VIETNAM INSTITUTE OF METEOROLOGY HYDROLOGY AND CLIMATE CHANGE

ISSN 2525-2496

JOURNAL OF CLIMATE CHANGE SCIENCE

No.15 - 2020

JOURNAL OF CLIMATE CHANGE SCIENCE

PUBLICATION LICENCE:
No. 604/GP-BTTTT
30th December 2016
Ministry of Information and Communications

JOURNAL OFFICE:
23/62 Nguyen Chi Thanh Str., Dong Da Dist., Hanoi
Tel:+84.2437731410
Email: tapchibdkh@imh.ac.vn
Website: http://imh.ac.vn

PRINTED IN:
Le Giang jsc
87/192 Le Trong Tan Str,
Hoang Mai Dist, Ha Noi

SPECIAL VOLUME TO CELEBRATE THE 75th TRADITIONAL DAY OF METEOROLOGY AND HYDROLOGY, OCTOBER 3rd, 2020

CONTENTS

No.15 - 2020

ASSESSMENT OF WATER GOVERNANCE CAPACITY AND PRIORITY ACTIONS FOR SESAN-SREPOK RIVER BASIN, VIET NAM

Do Thi Ngoc Bich, Nguyen Cao Don, Vo Ha Duong,
Nguyen Thuy Dung, Nguyen Hoang Bach
Water Resources Institute

Received 17 May 2020; Accepted: 15 June 2020

Abstract: *Improved water governance supports important social, economic, and environmental objectives. The existence of organizational and legal frameworks, the level of coherence between various actors, the knowledge by stakeholders of the texts in force and their attributions, roles, duty and right, and others are essential perspectives to be considered in water governance assessment. This paper offers a general assessment of water governance capacity in the Sesan - Srepok River basin. It gives an overview of the main water governance issues and a description of the assessment of water governance capacity which provide a basis to further development of related policies and reformations for the Sesan - Srepok River basin. The mobilization of experts from different disciplines and their interests for this study on water governance were the key factor determining the outcome of the research. The tool used for the synthesis (scorecard) enables a synthetic grasp on these complicated issues.*

Keywords: *water governance effectiveness, scorecard, IWRM.*

1. Introduction

Water scarcity is a globally prominent problem. It, thus, has gained more and more attention to the severity of its consequences. On one hand, water demand is increasing due to population growth, economic development and technological advance. On the other hand, water supply is depleting and becoming unstable due to natural and anthropogenic reasons. This situation challenges globally the Water Governance to compromise the common conflicting water demands of different sectors, which considers the interrelationship between various stakeholders in order to avoid potential conflicts and realize mutual gains. It is agreed upon that an improvement to water governance is an indispensable part of the solution to the water scarcity challenges in the context of climate change.

Over the past few years, water governance is gaining great attraction and attention from international and national agencies and organizations. Water governance refers to the political, social, economic and administrative systems that influence water use and management. An effective water governance will help manage and secure water access for everyone. A question immediately comes to mind: When water governance can be considered effective? At any level, governance systems must encourage all stakeholders to engage actively in order to solve the growing water problems; while at the local levels, financial resources and human capacity development are much needed. Therefore, a clear division of roles and responsibilities at different governance levels should be agreed upon and understood by all stakeholders. Furthermore, each nation must develop its own Integrated Water Resource Management (IWRM) plans and strategies mapping out the sequence of actions needed to take place for specific water-related problems. Overall, to achieve effective water governance,

Corresponding author: Do Thi Ngoc Bich
E-mail: bichdam555@gmail.com

it is necessary to fairly and impartially enforce a coherent legal framework with a strong and autonomous regulatory regime to facilitate open and transparent transactions between stakeholders (Rogers and Hall, 2003).

With that in mind, water institutions around the world are looking for the best methods to effectively assess water governance. Ghana, for example, used existing data, surveys, questionnaire, and interviews to identify major water users and their corresponding roles and responsibility in managing water resources. The responses were supposed to be an input for SWOT analysis to help them assess their operation. However, no clear roles or operations have been identified for the major water users in several sectors of the economy, which resulted in slow development in sustainable national water governance (GWP/WA, 2009). The Awash river basin, Central Ethiopia, on the other hand, chose to apply the Water Governance Assessment Method developed by the Water Governance Centre (WGC). This approach composes of a self-assessment report by local actors, an assessment report prepared by water experts, and comments from experts in the different disciplines. The information is gathered in workshops and in-depth interviews that provided information on the current gaps in water governance, which were then assessed using water governance scorecard (Hemel and Loijenga, 2013). This approach provides a more detailed assessment with SWOT analysis, which gives a better overview of water governance performance in the Awash river basin compared to Ghana.

According to the User's Guide on Assessing Water governance (UNDP, 2013), there are a range of assessment tools that aim to measure water governance effectiveness directly and indirectly.

Direct measurement of effectiveness focus on the degree to which results have actually been achieved. For example, at the time a national policy on water governance is evaluated, one may find that over a four-year period, access to clean drinking water in rural areas has increased from 50 percent to 60 percent of the rural population. Thus, in this situation, the effect is a 20 percent increase. However, to know whether the policy has been effective, one has to compare the results with the stated goals of the policy as evaluation of effectiveness is always relative to the desired goal. Simply put, if the goal was to increase water access by 20 percent, the policy can be considered effective. However, if the goal was to achieve 100 percent access to clean drinking water, then the policy was not effective. On the other hand, when a 30 percent increase is desired, a result of 20 percent increase may require qualitative and subjective judgement to evaluate whether it was considered effective or not. It is also important to note that direct measurement of effectiveness will only inform us about the degree to which a plan was effective, but not necessarily the reasons why. Without additional information, it may be hard to judge if the effect can be attributed to the initiatives that were put in place or if it was due to other factors.

Indirect measurement of effectiveness include tools that focus on the range of factors that need to be in place to ensure that institutions, policies and programs can operate as effectively as possible. These tools pick up the various constraints and opportunities that may hinder or further governance systems in achieving their initial intentions. A plan, institution, program or policy may look good on paper, but many factors may frustrate its implementation in reality. Such factors may include a variety of different governance elements, such as the low capacity of institutions, poor legislative frameworks, overlapping mandates, corrupted incentives, conflicts of interest and so on. Thus, evaluations of effectiveness will often need to consider governance elements when discussing why a policy, program or institution was effective or ineffective in achieving intended results. Typically, from the perspective of effectiveness, governance weaknesses can be construed as "governance bottlenecks". The label "bottlenecks" highlights processes in which the conditions for being effective are not in place and that typically delay and divert resources from the intention of the initiative. Many assessment tools therefore aim to identify such governance bottlenecks. The Water Governance Scorecard developed by the Overseas Development Institute (ODI) offers a checklist of important governance functions and regulations where bottlenecks can occur.

2. Study area

The Sesan-Srepok are trans-boundary basins in the Mekong River, which is shared by Cambodia and Viet Nam. The 18,800 square kilometers (km^2) Sesan Basin lies between the Sekong Basin, to the North, and the Srepok basin to the South. The 30,900 km^2 Srepok basin is the largest of the three basins (IUCN, 2015). As Sesan-Srepok basins is trans-boundary. There are attempts to apply IWRM to water governance from both the governments and international organizations in this basin. Nonetheless, as IWRM is recently introduced and recognized in Viet Nam, it has limited application and effectiveness in national water governance. Therefore, it is necessary to assess the effectiveness of water governance in Sesan-Srepok River basin.

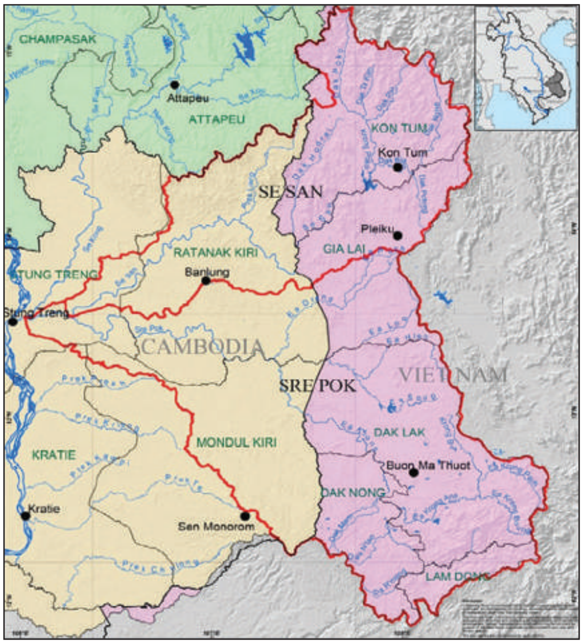


Figure 1. Sesan-Srepok River basin (MRC, 2017)

Governance in the Sesan-Srepok is complicated by the trans-boundary nature of the basins. The rivers are subject to the laws of both Viet Nam and Cambodia as they pass through these territories. Although existing mechanisms addressing some trans-boundary issues through dialogue (for example through the Mekong River Commission or MRC) and national laws under take precedence and Viet Nam and Cambodia have no comprehensive, enforceable treaties governing shared development and use of their shared waters. There have been long-running attempts to address this through the MRC's dialogue process. However, the Sesan-Srepok effectively remain managed under the legislation of Viet Nam in their upper reaches and Cambodian law in their lower reaches (IUCN, 2015).

In Cambodia, environmental protection falls under the auspices of the Ministry of Environment (MOE), which was also established in 1993. In practice, multiple ministries and government agencies have overlapping responsibilities which complicates development and conservation activities. Most of the legislation underlying environmental regulation in Cambodia was also written into law in the 1990s, including the Law on Environment Protection and Natural Resource Resources Management (1996), which is the primary environmental law in Cambodia.

In term of water resources institution in Viet Nam, the Ministry of Natural Resources and Environment (MONRE) is the most powerful government body that oversees environmental issues. Similar to its Cambodian counterpart, MONRE has significant overlaps with other ministries and agencies, including those that oversee development. For example, water resources are overseen by both MONRE and the Ministry of Agriculture and Rural Development (MARD). The provincial level equivalent to MONRE - the Department of Natural Resources and Environment (DONRE) - also has power to make decisions related to the environment, and is accountable to provincial People's Party Committees (PPCs). Below DONRE, sub-DONRE district-level offices help implement decisions from above.

Viet Nam has a wide variety of laws and decisions which address and are related to development and environmental impacts. At the highest level, there are laws such as the Water Resources Law, Construction Law, Land Law, and the Law on Environmental Protection. The National Water Resources Council, which was established by the 1998 Water Resources Law, is chaired by the Deputy Prime Minister and attempts to better coordinate the actions of various institutions, in relation to water resources. Land and water resources in Viet Nam are defined as being owned by all citizens, but "entrusted" to the central government.

Viet Nam has identified several priority projects focusing on integrated planning for sustainable development of water resources, climate change adaptation, flood forecasting, fisheries conservation, and watershed forest protection across the Basins. However, there are no plans that effectively integrate the development of industry, water resources, and socio-economic development. Although certainly not unique to Viet Nam, this lack of effective integration in legislation, governance, and development planning makes for a more complicated management situation.

3. Methodology

The approach used in the study included a review of existing literature on the water resources and water governance of Sesan-Srepok River basin. Besides, an indirect measure delivers The Water Governance Scorecard through a survey to assess effective water governance for the basin. Due to resource constraints, the survey was limited to collect expert judgements in which experts from different disciplines contribute their expertise and reflection on the outcomes of the assessment.

Most countries have taken several steps to improve/change water governance. Several new institutions, laws, policies and programs may have been put in place but have yet to become fully operational. What the Scorecard does is to take an overview of the governance arrangements that have been put in place and to assess how effective they are.

The Scorecard includes a small stakeholder assessment for each governance field, that will give depth to assess the effectiveness of water governance in the concerned area: In essence water governance concerns how the interests and stakes are balanced and how the different stakeholders effectively relate to each other.

With the Scorecard one can identify a number of priority actions to help getting effective water governance going on the ground. This is the main purpose - and not to give positive and negative 'marks', but to assess the areas of improvement.

The identified water governance capacity was assessed using a water governance scorecard, in which two parameters were evaluated (Effectiveness and Barriers).

Effectiveness: Are the governance tools working good to meet the initial targets?

Barrier: What are the bottlenecks preventing the tools from meeting the initial targets?

How effective is the governance tool?

- It is very effective (4)

- Many things happening but there are questions on quality and fairness (3)

- Only a few things happen - but not the really important actions (2)

- Nothing happens (1)

The main barriers to effectiveness are mentioned. These are:

- The law or new organization is not operational and has no authority (A)

- No one knows the laws or recognizes that the organization exists (B)

- No one makes an effort to enforce laws and/or there is no capacity to make the organizations function (C)

- There is no integration of different interests (D).

4. Results

The scorecard was completed on the basis of insights from interviews. The information was triangulated, to not based on the opinion of a single individual. The overview of the water governance capacity in Sesan-Srepok River basin is shown on the Table 1. In the overview a short description of the governance tool and gap is given and scores are given.

Table 1. Overview assessment of water governance capacity in Sesan-Srepok River Basin

Effectiveness	Governance tools	Barriers
	Legislative Framework	
2	Allocation of water rights between different uses	B
2	Conflict resolution mechanisms	C
3	Legislation for water quality	B
2	Other important laws on water	C
	Regulatory Instruments	
1	Regulation on groundwater	B
1	Regulation for water services	C
2	Land use planning	B
2	Nature protection (water related)	C
	IWRM Institutions	
3	Apex water bodies	C
3	Basin councils	D
3	Regulatory bodies	D
3	Enforcement agencies	D
3	Laws on community resource management organizations	C
3	Awareness raising	B
	Water Service Providers in IWRM	
3	Urban water supply services	D
3	Rural water supply services	D
2	Irrigation/ flood control services	C
2	Water treatment services	C
	Coordination	
3	Coordination with agriculture	B
3	Coordination with energy sector	B

Effectiveness	Governance tools	Barriers
Local Authorities		
3	In Providing Water Services	C
2	In Regulating Water Services	C
3	In Water Resource Planning	C
3	Other functions in IWRM	C

Legislative Framework

Sesan and Srepok basins located in Viet Nam and Cambodia, and thus, different parts of the basins are under different jurisdictions of the corresponding governments. This overlapping in legislation and jurisdiction complicates the already problematic water allocation issues. Notably, the water allocation priority order has not yet been determined by each region, as well as by each water use purpose for the whole region. As a result, in Sesan and Srepok basin in particular and Mekong basin in general, hydropower and industrial plants have been developed without comprehensive precaution and consideration for the impact on water allocation and water quality in the immediate downstream areas. Indeed, the lack of effective integration in legislation creates a more complicated management situation. Besides, transboundary management cooperation can only be effective with adequate and transparent data and information, which will support decision makers. However, the current monitoring network cannot provide sufficient data and information of water flow in/out between two countries or two provinces, which provides the basis for resolving conflicts

Regulatory Instruments

In general, regulatory instruments are plenty on paper. Nonetheless, there are no effective links between the water users with the official regulations nor with the power supply arrangements. For example, for groundwater, 50% of farmers depend on groundwater for irrigation, effectively contribute to groundwater level decline of 1.2m/year, jeopardizing drinking water and irrigation supply from shallow aquifers. In a few areas, water users have made rules on groundwater use, prioritising drinking water. In most areas, there is no groundwater management in place at all. At the same time, water quality in the river basin is deteriorating due to pollution mainly from agriculture sectors and industrial sectors. However, pollution from domestic wastewater as well as waste is increasing with elevating risks in cities such as Buon Ma Thuot, Pleiku, Kon Tum and other towns.

IWRM Institutions

There have been attempts from both countries on applying IWRM. At the national river basin level, a river basin organization - the Sesan-Srepok River Basin Council - was established in Viet Nam in 2008, which undertook some activities related to data collection and awareness raising but consequently failed to continue working due to legal implications. Meanwhile, currently in Cambodia, the Ministry of Water Resources and Meteorology is planning to establish a River Basin Management Committee for all River Basins in Cambodia. A Sub-decree on River Basin Management was approved in July 2015 and a decision of the Prime Minister on the composition of the National Committee for River Basin Management and its Secretariat was established in October 2015 (Lim, 2016). Following the establishment of the Water Resources Council, integrated plans will be prepared based on IWRM for better water management in each river basin.

Ultimately, applying IWRM to Sesan-Srepok River basin is essential to both countries. However, there are several obstacles that Viet Nam and Cambodia have to manage before successfully applying IWRM:

- Inappropriate and incompatible institutional setup.

- Poor communication/cooperation with stakeholders.

- Inadequate attention to create public awareness on the policy and strategy.

- No clear responsibilities for the private investors for sustainability of development of the basin.

- Lack of experience sharing IWRM.

- Weak participation of stakeholders/users for the management of the river basin.

Water Service Providers in IWRM

Urban and rural water supply for the whole region is sourced from surface water. Water is mainly acquired from reservoirs, small rivers and streams by self-flowing system or pumping. However, water service providers have not met 100% of the water demand for different purposes.

Coordination

In Sesan-Srepok River basin, coordination between different water use sectors is crucial to achieve the economic efficiency and social security. Currently, the two major water use sectors in Sesan-Srepok basins are agriculture sector and energy sector. Agriculture sector grows rapidly. However, this sector is heavily dependent on nature, which is unsustainable, especially when natural disaster occurs (i.e. flood, drought…). Meanwhile, the development of hydropower dams upstream is directly affecting the water allocation downstream, especially for irrigation, making agriculture sector more vulnerable. Therefore, coordination between different sectors need to be developed to share benefit among water use in the context of rapid socio-economic development, especially in energy sector where hydropower advancement has created many problems that need to be addressed.

Local Authorities

The Sesan-Srepok River basins are extensively influenced by local institutions and interests. Local governments have been given significant leeway in implementing development projects and overseeing environmental protection. This affords local authorities some autonomy to raise funds and carry out development projects at the district and provincial level. This autonomy level may increase in the future as both governments are experimenting with decentralization process. However, regulatory power and funding still rests with the respective central governments (IUCN, 2015). Therefore, despite the flexibility and autonomy given to local authority, budget constraint and administrative complication may prevent local government to effectiv ly tackle the issues in Sesan-Srepok basin.

It can be seen that the current water governance capacity in Sesan-Srepok River basin ranges from fair to very low. This means that in general the governance tools exist but is not properly working. The only negative score is the Regulatory instruments, all other tools are under management but their quality and fairness is ambiguous or only a small part of the mandate is implemented.

5. Proposed priority actions

In order to better approach IWRM in Sesan-Srepok basins, many actions have to take place. Based on the overview of the water governance capacity in Sesan-Srepok River basin above, several priority actions are proposed below.

Legislative Framework

- The priority order for water allocation by water use purposes have to meet 100% of the demand of domestic use, drinking water and essential needs for agricultural production.

- Harmonious allocation of water in dry season for domestic use, socio-economic demand and environment protection.

- The monitoring network in the basin must provide comprehensive monitoring of water users as well as water quality.

- Settle disputes among water users, local authorities and departments in river basins.

Regulatory Instruments

- Initiate program facilitating groundwater management dialogue in selected areas such as Legal awareness campaign (i.e. making administrators, farmers and legal specialists aware of the law).

- Land development and land-used planning in the river basins shall integrate agriculture development with regular survey.

- Natural disaster risk management shall be implemented.

- Provide guidelines on water users' financial responsibility.

- Develop regulations on responsibilities and solutions to restore surface water and groundwater pollution and degradation

- Develop regulations on protecting aquatic ecosystem and biodiversity of major rivers in the Sesan-Srepok basin.

IWRM Institutions

- Urgent need to found an organization, such as River Basin Commission (RBC), which plays a central role in coordinating different aspects of water management in the basin, varying from develop measures for monitoring, water use planning and resources protection.

- Strengthen cooperation between MONRE, MARD, local government and facilitate an organization similar to RBC.

- Protect aquatic ecosystems for inter-provincial water resources and ensure water security for international rivers.

- Build and manage monitoring system of water resource extraction as well as the discharge of wastewater into water sources in intra-provincial river basin.

- Elaborate and organize the implementation of plans based on survey, current regulation and distribution of water resources.

- Take measures to protect water resources in compliance with the current law.

- Develop response and remedy measures for water pollution incidents.

- Upgrade law/legal framework on community resources management organizations to adopt sustainable development.

Water Service Providers in IWRM

- The priority for water allocation by water use purposes have to meet 100% of the demand for domestic purposes, drinking water and essential needs for agricultural production.

- Impact assessment of aquaculture should be implemented.

Coordination

- Make prior policies available for scientists and experts working in agriculture sector.

- Provide regular training for staff of the RBC to update and apply advanced and modern technologies in their works and missions.

Local Authorities

- Allocation of water resources for agriculture shall be reduced to reserve for other purposes.

- Ensure efficient use of water, harmonize the benefits and promote equality among water users for each inter-provincial water resources.

6. Conclusion

From the assessment of water governance capacity, it can be concluded that IWRM is not properly applied in Sesan-Srepok River basin. Of all identified governance issues, the capacity in the basin ranges from fair to very low and thus, improvement is needed to achieve the goals and to meet the mandates. Therefore, in the discussions with experts from different disciplines, several priority actions were proposed for the follow-up of the assessment. Overall, the legislative frameworks and institutional arrangements for water sector development and management in Sesan-Srepok river basin remain uncoordinated and in need of improvement. Clarification of the roles and responsibilities of government agencies, and greater collaboration within different levels of administration and across sectors are key requirements to improve water planning and management. Increased involvement of the private sector in hydropower and other water-use sectors presents a greater need for transparent and accountable decision making, as well as thorough consideration of different stakeholders' perspectives. Therefore, an enabling environment needs to be created, in terms of legislative and institutional arrangements, human and technical resource capacities, to accurately assess the opportunities and risks of water development planning.

References

1. Constable, D (2015), *The Sesan and Sre Pok River Basins*, IUCN, Bangkok, Thailand.
2. Global Water Partnership West Africa (2009), *Assessment of Water Governance in Ghana*, GWP/WA, Ouagadougou, Burkina Faso.
3. Institute of Water Resources Planning (2005), *Planning on integrated use and protection of water resources in the Srepok River basin*, Ha Noi, Viet Nam.
4. Institute of Water Resources Planning (2007), *Planning on integrated use and protection of water resources in the Sesan River basin*, Ha Noi, Viet Nam.
5. Mekong River Commission (2017), *Transboundary Water Resources Management Issues In the Sesan and Srepok River Basins of Cambodia and Viet Nam*, MRC, Vientiane, Lao PDR.
6. Lim, P. (2016), *Water Resource Management in Cambodia: Participation of the economic sectors and citizens*, Presentation for INBO, 2016, 4th Roundtable.
7. Peter Rogers and Alan W. Hall (2003), *Effective Water Governance*, Global Water Partnership, Elanders Novum, Sweden.
8. Ronald Hemel and Henk Loijenga (2013), *Assessment of Water Governance Capacity in the Awash river basin*, Water Governance Centre, Den Haag, Netherlands.
9. UNDP (2013), *User's Guide on Assessing Water governance*, Phoenix Design Aid, Denmark.

STUDY ON CARRYING CAPACITY OF THE TRUONG GIANG RIVER, QUANG NAM PROVINCE

Mai Trong Hoang[1,2] , Tran Van Thuy[2] , Nguyen Dang Giap[3] , Nguyen Le Tuan[4]

[1]Viet Nam Institute of Meteorology, Hydrology and Climate Change

[2]Faculty of Environmental Sciences, VNU University of Science

[3]Key Laboratory of River and Coastal Engineering, Viet Nam Academic for Water Resources

[4]Viet Nam Institute of Seas and Island, Viet Nam Administration of Seas anh Islands

Received: 23 July 2020; Accepted: 20 August

Abstract: *The paper presents the study on environmental carrying capacity of Truong Giang River, Quang Nam province for BOD and NH_4^+, in the dry season (from April to June) and rainy season (from October to December) in 2017. The study used MIKE 21 model to simulate water quality and assess the carrying capacity of Truong Giang River by three different scenarios. Results show that, for the Scenario 1, all 4 river-sections of Truong Giang River were no longer able to withstand the load of BOD and NH_4^+. In particular, the section I had the best carrying capacity, followed by the section IV and section III, and the lowest one was the section II. For the Scenario 2, all 4 river-sections were still capable of receiving pollutants, except for BOD in section II and III in the rainy season. For the Scenario 3 with a warning meaning, in order to meet the minimum requirements of water quality to ensure the functions of the water source, it is necessary to limit the amount of pollution load discharged into the river by 1.94 times of BOD and 2.45 times of NH_4^+ compared to its of the year 2017. This result lays the foundation for further research on solutions to increase self-purification ability and improve water quality in the Truong Giang River.*

Keywords: *Carrying capacity, pollutants, Truong Giang River, Quang Nam province.*

1. Introduction

Truong Giang River is located in Quang Nam province, with a length of 67km, merging with the downstream in the north of Thu Bon River to flow into the sea through the Dai estuary, and merging with the downstream of Tam Ky River to flow into the sea through the Lo and An Hoa estuary. The Truong Giang River is of paramount importance to local people, providing water for aquaculture, water transportation and flood drainage for the coastal plain. This is also the habitat of many valuable aquatic and marine species.

Recently, people have arbitrarily encroached on the riverbed for aquaculture and built constructions on the river without planning. This has caused sedimentation of the riverbed and narrowed the flow. In particular, socio-economic development activities, such as aquaculture, industry and livestock farming in the region have been generating sources of polluting waste, pressurizes on water environment of the Truong Giang River.

Despite facing with the situation mentioned above, there has been no research on the pollutant carrying capacity of the Truong Giang River. Therefore, we conducted this study to assess the potential of major contaminants discharged into the Truong Giang River according to scenarios. The results serve as a basis for the orientation of planning, rational exploitation and use of the Truong Giang River for socio-economic development in association with environmental protection.

Corresponding author: Mai Trong Hoang

E-mail: tronghoangmhh@gmail.com

2. Methods and data

2.1. Object and scale of the study

- Object of the study: Pollution carrying capacity for parameters of BOD and NH_4^+ for Truong Giang River, Quang Nam province.

- Research scale:

+ Space range: The entire Truong Giang River has a length of 67km, starting from the junction of An Lac at Duy Xuyen district to An Hoa at Nui Thanh districts. Based on the characteristics of the Truong Giang River (the location of the river inlet, the distributary on the river; the purpose of using the water source in each river section), refer to the provisions of the Circular No.76/2017/TT-BTNMT in December 29, 2017 and the Decision No.154/QD-TCMT of February 15, 2019 relating to carying capacity of the water source [1, 6], the study has divided Truong Giang River into 4 sections to evaluate the pollution carrying capacity including: Section I (Duy Xuyen - Thang Binh), section II (Thang Binh section), section III (Thang Binh - Tam Ky - Nui Thanh) and section IV (Truong Giang lagoon) (Figure 1).

Figure 1. Location of Truong Giang River in Quang Nam Province (Zoom out from 1:100000-scale map)

+ Time range: This paper presents the results in the base year (2017) in the driest months in the dry season (from June to June) and rainy months (from October to December).

2.2. Research methods

As the Truong Giang River has a special morphology, influenced by tides at 3 estuaries (Dai estuary in the North, Lo and An Hoa estuaries in the South), there is a complex hydrodynamic regime that requires a set of strong modeling toolsfor simulation. The MIKE model, set up by the Danish Hydraulic Institute (DHI) integrates many powerful tools including strong modules such as rainfall-runoff (MIKE NAM) and one-dimension flow (MIKE 11) [8], two-dimension flow (MIKE 21) [9], advection-diffusion (MIKE AD) [10] and water quality (MIKE Ecolab) [11], etc. The MIKE is a specialized technical software, bringing high applicability to simulate discharge, flow, water quality in estuaries, rivers, canals and other water bodies. Therefore, this study used two MIKE model tools, MIKE 11 and MIKE 21, to study the pollution carrying capacity of the Truong Giang River. The MIKE 11 is used to simulate the flow of water through river crossings and provide input data for MIKE 21. MIKE 21 is responsible for simulating the flow field, distributing pollutant components and pollutant carrying capacity of the Truong Giang River according to different scenarios.

The study has implemented to simulate water quality of Truong Giang River with scenarios in 2017 in dry season (from April to June) and rainy season (from October to December). From there, the linear regression correlation function between the pollutant discharge load and the pollution parameter value at the representative point was determined, for each river section, through running the model with the change of input load with decreasing rate, 75%, 50% and 25%. From this linear regression function, it is possible to determine the carrying capacity of each section of the Truong Giang River with different scenarios according to the limitations of values of pollution parameters in QCVN (QCVN 08-MT: 2015/BTNMT) (Figure 2) [6].

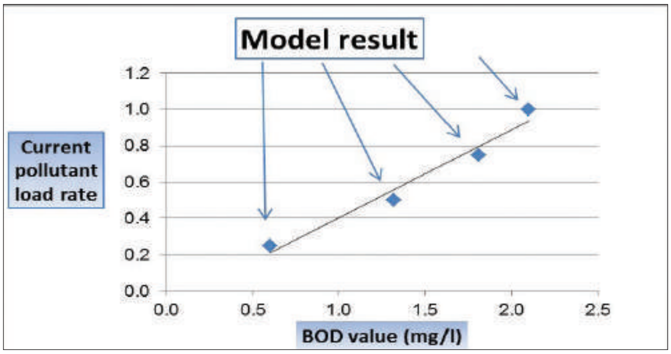


Figure 2. Relationship between pollution load discharged and concentration at the representative point (According to Decision 154/QD-TCMT, 2019 [6])

2.3. Data source

- Meteorological and hydrological data: Collected from stations as Cau Lau, Nong Son, Thanh My, Tam Ky and Son Tra between 2016 to 2018 and additional hydrological measurement data at Tam Ky river and Lo estuary when carrying out the national project with topic code: DTDL. CN-15/16 (Phase 1: From August 17, 2017 to August 22, 2017; phase 2: From August 16, 2018 to August 23, 2018) [4].

- Data of cross-section, terrain of Truong Giang Riverbed: Used from the project of building a flood map downstream of Vu Gia - Thu Bon River basins in 2018 and the dredging project of Truong Giang River [5,7]. The terrestrial one uses topographic map at 1:10,000-scale of Ministry of Natural Resources and Environment.

- Waste source data: Including 6 main sources, namely industry, living, aquaculture, livestock farming, soil leaching and 2 rivers of Thu Bon and Tam Ky, calculated from data of current development reports of each sector at Truong Giang River in 2017; Statistical Yearbook of 2017 for 4 districts [2, 3].

- Water quality data: Using the quarterly monitoring data of Quang Nam Department of National resource and Environment over the period of 05 years from 2014 to 2018. For supplementing data of water quality and serving verification and calibration, surface water samples were collected in 2 times (at the project with code number DTDL.CN-15/16) [4]. Phase 1: From November 15, 2016 to December 10, 2016 (rainy season); Session 2: From March 29, 2017 to April 21, 2017 (dry Season). Nine sampling positions locate in all the 4 river sections (sectionI: 02 points, section II: 02 points, section III: 03 points and section IV: 02 points); and the frequency was 5 times each point and the total was 90 samples. Water samples were collected and preserved in accordance with TCVN 6663-6: 2008, TCVN 6663-3:2016. The analysis of criteria BOD_5 and NH_4^+ was carried out at the Environmental Analysis Laboratory of Center for Monitoring and Modeling Research. environment (334 Nguyen Trai, Thanh Xuan, Ha Noi).

3. Results and discussion

3.1. Set up the MIKE 21 Ecolab model

Within the scope of this study, the Ecolab water quality model was established at Level 4 (MIKE 21 WQ Level 4) to simulate water quality for BOD and NH_4^+ parameters. This model level is suitable for studies on the effects of waste sources from urban, industrial and agricultural activities on water quality [11].

- Setting the calculated domain range of the model was limited from latitude X: 532099 to latitude X: 575086, from longitude Y: 1705442 to longitude Y: 1761194. The calculated domain scale has a range of 54km in the direction North-South, from 1-7km in the direction of East-West. The number of grid cells is 39,783 and the number of grid nodes is 21,695 with the smallest grid area is 167m^2, the largest grid area is 2.3 km^2 (Figure 3).

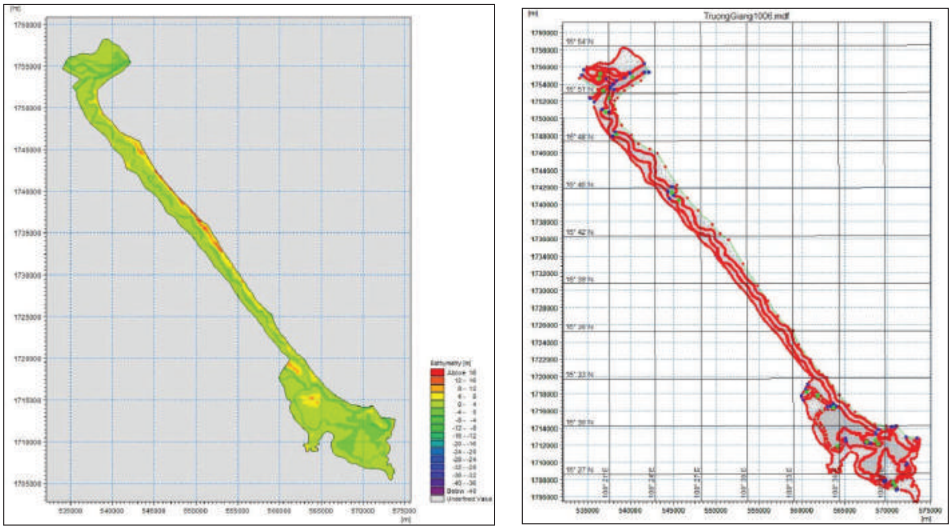
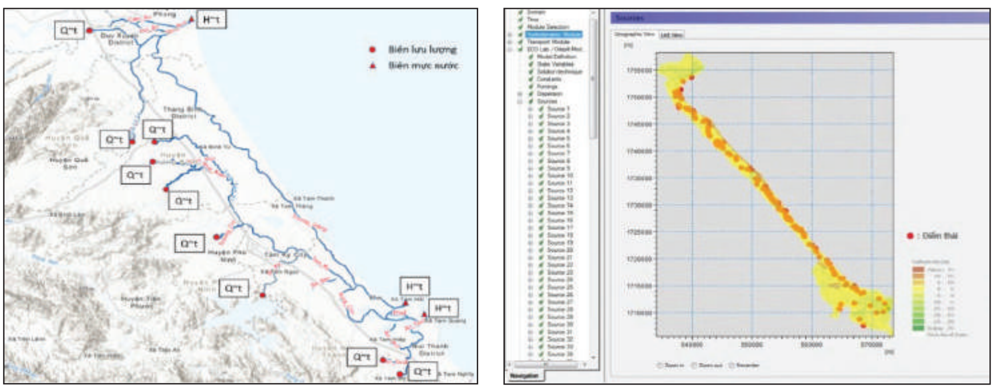


Figure 3. Topographic and grid area set for the Truong Giang River

- Setting boundary conditions:

+ Discharge and water level boundary: Including 09 flow boundary (at Thu Bon, Ly Ly, Tam Ky, Ngoc Kho, Phu Xuan, Truong Chi, Ba Ky and An Tan 2 (2 borders)), calculated from the overall picture of the Vu Gia - Thu Bon River basin [5] and 03 water boundaries at the 3 estuaries;

+ Waste source boundary: Based on the distribution characteristics of the 6 main sources of waste from socio-economic development, hydrological network, and topography of the river, the study has put into place 115 waste discharge points across the domain set.



a) Network diagram *b) Location of discharged points*

Figure 4. Establishing MIKE 21 model boundary conditions for Truong Giang River

3.2. Calibration and verification

Calibration and verification for MIKE 21 HD

The calibration of parameters of hydraulic model was mainly done by changing Manning's roughness coefficient and initial values. After calibrated the parameters, the model ensured the necessary accuracy with the calculated time step of 1 hour, roughness in the range of 0.02-0.035. The hydraulic model was calibrated with data series at the monitoring station on Tam Ky River from August 17, 2017 to August 22, 2017.

The calibration was assessed through correlation between measured and simulated water level (R^2) and errors between actual measurements and station calculations (NASH indicator), with the value of R^2 = 0.94 and the index NASH = 0.94.

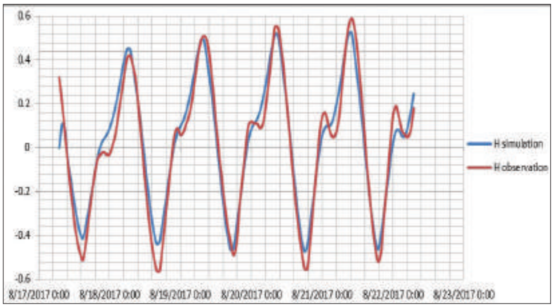


Figure 5. Simulated and measured of water level at the hydrology station on the Tam Ky River when calibration the model

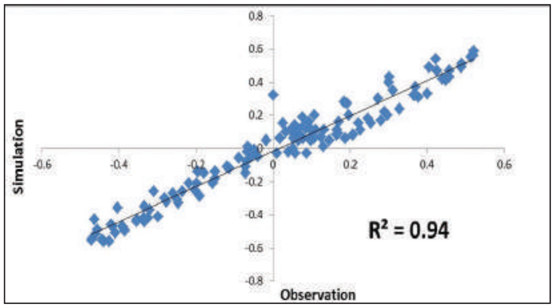


Figure 6. Relationship between simulated and measured water level at the hydrology station on the Tam Ky River when calibration the model

The purpose of verification was to assess the suitability of the parameters in the verification. The study used the actual water level data measured in the dry season (August 2018) at the hydrographic observation station of the Tam Ky River for verification.

Verification resulted the value R^2 = 0.90 and the NASH index = 0.88.

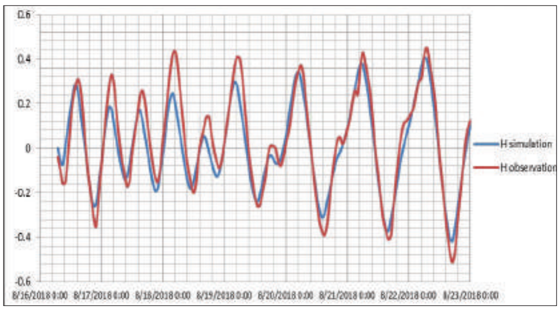


Figure 7. Simulated and measured water levels at the hydrology station on the Tam Ky River when verification the model

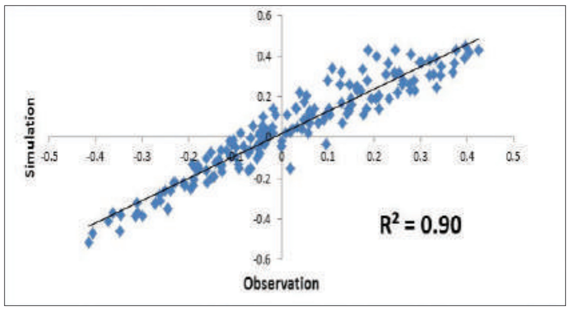


Figure 8. Relationship between simulated and measured water level at the hydrology station on the Tam Ky River when verification the model

The relatively high R^2 values and NASH coefficients show that the calibration and verification were very good. With the above calibration and verification results, the mathematical model shows the reliability of the calculated results.

Calibration and verification for water quality models, MIKE 21 Ecolab

The calibration was also evaluated by the correlation between observed and simulated values (R^2) and errors between monitoring data and calculations at 9 cross-sections (NASH) of the parameters. Specifically, the value of NASH (BOD)=0.66; R^2 value (BOD)=0.64; NASH (NH_4^+)=0.73; R^2 value (NH_4^+)=0.78.

Verification resulted the value NASH (BOD)=0.65; R^2 value (BOD)=0.62; NASH (NH_4^+)=0.75; R^2 value (NH_4^+)=0.76.

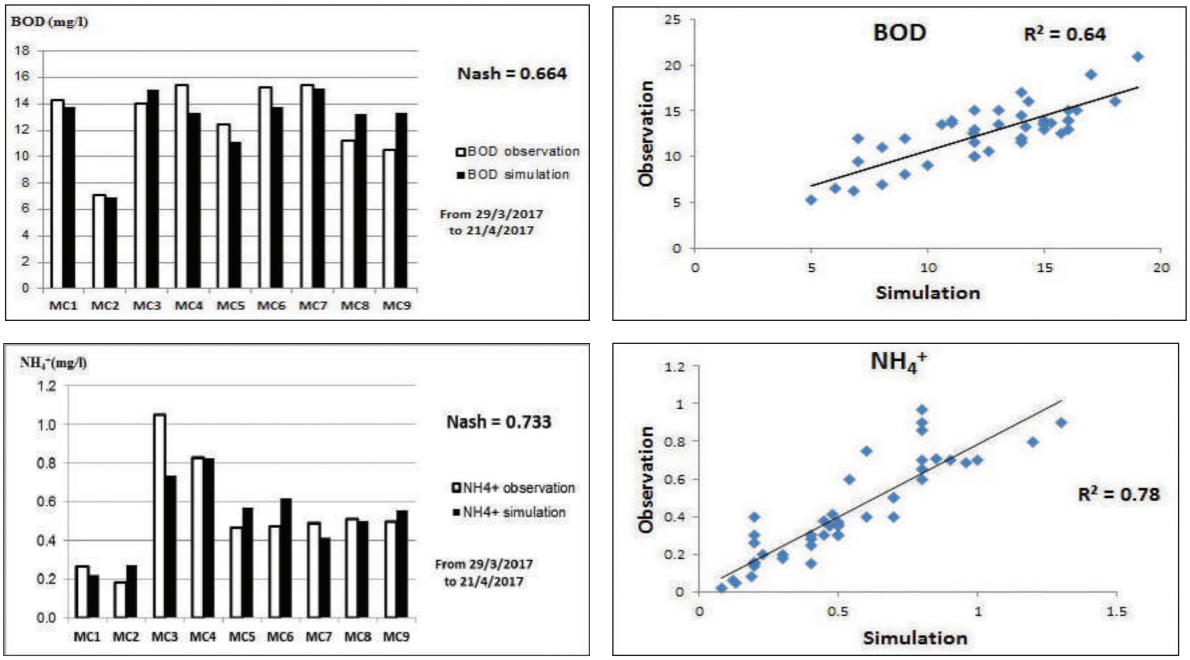


Figure 9. Relationship between simulation and measurement of the values of BOD, NH_4^+ values when calibration the model

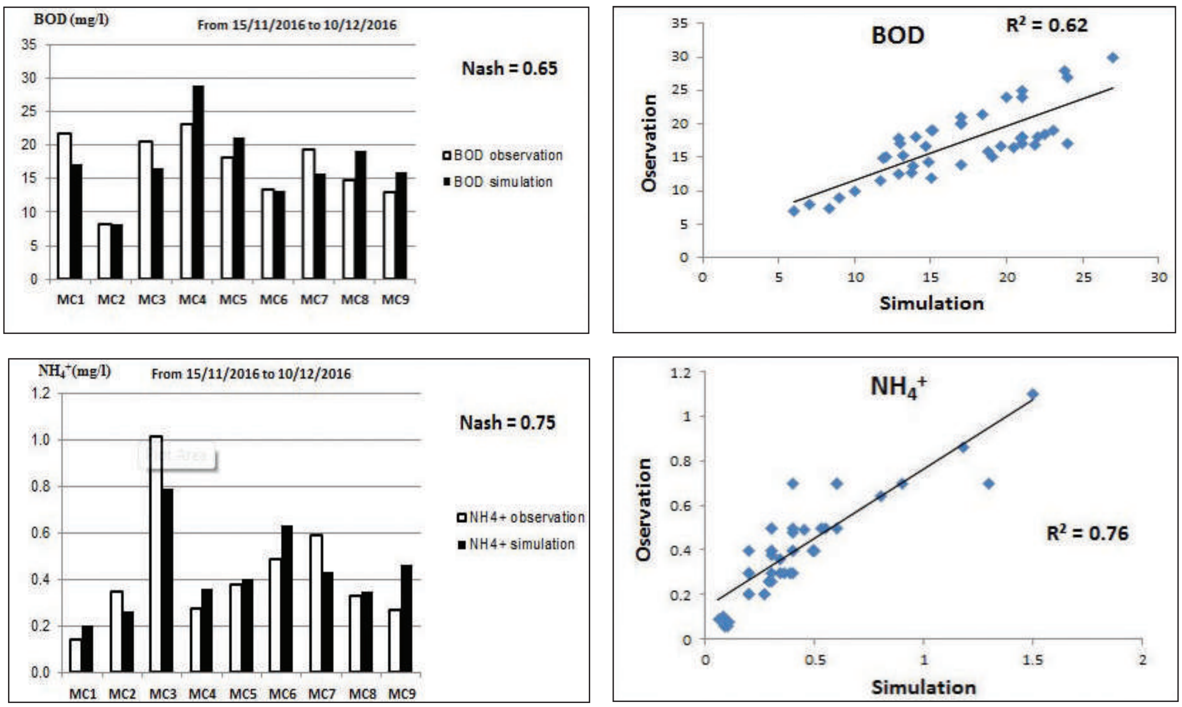


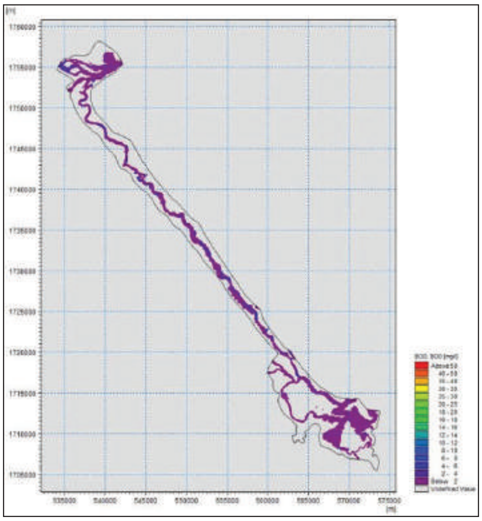
Figure 10. Relationship between simulation and measurement of the values of BOD, NH_4^+ values when verification the model

The NASH values ranged from 0.65 to 0.75, the determination coefficient R^2 was from 0.62 to 0.78, showing that the calibration and verification were quite good, the model shows reliability on the calculation results.

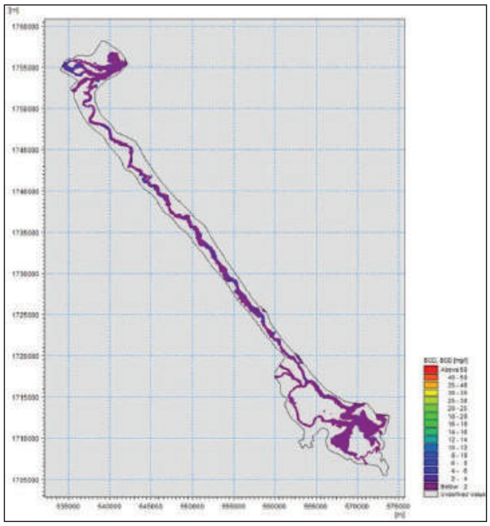
3.3. Pollutant carrying capacity of Truong Giang River

• *The contaminant concentration on the Truong Giang River*

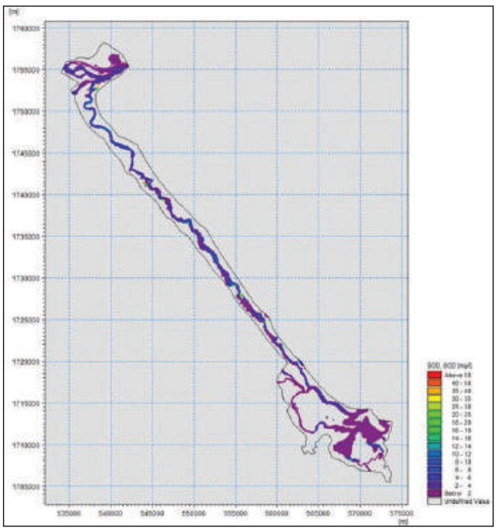
Simulation results of water quality of the Truong Giang River in 2017, using MIKE 21 model, show that BOD value varies widely among river sections, section III had the largest variation from 1.55 to 80.84mg/l, section IV (1.27-54.4mg/l), section II (1.89-29.17mg/l), the lowest was in section I (1.35-27.12mg/l). The average BOD value was not much different among the sections and mostly satisfied QCVN 08-MT:2015/BTNMT at B1-level. The BOD of the sections in the rainy season was higher than that in the dry season but not much. The reasons were the higher flow from the two rivers of the Thu Bon and Tam and the higher washing away of soil in the rainy months, from October to December. In addition, the amount of organic matter discharged into the river was quite large, while in the dry season, the seawater from the tides had contributed to cleaning up the organic matter in the river water.



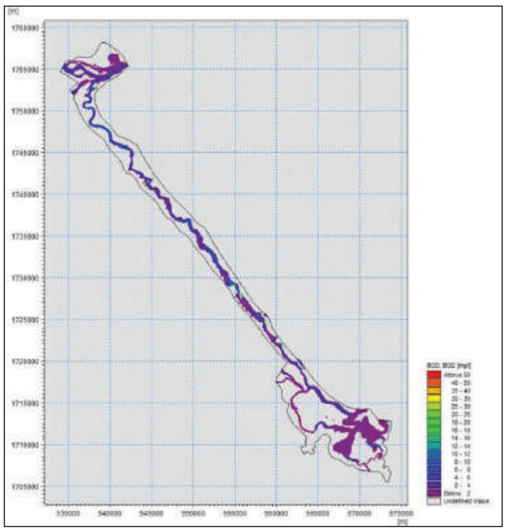
a)- Dry season - High tide



b)- Dry season - Low tide



c)- Rainy season - High tide



d)- Rainy season - Low tide

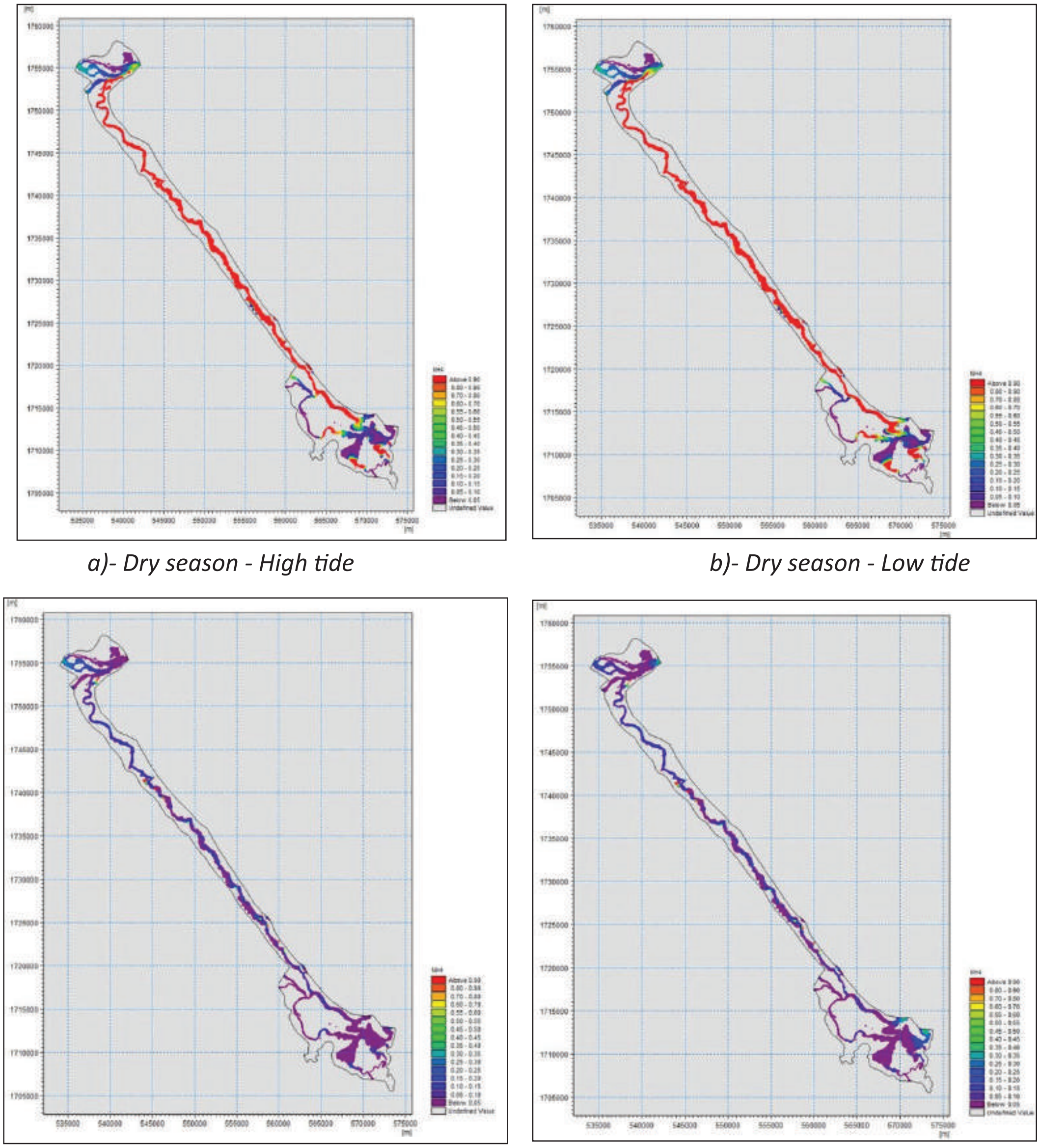
Figure 11. BOD value in the Truong Giang River according to seasons and tides

Notes: Dry season: April - June, 2017; rainy season: October - December, 2017;

High tide: From the time of the lowest tide level to the highest level of the day;

Low tide: From the time of the highest tide the water falls to the lowest of the day.

NH_4^+ value in the sections: Section I (0.07-3.07mg/l), Section II (0.04-3.6mg/l), Section III (0.05-4.79mg/l) and section IV (0.04-2.7mg/l). Simulation results of NH_4^+ in the dry season were higher than those in the rainy season. Section III had the highest concentration of NH_4^+, especially in section II, although the pollution load discharged into this section was quite low compared to other sections. Due to the narrow riverbed, and sedimentation, the flow of water through the section was low (average flow about 15-18m^3/s), reducing the ability to dilute and self-purification of water body, leading to high NH_4^+ value.



a)- Dry season - High tide *b)- Dry season - Low tide*

c)- Rainy season - High tide *d)- Rainy season - Low tide*

Figure 12. NH_4^+ value in Truong Giang River according to seasons and tides

Pollutant carrying capacity according to scenarios

After calibration and verification, the MIKE 21 Ecolab model was used to simulate and calculate for different scenarios. The development of a correlation function of pollution load discharged into each section of the Truong Giang River and the value of pollution parameters at the representative point of the section, thereby determining the pollution carrying capacity of each river section in kg/day. Based on the guidance in Decision 154/QD-TCMT [6], the study identified a representative point that coincided with the location of 9 water quality monitoring sections of 4 sections. Based on the limit value of surface water quality parameters according to QCVN 08-MT: 2015/BTNMT levels A2, B1, B2, we set up three scenarios to determine the pollutant carrying capacity of the Truong Giang River (Table 1).

Table 1. Scenarios of determining pollution carrying capacity of the Truong Giang River

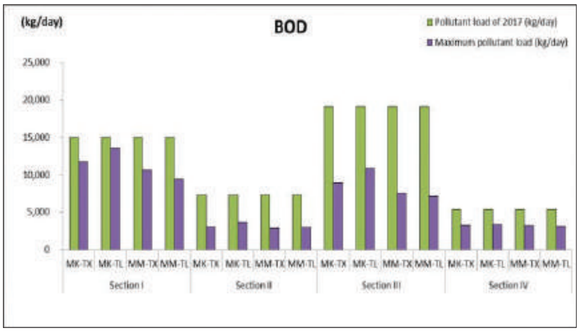
No.	Scenario	Limited value of parameters	The purpose
1	**Scenario 1.** Pollutant carrying capacity under A2 scenario (scenario for restoring river functions)	BOD ≤ 6 mg/l NH_4 ≤ 0.3 mg/l	In order to determine the ability of receiving pollutants into the Truong Giang River so that the river can restore some of previous functions which are no longer meeting such as aquaculture, domestic purposes and restoring valuable aquatic resources.
2	**Scenario 2.** Pollutant load capacity under scenario B1 (scenario for maintenance of current function)	BOD ≤ 15 mg/l NH_4 ≤ 0.9 mg/l	Assessing the ability to receive pollutants in the threshold of maintaining current functions of the Truong Giang River such as water supply for agriculture, water transportation, aquaculture and other equivalent functions.
3	**Scenario 3.** Pollutant carrying capacity under B2 scenario (Bad scenario)	BOD ≤ 25 mg/l NH_4 ≤ 0.9 mg/l	This is a warning, aiming to determine the maximum emission threshold of development fields so that Truong Giang River will not become a “dead river”, meaning losing the ability to regenerate and restore. Beyond this limit, water quality does not meet any water use function.

Scenario 1. *Pollutant carrying capacity under A2 scenario (scenario for restoring river functions)*

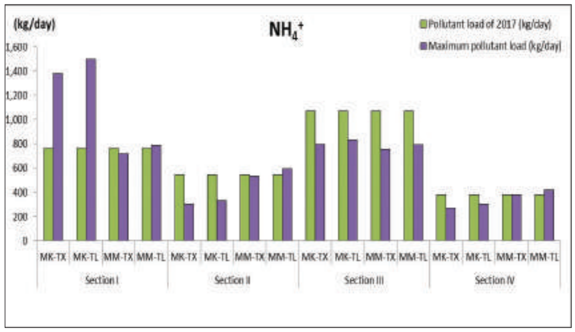
The results showed that the BOD load exceeded the maximum load from 1,430kg/day in section I (equivalent exceeded 10% of the base load in 2017) to 11,950kg/day in section III (equivalent exceeded 63%). For the parameter of NH_4^+, while section I was still capable of receiving 334kg/day (reaching 44% of the base), section II, section III and section IV are no longer able to receive pollutant (exceeding 105kg day, 280kg/day and 37kg/day, respectively) (Figure 13).

Compared to other sections, section I has the best load capacity, followed by sections IV and III. Section II has the lowest carrying capacity despite having a lower pollutant discharge load compared to other sections. Section II, which the riverbed was narrowed with strongly deposited, leading to the low flow of water sources, it is necessary to have solutions for dredging, clearing the flow, increasing the o pen-surface and the water depth. Seasonally, the carrying capacity in the dry season was higher than that in the rainy season for parameter BOD, and the trend of NH_4^+ was reverse. This result is suitable for the change in seasonal pollutant concentration of the two parameters.

Under this scenario, in order to meet the requirement in QCVN 08-MT:2015/BTNMT at A2-level, it was necessary to reduce by 20,358 kg BOD per day and 421kg NH_4^+ per day. For aquaculture, domestic and livestock farming sources, reductions can be made by increasing the efficiency of wastewater treatment before being discharged into the river (especially from aquaculture); For industrial source, it was necessary to maintain the existing treatment efficiency and prevent environmental incidents, and to control efficiently the waste sources in upstream river systems (Thu Bon and Tam Ky Rivers).



a)- BOD carrying capacity of scenario A2



b)- NH_4^+ carrying capacity of scenario A2

Figure 13. Pollutant carrying capacity of Truong Giang River under scenario A2

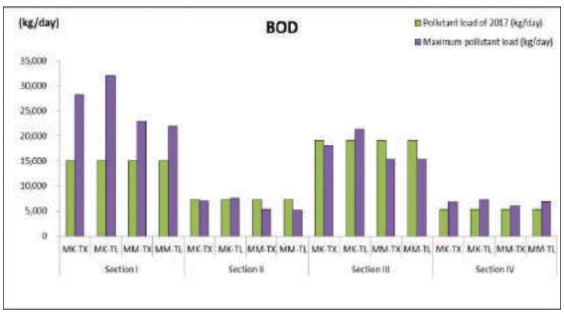
Notes: MK: Dry season; MM: Rainy season; TX: Low tide; TL: High tide.

Section I: The section of Duy Xuyen - Thang Binh; Section II: The section of Thang Binh;

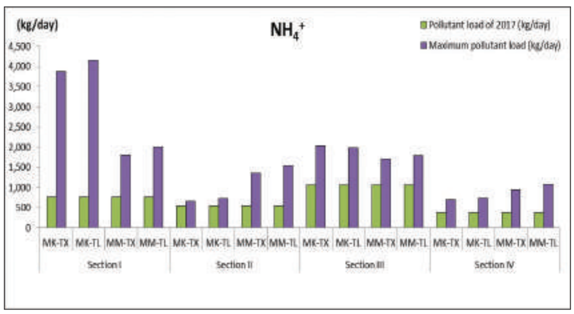
Section III: Thang Binh - Tam Ky - Nui Thanh; Section IV: Truong Giang lagoon.

Scenario 2. *Pollutant carrying capacity under scenario B1 (scenario for maintenance of current function).*

In scenario B1, the 4 sections were still capable of receiving pollutants, except for BOD in the rainy season in sections II and III, at 1,910kg/day and 3,767kg/day respectively. Compared to scenario A2, the pollution receiving capacity under this scenario with BOD, NH_4^+ increased by 7,622kg/day and 1,025kg/day, respectively (Figure 14).



a)- BOD carrying capacity of scenario B1



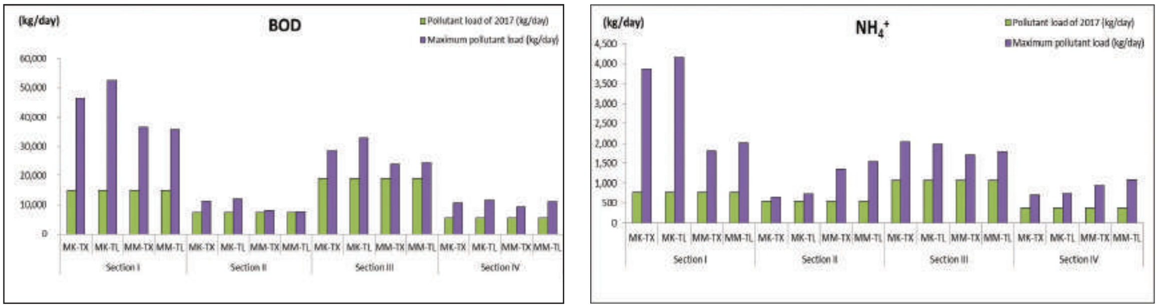
b)- NH_4^+ carrying capacity of scenario B1

Figure 14. Pollutant carrying capacity of the Truong Giang River under scenario B1

Scenario 3. *Pollution carrying capacity under B2 scenario (Bad scenario).*

Under this scenario, the 4 sections were still capable of receiving pollutants for the parameters. Compared with the scenario B1, the carrying capacity of BOD increased by 4.3 times while NH_4^+ did not change (Figure 15).

In order to ensure the minimum threshold of water quality in Truong Giang River (QCVN 08-MT: 2015/BTNMT at B2-level) for functions such as water transport and flood drainage without losing the ability to regenerate and recover, it was necessary to limit the amount of pollution load discharged into the Truong Giang River by reducing by 1.94 times of BOD and 2.45 times of NH_4^+ of the base year (2017).



a)- BOD carrying capacity of scenario B2 *b)- NH_4^+ carrying capacity of scenario B2*

Figure 15. Pollutant carrying capacity of Truong Giang River under scenario B2

4. Conclusion

For Scenario 1 corresponding to the water quality at level A2-QCVN 08-MT:2015/BTNMT, section I had the best capacity, followed by sections IV and III. Section II had the lowest capacity, due to the narrowing of the riverbed, strong sedimentation and low water flow. Under Scenario 2, the 4 sections were still capable of receiving pollutants, except for BOD in section II and III in the rainy season. For Scenario 3 with the lowest requirement of water quality, it was necessary to limit the amount of load discharged into Truong Giang River to not exceed 1.94 times of BOD and 2.45 times of NH_4^+ load of the base year. By this result, in order to improve the quality of water and ability of the carrying capacity, there should be further studies to zone the function of water resources of the River in each section, combine solutions of management and waste treatment from sources, especially the source of aquaculture along the river to ensure the regeneration and recovery ability of the River.

Acknowledgments: *The authors sincerely thank for the support of the state-level project "Overall study of Truong Giang River and surrounding areas for socio-economic sustainable development of Quang Nam province", code DTDL.CN-15/16 and project "Assessing the impact of climate change on natural conditions, natural resources and the environment in the coastal estuaries of the Red River Delta and proposing solutions proper use of exploitation methods", code BĐKH.33/16-20 provided the source of data and technical support for the authors to implement the article.*

References

1. Ministry of Natural Resources and Environment (2017), *Circular No. 76/2017/TT-BTNMT dated December 29, 2017 providing for assessment of sewage receiving capacity, carrying capacity of river and lake water sources,* 11 p.
2. Quang Nam Statistical Office (2018), *Quang Nam Statistical Yearbook in 2017, Statistical Publishing House*, 519 p.
3. Mai Trong Hoang, Ngo Xuan Nam, Tran Van Thuy and Mai Thi Huyen (2018), "Study on determination of pollutant discharge load into Truong Giang river, Quang Nam province", *VNU Journal of Science: Life Sciences Soil and Environment*, Volume 34, Issue 4 (2018), pp.71-79.
4. Nguyen Quoc Huy et al (2019), *Overall study of Truong Giang River and surrounding areas for socio-economic sustainable development of Quang Nam province*, Synthesis report of Science and Technology state-level project, code DTDL.CN-15/16, 520 p.
5. National Key Laboratory of River Dynamics (2017), *Mapping flooding of downstream reservoirs in the Vu Gia - Thu Bon River basin*, Project of Ministry of Agriculture and Development Countryside.
6. General Department of Environment (2019), *Decision No. 154 / QD-TCMT dated February 15, 2019 on issuing technical guidelines for calculation of river water load capacity,* 42 p.

7. People's Committee of Quang Nam Province (2011), *Emergency Flood Dredging Project of Truong Giang River.*
8. DHI (2011), *MIKE 11 A Modelling System for Rivers and Channels, Reference Manual*, 536 pp.
9. DHI (2011), *MIKE 21 Flow Model, Hydrodynamic Module User Guide*, 116 pp.
10. DHI (2011), *MIKE 21 Flow Model, Advection/Dispersion Module User Guide*, 52 pp.
11. DHI (2011), *MIKE 21 Flow Model, ECO Lab Module User Guide*, 70 pp.

BUILDING A FLOOD WARNING AND FORECAST SYSTEM IN THE SOUTH CENTRAL VIET NAM

Tran Tuan Hoang[(1)], Pham Thanh Long[(1)], Nguyen Thao Hien[(1)], Le Van Phan[(2)]
[(1)]*Sub-Institute of HydroMeteorology and Climate Change*
[(2)]*Ho Chi Minh city University of Agriculture and Forestry*

Received: 21 July 2020; Accepted: 18 August 2020

Abstract: *To raise the efficiency of warning and flood forecasting of forecasters at the Meteorological and Hydrological Station in the South Central region, Viet Nam. A system of meteorological, hydrological and oceanographic measurement stations has been installed throughout the studied area including 10 basins in 5 provinces with more than 114 stations. Data from these stations are automatically transmitted to the server associated with a model system for calculating flood levels and flood maps, then be uploaded to WebGIS. The combination of online data and WebGIS can provide immediated flood warning information; while the WRF weather forecast model system combines the MIKE FLOOD forecasting model to create flood forecast maps for river basins in the South Central region updated on the WebGIS. Users can, thus, refer to flood spots, flood statistics and download updated data from this website. The system has also helped forecasters entering data in advance and creating faster outputs. Results have helped departments and agencies make timely decisions in disaster prevention.*

Keywords: *Forecast and warning system, WRF, MIKE models, WebGIS, South Central of Viet Nam.*

1. Introduction

1.1. Overview

In fact, there are many research subjects related to flood warning and forecasting, such as: the main river system, the reservoir, managing and planning for river system and downstream.

Currently, hydraulic models is a tool for research and application widely applied, that for simulating and solving hydrodynamic problems in order to sever flood forecasting is very popular and applied in many ways. Combining the Bayesian Network model to estimate flood peaks from the forecast of atmospheric populations (AEFs) and the WRF weather forecasting reseach model of Leila (2019) [7]. K.Pennelly (2014) applied WRF model with cumulative parameter maps for flood events in Canada and demonstrated the accuracy of the model in precipitation simulation [9]. Li et al (2017) combined WRF model with a distributed hydrological model that predicted floods in a large basin in Southern China, the results showed that simulated flooding is reasonable and can be brought early flood prevention for the community [8]. Jinyin Ye et al (2016) used TIGGE software (observaiton system reseach and forecast testing) integrating precipitation products from all major forecast centers in the world and supplying evaluation of the multi-model system, rainfall is intergrated by TIGGE model that can provide flood probability prediction [6].

With the flood warning forecasts studies in the country, Tri (2019) applied the MIKE SHE - MIKE 11 - MIKE 11 GIS model combined with IFS rain forecast for downstream Vu Gia River - Thu Bon [2]. MIKE NAM model is selected to simulate, calculate and forecast the flow to the lake for the construction of the lake regulation tool [3].

This research paper focuses on the ability to predict flood flows, research and apply some common hydro-hydraulic forecasting methods

Corresponding author: Pham Thanh Long
E-mail: longpham.sihymete@gmail.com

in flood prediction. A new point in the study is to integrate weather factors such as rainfall to calculate runoff data and flood maps for advanced forecasting for a large basin system in the South Central Coast. In addition, for the convenience of managing the database: forecast data, real measurement data, flooded data, maps,... WebGIS supports to improve the ability to manage, query, update information, news quickly and instantly.

1.2. Introduction of study area

The South Central Coast region is a coastal area with a narrow territory with many types such as coastal plains, low mountains, criss-crossed by river system but short and steep, deep shorelines and narrow continental shelves. This area consists of 5 provinces Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan and Binh Thuan adjacent to the East Sea, the North to the Middle Central, the South to the Southeast and the West to the Central Highlands. There are large rivers such as Kon River - Binh Dinh, Ba River - Phu Yen, Cai River - Khanh Hoa, Cai Phan Rang River - Ninh Thuan, Luy - Ca Ty, La Nga - Binh Thuan but most of them have very steep slopes.

Downstream areas in the South Central region are prone to floods, on average, there are 2-4 floods a year. Major flooding, the flood retention time last from 2-3 days, causing flooding floor more popular of 0.5-1.0m. Due to short and sloping terrain conditions, small river basins, combined with no transition zone, when heavy rains happen, water control capacity of the buffer-surface is poor, floods focusing on the delta are primary reason causing prolonged inundation in coastal areas and downstream area. Meanwhile, the upstream area is at risk of causing flash floods, pipe floods; small and narrow plains, large extent of changing in topography cause great flooding depth [1, 4, 5, 10, 11, 12, 13].

2. Methodology

2.1. Modeling methods

The main task is to establish a regional flood forecasting model, which requires a model such as a flood model MIKE 11 (RR & HD), MIKE21 and MIKE FLOOD. Observed data used to calculate statistics, analyze, and run models.

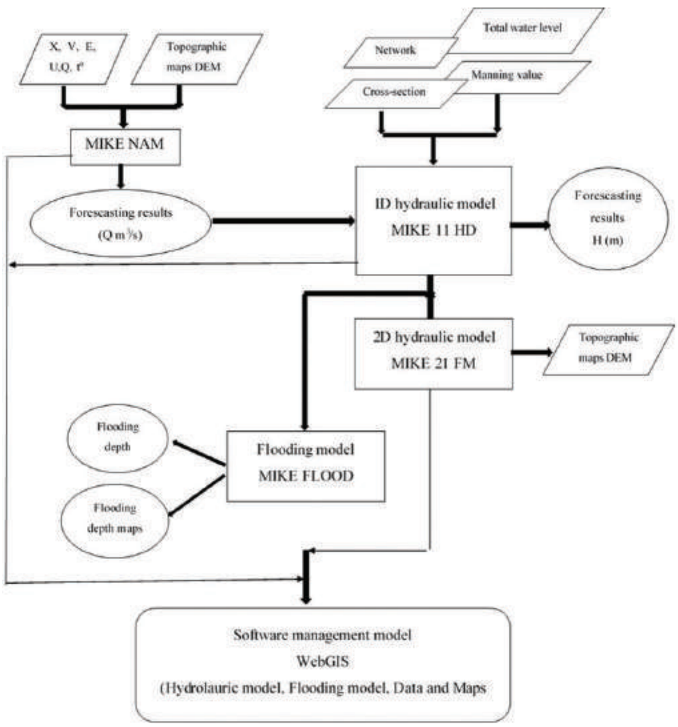


Figure 1. Diagram of steps to implement flood forecasting model

• NAM Hydrological Model (Rainfall - Runoff) is a rainfall-runoff simulation model, which is established to describe the volumetric flow rate approximate hourly or daily rainfall data.

• MIKE 11 modeling with the hydrodynamic modules (HD) is a one-direction flow hydraulic model used for the simulation of flow in rivers. The model is executed basing on data of river network, cross-section, river roughness and volumetric flow rate values from upstream to downstream.

• MIKE FLOOD is an integrated model package that simulates inundation for rivers floodplains, flooding in urban, drainage networks, coastal area, or any combination of these. Combination of this model's products with a GIS helps to present the results of the place which are likely to flood on map.

For ease of use and unity, the inputs and outputs from the model are managed by flood management software via WEBGIS with an intuitive graphical interface for users. The operation of WEBGIS has a property of a dynamic website, which divided into 2 parts including Client and Server. Client activities mainly interact with the map on the server via a web browser.

2.2. Research content

The South Central Coast region is a coastal area, a narrow territory. The terrain here includes coastal plains and low mountains, horizontal direction of East-West (averaging of 40-50km), narrow compared to the North Central and Central Highlands. There is a system of short and steep rivers, deep coast with many bends and narrow continental shelves. The plains are not large due to the western mountain range along the southern direction towards the sea and gradually narrowing in area. The delta is mainly formed due to the accretion of rivers and seas, often close to the foothills when forming.

The study area is bordered by the North to the North Central, the West to the Central Highlands, to the South by the Southeast, to the South and to the East by the East Sea. The South Central Coast consists of 5 provinces: Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan, and Binh Thuan (Figure 1). Because majority of this area belongs to the coastal areas with steep slopes, the short river is combined with heavy rains so there is usually the phenomenon of surge creating flash floods.

Our study focuses on the main river basins of 5 provinces in the South Central Coast including Binh Dinh, Phu Yen, Khanh Hoa, Ninh Thuan, and Binh Thuan. Due to the topographic distribution and rainfall, the river systems are complicated. Its main rivers are Lai Giang, Kon - Ha Thanh (Binh Dinh); Ky Lo, Ba (Phu Yen); Dinh, Cai (Khanh Hoa), Cai Phan Rang (Ninh Thuan); Luy, Ca Ty and La Nga (Binh Thuan) Rivers, as well as other tributaries. The river has a steep slope, heavy rains causing sudden flash floods concentrate here.

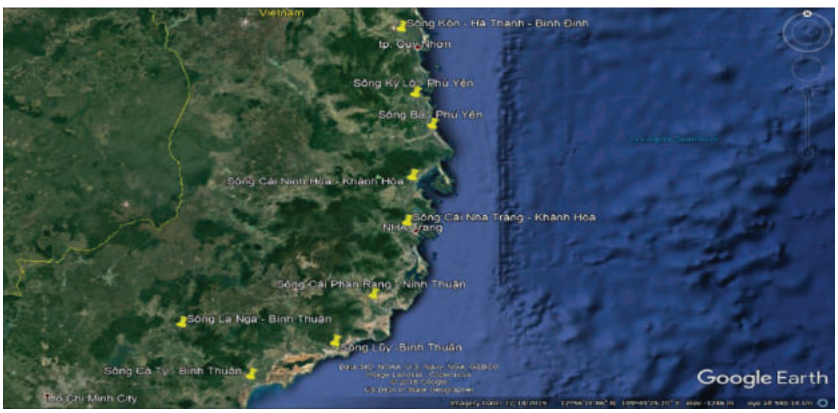


Figure 2. Map of the South Central Coast region

(Source: Sub-Institute of Hydrometeorology and Climate Change)

2.3. Data collection

2.3.1. Rainfall data

Observed rainfall data in the study area of 10 river basins is hourly rainfall data used as input data for the MIKE NAM model. This data set is covered by South Central Regional Hydrometeorological Center. Plans of calibration-test the model parameters in the flood season in 2013 and 2016.

- Binh Nghi, Thanh Hoa, An Hoa, Hoai An, Vinh Kim, Dinh Binh, Phu Cat, An Nhon, Van Canh, Quy Nhon, Vinh Son, Hoai Nhon and Bong Son stations: Binh Dinh province;

- Cung Son, Tuy Hoa, Son Hoa, An Khe, Ayun Pa, MaDrak, Ha Bang, Xuan Quang, Song Cau stations: Phu Yen province;

- Da Ban station, Ninh Hoa, Khanh Vinh, Dong Trang: Khanh Hoa province;

- Phuoc Binh, Song Pha, Tan My, Nha Ho, Phan Rang, Phuoc Ha, Nhi Ha stations: Ninh Thuan province;

- Song Luy, Phan Ri, Phan Tien, Phan Son, Song Mao, Bau Trang stations: Binh Thuan province.

2.3.2. Flow rate and water level data

Hourly water level and flow rate data is collected over 2 periods of 2 years (2013 and 2016). Data set is used to calculate the changing of water levels as well as to simulate flooding problems for 10 river basins. It is also used for calculating in NAM models, flooding models, and supporting checking the calculation results of models, calibration and tests.

- Binh Tuong, Thanh Hoa, Bong Son stations: Binh Dinh province;

- Cung Son, Phu Lam, Ha Bang stations: Phu Yen province;

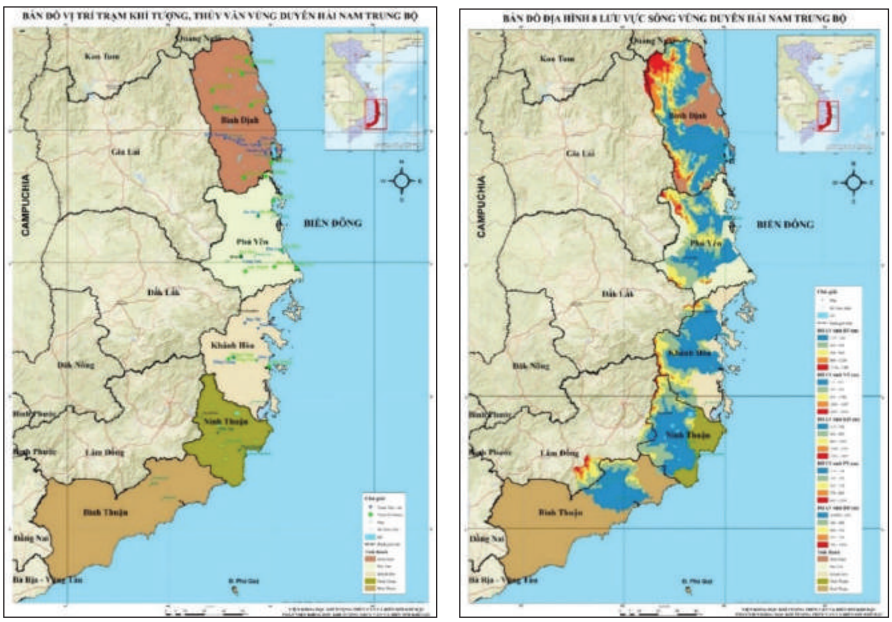
- Dong Trang station, Ninh Hoa: Cai River basin - Khanh Hoa province.

- Tan My station: Ninh Thuan province;

- Song Luy, Ta Pao, Vo Xu stations: Binh Thuan province.

2.3.3. Topographic data

DEM digital elevation map of research area used with resolution of 30×30m. The river network is digitized by using ArcGIS 10.1 on a 1:10,000 scale terrain. Topographic data has the resolution of 10×10m in the UTM zone 48N coordinate system, there is a diagram of hydrographic network, suitable topography with a closed network at the boundary values. Data of river networks and cross-sectional data are also collected and inherited from other projects that conducted by the Sub-Institute of Hydrometeorology and Climate Change.



a) Meteorology - Hydrology Station *b) Topographic data*

Figure 3. The input database of the flood forecast modeling system

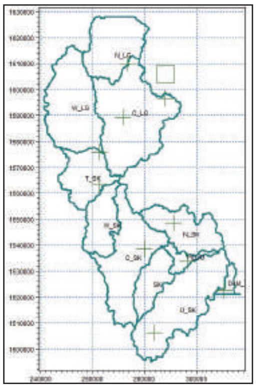
3. Results

We will put observed hydrometeorological data into the model for analysis, calibrating and testing results of flow rate over time (hours, days, months). After that, flooding simulation and inundated time in each small area and synthesized into flood maps. By combining with online data and actual results, the results are published on the WEBGIS flood warning system.

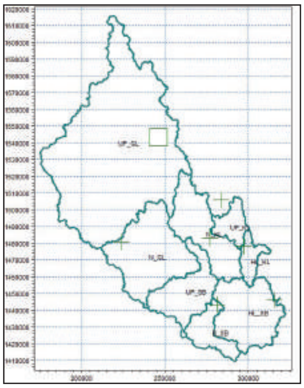
3.1. Results of rainfall-runoff model

3.1.1. Calibration of NAM model

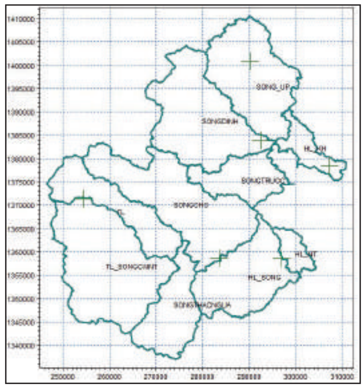
Calibration parameters of the NAM model aims to find out the most appropriate parameters for the research area. Parameters for sub-basins found basing on a test method of measured flow rates and calculated values at monitoring stations. When calibration results are quite close to the measured data at the sites, these found parameters is good and can be used in the simulating of the next plan. The errors between the calculated and measured values during calibration were assessed according to the Nash-Sutcliffe efficiency index.



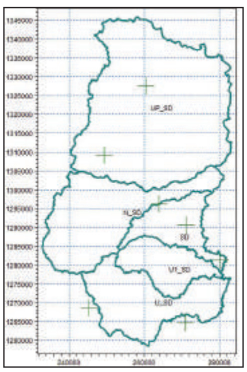
Kon - Ha Thanh and Lai Giang River



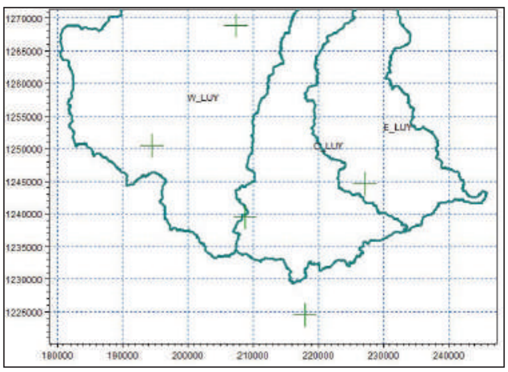
Ky Lo and Ba River



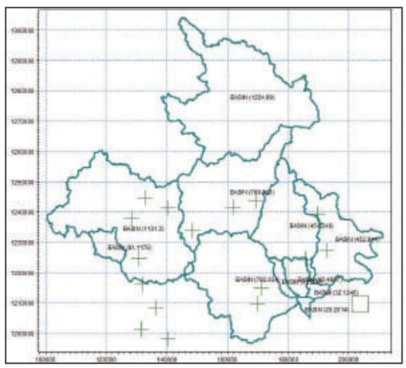
Dinh River



Cai Phan Rang River



Luy River



La Nga, Ca Ty River

Figure 4. Diagram of sub-basins division in South Central Viet Nam region

After testing the model, we conduct tests and determine the model parameters for the basins. Then, comparing the simulated values with the measured values (at the monitoring station), the results show that the flow rates from rainfall is quite similar. The effectiveness of the model is assessed by the correlation coefficient R^2 (if $R^2 \geq 0.8$ - it means satisfactory).

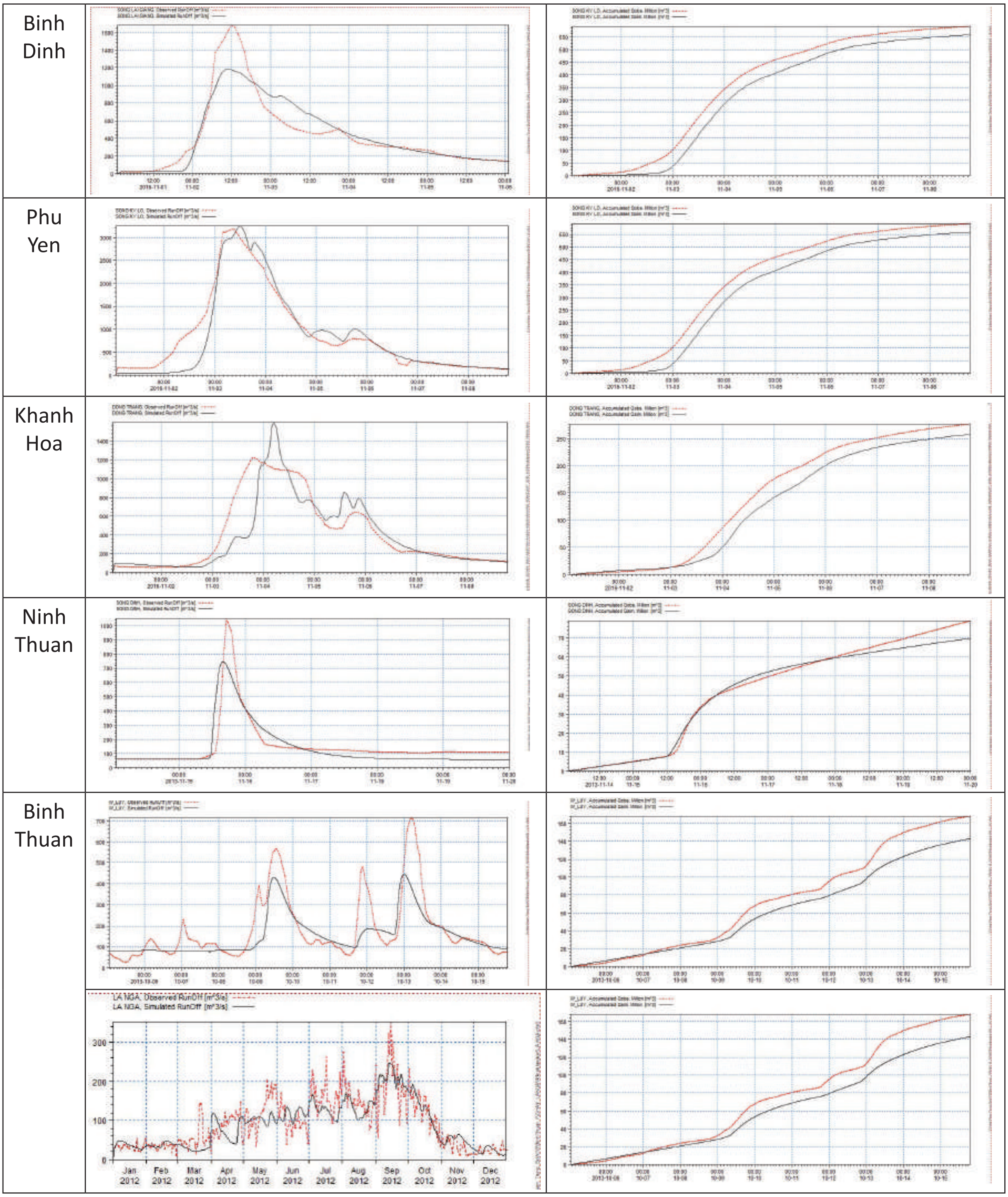


Figure 5. Calibration of rainfall-runoff model in the river basins

3.1.2. Testing of model parameters

After calibrating the actual floods for each province, we obtained the appropriate parameters to put into the model to assess the reliability when applied to the floods in the past corresponding to different time series. Calculated results of hydrological models for the sub-basins show that the highest flow-rates and peak floods are same phase during the flood season at the upstream. It can be seen that topographic conditions, fertility as well as natural conditions that make the difference from meteorological characteristics of each region. Heavy rainfall in the upstream causes large flow-rates in the s rivers and streams, affecting the water level of this area.

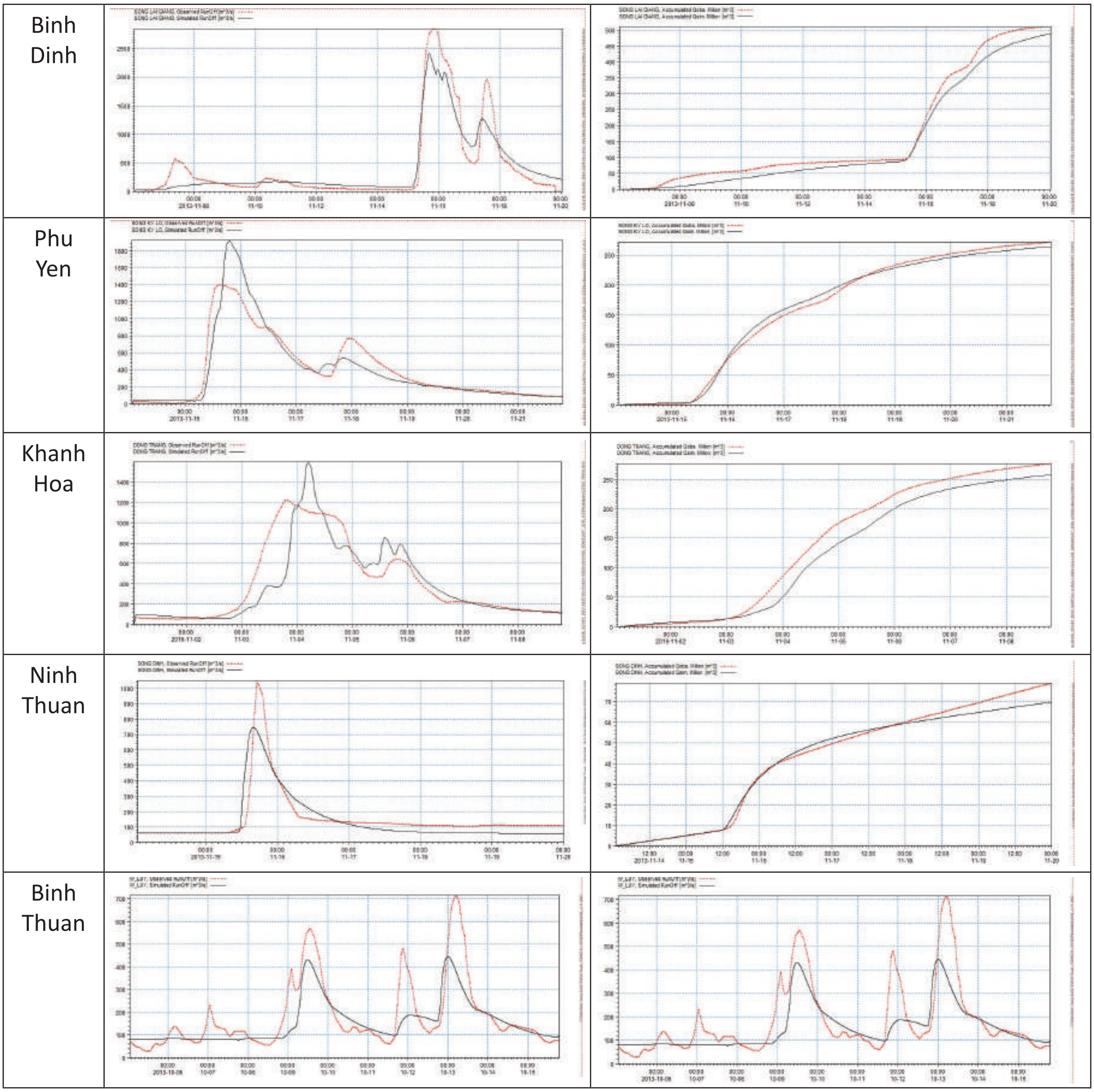


Figure 6. Testing of rainfall-runoff model in the river basins

Table 1. Correlation coefficient correction in the hydraulic model in the South Central region

Province	Basin river	Station	Correlation coefficient correction R^2	
			Correction	Accreditation
Binh Dinh	Kon - Ha Thanh	Binh Tuong	0.898	0.806
	Lai Giang	Bong Son	0.842	0.898

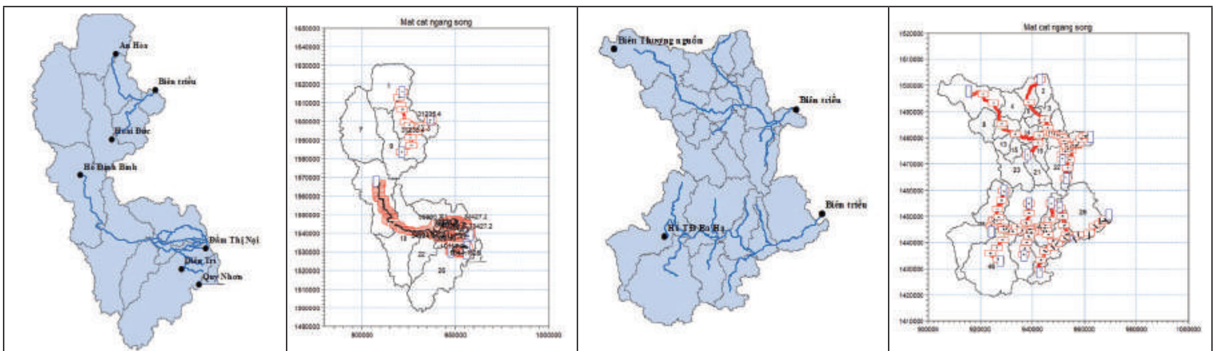
Province	Basin river	Station	Correlation coefficient correction R^2	
			Correction	Accreditation
Phu Yen	Ky Lo	Ha Bang	0.903	0.827
	Ba	Cung Son	0.83	0.82
Khanh Hoa	Dinh - Cai	Dong Trang	0.777	0.708
Ninh Thuan	Cai Phan Rang	Tan My	0.772	0.824
Binh Thuan	Luy - Ca Ty	Luy River	0.636	0.75
	La Nga	Ta Pao	0.649	0.784

3.2. Hydraulic model for South Central Region

To determine the Manning's roughness coefficients, we conducted the data testing put into the model and comparing to the measured data. The hydraulic diagram for the river basins is shown in Figure 5. The results of the Nash coefficients and the correlation coefficient R^2 are shown in Table 1. In general, correlation coefficients are higher than 0.8, it means good correlation between two dataset.

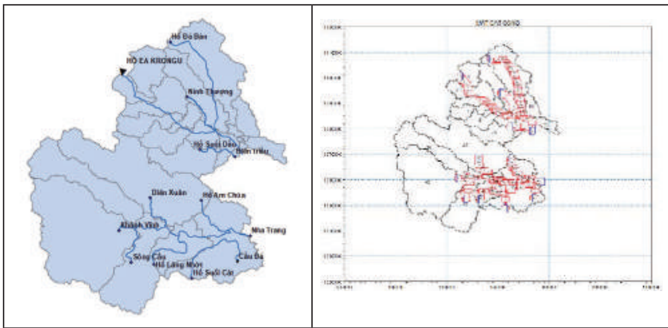
Table 2. Nash coefficients and correlation coefficient correction in the hydraulic model in the South Central region

Provinces	Stations	Nash coefficients	R^2
Binh Dinh	Bong Son	0.73	0.96
	Binh Tuong	0.88	0.97
	Binh Nghi	0.74	0.97
	Thanh Hoa	0.7	0.93
Phu Yen	Ha Bang	0.61	0.96
	Cung Son	0.82	0.92
	Phu Lam	0.7	0.89
Khanh Hoa	Dong Trang	0.87	0.95
	Ninh Hoa	0.858	0.98
Ninh Thuan	Tan My	0.86	0.94
Binh Thuan	Luy River	0.74	0.86
	Vo Xu	0.98	0.81

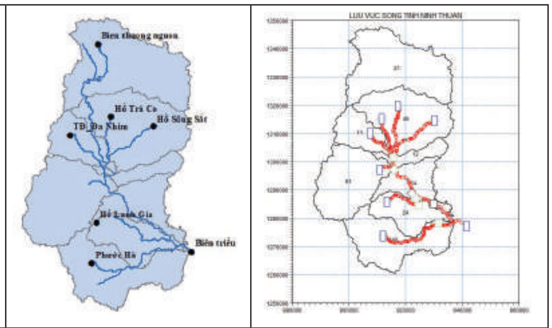


Hydraulic diagram of river basins in Binh Dinh	*Hydraulic diagram of river basins in Phu Yen*

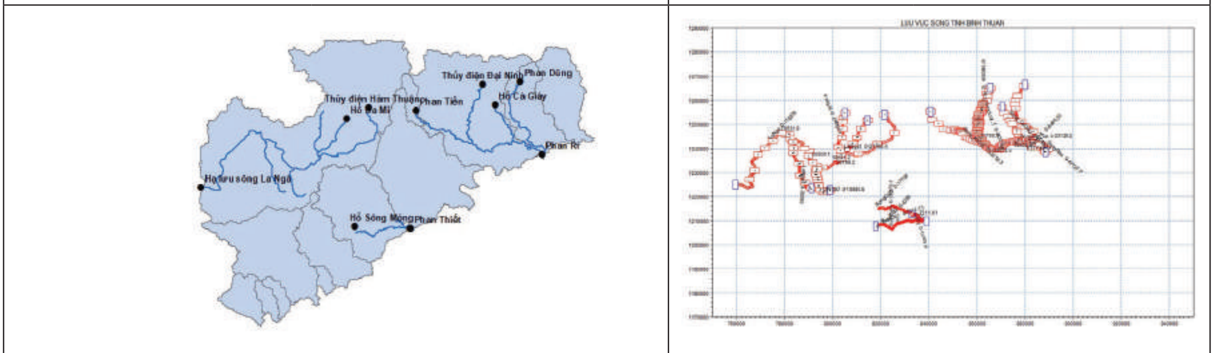
Figure 7. Hydraulic diagram of river basins of provinces in the South Central region



Hydraulic diagram of river basins in Khanh Hoa



Hydraulic diagram of river basins in Ninh Thuan

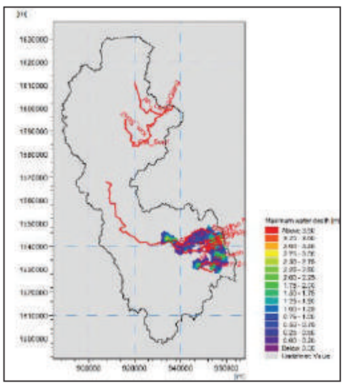


Hydraulic diagram of river basins in Binh Thuan

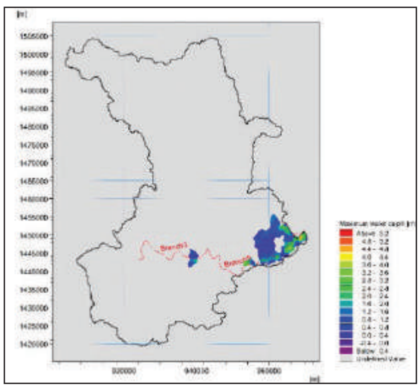
Figure 7. Hydraulic diagram of river basins of provinces in the South Central region

3.3. MIKE FLOOD model

The MIKE FLOOD model was set up to simulate past flood for 10 river basins in 5 provinces belonging to the South Central region. 1-D hydraulic model, MIKE 11 RR + HD model are shown above and digitized terrain (DEM) are digitized to put into 2-D model (MIKE 21 FM). When setting up a 2-D model, it is necessary to set up the topographic terrain, which is the basis for simulating the direction of flow movements as well as the hydraulic interactions in the whole system. Results of interpolated topography and MIKE FLOOD modeling for 10 river basins of South Central region will be presented following Figure 8.

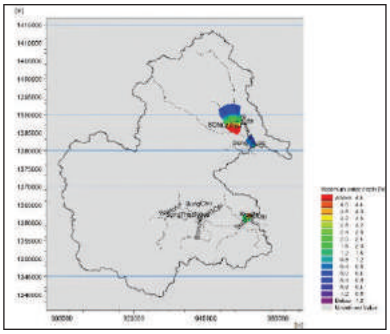


a) Binh Dinh

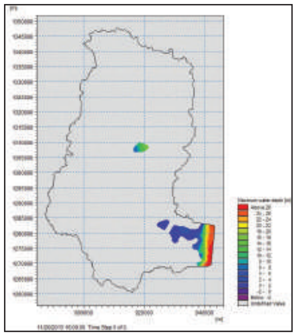


b) Phu Yen

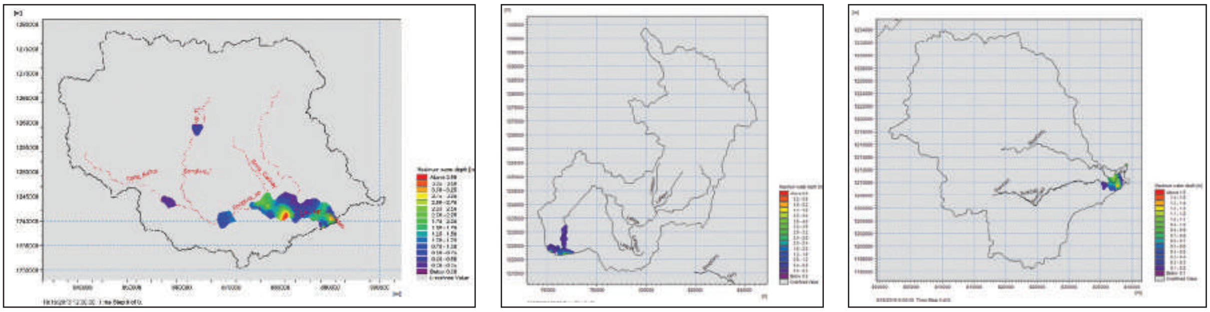
Figure 8. Results of simulation of flooding of South Central region



c) Khanh Hoa



d) Ninh Thuan



e) Binh Thuan

Figure 8. Results of simulation of flooding of South Central region

Accreditation of flooding model

Table 3. Results of flood water level simulation at the flood spot investigation locations in the Kon River basin, Binh Dinh province in 2007

Numberical order	Flood spot comparison location	Longitude	Latitude	Z Flood marks 2007 (m)	Z max (m)	ΔZ (m)
1	Song Kon	109°00'30	13°54'26	15.826	16.881	1.055
2	Song Kon	109°02'00	13°54'76	14.543	16.253	1.71
3	Dap Da	109°02'04	13°54'60	14.523	15.23	0.707
4	Dap Da	109°05'59	13°55'16	13.686	14.058	0.3686
5	Song Kon	109°05'49	13°54'98	14.052	14.114	0.062
6	Dap Da	109°09'08	13°57'17	7.189	8.563	1.374
7	Song Kon	109°06'40	13°54'05	10.891	11.542	0.651
8	Song Kon	109°07'07	13°54'30	9.101	10.21	1.109
9	Dap Da	109°06'46	13°52'82	10.297	10.377	0.08
10	Song Say	109°08'25	13°52'41	8.043	9.34	1.297

Table 4. Results of flood water level simulation at the flood spot investigation locations in the Cai River basin, Nha Trang province in 2009

Numberical order	Flood spot comparison location	Longitude	Latitude	Z Flood marks 2007 (m)	Z max (m)	ΔZ (m)
1	Suoi Cai	109°8'13	12°16'29	4.66	5.078	0.418
2	Suoi Cai	109°8'22	12°16'38	4.77	5.078	0.308
3	Suoi Cai	109°10'48	12°15'55	1.93	0.734	1.196

Numberical order	Flood spot comparison location	Longitude	Latitude	Z Flood marks 2007 (m)	Z max (m)	ΔZ (m)
4	Suoi Cai	109°11'4	12°15'56	1.74	0.734	1.006
5	Suoi Cai	109°6'8	12°16'3	6.39	6.041	0.349
6	Suoi Cai	109°6'19	12°16'18	6.14	5.135	1.005
7	Suoi Cai	109°5'25	12°16'44	5.73	5.135	0.595
8	Suoi Cai	109°5'59	12°16'15	6.86	6.783	0.077
9	Suoi Cai	109°1'33	12°15'33	10.43	9.798	0.632
10	Branch7	108°59'43	12°17'37	14.03	13.54	0.49

Table 5. Results of flood water level simulation at the flood spot investigation locations in the Dinh River basin, Ninh Thuan province in 2016

Numberical order	Flood spot comparison location	Longitude	Latitude	Z Flood marks 2007 (m)	Z max (m)	ΔZ (m)
1	Song Dinh	108°58'34	11°34'01	6.941	6.463	0.478
2	Song Dinh	108°58'32	11°34'01	6.963	6.463	0.5
3	Song Dinh	108°59'03	11°34'12	6.688	5.463	1.225
4	Song Dinh	108°58'57	11°34'18	7.127	6.463	0.664
5	Song Dinh	108°59'48	11°32'31	4.521	4.65	0.129
6	Song Dinh	108°59'50	11°32'34	4.876	4	0.876
7	Song Dinh	109°01'37	11°32'43	2.336	2.544	0.208
8	Song Dinh	109°01'37	11°32'44	2.370	2.544	0.174
9	Suoi Gia	108°55'05	11°29'45	17.490	16.077	1.413

3.3. Assessment the flood forecasting model

3.3.1. Results of the process of observed and predicted water level

Result of the test forecast with expected time (Tdk = 12h) is presented in the graph of comparing the measured and forecast water level at hydrological stations shown in Figure 11.

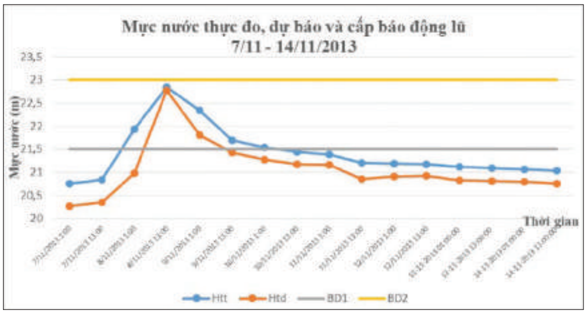
3.3.2. Results of quality forecast assessment

From the results of each prediction for the plan with forecast rainfall data from the weather model, we can give a general assessment for the stations as follows (Table 2). Assessment of flood prediction's capacity of the model corresponds to flood alert at stations according to National Standards in Table 3.

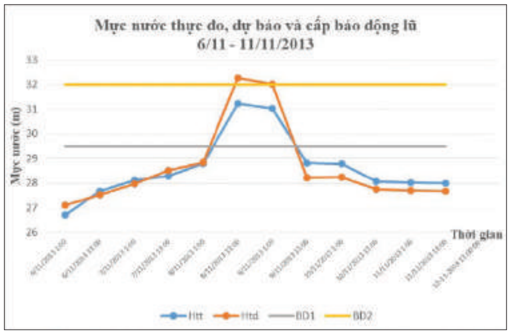
Basing on the overall evaluation of forecast results at Binh Tuong, Cung Son, Dong Trang, Tan My and Song Luy stations, the total number of correct forecasts are P = 93.33%, 90.91%, 93.33%, 54.54% and 71.43% respectively. The level of forecast quality from time to time has errors following to the extent possible.

At Binh Tuong, Cung Son and Dong Trang stations, flood peak values as well as flood alarm levels at the evaluation locations provide reliable results. At Tan My station, at the time of peak floods appeared exceeding alarm level I and II, these data values were accurately calibrated,... At Song Luy station, although the water level fluctuations limited in the flood and ebb trend, the water-level's phase both prediction and observation had similar. So, we regconized that it is suitable for flood alarm. At the time of flood peak appear exceeding alarms level II, these two datasets are calibrated accurately. Therefore, the reliability of the weather model needs to be revised to increase the level of flood simulation most accurate in flood forecasting for the Luy River basin in

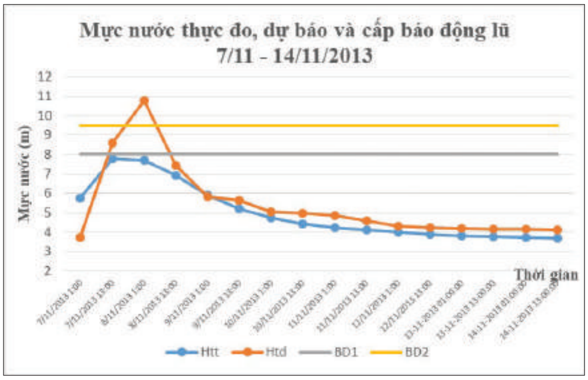
Binh Thuan province. Therefore, the reliability of the weather model needed to be revised to increase the most accurate flood simulation level in predicting for Dinh River in Ninh Thuan province and Luy River in Binh Thuan province.



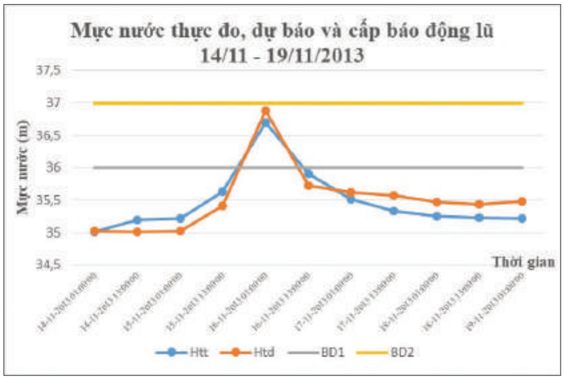
Binh Tuong station



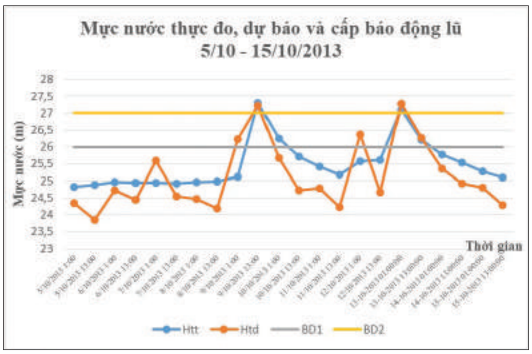
Cung Son station



Dong Trang station



Tan My station



Luy River station

Figure 9. Comparing of measured and predicted water level at the hydrological stations

Table 6. Assessing the quality of flood forecasting models

Assessment (%)	Stations				
	Binh Tuong	**Cung Son**	**Đong Trang**	**Tan My**	**Song Luy**
Excellent	1	4	2	1	5
Good	10	5	4	0	1
Mediate	3	1	8	5	9
Poor	1	1	1	5	6
P%	***93.33***	***90.91***	***93.33***	***54.54***	***71.43***

Table 7. Water level at stations correspond flood alarm levels
(according to QĐ 46/2014/QĐ-TTg)

Stations	Alarm level I	Alarm level II	Alarm level III
	m	m	M
Binh Tuong	21.5	23	24.5
Cung Son	29.5	32	34.5
Dong Trang	8	9.5	11
Tan My	36	37	38
Luy	26	27	28

3.3.3. Assessing the quality of general forecast in the South Central region

Result of the test forecast with flood event (Nov, 2013) in expected time Tdk = 12h basing on permissible errors according to Circular No. 722 (Table 4).

The results of the trial forecasts show that the use of the parameters of the past floods (in Nov, 2013) has a guaranteed level of over 50% for whole river basins with an expected time of 12 hours at qualified level. Flood prediction in locations with each prediction gives good results, consistent with the observed data. The time of occurrence of flood peaks is within the errors and the difference is small. The error depends on many objective factors, so it will need better calibration-test when additional automatic measurement stations are updated. This thing aims to calculate the flow generated from the precipitation over the basin, and then results will take higher accuracy.

Table 8. Assessment the number of accurate forecast
(according to Circular No. 722)

Provinces	Stations	Number of prediction	Number of accurate prediction	Guaranteed levels (%)	Assessment
Binh Dinh	Binh Tuong	16	14	87.5	Qualified
Phu Yen	Cung Son	11	10	90.91	Qualified
Khanh Hoa	Dong Trang	15	14	93.33	Qualified
Ninh Thuan	Tan My	11	6	54.54	Qualified
Binh Thuan	Luy River	21	15	71.43	Qualified

Table 9. Assessment the errors of forecast time of flood peaks's occurrence

Provinces	Stations	Hmax td (m)	H max db (m)	$\|\Delta H\|$ (m)	$\|\Delta t\|$ (hrs)	Difference error
Binh Dinh	Binh Tuong	22.77	22.854	0.084	1	Under the allowed tolerance, qualify
Phu Yen	Cung Son	32.28	31.232	1.048	4	Under the allowed tolerance, qualify
Khanh Hoa	Dong Trang	11.2	9.52	1.68	4	Difference 0.9m
Ninh Thuan	Tan My	38.37	37.364	1.006	3	Difference about 0.13m
Bình Thuan	Luy River	27.293	27.22	0.087	1	Under the allowed tolerance, qualify

3.4. Model management tool and WEBGIS map

WebGIS system uses statistical methods, analyzing to determine the necessary information for the flood forecasting database; collect and process information to construct map layers with both spatial and attribute information; WebGIS programming provides information on flood forecasts. Specifically, the research and implementation process is conducted as follows:

The process of implementing WebGIS system includes the following main steps:

- Step 1: Collect data and information related to the basemap of 5 provinces in the South Central region: administrative data, river network, traffic layer, residential area, self-measuring monitoring stations dynamic data,...

- Step 2: Editing spatial and attribute data.

- Step 3: Analyze the system and build the Database model.

- Step 4: Set up interfaces for WebGIS website and build functions for users and managers including accessing, searching information and updating data.

- Step 5: Build WebGIS website, conduct test functions. Finally, WebGIS products support management of professional flood forecasting and warning.

The process of updating information to WebGIS:

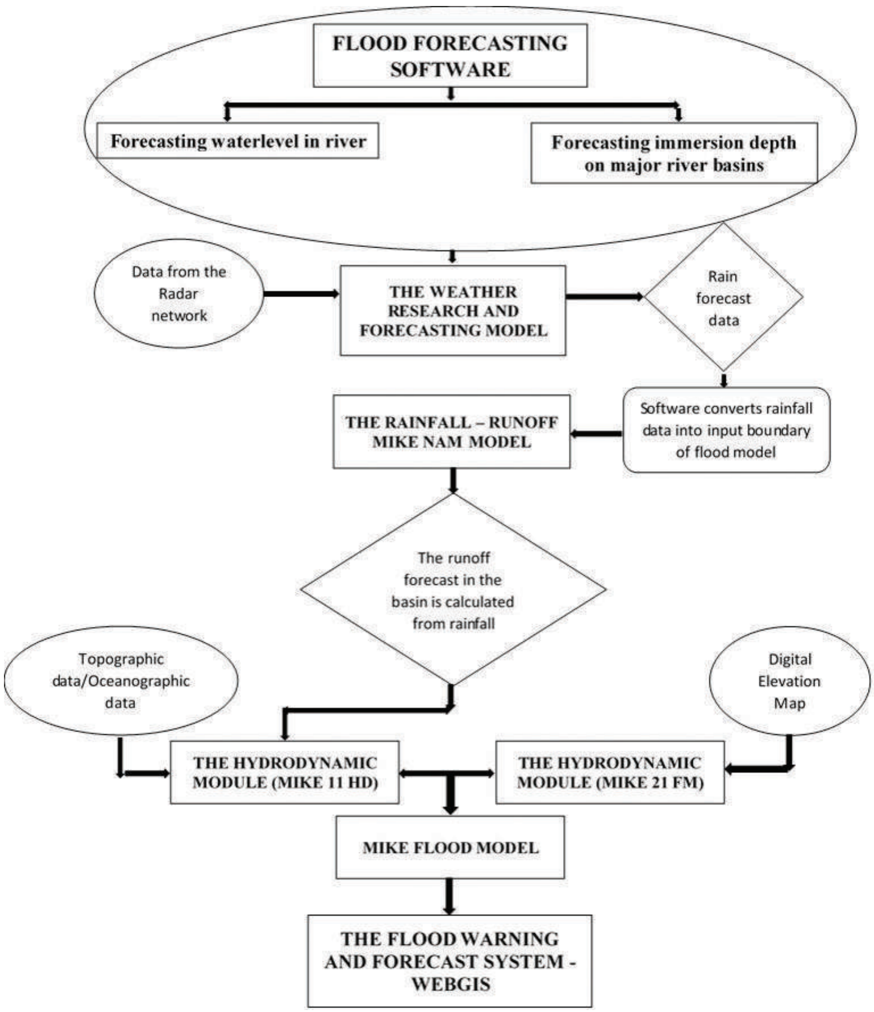


Figure 10. The forecast update process on WebGIS

Data from flood modeling results managed by WebGIS:

- The forecast rainfall data at the rain measurement stations in the main river basins of the 5 South Central provinces includes the following information: rain gauge station, rainfall represented under the column graph, time of appearance.

- Data of forecast water level at alarm stations and positions to display water level information is represented in the form of a line graph, including information: station name, station location, statistics and time forecast.

- Results from the flooding model are handled by WebGIS, converted into flood maps with information about the flooding layer such as: depth of inundation, level of alarm level corresponding to the possibility of flooding. on the basin.

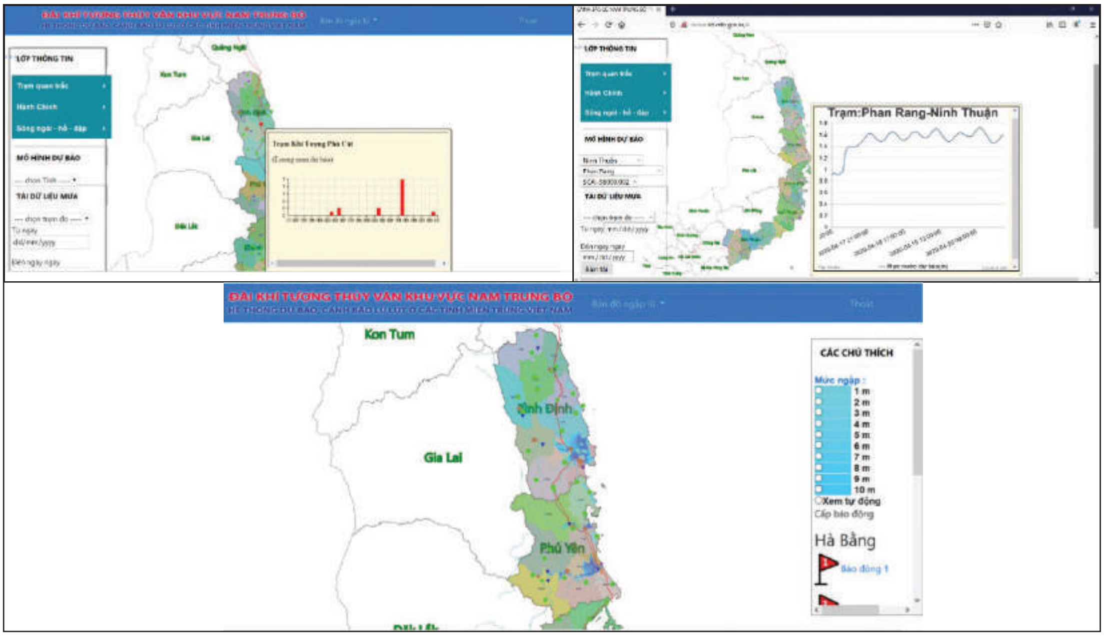


Figure 11. WebGIS data management tool

4. Conclusions

Main reason cause inundating this area is heavy rains and the topography characteristics in the South Central provinces. Low mountains and coastal plains accompanied by the topography of the river basin with high slope resulting, the floods often occur more unpredictable under weather condition changes. A set of flood models (rainfall-runoff model + hydraulic model + flood model) was built to serve the management as well as professional predicting in the future. Process of calibration- test of rainfall - runoff model has errors due to using only data from the presented rain gauge stations applied in a large area. A dataset of parameters for the model has been built with Nash coefficients and R^2 achieving reliability. Simulated results of calculated and observed flood catching up the flooding trend accurately, especially the time of flood peak occurrence. Difference from calculated water level of flood drainage locations and actual flood trace survey locations is not too significant. Thus, the condition of the parameters as well as the quality of the FLOOD model is reliable for applying in the future professional work.

WebGIS technology is popular day by day, applied in many different ways. It is convenient for users who do view attribute and spatial online information layers without installing GIS software. Interact data without requiring processing any specialized data. It is also easy manipulation. WebGIS supports the integration of flood predicted models, displaying and updating rainfall data, calculated water level values and managing maps, which is an effective solution to convey information on flood levels, inundated levels. The results are published on the WEBGIS flood warning system. Results of early flood warning have helped departments and agencies make timely decisions in disaster prevention.

Acknowledgement: *This aricle was completed with the support of the project "Strengthening flooding forecast and warning in Viet Nam - phase II" with the mission "Establishing a forecast flood model for South Central region", implemented in 2019-2020. The author sincerely thanks.*

References

1. Bui Minh Hoa, *Research to develop inundation map of Ba River basin*,12/2012.
2. Doan Quang Tri, (2019), "Application of hydrological - hydraulic model combined with IFS rain forecast for flood warning, flooding downstream Vu Gia - Thu Bon River", *Journal of Meteorology and Hydrology*.
3. Doan Van Hai, Doan Thi Van, Doan Quang Tri, (2020), "Studying and development a tool to forecast flow to Song Hinh lake for flood forecasting in the downstream Ba River", *Journal of Meteorology and Hydrology*.
4. Electronic information portal of Binh Dinh Provincial People's Committe.
5. Electronic information portal of Khanh Hoa Provincial People's Committe.
6. Jinyin Ye, Yuehong Shao, and Zhijia Li, (2016), *Flood Forecasting Based on TIGGE Precipitation Ensemble Forecast*, Hindawi Publishing Corporation Advances in Meteorology Volume 2016, Article ID 9129734, 9 pages. http://dx.doi.org/10.1155/2016/9129734.
7. Leila Goodarzi , Mohammad E. Banihabib , Abbas Roozbahani , and Jörg Dietrich, (2019), *Bayesian network model for flood forecasting based on atmospheric ensemble forecasts*, Nat.HazardsEarth Syst. Sci., 19, 2513–2524. https://doi.org/10.5194/nhess-19-2513-2019.
8. Li, L., Li, W., and Jin, J. (2014), *Improvements in WRF simulation skills of south eastern United States summer rainfall: physical parameterization and horizontal resolution, Clim*, Dynam., 43, 2077-2091. https://doi.org/10.1007/s00382-013-2031-2.
9. Pennelly, C., Reuter, G., and Flesch, T. (2014), *Verification of the WRF model for simulating heavy precipitation in Alberta, Atmos*. Res., 135, 172–192. https://doi.org/10.1016/j.atmosres. 2013.09.004.
10. Sub-Institute of HydroMeteorology and Climate Change, (2018), *Synthesis report - Action plan to respond to climate change for the culture, sport and tourism industry in Binh Thuan Province*.
11. http://www.ninhthuan.gov.vn/Pages/Dieu-kien-tu-nhien1.aspx.
12. http://kttvntb.gov.vn/Doc.aspx?d=229.
13. https://nhandan.com.vn/xahoi/item/30924402-binh-thuan-mua-lu-lam-ngap-800-can-nha-200-ho-dan-phai-di-doi.html.

STUDY ON OPTIMIZING SURFACE WATER ALLOCATION TO LOWER VU GIA – THU BON RIVER BASIN UNDER WATER SCARCITY AND DROUGHT CONTEXT

Than Van Don[1], Tong Ngoc Thanh[1], La Van Chu[2]
[1]National Center for Water Resources Planning and Investigation (NAWAPI)
[2]Viet Nam Institute of Meteorology, Hydrology and Climate Change (IMHEN)

Received: 8 July 2020; Accepted: 6 August 2020

Abstract: *Over the past few years, water scarcity and droughts have always been occurring in the Vu Gia - Thu Bon River basin, causing conflict water users. Water demand has also increased. Information and data on potential, the amount of water that can be allocated by 11 regions were used for calculating current water demand in 2014 and these by 2030, thereby determining the simulation model method (WEAP model) for allocating surface water resources to households exploiting and using water in the Vu Gia - Thu Bon River basin. The results showed that water demands of households are basically metcorresponding to inflow accounting for 85% (in 1998) of water demands in 2014 and of that by 2030, followed by sets of priority order and percent of water supplies. The total does not meet water demands corresponding to inflows 85% and 99% of water demands are 78.46 mil m^3 and 101.19 mil m^3, which is significantly less than existing water supplies plan with 146.99 mil m^3. This results in the conflicts in water use, decreasing water degradation and maintaining environmental stability of the river.*

Keywords: *Surface water allocation, Water scarcity, Droughts, Vu Gia - Thu Bon River basin.*

1. Background

Water resources in river basins can be seen as the total amount of water that reaches the basin over a period of a year, which should be used for a variety of needs, such as water supply for domestic, industrial purposes, irrigation in agriculture, aquaculture, navigation, recreational activities, and tourism services.

Water resource allocation is an important content of a water resource master plan of a river basin to address problems when this situation occurs. For river basins with abundant water resources with the demand for water being small compared to the potential, the problem of water resource allocation is not very pressing. However, for water-scarce river basins, the issue of water resource allocation is essential to alleviate water use conflicts, overcoming water degradation and maintaining environmental stability. Handling with good care the situation of the water allocation in river basins will contribute to protecting the legitimate water use of users, bringing about social equity and environmental sustainability.

Therefore, it is pivotable to conduct this study on methodology for determining surface water allocation in Vu Gia - Thu Bon River basin in a fair and reasonable manner.

Corresponding author: Than Van Don
E-mail: thandontnn@gmail.com

2. Water resource availability, current exploitation status and prospectus issues in Vu Gia - Thu Bon River basin

2.1. Geographic location and hydro-meteorological monitoring network

The Vu Gia - Thu Bon River in Central Viet Nam is one of nine major river systems. Catchment area is 10,350km^2. The basin has 2 meteorological stations (Da Nang and Tra My) working from 1976 to date, and 8 hydrological stations, 2 of which (Thanh My and Nong Son) measuring the flow and water level, 6 of which (Hoi Khau, Ai Nghia, Giao Thuy, Cau Lau, Cam Le and Hoi An) measuring water level, operating from 1976 to date [1].

Figure 1. Vu Gia - Thu Bon River basin

2.2. Surface water availability of major tributaries

Thu Bon River from upstream to Giao Thuy has a catchment area of 3,825km^2. The upstream area of the river flows within the high mountains of Phuoc Son, the center of heavy rain of Tra My. In Tien Phuoc and Ngoc Linh, the average rainfalls in the basin for many years reaches 3,300mm, the module of the annual flow in the whole basin reaches M_o=75.3l/s.km^2, Q_o=290 m^3/s. Total annual flow up to Giao Thuy W_o= 9,25x109m^3. Vu Gia River from upstream to Ai Nghia has a catchment area of 5,180km^2, annual rainfall reaches 2,420mm, annual flow module reaches M_o= 52.3 l/s.km^2, Q_o=271m^3/s. The total flow amount at Ai Nghia W_o=8.55x109m^3. The rest from Ai Nghia and Giao Thuy, Thu Bon River to the outlet in Da Nang and Hoi An have annual rainfall of 2,000mm, the total volume of water in the region reaches W_o=1.65x109m^3. Ly Ly River has a catchment area of 275km^2, Q_o=12.3m^3/s and the total volume of water in the region reaches W_o=0.39x109m^3. Tuy Loan River basin area of F_{lv} = 309km^2, Q_o=12.0m^3/s, total annual flow W_o=0.38x109m^3 [2].

2.3. Current exploitation status

In the river basin, there are 820 projects, of which: 72 reservoirs, 546 dams, 202 pump stations with the design capacity: 45,359 ha, actual capacity: 28,569 ha, accounting for 62.98% of capacity. design. Mainstream has 10 hydropower projects generating a significant amount of electricity for the Central region, helping flood, drought control, and water supplies to water users in downstream [1]. Speaking of the amount of water supplied for domestic and industrial purposes, there is Cau Do water plant with a capacity of 120,000m^3/day.night, Son Tra water plant with a capacity of 5,000m^3/day.night for Da Nang city, Hoi An water plant supplied to the Hoi An city and Dien Nam - Dien Ngoc industrial park with a capacity of 6,000m^3/day.night. In rural areas, there are about 30,100 wells and 44,760 wells supplying for about 394,610 people, the rest people often use rivers and streams for food and drink in the form of gravity [1].

2.4. Prospectus issues in Vu Gia - Thu Bon River basin

Due to the rapid socio-economic development, mechanical population growth, and especially the current massive development of hydroelectricity on the Vu Gia - Thu Bon River system in the years has changed the flow patterns, water supplies for areas in the river basin. This has caused controversy and disputes in the distribution and sharing of water resources among regions, typically the case of DakMil 4 hydropower plant.

The current method of water exploitation and use is still unsustainable because too many small-sized dams on the middle and upstream tributaries are developed to get water for irrigation in the wet season, which depletes the flow of many river branches during the dry season.

The exploitation and use of water resources is still separate by branch, and there is no coordination with each other. Especially, large-sized reservoirs do not have coordination in the whole system, during the time when rivers lack water like in limited years (2013, 2015, 2018, 2019), there is no coordination and cooperation between water use sectors to prevent drought, push salinity and consider ensuring water for environmental flow.

The efficiency of water works is low (irrigation canals, reservoirs,...) due to water loss in large canals, many deteriorated works have not been repaired in time, and actual irrigation capacity of the works is only 75% of the design.

The water resources development plans are still monophyletic, due to each branch.

Lack of coordination and cooperation between localities and sectors in integrated basin management.

3. Scientific basis of optimizing surface water allocation to lower Vu Gia - Thu Bon River basin under water scarcity and drought context

3.1. Scientific basis for determining method of water allocation

Based on data information on surface water resources, land cover, structural systems and water use of structures;

Based on water allocation of sub-basins in Vu Gia - Thu Bon River basin;

Based on the current situation of water exploitation and use of water supply works for domestic, agricultural, industrial purposes and socio-economic development orientation of Quang Nam province and Da Nang city to 2020 and vision after year 2030;

Topographic and geomorphological conditions in the entire river basin; Principles of allocation and sharing of surface water sources for households exploiting and using surface water sources in river basins;

The order of priority among households and industries using water (Living, Environment, Industry, Agriculture, Aquaculture and Power Generation);

On these basics, the authors proposed to apply the mathematical modeling method (WEAP) to allocate surface water resources in the Vu Gia - Thu Bon River basin. This decision is based on: Availability of information and data on meteorology, hydrology and water resources in the basin; the suitability of research basins selection along with the ability to approach the deployment of model tools; feasibility when constructing water source development scenarios in the basin by model and finally the ability to test the application of principles, rate, and priority order of distribution of water resources to water users. proposed for the problem of surface water distribution in the Vu Gia - Thu Bon River basin in the future.

3.2. Numerical model method

The simulation model is an important tool when allocating water resources to households exploiting and using water. The simulation method does not find the solution by the optimal model but uses the simulation model to find the optimal solution, unlike the optimization method, the simulation method uses the simulation model to find the largest (maximum problem) or smallest (minimum problem) among possible options by directly comparing calculated values. The solution of the problem is perhaps not to coincide with the mathematical optimal solution (the solution of the optimization method), so it is just a near-optimal value and is often called a reasonable solution.

3.3. Principles in water allocation

The allocation of water resources for households to use is based on the following principles:

Principle 1: Prioritize water supply according to the highest economic efficiency of water use: After having reserved enough water for domestic use (priority 1), minimum flow (priority 2), estimated remaining quantity priority will be given to those sectors with the highest water use efficiency (priority 3, 4, etc.) on the basis of a unit of water volume (m³) or water surface area (ha).

Principle 2: Prioritize water supply according to the guaranteed water supply level (or design frequency): After sufficient water has been supplied for domestic use, the remaining amount of water will be allocated according to the design guaranteed level of water supply on the basis of the frequency of the incoming water. Thus, any industry with a low level of guarantee for water supply must accept the risk.

Principle 3: Proportion of allocated water supply: Once sufficient for domestic use and minimum flow, the remaining amount of water will be proportionally distributed to water users on a proportional basis which has been already specified in the situation of sufficient water.

Principle 4: Prioritize water supply targeted political stability - social and poverty alleviation.

The above-mentioned priority principles of water allocation can be applied separately or in coordination depending on each specific case of the water source, at a certain time to suit the socio-economic conditions. specific areas and sub-regions are planned.

3.4. Determining priority order and proportion of supplies

3.4.1. DAME software

Decision Analysis Module for Excel (DAME) is a commonly used hierarchical analysis tool approach to assist decision-making to solve problems. There are many programs and software that use that approach, but they are commercialized and do not support intermediate computation. In that case DAME has the advantage of being able to work with scenarios or multiple decision-makers and display intermediate computations.

Users can structure their decision model into three levels - scenarios, criteria and variants. All levels above can be assessed by weights or pair-wise comparisons.

3.4.2. Determining criteria

The study identified 4 main criteria including: (1) Amount of water used by each object; (2) Production value to 2030; (3) Proportion; (4) Growth. There are other criteria: Ensuring social security; The importance of water users to socio-economic development of Quang Nam province and Da Nang city.

These criteria and their weight are determined through consultation with water resources experts and representatives of water management, exploitation and use departments in Quang Nam province Da Nang city during the survey and workshops.

3.4.3. Determining requirement

These criteria should satisfy the constraints to achieve the general purpose of the optimal allocation among water users listed below in DAME model as follows:

Table 1. The criteria and constraints in DAME

Criteria	**Water used**	**Production value**	**Importance**	**Growth rate**
Target	Minimum	Maximum	Pairwise comparison	Pairwise comparison

To clearly analyze the right to allocate an water resources of the Vu Gia - Thu Bon River basin flowing through Quang Nam and Da Nang provinces with scenarios weights based on the competitiveness index (PCI) of Quang Nam and Da Nang with the average series of PCI values from 2015 to 2019 as follows: Quang Nam 0.48; Da Nang 0.52.

Table 2. PCI values

PCI	**2015**	**2016**	**2017**	**2018**	**2019**	**TB**
Quang Nam	61.06	61.17	65.41	65.85	69.42	64.582
Da Nang	68.34	70	70.11	67.65	70.15	69.025

Table 3. Results of decision-making power among provinces in Vu Gia - Thu Bon

Quang Nam	Da Nang		

Names of criteria:

Water used	Production value	Importance	Growth rate

Names of variants:

Water used	Production value	Importance	Growth rate

Criteria weights evaluation method:

Method: Geom. mean

Scenarios comparison:

Scenarios	Value	*Scenarios weights*
Quang Nam	64.58	0.48
Da Nang	69.03	0.52

3.4.4. Results of priority orders and weights (proportions)

Based on the current socio-economic situation, water exploitation and use demand of Quang Nam and Da Nang, the availability of water in the basin, the input data into the DAME model includes the following water user sectors: farming, livestock, industry, aquaculture. Table below shows weights of different sectors.

Table 4. Results of weights of criteria with respect to DAME model

	Quang Nam					Da Nang				
Criteria	LDN	GTSX	TT	TTTT	Weights	LDN	GTSX	TT	TTTT	Weights
Water used	1	1	1	1	**0.243**	1	2	2	2	**0.40**
Production value	1	1	1/2	1/2	**0.172**	0.5	1	1	1	**0.20**
Proportions	1	2	1	2	**0.343**	0.5	1	1	1	**0.20**
Growth rate	1	2	0.5	1	**0.243**	0.5	1	1	1	**0.20**

(These criteria and their weight are determined through consultation with water resources experts and representatives of water management, exploitation and use departments in Quang Nam province Da Nang city during the survey and workshops)

Table 5. Results of weights of sectors with respect to DAME mode

Sectors	Quang Nam				Da Nang			
	Water used (m^3)	**Production values (billion VND)**	**Proportions (%)**	**Growth rate (%/year)**	**Water used (m^3)**	**Production values (billion VND)**	**Proportions (%)**	**Growth rate (%/year)**
Farming	0.003	0.067	0.079	0.205	0.003	0.005	0.011	0.124
Livestock	0.986	0.031	0.071	0.305	0.982	0.007	0.011	0.181
Industry	0.008	0.882	0.814	0.335	0.005	0.988	0.973	0.555
Aquaculture	0.003	0.020	0.036	0.155	0.009	0.001	0.005	0.140

Results of priority orders and proportion of allocated water by DAME: (1). Scenario with Quang Nam and Da Nang; (2). General scenario with the whole river basin:

Table 6. Results of weights and priority orders

CZn=	Weight	Rank
Farming	0.058	3
Livestock	0.389	2
Industry	0.509	1
Aquaculture	0.043	4

3.5. Applying model method (WEAP) for surface water allocation in Vu Gia - Thu Bon River basin

3.5.1. Data and modelling

a) The entire Vu Gia - Thu Bon River basin system is divided into 11 calculating regions and nodes as shown in Figure 3.

- *Bases for dividing calculation regions on river basins*

On the natural features, the division of the respective topography of the rivers; On the work system of exploiting and using water resources, considering the administrative boundary or the unit managing the system of works on the river basin or river branches; On the demand, the characteristics of water source and water supply use, including the direction of water drainage after use.

- *Results of division of regions in the river basin*

According to the view of dividing the calculated regions as above, the Vu Gia - Thu Bon River basin is divided into 11 regions as shown in Table 7 and Figure 2.

Figure 2. Map of dividing calculation regions on Vu Gia - Thu Bon River basin

Table 7. Results of dividing calculation regions on Vu Gia - Thu Bon River basin

No.	Sub-regions	Area (km^2)	Administration
Region 1	Upper Vu Gia	2,434.71	Nam Giang, Dai Loc, Tay Giang, Dong Giang
Region 2	Dak Mi River basin	1,133.61	Phuoc Son, Dak Glei
Region 3	Cai River basin	927.02	Nam Giang, Phuoc Son,Dai Loc, Dak Glei
Region 4	Tranh 2 River basin	1,082.83	Phuoc Son, Nam Tra My, Bac Tra My
Region 5	Tranh 3 River basin	1,660.49	Tien Phuoc, Hiep Duc, Phuoc Son, Bac Tra My
Region 6	Middle Thu Bon	775.17	Duy Xuyen, Hiep Duc, Phuoc Son, Dai Loc, Nong Son
Region 7	Quang Hue River basin	246.86	Nam Giang, Dai Loc
Region 8	Con River basin	672.95	Dai Loc, Dong Giang
Region 9	Tuy Loan River basin	450.27	Dai Loc, Thanh Khe, Hoa Vang, Hai Chau, Son Tra

No.	Sub-regions	Area (km^2)	Administration
Region 10	Ly Ly River basin	339.43	Thang Binh, Que Son
Region 11	Lower Vu Gia Thu Bon	626.66	Duy Xuyen, Ngu Hanh Son, Dai Loc, Dien Ban, Hoi An, Hoa Vang, Lien Chieu, Que Son
	Total	**10,350**	

b) Data input

- *Meteorological data:* Includes rainfall and evaporation data at stations in the basin. The inflow for the allocated calculation areas is the flow simulated by the Mike - Nam in the period 1991-2015 [4]. Results of calculation of the amount of allocable water to the entire basin corresponding to the frequencies of water up to P = 50% : 7,261 billion m^3; P = 85% : 4,494 billion m^3; P = 95% : 3,862 billion m^3.

- *Land use data:* Includes data on crop area, crop structure and water use demand data for other sectors [2].

- *Reservoir data:* useful capacity, dead capacity, total capacity; The relationship between reservoir capacity - water level W - Z; Discharge capacity of spillway; the design flow for downstream discharge; Coordination process [3].

Table 8. Specification of the reservoirs in the study area

Specification	Unit	Reservoirs				
		A Vuong	Song Bung 2	Song Bung 4	Dak My 4	Song Tranh 2
Catchment area	Km^2	682	337	1467	403	1100
Annual discharge	m^3/s	78.4		166		
High spill head	m	380	690	222.5	820	175
Normal spill head	m	340	645	195	770	140
Total W	10^6m^3	344	230	493.2	251	631
Useful W	10^6m^3	266.5	209.4	320	223	462
Dead W	10^6m^3	77.05	20.6	173.2	28	169
Design capacity	MW	170	126	200	225	135

3.5.2. Calculation of current water demands in 2014 and future 2030

a) Calculation of current water demands

Until 2014, the total amount of water needed to supply sectors in the Vu Gia - Thu Bon River basin is 2,112.69 million m^3/year. In which: That for living is 46.89 million m^3/year, for agriculture (Irrigation + livestock) is 1,774.32 million m^3/year, for aquaculture is 89.65 million m^3/year, for industry is 9.77 million m^3/year and for environmental flow is 192.06 million m^3/year.

Table 9. Current water demands of different sectors in 2014

No.	Sub-regions	Water demands in 2014 (10^6 m^3/year)					
		Domestic	Agriculture	Aquaculture	Industry	Environment	**Total**
1	Upper Vu Gia	1.34	140.32	5.38	0.00	14.70	161.75
2	Dak Mi River basin	0.56	32.22	2.51	0.00	3.53	38.81
3	Cai River basin	0.48	43.19	2.05	0.00	4.57	50.29
4	Tranh 2 River basin	1.12	74.31	3.16	0.00	7.86	86.43
5	Tranh 3 River basin	3.50	199.76	4.61	0.00	20.79	228.66
6	Middle Thu Bon	2.56	171.87	24.55	0.49	19.95	219.42

No.	Sub-regions	Water demands in 2014 (10^6 m^3/year)					
		Domestic	Agriculture	Aquaculture	Industry	Environment	**Total**
7	Quang Hue River basin	1.34	81.45	2.47	0.26	8.55	94.07
8	Con River basin	1.33	90.61	6.08	0.00	9.80	107.81
9	Tuy Loan River basin	16.47	79.59	4.36	1.07	10.15	111.64
10	Ly Ly River basin	3.37	290.45	4.38	2.00	30.02	330.23
11	Lower Vu Gia Thu Bon	14.83	570.54	30.11	5.96	62.14	683.58
	Total	**46.89**	**1,774.32**	**89.65**	**9.77**	**192.06**	**2,112.69**

b) Calculation of water demands by 2030

Based on the socio-economic development orientation to 2030 of Quang Nam and Da Nang provinces and water supply indicators for the water exploitation and use industries in the future, the authors calculated and forecasted total demand. Demand for water use of industries on the river basin Vu Gia - Thu Bon to 2030 is 2,444.07 million m^3/year. Of which: for domestic use is 101.55 million m^3/year, for agriculture is 1,969.35 million m^3/year, for fisheries is 123.44 million m^3/year, for industry is 27.54 million m^3/year and supply to the environment is 222.19 million m^3/year.

Table 10. Forecasted water demands of different sectors by 2030

No.	Sub-regions	Water demands in 2014 (10^6 m^3/year)					Total
		Domestic	Agriculture	Aquaculture	Industry	Environment	
1	Upper Vu Gia	2.59	155.75	4.52	0.00	16.29	179.14
2	Dak Mi River basin	1.11	35.76	2.63	0.00	3.95	43.45
3	Cai River basin	0.94	47.94	3.56	0.00	5.24	57.69
4	Tranh 2 River basin	2.09	82.47	5.94	0.00	9.05	99.55
5	Tranh 3 River basin	6.67	221.71	4.00	0.00	23.24	255.61
6	Middle Thu Bon	4.85	190.76	3.38	9.05	20.80	228.85
7	Quang Hue River basin	2.54	90.40	0.89	0.22	9.41	103.46
8	Con River basin	2.54	100.56	5.14	0.00	10.83	119.08
9	Tuy Loan River basin	39.85	88.34	11.01	1.58	14.08	154.86
10	Ly Ly River basin	6.39	322.38	7.42	5.48	34.17	375.83
11	Lower Vu Gia Thu Bon	31.98	633.26	74.96	11.22	75.14	826.56
	Total	**101.55**	**1,969.35**	**123.44**	**27.54**	**222.19**	**2,444.07**

3.5.3. Verification of WEAP

To verify the WEAP model, the authors used a specific series of 1-year data and based on the actual operation of the building system, the actual water use in the basin. Through the process of collecting and analyzing documents, the authors chose 2010 to test the WEAP model according to the actual construction conditions and irrigation water supply. This is the year that documents are collected quite fully about the construction as well as on land use. In 2010, most of the major hydroelectric projects such as DakMi 4 and terraced hydropower projects on the Bung River such as Bung 3, Bung 2, Bung 5, and Bung 6 have not been operated, so the flow on the main stream are less affected by hydroelectric works system. Thus, the data set to test the WEAP model are as follows:

- Actual 2010 water demand data.
- Current status of works in 2010.
- Monthly data with duration from 1/1/2010 to 31/12/2010
- Inflow to 11 regions in 2010 calculated from Mike - NAM [4].

Table 11. Comparison between simulated (s) and observed (o) data sets at Nong Son, Thanh My in 2010

Month	Inflow to Thanh My (Sub-region 3-1850 km²) m³/s		Inflow to Nong Son (Sub-region 5-3150 km²) m³/s	
	Q_s	Q_o	Q_s	Q_o
1	127.69	126.45	200.92	194.90
2	86.75	84.24	121.74	111.26
3	61.41	57.83	95.23	77.98
4	53.72	51.50	92.01	63.01
5	60.20	53.04	98.90	62.95
6	44.96	45.37	88.63	65.40
7	65.23	62.34	102.99	91.25
8	144.70	137.74	191.89	228.32
9	129.20	127.87	188.61	214.37
10	232.05	235.42	481.26	486.16
11	458.16	463.37	1,603.20	1,604.33
12	226.66	219.77	306.39	262.58

The verification results for 2 stations Thanh My and Nong Son in the period from showed that the difference between calculated and measured is in acceptable range and ensure reliability.

3.5.4. Order of priority and proportions of allocation of surface water sources

Order of priority, rate of distribution of surface water sources is determined by region and water use purpose and basing on catchment characteristics, planned area size, priority order, and rate of allocation is determined. According to the following criteria:

1st point: priotize allocating per regions: Based on water use agreements among regions and the decision issued by the competent authorities.

2nd point: the order of priority and proportion of distribution according to the following main water uses: Domestic; Environmental flow; Industrial production; Agricultural production; Aquaculture; Power production.

3.5.5. Results of surface water allocation

a) Scenario 1: Corresponding to the frequency of inflow of 85%, the current water demands in 2014, without priority as all users would get the same proportions.

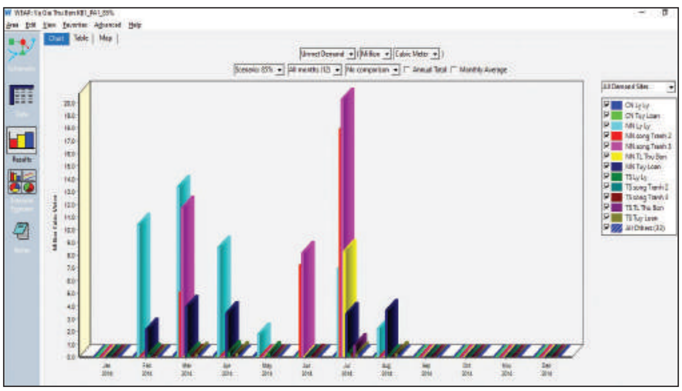


Figure 3. Water shortage in the calculated regions corresponding to the frequency of 85%, current water demand in 2014 and evenly allocated to users

Calculation results of surface water distribution on the river basin showed that total water shortage of industries is 146.99 mil m^3, of which: Industry: 0.86 mil m^3 (Ly Ly: 0.54 mil m^3; Tuy Loan: 0.32 mil m^3); Agriculture: 138.05 mil m^3 (Ly Ly: 43.13 mil m^3, Song Tranh 2: 30.10 mil m^3, Song Tranh 3: 40.70 mil m^3, Upper Thu Bon: 8.31 mil m^3, Tuy Loan: 16.45 mil m^3); Domestic: 4.17 mil m^3; (river basin Tuy Loan); Aquaculture: 3.91 mil m^3 (Ly Ly: 1.33 mil m3, Song Tranh 2: 0.26 mil m^3, Song Tranh 3: 0.38 mil m^3.

Upper Thu Bon: 0.88 mil m^3, Tuy Loan: 1.06 mil m^3). The water-shorted month are concentrated in months 2,3,4 and 6,7, the most water-shorted is in July with 59.39 mil m^3.

b) Scenario 2: Corresponding to water frequency up to 85%, current water demands in 2014, with different priorities and proportions among users. 1) Water supply for domestic use: 100%; 2) Environmental flow: 100%; 3) Water supply for industry: 80%; 4) Agricultural water supply: 80%; 5) Water supply for aquaculture: 80%; 6) Supply water for hydroelectricity according to the operating procedure. Details are shown in Figure 4.

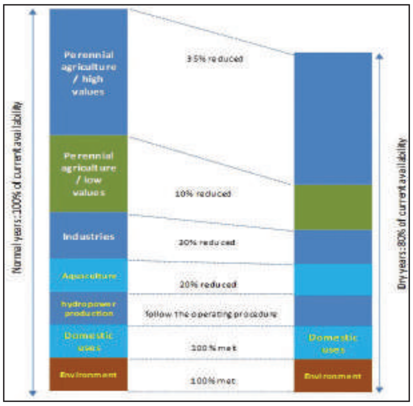


Figure 4. Priority and proportion of water supply to supply in dry years

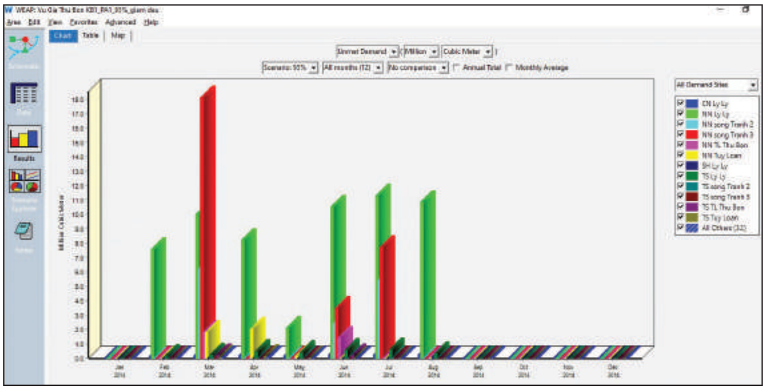


Figure 5. Water shortage on the calculated regions corresponding to the frequency of 85%, the current water demand in 2014 and the allocation of priority order and proportion to households

Calculation results of surface water allocation on the river basin showed that total water shortage of sectors is 78.46 million m^3, and the total water shortage in the whole region is about 78.46 million m^3, of which Industry: 0.84 million m^3; Agriculture: 75.16 million m^3; Aquaculture: 2.46 million m^3.

c) Scenario 3: Corresponding to water frequency up to 85%, water demands by 2030, with different priorities and proportions among users. 1) Water supply for domestic use: 100%; 2) Environmental flow: 100%; 3) Water supply for industry: 80%; 4) Agricultural water supply: 80%; 5) Water supply for aquaculture: 80%; 6) Supply water for hydroelectricity according to the operating procedure. Details are shown in Figure 4.

Calculation results of surface water allocation on the river basin showed that total water shortage of sectors is 101.19 million m^3, of which Industry: 1.88 million m^3 (Ly Ly: 1.28 mil m^3; Tuy Loan: 0.34 mil m^3; Upper Thu Bon: 0.26 mil m^3); Agriculture: 95.52 million m^3 (Ly Ly: 32.08 mil m^3; Song Tranh 2, 3: 42.93 mil m^3; Tuy Loan: 14.68 mil m^3; Upper Thu Bon: 5.82 mil m^3); Aquaculture: 3.79 million m^3. The water-shorted month are concentrated from Feb to Aug, the most water-shorted is in July with 43.59 mil m^3.

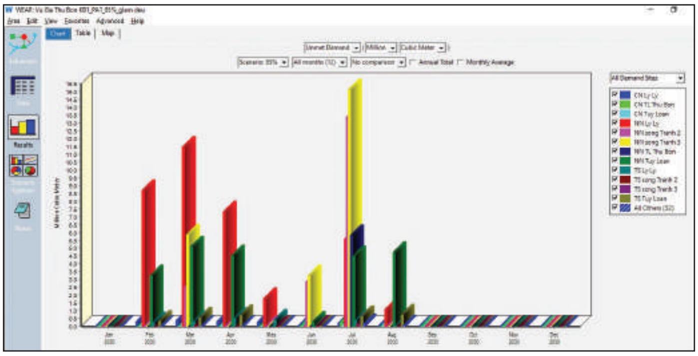


Figure 6. Water shortage on the calculated regions corresponding to the frequency of 85%, the future water demand in 2030 with different priorities and proportions among users

4. Conclusion and recommendation

Vu Gia - Thu Bon River basin is a large river basin in the central region of Viet Nam, supplying water to two provinces of Quang Nam and Da Nang city. Over the years on the river basin, droughts, water shortages have always occurred and resulted in water conflicts between different water users. This shortage phenomenon is due to the socio-economic development and the diversion of water from Vu Gia to Thu Bon through the DakMi 4 hydropower plant, making the downstream Vu Gia River severely short of water, especially Ly Ly River basin, Tuy Loan and Lower Vu Gia River. 10 years ago, Da Nang authority “demanded” hydropower plant to give water back for downstream, igniting a dispute between two localities Quang Nam, Da Nang on one side and hydropower plant owners on the other side. Up to now, this story has not ended yet.

In order to have a scientific basis for rational allocation of surface water sources for the Vu Gia - Thu Bon River downstream, the authors have developed a numerical model (WEAP), computational zoning (11 regions), calculation current water demand in 2014 and future 2030 (based on the socio-economic development orientation of Da Nang city and Quang Nam province), the priority order and resource allocation ratio are determined reasonably under context of droughts, water shortage corresponding to the frequency of water arrival is 85%. The results showed that:

- Corresponding to the frequency of inflow of 85% (the year when the drought or water shortage occurred) with the current water demand in 2014, without priority order, the proportion of water supplies are equal, the total water shortage of all sectors is 146.99 million m^3, of which agriculture is the largest: 138.05 mil m^3, concentrated in the basin Ly Ly basin: 43.13 mil m^3, followed by domestic: 4.17 mil m^3; (Tuy Loan River basin). The water-shorted month are concentrated in months 2,3,4 and 6,7, the most water-shorted is in July with 59.39 mil m^3.

- Corresponding to the frequency of inflow to 85%, the current water demand in 2014 and future in 2030, with different priorities and proportions among users: 1) Water supply for domestic use: 100%; 2) Environmental flow level: 100%; 3) Water supply for industry: 80%; 4) Agricultural water supply: 80%; 5) Water supply for fisheries: 80%; 6) Supply water for hydroelectricity according to the operating procedure. The total water shortage respectively of the sectors 78.46-101.19 mil m^3 has decreased significantly compared with the current plan, the amount of water supplied for domestic use in the regions is not inadequate and at the same time ensuring environmental flow in the downstream area.

In this study, the allocation of groundwater resources has not been considered. Therefore, it is necessary to thoroughly study the potential of groundwater resources in the basin and the possibility of exploiting and using groundwater resources for different uses. Ratios of groundwater to surface water use for each demand.

References

1. The National Center for Water Resources Planning and Investigation: *"Planning on water resources in the central key economic region"*, Ha Noi, 2010.
2. Institute of Water Resources Planning: *"Reviewing and updating calculation of water balance of Vu Gia - Thu Bon River"*, Ha Noi, 2010.
3. Power Construction Consulting Company I: *"Planning terraced hydropower plants on Vu Gia - Thu Bon River, Quang Nam province*", Ha Noi, 2002.
4. Than Van Don (2015), "Study on determination of minimum flow requirement on main river of Vu Gia - Thu Bon, serving ecosystem development", *Journal of Natural Resources and Environment*, No. 08, June 2015.
5. WEAP User Guide, Jan2011 (www.weap21.org/downloads/WEAP_User_Guide.pdf).

A REVIEW OF PROJECT RANKING AND CLASSIFICATION SCHEME IN CLIMATE CHANGE RESEARCH, STRIVING TOWARDS A SYSTEMATIC RESEARCH IMPACT ASSESSMENT IN VIET NAM

Nguyen Tuan Quang(1), Huynh Thi Lan Huong(2), Nguyen Xuan Hien(2), Tran Van Tra(2), Cung Hong Viet(2)

(1)Department of Climate Change, Viet Nam Ministry of Natural Resources and Environment

(2)Viet Nam Institute of Meteorology, Hydrology and Climate Change, Viet Nam Ministry of Natural Resources and Environment

Received: 2 July 2020; Accepted: 7 August

Abstract: *Climate change is expected to have negative impacts on earth environmental systems. Given the impacts, there has been a tremendous amount of research on the topic of climate change. From the research, a large volume of information has been provided, yet, lack a systematic organization. Therefore, research project ranking and classification form an important part for project transfer and dissemination. Research in the past attempted to create frameworks grading outputs, effectiveness, and efficiencies of research projects. Specifically, these frameworks are used to analyze organizations, studies, topics, projects, programs with their process of reaching its objectives; how their outputs interact with related factors and achieving the final goal; or how are they supposed to be applied into practical problems effectively, etc. This has been adopted in Viet Nam, however, the frameworks are still limited in its complexity and opted for more simplicity. In light of the National Research Program on Climate Change, Natural Resources and Environmental Management (NRPCRE) for the period 2011-2015 and 2016-2020, research projects on the topic of climate change has been conducted. Although information has been sorted, there is still a lack of collection and classification through a synchronic process. Hence, a comprehensive framework has been adopted in this study, based on the fundamental theory of efficiency, effectiveness. In this specific case study, 48 projects of NRPCRE 2011-2015 are ranked and classified, 04 of them are chosen for their outstanding results presented in the final total points (FTPs). This framework in our study might be uncomplicated, though, it is assumed as the most suitable version compare to recent available sources of information.*

Keywords: *Climate change, project classification, project ranking, framework.*

1. Introduction

"Climate change" (CC) is defined as the changes of the climate. It is worthwhile mentioning that the climate itself is in a stable state of changing. Therefore, climate change in this context refers to the changes in the composition of the global atmosphere that amplify natural climate fluctuations in comparable time periods due to anthropogenic activities [19]. Along with global climate change, adverse impacts are foreseeable. Viet Nam is among the nations expected to be severely impacted by CC, especially in the Mekong Delta region. Given both the scale of the impact in the future and the damaged currently exhibiting, there has been a large volume of research on climate change in Viet Nam [5,18,9,11,21].

Scientific and technological research activities supporting response efforts to CC are among the most viable solution. In particular, scientific and technological research activities play a crucial role since they provide not only information for decision makers but the outcomes of research also involve practical

Corresponding author: Nguyen Tuan Quang
E-mail: nguyentuanquang7@yahoo.com

solutions for the purpose of adaptation and mitigation. Yet too much information and too many technical solutions can be overwhelming for the user of such information. For such a reason, there is a strong incentive to better manage the information provided by researches. This provides a need for research project ranking and classification so that most useful outcomes could be easily detected and transferred where applicable.

Project ranking and classification is not in itself new. Rather, it has been done ubiquitously in the past. Most previous works relied on a ranking and classification framework with grades given to different aspects of the projects. There have been a whole host of frameworks adopted, such as the England Research Excellence Framework - a peer assessment of the quality of UK universities' research in all disciplines; Excellence in Research for Australia - Australia's national research evaluation framework, The Payback Framework of the Canada National Institute of Canadian Academy of Health Sciences Panel on Return on Investment in Health Research, etc [2,3,4].

Similarly, a lot of Vietnamese scientific institutes have already introduced their own frameworks with the main intention of evaluating the results of scientific research projects. Basically, these frameworks perform as an assessment tool, determining the benefits and disadvantages, potential opportunity of real-life implementation, and knowledge transferring for national management purposes.

This article summarizes the aforementioned frameworks with the intention of sorting out the advantages and drawbacks of the different framework. Based on this, an example for an Assessment Framework for Viet Nam National Science and Technology Program on CC will be introduced.

2. State-of-the-art on research project assessment

2.1. Definitions

Project ranking and classification is a multidimensional concept that can be conceptualizedand operationalized in several ways. According to the study of Bartuševičienė & Šakalytė (2013), the two main concepts that were used to assess studies, topics, projects, programs, or organizations are Efficiency and Effectiveness (Figure 1).

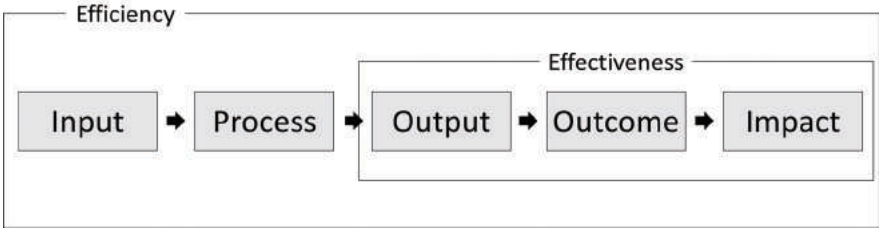


Figure 1. Efficiency, Effectiveness, and Impact Assessment [6]

In particular, efficiency measures the relationship between inputs and outputs or how successfully the inputs have been transformed into outputs [10]. Effectiveness assessment is concerned with output, quality, creation of added value, innovation, and cost reduction. It measures the degree to which a project achieves its objectives or the way outputs interact with other factors, usually has something to do with reaching final goals [22].

With regards to effectiveness assessment, the stage of impact is considered as the effects, changes, or benefits on the economy, society, culture, community policies and services, health, environment, or quality of life [16]. Meanwhile, according to [13], the impact of a project is understood as changes in perceptions, knowledge, understanding, ideas, attitudes, receptions, policies, practices straight from the project results.

Effectiveness assessment or project impact evaluation plays an important role in government's strategies determination [6]. Effectiveness assessment, especially impact evaluation is an important part. It is conducted focus on analyzing the outputs of the projects, then the decisions will be made whether those projects have potential benefits to realistic implementation or not, in lieu of they are belonging to different sectors. This is a stage where projects are ranked and sorted out into different categories, then, the most outstanding ones will be chosen to transfer and apply in suitable purposes.

By applying those ranking and classifying process above (Figure 1) the project assessors can consider all sides of the projects fully under control, then they can be aware of both benefits and drawbacks, followed with immediate actions such as modifications (if needed). In addition, they can also estimate the expected outputs and dealing with anticipated impacts as soon as possible.

2.2. Approaches

Evaluating the efficiency and effectiveness of projects have been conducted as early as 1990 [15]. Notable work includes the England Research Excellence Framework, Excellence in Research for Australia, The Australian Research Quality Framework, The Payback Framework of the Canada National Institute of Health Research, etc.

The England Research Excellence Framework (REF) is a tool used to assess scientific researches in English universities. However, it has also been widely adopted in other nations such as Finland, Norway, Denmark, Holland, Italia, Australia, Hong Kong, etc [20]. Effectiveness and impact are evaluated and given score based on the study manager. The evaluation process consists of 6 stages (Figure 2) below:

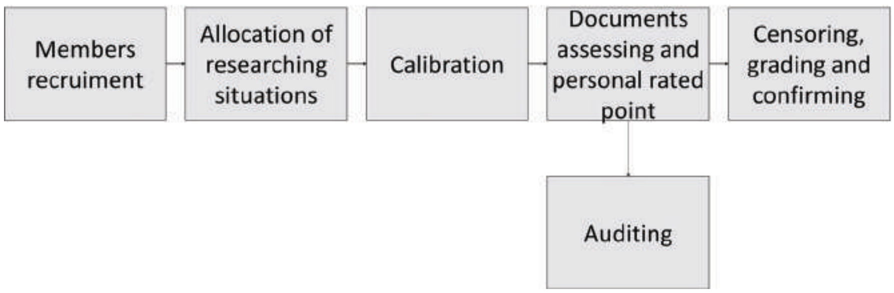


Figure 2. Assessing stages

The impact assessment results are developed into impact profiles based on a combination of case studies and model studies [12]. In 2009-2010, this framework was implemented to evaluate specific studies in five sectors of health, physics, earth science - environment, society, and literature - English language) at 29 institutions [16].

This framework was built on 03 theoretical basics, which are also 03 main factors: (i) Output quality of the study; (ii) Impact research and (iii) Research environment. The studies were evaluated by a group of qualified experts. In detail, the first factor accounted for 65% of the final assessment. The second and the last constituted of 25% and 15%, correspondingly.

The Excellence in Research for Australia (ERA) is developed to measure the effectiveness of pieces of researches and projects in Australia for the purpose of reporting the results implementation and used as references for expanding those researches. This framework was first used in 2010, after 3 years of consultation, evaluation and completion. It aims to provide the research quality, which was conducted in university and research institutions of higher education in Australia. The right of using this framework belongs to the Australian Research Council (ARC) - an Australian government unit.

Evaluation indicators of the framework include (i) Indicators on research quality; (ii) Indicators on volume and research activities; (iii) Indicators on research application; and (iv) Indicators on achievement.

The Australian Research Quality Framework (RQF) is a comprehensive assessing tool. In detail, it was built with a set of indicators, focused on the benefits of 04 main pillars (i) Economic benefits; (ii) Social benefits; (iii) Environmental benefits; and (iv) Cultural benefits. In this framework, researchers are required to demonstrate and also prove whether their study includes the four aforementioned benefits. It then is to be verified by a panel of experts for identification and conclusion [7].

The flow of RQF (Figure 3) follows:

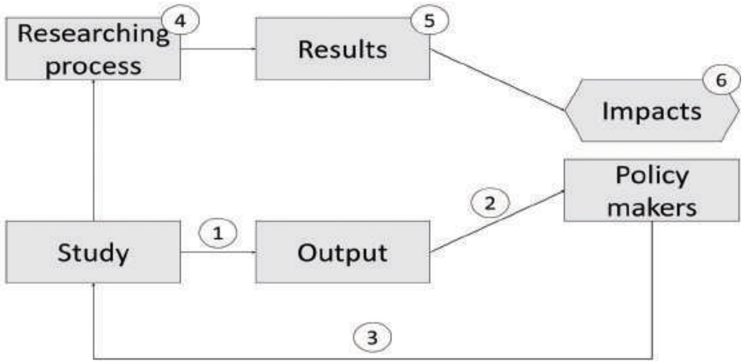


Figure 3. Data connection structure

where,

(1) The findings of the study, output included (for instance published papers or scientific articles);

(2) Communication and interaction with related-parties and the public (emails, visits, seminars, public promotion);

(3) Feedbacks of related-parties;

(4) Research development (based on input and discussion of related-parties);

(5) Results (e.g. commercial, culture, references);

(6) Impacts (changes in behavior and economy).

The Payback Framework of the Canada National Institute of Health Research (NIHR) uses an investment return approach for research in the medical system based on analyzing indicators in order to provide consistency and comparison between users and investors. Especially, this framework was designed to evaluate the effectiveness and impact of scientific researches in the medical system on end-users.

Those impacts that needed to be assessed in the framework are (i) Enhancing knowledge including new inventions and breakthroughs from medical research and contributions to the scientific database; (ii) Building capacity including developing and improving research skills for both individuals and organizations; (iii) Providing information for decision making including the impact of research in the field of science, publicity, clinical, and management; (iv) Medical effects including advances in prevention, diagnosis, treatment and mitigation, and (v) Others socio-economy impacts.

This framework is implemented nationwide and worldwide, for instance in Canada Health Research Institute, Dutch Public Health Agency, Australian National Health Research and Medical Council, and Hong Kong Welfare Office [4,15,17].

Meanwhile, in Viet Nam, the evaluation of scientific and technological activities at research institutions is mainly through works published in specialized scientific journals or the proceedings of domestic and foreign conferences, public transfer contracts. Research organizations arrange annual scientific evaluation activities individually in order to assess their research performances, as well as setting up scientific and technological strategic orientations. Otherwise, these activities are done with in-house assessing indicators, which are adopted from foreign frameworks and with the intention of improving the quality of scientific research application, and transferring either knowledge or technology.

Some of the popular in-use frameworks in Viet Nam can be listed as Framework for the evaluation of the scientific and technological performance of the Viet Nam Academy of Agricultural Sciences, Framework of evaluating the scientific and technological performance of the Vietnamese Institute of Forest Sciences, Framework of evaluating the scientific and technological performance of The Viet Nam Institute for Water Resources Research, etc. [15]. They share a similar structure of 06 main criteria: (i) Numbers of scientific studies; (ii) Numbers of researchers; (iii) Educational effectiveness; (iv) Information effectiveness on scientific research; (v) Effectiveness on science and technology; and (vi) Economic effectiveness.

Nevertheless, these frameworks have only been considered in a narrow scope, which is assumed inapplicable to organizations and institutes of different sizes and research fields. Hence, a revolution is needed to help the process of evaluating results as well as selecting outputs from research projects more systematically, effectively and efficiently.

3. An example assessment for the National Research Program on Climate Change, and Natural Resources and Environmental Management

Given the importance of ranking and classification of projects, the case study here proposed a framework to assess projects within the Viet Nam National Research Program on Climate Change, and Natural Resources and Environmental Management for the 2011-2015 period. In overall, the evaluation of these projects within the program is to go through 03 main steps. The first step involves collecting all relevant documents, general reports, and detailed results. The second step comprises of proposing and establishing an assessing framework. Finally, the assessment is performed to quantify the total final point that each project achieves. Eventually, in light of those definitions and worldwide-implemented frameworks mentioned above, a comprehensive assessing product quality framework (APQF) has been proposed. It goes with 02 main criteria Efficiency and Effectiveness which are described specifically as a list of indicators and grading methodology below (Table 1 and Table 2).

The foundation of the framework in this study is conducted based on previous frameworks which are shown in Table 2 - “References”). The framework is built up simply with 02 major criteria. Each indicator is chosen carefully based on the availability data provided in each project’s final report. The main purpose of using this framework is to find out how well each project have done with educating for researchers, and completing objectives.

Table 1. List of indicators

No.	Indicators	Units
Indicators of Efficiency		
1	The success rate of PhDs candidates	%
2	The success rate of MScs students	%
3	The success rate of bachelor/engineers students	%
4	The percentage of completed tasks compared to the original research objectives	%
5	The percentage of completed tasks compared to the original research design	%
6	The percentage of finished products compared to the original request	%
Indicators of Effectiveness		
7	Numbers of PhDs successfully defended	Person(s)
8	Numbers of MScs successfully defended	Person(s)
9	Number of bachelors/engineers successfully defended	Person(s)
10	Numbers of articles published in international journals	Articles
11	Number of articles published in national journals	Articles
12	Number of articles published at international scientific conferences	Articles
13	Number of articles published at national scientific conferences	Articles
14	Practical applicability after the transfer	Insignificant-Medium-High

No.	Indicators	Units
15	The urgency of the project in dealing with urgent practical issues related to climate change adaptation	Insignificant-Medium-High

Table 2. Grading methodology

No.	Indicators	Process					References
I	**Indicators of Efficiency**						
1	The success rate of PhDs candidates	<50	60-70	70-80	80-90	100	Framework of evaluating scientific and technological performance of Viet Nam Institute of Forest Science
2	The success rate of MScs students	<50	60-70	70-80	80-90	100	
3	The success rate of bachelor/ engineers students	<50	60-70	70-80	80-90	100	
4	The percentage of completed tasks compared to the original research objectives	<50	60-70	70-80	80-90	100	The Australian Research Quality Framework (RQF)
5	The percentage of completed tasks compared to the original research design	<50	60-70	70-80	80-90	100	
6	The percentage of finished products compared to the original request	<50	60-70	70-80	80-90	100	The Excellence in Research for Australia (ERA)
	Point levels	**0**	**25**	**50**	**75**	**100**	
II	**Indicators of Effectiveness**						
7	Numbers of PhDs successfully defended	0	1	2	3	≥4	Framework of evaluating scientific and technological performance of Viet Nam Institute of Forest Science
8	Numbers of MScs successfully defended	0	1-3	4-6	7-9	>9	
9	Number of bacelors/engineers successfully defended	0	1-3	4-6	7-9	>9	
10	Numbers of articles published in international specialized journals	0	1	2	3	≥4	
11	Number of articles published in domestic specialized journals	0	1-4	5-9	9-13	>13	
12	Number of articles published at international scientific conferences	0	1-2	3-4	5-6	>6	
13	Number of articles published at domestic scientific conferences	0	1-4	5-9	9-13	>13	
	Point levels	**0**	**25**	**50**	**75**	**100**	
14**	Practical applicability after the transfer	Insignificant	Medium	High			

No.	Indicators	Process			References
15**	The urgency of the project in dealing with urgent practical issues related to climate change adaptation	Insignificant	Medium	High	The England Research Excellence Framework (REF)
	Point levels	**25**	**50**	**75**	
	Final total point*				

(*) The final total point (FTP) of each particular project will be converted into of 100 scale point. In detail, there are 04 point-stages for assessing the FTP, which are divided into the following levels: (i) FTP≤40: Not achieved; (ii) FTP from 41-60: Good; (iii) FTP from 61-80: Very good; (iv) FTP from 81-100: Excellence.

(**) Projects after being assessed are compared with each other by the FTP that they achieved (converted into a scale point of 100). In the consequence of equal FTP, the comparison and selection will be based on the consideration of 2 indicators (14) and (15) (extra round of classification).

All of 48 projects belong to the NRPCRE program period of 2011-2015 have been evaluated using the APQF. In order to transfer the outstanding projects, it is a necessity tocarry out the evaluation, and at the time, selecting and refining the evaluated results in an integrated and consistent manner. Therefore, specific evaluating points of 48 projects will be demonstrated in this section, specifically:

Table 3. Detail indicators points of 48 projects

No.	Project name	Indicators															FTP*
		1	2	3	4	5	6	7	8	9	10	11	12	13	**14****	**15****	
Group of the first research content																	
1	BĐKH.03	100	100	100	100	100	100	25	25	00	00	25	00	00	**100**	**100**	**58.3**
2	BĐKH.04	100	100	100	100	100	100	25	50	00	00	50	00	00	**100**	**50**	**58.3**
3	BĐKH.38	100	100	100	100	100	100	25	25	00	25	25	00	00	**100**	**100**	**60**
4	BĐKH.39	100	100	100	100	100	100	25	25	00	00	25	00	00	**50**	**50**	**51.7**
5	BĐKH.50	100	100	100	100	100	100	00	00	25	00	25	00	00	**100**	**50**	**53.3**
6	BĐKH.61	100	100	100	100	100	100	25	25	00	00	25	50	25	**50**	**50**	**56.7**
Group of the second research content																	
7	BĐKH.01	100	100	100	100	100	100	00	25	50	25	25	25	00	**50**	**50**	**56.7**
8	BĐKH.02	100	100	100	100	100	100	00	25	00	00	50	00	00	**100**	**50**	**55**
9	BĐKH.15	100	100	100	100	100	100	00	25	00	00	25	00	00	**50**	**100**	**53.3**
10	BĐKH.17	100	100	100	100	100	100	25	25	00	00	25	00	00	**100**	**100**	**58.3**
11	BĐKH.43	100	100	100	100	100	100	50	25	00	25	25	25	25	**100**	**50**	**61.7**
Group of the third research content																	
12	BĐKH.05	100	100	100	100	100	100	50	25	00	00	25	00	00	**50**	**100**	**56.7**
13	BĐKH.06	100	100	100	100	100	100	00	25	00	00	50	00	00	**50**	**100**	**55**
14	BĐKH.07	100	100	100	100	100	100	50	25	00	00	25	00	25	**50**	**100**	**58.3**
15	BĐKH.08	100	100	100	100	100	100	100	25	00	00	25	25	50	**50**	**100**	**65**

No.	Project name	Indicators															FTP*
		1	2	3	4	5	6	7	8	9	10	11	12	13	**14****	**15****	
Group of the third research content																	
16	BĐKH.11	100	100	100	100	100	100	00	25	00	00	25	00	00	**50**	**100**	**53.3**
17	BĐKH.13	100	100	100	100	100	100	00	25	00	00	25	00	00	**100**	**100**	**56.7**
18	BĐKH.16	100	100	100	100	100	100	50	25	00	00	50	25	00	**100**	**100**	**63.3**
19	BĐKH.18	100	100	100	100	100	100	00	00	00	00	25	25	00	**50**	**100**	**53.3**
20	BĐKH.19	100	100	100	100	100	100	100	75	00	00	75	25	00	**50**	**50**	**65**
21	BĐKH.20	100	100	100	100	100	100	25	25	00	00	50	00	25	**50**	**50**	**55**
22	BĐKH.21	100	100	100	100	100	100	25	25	00	00	25	00	50	**100**	**50**	**58.3**
23	BĐKH.22	100	100	100	100	100	100	25	25	00	00	25	00	00	**50**	**100**	**55**
24	BĐKH.23	100	100	100	100	100	100	25	25	25	00	25	00	00	**50**	**50**	**53.3**
25	BĐKH.24	100	100	100	100	100	100	00	25	25	25	25	00	25	**50**	**50**	**55**
26	BĐKH.25	100	100	100	100	100	100	00	25	00	25	50	00	00	**50**	**100**	**56.7**
27	BĐKH.28	100	100	100	100	100	100	25	25	00	00	50	00	00	**50**	**100**	**56.7**
28	BĐKH.30	100	100	100	100	100	100	50	25	00	00	25	00	25	**50**	**100**	**58.3**
29	BĐKH.32	100	100	100	100	100	100	25	25	25	25	25	50	00	**50**	**50**	**58.3**
30	BĐKH.36	100	100	100	100	100	100	25	25	00	00	25	00	00	**50**	**100**	**55**
31	BĐKH.40	100	100	100	100	100	100	25	25	00	00	50	00	00	**50**	**100**	**56.7**
32	BĐKH.42	100	100	100	100	100	100	50	25	25	25	50	50	00	**50**	**50**	**61.7**
33	BĐKH.44	100	100	100	100	100	100	25	25	00	25	25	00	00	**50**	**100**	**56.7**
34	BĐKH.45	100	100	100	100	100	100	00	25	00	00	25	00	00	**50**	**100**	**53.3**
35	BĐKH.48	100	100	100	100	100	100	25	25	25	00	25	00	00	**50**	**100**	**56.7**
36	BĐKH.49	100	100	100	100	100	100	00	00	25	25	25	00	00	**50**	**100**	**55**
Group of the fourth research content																	
37	BĐKH.12	100	100	100	100	100	100	25	00	00	00	25	00	00	**50**	**100**	**53.3**
38	BĐKH.14	100	100	100	100	100	100	00	00	00	00	25	00	25	**100**	**50**	**53.3**
39	BĐKH.29	100	100	100	100	100	100	50	00	00	00	25	00	00	**50**	**100**	**55**
40	BĐKH.34	100	100	100	100	100	100	25	25	00	25	25	00	00	**50**	**100**	**56.7**
41	BĐKH.35	100	100	100	100	100	100	00	25	00	25	25	25	00	**50**	**100**	**56.7**
42	BĐKH.52	100	100	100	100	100	100	00	25	00	00	25	00	00	**100**	**100**	**56.7**
43	BĐKH.59	100	100	100	100	100	100	50	25	00	00	25	00	00	**50**	**100**	**56.7**
Group of the fifth research content																	
44	BĐKH.09	100	100	100	100	100	100	25	25	00	00	25	00	00	**50**	**100**	**55**
45	BĐKH.10	100	100	100	100	100	100	25	25	00	25	25	25	00	**50**	**100**	**58.3**
46	BĐKH.27	100	100	100	100	100	100	25	25	25	00	25	00	00	**100**	**100**	**60**
47	BĐKH.56	100	100	100	100	100	100	25	25	00	00	75	00	00	**50**	**100**	**58.3**
48	BĐKH.57	100	100	100	100	100	100	25	75	00	25	25	00	25	**50**	**50**	**58.3**

Eight projects were ranked with the highest grades, which are listed as (i) BĐKH.08; (ii) BĐKH.16; (iii) BĐKH.17; (iv) BĐKH.19; (v) BĐKH.27; (vi) BĐKH.38; (vi) BĐKH.42 and (vii) BĐKH.43.

The extra round of classification was conducted by comparing each specific scores of indicators number (14) and number (15). In the consequence, these 04 projects below are the final which have met all of the requirements:

- Project BĐKH.16;
- Project BĐKH.17;
- Project BĐKH.27;
- Project BĐKH.38.

4. Conclusion

Research on project ranking and classification forms an important task. This allows the assessment of the results and provides information for decision makers not only to obtain research results but to rationalize which projects to transfer. Due to its importance, a large volume of research in the past has proposed a large number of ranking and classification framework. The frameworks relied heavily on the concept of effectiveness and efficiency of a project to determine its ranking. Frameworks in the past provided a grading scheme where each criteria are given maximum amount of points. Each project is thus graded according to how well they meet each criterion.

Ranking and classification of projects in Viet Nam, however, are fairly new. It is not to say that there has been no effort in developing a ranking and classification of research projects in Viet Nam. Rather there has been limited success in developing a generic framework where research projects could be properly assessed. This study seeks to establish a framework for project ranking and classification with a case study using the NRPCRE of Viet Nam.

Ranking and classification of projects under the 2011-2015 NRPCRE as a case study not only serves the purpose of an example but also a necessary operation. Only on the basis of evaluation and classification, outstanding results from those projects can be delivered and applied properly in the most effective and efficient way. The study has indicated a systematic evaluating method for scientific projects, which was built on the foundation of other profound assessing frameworks around the world.

All 48 projects have been classified, the output comes out that all of them resulted in “Good” and “Very good”. Initially, 04 outstanding projects have been selected - which are all proved their urgency and importance in the field of climate change adaptation, natural resources and environmental management.

The proposed framework utilized the best available information from research projects for the purpose of ranking and classifying. It should be noted though, more useful information could be incorporated into the framework. This includes but is not limited to economic impacts of research, societal impacts, etc. This type of second order impact however, is harder to measure and record and may take years after the completion of the project. For this reason, these impacts have been omitted within the framework. More advanced method to address second order impacts of the projects could be incorporated in the future should there be more readily available information.

***Acknowledgements**: The authors wish to acknowledge the support of the “Scientific and practical basis for evaluating and transferring results of national science and technology programs on climate change response, natural resources and environmental management, proposing researching orientations for the period of 2021-2025” research project (project number: BĐKH.43/16-20), the National Research Program on Climate Change, Natural Resources, and Environmental Management for the period 2011-2015, and 2016-2020, the Viet Nam Institute of Meteorology, Hydrology and Climate Change, and the Department of Climate Change. Without this support, the research would not have seen the light of day, and for this, the authors are deeply grateful.*

References

1. Australian Research Council (2010), *Excellence in Research for Australia (ERA)*. Available at: https://www.arc.gov.au/excellence-research-australia.
2. Bartuševičienė and Šakalytė, E. (2013), *Organizational assessment: effectiveness vs. efficiency*, Social Transformations in Contemporary Society, 1, pp. 45–53.
3. Bernstein, A. et al. (2006), *A Framework to Measure the Impact of Investments in Health Research*.
4. CAHS (2009), *Making an Impact: A Preferred Framework and Indicators to Measure Returns on Investment in Health Research*.
5. Cuong, T. T. (2013), *Creating a scientific and pratical basis to establish a monitoring system for the impacts of climate change and sea level rise on the quality of the continental surface water environment.*
6. Donovan, C. and S., H. (2011), *The "Payback Framework" explained*, Research Evaluation, 20, p. 181.
7. Duryea, M., Hochman, M. and Parfitt, A. (2007), *Measuring the Impact of Research*, Research Global, 27, pp. 8–9.
8. Frey, K. and Widmer, T. (2009), *The Role of Efficiency Analysis in Legislative Reforms in Switzerland*, 5th ECPR General Conference, Potsdam, Germany.
9. Huong, H. T. L. (2015), *Researching and developing climate change adaptation indexes to serve the state management of climate change*.
10. J. Low (2000), "The value creation index", *Journal of Intellectual Capital*, 1(3), pp. 252–262.
11. Khiem, M. Van (2015), *Researching to develop a set of Atlas related to climate and climate change in Viet Nam.*
12. Manville, C. et al. (2014), *Assessing impact submissions for REF 2014: An evaluation*. RAND, Prepared for HEFCE, SFC, HEFCW and DEL.
13. Morton, S. (2015), *Progressing research impact assessment: A contributions approach*, Research Evaluation, 24, pp. 405–419.
14. Nason, E. et al. (2007), *Policy and practice impacts of research funded by the Economic and Social Research Council. A case study of the Future of Work programme, supporting data*. Technical report. Rand Europe.
15. Quang, N. T. (2019), *Topic Explanation of "Studying scientific and practical basis for evaluating and transferring results of national science and technology programs on climate change response, natural resources and environmental management, proposing orientations research f*.
16. REF2014 (2011), *Decisions on Assessing Research Impact*.
17. SIAMPI (Social Impact Assessment Methods through Productive Interactions) (2011), *SIAMPI Final Report*.
18. Thai, T. H. (2013), *Studying on the effects of climate change on water resources change in the Mekong Delta.*
19. Thang, N. V. et al. (2010), *Climate change and its impacts in Viet Nam*.
20. The 2014 Research Excellence Framework (REF) (2014). Available at: https://www.ref.ac.uk/2014/results/intro/.
21. Thuc, T. and Neefjes, K. (2015), *Viet Nam Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX Viet Nam)*.
22. W., Z., B., Y. and G, M. (2010), "Linking organizational culture, structure, strategy, and organizational effectiveness: Mediating role of knowledge management", *Journal of Business Research*, 63(7), pp. 763–771.

GLOBAL SCIENTIFIC PRODUCTION ON CLIMATE CHANGE ARTICLES: A BIBLIOMETRICS ANALYSIS

Nguyen Thu Minh, Nguyen Thanh Tuong, Ngo Kim Anh
Center for Environmental Research, Viet Nam Institute of Meteorology, Hydrology and Climate change, Ministry of Natural Resources and Environment

Received: 10 July 2020; Accepted: 4 August 2020

Abstract: *This research used Bibliometrics and spatial distribution to describe science research productivities in patterns of article types, country, and journal via climate change articles on SCI during 2007-2018. In 25278 articles on climate change field, total research publication and article form is increasingly from 2007 to 2018. Total research productivity increases sharply in 2018 year, gains to 3325 articles and 2800 article forms in 2018 year. Moreover, article form is the highest research production gaining 19917 articles (1st ranking). USA is a country, where has the highest publication outputs in all the article types and in total research productivity (23286 articles with 1st ranking) including 5369 independent articles (23.06%) and 17917 collaborative articles (76.94%). CLIMATIC CHANGE journal has the most research outputs with 1105 articles (4.37%), 1st ranking, and it increases sharply in the last years. NATURE CLIMATE CHANGE journal have not any research output in first years of publication period. This paper found out 163 countries in climate change article publication, whereas Vietnam is ranked the 45th with 159 articles (0.63%) including 33 independent articles (50th ranking, 20.8%) and 126 collaborative articles (44th ranking, 79.2%); and on the world map, Vietnam is performed by light blue color. Additionally, the map also shows that the research productivity is almost revealed on all countries with different research productivity quantities. The countries have high publication, are located highly in USA, Canada, Europe community, and some Asian countries (e.g. China, India, etc.). They are categorized into 5 ranks from low to high amount of publication and be colorized respectively. For example, independent publication is showed from small red round dot to big one, and cooperative publication is performed in different colors, in which USA has the most publications in dark blue and big red do. This paper, therefore, revealed science growth, research publishing trend, and spatial distribution of countries on climate change articles, and it also provides knowledge as well as more understanding about climate change field.*

Keywords: *Climate change, Bibliometrics, Spatial Distribution.*

1. Introduction

The past decade has demonstrated that the global environment has been altered by human activities (CGCR, 1999). Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007). It is attributed directly or indirectly to human activity that alters the composition of the global atmosphere such as burning of fossil fuels (CGCR, 1999), land use change and agriculture that are increasing the atmospheric concentrations of greenhouse gases, and aerosols (IPCC, 1995). This change is precisely temperature change, precipitation, humidity, wind patterns (IPCC, 2001) and they make alteration of the energy balance of the climate system lead to increasing risk of vector born diseases, widespread damage of natural ecosystem, loss of biodiversity, increase the frequency of extreme events like droughts, floods (AASA, 2011), typhoon, heat wave,

Corresponding author: Nguyen Thu Minh
E-mail: ruanthuminh@gmail.com

wildfire (Ken Ogilvie et al., 2004; Susanne C. Moser et al., 2007). According to the recent Intergovernmental Panel on Climate Change reported, the average global surface temperature has increased by 0.74 C over the last 100 years (1906-2005) (IPCC, 2007), it is caused by the build-up of greenhouse gases in the atmosphere accumulated from continual combustion of fossil fuels (Hatzigeorgiou et al., 2008) and warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places (IPCC, 1995) concurrently increasing in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC 2007). Consequently, global sea level has risen by between 10 and 25cm over the past 100 years (IPCC, 1995), leads to affect freshwater flows with dramatic adverse effects on biodiversity, people and livelihoods (Jinghai Li et al., 2011). Therefore climate change has become a major scientific, political, economic, and environmental issue during the last decade (Li et al, 2011) and scientific articles on climate change have demonstrated a rapid increase in quantity over the past several decades, a number of papers presenting the latest research achievements have been published in authoritative scientific journals such as Nature and Science (Jinfeng Li et al, 2011). And bibliometric is a research tool, regarded as cannot be absent in investigation of information science field because of its strength in quantitative (Almind and Ingwersen, 1997) and qualitative analysis (Zhang et al, 2010) to improve efficiency rates of information handling process (Ashwini tiwari, 2006) and increase understanding of the information science research (Gayatri mahapatra, 2009). Therefore, in this research based on 25278 articles, which were published on SCI from 2007 to 2028 year to find out a new method as calculation of research publications and spatial distribution of countries on the world map. Particular, the research aim to 1) describe and analyze total research productivity in 2007-2018, research productivity of article types, journals of climate change articles. 2) Analyze research publication of countries and perform its distribution on the world map. This can be helped authorizes to be easily in envision about climate change scientific productivity on the world.

2. Methodology

The whole data source was download from Science Citation Index (SCI) database from 2007 to 2018 with term "climat* chang*" including "climate changes", "climatic change", "climate change", and "climatic changes". It was used to locate publication containing these words in parts of titles, abstracts or keywords. After that, these 25278 articles were recorded and calculated into spreadsheet Excel with different types as article types, country, journal, and so on.

The common as other bibliometric method, before calculating total research productivities needs to implement some steps as group all the articles originated from England, Scotland, North Ireland, Wales were United Kingdom (UK) heading; the articles are from different States of America are reclassified as United State America (USA). Peoples R China, Taiwan, Hongkong are belonged to be China. Collaborative categories are determined when independent categories are assigned. Independent categories include one or many common authors which are designed researcher. Collaborative categories conclude many different authors from one or multiple countries.

3. Results and discussion

Total 25278 articles were derived from Science Citation Index database to calculate and analyze research publication in period 2007-2018. The results are presented as follow:

3.1. Research productivity in 2007-2018 year

After calculating in total 25278 articles, this research found out total scientific productivity for each year from 2007 to 2018 including alternately as 905 articles (2007); 1214 articles (2008); 1460 articles (2009); 1689 articles (2010); 2035 articles (2011); 1984 articles (2012); 2389 articles (2013); 2325 articles (2014); 2550 articles (2015); 2691 articles (2016); 2711 articles

(2017); and 3325 articles (2018). It indicates annual scientific productivity increases from 2007 to 2018 except for it has a bit decreased in 2012 year and 2014 year, particular in 2012 is less than 2011 year 51 articles, and the article number in 2013 is more than in 2014 year 64 articles - this vision seems contrast with growth rule of research publication on SCI. On the Figure 1 can be seen three growth lines of scientific productivity on total research productivity, article, and review type, in which next year is almost more published than last year, especially the scientific production increases sharp from 2007 to 2011 (905 articles to 2035 articles) and from 2017 to 2018 (2711 articles to 3325 articles) on climate change articles in article and total research productivity. However, in review type, scientific publication increases from 2007 to 2018, but that increasing is only slowly, approximately 400 articles in 2018.

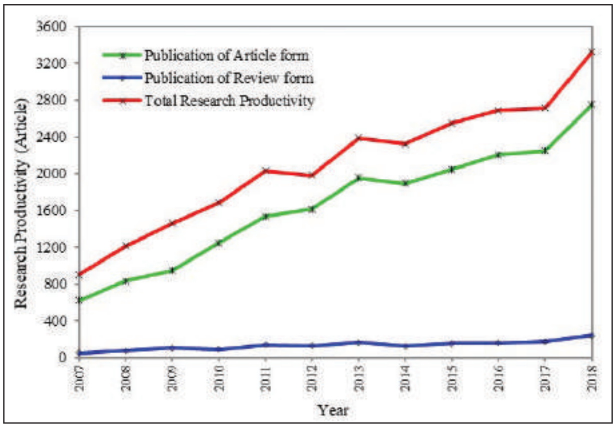


Figure 1. Annual research publication of climate change article

3.2 Article types

Article types are one in many science information categories which can be counted by bibliometric. They include many forms and table 1 is 6 forms with theirs research productivity attaching by ten countries as United State (USA), United Kingdom (UK), Canada, Germany, China, Australia, France, Spain, Italy, and Netherland. It indicates that Article form has the most publishing output with 19917 articles with the first ranking, following distantly as Editorial Material 1724 articles (2nd), Review 1631 articles (3rd), Proceedings Paper 572 articles (4th), Letter 416 articles (5th), and Correction 258 articles (6th) with the last ranking. Besides, the Article form is popular research production in total countries and it normally occupies the highest publishing output number in total research types. Particular, USA has 4370 articles and occupies 21.94% of total Article form, following as 2079 articles (China, 10.44%); 1493 articles (UK, 7.5%); 1202 articles (Australia, 10.44%); 1110 articles (Germany, 5.57%); 1089 articles (Canada, 5.47%); 608 articles (France, 3.05%); 589 articles (Spain, 2.96%); 507 articles (Italy, 2.55%); and 441 article belongs to Netherland with 2.21%. Furthermore, research publication of Article form is higher than other forms in big gap. It has 19917 articles in 2007-2018 while other forms only have some hundreds to thousands of research publication.

On the Table 1 can be also seen that USA is a country, which is always has the highest research output about all the Article forms in top ten countries, next is UK (2nd country) in Editorial Material form (202 articles, 11.72%) and Review form (248 articles, 15.21%). But in the Article form, the second ranking in countries is China with 2079 articles (10.44%). In Editorial Material form and Review form, China is ranked the fifth and Australia is ranked in 3rd, Germany and Canada are the fourth ranking about research output. Generally, in the article type has seen that Article form has the highest research publication whereas other forms merely has from some articles to hundreds articles.

Table 1. The distribution of article types by countries in 2007-2018

Type	TP (R)	USA (%)	China (%)	UK (%)	Australia (%)	Germany (%)	Canada (%)	France (%)	Spain (%)	Italy (%)	Netherland (%)
Article	19917 (1)	4370 (21.94)	2079 (10.44)	1493 (7.5)	1202 (6.04)	1110 (5.57)	1089 (5.47)	608 (3.05)	589 (2.96)	507 (2.55)	441 (2.21)
Editorial Material	1724 (2)	439 (25.46)	61 (3.54)	202 (11.72)	109 (6.32)	75 (4.35)	60 (3.48)	30 (1.74)	31 (1.8)	41 (2.38)	24 (1.39)
Review	1631 (3)	434 (26.61)	86 (5.27)	248 (15.21)	172 (10.55)	75 (4.6)	107 (6.56)	50 (3.07)	46 (2.82)	50 (3.07)	37 (2.27)
Proceedings Paper	572 (4)	98 (17.13)	40 (6.99)	49 (8.57)	23 (4.02)	30 (5.24)	22 (3.85)	18 (3.15)	20 (3.5)	20 (3.5)	24 (4.2)
Letter	416 (5)	82 (19.71)	8 (1.92)	54 (12.98)	34 (8.17)	10 (2.4)	19 (4.57)	8 (1.92)	3 (0.72)	3 (0.72)	3 (0.72)
Correction	258 (6)	29 (11.24)	5 (1.94)	23 (8.91)	7 (2.71)	5 (1.94)	5 (1.94)	4 (1.55)	5 (1.94)	6 (2.33)	2 (0.78)

TP Total research productivity; R Ranking;

3.3 Distribution of journal on climate change articles

On the SCI web, each article is published on a journal. Climate change articles can be published on one or many different journals. In the below table is 20 journal names with total the highest research productivity whereas has many famous journals on SCI, such as: CLIMATIC CHANGE journal has 1105 articles (4.37%) and 1st ranking including 49 articles in 2007 year; 61 articles (2008 year); 60 articles (2009); 71 articles (2010); 89 articles (2011); 109 articles (2012); 166 articles (2013); 99 articles (2014); 90 articles (2015); 84 articles (2016); 114 articles (2017); and 113 articles (2018). Following distantly as GLOBAL CHANGE BIOLOGY journal with 518 articles (2nd ranking, 2.05%); PLOS ONE journal with 495 articles (3rd ranking, 1.96%); REGIONAL ENVIRONMENTAL CHANGE journal has 326 articles (4th ranking, 1.29%); SCIENCE OF THE TOTAL ENVIRONMENT journal with 287 articles (5th ranking, 1.14%); NATURE CLIMATE CHANGE journal has 272 articles (6th ranking, 1.08%); GLOBAL ENVIRONMENTAL CHANGE journal has 253 articles (7th ranking, 1%); SCIENCE journal with 244 articles (8th ranking, 0.97%); JOURNAL OF HYDROLOGY journal has 241 articles (9th ranking, 0.95%); and ENVIRONMENTAL RESEARCH LETTERS journal with 219 articles (10th ranking, 0.87%). Thus, from table 2 shows that CLIMATIC CHANGE journal has the most "climate change" research production in top ten journals on SCI.

Besides, the table 2 can be seen that division of research production in each year in 2007-2018. It indicates some journals grow in publication output and increase sharply in the last years (2017 and 2018 year), such as CLIMATIC CHANGE journal (1st ranking), ENVIRONMENTAL RESEARCH LETTERS journal (10th ranking); and SCIENCE OF THE TOTAL ENVIRONMENT journal (5th ranking). Contrast, there are three journals, which have diminished in the last year as REGIONAL ENVIRONMENTAL CHANGE journal (4th ranking), PLOS ONE journal (3rd ranking), and GLOBAL ENVIRONMENTAL CHANGE journal (7th ranking). Moreover, there are not or very less publication output (0-6 articles in 2007-2010 year) in some journals of climate change articles as REGIONAL ENVIRONMENTAL CHANGE journal, SCIENCE OF THE TOTAL ENVIRONMENT journal, and NATURE CLIMATE CHANGE journal. But they reveal high publication output in many next years. This means climate change field has an important signification on the world and be paid attention by scientists.

Table 2. Distribution of journal in 2007-2018

Journal Type	TP (R)	TP (%)	2007 (%)	2008 (%)	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)
CLIMATIC CHANGE	1105 (1)	4.37	49 (4.4)	61 (5.4)	60 (5.4)	71 (6.4)	89 (8.1)	109 (9.9)	166 (15.1)	99 (9.0)	90 (8.2)	84 (7.6)	114 (10.3)	113 (10.2)
GLOBAL CHANGE BIOLOGY	518 (2)	2.05	14 (2.7)	21 (4.1)	29 (5.7)	31 (6.0)	50 (9.7)	48 (9.3)	55 (10.5)	54 (10.4)	56 (10.6)	48 (9.3)	52 (10)	60 (11.7)
PLOS ONE	495 (3)	1.96	2 (0.4)	3 (0.6)	11 (2.2)	10 (2.0)	23 (4.7)	34 (6.9)	70 (14.1)	75 (15.2)	73 (14.8)	70 (14.1)	60 (12.1)	64 (12.9)
REGIONAL ENVIRONMENTAL CHANGE	326 (4)	1.29	4 (1.2)	1 (0.3)	3 (0.9)	6 (1.8)	40 (12.3)	16 (4.9)	30 (9.2)	46 (14.1)	51 (15.6)	45 (13.8)	49 (15.1)	35 (10.8)
SCIENCE OF THE TOTAL ENVIRONMENT	287 (5)	1.14	2 (0.7)	2 (0.7)	4 (1.4)	3 (1.1)	8 (2.8)	15 (5.2)	14 (4.9)	16 (5.6)	22 (7.7)	51 (17.7)	48 (16.7)	102 (35.5)
NATURE CLIMATE CHANGE	272 (6)	1.08	0	0	0	0	17 (6.3)	29 (10.6)	37 (13.5)	30 (11.1)	54 (19.8)	40 (14.7)	25 (9.2)	40 (14.8)
GLOBAL ENVIRONMENTAL CHANGE	253 (7)	1	8 (3.2)	6 (2.4)	18 (7.1)	18 (7.1)	32 (12.7)	21 (8.3)	37 (14.6)	32 (12.6)	27 (10.7)	12 (4.7)	17 (6.7)	25 (9.9)
SCIENCE	244 (8)	0.97	43 (17.6)	37 (15.2)	21 (8.6)	19 (7.8)	19 (7.8)	13 (5.3)	13 (5.3)	13 (5.3)	17 (6.9)	18 (7.5)	12 (4.9)	19 (7.8)
JOURNAL OF HYDROLOGY	241 (9)	0.95	6 (2.5)	7 (2.9)	9 (3.7)	10 (4.2)	14 (5.8)	29 (12.0)	32 (13.3)	39 (16.2)	24 (9.9)	25 (10.4)	19 (7.9)	27 (11.2)
ENVIRONMENTAL RESEARCH LETTERS	219 (10)	0.87	5 (2.3)	5 (2.3)	12 (5.5)	9 (4.1)	13 (5.9)	10 (4.6)	23 (10.5)	19 (8.7)	28 (12.8)	28 (12.8)	24 (10.9)	43 (19.6)

TP Total research productivity; R Ranking;

3.4 Distribution of country

In calculation of climate change articles on SCI, country category gives us to be known which countries have independent articles or collaborative articles and its research productivity. Via 25278 articles, this research found out 163 countries published climate change articles in 2007-2018 years. Table 3 includes top 20 countries have the highest publication output and Viet Nam is a country, which is 45^{th} ranking. It indicates that USA is 1^{st} ranking with research output as 23286 articles (24.29%) concluding 5369 independent articles (23.06%) and 17917 collaborative articles (76.94%). The 2^{nd} ranking is China with 8782 articles (9.16%), whereas has 2241 independent articles (25.52%) and 6541 collaborative article (74.48%). United Kingdom is ranked the third with 8051 articles (8.4%), in which 2023 independent articles (25.13%) and 6028 collaborative articles (74.87%). The ranking list is followed by Australia 6153 articles (4^{th} ranking with 6.42%); Germany 5079 articles (5^{th} ranking, 5.3%); Canada (6^{th} ranking with 5.07%); France 3365 articles (7^{th} ranking, 3.51%); Spain 2701 articles (8^{th} ranking, 2.82%); Italy 2473 articles (9^{th} ranking, 2.58%); Netherlands 2164 articles (10^{th} ranking, 2.26%); India; Switzerland; Japan; Sweden; Brazil; Norway; South Korea; Denmark; South Africa; and Finland have research productivity from 974 articles (1.02%) to 2105 articles (2.2%) at the 11^{th}-20^{th} ranking. Finally in the below ranking table is Vietnam with 159 articles (45^{th} ranking, 0.63%) including 33 independent articles (50^{th} ranking, 20.8%) and 126 collaborative articles (44^{th} ranking, 79.2%).

Besides, in the Table 2 can be seen clearly that 8 countries are always top ranking in total research production, independent article and collaborative article as USA, China, UK, Australia, Germany, Canada, France, and Spain. Next is Italy (9^{th} ranking), it has independent article number (10^{th} ranking) less than India. Although India is the 9^{th} ranking in independent articles, but it is ranked the 11th in collaborative article and total publication output categories. More over, Japan and Sweden often exchange ranking with each other (13th and 14th ranking) in all three kinds of research output. This exchange ranking also happens in research productivity of Norway, South Korea, and Denmark (16th, 17th, 18th ranking). Some countries have not any ranked changing about research outputs as Switzerland, Brazil, South Africa, and Finland (12th, 15th, 19th, and 20th ranking). Thus, distribution of research productivity by countries demonstrated that USA where had the highest research publication and ranking in all three kinds of research output; Viet Nam ranks the 45th with 159 articles (Table 3).

Table 3. Distribution of country in 2007-2018

Country name	Research productivity		Independent article		Collaborative article	
	TP (R)	TP/TA (%)	P (R)	P/TP (%)	P (R)	P/TP (%)
USA	23286(1)	24.29	5369(1)	23.06	17917(1)	76.94
China	8782(2)	9.16	2241(2)	25.52	6541(2)	74.48
UK	8051(3)	8.40	2023(3)	25.13	6028(3)	74.87
Australia	6153(4)	6.42	1530(4)	24.87	4623(4)	75.13
Germany	5079(5)	5.30	1276(6)	25.12	3803(5)	74.88
Canada	4859(6)	5.07	1284(5)	26.43	3575(6)	73.57
France	3365(7)	3.51	702(7)	20.86	2663(7)	79.14
Spain	2701(8)	2.82	674(8)	24.95	2027(8)	75.05
Italy	2473(9)	2.58	609(10)	24.63	1864(9)	75.37
Netherlands	2164(10)	2.26	509(11)	23.52	1655(10)	76.48
India	2105(11)	2.20	666(9)	31.64	1439(11)	68.36
Switzerland	1644(12)	1.72	377(12)	22.93	1267(12)	77.07
Japan	1626(13)	1.70	367(14)	22.57	1259(13)	77.43
Sweden	1545(14)	1.61	376(13)	24.34	1169(14)	75.66
Brazil	1432(15)	1.49	339(15)	23.67	1093(15)	76.33
Norway	1115(16)	1.16	258(17)	23.14	857(16)	76.86
South Korea	1093(17)	1.14	306(16)	28.00	787(18)	72.00
Denmark	1073(18)	1.12	246(18)	22.93	827(17)	77.07
South Africa	1024(19)	1.07	242(19)	23.63	782(19)	76.37
Finland	974(20)	1.02	237(20)	24.33	737(20)	75.67
Viet Nam	159(45)	0.63	33(50)	20.8	126(44)	79.2

TP Total research productivity; P research publication; R Ranking; TA Total publishing article number

And below Figure 2 presents spatial distribution of independent and collaborative articles via countries on the world shows that research productivity is almost published on all the countries. Which country has big red round dot, it means the scientific productivity in that country is a lot, where as USA has the most research publication. Contrast, which country has small red round dot, it means that country has a few research publication, even there are some countries have very few research output. On the world map shows the countries, which have a lot of research publication almost belongs to USA and Europe country community; a few ones are in Asia countries. Left ones are low research publication. Moreover, the Figure 2 also shows the independent article number and cooperative article number belong to USA in big red round dot and dark blue color. The countries have few research output is revealed by small red round dot and light blue color (0-309 articles in cooperated output and 0-119 article in independent output). The countries are second ranked after USA belongs to China, Australia, Canada, etc. India has 1439 cooperative articles, is performed by light pink color on the world map. Thus, spatial distribution of research publication is divided by 5 classes. In independent publication, 0-119 articles is 1st class, 120-377 articles is 2nd class, 378-702 articles is 3rd class, 703-2241 articles is 4th class, and the last class includes 2242-5369 articles, the class has the most research publication. In cooperative publication has 5 classes as well and is distributed by 5 color kinds, from light blue, yellow, light pink, green, and dark blue, in which the dark blue has the most research publication on climate change articles from 2007 to 2018 year.

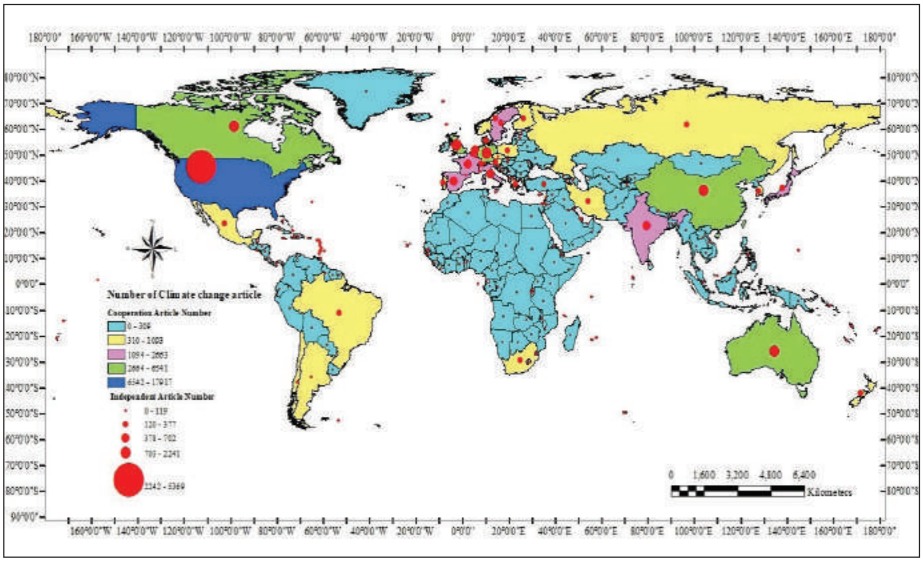


Figure 2. Distribution of independent and cooperative article on the world

4. Conclusion

From 25278 articles published on SCI during 2007-2018, analysis of research productivity provided to be more understanding about climate change field, knowledge deeply of calculation in publication output in many years, some significant points in this research are drawn following as:

Total research productivity increases in yearly and increases sharply in 2018 year, gains to 3325 articles, in which Article form also grows continuously to 2018 year and achieves about 2800 articles in 2018. Moreover, Article form is the highest research production as well with 19917 articles (1st ranking). USA is a country, where has the highest publication output in all the article types and in total research productivity (23286 articles with 1st ranking). It includes 5369 independent articles (23.06%) and 17917 collaborative articles (76.94%).

CLIMATIC CHANGE journal has the most research output with 1105 articles (4.37%), 1st ranking, and it increases sharply in the last years. NATURE CLIMATE CHANGE journal have not any research output in first years of publication period, but its publication grows highly in next year. Besides, there are 163 countries are found in climate change article publication and spatial distribution of research productivity is performed on the world map. The research productivity is almost revealed on all the countries with different scientific productivity quantities; they are classed 5 kinds from low to high publication. Particular, Independent publication is showed from small red round dot to big one, and cooperative publication is perform in different colors, in which USA has the most publication in dark blue and big red dot.

Moreover, the countries have high publication most belong to USA, Canada, Europe country community, and some Asia countries as China, India. Viet Nam is performed by light blue color with 159 articles in total research publication (45th ranking, 0.63%), concluding 33 independent articles (50th ranking, 20.8%) and 126 collaborative articles (44th ranking, 79.2%).

References

1. Almind, T. C., & Ingwersen, P. (1997), "Informetric analyses on the World Wide Web: Methodological approaches to webometrics", *Journal of Articleation*, 53(4), 404-426.
2. Committee on global change research, Board on sustainable development, Policy division, National research council (CGCR), (1999), *Global environmental change: Research pathways for the next decade*, National Academy Press, 2101 Constitution Avenue. N. W. Washington, D. C. 20418. Ian Burton. Antony, J. B., Radford, B., Robert, A. F., Richard, M. G., John, H., Dennes, L. H., Donald, F. H., Charles, F. K., Chrles, E. K., John, E. K., Jacques, L. L., Walter, C. O., Richard, C., Eugene, Z. S., Billie, L. T.
3. Gayatri, M. (2009), *Bibliometric studies in the internet era*, India Publishing House (pp. 1-98), New Delhi.
4. Hatzigeorgiou, E., Polatidis, H., Haralambopoulos, D. (2008), *CO_2 emissions in Greece for 1990-2002: A decomposition analysis and comparison of results using the Arithmetic Mean Divisia Index and Logarithmic Mean Divisia Index techniques*, Energy, 33, 492-499.
5. IPCC. (1995), *Climate Change 1995: The Science of Climate Change.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R. T., Zinyowera, M.C., Canziani, O., Petit, M., et al. Cambridge University Press, Cambridge, UK.
6. IPCC. (1996a), *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific Technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R. T., Zinyowera, M. C., Moss, R. H., et al. Cambridge University Press, Cambridge, UK.
7. IPCC. (2001e), *Climate Change 2001: Synthesis Report.* A contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Watson, R. T., et al. Cambridge University Press, Cambridge, UK
8. IPCC. (2007), *Climate change 2007: The Physical Science Basic.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate change, Solomon, S., Qin, D., Manning, M., et al. Cambridge, United Kingdom; New York, NY, USA, Cambridge University Press.
9. Li, J. F., Wang, M. H., Ho, Y. S. (2011), "Trends in research on global climate change: A Science Citation Index Expanded based analysis", *Journal of Global and Planetary Change*, 77, 13-20
10. Ogilvie, K., Chiotti, Q., Everhardus, E., Friesen, K. (2004), *Primer on Climate Change and Human Health,* Randee Holmes (pp. 6-29), Canada.
11. Susanne, C. M., Lisa, D. (2007), *Creating a climate for change: Communicating climate change and facilitating social change*, Cambridge University Press (pp. 264-289), New York.
12. The Association of Academics of Science in Asia (AASA), (2011), *Towards A Sustainable Asia: Environment and Climate Change*, Science Press BeiJing and Springer Heidelberg Dordnecht (pp. 26-85). Lon Don. New York.
13. Zhang, G. F., Xie, S. D., Ho, Y. S., (2010), *A bibliometric analysis of world volatile organic compounds research trends*, Scientometrics, 83(2), 477-492.
14. Zhang, L., Wang, M. H., Hu, J., Ho, Y. S. (2010), *A review of published wetland research 1991-2008: Ecological engineering and ecosystem restoration*, Ecological Engineering, 36, 973-980.

ASSESSING THE ECONOMIC EFFICIENCY OF CLIMATE CHANGE ADAPTATION MODELS IN THE MEKONG DELTA

Dang Ngoc Diep[(1)], Le Ngoc Cau[(2)], Pham Thi Quynh[(2)], Le Van Quy[(2)], Pham Van Sy[(2)]

[(1)]Ministry of Natural Resource and Environmental

[(2)]Viet Nam Institute of Meteorology, Hydrology and Climate change

Received: 2 July 2020; Accepted: 4 August 2020

Abstract: *The Mekong Delta is considered the largest granary of Viet Nam since most of its cultivated area is continuously supplied by annual alluvium which is significantly fertile and suitable for rice development. However, the region has been highly suffering from climate change such as sea level rise, inundation, salinity intrusion, and erosion which are seriously threatening to agriculture development, food security, and causing damage to social-economic region. As an adaptation to impacts of climate change, many new economic models have been applied in some regions of Mekong delta, and gradually brought certain efficiency in terms of economy such as mangrove cultivating seedling garden (vuon uom), large rice-field, and rice-fish system. In order to apply and replicate these models for other regions in the Mekong delta, it is necessary to have comprehensive assessments on such aspects as ability on climate change adaptation, climate change mitigation, ensuring efficiency and sustainability in line with environment, economy and society. This paper presents approach for formulating and defining a set of criteria used for assessing climate change adaptation models in the Mekong Delta. The results show that all economic models highly adapt to climate change and bring high economic benefits. However, the applicability of some economic models is still limited.*

Keywords: *Climate change adaptation economic model, set of criteria, climate change, Mekong delta.*

1. Introduction

The Mekong delta is the largest granary of the Viet Nam. It plays the most important role in food security policy with contributing more than 50% of rice production in the whole country [1]. Currently, the Mekong delta is facing two major challenges as climate change. It is considered as one of the world's three most deltas to the sea level rise. According to climate change scenarios, in late 21st century, if the sea level rise rises 1m, about 40% of the Mekong delta area will be inundated. In addition, due to the climate change, the intensity and frequency of natural disaster such as droughts, soil and water salinity and other calamities have increased. As a result, it threatens food security and agricultural development, causes great human and property loose, damages social economic and cultural infrastructure, and imposes negative impacts on environment of Mekong Delta [2,3,4]. In response to climate change, over the past years, hundreds of initiatives, solutions, practices and models of climate change adaptation have been implemented, and tested on different scales in many fields across the country [5,6,7,8,9,10,11]. Among them, emerged economic models as potential climate adaptive practices at commune and district levels are on agriculture and forestry such as mangrove cultivating seedling garden (Vuon uom) [6], large rice-field [12], and rice-fish system [6]. They initially bring efficiency in terms of economy and be engaged to expand in the whole region. However, there are only a few sets of evaluation criteria to evaluate the effectiveness of adaptation models. Besides, they still exist many limitations such as

Corresponding author: Dang Ngoc Diep

E-mail: diepvp.ttcp@gmail.com

the criteria set of CARE international in Viet Nam which has not given detailed criteria yet and has not evaluated point of criteria based on the priority of each locality [13]. Another set of criteria in Huynh Thi Lan Huong et al. (2015) also did not give appropriate scores criteria because of not considering the priority level in the context of each locality [14]. In addition, only a few studies have attempted to evaluate overall efficiency of such models with all aspects as ability on climate change adaptation, climate change mitigation/greenhouse gas mitigation, ensuring efficiency and sustainability in line with environment, economy and society. Therefore, the objectives of this work are: (1) Constructing and developing a set of evaluation criteria which covers all aforementioned aspects; (2) Evaluating three pilot economic models to identify their actual efficiency on climate change adaptation based on these criteria.

2. Methodology

The method of assessing the efficiency of climate change adaptation activities is different between scales as on global, national, provincial and local levels [15,16]. Therefore, the set of criteria/indicators evaluating the efficiency of the selected economic models is able to monitor the integration of climate change adaptation activities in sectoral and local plans as well as check their efficiency. These indicators not only measure adaptation processes but also quantify the results.

In Viet Nam, there have been a number of studies developing a set of criteria/indicators to evaluate the efficiency of climate change adaptation models. For instance, the Institute for Water and Environment, under the Viet Nam Academy for Water Resources belong to the Ministry of Agriculture and Rural Development (MARD) developed a set of indicators that evaluates the efficiency of climate change adaptation and mitigation models. CARE (2015) developed another set within its project in the Mekong Delta to identify climate change adaptation livelihood models [13]. Moreover, the SNV Netherlands in collaboration with the MARD proposed the indicators that need to be considered when developing a community-based livelihood model to respond to climate change. VNGO&CC and CCWG (2014) has conducted the research on criteria assessment for a model on response to climate change deployed in Viet Nam. Thereby, a model on response to climate change is assessed based on three criteria as adaptation, mitigation and sustainability index [17]. In the recent study of Le Van Thang et al. (2015), the method of investigation, interview, statistics, expert, SWOT and PRA method was used to develop a set of criteria to evaluate climate change adaptive capacity for models in the central provinces/cities [18]. Additionally, the Center for Sustainable Rural Development suggested a set of indicators for piloting measures to support farmers to develop sustainable livelihoods in the context of climate change. The Viet Nam Institute of Meteorology, Hydrology and Climate Change has also developed a set of climate change adaptation indicators that is appropriate and applicable for Viet Nam to serve the state management of climate change based on the world's index framework [14].

In this study, the major methodology is based upon the results from local consultation, through four main stages: (i) Identifying the content to be consulted; (ii) Identifying the opinions and consensus of the expert group on the content to be consulted; (iii) Identifying reasons in case of disagreement; and (iv) Final evaluation.

In order to have this indicator set of evaluating the economic efficiency of the adaptive models, it is necessary to clearly define each specific group of indicators and criteria. Based on an assessment of the advantages and disadvantages of the methods that monitoring and evaluating adaptation in the world and in Viet Nam along with the consultation results of local departments and the questionnaires from local people who are deploying and implementing the climate change adaptation model, this study has proposed a set of criteria according to the importance of each criterion. The purpose is to evaluate and select effective livelihood models which adapt to climate change to be proposed for replication. A general set of criteria is proposed with 6 main groups of criteria and 33 indicators corresponding to a maximum total score of 100 points; in which criterion on economic efficiency and the target of climate change adaptation showing the most important goal. The corresponding scores for each criterion are shown in the Table 1 below:

Table 1. Set of criteria for assessing economic efficiency of climate change adaptation models in Mekong Delta

Criteria	Content	Point
Socio-economic efficiency		**70**
Economic	1.1. Assessment of market needs	5
	1.2. Assessment of the investment scale	5
	1.3. Assessment of technical capacity	5
	1.4. Productivity	5
	1.5. Product quality	5
Institution	2.1. Regulation	5
	2.2. Financial policy	5
	2.3. Supporting program	5
Culture - Society	3.1. Diversify income sources and create jobs	5
	3.2. Increase number of beneficiaries	5
	3.3. Inherit and promote indigenous knowledge	5
	3.4. Mobilize the participation of women and ensure gender equality	2.5
	3.5. Mobilize the participation of ethnic minority groups	2.5
	3.6. Promote the participation of people with disabilities	2.5
	3.7. Promote the participation of vulnerable groups (single, etc.)	2.5
	3.8. The appropriateness of the model deployment location	5
Ability to cope with climate change		30
Climate change adaptation	4.1. Ability to adapt with current climate change	2
	4.2. Ability to adapt with climate change in the future	2
	4.3. Adjust the crop/seedling structure or source of materials to adapt with climate change	2
	4.4. Take advantage of beneficial opportunities from climate change	2
	4.5. Impacts of greenhouse gases	2
Environment	5.1. Impacts on ecosystems/biodiversity	2
	5.2. Sustainable use of natural resources	2
	5.3. Energy conservation and energy efficiently	1
	5.4. Using renewable energy	1
	5.5. Reduce discharge into water and soil environment	2
	5.6. Increase waste reuse and recycling	2
	5.7. Adaption capacity from the changes of ecosystems	2

Criteria	Content	Point
Ability to cope with climate change		30
Management	6.1. Resources	2
	6.2. Financial resources in the community	2
	6.3. Scientific and technical application	2
	6.4. Risk management plan	2
	6.5. Replication ability	2
Total		**100**

The efficiency of economic models based upon a set of criteria is evaluated according to the rank of scores as <50: poor efficiency, 50-60: low efficiency, 61-80: moderate efficiency, 81-90: high efficiency, and 91-100: very high efficiency.

3. Results

Over the past years, the emerged economic models such as mangrove cultivating seedling garden (Vuon uom) [6], large rice-field [12], and rice-fish system [6] have been recognized to bring benefit for farmer and be engaged to replicate to other regional and Mekong delta. In this section, such economic models are consecutively introduced first, then they are deeply analyzed and assessed based on the new set of evaluation criteria to identify their actual efficiency on both climate change adaptation and society-economy.

3.1. Climate change adaptation models

3.1.1. Mangrove cultivating seedling garden in An Thuy, Ba Tri, Ben Tre

The mangrove cultivating seedling garden is in large scale with area larger than 2.2ha. It is designed and built for long-term use of more than 10 years. Such mangrove species are cultivated including Sonneratia caseolaris (bần chua), Avicennia alba (Mấm), Rhizophora apiculata (Đước), Lumnitzera racemosa Willd (Cóc),... The mangrove cultivating seedling garden helps local resident to be more proactive in cultivating quantity, category and planting seasons than traditional model, in which mangrove trees are collected from natural sources and temporarily cultivated in the garden [6].

Climate change mitigation and adaptation/ GHG mitigation: mangrove species which are nourished for a long time in the garden, strongly develop root and trunk. Therefore, they can cope with serious ecological conditions in the afforestation areas along the outside of the dyke, so they help coastal mangrove ecosystems increase resistance and rehabilitated ability in the context of climate change. In addition, the development of coastal mangrove ecosystems increases carbon absorb ability, contributing to mitigation of greenhouse gas/mitigation of climate change.

Environmental efficiency and sustainability: The economic model helps to increase the resistance and resilience of the coastal ecosystems. Therefore, it has high efficiency and environmental sustainability.

Economic efficiency and sustainability: an area for mangrove cultivation is about 60% of garden's size. There are about 100 pots with an average potting bag of 15 × 25cm, and estimated density of bare-root seedlings is around 250 tree/m^2. An estimated production is approximately 1,000,000 small trees per year after reducing losses of about 20%. If the expected payback is 10 years and the annual depreciation is 223,736,000 VND/year equivalent to 224 VND/tree of depreciation, the price of seedling for sale still ensures profitable business.

Social efficiency and sustainability: Every year, the mangrove cultivating seedling garden provides 25,800 work for local labor, equivalent to 98 workers. Therefore, it contributes to the job creation for local idle workers, increasing income and improving living standards.

Policy efficiency and sustainability: The mangrove cultivating seedling garden is considered a "green model", therefore, it is easy to achieve the approval and support from local government and international organizations.

Replicating ability: the model is suitable for mangrove coastal ecosystem in Mekong delta. Therefore, coastal provinces in the Mekong delta can apply. However, it is depended on character of each region to select species for growing.

3.1.2. Assessment of production model of large rice field in Nga Nam district, Soc Trang

The large rice field is a model of linking 4 intensive rice-growing partners including local government and departments; scientists (from research institutes/university and local research organizations); businesses (input agents, traders, food companies, food security companies, mill and scrub companies); farmer (individual farmer and production cooperation groups). Farmers who join the large rice field, get more benefit than traditional production due to receive cultivated technical assistance (varieties, fertilizers and pesticides) and consumption of the product [12].

Climate change mitigation and adaptation/ GHG mitigation: The large rice-field model significantly depends on natural conditions, so it is still strongly influenced by weather and climate. However, due to receive the technical assistance and advice from experts and scientists, it's ability to adapt to climate change is higher than the traditional production.

Environmental efficiency and sustainability: It can reduce the level of increasing disease, but it has not yet effectively improved the level of impact on environment from natural resources and causing quite high impacts on biodiversity.

Economic efficiency and sustainability: The model reduces investment cost and get high profits compared to traditional production.

Social efficiency and sustainability: Timely risk forecasting and prevention; effective irrigation system; reducing working time; receiving instructions on farming techniques; and getting consumption and supplied product.

Policy efficiency and sustainability: Getting support from local government and scientists.

Replicating ability: The model is quite suitable for cultivation in Mekong delta, so most regional in Mekong delta can apply.

3.1.3. Rice-fish system

The rice-fish system is a model which inter-crops rice and fish. The model is based on the principle of support and using nutrition between rice and fish, it therefore, is energy saving, environmental friendly, and goo adaptation to flood conditions [6].

Climate change mitigation and adaptation/ GHG mitigation: The model is basically implemented on freshwater ecosystems. It is sustainable agriculture production, providing diversification of rice production and adapting quite well to changes of weather and hydrological regime.

Environmental efficiency and sustainability: Rice field is a huge reservoir to reduce flood in large areas, provide habitat for aquatic species and contribute to biodiversity conservation. Besides, fish can eat some harmful insects and limit weeds in the rice field, so farmers use less pesticides in killing grass for rice trees.

Economic efficiency and sustainability: The model helps farmer increase profit compared to just rice-monoculture model. According to survey results during 2005 to 2010, 100% of farmers get interest on average. Extra profit from raising fish is from 8 to 18 million VND/ ha/year.

Social efficiency and sustainability: Utilizing idle times of farmer, settling jobs well, and optimizing agricultural land use.

Policy efficiency and sustainability: It is easy to receive approval and support from local government and international organizations

Replicating ability: The model is easy to apply and implement, especially in localities with large areas of rice cultivation and low-lying terrain. Some other provinces in Mekong delta can apply this model such as An Giang, Dong Thap, Vinh Long,...

3.2. Assessment of economic models adapting to climate change

Table 2 describes the assessment of

economic models adapting to climate change based on the set of evaluation criteria on climate change adaptation, climate change mitigation/greenhouse gas mitigation, efficiency and sustainability on environment, economy, society and policy, and replication ability of the model. The results show that all economic models have a relatively high total scores, ranging from 70 to 80. Among three models, the mangrove cultivating seedling garden gets the highest total score with 85 points. The score of climate change adaptation, climate change mitigation, and efficiency and sustainability on environment are quite high because the mangrove cultivating seedling garden is considered as a green model to enhance the resistance and resilience of coastal ecosystem. However, the score of economic efficiency of the model is lower than the large rice field and rice-fish system because main target of this model is to create materials for coastal forest plantation to mitigate the impacts of climate change. Whereas, the main goals of the large rice field and rice-fish system are to increase economic efficiency, so their score of economic efficiency are higher than the mangrove cultivating seedling garden. However, their score of climate change adaptation, climate change mitigation and efficiency and sustainability on environment are lower. In addition to environmental effectiveness and ability on climate change, the mangrove cultivating seedling garden has the highest potential for replication because it receives a high consensus of local organizations and people. Besides, mangrove tree cultivation is not difficult for local people and the survival rate of tree is quite high. However, the large rice field and rice-fish system much depend on many factors such as topography and consensus among the stakeholders. Therefore, the ability of replication is still low.

Table 2. Assessment of economic models adapting to climate change based on the set of evaluation criteria

No	**Criteria**	**Score**		
		cultivating seedling garden	***Large rice field***	***Rice fish system***
1	Climate change adaptation	30	20	30
2	Climate change mitigation/greenhouse gas emission reduction	10	10	5
3	Efficiency and sustainability:			
	- Environment	10	5	10
	- Economy	5	10	10
	- Society	10	10	10
	- Policy	10	10	10
4	Replication ability	10	5	5
	Total	**85**	**70**	**80**

4. Conclusions

Based on the mentioned data and approach on assessing economic models from set of evaluation criteria, the main results of this study are as follow:

1. The set of evaluation criteria and its major methodology for evaluating the economic models in terms of climate change adaptation is based upon the results from local consultation. The set of evaluation criteria covers and evaluates all aspects such as climate change adaptation, greenhouse gas emission reduction, efficiency and sustainability on environment, economy, society and policy, and ability of replication.

2. The economic models including the

mangrove cultivating seedling garden, large rice field and rice-fish system, although the score for each aspect is quite different because of highly dependent on the main purpose, all models have quite a high total points, ranging from 70 to 85. All models have a high ability on adapting to climate change, mitigating climate change, reducing greehouse gas emission, and having economic and social effectiveness. However, the ability on replication of large rice field and rice-fish system are still limited.

References

1. Bui Chi Buu and Nguyen Thi Lang, (2003), *Application of molecular markers in rice breeding in the Mekong Delta of Viet Nam*, In book Advance in Rice Genetics, Volume 1.
2. Prime Mister Decision, (2011), *The National strategy on climate change*, 2139/QDD-TTg.
3. Central Steering Committee for Natural Disaster Prevention and Control, (2017), *Report on the situation of natural disasters and damage caused by natural disasters in 2017,* Ha Noi.
4. Department of Water Resources Management (DWRM), (2017), *Current situation of water resources - challenges and directions for the management and use of water resources towards sustainable development of Mekong delta*.
5. Le Anh Tuan., Chinawanno, S. (2011), *Climate change in the Mekong River delta and key concerns on future climate threats in a book "Environmental change and agricultural sustainability in the Mekong Delta. Advances in Global Research 45*. Doi 10.1007/978-94-007-0934-8_12.
6. Le Anh Tuan., Le Van Du., Truong Quoc Can., Pham Thi Bich Ngoc., Vu The Thuong, (2011), *Some activities cope with climate change in Mekong Delta*, the project: Capacity building on climate change for some civil organizations in Viet Nam, Can Tho, 2011.
7. Mackey, P and Russell, M. (2011), *Socialist republic of Viet Nam: Climate change impact and adaptation study in the Mekong Delta*, Technical assistance consultant's final report, ADB.
8. Phu Le Vo., Bang Quoc Ho. (2018), *Community-based adaptation to climate change: a case of Soc Trang, Viet Nam*, Resources and Environmental, 8(3): 155-163.
9. Huy Duc Dang. (2019), "Sustainability of the rice-shrimp farming system in Mekong Delta, Viet Nam: a climate adaptive model", *Journal of Economics and Development, Emerald Publishing Limited 1859-0020*.
10. Nguyen Hong Gam. (2019), "Transformation of Mekong Delta economic growth model adaptation to climate change: the situation and solutions", *VNU Journal of Science: Policy and Management Studies*, Vol. 35, No 2, 84-95.
11. Thanh Tam Ho ans Shimada, K. (2019), *The effects of climate smart agriculture and climate change adaptation on the technical efficiency of rice farming-an empirical study in the Mekong delta of Viet Nam*, Agriculture, 9, 99.
12. Nguyen Thi My Linh., Le Phan Dinh Huan., Huynh Van Phung., Phan Ky Trung., Nguyen Van Be., Van Pham Dang Tri. (2017), "Assessing effectiveness of the models of large-scale rice field and traditional rice cultivation in Nga Nam district, Soc Trang province", *Can Tho University Journal of Science: Environment and Climate Change*, 2: 45-54.
13. CARE. (2015), *Action Research on Climate Resilient Livelihoods for Land poor and Landless People Vietnamese*.
14. Huynh Thi Lan Huong. (2015), *Development of adaptation indicators sets for efficiency of adaptation actions to serve the state management of climate change activities*, Viet Nam Institute of Meteorology, Hydrology and Climate change (IMHEN).
15. Chu Thi Thanh Huong, Huynh Thi Lan Huong, Tran Thuc. (2017), "Developing the Indicators for Monitoring the Adaptation Actions for Quang Ngai Province, Viet Nam using the Delphi Technique", *International Journal of Sciences* 06(2017):80-86 DOI: 10.18483/ijSci.1341.

16. MCD. (2015), *Livelihood adaptations to climate change for local people in the Red River Delta.*
17. Le Van Thang et al. (2015), *Scientific basis for selecting and completing models of community-based adaptation to climate change in Central Viet Nam and replication proposal*, BDKH-18/11-15
18. VNGO&CC and NGO's (The Network of Vietnamese NGOs and Climate Change (Climate Change Working Group (CCWG)). (2014), *Livelihood Adaptation to Climate Change: Evaluation Criteria and Typical Performances.*

ASSESSMENT OF ENVIRONMENTALLY SUSTAINABLE CITY IN VIET NAM: A CASE STUDY OF BAC NINH CITY, BAC NINH PROVINCE

Cung Hong Viet[1], Pham Thi Mai Thao[2], Bui Hoai Nam[3]

[1] *Viet Nam Institute of Meteorology, Hydrology and Climate Change*

[2] *Ha Noi University of Natural Resources and Environment*

[3] *Institute of Environmental Science, Viet Nam Environment Administration*

Received: 6 July 2020; Accepted: 3 August 2020

Abstract: *The aim of this study is to indicate the pathways and activities in reaching sustainable development in Viet Nam. In particular, the process of becoming an environmentally sustainable city in Bac Ninh city (11th goal - National action plan for implementing the 2030 Agenda for sustainable development) is analyzed. Viet Nam's environmentally sustainable city criteria are selected as an assessment tool in this case study (introduced through the Prime Minister Decision No.196/QĐ-BTNMT on 18/02/2014). Documents and statistical data in this study were provided by the local authorities and companies located. The results showed that: (i) Viet Nam's general efforts in sustainable development is significant. They are planned specifically, followed by a clear pathway and detail objectives together with particular action in the Viet Nam's SDGs; (ii) With regards to Bac Ninh assessed results: Water indicators scored 400/500, atmospheric indicators scored 360/400, Solid Waste indicators, and Responding to Climate Change indicators are 260/300, and 240/400, correspondingly. Based on the assessment instructions, Bac Ninh city is ranked "Good" in relation to the Viet Nam's environmentally sustainable city criteria. The study could be otherwise adopted for other regions of Viet Nam given the similarity and homogeneity of Bac Ninh City to other developing urban areas. The set of criteria could possibly be used as an assessment tool with the intention of assessing the Viet Nam national action plan for implementing the 2030 Agenda for sustainable development.*

Keywords: *Viet Nam, Bac Ninh, sustainable development, sustainable development goals, environmentally sustainable city, criteria, indicators.*

1. Introduction

1.1. The term of sustainable development

"Sustainable development" was first introduced in the United "Nations Conference on the Human Environment. In most simple terms, "sustainable development" is achieved when all sectors within a country reached its sustainability. This comprises of the balance between worldwide economic development and ensuring the maintenance of core ecosystems. The significant growth of population size around the world leads to an over-increase in human needs. Therefore, the key point, which needs to be concentrated on is ensuring the sustainability of economic, social, and environmental systems.

Since urban areas management is included, "environmentally sustainable cities" appeared. According to Richard Register, "environmentally sustainable cities" are those designed with many requirements related to environmental impacts, human demands on input resources, such as energy, water, foodstuffs and minimizing as least as possible in the amount of solid waste, which causes air pollution, soil pollution, and water pollution" [11]. In summary, the relationship among three of them is shown in Figure 1 below.

Corresponding author: *Cung Hong Viet*
E-mail: hongviet97@gmail.com

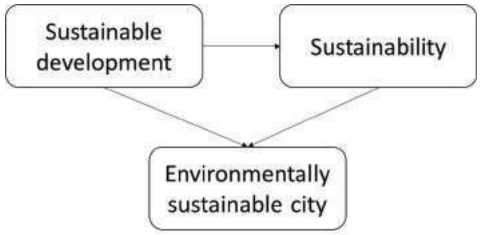


Figure 1. Formation history of the concept environmentally sustainable city

1.2. Orientation pathways to pursue sustainable development around the world and Viet Nam

The 2030 Agenda is considered as a final result - a combination of a long-period effort of finding a comprehensive direction that can lead the world to sustainable development. In detail, the 2030 agenda has been motivated from previous meetings including the United Nations Conference on Environment and Development at Rio de Janeiro, Brazil (1992); The World Summit on Sustainable Development at Johannesburg, South Africa (2002); and Brundtland report [21], the UN conference on environment and development [16], the Millennium Declaration [17], and the UN Conference on Sustainable Development [5]. The 2030 Agenda was agreed by The United assembly (leaders from 193 nations in the globe) in the 70th meeting took place from 25-27 September, 2015 in New York.

The release of the Sustainable Development Goals (SDGs) is a great endeavor of the United Nations Development Program (UNDP). They are a collection of 17 global goals (Figure 2), which are designed to be a "blueprint to achieve a better and more sustainable future for all" [19]. The SDGs are set in the year of 2015 and meant to be achieved by 2030.

The new 17 SDGs was associated with 169 targets. They are all linked to the three basic pillars of sustainable development system: the economic, social, and environment. Despite of being illustrated as 17 separate goals, they are systematically interrelated to each other. They can, in turn, affect each other whether positively or negatively.

The SDGs are assumed as a challenge but also opportunity for all countries. In order to achieve those goals and objectives, nations have to reach the establishment of an advanced and determined system at a country level. By initiating rules and regulations with follow-up assessment and review of these goals at local, national, even global level, governments and their associated bodies dedicate their responsibility and compromise in sustainable development. Otherwise, because of those goals require many changes of the economic system, for instance reconstruction and completing economic structure towards environmentally friendly; encourage using energy and natural resources efficiently with high added value, etc.

Opportunities gained from those actions appear when it comes to analyze foreign direct investment (FDI). Although many previous studies have showed that FDI has a positive influence on the environment. Baek has examined that FDI deteriorates the environment [5]. On the other hand, Zarsky has concluded that FDI inflow brought higher environmental standards and state-of-the-arts technologies, which are found that beneficial to the environment of a country [22]. The research of Asghari (2013) has calculated that FDI inflow showed a weak statistically significant negative relationship with CO_2 emission, which meant that it actually does not related to the environmental degradation [1]. Furthermore, a study of Kim and Baek applied an auto-regressive distributed lag model, the result came out that FDI has little effect on environment in both developed and developing nations. In general, it is clear that implementing SGDs can bring more positive rather than negative effects on the long run [7].

With the help of the United Nations Development Program (UNDP), Viet Nam has introduced its own National Action Plan for the Implementation of the 2030 Sustainable Development Agenda. Similar to the global SDGs, Viet Nam has introduced 17 SDGs with the consultation of ministries, provincial agencies, civil society, and development partners. However, as regards to the indigenous situation, there were only 115 targets (54 targets less than that of national SDGs) [10].

Figure 2. Seventeen sustainable development goals [6]

1.3. The appearance of environmentally sustainable cities around the globe and Viet Nam

Alongside the development of urban areas worldwide, many models of environmentally friendly and sustainable cities have been created. This study is to take the definition of “environmentally sustainable cities” throughout the article. There have been many environmentally sustainable cities sets of criteria adopted which can be mentioned as The United Nations Urban Environmental Accords (UNUEAs) (2005), EU Catalogue of Criteria for Sustainable Settlements (EUCCSSs) (Jaroslav Coplák, 2013), the ASEAN Green city index (AGC) (EIU), etc. All of the aforementioned criteria were created with an aim to set off objectives for an urban future of ecologically sustainable, economically dynamic, and socially equitable. Specifically, the UNUEAs has been signed by more than a hundred mayors who have been already started applying the accords for their own cities [15]. This was true to the EUCCSSs which has been researched and aimed to put forward its own vision of a sustainable city and also indicated its rationality under the special condition of the seven selected model areas in several European countries [6]. The AGC was supposed to measure and rate the environmental performances of a total of 22 cities in Asia. Those are similar as all of them are capital cities as well as certain leading business centers, which was chosen for their size and importance: Trnava (Slovakia), Bad Ischl (Austria), Barcelona, Győr (Hungary), Tampere (Finland), Tübingen (Germany) and Umbertide (Italy) [12].

In the area of Southeast Asia (SEA), the Working Group of Environmental Cities (AWGESC) was constituted in June 2003. The Group appeared in the circumstance that all 11 members of The Association of Southeast Asian Nations (ASEAN) were developing at distinctive levels, though, facing serious environmental-related issues such as environmental pollution, untreated solid waste, air pollution, water pollution, managing urban areas unsystematically, etc. After a whole host of working group conferences and meetings, in Brunei (2006), the 4th AWGESC meeting has met to an adoption of a comprehensive set of criteria related to environmental sustainability.

Viet Nam as a member of ASEAN, has already adopted a set of criteria of environmentally sustainable cities. This particular set of criteria is based on Viet Nam's National Environmental Protection Strategy to 2020 with the vision to 2030, Viet Nam's National Green Growth Strategy in 2011-2020 with the vision to 2050, Viet Nam's National Program on Urban Development in 2012-2020, Viet Nam's National Strategy on Climate Change. Viet Nam's environmentally sustainable city criteria (VNESC) are adopted by the Ministry of Natural Resources and Environment to serve as a comprehensive tool with the intention of providing raw information on assessing environmental sustainability and environmental challenges, which cities in Viet Nam are facing to both the authorities and residents. It is used to point out the problems, and the unmet requirements. Hence, those cities will have a broad perspective on what they have to put more effort into the pursuance of becoming environmentally sustainable cities [14].

This research provided a case study for the Bac Ninh City in Viet Nam. The effectiveness of developing toward environmental sustainably is thoroughly studied using the VNESC. Regards to this new global perspective and trend, it is now considered as critical to start evaluating and ranking cities throughout Viet Nam with those criteria. Furthermore, this study not only assesses the effect of evaluating a city using the VNESC but also provides valuable information for policymakers to both summarize, and also rank all potential environmental sustainable cities, which will be used to achieve the 11th goal SDGs in general down the road.

2. Study area

Bac Ninh city is an administrative unit of Bac Ninh Province with the population of 56,663 people. This city located in the north-eastern of the province, and located close to Bac Giang Province. The distance from the Ha Noi to Bac Ninh city is roughly 35km southward. The total area of the city measured is approximately 82.60km^2. Figure 3 below is a brief view of the study area in Bac Ninh city.

In particular, Bac Ninh city is divided into 19 hierarchy systems, including 16 sub-districts (Dap Cau, Thi Cau, Vu Ninh, Suoi Hoa, Ninh Xa, Tien An, Ve Anh, Van An, Kinh Bac, Dai Phuc, Vo Cuong, Van Duong, Hap Linh, Phong Khe, Khuc Xuyen, and Khac Niem) and 03 communes (Hoa Long, Kim Chan, and Nam Son). This city is the heart of the whole province, with developed economic and high-quality living standards. On account of this development, Bac Ninh city was awarded as Category-1 City in 2018. The development of a city shares a similar pattern of the increase of environmental pollution, such as untreated municipal solid waste or the growth of AQI index - which represents the level of air pollution in the area, etc. Therefore, in order to ensure the progress on track, the authorities need to redress the imbalance between economic, society, and environment. In other words, it means leading the city towards environmentally sustainable development in a long-term period.

Figure 3. Study area

3. Materials and research methodologies

This research flow is as described in Figure 4. Specifically, input data are statistical data and survey ones. The former is processed by applying the VNESC, while the latter is summerized from 101 samples. The comparison between the outputs illustrated that the city's reports are relatively detail, and citizens 'thoughts are with the authorities. Finally, the evaluating results of Bac Ninh city' accuracy is to confirm by sociological investigation and conclude at the end of the article.

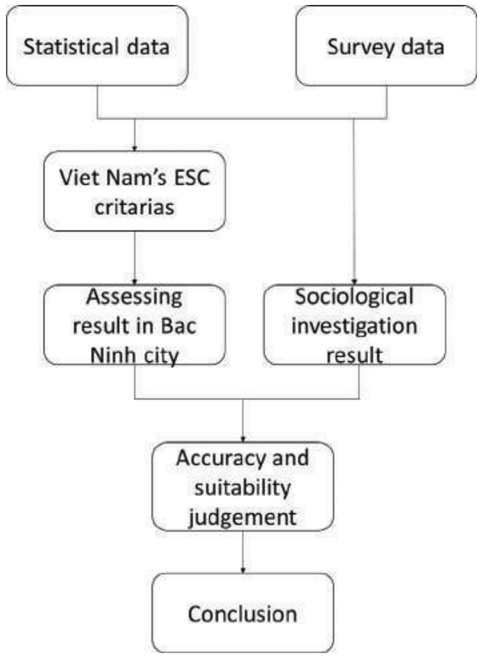


Figure 4. Research structure

In detail, those statistical data that needed and its sources are listed in Table 1.

Table 1. Sources of statistical data

No.	Name of Document	Source
1	Planning industrial clusters in Bac Ninh province to 2020, vision to 2030	People's Committee of Bac Ninh province
2	Statistical yearbook of Bac Ninh province in 2017	Bac Ninh Department of Statistic
3	Socio-Economic Situation Report 2018 in Bac Ninh Province	
4	Report on environmental protection in Bac Ninh province in 2018	Bac Ninh Department of Natural Resource and Environment
5	Regulation on drainage management of Bac Ninh city	
6	Project "Building a smart city model in Bac Ninh province in the period of 2017-2022 with a vision to 2030"	
7	Summary report on the implementation of the natural resources and environment monitoring network	Bac Ninh province Center for monitoring natural resources and environment
8	Bac Ninh Climate Change Action Plan period of 2021-2030, with vision to 2050	People's Committee of Bac Ninh city
9	Planning the network of passengers on fixed routes and bus stations in Bac Ninh province to 2025, orientation to 2030	

No.	Name of Document	Source
10	Report on the results of the implementation of socio-economic development tasks in 2018, directions for tasks in 2019 of Bac Ninh city	Bac Ninh city Natural Resources and Environment Department
11	Report on environmental protection in Bac Ninh city in 2018	
12	Summary report on the implementation of the network of natural resources and environment monitoring in 2018 of Bac Ninh province	
13	Report on current situation of water supply in Bac Ninh city	The Bac Ninh Water Supply and Sewerage Company Limited

Those statistical data above are collected and will be provided into the VNESC. After the calculation process, the result is indicated under a number (out of 100), which represents the environmental sustainability level of the city. Otherwise, there were a few surveys taken in-person with officials in Bac Ninh city Natural Resources and Environment Department to keep surveyed results neutral. It then will be compared with statistical data to ensure the correlation is rational. The final consequences will be a reference for decision-makers to find out the suitable management methodologies related to urban areas in light of sustainable development.

The total number of survey samples are calculated using the formulation of Yamane (1967)[(1)], which are 101 samples needed to be asked. Surveyed locations are chosen based on areas that containing many production activities with a bunch of environmental pollution phenomena occurred. Details are shown in Table 2.

Sociological questions in this study is constructed based on the pattern of the VNESC to reaffirm the reliability of statistical data provided by the authorities. A sample has 28 questions, divided into 05 main sections (i) Section 1: General information includes full name, age, gender, number of family members, and address (5 questions); (ii) Section 2: Safe water supply and collecting and treating wastewater assessment includes questions related to sources, quality, demands, supply systems and operating status of production facilities (7 questions); (iii) Section3: Air quality assessment includes questions related to air quality, air pollution and its impacts to human health (9 questions); (iv) Section 4: Collecting and treating solid waste includes questions related to solid waste and recycling (4 questions); (v) Questions related to urban areas includes questions related to green facilities, public transportation usages (3 questions).

Table 2. Numbers of samples (divided into areas)

No.	Surveyed areas	Numbers of samples
1	Centre areas (including sub-districts Suoi Hoa, Ninh Xa, Tien An, Ve An, Kinh Bac)	40
2	Sub-districts including Khac Niem, Phong Khe, and Vo Cuong	40
3	Hoa Long commune	21

[(1)] *The total number of samples* $n = \frac{N}{1 + N.e^2}$ *(with N: Bac Ninh population; e: error in this situation is taken 0.1)*

4. Results and discussion

4.1. Environmental sustainable development city assessing in Bac Ninh city

4.1.1. Implementing Water indicators results

There are 05 indicators in the Water indicators. In this case study of Bac Ninh city, they are evaluated based on these legal documents (i) National strategy on water resources to 2020 (promulgated under the Prime Minister's Decision No. 81/2006/QD-TTg on April 14, 2006); (ii) Decision No. 605/QD-UBND of Bac Ninh City People's Committee on water supply planning for Bac Ninh province to 2030, vision to 2050, dated May 27, 2013; (iii) National target program on new rural construction of Bac Ninh province in 2015 and the period of 2016-2020 (issued under Decision No.1085/QD-UBND of Bac Ninh province People's Committee (October 16, 2014); (iv) Decree No. 80/2014/ND-CP on drainage and wastewater treatment with regulations on domestic wastewater of Bac Ninh province People's Committee (August 06, 2014).

- *The ratio of clean water accessing population*: Most of sub-districts and communes in Bac Ninh city have been actively implemented and invested in installing both systems of water supplying and treating for the good of residents [8]. Up to now, there have been 03 water supply plants built with the total average water supply capacity of up to 37,000 m^3/day. Sources are mixed of surface water (Cau River, Duong river, and inland fields) and groundwater. According to reports from Bac Ninh authority, the percentage of households in Bac Ninh city has increased since 2017 and reached 95% [2].

- *The scope of service of the drainage system:* Bac Ninh city is currently using a pipeline sewer system, which was built over the different periods since the time the drainage system was formed. This system has 03 levels, drainage network level 1 to level 3. They are divided hierarchically, served with the objective of connecting the drainage system all the way from small towns to the city center. Hence, limiting flooding happens and draining water for a specific area, region, or inter-region. According to the consultation results of ministries working at Bac Ninh Department of Environmental Protection, currently, the estimated service area of the drainage system in Bac Ninh city is about 80%.

- *The ratio of water loss in supplying:* The Bac Ninh Water Supply and Sewerage Company Limited (a state-owned enterprise) is handed in charge of managing, operating, and also exploiting water supply in Bac Ninh city, issued by Bac Ninh Department of Planning and Investment. Since 2008, this company has been synchronously installing new water meters and implementing a detailed anti-water loss plan with flow control devices, pressure remotes, and leaked water detectors all equipped, simultaneously. As results of these efforts, water loss has been controlled, witnessed a gradual reduction over years, from 21.84% (2008) to under 18% in 2012, envisaged to be maintained under 19% down the road [13]. Furthermore, with regards to a report in 2013, the water loss ratio of Bac Ninh city ranged from 12-18%, the objective is to maintain at 17% for the urban area by the year of 2020 and the target for the period of 2030-2050 is reduced to 15% [8]. In conclusion, to sum all the figures above up, the current ratio of water loss in Bac Ninh city is estimated at 17% [20].

- *The ratio of domestic wastewater is collected and treated up to standards:* According to the thesis of Viet H. C. (2019), this ratio is calculated based on the Decree No. 80/2014/ND-CP, which is 76% [20].

- *The rate of production and business establishments that treat wastewater up to standards:* There are a total of 06 main industry-related areas in Bac Ninh city, with 01 industrial areas (Que Vo) and 05 industrial clusters (Vo Cuong, Phong Khe I, Phong Khe II, Khac Niem, Khuc Xuyen) [9]. Recently, there are only two out of 06 facilities mentioned above have already built concentrated wastewater treatment plants. It is estimated that the ratio is approximately 33.3% [20].

4.1.2. Implementing Atmosphere indicators results

There are 04 indicators in the Atmosphere indicators. The action of natural resources and environment monitoring system in Bac Ninh province, and in Bac Ninh city particularly is based on these legal documents (i) The Law 55/2014/QH13: Environmental Protection promulgated by The National Assembly 13 on June 23, 2014; (ii) Decision No. 16/2007/QD-TTg of Prime Minister on Approving the master plan on the national monitoring network of natural resources and environment till 2020 (dated January 29, 2007); (iii) Decision No.1618/ QD-UBND of People's Committee of Bac Ninh province of Approving the project "Reviewing and evaluating the natural resources and environmental monitoring network in Bac Ninh province in the period of 2010 - 2015 and adjusting the natural resources and environmental monitoring network in the period of 2016-2020" (dated December 23, 2015); (iv) National Technical Regulation on Ambient Air Quality (QCVN 05:2013/BTNMT) promulgated by the Minister of Natural Resource and Environment.

- *The frequency of monitoring ambient air quality each year:* Monitoring network of the natural resources and environment is one of the important tasks under the Master plan and strategies for natural resources and environment protection up to the year 2020. This task is assigned to Bac Ninh province Center for Natural Resources and Environment Monitoring cooperates with Viet Nam Academy of Science and Technology (VILAS 366, VIMCERT 079) and the Technical and Environmental Analysis Joint Stock Company (VIMCERT 006) [4]. Currently, there are a total of 12 ambient air quality monitoring locations around Bac Ninh city area (as described in Figure 5). They are distributed quite extensively, systematically, feasibly by socio-economic regions. In a specific year (2018), 06 monitoring rounds were done in February, April, June, August, October, and November, respectively.

Figure 5. Distribution of 12 ambient air quality monitoring locations in Bac Ninh city

- *The average concentration of PM_{10} per year, compared with the standards*: Ambient air quality monitoring data on PM_{10} for all 12 locations in Bac Ninh city (shown in Figure 6) are within the range prescribed by QCVN 05:2013/ BTNMT (average of 24 hours). However, 02 of the highest figures appeared in 02 industrial clusters Phong Khe I and Phong Khe II (101,9 μg/ m^3 and 91,5 μg/m^3, respectively). Furthermore, the monitoring round in April and November witnessed the highest PM_{10} average concentrations throughout the year of 2018 [21].

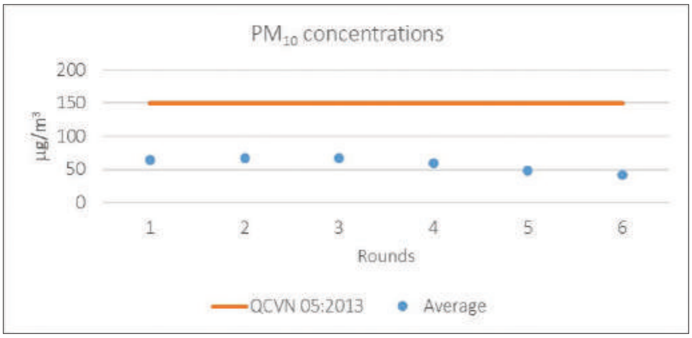


Figure 6. Average PM_{10} concentration results in 6 rounds

- *The average concentration of SO_2 per year, compared with the standards:* Figure 7 describes SO_2 concentration monitoring results over 06 rounds of the year 2018 in Bac Ninh city. An unprecedented result came out at Phong Khe I in the February monitoring round. It was higher than other locations with 127 µg/m³ (the limit is 125 µg/m³). In overall, the average of air quality data related to SO_2 monitored in 12 locations within Bac Ninh city in 2018 was under the limit of QCVN 05:2013/BTNMT (average of 24 hours). As regards the average SO_2 monitoring data in 2018, the highest number was seen in February and the lowest was 6th round in November.

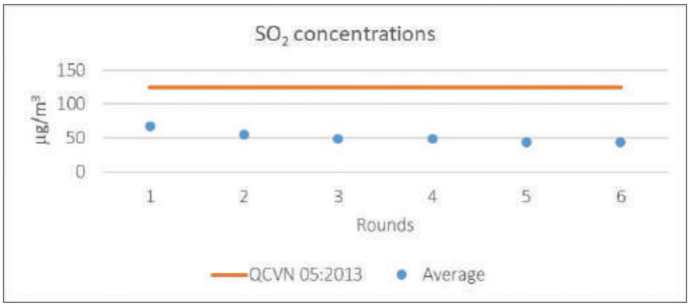


Figure 7. Average SO_2 concentration results in 6 rounds

- *The average concentration of NO_2 per year, compared with the standards:* The limit of NO_2 concentrations indicated in QCVN 05:2013/BTNMT is 100 µg/m³ (average of 24 hours). In 2018, there were 6 rounds conducted in all 12 monitoring locations on NO_2 concentration within Bac Ninh city. As consequence, the average results of all 6 rounds satisfied the required range. In comparison, the first round of 2018 showed the highest number with 61.3 µg/m³. Nevertheless, this reduced gradually in each round later, ended up at 48.4 µg/m³ in the round of November. Details are indicated in Figure 8 below.

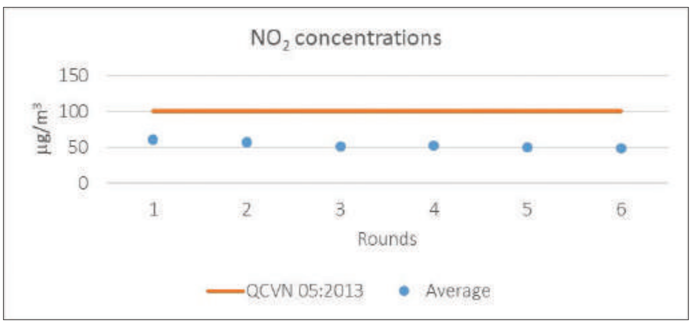


Figure 8. Average NO_2 concentration results in 6 rounds

4.1.3. Implementing Solid Waste indicators results

There is a total of 03 indicators in the Solid Waste indicators. Daily-life solid waste in Bac Ninh city is collected and treated following the scheme “Solid waste treatment in Bac Ninh province” and other related legal documents.

- *The ratio of collected and treated solid waste:* Solid waste collecting and treating in the area of Bac Ninh city is handed into the Bac Ninh Environment and Urban Works Company Limited (under the management of Bac Ninh city People’s Committee). On average, the whole Bac Ninh city generated approximately 130-150 tons of solid waste/day [20]. With regards to the report of environmental protection in Bac Ninh city 2018, the rate of domestic waste solid has been collected and treated was about 91.5%.

- *The ratio of collected and treated hazardous solid waste up to standards:* There are 03 fundamental sources of hazardous solid waste generation in Bac Ninh city, they are daily-life solid waste generated from households; industrial solid waste generated from factories, industry-related areas, industrial clusters; and medical solid waste generated from medical care centers and hospitals of sub-districts and communes. According to the statistic reports from Bac Ninh Department of Natural Resources and Environment, the volume of treated domestic solid waste in Bac Ninh province is up to 90% (20% higher than that of 2017). The standardized treatment ratio of hazardous medical solid waste and hazardous industrial one was 100% and 95%, respectively. In summary, the ratio of collected and treated hazardous solid waste is about 95% averagely [3,20].

- *The ratio of solid waste has been reused, recycled, energy recovered, or produced fertilizer:* These days, it is still witnessed a relatively low ratio in the rate of solid waste has been reused, recycled and energy recovered. Although there have been a little number of families approached this environmentally friendly activity, it still has a bunch of things to do in order to spread out all over the city. Recently, most households choose to sell those kinds of waste rather than recycling. According to a report from Bac Ninh Department of Natural Resources and Environment, the rate of recycling solid waste in the whole province in 2018 was 10% [3].

4.1.4. Implementing Responding to Climate Change indicators results

This criterion is a combination of 04 major indicators, which focus on green urban areas, green energy using, public transportation, and adapting to climate change.

- *The total area of public greenery per capita:* The socio-economic development in Bac Ninh city is on its high speed of growing with a large majority of land area has been converted into buildings. Hence, this tendency inadvertently has put pressure on the environment, in particular lack of trees and green facilities. Nevertheless, governors in Bac Ninh city have considered this matter carefully, many parks and green spaces were built. In 2018, the total area of trees and water surface in the city was 1,740.731m^2, which means approximately 7.4m^2 per capita.

- *The ratio of renewable energy in the total energy use structure:* The use of renewable energy in Viet Nam generally, and in Bac Ninh specifically is sill assumed as a difficult and complex action. There is not yet much specific information, data to analyze the ability and potentiality of renewable energy in Viet Nam enough for related organizations to invest in. Currently, the city has not yet reported the proportion of renewable energy consumption in the total energy structure on account of lacking evaluation data [20].

- *The ratio of public passenger transport:* The main means of public transports in Bac Ninh city is bus and coach. In fact, the more the socio-economic developed, the more increase in citizens’ demand for transportation. Therefore, passenger transport by bus has become an indispensable necessity, especially in densely populated areas. According to the proposal of “Proposing Bac Ninh city as Class-1 city under Bac Ninh province”, the public passenger transport system was reported currently meets 53.47% of residents’ traveling demands within the city.

- *Promulgating Action Plan on Climate Change:* The Action Plan on Responding to Climate Change of Bac Ninh province in the period of 2021-2030, vision 2050 was promulgated in the Decision No.699/QD-UBND by People's Committee of Bac Ninh province (It was built followed The National Target Programme for Climate Change Respond). The overall objectives of the Plan include strengthening the province's capacity to cope with climate change in the period of 2010-2015, vision to 2020. In particular, it ensures the socio-economic development towards sustainability, protects the livelihoods of residents, and mitigates hazards of climate change. All of those are tasks, step by step to be finished, and thereby contributing positively to Viet Nam's general efforts in climate change mitigation and adaptation.

4.1.5. Final results

By summarizing assessed parts of 04 main criteria above and following the instructions of the VNESC, this study has initially and fundamentally figured out the level of the environmentally sustainable city oriented process of Bac Ninh city. Indicators related to solid, atmosphere, and water have been done relatively well with completed ratios of 90%, 86%, and 80%, respectively. The criterion of responding to climate change has a total point of 240 out of 400 (60% completed). Specific grading is illustrated in Table 3 below:

Table 3. Summary of assessed indicators

Criteria		Indicators	Level of completion	Point
Water	1	The ratio of clean water accessing population	95%	100
	2	The scope of service of the drainage system	80%	100
	3	The ratio of water loss in supplying	17%	60
	4	The ratio of domestic wastewater is collected and treated up to standards	76%	100
	5	The rate of production and business establishments that treat wastewater up to standards	33.3%	40
	Total			**400/500**
Atmosphere	6	The frequency of monitoring ambient air quality each year	6 rounds/year	60
	7	The average concentration of PM_{10} per year, compared with the standards	Required QCVN 05:2013/ BTNMT	100
	8	The average concentration of SO_2 per year, compared with the standards	Required QCVN 05:2013/ BTNMT	100
	9	The average concentration of NO_2 per year, compared with the standards	Required QCVN 05:2013/ BTNMT	100
	Total			**360/400**
Solid waste	10	The ratio of collected and treated solid waste	91.5%	100
	11	The ratio of collected and treated hazardous solid waste up to standards	95%	100

Criteria		Indicators	Level of completion	Point
Solid waste	12	The ratio of solid waste has been reused, recycled, energy recovered or produced fertilizer	10%	60
		Total		**260/300**
Responding to climate change	13	The total area of public greenery per capita	7.4m^2 per capita	40
	14	The ratio of renewable energy in the total energy use structure	yet to record	0
	15	The ratio of public passenger transport	53.47%	100
	16	Promulgating Action Plan on Climate Change	Promulgated	100
		Total		**240/400**
Final total point (converted into scale point of 100)				**1260/1600 = 78.75**

The final total point (FTP) is represented for the level of environmental sustainability that Bac Ninh city is currently achieving. The scale points are divided into 04 different group: (i) FTP ≤ 40: yet to achieve; (ii) 41 ≤FTP≤ 60: achieved; (iii) 61 ≤ FTP ≤ 80: good; (iv) 61 ≤ FTP ≤ 80: very good. The FTP of this study conducted in Bac Ninh city is 78.75. Since it belongs to the range from 61 to 80, therefore based on VNESC's instructions, Bac Ninh city is evaluated as a good completed city.

4.2. Sociological investigation outputs

A total of 101 samples have been conducted in those determined districts and sub-districts in Bac Ninh city. Specifically, the ratio of genders between males and females are 51 samples (50.5%) and 50 samples (49.5%), respectively. They were from a wide range of ages, from 18 to 65 years old. Averagely, those who were asked said that there are 02-04 people in their family, accounted for 74.3%. All 101 citizens shared that they had access to the source of treated water came through the plant, and the water volume also met their demands. There are 70 residents told that Bac Ninh city already had a water treating plantIn particular, there are 68% of the total samples show that residents have access to the final drainage that leads to treating plants. When It comes to efficiency, nearly half of participants interviewed share their thought that they are satisfied with the outputs of the treating process. Details are shown in Figure 9 and Figure 10.

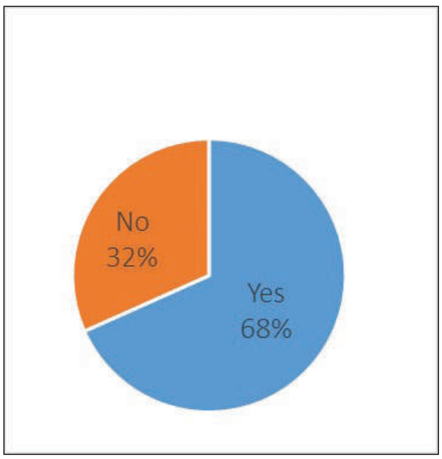


Figure 9. Ratio of having access to the drainage

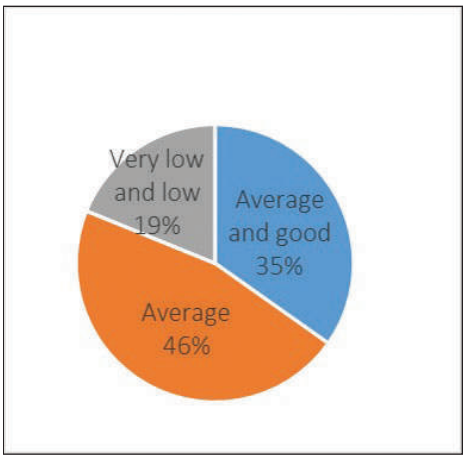


Figure 10. Ratio of households have waste water treated

Although the average monitored concentrations of 03 substances PM_{10}, CO_2, SO_2 showed positive results, 52 people (51%) sill presumed the air quality is polluted. These negative comments have a similar point, all come from citizens living in the areas near industrial areas and industrial clusters. The types of industry in Bac Ninh city are commonly producing paper and noodles, which release many smoke attached with hazardous contaminations.

In part of solid waste management, most people answered that waste is collected by the environmental company twice every day, however, they still do not treat garbage separately. The number of households did recycle accounted for 93% in total (94 samples), nevertheless, hazardous garbage such as old bulbs, batteries were not sorted out. Finally, the majority of respondents satisfied with the greenery with the city, stood at 86%. In the contrary, public transportations appeared uncommon in Bac Ninh city, there are just 37% of respondents have used this kind of transport, in particular, 25% of those were using it for everyday purposes.

The sociological survey provided the outcomes that are relatively comparable with analysis results. Nevertheless, some unprecedented points still occurred. Those differences are attributed to the uneven distribution of the environmental issues, majorly happened in the sectors of industrial areas, and industrial clusters. Hence, they polluted these areas and affected the livelihoods of citizens in surrounding neighborhoods. Others can be listed as the struggle in collecting solid waste, citizens within the city do not usually put their garbage at the right places; solid waste treating capacity is under pressure, garbage is still being buried in landfill side rather than using incinerator; hazardous waste has not been classified; public greenery is mostly located in the center, but sub-urban areas [20].

5. Conclusions

In the 1980s, a new pathway of developing the world has been considered and introduced. It was built based on the basis of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In 2015, according to the environmental situation, and also the socio-economic status, nations of The United Assembly gathered in New York have determined that the world need a comprehensive plan, hence, the Agenda 2030 was adopted, attached with 17 major objectives that nations have to reach by the year of 2030. Viet Nam as a developing nation, has indicated its responsibility to the global prosperity by adopting the National Action Plan for the Implementation of the 2030 Sustainable Development Agenda with 17 national objectives with each related targets. This plan is adopted, and served as Viet Nam's highest hierarchical legal foundation, which shows Viet Nam's efforts for sustainable development. It is the result of a long term period of striving and consultation process with the strict collaboration of ministries, sectors, localities, international corporations as well as social organizations. To date, Viet Nam is proud to have achieved a number of SDG targets related to fields such as reducing the national multi-dimensional poverty rate; Increasing the cover range of health insurance; gender equality; enhance the rate of households having access to safe water sources, and electricity; increasing forest cover; etc.

In particular, one of those objectives is developing sustainable and cities and communities with a relative balance between 3 main pillars of environment, economic, and social community, which is a similar interest that a lot of countries are sharing currently. Those kinds of cities have many models, however, the most ubiquitous is environmentally sustainable city. The first brick of the whole wall is built with the introduction of the VNESC, which allows authorities and policymakers to assess the current situation of an urban area, determining its potential opportunities towards improvements, evaluating the level of implementing the model of environmentally sustainable cities through a synchronic pointing system and releasing rational solutions for later enhancements. The study conducted in Bac Ninh city has shown that the VNESC is suitable with Viet Nam's cities conditions. The implementation of each criterion in the VNECS in Bac Ninh city has been basically implemented relatively well. The construction of the environmentally sustainable city in Bac Ninh city is assessed at "very good" stage, detail order of implemented level is arranged from high to low: solid waste criteria, atmosphere criteria, water criteria, and responding to climate change criteria. Furthermore, the reliability and accuracy of the VNESC are approved throughout the results of sociological surveys for citizens living within Bac Ninh city. Specifically, they were asked about the performance of tasks associated with each criterion. The results show that people's assessments are quite similar to the city's reported data.

The study also pointed out that the VNESC adopted by the Ministry of Natural Resources and Environment is applicable nationwide in Viet Nam for evaluating cities for their environmental sustainability. This set of criteria is to constitute progressive results for the process of enforcing the National Action Plan for the Implementation of the 2030 Sustainable Development Agenda. Moreover, there are a few actions need to be done for the improvement in Bac Ninh city in order to increase the level of implementing the environmental friendliness of the sustainable city. Specifically, these actions are: (i) Keep remaining tasks that are already done well; (ii) A clear renewable resources developing plan needs to be researched and released: (iii) Following the trend of developing sustainable cities around the world, encouraging research in this field and integrating the matter into development plans of the city, and province.

Acknowledgements: *The authors are deeply grateful to all of the authority's corporations in Bac Ninh province (mentioned above) for the kind permission of using the mass amounts of profiles and reported data in this research.*

References

1. Asghari, M. (2013), *Does FDI promote MENA region's environment quality? Pollution halo or pollution haven hypothesis*, Int. J. Sci. Res. Environ. Sci., 1, pp. 92–100.
2. Bac Ninh City Natural Resources and Environment Department (2019), *Report on environmental protection in Bac Ninh city in 2018*.
3. Bac Ninh Department of Natural Resource and Environment (2018), *The Information and Indicators Update Task Report of Bac Ninh Environment.*
4. Bac Ninh province Center for monitoring natural resources and environment (2018), *Summary report on the implementation of the natural resources and environment monitoring network*.
5. Baek, J. (2016), *A new look at the FDI income–energy–environment nexus: dynamic panel data analysis of ASEAN*, Energy Policy, 91, pp. 22–27.
6. Coplák, J. (2003), *The Conceptual Framework of the EU Project ECOCITY*, ALFA-SPECTRA, 10.
7. Kim, H. S. and Baek, J. (2011), *The environmental consequences of economic growth revisited*, Econ. Bull., 31, pp. 1198–1211.
8. People's Committee of Bac Ninh province (2013), *Decision on water supply planning for Bac Ninh province to 2030, vision to 2050.*
9. People's Committee of Bac Ninh Province (2013), *Planning industrial clusters in Bac Ninh province to 2020, vision to 2030.*
10. Prime Minister of Viet Nam (2017), *Viet Nam National Action Plan for the Implementation of the 2030 Sustainable Development Agenda*.
11. Register, R. (1987), *Ecocity Berkeley. North Atlantic Books*.
12. Stelzner, K. (2011), *Asian Green City Index: Assessing the environmental performance of Asia's*

major cities', Siemens AG.

13. The Bac Ninh Water Supply and Sewerage Company Limited (2015), *Report on current situation of water supply in Bac Ninh city.*
14. The Minister of Natural Resources and Environment (2014), *Promulgating a set of environmentally sustainable city criterias.*
15. UNDP and UNEP (2005), *World Environment Day.*
16. United Nation-UN (1992), *United Nations-Sustainable development- Conference on Environment & development Rio de Janerio, Brazil, 3 to 14 June 1992*. Available at: https://doi.org/10.%0A1007/s11671-008-9208-3.
17. United Nation-UN (2000), *United Nations millennium declaration: Resolution adopted by the general assembly*. Available at: https://doi.org/0055951.
18. United Nation-UN (2012), *The future we want: Resolution adopted by the General Assembly.* Available at: https://doi.org/A/%0ARES/66/288*.
19. United Nation-UN (2015), *Sustainable Development Goals: Knowledge Platform*. Available at: sustainabledevelopment.un.org/?menu=1300.
20. Viet, C. H. (2019), *Researching and assessing the ability to achieve environmentally sustainable citiy criterias of Viet Nam: Case study of Bac Ninh city, Bac Ninh province*.
21. World Commission on Environmental and Development (1987), *Our Common Future,* Oxford University Press.
22. Zarsky, L. (1999), *Havens, halos and spaghetti: Untangling the evidence about foreign direct investment and the environment*, Foreign Direct Invest. Environ., 13, pp. 47–74.

DEVELOPMENT OF A SET OF INDICATORS EVALUATING THE MODEL OF COMMUNITY - BASED MANAGEMENT OF DOMESTIC WATER SUPPLY IN ADAPTING TO CLIMATE CHANGE IN CA MAU PROVINCE

Pham Ngoc Anh[1], Huỳnh Thị Lan Hương[2]
[1]Office of Ministry of Natural Resources and Environment
[2]Viet Nam Institute of Meteorology, Hydrology and Climate change

Received: 14 August 2020; Accepted: 31 August 2020

Abstract: *In the context of climate change, Ca Mau province is facing to unstable water resources. So, it is requested to adjust and change the method of water resource management in order to adapt to climate change based on the community. Besides, strengthening socialization and governing towards the business model are important solutions to reduce water loss and waste and optimizing the State's resources.*

This work therefore, proposes a set of indicators to help assessing the appropriateness of community-based water resource management models in the context of climate change. In addition, the research proposes and recommends activities and solutions to improve, develop models as well as enhance community capacity in water resource adapt to climate change based on the community management.

Keywords: *Indicators, water resource management, climate change adaptation, community-based management.*

1. Introduction

In the context climate change, the Mekong River Delta in general and Ca Mau province in particular are facing to unstable water resource. Therefore, it is requested to change the method of water resource management (WRM) to adapt to such instabilities. In which, relying on the community for locality-adaptation and strengthening socialization will contribute to achieve the goal of water resource management.

Water resource is considered as the first component/factor transferring climate change impacts on society and environment; it is an intermediary for climate change to affect people, ecosystem and economy [2], [3]. Climatic stresses (including increase of temperature; droughts; changes in rainfall; storms; sea level rise) are considered in relation to non-climatic stresses (including domestic water supply services, poor irrigation, poor and backward infrastructure; unfairness of infrastructure investment support; lack of waste water treatment system; information inequality, especially, information related to water resource; poor management; high population and high population growth rate; high increase of poverty and unemployment, etc.). Therefore, water security becomes a global security challenge [1], [9].

In the world, community participation in the process of water resource management is considered as an inevitable rule. In 1977, at World Conference on Water in Argentina for the Decade International Program on freshwater supply and sanitation, the role of community was first mentioned; thereafter, the idea of community-based water management continued to be tested, strengthened and spread out, especially after the Global Fresh Water Consultation Conference held in New Delhi (1990) and the Dublin Declaration on water and sustainable development (1992); the summit on Earth in Rio De Janiero (1992); International Conference on Freshwater in

Corresponding author: Pham Ngoc Anh
E-mail: phamngocanhtnmt@gmail.com

Germany (2001), etc.

According to Molle (2005), Community-based Water Resource Management is a participatory process, in which community is a center of an effective water management system. Such community participation can be viewed as a tool (for better governance) or as a process (for community empowerment) [4]. Community participation can be established under the form of consumer associations, community action groups in urban areas, water user groups and irrigation cooperatives in rural areas [2].

In Viet Nam, according to Nguyen Viet Dung (2006), the community participation in water resource management has a long history. Thanks to the community's participation many km of dykes, dams, artificial reservoirs, canals and village wells have been built. However, the participation of community in the water resource management is different depending on the condition of each locality and region in different stages of development of the country [5].

Regarding to the legal basis for community-based water resource management, according to the National Strategy on Water Resources up to 2020, community participation has been recognized as a key measure ensuring the sustainable water resource management and use. The Law of water resources (2012) continues to mention the role of community in the management, protection, exploitation and use of water resources. Besides, it unifies view of integrated management of water resources and water resource management in the river basin.

For the Mekong Deltal, "Research on community model of sustainable water resource management in Mekong River Delta - Case study for 2 provinces including Ca Mau and Hau Giang" has reviewed the community models of sustainable water resource management in Viet Nam and the Mekong River Delta for the field of water use, including domestic and agricultural water supply. The research shows that most of the community models of water resource management are considered to be relatively sustainable, or less sustainable [7].

In fact, there are many models of community-based water resource management which being applied in the Mekong River Delta. However, their sustainability is not high or requiring a lot of state financial support [7]. Such models need to be managed according to the business model to reduce loss, waste and optimize the State's support resources. Therefore, the study approaches the organization's strategic governance system through the use of Balanced Scorecard to measure the implementation of 4 important aspects in an organization that have causality including *Finance, Customer, Internal Operation and Development* [8]. On that basis, a set of assessment indicators was established for the model of community-based management of domestic water supply in adapting to climate change in Ca Mau province.

2. Development of a set indicator to assess the model of community-based management of domestic water supply in adapting to climate change in Ca Mau province

2.1. Establishment of evaluation indicators

2.1.1. Method of developing a set of indicators evaluating the model of community-based management of domestic water supply in adapting to climate change

In order to evaluate the model of community-based management of domestic water supply in adapting to climate change in Ca Mau province with considering climate change to be a risk factor and affecting to water resource management in the region at present and in the future, four indicators at level I were established to assess four important aspects in the organization including: *Finance, Customer, Internal Operation and Development*. On that basis, the sub-indicators (indicators at level II) are proposed as follows:

*) The Financial indicators include 5 sub-indicators including: A1. How is the rate of the model of the WRM socialized in financial investment? A2. How is the rate of the WRM model with costs paid by community itself? A3. How is the rate of the WRM model having financial summary? A4. How is the rate of the WRM model having financial interest? A5. How is rate of affordability of water users?

*) The assessment indicators relating to Customers (water users) include 10 sub-indicators including: B1. How much proportion of households accessing to a water supply is? B2. How is the rate of the model of the WRM model having monitoring and evaluation activities on the quality of supplied water? B3. How does the rate of the WRM model meet the quality of domestic water supply according to the regular and standard? B4. What is the rate of people being consulted during the period of building works? B5. What is the rate of people who vote for management team for the water resource management model? B6. How is the rate of the WRM model being monitored by the community? B7. How is the proportion of people who want to continue operating the the WRM model? B8. How is the satisfaction rate of the people/community on the service price? B9. How is the rate of satisfaction of the people/community on the ability to meet sufficient quantity and quality? 10. What is the rate of satisfaction of people/community on handling complains/feedback?

*) The assessment indicators on Internal operation include 6 sub-indicators including: C1. How is the rate of the WRM model operated by the community itself? C2. How is the rate of the WRM model periodically checked, maintained by the community itself? C3. How is the rate of the WRM model having operation plan/ schedule? C4. What is the time to stop water supply from the WRM model? C5. How is the proportion of the WRM model having water reserve to supply water in the dry season? C6. How is the proportion of time of water supply from the reservoir in the dry season?

*) The assessment indicators on Model development guarantee include 5 sub-indicators including: D1. How is the proportion of the WRM model formed from community aspiration? D2. What is the rate of the WRM model established or recognized by local authorities? D3. What is the rate of the WRM model, which is registered as an enterprise model, established by the community? D4. How is the rate of the WRM model with community participation having Organization and Operation Chapter? (including Participation Mechanism; Coordination Mechanism; Election Rules and Regulations. etc.). D5. What is the rate of the model managers and operators participating in training on operational techniques and management?

2.1.2. Delphi method

Delphi method is applied in the research for selecting component indicators (level II indicator). In order to conduct the Delphi, a team of 10 experts with extensive knowledge and interests in the fields of water resource, climate change and other related fields were selected. In the Delphi process, expert opinions are consulted through two rounds (Round 1: assessing the suitability of the proposed indicators; Round 2: selecting additional indicators related to capacity building for the community-based water resource management in adapting to climate change in the Mekong River Delta and two provinces including Ca Mau and Hau Giang). Based on the opinion of experts, the research synthesized, analyzed, evaluated and completed the set of indicators to evaluate the model of community - based management of domestic water supply in adapting to climate change for selected areas.

2.2. Data collection and statistics

The WRM model with community participatory in Ca Mau province has: 220 works are built by Center for Water Supply and Rural Environmental Sanitation and are handed over to the Commune People's Committee for management; up to now, only 59 works are operating effectively, 105 works moderately operate, 73 works (accounting for 30% of the works) are ineffective, stopped working, serious deterioration, waiting for liquidation and dismantlement; 2 works supply water according to the socialization method of investor Phan Van Hien in Thanh Phu Commune, Cai Nuoc district [6].

Based on the aforementioned set of indicator and the actual survey of 20 fresh water supply works with 75 votes for the local people, 25 votes for local authorities and management unit of domestic water supply works, it is recognized that: state-invested works are seriously degraded; the funded works are ineffective (the number of water-use households is limited); the drilled wells that are not managed by household, are contaminated with alum, cannot be used, or if they can be used, they must be drilled in deep layers with a high cost; while the work, which is socialized investment by Pham Van Hien, is constantly reinvested, scaled up and improved quality to meet the demand for water use of people. Specifically: From the end of 2014, with the encouragement and support of the local government, Mr. P.V. Hien decided to borrow 200 million VND from a bank to invest in, upgrade and repair a water supply work which was funded by UNICEF and has been degraded (the People's Committee of Thach Phu commune supported the work with 40 million VND). By 2017, he continued investing in works including water stations, well and network pipes with a total capital of nearly 400 million VND; supplying water for more than 300 households within 3 km of hamlets in cluding Tan Hoa, Phan Thach and So Tai. By May 2020, the investment has been upgraded and expanded with a total capital of nearly 2 billion VND; His works can supply water for more than 1,000 households. Water quality is regularly verified people therefore, can use it with peace of mind. Turnover is over 50 million per month.

2.3. Indicator assessment and calculation

The analysis of the achieved value of each sub-indicator (level II Indicator) and level I Indicator play important roles in proposing recommendations and solutions to develop the model in the fact. For level I Indicator, the equivalent weight for each indicator is 1/4, indicating equal importance of the sub-indicators. For level II indicator of each level I Indicator, the equivalent weight for each indicator is equal and is calculated by average of the sub-indicators (in which, Finance is 1/5; Client is 1/10; Internal operation is 1/6; Mode development is 1/5). The model of community-based management of domestic water supply in adapting to climate change in Ca Mau province will be evaluated as appropriate in the context of climate change, if targets are met (as shown in the Sub-indicators) and the total score is met the average level of the selected scale (the scale is 1). Therefore, the model is appropriate if the total scale is above 0.5.

3. The result of evaluating the model of community - based management of domestic water supply in adapting to climate change in Ca Mau province

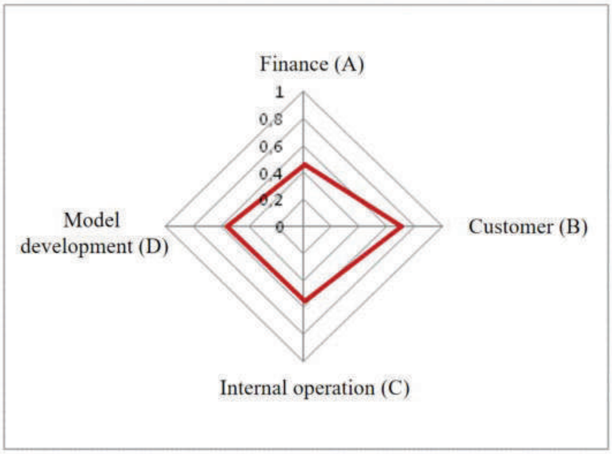
The evaluation results of the model achieved an average level of 0.56 and was assessed as a suitable model under local climate change conditions. Four basic level I indicators are calculated with fairly balanced values (in the range of around 0.5). However, in order to ensure sustainable and adaptive models to climate change in the future and consider the order of priority, it is necessary to focus first on investment in enhancing Financial indicator; following is Internal operation and Model development indicator; and Customer indicator (as shown in the Table 1).

The Financial indicator has low value with only 0.46 point: The socialization of water supply under the management and support of the State has brought a significant efficiency. This method receives high consensus from local people. However, up to now, there are very few individuals and businesses investing in rural fresh water supply works (the main unit is the Center for Water Supply and Rural Environmental Sanitation). Therefore, it is necessary to propose local preferential policies such as land assistance; concessional loans, etc.

The Customer indicator has high value of 0.7. Base on the local survey, it shows that network access and water supply services has been improved (over 90%). However, it still remains some problem such as capital recovery, solvency and financial sustainability planning. The promotion of non-state WRM model (including equitization, privatization and community-based) raises the need to improve the governance capacity towards customers, especially in the context of climate change. This means that ensuring Customer satisfaction is an important output criterion that must be addressed in order to maintain the evaluation results of this indicator.

Table 1. The evaluation results of the model of community - based management of domestic water supply in adapting to climate change in Ca Mau province

Level I indicator	Value of level I indicator
Finance (A)	0.46
Customer (B)	0.71
Internal operation (C)	0.55
Model development (D)	0.56



Evaluation results: 0.56

The Internal operation indicator is assessed to average (0.55). There are a lot of pressure making it difficult to achieve high point. The main reason is that water quality is declining (due to pollution and effect of climate change) in many areas of the province, the water source therefore, will be in difficulty and will be supplied from other water source, or will be treated with more expensive treatment processes. These increase the cost of water production and transportation. Therefore, consideration should be given to ensure that the model has a reserve reservoir to supply water during the dry season.

The Model indicator which shows the development trend of the model in the present and in the future, is rated at above 0.5. Ensuring water supply models are recognized by local authorities; promoting the development of WRM model established under the enterprise model; ensuring the organization's chapter with the community's participation will support to improve this indicator.

4. Conclusion

From the aforementioned analysis and application results of the set of evaluation indicators, it shows that there are important roles in the management of the model of community-based management of domestic water supply in adapting to climate change.

Firstly, the set of indicators can be considered as a tool to assist in assessing the capacity of the availables. If the indicators are met, the model will develop sustainably; from there, the State plays the role of an investor to help the models develop more (in terms of capital investment, technology and management, etc.); the models have not met the indicators, the State needs advice for them to achieve according principles of ensuring the "balance" of aforementioned Finance, Customers, Internal operations and Model development. Secondly, the orientation of the models that are not yet open or formulated should meet the criteria set out in the set of indicators.

In order to effectively implement such models, firstly, it is necessary to clearly define the role of community in the water resource management at appropriate scales; secondly, the model of community-based management of domestic water supply should be oriented to develop according to the enterprise model, market mechanism (having financially profitable; financial statements, etc.), through gradual satisfaction of the aforementioned indicators; Thirdly, promoting socialization of water supply under the management and support of the State will bring significant effect. This method receives the high consensus from the local people.

References

1. Asia-Pacific Water Forum, (2012), *Framework Document on Water and Climate Change Adaptation: For Leaders and Policy-makers in the Asia-Pacific Region.*
2. Cap-Net, (2014), *IWRM as a Tool for Adaptation to Climate Change.*
3. EPA, (2015), *Community-base adaptation to a changing climate*, EPA-230-F-15-001.
4. Molle. F., (2005), *Irrigation and water policies in the Mekong region: Current discourses and practices*. Colombo, Sri Lanka: IWMI. 43p. (Research report 95).
5. Nguyen Viet Dung et al. (2006), *Community-based water resource management in Viet Nam: A review of experiences and success models.*
6. People's Committee of Ca Mau province, (2020), *Report of providing information for the supervision team of the Provincial People's Council*, *May 2020*.
7. Pham Ngoc Anh et al. (2018), *Study on models of sustainable community water resources management in Mekong River Delta (case study for two provinces including Ca Mau and Ha Giang)*, Code: 2015.05.13. The final report of scientific research project at the Ministry of Natural Resources and Environment.
8. Robert S. Kaplan and David P. Norton, (1986), *Strategy map*.
9. WaterAid, (2012), *Water security framework*. WaterAid, London.

ASSESSMENT OF ADVERSE AGRO-CLIMATE CONDITIONS FOR RICE PRODUCTION IN THE 2019 SUMMER-AUTUMN ACROSS VIET NAM

Duong Van Kham, Nguyen Dang Mau, Trinh Hoang Duong, Nguyen Hong Son, Tran Thi Tam
Viet Nam Institute of Meteorology, Hydrology and Climate change

Received: 19 July 2020; Accepted: 25 August 2020

Abstract: *The data on daily sunshine hours, daily average temperature and daily precipitation collected from 143 meteorological stations across Viet Nam for 2018 and 2019 years is used for this studying. The effects of adverse weather conditions of light, temperature, wetness and drought during three main stages of rice growth and development in the 2019 summer-autumn is assessed and compared with the 2018 summer-autumn because rice varieties and cultivation conditions for two consecutive seasons are less different. Specifically, the assessment results show that adverse weather conditions affect the 2019 summer-autumn rice less than the one in 2018, which is one of the reasons contributing to the increase of 2019 rice productivity about 2 % compared with 2018.*

Keywords: *Adverse Agro-climate, rice production, 2019 summer-autumn.*

1. Introduction

Rice is the main food crop in Viet Nam's agricultural development target to ensure national food security and export. Currently, Vietnam is one of the world's biggest rice producers with about 7.3-7.4 million hectares of area harvested and with paddy output of about 43.4 million tons in 2019. Viet Nam is also the one of the world's biggest rice exporters with an annual shipment worth more than 6.34 million tons in 2019 (MARD, 2020). These data present that rice production in Viet Nam is a significant proportion of the economy, labor force, and world rice market.

In Viet Nam, weather and climate play important factors affecting the agricultural sector. As climate change harms rice yields, and as continuous growing population threaten food security, rice producers and the Vietnamese government will be forced to further address rice production's contribution to global climate change. Nevertheless, understanding of the environmental variables that affects regional rice yield is limited and econometric estimation of production functions to identify rice production average and variability have received little attention in Viet Nam.

According to the General Statistics Office in Viet Nam (GSO, 2020), there were about 1,595.7 thousand hectares of 2019 summer-autumn rice crop in Viet Nam including 1,163 thousand hectares in the North and 432.7 thousand hectares in the South. The country's rice yield in 2019 was estimated at 5,010 kilogram/ha, an increase of 100 kilogram/ha compared to the crop of 2018, the output reached 8.08 million tons, down 188.2 thousand tons compared to 2018. In particular, the productivity in the Northern provinces reached 5,070 kilogram/ha, an increase of 130 kilogram/ha compared to the crop in 2018 (about 2.7%), the output reached 5.43 million tons, a decrease of 24.6 thousand tons copared to 2018 (about 2.7%). Particularly in the Red River Delta region reached 5,550 kilogram/ha, an increase of 150 kilogram/ha; production reached 2.76 million tons, a decrease of 28.6 thousand tons compared to 2018. In the southern provinces,

Corresponding author: Nguyen Dang Mau
E-mail: mau.imhen@gmail.com

the estimated rice yield of 4,890 kilogram/ha, an increase of 40 kilogram/ha (about 0.82%); production reached 2.64 million tons, a decrease of 163.6 thousand tons.

Argo-climate conditions in 2019, less pests and more favorable than in 2018. Thus, growing and developing of rice was more advantage than in 2018. The 2019 rice yield was higher than in 2018, but the yield was lower. The number of natural disasters occurred less than in 2018, but caused serious damage to agricultural production. However, the main reason for the decrease rate in rice production is that localities continue to change land use purposes, change crop structure and crops. Some localities had a decrease in cultivated area compared to the previous year such as: Ca Mau decreased by 38.3 thousand hectares; Nghe An reduced 6 thousand hectares; Thanh Hoa decreased by 5.2 thousand hectares; Ha Noi decreased by 5.4 thousand hectares, etc (IMHEN., 2019).

In general, assessments of the Ago-climate conditions within the specific duration are the identification of detail climate condition following the growth procedure of rice. The growing duration can be the general growing duration or sub-duration, defined by weeks or months.

Weather conditions defined for agriculture are primarily sunshine and temperature as well as rain-fed. These are indispensable and replaceable factors for growth rice procedure as well development and composition of crop productivity. The impacts of weather and climate on agricultural activities are defined by both negative and positive ways. This study aims to answer the following open questions of adverse Agro-climate conditions in the 2019 summer-autumn rice crop in Viet Nam based on the meteorological observations.

2. Materials and methodology

2.1. Data

The 2018 and 2019 summer-autumn meteorological data collections implemented by following as:

- Sunshine duration (hours): Daily data
- 2m temperature (°C): Daily data
- Rainfall amount (mm): Daily data

These data were collected from IMHEN for 143 stations across Viet Nam.

2.2. Methodology

The approach to define the optimal and adverse Agro-climate conditions referred by Ha et al (2008). The optimal Agro-climate conditions assessed for three growing durations of rice: (1) Beginning crop (planting or soaking rice seeds, ricegreen-roots, branching); (2) Mid-crop (branching-flowering); (3) Late-crop (ripening process of rice grains and dead-ripe stage).

a) Normal Agro-climate conditions

In this study, the optimal Agro-climate conditions is defined by Ha et al (2008). The optimal Agro-climate condition is calculated for each growing durations of rice-crop and for each Agro-climate variable.

The normal Agro-climate conditions in temperature are optimal sunshine and temperature (Table 1) that referred by optimal total sunshine and temperature in assessment for developmental stages of rice (optimal value multiply by number days during developmental stages of rice).

For optimum moisture conditions (or the water requirement of rice) will be defined by:

$$W_{iopt} = kc \times PET_i \qquad (1)$$

Where:

kc: The coefficient of crop

PET_i: Daily potential evapotranspiration. PET_i is defined by the FAO Penman-Monteith method (Allen et al., 1998; Ha et el., 2008).

Optimum moisture conditions for developmental stages of rice is total optimal value of W_{iopt} in each day of stages.

Table 1. Optimal conditions of light (L_{opt}) and temperature (I_{opt}) (Ha et al., 2008)

TT	Condictions	Transplant-Branching (Beginning)	Branching-Flowering (Mid)	Flowering-Ripe (Late)
1	Sunshine (hours/day)	4.0	5.5-7.0	5.0
2	Temperature (^{0}C/day)	20.0-28.0	25.0-30.0	20.0-28.0

b) Satisfaction and adverse condition in sunshine

Satisfaction condition in sunshine for rice is defined by below equation, determined by $I(L_i)$.This index represents the optimum level of sastisfaction in the sunshine demand of rice (Ha et al, 2008).

$$I(L) = W(L_{tti})/W(L_{opti}) \quad (2)$$

Where:

I(L): Ssatisfaction sunshine index of rice

$W(L_{tti})$: Total real sunshine for all days during growth stages of rice

$W(L_{opti})$: Total opimal sunshine (L_{opt} * n)

i (day): 1 → n (n is daily number during growth stages of rice)

In the the equation (2), $W(L_{tti})=W(L_{opti})$ is that the sunshine duration is optimal condition (the most favorable sunshine condition for development of rice).

The adverse of sunshine defined by $W(L_{tti})-W(L_{opti})>0$ or <0, the level of adverse of sunshine for rice defined by below:

$$I'(L)=\begin{cases} 1-I(L) & \text{nếu } W(L_{tti}) - W(L_{opti}) < 0, \quad \text{lack of sunshine} \\ I(L)-1 & \text{nếu } W(L_{tti}) - W(L_{opti}) > 0, \quad \text{dry-hot condiction} \end{cases} \quad (3)$$

Equation (3) show:

$I(T) < 1$ when $W(L_{tti}) < W(L_{opti})$ and

$I(T) > 1$ when $W(L_{tti}) > W(L_{opti})$

The lower I'(L) is the adverse of sunshine duration condition due to shorter duration than normal. The bigger I'(L) is the adverse of sunshine duration condition due to longer duration than normal.

c) Satisfaction and adverse condition in temperature

Satisfaction level in temperature:

The actual satisfaction in temperature within difference duration scales (week, month, etc.) for rice is defined by satisfaction temperature index of each rice within each specific crop. Which is defined by the below equation 4 (Ha et al, 2008):

$$I(T) = W(T_{hđi})/W(T_{opti}) \quad (4)$$

Where:

I(T): Ssatisfaction temperature index of rice

$W(T_{hđi})$: Total actual temperature for all days during growth stages of rice

$W(T_{opti})$: Total optimal temperature (I_{opt} * n)

i: 1 → n (n is daily number during growth stages of rice)

Equation (4) show: $I(T)< 1$ when $W(T_{hđi}) <W(T_{opti})$ and $I(T) >1$ when $W(T_{hđi}) > W(T_{opti})$.

The adverse condition in temperature (temperature shortage).

When the $W(T_{hđi})$ > or < $W(T_{opti})$, the adverse condition in temperature is defined. In which, the adverse condition level in temperature calculated by below equation 5:

$$I(T)=\begin{cases} 1-I(T) & \text{if } W(T_{hđi}) - W(T_{opti})<0, \text{ lack of temperature} \\ I(T)-1 & \text{if } W(T_{hđi}) - W(T_{opti})>0, \text{ temperature shortage} \end{cases} \quad (5)$$

d) Satisfaction in wet condition and adverse condition due to wet condition

Satisfaction in wet condition:

The actual satisfaction of wet condition for rice is defined by equation 6:

$$I(H) = W(R_{hhi})/W_{iopt} \quad (6)$$

Where:

I(H): Ssatisfaction wet index of rice

Equation (6) show: The optimal condition defined by I(H)=1; the dry condition defined by I(H)<1 and the wetter (more water availability) condition defined by I(H) > 1.

W_{iopt} (Eq.1): Total water requirement of rice for all days during growth stages of rice

$W(R_{hhi})$: Total effective rainfall for all days in growth stages of rice

i (day): 1 → n (n is daily number during growth stages of rice)

Daily effective rainfall is defined in the below equation (R_{hhi}):

$$\begin{cases} R_{hhi} = (P_{itot}/25.4)^{0.75} \times 25.4 & \text{if } R_{itot} \geq 25{,}4\text{mm} \\ R_{hhi} = R_{itot} & \text{if } R_{itot} < 25{,}4 \text{ mm} \end{cases} \quad (7)$$

Where: R_{itot} is daily rainfall

The adverse condition due to wet condition:

The adverse condition due to wet

condition assessed in both case of below water availability (drier) and above water availability (wetter). The level of above water availability is defined by level of above rainfall with the 3% decrease rate of optimal rice product/100mm of rainfall (above 100mm level of rainfall causing rice-product decreased by 3%). This is defined fllow by Eq.8.

$$I'(H)=\begin{cases} 0 & \text{if } R_{tot} - W_{iopt} < 0, \quad \text{dry} \\ 3\% & \text{if } R - W > 100\text{mm}. \quad \text{wetter} \end{cases} \quad (8)$$

The adverse water availability condition due to dry condition is defined adverse dry condition base on the drought index (R/PET) in the Table 2.

Table 2. Classification of the drought index (Ha et al., 2008)

Level	Meaning	R/PET
I	Wetter	>1.2
II	Normal	0.8-1.2
III	Slight dry/drought	0.4-0.79
IV	Extreme dry/drought	<0.4

3. Result and discussion

3.1. The adverse Agro-climate condition in sunshine

The adverse Agro-climate condition in sunshine (I'(L)) of 2019 summer-autumn rice crop compared with its in 2018 showed in Fig.1. Assessment of the 3 development periods of rice shows that:

- **Beginning-crop duration:** The higher level of adverse sunshine condition in 2019 than 2018 is found in most of North-West, Red River Delta, Central Coast, northern-western Central Highlands and the South. In which, the significant higher adverse sunshine condition (more excessive sun exposure) is found in Ha Tinh-Quang Binh, Quang Ngai-Nha Trang and Mekong River Delta. The significant lower adverse sunshine condition in 2019 than 2018 is found in North-West and eastern Central Highlands (Fig.1a).

- **Mid-crop duration:** The significant higher adverse sunshine condition in 2019 than 2018 is mostly found in North-Central Coast, Binh Dinh-Phu Yen and eastern part of the South. Especially, the significant lower adverse sunshine condition in 2019 than 2018 spreads from North-West to western part of North-East, Red River Delta and Mekong River Delta (Fig.1b).

- **Late-crop duration**: The significant lower adverse sunshine condition in 2019 than 2018 is found in over the North. The significant higher adverse sunshine condition is found in North-Central Coast (Fig.1c).

3.2. The adverse Agro-climate condition in temperature

The adverse Agro-climate condition in temperature assessed by temperature and number of hot days. The calculation method is defined by equation (3).

Adverse temperature condition:

- Beginning-crop duration: The significant lower adverse temperature condition in 2019 than 2018 is found in North-West and northern part of Central Highlands. The higher adverse temperature condition in

2019 than 2018 is found in most Central Coast. In the South, the lower adverse temperature condition in 2019 is similar to in 2018 (Fig.2a).

- Mid-crop duration: Moving the mid-crop, the lower adverse temperature condition in 2019 than 2018 is found in larger area in the North and new area in the Mid-Central Coast. The significant higher adverse temperature condition is found in a part of North-East, and northern part of the South (Fig.2b).

- Late-crop duration: By the late-crop, the significant lower adverse temperature condition in 2019 than 2018 spreads over most North-East, Red River Delta, South-Central Coast and Mekong River Delta. The higher adverse temperature condition is found in North-West, and Central Highlands (Fig.2c).

Adverse in number of hot days:

From the beginning-crop to late-crop duration, number of hot days is defined by 0-10 days lower in 2019 than 2018 over most of the North, South-Central Coast, Central Highlands and the South. Especially, lower number of hot days in 2019 compared with 2018 is significantly found over most country by the late-crop duration (Fig.3c). The higher number of hot days in 2019 compared with 2018 is mostly found in the North and Mid-Central Coast during three growing durations. These results show that the adverse in number of hot days in 2019 is basically lower than 2018.

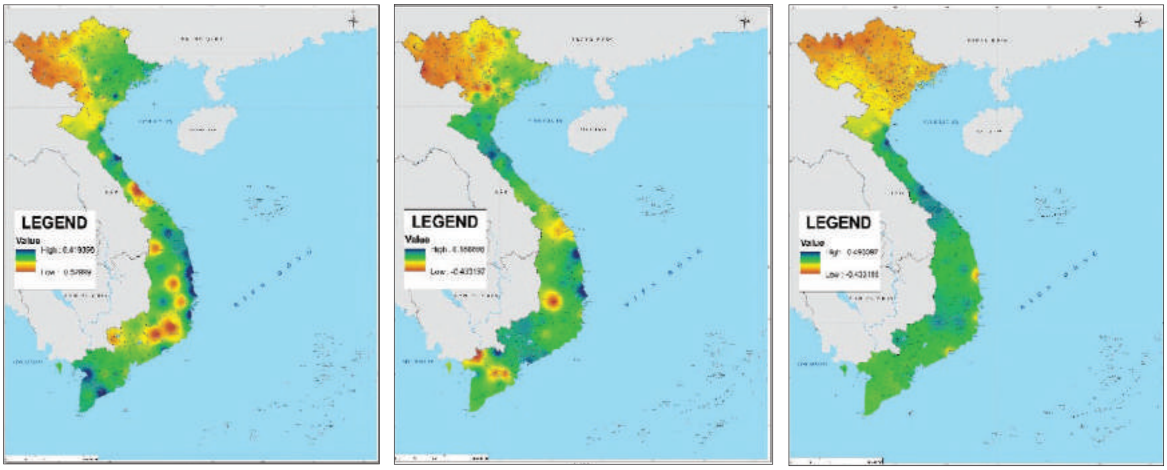


Fig.1. Changes in adverse sunshine condition I'(L) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

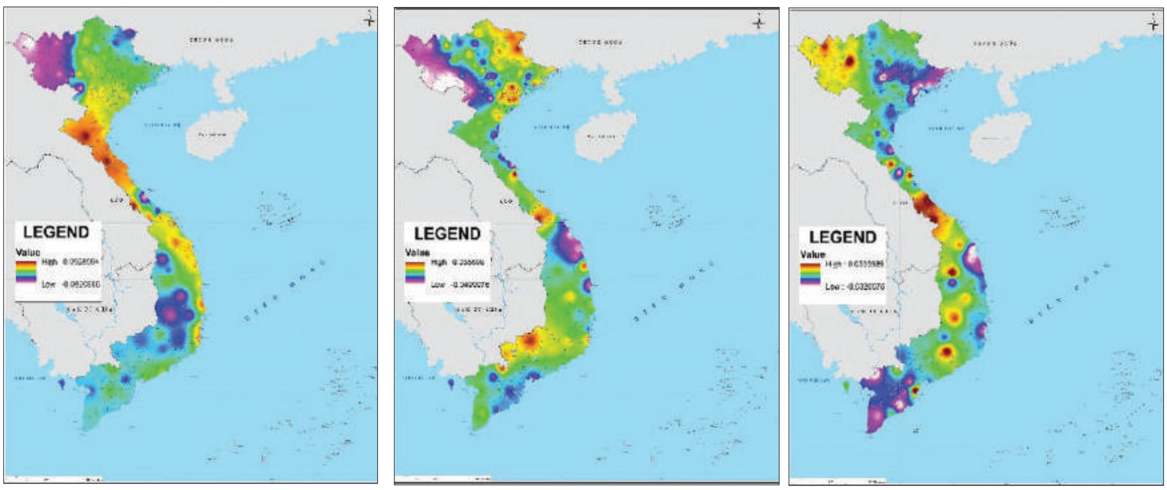


Fig.2. Changes in adverse temperature condition I'(T) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

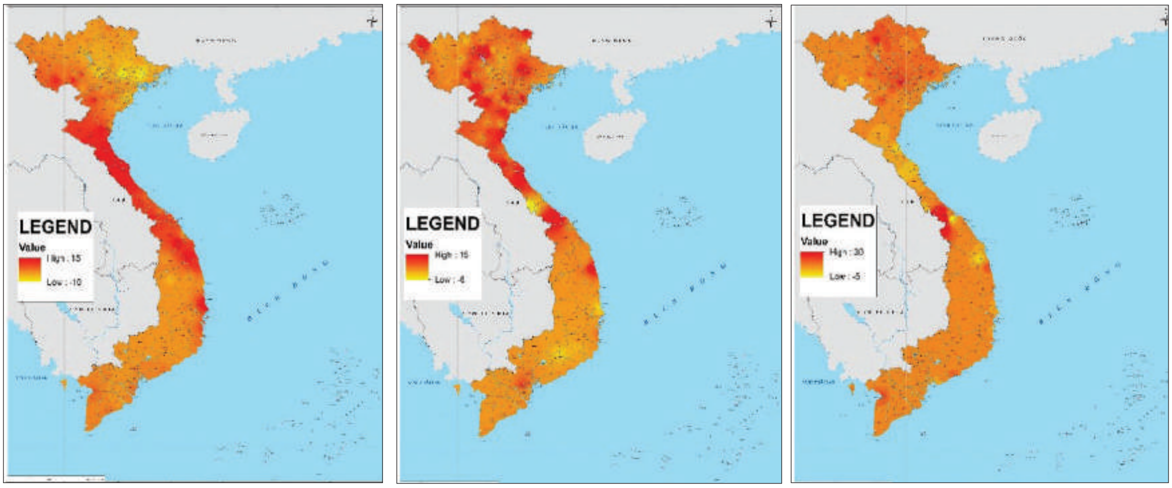


Fig.3. Changes in adverse hot days condition of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

3.3. The adverse Agro-climate condition in wet condition

The adverse dry/drought condition:

- **Beginning-crop duration**: The greater adverse dry/drought condition in 2019 than 2018 is found in most Central Coast and northern part of Central Highlands with the level from shortage to serious shortage. A slight greater adverse dry/drought condition is found in Red River Delta-Thanh Hoa. However, the wetter condition in 2019 is found in most of the North, southern part of Central Highland and South-Central Coast and the South (Fig.4a).

- **Mid-crop duration**: In compared with 2018, the adverse dry/drought condition in 2019 is only found in some very small areas in Mid to South-Central Coast and Central Highlands. Over most country, the wet (no shortage) and wetter (excess shortage) are found (Fig.4b).

- **Late-crop duration**: The adverse dry/drought condition in 2019 compared with 2018 is found in a part of the North. The wet and wetter conditions are found in most country (Fig.4c).

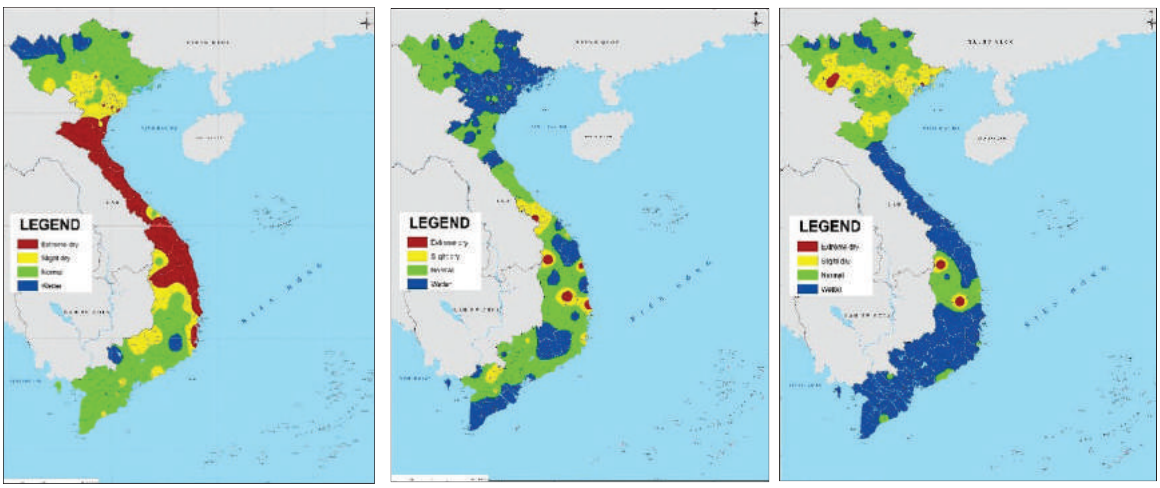


Figure 4. Changes in adverse dry condition (R/PET) and I'(H) of 2019 summer-autumn rice compared with that in 2018 for three growing durations: (a) Beginning; (b) Mid; (c) Late

Ability reducing rice product due to impacts of wetter condition in 2019:

- **Beginning-crop duration**: Compared with 2018, impacts of wet condition in 2019 on reducing rice product is ranged from lower to normal 2018. The higher impacts on reducing rice product can be found in some small area in Bac Quang (Ha Giang), Binh Thuan and Mekong River Delta (Fig.5a).

- Mid-crop duration: The higher ability reducing rice product due to impacts of wet condition in 2019 compared with 2018 is found in Central Coast, Central Highland and the South. However, the lower ability reducing rice product due to impacts of wet condition is found in the North (Fig.5b).

- Late-crop duration: Compared with 2018, the lower-normal ability reducing rice product due to impacts of wet condition in 2019 is found in the North, South Central, Central Highlands and the South. The higher ability reducing rice product due to impacts of wet condition is only found in the North-Central Coast (Fig.5c).

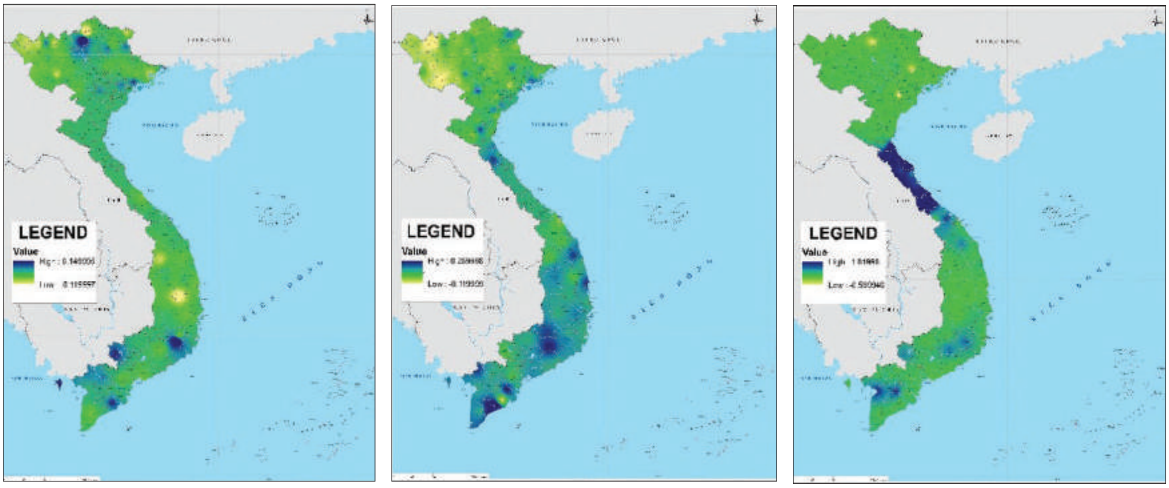


Figure 5. Possibility of decreasing rice yield due to excess moisture in 2019 compared with that in 2018: (a) Beginning; (b) Mid; (c) Late

3.4. Impacts of hydro-meteorological hazards on 2019 summer-autumn rice crop

The information of the hydro-meteorological hazards on 2019 summer-autumn rice crop is collected from IMHEN (2019).

Beginning-crop duration:

- June 2019: Good Agro-climate conditions for agricultural activities were found in over country.

- July 2019:

Heat waves event during early July caused extreme impacts on agricultural actives in Central Coast region. There were about 19.180 hectares of agricultural land being extreme drought and shortage due to heat waves. Extreme lower water level occurred at water reservoirs. The reservoir capacity is very low compared to the standard design; in particular, Trung Thuan reservoir (Quang Trach) is only 7% of the designed capacity. In Ha Tinh provinces, 16 serious forest fires occurred, damage over 160 hectares of forest cannot be recovered. In Quang Ngai, heat waves occurred in long days that cause 200 hectares of acacia plantations in Pho Thanh, Pho Cuong and Pho Khanh (Duc Pho district) to be died due to extreme drought.

Very heavy rainfall occurred in long days in Mekong River Delta combined with the floodwaters from upstream flooded very large area, causing flooding hundreds of hectares of summer-autumn rice fields in the ripe duration that damages 20-30% of total.

Very heavy rainfall also caused extreme loses in northern provinces, including 69 hectares of rice and vegetables damaged in Son La province; 1000 hectares of rice and vegetables damaged in Cao Bang; 1120 hectares of rice and vegetables damaged in Yen Bai.

During July 4 2019, the No. 2 typhoon travelled to Hai Phong-Nam Dinh area causing very extreme loses in agricultural sector, damages: 650 hectares of rice and 457 hectares of vegetables in Nghe An were flooded; 2,240 cattle and poultries, 1,000 hectares of rice and vegetables flooded, 182 hectares of aquaculture flooded and 110m of canals damaged in Thanh Hoa province.

Mid-crop duration:

- August 2019:

Extreme events due to heavy rainfall: Very extreme rainfall and flood events in the North, Central Coast and the South; thunder storm events in most country.

Foehn events occurred and impacted in provinces in Central Coast.

Impacts of typhoon: The No. 3 typhoon caused extreme loses in the northern provinces. In Thanh Hoa, is the most loses in the North, including 1,200 rice and vegetables damaged and 1,700 domestic animals died. The No.4 typhoon hitting Nghe An-Quang Binh area; and flash floods occurred in the mountainous area in the North.

- September 2019:

Major extreme events in September 2019 were typhoon, heavy rainfall, flash flood, flood, tornado and landslides. The damage occurred was 24.8 thousand hectares of rice and more than 4 thousand hectares of vegetables were damaged. The localities that suffered much from natural disasters including Ha Giang and Yen Bai; Thanh Hoa, Nghe An, Ha Tinh, Quang Binh and Quang Tri.

Late-crop duration:

The most extreme event during the late-crop duration is the No. 5 typhoon (Matmo typhoon) and its extreme rainfall in the Central Coast region. Damage occurred: 10-12 hectares of rice and 30 hectares of vegetables flooded in Phu Yen province; 4,500 hectares of rice and 20 hectares of aquaculture flooded and damaged in Binh Dinh province; 297 hectares of vegetables, 20 hectares of acacia and 15 hectares of fruit trees flooded and damaged in Quang Ngai province.

Compared with 2018, the lower-normal ability reducing rice product due to impacts of wet condition in 2019 is found in the North, South Central, Central Highlands and the South. The higher ability reducing rice product due to impacts of wet condition is only found in the North-Central Coast (Fig.5c).

During November 2019, the No. 6 typhoon caused great loses of agricultural production in Binh Dinh-Khanh Hoa area. In Dak Lak: 255 hectares of newly sown rice, 16 hectares of maize and 20 hectares of sweet potato flooded. 50 hectares of sugarcane locally flooded in Phu Yen province. In Binh Dinh, there were 15,2 hectares of fruit trees broken and fallen. In Khanh Hoa: 330 hectares of rice and 20 hectares of vegetables were flooded. In addition, pests and diseases appeared in some localities, causing difficulties for agricultural, forestry and fishery production.

Conclusion

From comparing the adverse Agro-climate conditions in the 2019 summer-autumn rice crop in Viet Nam with that in 2018, conclusions can be suggested as:

1) The beginning-crop duration: Agro-climate conditions (sunshine, temperature, water availability) in 2019 summer-autumn rice crop were more favorable for rice cultivation and green anise rooted rice over most country. However, the greater adverse dry/drought and hot conditions occurred in 2019 than 2018 in the Central Coast causing the disadvantages for the green-spring-rooted rice.

2) The mid and the late crop duration: Comparing with 2018 the Agro-climate conditions (sunshine, temperature, water availability) in 2019 were normally quite favorable for rice growth, especially in the Northern provinces. However, heavy rains occurred in the Central Coast and the South, causing significant disadvantages to rice fields, flowering and seed production.

The situation of pests and diseases rarely occurred, agricultural production losses due to meteorological disasters in the last 6 months of 2019 were mainly heavy rains and floods, causing widespread litter across the country. In the Northern provinces in the early months of the mid-crop and late-crop in the South.

References

1. Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998), *Crop evapotranspiration - guidelines for computing crop water requirements, FAO Irrigation and drainage paper 56,* Food and Agriculture Organization (FAO), Rome.
2. GSO (2020), *Overview of the socio-economic situation in 2019*, General report.
3. Ha, N.T, et al, (2008), *Developing forecasts of maize, soybean and peanut productivity and develop a process of Agro-climate monitoring for four main crops (rice, corn, peanuts, soybeans) using ground information in Viet Nam",* MONRE project.
4. IMHEN (2019), *Agro-climate bulletin and outlook, Months from May to Oct*.
5. MARD (2020), *National food security until 2020*, General report.

MAPPING 10 YEARS OF LAND COVER CHANGE IN THE MEKONG DELTA

Ta Hoang Trung, Nguyen Van Tuan
Center of Survey and Mapping Data - Viet Nam
Department of Survey, mapping and geographic information

Received: 9 July 2020; Accepted: 12 August 2020

Abstract: *In the last decade, the Mekong delta has seen a significant decrease in the total area of the wetland due to the expansion of the paddy field, and aquaculture farms. The expansion negatively affected the biodiversity of the region, threaten the environment. To conserve the biodiversity of the region and reach sustainable development, authorities have to monitor the transformation process effectively, thus an updated land cover map is necessary. This research used free satellite data, open-source library, and machine learning algorithm to create 10-meter spatial resolution land cover map of the region 2007 and 2017... In this study, Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), Sentinel-2, ALOS PALSAR, and PALSAR 2 mosaic, ALOS Global Digital Surface Model were employed to produce land cover map of the region by using Kernel Density Estimation classifier. Other ancillary data sources such as Open Street Map, regional geographical database was used as information supplement. To creating and validating the maps, 60,000 reference data points were created based on the field GPS photos as well as visual interpretation on Google Earth images. The overall accuracy of the maps is 82% and 84% in 2007 and 2017, respectively. The maps reveal the rapid loss of mangrove, mainly due to the expansion of aquaculture farms and the urban area between the two periods. The result also demonstrates the potentiality of automatically producing high-accuracy land cover maps in the large area.*

Keywords: *Land cover change, multi-temporal, machine learning.*

1. Introduction

The Mekong delta is intensely vulnerable to climate change and sea level rising (Birkmann et al., 2012). According to the Climate change and sea level rise scenarios for Viet Nam, if the sea level rises 100 centimeters, nearly 40% of the total area of the delta would be sub-merge beneath the sea (Ministry of Natural Resources and Environment, 2016), negatively affected to the livelihood of the farmers (Tuan and Chinvanno, 2011). Sea level rising also expedites the salinity intrusion (Smajgl et al., 2015) which caused a loss of 360 million US dollars in 2016 (Nguyen, 2017), and a lack of clean water for more than 200,000 households. As the largest and one of the most important agricultural areas, which produce half of Viet Nam rice export of the country, the delta has an important role in the food security of Viet Nam, requiring authorities have the plans to mitigate the impact of climate change, developing the region sustainably.

Human activities are among the major factor behind climate change (Trenberth, 2018). Human's need for food, raw materials are considered as the factor that accelerate deforestation which leads to soil erosion, loss of biodiversity, and climate change. For example, the high demand for shrimp and catfish has led to the rapid expansion of aquaculture farms in the Mekong delta, accompanying with the loss of mangrove (Tran et al., 2015) and wetland loss (Huu Nguyen et al., 2016), which is considered as one of the factors made the effect of climate change to the region more serious. Besides, intensification of agriculture degraded water

Corresponding author: Ta Hoang Trung
E-mail: tahoangtrung@gmail.com

quality of the region (Anh et al., 2010; Guong and Hoa, 2012).

To mitigate the impact of climate change, land cover maps are widely used to monitor the land cover transformation process. However, the current process to produce land cover maps is long, limit the effort of authorities to mitigate the impact of climate change. To produce land cover products, aerial photos were widely used as the main data source of land cover change detection. The photos usually were taken at altitude of 1,130 meters, at a scale of 1/15,000 thus it has the advantages of high spatial resolution. However aerial photo has a narrow field of view, thus to create maps in a large area, a big amount of images are required, requiring many times and effort to producing.

Recently, giant leaps of satellite image technology provide better quality, quantity, and easier to access data for users. As a result, it becomes popular, providing user variety of choices for their specific purpose. For instance, the U.S. Geological Survey (USGS) is providing Landsat satellite data that has been collected spectral information of the Earth's surface from 40 years ago. The Landsat data is a valuable data source for the studies which focus on the history of biophysical changes on the surface of the Earth. If the 30-meter spatial resolution of Landsat is not enough, users can use Sentinel-2 images, provided by ESA (European Space Agency) or ALOS-2 images, provided by JAXA (Japan Aerospace Exploration Agency). Both data have spatial resolution of 10 meters. The advantages of these data are the wide field of view and high temporal resolution (the revisit time fluctuates from 5-10 days). Besides, users can freely access the data. The easy access and adequate quality of satellite data are suitable for produce updated land cover products in a relatively large area. Also, the open-access data is suitable for countries that have limited financial resources for environment protection like Viet Nam where the low-cost land cover map is preferred.

Optical and Synthetic Aperture Radar (SAR) data are popular among data sources to create land cover maps. Optical sensors are widely used to create land cover mapping due to the valuable information it provides (Clerici et al., 2017). The sensor collects information of the earth's surface in several spectral bands, from visible to infrared, provide useful information for users. However, optical data, as a passive sensor, only observe the earth's surface on daylight, narrowing the chance to observe the Earth's surface. In contrast, (SAR) data, an active sensor is not limited by daylight. Unlike optical sensors, the SAR sensor, an active sensor, uses longer wavelength range, in comparison with the optical sensor, hence it is not affected by cloud, and can observe Earth's surface regardless of time and weather condition. Furthermore, SAR data collects information about the structure of the objects, provide useful information for the analysis required structure of the objects. The limitation of the SAR data is speckle which can reduce the classification accuracy (Joshi et al., 2016). Utilizing the advantages of both optical and SAR data, several studies combine the optical sensor with SAR sensor to create land cover maps (Bagan, Kinoshita, & Yamagata, 2012; Clerici, Valbuena Calderón, & Posada, 2017; Potapov, Hansen, Stehman, Loveland, & Pittman, 2008). These studies used SAR data to fill the gap that optical data left, for example, seasons that surface is covered by cloud, led to the missing data of the region. In This study, we also used the combination of optical and SAR data such as Sentinel-2, Landsat 5-8, and The Advanced Land Observing Satellite (ALOS) PALSAR mosaic to create 10-meter spatial resolution land cover maps of the study area.

2. Methodology

2.1. Study area

The Mekong delta is located in the southern of Vietnam, covers over 40,000km^2, spread from latitude 8^o to 11^o North, longitude 103^o to 107^o, including 13 provinces. The region has tropical monsoon climate condition, the average temperature is about 30 Celcius degree. Creating by the alluvium of the Mekong River, the region has natural advantages in producing agriculture products (i.e., rice, tropical fruits, catfish). The region also has rich biodiversity. It is the place where thousands of species call home and have some national wetland parks such as Cat Tien national park. The two conditions require authorities must have a suitable plan for the development of the region to balance development and conservation.

2.2. Data pre-processing

Optical data always contaminated by cloud and cloud shadow (Hughes and Hayes, 2014), thus requires methods for masking cloud and cloud shadow. Based on the characteristic of the spectral bands, different approaches for cloud removal are considered. For instance, (Zhu and Woodcock, 2012) utilized the difference between high reflectance value on the visible band and low value in thermal bands of cloud pixels to recognize contaminated pixels. In this study, Landsat data is cloud masking based on quality assessment bands of the data. The cloud of Sentinel-2 data is removed based on the reflectance value of each pixel. A threshold is set, if the reflectance value of Red, Blue, and Green band is bigger than this number, this pixel is considered as cloud, and will be ignored in the classification process. The cloud masking process is done by using open source software GRASS GIS.

Detecting objects using spectral features may be confusing because of the similarity in spectral behavior of different objects, thus in many studies, spectral indices are used for achieving higher accuracy (Ghasemian and Akhoondzadeh, 2018). Spectral indices are the arithmetic combination of different spectral bands, which are usually used as a classification enhancing technique because of its targeting on a specific land cover type (Mongus and Žalik, 2018). Furthermore, spectral indices help reduce the feature space size, by combining the spectral value of 2 bands into 1 index, thus increasing the speed of the classification process. In this study, three spectral indices NDVI, NDBI, NDWI are used (Table 1).

Table 1. Spectral indices used (Taufik and Ahmad, 2016)

Name	Definition
Normalized difference vegetation index	$\mathrm{NDVI} = \frac{NIR - Red}{NIR + Red}$
Normalized difference water index	$\mathrm{NDWI} = \frac{Green - NIR}{Green + NIR}$
Normalized difference built-up index	$\mathrm{NDBI} = \frac{NIR - SWIR}{NIR + SWIR}$

Texture information has been used in many studies to enhance the accuracy of the classification result. (Zhang et al., 2017) proposed using 4 types of statistics-energy for remote sensing images classification which is an Angular second moment (ASM), contrast, correlation, and entropy. To calculate the ASM, firstly, a grey level co-occurrence matrix (GLCM) is built based on the averages of the results of 4 GLCM over 4 orientations: 0, 45, 90 and 135 degrees with 9x9 pixel sliding window sizes and the distance between 2 samples is 1 pixel. The angles are counter-clockwise from the East. After that, ASM is calculated based on the equation proposed by (Ghasemian and Akhoondzadeh, 2018) where $P(i,j)$ is the mean GLCM value in position (i,j), L is the number of levels

$$ASM = \sum_{i=1} \sum_{j=1} P(i,j)^2 \quad (1)$$

In this study, the satellite images of the region of interest are collected at different times of the year (table 2), thus the phenological change of vegetation is detected more accurately. Furthermore, the date of capture was considered as one of the elements of the feature space. The time information is very important in the case of the Mekong delta due to the harvest of paddy field in each 3 to 6 months, thus time information could enhance the discrimination between paddy field and barren.

Table 2. Feature space size and data used

Data	Feature space	No of scenes	Resolution (m)	Year	Provider
Sentinel 2 TOA Product	Band: 2,3,4,8a,11,12, NDVI, NDBI,NDWI, ASM	138	10	2017	ESA
ALOS DSM	Slope	1	30	2017	JAXA
Landsat 5 TM SR product	Band: 1,2,3,4,5,7 NDVI, NDBI,NDWI, ASM	93	30	2007	USGS
Landsat 8 OLI SR product	Band: 2,3,4,5,7, NDVI, NDBI,NDWI, ASM	42	30	2017	USGS
ALOS PALSAR Mosaic	HH,HV	2	25	2007,2017	JAXA

2.3. Classification scheme

A classification scheme is a method for mapping objects on the Earth's surface into groups based on their characteristics in common (Congalton et al., 2014). Each current land cover product used its classification scheme based on the target of the products, however, Land cover Classification system (LCCS) which is developed by FAO (Food and Agriculture Organization) and UNEP (United Nation Environment Programme) has been used widely (Congalton et al., 2014). In this study, 9 categories were chosen base on the reference of LCCS and *"Circular of Technical Specifications for the Content, Structure model of the Geographic Database Scale 1:50,000"* to enhance the integration of the maps to current products. Details of the categories are shown in Table 3.

Table 3. Description of the classification scheme

No.	Categories	Code	Definition
1	Water	WB	Can be either natural or artificial water bodies.
2	Urban	UB	Land covered by buildings and other man-made structures.
3	Paddy	PD	The cover type is rice paddy influenced by the presence of water.
4	Crop	CR	Lands covered with crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems).
5	Grass	GR	Lands with herbaceous types of cover. Tree and shrub cover is less than 10 %.
6	Orchard	OR	An orchard is an intentional planting of trees or shrubs that is maintained for food production.
7	Mangrove	MG	Mangroves are a group of trees and shrubs that live in the coastal inter-tidal zones.
8	Forest	FR	Lands dominated by woody vegetation with a percent cover > 60% and height exceeding 2m. Almost all trees and shrubs remain green year-round. Canopy is never without green foliage.
9	Bare land	BR	Lands with exposed soil, sand, rocks, or snow and never has more than 10 % vegetated cover during any time of the year.

2.4. Classification method

To produce a land cover map of the Mekong region, firstly satellite data is collected, then pre-processing. Optical data such as Landsat and Sentinel are cloud removed and transformed into WGS-84 coordinate system. SAR data such as PALSAR and PALSAR-2 mosaic data is calculated backscatter value from digital number value. After that, each image is classified using the probabilistic approach of the Kernel Density Estimation classifier.

This study used the kernel-based probabilistic classification method, which based on Bayesian theory using a generative model of classification scheme and data. The model is built using kernel density estimation, which is a non-parametric method, estimating the probability density function of a set of random variables. Each image is classified independently, after that they are combined to produce the single land cover product. The flow chart of the process can be seen in Figure 1.

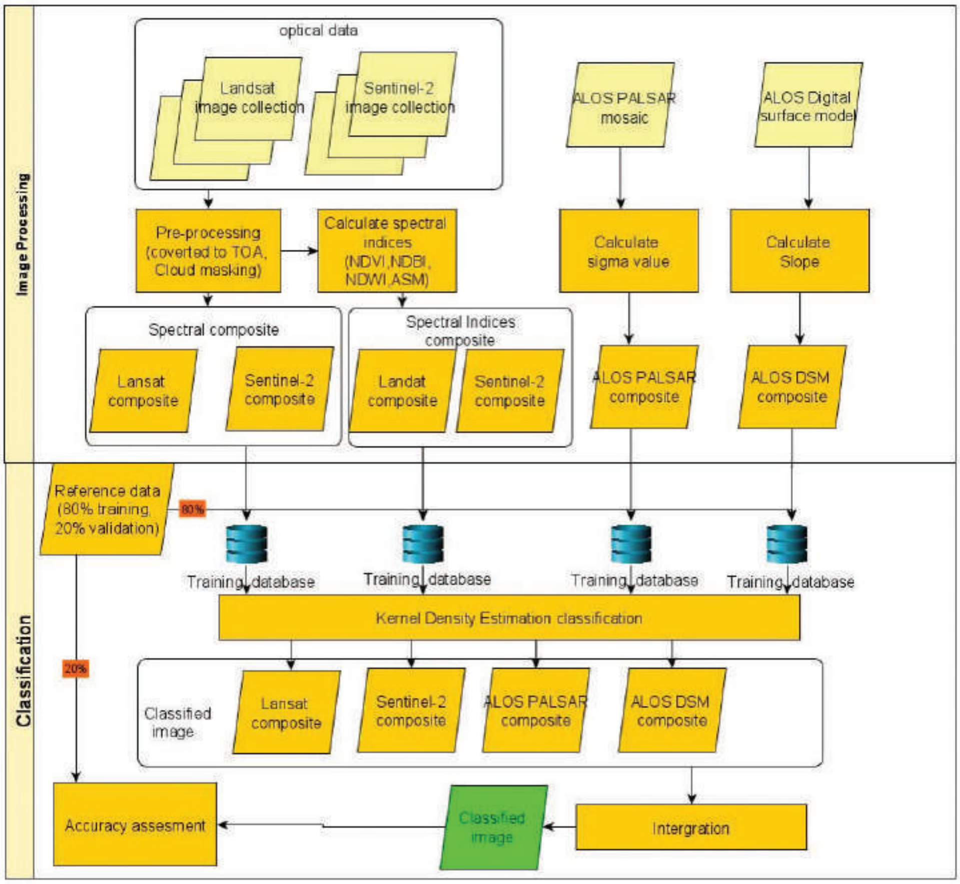


Figure 1. Flow chart of the classification process

Firstly, two dimensions of observation date are calculated by equation 1, where DOY is the Julian day of the year when the image is captured.

$$[t_1,t_2] = \left[\cos\left(2\pi\frac{DOY}{DOY_{max}}\right), \sin\left(2\pi\frac{DOY}{DOY_{max}}\right)\right] \quad (2)$$

KDE classifier approach is based on the Bayesian rule where $p(C_k)$ is prior probability of class k, $p(C_k|x)$ is the probability of class k when given feature vector x, so-called posterior probability, $p(x|C_k)$ is the probability of feature vector x when given class k, which can be derived by using kernel density estimation to training data, $p(x)$ can be considered as constant, in this study, it is equal to 1/(*Number of categories*)

$$p(C_k|x) = \frac{p(C_k)p(x|C_k)}{p(x)} \quad (3)$$

Each pixel of the resulted image is integrated by (Equation 4)

$$p' = \prod_{i=1}^{M} ap_i + \frac{1-a}{M} \qquad (4)$$

a is constant, in this study a = 0.7, M is the number of scenes.

3. Result and discussion

3.1. Result

Figure 2 shows the result of the classification process, which is the land cover map of the Mekong Delta in 2007 and 2017, respectively. Generally, the 2017 result has higher accuracy than 2007 result in overall accuracy, similarity; almost categories of 2017 result have user's accuracy higher than 2007 result whereas the fluctuation is seen on producer's accuracy. The overall accuracy of the 2017 result is 84%, around 1% higher than the 2007 result. User's accuracy of other crops and grassland is the two lowest accuracy numbers in both 2007 and 2017. In 2007, user's accuracy of other crops and grassland is 32% and 51.8%, respectively while in 2017 is 50.9% and 50.6% correspondingly. In contrast, water and evergreen broadleaf trees are two categories that have the highest user's accuracy, more than 95% for both categories in two years.

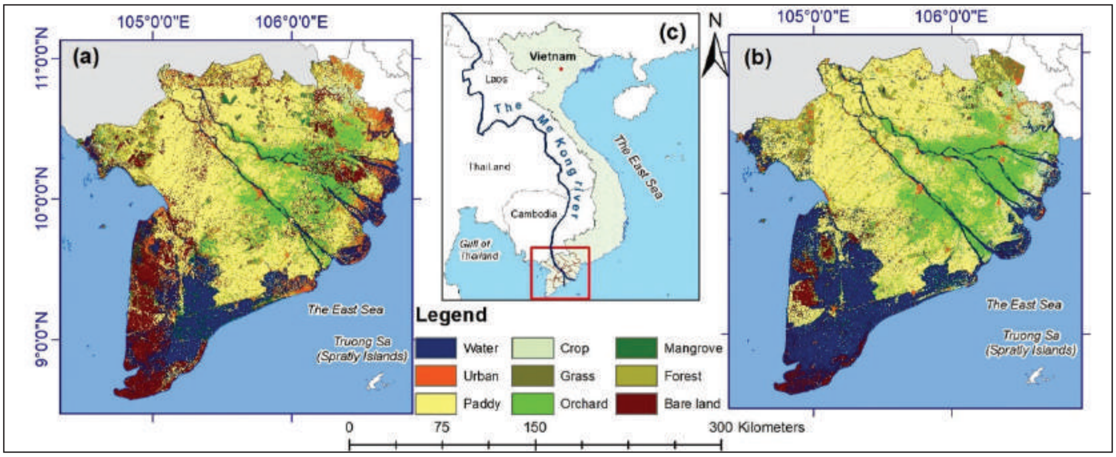


Figure 2. Land cover map of the Mekong Delta in 2007 (a), 2017 (b), and location of the study area in the red box (c)

Table 4. Confusion matrix of 2007 land cover map

		Predicted										
		WB	UB	PD	CR	GR	OR	BR	FR	MG	All	*PA (%)
Actual	WB	**338**	21	18	2	4	0	13	6	14	416	81.3
	UB	2	**205**	6	5	0	2	4	1	3	228	90
	PD	0	10	**390**	2	2	3	14	4	22	447	87.3
	CR	0	0	1	**39**	0	0	0	1	0	41	95.2
	GR	0	0	0	2	**45**	2	2	2	1	54	83.4
	OR	0	5	4	21	3	**65**	4	15	15	132	49.3
	BR	2	36	3	3	7	2	**97**	3	4	157	61.8
	FR	0	7	5	47	26	11	21	**640**	16	773	82.8
	MG	3	2	0	1	0	1	0	2	**269**	278	96.8
	All	345	286	427	122	87	86	155	674	344	**2526**	80.88
	*UA (%)	98	71.7	91.4	32.0	51.8	75.6	62.6	95	78.2	72.9	**82.70**

**UA: User's accuracy, PA: Producer's accuracy*

Table 5. Confusion matrix of 2017 land cover map

		Predicted										
		WB	UB	PD	CR	GR	OR	BR	FR	MG	All	PA (%)
Actual	WB	**955**	8	17	15	2	14	1	3	7	1022	93.5
	UB	33	**2646**	11	105	140	63	53	35	1	3087	85.8
	PD	9	36	**1646**	66	69	68	47	51	4	1996	82.5
	CR	0	12	10	**492**	17	12	3	14	5	565	87.1
	GR	0	18	9	22	**460**	28	30	25	4	596	77.2
	OR	0	6	1	8	6	**677**	1	1	11	711	95.3
	BR	6	105	46	36	135	15	**701**	27	1	1072	65.4
	FR	3	21	17	219	80	80	44	**2582**	60	3106	83.2
	MG	9	1	1	4	1	5	0	8	**440**	469	93.9
	All	1015	2853	1758	967	910	962	880	2746	533	**12624**	84.88
	UA (%)	94.1	92.8	93.7	50.9	50.6	70.4	79.7	94.1	82.6	78.77	**84.00**

**UA: User's accuracy, PA: Producer's accuracy*

To check the accuracy of the land cover products, we employed the confusion matrix which is widely used to evaluate the quality of land cover maps. The overall accuracy is 83% and 84% in 2007 and 2017, respectively (Tables 4 and 5). The low user's accuracy or error of commission, which one category does not belong to this category but is predicted as this category of other might be caused by the similarity in spectral (i.e, Crop and Grass). In both 2 years, many crop pixels are predicted as grass. In the classification process, we supposed that the 2 categories have the similarity in spectral bands however, crops usually are planted by human thus it usually appears in satellite images in the form of homogeneous area, while grass usually mixes with another type of plants resulting in texture information differences, hence the texture information is different between two kinds. However, the result shows that texture information might be not enough to clarify two categories.

After 10 years, while the total area of paddy field and orchard remained stable, the significant change can be seen on water body. In provinces along coastal area, a number of areas of other land type have been converted to water body, in this case is aquaculture farms. The expansion is confirmed by the statistic of the General Statistic Office of Viet Nam (GSO). According to GSO, in the last decade, the total area of aquaculture farm of 13 provinces of the Mekong delta increased from 724,000 ha in 2007 to 796,000 ha in 2017. The rapid conversion is considered to increase the fish production to meet the high demand of the market.

3.2. Discussion

This study employed a kernel-based probabilistic classification to create land cover maps for Southern Vietnam in 2007 and 2017, using multi-sensor, multi-temporal remote sensing data. The study proposed a method of fusion many different kinds of data to create a land cover products. This might be necessary to create land cover products in coastal areas where optical data is contaminated by the cloud, causing no-data pixel phenomena. Besides, the method notably increases the frequency of Earth observation, thus useful when monitoring the phenology changes of vegetation.

Our approach proposed an affordable method for creating a land cover map of Viet Nam. The study used open-data sources, which can be downloaded freely via the provider's website, and open-source package to process the data and classify images.

As a result, the product has an affordable price, suitable for countries that have a limited budget.

The study proposed a fully automatic process to produce land cover map. There are two main stages to produce the product, the first is download image, and second one is pre-processing and classifying the images. In this study, we used shell script which runs on the Linux operation system to automatic all the map-making process. As a result, the time to produce land cover product was significantly reduced. The only concern when produce land cover product is the creation of training data and the re-visit time of satellite data.

References

1. Anh, P.T., Kroeze, C., Bush, S.R., Mol, A.P.J., (2010), *Water pollution by Pangasius production in the Mekong Delta, Viet Nam: Causes and options for control*. Aquac. Res. https://doi.org/10.1111/j.1365-2109.2010.02578.
2. Birkmann, J., Garschagen, M., Van Tuan, V., Binh, N.T., (2012), *Vulnerability, Coping and Adaptation to Water Related Hazards in the Vietnamese Mekong Delta*. https://doi.org/10.1007/978-94-007-3962-8_10.
3. Clerici, N., Valbuena Calderón, C.A., Posada, J.M., (2017), *Fusion of sentinel-1a and sentinel-2A data for land cover mapping: A case study in the lower Magdalena region, Colombia.* J. Maps 13, 718–726. https://doi.org/10.1080/17445647.2017.1372316.
4. Congalton, R.G., Gu, J., Yadav, K., Thenkabail, P., Ozdogan, M., (2014), *Global land cover mapping: A review and uncertainty analysis*. Remote Sens. 6, 12070–12093. https://doi.org/10.3390/rs61212070.
5. Ghasemian, N., Akhoondzadeh, M., (2018), *Introducing two Random Forest based methods for cloud detection in remote sensing images*. Adv. Sp. Res. https://doi.org/https://doi.org/10.1016/j.asr.2018.04.030.
6. Guong, V.T., Hoa, N.M., (2012), *Aquaculture and Agricultural Production in the Mekong Delta and its Effects on Nutrient Pollution of Soil and Water*. https://doi.org/10.1007/978-94-007-3962-8_14.
7. Hughes, M.J., Hayes, D.J., (2014), *Automated detection of cloud and cloud shadow in single-date Landsat imagery using neural networks and spatial post-processing*. Remote Sens. 6, 4907–4926. https://doi.org/10.3390/rs6064907.
8. Huu Nguyen, H., Dargusch, P., Moss, P., Tran, D.B., (2016), *A review of the drivers of 200 years of wetland degradation in the Mekong Delta of Viet Nam*. Reg. Environ. Chang. 16, 2303–2315. https://doi.org/10.1007/s10113-016-0941-3.
9. Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jepsen, M.R., Kuemmerle, T., Meyfroidt, P., Mitchard, E.T.A., Reiche, J., Ryan, C.M., Waske, B., (2016), *A review of the application of optical and radar remote sensing data fusion to land use mapping and monitoring*. Remote Sens. https://doi.org/10.3390/rs8010070.
10. Ministry of Natural Resources and Environment (MONRE), V., (2016), *Climate change and sea level rise scenarios for Viet Nam.*
11. Mongus, D., Žalik, B., (2018), *Segmentation schema for enhancing land cover identification: A case study using Sentinel 2 data*. Int. J. Appl. Earth Obs. Geoinf. 66, 56–68. https://doi.org/10.1016/J.JAG.2017.11.004.
12. Nguyen, N.A., (2017), *Historic drought and salinity intrusion in the Mekong Delta in 2016: Lessons learned and response solutions*. Viet Nam J. Sci. Technol. Eng. https://doi.org/10.31276/vjste.59(1).93.
13. Smajgl, A., Toan, T.Q., Nhan, D.K., Ward, J., Trung, N.H., Tri, L.Q., Tri, V.P.D., Vu, P.T., (2015), *Responding to rising sea levels in the Mekong Delta*. Nat. Clim. Chang. https://doi.org/10.1038/

nclimate2469.

14. Taufik, A., Ahmad, S.S.S., (2016), *Land cover classification of Landsat 8 satellite data based on Fuzzy Logic approach*. IOP Conf. Ser. Earth Environ. Sci. 37. https://doi.org/10.1088/1755-1315/37/1/012062.
15. Tran, H., Tran, T., Kervyn, M., (2015), *Dynamics of land cover/land use changes in the Mekong Delta, 1973-2011: A Remote sensing analysis of the Tran Van Thoi District, Ca Mau Province, Viet Nam*, Remote Sens. 7, 2899–2925. https://doi.org/10.3390/rs70302899.
16. Trenberth, K.E., (2018), "Climate change caused by human activities is happening and it already has major consequences", *J. Energy Nat. Resour. Law*. https://doi.org/10.1080/02646811.2018.1450895.
17. Tuan, L.A., Chinvanno, S., (2011), *Climate Change in the Mekong River Delta and Key Concerns on Future Climate Threats*, *in: Advances in Global Change Research*. https://doi.org/10.1007/978-94-007-0934-8_12.
18. Zhang, X., Cui, J., Wang, W., Lin, C., (2017), *A study for texture feature extraction of high-resolution satellite images based on a direction measure and gray level co-occurrence matrix fusion algorithm*. Sensors (Switzerland) 17. https://doi.org/10.3390/s17071474.
19. Zhu, Z., Woodcock, C.E., (2012), *Object-based cloud and cloud shadow detection in Landsat imagery*. Remote Sens. Environ. 118, 83–94. https://doi.org/10.1016/j.rse.2011.10.028.

RELATIONSHIPS BETWEEN METEOROLOGICAL PARAMETERS AND PM_{10} CONCENTRATIONS AT URBAN LOCATION IN HA NOI CITY FROM 2010 TO 2019

Nguyen Anh Dung[1], Duong Hong Son[2], Nguyen Dac Dong[3]

[1]Department of Science and Technology, Ministry of Natural Resources and Environment

[2]Water Resources Institute

[3]Viet Nam Union of Geological Sciences

Received: 29 July 2020; Accepted: 26 August

Abstract: *This paper evaluates the effects of meteorological factors including temperature, humidity, wind speed and precipitation on PM_{10} concentration at Nguyen Van Cu air quality monitoring station in Hanoi during the period of 2010-2019. The Spearman correlation coefficient between PM_{10} concentration and precipitation is negative implying an appearance of the washing effect. In addition, the relationships between PM_{10} concentration and wind speed as well as temperature are also inversely correlated which means when the air was stagnant, less disturbed and diffused due to low wind conditions, the concentration of PM_{10} would increase. Moreover, humidity has a positive correlation with PM_{10} concentration. Through the linear correlation analysis, it can be determined that most of the PM_{10} that appeared in the area had an anthropogenic origin, largely due to emissions from transportation activities.*

Keywords: *PM_{10} concentration, meteorology, air pollution, Spearman.*

1. Introduction

Dust pollution has recently been considered one of the emerging issues in Viet Nam. In 2016, the National Environmental Status Report showed that the average annual concentration of PM_{10} (particulate matter with a diameter of 10 micrometers or less) in big cities such as Ha Noi, Ho Chi Minh, Hai Phong, and Da Nang generally exceeded the recommendations of the World Health Organization (20 µg/m^3) [8].

In general, meteorological factors (wind direction, wind speed, temperature, relative humidity, and precipitation) are closely related to the formation, accumulation and dispersion of air and dust pollutants into the surrounding environment [2]. According to Zheng et al. (2013) [12], air quality will be assessed as good with high temperatures and low humidity; meanwhile, high dust concentrations could appear at low or high wind speeds instead of moderate wind speeds. In general, wind speed is one of the most important parameters affecting dust concentration. Higher wind speeds lead to better dust dilution, or precipitation can create a washing effect [2]. Relative humidity can be positively correlated with finer dust particles by increasing their hygroscopic properties and solubility in the atmosphere, and inversely correlated with coarse dust particles because it reduces the formation of particles [7]. Changes in temperature during winter days may be related to heat inversions that reduce disturbed boundary layers height and dust diffusion [3]. Small dust concentration during summertime is associated with high temperatures and good disturbance [10]. Generally, in the context of climate change, the effects of meteorological factors on air pollutants become increasingly concerned [4]. The knowledge of weather conditions and their impacts on air pollution can assist in devising specific strategies to reduce pollution in cities [6].

Corresponding author: Nguyen Anh Dung

E-mail: nadung.monre@gmail.com

Until now, very few studies related to the impact assessment of meteorological factors on air pollution in general and dust pollution in particular have been published in the country. This study aims to evaluate the impact of meteorological factors such as temperature, humidity, wind speed, and precipitation on PM_{10} concentration in Ha Noi city from 2010 to 2019.

2. Data and Methodology

2.1. Data

This study mainly focuses on the evaluation and development of the relationship between PM_{10} concentration and meteorological factors. Meteorological data from 2010 to 2019 including hourly rainfall, temperature, humidity, and wind speed monitored 4 times/day (1 am, 7 am, 1 pm, 7 pm) was collected from Ha Dong meteorological station under the Viet Nam Meteorological and Hydrological Administration. Hourly PM_{10} concentration data from 2010-2019 was collected from Nguyen Van Cu air quality monitoring station under the Viet Nam Environment Administration (Figure 1).

Figure 1. Location of Nguyen Van Cu air quality monitoring station in Ha Noi city

2.2. Methodology

To quantify the relationship between dust concentration and meteorological factors, this paper applied the Spearman correlation coefficient, denoted by r. This is the correlation coefficient utilized to measure the degree of linear correlation between two variables when the distribution of the variables is assumed not to be the normal distribution or in case of abnormal observed values (too large or too small).

$$r = 1-6\sum d^2/n(n^2-1)$$

The Spearman correlation coefficient will receive the values from +1 to -1. If $r>0$, there is a positive correlation between two variables that means the value of one variable increases then the value of the other also goes up and vice versa. If $r<0$, there is a negative correlation between two variables that means the value of one variable increases then the value of the other will decrease and vice versa. The higher the absolute value of *r*, the greater the degree of correlation between two variables, or the more consistent the data of the linear relationship between two variables.

The utilization of the correlation coefficient combined with the graph analysis provides insights into the relationship between dust concentration and meteorological factors.

3. Results and Discussion

3.1. Current status of PM_{10} concentration in Ha Noi city

The concentration of PM_{10} was evaluated by analyzing data collected at Nguyen Van Cu monitoring station from 2010 to 2019 (Figure 2).

The average hourly PM_{10} concentration ranged from 42 to 61 $\mu g/m^3$. It can be seen that during the day, there were 2 times (during rush hours) with high PM_{10} concentration; specifically, the average PM_{10} concentration was 60 $\mu g/m^3$ at 8 am, the figure reached 61 $\mu g/m^3$ at 7 pm. These values exceeded maximum allowable concentrations as regulated in the National Technical Regulation on Ambient Air Quality QCVN 05:2013/BTNMT (the annual average is

50 μg/m³). This high PM_{10} concentration was in accordance with the two peak periods of large traffic volume during the day. The results also indicate that the average hourly pollution level in the afternoon (1 pm - 3 pm) had the lowest concentration during the day.

From 2010 to 2019, the monitoring results of PM_{10} concentration in spring (March-May) were in the range of 45-58 μg/m³ (Figure 3). During the day, the high PM_{10} concentration was observed from 8 am-9 am (57 μg/m³) and 6 pm - 7 pm (58 μg/m³). Conversely, the lowest concentration reached at 2 am to 4 am, this was also the time with the lowest traffic volume in a day.

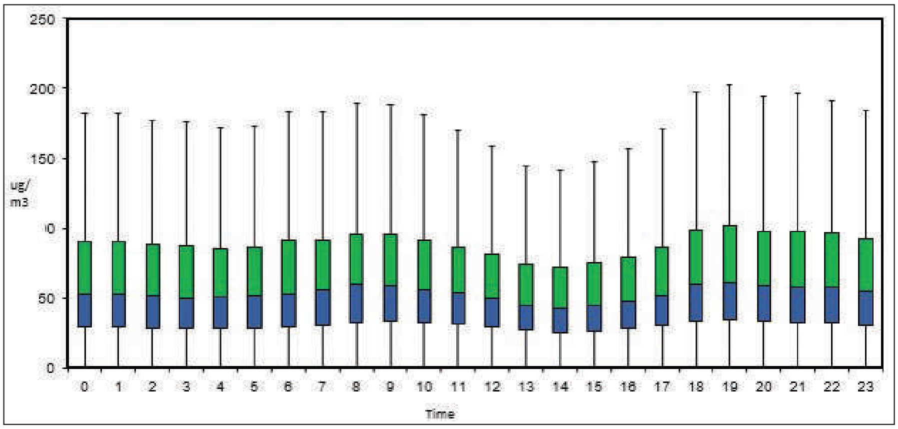


Figure 2. The hourly PM_{10} concentration between 2010 and 2019

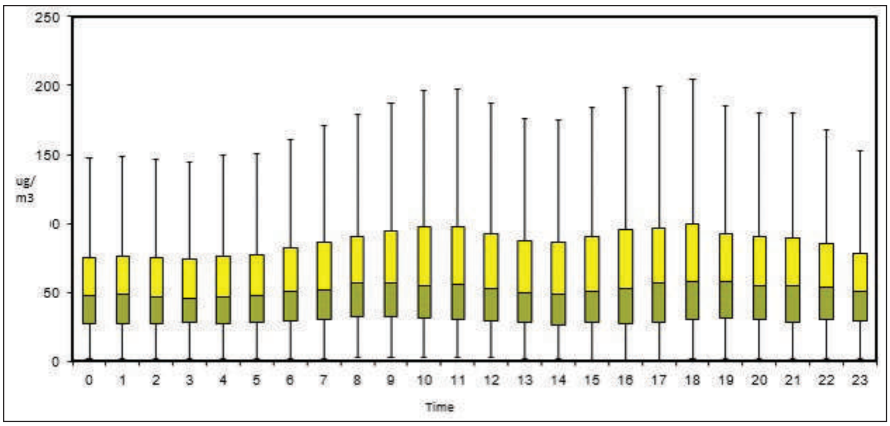


Figure 3. The hourly PM_{10} concentration in spring between 2010 and 2019

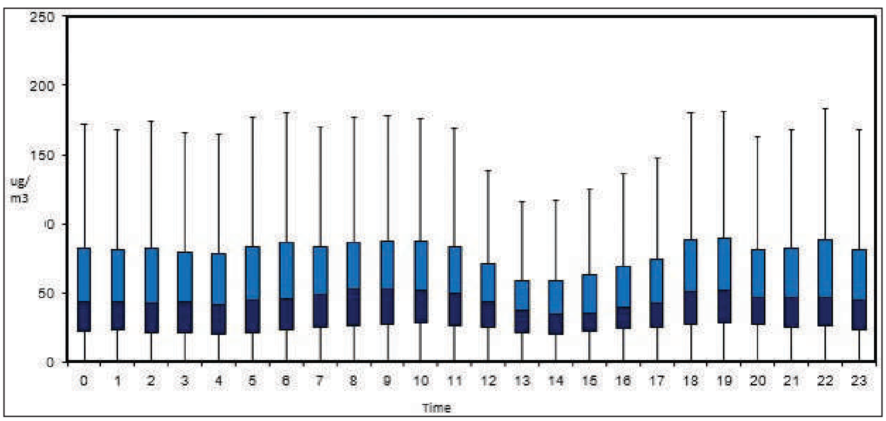


Figure 4. The hourly PM_{10} concentration in summer between 2010 and 2019

In the summertime, from June to August (Figure 4), the PM_{10} concentration showed the difference in the peak and off-peak hours during the day. The fluctuation level of the dust concentration was also greater in peak hours and lower in the remaining time frame, especially the lowest at 1-2 pm. In the afternoon, the traffic volume usually reached the lowest during the summertime, among hot days. Specifically, the monitoring result showed that the PM_{10} concentration in this period ranged from 34-53 µg/m^3. This PM_{10} concentration exceeded the QCVN 05: 2013/BTNMT (annual average) mainly in peak hours. In contrast, the values in off-peak hours were all below the standard.

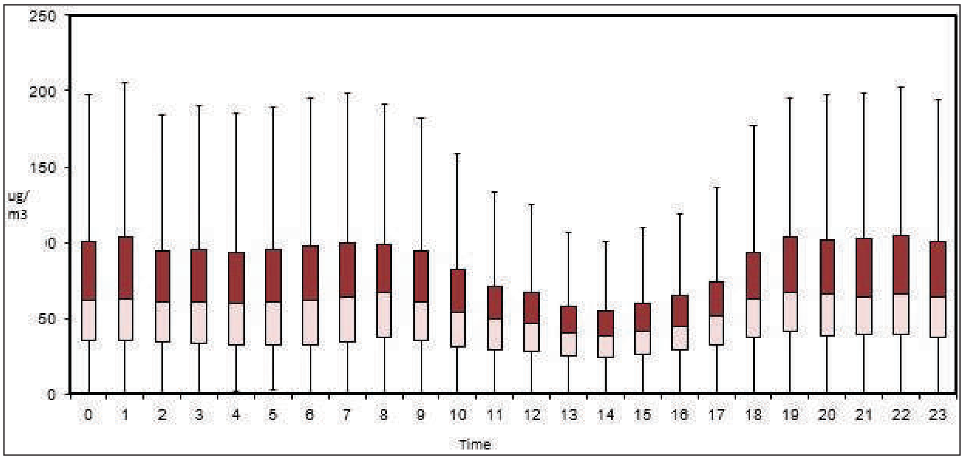


Figure 5. The hourly PM_{10} concentration in autumn between 2010 and 2019

The monitoring results of PM_{10} concentration in autumn (September - November) ranged from 38 to 67 µg/m^3 (Figure 5). Generally, the times with high PM_{10} concentration during the day were at about 8 am (67 µg/m^3) and 7 pm (67 µg/m^3). Conversely, the lowest concentration values were recorded at 2 pm (38 µg/m^3). It could be seen that the PM_{10} concentration exceeded the QCVN 05: 2013/BTNMT (annual average) at most hours of the day; some observed times were lower than the standard from 12 pm - 4 pm. During the nighttime, PM_{10} concentration still exceeded the permitted value when the traffic density decreased. It is well reported in the literature that transportation from neighboring areas is one source that contributed to the dust pollution in Ha Noi city.

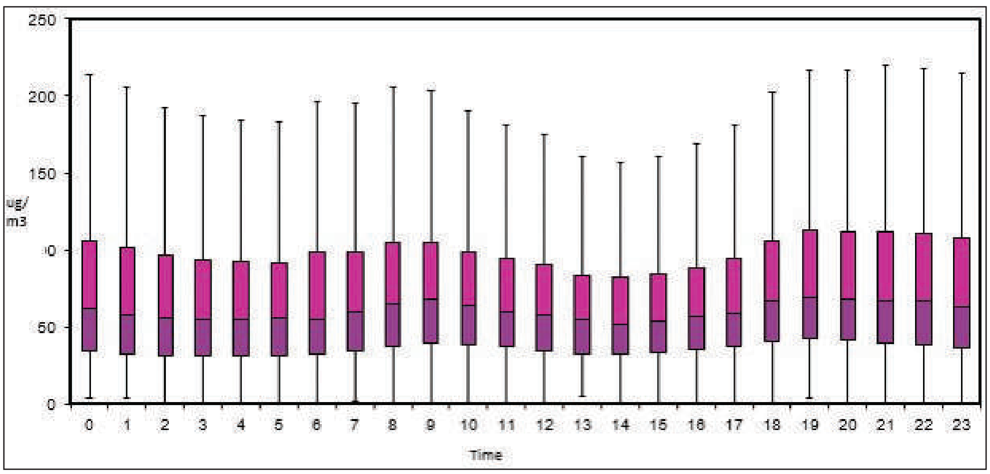


Figure 6. The hourly PM_{10} concentration in winter between 2010 and 2019

In winter, from December of the previous year to February of the following year (Figure 6), the average PM_{10} concentration was highest in the year and exceeded the QCVN 05: 2013/BTNMT (annual average) in all time frames. The fluctuation level of PM_{10} concentration in winter was also larger than the rest of the year. The monitoring result shows that the PM_{10} concentration in this period ranged from 52 to 70 µg/m^3. Specifically, the PM_{10} concentration reached the highest values at around 9 am (68 µg/m^3) and 7 pm (70 µg/m^3); on the contrary, the lowest concentration was monitored at 2 pm (52 µg/m^3).

From 2010 to 2019, the high PM_{10} level was observed in winter, followed by spring, autumn and summer. The average hourly PM_{10} concentration in summer (45 µg/m^3) was much lower than in spring (52 µg/m^3), autumn (57 µg/m^3) and winter (60 µg/m^3).

3.2. Data of meteorological factors

The analysis of meteorological data at Ha Dong station in the period of 2010-2019 (Table 1) indicated that the mean daily maximum and minimum temperatures in Ha Noi reached 30.0^{o}C and 16.6^{o}C in June and January respectively. Besides, the average humidity in summer and spring was higher than in autumn and winter. The average daily humidity value was highest in March (84.8%) and lowest in November (77.3%). In general, the humidity tended to decrease from spring to winter.

Table 1. Meteorological data at Ha Dong station from 2010 to 2019

Month	Temperature (^{o}C)	Average wind speed (m/s)	Humidity (%)	Precipitation (mm)
1	16.6	1.6	81.1	40.2
2	18.2	1.9	81.0	13.7
3	20.9	1.9	84.8	50.7
4	24.5	2.0	84.2	92.8
5	28.3	2.0	81.1	198.0
6	30.0	1.7	78.3	202.8
7	29.4	1.7	81.0	316.8
8	28.8	1.5	82.9	364.9
9	28.0	1.5	82.0	224.8
10	25.8	1.5	77.3	117.5
11	22.9	1.5	78.4	42.9
12	18.2	1.5	75.4	30.1

(Source: Ha Dong meteorological station, 2019)

The average wind speed was high in spring, highest in April and May (at 2.0m/s). In contrast, the average wind speed was lowest during the autumn months (at 1.5m/s). Overall, the difference in wind speed during seasons in Ha Noi was insignificant, staying at around 1.5-2.0m/s.

The total monthly rainfall in summer reached the highest amount (at 364.9mm in September) and the lowest at 13.7mm in February. It should be pointed out that in Ha Noi, the rainy season is from May to November, and the dry season is the remaining months.

3.3. The correlation between PM_{10} concentration and meteorological factors

The monthly tendency of PM_{10} concentration at Nguyen Van Cu station and the meteorological factors including temperature, humidity, wind speed, and precipitation are shown in Figure 7. As can be seen, the wind speed and rainfall did not change much in comparison with the temperature and humidity. The humidity reached the highest in summer and the lowest in winter. Specifically, in summer, the humidity reached 83% which corresponded to the relatively low PM_{10} concentration at 52 µg/m³. In winter, the prcipitation was very low and the lowest humidity stayed at about 73% in February. Meanwhile, the PM_{10} concentration was relatively high with an average of 74 µg/m³.

During the summer months, in the context of the increased temperature and high humidity, the concentration of PM_{10} reached the smallest value (about 51 µg/m³), which was 1.5 times lower than the winter months. Accordingly, there was an influence from the process of dust deposition and dust leaching.

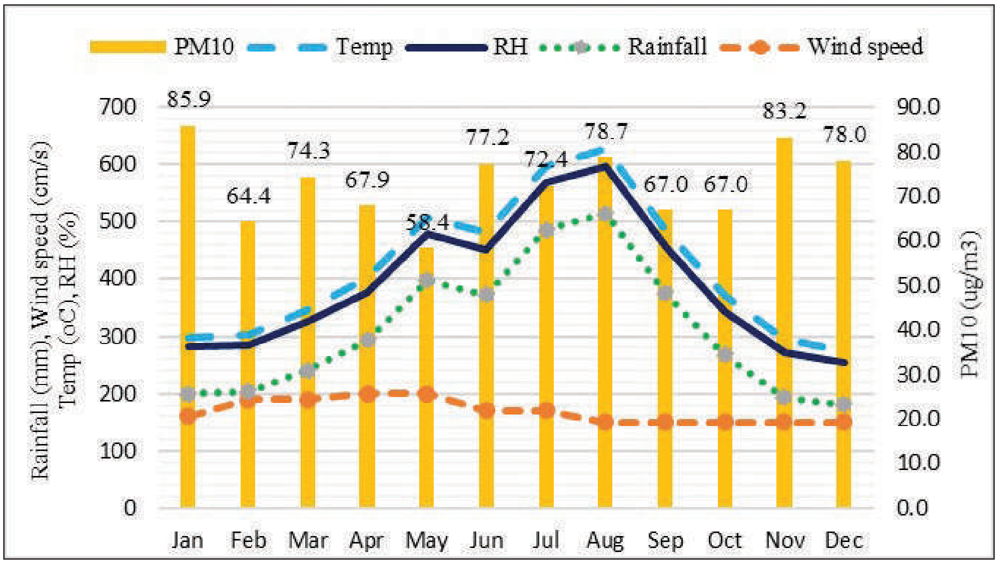


Figure 7. The monthly tendency of PM_{10} concentration and meteorological factors

The relationship between PM_{10} concentration and meteorological factors was assessed by the Spearman correlation coefficient as indicated in Table 2. The PM_{10} concentration was inversely correlated with wind speed (except summer), and the highest correlation of PM_{10} concentration with wind speed was shown in winter (r = -0.47). The temperature was positively correlated with PM_{10} concentration in winter, and inversely correlated in the remaining seasons. The precipitation is negatively correlated with PM_{10} concentration in all seasons which characterized the dust deposition and leaching process, even though this correlation is not high.

Table 2. The correlation between concentration and meteorological factors

Correlation coefficient	Temperature	Humidity	Wind speed	Precipitation
Spring	-0.43	0.20	-0.18	-0.09
Summer	-0.02	0.11	0.02	-0.03
Autumn	-0.31	-0.09	-0.16	-0.16
Winter	0.05	0.05	-0.47	-0.10

As can be seen from Table 2, the PM_{10} concentration was reversely correlated with wind speed in spring, autumn, winter, and positively correlated in summer. The high correlation was seen in winter (r = -0.47). The inverse correlation between PM_{10} concentration and wind speed could reflect the characteristics of the predominant local pollution sources. Zhang et al. (2015) [11] also indicated that the horizontal dispersion plays a role in the adjustment of PM_{10} concentration in spring, autumn, and winter in Beijing when there is an inverse correlation between PM_{10} concentration and wind speed.

Regarding the temperature, the PM_{10} concentration showed a negative correlation in spring, autumn, and summer and a positive correlation in winter. The correlation coefficients in summer and autumn were much better than in spring and winter. The highest correlation occured in summer (r = -0.43). Accordingly, this indicated that an increased temperature is unfavorable to the formation of fine dust particles.

The inverse correlation between temperature and PM_{10} concentration could happen from the temperature inversion phenomenon. In the study on heat inversion in Ha Noi published by Trinh Thi Thuy et al. (2019) [9], the authors found that PM_{10} concentration was higher during the temperature inversion. However, the correlation between the average monthly dust concentration and total days of temperature inversion was low. Gramsch et al. (2014) [5] also indicated the low correlation between the average daily $PM_{2.5}$ concentration and the intensity of temperature inversion in Santiago de Chile (r^2 = 0.1233). The reason is that the meteorological factors have changed; the wind speed and humidity are often lower when the temperature inversion occurs.

The PM_{10} concentration was positively correlated with humidity in all seasons, except for autumn. However, the correlation was relatively low, the highest was only at r = 0.20 in spring. The positive correlation was characterized by the fact that the boundary layer would be lower with more humid air; therefore, leading to the increase of concentration of major air pollution sources [12].

Regarding the precipitation, the PM_{10} concentration had a negative correlation in all seasons that reflected the dust deposition and leaching process. Studies on urban air pollution have demonstrated that the rainfall will reduce the return of dust from the road surface and remove airborne dust [1]. Although the calculation results showed that the rainfall had a relatively low correlation with the PM_{10} concentration.

4. Conclusion

In general, the assessment results on the correlation between PM_{10} concentration and meteorological factors in Ha Noi between 2010 and 2019 indicated that the effects of seasonal changes were clear. In particular, the correlation between wind speed and PM_{10} concentration in winter was most clearly seen, probably due to the pollutant transportation in the area. The meteorological factors such as air temperature, humidity were also the factors that affected the increase or decrease of dust concentration. The dust concentration tended to be inversely proportional to temperature and direct proportional to humidity. High temperature and reduced pressure during summer helped bring moisture from the ground to the air layer above or to other areas, leading to a reduction of the dust amount. The study suggested that, the greater the humidity the less dust would spread from the pavement or adjacent areas, which led to a reduction in the PM_{10} concentration. These findings could contribute to the air quality management in the city.

References

1. Barmpadimos, I., Hueglin, C., Keller, J., Henne, S., Prevot, A. (2011), *Influence of meteorology on PM_{10} trends and variability in Switzerland from 1991 to 2008*, Atmospheric Chemistry and Physics 11, 1813-1835.
2. Chen, L., Peng, S., Liu, J., Hou, Q. (2012), "Dry deposition velocity of total suspended particles and meteorological influence in four locations in Guangzhou, China", *Journal of Environmental Sciences 24* (4), 632-639.
3. Clements, N., Hannigan, M.P., Miller, S.L., Peel, J.L., Milford, J.B. (2016), *Comparisons of urban and rural $PM_{10-2.5}$ and $PM_{2.5}$ mass concentrations and semi-volatile fractions in northeastern Colorado,*

Atmospheric Chemistry and Physics 16, 7469-7484.
4. Fiore, A.M., Naik, V., Spracklen, D.V., Steiner, A., Unger, N., Prather, M., Bergmann, D., Cameron-Smith, P.J., Cionni, I., Collins, W.J. (2012), Global air quality and climate, Chemical Society Reviews 41, 6663-6683.
5. Gramsch, E., Caceres, D., Oyola, P., Reyes, F., Vasquez, Y., Rubio, M., Sanchez, G. (2014), *Influence of surface and subsidence thermal inversion on* $PM_{2.5}$ *and black carbon concentration*, Atmospheric Environment 98, 290-298.
6. Karagiannidis, A., Poupkou, A., Giannaros, T., Giannaros, C., Melas, D., Argiriou, A. (2015), *The air quality of a Mediterranean urban environment area and its relation to major meteorological parameters*, Water, Air and Soil Pollution 226, 1-13.
7. Laakso, L., Hussein, T., Aarnio, P., Komppula, M., Hiltunen, V., Viisanen, Y., Kulmala, M. (2003), *Diurnal and annual characteristics of particle mass and number concentrations in urban, rural and Arctic environments in Finland*, Atmospheric Environment 37 (19), 2629-2641.
8. Ministry of Natural Resources and Environment (MONRE), (2017), *National Environmental Status Report.*
9. Thi Thuy Trinh, Thi Tham Trinh, Thi Trinh Le, The Duc Hanh Nguyen, Binh Minh Tu. (2019), *Temperature inversion and air pollution relationship, and its effects on human health in Ha Noi City, Viet Nam*, Environment Geochemical Health 41 (2), 929-937.
10. Yin, Q., Wang, J.F., Hu, M.G., Wong, H. (2016), "Estimation of daily $PM_{2.5}$ concentrations and its relationship with meteorological conditions in Beijing", *Journal of Environmental Sciences 48*, 161 - 168.
11. Zhang, H., Wang, Y., Hu, J., Ying, Q., Hu, X.M. (2015), *Relationships between Meteorological Parameters and Criteria Air Pollutants in Three Megacities in China*, Environmental Research 140, 242 254.
12. Zheng, Y., Liu, F.R., Hsieh, H.P., (2013), *U-air: when urban air quality inference meets big data. Proceedings of the 19th SIGKDD Conference on Knowledge Discovery and Data Mining*. Chicago, USA. August, 11-14.

VIETNAM INSTITUTE OF METEOROLOGY, HYDROLOGY AND CLIMATE CHANGE

No.23 Lane 62 Nguyen Chi Thanh, Ha Noi, Viet Nam
Email: imhen@imh.ac.vn
Website: www.imh.ac.vn