

# Analysis of Appropriate Indicators to Assess Watershed Status in Thailand by Multi-Criteria Analysis

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## Abstract

Assessment of watershed status by the Office of Natural Resources and Environmental Policy and Planning, Thailand, in the past found that the watershed status in Thailand tended to be in a more critical state. The indicators and weights used to assess the status are different and varied, which affects the results to have an uncertain to compare and track changes. This research aims to select the appropriate indicators and weights to use to assess watershed status by using multi-criteria analysis. It is applied to the geographic information system that is widely used in spatial data analysis. The results of the study selected 17 indicators that were frequently used. The results of the assessment of Sakae Krang Basin revealed that the highest risk status was 2,662.79 square kilometers or 54.21% of the basin, followed by a Warning status of 1,206.37 square kilometers (24.56%) balance status of 1,038.10 square kilometers (21.13%) and critical status 5.10 square kilometers (0.10%), respectively. The results of field validation by the Confusion Matrix method showed that the percentage accuracy. 87.50 The results of the study can be used to assess the watershed status of Thailand. and planning to manage natural resources and the environment in the future.

**Keywords:** Watershed status, Watershed indicators, Multicriteria analysis

## 1. Introduction

At present, the watershed status in Thailand has deteriorated greatly. The assessment of the status by the Office of Natural Resources and Environmental Policy and Planning (ONEP) found that the watershed in Thailand tends to critical state. This may have a severe impact on natural resources and the environment in the future. Assessing the watershed status comprises the preparation of criteria methods and establishing a set of indicators for assessing watershed status. The indicators and weights used to assess watershed status are different and varied [1] [2] causing the assessment results to have an uncertain direction and cannot continuously compare and track changes. The watershed status assessment should select relevant criteria, and consistency and reflect the quality of the watershed. The multi-criteria analysis (MCA) in geographic information systems (GIS) can overlay the data and present alternative status forms varying weighting to natural resource and environmental management decisions. [3-5] Prepare an action plan for recovery. conserve and utilize natural resources and the environment Sustainable in watershed areas in areas of urgent

need and criticality according to the results of the status assessment. To be a tool to support the management of the watershed quality area more efficiently.

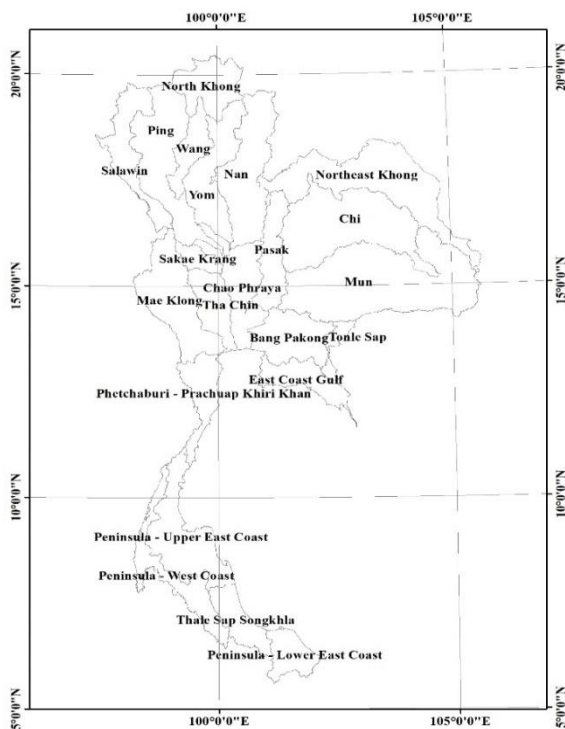
Geographic information systems are widely used in the analysis of spatial data, to assess the status of watersheds at the international and national level. GIS can import multi-layered spatial data. A suitability score or a watershed status score can be set for each factor with different weights. GIS can overlay many factors and use a variety of statistical techniques to classify spatial data to clearly distinguish the watershed status. GIS can create multiple analytical alternatives and trace back to find the cause of the spatial change by factors suitable for planning the watershed layer management by prioritizing the problem-solving from the most problematic areas.

Assessment of the watershed status of Thailand by defining indicators Appropriate scores and weights, together with GIS data analysis, are essential to create a suitable watershed status analysis model for Thailand. To be used to conserve natural resources, especially upstream areas, to function perfectly together with planning to manage

midstream and downstream areas covering the watershed area for efficient utilization conserving natural resources along with sustainable economic and social development. research objectives aimed at finding a core indicator for assessing the status of the watershed in Thailand, finding the appropriate weighting score for assessing the watershed status in Thailand, and assessing the watershed status by multi-criteria analysis based on core indicators and appropriate weighting score.

*Thailand Watershed*

The watershed in Thailand was divided into 25 main watersheds since 1993. Subsequently, in 2018 Office of National Water Resources (ONWR) together with Kasetsart University studied to review the new watershed area division. The results of the study concluded that the original 25 watersheds were improved to 22 watersheds, comprising the 1) Salaween River 2) North Mekong 3) Northeastern Mekong 4) Chi River 5) Mun River 6) Ping River 7) Wang River 8) Yom River 9) Nan River 10) Chao Phraya River 11) Sakae Krang 12) Pasak 13) Tha Chin River 14) Mae Klong River 15) Bang Pakong 16) Tonle Sap River 17) East Coast 18) Western Gulf Coast 19) Southern Upper East Coast 20) Songkhla Lake 21) Lower East Southern and 22) Southern River Basin on the west coast [6] shown in Fig. 1.



**Fig. 1. Twenty-Two Watersheds in Thailand**

Determination of watershed quality classes It is the zoning of the watershed area focusing on the properties of the area against soil erosion. and environmental vulnerabilities as guidelines for setting boundaries. Any area where soil and environment are fragile and prone to erosion must be preserved as a watershed. The areas that are resistant to soil erosion can be used for other activities. The watershed class was determined by using the relationship of various physical variables influencing the erosion of the area. It is a variable that is difficult to change. and independent of each other All five variables were slope (SLOPE) height (ELEV) landform (LANDF) geological feature (GEOL) and soil type (SOIL). Watershed (WSC) in the form of a standard correlation equation.

*Assessing watershed*

Guidelines for assessing the status of watersheds to achieve watershed management have adhered to the principles of environmental suitability and identified the importance of environmental elements in the watershed. Assessing the current state, their susceptibility and classified their status into 4 levels [7] 1) The natural equilibrium level (Nature Stage) is the watershed having composition/structure (Structure) in terms of type, quantity, proportion, and distribution of resources in various aspects under natural conditions. and can perform the function (Function) effectively, which is to produce good water yield in all aspects 2) Warning level: the watershed has slightly changed its composition/structure. But it's a short-term change. Therefore, it can restore its original nature in no time. The system can still function normally. but has resulted in more soil erosion and affects water quality at certain times, etc. 3) Risk level (Risky Stage) is the watershed that has changed its composition/structure significantly. It takes time to recover resources. causing the system to not function normally and have effects causing more problems such as soil erosion problems water quality problems, etc., as well as affecting the change in the proportion of runoff during the rainy and dry seasons. cause flooding or drought and 4) Critical Stage: the watershed has changed its composition a lot. Until unable to restore the original condition need to use technology to help so it can be restored to its original state. and it takes a very long time as a result, the watershed system is

unable to function normally for water production. and may cause severe natural disasters such as floods, droughts, and frequent landslides, etc.

Determination of weighted metrics Assessment of watershed status selected 4 groups of indicators, 1) watershed structure 2) watershed functions 3) social-economic, and 4) watershed management. These 4 groups have been obtained from the public participation of all stakeholders, such as government officials, local academics, community leaders and people involved in the watershed share their opinions and give group weights. The weighted assignment is based on the Rank Sum method. The Rank-Order Centroid Weight Method (ROC) is a reliable sequential weighting method, and the weighted sum was adjusted to equal 1 (Normalization).

Multi-criteria Analysis (MCA) is combining various spatial datasets through overlay analysis to help identify areas of concern or potential impacts. This technique allows for the assessment of the spatial relationships between different factors, such as land use and water quality, aiding in decision-making [8] Watershed multi-criteria analysis (WMCA) is an approach that combines quantitative and qualitative criteria to assess the condition and management options for a watershed [9]. It recognizes that watershed management involves a wide range of stakeholders and goals, necessitating the consideration of diverse criteria and objectives. Ground truthing is a fundamental technique for accuracy assessment in fieldwork [10] It involves comparing on-site observations or measurements with data collected remotely, such as through satellite imagery or remote sensors. Any disparities between observed and remote data can reveal discrepancies in accuracy. A confusion matrix, also known as an error matrix, is a table used to evaluate the performance of a classification model [11]. In remote sensing, they measure the performance of land cover classification models [12].

## **2. Research methodology**

From past studies of the Office of Natural Resources Planning and Policy in assessing the status of watersheds from 2016-2021, we select the indicators by order of the frequency used. "Expert judgment "brought by people who are involved in watershed status from representing the agency and

5 academics, including 1) representatives of the Office of Natural Resources and Environmental Policy and Planning 2) Representative of the Department of Natural Resources and Environment and 3 watershed academics jointly considered and selected indicators. They analyzed appropriate score and weighting by determining the weighting and score range by averaging existing data then adjusted the value by using Normalization total sum to one.

Selection of the study area was selected based on the results of the assessment of the status of Thailand's watersheds from the past to the present. Then select the percentage of river basins with the highest critical status as the study area from 2016 - 2021 by selecting from 22 main river basins of Thailand to be used as the study area for collecting indicator data. Score and weight values to further assess the status of the watershed.

Assessing the status of a watershed using multi-criteria analysis involves a structured methodology that considers various environmental, social, and economic criteria. Gather relevant data for each of the selected criteria. Data sources may include field surveys, remote sensing, government reports, and existing studies. Standardize the data, if necessary, to ensure that all criteria are on the same scale or unit of measurement. Assign weights to each criterion to reflect its relative importance. Apply multi-criteria analysis techniques, such as the Weighted Sum Model (WSM), to aggregate and analyze the standardized data. Calculate a composite score for each location within the watershed, representing its overall status.

Data validation through fieldwork, ground truth, and confusion matrix is a robust approach to assess the accuracy and reliability of data collected in the field. Overall Accuracy (OA) = (Number of Correctly Classified Instances) / (Total Number of Instances) in this research accepts OA over 80%.

## **3. Results**

The selection of indicators was done by experts to select indicators (Expert judgment). From the analysis of all 6 projects, there were a total of 81 indicators, selecting indicators that were highly repeating used. Data should be stored regularly and continuously. There are standardized classification criteria from the directly responsible agency. and is

used as a representative to assess the status of the watershed. Using selection techniques based on IDEA principles, including:

- 1) Investigate by determining the importance of preliminary indicators by each expert.
- 2) Discuss the preliminary specified indicators. By presenting the experiences and important opinions of experts.
- 3) Estimation: Adjust the priorities of the second round of indicators based on the opinions discussed earlier (individual).
- 4) Aggregate combines the scores of all experts by averaging each indicator. By averaging the total weighted results to be equal to 1.00.

The results of the selection of indicators used in the final assessment of status include a total of 17 indicators. Adjust the average weighting value from the original weighting value in the past to have a total value equal to 1 shown in Table 1. The indicator with the highest weight is forest cover according to the watershed class has a weighted value of 0.129, followed by Changes in forest areas and vegetation index the weighted values are 0.085 and 0.074 respectively. The indicators with the least weighted values are Forest fire area Landslide risk areas and budget for conservation of natural resources and the environment with weighted values are 0.027, 0.034, and 0.039, respectively.

**Table 1. Selected indicators using the IDEA method and weighting values.**

Indicators	repeating	Normalize weighting
Watershed structure		
The forest area is covered according to the watershed class.	5	0.129
Changes in forest areas	5	0.085
Drainage density	4	0.072
soil erosion	5	0.059
Watershed function		
Runoff volume per rainfall amount	6	0.070
surface water quality	6	0.056
duration of water flow	6	0.047
Irrigation potential of groundwater	6	0.039
Landslide risk areas	6	0.034
Areas at risk of flooding	6	0.050

Indicators	repeating	Normalize weighting
Drought risk areas	6	0.043
Vegetation Index	5	0.074
Forest fire area	5	0.027
Utilization		
Land use according to watershed quality classes	5	0.063
Declaration of conservation areas to protect natural resources and the environment	4	0.053
Society and Management		
Water management	4	0.055
Budget for natural resource and environmental conservation	3	0.039
Total		1.000

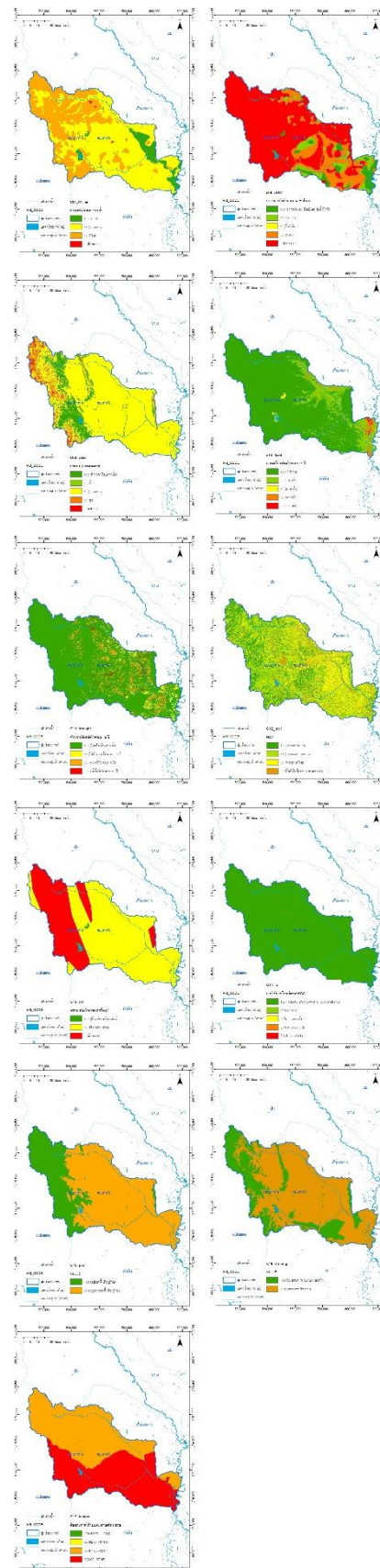
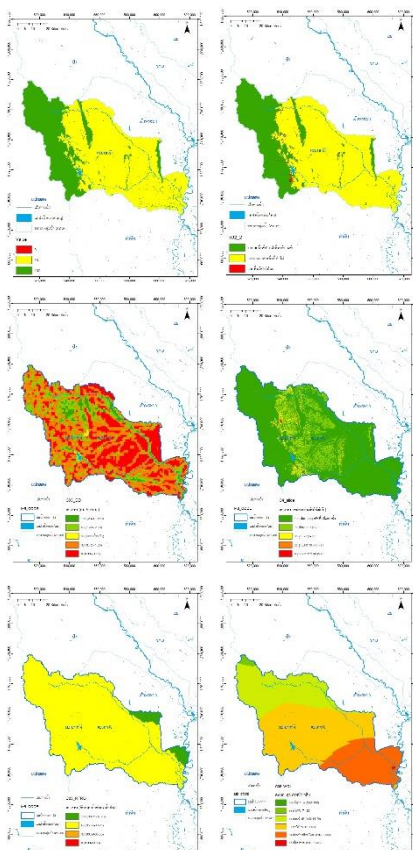
The study area was selected based on the results of the assessment of the status of Thailand's watersheds from the past to the present. Then select the highest critical status as the study area from 2016 - 2021 by selecting 22 main basins of Thailand for collecting indicator data. Score and weight values to further assess the status of the watershed. The watershed with the highest percentage of watershed status at the critical level is the Sakae Krang Basin in central of Thailand. There is a critical area accounting for 19.22 % (971.75 square kilometers). All 17 indicators determine score values to evaluate watershed status used in the same area. Shown in Fig 2.

Evaluate the status of the watershed by overlaying indicators using a multi-criteria analysis (MCA) with the following steps: Prepare indicators with score values in raster file format, pixels size 30 meters, by setting score values and weighting values. The score ranges from 0-100 points, arranged in order of status from critical. There is a score value equal to 0 to balance status. There is a score value equal to 100 points and the weighted value including 17 factors equals 1.00. The status analysis equation is.

$$WSI = (0.129.wsc\_fr) + (0.085.fr\_chg) + (0.072.dd) + (0.059.sloss) + (0.070.rorf) + (0.056.wqi) + (0.047.wtime) + (0.039.wyield) + (0.034.lslide) +$$

$$(0.050.flood) + (0.043.drought) + (0.074.ndvi) + (0.027.fr\_fire) + (0.063.wsc\_lu) + (0.053.envi\_pro) + (0.055.w\_manage) + (0.039.money\_ef)$$

- WSI* = watershed status Index
- wsc\_fr* = Forest cover area according to watershed quality class.
- fr\_chg* = Change in forest area
- dd* = drainage density
- sloss* = soil erosion
- roof* = amount of runoff per amount of rainfall
- wqi* = surface water quality
- wtime* = duration of water flow
- wyield* = irrigation potential of groundwater
- lside* = landslide risk area
- flood* = area at risk of flooding
- drought* = area at risk of drought
- ndvi* = Vegetation Index
- fr\_fire* = area of forest fire
- wsc\_lu* = Percentage of area with land use suitable for the measures specified in the watershed quality class.
- envi\_pro* = Announcement of conservation areas to protect natural resources and the environment.
- w\_manage* = water management and
- money\_ef* = budget for natural resource and environmental conservation

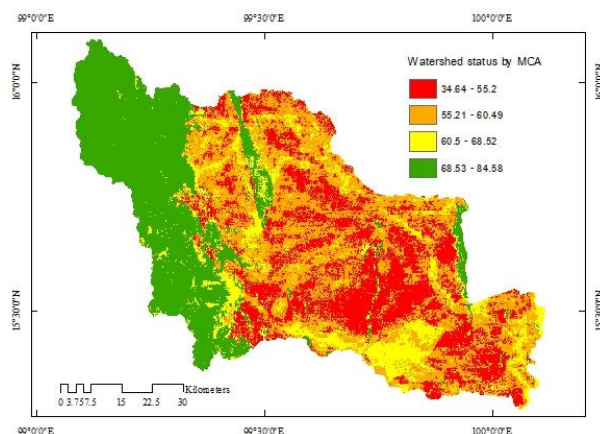


**Fig. 2.** 17 factors range from 0 – 100 that indicate critical watershed status (red) to balanced status (green).

Overlaying the data that has been multiplied by the scores and weighting. Divided the status scores into 4 levels by classifying with Natural Break statistics, it was found that the results of the assessment of the status of the Sakae Krang River Basin by MCA found that the highest risk area is 1,635.95 square kilometers or 33.30 percent of the basin, followed by balanced status of 1,434.98 square kilometers or 29.21 percent, critical status 1,205.35 square kilometers or 24.54 percent and warning status 636.08 square kilometers or 12.95 percent, respectively, as shown in Table 2, Figure 3.

**Table 2. Result of watershed status assessment of the Sakae Krang River Basin by MCA.**

Score range	Status	Area (sq.km.)	percent
34.64 - 55.20	critical	1,205.35	24.54
55.21 - 60.49	risk	1,635.95	33.30
60.50 - 68.52	warning	636.08	12.95
68.53 - 84.58	balanced	1,434.98	29.21
<b>Total</b>		<b>4,912.36</b>	<b>100.00</b>



**Fig. 3. Watershed status of the Sakae Krang River Basin by MCA. Classify to four classes 1) critical 34.64 - 55.20 (red) 2) risk 55.21 - 60.49 (orange) 3) warning 60.50 - 68.52 (yellow) and 4) balanced 68.53 - 84.58 (Green).**

Validity of the results by conducting field surveys to check the accuracy and reliability of the watershed status in the actual area. The checkpoints were determined on 4 statuses: critical, risk, warning, and balance in the Sakae Krang basin. The selection of inspection points to cover the study area using a systematic sample selection technique by grid sampling that covers all study areas and is distributed throughout the basin. The number of checking points in this study was determined to be

16 points, taking into account the duration and safety of data collection. Validation was done by visual observation compared with existing criteria maps such as land cover. Land use, slopes, forest areas, etc. We confirm some indicators by interviewing people in the survey area about other area conditions, such as natural disasters and the amount of water used, etc. The results of checking accuracy using the confusion matrix technique to find overall accuracy were equal to 87.5 %, shown in Table 3.

**Table 3. Confusion matrix table to check the status of watersheds in the Sakae Krang Basin.**

Confusion Matrix	Overall Accuracy Watershed status				total			
	Critical	Risk	Warning	balanced	point	true	percent	
Ground truth	Critical	3	1		4	3	75.0	
	Risk		4		4	4	100.0	
	Warning			3	1	4	75.0	
	balanced				4	4	100.0	
total	false	0	1	0	1	16	14	<b>87.5</b>

#### 4. Discussions

##### A. indicators and weighting

Indicators and weighting values for assessing the status of river basins in Thailand from the past to present. From a review of past and present studies related to the assessment of the status of watersheds both in Thailand and abroad. It was found that there were more than 80 indicators, most of them overlapping. Indicators can be classified into 3 groups:

- 1) Environmental indicator group which is the group of indicators with the largest used, such as forest area, surface water quality, drainage density, etc. These groups mainly reflect the structure and function of watersheds. This is consistent with the classification of indicators in classifying the status of watersheds by Prof. Dr. Kasem Chankaew on assessing the status of watersheds in Thailand [13]. In this group of indicators, information on the use of chemicals in agriculture such as fertilizers, directly affects the status of the watershed but there is no concrete collection from the relevant government agencies in Thailand. As a result, information on such indicators is missing.[14][15]
- 2) Social indicators group that is related to land use, management, and protection of natural resources and the environment. Water management and natural resource conservation areas, etc. This group of indicators reflects human use that may have a positive and negative impact on the status of the

river basin in the future[16]. Indicators in social groups that are interesting and should be added in future studies are Public participation in the conservation of natural resources and the environment. There should be clear guidelines for measuring participation and continuing to store information systematically. and

3) Group of economic indicators that include budget for conservation of natural resources and the environment. Some indicators are interesting and should be used to assess the future status of the river basin in this area, such as public income or the value of the ecosystem, etc. The reason there are fewer influent indicators is because They are indirectly related to the status of the basin or difficult to assess value[17].

#### *B. Watershed status of the Sakae Krang Basin*

The results status of the Sakae Krang Basin by MCA found that the Sakae Krang Basin has the most at-risk area of 1,635.95 square kilometers (33.30 %), followed by balanced status of 1,434.98 square kilometers (29.21%), critical status 1,205.35 square kilometers (24.54%) and warning status 636.08 square kilometers (12.95%). The area of critical status that scattered throughout the basin and found more in Thap Than District and Sawang Arom District in agricultural areas where monoculture crops such as sugarcane and corn are grown. This agriculture has a direct impact on the environment from burning before harvesting or indirectly from the use of chemicals and pesticides which affect directly some indicators such as surface water quality, Run-off volume per rainfall amount, Drainage density, or forest cover according to the watershed quality class, etc. In addition, it also affects the risk of drought, Landslides, and floods that cause the status of the watershed reach to a critical status.

The highest proportion of at-risk status is in the Sakae Krang Basin. It is a status that is at risk of changing into a crisis status in the future. If there is a lack of awareness in conserving natural resources and the environment or there is a lack of plans and measures based on important assessment results, such as increasing the area of perennial trees by promoting agroforestry. Water quality monitoring and reducing the use of chemicals, etc. In addition, promoting the establishment of appropriate measures may create a positive impact on the

Sakae Krang River Basin that will restore its status from danger to warning status in the future.

Balanced status is the second most common status after risky status. Especially at the boundary of the western forest in Pang Sila Thong District, Mae Wong, Mae Pen, and Lan Sak District. Most of which are in protected areas. Covered with forest areas which are the watersheds and can maintain a balanced state. Only some parts have been encroached on by people who want arable land. From the basis of economic needs such as land for farming, housing, or need for income, etc., which may affect the status of the river basin in the future. The government should therefore encourage villagers to be aware of natural resource conservation. Along with promoting careers that create additional income by using less or the same amount of agricultural land. To reduce encroachment on farming areas in the future.

#### *C. Overall accuracy*

The results of evaluating the accuracy of the watershed status assessment results with the field survey found that they were more than 80 percent accurate because most of the indicator data was continuously collected and standardized by main agencies, such as Information on changes in forest areas Land use information and information on flood risk areas, etc. The assessment can be analyzed efficiently and covers the study area. There is a visual inspection (observation) of at least 10 indicators and the use of questionnaire data and interviews with local people for another 7 indicators, which can accurately confirm the current condition of the basin. To be used as a guideline for future studies.

### **5. Conclusion**

The selection of indicators through expert judgment, data analysis, and the application of the IDEA method has resulted in a refined set of 17 indicators for assessing the status of watersheds. These indicators encompass various aspects, including watershed structure, function, utilization, and societal management. They were carefully chosen based on their relevance and importance in reflecting the health and quality of watersheds.

The study area, Sakae Krang Basin, was selected as a critical area for assessment based on historical data and the highest degree of risk. It was found

that approximately 33.30% of the basin falls into the critical category, indicating substantial environmental challenges. These challenges are largely attributed to agricultural practices, such as monoculture crops and the use of chemicals, which directly impact indicators like surface water quality, runoff volume, drainage density, and forest cover. However, there is hope for mitigating these risks and restoring the basin's status. Promoting agroforestry, water quality monitoring, reducing chemical usage, and protecting forested areas can positively influence the Sakae Krang Basin's future status. Additionally, the balanced status observed in certain areas, especially those under protection, highlights the importance of natural resource conservation and the need to discourage encroachment for agriculture and housing. The overall accuracy of the watershed status assessment, validated through field surveys and data comparison with criteria maps, yielded an impressive accuracy rate of over 80%. This level of accuracy is attributed to the continuous data collection and standardization efforts by key agencies, as well as visual inspections and local interviews that verified the current basin conditions.

In conclusion, this study demonstrates the significance of careful indicator selection, thorough data analysis, and accurate assessment methods in evaluating watershed status. The findings for the Sakae Krang Basin underscore both the challenges and opportunities for improving environmental conditions, and the high validation accuracy reinforces the reliability of the assessment results. These insights provide valuable guidance for future watershed management and conservation efforts, emphasizing the importance of sustainable practices and community engagement in preserving and enhancing the health of our watersheds.

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