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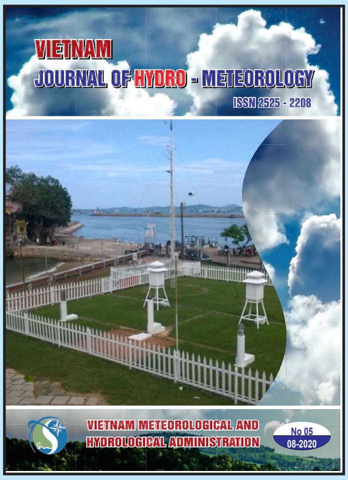

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Coastline changes detection from Sentinel–1 satellite imagery using spatial fuzzy clustering and interactive thresholding method in Phan Thiet, Binh Thuan

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Abstract: The coastline is an important component of coastal management studies. The coastline changes rapidly over time, therefore it is necessary to have methods of monitoring the shoreline quickly and continuously. In this study, Sentinel–1A satellite imagery is used to extract the coastline in Phan Thiet City. The boundary between land and water is determined by a two–step process: fuzzy clustering and interactive thresholding. Subsequently, the coastline in the study area was extracted into vector form. Finally, this shoreline is compared to manually digitized shoreline. There are 350 locations considered to determine the distance between two shorelines, of which 274 locations (77%) are 0 to 5 m (equivalent to ½ pixel) and 76 (23%) locations are over 5 m. In addition, the DSAS statistics has also provided a detailed view of the seasonal change of shoreline for two years (2016 and 2017). The study results showed that effective application capabilities of Sentinel–1A radar satellite image data to quickly assess the erosion/accretion of coastal areas.

Keywords: Shoreline extraction; Sentinel–1A; Fuzzy clustering; Interactive thresholding.

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1. Introduction

The shoreline is considered as one of the most dynamic linear features in the coastal [1] and it is simply defined as the physical interface between land and water [2]. The location of the shoreline changes continually through time under the influence of ocean elements (tides, waves, wind), coastal geomorphology contexts (erosion, accretion) as well as the human social and economic activities [3]. Therefore, researchers have used the term instantaneous shoreline to describe the position of the land–water interface in a certain time [4–5]. Determining shoreline change through time are required for application to in direction of sediment transport [6–8], monitoring coastal erosion/accretion [9–11] and management of coastal resources [12].

The shoreline position changes were obtained by collecting data and extracting shoreline information from ground surveying and aerial photography, but it is expensive and time–consuming methods [13–15]. Alternatively, the shorelines can be extracted directly through the analysis of satellite imagery data [16], including the use of multispectral/hyperspectral satellite images [17–21] and radar images [22–24]. The satellite image is being widely used in the detection of the coastline changes by setting a threshold for land and water separations which proved a cost–effective approach for the study of the coast. Based on the spectral reflectance of land and water, the optical images provide a simple way to extract shorelines. Unfortunately, those images are sensitive to weather conditions, especially in tropical marine climate areas. Radar interacts with the surface features in ways different from the optical radiation. Radar images receive the contrast of the dielectric properties and surface roughness to determine the boundary between land versus water [25–26]. Besides, the microwave energy radar is capable of penetrating cloud cover and sensing at night, so it is suitable for shoreline positions changes monitoring at short (monthly) intervals. In recent years, the shoreline indicators corresponding with reference to different tidal datums can be derived easily by light detection and range (LiDAR) data which are acquired at a low water level [27–28]. However, the created shoreline is often broken [29–30] and LiDAR is an expensive technique [31], therefore it is not suitable for continuous coastal monitoring with limited funding. In this research, the Sentinel–1 SAR (Synthetic Aperture Radar) satellite imagery data provided by European Space Agency (ESA) is used to extract shoreline information.

The interpretation of SAR images is difficult because of the presence of speckle noise and non–uniform signal characteristics [32]. In recent years, there are many studies involving the improvement of methods for extraction of coastlines from SAR data, such as edge detection and edge–tracing algorithm [33–35] setting threshold [36–38]; active contour model [39] clustering [40–43] or combining methods [43–45]. In particular, the clustering method is considered to be the removal of speckle noise from the satellite images [46].

Erteza extracted the shoreline automatically from SAR images based on the development of 3 algorithms [36]. Including, histogram equalization is used to accentuate the land/water boundary on pre–processing steps. The next step, a threshold is set to maximum filter to enhance the land–water boundary and produces a single–pixel–wide coastline. Finally, the contour tracing algorithm is applied to mark a single pixel wide as small islands. Modava presented an efficient approach to extracting coastlines from high–resolution SAR images [43]. The first, spatial fuzzy c–means clustering is applied to cluster pixel values into two classes of land and water. After that, reasonable threshold used to segment on the fuzzification results using Otsu's method and morphological filters are used to eliminate spurious segments on the binary image. Third, the active contour level set method was applied to refine the segmentation. Demir et al. proposed a fuzzy logic approach to classify the land and water pixels [47–48]. Pre–processing of SAR image is consisting of reducing radar noise and speckle by Lee filter using and terrain correction by the Shuttle Radar Topography Mission (SRTM) digital surface model. Then, the fuzzy clustering using mean standard deviation method is applied to classify the preprocessing result with calculated parameters. In the post–processing step, the morphological filter is applied to remove the zigzag effects of the detected shorelines.

In this present study, fuzzy membership functions are applied to assign fuzzy membership values to crisp values which has been successfully applied in the SAR image analysis by Demir et al [47–48]. The next method used in the shoreline extraction process is the application of an appropriate threshold for segmenting the image. From the result of determining the boundary between land and water, the data is converted to vector. The Digital Shoreline Analysis System (DSAS) used to calculate differences in the shoreline rates, which are extracted from the fuzzy clustering–interactive thresholding method and manually digitized method. Finally, a short analysis is used to compare the differences in the shoreline between two seasons of the year.

2. Materials and Methods

2.1. Study Area

A portion of Binh Thuan Province coast was selected as the study area, which its length is approximately 90 kilometers. Located in the Southeast Region of Vietnam, its geographical coordinate has the range of the longitude (105°48'33"E–107°35'58"E) and latitude (10°19'13"N–12°17'54") in Figure 1.

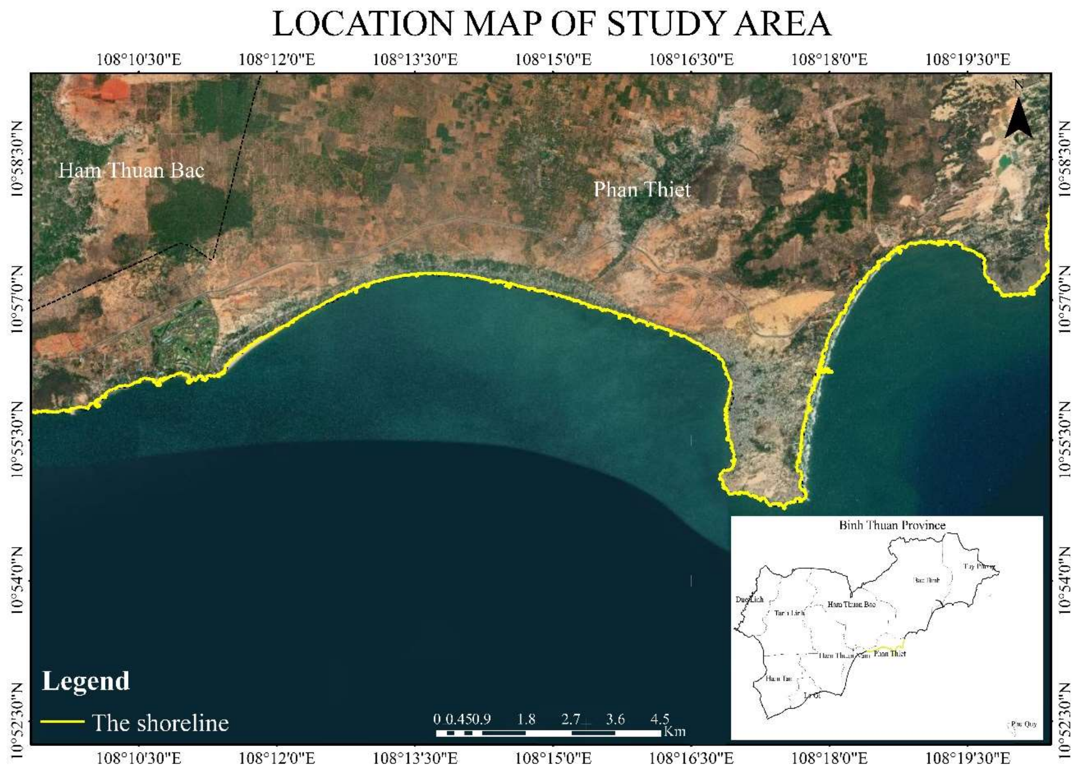


Figure 1. Map of the study area.

The study area province is located in in the tropical monsoon region, with two main wind directions: Northeast (from November to April) and Southwest (from May to October). The average yearly temperature is 27 °C and average rainfall is 1,024 mm. The average tide range is 2–3 meters [49]. This coastal area has enormous potential for aquaculture, seaports and especially for tourism. However, the coast has been experiencing severe erosion for years, although eroded sections have been constructed for protection. Some studies have shown that the construction of breakwaters affects the erosion–accretion law in this area. Understand the causes and rules of erosion–accretion is necessary to support the development of effective technical solutions for the planning and sustainable development of Binh Thuan's coastal zone.

2.2. Data Sets

To extract the shoreline from SAR data, Sentinel–1 images are obtained free of charge from European Space Agency (ESA) Sentinels Scientific Data Hub. The Sentinel–1 is the radar imaging mission, which provides continuous all–weather day/night imagery for land and ocean services at C–band with a repeat cycle of 12 days (a single satellite) or 6 days (two–satellite constellation). The dataset in this research for the extraction of the shoreline is two images of Sentinel–1 IW Level 1 GRD data acquired in VH/VV polarization with the ground resolution 10m.

For SAR image time series analysis, the time to collect image data sentinel should depend on the following factors: representing the northeast and southwest wind seasons, suitability of tide data and image acquisition. First, to describe the change of coastline in two seasons with different wind direction and wave direction, satellite imagery data will be collected in June–July and November–December. Secondly, attention should be paid to the characteristics of the tide because the shoreline is a dynamic line ranging between high and low tide.

A number of studies have adjusted tide–coordinated shoreline-based tide data, field data, digital model... However, this correction process is often difficult and inaccurate. In this study, based on the collected tide data at the Vung Tau tide gauge, both SAR images were acquired at equal high tide conditions (3,2 m), which are described in Table 1.

Table 1. Characteristics of Sentinel–1A level 1 GRD IW product used in this study.

Image		**Max Tide**	
Date	**Acq. GMT (HHMM)**	**Acq. GMT (HHMM)**	**H (m)**
Aug 2016	22:36	23:00	3.2
01 Dec 2016	22:36	23:00	3.2
06 Jul 2017	11:02	11:00	3.2
15 Nov 2017	11:03	11:29	3.2

2.3 Methodology

The implementation method consists of five steps as shown in Figure 2.

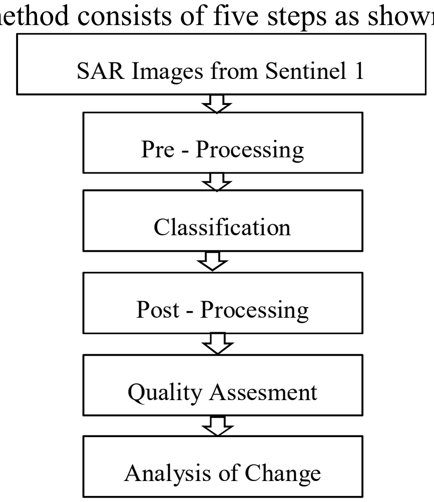
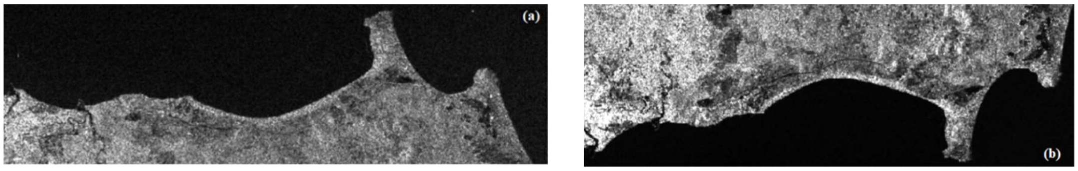


Figure 2. Processing workflow.

2.3.1 Pre–Processing SAR Images

All the obtained Sentinel images are refined with the orbit files which provides accurate satellite position and velocity information of each product. The data is acquired from the same sensor at different times, so radiometric correction is necessary for converting digital pixel values to radar backscatter in SAR images. The Lee filter, one of the spatial filtering methods is applied to reduce speckle noise and non–uniform signal characteristics of the signals returning from the ocean surface for calibrated SAR images. Then, filtered images are terrain–corrected using SRTM digital surface model for the purpose of repairing geometric distortions that lead to geolocation errors. The geographic coordinate system is the World Geodetic System 84 (WGS 84) and the selected projection is UTM zone 49 North. The SAR data are preprocessed by the open source software SNAP Toolbox which is provided by the European Space Agency (Figure 3).



(a) (b)

Figure 3. (a) Original SAR image; (b) image after Pre–Processing.

2.3.2 Determining of Land and Sea

The boundary between land and water is determined through a two–step process: fuzzy clustering and interactive thresholding. The ArcGIS software is used for solving the problem of determining of land and sea. Firstly, the fuzzy membership functions are used to transforms the averaged SAR image to a 0 to 1 possibility scale based on the designation of membership to a specified set. Because the average and standard deviations between soil and water pixels are very large, the fuzzy clustering function is set according to the formula (1) to optimize the data dispersion:

$$\mu(x) = 1 - \frac{bs}{x - am +} \quad if \quad x > am \quad otherwise \quad \mu(x) = 0 \qquad (1)$$

where m is the mean; s is the standard deviation; b and a are multipliers.

To initialize fuzzy membership function, a series of empirical values used for selection of the multipliers a and b. Experimental results show that a = 0.43 and b = 0.04 are appropriate to maximize the land surface membership of the study area. The results of using fuzzy clustering are shown in Figure 4.

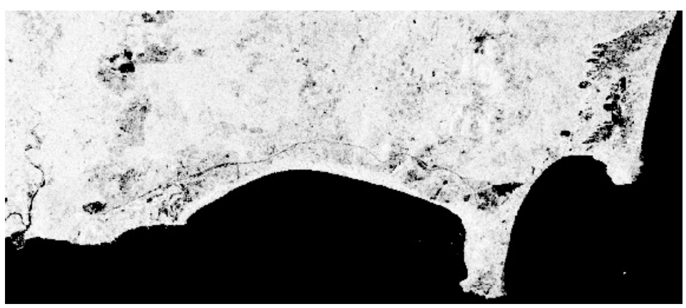


Figure 4. Results of applying fuzzy clustering.

At the next result of methodology, an optimal histogram thresholding in this case is 0.502, which is used to create binary images. The boundary between land and water is defined as a sign for extracting the shoreline. The created binary image contains pixel values of 1 (Red) or 0 (black), where the pixel values above the defined threshold was divided into the land (Red) and the opposite was divided into the sea (black). The boundary between the land and the water on the binary image is determined to extract the shoreline (Figure 5).

Figure 5. Result of applying the threshold for separation between land (red) and water (black).

2.3.3 Extraction of the shoreline data

After separation between the land and sea, the segment results are further processed as extraction of the line from the region–segmented result, generalizing to eliminate the lines zigzag vectors (Figure 6).

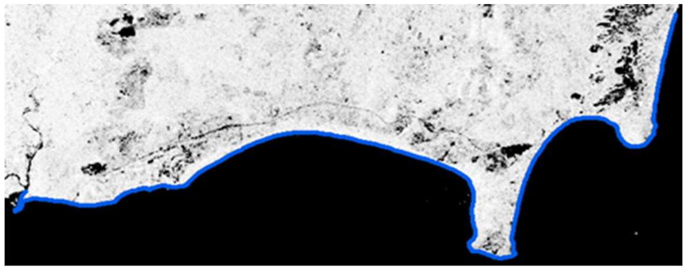


Figure 6. The shoreline results were extracted from the Sentinel–1A satellite image.

3. Results and Discussion

The shoreline result (15 Nov 2017) is assessed with digitized manual shoreline, by calculating the perpendicular distance between the two shorelines. The extracted shoreline from the digitization method are shown in Figure 7.

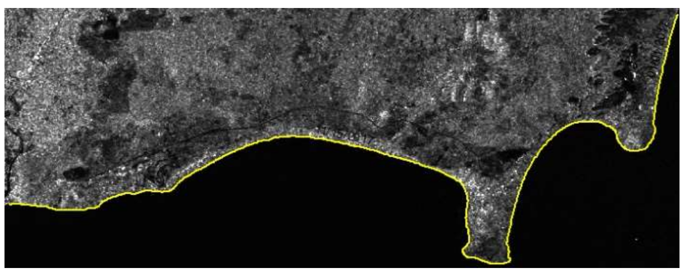


Figure 7. The shoreline results were extracted from the Sentinel–1A satellite image using digitization.

The DSAS (Computer Software for Calculating Shoreline Change) tool is used to calculate differences in the shoreline rates, which are extracted from the fuzzy clustering – interactive thresholding method and manually digitized method (Figure 8).

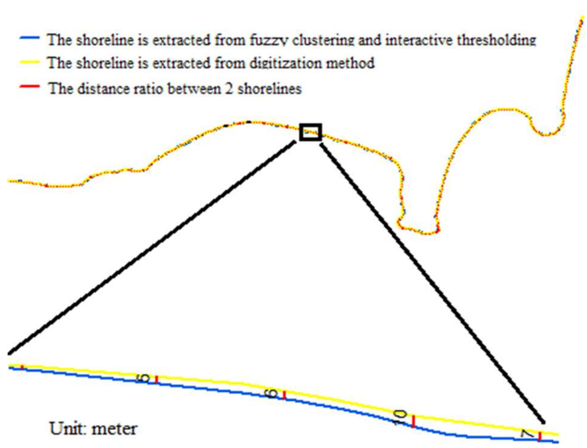


Figure 8. The location of the distance lines between the two shorelines is determined by the DSAS tool (15 Nov 2017).

Statistical results for 350 locations to calculate the distance between the two shoreline results are shown in Figure 9.

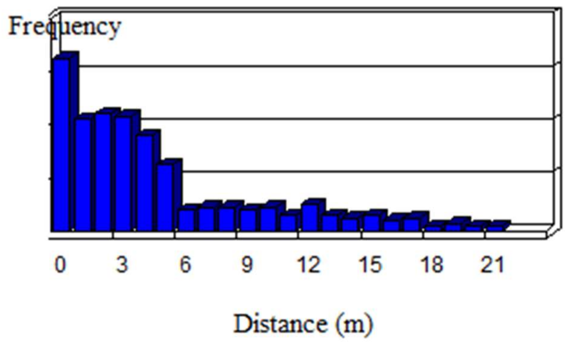


Figure 9. Differences in distance between 2 shorelines.

Of which, 274 (77%) locations had a distance between the 2 shorelines from 0 to 5 m (equivalent to the error of half a pixel), 76 (23%) of positions had a distance between the two shorelines over 5 m. The average distance between two coastlines is 3 m, the longest distance is 13 m. The results show that it is possible to clearly distinguish the boundary between land and water through the extraction of the shoreline from the Sentinel–1A satellite image fuzzy clustering and interactive thresholding. Further, additional field survey data or other data sources are needed to assess the accuracy of the result.

To consider how the wind factor affects the shoreline morphology, the DSAS tool is also used to analyze the position change of the shoreline over two seasons of the year. The Mui Ne and Hon Rom areas represent the study area. The results of extracting the shoreline from Sentinel–1 SAR images at 4 periods are shown in Figure 10.

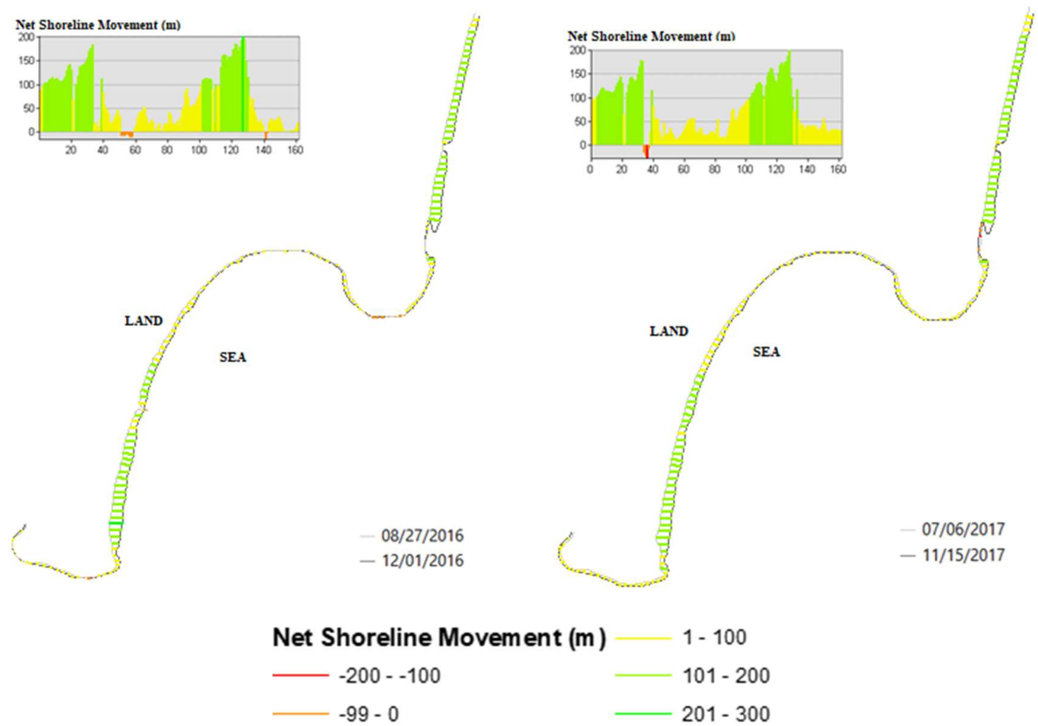


Figure 10. The shoreline results were extracted from the Sentinel–1A satellite image using digitization at 4 periods.

The DSAS statistics provided a detailed view of the seasonal change of shoreline for two years on the Binh Thuan coast. The results show similarity in the morphological change of the shoreline. During the southwest monsoon (from May to October), the coastline in the wind–receiving area tends to move inland. On the contrary, during the southeast monsoon (from November to April), the coastline tends to shift to the sea. The above results will be used for other research purposes in the future.

4. Conclusion

The results of the extracted shoreline from the Sentinel–1A satellite image show the applicability of radar satellite imagery in coastal monitoring. Sentinel–1A satellite image is not affected by weather, can be monitored over a large area, high spatial resolution and provided free of charge. These are important data sources and they can satisfy the need for continuous coastal monitoring. From there, it helps to support the right plans for erosion and deposition in the coastal area.

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Conflicts of Interest: The authors declare no conflict of interest.

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Responding to Climate Change at Provincial Level in Viet Nam

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Abstract: Responding to climate change at the local level plays an important role in building resilience and supporting the implementation of the National Climate Change Plan. Due to its geopolitical characteristics, Vietnamese provinces developed their own climate change action plans, taking the climate change impacts on that province, its financial capacity, and the homogeneity of the provincial plan with the national action plan into consideration. Currently, in the world, there are very few studies on assessing the implementation of climate policies at the local level as well as their effects on the national climate policies. From that perspective, this paper aims to fulfill that existing gap by assessing Viet Nam's city/provincial efforts on climate change response and their contribution to the national goals. The assessment applied both top–down and bottom–up approaches which is a combination of the review of legal documents and results of the implementation of 63 cities/provincial climate change action plans (PAPCs) and their relevance to the national goals. The study uses information from the PAPCs of 63 provinces/cities in Viet Nam to analyze their goals, content, and results to achieve the goals as set out in the National Strategy on Climate Change. On that basis, it was shown that in the coming time, it is necessary to further strengthen the coherence during the development process of central, ministerial, and local action plans in order to achieve the national goals to respond to climate change, contributing to the implementation of the Paris Agreement on climate change.

Keywords: Provincial action plans to respond to climate change; Impacts of climate change.

1. Introduction

The central aim of the Paris Agreement is to keep global temperature rise this century well below 2 °C above pre–industrial levels and to pursue efforts to limit the temperature increase even further, to 1.5 °C. Furthermore, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. On that basis, countries need to develop action plans to cope with climate change in order to achieve national commitments on adaptation and mitigation [1–2].

Cities and provinces are crucial actors in climate change response efforts [3–4]. However, how and why cities engage in climate policy is a matter of current debate [5–7] and the effect of national or international policies on the local level is not well understood [8]. Cities and provinces can play a key role in developing and implementing climate change programs because they are the main focus of local actions as well as national and international climate change commitments [9].

For years, the global community has focused on efforts responding to climate change at a national level, which has been mostly unsuccessful in terms of realizing comprehensive international agreements or taking action. Cities and provinces, by contrast, are preparing risk assessments, setting greenhouse–gas emission reduction targets, and pledging to act. Cities are crucial actors of climate change mitigation and adaptation efforts [3–4, 7]. Urban areas account for between 71% and 76% of CO_2 emissions from global final energy use and between 67 – 76% of global energy use [10]. At the same time, cities, nearly all being built on coasts or riverbanks, are particularly vulnerable to climate change effects [4]. Globally, efforts are underway to reduce anthropogenic greenhouse gas emissions and to adapt to climate change impacts at the local level. However, there is a poor understanding of the interlinked relationship between city strategies on climate change mitigation and adaptation and the relevant policies at the national level [8–9]. The mere existence of international or indeed national climate policies is no guarantee for local plans and action [9].

The capacity of cities is being increasingly recognized by international institutions and has been pointed out as crucial in the multi–level government scenario of the European Union (EU) [6]. Recognizing this important role, local governments have taken further efforts to mitigate and adapt to climate change. However, and despite the risks and cost of taking no action, many cities are struggling to introduce climate issues in their policy agenda on a sustained basis [6].

A "bottom–up" approach means that regional or local authorities are encouraged or allowed to go beyond national requirements or incentives to independently act to address climate change, either with the present national policies or not. In this model, learning and experience acquired through successful local programs diffuse to inform and steer policymaking at regional or national levels. Inevitably both directions of influence–top–down and bottom–up–co–exist to shape actions and policies across levels of decision making. Experience from the City of Portland and the State of Oregon in the US demonstrate this type of example [11]. There are a number of other examples of note in the US as well as in Spain, both of which have a decentralized approach to governance. In turn, this allows experimentation and room for innovation for those states and cities with the resources to do so. The State of California is notable for example. Also, at the local level, New York City has become a leader on the issue of adaptation and mitigation. This is due in part to a strong network of academic and government practitioners, working together to advance understanding and support decision making [4].

The study [9] reports the findings of studying the climate change strategies or plans from 200 European cities from Austria, Belgium, Estonia, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, and the United Kingdom. The study highlights the shared responsibility of global, European, national, regional, and city policies [9]. It was found that there's no archetypical way of designing for global climate change and multiple interests and motivations are inevitable. The research warranted the need for a multi–scale approach to climate policy in the future, mainly ensuring sufficient capacity and resources to enable local authorities to plan and respond to their specific climate change agenda for maximizing the management potentials for translating environmental challenges into opportunities. The analysis shows that a lot of cities tackle the causes (65 %) and consequence (28 %) of global climate change [9].

In France, the responsibility for climate change is also divided between national, regional, and local levels, but the national level has a strong guiding and directing function for cities which is different from Austria, Belgium, Germany, Estonia, and Finland [9]. The analysis shows that many European cities are proactive on climate change. However, climate change mitigation and adaptation potentials may lie outside the administrative boundary of the city and clear guidance in which case collaboration across city boundaries is needed. Cities search for national guidance and if this is often not available align themselves to international guidance and networks [9].

In Spain, the central Government has to rely on the involvement of regional governments and municipalities in order to fulfill its international commitments. This fact is even more evident as regions and cities have jurisdiction over housing, mobility, urban planning, and spatial planning, etc [6].

[12] examined 40 recently adopted local climate change action plans in the US and analyzes how well they recognize the concepts of climate change and prepare for climate change mitigation and adaptation. The results indicate that an action plan to respond to climate change at the local level has a high level of "awareness", moderate "analysis capabilities" for climate change, and relatively limited "action approaches" for climate change mitigation [12].

Viet Nam has issued its National Strategy on Climate Change. The strategy indicated that Viet Nam's climate change response must: i) be associated with sustainable development; ii) lead towards a low–carbon economy, iii) take advantage of opportunities to innovate development thinking and enhance national competitiveness, and iv) conduct adaptation and mitigation activities at the same time to effectively deal with climate change. This strategy is the basis for central and local authorities to identify and implement adaptation and mitigation activities as well as integrate climate change contents into their strategies, planning, and development plans. The strategy points out that each province needs to develop its own plan to respond to climate change [13].

After the National Assembly passed the Paris agreement, the Government issued document No. 2053/QD–TTg dated 28th October 2016. According to this decision, the Government identifies key objectives and tasks for implementing the Paris agreement. Besides ministries, localities and provinces are supported to develop their own action plans to respond to climate change [14]. Annually, provinces report the status of implementation of PAPCs to the Ministry of Natural resources and Environment. The report includes facts and figures about the ongoing adaptation tasks and projects, limitations, and problems faced in order to implement the PAPCs [14].

In 2014, which is the year with the latest GHG inventory results since Viet Nam ratified the Paris Agreement. The sources/sink of GHG emissions is identified for the energy, agriculture, LULUCF, waste, and IP sectors. The total GHG emissions in the base year 2014 were 284.0 million tons of CO_2eq. Viet Nam now has reviewed and updated the nationally determined contribution (NDC) [15]. After submitting the NDC to the United Nations Framework Convention on Climate Change (UNFCCC), the Government will develop the National action plan on responding to climate change. So, the Provincial action plans to respond to climate change (PAPCs) will play an important role in developing the National action plan.

Currently, 63/63 provinces and cities in Viet Nam have approved their Action Plans to Respond to Climate Change [16]. And perhaps, Viet Nam is the only country where all provinces have their own action plans based on climate change vulnerability and socio–economic development. Local action plans to respond to climate change mainly focus on assessing the impacts of climate change on sectors and local areas especially sensitive and vulnerable ones [17]. These plans also identify solutions and develop a list of priority projects to cope with climate change in their provinces. These action plans are an important basis for local authorities to effectively implement projects and call for domestic and foreign supports in order to respond to climate change. Funding sources for the implementation of local plans include central and local funding mobilized from development partners and international organizations and also the private sector [18].

In this study, the existing (PAPCs) of the 63 provinces and cities in Viet Nam will be reviewed [19]. The study addresses two principal research questions:

What are the impacts of implementing PAPCs on socio–economic development and on achieving the national climate change response goals?

What are the relative influences of local, national or international policies on the development of PAPCs?

The study will be conducted based on the evaluation and analysis of PAPCs in Viet Nam. The research method focuses on analyzing the following issues: (1) the process of developing action plans; (2) the objectives, scopes and contents of the action plans; (3) the contribution of the PAPCs to the national climate change response goals, and (4) the limitations and shortcomings of the PAPCs implementation.

2. Materials and Methods

2.1. Analysis of planning processes

a. Analyzing the level of response of PAPCs based on following criteria:

– The involvement of stakeholders, especially local communities;

– The conformity with short–term, medium–term and long–term national and local strategies, plans and socio–economic development programs;

– Identify priority solutions, activities and areas for each province in order to response to climate change;

– Integrate solutions to cope with climate change into ministerial and provincial strategies and programs;

– Ensure the feasibility in terms of timeline, resources, effectivity and outputs;

– Ensure the ability to examine, monitor and evaluate the implementation process as well as the final results.

b. In order to integrate climate change elements, the review of local development strategies, programs, planning and plans is crucial. Therefore, this study will also analyze this aspect by focusing on the following processes:

– The selection of measures to response to climate change to integrate into other strategies, programs etc... (identify and list all adaptation and mitigation measures related to the content of strategies, programs, planning and development plans);

– The integration of climate change goals and issues into strategic objectives, programs, planning and development plans;

– The comparison and considering of the priority levels of climate change issues that are integrated into development strategies, programs, planning and plans.

2.2. Analysis of Objectives, scopes and contents of the PAPCs

The objectives of the PAPCs are based on assessments of the impacts of climate change on each province as well as existing gaps in adaptation and mitigation. Research methodology will assess the extent to which these issues are addressed in order to set out goals of the PAPCs. In addition, the study will also assess the conformity of the scope and content of PAPCs, specifically:

– Whether the scopes of the PAPCs cover the main fields that contribute to the local socio–economic development including: natural resources and environment, natural disaster prevention, agriculture and rural development, public security, poverty reduction, public health, energy, transportation, tourism, industry and commerce and other fields.

– Whether the action plans include specific activities for each sector in order to adapt to climate change and reduce local greenhouse gas emissions.

2.3. Analysis of contribution of the PAPCs to the national goals

The study conducts an analysis of the objectives of the national action plan on climate change and on the results of the PAPCs. On that basis, an analysis of the effectiveness of the implementation of the action plan for the province/city for each specific national goal is set. The evaluation criteria were determined based on the set goals of the PAPC.

2.4 Research data

The study uses information from the PAPCs of 63 provinces/cities in Viet Nam to analyze their goals, content, and results to achieve the goals set out in the National Strategy on Climate Change [13,19]. The study also uses collected data from annual reports that provinces send to the National Committee on Climate Change. The Government issued Decision No. 2053/QD–TTg on the Plan for the Implementation of the Paris Agreement [14]. Accordingly, provinces and cities formulate their PAPCs to set out tasks to respond to climate change and annually report the results, status of implementation of ongoing projects to the Ministry of Natural Resources and Environment. With an integrated approach, the paper analyzes efforts to assess the local contribution to the implementation of national climate change goals. The collected data includes facts and figures about the ongoing adaptation tasks and projects; limitations and problems that provinces face in order to implement the PAPCs.

Survey and survey data were collected to further assess the impact of climate change on specific areas to analyze the suitability of action plans for local socio–economic development. Survey data is also used to assess the process of developing action plans of provinces/cities. The collected data includes local reports on assessing the impact of climate change; damages caused by natural disasters and climate change of annual reports of localities; results of climate change adaptation projects.

3. Results and Discussion

3.1. Analyze the appropriateness of the objectives of the PAPCs and national action plans

The National Climate Change Action Plan that was issued in 2012 set out 10 goals as following: (1) Strengthening climate monitoring and natural disasters warning capacity; (2) Ensuring food and water security; (3) Actively responding to natural disasters and flood for big cities; consolidating river and sea dykes; (4) Mitigating greenhouse gas emissions, heading toward a low carbon economy; (5) Strengthening management capacity, improving climate change–related mechanisms and policies; (6) Mobilizing the participation of all economic sectors, scientific, socio–political–professional organizations and non–governmental organizations in responding to climate change; building communities in order to effectively adapt to climate change; (7) Raising awareness, developing human resources; (8) Developing science and technology to assist policies formulation, impact assessment, identification of climate change adaptation and mitigation measures; (9) Enhancing international cooperation and Viet Nam's role in international activities on climate change; (10) Mobilizing financial resources to cope with climate change [20].

From the collected data, the authors have found that the overall goals of the PAPCs are elaborated based on the National Action Plan's objectives. In addition, the proposed targets in the PAPCs are also based on the results of local and sectoral climate change impacts assessments.

Specific targets identified in the PAPCs are as followed [19]:

1) Assess climate change vulnerability in various fields such as services, agriculture, natural resources, environment, energy exploitation and usage, transportation, telecommunications, security and national defense activities, and healthcare;

2) Assess climate change vulnerability in sensitive areas such as coastal, rural, or mountainous areas;

3) Assess the vulnerability for vulnerable groups such as poor households, migrant workers, elderlies and children;

4) Apply modern and advanced management models, approaches, technical methods in order to minimize losses and/or improve the climate change responding capacity of vulnerable sectors, areas, and groups;

5) Improve provinces and cities' legal framework to strengthen the coordination between agencies, businesses, organizations, and individuals in responding to climate change;

6) Integrate climate change contents and activities into provincial socio–economic development plans to increase long–term sustainability;

7) Strengthen cooperation with domestic and international climate change organizations to exchange experience and cooperate in climate change response activities.

The goals mostly aim to solve short–term issues and do not focus on long–term orientations of the province in order to cope with climate change in the future. The list of implementation tasks is not clearly planned. Most of the PAPCs lack monitoring and evaluation solutions to achieve their goals. The tasks proposed in the PAPCs are mostly implemented in the whole provinces/cities. Some specific projects focus on regions that are vulnerable to natural disasters and climate change.

For example, the PAPC of Quang Nam province focuses on assessing the impacts of climate change, sea–level rise and propose solutions to address areas such as biodiversity; coastline stability; drought; socio–economic development planning; agriculture; flood and storm prevention; health; tourism; general topographic; geological conditions, etc. of the province in the context of climate change.

The PAPCs of Ben Tre province focus on assessing the impacts of climate change, sea–level rise on coastal communities, biodiversity, tourism and proposes solutions. The PAPCs are mostly divided into 5–years periods of 2011–2015 and 2016–2020 (that are similar to the timeline of the local socio–economic development plans). This can create favorable conditions for the integration of climate change elements into local socio–economic development plans. The PAPCs focus on certain specific priority areas such as environmental resources, natural disaster prevention, agriculture and rural development, employment; social security; hunger eradication; poverty reduction; health; energy; construction; transportation; tourism; industry, and commerce.

3.2. Analyses of the PAPCs's contents

The PAPCs mainly focus on assessing the impact of climate change on areas and sectors; developing climate change and sea–level rise scenarios for localities; proposing actions to cope with climate change and sea–level rise. This is mainly a document for authorities to base on when integrating climate change into the provincial socio–economic development plans and mostly focus on key and vulnerable sectors such as agriculture, environmental resources, and natural disaster prevention [19]. The contents of PAPCs have partly met the set goals. However, the lists of tasks and projects are still fragmented and lack coherence and coordination among activities, sectors to achieve the desired results. Very few PAPCs are integrated into local long–term development plans (e.g. the Action Plan of Ho Chi Minh City) [19].

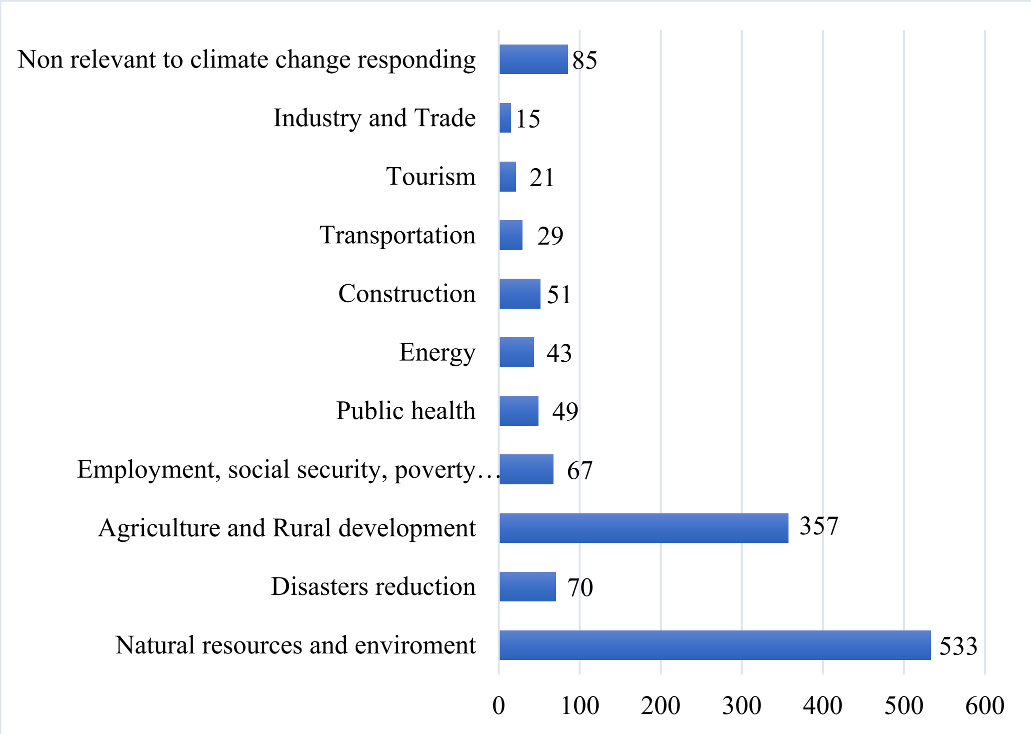

Figure 1. Total number of actions/projects by sectors in the PAPCs [19].

In Figure 1, it is clear that the PAPCs focus on sectors such as natural resources and environment (surveys, impact assessment, improving the capacity of climate change forecasting, planning climate change responses etc.) and agriculture and rural development (cultivation, livestock, natural disaster prevention, forestry etc.). The figures show that the natural resources and environment sector is prioritized to allocate the most funding in PAPCs and account for 35% of the total proposed funding (equivalent to VND 9927.67 billion). It is followed by agriculture and rural development sector for activities such as conservation and development of watershed forests, mangrove forests, development of animal husbandry and aquaculture adaptable to climate change and other infrastructures (Table 1, Figure 2).

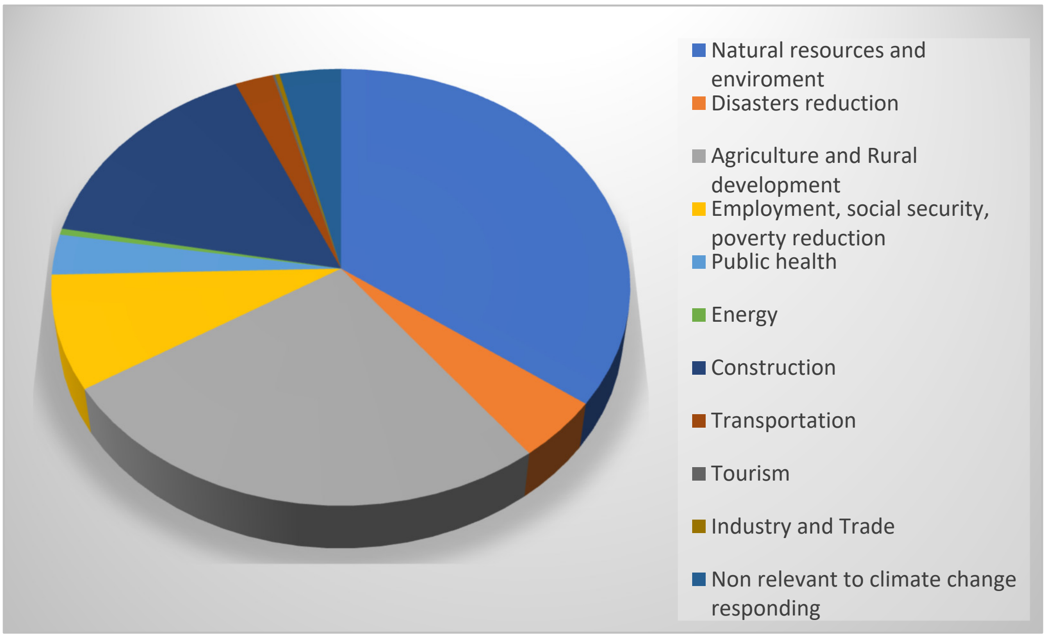

Figure 2. Total proposed funding for prioritizedsectorsin the PAPCs [19].

Table 1. Total proposed funding for prioritized areasin the PAPCs [19].

Sector	Total proposed funding for prioritized sectors in the PAPCs (billions of VND)
Natural resources and Environment	9927,67
Natural disaster prevention	1275,75
Agriculture and Rural development	7500,79
Employment, Society welfare, Poverty reduction	2392,87
Health	846,09
Energy	128,5
Infrastructures	4400,2
Transport	657
Tourism	41,3
Industry and Commerce	75,4
Others	1052,54

3.2.1 Prioritized sectors in the PAPCs

By analyzing the PAPCs, it can be seen that the two most focused sectors are environmental resources and agriculture and rural development [19]. These two sectors are deemed to be vulnerable to the impacts of climate change and natural disasters [21]. In the agriculture and rural development sector, cultivation is prioritized with many tasks/projects proposed. Rice is a common crop in coastal/delta provinces. Rice loss accounts for the majority of the total national annual losses due to climate change and natural disasters (66.1% in the period of 2011–2016 [22]. Drought and saltwater intrusion in 2016 damaged 527.7 thousand hectares of rice, of which 44% was completely damaged (damage level > 70%), 13.7% suffered serious damage (50–70%), 17.0% suffer moderate damage (30–50%) and minor damage (< 30%) [23]. Other crops are also affected: in most affected areas, crop yields are reduced by more than 50%. Therefore, provinces prioritize adaptation solutions in cultivation. The Red River Delta, the North Central Coast, the South–Central Coast, and the Mekong River Delta are the regions with the highest number of proposed tasks for cultivation. Particularly in the Mekong Delta, cultivation tasks/projects account for 65% of the total tasks in the agriculture and rural development sector (63 out of 97 tasks). The Mekong Delta region is one of the areas where cultivation is heavily affected by extreme weather events such as floods and saline intrusion. Thus, provinces in the area have strong needs to increase the efficiency and competitiveness of the agriculture sector and to adapt to climate change.

Provinces also prioritize the natural resources and environment sector, especially the water management area. According to the 2018 report of the Central Steering Committee for natural disaster prevention and control, the situation of drought and saltwater intrusion in recent years has increased both in terms of scope and intensity. A severe drought occurred from the second half of 2014 to the middle of 2016 on a large scale of 18 provinces and cities in the South–Central Coast, Central Highlands, and especially the Mekong Delta. This drought had great impacts on the socio–economical, environmental, and ecological of the region, especially in agricultural production. Drought may be increasingly severe for the Central region in the period of 2011–2050. Therefore, solutions to prevent drought and saltwater intrusion are prioritized in the action plans of the provinces in this region. In the North Central region, ensuring water supply for daily life and irrigation account for 32% of the total proposed tasks [23]. In addition, the PAPCs also focus on strengthening climate monitoring capacity, disaster warning, and ensuring food security, water security [19].

3.2.2 Differences between regions

The Red River Delta, North Central Coast, Central Coast and Mekong River Delta are areas with large population and are economic centers of the country. Thus, the PAPCs in these regions focused on reducing exposures, natural disaster prevention (floods, landslides prevention, the construction of national highways and railways etc.), urban planning to cope with climate change, encouraging the usage of clean and low–carbon fuel. These are regions with medium sensitivity and have better abilities to cope with climate change, so their solutions focus on sustainable development and the reduction of natural disasters' impacts [19]. On the other hand, the Northern provinces and the Central Highlands are the areas with lower exposure levels (they are not affected by sea level rise) but also have less adaptive capacity compare to delta and coastal areas due to the sparse population and complex landscapes. Solutions proposed in these areas focus on natural disaster prevention (such as flash floods and landslides) for each sector; improving safety conditions for poor households and other emergency measures in case of landslides etc [19, 23].

3.2.3 Gender issues in the PAPCs

Except for the Red River Delta and the Mekong River Delta, other areas have developed gender–focused solutions in their PAPCs such as: developing policies to support the development of vulnerable groups, especially woman from ethnic minority, in order to effectively respond to climate change and raise awareness in vulnerable areas; implement and expand community–based models etc [19].

3.2.4 Climate change issues integration into socio–economic development plans

Most provinces/cities have focused on integrating climate change issues into their socio–economic development plans, especially for major cities. The PAPCs are mostly established for a 5–years period which is the same period with the local socio–economic development plans [19]. For example, in the process of developing its PAPC, Da Nang City has paid high attention to its current master plan on socio–economic development vision to 2020. Da Nang City also identified the city's development plans that should be prioritized for integration, including: the development plan of making Da Nang into a driving force in the central part of Viet Nam; the proposal of the environmental city by 2020; the sectoral development plans such as transport, tourism, energy, agriculture and water management [19]. In addition, the integration of climate change issues in sectoral plans and strategies are also addressed. Some provinces and cities set out specific sectoral solutions, activities to suit with their climate change conditions. Integrating climate change into development plans is based on results of assessing impacts of climate change to the development of the respective province/city. Solutions and activities response to climate change proposed by the climate change agency will be considered and approved by the People's Committee of the province/city and will be the basis for implementation of integrating processes [19].

3.3 Results of of the PAPCs implementation process assessment

3.3.1. Results obtained in the PAPCs implementation process

Statistics show that all provinces pay high attention to the climate change response activities and provincial climate budgets have increased faster than the growth rate of the total provincial budget. For example, the climate budgets of three provinces of An Giang, Bac Ninh, and Quang Nam all have annual growth rates higher than the growth of the total provincial budget. An Giang is a province with the highest climate budget growth rate [19].

Provinces are more concerned about adaptation activities than mitigation ones. For example, Quang Nam province has funded a number of mitigation actions according to its PAPC with prioritizations for energy conservation measures in the transport, industry, and energy sectors. The summary shows that An Giang, Bac Ninh, and Quang Nam all spend a large part of the total budget to respond to climate change although the provinces still have other priorities. Climate budgets account for approximately 5% of the total budgets of the three provinces. Bac Ninh's climate budget accounts for about 4% of the total budget, mainly for river dykes and irrigation systems. Quang Nam's climate budget also accounts for about 4% of the total budget, mainly allocated to irrigation systems, forest development activities, waste management. About 1% of An Giang's total budget in the period 2010–2013 was allocated to climate change programs (mainly for dyke systems, river embankments, irrigation, and transport systems). In addition, the comparison between the funding from MARD to response to climate change with local funding confirms the fact that the provinces are directly sponsoring most of the climate change activities. The implementation of the local action plans achieved the following results [19].

1) Assessing climate change impacts on vulnerable areas and initially developed plans to cope with climate change and extreme weather;

2) Strengthening capacity to monitor climate change; forecast and warning of natural disasters, floods, droughts, saltwater intrusion in the context of climate change. Upgrading the warning system, hydro–meteorological forecasting, establishing a network to monitor climate change and sea–level rise;

3) Raising public awareness about the impact of climate change; building capacity for full–time officials and people responsible for climate change issues in provinces;

4) Planting and rehabilitating coastal mangroves to create dykes to prevent waves, enhance CO_2 absorption and create sustainable livelihoods for people; increase water retention, combat erosion, improve coverage, reduce damage caused by floods, flash floods, landslides, protect downstream facilities, regulate climate, maintain and sustain livelihood development;

5) Building irrigation structures such as lakes, dams to contain freshwater, guaranteeing the water supply for production in the dry season and regulating floods in the rainy season;

6) Upgrading and building sections of the sea and river dikes, preventing flooding and saltwater intrusion in areas that can greatly and directly affect production and livelihood;

7) Applying climate change adaptation models for cultivation, livestock, aquaculture, industry and commerce, restructuring and promoting local economic development taking into consideration climate change adaptation;

8) Applying adaptive models to improve health conditions, social security;

9) Utilizing resources from the central government, domestic and international social organizations to implement the Action Plan.

3.3.2. The effect of the PAPCs on the national goals of climate change

In general, the PAPCs closely follow the main objectives of the National Action Plan to respond to climate change. Therefore, they also contributed to the achievement of national climate change goals. The specific effects of the implementation of local action plan to the goals and tasks of the national action plan on climate change can be analyzed as follows [19]:

a. Strengthening of climate monitoring capacity, warning of natural disasters

Some provinces have taken the initiative in developing regional climate maps in order to forecast and inform the localities about different types of natural disasters. For example, Vinh Phuc Province has the task of "Building, zoning and mapping the risked areas of floods, flash floods under the impact of climate change in the province and establishing measures to prevent and mitigate damages". Besides that, the provinces have also identified the importance of building climate and environmental quality monitoring systems. The provinces have conducted researches and assessments of the impacts of climate change. The Da Nang City has elaborated on a climate change action plan which assesses the impact of climate change for each region and vulnerable areas. Sea level rise and climate change scenarios for each locality (updated in 2016) also contribute to improving the socio–economic development planning of provinces and cities. The tasks are developed and implemented in accordance with the Climate Change Action Plan to gradually improve the capacity of local climate change monitoring, forecasting, and warning; the management of climate change, natural disaster forecasting have also been gradually improved.

b. Ensuring food and water security

Agriculture and rural development have been given special attention by the provinces and cities in their PAPCs. There have been 357 tasks (accounting for 35.8% of the total) with a total proposed budget of VND 7,500 billion that focus on food security solutions by provinces and cities. The tasks proposed by the provinces included: researching a new types of rice; applying some agricultural production techniques to adapt to climate change; structural change, plant, and animal breeds, crop adjustment, etc.

Up until now, a number of rice varieties adapted to floods, salinity, alum... have been developed and cultivated. Measures to adapt to climate change have also been studied and implemented. In particular, a number of provinces in the Mekong Delta have changed the mode of agricultural production from "rice–aquaculture–fruits" to "aquaculture–fruit–rice", etc. The tasks in the field of water resources management mainly focus on building the monitoring system, planning water resources for agricultural production, and daily life.

c. Responding to natural disasters; flood control for big cities; consolidating river dikes, sea dikes, and reservoir safety

Disaster prevention is a special concern for localities and funding for these activities also accounts for a large proportion of the total local budget since they contribute to protecting livelihood in the area. The tasks of proactive response to natural disasters mainly focus on improving the safety of natural disaster prevention structures (river dykes, sea dykes, embankments, reservoir safety, etc...), strengthening rescuing actions, avoiding and mitigating natural disasters. These tasks especially focused on coastal areas, high mountains, and vulnerable areas to natural disasters.

According to statistics, damage caused by natural disasters has decreased compared to the previous period; human loss in the period 2008–2017 was 303 people/year, a decrease by 39% compared to the period 1998–2007 (497 people/year). In terms of property damage, the absolute value has not decreased significantly, but the damage ratio compared to the national GDP has decreased due to economic development in recent years. Some localities such as Hanoi, Ho Chi Minh City, Can Tho build and deploy many anti–flood tasks, projects, and structures. However, in general, the implementation of these tasks is still slow.

d. Reducing greenhouse gas emissions, developing a low carbon economy

There are not many solutions to mitigate greenhouse gas emissions in the PAPCs. Some related actions include measures to combat deforestation, forest degradation, forest protection, and development. The tasks concerning transforming the growth model and promoting a low–carbon economy were initially built and implemented by big provinces and central cities such as Ha Noi, Ho Chi Minh City, Da Nang, Can Tho ... The green economy model in the river basin concerning fisheries and coping with rising sea levels has been developed and implemented by provinces in the Mekong Delta. Currently, provinces have been developing action plans for green growth for the 2016–2020 periods with many types of models being implemented like green industry, green urban areas, and green transportation models in Ho Chi Minh City, Quang Ninh, Da Nang, Hai Phong, and Phu Yen. Some provinces have developed green agricultural and forestry models such as Gia Lai, Hau Giang, Tra Vinh, and Binh Thuan, etc.

e. Strengthening the management capacity, establishing mechanisms and policies on climate change

Many provinces and cities set up raising awareness and capacity building tasks concerning climate change for authorities due to the shortage of specialized climate change officials at a local level. The goal of completing climate change mechanisms and policies has not been clearly reflected in the PAPCs due to the difficulties faced during the development and implementation process. The integration of climate change into local socio–economic development plans has not been paid much attention by localities.

f. Mobilizing the participation of all economic sectors, scientific organizations, socio–political–professional organizations, and non–governmental organizations in responding to climate change

There are not many tasks in the PAPCs concerning this issue. This shows the problems faced by provinces and cities in mobilizing the participation of all economic sectors and social organizations in responding to climate change. In addition, this also reflects the fact that the importance of communities, economic sectors, social organizations in the response to climate change in Viet Nam is currently underestimated.

g. Raising awareness, developing human resource, promoting scientific research

These tasks focus on raising awareness for vulnerable groups such as women, students, etc... Scientific development activities that identify climate change adaptation and mitigation measures are also prioritized. Scientific and technological tasks mainly focused on studying the impact of climate change on socio–economic and promoting research on technologies to adapt to climate change and reduce greenhouse gas emissions.

h. International cooperation

Most localities are interested in strengthening international cooperation in order to take advantage of international funding sources including financing, new technology transfer, and participation in regional and global cooperation activities on climate change. Central cities propose many tasks in expanding cooperation with international organizations in developing climate change strategies.

i. Mobilizing financial resources

In the list of tasks and projects proposed by the PAPCs, most provinces and cities use the state budget to implement the tasks. This proves the difficulty in mobilizing financial resources from other economic sectors and international funding sources. In addition to some provinces and cities such as Quang Nam, Ben Tre, Da Nang, and Ha Tinh propose the use of foreign funding supported by non–governmental organizations and development partners. This also demonstrates the problem that provinces are facing in section 6 concerning the lack of participation of communities, economic sectors, and social organizations.

3.3.3. Analyze the limitations and shortcomings of the PAPCs implementation

1) Shortcomings and limitations in the process of developing the PAPCs: (i) The targets set out in the PAPCs are still sporadic and not systematic; (ii) Climate change adaptation

targets in the action plans have not really been integrated into the local socio–economic development plans; (iii) The plans still lack specific targets for specific periods. If this can be shown, it will be the basis for the provincial People's Committee to ask the relevant departments on focusing on prioritized targets, projects, and solutions; (iv) The roadmap to implement the prioritized projects and tasks has not been determined. Some provinces and cities also list the general objectives without specifying resources for each project and each stage. This will undoubtedly reduce the feasibility of the PAPCs.

2) Shortcomings and limitations in the implementation of the PAPCs: (i) The implementation is somehow passive due to the increased intensity of climate change; (ii) Lack of public awareness in climate change; (iii) Due to the limited budget, many tasks set out in the action plans cannot be implemented yet; (iv) The coordination among relevant authorities is not synchronized, lack of information sharing.

3) Shortcomings and limitations in terms of regulations: The legal framework for integrating climate change issues into national socio–economic development plans is limited. The coordination between relevant authorities is still ineffective. There is also a lack of methods to encourage and attract domestic and foreign investment, to mobilize businesses in order to participate in climate change adaptation activities. The national climate change database is insufficient and does not meet the requirements. The climate change legal system is not synchronized and has not been reviewed, adjusted in line with new domestic and international situations.

4) Shortcomings and limitations in terms of capacity: Most of the officials in charge of climate change response have not received proper training. There is a shortage of in–depth experts and technical staff in some areas especially concerning climate change assessment and adaptation activities. The public awareness is still low and communication capacities are still limited and thus, have not yet met the demand of the current state. There are still limitations in replicating suitable climate change adaptation models at the community level and in allocating resources to implement prioritized climate change adaptation activities.

5) Shortcomings and limitations in mobilizing resources: Although there have been policies, plans, and programs to adapt to climate change and the state resources can meet only 30% of the demand. Meanwhile, the demand for construction and upgrading structures concerning climate change adaptation is still high, the existing works only meet a part of the country's need.

6) Shortcomings and limitations in science and technologies: There is a shortage of advanced technology in hydro–meteorological monitoring and forecasting, warning of natural disasters, hazards, and climate change.

7) Shortcomings and limitations in evaluating and monitoring: Lack of monitoring, reporting, and evaluation system for local adaptation activities to improve their effectiveness.

4. Conclusion

The analysis of the PAPCs of 63 provinces/cities of Viet Nam shown that these plans have contents related to climate change adaptation and GHG mitigation. However, PAPCs do not propose many solutions to reduce GHG emissions. The solutions mainly focus on deforestation, forest degradation, development, and protection of forests.

The objectives of the PAPCs are determined based on the assessment of provincial climate change impact to propose specific solutions in order to respond to climate change and natural disasters and ensure social security and socio–economic development [24]. However, the list of tasks and projects is still fragmented, lacking coherence and coordination among activities and sectors to achieve the desired results. Very few local Action Plans are integrated into local long–term development plans.

Although the PAPCs have contributed effectively in achieving the objectives of the national action plan to cope with climate change, it is still necessary to further strengthen the cohesion in developing action plans from the central level to ministries, and provinces in order to achieve the overall climate change adaptation goals of the nation.

The study proves that all provinces that paid high attention to the climate change response activities have gained noticeable rises in socio–economic development. The implementation of the local action plans helped the local authorities in assessing climate change impacts on vulnerable areas; strengthening capacity to monitor climate change and raising public awareness concerning the impact of climate change.

The development of PAPCs is also impacted by international and national policies on climate change. Especially, the NDC and NAP process define priority targets and adaptation activities for vulnerable areas that localities should integrate in their PAPCs.

Currently, localities are developing action plans for the next stage. In order to be more effective, adjustments needed to be made compared to the previous period, including (1) selecting specialized authorities in developing these PAPCs; (2) including several concerned sectors with priorities to Natural Resources and Environment and Agriculture and Rural Development; (3) promoting the application of science and technology; (4) monitoring and evaluating on the implementation; (5) integrating climate change issues with local long–term development plans.

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Research Article

Studying the extent of scarcity of surface water in Lam Dong according to the socio–economic development plan up to 2030

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Abstract: Studying and assessment the scarcity of surface water resources in Lam Dong province based on the Socio–Economic Development Plan to calculate and forecast the water demand towards 2030 for economic sectors in the region, and based on this basis to calculate the extent of water scarcity occurring in this area by space and time using the calculation and classification method of Pfister (2009) combined with the GIS–RS mapping method. The results show that, the total water use demand of all sectors in the province in the period of 2018–2030 is forecasted to increase at a stable rate of about 6.5%. Although the total amount of surface water in the province is relatively plentiful, it can meet the demand for national economic sectors; However, water scarcity in the province still occurs in the dry season in some districts or cities.

Keyword: Water resources; Surface water resources; WSI; Lam Dong.

1. Introduction

Water resources is considered the top concern in countries around the world. Water resources are associated with human life activities and economic sectors. Today, the development of industries, urbanization and population growth, along with changes in precipitation and temperature caused by climate change, have led to a growing competition for water use. According to the Technical Report of IPCC, by 2050 about 40% of the world's population is at risk of living in severe freshwater scarcity [1]. Water resources tend to be gradually depleted while pollution is increasing. The change in the bad direction of the environment has an opposite effect on the socio–economic development of each country. In the world, there have been many researches on water resources such as: In the US, Pfister calculated the water pressure index of the states, the results showed that Arizona, Texas, Florida were areas under pressure. In terms of water resources, the reason is that the population in these areas is increasing while water is increasingly scarce [2]. Another study by Malin Falkenmark shows that, if the amount of water that can be satisfied is higher than 1,700 m^3/person/year, water shortage will only happen suddenly or locally. Below this threshold, water scarcity has varying degrees: less than 1,700 m^3/person/year, water pressure or stress occurs frequently; less than 1,000 m^3/person/year, water scarcity has constrained socio–economic development; less than 500 m^3/person/year, the study area is in extremely scarce water situation and this problem becomes the main obstacle of life here [3]. In Thailand, SH Gheewala and his colleagues calculated the water stress index on 25 basins; the results show that, in the Chao Phraya and Tha Chin watersheds (central), this is the second largest rice growing area where extreme water pressure has occurred during the dry season [4]. In China, a study using AWSI index to evaluate water scarcity in agricultural production in China from 1999 to 2014 showed that AWSI index tended to increase during critical period. due to the expanded scale of agricultural production, in 1999 AWSI was 0.32 (medium stress) and in 2000 AWSI was 0.49 (high stress); In particular, the autonomous regions and northern central cities (Delta Huang–Huai–Hai) are facing high water stress (AWSI > 0.8), in the south China has to face with increasingly serious water scarcity [5];… Therefore, the rational and efficient use of water resources to meet the needs of economic sectors is extremely necessary.

Lam Dong is one of 5 provinces in the Central Highlands, located in the South Central Highlands with an average altitude of 800–1500 m above sea level with an area of 9,773.54 km^2. The climate here is relatively cool, and the river system is relatively dense with 7 main river systems. This is the region where the development of perennial industrial crops, forestry, minerals, livestock husbandry and tourism and services is concentrated; attracting a lot of foreign investment capital, bringing many economic values to the province in particular and the whole country in general, helping to stabilize the population and reduce poverty. However, at present, water resources in Lam Dong province have had many warnings about the decreasing trend causing water scarcity in many parts of the province [6]. As for Lam Dong Province, many researches have been carried out for sustainable management and development in the future. Typically, [7] showed that climate change was clearly shown in Da Lat city (2000–2015): Average temperature increased by 0.4^{o}C, number of sunny hours, average annual rainfall tended to increase, the average annual humidity reduction is 0.15%. The extreme weather phenomena are increasing with more floods, flash floods, cyclones, hail and drought; Climate change has affected the farming industry in the area [8]; [9] used the MI moisture index to assess the level of agricultural drought in the province, the results showed that the drought occurred in most areas in the province; Each year, on average, there are about 1 to 2 droughts, mainly focusing on the winter–spring season lasting from 01 to 03 months. Areas with frequent drought are Don Duong, Lam Ha, Di Linh, Da Huoai, Da Teh and Cat Tien. Areas that are less prone to drought are Bao Lam and Bao Loc [10]; or some reports of the Department of Natural Resources and Environment of Lam Dong province on climate change [11], assessment of water resources in the province [12]. However, the research topics on water resources are still limited. Stemming from that situation, this study is done to calculate the scarcity of surface water occurring in Lam Dong Province in space and time. The results of the study can document follow–up studies and can be used by management planners as the basis for water resource management.

2. Research methods

Assessment of the level of scarcity of surface water resources is simulated through the diagram of figure 1. The research was conducted by collecting and synthesizing documents combined with expert methods and forecasting methods to assess surface water resources in the province; at the same time calculating water demand in 2018 and forecast by 2030 of Lam Dong province; from there as a basis for calculating the level of water scarcity occurring in the province by space and time by the method of calculating and classifying [2] together with the GIS–RS mapping method.

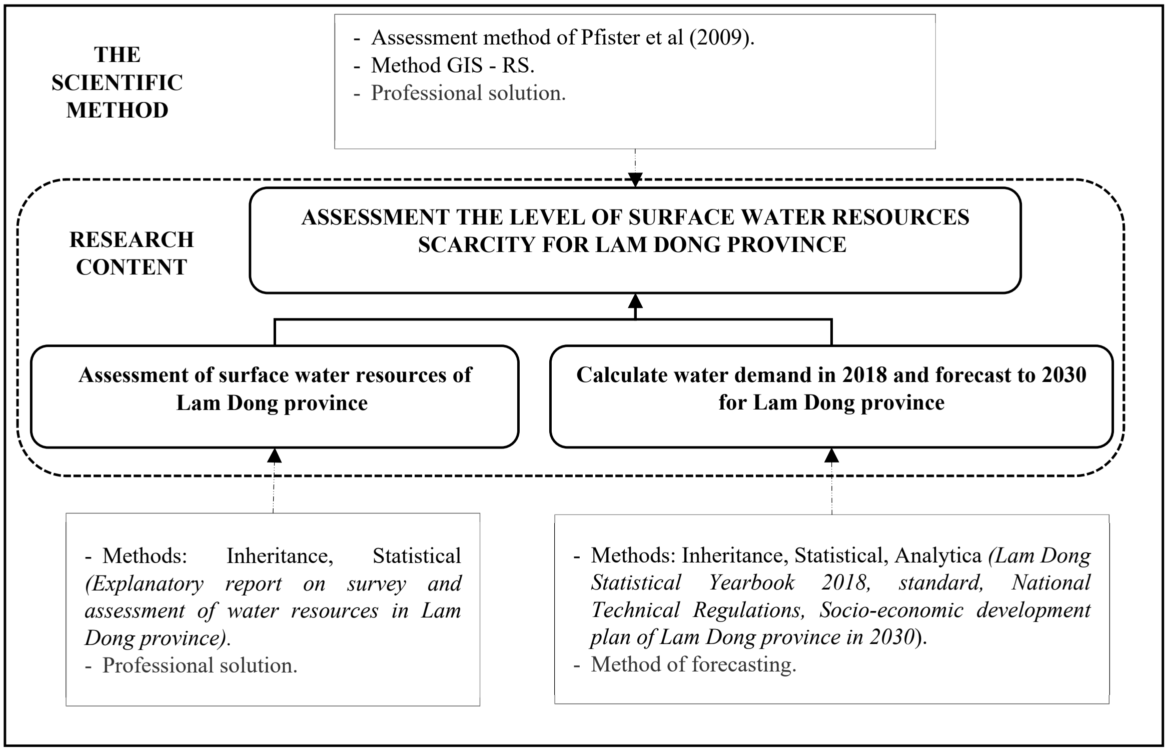

Figure 1. Diagram of assessment of surface water scarcity.

2.1. Methods of inheritance, statistics, analysis

The study uses selectively the research results from the Lam Dong water resources survey and assessment project report of Lam Dong department of natural resources and environment [11], to assess the current state of resource use. Surface water resources in the province; Using socio–economic statistics from Lam Dong Statistical Yearbook 2018 [13], to calculate the water use demand of sectors in the province, based on reference to the documents, that issued by the authorities of the State of Vietnam [14–16].

2.2. Prediction method

Based on Malthus' findings to forecast future water demand of sectors in the province, the model takes the form:

$$P_t=P_0(1 + r)^t \quad (1)$$

where P_t is forecast period composition; P_0 is the original period component; r is the rate of increase in the composition; t is time.

2.3. The method of consulting experts

With the desire to complete the report with the best possible results, this study has consulted and contributed by experts to clarify the problems in the research topic and contribute to the achievement of research results the best possible.

2.4. The ArcGIS map method

From the calculated results, the study used GIS–RS software to develop maps showing the level of water scarcity in Lam Dong Province.

2.5. Method of assessing water scarcity

Water scarcity is calculated based on WSI water pressure index. The Water Stress Index (*WSI*) is an indicator to quantify the pressure on water in an area or a country. It is related to the quantity of available water and the amount of water used, and is defined as the ratio between the annual water withdrawals and the total amount of fresh water recoverable. Therefore, the high water pressure index may be due to a small amount of available water or due to too high water demand. The WSI index has been verified for its effectiveness and reliability and is being used around the world [12].

Based on the results of interpretation and evaluation of the feasibility of each calculation method (advantages and disadvantages), combined with Lam Dong Province conditions and availability of calculation data of the topic, and requirements/research objective of the topic "Assessment of the stress level of surface water resources in Lam Dong province according to the socio–economic development planning period 2020–2030". Therefore, the study has selected one of the appropriate methods to calculate the scarcity of surface water in Lam Dong Province, which is Pfiter's method of calculation and classification [3, 12].

To calculate the WSI index, the WaterGAP2 global model is applied, describing the withdrawals–to–availability (*WTA*) ratio, the ratio between the amount of water withdrawn and the available water in more than 10,000 single river basins. This model includes the hydrological and socioeconomic component, the annual amount of available freshwater (WA_i) and the amount of water drawn by different users (WUij), respectively, for each basin i:

$$\mathrm{WTA_i} = \frac{\sum_j \mathrm{W_{ij}}}{\mathrm{WA_i}} \quad (2)$$

where $\mathrm{WTA_i}$ is the ratio of water withdrawn to water availability WTA in Basin i; and user group j is industrial and household.

The author just adjusted the water pressure index to a logistic function to achieve a continuous value between 0.01 and 1.

$$\mathrm{WSI} = \frac{1}{1 + e^{-6.4 \cdot WTA * \left(\frac{1}{0.01} - 1\right)}} \quad (3)$$

The WSI index according to Pfister can be categorized as follows:

< 0,1	Water scarcity is zero
0,1 – 0,4	Water scarcity is low
0,4 – 0,6	Water scarcity is moderate
0,6 – 0,9	water scarcity is high
> 0,9	Water scarcity is severe

Pfister's method of calculation and classification of input data is similar to that of OCED, Smakhtin and WRI; however, the calculation of the result to 0–1 by the logistic function and the classification level to determine water scarcity is different from the above methods. Therefore, this study can use the calculation and classification Pfister method [2] to suggest WSI index for Lam Dong Province.

3. Results and discussions

3.1. Surface water resources in Lam Dong Province

There are 3 major river systems in Lam Dong Province, including the Dong Nai River system, Krong No River, Luy River–Cai Phan Thiet. River and stream systems are divided into 7 river basins (Krong No River basin and vicinity; Da Dang River basin and vicinity; Da Nhim River basin and its vicinity; Thuong Dong Nai 1 River basin; Thuong Dong Nai 2 River basin; La Nga River basin and its vicinity; Luy River basin–Cai Phan Thiet and vicinity). The total average water volume in Lam Dong Province for many years is about 11 billion m^3. In particular, the total volume of water in the flood season in many years is about 6.9 billion m^3 (63%), the corresponding dry season is about 4 billion m^3 (37%). In the whole province, the amount of water is unevenly distributed across the province in both space and time [11].

Table 1. Flow, average total volume of water per month and year in the basins in Lam Dong province [11].

Months / River basin	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	TB	Wi (10^6 m^3)
Krong No	20.8	15.2	14.2	13.5	18.9	30.6	38.5	68.6	74.3	87.0	55.2	37.5	39.5	1,246.6
Da Dang	17.5	13.8	14.1	23.1	33.9	39.6	43.2	57.6	78.2	90.6	48.6	27.1	40.6	1,280.5
Da Nhim	27.4	21.7	22.1	36.1	53.1	62.0	67.6	90.3	122.4	141.9	76.1	42.5	63.6	2,005.6
Upstream Dong Nai 1	9.6	6.1	5.3	7.6	14.9	31.6	53.9	85.5	90.9	79.1	38.7	19.5	36.9	1,163.2
Upstream Dong Nai 2	22.2	14.2	12.3	17.6	34.6	73.4	125.0	198.4	210.9	183.6	89.8	45.3	85.6	2,699.5
La Nga	15.4	9.7	10.0	20.6	37.6	77.8	92.8	152.9	142.2	135.8	64.8	35.2	66.2	487.2
Luy–Cai Phan Thiet	2.7	1.4	1.4	2.4	8.9	11.1	12.0	12.6	23.6	41.9	17.8	6.2	11.9	373.8

3.2. Water use demand of sectors in 2018 and forecast to 2030 of Lam Dong Province

Water demand of the national economic sectors in the period of 2018 and 2030 is calculated specifically based on standards and norms (for living, agriculture, industry, tourism–services) according to regulations. Current regulations and available statistics from Lam Dong Statistical Yearbook 2018. Water demand estimate for 2030 is based on provincial planning data (socio–economic development orientation).

The calculation results of water use demand by sectors over the years are shown in Figure 2. According to the calculation results, the water demand for the entire Lam Dong province increases from 2018 to 2030. Total water demand the province's calculated for 2018 is about 1,225.42 million m^3/year. It is estimated that by 2030, the demand for this water will be about 1,305.54 million m^3/year, an increase of 80.12 million m^3 (ie an increase of 6.5%) compared to 2018. In 2030, water demand for the crop sector still accounts for the highest proportion (about 91.89%) of the total water demand in this period. The structure of water use demand has little change compared to 2018: the structure of water use in the farming sector tends to decrease slightly, down 1.43% and the rest tends to increase slightly. Demand for water increased mainly in December, January, February and March. The water demand of the sectors increases over time here, showing the population growth and strong development in socio–economic areas in Lam Dong Province, this puts great pressure on water resources; requires the response of water sources in both quality and quantity for the essential needs of life.

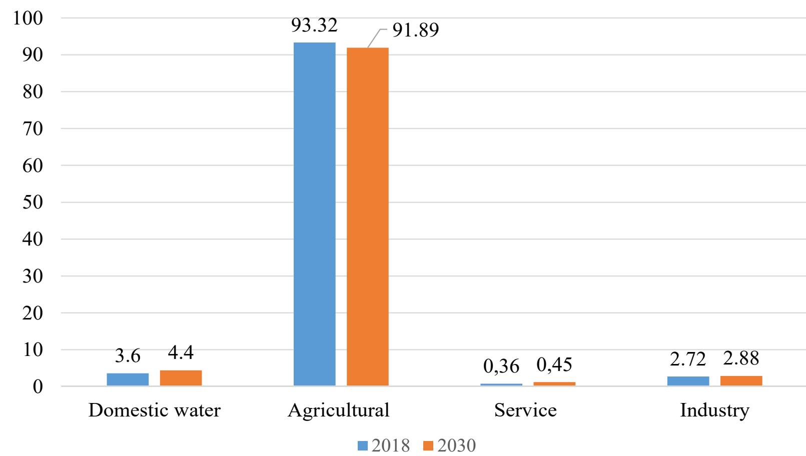

Figure 2. Water demand structure in Lam Dong Province in 2018 and 2030.3.3. Evaluate the level of scarcity of surface water resources in Lam Dong Province.

This study used the calculation and classification Pfister method [2] to assess the level of water scarcity in Lam Dong Province in the period of 2018 and 2030. This calculation method is based on water using demand by sectors and the total amount of available water in the province. For a comprehensive assessment, the study has calculated the WSI water pressure index according to the Pfister method on two cases: 1) The total available surface water in all basins in Lam Dong province; 2) The total amount of surface water available in 2 basins (Da Dang River basin; Da Nhim River basin), where there is a key economic region of the province in space and time.

When considering the total available surface water of all basins in Lam Dong Province, the WSI index for the entire region by 2018 and 2030 is 0.02 (<<< 0.1), so it is classified as at a level without water scarcity. The results show that on the whole Lam Dong province, the WSI index is positive; The total amount of surface water in the province is relatively abundant, meeting the needs of the national economy. However, according to each month of the year in the dry season months (especially January, February and March), WSI index is higher than the rest, but most of the months do not have any pressure or insignificant pressure (Figure 3).

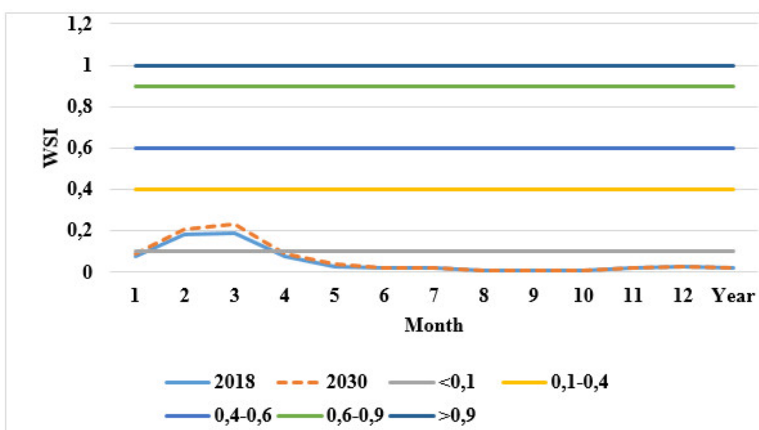

Figure 3. The level of water pressure according to Pfister method in the province through each stage considering the amount of available water by surface water.

However, considering the total amount of surface water available in 2 basins (Da Dang River basin and its vicinity; Da Nhim River basin and vicinity), where there is a key economic region of the province, the WSI index has obvious change. The research results show that the WSI index for the whole region by 2018 and 2030 is 0.03 and 0.04 respectively (<<< 0.1), so it is classified as no water scarcity. But, when looking at each month, the WSI index has differences by month in the present time (in 2018) as well as in the future (in 2030). The scarcity of water resources in the whole region occurs mainly in the dry season (December, January, February, March) of both times (Figure 4). In 2018, the serious water scarcity in January, February and March is 0.94 respectively; 0.99; 0.95 (> 0.9) and low water scarcity in December is 0.2 (0.1–0.4). In 2030, the serious water scarcity in January, February and March is 0.9; first; 0.96 (> 0.9) and low water scarcity in December is 0.2 (0.1–0.4). The level of water scarcity of districts in the key economic region of Lam Dong province is relatively similar; districts of Lam Ha, Don Duong, Duc Trong, Da Lat City has low water scarcity, only Lac Duong district has medium water scarcity (Figure 5).

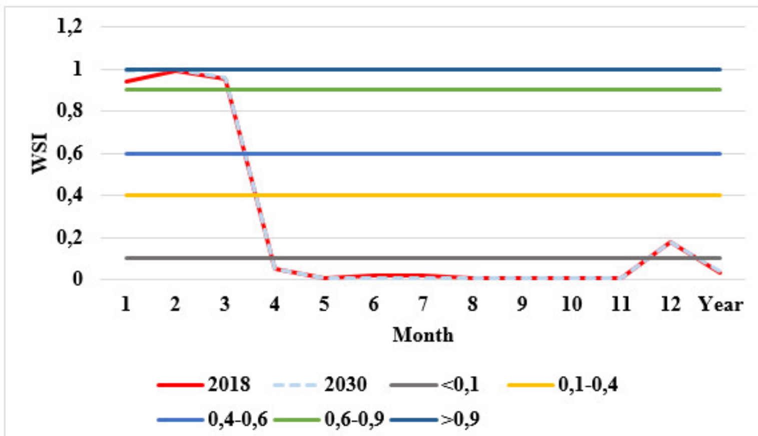

Figure 4. Diagram of the level of water pressure according to Pfister method in the key economic region of the province through each period, considering water availability equal to surface water volume over time.

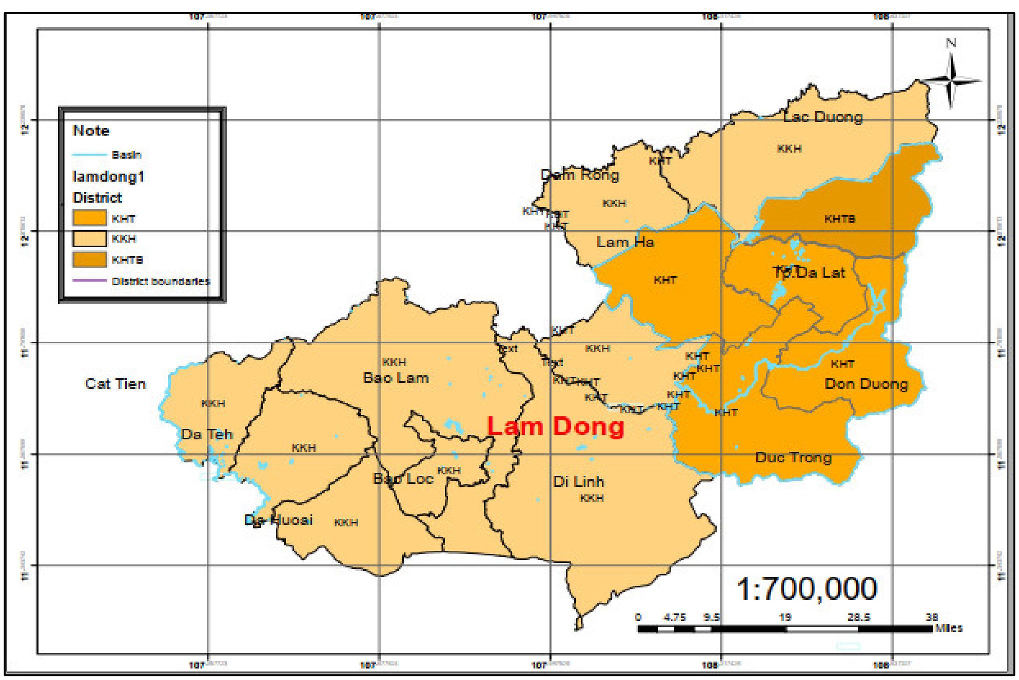

Figure 5. Map showing the level of water scarcity in Lam Dong Province.

4. Conclusions

The total water demand for all sectors in Lam Dong Province by 2030 increases in a stable direction (up 6.5%). The calculation is based on the socio–economic development planning of Lam Dong province in 2035 with a vision to 2050 (the orientation of population growth, changes in industry structure...) with accuracy and high reliability. Therefore, the calculation results of water use demand of the above mentioned sectors are considered reasonable, consistent with actual needs and exploited and used at an optimal level. Based on these results and assessments, we need to propose effective management methods to apply the plan well to socio–economic development in accordance with the proposed orientation. However, the results of calculating water scarcity in 2018 still take place in the dry season (12, 1, 2, 3) in some districts/cities in the province; By 2030, the level of water scarcity will not increase much compared to 2018 (because it is assumed that the water demand in 2030 is calculated according to the socio–economic development plan of Lam Dong province), so the calculation results do not show. The trend of water scarcity fluctuations between 2030 compared to 2018. Thus, it can be said that water pressure in Lam Dong province is mainly due to inadequate distribution of water resources. Therefore, it is necessary to develop an early water resource management plan in the area and incorporate the development of centralized water resources policies towards improving existing management capacity. At the same time, the results of this study can be a reference document in the planning for exploitation and use of water resources in Lam Dong Province.

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Research Article

Riverbank movement of the Mekong River in An Giang and Dong Thap Provinces, Vietnam in the period of 2005–2019

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Abstract: The development of remote sensing and Geographic Information System (GIS) techniques have given a substantial contribution to environmental studies in general and riverbank movement in particular. It helps the monitoring and calculation of the riverbank movement carried out more quickly and effectively. In this study, Alesheikh's method was used to classify the riverbank based on the multi−time Landsat image. The riverbank changes in Tan Chau in the period 2005−2019 were estimated. At the same time, the rate of riverbank change in An Giang and Dong Thap Provinces was calculated in this period by using the Digital Shoreline Analysis System (DSAS), an extension tool of GIS. The results showed that the process of erosion and accretion alternately occurred during the period 2005−2019 and most of the main river branches were eroded. The assessment of riverbank movements using multi−time remote sensing materials contributes a vital role in the management and protection of the shoreline for the socio−economic development planning in the region.

Keywords: Remote sensing; GIS; Landsat image; DSAS; Riverbank.

1. Introduction

Some studies show that erosion has more and more frequently occurred on a large scale along Tien and Hau rivers over the past few decades [1−3]. The average erosion intensity was presented based on the survey in the community living nearby these rivers. The causes, solutions to prevent erosion and to minimize erosion at critical locations have been mentioned by many authors [4−5]. Tan Chau, a town located in the upstream of An Giang province, is so−called a gateway of Tien River flowing into the Mekong Delta of Vietnam. The erosion along the riverbanks and canals happened more and more seriously in the Mekong Delta in general and Tan Chau in particular, causing considerable damage to people, land, houses, property, etc. It is due to the combined influence of natural processes such as river morphology, geological structure, river flow, and the socio−economic activities of the local citizens; for example, sand minion, dam and upstream residential reservoir constructions. Therefore, monitoring the riverbank changes and forecasting its trend in the

Tan Chau play a vital role in the protection and sustainable management of this area riverbank.

In recent years, there have been many studies using remote sensing to classify water surface from multi−time satellite images and to evaluate shoreline movements. Traditionally, medium resolution satellites (e.g., *Landsat and Sentinel−2*) have been used for riverbank studies that did not require very high accuracy [6−8]. NDWI and MNDWI indices for two different types of image sensors were used to study the shoreline movement of the East Coast Nile Delta. The NDWI was calculated as [(Green−NIR)/(Green + NIR)]. The Green and NIR refer to the reflection in the green and near−infrared spectra, respectively. On the other hand, the MNDWI was calculated as [(Green−MIR)/(Green + MIR), where MIR refers to the reflection in the middle infrared band [9−12]. Moreover, in a study of the Bhitarkanika Wildlife Sanctuary in Orissa, the Ration Band method which is using the ratio of image channels between channel 4 and channel 2 to channel 5 and channel 2 was suggested to analyze shoreline movement and sea−level rise along the coast. In particular, the study also indicated that channel 5, the infrared band between the sensor TM and ETM+, showed a strong correlation between water and soil because water absorbs the wavelength of the middle infrared channel (even cloudy water) [13]. Also, the AWEIsh index was used an automatic water extraction for the removal of non−water objects (built−up land) and removal of objects could not be removed [14].

There have been also many studies on shoreline changes carried out in Vietnam in recent years. The remote sensing application and GIS technique (*NDWI index*) were used to analyze the riverbank changes in Phan Thiet area [15]. For shoreline change, the method was applied to assess the erosion and accretion in coastal areas in Ca Mau and Bac Lieu provinces from 1995 to 2010. The pattern of coastline changes of Ca Mau and Bac Lieu was identified using Landsat TM images acquired in 1995, 2000, 2005, and 2010. In the study, a semi−automatic technique to extract the coastline was proposed [16]. Shorelines were also extracted the Da Nang Bay by calculating the ratio of spectral channels for Landsat MSS images based on channel 2 and channel 4, and for Landsat TM and ETM images based on channel 2 and channel 5. All Landsat images for the period from 1972 to 2017 were geometrically converted to UTM coordinate system with a resolution of 30m × 30m and 60m × 60m by using Alesheikh method [17].

Furthermore, many studies used the ratio method to extract the riverbank. Typically, a study in Quang Nam province, the regional riverbank changes of Dai and Thu Bon rivers was calculated. The results showed that the riverbank change was quite suitable, compared to measurement data [18]. Approached the exploitation and processing of multi−time satellite images on the cloud computing platform of Google Earth Engine (*GEE*) in riverbank fluctuation monitoring in the river delta brought about possible results. The study in Mekong Delta established the process of processing, calculating, extracting, and monitoring the riverbank/river bed changes by using Landsat−5, Sentinel−1 image data on the GEE cloud computing platform. The river movement of Tien and Hau rivers in the period of 1988−2018 was evaluated. The results showed the riverbank fluctuation tendency and especially the erosion and accretion speed in the Mekong River region. The results also showed that provinces located in the upstream river such as Dong Thap and An Giang, are more seriously affected by bank failure than the other ones [19], however, they did not consider the diurnal tidal and monsoonal impacts which make difficult to assess sedimentation processes. Also, the erosion and accretion rates were neglect. To deal with it, the results in the period from 1989 to 2014 of Khoi's research showed that the regional and local hydrodynamic characteristic is one of the reasons causing riverbank erosion and accretion. In the river−dominated zone, the erosion and accretion speeds are from medium rates (1–5 m/year) to high rates (> 5 m/year), and erosion processes commonly occur along the Mekong River branch (Tien River) [20].

For a segment flowing through An Giang, Dong Thap, and belongs to Mekong Delta. This section has complex terrain, stream folding, and substantial erosion. The assessment of riverbank change plays a vital role in protecting construction along riverbank [21].

The objective of the study is to assess the riverbank movement of the Mekong River, flowing through An Giang and Dong Thap Provinces in the period 2005 − 2019 by using the multi−time Landsat images and remote sensing image analysis techniques (*Alesheikh's method* [22]) which was evaluated as an effective method to extract riverbank from Landsat U.Duru image data (2017) [23].

2. Materials and Methods

2.1. Materials

The study area is a 24 km long river segment flowing through An Giang and Dong Thap Provinces which belong to Mekong Delta, Vietnam (Figure 1) from Vietnam−Cambodia boundary (X: 10°54'35.07"N, Y: 105°11'23.48"E) to Long Khanh islet downstream (X: 10°46'36.20"N, Y: 105°20'56.96"E). The study segment has braided−river−style. The riverbed has been getting wider, and there are sandbars formed in this area. The terrain of this study area is complex. The river shape is meandering and the river has been strongly eroded.

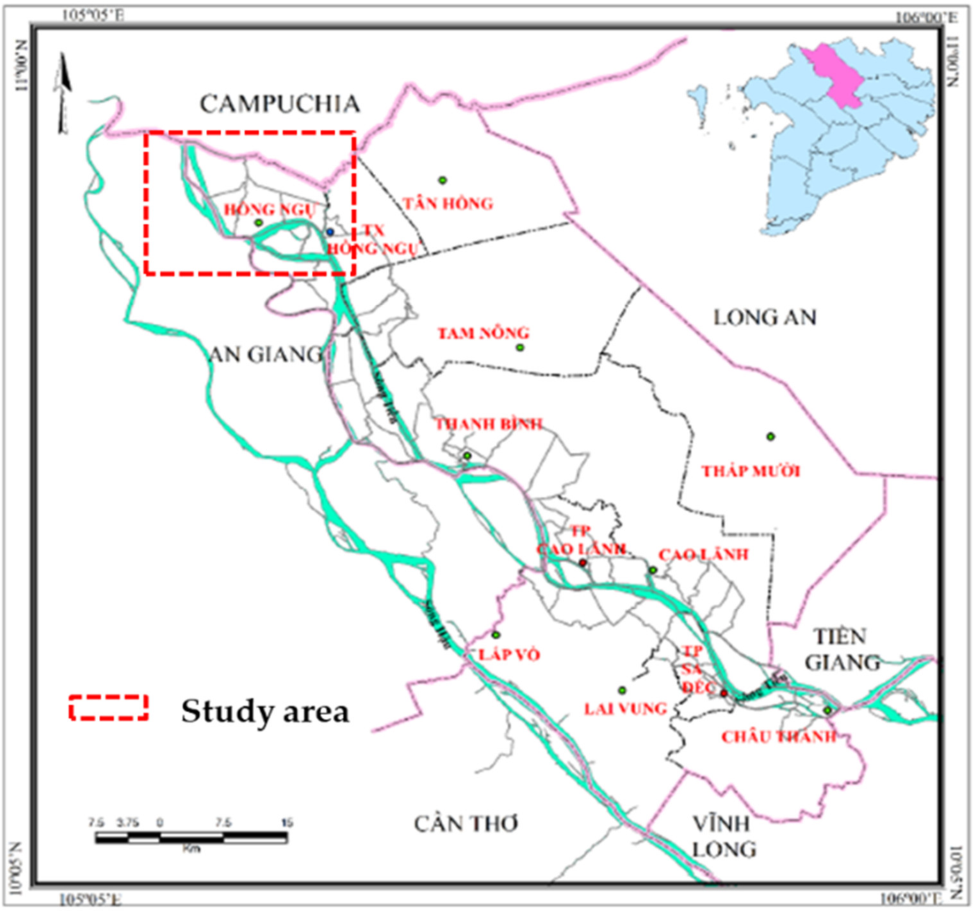

Figure 1. Map of the study area.

Multi−time satellite imagery including Landsat 4−5 (TM) and Landsat 8 Operational Land Imager (*OLI / TIRS*) images of the years 2005, 2010, 2015 and 2019 obtained from the US Geological Survey (*USGS*) (*www glovis.usgs.gov*) were used (Table 1). For the high quality of analysis, the images from July to December with less than 10% cloud coverage of the entire area and without sensor failure (near the riverbank) were selected.

Table 1. Remote sensing image data.

Column/row	Date	Satellite	Resolution	Number of image channels
126/052	19/11/2005	Landsat4−5TM	30m	7
126/052	27/12/2010	Landsat 8 OLI/TIRS	30m	11
126/052	9/12/2015	Landsat 8 OLI/TIRS	30m	11
126/052	28/12/2019	Landsat 8 OLI/TIRS	30m	11

2.2. Methodology

To evaluate the shoreline variation, three steps were carried out: (1) Image preprocessing; (2) Shoreline extraction based on the method of Alesheikh [22] (Figure 3); and (3) Shoreline variation calculation using DSAS (Computer Software for Calculating Shoreline Change).

2.2.1. Image preprocessing

Image geometry correction and atmospheric effects: The geometric and atmospheric corrections were made for the downloaded satellite images. The image coordinate system of these images was adjusted to the same with that of the Tan Chau base map, the UTM 48N projection zone (WGS84).

Merging and cropping: The study area captured by the Landsat satellite is on two separate images. So, it is necessary to crop and stitch the images together to obtain a complete study area image (Figure 2).

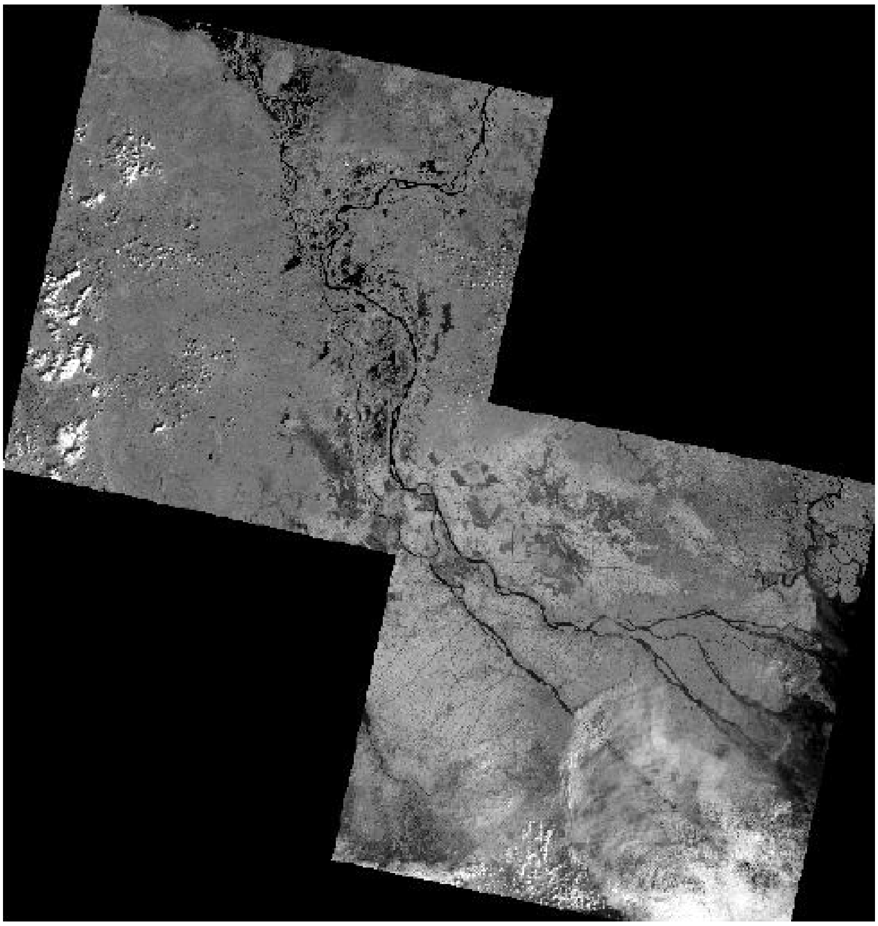

Figure 2. Channel 4 image after merging in 2005.

2.2.2. Shoreline extraction

The image channel ratio and the Filter High methods were used for image filtering to make the maps of shoreline movement. The implementation framework is shown in Figure 3.

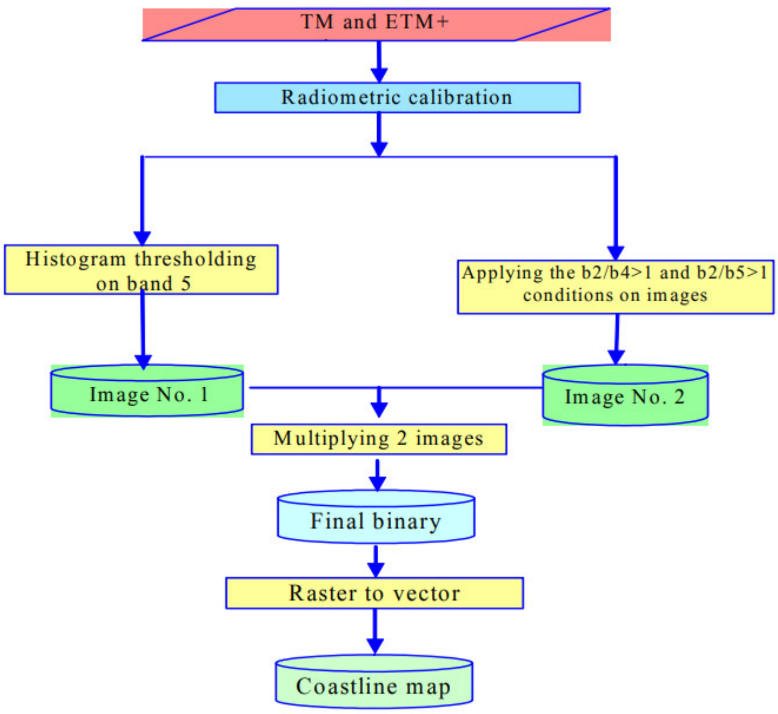

Figure 3. Shoreline separation is based on the method of Alesheikh [22].

2.2.3. Shoreline variation

The DSAS was used to calculate the differences in the shoreline rates, which were extracted from the fuzzy clustering – interactive thresholding method and manually digitized method.

The following statistical measures [24] are possible in DSAS to use [25]:

(i) Shoreline Change Envelope (SCE): The shoreline movement at available shoreline positions and the distances between them are measured and reported.

(ii) Net Shoreline Movement (NSM): The distances between the earliest and the lasted shorelines are reported

(iii) End Point Rate (EPR): It is derived by dividing the distance of shoreline movement by the time elapsed between the earliest and the lasted shoreline positions.

(iv) Linear Regression Rate (LRR): a rate−of−change statistic is determined by fitting a least square regression to all shorelines at specific transects. Further statistics associated with LRR include Standard Error of Linear Regression (LSE), Confidence Interval of Linear Regression (LCI) and RSquared of Linear Regression).

3. Results

The analysis results show that the fluctuation of erosion−accretion has occurred along the riverbank of the segment in the period 2005–2019 (Figures 4−6). Landsat images have a spatial resolution of 30 m × 30 m, so instead of illustrating riverbanks for each year, the remote sensing images once every five years (2005, 2010, 2015, and 2019) are collected in the research. The erosion and accretion area for each period is calculated as Table 2 and Figures 4−6.

Table 2. The erosion−accretion along the river for each period from 2005 to 2019.

Period	Accretion (ha)	Erosion (ha)
2005−2010	328	410.6
2010−2015	270.1	310.1
2015−2019	170	573.5

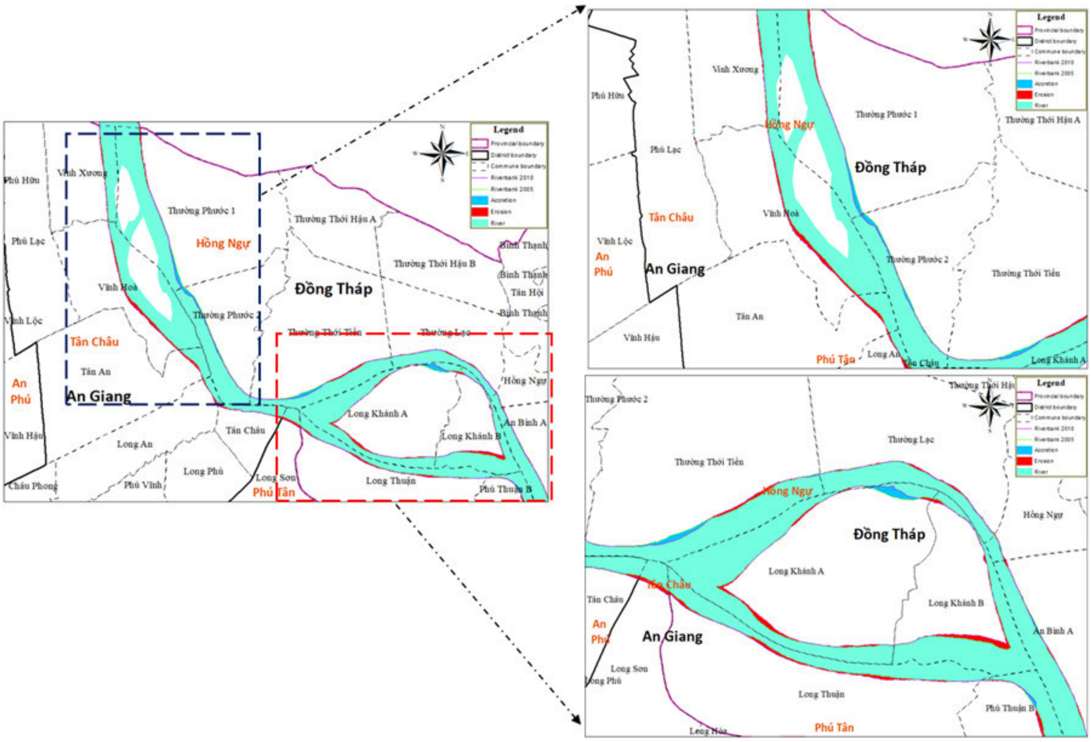

Figure 4. Riverbank erosion−accretion in the period 2005–2010.

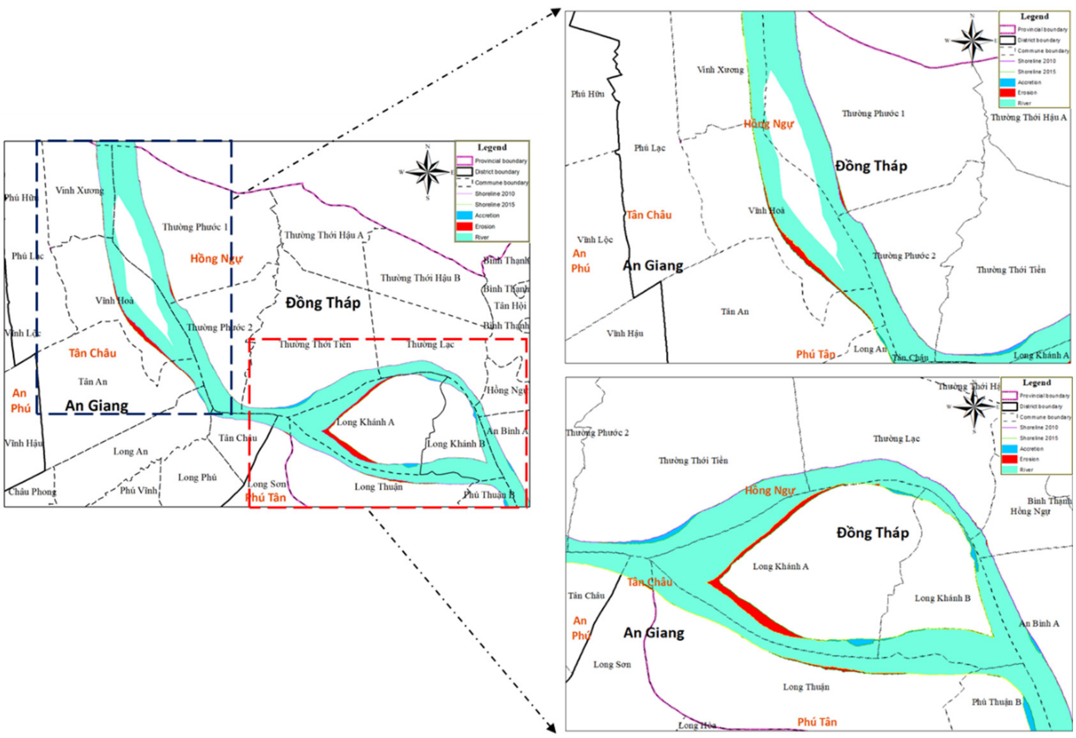

Figure 5. Riverbank erosion−accretion in the period 2010–2015.

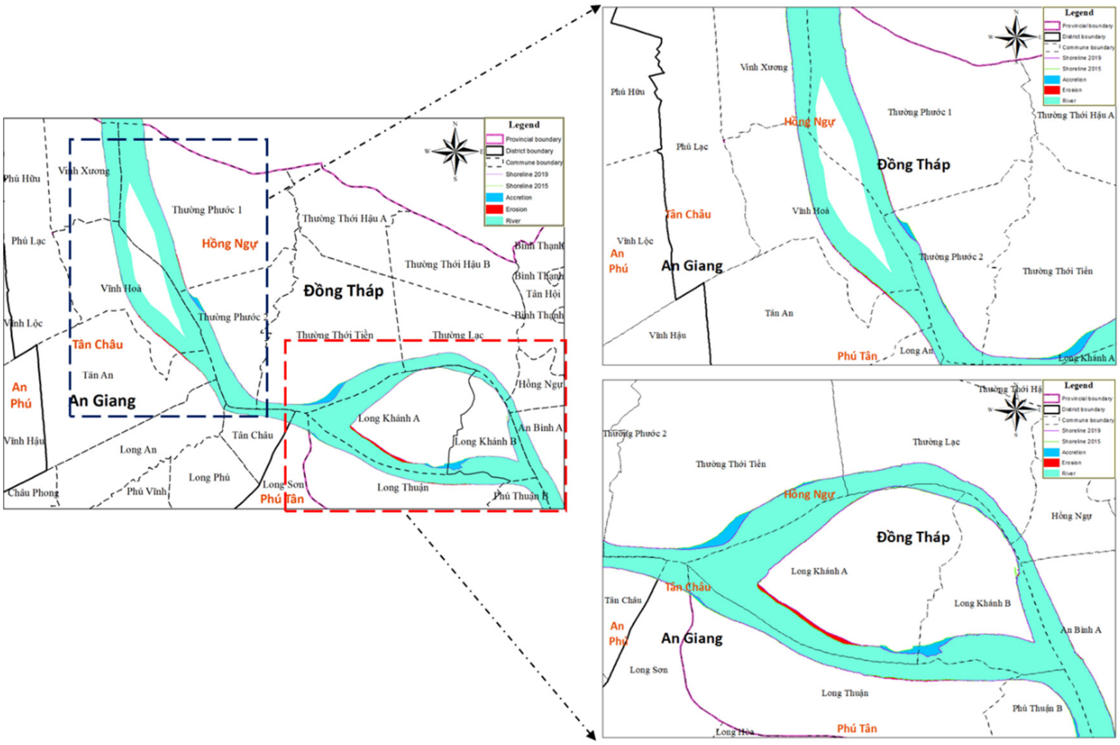

Figure 6. Riverbank erosion–accretion in the period 2015–2019.

From 2005 to 2010

Analytical results present that in the period 2005–2010, the left bank of the river segment from Vinh Hoa to Vinh Xuong Commune (in An Giang) was eroded at the highest rate of 21.56 m/year and Vinh Hoa commune eroded 49.42 ha (Figure 7 and Figure 4). Besides, a slight erosion was recorded in the riverbank in Long Thuan Commune. The measurement results showed that the bottom was more eroded and skewed towards the An Giang Province. During the data collection, we discovered that sand mine made the bed river more eroded [21]. Due to Tan Chau embankment built–in 2003, the riverbank of the segment was quite stable at Tan Chau Commune. In general, erosion was more dominant than accretion in this period in An Giang.

In Dong Thap Province, the Thuong Phuoc 1 and Thuong Phuoc 2 communes (Hong Ngu district) were accreted at medium rates of about from 10.4 to 12.06 m/year. High erosion could be observed not only in this segment but also in the upstream islet of Long Khanh A commune with 12.29 m/year. According to Khoi D.N.'s research, 2020 [20], the most influential erosion mechanism in this area was toe scouring, with the consequent bank failure. In contrast, the accretion was negligible. The rate of change in shoreline in An Giang and Dong Thap Province of the period 2005–2010 is shown in Table 3.

From 2010 to 2015

The analysis shows that the erosion segments mainly occur in Vinh Hoa, Vinh Xuong Commune (An Giang Province) with the highest erosion 25,26 m/year (Table 3). Slight accretion was observed on the riverbank of the Tan Chau embankment (Figure 5). In the period, erosion was still more dominant than accretion in An Giang.

Compared in the period 2005–2010, the erosion rate has shown a slightly decreased temporal tendency in the upstream islet of Long Khanh A commune at 21.3 m/year. Although the erosion area showed notable erosion (highest erosion in Long Khanh A commune), the riverbank of the segments in other commune was quite stable. The rate of change in shoreline in An Giang and Dong Thap Provinces of the period 2010–2015 is shown in Table 3.

From 2015 to 2019

During this period, alluvial sediment was reduced by two−thirds compared to the previous period [26], and, accordingly, the sediment boundary was also reduced. The calculation results show that the whole study area tended to erode. The major erosion segment was approximately 5 km−long and located in Vinh Hoa with an erosion speed of 28,56 m/year.

A higher erosion tendency which is compared in the period 2005–2015 was observed in Thuong Phuoc 2 Commune the upstream islet of Long Khanh A commune at 16.4−29.27 m/year (Table 3). The rate of change in shoreline in An Giang and Dong Thap Provinces of the period 2015–2019 is shown in Table 3.

Table 3. Rate of change in shoreline in An Giang and Dong Thap Provinces of the period 2005–2019.

Province	Commune	2005 − 2010		2010 − 2015		2015 − 2019	
		Accretion rate (m/year)	Erosion rate (m/year)	Accretion rate (m/year)	Erosion rate (m/year)	Accretion rate (m/year)	Erosion rate (m/year)
An Giang	Vinh Hoa	3.45−4.08	4.71−21.56		2.45−25.26	2.15−5.02	2.45−28.56
	Vinh Xuong	0.19−0.28	0.14−2.92		0.28−2.92	0.28−2.92	0.28−2.42
Dong Thap	Hong Ngu	0.32−2.13	0.42−2.16	0.37−1.9	0.42−2.16	0.42−1.93	0.42−2.16
	Long Khanh A	8.03−25.75	12.28−22.96	2.28−19.02	16.4− 21.3	9.38− 19.27	16.4− 29.27
	Long Khanh B	0.09−11.64	3.78 − 12.29	1.98−12.20	3.78− 10.45	3.78− 12.29	2.77− 14.29
	Thuong Phuoc 1	3.2−11.33	0.33−1.27	3.2−11.33	2.31− 2.52	2.98− 3.57	1.93−2.77
	Thuong Phuoc 2	10.4−12.06	7.87−8.43	10.27−11.69	2.37− 3.43	4.04− 10.43	2.37−4.43
	Thuong Thoi Tien	10.24−12.43	6.37−9.1	11.92−12.43	2.16−9.1	2.36−12.26	2.3−9.1

In comparison with the observation data of 12 July 2006 and 21 December 2019 (from the Department of Investment and the Tan Chau Construction Project) (Figure 7), the trend of the riverbank movement was adapted to the actual process. However, the rate of analysis accretion on the left bank of the river segment (Dong Thap) was 0.28 km in the period 2005 – 2019, compared to 0.42 km of observation from 2006 to 2019. This is explained as due to the time of data collection, hence, the change of water level had affected the mudflat area. The limitation of this study was that it focused on analysed the riverbank movement without islet change (Chinh Sach islet as Figure 7).

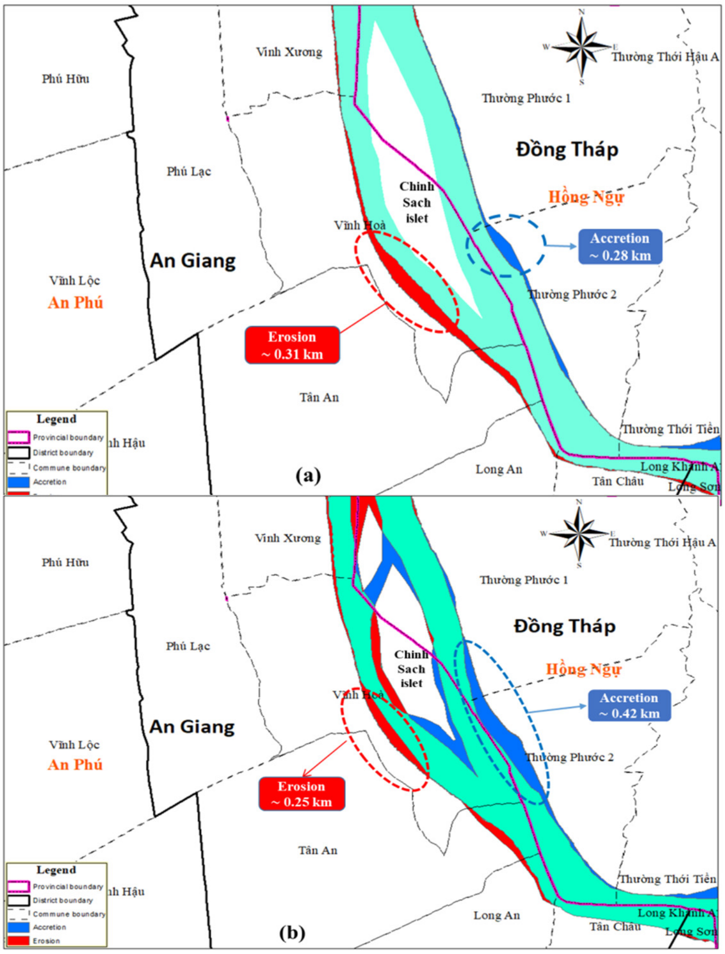

Figure 7. Analysis results in the period 2005–2019 (a) and observations in the period 2006–2019 (b).

4. Conclusions

In summary, the analysis results of riverbank movements in An Giang and Dong Thap Provinces achieved quite good results when compared to measurement data and previous studies [20]. Therefore, the research's method can be applied to a typical large area such as the Mekong Delta, giving optimal results on each main river branch. In this study, Landsat 5 and Landsat 8 remote sensing images were used to evaluate shoreline changes in An Giang and Dong Thap Province of the period 2005–2019, each segment has a different rate of variation.

The analysis results were observed that the erosion was more dominant than accretion in this period for both An Giang and Dong Thap Provinces. In An Giang, the erosion segments mainly occur in Vinh Hoa, Vinh Xuong Commune with the highest erosion of 21.56 m/year from 2005–2010, 25.26 m/year from 2010–2015 and 28.56 m/year from 2015 to 2019. At Tan Chau Commune, due to Tan Chau embankment built−in 2003, the riverbank of the segment was quite stable.

In Dong Thap Province, high erosion was observed not only in the river segments but also in an upstream islet of Long Khanh A commune. The erosion rate of the islet decreased from 2005−2010 to 2010−2015 (22.96 and 21.3, respectively) and then suddenly creased from 2015−2019, and the value has been creased to 29.27 m/year.

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editing, T.T.K., P.T.M.D.; Visualization, T.T.K., P.T.M.D.; Supervision, N.K.P., N.T.B; Project administration, N.K.P.; Funding acquisition, N.K.P.

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VIETNAM JOURNAL OF HYDROMETEOROLOGY

Research Article

Development of a framework for climate change adaptation actions' effectiveness evaluation

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Abstract: This paper presents the development of a framework for effectiveness evaluation of climate change adaptation actions. The top–down approach was used to develop criteria for evaluating adaptation actions at national level and their effectiveness in enhancing adaptive capacity at provincial level. The bottom–up approach was used to develop criteria for evaluating the results of adaptation actions at provincial level and their effectiveness in achieving the national adaptation objectives. The criteria are expected to be part of the results–based climate change adaptation monitoring and evaluation system to be developed for Viet Nam.

Keywords: Climate change; Adaptation actions; Criteria for effectiveness evaluation; Monitoring and evaluation (M&E) framework.

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1. Introduction

Being one of the most affected countries by climate change, in recent years, Viet Nam has been implementing many climate change adaptations (CCA) actions, and thus, it is necessary to evaluate the effectiveness of these actions with the aim to scale up or make adjustment accordingly. Viet Nam is in the process of development of a monitoring and evaluation (M&E) system, in which, effectiveness of CCA actions is the most important part of the system. Results of M&E system will be used in preparing reports on progress and achievements of national adaptation actions to submit to the National Committee on Climate Change, the Government. The results will be also used in the National Communication, Adaptation Report, and Transparent Report to be submitted to the Secretariate of UNFCCC.

The M&E of CCA policies and actions is necessary for efficient implementation and management of CCA actions. According to [1], the M&E of CCA actions can be conducted during the implementation (mid–term) or after completion and has important implications, including: (i) M&E of CCA actions can help to identify efficient and inefficient actions and causes as the basis to develop and carry out mechanisms and solutions for adaptation adjustment, making adaptation actions more efficient; (ii) M&E of adaptation actions can be used to check whether the adaptive capacity of a country, sector or community has been strengthened to face potential future climate change (CC) impacts or not; (iii) Indicating the effectiveness of national and international resources for adaptation.

Currently, the number of national adaptation strategies and actions in countries around the world and in Viet Nam is increasing and the financial need for adaptation is also greater. Therefore, the M&E of CCA actions has become an urgent requirement to ensure efficient and rational fund allocation for the implementation of CCA actions. Effectiveness evaluation for CCA actions can be done using criteria, which can be used to quantify the level of contribution to achieving CCA objectives. These criteria must be selected to ensure that the effectiveness of CCA actions can be monitored. In addition, these criteria need to be able to measure adaptation processes and quantify their results.

Based on the analysis of international experience in building M&E system for CCA, this study will propose methods and criteria framework for assessing climate change adaptation activities in order to serve state management.

2. International experiences in M&E of CCA

The M&E system mainly focuses on three directions, including: (i) community–level M&E; (ii) action–level or project–level M&E (program/project); (iii) policy–level M&E (local, national or regional) [1–2]. The process of developing M&E frameworks and criteria for effectiveness evaluation for CCA actions often apply a top–down approach, based on the reporting and information needs of climate finance mechanisms and donors' requirements. On the other hand, the community–level M&E framework tends to apply a bottom–up approach. This framework is often developed for sectors related to livelihood and disaster risk management based on consideration of community's vulnerability. Recently, many M&E frameworks are being developed based on a two–way approach with the interaction between top–down and bottom–up components. The United Nations Development Program (UNDP's M&E framework has been developed for implementation activities within the CCA financing framework of the United Nations Framework Convention on CC (UNFCCC), including: The Least Developed Countries Fund (LDCF) and the Special CC Fund (SCCF) [2].

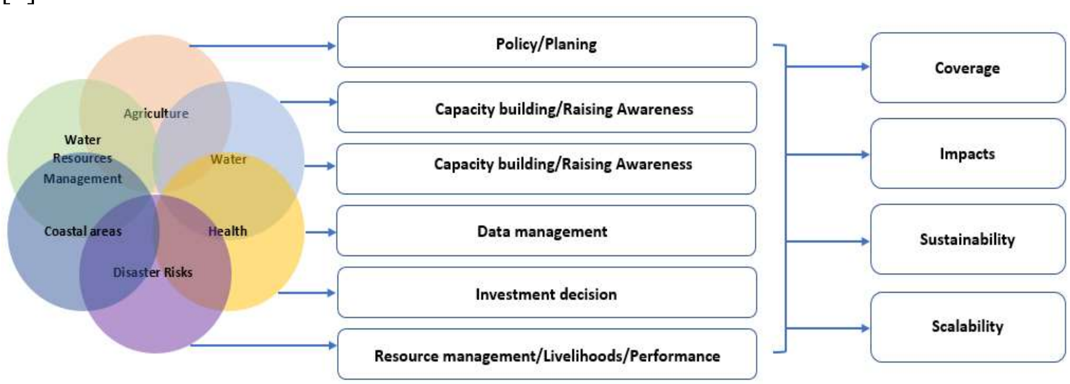

Figure 1. UNDP's M&E Framework [2].

UNDP's M&E framework is designed to aggregate data from the project to portfolio level and to encourage the use of consistent metrics, organized into six adaptation sectors of IPCC, including: food security/agriculture, water security, public health, disaster risk reduction, coastal areas and natural resource management. A set of criteria for effectiveness evaluation of CCA actions is designed to determine: (i)the level of stakeholders' involvement in the project; (ii) the level of achieving intended outcomes or changes made to support the project objectives; (iii) the project sustainability; (iv) the project scalability (Figure 1). Some of the criteria outlined in the UNDP's M&E framework seem too be too simple, e.g. "the number of communities involved in the project" or not clear, e.g. "the percentage of change in terms of participation" and evaluation results are more quantitative than qualitative. However, the UNDP's M&E framework is still a typical example of an M&E approach towards aligning and aggregating criteria of key sectors, providing and shaping a newer approach compared to earlier frameworks.

Guideline "Implementing adaptation measurement: Concepts and options for M&E in CCA" [1] developed by the World Resource Institute (WRI) and GIZ. This document guides readers to use a step–by–step approach in developing M&E systems for adaptation, incorporating a specific adaptation program socio–economic, environmental, climate, institutional contexts and other important issues (Figure 2). The Guideline proposes a three–pillar framework designed to reflect contributions of adaptation actions, including: adaptive capacity; adaptation actions; and, sustainable development in the context of CC.

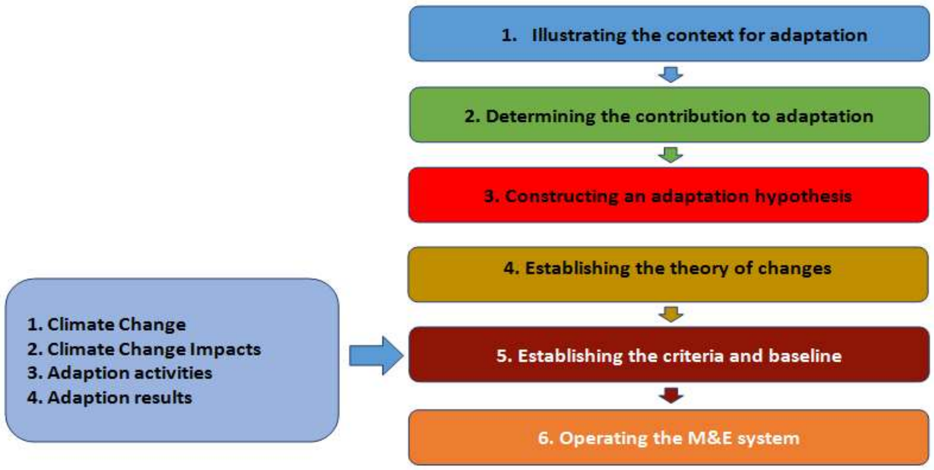

Figure 2. Steps to develop an adaptation M&E system under the adaptation measurement implementation framework [1].

"Adaptation is made to measure: Guideline for results–based design and monitoring in CCA projects" is GIZ's guideline developed by [3]. This document applies a step–by–step approach developed by [1] (Figure 2) with some modifications. Accordingly, Step 3 – developing adaptation hypothesis and Step 4 – presenting the theory of adaptation changes is combined into one step, Step 3 – Developing the result framework (Figure 3).

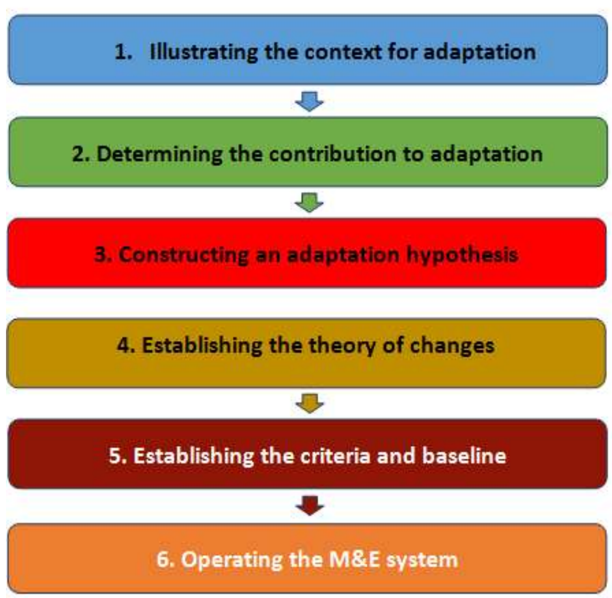

Figure 3. Developing the Results–based M&E system for adaptation [3].

GIZ also provides a set of indicators available online from adaptation projects in a variety of sectors [4]. The authors classified indicators according to measured results of specific adaptation processes [1]. The first pillar focuses on developing adaptive capacity. Indicators related to developing potential capacities to improve the readiness to CC response, focusing on the governance, information, risk management and underlying strategies, frameworks and support systems for developing adaptive capacity. The second pillar focuses on actual adaptation actions on vulnerability, resulting in output and outcome indicators for these actions. The third pillar ensures global development goals in the context of CC, using climate–adjusted sustainability indicators.

The Tracking Adaptation and Measuring Development (TAMD) framework has been developed by the International Institute for Environment and Development (IIED) to evaluate adaptation actions and adaptation–related development in different situations. The first M&E direction (Direction 1) uses top–down criteria, focusing on institutional and policy capacity of institutions to efficiently undertake climate risk management actions. Meanwhile, the second M&E direction (Direction 2) focuses on impacts of adaptation measures to reduce vulnerability, process and results that those actions contribute to bottom–up development [5].

The top–down criteria assess the CC risk management level integrated into development processes, actions and institutions. These criteria assess the reduction of human vulnerability level to CC. The TAMD Framework and Criteria are currently being piloted in five countries: Ghana, Kenya, Mozambique, Nepal and Pakistan.

TANGO's Resilience Assessment Framework was developed by the Food and Agriculture Organization (FAO) of the United Nations and the World Food Program in 2013. This framework integrates livelihood, natural disaster risk reduction and CC to address the underlying causes of vulnerability. The assessment criteria belong to three groups similar to those used by [1, 3], including: (i) strengthening risk management capacity (with short–term adaptation actions); (ii) enhancing adaptive capacity; (iii) enhancing development (can be understood as towards the possibility of transformation).

Later, the TANGO framework was modified by [6], differentiating community assets, types of competencies required and five general action groups including: disaster risk reduction; conflict management; society protection; natural resource management; property management and public services.

Germany is one of the countries that developed the M&E framework for CCA actions. The M&E framework includes 3 components: (i) Vulnerability assessment, which is a descriptive form of assessment of the progress achieved in the adaptation process; (ii) Evaluation is based on criteria to assess adaptation actions over time (past and present); (iii) Assess the level at which actions have been taken or planned to address potential risks and opportunities caused by CC [7].

The German M&E system's criteria are developed based on the DPSIR approach (Driving Force–Pressure–State–Impact–Response), focusing on developing impact and response criteria. These criteria have been developed for 15 sectors including agriculture, forest and forestry, and fisheries, etc. These criteria aim at policy makers and communities interested in and affected by CC. For example, criteria assessing impacts on crop yield and quality include: variation of wheat yield in winter season (per hectare), and year–on–year yield variation [8].

Kenya based on TAMD framework developed IIED to propose M&E criteria for provincial, sectoral and national level. Accordingly, in the first M&E direction, Kenya developed 63 national–level criteria, which are process criteria to measure institutional adaptative capacity for more than 300 proposed adaptation actions. From these 63 criteria, 28 criteria based on provincial results were proposed. Through consultation, these criteria were then short–listed into 10 criteria.

In the second M&E direction, consultation with stakeholders is necessary to assess and measure the vulnerability criteria to complement 62 institution–related criteria on adaptive capacity developed in the first M&E direction. Accordingly, 62 provincial–level criteria (bottom–up) for vulnerability assessment were developed, such as changes in rainfall and drought, heavy rain and flood, sea level rise, hail and frost, etc. Based on these provincial–level criteria, 27 national performance–based criteria were developed, then 10 were selected. These criteria aim to assess and measure the effectiveness of adaptation actions at local and provincial level and efforts to reduce vulnerability at national level [7].

The UK's M&E system has been developed to monitor the implementation of the NAP. The country's CC readiness is monitored and evaluated through UK's vulnerability assessment, planning and reporting process in the context of CC, particularly focusing on climate risk management. Therefore, this approach is based on the CC risk management framework (i.e. focusing on monitoring exposure, vulnerability and impacts). At the local level, monitoring is not usually carried out. However, in many cases, national criteria can be assessed and data can be collected from local or regional level to identify trends of vulnerability.

The M&E framework includes a set of criteria focusing on three main groups: (i) criteria on the level of risk, exposure and vulnerability; (ii) criteria on climate impacts; (iii) criteria on adaptation actions. The data system for M&E is mainly based on existing data sources collected and reported by the Government or related agencies. For example, flood and water resource risk data are provided by the Environment Agency (EA). M&E is carried out with a combination of qualitative and quantitative assessments, expert judgments on interpretation of criteria and economic and policy analysis. In addition, with the implementation of M&E through continuous and cyclical vulnerability reports, lessons learned will be drawn, promptly applied and integrated into the main policy making cycle. This is a highly scientific and efficient way to ensure that policies and adaptation actions are update and inclusive. However, this approach required sufficient data sources and political support, particularly in ensuring that data are cross–checked, compared and updated over time [9].

3. Approaches for assessing effectiveness of climate change adaptation

3.1. Climate change adaptation evaluation and monitoring framework

From the review of M&E criteria and frameworks in the world, the authors have proposed to develop a set of criteria to evaluate CCA actions in Viet Nam based on the result–based evaluation and monitoring framework for adaptation projects proposed by GIZ [3] combined with the TAMD proposed by IIED [5]. The M&E framework is developed using "step–by–step approach" with the following four (04) basic steps: (i) Step 1: Assessing adaptation context; (ii) Step 2: Identifying contributions to the adaptation process; (iii) Step 3: Developing a result–based analytical framework; (iv) Step 4: Defining criteria; with a top–down and bottom–up assessment approach (Figure 3).

Adaptation targets corresponding to specific actions/action groups are identified based on two (02) recent CC adaptation and response policies of Viet Nam, including: The NAP for the period 2021–2030, with a vision to 2050 (Decision No.1055/QD–TTg dated 20th July, 2020) and the Draft National Action Plan on CC Response for the period 2021–2030 (to be submitted to the Prime Minister by the end of 2020).

Accordingly, adaptation actions/action groups are classified according to three (03) main objectives, including: (i) Strengthening resilience and adaptive capacity; (ii) Being proactive and ready to respond to natural disasters, mitigate disaster risks and damages caused by natural disasters and CC; and (iii) Strengthening national adaptive capacity through institutional improvement, capacity building, securing resources, promoting international cooperation and implementing international obligations corresponding to priorities of the national development strategy. The steps for developing an M&E framework are presented in the following steps:

Step 1: Assessing adaptation context

Information on climatic and non–climatic factors that are likely to affect the implementation of adaptation measures plays an important role in the process of developing assessment criteria for CCA actions. This information will help regulators to define the baseline to calculate results to be obtained during and after adaptation actions are taken. Information used in determining adaptation context includes indicators and potential CC impacts, risks and vulnerability of sectors, areas and localities to CC (Figure 4).

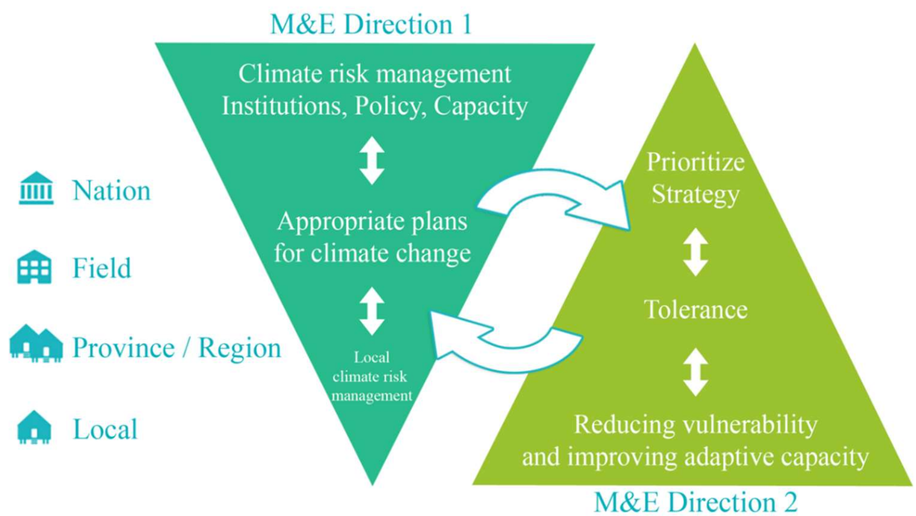

Figure 4. Top–down and bottom–up M&E model according to TAMD.

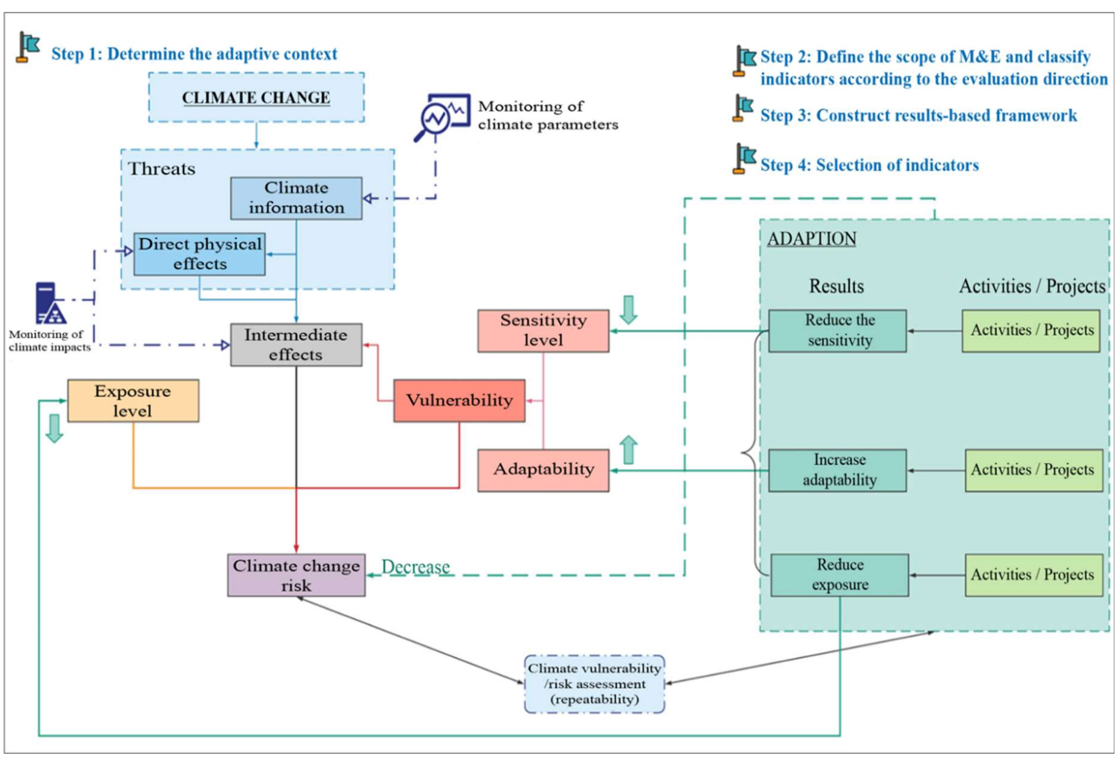

Figure 5. Steps to develop M&E criteria for the adaptation process in Viet Nam [3,10,11].

Assessing the risks and vulnerability to CC will support regulators and the implementation of adaptation projects to:

- Recognize and better understand climatic (and non–climatic) factors affecting and affected by adaptation interventions. These impacts can be direct or indirect including what risks specific actors will face, what non–climatic factor lead to vulnerability and resilience to social risks;
- Describe stakeholder needs and priorities such as livelihood and public health;
- Identify dual underlying impacts such as the likelihood of increasing risks or overlapping with other development efforts;
- Ensure flexibility in the implementation process towards objectives by applying different options when the original strategy fails.

Data sources used to develop criteria on CC and CC impacts in Viet Nam are as follows: CC manifestations and trends put forward in 2016 CC and sea level rise scenario of Viet Nam [12] and CC impacts can be synthesized and analyzed based on scientific research, results of domestic and foreign studies and projects. CC impacts are normally assessed by: (i) sectors, including natural resources and environment, agriculture and rural development (farming, livestock production, forestry, fisheries, and transportation, housing and urban development, tourism, public health, commerce, energy, industry and gender equality; (ii) regions including the Mekong Delta, the Northern Delta, coastal areas, mountainous areas.

Step 2: Determining the scope of CCA action assessment and classifying criteria by approach

Adaptation actions will be monitored and evaluated at national, sectoral, sub–national and project levels. The M&E framework will be implemented in two directions, including: (i) Direction 1 – top–down assessment of adaptation actions related to institution, policies, and overall capacity building in climate risk management (CRM); and (ii) Direction 2 – bottom–up assessment of adaptation actions, addressing factors directly related to CC vulnerability. Depending on objectives and scope of M&E, directions and assessment objects are applied. For example, the national M&E of adaptation actions covering sectors/areas focuses on evaluating the effectiveness of CRM policies and mechanisms at national level and how these policies are linked to the national development goals (strategic priorities) or the ability to contribute to the resilience of the respective sector/area. Table 1 lists the directions and subjects for assessment at different levels for the adaptation process in Viet Nam.

Step 3: Developing a result–based analytical framework

Based on the context of adaptation identified in Step 1 and the scope of CCA action assessment in Step 2, Step 3 will identify the expected outcomes of an adaptation action/policy and the method to achieve them (strategy) with the Theory of Change (TOC) (Figure 5). Accordingly, for the bottom–up assessment direction, the assessment framework is identified along the roadmap of adaptation action impacts starting from those actions to outputs, direct results to impacts for national development to describe the logical and reciprocal relationship between results and how they contribute to overall development goals. For the top–down assessment direction, enhancing CRM at the national level leads to a better CRM system at the sector/area level, thereby enhancing resilience and adaptive capacity of institutional, environment, economic and social systems for CC.

Step 4: Determining criteria for effectiveness evaluation of CCA

Criteria for effective evaluation of CCA are determined (Step 4) after assessing the adaptation context (Step 1), determining the scope of CCA action assessment and classifying criteria by approach (Step 2) and result–based framework (Step 3) for policies, action/group of actions.

The criteria are designed according to quality criteria of the SMART rule (Olivier, Leiter, and Linke 2012) including: (i) Specific: criteria are precise and well–grounded; (ii) Measurable: criteria are quantifiable; (iii) Agreed: criteria are accepted by project partners; (iv) Relevant: criteria are valid and can describe underlying problem; (v) Time–bound: a temporary time reference is given. Accordingly, monitoring criteria according to objectives of adaptation action/group of actions; monitoring the process and effectiveness of adaptation actions at national, sector/area, sub–national and project levels are implemented.

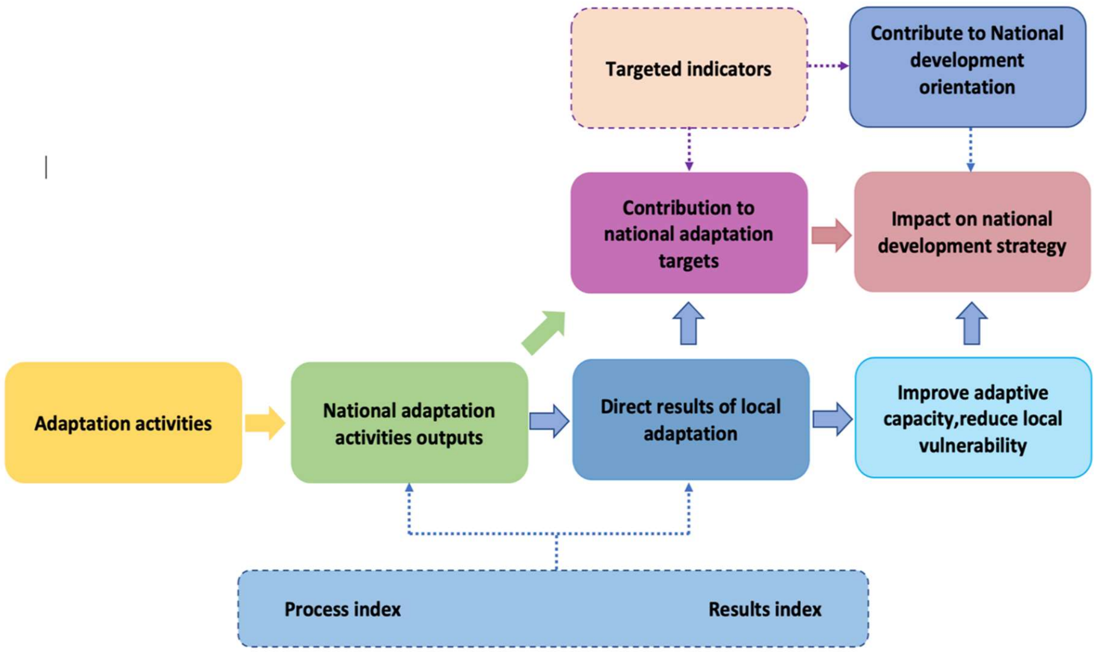

Figure 6. Model for determining assessment criteria according to the impact roadmap.

Table 1. The relationship between the CCA action assessment levels applied for Viet Nam [10].

Objectives of evaluation	Evaluation with TAMD framework	Space and time
Tracking adaptation effectiveness at national level	National institutional mechanism for climate risk management (Direction 1) National strategy priority (Direction 2)	National level Long–term (up to 10 years)
Tracking adaptation effectiveness of specific sectors/areas	Climate risk management at sector/area level (Direction 1) Sector/area resilience (Direction 2) Sector/area adaptation actions (Direction 2) Resilience of people and communities related to sector/area (Direction 2)	National level Long–term
M&E of specific adaptation actions	Specific projects/activities related to climate risk management (Direction 1) and/or resilience (Direction 2)	Local or regional level Short–term
M&E of specific adaptation policies	Specific policies related to climate risk management (Direction 1) and/or resilience (Direction 2)	National or local level From short to medium term

3.2. Determining criteria for effectiveness evaluation of CCA

3.2.1. Monitoring criteria according to adaptation objectives

For each strategic adaptation priority, monitoring criteria that can be used include:

- Is there a plan? Assess if there are policies and plans to adapt to respective climate risks;
- Have actions been taken? Have the adaptation action/group of actions listed in the NAP and the National Action Plan been implemented and are they in line with the set objectives or not;

Have contributions been made to reduce vulnerability? This criterion is used to assess whether, although plans and adaptation actions are being implemented, the vulnerability to CC continues to increase?

3.2.2. Criteria for process and adaptation effectiveness monitoring

As mentioned in the above sections, the criteria are developed with two (02) evaluation directions: (i) top–down (CRM) and (ii) bottom–up (actions aiming at increasing resilience to CC). Table 2 shows criteria in different directions and evaluation levels.

Table 2. Classification of M&E criteria by evaluation and evaluation level.

M&E level	Direction 1: Climate Risk Management (CRM)	Direction 2: Adaptation results and development
National	- Integrating CC into the planning process; - Institutional coordination; - Budget and finance for integration and adaptation; - Institutional understanding of CC integration and adaptation; - Use of climate information; - Use appropriate information and methods in planning; - Stakeholder participation in the national planning process; - Stakeholders' awareness of CC, risks and responses.	- Synthesize local/regional data on the number of changes achieved in terms of vulnerability and status of development; - Changes related to economic loss and other CC impacts such as the number of people affected by natural disasters at national level combined with increased climate hazards (exposure).
Sector/Area	- Similar to national criteria but applicable within area/sector.	- Similar to criteria at the local level but applicable within sectors/areas

M&E level	Direction 1: Climate Risk Management (CRM)	Direction 2: Adaptation results and development
Provincial/Regional	- Similar to national criteria but applicable within Province/Region;	- Synthesize local data on the number of changes achieved in terms of vulnerability and status of development; - Changes related to economic loss and other CC impacts such as the number of people affected by natural disasters at the provincial/ regional level combined with increased climatic hazards (exposure).
Locality/project	- Similar to national criteria but applicable to the local scope; - Apply CRM measures; - Climate risk awareness, response options; - Availability, accessibility and use of climate information	- The number of people becoming less vulnerable–assessed by vulnerability criteria; - Changes in poverty rate and other development criteria related to climate hazards.

These criteria can be synthesized and selected from the criteria for assessing CCA' effectiveness in Viet Nam [13] and GIZ's Library of Adaptation Criteria [14].

4. Conclusions

Through the study, the authors have developed a framework for climate change adaptation actions' effectiveness evaluation for possible inclusion in the M&E system of CCA. The top–down approach was used to develop criteria for evaluating adaptation actions at national level and their effectiveness in enhancing adaptive capacity at provincial level. The bottom–up approach was used to develop criteria for evaluating the results of adaptation actions at provincial level and their effectiveness in achieving the national adaptation objectives. In order to evaluate of CCA actions, two set of criteria should be considered: (1) Effectiveness evaluation of CCA actions at a national level; and, (2) Effectiveness evaluation of CCA actions at a provincial level.

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Conflicts of Interest: The authors declare no conflict of interest.

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Research Article

Artificial intelligence (AI) application on plastic bottle monitoring in coastal zone

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Abstract: Plastic bottle is using everyday causing critical problems to environment, especially sea environment. A large number of plastic bottles come back to continent from sea by wave and stuck at coastal zone. Plastic waste in general or plastic bottle in particular has bad effects on coastal ecology. Artificial intelligence (AI) is widely applied in many fields, including environment. In this research, we developed a plastic bottle waste detection AI model by using Python, Yolo3, TensorFlow, ImageAI to detect and monitor plastic bottles in a coastal zone. Thousands of photos have been used to train the AI model for increasing detection accuracy. An AI model for plastic bottle detection has been built. The AI model then was applied to monitor plastic bottle waste in a coastal zone. The results showed that AI could detect plastic bottles from video sources better than from photo sources. The AI detected 68.52% sample bottles from photo sources while it could detect 100% a single bottle and 96.05% multiple bottles from video sources. Color bottles were detected better than transparent bottles. The research found that AI is an efficient tool to monitor plastic bottle in a coastal zone. It can automatically monitor and detect plastic bottles at a beach or floating bottles on sea surface.

Keywords: plastic bottle, AI, artificial intelligence, plastic monitoring

1. Introduction

Plastic waste is now one of critical environmental problem in the world. It threatens to both environment and habitat. Marine environment is a major victim of this menace [1]. When plastic debris enters into oceans, it causes damages to ecology, aesthetics, and economy [2]. Recent study reported that, more than 300 million metric tons of plastics are generated every year [3], in which 8 million metric tons of plastic waste have been released into the ocean [4]. Plastic bottle is widely used in households. Almost all bottled–water are used plastic bottles [5]. Used plastic bottles are generated everyday. About 600 billion plastic bottles are released every year in the world, and only about 47% is collected [6]. Uncollected plastic bottles go into water, soil, and sediment environment. Used plastic bottles also move to river and oceans. Uncollected plastic bottle waste moves from ocean back to continent by waves causing environmental problems to coastal zone. Therefore, monitoring plastic bottle waste in the environment is an important work of environmental management.

Artificial Intelligence (AI) application is growing rapidly recently. AI has been applied widely in medical [7], production [8], security [9], transportation [10], telecommunication [11]. In the environmental research, AI has been applied to model the formation of methane gas hydrate [12], to monitor soil water content [13], to estimate gas production rate in reservoirs [14]. It is lack of knowledge in applying AI to monitor environment, especially in monitoring plastic bottle waste in coastal zone.

TensorFlow is the most popular deep learning math libraries created by researchers at Google [15]. Tensorflow has been applied in machine learning [16–18], object detection [19–21]. Tensorflow works well with Python, a high level programing language, to build AI application [22]. You Only Look Once (YOLO) is a deep learning model, real time object detection system [23–24]. YOLO was used to localize and recognize license plate [25–26] or human action [27], to detect surface defects of steel strip [28]. The combination of Python, TensorFlow and Yolo3 help to build an AI for object detection application more accurately.

Analytic hierarchy process (AHP) was developed by Saaty [29]. It is a good tool to perform multi–criteria analysis. AHP has been widely applied in choosing groundwater potential zones [30], selecting mobile health [31], and analyzing oversize cargo transportation [32]. AHP also was used in machine learning to perform decision making [33]. Therefore, AHP is a good method to analyze multi–criteria.

With the lack of knowledge about applying AI to monitor plastic bottle waste, this research has 3 objectives that include: (1) to build an AI model to detect plastic bottle waste; (2) to apply developed AI to monitor plastic bottle waste in a coastal zone; (3) to compare between the AI application and human ability in monitoring plastic bottle waste.

2. Materials and methods

2.1. YOLO algorithm

The YOLO divides input image into GxG grids. If the center of a detecting object falls into a grid cell, the object is detected by that grid cell. Each grid cell predicts N bounding boxes and confidence scores for those boxes. Each bounding box has 5 predictions: x, y, w, h, and confidence. The x, y coordinates represent the center of the box relative to the bounds of the grid cell. The w and h are predicted relative to the whole image width and height. The confidence prediction represents the Intersection over Union (IOU) between the predicted box and any ground truth box. Each grid cell also predicts C conditional class probabilities. Finally, the predictions are encoded as an $G \times G \times (N*5+C)$ tensor. The best results for YOLO V.1 on Pascal Visual Object Classes is 7x7 grid cells predicts 2 bounding boxes, PASCAL VOC has 20 labelled classes so C = 20. Therefore, YOLO prediction is a $7 \times 7 \times 30$ tensor (Figure 1) [34].

YOLO V3 is much deeper and more accurate than the other two versions. YOLO V3 is able to get more meaningful semantic information during the training process. However, YOLO V3 takes more time to train and detection of very close objects still has some limitations [35].

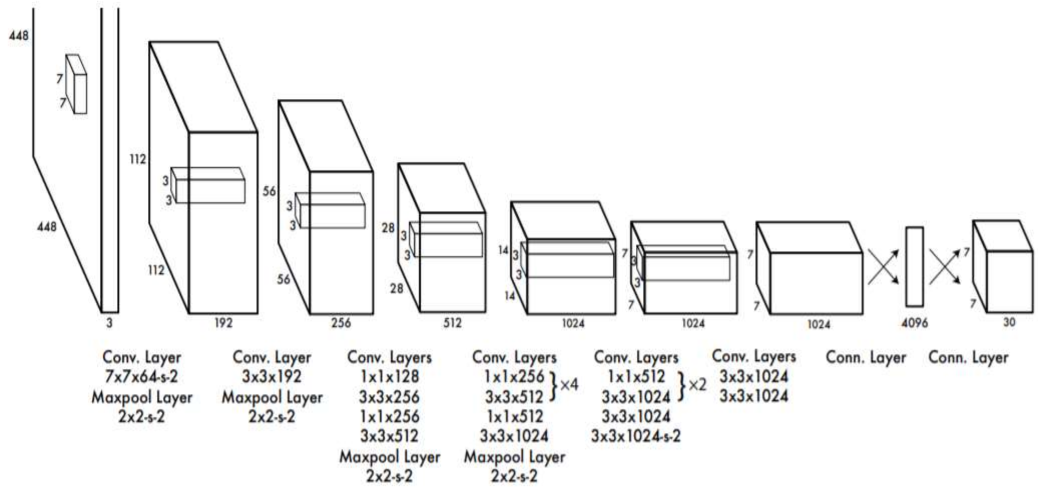


Figure 1. Structure of YOLO V1 [34].

2.2. Programing language

In this research, we used Python programing language (version 3.6), TensorFlow math libraries (version 1.15), YOLO real time object detection model (version 3) to build an AI for plastic bottle waste detection. For faster Python coding, we used ImageAI (version 2.1.5), an open–source python library developed by Moses Olafenwa and John Olafenwa. It helps to build systems and applications with self–contained computer vision and deep learning capabilities [36]. ImageAI requires dependencies: TensorFlow, OpenCV, Keras installed via pip under Python 3.6 environment.

2.3. Dataset preparation

To prepare a dataset for training the AI model, we used the Pascal Visual Object Classes (VOC) to label 1125 images. The dataset contains a list of each individual plastic bottle annotated from every single image in the plastic bottle dataset. Two labels set in the dataset were bottle and plastic. These labels helped machine learning objects and remember in its database. Then we created a folder for our dataset. In this parent folder, we created two child folders: train and validation folder. In the train folder, create images and annotations sub–folders. We put about 80% of our dataset images in the images folder and put the corresponding annotations for these images in the annotations folder. In the validation folder, we put the rest of your dataset images in the images folder and put the corresponding annotations for these images in the annotations folder.

We used LabelImg software to annotate the dataset with the Pascal VOC format. The Pascal VOC format uses XML files to store details of the objects in individual images (Figure 2).

Figure 2. Labeled images followed the Pascal VOC format.

2.4. Initiate the detection model training

To ensure that our trained model have better detection accuracy, we used transfer learning from a pre–trained YOLOv3 model in the training and the ImageAI. A personal computer (PC) was used for training with the GPU NVIDIA GeForce GTX 1060 6GB and use 2 Ram 16Gb DDR4 3000Mhz to ensure the training speed with large epoches. The processor was AMD Ryzen 5 2600X Six–Core Processor, 3800 MHz, 6 cores, 12 logical processors. The model trainer will run in CUDA developed by NVIDIA. The trained model was run under 100 epoches, batch size equal to 2 due to the maximum capacity of the GPU.

2.5. Evaluate the model

During the running process, new models were saved based on the decreasing in the validation loss. In most cases, the lower the loss, the more accurate the model will be detecting objects in images and videos. However, some models may experience over–fitting and still have lower losses. To ensure we picked the right model for highest accuracy, we used ImageAI to evaluate and calculate the mAP of all the trained models saved in the dataset/models folder. The higher the mAP, the better the detection accuracy of the model.

2.6. Samples

To evaluate the developed AI model as well as its ability in monitoring plastic bottle waste in coastal zone. We took 70 sample photos (dimensions 1276 x 956) and recorded 20 videos (frame width 1920, frame height 1080, frame rate 30.01 frames/second) at different places of coastal zone in Halong City, Quang Ninh, Vietnam. Photos and videos were divided into different background environmental categories: uniform environment and noise environment; single bottle and multiple bottles in a photo or video. The research flowchart is showed in the Figure 3.

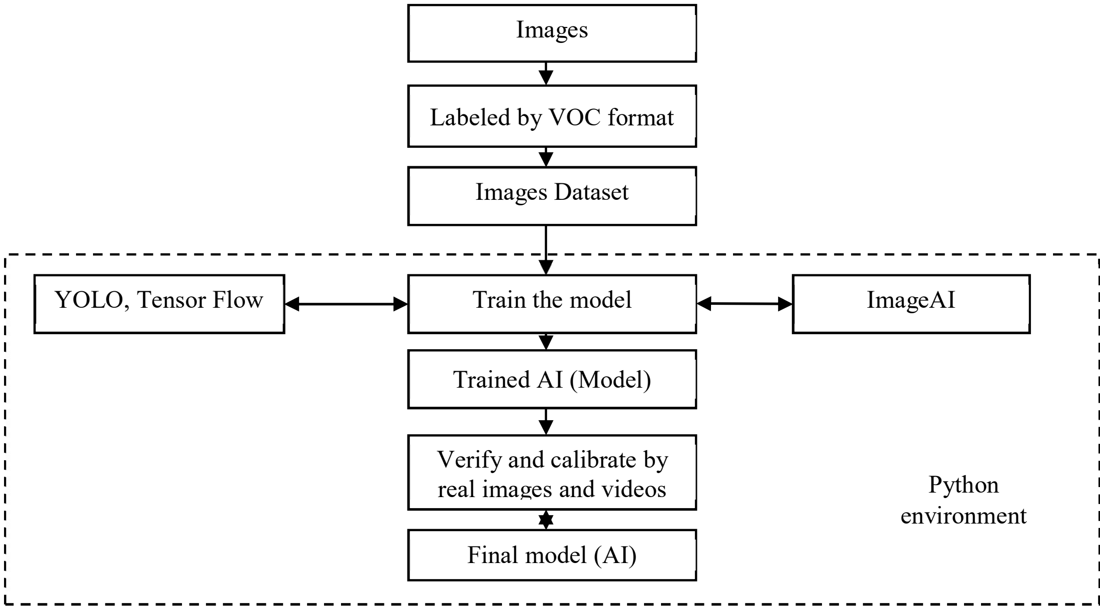


Figure 3. Research flowchart.

2.7. Multi–criteria analysis

To compare between human and AI in detecting plastic bottle waste, we selected 7 criteria to compare under the condition of industrial revolution 4.0 that include: automation, low initial cost, low operation cost, connecting ability, accuracy, 4.0 compatibility, large scale application. The pair comparison of these criteria was performed by the AHP to determine the weighting values of each criteria and between human and AI.

3. Results and discussion

3.1. Plastic bottle waste detection model

After training the AI plastic bottle detection model, we selected the most appropriate model with highest mAP equal to 0.1916, the lowest loss 3.015. The selected model was used to detect real images and videos to evaluate the detection accuracy.

3.2. Plastic bottle waste monitoring from photos

3.2.1. One plastic bottle in a photo

When a bottle appeared clearly in the photos, it could be easily detected in both uniform background (Figures 4a, 4c, 4d, 4k), and noise background (Figures 5a, 5b, 5d, 5f). These photos had high contrast between environmental backgrounds and bottles. When the contrast was low, the bottles were not well detected (Figures 4i, 5c, 5h). Color of background environment also affected to the detection. If the color of bottles are similar to background color, it is not only hard to detect by human but also by the AI model (Figures 4i, 4h). In average, the developed AI model could detect 68.52% of plastic bottles in the photo samples. The AI model could detect bottles even the original shape of bottles changed (Figures 4b, 4f) or submerged in sand and water (Figures 4g, 4h, 4j, 4l). In very noise environment, the bottles were well detected when the color of background environment differ from color of bottles (Figures 5a, 5b, 5g, 5i).

3.2.2. Two or more plastic bottles in a photo

In the case of two or more plastic bottles appeared in the photos, the detection ability of the AI is 63.33%. The results showed the significant decrease in detection percentage in noise environment dropped to 50%. Bottles located at the corner of the photos, the AI model could not well detect (Figure 6i). Opposed to bottles located at the center or near center of the photos, the AI model could well detect (Figures 6b, 6f).

Figure 4. Detection in different kind of plastic bottles in uniform environment.

Figure 5. Detection in different kind of plastic bottles in noise environment.

Figure 6. Detection of multiple plastic bottles in a photo.

3.3. Monitor plastic bottle waste from videos

When a single bottle appeared in a video frame, the AI could recognize 100% samples of both uniform and noise background (Table 1). Comparing with single bottle in photo sources (68.52%), bottles in video sources could be detected better. In the case of the color of bottles are similar to background color, AI could detect them from video sources (Figures 7i, 7j), while the AI could not detect them from photo sources (Figure 5h). When the data sources are images, the frames of the images are static. If the AI can not detect the bottles at the first time, it is finitely can not detect them. However, when the data sources are videos, the frames of images are dynamic. If the bottles can not be detected at the first time, they can be recognized when the image frame changed.

In the case of multiple bottles in a video frame, the AI could recognize 96.05% bottles in the video samples. In which the AI could recognize 95.65% bottles in the uniform background environment. In the noise background environment 94.44% bottles could be detected. Bottles in the video sources appeared in the different positions (close, far, corner, center of the videos), and shapes.

Table 1. Plastic bottles detected from videos sources by the AI.

Background	Detected	Not detected	% detected
Single bottle in a video frame			
Uniform	6	0	100%
Noise	6	0	100%
Multiple bottles in a video frame			
Uniform	44	2	95.65%
Noise	17	1	94.44%
Total	73	3	96.05%

Figure 7. Detection of plastic bottles in videos (screenshot from videos).

3.4. Comparison between statuses of plastic bottles

The appearance of bottles at different status, different location affects the detection ability of the model. The model can detect clear bottles easily than a part of bottles being covered, sunk or shape changed. 72.29% of clear plastic bottles in the photos could be detected (Figure 8), however the model could only detect 50% unclear plastic bottles in photos (Figures 4e, 4g, 4h, 4i, 4j, 4l, 5d, 5e). While 98% of clear plastic bottles and 78.56% of unclear plastic bottles could be detected from video sources. The detected results showed that colored bottles could be detected better than transparent color bottles. This could be explained by the color bottles could be easily distinguished with background environment than transparent color bottles.

3.5. Comparison between human and AI in monitoring plastic bottle waste.

The weighting values of compared criteria is shown in the Figure 9. In the 7 criteria, accuracy is the most important (0.345) one for both human and AI. Combining 7 criteria in the calculation to compare between human and AI in monitoring plastic bottle waste, weighting values of AI and human are 0.625 and 0.375. Therefore, in the trend of industrial revolution 4.0, the application AI in monitoring plastic bottle waste is better than human. Paired comparison among criteria showed that the criteria: large scale, 4.0 compatibility, connecting ability, automation, and low operation cost, the AI application performs better than human. While accuracy, and low initial cost human performs better than the AI.

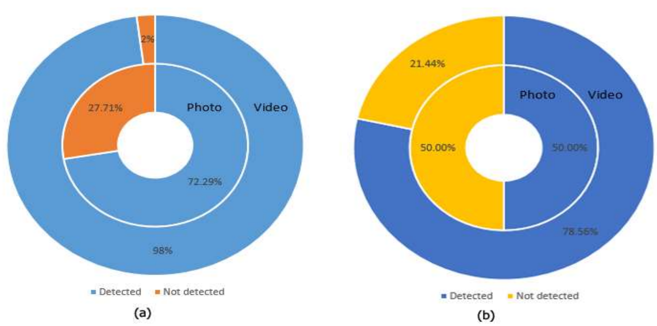
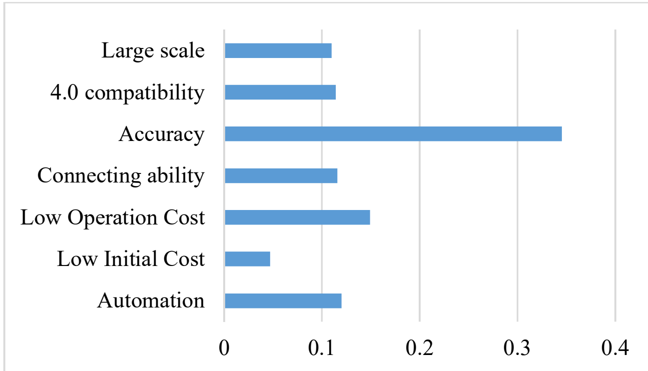
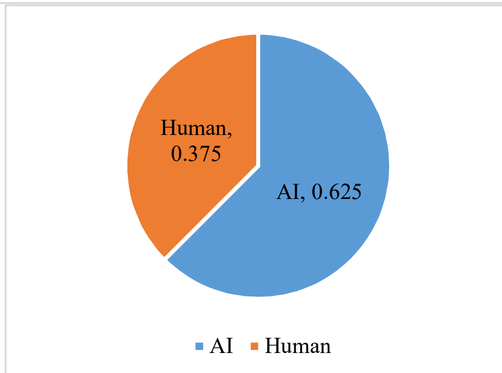


Figure 8. Comparisons between statuses of plastic bottles–clear (a) and unclear (b) in photos and videos.





(a) (b)

Figure 9. Weighting values of compared criteria (a) and human and AI (b).

4. Conclusion

In this research, an AI for detecting plastic bottle waste has been successfully developed. The AI model has been tested and verified the accuracy with real practice samples. The detection results showed that the AI could detect 100% of single plastic bottle and 96.05% multiple bottles in a video in both uniform and noise background environment. The detection accuracy of the AI with photo source was 68.52%. The percentage of detection for clear and unclear plastic bottles in videos were 98% and 78.56% respectively. While clear bottles from photos accounted for 72.29% and unclear bottle is 50%. Color bottles were detected by the AI better than transparent bottles. Under industry revolution 4.0, the application of AI in monitoring plastic bottle waste at coastal zone was determined more efficient than human force. In the further research, the AI model can be applied to detect plastic bottles from satellite data.

Author Contributions: The AI model was built and trained by H.T.D., A.D.T. The real plastic bottle images and videos were taken and recorded by H.T.D., L.A.P.T., T.H.P. The video and image samples were analyzed by H.T.D., A.D.T. Finally, the paper was written by H.T.D., A.D.T.; commented by L.A.P.T., T.H.P.

Conflicts of Interest: The authors declare no conflict of interest.

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Review Article

The Economics of Water Resources: A Review of Recent Research

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Abstract: Water is essential for human survival and all human activities. It is also widely accepted that there is a growing demand for water due to socio–economic development while there is a shrinking supply due to global climate change. The finiteness and increasing shortage as well as scarcity of water have thus created worldwide water related problems. However, in the past, the management and allocation of water resources global have been far from optimal. Both water quantity and quality have been deteriorating at an alarming rate, and without proper water resources management and allocation practices in place to tackle this situation, water shortage and depletion would be inevitable in the future. The failure of proper management and allocation in the past was mostly attributed to the failure to understand the true nature of water as an economic good. Compounding to the problem, water is a special economic good as it can be both a private and a public good depending on its source and use, thus requiring special market–based mechanisms in place of a pure command–and–control approach in management and allocation. This paper provides up–to–date information on the research of water resources economics through the review of more recent advances in concepts and policies. Through the improved understanding, it is expected that better management practices could be established for the sustainable management and allocation of water.

Keywords: Water; Water economics; Economic policy; Water management.

1. Introduction

Water is one of the most important resources as no life could exist without it. However, water sources are definite, and with the growing global population, the increase in living standards and the intensifying effects of climate change, water scarcity is becoming an imminent threat to further sustainable development [1]. Economics is the science of research on how people and society choose to use scarce resources to produce goods (services) and distribute them for current or future personal consumption and groups of people in society. As water is no longer an abundant resource, there is an emerging consensus that effective water resources management includes the management of water as an economic good. In the 1960–1990 period, a number of studies related to water economics and economic values of water stemming from the research branches of scientists studying microeconomics, customer behavior theory and the formation of a water trade market were introduced. These studies can be seen as prerequisites for proposing principle 4 – “Water has an economic value in all its competing uses and should be recognized as an economic good”, which was recognized and approved by the international community at the association Dublin–Rio Conference 1992. Previous failure to acknowledge the economic value of water has resulted in wasteful use of water resources and environmental damage. Managing water as an economic good is an important way to use it effectively and efficiently, to encourage the conservation and protection of water resources, and to formulate policies for water investment and development.

There have been a number of practical studies to determine the economic value of water use based on geographical locations and water uses. At the basin level, the economic value of water has been determined at the Zambezin basin [2]. At the national level, water resources have been valued in Namibia [3] and Jordan [4]. These studies provided the foundations for numerous other studies on water resources economics. This includes the study by [5] introducing the principles and methods of determining the economic value of water resources.

It is commonly agreed that water is not just an ordinary economic good. Traditional demand rationing of water in the past had led to market failures and the ineffectiveness of water allocation. As an example, water prices do not truly reflect delivery cost. Thus, economic policies to allocate and manage water is crucial to the sustainable use of water as a scarce resource.

The aim of this paper is to perform a review of recent advances made in water resources economics to give a more comprehensive view for future researches. Firstly, special characteristics that make water different from other ordinary economics goods and difficult to allocate and manage, will be identified. The article will then present the problems in water cost and price that should be addressed to avoid market failures. Finally, we will discuss new advances made in efforts to balance water demand–supply and economic policies to enable water economics.

2. Water as a special economic good

Based on the degree of excludability and rivalry, it is complex to classify water into just one type of economic good. Exclusion reflects whether it is easy or difficult to exclude or limit consumption by other users, and rivalry refers to the degree to which the use of a unit of a good by one individual reduces the potential for others to use that same unit. These two concepts define interchanging characteristic of water [6–7] that has created serious challenges in water management.

This complexity of water characteristic is highly relevant in the case of domestic water. Domestic water use can be understood as rivalrous in that an individual drinking a glass of water can prevent others from drinking it, and excludable in that when it has been used nobody else can use it. In this case water is considered as private good. However, access to safe drinking water and sanitation was declared a 'human right' by the UN in 2010, which makes water, unlike most private goods, unable to be traded in markets and allocated to its highest value uses [8]. In this view, it can only be used and distributed effectively after basic needs have been satisfied [9].

A change of classification has also been observed moving into more recent times. In the past of abundance, water in its original state was once an open access resource. No one had exclusive property rights to water and one person's use did not prevent others from using it (rivalry). However, in the current face of water scarcity, water has become a "rival" and "non–excludable" good, thus defined as common–pool resource [10].

Moreover, the intended use of water can also change its definition as an economic good. Water can be "excludable" when water infrastructure projects only benefit a group of people. An example for this would be community based irrigation schemes. In this case, water is defined as club–good. On another hand, it will be described as public good when these benefits are both non–rival and non–excludable, for example: people can all be protected from flooding when a dam is built [11].

As evidenced above, the classification of water will depend on water sources and its uses, as well as the particular context. For example, Dosi distinguished differences in rivalry and exclusion at each step in one value–added use, classifies irrigation water as a club good [12] while Ostrom, Elinor, Wai Fung Lam, and Myungsuk Lee figured it as a common pool resource–reflecting different perspectives and contexts for their analyses [13]. In other words, the chosen frame of reference for analyzing rivalry and exclusion can result in a particular characterization of the resources. Thus, under changing circumstances, water can transform from one type to another. This complexity means that while markets can be used to allocate water resources, it requires management to adapt to better incentive compatibility and improve economic outcomes [14].

3. Water prices–Water costs

Around the world, water is generally underpriced. Firstly, most water agencies set price to cover the past cost of the water system rather than the anticipated future replacement cost. The gap between these two expenses is often large because of the longevity of water supply infrastructure. Secondly, after a major water system is completed, since supply capacity so far exceeds current demand, the price tends to be set just to cover the short–run marginal cost (operating cost). However, as demand eventually grows, it will be economically optimal to switch to charging on long–run marginal cost (replacement cost). Despite this, water agencies are often politically locked into a low water price schemes and lose incentive to invest in future system [15–16].

It is also important to emphasize that the water prices paid by most users does not reflect its value of scarcity. Users pay for the capital and operating costs of the water supply infrastructure but there is no actual charge for the water itself. The reason water cost does not cover a scarcity cost is that most monopolies don't have to pay for their water. Water is thus treated differently than oil, coal, or diamond for example. While some European countries charge fees to withdraw water, they are often just administrative fees and are not based on the economic value of the water being withdrawn.

Due to water's special characteristics and the ensuing impacts, a traditional market trading scheme would be suboptimal for social welfare. In a well–functioning market, the efficient allocation of goods is reached at the point where the market price balances supply and demand. At this point each water user consumes a level of water where the additional or marginal benefit to withdrawing an additional unit of water is equal to the cost of withdrawing it. However, unlike other goods, the impact of water uses may result in negative externality costs that the users are unaware of. Water use in the agricultural sector, for example, is often associated with negative externalities such as groundwater contamination by fertilizers and pesticides. These external impacts of water use are not typically reflected in water prices and included in the costs, so regulators and users do not take them into account when making decision about how much water to withdraw. Due to these negative externalities, social welfare is decreased and water resources are often undervalued and overused (Figure 1).

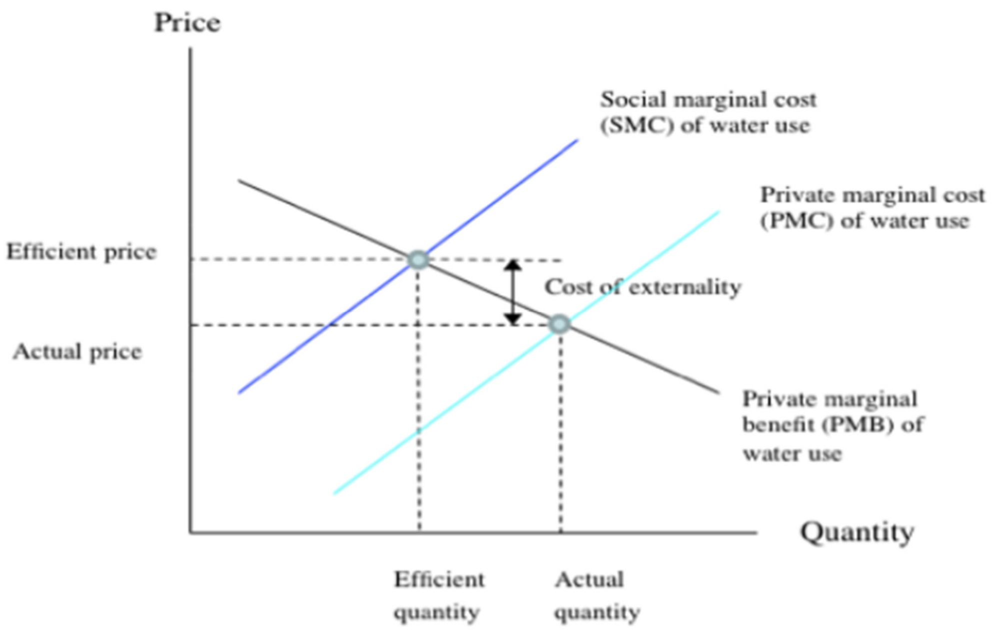

Figure 1. Cost of externalities [17].

4. Water demand – Water supply

Water shortages consistently rank among the global risks of greatest threat to world leaders and policy makers around the world (World Economic Forum, 2019), and without thoughtful solutions these challenges will keep intensifying and spreading as demand grows [18–19]. To adapt to this situation, sustainable water economics has been created, researched and become the highest rated solution to water scarcity. Over the last few years, many authors have set the focus on sustainability and most works are devoted either to water supply enhancements or to water demand strategies [20].

Water price is, as discussed above, way too cheap and being heavily subsidized in many countries [21]. As a consequence, the scarcity cost is not visible to water users. In developed countries, the fact that water is essential for human life is almost irrelevant because people use it more as a commodity than as a necessity. Even in some developing countries people are not fully aware of water scarcity and have comfortable water consumption as their income rises. That consumption patterns together with population growth, economic development are the reasons why water demand more often exceeds water supply.

Whenever water demand exceeds water supply, there are two types of measures to balance supply and demand [22]:

Supply Enhancement Strategies	Demand Management Strategies
1. Build/enlarge dams	1. Establish water-conserving plumbing codes requiring certain fixture types (such as low-flow toilets and showerheads)
2. Drill/improve wells	2. Establish drought contingency plans
3. Build interbasin water transfer facilities	3. Ration water or constrain water use (e.g., alternate-day watering schedules)
4. Repair leaky infrastructure	4. Buy/lease/sell water rights
5. Build desalinization plants	5. Raise water rates
6. Reprogram reservoir operations (e.g., more storage with less flood protection)	6. Educate water users about conservation options

Figure 2. Supply Enhancement and Demand Management [22].

Supply enhancement methods have always dominated, but with fresh water supplies being physically limited, these methods are getting more and more expensive than in the past. We can spend money on new supply and new technologies, but those too will not be able to meet the increasing demand if the consumers do not have to pay the full cost of delivering their water [23]. Recent sustainable supply researches took advantage of another distinctive feature–water's mobility–to create water circular economics concept. This makes water different from other goods because it can be used/reused sequentially. For example, water used for irrigation will then seep into the ground and become available to other users. Furthermore, it is very costly and often difficult to keep track of water flows, thus often making it impossible to establish property rights to return flows. Water reuse would then be an opportunity to create the availability of safe and clean water supplies. This model's goal is to optimize water resources use and reuse, and at the same time minimize the generation of wastewater. Examples of this include generating biofuels from sewage mud to provide energy [24] and using wastewater sludge for the manufacture of construction materials [25–27]. Also, water can be treated for different reuse purposes like supplying agricultural systems, irrigation of parks and gardens, lawn and car washing, or even for drinking water.

The key concept is simple: water is withdrawn from streams, reservoirs, oceans, and groundwater aquifers or collected directly as rainwater and used in four traditional categories: Agriculture, Municipality, Industries, Environment. This includes both consumptive and non–consumptive uses. Non–consumptive used water is then returned to the basin directly or through a municipal treatment facility. Depending on the location within the basin this returned water can then be reused downstream or lost to the basin in similar ways as the consumptive uses.

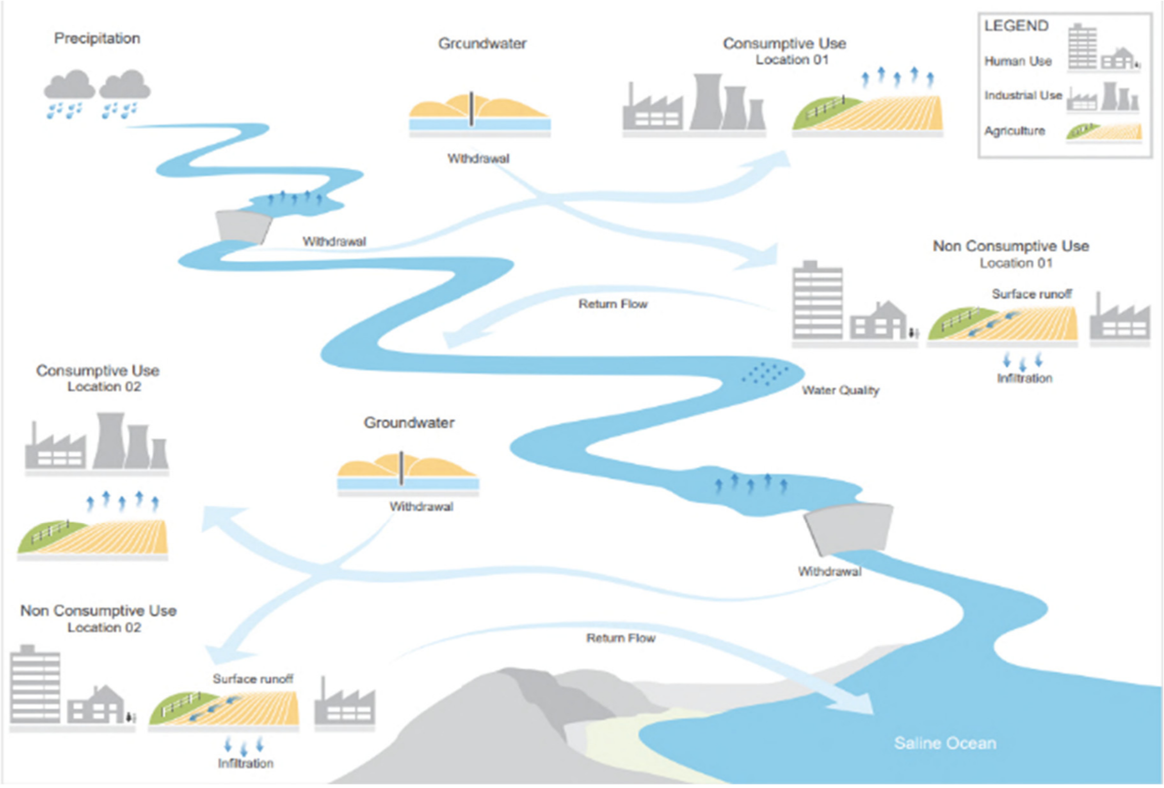

Figure 3. Water flows in a basin [28].

As the progression for supply enhancement slow down, the opportunities of demand control have simultaneously increased. The importance of water demand management rises as the threat of scarcity looming large. If demand management strategies can be applied effectively, they will become very powerful tools for balancing demand and supply. There are now many examples of how demand–side control can be designed: The US has developed numerous conservation strategies to reduce water demand by utilizing pricing schemes, educational measures, efficient equipment subsidies and water rationing. Water rationing is a widely used method in the US; however, there are ongoing discussions about consequent welfare losses as the water is not allocated according to the marginal willingness to pay of customers [29].

Similarly, Australia developed a mix of water instruments to reduce demand to effectively cope with severe drought. The Cairns regional council has launched a campaign to promote wise water use in addition to mandatory restrictions [30]. Many municipal cities in Australia have implemented water–wise rules. These rules aim to save water in the everyday life of households. Households in Sydney must use hoses fitted with a trigger nozzle and irrigation systems when irrigating the garden. The irrigation time is restricted from 4 pm to 10 am and there is a fine of $220 for households breaching this rule. However, the water–saving impact is often smaller than expected because behavioral changes partially neutralize the efficiency effect of the water–saving techniques [31].

5. Economic policy of water resources

As discussed above, water can be better described as a rather complex economic good than a homogeneous good because of its special characteristics, leading to three very potential tasks for governments to enable water economics potential: managing water infrastructure, redefining property rights and pricing water. The first one, financing water infrastructure, in comparison to other economic goods, is a struggle. As previously noted, water supply systems are exceptionally capital intensive. This capital is very long lived and has no other values. In the US, for example, the water industry is 2.3 times more capital intensive than that of electricity, and 2.4 times more capital intensive than the telecoms industry [32]. Therefore, the main financing pathway most desirable is direct financing supported by foreign aid. The question is whether this is a realistic proposition as the water sector is relatively unattractive for private investors. Furthermore, climate extremes have magnified the challenges of water scarcity and its temporal variability. Variability and uncertainty caused by climate change have led to a range of unsuccessful infrastructure measures [33].

The benefits of defining property rights increase as scarcity intensifies and, property rights will develop when the benefits outweigh the costs [34]. Tradable water rights gain has been estimated to reflect the benefits of property rights reform [35]. In Australia, models of water trading point out that annual gains from trade are over AU$2.5 billion, which could be further increased with the removal of barriers to trade. The strategy for communication and compensation is pivotal when discussing property rights of water [36]. In this case, the key issues concentrate on who receives and who pays the compensation, how much and how to limit future adjustments [17]. Property rights reform, like all economic policy, is a political choice that requires special attention to distributional conflicts.

Pricing is often the first and the most important effective tool in economics, which goes the same for water. To ensure efficient use of a typical economic good, it should be priced at its (long–run) marginal cost. However, this is usually not the case for water. As discussed above, the price of water almost never equals its value and rarely covers its costs. Because there is a human right to water, rationing it using price may seem unethical. When price raising is not cost–justified, it could be politically infeasible and even sometimes illegal. In California, for example, Proposition 218 stipulates that municipal water rates be “proportional to the cost of service”.

In Europe, an effort aimed at such policy has been made with the Water Framework Directive (WFD). WFD responds to the increasing threat of water pollution and increasing public demands for cleaner water bodies. It aims to protect and achieve good chemical and ecological quality in all bodies of water. In each EU nation, WFD is then translated to national laws and governance. Within this framework, the European Commission commanded that significant water–related project must conduct Cost Benefit Analysis (CBA) to calculate the financial rate of returns (FRR) and the economic rate of returns (ERR). While the FRR corresponds to the financial profit from the private sector’s point of view, ERR represents the socio–economic benefits of the project to the society in a whole. As discussed before, profit–oriented perspectives may cause undesirable effects on the society. In CBA, these harmful effects are in the form of shadow prices, externalities and other nonmarket effects, which make up the difference between FRR and ERR. In general, for a project to be approved, the ERR shall be greater than FRR, which means society as a whole will benefit from such project.

There has been a group of researches contributed to good water governance by addressing best practices for stakeholder engagement and political decision–making. [37] address an innovative approach to implementing Ostrom principles in a community–based governance context. [38] analyze public participation and stakeholder engagement and knowledge co–creation in water planning in the context of EU WFD regulation. [39] also review the application of the concept of disproportionate cost in the WFD, which should be used when a water mass cannot achieve a good environmental status (GES). Finally, also in the WFD context, [40] explore the concept of GES in German waters.

Looking closely at surface water and ground water laws, all the property forms are represented, albeit with an exception: clearly defined open access resources laws. Nevertheless, these institutions are not rigidly established; they are all evolving. Where water scarcity is increasing, eastern permits will soon replace riparianism (rights to an unspecified share of the flow). If these permits become transferable, another transition to private property will take place. Moreover, absolute ownership (weak common property), reasonable use (common property), correlative rights (common property), prior appropriations (incomplete private property), and the Vernon Smith system (advanced private property) are listed when examining groundwater law. All of the existing institutions are deficient in most cases, leaving water depletion decisions to those who are not rewarded for water conservation and therefore, are not fully incentivized to act in the public interest. Current institutions are still incoherent and inconsistent. In addition, all societies require a mixed system of water management institutions, involving both private and public rights to allocate an efficient amount of water to instream and inground applications. Therefore, efficiency cannot be achieved until all incentives encourage people to behave with the understanding of scarce water value.

6. Conclusion

In the traditional market–based approach, commodity is allocated efficiently for competing demands where producers and consumers interact and agree upon the price and allocation for the available resources. However, as discussed above, water is a special economic good, not just a homogenous good, traditional market based approach alone will lead to market failures. In this case, it is best to apply a mix of public and private roles to create a sustainable market–based mechanism to allocate scarce water resources. The government, with a broad range of social goals rather than profit–oriented goals of private sector, may intervene and mitigate social inequalities to provide substantial access to water for all people and limit market failures.

The goal of this paper is to review recent advances in concept and policies of water economics. To give a better understanding of the transitions in recent years, some change in key elements of water resources economics is presented in this review article. Researches devoted to sustainable water economics in recent years have a prominent growth due to growing population concerns about increasing water shortage and its worldwide related problems. Many authors have been studying different disciplines in order to develop a comprehensive analysis framework for the sustainable management of water resources. However, most works are focused either on water supply or water demand. Different authors from the economic field prefer the control of demand using technologies and policies to solve water shortage problems since the supply side requires huge investment in time and money. There are also works that analyze the sustainable increase of supply through new concept of circular water economy, which might be the key to solve the incoming threat of water scarcity.

To support the sustainable use of water, there is a need to make the problem of scarcity visible to water consumers through water pricing. Price should be able to reflect full costs of water including externality costs and scarcity costs to promote efficient water use by the consumers. However, we should also consider that improved pricing requires attention to inequalities and affordability concerns that have fueled resistance and perverse consequences in the past. Thus, this creates a challenge to align the incentives of individuals with the interests of the community.

The article attempted to review the state of the art of the economic management of water. However, this paper has only reviewed water resources economics in general. There is a need for a specific basin research along with further researches on surface and ground water separately.

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Conflicts of Interest: The authors declare no conflict of interest.

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Research Article

Application on shallow neuron network (SNN) in flood forecasting, case study in Vu Gia Thu Bon river basin

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Abstract: Flood forecasting is one of the most important thing for flood prevention. Upto date, there are many techniques that can be used for this work, from simple ones like linear regression model (AR, ARX, ARMA, etc.) to very comlex models like hydrological and hydrodynamic models). Recently, Artificial Inteligent (AI) become an cleve approach for many field including hydrological forcasting. Shallow neuron network is one of a simplest algorithm of AI but it can help to get a great result of forcasting problem due to its non–linear and automata technique. This paper present the test on applying Shallow neuron network for flood forcasting in Vu Gia Thu Bon river basin. The result show comparetable with the complex hydrological and hydraudynamic model.

Keywords: Artificial Inteligent; Flood forrecasting; Shallow neuron network; Vu Gia–Thu Bon; Machine learning.

1. Introduction

Flood is one of the most frequent and dangerous natural disaster in Vietnam [1]. They can affect an area as small as a local neighborhood or community in the mountain watersheds, to as large as an entire river basin in the Central part of Vietnam. In the past, the first option to reduce the flood damage is structural measures [2] such as dikes, reservoirs, division dam, etc. However, due to the limit of structural scale, budget and their truly effective function, they are not always the first or only option in flood management [3]. Nowaday, early warning system is usually designed and operated instead of/or parallell to structural measures to give flood forecasting services, civil protection authorities and the public adequate preparation time to eliminate the lost [4]. The key part of early warning system is flood forecasting. Flood forecasting provides the advance flow's information (magnitude and timing) at key locations of a river which helps to accelarate response system to prevent flood impact on the community exposured to flood event [5]. Unlike several other disasters, approaching flood can be forecast ahead of its occurrence with advance collection of hydro–meteorological data, and its transformation into flood water level or flood hydrograph. Therefore, there are many techniques have been developed to implement the flood forecasting, ranging from the simple ones like correlation/coaxial diagrams between two variables and mathematical equations developed using regression/ multiple linear regression to the more complecated ones like hydrological models or hydrodynamic models [6]. These methods usually contain many kind of uncertainties in their results. The linear regression models has the assumption of linearity between the dependent variable and the independent variables which can not exist in the real work therefore the error of this one usually larger than other methods [7]. In the other hand, hydrological models and hydrodynamic models which describe the process of transforming of rain water to flow rate in the river can have more accuracy results. However, they errors still come from many sources such as the uncertainty of meteorological forecast as their inputs [8]; or models' initial conditions which are assumped in the networks of hydrodynamic models [9] or initial soil moisture, overland flows, intermediated flow, baseflow in the case of hydrological modes [10]; or the uncertainty of model parameters due to the ways of their estimation such as try and error method [11]. In the 4.0 era, data driven approach becomes more resonable ones among flood forecast techniques in which machine learning (ML) algorithm are the popular one. ML are known as a computer can learn to do some tasks by itself without giving them the instruction of how to do these tasks [12]. Therefore they can overcome these above uncertainties. Infact, they describe the nonlinear relation of inputs and outputs instead of linear ones in traditional regression model. In addition, unlike physical based model like hydrological/ hydrodynamic models, they can use only the historical data in forecasting without requiring the initial conditions and automatically estimating their parameters by iteratively correcting their values until the criteria's termination matched [13]. This paper test a simplest algorithm of machine learning: Shallow Neuron Network (SNN) in the task of flood forecasting in Vu Gia Thu Bon river basin in Vietnam.

2. Methodology and Materials

2.1. Methodology

In this research, Shallow Neuron Network (SNN) is exploided and applied to forecast the flood in Vu Gia–Thu Bon river basin. SNN is the simplest supervised learning algorithm of the modern machine learning technique. However, in many cases including forecasting problem, it gives a very good result [14]. SNN, as its name, is composed by a neuron network with a simple feed–forward structure. They contain only one input layer, one hidden layer and one output layer (Figure 1).

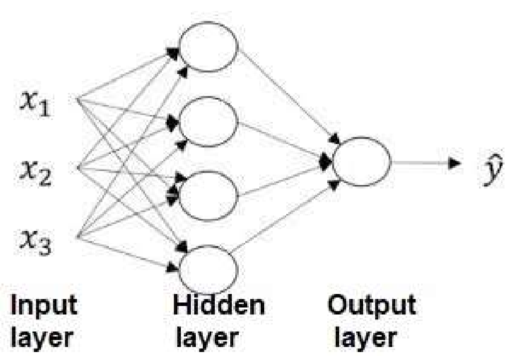

Figure 1. An example structure of SNN.

In SNN structure, each hidden neuron will receive the information from all inputs and transmit them to the outputs. In other word, each hidden neuron can be considered as the combination of 2 parts (Figure 2):

– The first part estimates its intermediated output ***z*** using the input ***x***, the weight ***w*** and the bias ***b***.

– The second part implements an action on ***z*** to give the final output ***a*** of the hidden neuron.

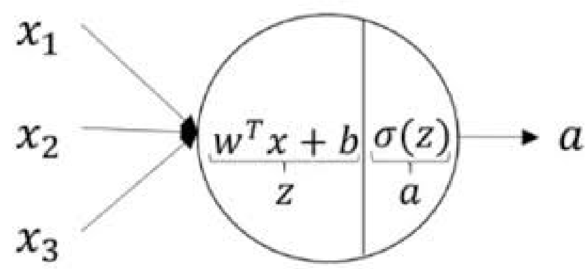

Figure 2. The structure of one hidden neuron.

Therefore, in the mathermatic term, the hidden layer can be vectorized and writen down as in Eq.1:

$$Z^{[1]} = W^{[1]T} X + b^{[1]} \tag{1}$$

$$A^{[1]} = \sigma\left(Z^{[1]}\right)$$

where $Z^{[1]}$ is the intermediated output vector of hidden layer; $W^{[1]}$ is the weighted vector of hidden layer; $b^{[1]}$ is bias vector of hidden layer; $A^{[1]}$ is the final output of hidden layer as the active function σ of $Z^{[1]}$.

If we call $Z^{[2]}$ is the intermediated output of output layer, the final result of output layer $\hat{y}$ can be estimated as Eq. 2:

$$Z^{[2]} = W^{[2]T} A^{[1]} + b^{[2]} \tag{2}$$

$$\hat{y} = A^{[2]} = \sigma\left(Z^{[2]}\right)$$

At the beginning, the random values of parameter set (weighted matrix and bias matrix) are automatically generated. Through training process, they are corrected at each iterative loop. The technique used for parameter correction is backpropagation. The principle of the backpropagation approach is modifying internal weightings of input signals to produce an expected output signal. The system is trained using a supervised learning method, where the error between the system's output and a known expected output is presented to the system and used to modify its internal state [13].

To optimize the parameter sets, Levenberg–Marqardt algorithm was used because they typically require less calculated time [14]. Training automatically stops when the generalization stops improving, as indicated by an increase in the mean square error of the validation samples (Figure 3).

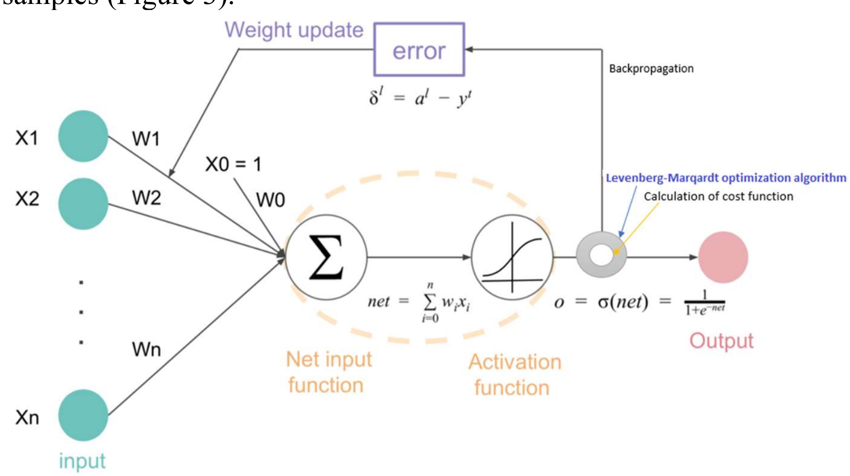

Figure 3. The training SNN's procedure (adapted figure from [15]).

2.2. Materials

Vu Gia–Thu Bon (VGTB) River basin is one of the most prominent river basins in the Central region of Vietnam. The total length of the river is 205 km while the total surface of the river basin is 10,350 km^2 (Figure 4). The river runs through 3 provinces Quang Ngai, Kon Tum, Quang Nam and Da Nang city, starting in Truong Son mountain in the West and flow toward the sea into Da Nang bay in Da Nang city and at Cua Dai in Quang Nam province. The system consists of two main tributaries: Vu Gia river and Thu Bon river. Finally, Quang Hue river connects the two rivers throughout the year. The Vu Gia river consists of significant tributaries like Cai River, Bung River, A Vuong River, and Con River. The river basin is one of the most strategic and productive areas of Vietnam with an average growth rate of the GDP in the last 5 years of 11.8% but with an average poverty rate of 66.8%.

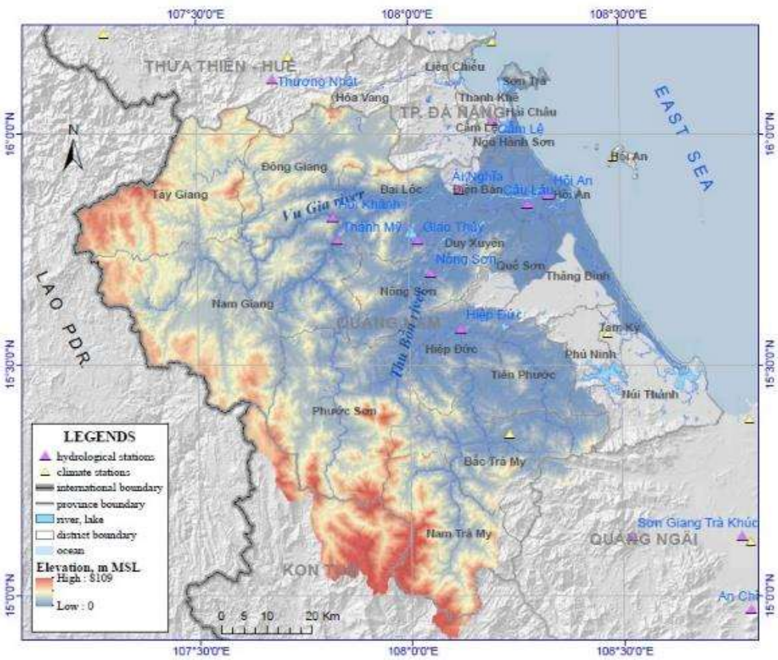

Figure 4. Vu Gia Thu Bon River Basin.

The main damages and disasters in the river basin are caused by tropical storms, flooding, drought, saline intrusion and landslide, of these, the most dangerous natural phenomena are storms and floods that causing the most significant damages in terms of human lives and property. Storms occur from May to July and October to November and typically associated with heavy rain leading to flooding. According to the provincial reports, from 1997 to 2009, the disasters due to these natural events caused 765 deaths, 63 missing persons and 2,403 injuries, with total property damage of over 18,000 BVND in Quang Nam and Da Nang city.

This research present the evaluation of applied SNN to flood forecasting at Cam Le and Hoi An stations. In data driven model, data set is the most importain one decided the suscess of the model. Therefore the related data have been collected. After analysing the correlation between Cam Le and Hoi An's flow with the surrounding location, the most affect ones are Nong Son, Thanh My, Ai Nghia, Giao Thuy and Son Tra. Therefore, the following time series are collected with their longest avalaible data set of flood events. This costly data can guarantee the sufficient condition for the data driven model with more than 100 past flood events:

– Discharge time series at Thanh My and Nong Son from 1978 up to 2018.

– Water level time series at Ai Nghia, Giao Thuy, Cam Le and Hoi An from 1978 up to 2018.

– Water level time series at Son Tra station from 1990 up to 2018.

3. Results and discussion

The forecasted locations are Cam Le in Vu Gia branch and Hoi An in Thu Bon branch. The lag time of flood propagation along the Vu Gia river from Thanh My and Ai Nghia to Cam Le are around 24 and 10–12 hours, respectively. Therefore lead time of 12 hours and 24 hours were chosen as ones of requested lead times by MONRE [16].

The first model (Model 1) predicts the water level at Cam Le station based on the information of last 12 hours discharge at Thanh My station, last 12 hours water level at Ai Nghia station and last 2 hours water level at Son Tra station. Because the water level at Son Tra can be forecast nearly 1 year in advance except the case of wave raising in the storm. In that case, Son Tra's water level still can forecast 24 hours in advance with certain accuracy. Therefore the last 2 hours water level at Son Tra can be known in advance of 24 hours. The model has 1 input layer with three neurons, 1 hidden layer with 10 neurons and one output layer with one neuron (Equation 4).

$$H_{t+12}^{CL12h} = f(Q_t^{TM12h}, H_t^{AN12h}, H_{t+10}^{STr2h}) \quad (4)$$

The result of model are so good. The mean square error go down expotentially through 10 epoches and can not improve significantly after 24 epoches (Figure 5).

The corelation coefficient R also very good (larger than 0.95) through training, testing and validating the model. Scater plot between the forecasted data set with the recorded ones locating along the fitted line in all cases (Figure 6).

The profile of forecasted water level at Cam Le show the same good result with the magnitude and time at peak matching the recorded one through three big events (Figure 7). The error is smaller than 28 cm which is an accepted value by MONRE. Other criteria also show the good values as in Table 1.

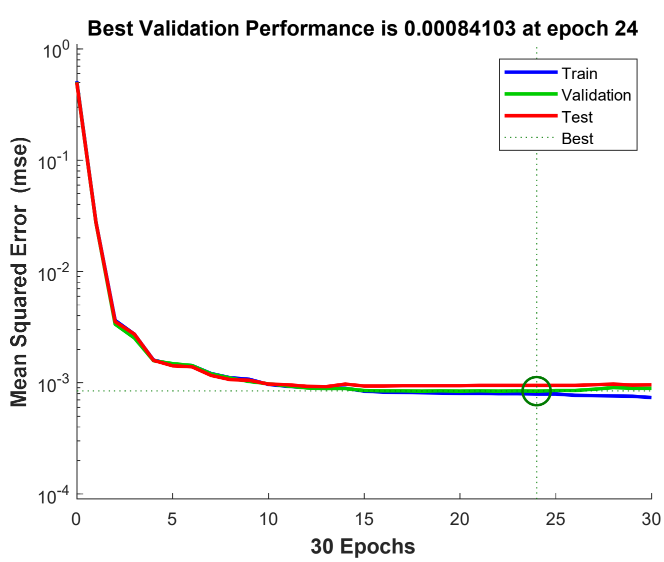

Figure 4. Mean squared error improving through epoches.

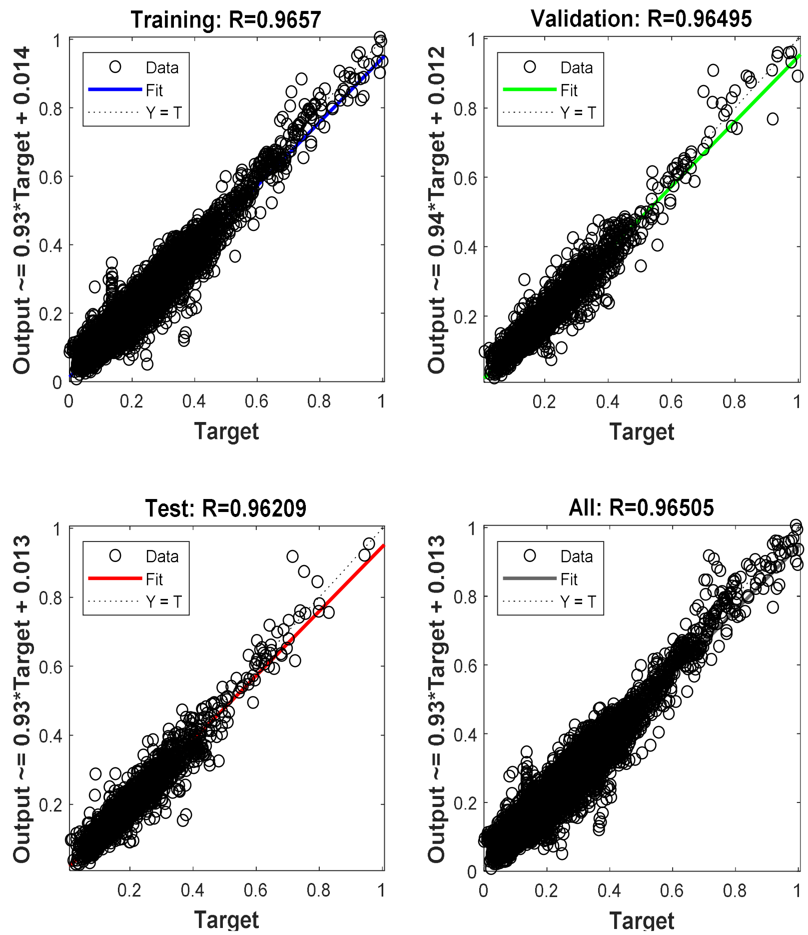

Figure 5. The corelation coefficient throught learning process.

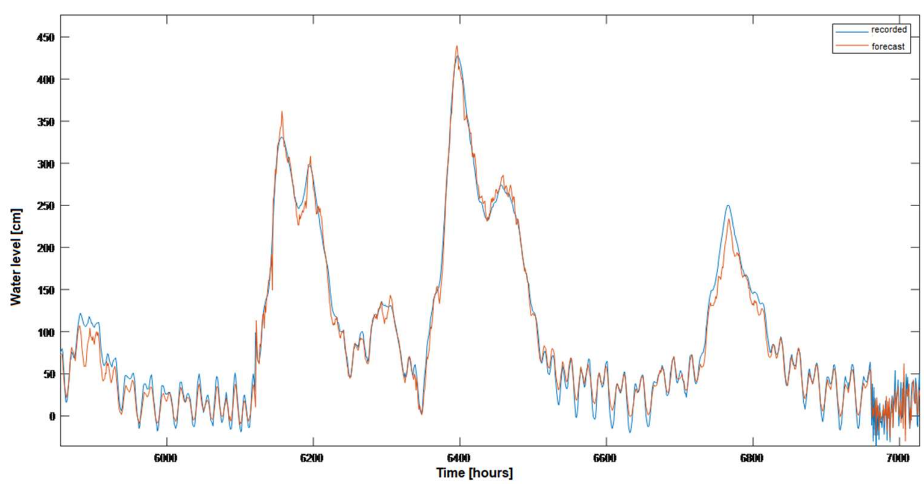

Figure 6. Forecasted water level (red) by 12 hours forecasted model and recorded ones (blue) at Cam Le.

The model of 24 hours lead time at Cam Le show similar results. It has a form as in Eq.5

$$H_{t+24}^{CL24h} = f(Q_t^{TM24h}, H_t^{AN24h}, H_{t+22}^{STr2h}) \quad (5)$$

One can see that, 2 inputs are past events which is known in advance, the only one need the forecasted value is the water level at Son Tra. However, as above analysis, Son Tra level can be predicted with a very high accurancy based on the tide lookup table created one year in advance. Therefore, we can elimimate the uncertainty of forecasted input data. The model find the best parameter set after 20 epoches. R values are still high in all learning phases (larrger than 0.94). Other criteria are good as shown in Table 1.

Table 1. forecasted criteria for flood forecast model at Cam Le station with the lead time of 12 hours and 24 hours.

Model	Sumary evaluation	Acceptable Error	$\frac{S}{\sigma}$	η	P(%)
12 hours lead time at Cam Le	good	35.75	0.36 < 0.4	0.93 > 0.9	89.31%
24 hours lead time at Cam Le	good	35.75	0.36 < 0.4	0.916 > 0.9	88.94%

Hoi An station locates in downstream of Thu Bon branch. The lag time of flood propagation along the Thu Bon river from Nong Son and Giao Thuy to Hoi An are around 20 – 22 hours and 7–9 hours, respectively. Therefore lead time of 12 hours and 24 hours were chosen as ones of requested lead times by MONRE [16].

The first model predicts the water level at Hoi An station based on the information of last 12 hours discharge at Nong Son station, last 12 hours water level at Giao Thuy station and last 2 hours water level at Son Tra station. The model has 1 input layer with three neurons, 1 hidden layer with 10 neurons and one output layer with one neuron (Equation 6).

$$H_{t+12}^{HA12h} = f(Q_t^{NS12h}, H_t^{GT12h}, H_{t+10}^{STr2h}) \quad (6)$$

The result of model are so good. The mean square error go down expotentially through 30 epoches and can not improve significantly after 18 epoches (Figure 8).

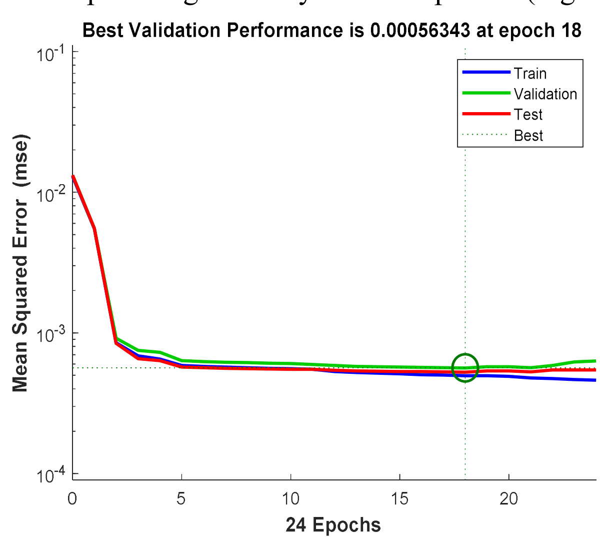

Figure 7. Mean squared error improving through epoches.

The corelation coefficient R also very good (larger than 0.96) through training, testing and validating the model. Scater plot between the forecasted data set with the recorded ones locating along the fitted line in all cases (Figure 9).

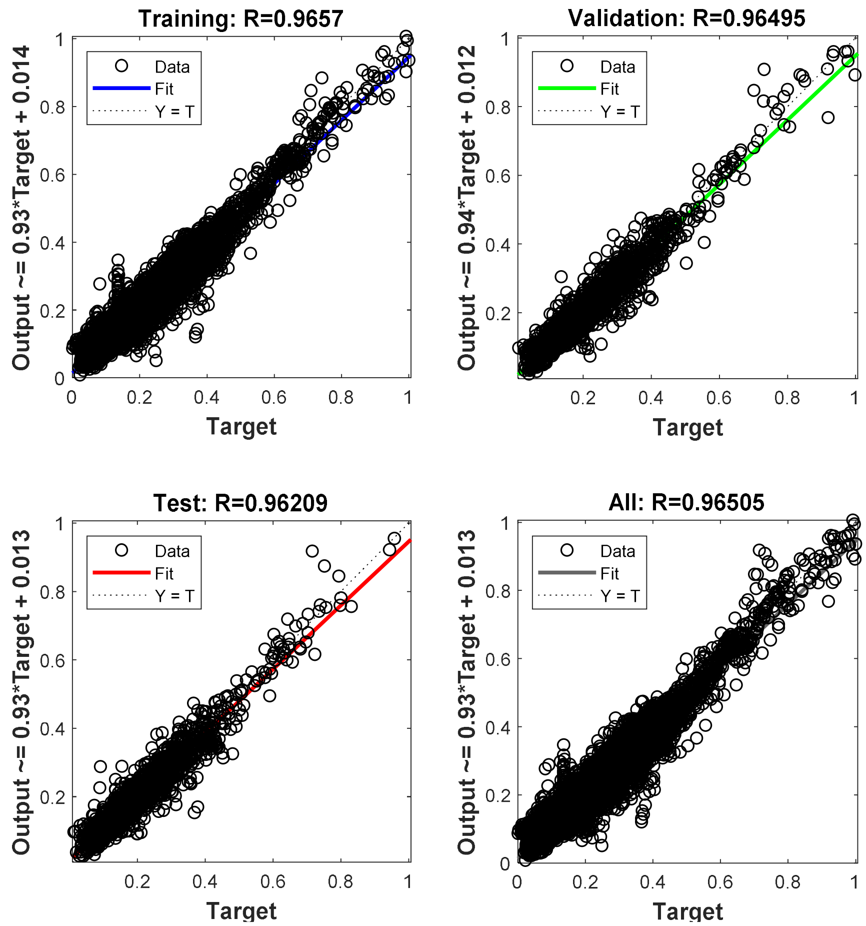

Figure 8. The corelation coefficient throught learning process.

The profile of forecasted water level at Hoi An show the same good result (Figure 10) with the magnitude and time at peak matching the recorded one in three big event. The error is smaller than 28 cm – the accepted error. Other criteria also show the good values as in Table 2.

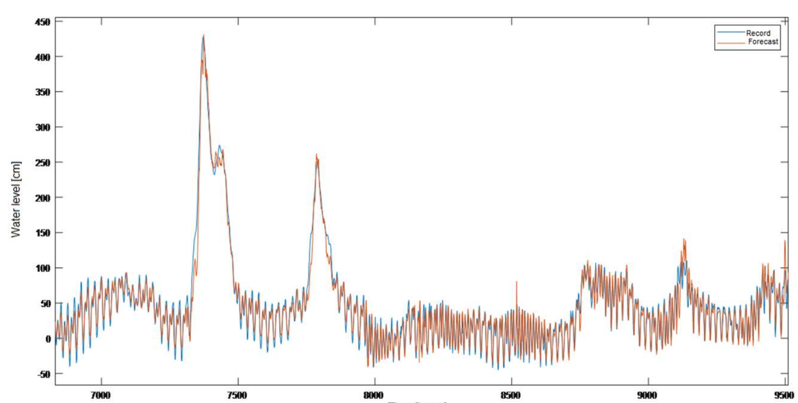

Figure 9. Forecasted water level (red) by 12 hours forecasted model and recorded ones (blue) at Hoi An.

The model of 24 hours lead time at Hoi AN show similar results. It has a form of

$$H_{t+24}^{CL24h} = f(Q_t^{TM24h}, H_t^{AN24h}, H_{t+22}^{STr2h}) \quad (7)$$

One can see in this kind of model, only water level at Son Tay is forecasted in 10 hour advance. However, as above analysis, Son Tay level can be predicted with a very high accurancy based on the tide lookup table created in one year in advance. Therefore, we can elimimate the uncertainty of forecasted input data. The model find the best parameter set after 17 epoches. R values are still high, all learning phases have value R of 0.94. Other criteria are good as shown in Table 2.

Table 2. forecasted criteria for flood forecast model at Hoi An station with the lead time of 12 hours and 24 hours.

Model	Sumary evaluation	Acceptable Error	$\frac{S}{\sigma}$	η	P(%)
12 hours lead time at Hoi An	good	28.60	0.26 < 0.4	0.965 > 0.9	97.52%
24 hours lead time at Hoi An	good	28.60	0.34 < 0.4	0.94 > 0.9	95.85%

4. Conclusion

It can be seen that, neural network is an advanced approach in hydrological forecasting. Through the application process, some conclusions are drawn as follows:

– SNN is very flexible in using data. One can use discharge series and water level series in cm to predict water level in a given location without any physical process description. It just needs to normalize the data into dimensionless form to have the same range of their values.

– Model learning time is quite fast compared to physical based models. It takes only about 5–10 minutes to train the network with 1 hidden layer of 10 neurons.

– Neuron network with only 10 neurons but it generates a quite close correlation between upstream flow and tidal fluctuation to control station flow. This is an advantage of the nonlinear data–based model compared to tranditional ones such as AR, ARMA, ARIMA or even physical based model in some case.

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Author Contributions: Conceptualization, N.M.V.T: Data sets, V.A.T: Methodology, N.M.H.T: Verification of results, V.A.T: Writing–original draft preparation, N.M.H.T: Writing–review and editing.

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