Lecture note

Floods and drought

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by

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Lecture notes have been prepared on the following topics:

- *Aggregate water balances for basinwide planning*
- *Case study: Kok River Basin*
- *Case study: Lower Mekong Basin*
- *Environmental management*
- *Floods and drought*
- *Glossary*
- *Good governance strategies (example from Thailand)*
- *Internet applications in river basin management*
- *Paddy cultivation*
- *Poverty alleviation*
- *Project design*
- *Public administration*
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- *Reporting*
- *River basin ethics*
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- *Sector planning and integrated planning*
- *Socio-economics*
- *Strategies for natural resources and environmental management (example from Thailand)*
- *Technology management*
- *UTM coordinates*
- *Water demand management*
- *Water resource economics*
- *Water user associations*

Each note is intended as a quick introduction of a subject prepared for professional practitioners who are specialists in other subjects.

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Suggestions and comments are most welcome!

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Glossary

Please note that within flood management, several *'schools'* of language exist. Often, different words are used in connection with inland and coastal floods, and depending on whether the floods are regarded as beneficial or detrimental. The following explanations are *examples* of the meaning of each word. Most of the words have different meanings as well.

Benefits of floods: The value (to agriculture, fisheries, and floodplain habitats and ecosystems) generated by floods. The value is highest on flood plains exposed to regular (seasonal) floods

Coastal flood: A flood in a coastal area (for example caused by a cyclone)

Cyclone: A strong depression, characterised by heavy rainfall, high wind speeds, and high storm surge set-up, particularly in shallow coastal areas. In the sub-tropics, extreme cyclones can have wind speeds of 200 km/hour or even more. In most coastal areas, cyclones are systematically monitored, but their route is difficult to predict

Drought: *'A period with an extraordinary water shortage'* (due to the rainfall being less than normal)

Flood: Expansion of a surface water body due to a water level that is significantly above average

Flood exposure: The actual occurrence of a flood at a given location

Flood preparedness: Due awareness of the flood risk, and knowledge and ability of appropriate response. An appropriate flood preparedness is supported by measures such as awareness campaigns, education, and flood forecasting services, as well as flood proofing measures

Flood protection: Measures (such as embankments) to reduce the flood risk

Flood-prone: With a high flood risk

Flood proofing: Preventive (structural and non-structural) measures to reduce the vulnerability to floods

Flood pulse: The shape of the hydrograph during a seasonal flood

Flood risk: The general probability that a location or an area will be flooded, expressed as a frequency of occurrence, or sometimes as the relation between inundation depth, duration, and frequency of occurrence. The flood risk can be influenced in many ways by human activities

Flood volume: The volume of the annual flood flow in a river

Flood warning: An official message to the public about an imminent, severe flood event

Flood vulnerability: The value lost due to a given flood (depending on the population density, land use, infrastructure and ecosystems in the area)

Hindcast simulation (of floods): Simulation of historical flood events, for the purpose of cause-effect analysis, risk assessment or design basis, often supplemented by simulation of *'synthetical storms'*

Hurricane: Caribbean name for a cyclone

Hydrograph: A time series of water level (or stage) at a fixed location

Impact (of floods): Same as effects. These can be positive and negative; and can be actual effects (of an actual flood) or potential effects (of a given, hypothetical flood)

Inundation (same as flooding): Occurrence of a free water surface (at a place that is otherwise dry). Inundation depth is the level difference between the water surface and the ground. An inundation map shows contours of inundation depth

Lead time: The time between a (flood) forecast and the actual event

Seasonal flood: The annual flood in a (large) river with a typical seasonal stage variation (for example determined by a monsoon weather system, and/or by the melting of snow during summer)

Stage: Same as water level (of a river)

Typhoon: Chinese name for a cyclone

1 Introduction

The present note is an introduction to flood and drought management. It lists some basic aspects and considerations to keep in mind in connection with planning and decision-making that affect - or are affected by - the risk, the vulnerability, and the response to floods and droughts.

2 Flood management

Flood management is important because many people live in flood-prone areas at the coast or on floodplains, and a lot of investments in towns, plants and infrastructure have been made in such areas.

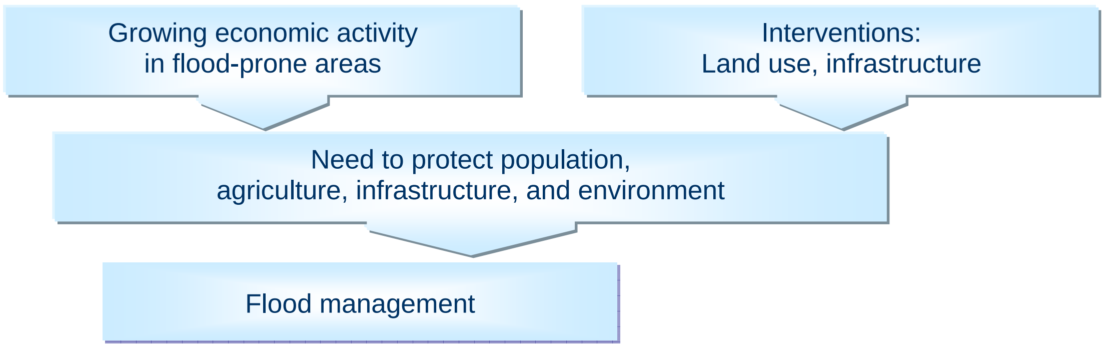

Figure 1: Rationale of flood management

Flood management can aim at

(i) a reduced risk of floods;

(ii) a reduced vulnerability to floods;

(iii) improved preparedness;

(iv) streamlined emergency management once a flood damage has occurred; and

(v) improved knowledge (about cause-effect relationships, driving forces and management options);

The management can comprise activities such as

- forecasting services;
- education and awareness campaigns;
- flood proofing;
- land management *('keeping people away from floods');*
- water management (storage operation);
- structural protection (dykes) *('keeping floods away from people');*

- contingency planning;
- timely and appropriate response to events (such as disasters) and developments;
- studies of cause-effect relationships and of impacts of intervention; and
- capacity-building, research, and knowledge-sharing.

It is the poor people and the children who are most vulnerable to floods [2]. Therefore, a particular attention must be extended to these parts of the population.

Good flood management would take its starting point in a suitable knowledge about

(i) the flood risk (so that high-risk areas are delineated); and

(ii) the flood vulnerability (so that the most important potential consequences are identified).

If this knowledge is not adequate, studies should be made.

3 Coastal floods

Coastal floods can be caused by storm surge, which is generated by a combination of wind friction and low air pressure. Local wind waves will add to the water level, and the storm surge can be amplified (or reduced) by interference with the strictly regular astronomical tide. Extreme floods can be related to extreme storms - like cyclones - that attack the open coast. In areas that are otherwise more sheltered (like the Baltic Sea), extreme floods can be generated by unusual sequences of wind set-up and air pressure variations.

Irrespective of the weather, flood waves can be generated by distant, sub-sea earthquakes (such flood waves are called tsunamis), or, in arctic areas, by breaking glaciers.

Saxo Grammaticus [2]

Around 1200, the scholar Saxo Grammaticus finished a colourful history of Denmark. The account describes the *'Accomplishments of the Danes'* until 1185 in 16 thick volumes. According to its preample, the work is based on *'reliable information about ancient times'.*

In his geographical summary, Saxo mentions about the coastal marshes of southwestern Jutland, facing the North Sea. He notes that this land is particularly fertile, due to flooding by the sea. He questions, however, *'whether this is perhaps a case of buying gold too dear. Because, it is a risky affair with that coast. When a violent storm comes about, it may well happen that the sea breaks the dikes that are built for protection, and intrudes so fiercely that not only the standing crop is flushed away, but also the houses together with the people and whatever'.*

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[2] In Viet Nam, 1,683 people were killed during the floods in 2000, 2001 and 2002. Out of these, 72 percent were children. (Unicef data, quoted by *'Disaster risk management in Asia'*, ADPC, July-September 2003)

[2] This and the following 3 text boxes are from *'Flood management'*, Danish Hydraulics no. 19, by DHI Water & Environment

The effect depends on the coastal profile. A gently sloping profile causes a high amplification of an approaching flood wave (and tidal wave) and a high set-up in response to local wind. A steep profile will tend to reflect the flood wave (and tidal wave), rather than amplifying it, and the locally generated set-up will be small if the water depth is large. Often, a shallow coastal profile occurs in places with low-lying lands. If so, the flood risk will be high.

It is the weakest part of the poor population - rural women, elderly, and children - who are most at risk. Even those who escape unharmed in the first place may be victims to diseases in the days to follow, and may in any case have lost whatever they owned.

Coastal floods can be predicted with an accuracy that is largely determined by the accuracy of the meteorological forecasts (which is within a couple of days). A major problem in this connection is that it is not possible to predict the route of a moving extreme depression like a cyclone.

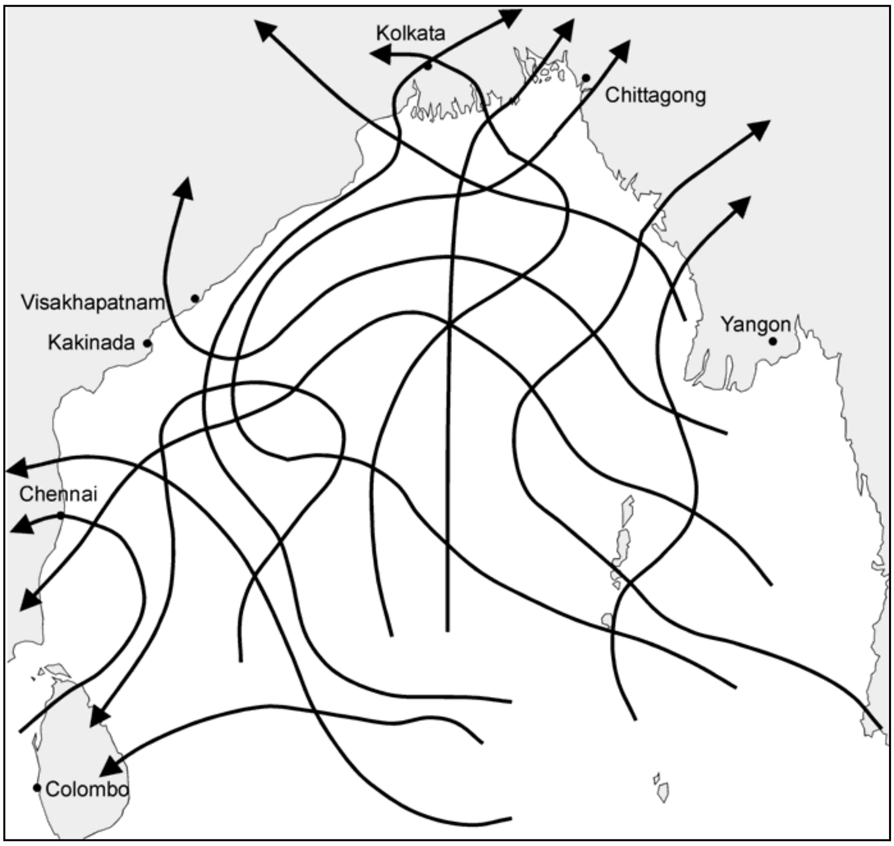

*Figure 2: Cyclone tracks in the Bay of Bengal
(examples, 1921-64, from the British Admiralty Bay of Bengal Pilot)*

Analyses of the general risk of coastal floods are made in connection with emergency preparedness planning, and also as a basis for design of coastal facilities and structures, such as flood embankments. The analyses are difficult, because an *'observed flood'* is not a single independent event in statistical terms. Rather, the flood is a consequence of a set of different determinants, like the tide, the wind and the air pressure, or of a set of sequences of these factors. Both the mean sea level and the flood height will vary along the coast, with a distinct slope relative to horizontal.

Cyclones in the Bay of Bengal

Cyclones are frequent in the Bay of Bengal. In Bangladesh, where around 2 mio. people live in the coastal areas and the islands of Meghna Estuary, a severe cyclone is expected to hit the coast (at one place or another) once in 5 years on the average. During a severe cyclone, wind speeds range from 90 km/hour and upwards. In the northern Bay of Bengal, the associated storm surge can reach 5 10 m. This is well above the land level of the coastal areas, which is typically only slightly above sea level.

The 1991 cyclone in Bangladesh

The cyclone that hit the coast of Bangladesh in April 1991 was among the most severe in recent times.

It was forecast in due time, but the warnings were not heeded until the very last moment, or, in many cases, until it was too late.

Furthermore, the protective coastal embankments were in a poor state of maintenance. As it turned out, in some places, the damaged embankments amplified the impact, rather than controlling it.

It is estimated that over 100,000 people died. Most of the livestock and all the poultry of the affected area was lost. Buildings, structures and crops were gravely damaged.

The following accounts were reported in the Daily Star of Bangladesh:

'It was four in the afternoon when Faizul Karim heard the warning on the megaphone. Recalling some earlier forecasts which turned out to be wrong, Karim hardly paid any attention to the warning. Not until about eight, he became sure that a cyclone was about to hit the island. As he and his family members ran for shelter, he saw tin-roofs flying and trees being blown away. The only building was already filled with people, and several hundred others were standing outside. In the dark of the night, Karim was carried by the waves some six kilometres, until he managed to climb a coconut tree. He survived, but lost nine family members and his left arm.'

'Mohamed Patan Ali took shelter in a building together with three hundred other people. Just after midnight, the building was broken by the waves. Many people drowned or were killed by flying tin-roofs. Ali survived climbing a tree. The nightmare ended after about 4 hours. Afterwards, Ali and a few other survivors lived on coconut and banana for three days before they were rescued.'

Cyclone shelters

Built to be used only once in a lifetime, cyclone shelters are an expensive means of protection against the flood peril. On the low islands in the Meghna Estuary, however, they are the only refuge within reach.

After the 1991 cyclone, different donor organisations have funded the construction of some 1,200 cyclone shelters in the coastal areas of Bangladesh. They are impressive reinforced concrete structures, often built in places accessible by narrow footpaths only. Even if their present capacity is well below half of the demand, they represent a highly visible commitment to safeguarding the rural population.

Apart from their primary objective, the cyclone shelters serve as schools, mosques, storage, or clinics.

Figure 3: Cyclone shelter in Noakhali, Bangladesh

4 Inland, seasonal floods

Inland, seasonal floods in the floodplains of river basins are generated by the seasonal melting of snow and ice, and/or seasonal rainfall variations, for example determined by the monsoon weather system.

The variation can be strong and regular in case of large rivers that origin in mountainous areas with snow and glaciers (like the Himalaya Plateau) and proceed through areas with a monsoon climate (like South and Southeast Asia).

In such areas, in the course of time, the environment and the economy have adapted to the occurrence of floods, to an extent that some livelihoods (and ecosystems) depend on it, while others are strongly supported by it.

Problems occur in case of deviations from the normal pattern, with floods being higher than usual, or if they take place at an unusual time of the year. This can be for natural reasons, or due to human intervention, or both.

Also, problems can occur when the development takes a course that does not conform well with the occurrence of floods. This can relate to land use, investment in physical infrastructure, or new ways of natural resources utilisation.

The ***vulnerability*** to floods depends on

- ... the flood risk
- ... land use in flood-prone areas
- ... awareness and preparedness
- ... options for response & mitigation

which can be ***planned for and managed***

Apart from the climate, ***the flood risk*** depends on

- ... the runoff
- ... the flow resistance - upstream & downstream
- ... the storage capacity
- ... structural protection

which ***respond to intervention***

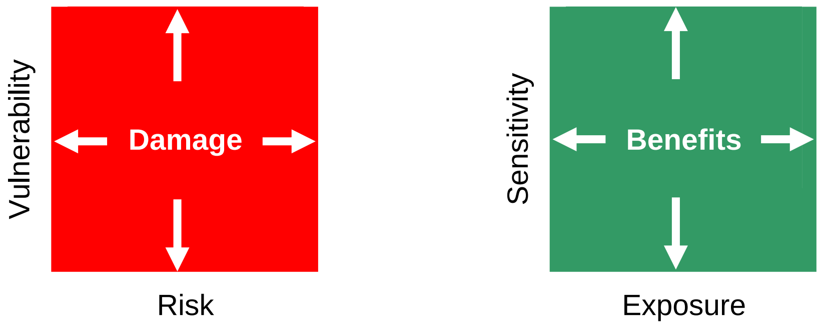

Figure 4: Flood damage and benefits

The flood risk is influenced by

- the climate (which can fluctuate over small, medium and long periods of time);
- morphological changes of the river system, whether of natural or human origin; and
- any human intervention in the river system that changes the runoff, the flow resistance, or the wet season flow itself.

Comprehensive deforestation can occur due to forest fires and human intervention. Deforestation can increase the flood risk, both by changing the runoff pattern and by increasing the sediment yield and hereby increase the flow resistance in the main river channels.

Dredging of navigation channels and regulation of bends can at the same time increase and reduce the flood risk at different places. Likewise, a flood protection scheme can reduce the flood risk at one place while increasing it at other places.

Earthquakes can change the flood risk by changing the planform of the river, and by releasing large pulses of sediments.

In some cases (like in Bangkok and in Venice), the flood risk can be enhanced by irreversible subsidence caused by excessive groundwater withdrawal.

The damage is the product of risk and vulnerability. Damage caused by floods can comprise

- loss of life, property, crops and livestock;
- diseases related to interrupted water supply and sanitation;
- damage to buildings and different types of infrastructure;
- pollution caused by flooding of waste deposits, storage facilities, and waste disposal facilities; and
- disruption of livelihoods and education.

As it is the case with coastal floods, it is the poorest part of the population that is most vulnerable. In broad general, floods tend to affect the rural population to a higher extent than the urban population, and the poor part of the population to a higher extent than middle- and high-income groups. This can be due to inadequate information, knowledge and awareness, but also due to a lack of capacity to sustain one or two failed crops, or to sustain a disruption of paid employment.

Benefits of floods comprise

- water being retained for (paddy) cultivation;
- improved soil fertility [3];
- maintenance of primary production on the flood plains;
- maintenance of the fish yields; and
- preservation of wetlands ecosystems.

Benefits of floods occur on natural, un-regulated flood plains with regular, seasonal floods (like the Bangladeshi flood plains and the Cambodian parts of the Lower Mekong Basin). The benefits become less and eventually nil when the river is regulated, and the surrounding lands are protected against floods. The benefits are minor or nil in river systems with irregular floods. Benefits are site-specific and different to agriculture, fisheries, and biodiversity.

In Cambodia, the most beneficial flood (in relation to agriculture) is called a *'beautiful flood'* - it is characterised by a maximum height near warning level. If the flood height gets higher or lower than this level, the benefits to agriculture will diminish, and eventually become negative. In relation to fisheries, the higher flood the better. So, in general, an extremely high flood will be beneficial to the fish stock but harmful to crop cultivation.

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[3] This can be due to (i) supply of sediments and nutrients carried by flood waters (although possibly in small quantities); (ii) nutrients captured by local primary production during the flood; and/or (iii) physical flushing and resting of the soil, in combination with a high moisture of the top-soil

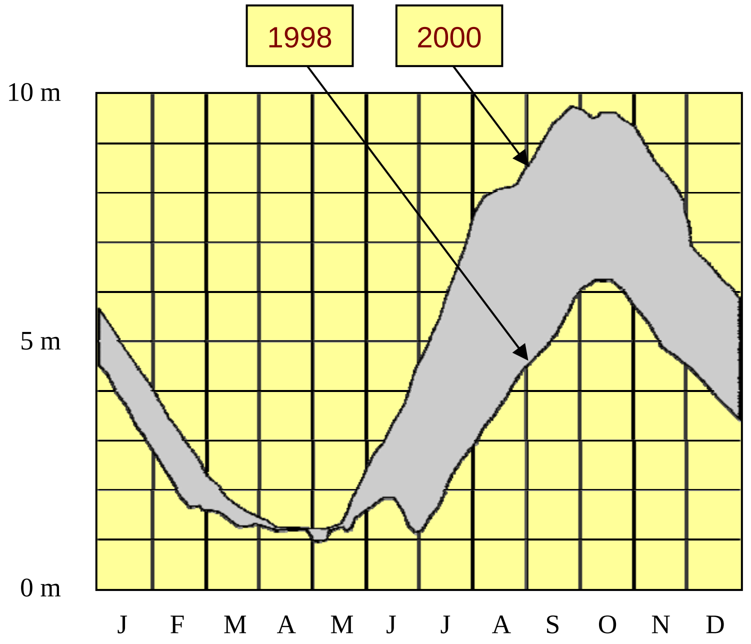

Figure 5: Hydrographs from recent years with high and low floods (Tonle Sap, Cambodia) [4]

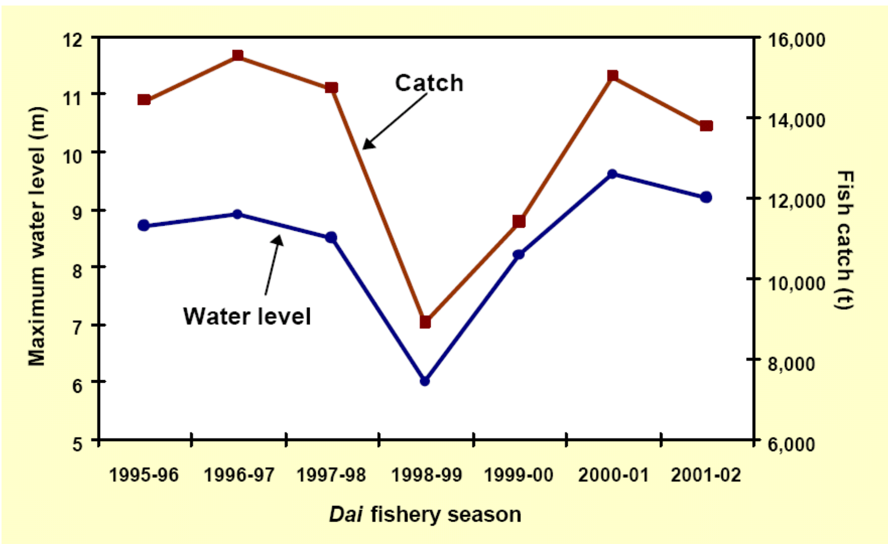

Figure 6: Relationship between maximum flood level of the season and catch of the dai (bag-net) fishery in Tonle Sap, Cambodia [5]

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4 Data: Mekong River Commission, Prek Kdam gauging station. Zero level is 0.08 m above Mean Sea Level, alarm level is 9.5 m above zero level, flood level is 10 m above zero level

5 Figure from Nicolaas van Zalinge, Deap Loeung, Ngor Pengbun, Juha Sarkkula and Jorma Koponen: Mekong flood levels and Tonle Sap fish catches. Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, February 2003

5 Flash floods

Flash floods are caused by local rainfall in mountainous catchments. They got their name because they occur unexpectedly and develop rapidly. They can cause loss of human lives and comprehensive damage to buildings, infrastructure and crops.

A related type of disaster is dam breaks.

In Southeast Asia, there are indications that flash floods have become more frequent and/or more serious in recent years. In some cases it may be speculated that deforestation plays a role. In other cases, the observation may be due to new settlements in areas that have hitherto been undeveloped. Another development is that today, due to effective communication, any serious flash flood will become a spectacular news item.

Flash floods cannot be predicted with any reasonable lead time. Only, a warning can be issued once a flash flood is imminent or in progress. A simple and inexpensive warning system based on dissemination by mobile telephone has been developed in Thailand [6].

The risk of flash floods can in many cases be estimated in general, statistical terms. The risk can sometimes be reduced by emergency storage reservoirs, and/or by diversion spillways. Such measures are not always practical, however, and even when they are technically feasible, they can be extremely expensive.

The vulnerability to flash floods can be reduced by

- identification and delineation of high-risk areas;
- suitable land management (preventing undue settlement and infrastructural investment in high-risk zones, and suited for restoration of land owner rights after a flash flood); and by
- a suitable emergency preparedness, including contingency plans for warning, evacuation, and mitigation.

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[6] Sutat and Uruya Weesakul, Ole Mark and Lars Chr Larsen: A new concept for flash flood monitoring and warning. 2nd Annual Mekong Flood Forum, October 2003, Phnom Penh

6 Drought management

Socio-economic and environmental consequences of extreme droughts can be as severe as the impacts of extreme floods, particularly in case of several successive dry years, where small-scale farmers risk to lose their land. Drought can undermine the national food security and the economy, and can, at worst, cause famine (although this should not occur in a well-managed society).

The occurrence and severity of extreme weather, including extreme droughts, can escalate in case of global warming or general climate fluctuations.

The vulnerability may increase in connection with new (but otherwise more attractive) crops, which are introduced in order to save water and increase earnings. On the other hand, even though new crops are always risky, they can sometimes be more drought-resistant than traditional ones, or they can offer a wider range of options for consideration in connection with delayed rainfall.

Surface water supplies are much more vulnerable than groundwater supplies. This circumstance is of little relevance in an operational context, but may be kept in mind in connection with feasibility studies of groundwater supplies. Access to at least some amount of groundwater (where available) can ease the damage caused by a drought.

Good management can highly reduce the general vulnerability and the actual damage caused by drought. Drought management can be divided into the following components:

	Urban	Rural domestic	Cultivation
Strategic	Preparedness	Preparedness	Preparedness
Operational	Response	Response	Response

In broad general, the strategic preparedness aims at a reduced vulnerability and preparations for an appropriate response. This, in turn, requires routines for timely and adequate information flow, and smooth operational communication. At the operational stage, routines must be in place for support to prompt and appropriate decision-making during a drought (for farmers and producers as well as for administrators).

The strategic preparedness can comprise elements such as:

- A knowledge-base (of weather, crops and cultivation);
- education in order to support the drought-related decision process;
- streamlining of the management framework (clarifying *'who does what'*, and assuring a smooth flow of data and information); and
- suitable contingency plans and response tactics.

During a drought, the management aim shifts from *value optimization* to *risk minimization.* Once one crop has failed, it is important that the next crop does not.

Operational drought management can be regarded as a continuous decision process - somewhat like a long battle against an enemy with an unknown course of action [7]. The decision-making is supported by *knowledge of risks and options.* This knowledge (about weather statistics, storage operation, and cropping and cultivation options) can be compiled beforehand. Once the drought occurs, there will be no time to do it.

The preparedness can comprise emergency stocks of water, seeds, pesticides, or even food.

A close collaboration with farmers, including small-scale farmers, should be maintained throughout strategy formulation and contingency planning.

In urban areas, supply restriction is a standard measure, supported by awareness campaigns and enforcement.

High-level support must be mobilised, as well as support from the media. International support can be available in case of severe disasters.

In the agricultural sector, access to extraordinary credit and debt relief is important, in order to reduce the social vulnerability to droughts. While farmers are familiar with occasional droughts, many small-scale farmers risk to lose their land in the event of two successive droughts, particularly in a context of escalating prices for agricultural land. A national emergency fund can be generated for the purpose, and can serve other disaster-related purposes as well. Disbursement channels and procedures should be readily in place once needed (conveniently via existing banks). Such preparations will also highly add to the efficiency of foreign emergency aid, when available.

Stockpiling of seeds (and/or routines for emergency acquisition) is another element. For example, the choice between a transplanted long-term rice variety (with a long cultivation period) and a direct seeded short-term variety (with a much shorter cultivation period) is only open if seeds are available to the farmers at the time when they need it.

Supportive research can improve the knowledge about the performance and sensitivity of various crop species and varieties. For example, crops with a short cultivation period can represent an option in case of a delayed monsoon.

As in many other ways, *new technology* can offer attractive benefits, but should be implemented in small steps and with due regard to unexpected side effects.

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[7] The Internet provides examples of decision flow charts for specific areas and specific crops, describing appropriate response at different stages of a drought

Appendix: Development needs

In the Lower Mekong Basin, the following development priorities have been identified in relation to flood and drought management:

Technical/scientific

- Improved coverage of basic data in general, and improved operational exchange of real-time data in particular
- Improved knowledge about cause-effect relationships
- Tools for medium- and long-term weather forecasts [8]
- Improved tools and data coverage for flood risk mapping and damage assessment

Operational

- Improved awareness and preparedness in affected communities (including promotion of well-established local knowledge, practices and technology) [9]
- Improved dissemination (of emergency warnings as well as ordinary weather forecasts), and dissemination extended to remote areas
- Flash flood monitoring and warning

Institutional

- Capacity-building at all levels
- Integration of flood and drought management
- Extended collaboration between states
- Extended collaboration between river basin organisations
- Extended collaboration between decision-makers, affected people, and the scientific community
- Extended collaboration between agencies

From: Proceedings of 2nd Annual Mekong Flood Forum, Phnom Penh, October 2003

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[8] Long-term weather forecasts may be a mere dream - but any achievement in this regard will be of immediate, high value to farmers and to any economic activity related to cultivation

[9] In Viet Nam, it has been observed that new settlers are more vulnerable to floods than original residents - and that it can save lives if children learn to swim