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Development Indicators of City Resilience for Water Resources Management in Chiang Rai Province, Thailand

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Chiang Rai province, Thailand, one of ten cities in Asia, was selected to participate in the Asian Climate Change Resilience Network (ACCCRN) project, and is one of the cities facing effects of climate changes: floods, landslides, inadequate water supplies, as well as urbanization. Regarding climate changes, there must be the process of building city's response and development of indicators in order to cope with the climate changes. Thus, the objectives of this study were to develop indicators and provided information, which are useful for related organizations and communities to understand the situation of city resilience for water resource management. The indicators development process were comprised of three steps: 1) literature review of knowledge about concepts, theories, research, as well as forming the proposals of development indicators of city resilience, (2) selecting evaluation criteria, and (3) grouping and developing indicators. The results revealed that there were totally 13 indicators divided into two targets to develop city resilience indicators. The first target was Chiang Rai must have sufficient clean water for sustainable use (9 indicators), and the second target was agriculture and community must have adequate and goo quality water (4 indicators). The good indicator for the first target was "Chiang Rai required sufficiently clean water for sustainable use", while the bad indicator was "there must be an improvement is enhancing community level to participate in water management". Regarding the second target, the good indicator was "agricultural and community sectors had sufficient quantity and good quality water", whilst the bad indicator was "there was a requirement for planning improvement to seek new or alternative water sources".

Keywords: Resilience Indicator, Water Resources Management, Chiang Rai Province

Introduction

Chiang Rai province, Thailand, one of ten cities in Asia -- two cities in Thailand, three cities in Vietnam, three cities in India, and two cities in

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Indonesia, was selected to participate in the Asian Climate Change Resilience Network (ACCCRN) project, which was funded by the Rockefeller Foundation. The objectives of this project are to assist the target cities to strengthen their capacity to understand, plan, and respond to the change in climate and rapid urban, and action to strengthen cities' resilience to climate change impacts (Sharma *et al.*, 2013). The Institute for Social and Environmental Transition (ISET) provided technical support to develop a methodology for planning for climate resilience in all 10 cities, working in collaboration with local and regional partners (Moench *et al.*, 2011).

Regarding the resilience strategy development, the target cities was supported and assisted in developing indicators in order that those cities can prepare, withstand, and recover from the impacts of climate change which can lead to drive, monitor, execute, and plan in the future. The development of such indicators needs close collaboration from many stakeholders, such as public and private sectors, NGO, as well as academics. Chiang Rai has participated in the ACCCRN since 2010. Chiang Rai is to locate floodplain on Kok river basin. Urbanization is exerting pressure on resources, in particular water supplies, the rising of temperatures, more variable rainfall, and water scarcity pose major risks for the city agricultural sectors. The key vulnerability of Chiang Rai is water resources. The effects of climate change and urbanisation will be felt through water security across sectors (Thailand Environmental Institute, 2012).

The previous actions of Chiang Rai consists of assessing the city vulnerability and risk, developing strategies for city resilience, and conducting pilot projects focusing on the city's developed strategies for city resilience. Chiang Rai developed four main areas of development in line with the city resilient strategies, namely 1) develop the potential of the city, 2) agricultural city; 3) agro-tourism city; and 4) the quality of life. In addition, this city desired to develop land use ability, decision-making on land utilization, and sustainable resource management.

With the strategy and principles developed in Chiang Rai, the city indicators are mainly focused on water management and space utilization. The process of developing indicators is relied on stakeholders, both public and private sectors (agents, systems, and institutions) that affect climate change to plan the total water use requirement. Vulnerability and resilience indicators are also considered as critical constructs relating to climate change (Ellis, 2010). Resilience thinking is important for achieving sustainable communities (Sharifi and Yamagata, 2015), as such, resilience indicator as a key tool to evaluate cities' resilience to climate change impacts.

Developing resilience indicators is important to understanding resilience, shared an understanding of concepts, measured and established a common platform for future planning and monitoring of climate adaptation interventions at the city level (Tyler *et al.*, 2016). Therefore, this study focused on the development of criteria and indicators for evaluation of urban resilience. There were two key goals for developing the city response to climate change in water management issues -- Goal 1: Chiang Rai city must have sufficient clean water for sustainable use, and Goal 2: Agriculture and community have sufficient quantity and good quality water. The indicators obtained from this research are beneficial to help planners and decision makers to make systematic decision.

Materials and methods

The framework of indicator development

In order to determine the measure of Chiang Rai's ability to cope with water issues, three main stages involved in this study: 1) the review of the research on the indicators of the relevant agencies (literature review), 2) issue identification for assessment, and 3) selecting and grouping indicators as presented in Figure 1.

Figure 1. Step for developing indicator

Step 1: Review of literature, There are three levels of literature review: international collaborative studies, international research, and national agency studies. This study conducted literature review to identify criteria and indicators adopted from Water for People Water for Life (The United Nation World Water Development Report 1, 2003), Water a shared responsibility (The United Nation World Water Development Report 2, 2006), and incorporating resilience into sustainability indicators: an example for the urban water sector (Milman and Short, 2008). Another conceptual framework for climate resilience has been developed by ISET (Tyler and Moench, 2012).

Step 2: Identifying issues for assessment, this step is divided into three sub-steps:

1) Understand the physical features of Kok River Basin,

Chiang Rai located in the north of Thailand (Figure 2), and located at the mid-stream of the Kok River which frequently experiences flood. Kok River Basin is mainly composed of high mountain range --Dan Lao Mountains, to the north, and Khun Tan Mountain Range to the south. The climate of the Kok River basin is influenced by the the north-east monsoon. Hence, the rainfall in this watershed is manipulated by the tropical storm from the South China Sea that blows into eastern Thailand.

From the collection of runoff data from the Tang River Station, Chiang Rai is located in the Kok River Basin, 30 Kok Basin stations, the rain fed area ranges from 49 to 10,300 square kilometres. The average annual runoff per storm water receiving area is 4.84-52.40 litres/sec/km.

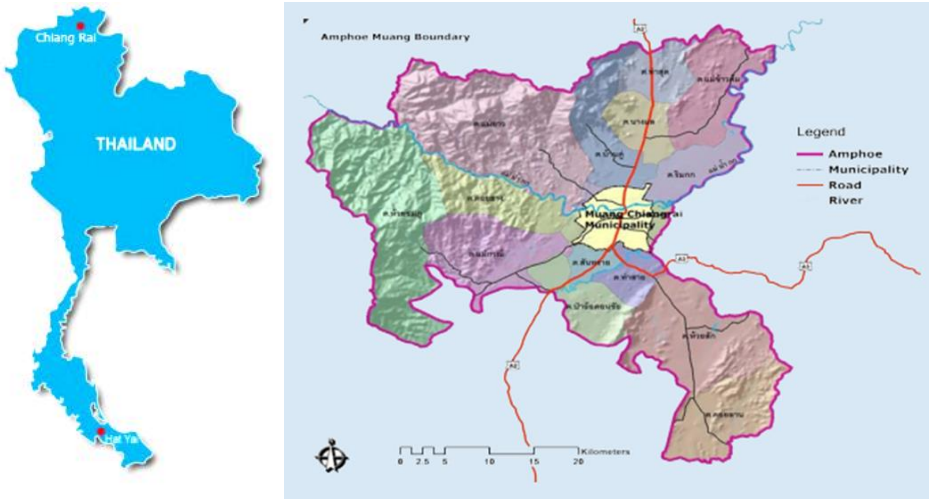

Figure 2. Location of Chinag Rai, Thailand
Source: Adapted from Thailand Environmental Institute (2012)

2) Describe Demand and Supply in the Watershed.

Overall, the water demand for all activities in the Kok River Basin in the current and in the future for 12 years (2025) reveal that the current water demand is 1,946.38 million cubic meters/year, and in 12 years (2025), the demand for water is estimated to 2,684.12 million cubic meters / year.

The overview of water demand in Kok River Basin was divided by the main purpose into 4 sectors: first, agriculture is divided into two parts: industrial sector accounting for 1.18%, industrial sector accounting for 0.61%, and downstream ecology accounting for 38.96%. Water sources were concluded that the water areas in Thailand were 7,300.41 square kilometres.

The natural flow was 3,380.4 million cubic meters per year. Average drinking water consumption per day was 14.68 litres per second per square kilometre.

The average rainfall during the rainy season (May-October) was 2,456.3 million cubic meters (72.66% of the average annual rainfall) and the average rainfall during the dry season (November-April) was 924.1 million cubic meters (27.34% of the average annual flow). The distribution of average monthly runoff of Kok Basin and summary of the average monthly flow of Kok River Basin are presented in Table1.

Table 1. Summary of the average monthly runoff of Kok Basin.

Unit : Million cubic meters

Apr.	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Annual**
72.5	114.7	177.8	321.4	569.6	742.6	3,380.40
Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar**	
530.2	321.7	195.0	147.8	101.1	86.0	

Source: Royal Irrigation Department (2016)

Step 3.Select and group indicators

There are two key goals for the development of Chiang Rai's response indicators for climate change for water resources management as shown in Figure 3. Goal 1 is Chiang Rai must have sufficient clean water for sustainable use, and Goal 2 is Agriculture and community have sufficient quantity and good quality water. The creating of city response to climate change is a based-on urban system which was adopted from Tyler and Moench (2012).

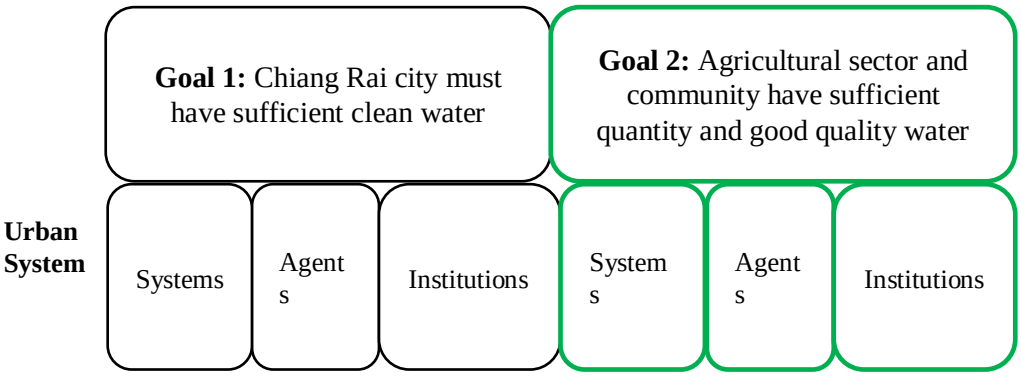

Figure 3. Criteria to grouping indicators

Indicator scores

In order to express the urgency to improve the lowest scoring indicators (Koop and Van Leeuwen, 2015), each indicator scored from 0–5, where 0 indicated poor performance, with urgency improvement required and 5 indicated excellent performance.

Results

Development of indicators of city resilience

The metric group was divided into three major groups, based on the Urban System. The report cited the city's response to climate change by ISET, namely 1) systems were enable networks to provide and exchange for urban populations which was essential element of urban resilience, 2) agents were an important part of any urban climate resilience framework, and 3) institutions may enable and support, or constraint and inhibit, the capacities of vulnerable urban groups (Moser and Satterthwaite, 2010; Tyler and Moench, 2012).

***Goal 1*:** Chiang Rai city must have sufficient clean water (9 Indicators)

In order to achieve this goal, 9 indicators were provided to measure progress (Figure 4), namely indicator 1: number of related agencies participated in monthly water workshop, indicator 2: number of water reserves resource, indicator 3: the total quantity of water reserve compared to quantity of water used, indicator 4: number of wastewater points and wastewater treatment, indicator 5: number of wastewater points which treated wastewater, indicator 6: the volume of wastewater treated, indicator 7: number of institutions compliance with an agreement, indicator 8: number of communities that have a clear agreements, and indicator 9: number of communities that have a clear agreements and practical.

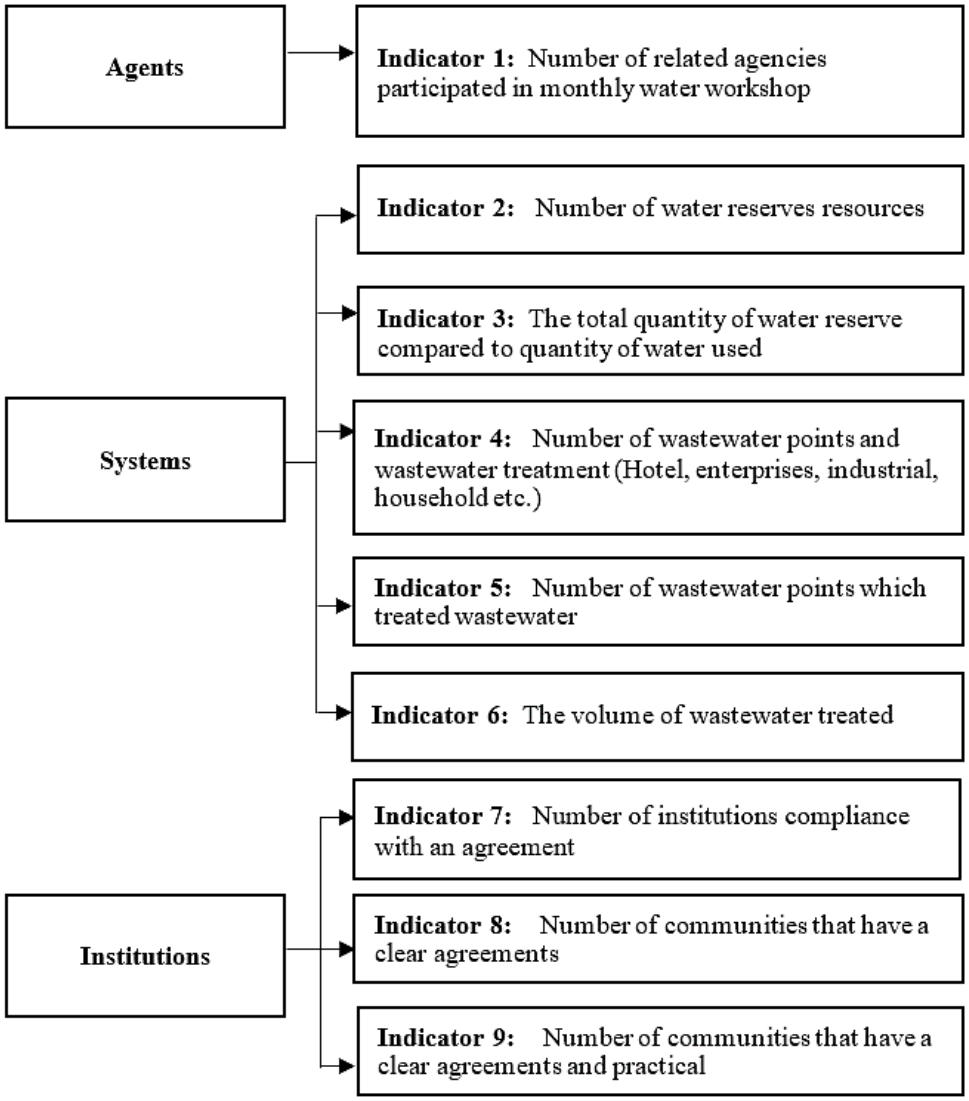

Figure 4. Indicators for goal 1; Chiang Rai city must have sufficient clean water

Goal 2: Agricultural sector and community have sufficient quantity and good quality water (4 indicators)

To achieve this goal, four indicators has been addressed (Figure 5), namely indicator 10: number of agencies participated in monthly water workshop, indicator 11: Type of water resource in the community, indicator 12:

number of water resources in the community, and indicator 13: number of projects/ activities/plans.

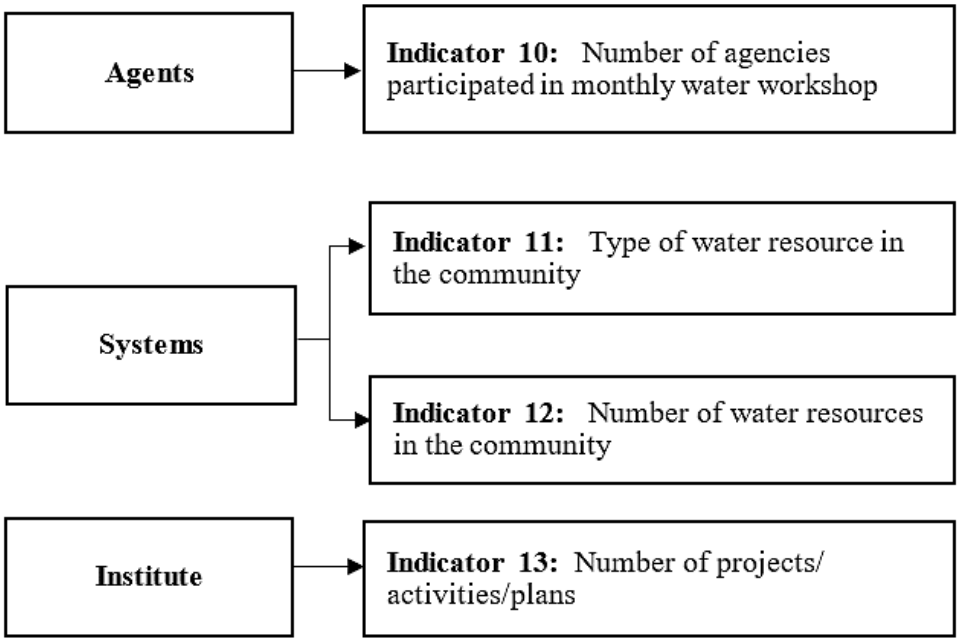

Figure 5. Indicators for Goal 2: Agricultural sector and community have sufficient quantity and good quality water

The evaluation of indicators

The evaluation of indicators by team generally consisted of at least two persons having different professional qualifications. Two experts from different professional qualifications were integrated into the evaluation team, and were responsible for making comment and recommendation on each indicator. Table 2 demonstrates the experts' comments and recommendation on indicator 1: number of related agencies participated in monthly water workshop.

Table 2. Experts' comments and recommendation on indicator 1: number of related agencies participated in monthly water workshop

Comment and recommendation from the first expert	Comment and recommendation from the second expert
1) The meaning of the word "all sectors", should be able to clearly identify which sectors and organizations, namely municipal office, water supply, agriculture offices (district or province), irrigation offices (province or water supply and maintenance project), public health, Ministry of Natural Resources and Environment (province), community affected by policy of sectors and/or organizations. (Where and how?)	1) Must be able to clearly identify which agents should be aware of the water situation. - To be able to identify the agents, water situation both quantity and quality of water. Soil and/or groundwater, groundwater should be clarified.
2) Consider "quantity/quality of the plan related to improving water management" (should be an aggressive plan). This plan should be one part in the annual work plan of each agent.	2) If the goal of this criterion is simply to acknowledge the use of the number of related agencies as indicators, it is reasonable.
3) Create new scoring for – "annual action plan" or "proactive plan" to solve the problem. – Successful completion of all plans - Budget per plan.	However, if the goal of this criterion requires awareness, knowledge, and knowledge to be useful, then indicators should be added to the number of water management related initiatives as one of indicators.
4) After having a consistent understanding, everyone can apply these indicators.	

Expert opinions and recommendations on indicators

Experts' opinions and recommendations on indicators 1: Number of sectors involved with local government organizations in the planning of reservoirs are demonstrated in Table 3.

Table 3. Comment and recommendation from the experts' towards indicator 1: number of sectors involved with local government organizations in the planning of reservoirs.

Comment and recommendation from the first expert	Comment and recommendation from the second expert
1) The meaning of the word "all sectors", should be able to clearly identify which sectors and organizations, namely municipal office, water supply, agriculture offices (district or province), irrigation offices (province or water supply and maintenance project), public health, Ministry of Natural Resources and Environment (province), community affected by policy of sectors and/or organizations. (Where and how?)	1) Must be able to clearly identify which agents should be aware of the water situation. – To be able to identify the agents, water situation both quantity and quality of water. Soil and/or groundwater, groundwater should be clarified.
2) Consider "quantity/quality of the plan related to improving water management" (should be an aggressive plan). This plan should be one part in the annual work plan of each agent.	2) If the goal of this criterion is simply to acknowledge the use of the number of related agencies as indicators, it is reasonable.
3) Create new scoring for – "annual action plan" or "proactive plan" to solve the problem. – Successful completion of all plans - Budget per plan.	However, if the goal of this criterion requires awareness, knowledge, and knowledge to be useful, then indicators should be added to the number of water management related initiatives as one of indicators.
4) After having a consistent understanding, everyone can apply these indicators.	

Assessing resilience indicators with relevant agencies

Goal 1: Chiang Rai must have sufficiently clean water

Table 4 shows the result of indicators for Goal 1: Chiang Rai must have sufficient clean water to maintain a good level. Since organizations involved in the management of the city of Chiang Rai, the meeting was important for the annual plan. All wastewater facilities were equipped with a wastewater treatment system. However, at the community level, communities needed to involve more in water management, and community participation in water management should be improved.

Table 4. The summary result of indicators for Goal 1: Chiang Rai must have sufficiently clean water

Urban systems	Indicators	Interpretation
Agent: (All sectors are aware of the water situation)	**Indicator 1:** Number of related agencies participated in monthly water workshop	Excellent
System:	**Indicator 2:** Number of water reserves resources	Fair
(Sufficient water to use)	**Indicator 3:** The total quantity of water reserve compared to quantity of water used	Good
	Indicator 4: Number of wastewater points and wastewater treatment	Excellent
	Indicator 5: Number of wastewater points which treated wastewater	Fair
	Indicator 6: The volume of wastewater treated	Good
Institution:	**Indicator 7:** Number of institutions compliance with an agreement	Excellent
(Related organization)	**Indicator 8:** Number of communities have a clear agreements	Should be improved
	Indicator 9: Number of communities have a clear agreements and practical	Excellent

Goal 2: Agricultural sectors and community have sufficient quantity and good quality water

Table 5 shows the evaluation of indicators for Goal 2: agriculture and community/city have adequate and good quality water supply. The result indicated that Chiang Rai had sufficient quantity and good quality water supply in a good level. The reason to support this finding is all sectors, namely government, state-owned enterprises, the private sectors, NGOs, academia sectors, and public sectors, are involved in the planning of alternative water supply with local authorities. In addition, the type of water sources in the community including both large natural water sources and more than five man-made water sources, thus providing sufficient water supply. However, the community has very few plans/projects/activities for reserving water resources that urgently required to be improved.

Table 5. The summary result of indicators for Goal 2: agricultural sectors and community have sufficient quantity and good quality water

Urban systems	Indicators	Interpretation
Agents: All sectors are involved in the planning of reservoirs and water supply.	**Indicator 10:** Number of agencies participated in monthly water workshop	Excellent
Systems: Database of water resources	**Indicator 11:** Type of water resource in the community	Excellent
	Indicator 12: Number of water resources in the community	Excellent
Institutions: The municipality has projects / activities /plans to provide water resources in the community	**Indicator 13:** Number of projects/ activities/ plans	Should be improved immediately

Conclusion and Recommendation

Chiang Rai province, Thailand, one of ten cities in Asia, have participated in the ACCCRN since 2010. Regarding the resilience strategy development, the cities were supported and assisted in developing indicators in order to prepare, withstand, and recover from the impacts of climate change by driving, monitoring, executing, and planning in the future. Resilience indicators are a key tool to evaluate city resilience to climate change impacts. This study developed indicators used as a tool to help the city. The city response to climate change will lead to the drive for monitoring, action, and plan in the future.

Indicators were divided into three groups according to urban system, namely Systems, Agents, and Institutions. Thirteen indicators were selected and grouped into two goals. Goal 1: Chiang Rai city must have sufficient clean water was composed of 9 indicators, namely indicator 1: number of related agencies participated in monthly water workshop, indicator 2: number of water reserves resource, indicator 3: the total quantity of water reserve compared to the quantity of water used, indicator 4: number of wastewater points and wastewater treatment, indicator 5: number of wastewater points which treated wastewater, indicator 6: the volume of wastewater treated, Indicator 7: number of institutions compliance with an agreement, Indicator 8: number of communities have a clear agreements, Indicator 9: number of communities have a clear agreements and practical. While, Goal 2: Agricultural sector and community have sufficient quantity and good quality water was composed of 4 indicators, namely: Indicator 10: number of agencies participated in monthly water workshop, Indicator 11: type of water resources in the community, Indicator 12: number of water resources in the community, and indicator 13: Number of projects/ activities/plans.

Regarding application indicators with related organizations, it was found that for Goal 1: Chiang Rai city must have sufficient clean water, Chiang Rai revealed good resilience indicators. Similarly, for goal 2: Agricultural sector and community have sufficient quantity and good quality water also indicated that Chiang Rai had good resilience indicators.

However, this study suggested the implementation of the indicators used in Chiang Rai response to water issues as follows:

1) Agencies with tasks related to the indicators should be aware of the importance of systematic and continuous data storage.

2) Relevant agencies and local authorities should prioritize the assessment of the city ability to cope with water issues and bring the results to the action plan in responsibility areas.

3) The assessment results should be published to the public continuously. In addition, the campaign encourages people to consciously conserve should be implemented in a cost-effective manner in order to cooperate in preventing and solving problems related to water resources.

4) Relevant agencies should promote and support the community to have a water resources management plan for community. Local government and people should take part in a plan.

5) Relevant agencies should improve the set of indicators consistent with the study area, for example holding a joint action meeting between the agencies involved in each indicator. The goal or standard of each indicator is derived from the participation of different sectors.

6) The successful implementation of water resources in Chiang Rai requires cooperation from all sectors, including government agencies, local government organizations, and people in the community.

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