Research Paper

VULNERABILITY ASSESSMENT OF WATER RESOURCES SYSTEMS IN LAM DONG PROVINCE

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ABSTRACT

In recent years, Lam Dong's water resources have not only changed in terms of quality and quantity of water, but this has affected the economic, social and living environment in the region. Based on UNEP guidelines, the vulnerability of water resources in the study area has been explored by isolating important issues related to the different functions of the water resource systems in a storage facility. area. At present, the vulnerability index for the river basin in Lam Dong (VI) reaches 0.29 in the river basin with a vulnerability index for medium water resources. Assessing the vulnerability of basin water resources is the basis for scientists to provide appropriate management solutions in the direction of sustainable development.

Keywords*: Vulnerability assessment, Lam Dong.*

1. Introduction

Water is the most important resource of the river basin. The use of water is closely related to land use and the impact on the watershed, therefore, water management by river basin will support better protect land and environmental resources. In order to implement an effective management policy of water resources, it is necessary to understand and assess the vulnerability 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 resource system to changes of water resources to propose risk mitigation measures.

Intergrated river basin management is one of the most nescessary tasks. Vulnerability Assessment of Water Resources Systems is a basis for scientists generate adequate management methods in order to subtainable development. This paper presents the result of vulnerabilty indicators of water resources for river basin in Lam Dong province.The assessment of water resource vulnerability of this river basin is based on the premise of four components of the water resource system, including: Management challenges, Resource stress, Development pressures, Ecological insecurity.

2. Methodology and Data

2.1. Theoretical basis for determining parameters to assess the vulnerability of water resources

Based on UNEP and Peking University guidelines (UNEPPKU, 2008). The vulnerability of water resources has been explored by isolating important issues related to the various functions (uses) of water resource systems in a basin. Therefore, this analysis is based on the premise of assessing the vulnerability of water resources in a river basin to be linked by four

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components of the water resource system, including: Total water resources, developing water resources and pressure to use water resources, ecosystems and water resources management.

According to this approach and assessment, a sustainable water resource system can only operate in an integrated operational framework that combines both natural systems and management systems.

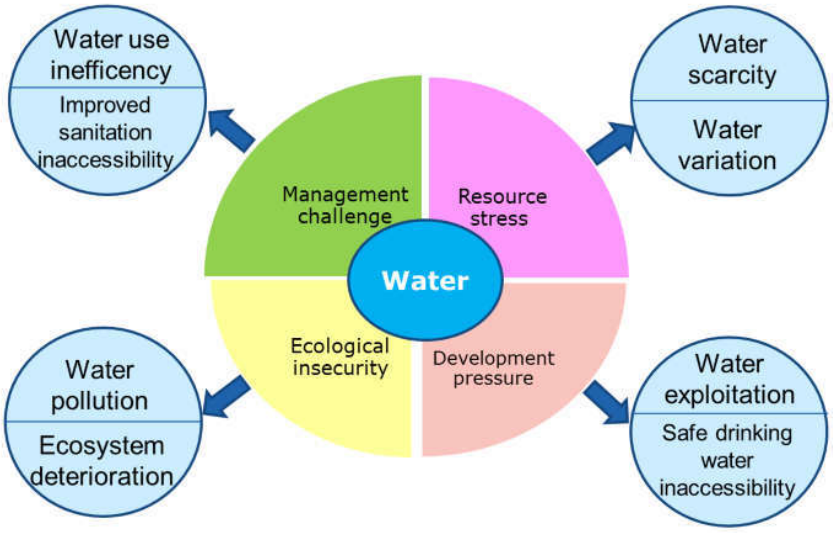

Fig. 1. Vulnerability to freshwater resources and indicators

2.2. Resource Stress (RS)

Water resources of a river basin are the total amount of fresh water available for maintaining ecosystems and socio-economic development, the water resources of a river basin may be characterized by water scarcity coefficient. and precipitation fluctuations in the basin.

Water Stress parameter (RSs): can be expressed by per capita water and compared to the average per capita water volume worldwide (1,700m^3/year) and determined as follows:

$$RS_S = \begin{cases} \dfrac{1700 - R}{1700} (R \le 1700) \\ 0\,(R > 1700) \end{cases} \quad (1)$$

where R is per capita water resources (m^3.person-1).

Water Resources Variation parameter (RSv): The variation of the water resources can be expressed by the coefficient of variation (CV) of total annual average precipitationof whole the basinand determined by the formula:

$$RS_V = \begin{cases} \dfrac{C_V}{0.3} (C_V < 0.3) \\ 1 (C_V \ge 0.3) \end{cases} \quad (2)$$

where CV is the coefficient of variation (CV) of precipitation.

2.3. Water Development Pressures (DP)

Development pressures (DP_S): Freshwater resources are recharged through a natural hydrological process. Over-exploitation of water resources will disrupt the normal hydrologic process, ultimately causing difficulties for the recharge of the water resourcebase. Thus, the water resourcesdevelopment 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. Thus:

$$DP_S = \frac{W_u}{W} \quad (3)$$

where W_u is the total water supply (capacity); and W is the total water resource

Safe Drinking Water Inaccessibility Parameter (DP_d): The ability to access clean water sources is also developed to indicate the status of adaptation to social factors. This is a comprehensive parameter reflecting the impact of capacity of all households using water as well as available techniques. This coefficient can be determined by the ratio of the total population able to receive clean water compared to the total population in the basin:

$$DP_d = \frac{P_d}{P} \quad (4)$$

where P_d is the population without access to improved drinking water sources; and P is the total Population.

2.4. Ecological Health (EH)

Ecosystem Deterioration Parameter (EH_e): As a result of the population expansion, the natural landscape was modified by the consequent urbanization and other socioeconomic development activities. Removing vegetation from landscapes changed the hydrological properties of the land surface, and can cause severe problems in supporting the functioning of ecosystems, in terms of water resources conservation, and contributed to the vulnerability of the region's water resources. Thus, the land ratio without vegetation coverage can be used to represent the contribution of ecosystemdeterioration to the vulnerability of water resources, expressed as:

$$EH_e = \frac{A_d}{A} \quad (5)$$

where A_d is the land area without vegetation coverage (i.e., total land area, except that covered with forests and wetland,expressed in km^2); and A is the total land area (km^2).

Water Pollution Parameter (EH_p): Vietnam is a country with relatively abundant surface and groundwater resources. However, the management, use and protection are not good, causing surface water sources to be increasingly polluted due to a large amount of industrial and domestic waste, and the source of groundwater is contaminated with persistent organic matter. In addition to their influence on the hydrologic process, water development and use activities will produce wastes, polluting the water resources base. Thus, another very important factor influencing the vulnerability of water resources 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.

$$EH_p = \frac{W_W}{W} \quad (6)$$

where W_w is the total wastewater discharge (m^3); and WR = total water resources (m^3).

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 conflicts.

Water Use Inefficiency parameter (MC_e): This can be represented by the GDP value of $1m^3$ of water, compared to the world average for selected countries, as follows:

$$MC_E = \begin{cases} \frac{WE_{WM} - WE}{WE_{WM}} & (WE < WE_{WM}) \\ 0 & (WE \geq WE_{WM}) \end{cases} \quad (7)$$

where WE is the GDP value produced from $1m^3$ of water; WEWM is the WE of selected countries.

Lack of information, or weak specific regulations on management, directives and human capacity institutions create a threat to the implementation of people, communities, where the public expects demand. when it comes to water supply. Water use policies and techniques deter-

mine the efficiency of water use. Therefore, the effectiveness of the water resource management system can be expressed through the difference between the water efficiency of the basin and the average water efficiency in the world.

Improved Sanitation Inaccessibility Parameter (MC_s): The ability to receive sanitation depends on the availability of clean water in the basin. Actual environmental pollution caused by community consciousness. Therefore, the best way to manage water resources is to create favorable conditions for people to receive and be aware of environmental sanitation conditions. Therefore, a management system must meet the above criteria is to strengthen the water supply to the community to meet the water demand for production life and at the same time be aware of the protection of water resources of me With the criterion on environmental sanitation parameters MC_s can be used as a typical parameter to assess management capacity in terms of ensuring improvement for human livelihood activities. and is calculated by the proportion of people not receiving sanitation with the total population calculated. With P_s is the total number of people not receiving sanitation and P is the total population of the basin. The formula for calculating MC_s is as follows:

$$MC_s = \frac{P_S}{P} \quad (8)$$

where P_d is the population without access to improved sanitation; and P is the total population.

Management Capacity (MC_c): In fact, any problems have any conflicts. Solution is always an important issue to determine the effectiveness of a job. Conflict management capacity parameters (MC_c) represent river basin management capacity for different types of conflicts. A good management system can be assessed through its effectiveness in aligning mechanisms and establishing effective management policies. Conflict management capacity, can be assessed through the matrix of contradictory management capacity parameters:

Table 1. Conflict management capacity parameter assessment matrix

Category of capacity	Description	Scoring Criteria →		
		0,0		0,25
Institutional capacity	Transboundary institutional arrangement for coordinated water resources management	Solid institutional arrangements	Loose institutional arrangements	No existing institutions
Agreement capacity	Writing/ signed policy/ agreement water resources management	Concrete/ detailed agreement	General agreement only	No agreement
Communication capacity	Routine communication mechanism for water resources management	Communication at policy and operational levels	Communication only at policy level or operational level	No communication mechanism
Implementation capacity	water resources management cooperation actions	Effective implementation of basin – wide river projects/programs	With joint project/program but poor management	No joint project/program

2.6. Vulnerability Index (VI)

To determine the vulnerability index of water resources (VI), it is necessary to determine the above parameters by weight. In each type of parameters their weights must have a sum equal to 1.

$$VI = 0,25RS + 0,25DP + 0,25EH + 0,25MC \quad (9)$$

Once the vulnerability index of the water resource has been identified, it is necessary to assess the situation of water resources based on the following criteria:

Table 2: Reference sheet for interpretation of Vulnerability Index

Vulnerability Index	Interpretation
Low ($VI \le 0,2$)	This indicates a healthy basin, in terms of resource richness, development practices, ecological state, and management capacity. No serious policy change is needed.
Moderate ($0,2 < VI < 0,4$)	This indicates the river basin is generally in a good condition in regard to realization of sustainable water resources management. It may still face major challenges, however, in regard to either technical support or management capacity-building. Thus, the basin's policy design should focus on the main challenges identified after examining the VI structure, and strong policy interventions should be designed to overcome key constraints for the river basin.
High ($0,4 \le VI < 0,7$)	This indicates the river basin is experiencing high stresses, and great efforts should be made to design policy to provide technical support and policy backup to mitigate the pressures. A longer-term and appropriate strategic development plan should be made, with a focus on rebuilding management capacity to deal with the main threatening factors.
Severe ($0,7 \le VI \le 1,0$)	This indicates the river basin is highly degraded in regard to being a water resources system with a poor management structure. Restoration of the river basin's water resources management will require major commitment from both government and general public. Restoration will be a long process, and an integrated plan should be made at the basin level, with involvement from international, national and local level agencies.

3. Results and discussion

3.1. Resource Stress

Water Stress parameter (RS_s): The rivers and streams in Lam Dong are plentiful, the average per capita is 168,345 m^3/day, compared to the one-person water standard in the world, the water resources in the river basin of Lam Dong province are evaluated. At a very plentiful level and can meet the demand for residential and some economic sectors. Therefore the water scarcity coefficient RSs of the basin are zero.

Water Resources Variation parameter (RS_v): According to average rainfall statistics from 1980 to 2015, Lien Khuong, Bao Loc, and Da Lat stations calculated the average Cv coefficient of 0.123 in the whole basin. Accordingly, the calculation of the coefficient of RS water pressure on the average of the entire basin is 0.207.

3.2. Development pressures

Development pressures (DP_s): The average total water demand of all industries in rural and urban areas in Lam Dong is 1610,12x106 m^3. At that time, calculate the average DPs of Lam Dong province by 0.039.

Safe Drinking Water Inaccessibility Parameter (DP_d): From the statistics of the number of households using clean water in Lam Dong province, in Da Lat and Bao Loc, the districts with households using clean water have a high rate. Lam Ha district has the lowest percentage

of people using clean water in the province only accounting for 35.73%.

According to the statistics of Lam Dong Statistical Yearbook in 2015, on average of Lam Dong Province, the proportion of people not using clean water is 10.77%.

After that, calculating the coefficient of receiving clean water in Lam Dong province is 0.11.

3.3.Ecosystem Deterioration Parameter (EH)

Water Pollution Parameter (EH_p): Climate change and many changes such as population growth, industrial development and increasing demand make water pollution and land degradation affect ecosystems. Calculating the total amount of industrial wastewater, animal husbandry and living is very difficult to collect as much as possible. According to the experience of experts, the calculation of domestic wastewater will be equal to 85% of the amount of water used, the amount of wastewater produced by livestock depends on the livestock. According to the data collected from Lam Dong province in 2010, from the calculation of water use needs of the sectors (calculated in detail in the calculation of water balance in Lam Dong province, calculating the coefficient of water pollution pollution $EH_p = 0.03116$.

Ecosystem Deterioration Parameter (EH_e):In Lam Dong, the land is mainly used for agriculture, accounting for 93.05%, non-agricultural land accounts for 5.58% and unused land accounts for only 1.39%. According to the statistics, the districts calculated the ecosystem decline coefficient of this area of 0.93.

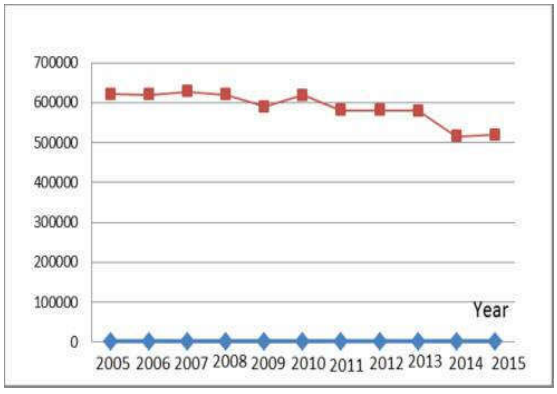

Fig. 2. Fluctuation of forest area in the past time in Lam Dong (ha)

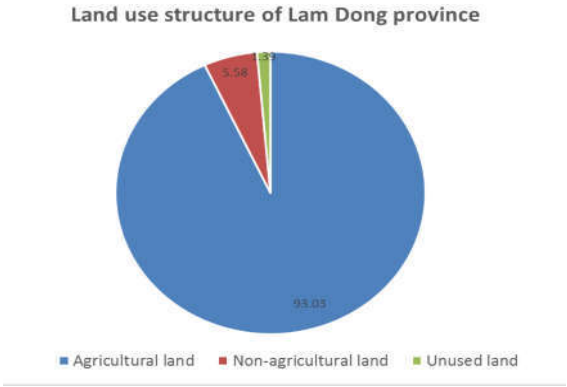

Fig. 3. Allocation of land use rates in Lam Dong

3.4. Management Capacity(MC)

Water Use Inefficiency parameter (MC_e)

Parameters used to calculate are investigated and surveyed in some areas in the basin. GDP income of regions calculated on average by Lam Dong province in 2015: (With the conversion of 1 USD = 23.000 VND), urban areas: 3137.4 thousand VND/month, equivalent to 49789,17 USD/year; rural areas: 2325,05 thousand VND/month, equivalent to 36897.53 USD/year.

According to the Decision No. 48/2013/QD-UBND dated the 18th October 2013 of Lam Dong Provincial People's Committee on regulating clean water consumption price of Lam Dong Water Supply and Sewerage Company Limited, the average of the region is 12100 VND/m^3 equivalent to 0.53USD/m^3. Meanwhile, in China, France, Mexico, the US is 23.8 USD/m^3. The average water use efficiency is 8.6.

The results of calculating the efficiency parameters of water use in Lam Dong are: MC_e= 0.94.

Improved Sanitation Inaccessibility Parameter (MC_s)

According to the global report of the United Nations Development Program (UNDP), Viet-

nam's human development index has increased by 41% over the past two decades. In 2012, Vietnam ranked 127th out of 187 countries - within the average category of human development with the Human Development Index (HDI) of 0.617 (China is 0.699, Thailand is 0.690).

According to the statistical data of Lam Dong province, by 2015, the proportion of households using hygienic drinking water accounted for 89.23%, of which 97.66% in urban areas and in rural areas was 85.45%. About 96.36% of households have hygienic toilets, of which urban areas account for 99.61%, and rural areas account for 93.23%.

According to Decision No. 1404/QD-UBND dated June 30, 2015, approving the rural water supply and environmental sanitation planning of Lam Dong province by 2020 as follows:

- Regarding clean water supply: 99% of rural population use hygienic water; 73% of rural population use clean water to meet QCVN 02/2009 standards of the Ministry of Health; 100% of schools and commune health stations in rural areas have enough hygienic water (completed before 2018); 99% of the rural population uses hygienic toilets and performs well personal hygiene, keeping the village and commune environmental sanitation clean; 100% of preschool and general education schools and health stations in rural communes have hygienic latrines (completed before 2017).

- Rural sanitation: 71.77% of rural households have hygienic latrines. 100% of preschool and general education schools and rural health stations have adequate hygienic latrines. 58% of breeding households have hygienic breeding facilities.

With the statistics of the province, calculating the number of people with access to sanitation in the basin of the province is: MC_s= 0.0364.

Management Capacity (MC_c)

Currently, in the basin, there are many investment projects for industrial and agricultural development, especially high-tech agriculture, with priority given to development. However, there are areas that are interested in investing and developing synchronously, ensuring sustainable economic development, such as Bao Loc and Da Lat. In parallel, with this problem, there are areas of incomplete development, there are still many agricultural production companies but no wastewater treatment system and environmental protection, causing pollution to the environment, aquatic ecosystems are strongly affected by population growth and economic development. These are very sensitive and pressing issues of society.

Management is the center for water resources issues in the river basin of Lam Dong province as well as the water quality and environment of the province. This also creates challenges in management. In general, the current status of water resources management in the river basin can see some points:

Rivers in Lam Dong province many rivers do not fit in the territory of Vietnam (located on the territory of neighboring Cambodia) and go through many provinces and cities (Dong Nai, Dak Nong, Dak Lak) so the problem to Developing an integrated water resource management program here is not easy to implement.

There is currently no institutional management of water resources here.

Community mechanism issue: there has been concern about the community in the use of water resources, there is a waste charge to limit discharge but there is no strict and effective.

Regarding the use of water in combination with environmental sanitation is not synchronized across the province, areas, residential areas in general, the poor in particular.

Regarding implementation capacity: there have been projects in operation but so far, in general the implementation capacity for the locality is still limited.

Through the basis to determine the capacity of conflict management capacity, there are results for river basins in the scope of Lam Dong province as follows: Institutional capacity: 0.25; policy capacity: 0.25; Community mechanism

capacity: 0.2 and enforcement capacity: 0.2. Accordingly, calculate the conflict management capacity MCc = 0.225.

3.5.Vulnerability and indicators for river basins in Lam Dong province

Based on the results of calculation of water pressure parameters, pressure on water exploitation and use, ecosystem parameters, management capacity, and calculated value of damage to water resources in Lam Dong province as follows: VI = 0.2903. That is, the index of water resource vulnerability of the basin of medium and basin level with good conditions for sustainable management of water resources still faces technical pressure and management policy. Therefore, it is necessary to develop a new management policy to match the water resource challenge.

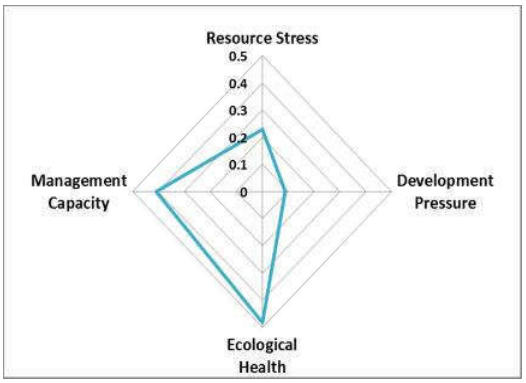

Fig. 4. Vulnerability Index of Water Resources Systems in Lam Dong province

Through these vulnerability values, the province should have a priority plan for higher vulnerability values to reduce the level of vulnerability. Since then, reducing the index of water resource vulnerability for each region as well as for the whole study area.

Results of calculation of vulnerability coefficient for water resources in river basins in Lam Dong province gives an overview of the situation of environmental sanitation and water resources in the basin. Since then, managers have a policy of integrated management of water resources for the basin within their scope more effectively. The problem of rational use of water is useful, the use is associated with very important protection. Not only can the waste source be grasped, but also to minimize the waste source into the environment, affecting water resources.

Ecosystems represent the survival of a river basin. The percentage of non-vegetation land (1.39%) indicates vulnerability to water resources. Parameters of conflict management capacity are social and not mathematically and natural with high accuracy and concretization, so the final calculation value has not reached absolute.

4. Conclusion

Integrated management of water resources by river basins is an urgent issue. Assessing the vulnerability of basin water resources is the basis for scientists to devise appropriate management measures towards sustainable development. The study results show that the current index of water resource vulnerability in the river basin in Lam Dong (VI) reaches 0.29 in the river basin with a vulnerability index for medium water resources. Although this index has not reached the absolute level, due to its social nature, it has partly shown the situation of environmental sanitation and water resources in the basin, especially Lam Ha and Don Duong districts. Since then, managers have a policy of integrated management of water resources for river basins that is better and more efficient.

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