A COMPREHENSIVE INTERGRATED MANAGEMENT APPROACH FOR WATER RESOURCES MANAGEMENT

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ABSTRACT

Integrated Water Resources Management (IWRM) takes the view of sustainable development and applies it to the water sector. The study identified the indicators was constructed classifying them according to the environment indicators and parameters. These are resource availability stress (RS), water development pressure (DP), ecological heath (ES), and management capacity (MC). The studied area were divided for the 12 sub-regions for Thach Han river basin (Quang Tri, Vietnam) and illustrated in vulnerability map. The results of assessing the vulnerability of sub-regions found that all sub-regions are highly vulnerable. However there is still differentiation in vulnerability levels. Dong Ha city, The coastal plain of Gio Linh coastal plain, Trieu Phong coastal plain is under high water pressure. Due to economic development, the demand for water is high, susceptible to local pollution, and water is contaminated with alum and lime, which fail to ensure environmental hygiene. For midlands and mountainous region, water supply conditions are still poor, or in other words, local people have no access to clean water. In the areas of developed fisheries and animal husbandry, water is susceptible to contamination system of breeding facilities or aquatic environment hygiene which fail to meet relevant requirements. Forest development is currently at low level. The results demonstrate the interaction between different regional resources and activities and are one of the decision makers to adopt policies for each sector in this region.

Keywords: Component, formatting, style, styling,maximum 5 keywords

1. INTRODUCTION

Water is an important resource and an essential component of the life on Earth, affecting the survival and sustainable development of anation. Along with the development of mankind, the water shortage should become more and more widespread and serious in many countries around the world. That requires appropriate solutions to exploit, manage and sustainably protect water resources, in other words, to implement sustainable development of water resources in river basins. Therefore, since the beginning of the 21st century, water resource managers were interested in the management approach for sustainable development. The United Nations Conference on People (Stockholm, 1972) and the United Nations Conference on Environment and Development (Rio de Janeiro, 1992) set the goals of water resources management: effective use and conservation of water resources, ensuring integrity and ecological restoration, ensuring clean water and ensuring equity in the decision-making process. Addressing water-related issues, it is necessary to consider the relevant factors from an integrated, comprehensive view and the ultimate goal of achieving harmony in economic, social and environmental protection.

It is highlighted in the Dublin Statement, 1992 that “Integrated water resources management (IWRM) approaches involve applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. As such, IWRM is comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations"[1]. Thus, IWRM aims for not merely planning, a plan but a process, in which efforts should be made in an integrated manner, good interactions are needed between man and nature; between soil and water; between surface water and groundwater; between volume and quality; between upstream and downstream; between fresh water and coastal areas; between domestic and foreign; between water users.

The Dublin Conference also introduced 4 principles in IWRM that were introduced (hereinafter referred to as the Dublin principle). These principles reflect the changing perceptions of water resources. The most notable of which is Principle 1: Fresh water is a finite and vulnerable resource, it plays an essential role to maintain life, development and environment). This principle states that water maintains life in all its forms and is required for many purposes, functions, and services. Therefore, integrated management, must consider the requirements of resources and threats to it. Comprehensive management not only involves the management of natural systems, but also requires coordination of human activities that create water demand, identify land use

and create products that cause waste of water. Access to integrated management and sustainable development must take into account the water balance components, development activities and impacts in each region, multi-purpose use, multi-sectoral linkages, and connection between human society and nature (figure 1). Therefore, when approaching the integrated management of water resources, it is necessary to consider weaknesses in the internal water resources system of a region, the pressures and conflicts in water resources management, or in other words, the vulnerability of the water resources system.

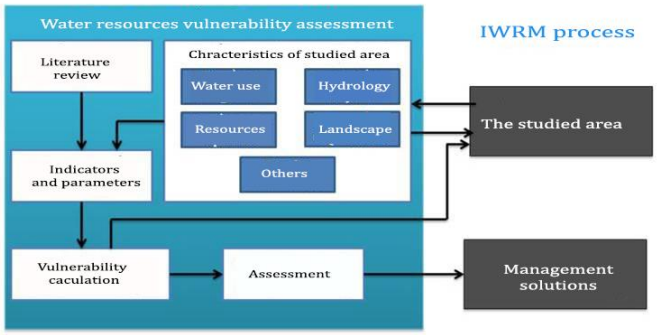

Figure 1. The relationship between vulnerability assessment and IWRM process

Moreover, in the face of future challenges, water resource protection policies should be formulated and implemented on the basis of appreciating the economic value of water and its value to the community. In addition, the role of the community in protecting water resources should be strengthened, the community needs to have a voice to protect its own rights. However, watershed management is an iterative process. The watershed management must include sequential steps when making policy and planning. The first step is to draft broad policy objectives. The next steps are to identify water management issues to be addressed (problem identification), a list of potential strategies (how we will get there), and to evaluate each of the strategies, select one strategy or combine the strategies, implement the strategies, evaluate the results, learn from these results, and adjust our plan to make it better in the future. These steps are included in one process. Of course, in practice, this process can be interrupted by external forces, and the "learning-by-doing management cycle" management process helps us incorporate what we learned during water planning and management and taking into account new information. This means that we can adapt to how we manage water in the face of changing circumstances, for example, political changes, natural disasters and demographic changes. Therefore, it is necessary to establish information to support decision makers in using different data and models in integrated water resources management to address water related issues. In fact, this information must ensure adequate aspects of water resource use and exploitation, electricity production, flood prevention and environmental protection. Such decision support systems for water resources issues began to appear in the mid-1970s. However, the systems were only limited to the Tools for Management in a certain aspect. Regarding exploitation and use of water resources, there is no system addressing integrated management and sustainable development. In recent years, in order to solve the problems in integrated management of water resources and sustainable development, many scientists have taken a multidisciplinary approach to solving complex problems in integrated management at river basin scale. Programs and projects have been implemented with a system of vulnerable indicators combined using hydrological models, information systems and multi-criteria analysis. This method is valuable to assist in making decisions which include stakeholder agreements, social awareness, and coordination among decision makers. That is the use of the vulnerability assessment framework and vulnerability indicators in integrated management approach at basin scale.

2. DESCRIPTION OF KEY TERMS AND METHODOLOGY

2.1 Water resources vulnerability

The concept of vulnerability has changed a lot over the past 20 years. There have been many different research directions to classify the components and factors to assess vulnerability. In particular, in recent years, the concept of vulnerability has been paid more attention by scientists, especially in water resource management. According to Varis et al. (2012), the concept of vulnerability is theoretically multidimensional. This leads to different approaches to vulnerability assessment, moreover it affects the comparison of studies at the global level (Jun et al., 2011). [6]

In theory, there are many perspectives on vulnerability that are approached in many directions, interdisciplinary or in a specific science (for example, computer science, psychology, environment, etc.). In order to meet specific research requirements, Turner et al. (2003) gave a basic definition of vulnerability in the

context of sustainable development: “vulnerability is the degree to which a system, subsystem, its components face the harms caused by exposure to a risk (the situation causing harmful events), conflict, or pressure.” [7]

In the context of sustainable development, Bizikova et al. (2009) gave a commonly used definition of vulnerability: “Vulnerability is the ability of a system to have can be harmed under pressure (such as threats). It is defined as a function of exposure, sensitivity and adaptability. The exposure may be due to the system's exposure to a risk such as drought, conflict, or price fluctuations, or potential risks to environmental, socio-economic, and institutional conditions. The severity of impacts depends not only on exposure, but also on the sensitivity of the specific entity exposed to that risk (such as an ecosystem, a basin, an island one household, village, city, or country) and its adaptive and adaptive capacity.”[7]

In line with the development of the vulnerability concept, a number of vulnerability/sustainability assessments, vulnerability/sustainability indicators, mitigation and action assessments have been implemented by various organizations around the world (Gleick 1990; Laneetal, 1999, Meigh et al. 199, MCSD 200; UNDP-GEF, 2000, Vogel 2001; IPCC 2001; Kabat et al., 2002; Adger et al. , 2004; Brooks et al. 2005) [9]. The first studies are multidisciplinary in nature and begin to provide a clearer picture of vulnerability to global climate change. “Injury is the degree to which a system is susceptible to, or incapable of coping with, detrimental to the effects of environmental change. The vulnerability of a natural and socio-economic system is determined by the character, intensity, and ratio of the risk in terms of the aspects and the sensitivity of the system and its adaptive capacity”(IPCC 2001; NERI 2002). Therefore, the degree of vulnerability can therefore be described as a combination of three exposure factors, system sensitivity and characteristics related to system adaptive factors. [10]

Regarding the aspect of water resources management, Huang Cai (2009) defined the vulnerability of water resources to changes over time as "weak characteristics and errors of the system." Water resources make it difficult for the system to operate in the face of socio-economic and environmental changes”[14]. Water resources, which are the "blood" of natural ecosystems, have an indispensable role for most of the functions of the ecosystem. Water is also one of the most important resources needed to support the socio-economic development of a society. As a result of the population boom, rapid economic development, and poor management of water resources, water is becoming increasingly scarce. Sustainable water management is therefore on the priority list of national agendas. Developing an integrated water resources policy will require integrated knowledge and understanding of the vulnerability of water resources. Vulnerability is a concept, as described above, often used to describe weaknesses, or remaining flaws in a system, the exposure of a system to a particular threat. From a water resource management perspective, vulnerability can be defined as “the weaknesses of the water resources system make it difficult for the system to perform its functions in the face of socio-economic system and environmental changes”. Therefore, water resources vulnerability is considered in two issues: (1) the exposure of the water resources system to pressures at the river basin scale, and (ii) the capacity of the ecological system and society can cope with threats to the healthy functions of a water resource system. [13]

Thus, assessing the vulnerability of water resources to changes over time is a process of investigating and analyzing and evaluating the system's sensitivity to potential threats, and to identify challenges to the system in minimizing risks associated with the negative consequences of impact activities. Assessing the vulnerability of such a water system involves the balance between supply and demand, ownership systems and policies to support water management and protection, as well as hydrological variability under impact of the climate and the environment. It also considers the risks to surrounding communities that may affect the water resource system. An assessment of effective water resources vulnerability plays a role in the development of effective water use planning. In fact, assessing water vulnerability requires identifying dynamics, estimating pressures, understanding the current situation and trends, analyzing impacts, and identifying responses to weaknesses in the system of water resources.

Assessing the vulnerability of water resources is a process of investigating, surveying and analyzing the water resources system, thereby assessing the sensitivity of the water resources system to changes In the impact factorsin order to propose risk mitigation measures. This process involves considering the balance between supply and demand, reviewing water management and conservation policies, and changes in water resources under the influence of climate change and other environmental factors. In addition, it is also necessary to consider the impacts of social and human factors affecting the water resource system. An effective vulnerability assessment is to provide guidance on water use by providing a plan to enhance water security, policies to mitigate natural disasters and their impacts on water resources, reducing the sustainability of water sources. In order to assess the vulnerability of any entity, indicators are often developed to guide management. [12]

2.2. Indicators

In order to establishing a method that can determine the vulnerability of water resources systems, it is necessary to consider the indicators and numbers of vulnerability used by the previous authors. There are many examples of national indicators related to vulnerability. Some are formulated as general welfare indicators, economic status as well as development, while others are specifically for vulnerability assessment. [89,103]. According to UNEP, an indicator is a collection of data into an aggregate information about an environmental aspect of a country or a locality. According to the Vietnam Law on Environmental Protection (2005), an environmental indicator is one or a set of directives to show environmental characteristics. Environmental indicators are the basis for quantifying environmental quality and, according to the evolution of environmental quality, many environmental indicators are combined into one set of environmental indicators of a country, a region or a locality.

Indicators may be based on physical, chemical or biological measurements associated with the quality of natural resources or the environment [3]. They can generalize some aspects of the environment, natural resources or human activities. To be used in the framework of sustainable development, environmental indicators need to create a link between environmental aspects and socio-economic factors. A key feature of environmental marketing is that it helps change over time. The level of request and information generalization can be expressed in order from low to high as shown in Figure 2.

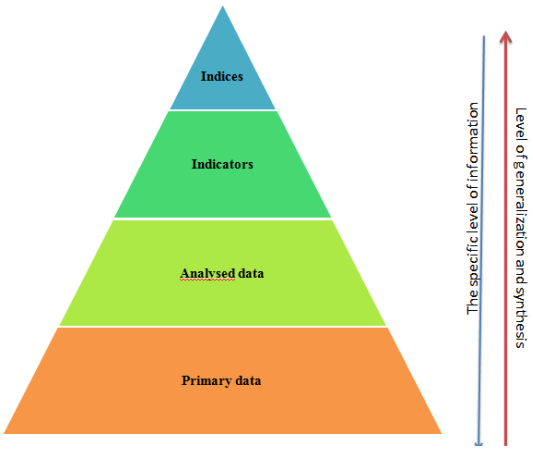

Figure 2. Information levels and indicators tower [2]

The indicators have significant implications for the community as well as the leaders of decision makers. The meaning of the environmental indicators is shown as follows:

- Effective informations: they reduce the number of measurements and directives required for normal environmental status presentation.

- Simplify information: through them, measurement results are provided to users.

- Prevention: summarize the current environmental and social status to give signals of changes in environmental status.

- Decision: provide effective guidance for planning a sustainable environment in the future. [2]

The author applies the method of assessing water vulnerability of UNEP (The United Nations' environment programs) for Thach Han river basin. Therefore, the study area will be assessed through 4 indicators (water pressure - RS, water development pressure - DP, ecological heath - EH, management capacity - Mc) and 12 coresponding parameters [14]. The vulnerability of a river basin can be expressed as: VI = f (RS, DP, EH, MC). High vulnerability is apparently linked with higher resource stresses, development pressures and ecological insecurity, as well as severe management challenges. In order to quantify the vulnerability index, the indicators for each variable should be determined and quantified. In this research, the total of weights given to all parameters in each category should be equal to 1; and the total of weights given to all categories should be equal to 1.

3. THE STUDIED AREA

The Thach Han River basin ranges from 16º18 'to 16º54' north latitude and from 106º36 'to 107º18' East longitude. Thach Han River originates from Truong Son mountain range and has a length of 150km. Thach Han main stream, the upstream part (Dakrong river) flows around the Da Ban mountain range, when it reaches Ba Long, the river turns northeast and flows into the sea at Cua Viet with a basin area of 2660 km2 located on cities. Dong Ha, TP. Quang Tri and districts of Gio Linh, Hai Lang, Cam Lo, DaKrong and Huong Hoa. Thach Han river system (also known as Quang Tri River) has 37 rivers including 17 river branches of level I with 3 typical branches namely Vinh Phuoc, Rao Quan and Cam Lo, 13 branches of level II and 6 branches of level III. Thach Han river basin is formed in narrow area, poor soil, sloping terrain, easy to erode and divided

by many short tributaries.The surface water potential of rivers is quite large but very unevenly distributed throughout the year and over the years, causing natural disasters such as floods, droughts; interfering with the use of water. Heavy floods in the river are often caused by storms and tropical depressions, sometimes with a combination of cold air. The flood season lasts for 4 months, from August to November. Large floods on alert 3 usually occur in October, September and November (in districts such as Gio Linh and Trieu Phong). [58] People are affected by environmental pollution after floods and accompanied by epidemics. Water resources of the basin vary according to topographic conditions and are strongly influenced by natural and human processes. Research and analysis of factors affecting water resources together with the relationship of human impact on water resources of the basin has created a diversified and complex division in the system of water resources in the basin. Based on the topographic elevation criteria, the study area is divided into 4 regions, and 12 sub-regions (based on the criteria of rainfall, discharge, groundwater level, water quality and population density).

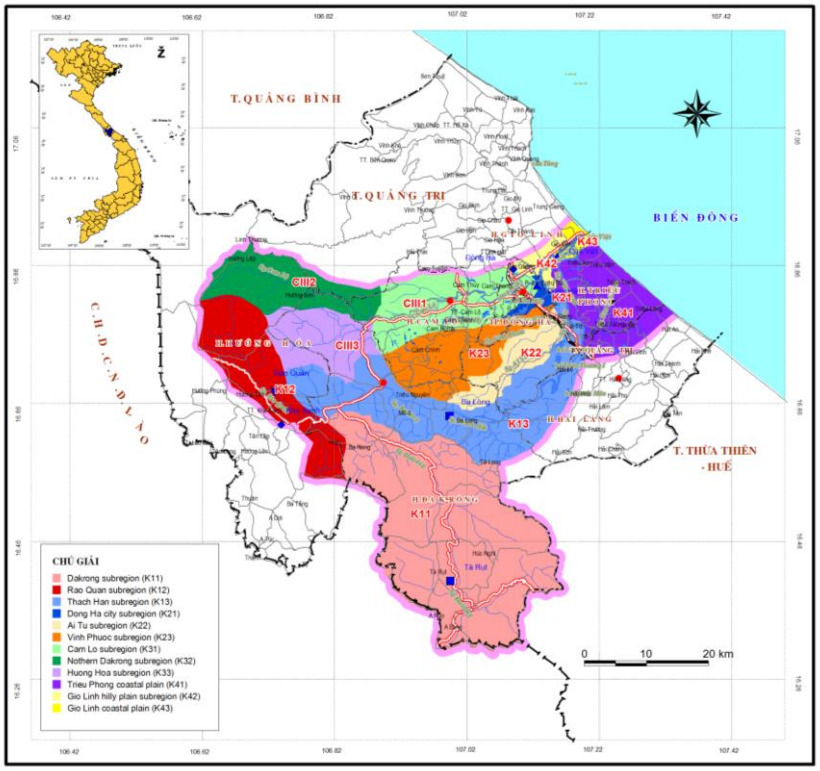

Figure 3 . Map of the studied area distribution - Thach Han river basin

K1- the low mountainous area upstream Thach Han River including K11, K12 and K13 sub-regions

K2 - the middle area of Thach Han River including K21, K22 and K23 sub-regions

K3 - low mountainous region of Cam Lo River basin including K31, K32, K33, K34 sub-regions

K4 - downstream delta area of Thach Han River including K41, K42, K43, K44 sub-regions

4. RESULTS

The general influence of water resources to vulnerability will be the quantity and quality of water resources, with the pressures from them being expressed as the “stress” and “variation” of water resources. Water Stress Index is the richness of water resources will decide to what extent it can meet the water demands of the population. Thus, the water resources stresses can be expressed as the per capita water. The water scarcity index for the entire basin is zero, compared to the generally-agreed minimum level of per capita water resources. Water Variation index can be expressed by the coefficient of variation (CV) of precipitation over the last 50 years. The parameter of water variation varies by 12 sub-regions and is expressed by figure 4. Indicator of water development (DP) is assessed through water exploitation parameter (for dry season) (DPs) and Safe Drinking Water Inaccessibility Parameter (DPd). Water Exploitation Parameter the water resources development rate (i.e., per cent of water supply, compared to the total water resource), can be used to demonstrate the capacity of a river basin for a healthy renewable process (Figure 5). Safe Drinking Water Inaccessibility Parameter indicates the natural process of adaptation capacity, the safe drinking water accessibility parameter is designed to present the state of social adaptation of freshwater use (i.e., how freshwater resources development facilities address the population’s fundamental livelihood needs) . This is an integrated parameter that reflects a comprehensive impact of the capacity of all stakeholders, from farmers to the government, to cope, as well as the availability of technologies, etc. Thus, the degree of stratification of water accessibility can be demonstrated by analysis of the proportion of the population with/without accessibility to improved water sources (Figure 6). The ecological health of a river basin can be measured

with two parameters; namely, the water quality/water pollution parameter and the ecosystem deterioration parameter. Water Pollution Parameter is the total wastewater produced within the basin. The contribution of water pollution to water resources vulnerability, therefore, can be represented by the ratio between the total untreated wastewater discharge and the total water resources of a river basin (figure 7). Ecosystem Deterioration Parameter can measured by the land ratio without vegetation coverage can be used to represent the contribution of ecosystem (figure 8). This component will assess the vulnerability of freshwater by evaluation of the current management capacity to cope with 3 types of critical issues, including: (i) efficiency of water resources use; (ii) human health condition closely dependent on, and heavily influenced by, accessibility to freshwater resources; and (iii) overall capacity in dealing with transboundary conflicts. Thus, the management capacity will be measured with 3 parameters representing the above 3 key management issues; namely (i) water use efficiency parameter; (ii) improved sanitation accessibility parameter; and (iii) transboundary management capacity parameter. Water Use Efficiency Parameter can be demonstrated by examining the gap between water use efficiency and the defined world average water use efficiency. This can be represented by the GDP value of 1 m3 of water, compared to the world average for selected countries. Improved Sanitation Inaccessibility Parameter is used as a typical parameter to measure the capacity of a management system to deal with livelihood improvement matters. Conflict Management Capacity Parameter demonstrates the capacity of the river base management system to deal with transboundary conflicts. A good management system can be assessed by its effectiveness in institutional arrangements, policy formulation, communication mechanisms, and implementation efficiency. The management capacity indicator (MC) is calculated for the whole basin through social questionnaire [4] (figure 8).

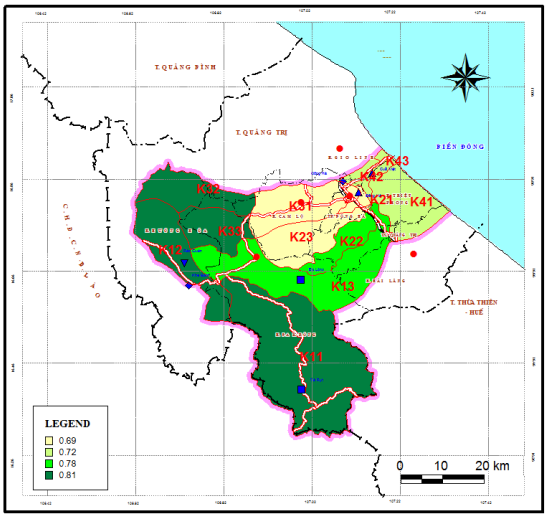

Figure 4. Water variation parameter

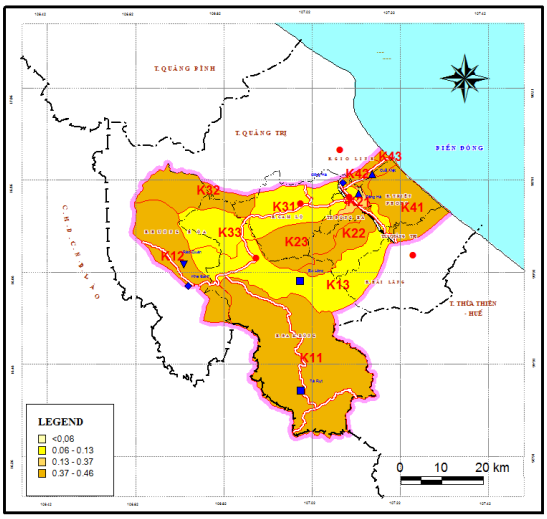

Figure 5. Water exploitation parameter

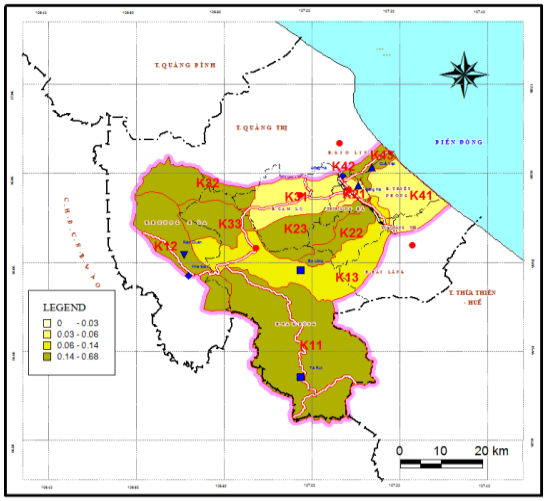

Figure 6. Safe Drinking Water Inaccessibility Parameter

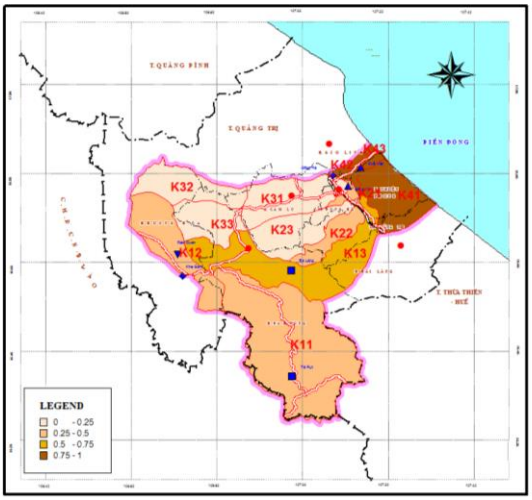

Figure 7. Water pollution parameter

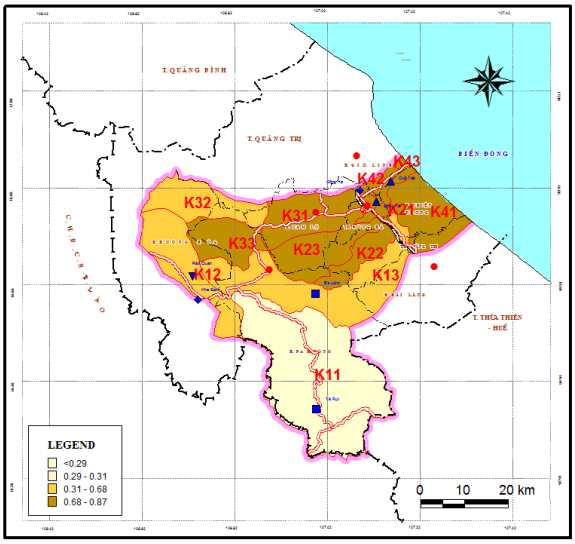

Figure 8. Ecosystem Deterioration Parameter

Water vulnerability map for the sub-regions Thach Han river basin is built based on the proportional topographic base map 1: 50,000. The results show that all sub-regions are vulnerable: range from 0, 4 - 0.7. Although the whole basin is generally in good condition (water availability is abundant), the amount of clean water provided for each sub-region is almost sufficient, the amount of water provide to other industries relatively). The sub-regions K13, K31 and K32 are affected the lowest vulnerability in the whole basin. The reason is due to this area receiving abundant water every year is plentiful and under water pressure for water use industries, the demand for clean water is not good people in the area. The remaining basins are under high pressure, so efforts are needed to build a mechanism to provide technical and political assistance to alleviate these pressures. Sub-region K41 (plain with a vulnerability of 0.62 inclusive of communes: Hai Vinh, Hai Ba and Hai An communes of Hai Lang district; Trieu Son and Trieu Tai, Trieu Trach and Trieu Lang belong to Trieu Phong district. These communes near the sea so that the hydro-meteorological elements are more variate than the other sub-regions, so the demand for water and its impacts to water resources has a significant impact on the development of water resources in the region. Next, the sub-regions K42 and K43 are all coastal plains or midland, water resources are susceptible to salinity or pollution due to civil activities and economic development, the status of poor environmental sanitation. The remaining sub-regions are all highly vulnerable, this is one of the numbers alarming managers to implement appropriate development policies suitable for each region.

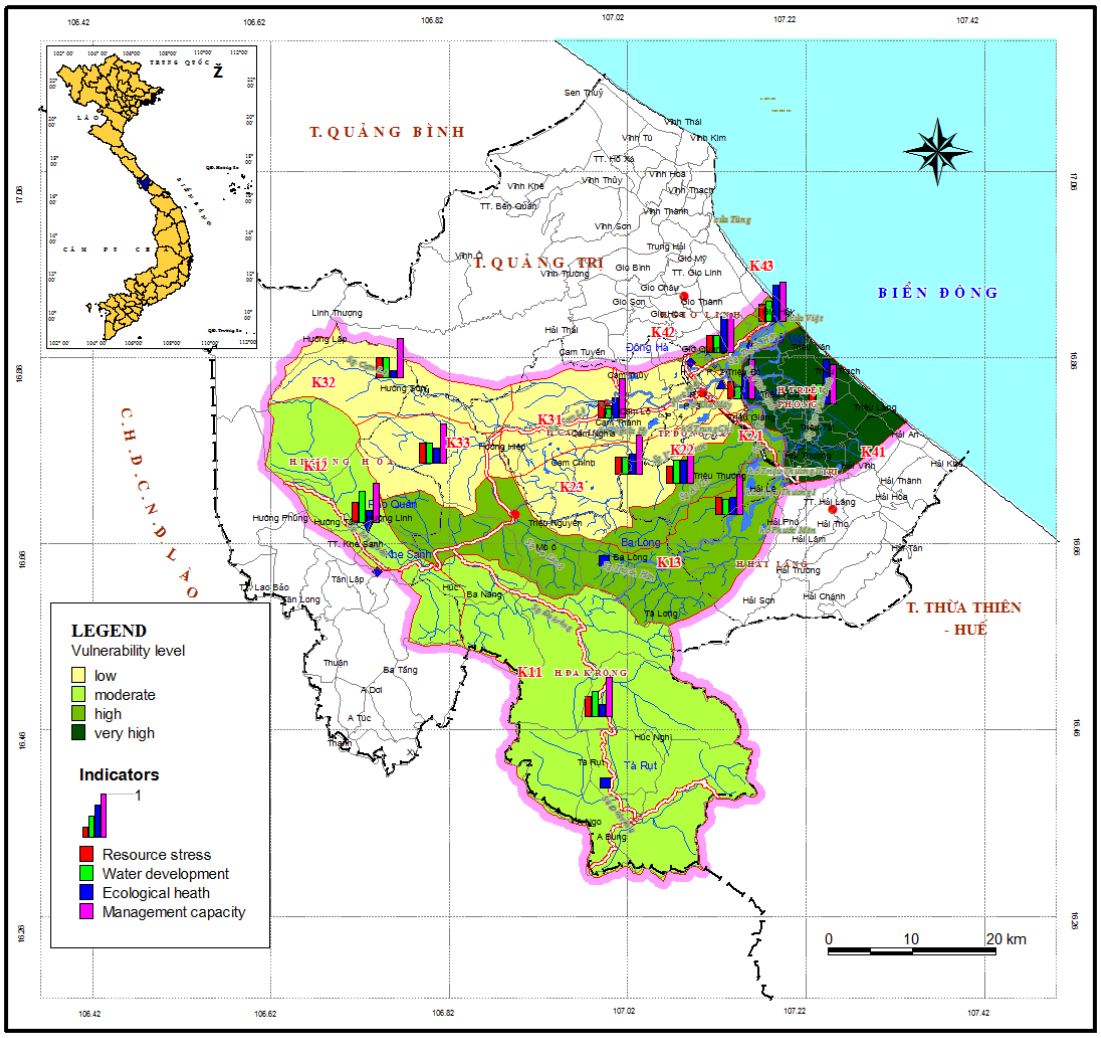

Figure 9. Vulenariblity map of Thach Han river basin

The author proposes a number of solutions to manage water resources issues for the sub-regions as follows

- Region 1 (The upland mountainous area of upstream Thach Han river - K1) covers the whole district of Huong Hoa and Dakrong. The terrain is mainly strongly divided high mountains, many ethnic minorities live, Low economic development level, limited underground water. Current situation of water supply is still inadequate. It is necessary to build more water collection works and reservoirs to store surface water for the dry season. Water collection facilities are located in river and lake beds, with sufficient depth to facilitate the arrangement of other auxiliary works.

- Region 2 (Middle area of Thach Han river - K2): including Dong Ha city, Trieu Phong district and Cam Lo district: this area is fertile soil, which is very convenient for cultivation and introduction of crops. Only produce high quality products into production, encourage the cultivation of industrial crops, timber trees in combination with cash crops, food crops and develop farm economy. The level of economic development of the region is quite. People should be encouraged to build breeding facilities hygienic environment, apply animal waste treatment by dry composting. It nesscessary to create tye coordination between the specialized management agencies and forces (Police, Military, and Forest Protection) in forest protection .

- Region 3 (lowland mountainous region of Cam Lo - K3 river basin) includes Cam Lo commune, the Northern Dakrong district, Huong Hoa district. The area has relatively high terrain. Some areas which have basalt bedrocks, with an average level of socio-economic development such as animal husbandry and fisheries should be encouraged. However, it is necessary to carry out integrated management of fishery resources in combination with integrated management of water resources. Aquatic species that are resistant to harsh environments could be developed too. It is also important to develop the capacity of preserving and propagating aquatic products, and at the same time, limit the excessive exploitation of the allowed levels.

- Zone 4 (the lower delta of Thach Han river - K4) including Trieu Phong and Gio Linh districts has low-lying terrain characteristics, relatively crowded population, shallow groundwater level, so it is advisable to change the farming season structure. It is essential to grow suitable crops such as crops demanding less water (corn, peanuts, etc.). Or switch to short-term crops (using new short-term rice varieties) to take advantage of the water and avoid farming in the dry months. At the same time, adjust the production season and change farming techniques. For water sanitation, it is necessary to build a system of rainwater drainage systems that

are reasonable and renovate and treat waste water by natural constructions such as biological lakes and wetlands. These works can be combined with fish farming, water hyacinth, and algae, etc. In order to combat minor floods (in May and June), avoid main floods by: designing dyke to protect crops; finding short-term plants that capable of harvesting before the flood season; raising cattle and poultry; expanding summer-autumn crops; building high quality of irrigation works such as spillways, reservoirs and sea dykes.

5. CONCLUSIONS

The integrated management of water resources for basins is an effective management method that has been studied and applied by many countries. Assessing the vulnerability of water resources to a basin is a scientific basis for policy makers, managers, and experts to access and exploit information on water resources related to the decision making of environmental and natural resource protection policies. Through the vulnerability assessment of the sub-regions, it was found that all sub-regions were highly vulnerable. The sub-areas of Dong Ha city, Gio Linh coastal plain, Trieu Phong coastal plain, and Gio Linh high region are sub-areas under great water pressure, which is due to economic development then fresh water demand rasing. If fresh water is not fully and promptly met, it will lead to the bad effects in social t development and inadequate supply of clean water to people in mountainous and hinterland. fresh water is easily pollutedcontaminated with alum and lime, not ensuring environmental sanitation. From the results of this study, we can make some reasonable proposals to manage water resources for the basin.

REFERENCES

[1] National Agency for Science and Technology Information, (2015). *Intergrated water resrouces management, Water resources management situation in Vietnam.* Hanoi.

[2] Che Dinh Ly, (2008). *Indicators and Parameters to assessing environmental status for cities in basin.* http://www.vnulib.edu.vn:8000/dspace/bitstream/123456789/2063/1/sedevmttn06-03.pdf

[3] Che Dinh Ly, (2010). *Tools and Methodologies in enviromental management. Ho Chi Minh University Publishing.*

[4] Pannature, (2006). Water resources management with Vietnam community. Hanoi

[5] AMCOW, (2012). *Status report on the application of integrated approaches to water resources management in Africa.*

[6] Brooks N. (2003), *"Vulnerability, risk and adaptation: A conceptual framework",* Tyndall Centre for Climate Change Research Working paper

[7] EnviroGRIDS - FP7 European project, (2012). *Integrated water resource sustainability and vulnerability assessment.* EnviroGRIDS_deliverableD5.8, 45p.

[9] IPCC (2001a), *"Climate change 2001: Impacts, Adaptation and Vulnerability"*, *Summary for Policymakers,* WMO.

[10] IPCC-CZMS (1992), "*Global Climate Change and the Rising Challenge of the Sea. Report of the Coastal Zone Management Subgroup",. Intergovernmental Panel on Climate Change.* Ministry of Transport, Public Works and Water Management, The Hague, Netherlands,

[11] Global Water Partnership (GWP) (2009*). A Handbook for Integrated Water Resources Management in Basins*. Elanders, Sweden, 2009. ISBN: 978-91-85321-72-8

[12] Villagran de Leon JC (2006). *Vulnerability - conceptual and methodological* review, *Studies of the university: research, counsel, education, publication series of UNU-EHS4*/2006. Bonn.

[14] UNDP, (2009), *Methodologies guidlines, Vulnerability assessment of freshwater resources to environment changes,* Thailand