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Floods and droughts: sustainable prevention and management

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Abstract

The world is experiencing a dramatic increase in disasters related to precipitation. The lack of precipitation as well as heavy downpours are causing disasters ranging from extreme droughts to unprecedented floods. Climate change, environmental degradation, population growth, urbanization and augmenting poverty cause human society to be more vulnerable to flood and drought disasters. Preparedness systems should be built to reach sustainable levels to relieve the human vulnerability against water-related extreme events in ways that avoid the past mistakes and satisfy a wide range of needs. Due to the complexity of interaction, there is no single universal remedy against water-related extremes. A holistic perspective calls for a joint consideration by applications of sustainable integrated water resources and comprehensive disaster risk management. Flood and drought prevention and management of Thung Kula Rong-hai in northeast Thailand is presented as the example of a pilot study.

1 Introduction

In the past decades, natural disasters around the world have been apparently due to water-related extreme flood and drought events. The lack of precipitation as well as heavy downpours cause disasters of different types, ranging from extreme drought to unprecedented flood. Climate changes, environmental degradation, population growth, urbanization and augmenting poverty cause human society to be more vulnerable to flood and drought disasters. They cause serious destruction to the agriculture area, industry, services and the ecosystem with long lasting negative consequences, in particular in the poor developing countries. They have become a limiting factor to economic and social development. Various efforts have been set out for the establishment of appropriate prevention and management measures to cope with this problem. This paper presents an example of a master plan study on a sustainable level of integrated water resources and comprehensive disaster risk management to relieve flood and drought stress in such a way so as to avoid past mistakes and which results in satisfying a wide range of needs including agriculture, irrigation and maintenance of the natural ecosystem of Thung Kula Rong-hai in northeast Thailand.

2 Flood and drought

Floods can be divided into 4 types: *flash floods,* due to heavy rainfall in a short period, i.e. a tropical cyclone causing very high rainfall intensity, *over-bank floods,* due to continuous heavy rainfall in the watershed area for a long period overloading the water course—the level of violence depends on the river size, quantity of rain and duration (normally, hydrological floods prolong more than flash floods); *flood tide*s, which occur at the river mouth connected to the sea; and *storm surges*, which occur along the beach because of tropical cyclones in the sea.

A drought is an arid period with less or even no rainfall occurring than is the usual case. It occurs whenever the groundwater level and river flow decreases and a water shortage for human, industry, service and agricultural uses occurs. It can be classified into 3 types: *meteorological drought*, evaporation from the soil and plants is more than the annual rainfall; *hydrological drought*, characterized by a meteorological phenomenal change with prolonged period with only a small quantity of average rainfall intensity—groundwater and river water levels remain low causing a lack of water during the dry season; and *agriculture drought*, the situation of water shortage for agriculture which may occasionally occur in the early rainy season and widely causes a destruction of agriculture.

3 Integrated water resources management (IWRM)

From Agenda 21, Chapter 18 as endorsed at the United Nations conference on the environment and development, Rio de Janeiro in June 1992, IWRM is based on the perception of water as an integral part of the ecosystem, natural resources and social and economic good. Therefore, water resources have to be protected taking into account the function of the aquatic ecosystem and perennially of the resource in order to satisfy and reconcile the needs for water in human activities.

4 Comprehensive disaster risk management (CDRM)

One of the sound policies used to mitigate the effect of flood and drought risks is to change from one that reacts to disasters to one that prevents them by taking awareness more seriously. CDRM will help ensure that there is less consequential damage due to floods and droughts. Achieving prevention requires better system

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of early warnings of impending disasters to give the vulnerable population time to move out of harms way. However, risk management will achieve little unless it is used in a combined effort by all sectors to plan ahead for integration into an overall economic plan and emphasizes that the distinct nature of flood and drought prevention needs to be preserved.

5 Flood and drought management options [1, 2]

Any single alternative would not, by itself, be expected to provide the degree of effectiveness needed to deal with the severity of floods and droughts. The potential actions are classified in terms of the joint consideration of structural and non-structural management of possible effectiveness based on IWRM and CDRM as follows.

5.1 Structural measures

The strategy components that can be taken to contribute to flood and drought management with structural measures are namely:

- provide local drainage, if necessary using dikes to exclude overflow,
- provision of local flood storage, natural depression and drainage capacity,
- land use regulation,
- enhancing the effectiveness of existing reservoirs and development of a new reservoir operating rule that gives the fullest practical recognition of the objective,
- improvement in channel drainage capacities, dikes and river cut offs,
- enhancing the flood water detention area,
- drought prevention using supply management, e.g. new water resources—large upland storage, medium/small-sized storage, coastal storage, basin transfer, etc.

5.2 Non-structural measures

Options for non-structural management are as follows:

- essential data collection, flood and drought risk mapping to identify areas where flood and drought resistance design standard, land use restriction, flood and drought forecasting and warning programs should be applied,
- adoption of flood and drought warning and emergency relief programs together with the application of flood tolerant design and construction standards,
- drought prevention using water management, e.g. conjunctive use, recycling of drainage water from domestic use for agriculture, efficiency savings, etc.,
- drought prevention using demand management, e.g. application of water rights, fee/land charges, crop diversification/subsidies.

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6 Example of a pilot study: Thung Kula Rong-hai

6.1 State of the problems

Thung Kula Rong-hai, the best source of the famous Thai Jasmine Rice in northeast Thailand (as shown in Figure 1), covers an area of some 340,000 hectares. The area lies in the tributary catchment of the Mun river. The upper part of the fields is bounded to the north and west by a moderated ridge and by a low ridge on the south. There are five major streams in the area, in descending order in terms of the sub-basin areas, namely Lam Sieo Yai, Lam Phlab-phla, Lam Tao, Lam Sieo Noi and Lam Phang Chu. They flow eastwards and join with the Mun river at the east end of the field area. The terrain in Thung Kula Rong-hai is largely paddy field. The landscape in the central area is nearly flat with little change in elevation. More than 90% of the households are classified as agricultural and nearly all the population is engaged in agriculture or agriculturally related activities. In the basin, wet season rice cultivation is almost 99% of total agricultural area.

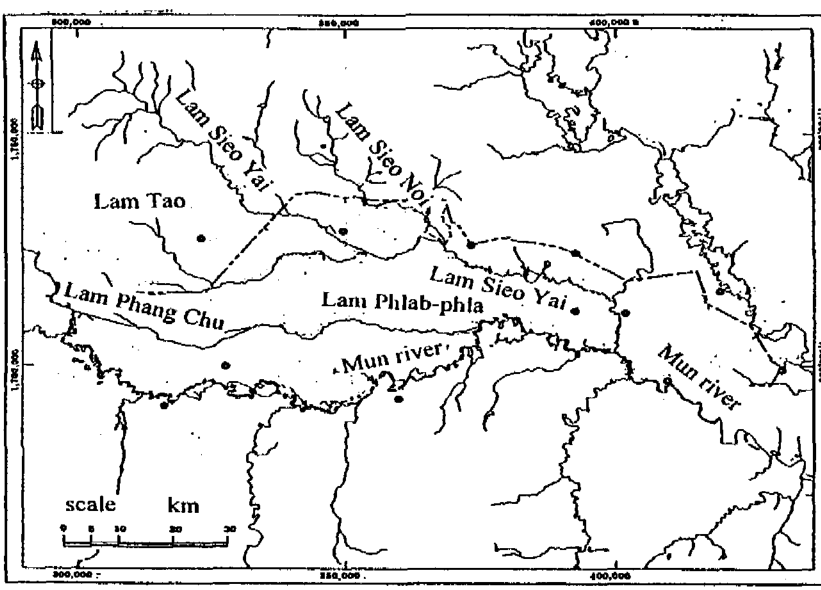

Figure 1: Study area of Thung Kula Rong-hai, Thailand.

The average rainfall over the basin area is 1,270mm per annum. About 90% of the annual rainfall occurs in the wet season form May to October (see Figure 2). Rainfall is highest in August and September due to the passage of cyclones. The monsoon may sometimes be displaced during June and July and this can lead to a dry spell known as the early growing season drought. In the wet season, monthly rainfall exceeds potential evaporation. So, there is an excess of water available and produces a flood. In the dry season, there is very little rainfall. Water for crops and other vegetation is rarely available. Therefore, agriculture cultivation in the project area is mostly under rain-fed conditions.

The pattern of distinct wet and dry seasons of rainfall is reflected in the streamflow in the basin, which shows marked seasonal fluctuations. Following the start of the rains in May, there is generally a period before significant runoff occurs, when the soil moisture store, depleted during the dry season, is refilled. Discharges reach their maximum during September to October and wide-spread inundated flooding usually occurs. Due to the lack of storage in the catchment, the recession at the end of April is rapid. The lowest discharges are observed during March and April. On average, the specific yield of all streams in the project area is about 2–6 litre/s/sq.km. Over 60% of the annual runoff occurs in the three consecutive months, August to October. But even during these months, a wide variation in the minimum daily flow can occur from year to year.

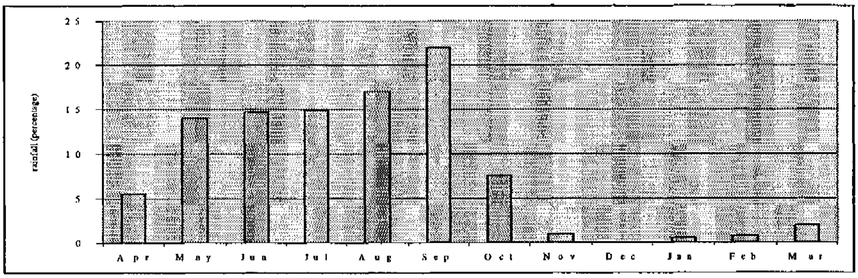

Figure 2: Pattern of rainfall in Thung Kula Rong-hai.

It can be concluded that at present water-related extreme events, floods and droughts, are a natural phenomena in Thung Kula Rong-hai. Residents in the area have historically adapted their lifestyle to deal with the annual disasters. To improve the quality of life, The Royal Thai Government (RTG) has attached high priority to addressing the problem of floods and droughts in the area and in June 2002 completed a master plan study for water resource development in this project area [1]. The study is mainly coordinated between the Royal Irrigation Department (RID) and the consultants to intensified efforts to lower flood and drought risks. The outputs of the master plan study are a macro-level flood and drought study to better understand the location, extent, causes and damage in the past. Then, a review of actions which can be taken to contribute to sustainable management are finally identified.

6.2 Present flood and drought management activities

Flood and drought management is not the primary responsibility of any single agency in Thailand. Many national agencies involved in irrigation, electrical supply, navigation, sciences, technology and meteorology, metropolitan and local administration together with provincial and local governments all have responsibilities for some aspects of management. Flood and drought management and planning in the study area is also largely carried out by civil administrative region rather than by catchment. In addition, management and planning is undertaken largely by organizations from their central offices. Planning tends to emphasize development focused on the problems of a particular area, sometimes at the expense of other water-related activities.

Currently in Thung Kula Rong-hai, the principal means of managing the flooding process is through physical control of water movements by engineering works. The means of control are storage and delay of flood flows by weirs and drainage canals, diversion of flood flows away from affected areas and excluding flood water by means of dikes and other flood defense structures. But these strategies have not had much effect in reducing floods. This is due to lack of large storage to maintain floodwater in the catchment. And the basin area of pan-shaped like considerably obstructs the flooding water draining into the Mun river. In addition, the flood wave at the confluence of the Mun river usually propagates upstream and overtops the tributary's banks. The flood duration in the basin area is about 2–6 weeks long. The water resources of Thung Kula Rong-hai and their development have been made in considerable detail over a number of years. Some of these are focused on a single-purpose use of a particular area without considering the impact of proposed developments on the basin as a whole. To cope with the drought problem in Thung Kula Rong-hai, modern water resources development was first started by the Land Development Department in 1981 with the 15-year plan during 1981 to 1996. It consists of re-modeling the farm lands, flood and drought relief by the construction of drainage canals and roads. This made the household incomes increase from US$250 in 1977 to US$1,200 in 1991 (at 1993 constant prices). Even though, it is still far from the target of the Eighth National Economic and Social Development Plan (1997–2001) which sets a target for 2020 of *"an average per capita income of not less than US$12,000 at 1993 constant prices"* [2]. Therefore, water resource development in the project area has to be taken in a wider view of impacts. There is a need to develop an integrated sustainable approach for future basin development.

6.3 Recommended sustainable prevention and management

With regards the regional, national and local policies and the coordination of sustainable flood and drought management, there have been attempts to deal with these types of natural disasters by various measures. But full flood and drought control and elimination of damage is not possible. The only affordable solution lies in investment in sustainable prevention and management measures.

The sustainable development principle was formulated by the Brundtland Commission, the World Commission on the Environment and Development [3], as the development principle for the future in the 1992 United Nations Conference on the Environment and Development (UNCED) in Rio. This principle was made the basic goal of development strategies. According to this,

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development is sustainable if it enables the current generation to meet its own needs without impairing future generation possibilities to satisfy their own needs. Development can only be considered as sustainable if its enables societies to prevent or manage disasters. The landscape of Thung Kula Rong-hai is nearly flat and most of the better reservoir sites in the adjacent areas are already used up. A review of all the possible actions which can be taken to contribute to flood and drought management in the study area has therefore led to both water management (non-structural measures) and structural measures. The recommended sustainable prevention and management based on IWRM and CDRM emphasizes self-support within the basin by improvement and management of the water resources in the project area first. The policy is directed to viewing the basin in its geographical and institutional entirely. The next step is to ensure that the development is designed or incorporates measures to minimize the adverse effects on other basin areas and on future generations. The recommended actions are as schematically shown in Figure 3 and can be described as follows.

1. *Structural measures*. The structural measures applicable to Thung Kula Rong-hai are as listed below.

1.1 Each farmer provides his own storage for paddy cultivation during the dry spell of agricultural drought during the wet season cultivation for approximately 300,000 hectares. The storage size is dependent on agricultural area and is 1200 cu.m/hectare. The area spent for the farm storage is approximately 3–5% of each farm plot. The actual size of the farm plot in the project area is about 3.5 hectares. In addition, intercepted runoff at the end of wet season might be effective for dry season cultivation for 13,000 hectares. The full development of self–storage in each farm might be added up for flood relief during the wet season and for dry season cultivation to an effect of 287 mcm.

1.2 Rehabilitation of 46 existing weirs in the project area might have the effect of slightly increasing the total upstream storage volume from 17 mcm to 22 mcm. In addition, it might have the effect of decreasing the flooded area by approximately 21%. Construction of new weirs is not recommended in this area, since the existing ones were designed and constructed by various sectors without considering the water resources system as a whole basin. They create the consequential problems of conflicts among water user groups and some hydraulic structures obstructing the flood way.

1.3 Little additional flood and drought benefit can be expected from refined operation, intensification of the existing drainage canal network and upgrading some canals. In the wet season, these canals may enhance the effectiveness of the flood detention by permitting a significant volume of floodwater to be systematically drained away to the Mun river during the several week duration of the flood events. In the dry season, the stored surplus water might be directed at the time of need to the agriculture areas close to its source. This might increase agricultural water during dry season for 7.1 mcm.

1.4 Available water resources within the Thung Kula Rong-hai would be increased by the construction of schemes transferring surplus water from the Mun river. Transfers can be stored within the existing drainage canal network for use at the time of need. The surplus water transferred from the Mun river is approximately 22.4 mcm per annum from August to March. This might be effective for dry season cultivation to the extent of 5,300 hectares.

1.5 It has been estimated that the dredging and expansion of natural channels in the study area might cause a reduction in the flooded area by 10% of that severely effected in 2000.

2. *Water management (non-structural measures).* The following is a list of non-structural measures applicable to Thung Kula Rong-hai.

2.1 Crop calender modification. Thai Jasmine Rice is the most important crop in the study area. The photosensitive variety is the most common. For wet season rice, the farmers in the project area actually start sowing either in July or August. The harvesting time is in November for both cases. According to the crop water requirement study, it was found that paddy cultivation during August to November requires 60% less water than that grown during July to November. It is therefore recommended that paddy sowing should occur in August instead of July.

2.2 Crop diversification. Water demand in agriculture could be reduced by the positive encouragement of alternative high-value crops, such as field crops and vegetables that use less water than the perennial crops currently grown, such as fruit trees.

2.3 Flood and drought forecasting and warning systems, especially for agriculture purposes, should be further studied in detail for later implementation.

A combination of the above actions should be adopted as a prevention and management scheme in order to deal effectively with flood and drought disaster management. It will have very important effects on the form of sustainability in the future. As shown in Figure 3, all the possible actions will have beneficial impacts on each other. For example, improvement of the existing weirs and drainage canals could be efficient in flood mitigation during wet season and might be also effective for dry season cultivation. A more secure irrigation supply and a reduction of flood damage would decrease the risk to paddy cultivation. Economic evaluation of this study indicates that the project cost is approximately US$370,000 at constant 2001 prices. The project will provide a rate of return at 12%. Finally, it was recommended that coordination among the responsible agencies in pursuing the recommended management actions will be vital to the success of the overall program. Early consideration should be given to institutional arrangements suitable for assuring that decisions on various bases are taken with appropriate consultations and that the responsibility for

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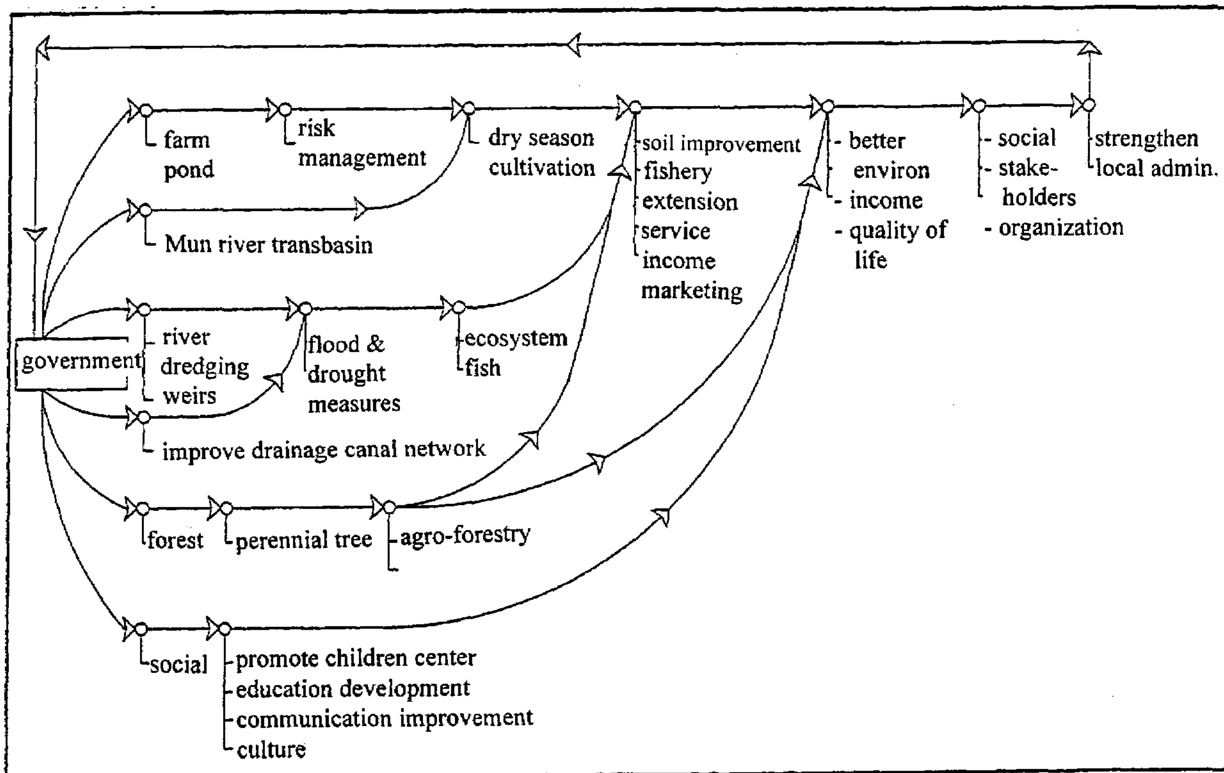

Figure 3: Schemiatic relation of recommended flood and drought sustainable prevention and management for Thung Kula Rong-hai, Thailand.

implementing each action is assigned to the most appropriate agencies. A ThungKula Rong-hai Authority should be established comprising representatives from central government and local water users. The authority should have a legal status, absorb all functions of the aother agencies in the project area and contain both regulatory and management functions. This alternative is desirable when there are still large development needs in the project area and existing agencies are weak.

7 Conclusion

The master plan study of water resource development in Thung Kula Rong-hai has demonstrated that the causes of flooding that lie throughout the project area are heavy rainfall in the basin area, severe rainstorms in upstream and the flood wave from the Mun river. Even though the area has a dense network of drainage canals, the general land level in the central part is flat. Therefore, the flood duration in the basin area lasts about 2–6 weeks. The cause of drought is mostly due to a lack of appropriate sites to store surplus water during the wet season for the purpose of dry season agriculture.

It is essential that flood and drought policies be directed to viewing the basin in its geographical and institution entirely. The next step is to ensure that the developments are designed to or incorporate measures to minimize the adverse effects on other areas in the basin and on future generations. This has to be carried out at the planning stage of any new development scheme. Certain basic principles should guide future sustainable management. They are namely:

1. flood and drought management should be for prevention and management rather than to provide full protection, since it is impractical on economic and environmental grounds,
2. standards of prevention should correspond to current land use patterns and future development,
3. future development should be based on the satisfaction of various stakeholders without jeopardizing the environment, the other basin areas and the next generation's chances,
4. institutional organization should be established to provide comprehensive water resource management in the project area.

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