導水事業位置図

本報では、霞ヶ浦導水事業の目的の一つである「水質改善」について、水戸市を流れる桜川及び千波湖を対象として効果予測を報告するものである。

2.　水質汚濁の状況

桜川は、水戸市と笠間市の市境に位置する朝房山に源を発する那珂川の一次支川であり、水戸市・笠間市を流域に持つ、全長約 19km の一級河川である。上流部は笠間市の豊かな緑の中を流れ、中・下流は近年都市化の発展がめざましい水戸市の市街地を流れており、沿川には日本三名園の一つである偕楽園や千波湖などもあり、市民の貴重な憩いの場となっている。

しかし、一方で桜川は、流域の都市化の進展と共に生活排水の流入等による水質悪化が進み、夏には千波湖や桜川下流においてアオコによる水面景観の悪化や悪臭が発生するなど、親水性が損なわれており、流域住民から水環境の改善が強く望まれている。

桜川の水質は、環境基準点である駅南小橋地点では平成 10 年度から調査されており、BOD（75%値）が環境基準値の 5mg/L 前後で推移している。平成 26 年度のBOD（75%値）は 3.6mg/L であった。平成 10 年度以前から調査されている搦手橋地点のBOD（75%値）の変化をみると、下水道整備の進捗等により、平成 6 年度以降から水質が改善され、平成 26 年度のBOD（75%値）は 4.0mg/L であった。近年は環境基準値を満足する傾向にある。しかしながら、千波湖からアオコ混じりの水が桜川へ流出されることから、下流では夏季にアオコの発生が認められ、夏場における更なる水質改善

が望まれている。

千波湖の水質は、昭和 63 年に開始された渡里暫定導水によりCOD（平均値）が 28.5mg/L から 10mg/L 程度に改善された。平成 23 年度から 25 年度にかけては東日本大震災や渇水による千波湖導水量の減少によってCODがやや高くなっている。平成 26 年度のCOD（75％値）は 14.0mg/L であり、更なる水質改善が必要である。また、千波湖は、条件がそろえば、いつでもアオコが大量発生し、社会生活に影響を与える可能性がある。アオコの発生要因は滞留時間、栄養塩類、水温、日射の 4 条件であり、これらの条件が全て揃うとアオコが発生する。千波湖はアオコ発生に必要な条件が全て揃っており、夏場になれば、ほぼ毎日アオコが発生している状況にある。

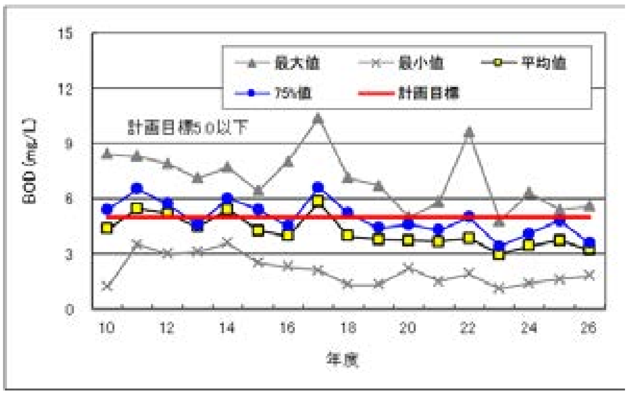

図 2　桜川（駅南小橋地点）水質経年変化

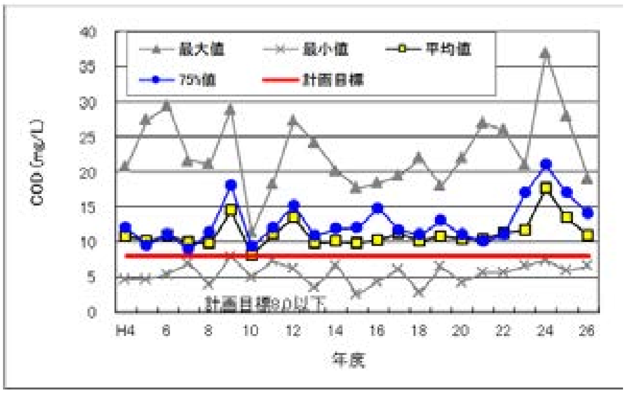

図 3　千波湖（千波湖中央地点）水質経年変化

図 4　千波湖アオコ発生状況（平成 24 年 8 月撮影）

こうした状況から、平成 19 年に策定（平成 28 年改定）した「第二期水環境改善緊急行動計画　桜川清流ルネッサンスⅡ」（以下「行動計画」という。）において、桜川・沢渡川・逆川の目標水質は、散策等の親水活動、環境基準（C類型）等を考慮して、BOD（75％値）5mg/L 以下とし、また、桜川下流については夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもBOD 5mg/L 以下を目指すものとした。また、千波湖の水質目標は、アオコの発生の削減、親水活動や水戸市の水質保全計画等を考慮して、COD（75％値）8mg/L 以下とし、特に、夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもCOD8mg/L 以下を目指すものとした。

3.　霞ヶ浦導水事業による水質改善

行動計画に基づく下水道の整備などの取り組みにより、桜川のBODが大きく改善するなどの水質改善の効果は現れてきているが、千波湖や桜川の下流部では依然として夏季にアオコが発生しており、さらなる水質改善が急務となっている。そこで、行動計画の水環境の改善に関する施策の 1 つとして位置付けられている霞ヶ浦導水事業の推進により、桜川及び千波湖の水質浄化を図るものである。霞ヶ浦導水路は、那珂川と霞ヶ浦とを結ぶ延長約 43km の第一導水路（那珂導水路）と霞ヶ浦と利根川とを結ぶ延長約 2.6km の第二導水路（利根導水路）から構成される総延長約 45.6km の地下トンネルである。このうち、第一導水路は水戸市渡里町地先（那珂川）から石岡市三村干拓地先（霞ヶ浦高浜沖）を経て土浦市湖北地先（霞ヶ浦土浦沖）に至り、導水管の他、那珂機場、桜機場、高浜機場及び放流口から構成され、桜川及び千波湖の水質浄化としては、那珂機場で取水した那珂川の水が導水路を流れ、桜機場から桜川へ最大毎秒 3 ㎥を注水するものである。

図 5　那珂川から桜川・千波湖への導水経路

4. 水質改善効果

霞ヶ浦導水事業を含む行動計画の実施による桜川及び千波湖における水質改善効果を予測するため数値シミュレーションにより予測を行った。予測方法は、河川については負荷量と河川流量を基に流達率・浄化残率を考慮した汚濁解析モデルを用い、千波湖については内部生産を考慮した富栄養化モデルを用いた。なお、水質予測モデルについては、近年の水質状況を踏まえて計算を行った。

平成 22～26 年度時点（実測値平均）において、桜川については、駅南小橋地点BOD（75％値）が 4.2mg/L、搦手橋地点BOD（75％値）が 4.1mg/L となっていることから、環境基準及び行動計画の目標値であるBOD（75％値）5mg/L 以下を満足する結果を得ているが、千波湖については、千波湖中央地点COD（75％値）が 16.0mg/L となっていることから、行動計画の目標値であるCOD（75％値）8mg/L 以下を満足できていない状況である。そのような状況に対し、行動計画を実施した場合の予測では、桜川については、駅南小橋地点BOD（75％値）で 3.0mg/L、搦手橋BOD（75％値）で 3.1mg/L、千波湖については、千波湖中央地点COD（75％値）で 6.7mg/L といずれも改善され、行動計画で示されている目標水質であるBOD（75％値）5mg/L 以下、また、桜川下流については夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもBOD5mg/L 以下、千波湖の水質目標であるCOD8mg/L 以下、特に、夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもCOD8mg/L 以下に改善という目標値を概ね達成することが出来る。[1]

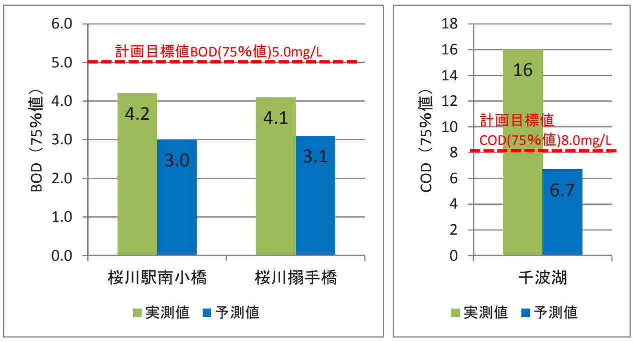

図 6 桜川・千波湖の水質予測値

さらに、アオコの発生原因の一つである滞留時間について、霞ヶ浦導水事業による那珂川から桜川への注水により、千波湖への流入量も増加し、湖水の 4～10 月上旬の平均滞留時間が約 8 日から約 4 日に短縮される。そのため、アオコに不規則な移動を強い、その微環境に変動が生じるため、アオコの増殖を抑制することが出来る。

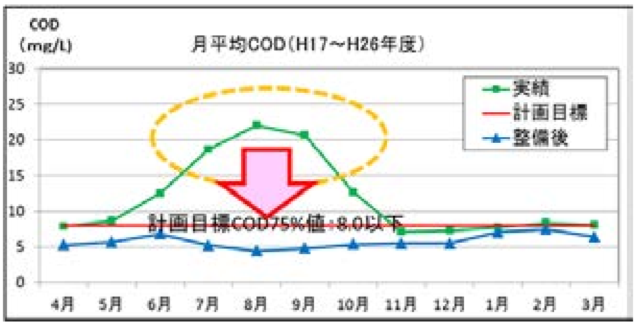

図 7 千波湖の水質予測値（月別）

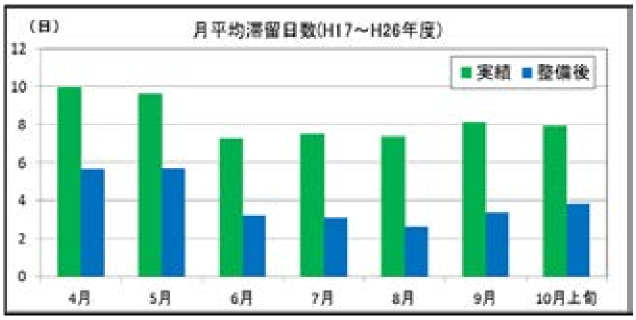

図 8 千波湖の滞留日数予測

5. おわりに

桜川及び千波湖では行動計画に掲げる水質目標値を満足するために、様々な対策を講じている現状においても未だ目標値を満足出来ない状況にある。

霞ヶ浦導水事業は、那珂川、霞ヶ浦及び利根川の 3 つの水域を地下トンネルで結び、それぞれの河川の水を相互に融通する流況調整河川として、霞ヶ浦及び桜川・千波湖の水質浄化、那珂川下流部及び利根川下流部の渇水時の既得用水の補給及び新たな都市用水の確保を図ることを目的とした事業であり、行動計画の施策の一つである。

霞ヶ浦導水事業を含む行動計画の実施により、桜川の水質目標値（環境基準値）であるBOD（75％値）5mg/L 以下を満足するとともに、桜川下流部の夏季におけるBOD5mg/L 以下も満足する。また、千波湖の水質目標値であるCOD（75％値）8mg/L 以下を満足するとともに、夏季においてもCOD8mg/L 以下に改善するという目標を概ね達成することから、多くの市民や観光客等の憩いの場である桜川・千波湖の景観維持や、アオコ悪臭問題の解決とともに、親水活動の促進に寄与するものである。

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O2-3

Assessing Threats to Transboundary Lakes and Reservoirs

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ABSTRACT

The International Lake Environment Committee (ILEC) conducted the transboundary lakes component of a global-scale assessment (TWAP) of five major transboundary water systems (lakes; rivers; groundwater; large marine ecosystems; open oceans), ranking them regarding the type and magnitude of the threats facing them. The study results highlighted that selecting different context for interpreting the significance of the threats changed the relative lake threat rankings. A sensitivity analysis changing the relative magnitude of the threats also produced differing threat rankings. The need to infuse Integrated Lake Basin Management (ILBM) within the context of the Water Resources Management (IWRM) framework also is discussed.

Keywords: basin governance; wise use and development of water resources; future scenarios of surface waters

1. INTRODUCTION

Lakes and reservoirs (terms used interchangeably herein) are fundamentally important for human health and socioeconomic development, and sustainable terrestrial and aquatic ecosystems. More than 90% of the liquid freshwater on our planet's surface exist in lakes and other lentic (pooled) water systems, collectively covering approximately 4.2 million km2 of land area (Downing et al. 2006).

Lakes possess unique characteristics making it difficult to assess their status, including a long water residence time (resulting in slow, incremental responses to environmental stresses), an integrating nature (ensuring in-lake problems cannot readily be separated) and a non-linear response to stresses (making lake behaviour unpredictable and uncontrollable).

2. METHODOLOGY

The transboundary lakes component of UNEP's Transboundary Waters Assessment Programme (TWAP) comprised 156 transboundary lakes in developing countries, plus 50 lakes in developed countries (for comparison), using GIS—based spatial analysis of NASA and other global-scale databases to identify the lakes and delineate their drainage basins (Figure 1; ILEC and UNEP 2016). Because of lack of uniform global-scale data for in-lake comparisons, their drainage basin characteristics were used to assess their potential threats, adapting the results of a global-scale study by Vörösmarty et al. (2010) on river basin human water security (HWS) and biodiversity (BD) threats.

After eliminating small lakes with sparse basin populations and/or lakes frozen for significant portions of the year, a Scenario Analysis Program (SAP) was used to calculate the relative HWS and BD threats. The SAP reduced the final study list to 53 transboundary lakes meriting most attention regarding potential management intervention needs (23 lakes in Africa; eight in Asia; nine in European region; six in South America; seven in North America; ILEC and UNEP 2016).

3. RESULTS

Based solely on one set of screening criteria (see ILEC and UNEP 2016), the top five lakes exhibiting the highest computed HWS and BD threat scores included two European (Cahul; Galilee) one North American (Falcon), and two Asian lakes (Mangla; Aras Su Qovsaginin Su Anban). The African lakes as a group generally ranked in the bottom half of the 53 study lakes.

Vörösmarty et al. (2010) also considered the ability of the basin countries to make investments to address water threats (water supply stabilization, improved water services, etc.), producing a refined threat criterion (Adjusted Human Water Security, Adj-HWS). This refined criterion demonstrated that, even if initially exhibiting a high HWS threat rank, more economically developed countries exhibited lower Adj-HWS threats. In contrast, many developing countries lacking such resources exhibited higher Adj-HWS threats and, therefore, a greater need for management interventions. The relative threats to many African transboundary lakes increased substantially on this basis, while those of the European and North American countries decreased, with 11 of the 13 highest ranked transboundary lakes being located in Africa. The Asian Adj-HWS threat ranks also generally increased, although not the same magnitude as for Africa. Further details for interpreting the results regarding management intervention needs are provided by ILEC and UNEP (2016).

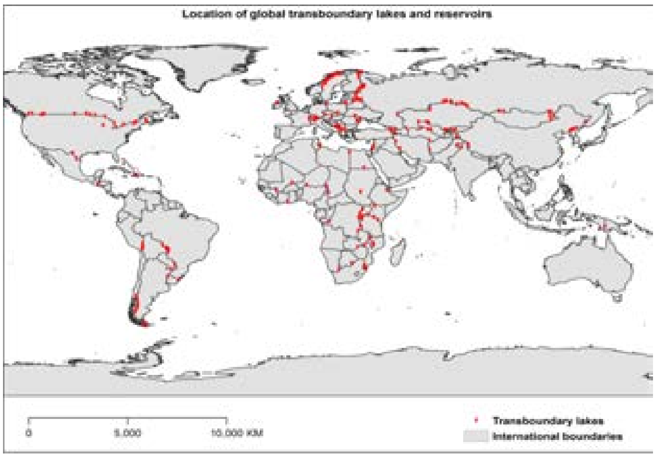

Figure 1. Global Distribution of Initial Group of Transboundary Lakes/Reservoirs in TWAP Study

Because the magnitude and significance of a lake threat(s) is a function of what a lake decisionmaker considers most important factor(s) regarding management interventions, it was also necessary to identify the appropriate context for interpreting the transboundary lake threats. Doing so involved supplemental activities, including Expert Group Meetings in Brazil, Ghana, India, Italy, Kenya, Malaysia, Mexico, Turkey and the Philippines, as well as a lake basin Questionnaire. A knowledge-based system with an extensive literature resource base, LAKES-III ("Learning Acceleration and Knowledge Enhancement System") also was developed to derive more accurate, meaningful conclusions regarding the status and potential for addressing lake threats. Used in conjunction with the SAP, it highlighted that calculated threat ranking scores can be very misleading for transboundary lake comparisons or lake management decisions unless the most important factor(s) for the user of the rankings was also considered (ILEC and UNEP 2016).

A parametric sensitivity analysis, which involved applying differing importance (weight) to the Adj-HWS and BD threats, as well using as the Human Development Index (HDI), also was undertaken, with the African transboundary study lakes continuing to exhibit the greatest threats, comprising 20 of the top 24 most threatened. The remaining four lakes comprised three South American and one Asian lake (ILEC and UNEP 2016).

The transboundary lakes analysis also provided guidance regarding the lakes most likely to benefit from Global Environment Facility (GEF)-facilitated management interventions, indicating some interventions should consider addressing multiple lake needs (e.g., Lakes Albert and Edward; Chilwa and Chiuta; Cohoha, Ihema and Rweru/Moero in Africa), while others required further evaluation of their scientific and/or political situation prior to considering interventions (e.g., Asian Lake Danbandikhan; South American Salto Grande). Still other lakes merited consideration of the larger river basins in which they were located (e.g., Cahora Bassa in African Zambezi River basin), while a large number also merited review of their current GEF status. Further details are provided in ILEC and UNEP (2016).

Integrated Lake Basin Management

Integrated Water Resources Management (IWRM) has become a widely used management approach for addressing freshwater resource issues (Global Water Partnership 2000). However, experiences within the lake scientific and management community have demonstrated 'operationalization' of IWRM principles to be difficult in many cases, including not being able to consider the unique characteristics of lakes, or their lentic (pooled)-lotic (flowing) linkages. To this end, ILEC developed an integrated management approach (Integrated Lake Basin Management, ILBM) to address the sustainable management of lakes through gradual, continuous and holistic improvement of basin governance elements, comprising sustained efforts for integrating institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technical possibilities, and funding prospects and constraints (ILEC 2005). The conceptual ILBM framework was developed in the form of ILBM 'Platforms' for collective stakeholder actions to improve lake basin governance, thereby complementing the existing IWRM approach (Figure 2). Used in combination with the SAP and the LAKES-III knowledge-mining system, the ILBM Platform process represents a comprehensive, versatile assessment and management guidance tool for addressing transboundary water systems and related governance concerns (ILEC and UNEP 2016).

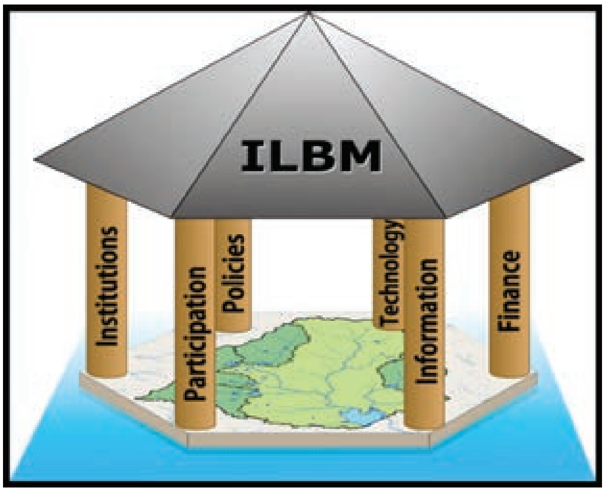

Figure 2. Overview of ILBM Governance Framework (Nakamura and Rast, 2014)

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O2-4

Sensitivity Analysis of Structure of the Stratification in Lake Biwa by Changing Meteorological Elements

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Keywords: Lake Biwa, hydrodynamic model, structure of stratification, and impacts of climate change

ABSTRACT

Climate change such as the change of air temperature and wind speed can affect the structure of the stratification in Lake Biwa. In general, the rise in air temperature and the decrease in wind speed weaken the vertical mixing, and strengthen the structure of the stratification, which interrupts the vertical transport of the substances. However, how much the change of each climate element can influence the structure of the stratification is not clarified. Therefore, it is important to distinguish the effects of each element on the stratification and evaluate them quantitatively. In the present study, we investigated the effect of the increase or decrease in air temperature and wind speed on the seasonal change of stratification in Lake Biwa by using a three-dimensional hydrodynamic model. Numerical simulations were carried out for a baseline case using realistic meteorological data from 2007 to 2011 and experimental cases using meteorological data with modified air temperature or wind speed for sensitivity analysis. The analysis showed that the increase and decrease in air temperature changed the vertical water temperature uniformly in almost all layers. The strength of the stratification hardly changed. The increase and decrease in wind speed, however, changed the structure of the stratification. The increase in wind speed made the water parcels of the surface layer well mixed, and the decrease in wind speed made the mixed layer and thermocline thinner.

1. INTRODUCTION

Some deep lakes face a lack of oxygen occurred in the deep layer during the stratified season because of the thermocline. In recent years, the dissolved oxygen has also decreased at the bottom of the northern part of Lake Biwa, the largest freshwater lake in Japan. The strength of stratification plays an important role in the change of concentration of the dissolved oxygen in the lake. The main cause of the change in stratification is weather and climate conditions such as air temperature, wind strength, and precipitation[1].

An increase in air temperature leads to the prolonged periods of stratification in lakes. In Lake Zurich, Switzerland, higher warming rates of water temperature near the lake surface (~ 0.024 K/year) and lower warming rates in the deep layer (~ 0.013 K/year) from the 1960s to the 1990s resulted in an increase of about 2-3 weeks in the duration of the summer stratification[2]. This directly affected the characteristics of the vertical mixing processes.

As for the effect of wind, wind-driven currents in the surface layer provoke the movement of the lower layer, leading to the destratification. Moreover, wind also provokes the internal waves, and the breaking of the waves with large amplitudes induces vertical mixing. When severe winds associated with the passage of a typhoon blew in 1992, the depth of the thermocline rose gradually in Lake Biwa[3]. After the wind ceased, it declined suddenly more than 20 m. This movement generated waves that affected the deep layer.

In U.S. lakes and reservoirs, Butcher et al.[4] assessed the lake response to climate change by using one-dimensional model and reported that the increase in surface water temperature increases thermal resistance to vertical mixing and changes in wind could also have an important effect, with increased wind stress potentially counteracting the increase in thermal stratification.

Since the structure of the stratification changes seasonally with changes in water temperature, it is important to seasonally analyze the variation of the stratification in lakes. It is not clarified how the stratification changes due to meteorological changes throughout the entire waters in Lake Biwa.

In the present study, we investigated the effect of air temperature and wind speed on the seasonal change of stratification in Lake Biwa by using a three-dimensional hydrodynamic model. Numerical simulations were carried out for a baseline case using realistic meteorological data for validation and experimental cases using modified meteorological data for sensitivity analysis.

2. METHOD

This study utilized a three-dimensional hydrodynamic model described in detail by Koue et al.[5]. They reported that the model well simulated the vertical distribution of water temperature and the characteristics of flow field in Lake Biwa.

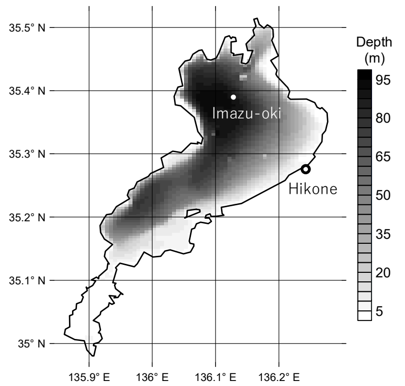


Fig. 1 Calculation domain with the topography of Lake Biwa

Fig. 1 shows the calculation domain and water depth in the hydrodynamic model of Lake Biwa. The horizontal domain is 36 km × 65.5 km with a horizontal resolution of 500 m. The vertical domain consists of 86 layers from the lake surface to the depth of 107.5 m. The vertical grid size is 0.5 m from the surface to the depth of 20 m and gradually increases up to 2.5 m.

For the initial conditions, the current velocity was set to be 0 m/s, and the water temperature was derived from linear interpolation of observed vertical profile data. The observations were conducted by the Lake Biwa Environmental Research Institute twice a month at the monitoring point in Imazu-oki (35°23'41" N, 136°07'57" E), the depth of which was 0.5 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40 m, 60 m, 80 m, and approximately 90 m.

The baseline simulation (BASE) was conducted for a period from April 1st, 2006 to March 31st, 2012 including a spin-up period from April 1st, 2006 to March 31st, 2007 using meteorological data derived from Meso-Scale Model of Japan Meteorological Agency (GPV MSM). In addition, experimental simulations were conducted for the same period using meteorological data with modified air temperature and wind speed in order to investigate their effects on the stratification structure. For sensitivity analysis, the coefficient of variation (σ/μ) were obtained from the mean value (μ) and standard deviation (σ) of the annual mean air temperature and wind speed for 30 years from 1981 to 2010 at Hikone meteorological observatory (35°16'30" N., 136°14'36" E.). The coefficients $(\mu + \sigma) / \mu$, $(\mu - \sigma) / \mu$ were 1.0021, 0.9979 for air temperature and 1.04, 0.96 for wind speed. Each pseudo-weather data was created by multiplying $(\mu + \sigma) / \mu$, $(\mu - \sigma) / \mu$ by the air temperature and wind speed of GPV MSM data. The simulation cases named as AT+ (AT-) and WS+ (WS-) indicate the increase (decrease) in air temperature and wind speed, respectively.

3. RESULTS AND DISCUSSION

In this study, the mixed layer and thermocline were defined as the area that the change of water temperature was less than +0.1 K/m and the area that the one was more than +0.1 K/m, respectively. The depths of mixed layer and thermocline were calculated by averaging the values matching the middle point of observed data vertically and all horizontally. In each case, the periods from April to June, July to September, October to December, and January to March were defined as spring, summer, autumn, and winter respectively. Fig. 2 shows the mean depths of mixed layer and thermocline in the sensitivity analysis of air temperature and wind speed. Fig. 3 shows the vertical distributions of the difference of water temperature between BASE and the experimental cases.

In case of AT+, the structure of stratification changed little compared with the one in BASE. Water temperature in all layers increased almost equally (+0.2~+0.5 K), therefore, the stratification strengthened little (Fig.3 a).

In case of AT-, the 5-year mean depths of mixed layer and thermocline were shallower than those in BASE (Fig.2 a). Although the rate of decrease in water temperature in the surface layer was slightly higher than that in the bottom layer, water temperature in all layers decreased almost equally (-0.2~-0.5 K), thus, the stratification weakened just a little (Fig.3 a).

In case of WS+, the thickness of mixed layer became large in autumn (Fig.2 b). It is considered that the stratification easily collapsed so that the vertical mixing due to the wind occurred during the cooling period. The 5-year mean thicknesses of mixed layer in autumn was 1 m larger than that in BASE, and the depth of mixed layer and thermocline were also larger (Fig.2 b). The reason why the position of thermocline deepened was that due to the effect of the wind, the amplitude of internal wave was large and the effect of wind stress reached the lower layer. Furthermore, water temperature in the surface layer decreased more than that in BASE (-0.2~-0.1 K) from spring to autumn, the one near the thermocline increased (+0.4~+0.6 K) from summer to autumn, and the other one in the bottom layer increased approximately 0.1 K in all seasons (Fig.3 b). As the wind speed increased, the diffusivity increased. Thus, the vertical mixing was promoted. In addition, the warm water parcels were transported to the lower layer. Then, the colder water parcels near the thermocline were transported to the upper layer, and the vertical mixing was promoted.

In case of WS-, the mixed layer and the thermocline became thinner than those in BASE in all seasons (Fig.2 b), and it shows that the vertical mixing due to the wind weakened. The 5-year mean thickness of mixed layer was approximately 1 m thinner, the one of thermocline was approximately 50 cm thinner and the depths of them were shallower than those in BASE. In addition, water temperature in the surface layer increased more than that in BASE (0.1 K) from spring to autumn, the one near the thermocline decreased (-0.5~-0.2 K) from summer to autumn, and the other one in the bottom layer decreased (-0.2 K) in all seasons (Fig.3 b). When the wind speed decreased, the water parcels between the surface layer and the thermocline became less mixed, and the stratification strengthened.

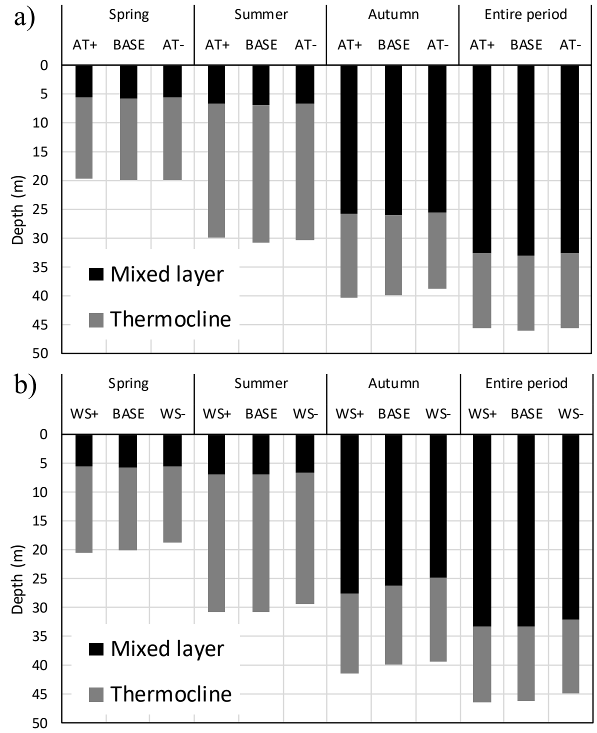
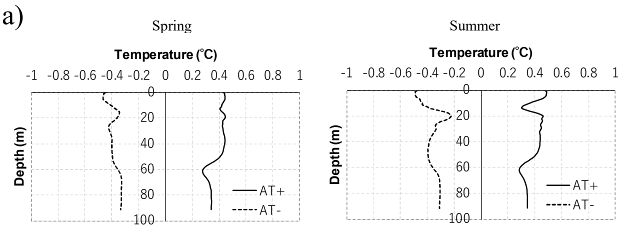


Fig.2 Average depths of mixed layer and thermocline in spring, summer, autumn, and entire simulation period for sensitivity analysis on (a) Air temperature and (b) Wind speed.

a)



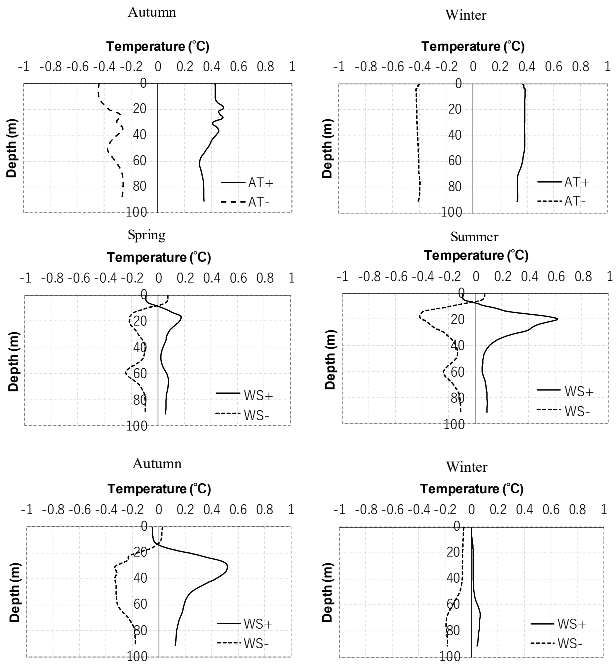


Fig. 3 Vertical distributions of difference of seasonal mean water temperature from the baseline case in a) AT+ and AT-, and b) WS+ and WS-.

4. CONCLUSION

When the air temperature increased or decreased, water temperature in all layers increased or decreased almost uniformly in all layers, therefore, the structure of stratification little changed. On the other hand, as the wind speed increased, the diffusivity increased. Thus, the vertical mixing was promoted. In addition, the warm water parcels were transported to the lower layer. Then, the colder water parcels near the thermocline were transported to the upper layer. When the wind speed decreased, the water parcels between the surface layer and the thermocline became less mixed, and the stratification strengthened. The effect of the change of wind plays an important role in the change of stratification.

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O2-5

Sustainability Challenges in Egypt under Limited and Threatened Water Resources

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Keywords: Water crises, Reuse, Water treatment

ABSTRACT

The water deficit that increases rapidly and the degradation of the irrigation network in Egypt resulted in serious irrigation problems and in higher dependence on the drainage water at tail end regions. During last decades and due to the degradation of the drainage water and the spread of the municipal water stations on the main canals, the strategy of the dependence on the drainage water has changed. The reuse has started in Egypt through mixing the drainage water with the fresh water in the main canals (official reuse). Currently, the trend changed to the direct dependence on the drainage water at the tail ends, where there is no municipal stations; either through lifting the drainage water to the tail ends of the branch canals (intermediate drainage reuse), or through direct use of the drainage water by the farmers (unofficial drainage reuse). With the operation of Grand Ethiopian Renaissance Dam, the Egyptian water resources will decrease, and this will have serious impact of the sustainability of agricultural sector. Currently, the per capita share of water is around 600 m^3/year. With the reduction of the irrigation water, the salinity of agricultural drainage water and the concentration of sewage and industrial wastes that are dumped in the drainage network will increase. In the same time, the dependence on the drainage water will increase. The situation might be critical during the coming years unless a new strategy is developed to enhance the quantitative and qualitative equity of water distribution and to ensure the sustainability.

1. INTRODUCTION

Egyptian agricultural is one of the oldest agricultural systems that remained sustainable for thousands of years. Such system is currently facing challenges with the increase of water demand in the other sectors and with the threatening of Egyptian water resources. The sustainability is also threatened due to the degradation of the irrigation network, which prevent water from reaching many tail end regions, and by the degradation of the quality of the drainage water with dumping of untreated sewage and industrial wastes in the drains. Big portion of dumped sewage and industrial wastes is untreated and the ability to treat them is limited due to the financial constraints. The attempts to improve irrigation efficiency, either through the implementation of Irrigation Improvement Projects (IIP) or through introducing new irrigation techniques had limited impact, and therefore the decrease in water resources is faced by depending on the reuse of drainage water, which contains different wastes from agricultural, sewage and industry. Some regions currently depend mainly on the drainage water to irrigate, and with the decrease of water resources, these areas will depend totally on these resources and in the same time, the quality of the drainage water will degrade significantly. Developing a strategy that could decrease the side effect of the reuse and distribute the burdens between head and tail farmers became essential. Such strategy depends on introducing simple and cheap water-treatment techniques that mitigate the pollution problem, return to the official reuse based on the quality of the drainage water, and define the suitable crops to be cultivated at different areas based on water quality.

2. Methodology

The study presented the current situation regarding the dependence on the reuse, anticipated the new situation with the reduction of water resources, and then it discussed the suggested steps to face the expected water crises. Regarding the current situation, the study presented the current deficit in water resources and the economic challenges for water treatment. Then, the study discussed the magnitude of the dependence on the drainage water, the quality of the drainage water, and the impact of using such water on the productivity. For the anticipation of the new situation, the expectation about the reduction in the water resources will be used as the base for the discussion. The suggested strategy to face the irrigation deficit will be presented in its three steps.

3. Current situation

3.1 Limited water resources & increasing demand

Total Egyptian water resources is less than 60.0 BCM/year. River Nile is the main source (55.5 BCM/year). Other resources include the deep groundwater, the precipitation at the north shores, and tiny amount of desalination [1]. In the same time, there was a gradual increase in municipal and industrial water use. During 20 years (1990-2010), and while the population increased 50%, municipal water use increased from 3.1 BCM to 8.8 BCM (184%). Industrial water use increased during the 13 years (1997-2010), from 2.0 BCM to 4.4 BCM (120%). Based on the minister of Water Resources and Irrigation (MWRI) in Egypt, the current water deficit is around 20.0 BCM/year, and this is covered through intensive reuse. He added that our municipal requirements is increasing by 4.0 BCM each 10 years, which is a big challenge [2].

3.2 Water treatment and the economic challenge

The spread of municipal service was not associated with the sanitation service. While municipal service almost covered the whole country, the sanitation service covered only 56% of the country. Current capacity of municipal stations is 9.23 BCM/year, while the capacity of water treatment plants is 3.88 BCM/year. Considering that municipal consumption is ~20%, only 50% of the sewage is treated, and it is only primary treatment. During 2010, around 7.0 BCM of sewage returned to the system, 3.4 is primarily treated and the other are dumped without treatment [1]. The treatment of industrial wastes is limited as well. The budgeting for the agency of municipal and sanitation increased from 5.3 Billion L.E in 2015/16 to 8.3 Billion L.E in 2016/17, but this is still not enough to face the problem. The national plan for water resources until 2050 requires 900 Billion L.E, and a major part of it is water treatment [3]. Such big investments might not be available considering current economic situation in Egypt. Therefore, cheap and simple techniques should be introduced, in parallel with the current effort for water treatment.

3.3 Current dependence on the reuse

In 2010, and based on the strategic plan for 2017, total water reuse is around 14.0 BCM/year (more than 20% of irrigation water). Recently, and as stated before, the reuse is around 20.0 BCM/year. In some irrigation directorate at the tail end of the Egyptian irrigation network, the dependence on the drainage water constitutes around one third of the total water resources. In such areas, the drainage water is used directly without mixing with fresh water (intermediate drainage reuse & unofficial drainage reuse). Based on Molle et al., (2012), the intermediate drainage reuse exceeded 25% of water budget at some irrigation networks, besides big amount of unofficial drainage reuse [4]. Regarding the quality of the drainage water, and based on Satoh et al (2017), total coliforms exceeded 320 times the standard, and Ammonia exceeded 58 times the standard in some main drains [5]. The dependence on the drainage water has serious impact of the productivity, and based on different measurements, using the drainage water could reduce the productivity by 20-32% based on the crop and water quality.

4. Expected scenarios in the future

There is no confirmed number about the reduction in Egyptian water resources with the filling and the operation of the Ethiopian dam. However, many researchers / expertise expected that Egyptian water resources would be affected seriously. Based on Diab (2017), there will be a reduction of 7.5 BCM/year [6]. It is hard to split specific command area and stop cultivating it to reduce water consumption due to the spread of municipal stations along the Egyptian irrigation network until the tail end. The reduction will be partly at some branch canals or some tail end regions. These areas will try to use drainage water (or shallow groundwater), which will degrade with the reduction of water supply as explained before. If these areas can complete their requirements from drainage or shallow ground water, the consumption will be the same. Total drainage water that is dumped to the Mediterranean Sea and northern lakes will be reduced by the reduction in water resources (4.0~5.0 BCM/year). Most of the studies defined the minimum amount of the drainage water to maintain the salinity in the old land by 8.0 BCM/year, and therefore the salinity will be accumulated in the cultivated lands. If these areas could not complete their requirements from unconventional water, there will be serious impact on productivity and salt accumulation as well. The sustainability is threaten at different scenarios, and new strategy should be developed to avoid such destination.

5. Facing the Challenge

Facing the new challenges required new strategy, which depends on three axes: introducing simple cheap techniques for water treatment, returning partially to official reuse, and introducing new cropping pattern strategy

5.1 Mitigating wastewater problem with low-cost treatment techniques and with the cooperation of civil societies

The objective of this component is to implement low cost wastewater treatment techniques with the cooperation of the non-governmental organizations. These techniques should achieve significant microbiological decontamination, offer very low O&M costs, and could mitigate the pollution in the drainage canals. Aeration and wetlands are among the suggested techniques. The role of non-governmental organizations is crucial. They should share in the construction, operation and maintenance of these techniques. The society should share in the cost through these organizations. Enhancing the capacities of these organizations and increasing the awareness about pollution problem are essential parts as well.

5.2 Partial return to official drainage reuse

With the degradation of the drainage water, many lifting stations on the main canals stopped. This cost the Egyptian water budget around 2.3 BCM/year. The main problem of the official reuse was the degradation of the drainage water with the spread of the municipal stations in the main canals. Mitigating the pollution in the drains through the previous step could give a chance for return, even partly to the official reuse. Good monitoring approach should be applied to define the amount of the lifted drainage water, based on its quality. Lifting the drainage water to the main canals decrease the burdens on tail end farmers, and enhance the chance of sustainability. Returning to official reuse might require changing the abstraction points of the municipal stations or using better technology in municipal stations for drinking water treatment.

5.3 Developing new cropping pattern strategy

The first two points decrease the burdens on tail end farmers. However, avoiding the direct dependence on the drainage water completely is very hard. The decrease of water supply will result in worse drainage water as explained before, and therefore the dependence on such drainage water should be associated with specific cautions. To avoid serious health risks, cultivating some crops should be prohibited in tail end regions. spreading of some crops, such as cotton crop, which was the famous Egyptian crop, and decreased significantly in last decades, became an important task.

6. Conclusion

Egyptian water resources is currently threatened. In the same time, water requirements will increase rapidly with the increase of the population. The gap between water supply and demand will be filled through higher dependence on unconventional water resources (drainage water and shallow groundwater) as improving water use efficiency faced different problems in Egypt. During last decades, the direct dependence on the drainage water increased with the decrease of the official drainage reuse, and the quality of the drainage water degraded with the increase of sewage and industrial wastes in it. Water treatment is the backbone of the sustainability. However, it is hard to improve water treatment rate to catch the expected reduction in water resources in coming years. Therefore, introducing cheap and quick treatment techniques, in parallel to the original water treatment, is essential. This should be associated with partial return to official drainage reuse and introducing new cropping pattern strategy to avoid any health risks.

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O2-6

Climate Action in lakes of *Haor* basin of Bangladesh

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Key words: Climate Action, Haor Basin, Adaptation, Institution, Policy

ABSTRACT

The Haor is a form of a back swamp, a bowl shaped shallow depression found in the north-east part of Bangladesh. Haor basin the second most climate change vulnerable ecosystem in Bangladesh. The people gain their livelihoods from wetland and floodplain resources. During monsoon, the whole area goes under water and there is no option in engaging earning activities except fishing. The rainfall pattern of the basin has changed and first flash flood is around two week ahead comparing with last decade. While flooding enhances floodplain fisheries, the early flashfloods, unique to this region, caused due to sudden onrush of rainwater from adjacent Indian Hills poses a high risk of damage to the standing crop just before harvesting. Data reveal that rainfalls in Meghalaya, India have increase in March and April that intensifies the severity of flashfloods. Submergible dykes to delay flashflood entry into crop fields is an action from the government. The community is diversifying the cropping. Building resilience into both human and ecological systems is the best possible way to deal with climate change risk. Climate response capacity and social acceptance build social and ecological resilience. The cross-sectoral multi-scale stakeholder engagement of the actors who influence or who are affected by the complex human-ecosystem interactions is the way towards building the social acceptance in an ecosystem. The current paper is based on observation of climate change impact and coping practices in the Haors of Moulvibazar and Sunamgang districts in the year 2017.

1. INTRODUCTION

Because of the local hazards, economy, local livelihood patters, impact of climate change and so on have made the Haor basin the second most vulnerable ecosystem after the coast. Haors, which are bowl-shaped depressions between the natural levees of a river subject to monsoon flooding every year, are mostly found in the eastern region of the country, known collectively as the Haor basin covering an area of approximately 24,500 km2. There are altogether 411 Haors comprising an area of about 8000 km2 dispersed in the districts of Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona & Kishoreganj. The main hazard of Haor is flash flood. The major Constraints of Haor are; (1) Degradation of natural resources and biodiversity. (2) Natural disasters are the main reason of poverty, lack of availability of basic infrastructure and social amenities, inequity in resources acquisition and poor access to natural resources. (3) Crop damage by flash flood. (4) Declining productivity of crops. (5) Poor Market linkage and value addition.

The Haor is subject to deep monsoon flooding, supporting rich fisheries while the drier winter yields a bumper rice crop. While flooding enhances floodplain fisheries, the early flashfloods, unique to this region, caused due to sudden onrush of rainwater from adjacent Indian Hills poses a high risk of damage to the standing winter rice crop just 2/3 weeks before harvesting. Flashfloods remains the major climate risks to thousands of rice farmers in the region over years. Data reveal that rainfalls in Meghalaya, India have increase in March-April that intensifies the severity of flashfloods. Creating submergible dykes to delay or divert the entry of flashflood water into the crop fields is the only adaptation response from the government. However, there are incidents of failure of dykes almost every year and consequent losses of winter rice, the only crop in this vast basin covering 97% of the total cropped area. In 2003 over 80% of rice amounting to 0.6 million tons was completely damaged due to flashfloods [1].

2. METHOD

A number of tools were used in the study, including

1. Review of literature: Review of documents published by Government and NGO from 2010 to 2017
2. Community Consultation: 4 Consultations with fisher male and 2 with female fisher
3. Process documentation of the adaptation practice, and
4. Key Informant interview: 7 Key informants were interviewed

3. RESULTS

Climate Action on Haor:

(i) Community-Based Resource Management Project: project period was 2000-2010 and key roles were to improve participants' access to essential services and resources, to diversify their livelihood options, to empower women in a district that is remote, neglected and characterized by destructive flooding patterns, supports the transfer of water and land management rights, provides access to savings and credit services at the village level, empowers women by addressing strategic gender needs.

(ii) Sustainable Environmental Management Programme (SEMP): prevent and reverse present trend of environmental degradation, promote sustainable development, reduce poverty, capacity strengthening at community, local and national levels.

(iii) Fourth Fisheries Project (FFP): project period was 200-2006 and major roles were to support sustainable growth in an equitable benefit distribution fashion, community based inland open-water fisheries management, development and management of coastal shrimp aquaculture, supply of equipment, transportation, and, studies for freshwater aquaculture extension and training; support to management, and assessment of ecosystems' sustainability, and, that of exotic species; institutional support, to include training, civil works, and/or equipment as needed.

(iv) Community Based Fisheries Management (CBFM)-I &II: project period was 2001-2007 and prime objectives were to ease the growing fishing pressure and stop fishing during the breeding season, usually for a three-month period – April to June each year, to establish fish sanctuaries where no fishing is allowed.

(v) Costal and Wetland Biodiversity Management Project (CWBMP): had been implanted since 2006 in the Ecological Critical Areas (ECAs), viz., Sonadia island, St. Martin's island and Teknaf peninsula and in Hakaluki haor, main objectives were to ensure the conservation and sustainable use of globally significant coastal biodiversity through management of ECAs,

(vi) Aquatic Ecosystem through Community Husbandry (MACH): project period was 1998-2008 and it included all floodplain resources (fish, plants, wildlife), support entire resource users (poorer fishers, farmers, landless labourers, women, local elites & govt. officials), two groups at each region of the sites, federation for Resource Users Groups and Resource Management Organization..

(vi) Integrated Floodplain Management (IFM): significant use of RNRSS and other natural resources research outputs for the benefit (direct/ in-direct) of poor men and women in diverse contexts, test, demonstrate and assess adaptive learning networks for co-production of knowledge, identify lessons and processes involving CBOs, generate comparisons between floodplain environments which are expected to improve understanding of generic lessons and issues of context specific organizational development and performance.

Sectoral Adaptations in Haor

Potential adaptation strategies exist for all sectors which can also be implemented as community based adaptation projects to address future risks:

Agriculture Sector

- Diversification of crop agriculture is a key approach in addressing climate change, but requires research on appropriate varieties for the new physical, social and climate conditions. Diversification should be coupled with the revitalization of local varieties that have a greater resilience to extreme climate events.
- Household and community assets can be reinforced through alternative livelihood options such as homestead gardening, horticulture, floating gardens and handicraft production. Increasing assets and diversifying livelihood options are key components in ensuring that communities are able to adapt to meet the challenges that climate change brings.
- Information on pest control and methods to protect winter Vegetables from extreme cold and fog needs to be disseminated
- Seeds banks can be established to ensure that varieties remain available following disaster periods.
- Awareness raising on strategies for building adaptive capacity and the implications of climate change amongst local level non-government organizations, agricultural extension officers, block supervisor of Department of Agricultural Extension (DAE), and farmers.

Housing and Settlement

- Flood risk can be alleviated through building raised house plinths for the homes of affected people.
- Homestead plantations can protect settlements from flood and erosion.
- Raising water pumps so that flood water does not contaminate drinking water.

Rivers

- Dredging of river beds combats increased sedimentation, thereby improving navigability.
- Increasing vegetative coverage along river banks protects against erosion resulting from increased flow and flooding.

Enabling Environment: Policy, Strategy Institutional Support

The success of any adaptation strategy will depend to a large extent on the proactive organizational environment as well as policy and institutional set-up.

- The services necessary to support capacity strengthening may be tailored according to the gaps and needs identified through 'knowledge management' and 'proper communication' activities in respective scope of work.
- Multi-stakeholder national coordination committees may be required, chaired by a 'national level authority' with sufficiently empowered to influence over macro policy formulation, planning

and implementation of risk reduction and adaptation initiatives within and among the Sectors.

- Basic framework should centre around existing government structures (institutions) through providing necessary technical assistance in order to build sufficient capacity through technology transfer to deal with Disaster Risk Reduction, and Climate Change and Adaptation matters, and to reflect the later in all development activities.
- Revisiting the roles and functions of existing institutions to have necessary adjustment/ revision towards response implementation' to disaster and Climate Change impacts should be the key strategy. This should be done in a harmonized way through the high powered multi-sect oral national level coordination mechanism.

4. Discussion

The Government of Bangladesh considers climate change as a development concern and is committed to take urgent and long term actions to reduce the vulnerability of its people and risks to national development. [2] Crop agriculture in Bangladesh is highly susceptible to variations in the climate system. It is anticipated that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk. Despite being highly vulnerable, very little efforts have so far been made to understand potential of agricultural adaptation in Bangladesh [3]. Haor produces around 8% of the crops of the country. It is reported that the existing institutions had inherent inefficiencies, lack of foresight in planning for the future, poor coordination among relevant institutions, poor information assimilation capacity and lack of trained and motivated personnel [4]. As a result, those often proved to be ineffective. The central government could not successfully utilize the full potential of the local government and the latter could not assume the full responsibility of implementing local-level planning due to weaknesses in governance system. This made it difficult to implement development activities at the grassroots. All these are possible barriers to successful adaptation, which might have direct implications in agricultural sector.

The effort, experience and lessons in implementing and operationalizing the integration process need to be shared within organizations as well as between different organizations and agencies participating in the integration process. Development of Tools, Methods, Techniques, etc. may be required to facilitate awareness raising training and technical support change in operational practice, measuring progress and learning and experience sharing among the institutions and professionals involved throughout the processes.

5. Conclusion and Way forward

Adaptation to climate change at community level is considered as spontaneous or planned actions, modification, changes in behaviors, attitudes and practices in the way people struggle to maintain or improve their well-being and security owing to global warming and climate change, through formal and informal institutions. This includes a range of approaches currently practiced in the development and climate discourse, including community based adaptation, community led adaptation, community based disaster preparedness, disaster risk reduction, village and community development, sustainable livelihoods for communities/ households/ families, etc. It should be noted that each case where communities adapt successfully to address climatic risks provides useful lessons on how they engage and participate in assessing vulnerability, decide and plan to take actions, and implement those actions to reduce vulnerability and increase resilience. To make community based adaptation approach to be successful, a core pre-requisite is community participation. Another important pre-condition is that the adaptation required at the community level is considered as a part of on-going local development processes and actions, not as an isolated, ad-hoc or externally driven action. In Haor basin of Bangladesh as the water sources in upstream water governance and trans-boundary cooperation is also important.

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O2-7

The Lake Fund of Russian Federation, Spatial Heterogeneity and Established Trends

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Keywords: water resources, lake fund, lake water, federal districts

ABSTRACT

The results of estimation of the Russian Federation (RF) lake fund, carried out according to an original methodology involving modern satellite information, are presented. According to the assessment, ~3,900,000 water bodies of various origins are identified within the RF, the water resources of the water bodies of natural origin are estimated at ~25,910 km^3 of water, of which 91% is in Lake Baikal. In the artificial water bodies the reserves of waters are about 890 km^3. In spite of the huge lake water resources, their spatial distribution is extremely uneven and is weakly coordinated with the location of the population and industrial and agricultural production. The scarcity of water resources in the economically developed regions is usually overcome by the active construction of artificial reservoirs, which, as the analysis shows, is often accompanied by a decrease in the areas of natural water bodies. Quantitative changes in the lake fund are still localized. At the same time, the downward trend in natural water bodies fund in the most developed parts of the country is quite clear and can be intensified by climate change.

1. INTRODUCTION

The Russian Federation is one of the world's most well-endowed with water resources country. Along with the rapidly renewable water resources estimated at 4,322 km^3/year [1], the country has huge reserves of lake waters. At the same time, insufficient attention is paid to the assessment of lake waters, classified as static stocks. Due to their easy availability, lake waters are intensively exploited, which is affects both in their quality and volume. Changes in the lake fund occur due to anthropogenic factors and due to climate change. The work on the estimation of the Russian lake fund was carried out at the Institute of Limnology, Russian Academy of Sciences and includes calculation of the total number of water bodies, total water surface areas and total lake water volume [2]. Along with water resources, contained in natural water bodies, the resources of waters contained in artificial reservoirs were calculated.

2. METHOD

The assessment of the Russian Federation's lake fund was carried out on the basis of a specially developed methodology [3] based on a detailed accounting of the areas of water bodies, data on which were obtained from current satellite images, and on a subsequent calculation of the volumes of waters with due regard given to the mean depths of the water bodies. Mosaic of satellite images for various seasons and years (from 2003 to 2015) was used for determining the areas. This suggests that the obtained total areas of the water surface with respect to any significant territory can be taken for averaged value for the beginning of the 21st century.

During the work, a complete assessment of the water surface area of the lakes, the areas of which exceeded 1 km^2 (or 0.2 km^2 - with low lake coverage of a particular region), was made. This allowed to form an extensive base of modern morphometric characteristics of Russian lakes. For all water bodies, the values of water volumes were determined taking into account their mean depths, which for the morphometrically studied lakes are the measured characteristics whereas for morphometrically unexplored lakes the depths were determined on the basis of regional dependences [4], which characterize the relationship between different morphometric parameters of lake pans.

Morphometry of water bodies of a smaller area due to their huge quantity was estimated using the method of "sampling squares". Essentially, the method implies that the characteristics obtained in a detailed assessment of the water surface area in the “sampling squares” are used as representative analogues and are transferred to the remaining part of the explored area. The procedure assumed the hypothesis of a normal distribution of the characteristics of small water bodies throughout the territory. The number and size of the squares were determined depending on the area of a constituent entity; they were built in a staggered pattern and covered about one-eighth of this area. As a result, the areas for all water bodies falling into squares which identified on space images from an observation altitude of ~2 km were digitized and calculated. In contrast to the first group of lakes for which volumetric characteristics were obtained for each particular entity, the total water surface and mean values averaged over the territory were used for small water bodies in the transition from area characteristics to water volumes. Homogeneity of the territory, its orographic features, the origin of the lakes and it`s belonging to one or another category of size was taken into account when carrying out averaging.

3. RESULTS & DISCUSSION

According to the assessment, ~3,800,000 water bodies of natural origins (including ~1,370,000 lakes with the area of >1 ha) and ~100,000 of artificial ones are identified within the RF. The total surface water area of the natural water bodies is ~335,000 km^2 (including lakes with saline water ~20,000 km^2) and of the artificial ones is ~65,000 km^2. These values were averaged using the images of the beginning of the 21st century, and they are characterized by intra-annual and long-term variations which are most significant in the zone of insufficient humidification as well as in the northern flat regions. The water resources of the water bodies of natural origins are estimated at ~ 25,910 km^3 (~55 km^3 are characterized by increased mineralization) and of artificial ones at 890 km^3.

The main quantity of lakes of the RF is located within the northern territories characterized by a low population, as well as Western Siberia, including its southern part, located in the zone of unstable and insufficient moistening. The Urals District has the largest number of lakes among the federal districts (FD) of the RF, this district accounts for slightly less than half of all water bodies that are decoded on satellite imagery, but their main part is characterized by small dimensions. The Far East, Northwest and Siberia FD are also characterized by significant number of lakes, with the share of medium and large lakes for each of them higher than for the Urals.

Since the main masses of water are concentrated in large and deep water bodies, the Siberian FD is characterized by the greatest resources of lake waters (24,636 km^3), even after deduction of the lake Baikal (234,615 km^3) more than 1020 km^3 of water is contained in Siberian lakes and reservoirs. Comparable stocks of lake water are observed only in the Northwest FD (see Table). In the lakes of the Far Eastern FD there are 276 km^3 of water, while in artificial reservoirs there are ~ 144 km^3. At the same time, despite the highest lakes numbers in the Ural FD, the total volume of its waters is only 118 km^3. The Central, Volga, South and North-Caucasus FD, within which more than half of the country's population live, and in which production of more than half of GNP falls on their joint share, are characterized by the least number of water bodies, even taking into account ponds and reservoirs. The lakes of these four districts contain only ~ 13.6 km^3 of water, including ~ 10 km^3 of fresh water.

Table. Distribution of lake water resources by federal districts of the Russian Federation

Federal district	Total volume of water (lakes and reservoirs), km^3	Mean lake percentage, %
Northwest	1 386	4.98
Central	39.7	1.42
Volga	130	1.86
South	57.4	2.65
North Caucasus	6.16	0.70
Ural	118	3.94
Siberia	24 636	2.07
Far East	420	1.53

Analysis of regional data indicates a weak coherence of the total number of water bodies in comparison with the total area of the water surface and water resources. That is, the high lake content of the territory is not yet an indicator of significant water resources. Within the Asian part of the RF, about 98% of the lake waters are concentrated in its mountainous part, at the same time, only 6% of the total number of water bodies are located here. The values of the total water surface (or mean lake percentage, as its specific index) calculated for different territorial formations along with the general water resources give a clear view of the distribution of the lake fund. Wherein mean lake percentage reflects the possibilities of the formation and continued existence of lakes in these physical and geographical conditions, but it may weakly reflect general water reserves, and the amount of water resources is primarily determined by the presence of large and deep lakes and is virtually independent of the total number of water bodies within the explored area. Despite the significant country's lake water resources, their spatial distribution is weakly coordinated with the centers of population distribution, industrial and agricultural production. The water reserves of many most in need regions is quite low.

Assessment of water resources of the lakes of Russia was accompanied by an analysis of quantitative changes in the lake fund during the 20th century. Changes occurred in two main directions: the number of creating artificial reservoirs increased, but at the same time a gradual reduction in the fund of natural water bodies took place, primarily in the most developed areas of the country.

Because of the construction of artificial reservoirs, the total reserve of water available for use has been increased in the country since the beginning of the 20th century by 890 km^3. Water reserves of the most demanding regions were significantly increased. In the early twentieth century 99% of the lake waters of the European part of Russia (EPR) were in the lakes of the North and North-West. To date, as a result of hydroconstruction the volume of fresh water in the central and southern parts of the EPR has increased 22 times (up to 220 km^3) and their total share has increased up to 15%.

At the same time, the analysis of modern lakes characteristics indicates significant changes that have occurred with the fund of natural water. Substantial area reduction of some lakes and its completely disappearance were revealed for the most economically developed regions of the country. It is most noticeable in the south and in central parts of the Russian Plain. For a number of river basins the disappearance of small water bodies is up to 20% and more. A significant reduction in the lake areas occurred in the lower reaches of the Volga, and the area of the western substeppe ilmens is most seriously affected, as the result of changes that occurred after the regulation of the Volga. During the period from the 1960s till the present the total water surface area of the water bodies exceeding 1 km^2 decreased in this region by more than 40%.

With the continuing pattern of land use and economic activity, the reduction in the lake fund can be up to ~ 10% in the central part of the ECHR and up to 20% in the southern part by the middle of the 21st century. At the same time, the state of the majority of lake ecosystems will remain ecologically extremely unfavorable in these regions.

Certain changes are also observed in a number of regions of Russian Asia. However, it is difficult to identify stable trends here based only on accumulated observational data. For areas of unsustainable and inadequate moistening, there are significant changes in the volume of lake water, both during the year and in the multi-year section. These changes are determined by the alternation of the watering phases caused by the intra-century fluctuations in climatic characteristics. Only in some cases it is possible to track a clear trend of changes in the area of lakes and associate it with anthropogenic activity. In comparison with the center and south of the EPR, the environmental situation in Russian Asia is generally more favorable, but it is significantly deteriorating in years of low water availability, when the majority of negative processes on lakes are sharply exacerbated. The climate change can significantly affect the deterioration of the current situation. Decrease the amount of precipitation will lead to a reduction in water flow from the catchment areas, which will lead to a general decrease in lake water supplies and aggravation of environmental problems. Along with the disturbances in the natural hydrological regime, climatic changes will also affect the hydrochemical regime of lakes, the water salinity will increase with a decrease in the inflow, and an increase in temperature will lead to activation of eutrophication processes.

4. CONCLUSION

The assessment of the RF lake fund has shown a significant spatial heterogeneity in the distribution of lake water resources across the country and their poor consistency with the distribution of the population and industrial production. A decrease of the lake fund in the regions of the main economic activity was revealed, moreover, further reductions can be expected in the coming decades.

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O2-8

Paper title : Integrated Management Approach of Selangor Dam and Ex-Mining Pond to Mitigate El-Nino Effect on Water Resources in Selangor, Malaysia

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Keywords: ex-mining ponds, Sungai Selangor Dam, water quality

ABSTRACT

Sungai Selangor Dam is among of seven dams in Selangor State together with ex-mining ponds located along Selangor River which are gazetted as Protected Zone under Section 48, Selangor Water Management Authority (SWMA) Enactment 1999. Management of the dam is inclusive of impounding water body and water catchment area to ensure the water resource security. Both dams and ex-mining ponds are functioning as water supply to the nearest Water Treatment Plant. Sungai Selangor Dam have been established in the basin to regulate the river flow and ensure sufficient amount of water is available to all even during dry seasons. LUAS monitor the water quality as well as water level and report regularly to the State of Selangor. Water resource from the ex-mining ponds are utilized by pumping from the ponds to the Selangor River. The total capacity that can be abstracted from the ponds is 1,000 million litres per day (MLD). The utilization of the ponds has been proven to reduce the dependency on the release of water from Selangor River Dam thus can increase the storage life of the dam. Weekly monitoring of the water quality from the ponds is also implemented to ensure that the raw water quality meets the Malaysian National Raw Water Quality Standard. Other initiative undertaken by the SWMA is the cloud seeding operation over the catchment areas of the 7 dams in the state of Selangor inclusive of Selangor River Dam. The cloud seeding operation is conducted daily depending on the meteorological conditions to increase the possibility and intensity of rainfall thus increasing the storage of the dams.

1. INTRODUCTION

SWMA is a one stop agency for water resource management in Selangor State of Malaysia. Selangor River Basin plays a very important role in water supply, accounting for about 60% of total water supply for Selangor, Wilayah Persekutuan Kuala Lumpur and Putrajaya.

2. SELANGOR RIVER AND WATERBODIES

Selangor State has seven water supply dams in total and more than 10 ex-mining ponds located along the Selangor River (Fig. 1). The Sungai Selangor Dam which is located at the most upstream of the rivers and all the ex-mining ponds have been gazetted as Protected Zone under Section 48, Selangor Water Management Authority (SWMA) Enactment 1999[1].

Management of the dam is inclusive of impounding water body and water catchment area to ensure the water resource security. Both dams and ex-mining ponds are currently functioning as water supply to the nearest Water Treatment Plant. Sungai Selangor Dam have been established in the basin to regulate the river flow and ensure sufficient amount of water is available to all even during dry seasons. El Nino phenomenon involving scorching heat conditions and long drought have been threatening the water resources throughout the country including Selangor. One such phenomenon was reported in 2014 in Malaysia of which dry conditions lasted from February to August and led to substantial drop in dam water level. To ensure management of the water, LUAS continuously monitor the water quality as well as water level and report regularly to the State of Selangor.

Water resource from the ex-mining ponds are utilized by pumping from the ponds to the Selangor River. The water abstraction is regulated and the total capacity that can be abstracted from the ponds is set at 1,000 million litres per day (MLD). The utilization of the ponds has been proven to reduce the dependency on the release of water from Selangor River Dam thus can increase the storage life of the dam. Weekly monitoring of the water quality from the ponds is also implemented to ensure that the raw water quality meets the Malaysian National Raw Water Quality Standard.

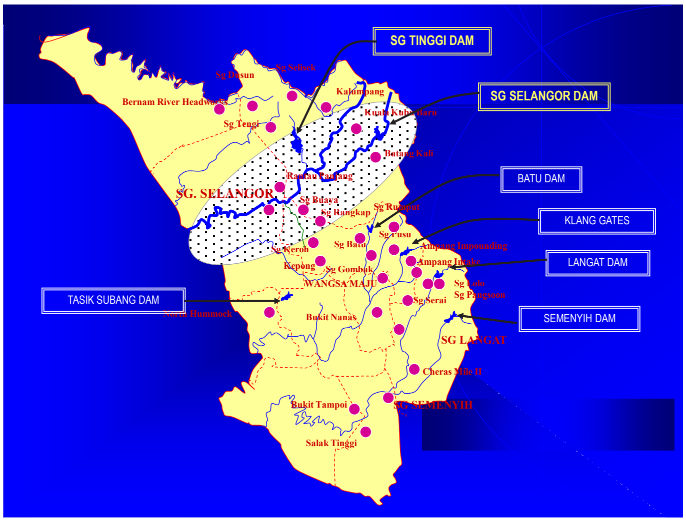

Fig. 1 Dams in Selangor

3. CLOUD SEEDING OPERATIONS

Another initiative that is undertaken by the Selangor Waters Management Authority (SWMA) during El Nino condition is the cloud seeding operation over the catchment areas of the seven dams in the state of Selangor inclusive of Selangor River Dam. The cloud seeding operation is conducted daily depending on the meteorological conditions to increase the possibility and intensity of rainfall thus increasing the storage of the dams.

4. CONCLUSION

Various initiatives that have being carried out is a commitment that sufficient water resources in the State of Selangor can be secured through efficient management of water resources.

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O2-9

Impact of LULC Change on Hydrological Response in Lake Maninjau Catchment Area

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Keywords: Land use change, Lake Maninjau, Hydrological Response, SWAT model

ABSTRACT

Lake Maninjau belongs to the type of volcanic lake in the form of caldera lake. Its eruption spouted 220-250 km^3 of volcanic herb spread over 75 km from the center of the eruption. This lake has a very small ratio of watershed and lake, where Maninjau watershed reaches 13,260 Ha and lake surface area 9,737.5 ha. Currently the water quality of the lake is decreasing due to the development of floating cage in the lake, but the change of land use in the catchment should also be considered, which can lead to changes in lake hydrological conditions. Based on classification on Landsat-8 Satellite image. Land use is dominated by agricultural area of 5,355.4 ha (37.8%); residential area of 216.9 ha (1.53%); forest area of 6,737 ha (47.4%); and the shrub and open area of 1,861 ha (13.1%). Land use changes may impact the hydrological characteristic such as water yield, surface runoff and base flow. The purpose of this study is to analyze the impact of land use changes on hydrological response in Lake Maninjau Catchment Area. SWAT hydrology model was used to assess the impact of land use changes from 1991 to 2018. The analysis of land change shows a reduction of forest area by 2.2%, 1.1% agriculture and 0.3% settlement increase. The SWAT model simulation results under land use conditions 1991 and 2018 showed the addition of surface runoff from 54 mm/year to 55 mm/year. While base flow is reduced from 406 mm/year to 334 mm/year.

1. INTRODUCTION

Lake Maninjau (0^o 19' S, 100^o 12' E) is volcano-tectonic lake situated in Agam District with altitude 461.50 m above sea level. The lake has an area of about 9.737,5 ha and catchment area 24.800 ha. The utilization of lake is for power plants that produce an average annual energy of 205 Giga watt hours (GWh), source of irrigation water, fish cultivation in floating cages, and as tourism destination. Based on rainfall data from 1984 to 2000 showed the monthly rainfall pattern that relatively uniform over the year, with average monthly rainfall of 299 mm and annual rainfall averaging 3.661 mm [1].

Currently, the water quality of the lake is decreased with the increasing number of floating cages in Lake Maninjau. This condition can lead to changes in lake hydrological conditions and reduce the ecological function of the lake. However, there is another factor to consider, which is a land use change. Land use change is very influential on the decline of water availability [2].

The existence of anthropogenic activity around the lake can contribute in lowering the environmental quality of Lake waters such as: disposal of domestic waste, hotels, restaurants, agriculture and fish feces produced from floating net cultivation. It is estimated that the total amount of organic waste entering the lake from residential area is around 209.93 kg /day or 75,574 kg/yr, while from KJA's fishing activities is 111,889.84 tons (from 2001-2013) [3].

Sensitivity and carrying capacity of the hydrological system as a result of land use change can be done in three stages: (i) the development of land use change scenarios; (ii) hydrology simulation; and (iii) evaluation of the impact of hydrological variations produced water resources system. These steps include aspects of the development and management as well as assess the performance of the system due to disasters such as floods and drought, the operation of reservoirs, channels, water quality, and environmental issues [2]. Analysis approach in the study of the hydrological system is a cornerstone of information theory to integrate the components of a watershed system into hydrological models [4].

The purpose of this study is to analyze the impact of land use changes on the hydrological response in Lake Maninjau Catchment Area.

2. METHOD

SWAT is a continuous model that simulated the hydrological cycle in two main parts, namely; land phase and routing phase. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrients, and pesticides into the main channel. While the search phase of the hydrologic cycle to simulate the movement of water, sediment, through a network of channels in the watershed to the outlet point. In the process of setting up and running the model input file with SWAT required a series of stages [5]. The first step is to delineate watersheds and sub-watersheds using the data DEM (Digital Elevation Model). After that, we define and enter the file of Hydrology Response Unit (HRU). Fig 1 shows a schematic framework SWAT models.

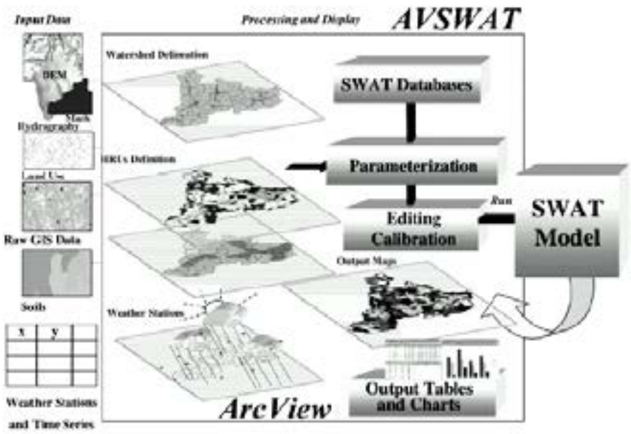

Fig 1. Schematic system of SWAT model

Analysis of the impact of land use change on the hydrological response is done by simulating the SWAT on different land use condition. Remote sensing method was used for satellite image classification. This study uses three series land use obtained from Landsat imagery, 1991 and 2018. Land use classes used in hydrologic modeling using eight categories SWAT model simulation results satellite image classification so that the natural adjustments HRU process definition, To compare the model output for each input map different land use needs to be done the same formation watershed characteristics through the process of Automatic Watershed Delineation.

3. RESULTS

Based on classification on the Landsat-8 Satellite image, Lake Maninjau Catchment area is a densely populated area with moderate land use changes. Land use is dominated by forest area of 6.375 ha (45%); Agriculture (including paddy field) of 2.322 ha (1.53%); and the settlement area of 283,5 (2%). Fig 2 shows the land use of Maninjau lake Catchment area.

The results of the analysis of land use changes over the 27-years (1991 to 2018) showed decreased of forest area (132 ha) and agricultural by 767 ha, while settlements over that time increased by 202 ha. Table 1 shows land use changes from 1991 to 2018 in detail.

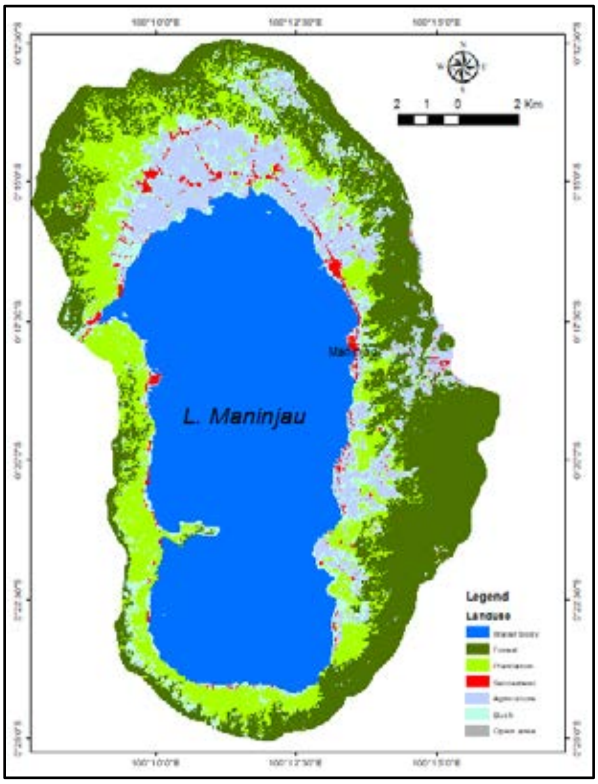

Fig 2.Landuse map of Maninjau Catchment Area (2018)

The results of the analysis of land use changes over the 27-years (1991 to 2018) showed decreased of forest area (132 ha) and agricultural by 767 ha, while settlements over that time increased by 202 ha. Table 1 shows land use changes from 1991 to 2018 in detail.

Table 1. Land use change in Lake Maninjau Catchment Area

Land use	1991		2018	
	Area (Ha)	%	Area (Ha)	%
Forest	6507.4	46.2	6375.0	45.3
Agriculture	3089.0	21.9	2322.0	16.1
Plantation	2821.1	20.0	3347.5	23.8
Settlement	81.5	0.6	283.5	2.0
Bush	1575.8	11.2	1679.2	11.9
Open area	2.1	0.0	50.7	0.4
Total	14,076.9	100.0	14,057.9	100.0

To get the impact of land use change on the hydrological response both land use conditions were simulated with the SWAT hydrology model, the simulation used the climate data measured in the weather station. The calibration and validation of the model are still in process so that the simulation results in two conditions compared to the magnitude of the parameters; surface flow, base flow and water yield. The model simulation results are shown in Fig. 3 which is a river inlet flowing into Lake Maninjau. This result is still in the process of calibration and validation.

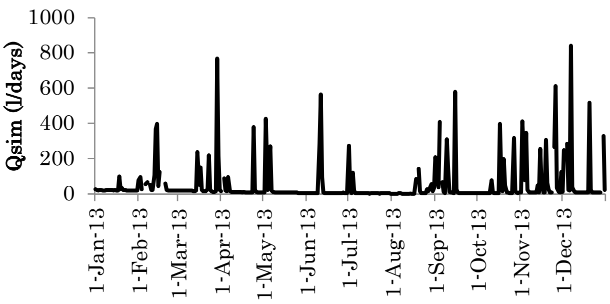

Fig 3. Discharge in river inlet

Simulation results show a 65% rise in surface flow, up from 247 mm/ year to 409 mm/year, while base flow drops by 17% from 406 mm/year to 334 mm/ year. As a result of changes in land use also resulted in a decrease in water yield of 51 mm/ year.

4. DISCUSSION

Maninjau Lake is a volcano-tectonic lake that has a wide ratio of the water body and catchment area. Therefore the water balance is essential in the processes that occur in the lake and is very sensitive to nutrient input due to the retention time of 25 years. Changes in land use will affect not only the water balance but also the nutrients flowed into the lake. Nutrients entering the lake will further trigger algal blooming events in Lake Maninjau. SWAT model can be used to calculate water balance and the loading of sediments and nutrients entering the lake, with this scenario as well as sediment loading and nutrient loading scenarios can be built.

5. CONCLUSION

For 27 years there has been a change of land use in the form of forest conversion, agriculture and the addition of large settlements in the catchment area. Consequently, there is a change in the water balance cycle such as runoff (65%), decreased base flow (15%) and water yield (51 mm /year).

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O2-10

Sustainable Development of Local community through Lake Economy

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Keywords: Economy, lake, Sustainability, Pollution

ABSTRACT

The Importance of Lakes. Healthy lakes and their shores not only provide us with a number of environmental benefits, but they influence our quality of life and they strengthen our economy. Lakes can also be used as a water supply for industry and an irrigation source for agriculture. We can consider Lake as fresh water resource. All great civilization in the human history flourished alongside lake or rivers. This was because of availability of fresh water easily for daily activities, and fertile land available for agriculture. India's huge water resources have helped in sustaining the agricultural output necessary to support a huge population.

1. INTRODUCTION

Lakes are one of the main drivers of tourism industry to strengthen local economy in all over the world. In India, river ganga is a huge source of religious tourism. In the mountain stretches, rivers serve as means for adventure sports. India has a large number of beautiful lakes and great rivers spread all over the country from Kashmir to Kerala and from Rajasthan to Assam. Lakes in India can be dividing as manmade as well as natural, further natural lake again divided as freshwater lake and brackish water lakes. Indira Sagar reservoir the big lake is the biggest reservoir in India and The Sambhar Salt Lake is India's largest inland Salt Lake. Most of the lakes in India are fresh water lakes, Dal Lake in Kashmir and Sasthamkotta Lake in Kerala are the example of freshwater lakes. These water bodies on the land surface are one of the most beautiful tourist attractions in India. Key word: Economy, Lake, Sustainability Pollution.

Economic sustainability of community through Lake Ecosystem development. Anyone who lives on, plays in, or otherwise appreciates lakes values them. But what are they worth? And should that worth only be determined for the lake's value to humans? In today's society, there is an undeniable "paradox of lake values."

We take lakes for granted in much the same way that Garret Hardin wrote in his famous 1968 essay, "The Tragedy of the Commons." Hardin referred to the village green of Colonial America on which folks grazed their horses and livestock when they came into town. Over time, the overuse of this shared limited resource resulted in its degradation, even though it was clearly in no one's interest for this to happen. Public lakes, as we now use and manage them, are a modern-day tragedy of the commons.

The economic importance of lakes is presumed to be high but is difficult to assess. What is the value of clean water? What would you be willing to pay to enjoy the peace and tranquillity of a quiet lakeshore or to take your child fishing? The "willingness to pay" has long been used to place economic importance in nature. But is this enough? If a polluter damages your lake, how much should the fine be? Courts follow the "law of economic waste" in which environmental damages are limited to the value of reduced property values. So what is the economic importance of a lake for sustainable development? Willingness to pay for lake water quality has not been observed across the Indian State.

A 2012 study conducted by SEERAM, in Maharashtra state India, reported that assessed residential property value was 60 to 65 percent higher than other part of the country with similar size and characteristics but without as many lakes. The study concluded that the increase in property values, and thus tax revenue, was due to the lakes.

Clearly, lakes have economical value and clear lakes have more value than turbid lakes. But these values are all based on Rupees and kind to humans. Are there not intrinsic values to lakes? A recent article (http://www.time.com/time/business/article/) quoted Pavan Sukhdev, a senior banker with Deutsche Bank and Special Advisor to the United Nations Environment Programmer's (UNEP) Green Economy Initiative as saying, "Biodiversity is the living capital of the planet." Currently, "the economic value attached to nature is zero. Our metrics are geared toward consumption and production of man-made goods and services, and we tend to gloss over nature." This, he says, has led to "bad accounting," which, in turn, has contributed to rapid biodiversity loss.

What kind of value are we talking about? According to the UNEP study, an annual investment of $45 billion to biodiversity conservation worldwide could safeguard about $5 trillion in ecosystem services – a benefit to cost ratio of 100 to 1. Just how "ecosystem" nourish us?

Healthy Ecosystem of the Lakes can be the sure sustainable way to survive. Local population can obtain lots of benefit from ecosystems. These include provisioning such as food, water, timber, and fiber; regulating activities that affect climate, floods, disease, wastes, and water quality; cultural activities that provide recreational, aesthetic, and spiritual benefits; and supporting to soil formation, photosynthesis, and nutrient cycling. In eutrophic Lake, especially in the various parts of India is rapidly decreasing, the historic loss of ecosystem outcome (soil stability, nutrient sinks, sustainable shorelines, etc.) due to human development of the lake's watershed has been costly. Lake water quality has been degraded by a multitude of human activities influencing water and nutrient flows. Addressing the eutrophication of Lake could be realized by preserving and restoring environmental assets at the watershed scale. For example, if pre-settlement landscapes could be re-created, they would provide, on an annual basis, between $300 million and $2.1 billion of ecosystem outcome, and between $40 million and $1.1 billion worth of carbon offsets in the emissions market as per ecosystem financial expert. This is three times the current value of Lake Ecosystems economic.

Table No. 01:

Contextual Relevance	Ecosystem Service	Description – Function
Water Quantity and Quality - Lake Eutrophication	Water Regulation	Regulation of water flows, which entrains pollutants and purifies water – Regulating.
	Water Supply	Filtering, retention, and storage of fresh water – Provisioning.
	Erosion control	Maintains arable land and prevents water silting by lowering soil losses by wind and and sediment retention and runoff – Regulating.
	Waste Treatment	Removal, breakdown, or abatement of pollutants – Regulating.
Climate Change	Atmospheric Regulation	Regulation of atmospheric compositions by various processes such as carbon sequestration – Regulating.
	Climate Regulation	Influence of land covers on climate (temperature, precipitation, etc.) – Regulating.
Biodiversity	Biological Control	Control of populations, pests, and diseases through trophic-dynamic processes – Regulating.
	Habitat/Refugia	Suitable living space for species to evolve and breed – Supporting.
Material Benefits	Food Production	The conversion of solar energy into edible plants and animals suitable for human consumption – Provisioning.
	Raw Materials	Conversion of solar energy into materials suitable for construction – Provisioning.
	Genetic Resources	Genetic evolution in plants and animals – Provisioning.
Social Well-being	Disturbance Prevention	Dampening of environmental disturbances such as storm protection and flood prevention – Regulating.
	Recreation	Opportunities for recreation, relaxation, and refreshment – Cultural.
	Cultural	Spiritual, religious, historical, and symbolic values – Cultural.
Environmental Integrity	Soil Formation	Rock weathering and organic matter accumulation leading to the formation of productive soils – Supporting.
	Nutrient Cycling	Storage processing and acquisition of nutrients within the biosphere – Supporting.
	Pollination	Movement of plant genes for reproduction – Supporting.

Source: Voora and Venema (2008)

While some of these ecosystem services may seem esoteric.

3. CONCLUSION: As you can see, the value of our

lakes can be measured by more than lakefront property values, tax bases, or fishing license revenue.

Lakes provide value for sustainable development to all community, whether that community lives on them or never even visit them. Quantifying and valuing ecosystem services losses or gains provides an economic rationale for the preservation and restoration of environmental assets.

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O2-11

Effect of soil type, slope and land use change on sediment yields in Tonle Sap Lake basins

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Keywords: sediment yield, soil type, slope, land use change, Tonle Sap Lake

ABSTRACT

Environmental factors such as soil type, slope and land use type are considered to have significant impact on sediment erosion and production in the river basin. Understanding their effects on sediment erosion and sedimentary process is crucially important in sediment erosion management and control. These effects of environmental factors have not been investigated in distributed and quantitative manner in river basins in Southeast Asia. Therefore, this study aims to assess the effect of shifting of environmental factors affecting sediment loads using a physical-based sediment model. A distributed hydrological model was coupled with a process-based distributed model describing soil erosion, sedimentary processes at hillslope units and channels. Model was then applied in two rivers, Chinit River and Sen River, that its tributaries of the Tonle Sap Lake basin located in central of Cambodia. The calibrated model was applied to assess the effect of soil type, slope (<0.2%, 0.2-2%, 2-5%, >5%), and land use change from 2000–2014 on the sediment load. River basins which have just only one soil type or lower slope (<0.2%, 0.2-2%) river basins tend to produce about 5 times higher sediment loads compared to some kinds of soil type or have a higher slope (2-5%, >5%). Changing in land use, specifically forest cover decreasing about 15%, resulted in increase of sediment load in all rivers (about 15%). The findings are useful for soil and land use management, agricultural practices and environmental management in the Tonle Sap Lake basin. The findings are also, in many cases, be likely extended to other river basins around the world which have similar environmental conditions or serve as useful cases for comparison with different environmental conditions.

1. INTRODUCTION

Erosion and sedimentation refer to the processes of erosion, transportation, and deposition which have been active throughout geological time and have shaped the present landscape of our world[1]. However, due to rapid increasing human activities, these processes are now progressing rapidly and leads to environmental damage through sedimentation, pollution and increased flooding [2][3]. Especially, soil erosion is serious environmental problem that human society is facing, as every year at global scale almost 10 ha of cropland are lost due to soil erosion[4]. Effective management of sediment in river is becoming increasingly important from an economic, social and environmental perspective[2]. One of the effective tools in the management of sediment is using sediment model to describe the sediment dynamics and to predict the changing in sediment loads due to Environmental factors and human activities. Environmental factors such as soil type, slope/elevation and land use type are considered to have significant impact on the sediment erosion and production in the river basin. Understanding their effects on the sediment erosion and sedimentary process is crucially important in sediment erosion management and control. In addition, in Tonle Sap Lake basins, sediment erosion is progressively increased and eventually leads to not only environmental damage through sedimentation, pollution and increased flooding but also to our human life due to environmental conditions of river basins (slope/elevation, soil type and land cover) and land use change by human activities (e.g. deforestation for agricultural land). These effects of environmental factors have not been investigated in distributed and quantitative manner in river basins in Southeast Asia. Therefore, this study aims to assess the effect of shifting of environmental factors affecting sediment loads using a physical-based sediment model.

2. METHOD

(2.1) Study area

The study area is Tonle Sap Lake (TSL) basin located in the central of Cambodia. The watershed extends over 43% (85,786km^2) of the national land[5] and has 11 tributaries.

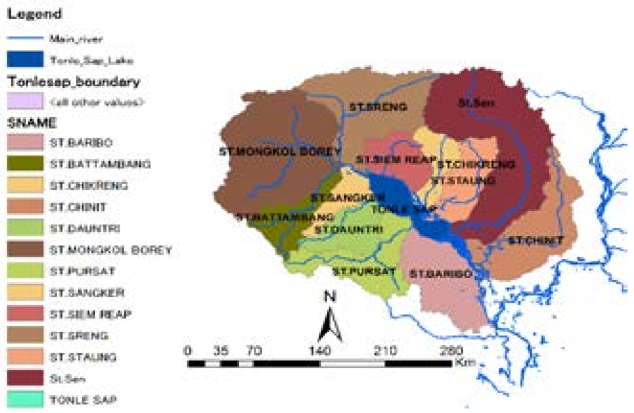

Fig. 1 Tonle Sap Lake basins

Tonle Sap area has a tropical monsoon climate and can form two distinct seasons, rainy and dry season. Rainy season from May to October, maximum and minimum mean daily temperatures in this season are 32.7ºC and 24.6ºC respectively. Mean total rainfall is 1222 mm in rainy season, which is around 75% of the whole annual rainfall. Dry season lasts from early November to March. Maximum and minimum mean daily temperatures are 32.40ºC and 23.1ºC respectively and the mean total rainfall is 411.3 mm is this season. In different seasons, relative humidity in TSL area changes from 65-70% in January to 85-90% in August. Annual evaporation is around 2,000 mm, monthly evaporation ranges from 240 mm in April to 150 mm in September [6].

(2.2) Geomorphology based hydrological model (GBHM)

We applied the distributed geomorphology based hydrological model (GBHM) that was developed by Yang et al. (2002). It solves the continuity, momentum, and energy equations using two modules: hillslope module and river routing module. Further details are described by YANG et al. (2002). GBHM was coupled with a process-based distributed sediment transport model describing soil erosion and sedimentary processes at hillslope units and channels and applied in 2 rivers of the Tonle Sap Lake basin. The input data for the model include weather data, topography data, soil properties and land cover. Shuttle Radar Topography Mission (SRTM) DEM of 90 m resolution was downloaded from http://gdex.cr.usgs.gov/gdex/ (Farr et al., 2007) was used to delineate the Tonle Sap Lake Basin. The land cover of year 2000 and soil type for the basin were obtained from Global Land Cover and the FAO soil map of the world (FAO, 2003), respectively. The elevation data was first converted to 900 m by 900 m resolution was used also to calculate the slope (in %). The Nash–Sutcliffe efficiency (NSE) was used to evaluate the agreement between the simulated and observed suspended sediment loads. The simulation showed a good agreement with the observed suspended sediment load in both rivers. NSE ranged 0.42–0.51 and 0.44–0.63 for calibration and validation, respectively[7].

(2.3) Effect of soil type, slope and land use change on sediment yields

Environmental factors such as soil type, slope and land use type are considered to have significant impact on the sediment erosion and production in the river basin. Their effects on the sediment load were calculated as:

$$Y_i = P_i \times SSL_j$$

where Y_i is the specific sediment yield of the i effects (e.g. soil type, slope) in ton/km^2, P_i is the proportion of the i effects in %, and SSL_j is the specific sediment load in the basin j calculated as the division of the annual sediment load by basin area (ton/km^2). In addition, the effect of land cover change (2000-2014) was analyzed by comparing the annual sediment load between the land use 2000 and 2014.

3. RESULTS

(3.1) Effect of soil type

Acrisol yielded the highest sediment load (18.07±13.5 ton/km^2) followed by Luvisol (14.88ton/km^2), Nitsol (12.16±14.08 ton/km^2), Gleysol (4.23±3.28 ton/km^2), Lithosols (1.3 ton/km^2), Vertisol (1.02 ton/km^2) and Fluvisol (0.39 ton/km^2) (Fig. 2).

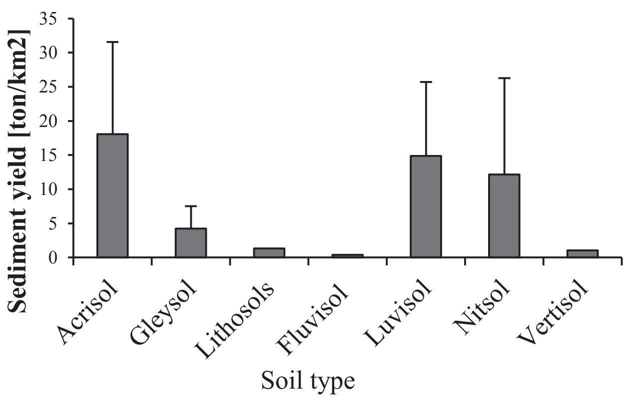

Fig. 2 The average sediment yield of each type of soil in the whole Tonle Sap Lake basin

(3.2) Effect of slope

The slope of less than 0.2% yielded the highest sediment load (13.17±10.63ton/km^2) followed by 0.2–2% (10.51±7.14ton/km^2), 2–5% (2.83±3.75ton/km^2) and The slope of greater than 5% (2.57±4 ton/km²) (Fig. 3).

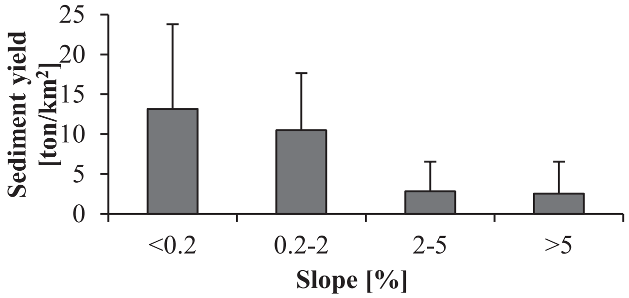

Fig. 3 The average sediment yield in different range of slope

(3.3) Effect of land use change

Due to the decreased of forest cover between the year of 2000 (26%) and 2014 (11%), the average sediment yield was 15.22 ±7.33 ton/km², and 18.26±9.38 ton/km² in 2000 and 2014, respectively, in the whole Tonle Sap Lake basin (Fig. 4).

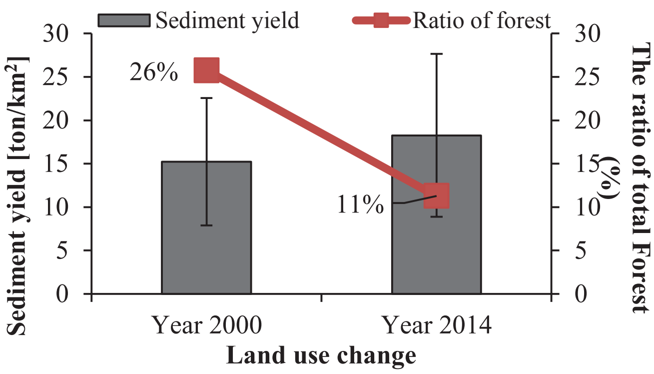

Fig. 4 The average sediment yield of each land use

4. DISCUSSION

Acrisol (67.9%), Luvisol (7.8%) and Nitsol (12.1%) soil showed the highest yield of sediment load compared to other soil type. These soil types are the important source of sediment erosion and sedimentation. Especially, Acrisol is high erosivity because of its low structural stability. Moreover, the topography in Tonle Sap Lake is relatively flat. Thus, the dominant slope ranged between 0–5%, in which the slope of less than 0.2% and 0.2–2% showed similar yield of sediment load while the slope greater than 2% showed significantly smaller. Furthermore, changing in land use, specifically forest cover, resulted in increase of sediment load in all rivers (about 15%) in the Tonle Sap Lake basin between 2000 and 2014. One of the reasons is because of the ratio of forest cover dropped from 26% to 11% resulting higher in sediment. Especially, the ratio of agriculture land is 42% in Siem Reap river catchment and 56% in south area of Cambodia including Dautri river and Pursat river catchment. From previous papers, the area dominated by Acrisol is easier to progress soil erosion but the erosivity has relationship with sediment size and shape in small catchments of central-south China and the Silesian Beskidy [7][8]. One of high erosivity area is Michigan in United States, and around this area human activities progress rapidly so land use change should be caused and the important factor of thinking about sediment dynamics[9].

5. CONCLUSION

The study assesed the effect of environmental factors affecting sediment loads using a physical-based sediment model. The environmental factors such as soil type, slope and land use change showed different effects respectively. Especially, the most important factor is land use change because the differences obviously were found. Soil type and slope doesn't change so much in short period, but at only 10 years sediment yield increases certainly. Human activities and recent development are the potential causes the increased in sediment yields in the basin.

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O2-12

The Effects of Climate Change to the Major Surface Water Resources and Treatment Facilities in the Western Part of Metropolitan Manila, Philippines

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Keywords: effects of climate change, water quality, effects of sediment, hypoxia, and eutrophication

ABSTRACT

From the recent years, the Philippines already experienced the effects of climate change such as facing numerous typhoons with record-breaking amounts of rainfall and severe drought in some areas. However, direct impacts of climate change to the major surface water resources, specifically in the country's capital city, are seldom being discussed. Hence, this proposal will talk about the current scenarios of Metro Manila's two major water sources, Angat Dam and Laguna Lake, and how climate change will affect the water quality as well as the current setups of water treatment facilities. Currently, Maynilad, the company tasked to deliver water in the western part of Metropolitan, Philippines, is investing an estimated amount of at least USD 135M to provide safe and potable water to over 9 million customers. Upgradation of plants requires both minor and major changes on its treatment processes. Some of the solutions are specific to the process train that would directly treat a certain parameter that was considered in the design but has to be updated due to the effects of climate change. These water quality parameters include turbidity, total suspended solids (TSS), manganese (Mn), taste-and-odor (T&O) and total dissolved solids (TDS), among others. Previous actions to lessen the effects of climate change were quite successful. But since climate change seemed to be "normal" globally, Maynilad opted to address the challenge through long-term solutions.

1. INTRODUCTION

For the past decades, the Philippines experienced the effects of climate change through El Nino and La Nina phenomenon. The Philippines ranked as one of the most affected countries by extreme weather events last 2013 and placed 5th for the countries affected most in the period 1994-2013[1]. The country also faced major drought years which were associated with El Nino events. According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in the Philippines, El Nino could affect the normal rainfall pattern that generally leads to precipitation reduction. Aside from extreme heating and rainfall events, the country is also exposed to other risks brought by climate change such as sea level rise, disturbed water budget, and increasing ocean temperature [2].

Consequently, the risks mentioned by Department of Environment and Natural Resources (DENR) affect different sectors such as water resources, forestry, agriculture, coastal resources and health [3]. For the water resources, the effects of climate change are classified into four categories: increased precipitation intensity, decreased water flows, greater precipitation variability and sea level rise [4].

In the West Zone of Metropolitan Manila, there are two major surface water sources: (i) Angat Dam and (ii) Laguna Lake. For many years, the former has been the only water source for the majority of the customers. However, due to the increase in demand, Maynilad Water Services, Inc. (Maynilad) opted to use the lake as an additional raw water supply for the customers last 2009. Since then, the water treatment facilities of the company experienced different effects of climate change through variations on water quality parameters.

This paper aims to discuss how climate change affects surface water resources, the current setups of treatment plants and how these facilities will adapt on the inevitable impacts of climate change to provide an uninterruptible potable water supply to the customers.

2. METHOD

Sampling and analyses of physical and chemical parameters are done more frequently due to the unpredictability of raw water quality. Turbidity and total dissolved solids (TDS) are measured through the methods of turbidimetric and electrometric, respectively. Mn content was analyzed as described by the principal equipment manufacturers [5]. Procedures from the Standard Methods of Water and Wastewater are followed to analyze the threshold odor number (TON) and biological counts of the samples [6]. TON analysis is completed thrice while biological analysis is accomplished once a day.

3. RESULTS AND DISCUSSION

Since 2010, the three water treatment facilities of Maynilad utilized raw water from Angat Dam and Laguna Lake. The La Mesa Treatment Plants 1 and 2 (LMTP1 and LMTP2) are using the former while Putatan Water Treatment Plant 1 (PWTP1) is extracting water from the latter. There were annual patterns observed for some water quality parameters that might be connected to climate change due to its occurrences and extreme values.

A. Turbidity and Total Suspended Solids

For Ipo Dam, the diversion dam after Angat, turbidity and suspended solids are expected to increase during southwest monsoon that usually occurs from April to October each year. While for Laguna Lake, turbidity is expected to increase during northeast monsoon which takes place from around September until April of next year. To treat turbidity and suspended solids, LMTP1 used sedimentation; LMTP2 is equipped with pulsation-clarification while PWTP1 has dissolved air flotation. It was observed that these three plants efficiently removed suspended solids whenever the raw values were within the design limits. But last August 2012, the average turbidity from Ipo Dam increased to almost 830 NTU with a maximum value of 1,836 NTU that retained for at least one hour. This maximum turbidity is almost 5 times higher than the design. Consequently, the volume produced by the treatment facilities at La Mesa was decreased to almost 25-35% of their capacity. Hence, the customers were also affected.

For Laguna Lake, the turbidity at the intake of the plant is starting to increase to a value higher than the design, lately. But due to the established operational procedures such as scheduled cleaning of dissolved air flotation (DAF) tanks and sludge extraction, the plant could still produce water, accordingly.

B. Manganese

Manganese is one of the most common metals in Earth's crust which is also occurring with iron [7]. It is also one of the concern parameters in other water treatment plants because it may discolor the product water once chlorinated.

For Maynilad's treatment facilities, high values of manganese can happen seasonally or on a daily basis. Due to high temperatures brought by El Nino, the Angat Dam might not be able to get enough to replenish the water consumed by the people. In addition, excessive temperature may also hasten evaporation rates in water resources. Hence, water with high levels of dissolved contaminants like manganese will be the remaining source for water treatment plants. As mentioned by (Van Benschoten et al. 1992), the soluble form of manganese is the most stable specie under reducing conditions like ground waters and the bottom parts of stratified lakes and reservoirs.

Maynilad experienced the first recorded high manganese at Angat Dam last 1998. This led to discoloration of product water after chlorination. Since then, it was observed that high dissolved manganese could occur whenever Angat level reaches below 180 m during El Nino.

On the other hand, manganese contents from the intake of PWTP1 might not be related to climate change only since these might also came from anthropogenic activities. Aside from domestic water supply, the lake is also being used for other purposes such as irrigation, aquaculture, power generation, and cooling water in surrounding industries, retention basin for flood control and a sink for treated and untreated waste [9].

C. Taste and Odor

Monitoring of taste-and-odor producing algae in PWTP1 Intake started last 2011 due to incidents and complaints related to water with objectionable odor. According to customers, the odor was musty and/ or grassy. However, there was no apparent trend on their appearances except during summer and/ or northeast monsoon seasons. Aside from these, there were also factors that could contribute to algal bloom that were seen such as long dry spell, low water level, high insolation and high contents of nutrients.

Based on 7-year monitoring data, the dominant algal species every T&O events were anacystis, anabaena and microcystis. Furthermore, it was also observed that at least 200 counts/mL of T&O algae could result to TON of 2.6. The event last June 2015 seemed to be different as the total count of algae analyzed was almost 4,000 counts/mL. Consequently, plant production was reduced to 70million liters per day (MLD).

D. Total Dissolved Solids

The problem on high TDS happened more often on Laguna Lake. This is because the lake is connected to Manila Bay through the 27 km Pasig River. Interaction between these two bodies of water took place when the lake level is lower than Manila Bay. It was observed previously that the TDS value can increase if the intake level of the plant is lower than 11m.

The highest TDS value occurred last 2014. As a result, the plant production was also reduced to 35% of its designed capacity in order to produce water that was compliant to the drinking standards.

E. Current and Long-Term Solutions

At the moment, Maynilad already imposed solutions to solve these past episodes on water quality brought by unpredictable weather conditions. But please take note that most of the implemented solutions were not considered in the original designs of the treatment plants. To solve discoloration due to high dissolved manganese from Angat Dam, Maynilad opted to upgrade and construct potassium permanganate and sodium hydroxide dosing facilities for LMTP1 and LMTP2. The project was amounted to be almost USD 327,000. By having these facilities, LMTP1and LMTP2 were able to treat the raw water with high amounts of dissolved manganese every severe El Nino episodes. A quick reference guide was also established to optimize chemical consumption.

Previously, one of the strategies of LMTP1 and LMTP2 was to reduce plant production just to treat turbidity values greater than what were designed. But since high turbidity values seemed to occur more frequently these past five years and the facilities must still produce enough water during these spikes, the company decided to invest an estimated amount of USD 135M to improve the existing processes. These upgradation projects would include but not limited to improvement of clarifiers, modification of sedimentation tanks, replacement of existing equipment, upgrading of sludge extraction system, construction of new sludge treatment facility and replacement of filter media. But since this is an on-going capital expenditure (CAPEX) project, the realization of these improvements will be seen during the project process proving period. Some of the expected results that are process-related would be: (i) ensure compliance with Philippine standards and achieve 1,500MLD treated water production at 2,000 NTU, (ii) to effectively manage sludge and (iii) to reduce plant operational costs. In addition, existing laboratory procedures should also be updated based on these improvements, accordingly.

For the T&O challenge at PWTP1, Maynilad invested at least USD 77,000 during the 18-day incident last December 2016. The cost only includes the powdered activated carbon (PAC) applied in the raw water to reduce TON. The cost of temporary dosing facility was excluded to this amount since some of the equipment used already existed in the plant. Currently, the PAC dosing facility is temporary and as need basis of application. Exploration for the permanent strategy to solve T&O, such as ozonation, is currently ongoing.

Lastly, solving the problem connected to high TDS involved construction of additional 20MLD reverse osmosis (RO) system in PWTP1 which is amounting to at least USD 2.89M. Though there was an existing 30MLD RO system at PWTP1, recent events dictated that the current RO facility would not be able to produce enough water volume based on the raw water TDS level. Hence, the company decided to add 20MLD RO system to ensure more than 130MLD product water despite high TDS raw water values.

4. CONCLUSION

Effects of climate change in different sectors like the water industry seemed to be normal based on what is happening in the Philippines these past few years. Hence, private companies such as Maynilad opted to invest on high-costs projects. This is to continue their commitments to the public despite unpredictability of raw water sources in terms of water quality. This scenario should also be expected by other industries especially the ones that are dependent on natural resources.

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