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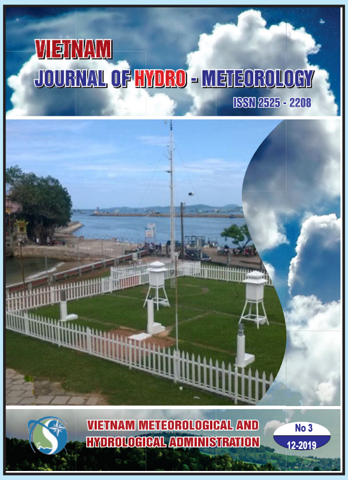

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Research Paper

THE SCIENTIFIC AND PRACTICAL FOUNDATIONS FOR SUSTAINABLE DEVELOPMENT AND CLIMATE CHANGE RESPONSE IN MEKONG DELTA, VIETNAM

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ABSTRACT

Mekong Delta in Vietnam plays an important role of national economy and has highly diverse natural conditions and resources. In the context of climate change, sea level rise, and increasing the impacts from water utilization in the upstream Mekong River and natural resource exploitation within Mekong Delta, it is needed to have the scientific and practical foundations, strategies, solutions and models for large scale transformation in Mekong Delta towards sustainability and climate change response. However, the combination of the existing dam systems and water utilization from upstream of Mekong River have caused a quick decline of sediments and water discharge into the Mekong Delta. Additionally, the unsustainable use of natural resources within Mekong Delta is directly threatening the sustainable development. Therefore, it is needed to implement: i) integrating solutions of policies, integrated strategies, models and solutions to large scale transformation of socio-economic models; nature and ecosystem based sustainable natural resource use planning for proactive response to climate change and human impacts; ii) ensuring non-traditional security, smart response to climate change and disasters and other negative impacts in Mekong Delta; iii) enhancing science and technologies, human resource development and smart governance. Besides, it needs to promote international cooperation for building "Smart water governance in Mekong River and Delta" for sustainable development and climate change response.

Keywords: *Climate change, Mekong Delta, Transformation, Sustainable development.*

1. Introduction

Mekong Delta (MD) in Vietnam has 13 provinces and cities, with a total population of 17.66 million people, accounting for 19% total population of Vietnam, with a population density of 433 people/km^2 (GSO, 2016). The MD is the biggest rice producer area in Vietnam, plays an important role for socio-economic development of Vietnam. In term of economic development, the MD contributes an important proportion in the overall national economy. However, its economic development is not commensurate with favorable natural conditions and rich in natural resources. In recent decade, climate change, sea-level rise and increasing in number of dam construction in the upstream of the Mekong River have caused the integrated impacts from climate change and anthropogenic activities for the MD.

Consequently, the MD has been reported to

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be one of three most vulnerable delta plain to climate change in the world. Therefore, it is urgently needed to implement research programs and research projects for gaining the scientific and practice foundations for enhancing sustainable development of the MD. This paper aims to analyze and evaluate the natural characteristics, natural resources, environment and climate change; strategies, policies and development models in the MD for proposing solutions, orientation and models for comprehensive sustainable development, effective response to integrated impacts and ensured non-traditional security in the MD.

2. Natural characteristics, natural resources and environment in mekong delta

2.1 Natural characteristics

2.1.1 Evolution of geology and geomorphology

Since about 20 thousand years before present (B.P.), global sea level started to increase continuously at a rapid rate, up to 8000 years B.P., when the sea level decreased slowly to at a rate of approximately 2 mm/year (Nittrouer et al., 2017). The reduction of the global sea level rise has created conditions for the delta plain to develop. During this period, the MD was expanded and accreted in a total length of 200 km from the Cambodian border to the present coast during a period of nearly 2000 years from 5500 to 3500 years BP (Anthony et al., 2015; Oanh and Lap, 2008). Total area of the MD was formed to be approximately of 62.520 km^2 (Truong et al., 2011). The average elevation of the MD is less than 2 m in height in comparison to mean sea level (Nittrouer et al., 2017).

Geomorphological characteristics of the MD are divided into two distinguished parts, consisting of the high elevation delta plain and the low delta plain. The high elevation delta plain is strongly influenced by river development, which is developed in swamps and inundated floodplains with elevation of 0.5m - 1.5m and delimited by Late Pleistocene formation with elevations of 3m - 5m in the Cambodian border. The high elevation delta plain extends through An Giang, Dong Thap, Can Tho, Hau Giang, Vinh Long, Long An, Tien Giang and Kien Giang provinces(Hoang et al., 2016). The low delta plain is strongly influenced by the wave and tidal regime and charaterizes by sand dune systems with the elevation of 3m -10m in height, which distribute parallelly to the shoreline in the direction of North East - South West, between the sand dunes is the lowlands with the elevation of 1.5m - 2.5m in height (Oanh and Lap, 2008). The low delta plain includes the coastal areas of Long An, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau province (Hoang et al., 2016). The coastal area from Long An province to Bac Lieu province is strongly influenced by wave regime, so the accretion rate of the land toward the sea is approximately 16 m/year. While the Ca Mau peninsula is strongly influenced by the tidal regime, so it can extened toward the sea upto 26 m/year năm (Anthony et al., 2015; Liu et al., 2017).

2.1.2 Reduction of suspended sediments transported by river systems

Major dam systems on the upper MD were started to build in the year 1993 by China (Manwan dam). By April 2016, a total of 35 dams were built for the purposes of electricity production and agricultural irrigation, water supply and others. In the future, there will have more 226 dams that are proposed to build (Allison et al., 2017). Before the dam systems were built, the suspended sediment transported by Mekong River was estimated to be 160 million tons. However, after the Manwan dam was built, the suspended sediment in river was significantly reduced in the downstream of the dam (Wang et al., 2011). Further studies by Kondolf et al. (2014) demonstrated that if all dams are being constructed and put into operation, 51% of the suspended sediment transported by the Mekong River downstream will be reduced; and if all the planted dams will be constructed, 96% of the suspended sediment transported by Mekong River will be reduced. The reduction of suspended sediments transported downstream will cause significant impact on the stability of river flows, canal flows and geological and geomorphological evolution of the MD (Nittrouer et al., 2017), affecting soil fertility, ecosystems and natural aquatic productivity in the MD (Pukinskis, 2013).

2.1.3 Shoreline erosion characteristics

There are many studies on the characteristics of shoreline erosion in the MD. Results from analysis of SPOT 5 high resolution satellite images demonstrated the changing of shoreline in different subzones. The estuarine subzone composes mainly by sand, the East coast and West coast is formed by mud (Anthony et al., 2015). The mud coasts are being eroded at a rate of about 50 m/year, of which 90% of the length of the mud coasts in the East coastline are eroded. The total area of eroded land is estimated to be 5 km^2 during a period from 2003 - 2012. In the estuarine area, the annual accretion area is significantly reduced from 0.78 km^2 to 0.26 km^2 during above period. The major causes for increased coastal erosion are the reduction of sediment supply from the river, sand extraction in rivers and canals, and increased surface subsidence (Anthony et al., 2015).

2.1.4 Salinity intrusion

Coastal salinization can occur in two major mechanisms, saline intrusion of surface water at river mouths, and salinization of groundwater. In the MD, salinity intrusion into the delta plains is occurring very seriously and increased rapidly over time. The estuarine areas where significantly increase in salinity are Vam Co Tay, Tien River, Ham Luong River, Co Chien, and coastal plains of Tra Vinh, My Tho and Ca Mau provinces. Some areas have high salinity in water reached to 30‰ in Thuan An (6 km far from the coastline), 27.6‰ in Ben Trai (12 km far from the coastline), 9.5‰ in Tra Vinh (Duc et al., 2008). The delta plain area affected by salinity and alkalinity in the MD has increased rapidly in recent years. The main causes of salinity intrusion is due to the low terrain and rapid decline of river water caused by upstream dam systems. Salinity intrusion accurs rapidly and expands in area if the flood season in the MD is abnormally late. Other causes such as aquaculture in the Mekong Delta have caused large amounts of seawater to spill over into the surrounding areas (Tho et al., 2014).

2.2 Characteristics of the main types of natural resources

2.2.1 Land resources

Total natural land area of the MD is nearly 4 million hectares, accounting for 12% of the total land area of the country. The total land area using for agriculture and aquaculture is about 2.6 million ha. In which, the proportion of annual crop land accounts for greater than 50%, consisting of paddy land > 90%, land for cultivation of crops and short-term industrial crops of about 150,000 ha, perennial cops of 320,000 ha (Communist Review, 2017). The main characteristics of the soil groups in the MRD are shown as follows: alluvial soil accounts for about 1.2 million ha, with high natural fertility and no serious limiting factors; alkaline soil (1.6 million ha), which is characterized by high acidity, high aluminum concentration and low phosphorus. This soil group also includes saline and heavy saline soils. The alkaline soil distributes in Dong Thap Muoi and Long Xuyen quadrangle. The salty alkaline soil is concentrated in the central part of Ca Mau peninsula. Saline soil (0.75 million ha) is affected by salinity intrusion during the dry season. These land areas can hardly be supplied with fresh water. Other soils (0.35 million ha), including peatland (U Minh forest), gray soil on ancient alluvial soil (northern of MD) and hilly land (west-north of MD).

2.2.2 Water resources

a. Surface water resources

MD has a entangled system of rivers, streams and canals, with major river systems of the Tien and Hau rivers that segregate to discharge into the sea at following estuaries Co Chien River, Ham Luong River, Ba Lai River, Cua Dai River and Cua Tieu and Hau Rivers through Dinh An and Tran De. Hydrological regimes in the MD are directly affected by upstream flow, tidal regime in the East Sea and West Sea. Annually, the Mekong River transports about 475 km^3 of water into the MD (Yadu et al., 2018) and the total amount of rainwater within the MD is about 52 billion m^3. The average annual flow discharge into the MD is about 12,900 m^3/s, in which an amount of 10,100 m^3/s occurs in Tan Chau station and of 2,800 m^3/s occurs in Chau Doc station. Most of the inflow occurs during the flood season, accounting for 90%, while the rest occurs during the dry season (Tran, 2014).

In recent years, the total flood flows discharge into the MD being tended to decrease at an average rate of 1.87 billion m^3. The total flows during the flood season in the years of 2010, 2012, 2015 and 2016 were significantly declined in comparison to the average value of many years, accounted only for 75-90% of the average value of many years, causing a decline in water stockpiles for the dry season. Total flows during the dry season flows in the MD has a decrease tendency, with an annual rate of about 0.18 billion m^3(equivalent to about 11.7 m^3/s). Total flows during the dry season in the years of 2010, 2013, 2015 and 2016 were much smaller than the multi-year average, accounted for only 75-90% of the multi-year average, causing severe drought and water shortage (Tran, 2014).

b. Groundwater resources

The MD has a great potential for groundwater resources, with five to seven groundwater layers, distributed in the depth from a few dozen meters to 500-600m. The areas with high groundwater potential are Bac Lieu, Long An, Dong Thap, Ca Mau, Tra Vinh and Can Tho. The total natural reserve is approximately 21 million m^3/day (MRC, 2010). Groundwater plays an important role in supplying water for urban, rural and industrial use in the MD. About 80% rural population is using the groundwater, many urban areas such as Soc Trang, Bac Lieu, Ca Mau and Tra Vinh depend entirely on the groundwater). For the whole MD, there are about 2 million wells to exploit the groundwater. Of which there are over 550,000 large drilled wells that are exploiting a total water volume of two million m^3/day (MRC, 2010).

Due to the large scale of exploitation, most the groundwater level of the aquifers in the MD tends to be depressed rapidly with an average rate from 0.2 to 0.4 m/year, with a maximum of 0.93 m/year. The major cause of the depressed groundwater level is the continuously increase in exploitation of the groundwater of both numbers and sizes of wells (MRC, 2010).

2.2.3 Biodiversity and ecosystems

The MD has a high level of biodiversity of both the number of species (fauna and flora) and ecosystems. Ecosystems are classified into tidal, sand dunes, and swamp in the coastal plains, estuarine areas, floodplains, large lowland areas, peat swamps, stripes of land alluvial riverbank and ancient alluvial terrace. Aquatic ecosystems are divided into freshwater aquatic ecosystems, including the upper stream Mekong river, Vam Co Tay, the Thuong, the Lower, Cai Co and Long Khot rivers and large natural lakes, wetlands and semi-subsurface waterways, lowland areas, riverside alluvial areas, protected and protected areas, canals and agricultural production facilities; the brackish-water and saline-water ecosystems in the coastal areas include the mouths of the Mekong river and the canals near the sea. The ecosystems in each region of the MD are characterized by the regimes of flooded, submerged, and tidal areas (Tri, 2015).

Coastal mangrove ecosystems: Mostly distributed in the coastal areas of the MD, most developed mangroves are concentrated in the Mekong River estuaries and Ca Mau Peninsula.

Melaleuca forest ecosystem: In the past, Melaleuca forest covered half of the area of alum soil, but now it is only distributed in U Minh peat areas and some places in Dong Thap Muoi and Ha Tien plains. The ecosystem plays an important role in stabilizing soil, hydrological regimes and the conservation of animals.

The fauna of the MD consists of 23 mammal species, 386 species and orders of bird, 6 amphibian species and 260 species of fish. The largest number and diversity of fauna are often observed in the Melaleuca and mangrove forests. The fish fauna of the MD contains 216 species belonging to 60 families, 19 orders (Tri, 2015).

2.3 The natural factors affecting sustainable development of the Mekong Delta

Based on the research results, the MD is a dynamic system that has developed and evolved continuously from 8.000 years ago.The amount of suspended sediment transported by the Mekong River into the MD is one of among important factors for delta evolution and expansion towards the sea, in which approximately one-third of such transported sediments will be deposited in the estuaries and near shore sea to form the delta front (Nittrouer et al., 2017), to reduces hore line erosion and land surface subsidence. In addition, the suspended sediment transported by the river directly contributes to stabilize the geomorphological streams, canals and to develop the agriculture. Another important factor for the evolution of the MD is the water transported from the outside Vietnam by the river systems. Freshwater flows in the river system directly contribute to maintain the aquatic biodiversity in water bodies, creating different ecological habitats and ecosystems, promoting the socio-economic development in the MD. Additionally, flows in river and canal systems can directly flush the seawater intrusion toward the sea.

In recent decades, the dam and water regulation construction in the upstream of the MD have significantly reduced the mass of suspended sediments and water flows in the Mekong River to the MD.These factors certainly affect the natural development of the MD, contributing to increase severe erosion of shoreline and riverbank, land subsidence, inundation, and salinity intrusion, shortage of freshwater and fertilized alluvium for the natural ecosystems, agriculture, industry and other socio-economic activities. Therefore, it is necessary to implement the researches that will determinethe scientific and practical foundation to response to unfavorable conditions in order to enhance resilience, adaptation and sustainable development in the MD.

3. Policies, strategies and sustainable development models for the mekong delta

After "Innovation" period, the MD has made a remarkable change and plays an important role in the socio-economic development of Vietnam. Parallel with the rapid development of industrial and service activities, the agricultural share is continuously decreasing. Currently, the provinces in the MD occupy for approximately 20% GDP, 57% rice production and 56% aquaculture production in the total production of Vietnam (GSO, 2015b). However, other sectors, including health, education, trained labor force and the level of poverty reduction in the MD are quite low in comparison to the national average, affecting the socio-economic development in the context of climate change. Nowadays, the agricultural and aquaculture production of the MD are facing many risks, including lack of the land resources and financial capital,weak development of science and technology, shortage in information and difficulty in accessing the market directly; competition in the international market on price and international quality of the production, limited storage capacity of production, and heavily depending on seasonal crops (Renaud and Kuenzer, 2012). Besides, the impacts related to climate change, the decline of water resources from upstream, sea level rise and salt intrusion have also put more pressure on the development of the MD (Smajgl and Ward, 2013), affecting the transformation of the model, the socio-economic development plan of the regions.

3.1 Transforming agricultural production

The transformation of agriculture in the MD will highly depend on policies, development of irrigation systems, and soil and water environment (Renaud and Kuenzer, 2012). Three major agricultural transformation periods in the MD are presented as follows (Renaud and Kuenzer, 2012):

- From 1975 to 1990: Rice cultivation area was expanded due to the development of the irrigation system (irrigated rice cultivation area annually increased about 85.000ha). In this period, the rice cultivation was extensively developed for 2-3 crops per year.

- From 1991 to 1999: Rice cultivation for export was priority developed due to the socio-economic transformation (post 1986) and development of irrigation infrastructure to ensure drainage, irrigation, dike construction and minimize salinization. The MD plays as major region to contribute the share of rice export of Vietnam to be one of the largest rice exporters in the world.

- From to 2000- now: This period is observed as highly development of intensive and extensive aquaculture which has a higher value than the rice farming. The aquaculture is mainly grown fish Pangasius, basa fish in fresh water, tiger shrimp (as Penaeusmonodon) in brackish water. Additionally, this period is also promoted the fruit trees with high economic values, including mango, rambutan, durian, etc. However, the extensively development of the aquaculture caused the degradation of coastal ecosystems, particularly mangroves and increased the high risks to the local people.

Nevertheless, agricultural and aquaculture activities are strongly influenced from climate change and degradation of water resources transported from the Mekong River (Smajgl and Ward, 2013). Negative impacts such as shortage of water resources, decreasing water flows and quality, salinity intrusion have increased the vulnerability for agriculture and aquaculture development, directly affecting livelihoods and degradation of economic potential of people in the MKD. As a result, agricultural and aquaculture development in the MD must be transformed into new development model for better response to impacts from climate change and shortage of water resources.

3.2 Reclamation strategy, migration of people in new economic development programs in the Mekong Delta

From 1975 to 2000, the migration flows to the MD under several new economic development programs that have motivated economic growth for the whole region with high commodity agricultural production (Anh, 2010). The most intensive migration of people to the MD was taken place during the period from 1975-1986 and the period from 1986-1995 (Anh, 2010). Due to the favor condition for the agricultural development and available of natural resources, the total migrants to the MD markedly increased annually. Although the migration policies have many advantages for socio-economic development in the region, but there also brought many negative impacts on natural resources and environment such as the destruction of inland wetland ecosystems and coastal mangrove forests. These activities have brought immediately economic benefits, but it has caused a degradation of the resilience of the natural and social systems to climate change, influencing non-traditional security, increasing the vulnerability of the local communities, particularly in the coastal area (Cosslett and Cosslett, 2013; Renaud and Kuenzer, 2012).

However, in recent years, the migration trend in the Mekong Delta has obviously increased (GSO, 2015a; Renaud and Kuenzer, 2012). Migration is a consequence of the transformation of the socio-economic model in the Mekong Delta in both urban and rural areas (Entzinger and Scholten, 2016). A specific example, such as the shift from rice cultivation to aquaculture or agricultural mechanization will increase the number of unemployed workers, promoting migration of these workers to other areas. Other reasons to promote migration are also evident in the desire of many households when they want to have stable career in urban areas and large cities with high incomes. Another source of remittances to the Mekong Delta gradually increased over the years leading to the transformation of the economic model and job of many households (Renaud and Kuenzer, 2012; World Bank, 2016). In summary, migration has played an important role in the development of the MD in history, but it has become a challenge for maintaining socio-economic development in the present period.

3.3 Industrialization

Currently, there are 74 industrial areas and 214 industrial clusters in the Mekong Delta (https://goo.gl/bGvX8C). However, the total value of industrial production of the region accounted for only a small proportion of the country. Major industries of the MD are food processing, producing materials and consumer goods, lacking high engineering and technology sectors. The reasons of poor development of industrial activities include (Renaud and Kuenzer, 2012): The potential of businesses and the private sectors has not been effectively used as a motive force for industrial development; human resources, particular high-technology human resources is relatedly low. The level of creativity and technology is weak, the scientific and technological capacity of the MD must be strengthened; Infrastructure should be investigated intensively to make as a driving force for industrial development.

3.4 Urbanization

Urbanization is an important driver for socio-economic development in the MD. With four large urban centers My Tho, Long Xuyen, Rach Gia, Vinh Long and a central urban Can Tho city where are surrounded by industrial areas and clusters, seaports to form regional links in socio-economic development. However, development plans and strategies for urban construction in the MD are less sustainable, particularly vulnerable to climate change and non-traditional security (water conflict in the border, free migration) (Renaud and Kuenzer, 2012; Smajgl and Ward, 2013). Therefore, urbanization will play acrucial role in the MD, contributing to the economic restructure in the region towards sustainable development.

3.5 Strategy for agricultural and aquaculture development

The strategy for agricultural and aquaculture development has been carried out in each periodwith the overall goal that were transformed from ensuring food security (through rice production) to the harmonious development between value of economic and quality of agricultural and aquatic products with national interests and community benefits. Therefore, the agriculture and aquaculture development strategy for the MD was promulgated in Decision No. 639 /QD-BNN-KH dated 02/04/2014 of the Ministry of Agriculture and Rural Development. Generally, the main objective of the strategy is "Developing comprehensive, sustainable agriculture and rural areas in the MD with high-adaptability to climate change; effective producing with high quality and competitiveness; the sensible economic structure and production organization; modernizing the socio-economic infrastructure gradually; increasing the income and living standard of citizens; using natural resources effectively; protecting and improvingthe environment" (https://goo.gl/sXhPoU).

Therefore, the transformation of the economic structure between agriculture and aquaculture with high adaptation to climate change will be the future development model of the MD.

3.6 Strategies for industry and services development

The development strategy for industry and services is an important part of the MD's socio-economic development plan approved by the Prime Minister with Decision No. 939/QD-TTg dated July 19, 2012 (https://goo.gl/hXg5MU). The Mekong Delta's industrial and service development orientations are closely linked with processing industries of agricultural, forestry and fishery products in the export; power and energy industries, textile and footwear industry, mechanical industry, commercial services andtourism services. In general, the service industry development strategies of the MD willpriority for agriculture and light industry, developing energy to ensure national energy security. However, the issue of a sustainable water development strategy in the MD is facing many difficulties due to cross-border water security issues.

3.7 Strategy for using and exploiting natural resources

Strategiesfor using and exploitingnatural resource in the MD a concentrated in two main objectives: water and mineral resources (construction sands). However, the issue of strategy'sdevelopment for sustainable water resources using in the Mekong Delta is facing many difficulties due to transboundary water security issues (the construction of upstream dams) and the context of climate change impacts (salinity intrusion, sea level rise, etc.) (Cosslett and Cosslett, 2013; Smajgl and Ward, 2013). In addition, the degradation of transported sediments in the MD leads to the loss of construction sand and to increase erosion of riverbanks and shoreline, resulting in loss of land for economic development. Therefore, the strategy for sustainable exploitation of water resource and minerals need to enhance sustainable use of these natural resources, to enhance the resilience with climate change and non-traditional security but must be also integrated, closely linked to the national strategy.

3.8 Impact of changes in policy and strategies for socio-economic development in the Mekong Delta

According to the analysis of changes in socio-economic factors and strategic policy for the MD, the important factors in the development of theregion's economy are agriculture and aquaculture (Stewart and Coclanis, 2011). The most important factor of socio-economic development of the MD highly depends on the conversion of wet rice cultivation into higher economic forms such as aquaculture and fruit trees planting. The food processing industry also develops in the region but its share in the total economy is still small. Urbanization and the increase in services are limited, below the region's potential. In the current characteristics of the MD, there are challenges to balanced development between market economy, private enterprises and international integration (Renaud and Kuenzer, 2012). In addition, factors such as salinity intrusion, water shortage, phenomena related to climate change have a strong impact on socio-economic development in the MD and the region's sustainable development goals. Therefore, in order to achieve the SDGs for the MD, it is necessary to make development plans and synchronous management among different departments and sectors, especially under the impacts of climate change and non-traditional security scenarios.

4. Orientations, models and solutions to towards sustainable development in the Mekong Delta

4.1 General principles

The general principles for developing solutions to model of sustainable development in the MD should be based on three main factors: water resources, sediment transported from Mekong River and human resource development. In which, water and sediments are importantly initial inputs to maintain the balance of the dynamic natural system of the MD, being important resources for socio-economic development. Another factor of human resources will determine the management and utilization of natural resources and better response to challenges of climate change. However, the scenarios for water resources and sediments will tend to follow the factors:

- The flow and quality of water resourcesin the MD are both decreasing;

- The suspended sediments transported by Mekong River to the MD tend to be decreasing;

- Hazards such assea level rise, riverbank erosion, shoreline erosion, land subsidence, salinity intrusion is increasing in both scale and intensity;

- The benefits and challenges from sea water/brackish water resources to the MD are increasing to impact significantly, leading to shift the coastal and estuarine ecosystems;

- Human activities at the upstream of Mekong river are difficult to predict and control.

Thus, the overall solutions to ensure national security and response to climate change, minimize the impact of natural disasters on the MD need to be in harmony between socio-economic development and the environmental protection including: 1) Harmony between nature, socio-economy, and humanity; 2) Application of science and technology to sustainable exploitation of natural resources; 3) Harmonization in the policy for all stakeholders,and 4) Enhancement of resilience and adaptation to vulnerable factors (salinity intrusion, water source security, migration, etc.).

4.2 Recommended solutions to sustainable development for Mekong Delta in the context of climate change

4.2.1 Policy solutions

- Development policy on regional integration, especially to respond to natural disasters and climate change such as salinity intrusion, drought, water shortage, to develop the master plan and apply to the whole region's economy in order to encourage the exchange and support among provinces and cities in the overall goals of the sustainable development of the MD;

- Policy on encouraging and supporting farmers to transform the agriculture in term of shift the traditional into new plants and animals and change their careers accordingly;

- Policy on encouraging enterprises to invest in production of agricultural materials (currently foreign enterprises are dominant) and processing high-quality products to increase the added value of products.

- Prohibition against exploiting sand in main canals;

- Policy on reducing ground water exploitation;

- Develop, conserve and plant new coastal mangrove forest.

4.2.2 Scientific and technological solutions

- To build and complete the infrastructure system of freshwater reservoirs in the delta area and conserve the existing wetlands in order to ensure the replenishment of fresh water during the dry season;

- To construct sea and river dyke systems with the ensure the principle of circulating water sources from rivers to the sea, avoiding the inundation of waterways in the delta area;

- To conserve and replant new mangrove forests for reducing greenhouse gas emissions and increasing sedimentation and protect the coastlines;

- To develop infrastructure for strengthening the regional integration in socio-economic development and respond to climate change, non-traditional security;

- To research and develop plans that are highly adaptable to changing environmental conditions, especially salinity intrusion;

- To develop simulating models to have scientific foundation for developing long-term response plans;

- To evaluate changes in terrains, geomorphology, hydrology, navigation and evolution in the MD based on GIS and high-resolution remote sensing technologies;

- To implement a real-time monitoring network for proper and sustainable water allocation and utilization.

4.3 Solutions for training human resources and smart governance for climate change

4.3.1 Solutions for training high-quality human resources

- To invest in development of human resources in research institutes and universities in the fields of smart climate change response to climate change in the MD;

- To invest in development of undergraduate and graduate programs in universities; education curricula in schools about the smart response to climate change in the MD.

4.3.2 Solutions to governance of smart response toclimate change

- To invest in researching solutions to increase the governance capability of smart responses to climate change for managers at all levels;

- To invest in the research and development of high-quality human resources for the management of projects related to climate change in the MD;

- To research on the overall strategy of active response to climate change, wise use of natural resources, environmental protection for sustainable development of the MD.

4.3.3 Diplomatic and international cooperation

- To negotiate with countries in the upstream Mekong river to reduce the number of dams in the upstream and reduce the hydrological adjustment of the Mekong river;

- To support Cambodia in the protection of Tonlesap Lake;

- To support Laos in sustainable economic development based on non-hydropower;

- To cooperate with Laos, Thailand and China in the exchange of flow data, flow coordination, ensuring no-impacts on the fish migration and sediment flow to the MD.

5. Conclusions

The MD has an evolution based on a "dynamic system" with major components to stabilize its natural development being water flow and sediments transported by the Mekong river system. These natural processes have been occurring for the last 8,000 years but will be strongly affected by the decline in river flow from the upstream, sea level rise and human activities in the current socio-economic development scenarios. Degradation in river flows from upstream will result in decreasing water resources and nutrients for ecosystems' development, rapid degradation of ecosystems, and increasing salinity intrusion. The decrease of sediment sources will cause instability of riverbank, coastlines, surface subsidence and deterioration in the quality of land resources in the MD. These challenges together with sea level rise and climate change will bring great challenges for sustainable development. Therefore, it is necessary to implement policies, scientific and technological solutions, education and training human resources and smart governance. Besides, it is necessary to promote extensively and comprehensively diplomatic solutions and extensive international cooperationto leadthe MD towards "Smart Water Resourcesgovernance" for sustainable development.

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Research Paper

VALUATION OF BIODIVERSITY, LANDSCAPE CONSERVATION VALUE OF THE MAGROVE ECOSYSTEM IN CAN GIO DISTRICT, HO CHI MINH CITY

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ABSTRACT

Utilisation plans of wetland ecosystems in general and mangrove ecosystem in particular are usually determined based on direct use values of the ecosystems such as fisheries, timber, wood rather than indirect and non use values. However, decisions on the use of resources should take into consideration other costs such as opportunity costs and biodiversity conservation willingness so that conservation measures could be developed for sustainable development. From environment economy perspective, non use values can be interpreted as social perception and satisfactory on the conservation of biodiversity at a certain level and social willingness to pay for that. This paper presents the study on valuation of non use values of the Can Gio mangrove biosphere reserve, Ho Chi Minh City. The results show that the non use value of the study area is approximately VND 105 billion per year. The paper also shows the recommendations for managers, policy-makers and researchers in the conservation and sustainable use of resources's Can Gio mangrove ecosystem in the context of climate change and sea level rise.

Keywords: *Can Gio mangrove biosphere reserve; Mangrove ecosystems; Economic values; Biodiversity; Landscape conservation.*

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1. The concept of total economic value

From economy perspective, values of resources and environment comprise of various values that accumulate in total economic value - TEV. Although the terms has yet to be fully agreed, this set a basis for the interpretation of valuation of values, i.e. based on the interaction between human - valuator and subjects to be valuated.

The total economic value concept was introduced 20 years ago (Pearce and Turner, 1990; Bateman and Willis, 1999; Dinh and Le, 2013). Since then, this concept has become a norm to determine and classify values of ecosystems in general and of mangroves in particular.

In the market economy, there are many kinds of goods traded in the market. They have a certain price, and their value is simple. However, when considering public goods (which do not have market prices and which are under common ownership), the determination of their value in the form of currency will be difficult. One of them is environmental goods. This is a type of goods that is new to research in environmental economics. And to look at the value of this goods fully, we must look at the total economic value (TEV).

Thus, the total economic value (TEV) is the sum of the monetary values of the component values of the ecosystem, which is calculated according to the Fig.1.

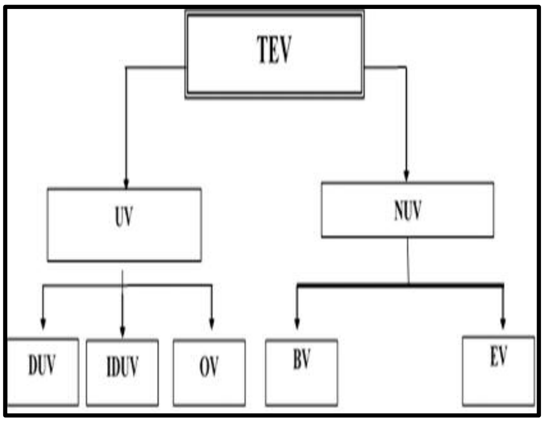

Fig.1.Total economic values.

where **UV** is the use value; **NUV** is the non-use value; **DUV** is the direct use value; **IDUV** is the indirect use value; **OV** is the option value; **EV** is the existence value; **BV** is the bequest value (Turner et al., 2000; Adger et al.,)

- Use value (UV): understood as values used by humans for their own purposes and for the benefit of humans, which can be used in two forms:

+ Direct Use Value (DUV): These are the values that in reality relate to the output of an environmental product that people can establish in the market through price. Usually, the price is established as the real price. That is, if we determine the volume of goods at market prices and subtract the costs, then we will determine its value in real terms.

+ Indirect use value (IDUV): These are values related to the function of the environment in supporting economic activity and human life. It helps people avoid the disaster of nature (floods, climate change ...)

+ Optional Values (OV): Values that depend on the nature or environment of the ecosystem that the assessor needs to consider. It includes the benefits of the resources that serve current human needs and shows the difference between those resources.

- Non-Use Value (NUV): Value is usually in the subconscious of the person who judges it but does not have a place in the market (no market value). This is the most complex issue in environmental economics that is thought to require positive assessments for policy-making. Environmental economists now point out that there are two fundamental values in this group. That is Existence Value (EV), Bequest Value (BV).

+ Existence value (EV): This is the value within the body of things that humans think it can not lose. It must be sustained because of its economic, political and social significance.

+ Bequest value (BV): This value depends on the ability to meet ecosystem services or environmental services for future generations and is within the human horizons of the issue.

Total economic value comprises two main groups, meaning use values and non use values. This paper presents results of valuation of non use values of Can Gio mangrove forest based on contingent valuation method - CVM. Non use value is an indispensable component of total economic value of resources. However, it is difficult to quantify this value as there is no market for environment attributes. It is expected that the study results, under the national projects coded MS: ĐTĐL-G/77 and KC.09.21/16-20, could provide a view of economic values of Can Gio mangrove forest, Ho Chi Minh City.

2. Methods

2.1. Theoretical models

Contingent valuation method (CVM) is the most common one for valuation of non use values of resources and environment (Dixon, 1989;Turner and Daily, 2008; Turner et al., 2008). There is no market for the non use values and natural resources and environment are public goods that require financial resources to provide an effective amount to the public. Currently, there are various variations of CVM that have been used in the world such as continuous CVM, bidding game, payment card and binary CVM. The binary CVM has been widely used due to sound theoretical basis and model as well as its capability for minimizing biases in field surveys. Therefore, this study used this method to valuate conservation values and non use values of the study area. The theoretical basis of the binary CVM is the Random Utility Model - RUM.

The Random Utility Model - RUM

Call V_{ij} is utility of the household j gained from the conservation or improvement of mangrove forest by the solution i, in which i = 1 if the environment is improved and i = 0 if the environment state is unchanged. V_{ij} is a function of attributes of values of mangrove forest conservation and social - economic characteristics of households:

$$V_{ij} = V_i(M_j, z_j, \varepsilon_{ij}) \quad (1)$$

In which M_j is the income of the household j; z_j is the vector of social - economic characteristics of the household and the attributes of the mangrove forest ecosystem; ε_{ij} is random error. The binary question asks interviewees to select either to improve quality of mangrove forest ecosystem or keep it unchanged at the montly cost of t.

Benefits of the market participants are measured by the logarithmic utility model. While the random utility model with the linear income function presumes that the marginal utility of income is unchanged in all answers, the logarithmic utility model allows this variable to be changed as the actual income varies.

Probability for the answer "Yes" for the "change" scenario is calculated as the following:

$$P[Yes_j] = P[(\alpha_1 z_j + \beta \ln(M_j - t_j) + \varepsilon_{1j}) \geq (\alpha_0 z_j + \beta \ln M_j + \varepsilon_{0j})] \quad (2)$$

$$P[Yes_j] = P\left[(\alpha z_j + \beta \ln\left(\frac{M_j - t_j}{M_j}\right) + \varepsilon_j \geq 0\right] \quad (3)$$

Presume that the ε_j is the standard distribution with the mean value is 0 and the variance is σ^2, the distribution function of the answer "Yes" is as the following:

$$P[Yes_j] = \Phi\left[\left(\alpha z_j + \beta \ln\left(\frac{M_j - t_j}{M_j}\right)\right) \Big/ \sigma\right] \quad (4)$$

The $\ln\left(\frac{M_j - t_j}{M_j}\right)$ is called standard income. Vector $\{\alpha/\sigma, \beta/\sigma\}$ can be estimated byrunning the model probit/binary on the matrix data $\left\{z_j, \ln\left(\frac{M_j - t_j}{M_j}\right)\right\}$ leading to the mean value of WTP:

$$MD_\varepsilon[WTP_j] = M_j\left[1 - \exp\left(-\frac{\alpha}{\beta} z_j\right)\right] \quad (5)$$

The contingent valuation method was developed by Davis (1963) for marketing analysis and subsequently be applied for environment valuation. By developing scenarios on environment quality and information on behavior and choices of individual consumption in the scenarios, it can be estimated the changes in individual benefits when environment quality changes. From this, individual consumption surplus in assumed market can be calculated. This benefit measures environment values for this individual. This method is usually used for valuating non use values of environment because such values do not have market.

Although CVM has a number of variations and has continuously been developed, it has common procedures i.e. (i) determination of subject group and scope of valuation; (ii) development of questionnaire, testing and adjusting the questionnaire and approaches for information collection; (iii) development of detail questionnaire including information on assumed market, situations, payment medium, willingness to pay; (iv) collection and analysis of information; and (v) calculation of benefit based on model.

2.2. Study procedures

2.2.1. Focus Group discussion - FDGs

To develop the questionnaire that fits in actual condition, two group discussions were held in the studying area.

The first group discussion was organised for the local government and environment authorities that comprised the district Department of Agriculture and Rural Development, Department of Environment Management, and the Can Gio biosphare reserve management board. The objective of the discussion was to provide a forum for the authorities to discuss issues related to the use and non use values of the biosphare reserve, pressures and threats imposed on the biosphare reserve, current state and difficulties in management, indentification of stakeholders in mangrove forest ecosystem management. The draft questionnaire was distributed to the authorities for comments.

The second group discussion was organised for some households in the buffer zone of the biosphare reserve. The household's livelihood depends mostly on the mangrove forest. At the discussion, participants were asked about issues related to awareness on values of the mangrove forest, indentification of threats, determination of bids and suggestion of payment medium as well as reasons for willingness and unwillingness to pay. In practice, participants were asked if they are willing to pay an amount of money for conserving biodiversity and landscape of the area. For those whose the answer was "Yes", a second question on the maximum amount of money that they are willing to pay per year was asked. The amounts of money that the participants proposed were VND 30,000, 50,000, 100,000, 150,000, 200,000 and 300,000.

2.2.2. Determination of sampling size

Table 1.Household samples in Can Gio District (Can Gio statistics, 2011-2016, 2018)

Commune	People above 15 years old	Sample
Binh Khanh	13,931	30
An Thoi Dong	9,068	30
Tam Thon Hiep	4,128	30
Ly Nhon	4,039	30
Long Hoa	8,274	30
Thanh An	3,326	30
Can Thanh	8,391	30
Total	51,157	210

There were approximately 51,157 people whose age is over 15 in 5 communes in the studying area. There were approximately 5 people in 1 household, hence there were approximately 5,100 households.

2.2.3. Questionnaire

The questionnaire that was used to assess non use values of the Can Gio biosphere reserve comprised 4 main sections. Apart from the introduction on the objectives of the survey and security of information provided, the section 1 provided general introduction to the biosphere reserve, main values of the biosphere reserve and asked interviewees about attitude and awareness on the conservation of values of the biosphere reserve as well as their participation in conservation process.

Section 2 comprised questions on willingness to pay of people for conserving biodiversity values and landscape of the biosphere reserve. At the start, with supports provided by mangrove forest conservation expert, a conservation scenario was developed and introduced to people. The scenario introduced typical characteristics, general data on biodiversity values, landscape and ecosystems of the Can Gio biosphere reserve as well as relationship between biodiversity values and other value groups. Subsequently, people provided current threats on biodiversity and landscape conservation in the biosphere reserve (shrimp farming, environment pollution, and illegal exploitation). These were reasons that caused degradation of biodiversity and ecological values and would continue to be the threats if control and management measures are not taken. Therefore, there is a need for conservation and management measures with participation of stakeholders including local people for biodiversity and landscape to be maintained.

After the conservation scenario had been introduced, people were asked if they are willing to pay a certain amount of money for biodiversity and landscape conservation. The amount of money that they are willing to pay was randomly selected from 6 levels determined in the pilot survey. Contribution medium identified was a local environment fund. Debriefing questions were asked after the questions on willingness to pay to determine reasons for the answers "willing to pay" and "unwilling to pay".

The last section of the questionnaire comprised questions on demography such as sex, qualifications, the number of family members and incomes. The question on the incomes provided a range of household incomes for the interviewees to select. This approach demonstrated its effectiveness in Vietnam rather than open question. The mean incomes were to be selected for statistics.

3. Biodiversity values of the Can Gio mangrove biosphere reserve

3.1. Biodiversity value of Can Gio

Can Gio mangrove forest was recognized as protection forest in 1991. It was recognized as biosphere reserve by UNESCO in 21 January 2000. It is the most beautiful mangrove forest in Southeast Asia that was recovered after it had been destroyed by toxic chemical in the war (UNESCO/MAB, 2000). Before 30 April 1975, the Can Gio mangrove forest was 40,000 ha area; thick canopy with forest tree above 25 m in height and at 25 - 40 cm diameter. *Rhizophora apiculata* was predominant species together with other communities including *Sonneratia alba, Avicennia alba, R. mucronata, Bruguiera spp., Xylocarpus spp., Lumnitzera spp., Phoenix paludosa, Excoecaria agallocha, etc*. Apart from mangrove forest, the Can Gio district also had bazan hills such as Giong Chua, Giong Ao, etc. that were home to weed, shrub and recovered tropical raining trees. From 1964 to 1970, American sprayed defoliation chemical along the Long Tau river and to forest ward hundreds of meter. Defoliation chemical that had been sprayed several times for almost 10 years (1964 – 1972) destroyed more than 80% area of the forest. R. *apiculata* and R. *mucrolataspecies* almost disappeared. Some trees of Ceriops spp. and Excoecaria Agallocharecoveredhere and there along canals. There were Mam in tidal zone, and Phoenix paludosa, Acrostichum aureum, Gymnanthera mitida, Derris trifoliate, Azima sarmentosa, Pluchea indica and Clerodendrum inerme, etc. in upper land. After the liberation of the South in 30 April 1975, Can Gio mangrove forest belonged to Duyen Hai District, Dong Nai Province. In 1978, the Duyen Hai District was handed over to Ho Chi Minh City with total area of 71,361 ha in which 34,468 ha was mangrove forest and forestry land. Since 1984, some trees such as Intsia bijuga, Ceriops tagal, C. decandra, Lumnitzera racemosa, Xylocarpus granatum, Thespesia populnea, etc. were plantedto re-green upper land. Aquatic species composition is diverse in Can Gio forest. There are more than 130 algae species belonging to three phyla i.e. Bacillariophyta, Pyrrophyta and Cyanophyta, in which Bacillariophyta predominates. Aquatic invertebrate fauna comprises 700 species belonging to 44 families, 19 orders, 6 classes, 5 phyla. Fish fauna comprises over 137 species, belonging to 39 families and 13 orders (Tuan, 2016; Tuan et al., 2018). Terrestrial vertebrate comprises 9 amphibian species, 31 reptile species and 4 mammal species, in which 11 reptile species are listed in the Vietnam Red Data Book such as Gekko gecko, Varanus salvator, Python molurus, Python reticulates, Bungarus fasciatus, Naja naja, Ophiophagus hannah, Chelonia mydas, Crocodylus porosus, etc. Bird fauna comprises 130 species, belonging to 47 families and 17 orders, in which 51 species are water bird and 79 species live in different habitats.

3.2. Identify important economic values of Can Gio mangroves

The coastal mangroves of Can Gio provide a wide range of economic values for the people and the community. The following important economic values were identified through the author's research process by means of consultations with experts, people with direct livelihoods and mangrove resources, secondary literature study and primary, combined with a comparison with some other mangrove ecosystems that have the same basic natural conditions as the study area.

A number of other economic value types, though present in the field, are not considered important and will not be listed here (Table 2).

Table 2. Important economic values of Can Gio mangrove forest

Direct use value	Indirect use value	None-use value
- Tidal fishing value - Honey value - Aquaculture value (shrimp, sea bass, clam) - Tourism value	- Protection value - CO_2 absorption value - Values environment	Biodiversity conservation value

4. Non use values of the Can Gio mangrove forest ecosystem

Non use values are more abstract than use value. Non use values are intrinsic value of mangrove forest and comprise existence values and bequest values.

Non use values are part of values of environment asset that do not derive from direct or indirect consumption of goods and services provided by environment asset. The values reflect choices of human, care and respect rights and existence of other species. The values are also called awareness values on the existence of other species or of ecosystem. Non use values comprise the following components:

- Bequest values are satisfaction in individual feeling in knowing that resources is to be handed over and received by future generations. The values are usually measured by individual willingness to pay for conserving resources for future generation.

- Existence values are satisfaction in individual feeling in knowing that attributes of mangrove forest exist in a certain state and are usually measured by individual willingness to pay for having this state. In general, society also gain benefits from environment goods apart from direct or indirect uses (Barbier, 1989; ADB, 1996; Turner et al., 2007). This is not a tangible consumption but individuals obviously feel happy in knowing that the resources still exists. It is difficult to explain why society appreciates these values. However, we know that society is willing to pay for conserving this asset. In such cases, benefits of society simply derive from knowing that the asset exists and is protected. This component of total values is known as existence values.

Non use values of mangrove forest lie in individual feeling, knowledge and satisfaction in knowing that mangrove forest exist and to be handed over to future generation at a certain state. As mentioned above, the study selected mangrove forest biodiversity conservation and landscape values for valuation. The method used was CVM. The exercise was undertaken based on data gained from interviews by the questionnaire.

5. Valuation results

5.1. Estimation results

The Random Utility Model was used to estimate WTP of households for conserving biodiversity values in Can Gio. Theoretical basis and economic nature of the model were presented in Section 2.1. In practice, the study applied the Binary Logistic model and the Maximum Likelihood estimation to estimate expected values of willingness to pay for conserving biodiversity and landscape in the Can Gio biosphere reserve. Factors influencing payment capability were also analyzed. In the study, two models were used to estimate variation range of expected WTP.

Table 3. Descriptions of WTP estimation models (Analysis of survey data, 2012, 2016, 2018)

No	Models	Explanation	Sample size
1	A	Payment for biodiversity conservation model	210
2	B	Payment for landscape conservation model	210

WTP practice model is a probability function on payment for biodiversity and landscape conservation:

Pr (Yes) = a1 + b1 BID + b2 EDU + b3 MEMBER + b4 INCOME + b5 AGE + b6 SEX (6)

Table 4. Descriptions of variables in binary CVM model (Analysis of survey data, 2012, 2016, 2018)

Variables	Explanations	Codes
Pr (Yes)	Probability for willingness to pay a certain Bid for biodiversity and landscape conservation	Willingness to pay = 1 Unwillingness to pay = 0
BID	Bid proposed and asked if people are willing to pay that Bid (VND thousand/year)	Bid levels: VND 30,000, 50,000, 100,000, 150,000, 200,000 and 300,000
EDU	Education (school years)	Continuous variable
MEMBER	Number of people in family	Continuous variable
INCOME	Household income (VND/year)	Continuous variable
AGE	Age of interviewee	Continuous variable
SEX	Sex of interviewees	Male = 1; Female= 0

Table 5. Results of model

Variables	Model A	Model B
EDU (mean)	8,65(2,70)	7,59(3,5)
MEMBER (mean)	3,94(2,15)	4,1(1,27)
INCOME (mean)	23170(7318)	25041(7241)
AGE (mean)	38,94(15,76)	34,59(14,02)
SEX (mean)	0,46(0,30)	0,53(0,22)
Model		
Constant	1,124(0,653)	1,030(0,67)
BID	-0,04***(0,006)	-0,036***(0,008)
EDU	-0,013(0,059)	-0,016(0,08)
MEMBER	0,060(0,045)	0,067*(0,077)
INCOME	0,000*(0,000)	0,000(0,000)
AGE	0,005(0,008)	-0,009(0,01)
SEX	0,186(0,191)	0,202(0,271)
-2 Log likelihood	633,730	323,064

Note: (…): Standard deviation

***: Error = 1%. **: Error = 5%. *: Error = 10%.

Results gained from processing the model by SPSS software with binary logistic are as follows.

In all models, coefficient of the BID variable is negative and valid at error = 1%. This in accordance with theory that when BID increases, probability of willingness to pay decreases.

INCOME variable is positive and valid at error = 5% in model A. Hence, in this model, individual income slightly influences willingness to pay for biodiversity conservation. When household income increases by VND 1,000/year, probability of payment for a BID level raises less than 1/1,000.

Expected WTP for biodiversity and landscape conservation of each model was estimated by theoretical function and presented in the Table 5.

$$E_{\varepsilon}\left[WTP_j\right] = M_j\left[1 - \exp\left(-\frac{\alpha}{\beta}z_j + \frac{1}{2}\frac{\sigma^2}{\beta^2}\right)\right] \quad (7)$$

The estimation result shows that expected WTP for biodiversity conservation is VND 126.3 thousands/year and WTP for landscape conservation is VND 78.7 thousands/year.

Therefore, if the number of people above 15 years olds in the studying area is 51,517, the estimated total biodiversity conservation value of Can Gio is VND 64.6 billions/year and estimated total landscape conservation value is VND 40.26 billions/year.

Table 6. Estimation of WTP from the models (Analysis of survey data (2012-2016, 2018))

No	Models	Expected WTP (VND thousands per year)	Generalization (VND thousands per year)
1	A (biodiversity conservation)	126.3	64,611,291,000
2	B (landscape conservation)	78.7	40,260,559,000

5.2. Total non use value of Can Gio mangrove forest

Non use value of Can Gio mangrove forest is presented in the Table 7.

Table 7. Non use value of theCan Gio mangrove forest (Analysis of survey data, 2012, 2016, 2018)

No	Economic values	Annual total value (VND billions)	Percentage in total value
Non use values			
1	Biodiversity conservation value	64.61	2.63
2	Landscape conservation value	40.26	1.64
Total non use value		104.87	4.27
TOTAL ECONOMIC VALUE (TEV)		2,460.23	100

6. Conclusions and Recommendations

Valuation of non use values of wetlands in general and the Can Gio mangrove forest in particular is significant in policy and decision making on resources use and management. From economic perspective, non use values are interpreted as social feeling and satisfaction in maintaining biodiversity values at a certain state and society's willingness to pay for that. The results of the valuation of non use value of Can Gio mangrove forest biosphere reserve by CVM method using questionnaire in 7 communes show that non use value of the studying area is approximately VND 105 billions/year, making up 4.27% total economic value of the area. The results lead to the following recommendations:

Firstly, selection of utilization plan of mangrove forest in land use planning should take into consideration of non use values of mangrove forest ecosystem. This helps to reflect practical effectiveness of the resources utilization plan from social perspective. Wetland utilization plans usually take into consideration only direct values of the wetland ecosystem such as shrimp, fish, and wood rather than indirect and non use values. However, resource utilization always has opportunity costs and biodiversity will possibly be degraded if conservation plan is not put in place in development plan.

Secondly, results of valuation of non use values of wetland ecosystems provide resources and environment management authorities with input data to develop conservation and sustainable management mechanisms such as Payment for Environment Services (PES). PES is provided in the Law on Biodiversity Conservation as a market based tool to facilitate biodiversity conservation by influencing economic motivation of stakeholders.

Thirdly, information on non use values of wetland resources in general and mangrove forest in particular helps authorities to develop database on the wetland ecosystem. The information plays an important role as a basis for resolving conflicts in wetland uses. The results play the important valuable which provide the manager, researchers with practical and scientific basis to propose policies for sustainable management, exploitation, use of mangrove ecosystem resources to cope with climate change and sea level rise.

Finally, authorities can use information on biodiversity value conservation for communication and education campaigns to raise awareness, attitude and behavior on conservation and sustainable management of wetland ecosystem in general and mangrove forest ecosystem in particular.

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Research Paper

GERMINATION TEST FOR DIATOMS FROM COASTAL ESTUARY SEDIMENT

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ABSTRACT

Planktonic diatoms produce resting stages that survive in the sediment and allow species persistence over periods in which vegetative growth does not occur. Sediments from coastal estuary in the Mokpo Harbour, Korea were took and investigated. Diatom germination tests from sediment were carried out in laboratory. Diatom cells were identified by microscope based on standard method. This study provided more understanding of diatom germination from in situ sediment, seasonal condition as nutrient, light, moonson might also affect and decide significantly phytoplankton growth and bloom in coast. The study is very useful for investigation about plankton dynamic, food chain in coastal areas in general.

Keywords: *Diatom, Germination, Sediment, Coastal estuary*.

1. Introduction

Diatoms were an important component to phytoplankton communities in coastal estuarine system (Sarthou et al., 2005; Tsuda et al., 2005; Wysocki et al., 2006; Gameiro et al., 2007). Diatoms account for 20-25% of the total global primary production (Werner, 1977), and the majority of variability in phytoplankton biomass in coastal waters is due to changes in the abundance of chain-forming diatoms (Moses and Wheeler, 2004; Whitney et al., 2005; Shipe et al., 2006). Phytoplankton size structure or phytoplankton taxa, especially diatoms were impacted by alterations of surrounding environmental conditions (Sin et al., 2000; Domingues et al., 2005; Shimada et al., 2006; Popovich and Marcovecchio, 2008). In the coastal aquatic food web, phytoplankton in terms of primary producers has relationships with various grazers (Semeneh et al., 1998; Froneman et al., 2004). Diatoms, especially, have played an important role in coastal microbial food web dynamics (Garrison et al., 2000; Rousseau et al., 2000). For instance, mesozooplankton such as copepods mostly feed on diatoms during diatom bloom (Paffenhöfer, 2002; Vargas and González, 2004; Schultes et al., 2006). In this context, it is important to examine diatom dynamics for better understanding of the estuarine phytoplankton dynamics.

Recently, the human activities such as industry and embankment construction and increasing population density have impacted marine ecosystems. The embankment constructions significantly restricted the circulation of water masses and changed the surrounding properties such as water temperature and turbidity (YSLME, 2001). A study of diatom germination from sediment can provides useful information on characteristics of phytoplankton communities and the microbial aquatic food web since diatom

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dynamics and related parameters have not been reported. In this study, we investigated the importance of diatom germination from coastal estuary sediment under different conditions in laboratory.

2. Materials and Methods

2.1 Sediment collection

Sediments were collected as grab samples at depth 10 m from an estuary immediately adjacent to an embankment in the Mokpo Harbour, Korea. Seawater was also collected from the site. The sediment and seawater were kept at 5°C during transportation and stored in the dark prior to use.

2.2 Experimental design

In situ seawater was filtered through PTFE 0.45 μm membrane (Fig. 1b). Fritz F/2 (solution A , solution B, Si) algae food was used to enhance phytoplankton germination. Diatoms from sampled sediment were inoculated into growth bottles (2g wet sediment + 1L filtered sea water) and resuspended. Nutrient to grow diatoms was added to a bottle (Adding nutrients: solution A + solution B+Si) and another bottle was not (Non Adding nutrients) (Fig. 1c). Both of bottles were incubated in Labtech® incubator (temperature 20°C, light cycle 12h light/12h dark) (Fig. 1d). Sampling schedule arranged after day 1, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 during incubation period.

2.3 Diatom identification

10 ml water samples from each incubation bottle were daily taken and insert into 15 ml test tube containing 3 drops Lugol's solution (I2 final concentration: 250 mg L-1). Phytoplankton samples were stored in the laboratory at least 48h for settling down. After the storage, samples were slowly decanted to 8 ml surface water. The remaining 2 ml sample was mixed and 1 ml was taken to drop into a Sedgwick-Rafter counting chamber (50 x 20 x 1 mm). Diatom cells were identified (Tomas, 1997) and 200 chambers were counted by using Axioskop® 2 MAT (ZEISS).

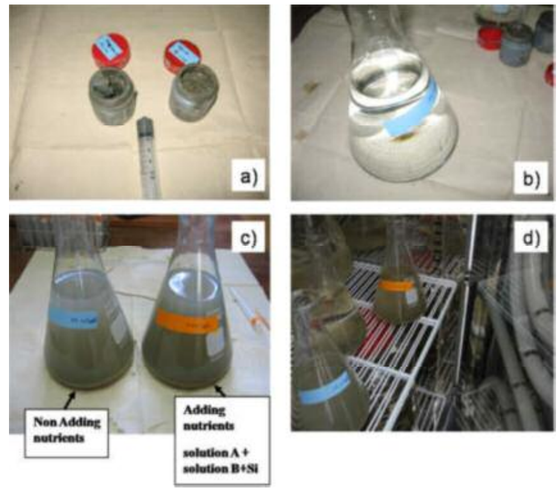

Fig. 1. Experimental setup for diatom germination test: a) wet sediment collection; b) filtered sea water preparation; c) Inoculated (2g wet sediment+ 1L filtered sea water), resuspended, nutrient added; d) incubation in Labtech® incubator (temperature 20°C, light cycle 12h light/12h dark).

3. Results

3.1 Vegetative diatom from resting stage

Many planktonic diatoms produce resting stages that survive in the sediment and allow species persistence over periods in which vegetative growth does not occur. Diatom benthic stage is evident, we used surface sediments from the Mokpo Harbour, Korea where diatom in resting stages to seed as source for this study. The diatom species recorded to germinate from sediments into seawater, showing that the formation of resting stages is a widespread life in coastal areas. The most abundant taxa recorded in the plankton were several species of the genera Cylindrotheca, Pseudonitzschia Skeletonema, Thalassiosira, Navicula, and Chaetoceros (Fig. 2 and Fig. 3). Peaks of growth stage from resting stage were generally recorded during incubation process in laboratory.

Fig. 4 shown that variation of vegetative cells in surface water samples and of viable resting stages in sediment was represented. The most abundant species in the incubated sediment samples were Cylindrotheca closterium, Pseudonitzschia seriata, Navicula distans, Navicula directa, Skeletonema costatum, Thalassiosira rotula, Chaetoceros socialis. Cylindrotheca closterium reached the highest cell concentrations in both incubated bottles. Nutrient addition was a important role for growth of diatoms from resting stages. Peaks of diatom cell appeared 2 times during 15 days incubation with nutrient addition, however there was one low peak in non-adding nutrient condition (Fig. 4). Mixing condition was also key effect for the diatom bloom.

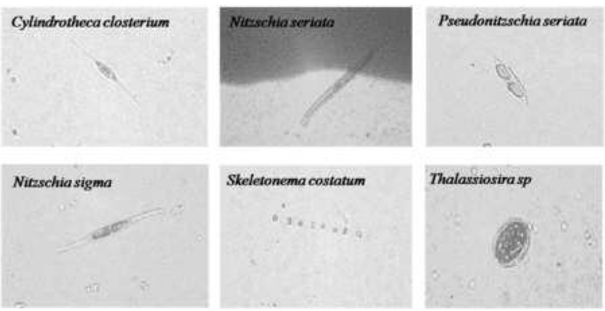

Fig. 2. Diatom dominant species taken by microscopy and software in laboratory germination test.

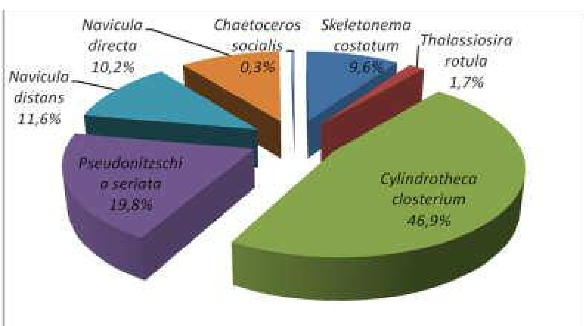

Fig. 3. Component of diatom dominant species was observed after 7 day incubated

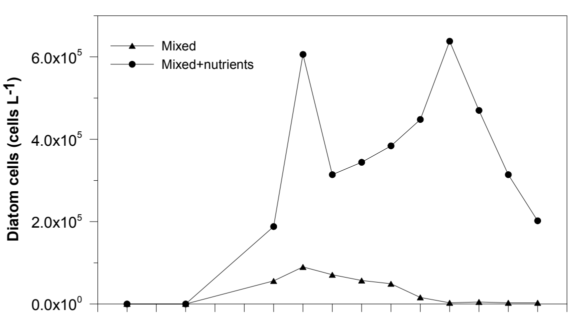

Fig. 4. Germination of diatom in field seawater from sediment with laboratory incubation conditions: mixed and mixed + nutrients

3.2 Discussion

Temporal variations of physio-chemical factors can influence the abundance, biomass contribution and dominant genera of diatoms in coastal estuaries (Pratt, 1965; Goffart et al., 2002; Madhu et al., 2007). In coasts and estuaries, spring diatom blooms were developed by: (1) germination increase from diatom resting stage in sediment due to well mixing, (2) increase of water column irradiance (Pitcher, 1990; Iriarte and Purdie, 2004; Ishikawa and Furuya, 2004; Gloria et al., 2009). According to Andersson et al. (1994), diatoms were dominant concomitant with netphytoplankton even temperature was lower than 10 oC. Increase of wind speed during February-March can resuspend sediment in shallow water such can force germination of diatoms from resting stage in sediment. Diatom genera such as Thalassiosira spp., Skeletonema costatum and Chaetoceros spp. were dominant during spring both in the sediments and water column (Zhang et al., 2010). These species were also listed by Ishikawa and Furuya (2004) whereas diatoms having resting stages in the sediments. The results indicate that the spring bloom may be characterized by diatom species adapted to the physio-chemical properties of cold season and wind forced mixing in the coastal estuary.

When water temperature increased diatom bloom could exhaust ambient nutrients from the water for growth. According to Wong et al. (2002), nutrient depletion occurred due to enhancement of diatom production. The nutrient depletion and temperature increase may be catalysts for the shift in size structure of phytoplankton to nanophytoplankton. In case of diatoms, photosynthesis relates to cell size and the smallest cells have the highest growth rates due to high harvesting light and high nutrient uptake; they can adapt to low nutrient concentrations (Sarthou et al., 2005).

In the estuary, the embankment restricted freshwater discharge during dry season (winter-spring). Wind mixing increased in early spring due to moonson caused resuspension of the sediment in shallow water depth. The scattered freshwater discharge may supply better nutrient such as silicate for diatom growth at the upper region in early spring. This suggests that diatoms favor at the upper region with resuspended water and nutrient input during early spring. This may be due to the dramatic increase of freshwater discharge from embankments during the wet season that directly impacted the growth and abundance of diatoms by altering physical properties such as low salinity, short residence time at the upper region (Mallin et al., 1991; Madariaga et al., 1992; Muylaert and Sabbe, 1999).

All species found in the sediments were components of the plankton. Resting stage species composition in the sediments was related to historical records of planktonic diatom composition in the water (Roberta et al., 2017). However, several species vegetative cells those were important components of the plankton did not germinate from bottom sediments: Cylindrotheca closterium, Pseudonitzschia seriata, Navicula distans, Navicula directa. Their absence may be a result of (1) poor viability such as nutrients, (2) unsuitable growth conditions for this particular population such as light and mixing by moonson, (3) competition with other diatoms in the cultures, (4) relying on other mechanisms than benthic resting stages to repopulate surface waters, or (5) too low density (Zhang et al., 2010)

The temporal variability of species specific diatom resting stage abundance in surface sediments of a coastal site in comparison with the abundances of vegetative stages in the plankton (Tatiana and Tatiana, 2009; Marina et al., 2013). In this study, germination of individual species appears to occur whenever sediments were exposed to light, mixing and nutrients. The lack of a connection from benthos to plankton points to the complex relationship among the key diatom species was not clear yet, but could also be due to the intrinsic limitations.

Top-down control of diatoms by mesozooplankton during spring bloom was documented in the previous studies (Kuuppo et al., 1998; Hansen et al., 2000; Bode et al., 2005). Diatoms also highly contributed to netphytoplankton in early spring. Therefore, the species may be suitable for grazing by mesozooplankton.

4. Conclusion

Diatoms staying in resting stages in coastal sediment are phenomenal. Nutrient enrichment can enhance diatom germination faster than normal condition. Nutrient has driven the abundant of diatom species in coastal estuary. Size-structure of planktonic diatoms was affected highly by nutrient in coastal water. Mixing condition is very important for germination of diatom. This explained that diatom always bloomed during windy season (early spring) caused resuspended shallow water in South Korea coasts. Understanding of diatom germination from in situ sediment is significant to investigate ecosystem in coastal estuary. Seasonal condition such as nutrient, light, moonson could also affect and decide phytoplankton growth and bloom in coast. The study is very useful for investigation about plankton dynamic, food chain in coastal areas in general.

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Research Paper

INTEGRATION OF CLIMATE VULNERABILITY ASSESSMENT OF CIVIL SOCIETY ORGANIZATIONS INTO NATIONAL ADAPTATION PLAN (NAP) IN VIETNAM

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ABSTRACT

Civil society organizations (CSOs) in Vietnam have been making significant contributions to climate change adaptation at both local and national levels. CSOs have been applying various methods in climate vulnerability assessment (CVA) to develop practical adaptive measures, with the more commonly used ones being "community-based", "participatory", and so on. The CVA methods that most CSOs have applied to climate change studies and projects in more than 30 provinces and cities include: HVCA, PVCA, CVCA and VA-EBA. The process and effectiveness of each method is different, depending on the technical capacity and support resources. Overall, the CVA results obtained are not only an important input for various adaptation programs, projects and models in localities but also a major contribution of non-governmental organizations to the National Adaptation Plan. This paper aims to provide evidence of climate vulnerability assessment for adaptation projects that have been implemented by CSO in the last 10 years as well as feedback of vulnerable communities and policy recommendations.

Keywords: *Civil society organizations (CSOs), Climate vulnerability assessment (CVA), Climate change, National Adaptation Plan (NAP).*

1. Introduction

Climate change is becoming more intense globally, causing ever greater damage to the environment, and the natural resources and the socioeconomic aspects of human communities. In October 2018, as nominated by the Intergovernmental Panel on Climate Change (IPCC), Vietnam was selected to be the very first nation to present the Special Report on Global Warming of 1,5°. The "Paris Agreement on Climate Change" in 2015 also showed the countries' determination to limit the increase of Earth's temperature to less than 2°C, or even to less than 1.5°C by the end of the century (compared to pre-industrial period) (TTCP, 2016). The Government and people of Vietnam have made great efforts in dealing with climate change, reflected in local policies and actions. Revisions and amendments of the Nationally Determined Contributions (NDC) and the National Adaptation Plan (NAP) are also underway. Priority and long-term adaptation measures will be identified by NAP to increase national resilience to climate change impacts. This is an important tool that contributes to reducing Climate Change Vulnerability, building community and ecosystem adaptive capacity (UNFCCC, 2015). The development of NAP requires the involvement

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of regulatory agencies, scientists, communities and social organizations. The process of adaptive with climate change in general and the development of NAP in particular has recognized the contributions of social and non-governmental organizations in Vietnam. CSOs have developed hundreds of initiatives and activities in order to respond to climate change and to reduce disaster risks across different fields and localities with a greater focus on vulnerable groups. By implementing proactive, innovative and transparent operations, CSOs have achieved tangible results in enhancing the awareness of adaptation and resilience capacity of communities and stakeholders. Outstanding among them is the Climate Vulnerability Assessment (CVA) approach adopted with the engagement of vulnerable communities. There is a need for CVA implementation to identify objects, sectors, and areas susceptible to climate change impacts in the present and future and assess their vulnerability status and level so that effective adaptation measures can be defined and adopted in order to enhance resilience and foster sustainable development (Füssel and Klein, 2006).

2. Methodology

The research was conducted on the basis of reviewing and evaluating the results of the implementation of studies and projects of more than 20 representative CSOs in Vietnam, who have conducted climate vulnerability assessment at community level over the past 20 years. The Center for Eco-community Development (ECODE) conducted this research with the technical and financial support of the Friedrich-Ebert-Stiftung (FES), Germany and Climate Change Working Group in Vietnam (CCWG).

This research adopts the users' perception of satisfaction approach. The authors examine the perceptions and feedback of CSOs that implemented CVAs in their programs and projects in more than 30 provinces in 7 priority sectors of NAP. The main used methodologies are secondary research, focus group discussions, interviews with information providers/major stakeholders, baseline survey and consult expert. Questionnaires with pre-defined questions were sent to sample CSOs to fill out and in-depth interviews were conducted with staff of CC related-government offices and representatives of lead CSOs in the CC sector. The purpose is to clarify the awareness and capacity of CSOs as well as the results of their CVA implementation. The research also aimed to draw lesson learn from stakeholders who have been contributing to the suitability, feasibility and effectiveness of the CVA methodology that CSOs have applied. By engaging various stakeholders, the research was able to capture voices and feedback from vulnerable communities.

The research has three main objectives: (1) conduct a baseline survey of CVA methods and results that CCWG members have conducted in priority sectors of Vietnam's NAP process; (2) Analyze and identify the most common and appropriate CVA methods with insights from CSO perspectives; (3) Identify adaptation measures and models from grassroots CSO projects that need to be considered by government agencies as they develop specific implementation plans on adaptation options in the this priority sectors.

3. Results

A review of CSO action plans, programs and projects shows that CSOs in Vietnam have conducted CVAs to meet specific objectives: i) Define and describe local climate hazards and their impacts and potential impacts; ii) Identify objects, areas, services and functions that are most vulnerable to current climate hazards and subject to high risks in the future due to climate change; iii) Identify direct impacts of climate change on the most vulnerable groups of people, infrastructure and areas; understand how indirectly impacts affect others; iv) Assess people's capacities and needs for adaptation; Assess the way services and ecosystem functions can respond to on-going pressure; and v) Provide information, develop appropriate intervention models, and enhance adaptive capacity for localities and people. CSOs emphasize that the core and most important factor of CVAs is that CVA results and the process of CVA implementation must be connected to development of adaptation models to mitigate vulnerability. CVA results enable CSOs to define "gaps" and design adaptation models and activities which can "fill the gaps".

Most common CVA methods implemented by CSOs in Vietnam

CSOs' initiatives and solutions to support community adaptation were implemented in many provinces and have achieved positive results. Many adaptation models have been created based on the results of Climate Vulnerability Assessments (CVAs). CVA results not only facilitate the development of adaptation strategies, plans, and measures at provincial level but also make great contributions to macro and long-term adaptation policies.

The integration of CSO's CVA approach and results into the NAP helps to clarify the CSOs' roles and contribution (in concurrence with government activities) and institutionalize their recommendations in national adaptation policies. Assessment results show that poor and disadvantaged people are most susceptible to impacts of climate change. Climate vulnerability assessments are of great importance in identifying vulnerable subjects, areas, and sectors and in finding appropriate adaptation strategies and measures to reduce risks and leverage development opportunities.

Two major approaches of CVA implementation observed in Vietnam are: 1) the top-down approach that mainly done by government agencies and research institutions; and 2) the bottom-up community-based approach. This approach is participatory, providing community's perspective and allowing space for practical vulnerability information and feedback. The CVA methods described below are the most common adopted by CSOs in many of their programs and projects.

• HVCA - Hazard Vulnerability Capacity Assessment

Nearly 71% of the surveyed CSOs claimed that they have used this approach. HVCA is a prevailing CVA method whose development and adoption are pioneered by the Vietnam Red Cross from the late 1990s, assessing the hazards of natural disasters and climates so as to offer solutions to minimize risks and ensure safety for the community. HVCA puts emphasis on five aspects: (1) Livelihoods, (2) Basic living standards, (3) Self-protection, (4) Social protection, and (5) Civil society organizations (Le, 2017). HVCA's major components are designed to identify exposure levels, locations, vulnerable groups, and adaptive capacity of vulnerable groups. Measures following the implementation of HVCA tend to be developing plans for community safety enhancement and risk reduction, such as establishing early warning systems and building shelters. Therefore, HVCA is suitable for projects that focus on community safety. Qualitative and less-mentioned long-term climate risks are the drawbacks of this approach.

• PVCA- Participatory Vulnerability Capacity Assessment

64% of the interviewed CSOs used this method. PVCA is a combination of tools to help communities develop and implement plans to enhance resilience to climate change. This method is based on the participation of community members to identify and classify climate hazards as well as to analyze resources (capacities) and local availability opportunities in order to reduce risks. PVCA is more about disaster risk reduction and emphasizes the participation of vulnerable groups (the poor, children and people with disabilities). PVCA is very useful for poverty reduction and gender equality related programs.

• ***CVCA - Climate Vulnerability Capacity Analysis***

35% of CSOs and experts have used CVCA for the last 6 - 8 years, mainly for natural resource-related sectors, such as agriculture, water, mangrove forests, and so on. The key components of CVCAs are exposures, sensitivity, potential impacts, and adaptive capacity. CVCA enables identification of practical solutions or strategies, boosting community-based adaptation measures. As an open tool, its results depend on community discussions to setpriorities before developing adaptation plans, models, and solutions. CARE is a lead organization in CVCA application in Vietnam. CARE joined in a mission with UNDP-GCF Project to combine PVA and CVCA into a less sophisticated method which can be applied across NAP special sectors. GCF is now extending the application of this method.

• ***VA-EbA - Vulnerability Assessment-Ecosystem-based Adaptation/EbA***

This approach has been strongly recommended in Water, Land, Biodiversity and Transpotation sectors, which are significantly affected by the quality of the ecosystem. It is an evolution from the Ecosystem-based Adaptation (EbA) approach proposed by the UN's Convention on Biological Diversity (1992). Currently, many researchers in Vietnamare extending the application of this approach to their research. EbA proves to be helpful in the pursuit of a fair balance between the protection and the rational use of biodiversity, enabling vulnerability mitigation, resilience to climate change, and sustainable development (Hoang and Truong, 2016). VA-EbA provides detailed assessments of factors contributing to vulnerability, boasts a harmonious combination of quantitative and qualitative methods; prudently examines potential natural risks (ecosystems), conducts assessments at both the provincial and locallevel, and promotes involvement and coordination of provincial specialized officials and local people. VA-EbA-based adaptation measures will meet three objectives (socio-economy, environment, and biodiversity preservation) and highly accurate (Doswald et al., 2011). However, VA-EbA requires years of meteorological, climate and natural disaster data as well as relatively sophisticated vulnerability treatments and mapping techniques, which are mostly appropriate for the assessments bya key technical expert. This is a difficulty for the expansion and transfer of CVA at the local level.

In addition, CSOs and other agencies also use different methods depending on their objectives, targets and evaluation scale, such as: Urban Vulnerability Index (UVI), Livelihood Vulnerability Index (LVI), Social Vulnerability Index (SVI), Ecological Risk Assessment (ERA), Simulation methods, IPCC climate impacts assessment framework, Flowing Forward, Oxfam's Vulnerability and Risk Assessment (VRA) and CVA of agriculture value chains. The most popular tools used in Participatory Rapid Appraisal (PRA) by CSOs in CVA are: Seasonal calendars and disaster brief history, Community risk maps (hazard maps), Problem tree, Transect survey and analysis, Venn diagram and Group discussion.

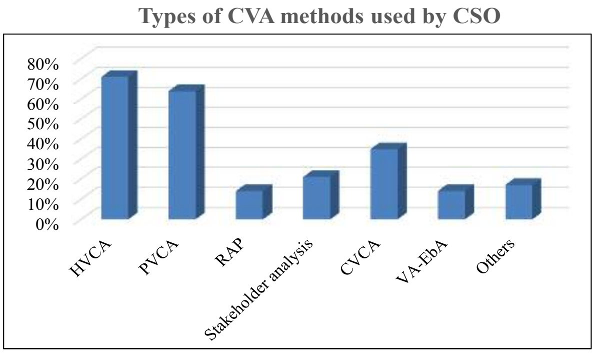

Fig. 1. CVA methods

According to the findings of the research: CSOs implemented disaster risk and climate change-related programs and projects; supported communities in livelihoods development with the application of CVA; and each organization applied several tools. The Center for Rural Development in Central Vietnam (CRD) and WWF Vietnam used a variety of methods. CSOs that mainly working on climate change and disaster risk reduction in Vietnam, like CARE, Oxfarm, World Vision, Plan, SNV, SRD and MCD, tend to apply HVCA and PVCA. Meanwhile, WWF and GIZ are pioneers in the application of VA-EbA with an attention the vulnerability of ecosystems in relation to livelihoods. It should be noted that components of the method(s) should be appropriate adjusted according toobjectives, conditions, and contexts.

• ***Sources of information and data***

Information and data for CVA mainly come from secondary (available) sources as well as-primary ones (surveys, questionnaires, synthesis, analysis, calculations). Depending on CSO's operational areas, the most popular locations for CVA application are in the regions where are vulnerable to climate change and natural disasters. These localities were identified through scientific and practical evidences because they are very sensitive to climate change factors. They are vulnerable and suffered many risks, as well as losses in life and production; Climate change and sea level rise scenarios (2009, 2012 and 2016) have predicted high risks in the next 100 years for these areas .

• ***Participants in CVAs and gender equality***

Among CSO's strengths and priorities in CVA is the attraction of many stakeholders to take part in the implementation and support process. Most CVAs are implemented at the grassroots level and some at the commune, district, and provincial levels. Whilst HVCA is widely applied at the community (village, hamlet) and commune level, PVCA is more popular at the commune and district level. CVCA, meanwhile, is adopted in a more balanced manner at all levels. Although several organizations (including World Vision, SNV, GIZ, SRD, MCD, Plan, AMDI, CRD, WWF and others) managed to get district officials involved. Their participations are mainly related to monitoring and facilitating working process with people at the commune and hamlet level. CVCA implementation mainly lies in the hands of consutants, project officers, commune officers who provided information and feedback. Local social organizations act as important partners, as main force working with CSOs and as collaborators during CVA implementation. They are Vietnam Red Cross Society, Women's Union, Farmers' Union, and Youth Union. Schools are an object for climate risk assessments, so students and teachers also take part in CVAs and are instructed to create plans for safe learning environment themselves. CSOs like Plan, World Vision, and Live and Learn have excelled in their CVA activities applied for schools.

• ***Ensuring gender equality***

The following aspects are mainly considered: who are most vulnerable to climate change; Men's and Women's participation in CVA implementation; and each gender'svoice and feedback in decision making or adaptation planning. Vulnerable groups: Women in many rural areas in Vietnam are most affected by climate change impacts, including natural disasters. They have limited disaster response skills. This is more common among women aged above forty-five. Consequently, following CVAs, many CSOs supported women in focusing on knowledge enhancement and livelihood development. Men's and Women's participation in CVA implementation: Over 90% of surveyed CSOs said that both men and women were encouraged to take part in CVAs at the district and commune level.However, there is a clear distinction in the proportion of men and women participating in CVAs at different levels: At district and provincial level: Men's participation in CVAs accounts for an approximate 80%, they are mainly support project officers. They make connections to localities, monitor the implementation process, and take part in interviews; Opposite, Women's participation is greater at the grassroots (commune, hamlet) level. They are ordinary people and female officiers who work in social organizationssuch as: Women's Union, Farmers' Union, Youth Union,... (Fig. 2). As a result, insome occasions, adaptation plans implemented by local authorities are not totally suitable to meet the demands and resources of vulnerable groups. The expectation of CSOs is that women in districts and provinces will have a greater and deeper participation in CVA-related training courses, adaptation recommendations and plans, as well as in the supervision and assessment of the adaptation implementation process.

Fig. 2. Participation of local stakeholders in the implementation of CVA

• ***Relevance to local context***

Self-assessment results show that the relevance of each method related to the local context at three levels (Irrelevant, Relevant and Highly Relevant) is rated mainly between“Relevant” and “Highly relevant”. CVCA and HVCA have the highest percentages of “Highly relevant” (at 80% and 60%, respectively), followed by PVCA, RAP, and VA-EbA with over 50%. For methods that were assessed as “Relevant”, the reason is that these methods are qualitative.if they are combined with methods/tools using local meteorological parameters such as rainfall, temperature, etc., the higher levels of relevance will be achieved.

• ***Significance of changes from CVAbased models, solutions***

For whether the CSOs’ CVA based models and solutions can lead to the expected changes or not, the Flowing Forward and VAR approaches are scored at 100% as “Very significant”. The changes created by VA-EbA were assessed as “significant” and “very significant” at a rate of 50%. In particular, the Flowing Forward, VAR and CVA methods in the agricultural value chains are evaluated to bring about “Very significant" changes but the actual number of CSOs implementing the method is limited, possibly due to the high demand for secondary data from specialized agencies. Many CSOs (such as MCD, AMDI, CECR) have introduced initiatives to support coastal districts to self-develop district-level adaptation action plans with the active participation of specialized departments and expert technical guidance. This is also a way to improve the capacity of local officials.

• ***Impacts/Number of beneficiaries***

Most CSOs say it is difficult to collect the number of CVA beneficiaries’ localities as communities are very diverse, scattered throughout the climatic regions of Vietnam or forecasted to be vulnerable to current and future climate change. Some typical examples such as: The IRRI Institute - CCAFS uses the PVCA method to benefit households in 13 Mekong Delta provinces; The 5-year HVCA application by World Vision benefits roughly 10,000 people. In communities and communes where CVA is applied by World Vision, beneficiaries are mostly women (about 65%) and the poor (about 80%); CARE International uses HVCA and CVCA methods for around 20 years to help thousands of people (specific data is not available) across Vietnam’s three regions (the North, the Centre and the South); SNV, Plan, GEF, SRD, MCD, WWF, CRD and others conducted CVA integration in more than 15 provinces, and enabled many districts, communes with thousands of people in mountainous, coastal and desert areas to cope with natural disasters and to improve their livelihoods.

• ***Effectiveness of CVA implementation in 7 priority sectors of the NAP.***

The sectors in which CVAs are conducted by CSOs are relatively similar to the seven priority sectors of the NAP. They are Water, Agriculture, Land, Biodiversity, Transportation, Gender and

Poverty Reduction, and Healthcare and Education. However, CVA methods are applied at different levels in each sector (Table 1).

Table 1. Summary of CVA methods applied by CSOs in priority sectors in Vietnam's NAP

Sector	Common CVA methods in priority sectors		
Water	HCVA	PCVA	PVCA
Agriculture	PCVA	HCVA	HCVA
Land	CVCA	VA-EbA	VA-EbA
Biodiversity	HCVA	PCVA	VA-EbA
Transportation	HCVA	PCVA	UVI
Gender and poverty reduction	HCVA	PCVA	Stakeholder Analysis
Health care & Education	HCVA	PCVA	CVCA

As shown in Table 1, HVCA is the most popular methods. According to the statistics, more than 50% of the interviewees applied HVCA, PVCA seconds with 42,9%, third being CVCA (43%) and fourth being VA-EbA (14%).

Adaptation measures that are applied as a result of CVAs implementation

CVA implementation and results are applied most in the agro-forestry-fishery sector, medicinal plant development closely connected with preservation and livelihoods, and husbandry accompanied by technical improvements. There are many adaptation models, solutions and practices that refer to and use results from CVA, mainly in livelihoods, resource management (water, biodiversity, land use), education, and lowering floors, environment, health. CVA have been developed and used in more than 30 provinces. It is used as an input for design and implementation of livelihood interventions in the direction of a livelihood-centered approach. This is because at community and household levels, livelihoods are most affected by and vulnerable to climate change and are the greatest concern and need of households. Promoting adaptive livelihoods will mitigate vulnerability and build up community resilience. Fig.3 summarizes a number of local stakeholders where CSOs play central role in climate vulnerability assessment and then chair or coordinate implementation of climate change adaptation models in the priority sectors of the NAP.

CSOs' capacity and roles in CVA implementation

The survey results show that CSOs are confident in the CVA implementation at local and community level and that CVA results have made significant contribution to local adaptation capacity. Most interviewed organizations (57%) hire consultants to support local officials and assessment projects. 37% of CSOs actively work with officials and collaborators to conduct CVAs, and a few of them rely completely on external consultants for assessment processes. CSOs' strengths in CVA implementation: (1) They adopt a community-based approach based on a community perspective, mobilize the participation of local people and other stakeholders; focus on disadvantaged and vulnerable groups, develop adaptation solutions that generally meet the needs and capabilities of the population while being in line with the local natural context and policies; (2) CSOs have shown great performance in raising awareness and in building local capacity via organizing training courses, conducting community communication, and creating favorable conditions for local people to participate in projects' activities; (3) They are also flexible in method application, adopting quantitative and qualitative methods involving participatory tools. Collaborators are trained in advance and are local residents so information collection is facilitated. Collected information is helpful as it is diversified, embeds history, truly reflects the current vulnerability status, and receives verification and on-the-spot feedback, 4) CSOs appreciate indigenous knowledge and often actively compile this knowledge and experiences of different communities, which enables them (to have important information as a reference for future recommendations which are in line with local demands, capacities, and cultural practices, (5) Thanks to their reputation of maintaining flexible working mechanisms and transparent finance processes, CSOs can easily gather groups of experts, technicians and scientists of different sectors and competences and enthusiasm into play in assessment activities as well as insight into methodologies. CSOs are also experienced in effectively organizing multilateral group work, ensuring good results, timeline, and cost saving needs, (6) CSOs are typically transparent and proactive in sharing information and results of both CVAs and projects with stakeholders (authorities, specialized agencies, scientists, and communities) as well as with other CSOs and localities. As a result, the CSO network in Vietnam will likely expand, helping to extend the benefits of CVAs while saving time and human resources during the implementation of new CVAs.

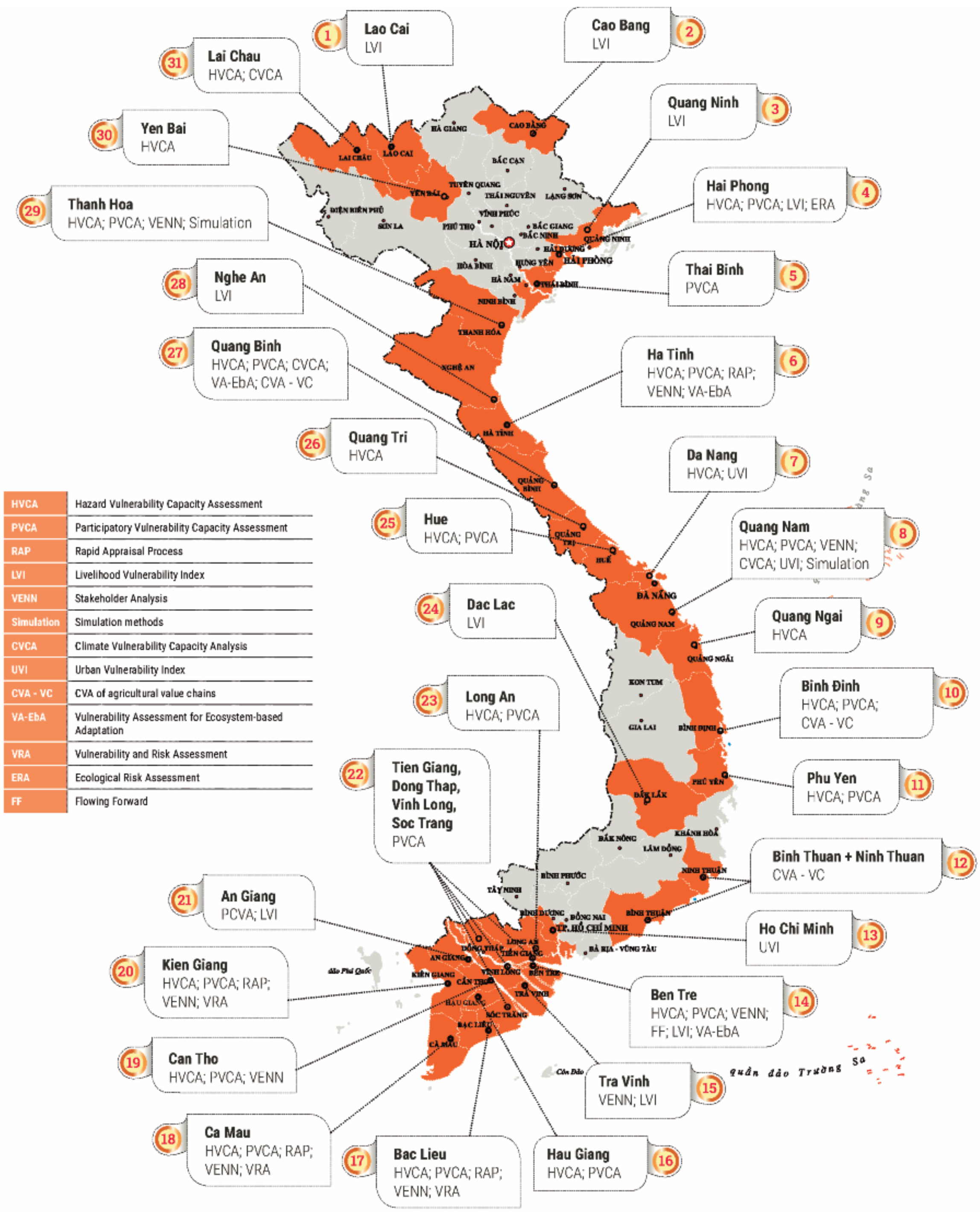

Fig. 3. CVA areas applied by CSOs in Vietnam

Despite its own advantages and strengths, the implementation of the CVA still faces difficulties in data sources, capacity of local officials and information channels of CSO network:

(1) Information and data: CSOs state that they have difficulties getting access to official updated sources of information and data by specialized agencies during CVA implementation. For this reason, input data is insufficient for the assessment of potential impacts and risks in the long run. Limited access to specialized database sources makes assessment results more quantitative than qualitative and there are limitations regarding CVA long-term forecasts on local potential climate risks. It also makes it hard for CSOs to convince local authorities and specialized agencies to integrate CVA results in their development plans;

(2) CVA human resource: Direct engagement of officials from specialized agencies at the provincial and district level is limited resulting in a lack of monitoring and correction of the accuracy of the assessment results, and affecting the CSO's goal of "enhancing community participation to improve adaptive capacity".

(3) Information sharing of CSOs: Currently, the network of NGOs in Vietnam has not yet established and maintained a stable, complete and updated database about activities that CSO has been implementing. Therefore, restricting the sharing, exchanging information among CSOs as well as limiting timely and formal information delivery from CSOs to government agencies, partners, and sponsor.

(4) CVA for urban areas: There are currently few vulnerability assessments conducted by CSOs for climatic risks in urban areas such as flooding, heat stroke, prolonged heat stress causing environmental risks, health and transportation. The main reason is due to the lack of technical, financial and data capacity.

4. Conclusions and recommendations

Conclusions

CVAs implemented and supported by CSOs have brought about significant results, helping local communities and authorities effectively develop and implement adaptation plans and solutions. At the provincial level, disaster-climate change-related information and events as well as indigenous knowledge, which is acknowledged, collected from stakeholders and analyzed is of high credibility and practicality.

With a point of view to enhancing the communities' voices and ability to take action, CSOs in Vietnam are implementing vulnerability and adaptive capability assessment methods which pave the way for interventions as well as for adaptive support and promote the integration of climate change factors into development planning and plans.

The CVA results are important, practical and up-to-date input information for adaptation plans and solution development in localities; Authorities, sectors, development organizations and households can easily use and integrate the results from CVA for climate change adaptation goals.

CVA helps strengthen the knowledge, awareness, skills and responsibilities of stakeholders at all levels regarding climate change response and sustainable development.

Gender issues have been emphasized in CVAimplementation and women have participated. The voices and aspirations of women and girls in CVAs are encouraged and promoted. Many adaptive models that were implemented after the CVAs significantly improve women's lives and reduce their vulnerability.

Regular CVA reviews (annually or every 5 years) are of great significance for annual socio-economic plan development of localities.

CSOs have not implemented CVA in urban

areas. They also face difficulties when information quality from assessment are still poor due to limited capacity of each CSO, financial resources and other reasons.

Recommendations

To supportthe government to enhance the use of CVAs in the NAP implementation after 2020, the following recommendations are put forward:

Mechanisms and policies: The CVA implementation in localities should be institutionalized in national documents to create a legal status for periodic or annual CVA implementation. CVAs should be considered as a necessary requirement for projects, planning and development plans to ensure a timely review of current and potential climate risks which allows for preventive response measures in line with the local capabilities. The application and integration of CVA results should be systematically enhanced into planning at all levels, and in all sectors and priority areas of the NAP.

CVA implementation in climate change projects: The combination of bottom-up approaches, top-down approaches and inter-sectoral, ecosystem-based approaches should be enhanced in CVAs. Local authorities at the provincial and district levels need to participate more actively in the whole process of CVA.

CVA methods, information, data and area expansion: The authorities and specialized agencies need to be more open regarding their databases, materials and information sharing as well as generally giving access to CSOs and the communities. The CSOs network needs to build and maintain website information, database of CSO activities and results.

CVA areas: Climate Vulnerability Assessments in large urban areas need boosting, especially in densely populated areas that are facing increased flooding and heat impacts due to rising temperatures. Such directly impacts of environment, health and transportation are under priority areas of the NAP.

Gender equality: The participation of vulnerable groups, including women, should be ensured and enhanced in the NAP process. Gender segregated data should be used in vulnerability and adaptation assessments. Training on a general understanding of gender should be provided for parties in charge of the NAP development and implementation.

Information exchange and communication: Multi-lateral information exchange take place among parties, including local authorities, leaders, CSOs, scientists, communities, and the private sector on CVA implementation and application of its results. Information needs to reach the majority of the population, specialized officials, as well as local leaders. It is also necessary to facilitate business involvement in CVA assessments and feedback processes and reference of CVA results in their investment decisions to minimize risks.

International cooperation enhancement: The Department of Climate Change, CSOs and CCWG need to enhance their cooperation with international partners in terms of pushing forward CVA in NAP development and implementation. This should be done together with diversifying mechanisms and sectors: recommended areas include information and data sharing, fundraising, joint-implementation and monitoring and evaluation.

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Research Paper

IMPROVING THE QUALITY OF SEVERE WEATHER WARNING WITH HIGHRESOLUTION NUMERICAL WEATHER PREDICTION PRODUCTS FOR THE WMO-SEVEREWEATHER FORECASTING DEMONSTRATION PROJECT IN SOUTHEAST ASIA

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ABSTRACT

WMO mission to Hanoi in February 2011 determined that the NCHMF appeared to have an excellent development potential to undertake the role of the Regional Forecasting Support Centre (RFSC) in the Severe Weather Forecasting Demonstration Project for Southeast Asia project. To provide better product for developing the guidances for SWFDP-SeA, based on new capacities of High Performance Computing (HPC) of VNMHA, this paper presents new high-resolution numerical weather prediction products including very high-resolution deterministic products (WRF3kmIFS) and high-resolution regional ensemble systems (SREPS-32). WRF3kmIFS is configed by using the recently released version of Weather Research and Forecasting model with ARW dynamical core - WRF-ARW (version 3.9.1.1) with IFS (ECMWF) for boudary conditions while SREPS-32 is a set of combination of physical parameterizations. Some improved performances are shown relating to heavy rainfall and tropical cyclone over Southeast Asian domain and for the South East Asia Flash Flood Guidance Systems.

Keywords: *SWFPD-SeA, RFSC's Hanoi, High-resolution regional products.*

1. Introduction

The Severe Weather Forecasting Demonstration Project (SWFDP) is a WMO Commission of Basic Systems (CBS) initiative, commenced in 2005, to demonstrate how warning services provided by NMHSs in developing countries can be enhanced and links with disaster management authorities improved through cooperative work among meteorological centers. The scope of the project is to test the usefulness of currently available and promising experimental products available from Numerical Weather Prediction (NWP) centers in improving severe weather forecasting services in countries where sophisticated model outputs are either not available, or not effectively used (GDPFS, 2010).

The first meeting of the SWFDP-SeA Regional Subproject Management Team (RSMT) to develop an implementation strategy for the SWFDP-SeA was held in September 2010 in Tokyo. The meeting reviewed a draft SWFDP-SeA Implementation Plan which proposed three types of Regional Centers with the roles: regional forecasting support (Hanoi), training and technical support (Hong Kong Observatory, HKO), and tropical cyclone forecasting support (RSMCs Tokyo and New Delhi). Although the National Centre for Hydrological

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and Meteorological Forecasting (NCHMF) in Hanoi is not a designated RSMC within the WMO GDPFS, the SWFDP concept of operation requires an operational regional centre to support severe weather forecasting in the participating NMHSs. A follow-up WMO mission to Hanoi in February 2011 determined that the NCHMF Hanoi appeared to have an excellent development potential to undertake the role of the Regional Forecasting Support Centre (RFSC) in a SWFDP-SeA project. It is proposed that NCHMF Hanoi be designated the Regional Forecasting Support Centre to perform the function of the lead regional centre for the SWFDP-SeA.

The SWFDP implements a cascading forecasting approach via the three-tier GDPFS network of global, regional and national meteorological centers. Global centers provide NWP products, including probabilistic forecasts, and other forecasting guidance, while Regional Centres interpret this information often from multiple sources, and produce regional-scale products to guide National Meteorological and Hydrological Services (NMHSs) in their forecasting functions for their respective countries. For the main purposes of SWFDP regarding to the enhance of supplying regional scale products, with the new HPC system, in 2019, the regional NWP products have been significantly upgraded, especially of very high resolution of deterministic forecast (3km, Southeast Asia domain, named WRF3kmIFS) with better boundary conditions (from ECMWF) and higher resolution of regional ensemble forecast (10km, Southeast Asia domain, named SREPS-32). The product of SWFDP-SeA can be seen with link in reference list (SWFDP-SEA).

Section 2 will provide technical information for WRF3kmIFS and SRESP-32. The performances of these systems will be shown in section 3 and some remarked conclusions are shown in section 4.

2. Materials and Methodology

2.1. WRF-3kmIFS

This study used the recently released version of Weather Research and Forecasting model with ARW dynamical core WRF-ARW (version 3.9.1.1) with multi-nested grids and two-way interactive options. One of the most important things is that the WRF model has been a very flexible and useful tool for both researchers and operational forecasters as it is integrated with various recent advances in physics, numerics, and data assimilation contributed by scientists and developers from the expansive research community.

2.2. SREPS-32 system and boundary conditions

A set of combination of physical parameterizations has been generated based on (a) the modified KF and BMJ cumulus parameterization schemes; (b) the Goddard and Dudhia schemes for the shortwave radiation; (d) the YSU and MYJ planetary boundary and (e) the Lin, WSM3, WSM5 and WSM6 schemes for the cloud micro-physics.

There are maximum 32 different configuration forecasts. The other options are the Monin-Obukhov surface layer scheme and the Rapid Radiative Transfer Model scheme for longwave radiation. Note that with MYJ scheme, the surface layer option will be switched to Janjic-Eta-Monin-Obukhov scheme which based on similar theory with viscous sub-layers both over solid surfaces and water points. Skamarock et al. (2008) provided the detailed description of the WRF-ARW model. The performances of different members can be found in Tien et al. (2019) regarding to the heavy rainfall over the northern part of Vietnam.

For SREPS-32, WRF-ARW is set to 10km for horizontal resolution and the GFS model by NCEP is used to provide boundary conditions for WRF-ARW and be prepared every three hours at pressure levelsfrom 1000hPa to 1hPa. More information for GFS data can be found at:

https://www.nco.ncep.noaa.gov/pmb/products/gfs/.

2.3. WRF3kmIFS system and boundary conditions

With WRF3kmIFS, there is no cumulus parameterization. Using WSM6, MYJ and the Goddard and Dudhia schemes, WRF-ARW is set to 3km for horizontal resolution and the IFS model by ECMWF is used to provide boundary conditions for WRF-ARW and be prepared every three hours at 27 pressure levelsfrom 1000hPa to 1hPa. The IFS has been bought by VNMHA since 2011.

3. Results and Discussion

3.1 Performance of high resolution NWP products

To examine the performance of numerical weather prediction products, a number of deterministic and ensemble models will be briefly assessed in two cases studies in this section. The event of heavy rainfall in the northern Vietnam occurred on 23 June 2019. Fig. 1 illustrates the surface analysis chart at 00Z UTC with a low pressure trough which was squizzled by the high pressure in China. As a result of the southward movement of this trough, the north of Vietnam experienced moderate to heavy rain in the night of 24 Jun 2019 in the mountainous and midland area, especially very heavy rain was observed in some places. The common rainfall is about 40-80mm/24h, particularly in Lai Chau, Ha Giang and Bac Giang regions, rainfall is up to 80 - 1600mm/24h (Fig. 1a).

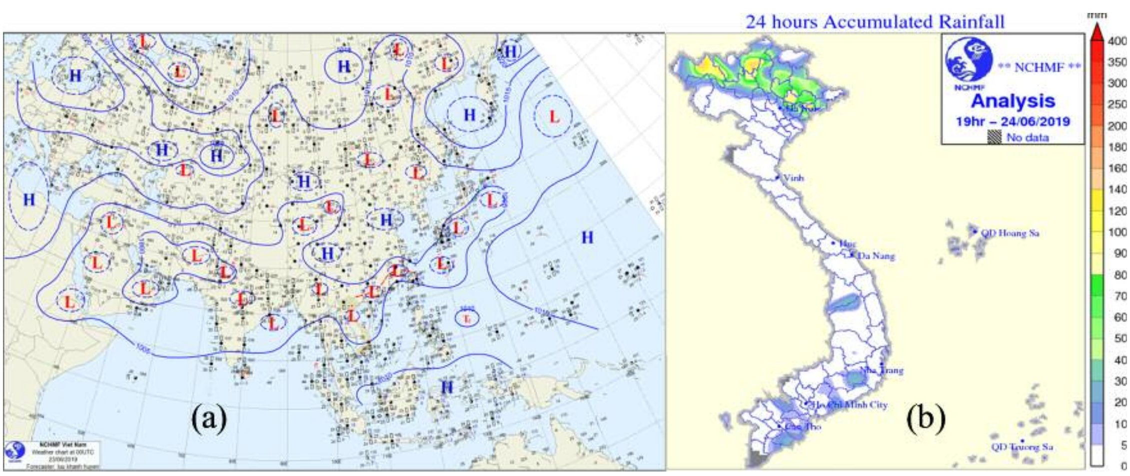

Fig. 1. Surface analysis chart on 00z 23 Jun 2019

Regarding the determistic models in Fig. 2, it is clear that WRF3kmIFS provided the best forecast among all the NWP models. The amount of rain with threshold 60-80mm/24hours was forecasted by GSM and IFS models in the north and northeast of Northern Vietnam respectively, whereas the GFS model only forecast the rain with the amount of 10-40mm/24 hours. In comparison with global models, both of WRF model forecast (using IFS and GFS)provided the more widespread heavy rain area with the common rainfall occurred at 60-80mm/24h all over the northwest, northeast and upper north of Vietnam.

Ensemble products also reveals the high probability of heavy rain in the north of Vietnam in Fig. 3. For SREPS, the probability of heavy rain with threshold over 20mm/24 hours was at 40-60%, while this figure for threshold over 50mm/24 hours was slightly lower, at 30-40%. Similarly, ECMWF ensemble products also predicted the heavy rain in the Northern Vietnam even though the heavy rain area was forecasted to occur in the northeast. In ECMWF products, 80-90% of rainfall at over 20mm/24h and 30-60% of rainfall at over 50mm/24 hours were forecasted, mainly in the northeast of Northern Vietnam

Based on numerical products, SWFDP warnings for short range was issued (Fig. 4).

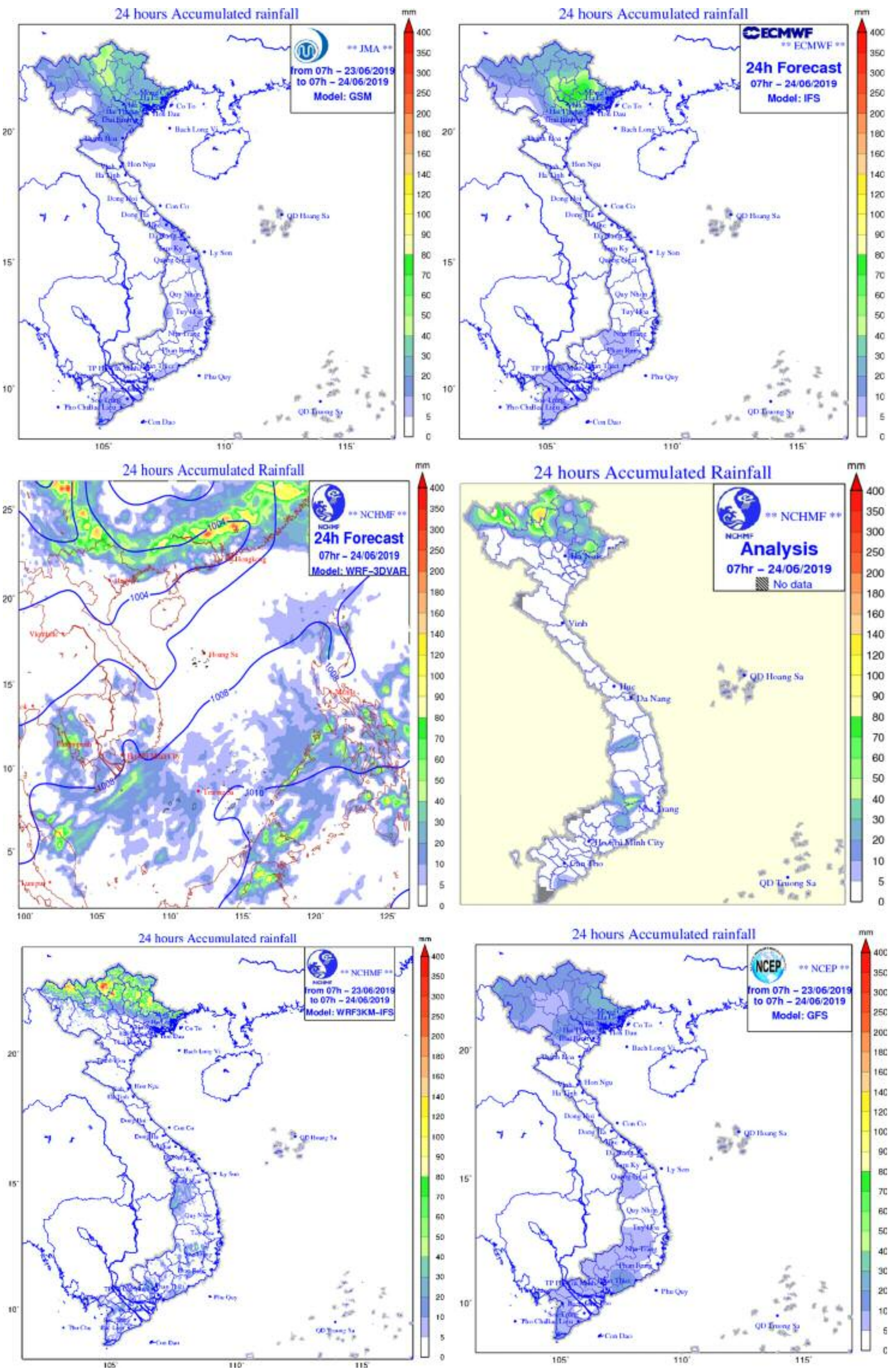

Fig. 2. Illustration of Comparison of global and regional models for heavy rainfall over the northern Vietnam in 24/6/2019

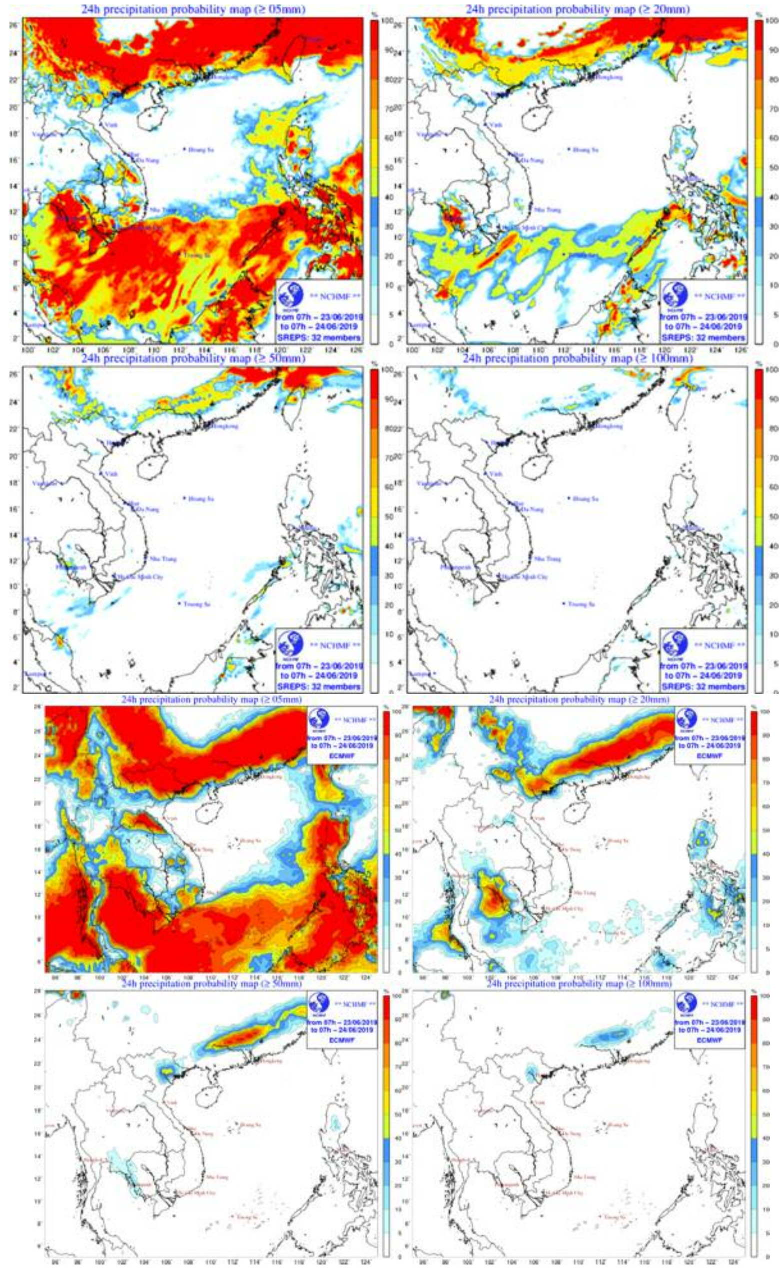

Fig. 3. Ensemble products

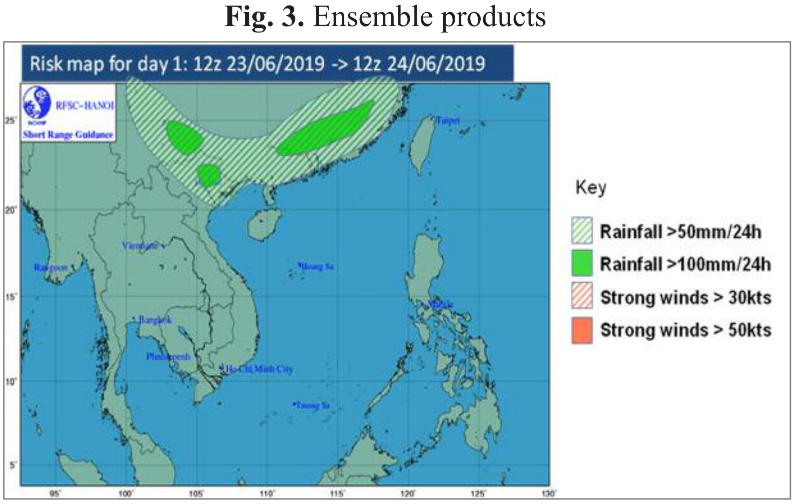

Fig. 4. Warning map from SWFDP-SeA with new NWP products

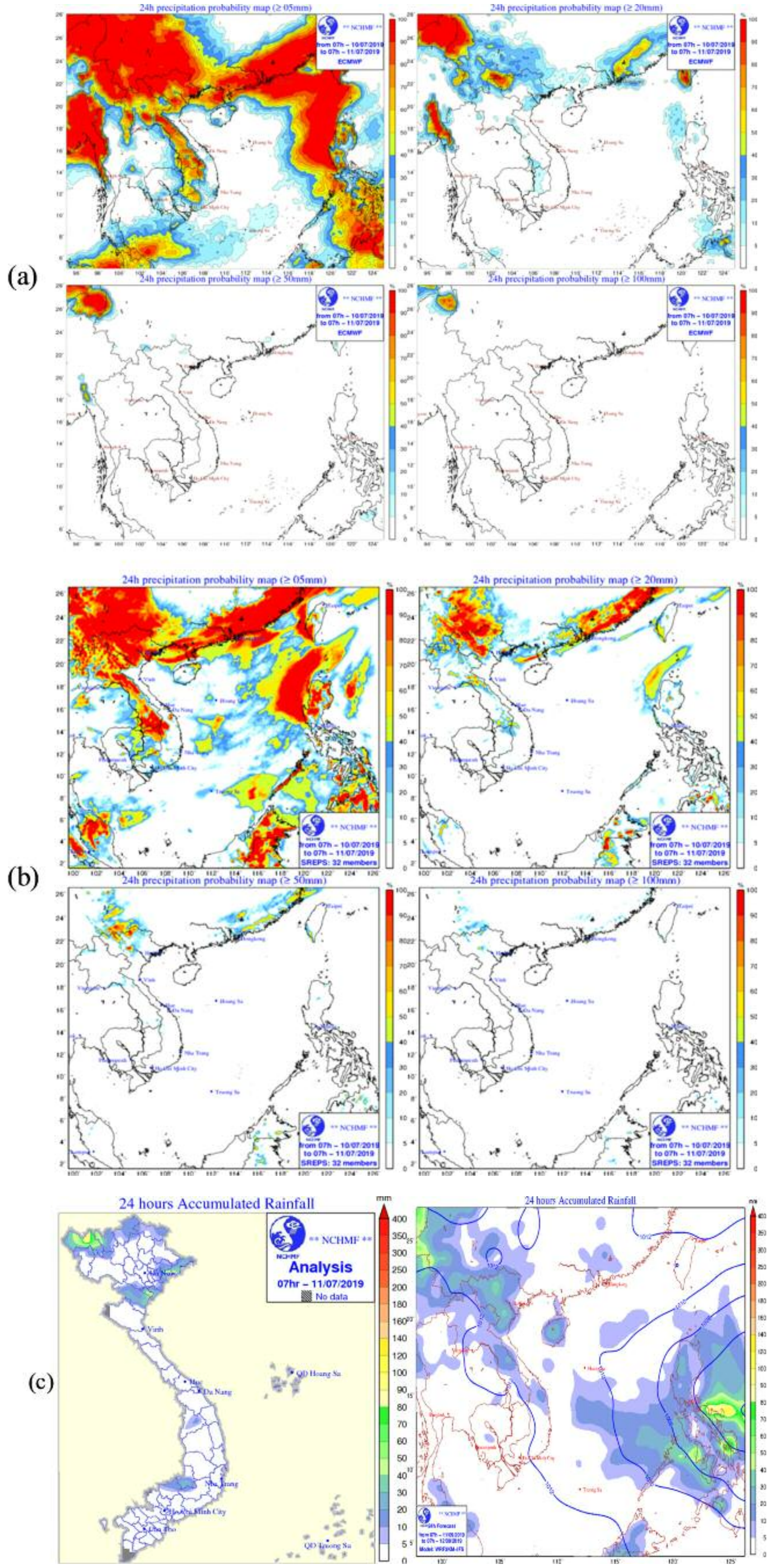

Fig. 5. Illustration of SREPS-32 (b) in case of providing better forecast for heavy rainfall Event over the Northwest of Vietnam than ensemble-ECWMF-51 in 11/7/2019, (a) is observation of precipitation

Another example can be seen in Fig. 5, for the heavy rain event on 11 July 2019, WRF3km and SREPS-32 still showed the improved forecast in the heavy rain warning. Both ensemble products provided the high probability of heavy rainfall in the northwest of Vietnam with 60-80% at the amount of over 20mm/24 hours and 40-50% at the amount of over 50mm/24 hours. Similarly WRF3kmIFS forecasted the common rainfall of 50-70mm/24 hours in the northwest. The final warning map is shown in Fig. 7.

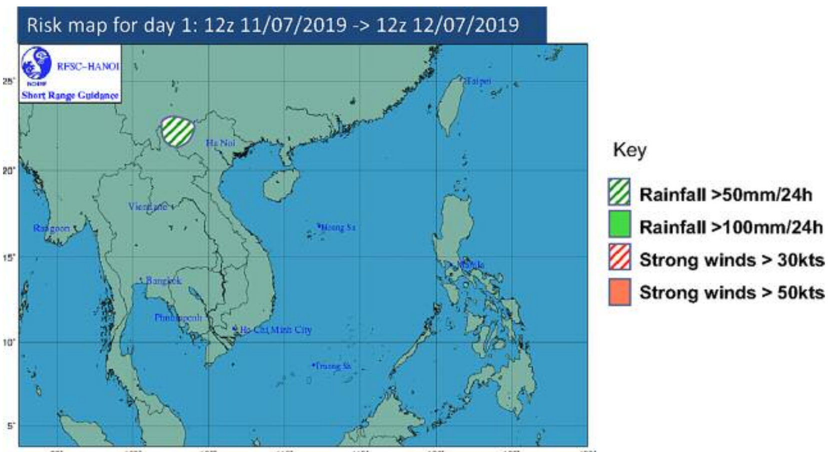

Fig. 6. Warning map regarding to the event in 11/7/2019

3.2 High resolution precipitation forecast for the South East Asia Flash Flood Guidance Systems

During 30 September 11 October, 2019 a delegation from Hydrologic Research Center (HRC) and the World Meteorological Organization (WMO) visited the national hydrological and meteorological offices of Lao-PDR, Vietnam, Cambodia and Thailand. The main objective for these visits was to establish the real-time data transfer of the key datasets to the South East Asia Flash Flood Guidance Systems (SeASIA-FFGS) and to assemble historical datasets that are needed for the FFGS development.

As of October 4, 2019, we are receiving WRF-ARS 3 km2 rainfall forecast extending out to 72 hour in 6-hour intervals for the entire domain of the SeAsiaFFGS. The files are in NetCDF format that can be ingested into the FFGS. The forecast is updated twice daily (00:00 and 12:00 UTC) using a cold start and boundary conditions from ECMWF. This WRF was developed with WMO support as part of the Severe Weather Demonstration Initiative. VNMHA is also producing a ten members WRF ensemble at a 10-km resolution using the GFS for boundary conditions. The output of this ensemble is readily available and was offered for the FFGS.

An example of using higher resolution of deterministic forecast (3km) in providing better precipitation forecast for landslide warning can be seen in Fig. 7.

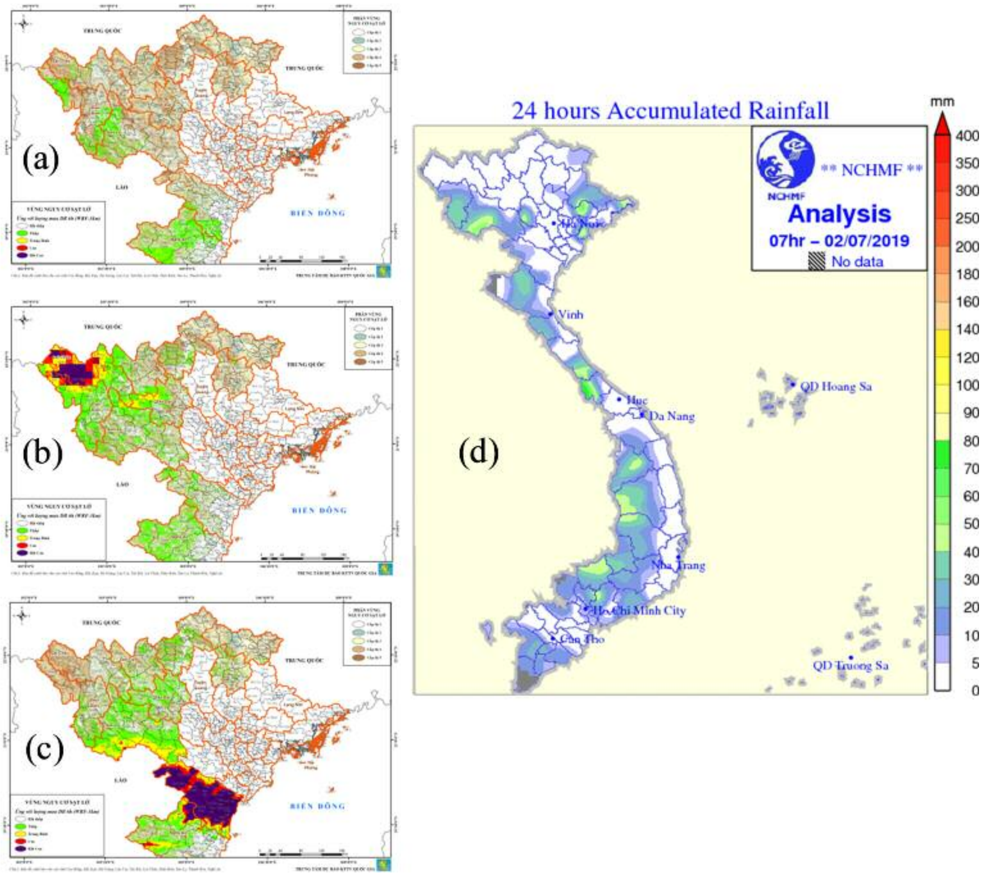

Fig. 7. The detail of landslide warning based on different rainfall meteorological model forecast: (a) GFS, (b) IFS, (c) WRF3km-IFS, 02-Jun-2019 and (d) observation

4. Conclusion

Based on new capacities of HPC of VNMHA, the new high-resolution numerical weather prediction products including very high-resolution deterministic products (WRF3kmIFS) and high-resolution regional ensemble systems (SREPS-32) showed improving performances relating to heavy rainfall and tropical cyclone over Southeast Asian domain and for the South East Asia Flash Flood Guidance Systems. Next steps, further detail verifications of WRF3kmIFS and SREPS-32 will be conducted.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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Research Paper

A VERIFICATION OF HEAVY RAINFALL EVENS FORECAST SKILL OF IFS MODEL AT THE MIDDLE CENTRAL OF VIET NAM

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ABSTRACT

The paper presents the verification of capacity of heavy rainfall forecast IFS model by using the dataset of 75 automatic rain gauges collected of 59 heavy rainfall events of 2011-2018 rainfall seasons. The verification results based on ME, MAE, RMSE, R, BIAS, POD, FAR and ETS indices shown that the heavy rain forecast of IFS has good skill in forecast range of 1-3 days ahead. In addition, rainfall forecast of IFS model is over-estimated at small and medium rainfall thresholds and under-estimated in large and extreme large rainfall thresholds. The extreme rainfall forecast predictability of IFS model is good in some heavy rainfall events that caused by large-scale weather patterns.

Keywords: *Heavy rainfall forecast, verification, IFS model.*

1. Introduction

According to statistics in the last 20 years, The big floods occurred in November and December 1999 in the Central region of Viet Nam which engulfed hundreds of villages, causing deaths and huge material losses. In 1999, within just over 1 month (from November 1st to December 6th), in most provinces of Central Vietnam, there were 2 extremely heavy rainfall events causing 2 rare floods in wide area in history. As a result, more than 700 people died, nearly 500 were injured, tens of thousands of households lost their houses and assets, the damage was estimated at nearly 5,000 billion of VND, far exceeding the level of damage occurred in 1996. The natural disasters in the Central region are mainly associated with flood phenomena, which are mainly caused by heavy rains event in the Central region of Viet Nam. Therefore, accurate rain forecast for the Central region is a prerequisite for serving disaster prevention and mitigation.

In the past 10 years, rain forecast products from numerical weather forecast systems in global and regional scale in both of deterministic and ensemble prediction approachs have been widely used in daily operations. There are a lot of applied research and development of rain forecast technologies for the central region of Viet Nam has been carried out in the past 10 years (Cuong et al., 2008; Hang and Xin, 2007; Hoa, 2016; Hoa et al., 2002, 2007; Tang et al., 2017). The research results have shown that the rain forecast problem in the Central region, especially the heavy rain forecast, is still challenging and requires more technological breakthroughs for quality to improve heavy rain forecast and meet social requirements.

In order to improve the weather prediction skill in Viet Nam from short to seasonal scale, the products and dataset of global intergrated forecast system (IFS) of European Centre for Medium range Weather Forecast (ECMWF) had been purchasing and using in daily operations at Viet Nam weather forecast offices from national

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to provincal level. However, the verification of forecast quilaty of IFS model has been carried out for medium, monthly and seasonal range (Tang et al., 2014; Hoa, 2016). In fact, the short range forecast products of IFS model has been widely using in daily rainfall forecast operations in all weather forecast offices. Hence, the verfification of rainfall forecast of IFS model is really necessary and important.

The paper present the results of verfification of short range heavy rainfall forecast (1-5 days ahead) of IFS model for the middle central region of Viet Nam basing on the 59 heavy rainfall events during 2011-2018 rainfall season. The following sections will present the dataset and verification method. The verification results will be deeply analyzied in 3rd section. Final is some conclusions and remarks.

2. Data and methodology

2.1. Rainfall foreacst verification method

In order to verify the heavy rainfall forecast quality of IFS model, the vefication space at observation station is chosen basing on as the following:

- Preserving the observed rainfall value and keep the data truthful

- The rainfall value at the grid node is essentially the rainfall value of the atmospheric column with size equal to the resolution of the model and the mesh node is centered. Hence, taking the forecasted rain value at the grid node to assign it to the point in the grid with the grid node as the center does not change the forecast value of the model.

The neareast point interpolation method is used in order to take rainfall forecast from model grid points to observation station. According to this method, from the position of the interpolation point, the algorithm will calculate the distance of the nearest model grid point and use the value at this grid point to assign the interpolation point (see Figure 1). To limit the effects of the gradient smoothing effect along the coast, land/sea masks are used to determine whether the selected mesh nodes are land or sea. Using the wrong mesh node to interpolate (especially in the nearest interpolation method) can lead to large errors. For example, if the station point is on land, while the nearest grid point is on the sea, it may cause errors in rain forecast because the characteristics of rain on land are different from that at sea due to the different thermal, moisture and physical characteristics.

This research used the 24hrs accumlated rainfall amount (here after is R24) to verify for forecast range at 24hrs (daily rainfall of 1st day), 48hrs (daily rainfall of 2nd day), 72hrs (daily rainfall of 3th day), 96hrs (daily rainfall of 4th day) and 120hrs (daily rainfall of 5th day). Although the object of the study is heavy rainfall, in order to evaluate the overall rain forecasting skills, in the following assessments we will use four threshold to verify rainfall phase forecast skill including: light rainfall event (0.1mm/24hrs $< R24 \leq$ 15mm/24hrs), moderate rainfall event (16mm/24hrs $< R24 \leq$50mm/24hrs), heavy rainfall event (51mm/24hrs $< R24 \leq$ 100mm/24hrs) and extreme heavy rainfall event ($R24 >$ 100mm/24h). The rainfall phase forecast verification indices is ultilizaed including frequence bias (BIAS), probability of detection/hit rate (POD), false alarm ratio (FAR) and equitable threat score/Gilbert skill score (ETS). For quantitative precipitation forecast skill verification purpose, we uses 4 indices including mean error (ME), mean absolute error (MAE), root mean square error (RSME) and correlation (R). The more detail about these verfication indices can see in Wilks (2006). The indices is calculated for hole verification area by using all dataset from all of give stations (aggregate data of all stations into a unique series of evaluation data).

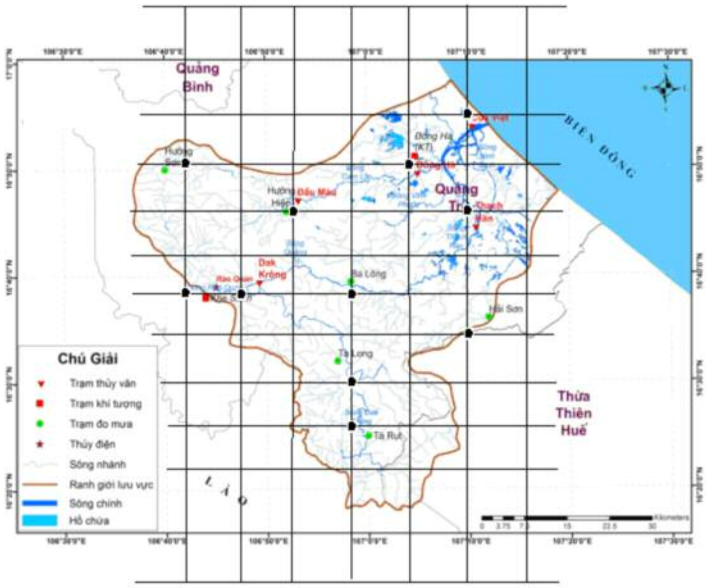

Fig. 1. The demontrative scheme of neareast point interpolation method

2.2. Verification dataset

The observed 24hrs accumulated rainfall data at 75 automatic rain gauges is collected during the days of 59 heavy rainfall events during 2011-2018 rainfall seasons. The spatial distribution of used 74 automatic rain gauges is shown in Fig. 2 and the some spatial characteristics is given out in Table 1. The rain forecast data from the IFS model with a resolution of 0.125 degrees x 0.125 degrees (approximately 14km) was collected as GRIB2 code files. The predicted rainfall amount of IFS model is accumulation of rainfall every 6 hours and provided up to 5-day forecast ahead. The rain forecast data from IFS model at 00GMT analysis time (7am local time) is used. To ensure that there is enough sample size for long-term forecasting periods (4-5 days), we taken rain forecast data started from three to four days prior to the onset of heavy rainfall (the rainfall forecasts started from 12GMT are not used because the forecasting quality at this analysis time is not as good as the time of 00GMT and it is difficult to match the forecasted rainfall to observed 24hrs accumulated rainfall (usually taken from 00GMT of previous day to 00GMT of the next day).

Table 2 gives out the number of heavy rainfall events for each of year in 2011-2018 period. In each of heavy rainfall event, the criteria of day that satisfy heavy rainfall threshold is at least 2/3 of rain gauge station in given area in which has observed 24hrs rainfall amount is greater than 50mm. In 59 given heavy rainfall events, the longgest heavy rainfall events is last in 8 days. In everage, heavy rainfall events in 2011-2018 period is last 3-4 days. Table 2 presents the number of heavy rainfall events for each of year. The 2015 and 2017 respectively are the year has smallest and largest number of heavy rainfall is used to verify

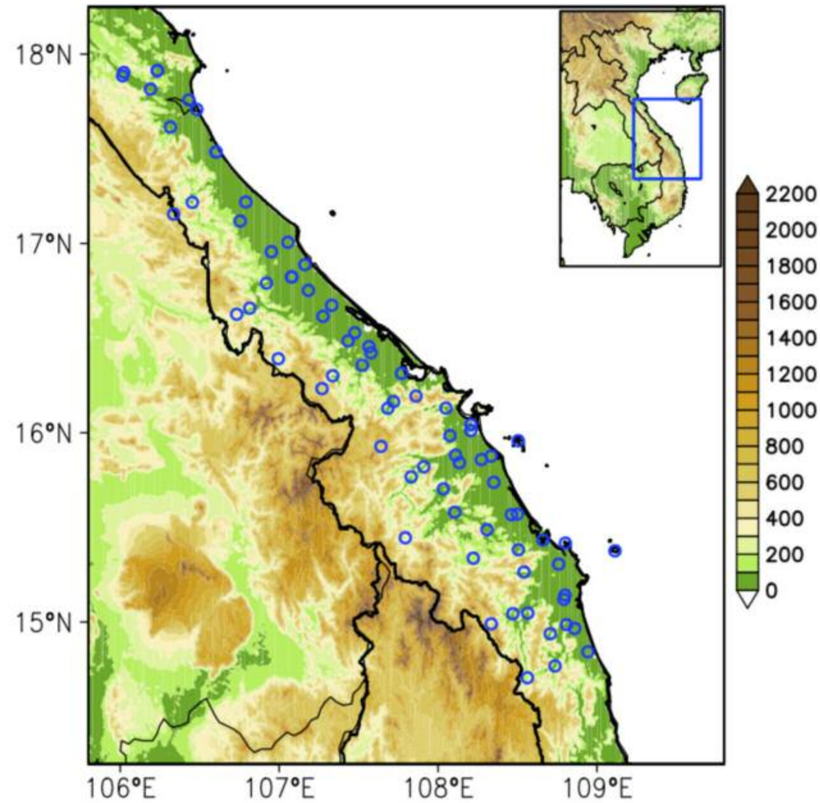

Fig. 2. The spatial distribution of used 74 automatic rain gauges in the the middle central region of Viet Nam

Table 1. The spatial characteristics of 75 automatic rain gauge network in the middle central region of Viet Nam

No.	Province name	Area Size (km^2)	Number of rain gauge station	Ratio of area size/station (km^2)	Average distance between stations (km)
1	Da Nang	1285	4	321.25	17.92
2	Quang Binh	8065	13	620.38	24.91
3	Quang Nam	10438	19	549.37	23.44
4	Quang Ngai	5153	15	343.53	18.53
5	Quang Tri	4740	12	395.00	19.87
6	Thua Thien Hue	5033	12	419.42	20.48

Table 2. The number of heavy rainfall event for each of year in 2011-2018 period is used to verify heavy rainfall phase forecast skill

Year	2011	2012	2013	2014	2015	2016	2017	2018
Number of heavy rainfall event	7	8	8	7	5	7	9	8

3. Verification results

The results of calculation of ME, MAE, RMSE and R index is respectively given out in Table 1 to Table 4. In verification period, the rainfall forecast of IFS model is usually over-estimated at light and moderate rainfall threshold and under-estimated at heavy and extreme heavy rainfall threshold. For MAE and RMSE index, the longer the forecast range, the larger the forecast error magnitude, and the longer the forecast range, the more correlation decreases. These results is found when considering the relation between verification indices and rainfall threshold. That is, at a given forecast range, the larger the rainfall amount, the larger the forecast error magnitude. Basing on MAE and RMSE index, it can be found that the error in rainfall forecast of IFS model is more stable because the different between MAE and RMSE index is not large. It means that there was no extreme large error in all cases of given verification dataset. The predicted rainfall amount from IFS model is quite well correlated with observed rainfall at 24hrs, 48hrs and 72hrs forecast range and at light, moderate and heavy rainfall threshold (Table 6).

For the rainfall phase forecast skill, the verification results is given out in Tables 7 to 10 shown out at light and moderate rainfall thresholds, the IFS model has overforecast tendency (frequency of forecasting occurred events is greater than observed frequency). In contrast, the underforecast tendency is found at heavy and extreme heavy rainfall thresholds (Table 7). The IFS model has good ability in detecting light, moderate and heavy rainfall event at 24hrs, 48hrs and 72hrs forecast ranges (POD is about 0.5 to 0.7). However, ability of correct detection of occurred rainfall events at extreme heavy rainfall threshold is not good (see Table 8). The similar result is found when analyzing POD index at heavy rainfall threshold and 96hrs and 120hrs forecast range. In spite of having good occurred rainfall event detection ability at short-range forecast range and some rainfall thresholds, IFS model also has quite large false alarm ratio at light and moderate rainfall thresholds (see table 9). However, at heavy and extreme heavy rainfall thresholds, the FAR is near rezo. Finally, the overall rainfall phase forecast skill of IFS model is quite good for light and moderate rainfall threshold at all forecast range and for heavy rainfall threshold at 24hrs, 48hrs and 72hrs forecast ranges (see table 10). At extreme heavy rainfall threshold, the ETS is eventhough near rezo or negative value at 72hrs, 96hrs and 120hrs leadtime. It means that there is no forecast skill at given forecast ranges.

Beside of above-mentioned verication results for quantitative rainfall forecast and rainfall phase forecast of some given thresholds, we had also verified the rainfall forecast skill of IFS model according to weather patterns that caused 59 heavy rainfall events during 2011-2018 rainfall seasons. The analysis of weather patterns that caused heavy rainfall events in the middle central region during 2011-2018 period shown out that there were some key weather patterns as following:

- The alone direct or indirect influence of tropical cyclone including tropical deppresion and tropical storm;
- The alone activity of cold surge;
- The alone activity of Intertropical Convergence Zone (ITCZ);
- The alone strong activity of east wind field;
- The combination of at least 2 weather pattern is mentioned above.

The verification results based on above-mentioned indices shown out that the IFS model has better predictability when heavy rainfall event caused by cold surge or ITCZ. For heavy rainfall event caused by tropical cyclone, rainfall forecast of IFS model is usually wrong in rainfall area and under-estimated in quantitative precipitation forecast. The predictability of IFS model in case of strong activity of east wind field or combination of at least 2 above mentioned weather patterns is worse than these other. If comparison of heavy rainfall forecast skill for cases of combination of at least 2 weather patterns, then the IFS model has best predictability in case of heavy rainfall event caused by the combination of tropical cyclone with cold surge. The heavy rainfall predictability of IFS model is worst in case of alone strong activity of east wind field. The reason for results like this may be due to limitations in the physical parameterization schemes of the IFS model or can derived from the horizontal resolution that not enough high to capture all sub-grid scale physical processes.

Table 3. The ME index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	5.5	8.9	16.2	20.1	30.5
Moderate rain	6.2	11.5	19.3	25.4	31.2
Heavy rain	-8.2	-15.6	-22.5	-29.5	-35.6
Extreme heavy rain	-17.2	-28.3	-35.8	-42.6	-65.4

Table 4. The MAE index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	5.8	10.5	18.3	24.6	34.5
Moderate rain	9.3	15.4	25.4	32.6	40.5
Heavy rain	12.2	25.4	32.1	49.5	55.6
Extreme heavy rain	19.1	28.3	45.8	52.2	70.2

Table 5. The RMSE index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	6.2	8.9	16.2	20.1	30.5
Moderate rain	10.2	16.5	27.3	33.4	41.8
Heavy rain	15.5	28.3	35.6	52.1	58.3
Extreme heavy rain	20.3	30.1	46.7	55.8	75.4

Table 6. The R index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.75	0.60	0.41	0.35	0.27
Moderate rain	0.68	0.58	0.39	0.32	0.22
Heavy rain	0.62	0.56	0.35	0.30	0.20
Extreme heavy rain	0.45	0.38	0.19	-0.05	-0.15

Table 7. The BIAS index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.35	0.30	0.26	0.2	0.18
Moderate rain	0.28	0.25	0.18	0.12	0.10
Heavy rain	0.13	0.10	0.06	0.01	0.01
Extreme heavy rain	0.08	0.00	0.00	-0.12	-0.18

Table 8. The POD index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.85	0.72	0.63	0.56	0.45
Moderate rain	0.72	0.63	0.58	0.49	0.43
Heavy rain	0.55	0.52	0.43	0.35	0.30
Extreme heavy rain	0.41	0.36	0.30	0.22	0.18

Table 9. The FAR index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.71	0.65	0.54	0.46	0.41
Moderate rain	0.62	0.55	0.43	0.38	0.33
Heavy rain	0.15	0.10	0.10	0.00	0.00
Extreme heavy rain	0.00	0.00	0.00	0.00	0.00

Table 10. The FAR index for verification based on 59 heavy rainfall event in the middle central region of Viet Nam during 2011-2018 period

Rain type/Leadtime	1st day (+24hrs)	2nd day (+48hrs)	4th day (+96hrs)	4th day (+96hrs)	5th day (+120hrs)
Ligh rain	0.35	0.30	0.26	0.2	0.18
Moderate rain	0.28	0.25	0.18	0.12	0.10
Heavy rain	0.13	0.10	0.06	0.01	0.01
Extreme heavy rain	0.08	0.00	0.00	-0.12	-0.18

4. Conclusions

The rainfall forecast from global intergrated forecast system (IFS) of European Centre for Medium range Weather Forecast (ECMWF) had been using in daily operations at Viet Nam for weather prediction from short to seasonal range forecast since 2011. However, there was a little verification research that was done in order to show out the heavy rainfall forecast skill of IFS model in Viet Nam region. The paper was carried out verification of heavy rainfall forecast of IFS model by using the dataset of 75 automatic rain gauges is collected during the days of 59 heavy rainfall events of 2011-2018 rainfall seasons. The verification results based on ME, MAE, RMSE, R, BIAS, POD, FAR and ETS indices shown that the heavy rain forecast of IFS has good skill in forecast range of 1-3 days ahead. For larger leadtime, the predictability of IFS is not good, eventhough is negative skill. In addition, rainfall forecast of IFS model is overestimated at small and medium rainfall thresholds and under-estimated in large and extreme large rainfall thresholds in quantitative precipitation forecast aspect. For rainfall phase forecast, IFS model is overforecast in light and moderate rainfall thresholds (frequency of forecasting occurred events is greater than observed frequency) and under-forecast in heavy and extreme heavy rainfall thresholds. The extreme rainfall forecast predictability of IFS model is good in some heavy rainfall events that caused by large-scale weather patterns. In order to have more detail view of heavy rainfall forecast of IFS model, it should be needed to verify with larger sample size. In addition, the assessment should be continued using other methods to provide additional results of forecasting quality accroding to spatial and temporal aspects.

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Research Paper

ASSESSMENT OF URBAN FLOODING IN YEN HOA - HOA BANG AREA, CAU GIAY, HANOI

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ARTICLE HISTORY

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ABSTRACT

Hoa Bang street is known as one of flooding hot spots in Hanoi with 30 inundated times during last 4 years. In 2019, a new conduit has been set up to drain the water from Hoa Bang street to To Lich River. However, the flooding situation has not been significant improved. Therefore, it is necessary to evaluate the capacity of the drainage systems as well as effectiveness of flooding mitigation measures. In this research, the numerical model MIKE URBAN is used to simulate the rainfall-runoff, routing and surcharge processes in Yen Hoa - Hoa Bang areas. Water depth and flood durations are indicators to assess the performance of the proposed solutions. The result of this research indicates that the renovation of the drainage system, i.e. enlargement in conduits' diameter, can reduce inundation time significantly.

Keywords: *MIKE FLOOD, MIKE URBAN, urban flooding, drainage system.*

1. Introduction

In recent years, in big cities of Vietnam as well as in Hanoi, the population has been growing rapidly and the speed of urbanization have resulted in natural land's contraction and the spread of concretized land. The fact that many rivers and lakes have been filled, canals have been encroached, and high-rise buildings have been built closely to replace vacant land reduces the area of natural drainage as well as the permeability and the time of overland flow on the surface. It can be seen that, the urban drainage system of Hanoi is old and not designed to keep up with urban planning of the City. At the same time, the projects to renovate the drainage system in the inner-city area are still slow due to many reasons. Combined with heavy rains caused by climate change, Hanoi has continuously faced with large-scale floods in recent years, which greatly affected socio-economic activities, especially in the inner-city area. Historical rains occurred in late October and early November 2008 with a total rainfall common from 350 to 550 mm, causing serious inundation throughout Hanoi, many flooded spots appeared. length of 100-300 meters, depth of less than 1m, causing economic losses of up to 3,000 billion. Hoa Bang street is known as one of flooding hot spots in Hanoi. There are 9, 7, 3 11 flooding events with total flooding time of 1062, 1669, 884, 2188 minutes corresponding to year 2016, 2017, 2018 and 2019. The water depth varies from 0.1 to 0.4 m.

In recent decades, mathematical models have been increasingly applied to urban flood simulation problems. These include 1D sewer model approach, e.g. SWMM (Rossman, 2010), HydroPlaner (Fareed, 2013), or coupled with 1D sewer model with 2D surface flow models, e.g.

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SOBEK 1D/2D (Deltares Delft Hydraulics, 2019), InfoWorks ICM (Innovyze 2019). According Leandro (2009), overflow is better modeled by 2D models, whereas 1D models provide a good approximation flow in pipe. Pham et al. (2015) applied MIKE URBAN to simulate the inundation in 8 inner districts of Hanoi. In their research, only main drainage routs were conducted in the networks. This means the drainage capacity of the tributaries were not considered. In this research, the coupled with 1D sewer model with 2D surface flow model has been performed for Yen Hoa - Hoa Bang area with a detailed drainage system (Fig. 1).

Yen Hoa - Hoa Bang area is located in territory of Cau Giay district. The case study covers an area of 40.47 ha. This is one of the lowest areas in Hanoi but the topography is complex with the altitude from 4.4 m to 7.8 m. The heavy rains appear frequently in the summer with maximum hourly precipitation varying from 31.9 mm to 114.9 mm. The main drainage routs are located along Hoa Bang, Yen Hoa, alley 381 of Nguyen Khang street, the Nguyen Khang street from Cot bridge to Yen Hoa bridge. The drainage systems discharge flow to To Lich river at 2 outlets.

Fig. 1. Map of the study area

2. Materials and Methods

The research was implemented in 3 main steps (Fig. 2).

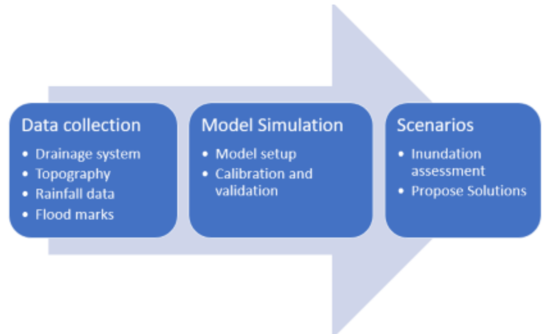

Fig. 2. The scheme of research implementation

2.1 Data collection

The collected data includes meteorological data, inundated depth and drainage system information. 10 minute rainfall data of heavy rains since June to September of 2019 at Cau Giay rain gauge were assembled. During this period, the study area were most suffered from the 2 heavy rainfall events at the end of April and early August 2019. Therefore, these 2 rainfall events were selected for calibration and validation correspondingly. Besides the meteorological data, the information on the drainage system updated to August 2019 were collected. This information includes locations of water collection stations, sewer diameter, manhole diameter, surface elevation, elevation of manhole bottom, slope slope ... Moreover, the 1/10000 scale topo data of the area has also been collected. In order to conduct validation process, flood marks corresponding to the above flood events were also studied and collected.

2.2 Description of MIKE FLOOD model

To conduct the simulations, MIKE FLOOD model was used for calculation. In this model, MIKE URBAN and MIKE 2D FM are linked together. MIKE URBAN model works based on a link of hydrological models and hydraulic models (DHI 2014c). The model structure can be described as Fig. 3.

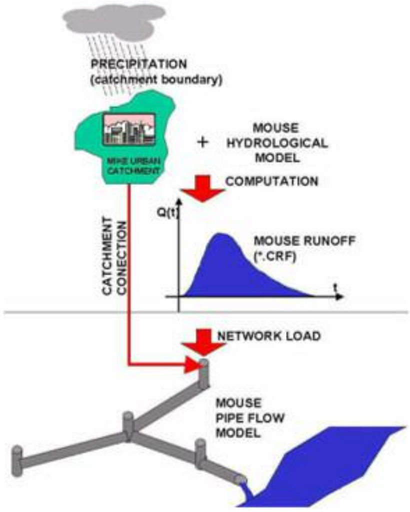

Fig. 3. The structure of MIKE URBAN

In this study, the calculated area was divided into 414 sub-basins. In each of these sub-basins, the Time-Area (T-A) method was used to convert the precipitation that falls on the sub-basin into the flow which discharges into the culverts (DHI, 2014a, 2014b). The hydraulic module routs flow in the sewer system by solving Saint Venant equations (Eq. 1, Eq. 2).

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=q_{lat} \quad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{\alpha Q^2}{A}\right)+gA\left(\frac{\partial h}{\partial x}-S_o\right)+g\frac{AQ|Q|}{K^2}=0 \quad (2)$$

These two equations are applied for free surface flow. For the pressurised flow, the fictitious slot is introduced and the continuous equation Eq. 1 can be written as Eq. 3.

$$\frac{\partial Q}{\partial x}+\frac{Q}{\rho}\cdot\frac{\partial \rho}{\partial x}+\frac{\partial A}{\partial t}+\frac{A}{\rho}\cdot\frac{\partial \rho}{\partial t}=0 \quad (3)$$

2.3 Setup model

In the study area, a network of 461 sluices are simulated for the three main streets of Hoa Bang, Yen Hoa and a part of Nguyen Khang street. In addition, some main lane routes are also modeled. Roughness coefficients of sewer system are taken according to the instructions in TCVN 7957: 2008 (VIWASE, 2008). The water in the system is discharged to the To Lich river through 2 outlets. The drainage network of the area is shown in Fig. 4.

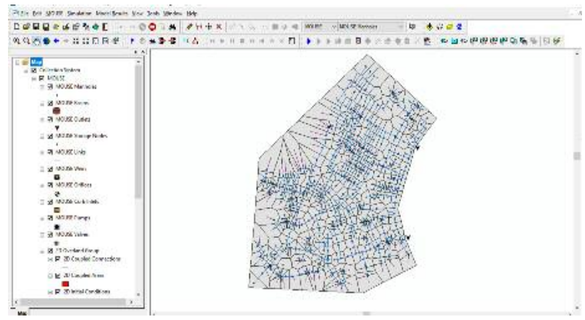

Fig. 4. MIKE URBAN model for research area

MIKE URBAN is combined with MIKE 2D FM to account for flooding when the drainage capacity of the system does not meet the runoff from in the catchments. The mesh of this 2D model was constructed from detailed grid cells with an area of 1 to 5 m2. MIKE URBAN and MIKE 2D FM are connected at the manholes. The water level at the manholes is calculated at each time and compared with the water level in the 2D grid at that location. If there is a water level difference, the water exchange between the two models will be performed.

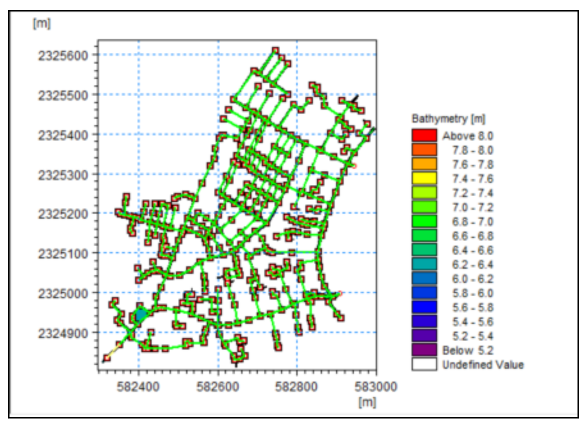

Fig. 5. MIKE FLOOD model for research area

The data collected for the rain since April 29th, 2019 to April 30th, 2019 was used for calibration and the data since August 1st, 2019 to August 4th, 2019 was used for validation. The simulation results were compared with observed inundated depths to ensure the accuracy of the model.

After calibration and validation, the model will be used to simulate the design rains. Besides, a flood mitigation measure was proposed. The calculation scenarios are shown in detail as Table 1.

Table 1. The scenarios

ID	Description
KB 01	Simulate the rain of April 29th, 2019 to April 30th, 2019 to adjust the model
KB 02	Simulate the rain of August 1st, 2019 to August 4th, 2019 to test the model
KB 03	Simulation of design storm with current condition
KB 04	Simulation of design storm with expanded conduits' diameter in Hoa Bang street

3. Results and discussions

Tables 2 and 3 shows that the calculation results are quite consistent with the reality at some typical flooding points in both calibration and validation.

It was found that the flooding in the study area is still severe with the current drainage system condition. Especially, the storm event since August 1st, 2019 to August 4th, 2019 affected by typhoon No. 3 with heavy rain on August 3rd and August 4th, 2019 made Hoa Bang area was inundated for a long time. Especially the water depth at alley 90, Hoa Bang street was 0.35m, Lane 35 was 0.23m. Some specific points such as 90 Hoa Bang flooded 0.35m and 35 Hoa Bang flooded 0.29m. there is no flooding in some areas such as Nguyen Khang and Yen Hoa streets because the sewers in these areas have sluices' diameter from 0.8m to 1m. Additionally, these areas are closed to To Lich River so the amount rainwater quickly drains into the river. The cause of inundation at Hoa Bang street can be caused by two main reasons. First, heavy rains occurred, the drainage capacity of the existing sewer system could not address. Especially Hoa Bang street, when the drain diameter of the main line is only 0.6m. The second, the concave terrain of this area is also a major factor causing flooding in the area. Figure 8 describes the longitude profile along the Hoa Bang route. Looking at the figure, it is noticed that the topography of Hoa Bang Street in the middle creates favorable conditions for forming local flooding spots. Overflow is unable to drain into the river but stays and waits for flow through the public system. Therefore, reducing the depth of flooding in this area is very difficult to overcome. However, it is possible to reduce the flooding time by increasing the likelihood of drainage through the sewer system.

Table 2. The observation and calculation depth in calibration process (m)

Location	D obs.	D cal.
No 35 Hoa Bang	0.4	0.31
No 90 Hoa Bằng	0.4	0.38
Alley 35 Hoa Bang	0.3	0.22
Alley 90 Hoa Bang	0.5	0.41

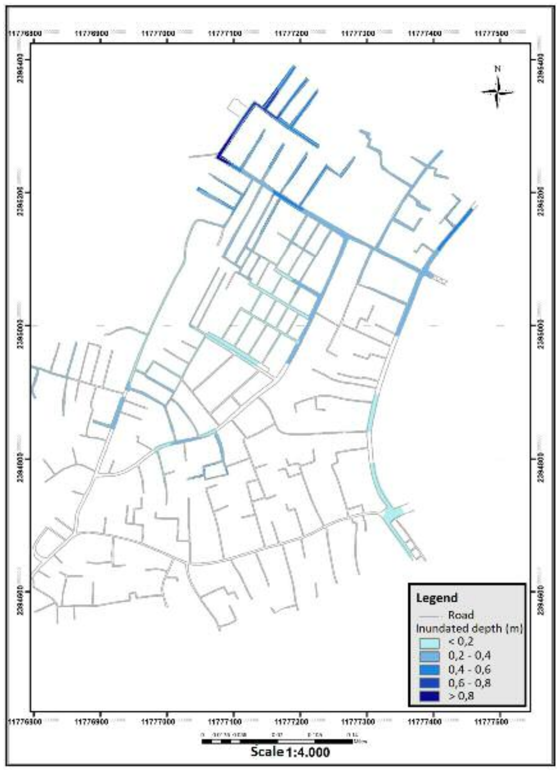

Fig. 6. Flood area for storm event in 29/04-30/04

Table 3. The observation and calculation depth in validation process (m)

Location	D obs.	D cal.
No 35 Hoa Bang	0.4	0.31
No 90 Hoa Bang	0.4	0.38
Alley 35 Hoa Bang	0.3	0.22
Alley 90 Hoa Bang	0.5	0.41

Based on the analysis, the study proposes mitigated solution. According to decision 725/QĐ-TTg (Prime Minister 2014), Hanoi urban area must respond to design rain with a frequency of

10%. In this study, two scenarios were simulated. In the first scenario (KB03), the inundation situation was calculated based on the current condition of the area. In the second scenario (KB04), the size of some sewers in the flooded area was expanded to increase their drainage capacity. Specifically, the drainage routes at Hoa Bang street were increased from 0.6m to 0.8m. This value is selected so that the diameter of the conduits in the Hoa Bang area is homogeneous with surrounding system. The simulated results are shown in the Tables 4 and 5.

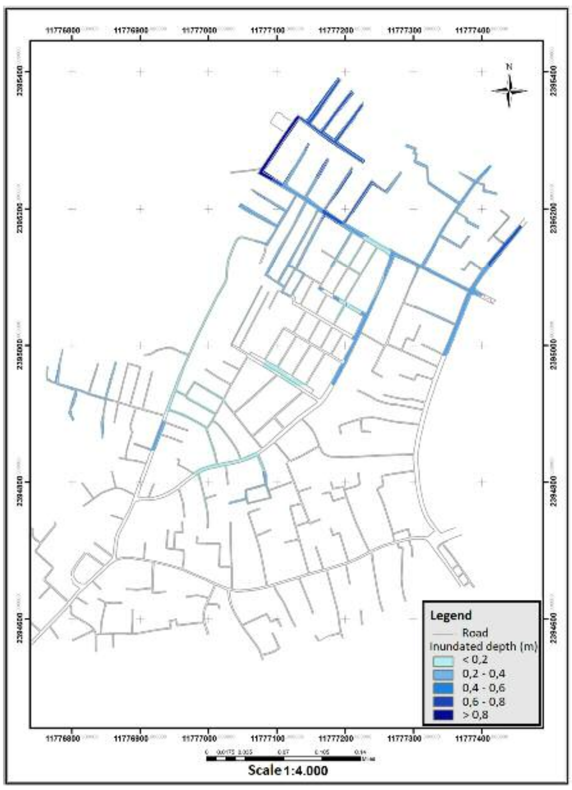

Fig. 7. Flood area for storm event in 01/08-04/08

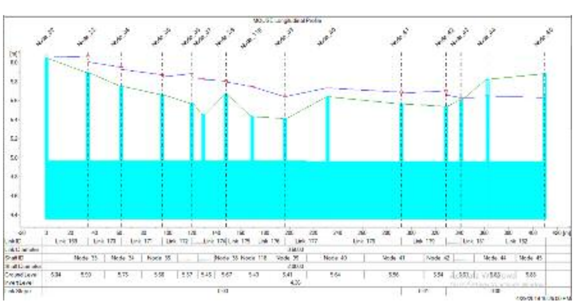

Fig. 8. Longitude profile of Hoa Bang street

Table 4. The flooding duration in scenarios (h)

Location	KB03	KB04	Δt
No 35 Hoa Bang	4.5	3.75	0.75
No 90 Hoa Bang	4.83	4	0.83
Alley 35 Hoa Bang	3.75	3.25	0.5
Alley 90 Hoa Bang	4.83	4	0.83

Table 5. The flooded depth in scenarios (m)

Location	KB03	KB04	Δh
No 35 Hoa Bang	0.82	0.77	0.05
No 90 Hoa Bang	0.89	0.8	0.09
Alley 35 Hoa Bang	0.7	0.6	0.1
Alley 90 Hoa Bang	0.9	0.8	0.1

The Tables 4 and 5 shows the flooding duration and flooded depth in scenarios and their differences. In this tables, we can see that, when the sewer size increases, the inundation depth is not reduced significantly (0.05 - 0.1m), but the flooding time is significantly decreased. This is also reasonable with the original judgment of the authors.

4. Conclusions

The research has developed a MIKE FLOOD model that simulates urban flooding for the study area. The model was calibrated and validated to ensure the reliability of the calculated results.

According to the research results, the current statement of the drainage system of the Hoa Bang route is not able to escape the heavy rainfall corresponding with frequency P = 10%. The solution introduced in the direction of increasing the size of the work shows that the time of inundation is reduced significantly. The inundation duration at heavy flooding points can be reduced from 30 to 50 minutes.

The study proposes only one traditional measure to indicate the application of the numerical model in urban drainage planning. In the coming time, more green solutions should be considered.

Acknowledgement

This research was supported by “Assessment of urban flood hazard in Hanoi under current and future climate conditions" project funded by VLIR-UOS (VN2019SIN267A101). We would also like to show our gratitude to the Ha Noi Sewage and Drainage limited company for sharing the data during this research.

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Research Paper

IDENTIFICATION OF RELEVANT METHOD FOR FLOOD EVENTS DESIGN AN APPROACH TO FLOOD HAZARD ASSESSMENT AT RIVER BASIN SCALE

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ARTICLE HISTORY

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ABSTRACT

Flood is one of the most dangerous natural disaster in Vietnam. Assessing flood hazard is a long term ambition of the society, especially in low-land cities where almost its communities expose to flood caused by heavy rainfall over its upstream river basin. In order to do that, designing flood events is one of the very first step. This paper evaluates some methods of flood design and give an advise for choosing relavant method in Vietnam which have been test in Vu Gia Thu Bon river basin. The procedure includes several steps: 1. Design a storm event which cause heavy rainfall over the basin; 2. Estimate the Arial Reduction Factor (ARF); 3. Estimate the flood peak; and 4. Design the flood events. The first step have been done by develop IDF curve over the basin; then several combination methods of Arial Reduction Fator and flood peak estimation have been applied and evaluated to choose the most relevant one with respect to literatural flood peak values. The result show that, USWB method for ARF identification in combination with Rational method for flood peak estimation give a very good result for flood hazard design.

Keywords: *Flood design, Vu Gia Thu Bon, Flood hazard, Flood risk.*

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1. Introduction

Flood is one of the most dangerous natural disaster in Vietnam (Assistance, 2018). Assessing flood hazard is a long term ambition of the society, especially in low-land cities where almost its communities expose to flood caused by heavy rainfall over its upstream basin. The very first step of hazard assessment is designing flood scenarios. In a literature, a design flood is a hypothetical flood (peak discharge or/and hydrograph depending on the purpose of each study) adopted as the basis in engineering design of a water resources system (Jain, 2003). The two most used-approaches for generating the design flood are flood frequency analysis (FFA) and rainfall - runoff analysis (RRA) (Daniel and Wright, 2016). The first one designs a flood via statistical analyses of the observed discharge data. This method is usually used to estimate peak discharge at a certain location during a flood design event. The second one designs a flood by estimating the runoff from design rainfall event which is induced by statistical analyses of observed rainfall data. This method is usually used to design the peak and hydrograph of an expected flood event.

For many developed countries like US or

western regions, they use FFA to estimate the design floods because they have densed discharge stations which cover almost represenative locations in their river basins (Survey, 2006; Hydrology, 1999; Hydrology, 2012; Engineers, 2001). However, in the developing country like Vietnam, where the observed data is usually not long enough for frequencies analysis, the FFA can cause a bias error. Infact, many authors found that the RRA is more reliable than the FFA when applied to the basin with fews observations (MCKerchar and Macky, 2001; Calver et al., 2009; Lee et al., 2011). That is why RRA is recommended to use in many regions in the world.

Vietnam have been issue some technical stardard on flood design for the purpose of engineering design at the site without data such as TCVN 9845:2013 on Calculation of flood flow characteristic which usually used to design transportation structures or TCVN 7957:2008 on Drainage and sewerage - External Networks and Facilities - Design Standard. The first one guides to estimate the flood peak based on the rain height of given frequencies and use a referent-historical-flood for scaling flood peak and defining the hydrogaph. The second guides to design IDF curve over the basin to estimate the rain height of certain frequency needed to be drained in urban area. Both cases give a difficult approach for analyzing the flood hazard at the large basin scale where the rainfall is spacially distrubuted. In Vietnam, the engineer usually choose a reference storm event which happened in the past and be scaled up to the relevant value of design frequency such as 10, 20, 50 or 100 year return periods based on the purpose of the studies. However as we all know, the storm is stochastic event which can not be happen twice in reality. In addition, in flood hazard analysis, the extreme flood is the one contributed by rainfall over the whole basin. This paper introduce a procedure for flood designing using RRA approach for supporting flood hazard assessment. This procedure will be tested on Vu Gia Thu Bon River basin.

2. Method

2.1 Description of study site

Vu Gia Thu Bon River basin is one of the four biggest basins in Vietnam. Base in the Central part of Vietnam and cover the part of Kon Tum, Da Nang and Quang Nam provice, its delta usually face to flood due to its special topography and geographic location (Fig. 1). It has the area of about 10,350 km2. Only approximately 15% its area is low land delta where collects all water from its upper basin when they cover by a storm. That is why the delta annually surffer to inundation and flooding which have been caused human lost and extreme damage in Da Nang and Quang Nam every year. Therefore the study of flood hazard is valuable for this region. However, the mornitoring sites and observed data in this basin are till scarce. There are only two discharge stations in the basin: Nong Son in Thu Bon river and Thanh My in Vu Gia river which are located in the upstream of the system (Fig. 2). Therefore, FFA is difficult application in the basin. This situation is being a case of almost river basins in Vietnam where the data is scarce and short. Hence, to analysis the flood hazard, we should use DRRA method and start from rainfall data instead of discharge data.

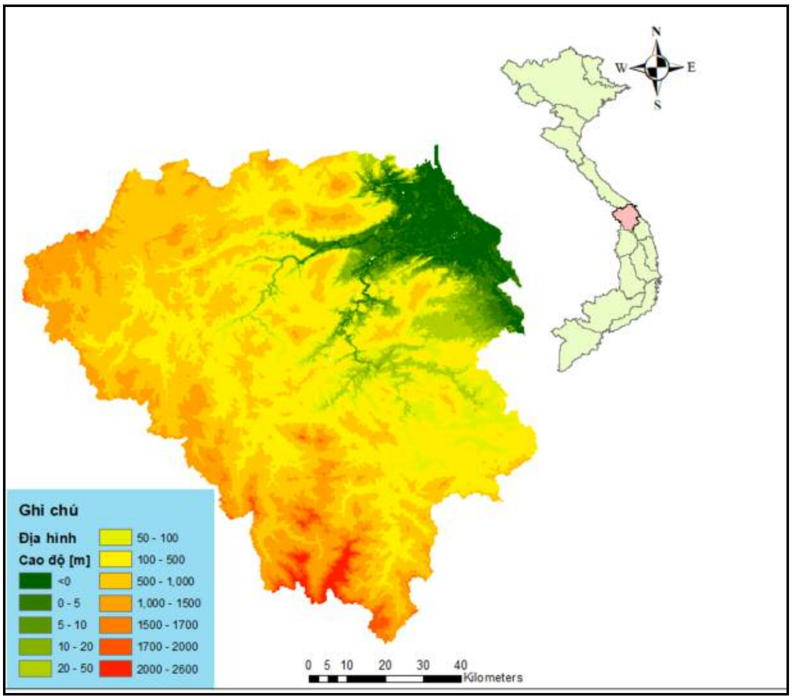

Fig. 1. Geographical location and topographic map of Vu Gia Thu Bon basin

2.2 Methodology

The methodology of flood design for flood hazard assessment at river basin scale is the RRA approach. Starting from rainfall analysis, the hourly data for 20 - 30 years should be collected and make the frequency analysis of the event with different durations from 10 mins upto 72 hours based on the time concentration of the sub-basin. The procedure is presented in Fig. 2.

Step 1: Design point rainfall

Current approach of analyzing the point rainfall at each station within and vincini the basin is using Itensity Duration Frequency curve (IDF) of rainfall data at gauged station. Each curve shows the intensity of rainfall during specific duration at a given frequency. In this study, the DDF curves were developed instead of IDF curve for rainfall design purpose, referring to the rain height instead of the rain intensity for easier use in following phases, as described by Eq. 1.

$$h = axt^n \qquad (1)$$

where h is the rainfall depth (mm) for the duration t; a, n are parameters to estimate from the data series; then i = h/t is the rainfall intensity. DDF curves are computed using this procedure for 10, 20, 50, 100 and 200 years return period for each available station in the basin area using the set of parameters a &n specified for each rain station.

Step 2: Design arial rainfall

After having point DDFs at each station, transformation of point rainfall to areal rainfall can be made by interpolating spatial the parameters of Depth-duration-frequency curves and applying an empirically-derived areal reduction factors (ARFs). Usually, the regionalized rainfall over the sub catchments can be estimated by some popular methods such as Thiessen polygon, gauged rainfall average, etc. In this study, to overcome the lack of measured data and make an homogeneous analysis for the whole basin, maps of regionalized DDF curves parameters (a&n)were developed, similarly to the method proposed in the paper of (Nhat et al., 2008) for ungauged areas.

For each sub-basin, rainfall critical height according to various RP (100, 50, 20, 10) is evaluated based on the DDF curves ($h=axt^n$), considering a duration t equal to concentration time t_c. An area reduction factor is applied to resulting height, considering USWB formula (from U.S. Weather Bureau with coefficients recalibrated by Benaglia (1997):

$$ARF(t, A) = 1 - \left(1 - e^{-0.01298.A}\right).e^{-0.6786.t^{0.332}} \quad (2)$$

This formular will be valid as the best performing concerning flood peak estimation.

Step 3: Design hyetographs

Design hydetographs are developed from design rainfall event which occur in the duration equal to concentration time of the basin. Concentration time can be estimated by some empirical formula, such as SCS formula or Giandotti formula, etc. These methods require some basin's characteristics defined from DEM and land use maps to extract the area, mean elevation, mean slope, hill slope sides of each sub basin, etc.

Step 4: Design hydrographs

By applying a conceptual rainfall-runoff model (rational model). According to this model, the hydrograph shape is triangular, with a central peak and a total time equal to double the concentration time of the sub-basin.

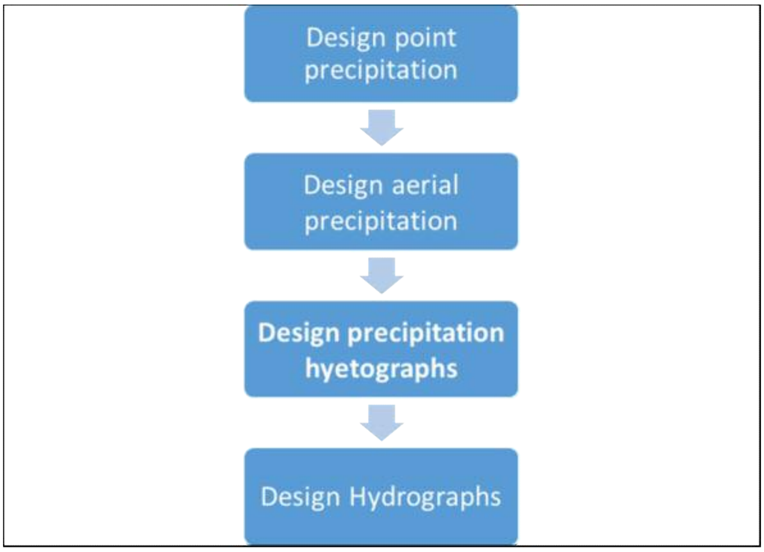

Fig. 2. Flood design procedure

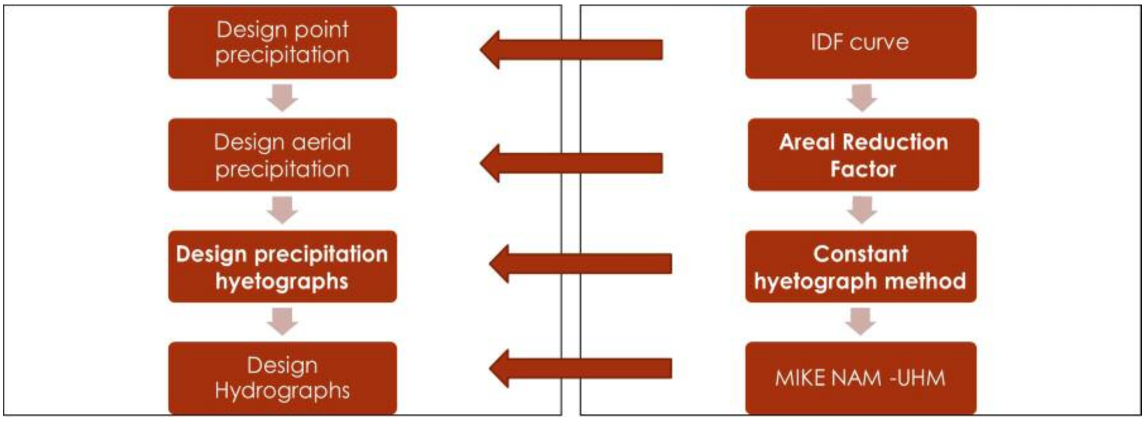

Fig. 3. Solution for each step of the design flood procedure

3. Results and discussion

Vu Gia-Thu Bon River basin is devided into 30 sub-catchments (Fig. 4) which can be analyzing as one unit of hydrograph of a flood event and concatinate each with the other to create the flow of whole system.

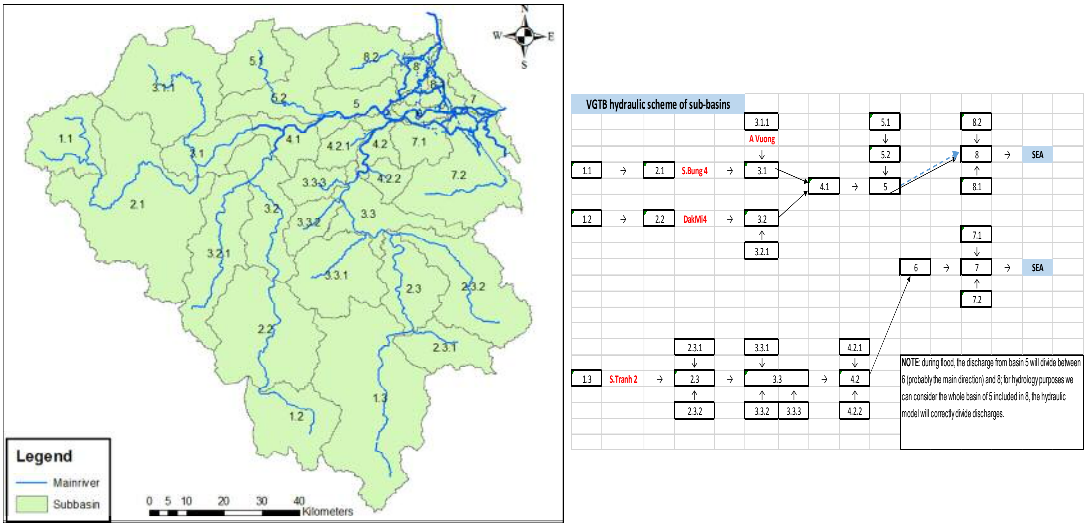

Fig. 4. Sub-basins defined in Vu Gia-Thu Bon River basin for flood analysis

Step 1: Design point rainfall: Designing heavy rainfall events at rain stations

Within the Vu Gia-Thu Bon basin, only observed data of discharge at the stations Nong Son on the Thu Bon river and Thanh My on the Vu Gia are available. Therefore, only two sub-basins are considered for hydrological models' calibration and validation and design flood peaks. Other sub-basins have to be estimated from rainfall. This is the reason why IDF curves of rainfall at all rainfall stations have been built to estimate the discharge peaks of flood events.

For homogeneous analysis, the flood peaks at Nong Son and Thanh My are also estimated based on the rainfall events extracted from IDF curve. A total of 15 rainfall stations within this basin is available, as shown in Fig. 5.

In this study, the DDF curves were developed for rainfall design purpose, referring to the rain height instead of the rain intensity for easier use in following phases, as described by Eq. 1.

DDF curves are computed using this procedure for 10, 20, 50, 100 and 200 years return period for each available station (Fig. 6) in the basin area using the set of parameters &n specified for each rain stations.

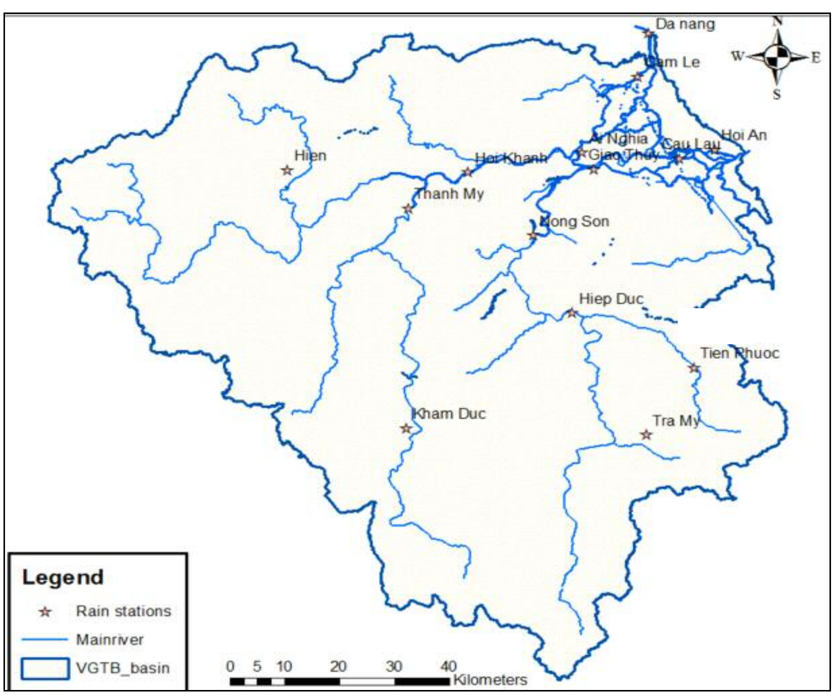

Fig. 5. Rainfall stations in Vu Gia-Thu Bon River basin

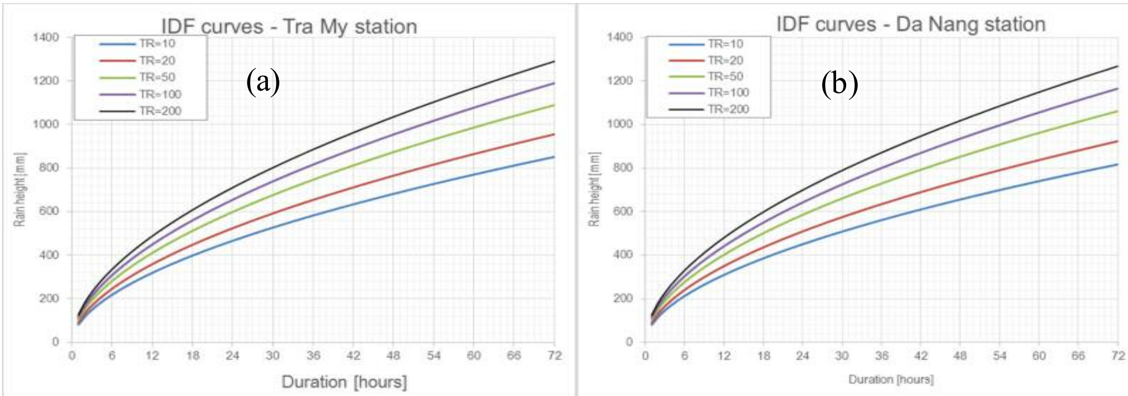

Fig. 6. DDF curves for Tra My (a) and Da Nang (b)

Step 2: Design arial rainfall: Estimating rainfall spatialization over each subbasin

Usually, the regionalized rainfall over the sub catchments can be estimated by some popular methods such as Thiessen polygon, gauged rainfall average, etc. In this study, to overcome the lack of measured data and make an homogeneous analysis for the whole basin, maps of regionalized DDF curves parameters (a&n)were developed, similarly to the method proposed in the paper of Nhat et al. (2006) for ungauged areas.

The validation was made with rain gauges additional to those used for DDF curves estimation. Fig. 7 presents an example of contour maps of a and n parameters under 10-year return period. Then the rainfall heights (Fig. 8) show a more regular and gradually varied distribution on the basin area, as the combination of a and n values tend to attenuate the steeper gradient that can be observed in some area from the contour maps. In any case, the absolute variations in a, n parameters and in obtained rainfall heights are not too relevant between considered gauging stations in the basin area, therefore the use of a regionalization procedure can provide good results.

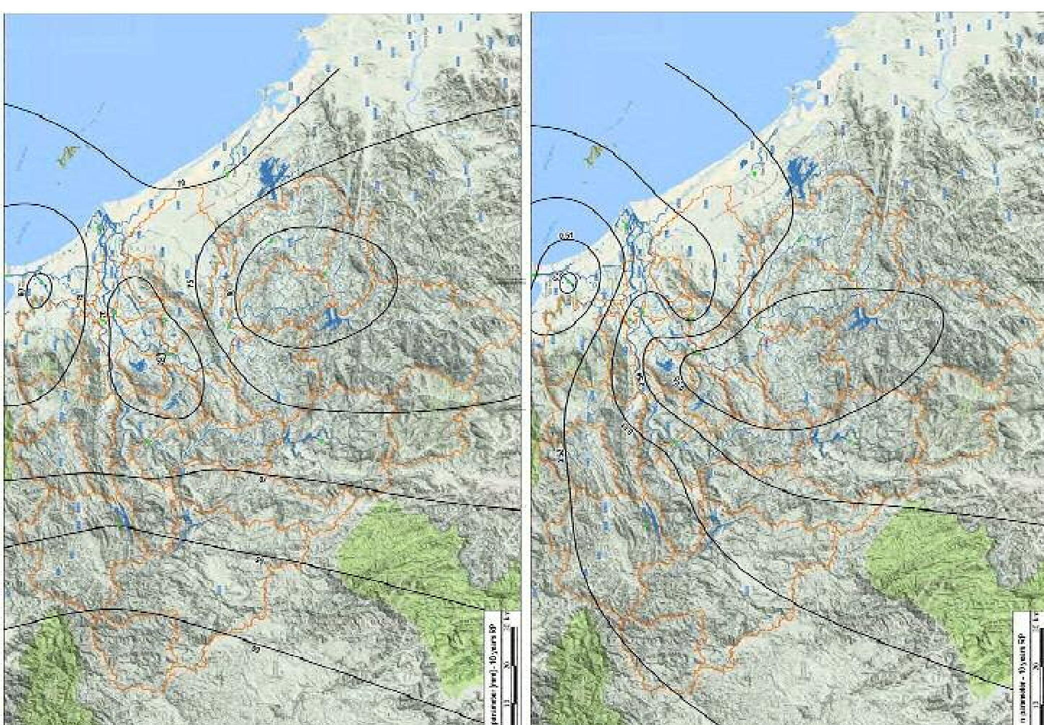

Fig. 7. Spatial values of “a” (left side) and “n” (right side) of 10 year RP

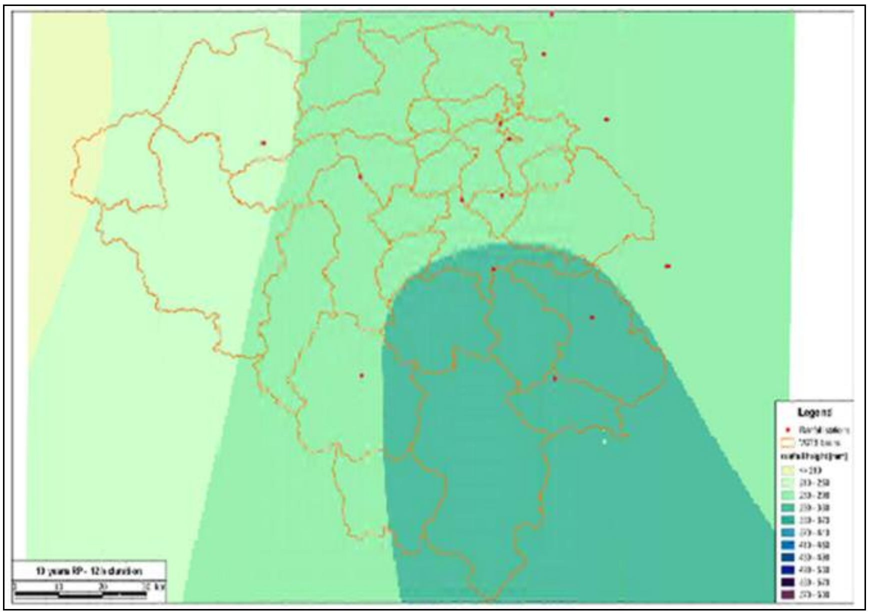

Fig. 8. Distribution of maximum rainfall height for a 12 hour duration and 10 year return period

Step 3: Design hyetographs: ARF values assigned for each sub-basin

For each sub-basin, rainfall critical height according to various RP (100, 50, 20, 10) is evaluated based on the DDF curves ($h=axt_n$), considering a duration t equal to concentration time tc. An area reduction factor is applied to resulting height, considering USWB formula.

Infact, other formulas were tested in pilot basin, as Wallingford formula and a formula cited by Mekong River Commission Secretariat, applied in Cambodia. The latter is the only ARF formula that is found developed in South East Asia, but it is meant for small basins, giving negative values for A > 2500 km^2. USWB formula was identified in pilot basin as the best performing concerning flood peak estimation.

Step 4: Design hydrograph: Flood peaks of relevant frequencies for each sub-basin

Flood peak discharge is computed using a simple rainfall-runoff model, as the rational method (or kinematic method). Thus the flood peak for a given RP will be computed as:

$$Q\left[m^3/s\right] = \frac{\phi.h.a}{3,6.t_c} \qquad (3)$$

where Φ is the runoff coefficient, h the rainfall height for given RP (reduced by ARF coefficient as stated above), the basin area and tc the basin concentration time.

For calibration analysis, maximum flood peaks associated to given frequencies were estimated from available observed discharge series in some gauging station (or official estimates made available from MONRE or previous studies). Hydraulic parameters (CN, runoff coefficients associated to different land use types) were calibrated to have a better representativeness in flood peak estimation from DDF curves.

Table 1. Best presentation of estimated flood peaks at Nong Son and Thanh My

Sub-basin	Estimated flood peak by Rational formula				
	Frequencies	10%	5%	2%	1%
Nong Son	Estimated values	9,201	10,375	11,893	13,032
	Frequencies analysis	9,600	10,860	12,410	13,520
	Different percentage	-4.16%	-4.47%	-4.16%	-3.61%
Thanh My	Estimated values	6,301	7,171	8,298	9,143
	Frequencies analysis	5,990	6,795	7,750	8,420
	Different percentage	5.19%	5.54%	7.08%	8.59%

Table 2. Comparision between statistic design water level and estimated ones at Hoi An (Thu Bon) and Cam Le (Vu Gia)

Station	River		$H_{max}P$ (cm)			
			1%	2%	5%	10%
Hoi An	Thu Bon	Estimate from stage discharge function	386	340	307	267
		Frequency analysis base on observed data	392	358	311	273
Cam Le	Vu Gia	Estimate from stage discharge function	484	422	331	276
		Frequency analysis base on observed data	506	440	355	292

Hydrograph of relevant frequencies for each sub-basin

According to flood peak estimation methodology, the schematic flood hydrograph is developed with an isosceles triangular shape, with a duration equal to the double of the concentration time. This can be smoothed using UHM module of MIKE software, i.e. with SCS model, with parameters calibrated to obtain the same flood peak resulting from previous described methodology. However, this passage is not necessary, as the two shapes are very similar, and considering that the triangular hydrograph will soon smoothen due to hydraulic propagation in the MIKE11 model. The triangular shape is easier to combine in order to define lateral contribution of downstream sub-basins, as described in following point. Hydrographs is defined for every RP (scenario) and every sub-basin with closing section within modeled branches (Fig. 9).

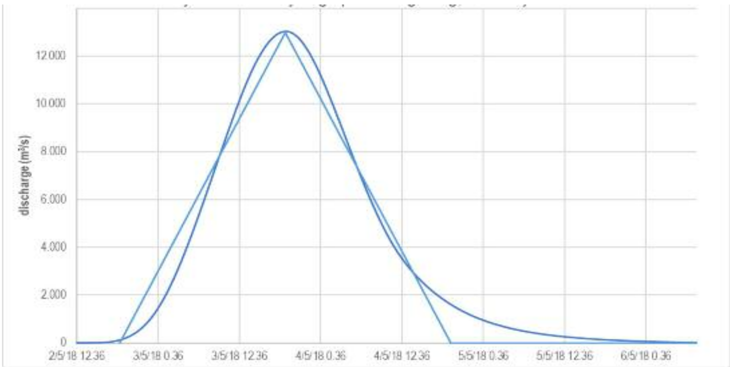

Fig. 9. Comparison between 2 hydrograph shapes: triangular and obtained with UHM - SCS model: an example for Nong Son with 10 year return period

4. Conclusion and Recommendation

The paper have intrduced the procedure on flood design to support flood risk assessment. The procedure have been successfully tested in Vu Gia Thu Bon River basin. The results are compare with references values of discharge at Nong Son and Thanh My and statistical values of water level at Cam Le and Cau Lau in the downstream of the basin. It means that this method can be applied widely for other river basin in Vietnam in the study of flood risk assessment.

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