Integrated Water Resources Management in Vietnam under the Challenges of Climate Change

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Abstract

Since the concept of Integrated Water Resources Management (IWRM) arose several decades ago, it has been recognized worldwide as the most effective approach to achieve successful and sustainable management of water and related resources. However, as the world is facing numerous problems, among which global climate change is one of the biggest challenges, how much success this approach can bring about depends on its flexibility over time. In Vietnam, moving from concept to successfully practical implementation of IWRM seems to be more difficult as the country is likely to be among the countries most affected by the changing climate. Being located in a region sensitive to climate change, the country has experienced large changes in climate variability and its effects. Over the past 50 years, the average temperature has increased 0.7^{o}C, sea level has risen 20cm, thousands of hectares of wetland in coastal areas have been permanently inundated by saline water, and flood and drought have been occurring more frequently and more severely. It is predicted that during this century, such problems will happen at catastrophic levels, consequently producing large negative impacts on socioeconomic development, and challenging the natural resource management systems of the country. This paper analyzes the observed and potential effects of climate change in Vietnam and discusses how the IWRM approach should be developed and implemented in the context of the changing climate. The study emphasizes the importance of integrating IWRM and climate change mitigation and adaptation (CCMA). Thus, sustainable water resources management can only be achieved when CCMA actions are well integrated into the IWRM implementation process.

Key words: Adaptation/ Climate change/ IWRM/ Mitigation/ Water resources

1. Introduction

Vietnam has relatively abundant water resources with a dense river network consisting of 2,372 rivers (of more than 10 km length), including 13 large river basins. The total annual river flow volume is approximately 847 billion m^3. The 13 river basins, 10 of which originate from catchments in riparian countries with the Red and the Mekong rivers being the most important international rivers, cover 80% territory of the country (MONRE, 2006a). Groundwater resources still appear abundantly with an estimated volume of 48 billion m^3 per year (ADB, 2007; ADB, 2008a; ADB, 2008b). There are some 3600 reservoirs of various sizes and thousands of major natural lakes distributed over the country. 400 mineral and thermal water sources have been discovered, out of which 287 sources have been exploited so far (Gabi, 2010). Additionally, Vietnam has a long coastline of 3,260 km (ADPC, 2003).

These water resources have been playing very important roles in the development of the country, especially in the rapid growing economy over the last several decades when the country started its economic reform period (originally called "Doi Moi" in Vietnamese). There have been significant achievements in the exploitation and utilization of water resources, which is crucial to domestic water use, agriculture, aquaculture, industry, energy production, waterway transportation, tourism and other

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sectors. Thus, water resources have long been recognized as a key resource for the socio-economic development of the country, and managing this vital resource becomes a critical task to ensure the nation's well-being and sustainability. Over many years, the Government and its specialized agencies, especially the Ministry of Natural Resources and Environment (MONRE) and the Ministry of Agriculture and Rural Development (MARD), have undertaken considerable work regarding both policy and management practice with aims at protecting and utilizing water resources in a sustainable way (MONRE, 2006b) This included introducing and implementing Integrated Water Resources Management (IWRM), a new paradigm for managing water resources towards sustainable development (Global Water Partnership, 2000a; Global Water Partnership, 2000b). Although some short-term achievements can be seen, long-term targets of IWRM as to "balance social and economic needs and to ensure the protection of ecosystems for future generations" remain questionable. This is due to numerous factors, ranging from the internal problems of the management system itself, and the pressures of surging population as well as the national urbanization and modernization process to the external problems caused by changing natural conditions and disasters, among which global climate change has recently become a major and permanent concern (MONRE, 2006).

It has been well recognized that the location and topography of Vietnam, with an extensive coastal line, and 50% of the total population living on the coast, make it one of the most climate change-vulnerable and disaster-prone countries in the world (The World Bank, 2010). In fact, over the past several decades, the country has experienced large changes in climate variability and its effects. The average temperature has increased 0.7^{o}C, seasonal and regional patterns of precipitation have changed negatively, sea level has risen 20 cm, thousands of hectares of wetland in coastal areas have been permanently inundated by saline water, and flood and drought have been occurring more frequently and more severely (MONRE, 2009a). It is predicted that during this century, such problems will happen at catastrophic levels, consequently producing large negative impacts on socioeconomic development, and challenging the natural resources management systems of the country, especially water resource management systems. In that context, the success of IWRM will not only depend on the concept itself but also depend on how much change of the climate will be mitigated, and how well the society will adapt to the changing living conditions caused by climate change.

Taking climate change into consideration for water resource management (WRM), this paper gives a discussion on how the IWRM approach should be developed and implemented in Vietnam. It argues for the importance of integrating IWRM and climate change mitigation and adaptation (CCMA).

2. Methodology

This paper is based on documentary research, drawing from a large set of literature and documents, including academic writings, research papers from governmental and non-governmental organizations' research projects, official government documents and specialized agencies' reports. A snapshot of observed impacts of climate change in Vietnam, particularly on water resources was drawn based on analyses of the available historical data associated with recent studies on the climate change issue. The potential change of the climate and

physical, social, economic and environmental aspects of its impacts were then presented as results of predictions based on climate change modeling methods and emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) (at global scale) and MONRE (for the specific condition of Vietnam). As water is closely related to and first affected by climate change, we then focused on water management and analyzed the function of IWRM as a tool to cope with climate change and uncertainties in order to identify the importance of IWRM associated with CCMA. The close linkage between IWRM and CCMA was then drawn and discussed. Finally, based on strategic analyses of the policy, regulatory, and institutional framework of the current water resources management systems of Vietnam, an appropriate implementation of IWRM which aims to effectively cope with adverse impacts of future climate change was proposed.

3. Result and discussion

3.1. Integrated Water Resources Management

Since the industrial revolution, human activities have been seriously affecting the environment causing rapid negative change. During the early 1980s, it came to was started to realization that the overall global water situation was not as good as it appeared and water problems had become increasingly more complex, encompassing various environmental, economic and social dimensions, which could be resolved only through a appropriate multi-disciplinary, multi-institutional and multi-stakeholders coordination. A new paradigm for management, known as Integrated Water Resources Management (IWRM) has risen as a response to such pressing necessity. IWRM has been developed over many years, and was formally defined by the Technical Committee of the Global Water Partnership (GWP) as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, 2000a; Global Water Partnership, 2000b).

Operationally, IWRM approaches involve applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. As such, IWRM is a comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations (Global Water Partnership, 2000a; Global Water Partnership, 2000b). IWRM is widely recognized as the most effective approach for water resources management.

Nowadays, the complexity of water management is being embarrassed more by global climate change. IWRM is for a long time considered to be able to cope with this complexity. In 2001, the IPCC recognized the potential of IWRM to be used as a means of reconciling varied and changing water uses and demands, and it appears to offer greater flexibility and adaptive capacity than conventional water resource management approaches. In addition, the GWP suggests that IWRM provides the best approach to manage the impact of climate change on water. However, faced with an increasingly complicated and uncertain environment, there is an increasing question whether IWRM is ready and robust enough? It is acknowledged the importance of learning

while managing and IWRM itself needs to be more flexible and more adaptive (Timmerman et at., 2008)

3.2. Water-Related Impacts by Climate Change in Vietnam

Global climate change has been strongly affecting water resources all over the world. In Vietnam, major manifestations of climate change impact on water resources are: change in water availability and distribution, change in flood and drought patterns, change in typhoon patterns, and rising sea levels. Some of those are illustrated on the map below (Figure 1).

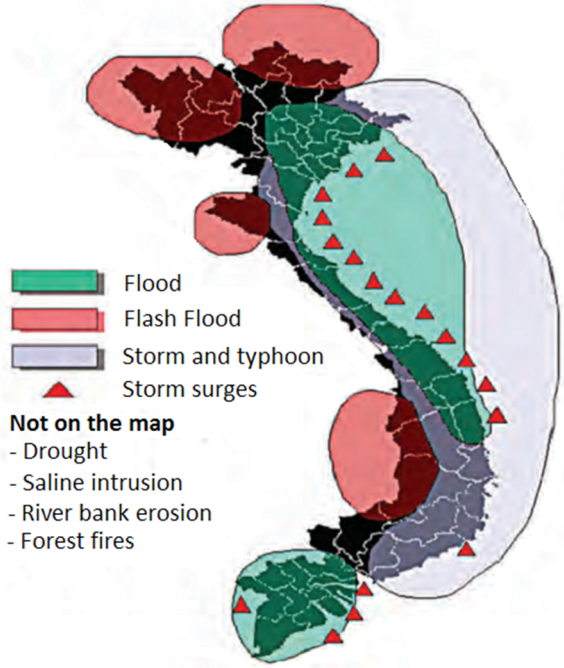

Figure 1 Geographical distribution of primary climate exposure hazards in Vietnam (*Adapted from:* Vietnam Natural Disaster Risk Management Program, 2010)

3.2.1. Change in water availability and distribution

Global climate changes will lead to a decline in water quantity. Recent studies have predicted that the total surface water volume of Vietnam in 2025, 2070 and 2100 will be around 96%; 91% and 86% respectively of today's quantity. Although Vietnam has abundant water resources as previously stated; the amount of flow generated outside Vietnam's territory is accounts for over 60% of total flow. The current average per capita surface water availability from the total volume of water in rivers within Vietnam is about 3,840 m^3/ year. If water inflows from outside the country are included, the average per capita river water availability is 10,240 m^3/year. Taking population growth into account, by 2025 the average per capita surface water availability will be 2,830 (internal) and 7,660 (internal and external) m^3/ year. According to standards of the International Water Resources Association (IWRA), nations with average per capita water availability lower than 4,000 m^3/ year are considered nations with inadequate water supply. Thus, if only the volume of surface water generated within the territory is considered, Vietnam is already a water deficient nation and will face many challenges with water resources in the near future (MONRE, 2006).

Water resources are not distributed evenly over different regions. Over 60% of river water is concentrated on the Mekong River Delta in the south of the country. The remaining 40% is spread over nearly 80% of the nation's population and over 90% of production, trade and service activities. As predictions, under the effects of global climate change, this uneven distribution will become considerably worse. While water in rich water areas such as the Mekong River Delta will be still abundant, the problem of water scarcity will occur severely in other regions such as the Central Coast and Central Highland regions (MONRE, 2006a; MONRE, 2006b).

Presently, the seasonal distribution of water resources is uneven. The average volume of water in 4 or 5 months in the wet season accounts for 75-85% of the total volume, while the 8 or 9 months of the dry season only

receives 15 - 25% of the year's water quantity (MONRE, 2006; ADB, 2007; ADB, 2008a; ADB, 2008b). In the context of future climate change, the problem will become of greater concern due to the change in rainfall. Rainfall is predicted to be more concentrated in some months in the wet season with higher amounts than it used to be. The rainy season finishes one month earlier than usual. In the dry season or winter-spring period, there have been long spells with no or negligible rainfall. This will lead to an increase in intensity of flooding in the wet season and drought in the dry season (MONRE, 2009a; IMHEN, 2007)

3.2.2. Change in flood and drought patterns

Due to topographic and climatic characteristics, in several regions such as the Central Coast and the Southeast, floods are common during the rainy season. More than 2,000 km^2 of the country's coastal zones is at risk from annual flooding, with the Mekong River Delta accounting for 75 percent of this total and the Red River Delta a further 10 percent (MHC, 1996). In the dry season drought is often recorded, especially in the South Central Coast region, including Ninh Thuan and Binh Thuan provinces, where rainfall is on average 500-700 mm but can drop as low as 350 mm in some years. Frequently prolonged droughts contribute to desertification processes, affecting large areas and population (Peter, 2008).

Under changing climate, floods have been occurring with increasing intensity compared with those in the first half of the last century. Flood damage is expected to be aggravated by an increase in daily rainfall of 12-19 percent by 2070 in some areas, affecting both flood peak discharges and the return period of floods (MONRE, 2003). Drought problems will intensify through increased variation in rainfall and increased evaporation (3 percent in coastal zones and 8 percent in inland areas by 2070) triggered by rising temperatures (MONRE, 2003).

3.2.3. Change in typhoon patterns

Another phenomena which will change negatively due to changing climate is the frequency of typhoons. As Vietnam is located along the northwest Pacific Ocean's typhoon route, UNDP (2003), it ranks as one of the ten countries worldwide most vulnerable to tropical cyclones. On average, seven typhoons (tropical cyclones) a year hit Vietnam's coast, especially in the central and northern regions (MONRE, 2003). Although there has been a fluctuation in the number of typhoons that Viet Nam experienced, with an increasing trend between the 1950s and the 1980s and decreasing trend in the 1990s, the intensity of typhoons has increased, resulting in higher peak wind speeds and more intense precipitation (MARD, 2001; IPCC, 2007). Additionally, the trajectory of typhoons appears to have moved southwards in recent years (European Union, 2006) causing negative changes in local people's lives and ecosystems in the southern part of the country. In coming decades, coastal areas will be faced with more severe typhoons, posing higher threats to local population, livelihoods, infrastructure and agricultural production. Upland communities will suffer from increasing risks of flash floods and landslides from intense rainfall. An estimated 80-90 percent of Vietnam's population could potentially be directly affected by typhoons (MARD, 2001).

3.2.4. Sea level rise

In addition to changes in inland water systems, Vietnam is particularly vulnerable to rising sea levels, another important manifestation of climate change, due to the extensive coastline and low-lying river deltas. Rising sea levels have been observed along the Vietnam

coasts, with a rate of 3mm/year during the period of 1993-2008. It is predicted that sea level will rise 30cm by 2050 and 75cm by the end of this century compared to the period of 1980-1999 (MONRE, 2009). Costal and semi-coastal low-lying areas are particularly vulnerable to sea level rise related hazards. Total submergence will be likely the destiny of the Ca Mau peninsula (southern tip of Vietnam), which will cause a land loss of 8000 square kilometers and the resettlement of a population exceeding 1.5 million inhabitants (Liem, 2009). Increased flood inundation and salinity intrusion under rising sea levels will result in cropland shrinking in the most fertile river deltas, damage to infrastructure, and irrigation water quality deterioration, consequently jeopardizing agricultural production of the country. For instance, annual rice production may be reduced by 2.7 million tons by 2050 under complex impacts of climate change, including sea level rise (Bingxin et al., 2010). Rising sea level also causes salt water penetration further upstream in the dry season, especially during droughts, and salinization of coastal groundwater (Figure 2). This event will endanger water supplies of all coastal cities, including Ho Chi Minh City, Da Nang and Ha Noi (MONRE, 2009a; Liem, 2009). A widely-quoted World Bank study ranks Vietnam as one of the top two countries in the world most affected by one meter rise in sea level with 10.79% of the population, 10.21% of GDP, 10.74% of urban areas and 28.67% of wetlands affected (Dasgupta et al., 2007).

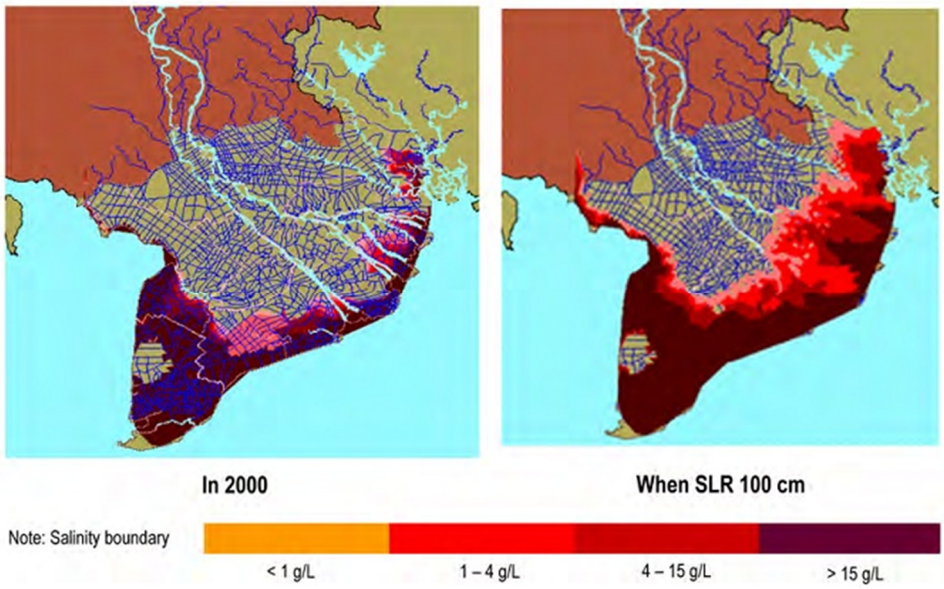

Figure 2 Salinity boundary in the Mekong River Delta in 2000 and projected for 1m sea level rise (SLR) (*Source*: Delta Research and Global Observation Network, 2010)

3.2.5. Water quality

Although no historical data or research regarding change of water quality due to climate change in Vietnam is available, the impacts of warmer temperature on water quality have been predicted. For example, higher temperatures will lower dissolved oxygen levels, which can affect aquatic life (USEPA, 2007). Where stream flow and lake levels fall, there will be less dilution of pollutants; however, increased frequency and intensity of rainfall will produce more pollution and sedimentation due to runoff. Higher temperatures will also

promote algal blooms and microbe development, resulting in the deterioration of environmental water quality (Bates et al., 2008).

3.3. Climate Change Mitigation and Adaptation (CCMA)

There are two ways to tackle climate change: mitigation and adaptation.

Mitigation refers to an anthropogenic intervention, undertaken to limit the adverse impacts of climate change either by reducing greenhouse gas (GHGs) sources and emissions, or by enhancing greenhouse gas sinks (IPCC, 2007). Examples of mitigation include using fossil fuels more efficiently, promoting renewable energy sources such as wind power, hydropower, and solar power, and expanding forests and other carbon sinks to remove larger amounts of CO_2 from the atmosphere.

Adaptation, on the other hand, is the change in processes, practices, or structures to moderate or offset potential damage or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to accommodate to climatic change and variability (IPCC, 2007; Cap-net, 2009). A variety of adaptation actions can be undertaken depending on sectors. Examples of adaptation in water sectors include modernizing irrigation and water supply systems, storing rainwater as an alternative source of drinking water, and promoting drought resistant crops which require less water input and hence have less impact on water tables.

3.4. Present Responses of Vietnam to Climate Change

Recognizing the serious potential impacts of climate change, Vietnam has been actively attempting to develop a legal framework to respond to future climate change. Vietnam signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992, and ratified the Kyoto protocol on September 25, 2002. An inventory and assessment of vulnerability of Vietnam's coasts and deltas based on the methodology developed by the IPCC was conducted in 1996, which set the framework for the identification of a long-term program of assistance to the coastal zone. In 2008, the National Target Program to Respond to Climate Change (NTP-RCC) was created by the Government of Vietnam, of which the strategic objectives are to assess climate change impacts on sectors and regions in specific periods, and to develop feasible action plans to effectively respond to climate change in the short and long terms. In order to support the implementation of NTP-RCC, the Government and donors decided to formulate the Support Program to Respond to Climate Change (SP-RCC). The main objective of SP-RCC is to promote climate change adaptation activities and GHG reduction, and to ensure sustainable development in terms of economic, social and environmental aspects. As water is the most vulnerable sector to climate change, those actions more or less focus on water resources and water resource management.

3.5. The linkage between CCMA and IWRM

Water is the first sector to be affected by climate change. It is the primary medium through which climate

change impacts will cut across all sectors. CCMA actions therefore have to set their first focus on the water sector. Conceptually, IWRM aims to achieve sustainable development while climate change compromises the integrity of ecosystems and threatens socioeconomic development. In other words, climate change challenges IWRM, and the targets of IWRM may not be achieved due to effects of climate change. Under that circumstance, CCMA is a means to reduce and eliminate such challenges for IWRM. IWRM, on the other hand, provides a framework for action in water and related resources, planning to cope with climate change effects. It is then becoming a tool for CCMA. The following part gives a discussion in support of the above ideas, focusing on some major points of particular conditions of Vietnam.

3.5.1. Creating resilience to climate change through IWRM

IWRM, as a holistic approach for managing water and related resources, builds social, economic and ecological resilience to climate change by taking into account the competing demands on water and the need to guarantee minimum environmental flows. Effective water allocation systems supported by participatory water governance and fair water rights help enable flexible responses to risks and uncertainty caused by climate change (The Water and Climate Coalition, 2010). The implementation of IWRM in the context of climate change therefore must be supported by all stakeholders from all sectors to strengthen and bring into play IWRM as a tool to tackle climate change effects. On the other hand, any climate change adaptation strategy must be developed in consultation with water resources managers and build on existing solutions available from IWRM processes and plans (The Water and Climate Coalition, 2010; Wilk and Wittgren, 2009). In the particular case of Vietnam, where both IWRM implementation and climate change adaptation actions have just been instigated, a strong legal framework and an appropriate plan which take into account climate change scenarios of the country must be immediately created.

3.5.2. Enhancing transboundary water resources management

Climate change impacts through the water cycle do not respect national and political boundaries. It is critical that responses to climate change be undertaken with the cooperation and participation of all nations, especially nations with shared natural resources. Being a downstream country with over 60% of total water volume generated outside the country's territory, Vietnam is affected by activities from upstream countries. In the dry season, water scarcity will occur when water is stored in reservoirs and hydropower dams in upstream areas. Meanwhile in the rainy season, floods will occur when floodwater is released from those storage facilities. With climate change circumstances, the conflict of utilizing shared water resources will increase and transboundary water resource management will become more important. Treaties and other cross-border agreements can help reduce conflicts. Thus, adaptation strategies for climate change in Vietnam must involve regional cooperation and strengthen regional responses to climate impacts on transboundary water resources.

3.5.3. Promoting ecosystem-based CCMA and WRM

Healthy ecosystems are critical

natural infrastructure for water storage, flood regulation and coastal defence (The Water and Climate Coalition, 2010). The availability of water resources depends on healthy ecosystems, and healthy ecosystems rely on a reliable supply of freshwater. Protecting, preserving and conserving ecosystems are critical to building resilience to natural disasters and climate change impact on water resources. Vietnam has a diverse ecosystem such as tropical forests and mangrove ecosystems, which provide great assistance in the development of livelihoods for local communities as well as natural water storage and disaster prevention. However, due to over exploitation and land use conversion, these ecosystems have been drastically degraded. For example, Vietnam has lost more than 80% of its mangrove forest over the last 50 years, reducing the mangrove forest cover from 400,000 ha in the 1960s to less than 100,000 ha at present.

Viet Nam Environment Protection Agency (VEPA) (2005) Mangrove forests play a critical role in storm protection and erosion control, the degradation of mangrove forests is therefore harmful to coastal and estuarine regions. To enable ecosystem-based CCMA and WRM, actions such as reforestation, afforestation, forest rehabilitation, and other natural resource conservation, they must be seriously promoted.

3.5.4. Enhancing resilience of water supply and sanitation systems

Water supply and sanitation is highly sensitive to any weather and climate-induced impact, both in terms of infrastructure and non-infrastructure aspects. In terms of infrastructure, drinking water, waste water treatment, irrigation, drainage, hydropower and navigation systems are directly affected by weather conditions and climate change. Meanwhile, non-infrastructure, i.e., water governance and management systems, including policy, education, research, monitoring, and forecasting is also highly vulnerable to climate change and climate related disasters (The Water and Climate Coalition, 2010). In Vietnam, the present weak and inadequate water infrastructure must be ameliorated, and the incomprehensive water governance and management must be improved to build better resilience to cope with more severe climate change in the near future.

3.5.5. Integrating IWRM and Disaster Risk Reduction (DRR)

As the country is seriously affected by disasters every year, especially floods and storms, for many years, the Vietnamese government has paid serious attention to DRR, such as the construction of reservoirs, river embankments, anti-salinity dams, and sea dikes. However, national DRR strategies must be well integrated with WRM to build preparedness to cope with floods, droughts, and other disasters, and concurrently to ensure water supply for production. For instance, the construction of upstream reservoirs for preventing flash floods should be combined with irrigation systems for stabilizing agricultural production. On the other hand, these constructions must be well planned to ensure smooth flood release and reduce the danger for downstream water infrastructure system, especially the dyke system.

3.5.6. Linking WRM and CCMA through energy usage and development

The IPCC (2008) (Bates et al., 2008) states that ‘the relationship between climate change mitigation

measures and water is a reciprocal one'. Climate change mitigation measures introduced to reduce GHGs emissions by developing renewable energy infrastructure such as hydropower have direct implications for WRM. In contrast, WRM measures have impacts on carbon emissions due to the energy used in the water sector. Therefore, climate change mitigation and WRM are linked together through energy usage and development.

Water is an energy-intensive sector, it contributes about 4% of the global GHGs emissions, in the same order of magnitude as air traffic, and urban drinking water and waste water utilities are often the largest energy consumers (The Water and Climate Coalition, 2010). More efficient use of water and better water infrastructure development will contribute to reduced GHGs emissions. In Vietnam, water infrastructure is inadequate and uses low technology, causing high water loss rate of water supply systems of over 30% (MONRE, 2009b). It is estimated that if the water loss rate is reduced to 10%, the amount of supplied water saved each year will be about 20 billion cubic meters (Xuan et al., 2011). To achieve this, the existing water infrastructure, especially in large cities, need to be upgraded.

Having a dense river network, Vietnam has advantages in hydropower infrastructure development in order to meet an increasing energy demand and to reduce large amounts of non-renewable energy used in electricity generation. Construction of hydropower plants also brings about many positive effects, including flow regulation, flood control, and availability of water for supply and irrigation during dry seasons. However, some negative impacts on existing river ecosystems and local livelihoods induced by change in flow regime and resettlement may occur. Consequently, planning of hydropower plants must be approved only in the context of an IWRM system that can identify whether particular planning is feasible, in addition to other appropriate social and environmental safeguards.

In addition, other renewable energies such as wind and solar energies should be promoted in order to reduce the burden for hydropower, and contribute to reduce GHG emissions. A survey by the World Bank found that Vietnam has great wind energy potential, capable of producing 513,360 megawatts annually, or 200 times the output of the Son La Hydroelectric Plant in the north of Vietnam - Southeast Asia's largest power plant - and ten times the entire national capacity forecast for 2020 (Vietnamnet online newspaper, 2010). Located in the subequatorial region, Vietnam also has good solar resources with solar radiation from 3 to 4.5 kWh/m^2/day in winter and to around 4.5 to 6.5 kWh/m^2/day in summer. Presently, solar power is mostly utilized as solar-powered water heaters on a small scale. It is estimated that if the national program launched by the Vietnamese government which aims to put into operation 30,000 solar-powered water heaters each with a 180-liter capacity is implemented, the country could save 57 million kWh of electricity power and cut greenhouse gas emissions by 23,541 tons every year (Thai, 2009).

3.5.7. Enhancing adaptive capacity for local communities

Climate change is already occurring, and its effects are first felt in local communities, especially those whose livelihoods rely on natural resources and depend on climatic conditions, such as farmers, fishermen,

and salt workers. The effects of climate change to local communities is direct and cannot be avoided, thus local communities have no alternative but to adapt their livelihood systems to the new climatic conditions and disasters. An example can be drawn from the case of the Mekong River Delta, where the policy slogan 'living with the floods' is widely accepted as the best way for local people to cope with frequent flooding. The slogan reflects recognition that ever higher dykes in the delta are not the answer to seasonal floods that fields and forests must store floodwater instead, and that people's livelihoods must adapt (Peter, 2008). That is because resettlement which aims to relocate local residents to a safer place is not a better choice as it limits people's access to their fields and canals, whilst fishing is a crucial livelihood strategy. Therefore, it is critical that climate change in water governance be considered in the context of enhancing adaptive capacity, building resilience, reducing vulnerability of local communities, especially poor people, in maintaining sustainable livelihoods and supporting sustainable development (The Water and Climate Coalition, 2010). Solutions vary from non-infrastructure to infrastructure and depend on particular levels. At farm level, there is a need to change crop types and patterns, promote non-farm techniques, and apply new crop varieties suitable to severe climate conditions. At community level, it is important to protect common resources such as lakes and fish ponds, enhance rainwater harvesting systems, and develop community funds and shared processing facilities. Meanwhile, at the national level, measures must be focused on improving infrastructure systems, promoting research, strengthening monitoring and forecasting systems, and enhancing public awareness about climate change and adaptation actions.

4. Conclusion

The observed impacts of irreversible climate change on water resources in Vietnam stand to have disastrous effects on the environment and socioeconomic development of the country. Future climate change is expected to bring more negative changes in weather patterns and increase disaster events which will impact on agricultural and aquacultural production, increase water pressures, and damage infrastructure. Sea level rise is a particular concern which could have devastating effects on the country's densely populated deltas, threatening local livelihoods and alter coastal ecosystems. As water is the primary medium through which climate change impacts will be felt by all other sectors, it is critical that water resource management be placed at the heart of policy response to climate change. IWRM is an effective tool to address challenges of climate change, but the success of IWRM will not only depend on the concept itself but also depend on how much change of the climate will be mitigated, and how well the society will adapt to the changing living conditions caused by climate change. Being a developing country with a weak infrastructure system, limited and financial resources, and weak institutions, the capacity of Vietnam to adapt to future climate is limited. IWRM which involves holistic measures with participation of all stakeholders and international collaboration therefore becomes of importance to strengthen the adaptive capacity and reduce vulnerability. However, as IWRM implementation and climate change adaptation actions have only just been

started, Vietnam still has a long way to go in its progress to build resilience to climate change. Infrastructure measures such as improving water supply, waste water treatment, irrigation, and shoreline and riverbank protection systems deserve immediate attention. Meanwhile, non-infrastructure measures, including strengthening policy and legislation, promoting scientific and technological activities (research, monitoring, forecasting, and planning), enhancing public awareness, responsibility and participation, developing human resources, and promoting international cooperation are long-term programmes necessary to tackle future climate change effects.

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