CLIMATE CHANGE IMPACTS ON WATER RESOURCES IN VIETNAM: ADAPTATION STRATEGIES FOR AGRICULTURE AND HYDROPOWER – A REVIEW

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ABSTRACT

Vietnam is one of the countries most suffered by climate change, as a result, the water resources is also significantly affected. As a developing country, extreme weather events such as floods and droughts have caused considerable damage to agricultural production and hydropower.

Different strategies for agriculture and hydropower are analyzed to adapt to climate change. Alternative wetting and drying (AWD) is a water saving technology. It reduces the water use up to 30%. In addition, it reduces CH_4 emissions up to 48%.

Hydropower plants contribute about 40% to the electricity demand in Vietnam. Furthermore, the reservoirs play an important role to prevent flooding and to ensure water supply. Multi-objective deterministic and stochastic optimization was used. This method can mitigate flooding and increase the hydropower production by 7%. Building a hydropower dam is a big encroachment into the environment. Different scenarios are investigated to reduce hydrological alteration and to increase the hydropower production at the same time. One scenario was able to increase the hydropower production by 4% and decreased the hydrological alteration by 27%.

Keywords: *Climate change, agriculture, hydropower, alternative wetting and drying (AWD), water reservoir*

INTRODUCTION

Climate change is one of the most serious challenges in the 21st century. Due to human induced emission of greenhouse gases (GHG) the global average temperature increased by 0.85°C over the period 1880 to 2012[16]. The total emissions in 2010 were 151 million tons of GHG in CO_2 equivalent in Vietnam, 53% of the emissions were attributable to agriculture and land use change [21]. The impact of climate change in Vietnam is clearly visible. For example, in the Mekong Delta droughts have become more severe and water scarcer [20]. Ngo-Duc [16] found out that the number of hot days would increase and the number of cold winter nights would decrease as a consequence of global warming, as well as heavy rainfall events would increase significantly over South-Central Vietnam. Furthermore, researchers forcast a decrease in available water resources. In 2025 and 2100 the total volume of surface water will be about 96% and 86%, respectively, of the current quantity [20]. The country is also strongly affected by sea level rise, because of the high density of inhabitants on the coastal plains. The sea level has already risen by approximately 20cm [20]. About 11% of the population will be directly affected, if the sea level rises by 1m and the loss of the gross domestic product (GDP) will be about 10%. [8]

The agricultural sector was assessed to be the most vulnerable sector to climate change impacts [15]. Today, more than 70% of the population in Vietnam is working in the agricultural sector [9]. Farmers already have to deal with changing weather patterns and an increasing frequency and intensity of extreme weather events [14]. An interview with farmers also confirmed that drought, storm, pest and disease were the main cause losses of rice production due to climate variability [6]. In 2050 Alexandratos & Bruinsma [1] predict an increase of food production by 60% to meet future consumption trends. This will also increase GHG emissions like CH_4 and NO_2 from agriculture, particularly from regions with low current productivity [4].

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Hydropower contributes 38% to the total electricity generation in Vietnam [10]. Zhang et al. [23] stated that Asia is one of the hotspot in promoting hydropower development with large capacity expansion. New ongoing hydropower projects in Vietnam will further increase the electricity generation. The country is also vulnerable to flooding, in particular the Red River Delta and the Mekong River Delta, threatening the population and the food production. Hence, hydropower is attractive to prevent flooding. Furthermore, GHG emissions from hydropower are relatively low compared to other energy sources like coal power stations [23].

Agriculture and hydropower are strongly connected, because both are in need of water resources. With rapid population growth and socio-economic development in Vietnam and additional pressures from climate change, the interactions between hydropower and agriculture will increase in both intensity and frequency [23]. Campbell et al. [4] stated that reducing risks to food security from climate change is one of the major challenges of the 21st century. On the other hand, it's important to promote renewable energy technologies like hydropower to ensure the growing electricity consumption. Therefore, it is important to investigate common adaptation strategies for agriculture and hydropower.

Therefore, it is extremely important to identify the effect of climate change on agriculture and hydropower production as the basis the determine the methods to reduce the effect of these extream phenomena, hence, the significant of the study. The research aims to review related papers and studies, identify the problems, and conduct in-depth discussion with specialists in related fields in order to paper presents different adaptation strategies to use water resources in a sustainable way

CLIMATE CHANGE IMPACTS

Agriculture

Investigating in food security is important due to climate change. Chung et al. [6] showed that droughts occurred more frequently in recent years in the central highlands of Vietnam, which caused a negative impact on the rice yield. An interview with farmers confirmed that drought, storm, pest and disease were the main reasons of yield losses.

Table 1 shows different climatic events and the impact on the rice production. Droughts affected the rice production and were responsible for pests and diseases. Winter was warmer than usual and the summers were hotter. In addition, the rainfall decreased in the rice growing seasons and the appearance of stroms and flooding was abnormal. The consequences were yield loss and landslides on rice fields. [6]

Table 1. *Farmers experience of climate variability [6]*

Climate events	Impact on rice production
Drought occurred more frequently and severely (2003, 2005, 2011, 2012)	-Paddy fields were dry -Streams dried up -Pests and diseases outbreak
Temperature tent to increase: +Winter was warmer +Summer was hotter	-Lacking water for rice field -Rice plants were withered
Rain in rice growing season was lesser Rainstorm in WS disappeared	-Lacking water for rice fields -Low yield -Pests and diseases outbreak
Storms and flood happened suddenly and unusually (2006, 2009)	-Lost yield -Landslide

Table 2 shows the impacted area by drought, storm and pest&disease in the Summer-Autumn (SA) and in the Winter-Spring (WS) season. Pest and disease were the most serious causes to the rice yield loss. For example in SA 2012 the yield loss was over 120 tons.[6]

Table 2. *Losses of rice production caused by climate variability over 10 years. [6]*

Crops	Impacted area (%)			Yield loss (ton)	Remarks
	Drought	Storm	Pest&Disease		
SA 2003	7.23	-	-	86	Complete loss
WS 2005	-	-	8.42	3.3	Yield decreasing
SA 2005	2.10	-	-	31.5	No planting
WS 2006	5.96	-	12.24	51	Yield decreasing
SA 2006	2.58	0.68	-	38.4	Complete loss
SA 2009	-	0.48	27.20	24	Yield decreasing
SA 2010	-	-	39.33	56	Yield decreasing
SA 2012	1.77	-	8.90	127.1	Complete loss

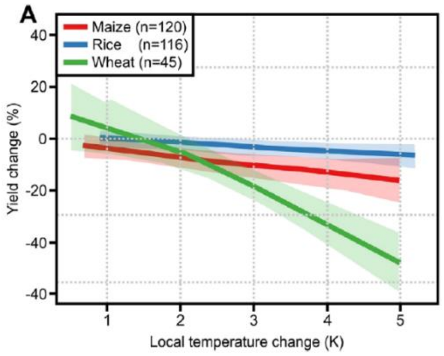

Fig. 1. *Impacts of climate change on the productivity of tropical cereal crops. Adapted from Porter et al. [18], who develop yield response curves from a meta-analysis of published crop simulations [4]*

Climate changes as increasing temperature, it made evaporation and drought, the Figure 1 shows the yield change with increasing temperatures. Maize and rice are more temperature resistant than wheat, both decrease only a little bit with increasing temperature. If the temperature rises 4°C the rice yield decreases about 5%, the maize yield decreases about 10%. While the yield of wheat decreases strongly with increasing temperatures. Asseng et al. [2] estimated a wheat yield reduction of 6 % per degree of warming.

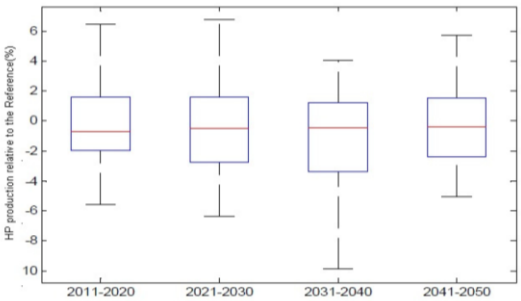

Fig. 2. *Production relative to the baseline. [12]*

Hydropower

According to EVN (2015), the shortage of water in hydropower reservoirs has led to the reduction in power production to 3.2 billion kWh. Currently, hydropower plants (HP) are producing 10'320 MW in Vietnam. The total installed capacity is expected to increase by 4'760 MW until the end of the 2020. Figure 2 shows the hydropower production relative to the baseline. The median level (red) of the hydropower production shows a slight decrease over the climate change scenarios. The uncertainty of the reliability is relatively high in particular for bigger HP such as Hoa Binh or Son La reservoirs. [11]

ADAPTION STRATEGIES

Adatation on agriculture (Alternative wetting and drying - AWD)

AWD is a water saving technology in rice production, it reduces water use by up to 30% and can save farmers money on irrigation and pumping costs. In addition, it reduces the emission of methane. It has also other benefits like better root development, lower damage due to pests and diseases, better soil conditions for machine operations, all without reducing yield. Compared to continuous flooding AWD does not reduce yields and it may increase yields by promoting more effective tillering and stronger root growth [17] [7].

AWD uses alternative draining and reflooding 1-2 weeks after transplanting. The fields are drained until the water levels is 15cm below the soil surface. After that, the field is re-flooded to a depth of 5cm before it re-drains again. [4]

AWD can be practices in areas where soils can be drained in 5-day intervals. High rainfall may hamper AWD, because the field will be unable to dry during the rice-growing period.[17]

Flooded rice fields emit significant amounts of methane, recent work suggests that flooded rice contributes about 10–12% of the human induced emissions from agriculture. AWD can reduce the CH_4 by 48% compared to continuously flooded irrigated rice systems [18]. Unfortunately, AWD (multiple aeration) emits more N_2O than continuously flooded (Figure 3). Nevertheless, the total emission of GHG from AWD is still significantly lower. The technology is widely accepted as the best practice for reducing GHG emissions from irrigated rice [17].

The incentive for farmers to adopt AWD strongly depends on the irrigation scheme. If they use gravity-driven canal irrigation, the incentive is small, because farmers pay a flat irrigation fee (per ha and season) regardless of the m^3 water they need. In regions where farmers often us pumps, they have to buy the fuel individually to operate the pump. In this case AWD allows them to save money, by irrigating less frequently. In Vietnam, AWD is now promoted in development projects [4].

Water reservoir management

Water resources are needed for hydropower, for irrigation for agriculture as well as for human live. Unfortunately, water is also responsible for the worst natural disasters during the heavy rain monsoon season [13]. The rainfall distribution is very uneven, 80% falls from May to October. Castelletti et al. [5] investigated the operation of the Hoa Binh reservoir, that produces 15% of the national electricity. The Red River Delta is the second largest area for rice production after the Mekong Delta. It contains 850000 ha of irrigated agriculture [19]. Unsuccessfully, the water demand from irrigation is hard to estimate due to the lack of data [13].

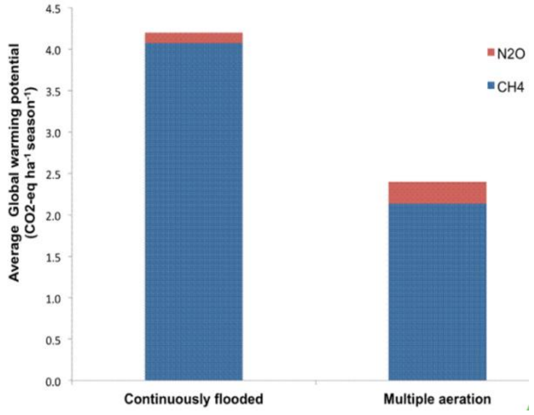

Fig. 3. *Research in Asia has found a reduction in Global Warming Potential of 43% associated with AWD*

Multi-objective deterministic and stochastic optimization was used to improve the reservoir management of the Red River basin. In particular, Multi-Objective Genetic Algorithms (MOGA) as well as Deterministic Dynamic Programming (DDP) were used. The models were able to increase the electricity generation and to improve the flood mitigation, in particular with DDP. Figure 4 shows the water level in Hanoi during a flood season in summer. The black line displays the threshhold of flooding. If this level is exceeded the flood causes severe damage in the city. DDP was able to mitigate the flood peak in the middle of August. Nevertheless, the cyan line (DDP) still exceeded the flooding threshold [5].

Castelletti et al. [5] concluded that the current reservoir operation could be improved with respect to hydropower, water supply for irrigation and flood mitigation. Hydropower could be significantly increased and water shortages were almost completely avoided. MOGA modelling reduced the magnitude and duration of flooding in Hanoi, while producing about 7% more electricity compared to the historical value.

Adaptation on Hydropower and environmental flow

Hydropower is principally focused on meeting the electricity demand of the society.

Unfortunately, hydropower operation often does not really care about environmental sustainability and the water demand for agriculture [3]. The construction of dams impair river ecosystems in terms of the hydrology and geomorphology [28]. In catchments with alterated flow regime, the provision of environmental flow (EF) for aquatic ecosystem is very important. Therefore, tradeoff analyses among different water users are necessary for efficient water resources management [3].

Babel, et al. [3] investigated the La Nga river basin in Vietnam with the Range of Variability Approach (RVA) method to indicate the hydrologic alteration caused by dam construction. The La Nga catchment has two reservoirs the Ham Thuan and the Da Mi. RVA uses a set of Indicators of Hydrologic Alteration (IHA) to compare the natural and altered flow regimes. The degree of hydrologic alteration measures the deviation of the post-dam flow regime from the pre-dam one. 0-33% represents low alteration 33-67% represents moderate alteration and 67-100% represents high alteration.

Babel, et al. [3] analysed 5 different scenarios using a simulation model:

Scenario 0 : The operation of the reservoirs are using the existing operation policy.

Scenario 1 : The power plants are run at their full capacities.

Scenario 2 : The hydropower system uses the operating policy developed to optimize the power production.

Scenario 3 : The hydropower plants are operated in such way that the flow at a gauging station always falls within 25-75% RVA range.

Scenario 4 : The Ham Thuan reservoir is operated to generate maximum power and the Da Mi reservoir is operated to generate electricity and also meeting the environmental flow requirements.

Scenario 0 is the worst case in terms of hydrologic alteration of the natural flow regime. Scenario 1 has the highest hydropower production. The degree of alteration is the lowest in scenario 4 with 46%. Unfortunately, the hydropower production decreases by 11%. Scenario 3 seems to be the best alternative among the scenarios analyzed. The hydrologic alteration is 47%, which is only one percent more than scenario 4. On the other hand the power production has increased by 4% compared to the power production under scenario 0. Scenario 3 reduces the hydrological alteration by 27% and at the same time it is able to increase the electricity production by 4%. [3].

DISCUSSION

Water resources adapation strategies for agriculture and hydropower are important in order to ensure food security and electricity demand in a changing climate. An important part of adaptation strategies is to reduce the damage to the environment (e.g. by applying environmental flow release) and to reduce the emission of GHG (e.g. AWD). The presented strategies to adapt to climate change have their advantages. Unfortunately, they also have weak points and they are difficult to apply in some regions of Vietnam.

Table 3. *Hydropower production and hydrological alteration under different scenario [3]*

Scenario	Method	Hydropower production [%]	Hydrological alteration [%]
0	Existing operation policy	0	74
1	Full capacities	8	50
2	Policy to optimize the power production	5	65
3	25-75% RVA range	4	47
4	Meeting environmental flow	-11	46

AWD is a technology applied in agriculture. The advantages of AWD are reduced water use and the reduction of CH_4 emissions. The technology saves up to 30% of water and reduces the methane emission up to 48%. But in order to apply the technology correctly, farmers must have control over the irrigation of their fields and know that they will have access to water after the field is dry. AWD in rainfed rice cultivation is not recommended, because the irrigation cannot be controlled. Therefore, AWD cannot be applied everywhere in Vietnam. Furthermore, the GHG emission mitigation depends strongly on the execution of the AWD technology. If the drainage is incomplete, that is to say, the water table is higher than 15cm below soil surface, the reduction of CH_4 can be negligible. In addition, AWD might be hampered due to heavy rainfall, because the field will be unable to dry during the rice-growing season. [17]. Nevertheless, AWD is now promoted in developed projects in Vietnam. And it is recommended to promote this adaptation strategy in suitable regions in the country.

Water reservoirs management is a useful tool to provide optimal water allocation to hydropower and water supply for agriculture and at the same time it can prevent flooding. Multi-objective deterministic and stochastic optimization in particular MOGA can reduce the magnitude and duration of the flood and is able to increase electricity production. Nevertheless, floodling in Hanoi could not be completetly avoided, even under ideal assumptions. The problem is insufficient storage capacity of the reservoirs. [5]. Gebretsadik et al. [11] predict a decrease in runoff in the dry season and an increase in runoff in the wet season. Climate scenarios forecast an increase in the wet season up to 20% and a decrease in the dry season up to 16%. Therefore, it is recommended to construct new reservoirs upstream of the Red River Delta in order to prevent flooding, increase the electricity production and to supply water for agriculture in the dry season. [5].

Environmental flow release is vital for the downstream ecosystems. Babel et al. [3] investigated different scenarios in order to reduce the hydrological alteration and to increase the hydropower production at the same time. Scenario 3 increased the hydropower production by 4% and reduced the hydrological alteration by 27%. However, scenario 3 might be vulnerable during the dry years, due to reduced inflows and less storage [3]. It might be difficult in the future to accomplish increased hydropower production and reduced hydrological alteration at the same time especially in the winter month due to predicted decrease in runoff during that season.

Overall, the agricultural sector is curretly more affected by climate change, while hydropower show a slight tendency for negative impacts [11]. Therefore, the next section focuses more on policies for agriculture.

Today in Vietnam, there are different policy arrangements to ensure better response to climate change for example the National Committee on Climate Change. Part of their objectives are identified as ensuring food, energy and water security. By 2020, they targeted that climate change and disasters will be proactively adapted and GHG emissions will be reduced by 20% in agriculture and rural development. In general, agriculture and rural development sectors in Vietnam have a quite comprehensive policy system for climate change response, where mitigation and adaptation are taken into account. Nevertheless, the current policy system does not properly adress local community into climate change response. There are no concrete policies to create incentives for local people. Furthermore, there are no clear policies for financial investment.[8]. As Campbell et al. [4] stated : There is a gap between research and implementation.

Therefore, it is important to create concrete policies for the local farmers in order to adapt the agricultural sector effectively to climate change.

CONCLUSION

Climate chance impacts the agricultural sector more than hydropower production in Vietnam. The hydropower production is projected to only decrease slightly until 2050. Agriculture is recently affected by droughts that occured more frequently and severly.

Different strategies for agriculture and hydropower were introduced to adapt to climate change. AWD is a water saving technology for rice cultivation and at the same time it reduces the emissions of methane up to 48%.

Almost 40% of Vietnams annual electricity demand is produced by hydropower. Beside electricity production the dam reservoirs play an important role to prevent flooding and ensure water supply for agriculture. Multi-objective deterministic and stochastic optimization was able to improve electricity production by 7% and to mitigate the damage of flooding. Environmental flow release is vital to reduce the damage on ecosystems downstream of a dam. Different scenarios were investigated. The best scenario was able to increase hydropower production and to decrease the hydrological alteration significantly.

In order to apply these strategies, concrete policies have to be developed and incentives for local people have to be created. With this, it is possible to ensure food security, electricity demand, flood mitigation and water supply in Vietnam on the evidence of a changing climate.

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TÓM TẮT

TÁC ĐỘNG CỦA BIẾN ĐỔI KHÍ HẬU ĐẾN TÀI NGUYÊN NƯỚC TẠI VIỆT NAM: CHIẾN LƯỢC THÍCH ỨNG CHO NÔNG NGHIỆP VÀ THỦY ĐIỆN

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Do tác động của biến đổi khí hậu, nguồn tài nguyên nước tại Việt Nam đã và đang bị ảnh hưởng sâu sắc. Biến đổi khí hậu tác động đến nông nghiệp và thuỷ điện như lũ lụt hoặc hạn hán, đây là nguyên nhân ảnh hưởng đến năng suất nông nghiệp cũng như sản lượng điện. Nhiều chiến lược khác nhau đã được đề xuất nhằm giúp ngành thủy điện và nền nông nghiệp nước nhà có thể ứng phó với những tác động này. Kỹ thuật tưới lúa ngập khô xen kẽ được xem là một trong những phương pháp tối ưu, tiết kiệm lượng nước sử dụng. Ưu điểm của kỹ thuật này là có thể giảm tới 30% lượng nước tưới tiêu mà không ảnh hưởng tới năng suất canh tác, đồng thời giảm tới 48% lượng phát thải CH_4.

Các nhà máy thủy điện đóng góp khoảng 40% nhu cầu điện ở Việt Nam, các hồ chứa đóng vai trò quan trọng để ngăn ngừa ngập lụt và đảm bảo việc cung cấp nước. Xây dựng hồ thủy điện đa mục tiêu sử dụng có thể giảm lũ lụt, tích trữ nguồn nước và tăng sản lượng thủy điện lên 7%. Xây dựng các đập thủy điện gây nên những ảnh hưởng nghiêm trong tới môi trường. Rất nhiều các kịch bản đã được đề ra, điều tra nhằm cùng lúc có thể giảm các thay đổi thủy văn, và tăng sản lượng thủy điện. Một kịch bản có thể tăng sản lượng thủy điện lên 4% và giảm 27% các thay đổi thủy văn.

Từ khóa: *Biến đổi khí hậu, nông nghiệp, thủy điện, ngập khô xen kẽ (AWD), hồ chứa nước*

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