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# Wetland Development in Paddy Fields and Disaster Management

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# Preface

Extreme weather conditions have increased the risk of flood damage in Japan. Increases in flood disasters associated with global warming are occurring not only in Japan but also around the world. Land use practices must be reformed to protect cities from flood damage. I propose using green infrastructure to balance biodiversity conservation and flood control. Paddy fields can be used as green infrastructure.

Paddy fields hold water during heavy rains, protecting cities, and they can be referred to as paddy field dams. However, abandoned cultivated land is increasing in paddy fields due to an aging population and depopulation. Therefore, the flood control effects of paddy field dams are no longer utilized.

I propose combining abandoned cultivated land in one area and creating wetlands. The wetlands will not only hold water during the flood season but also provide habitat for aquatic animals and a place for children to learn about the environment. In addition, fish farming in wetlands could provide food for many people. Recreational activities such as fishing could also be conducted.

This proposal will help government officials across the world, especially those involved in urban and rural planning. It is expected that this concept will be supported by not only engineers but also biologists.

This book's primary theme was developed based on the following three books *Effects of Dam on Downstream Aquatic Community in Japan* and *Aquatic Animal Ecology in a Consolidated Paddy Field, Japan*, published by LAMBERT Academic Publishing and *Dam Construction, Paddy Farmland Consolidation and Aquatic Community in Japan* published by Tokyo Tosho Shuppan.

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# Flood Control

# Chapter 1
# Characteristics of Flood Disasters

**Abstract** When comparing Japanese and foreign rivers, Japanese rivers are steeper. Therefore, the damage caused by flooding in Japan is likely to be greater than that caused by flooding abroad. Due to the effects of urbanization and global warming, the possibility of flooding is extremely high. The number of short-duration rainfall events exceeding 50 mm/h has increased, and these rainfall events have become localized, centralized and severe recently. Because of the influence of climate change associated with global warming, it is predicted that the frequency of heavy rainfall will increase approximately 1.4-fold. It is unequivocal that human influence has resulted in the warming of the atmosphere, oceans and land. Consequently, there is concern that a large-scale flood-related disaster will occur.

**Keyword** Flood disaster · Global warming · Rainfall · River · Urbanization

## 1.1 Comparison of Rivers in Japan and the World

Japanese rivers are short in length and have a steep gradient from upstream to downstream. Therefore, they are characterized by rapid flows into the sea. When it rains, river water levels suddenly rise, and the flood peak is reached in a short time (Fig. 1.1).

In London, the Thames River flows through the lowest part of the city. On the other hand, in Tokyo, many rivers flow through the highest parts of the city. Therefore, the damage caused by flooding in Tokyo is likely to be greater than that in London (Fig. 1.2).

## 1.2 Impact of Urbanization

Before development, rainwater penetrated the ground, and surface water mainly flowed into rivers. After development, because the impervious area covered with concrete increased, a large amount of rainwater began to flow into rivers in a short time. As a result, floods have become more frequent (Fig. 1.3).



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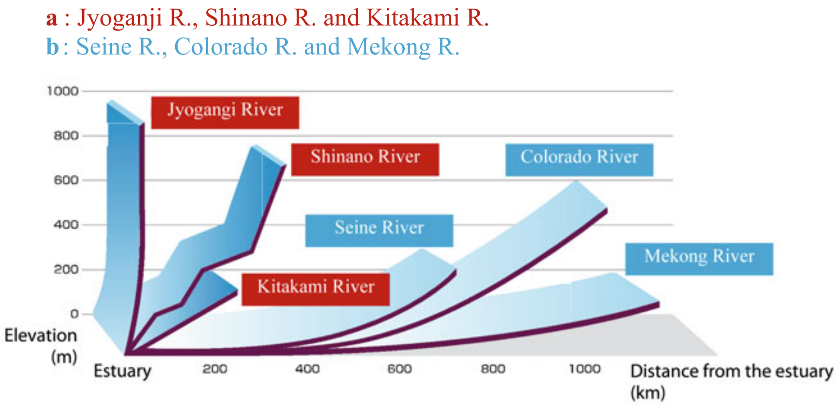


**Fig. 1.1** Comparison of rivers in **a** Japan and **b** the world. *Source* Modified from the Ministry of Land, Infrastructure, Transport and Tourism of Japan, https://www.mlit.go.jp/river/pamphlet_jirei/kasen/gaiyou/panf/gaiyou2005/pdf/c1.pdf, Accessed October 30, 2021 (in Japanese)

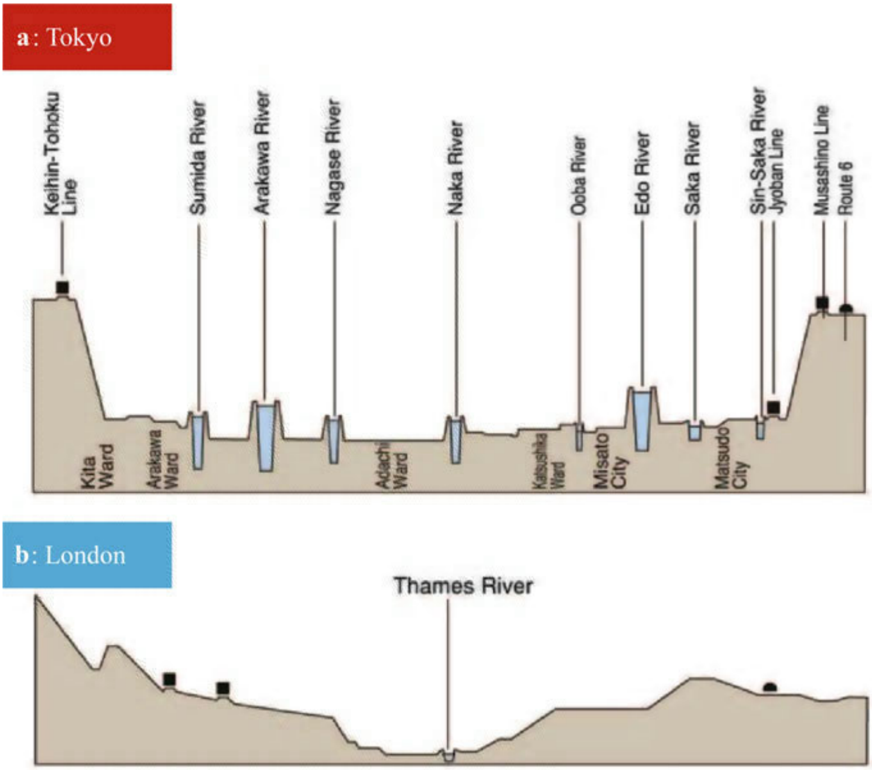


**Fig. 1.2** Comparison of **a** the rivers in Tokyo and **b** the Thames R. in London. *Source* Modified from the Ministry of Land, Infrastructure, Transport and Tourism of Japan https://www.mlit.go.jp/river/basic_info/english/pdf/riversinjapan.pdf, Accessed May 18, 2022 (in Japanese)

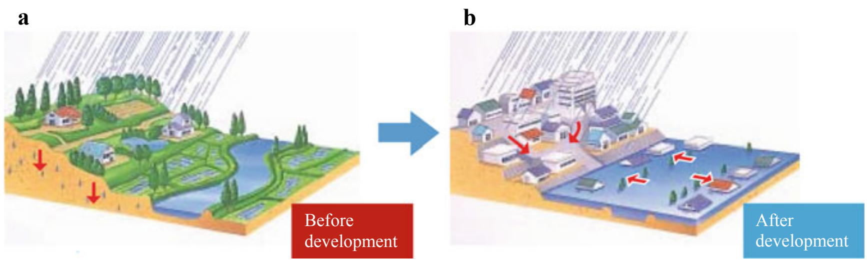


**Fig. 1.3** Changes **a** before development and **b** after development. *Source* Modified from the Ministry of Land, Infrastructure, Transport and Tourism of Japan, https://www.mlit.go.jp/river/pamphlet_jirei/kasen/gaiyou/panf/gaiyou2005/pdf/c1.pdf, Accessed October 30, 2021 (in Japanese)

Global land use changes are four times greater than previously estimated (Karina et al. 2021), and such changes in land use likely affect climate change and cause disasters such as floods.

## 1.3 Global Warming and Flood-Related Disasters[1]

Human activities have influenced climate warming at a rate that is unprecedented in at least the last 2000 years (Fig. 1.4). It is unequivocal that human influence has resulted in the warming of the atmosphere, oceans and land. Widespread and rapid changes in the atmosphere, oceans, cryosphere and biosphere have occurred. Many changes in the climate system have increased in direct relation to increasing global warming. These changes include increases in the frequency and intensity of high temperature extremes, marine heatwaves, heavy precipitation, agricultural and ecological droughts in some regions, the proportion of intense tropical cyclones and reductions in Arctic sea ice, snow cover and permafrost (IPCC 2021).

Such temperature increases have also occurred in Japan (Fig. 1.5). The number of short-duration rainfall events exceeding 50 mm/h has increased, and these rainfall events have become localized, centralized and severe in recent years (Fig. 1.6). Because of the influence of climate change associated with global warming, it is predicted that the frequency of heavy rainfall event will increase approximately 1.4-fold. Consequently, there is concern that a large-scale flood-related disaster will occur. Rising temperatures are expected to have impacts on food and ecosystems and result in rising sea levels, increasing frequencies of heavy rainfall event, increasing tropical cyclone intensities and changing water availability in aquatic and coastal areas (Fig. 1.7).

[1] *Source* Reprinted from the UN Environment Programme, https://www.unep.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity, Accessed October 30, 2021.

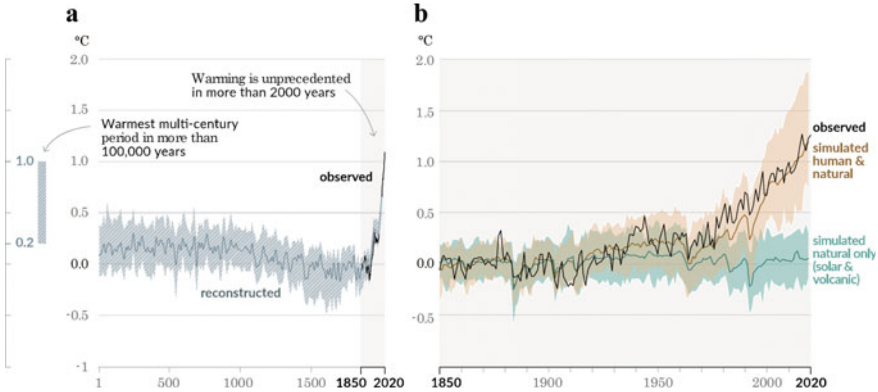


**Fig. 1.4** History of change in global temperature and causes of recent warming. *Notes* **a** Change in global surface temperature (decadal average) as reconstructed (1–2000) and observed (1850–2020). **b** Change in global surface temperature (annual average) as observed and simulated using human and natural influences and only natural influences (both 1850–2020). *Source* Reprinted from IPCC (2021)

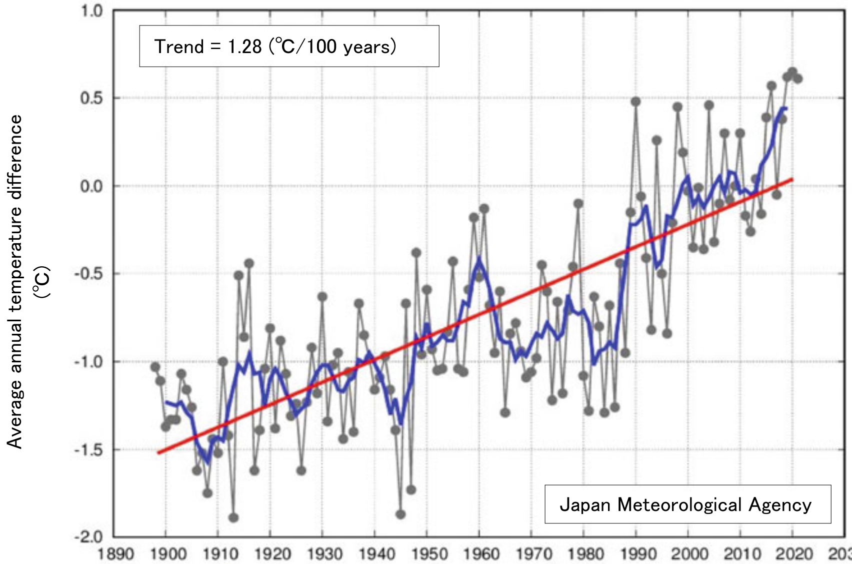


**Fig. 1.5** Overall change in average annual temperature difference in Japan. *Note* The blue line shows the 5-year moving average, and the red line shows the long-term change trend. *Source* Modified from the Japan Meteorological Agency, https://www.data.jma.go.jp/cpdinfo/temp/an_jpn.html, Accessed May 18, 2022 (in Japanese)

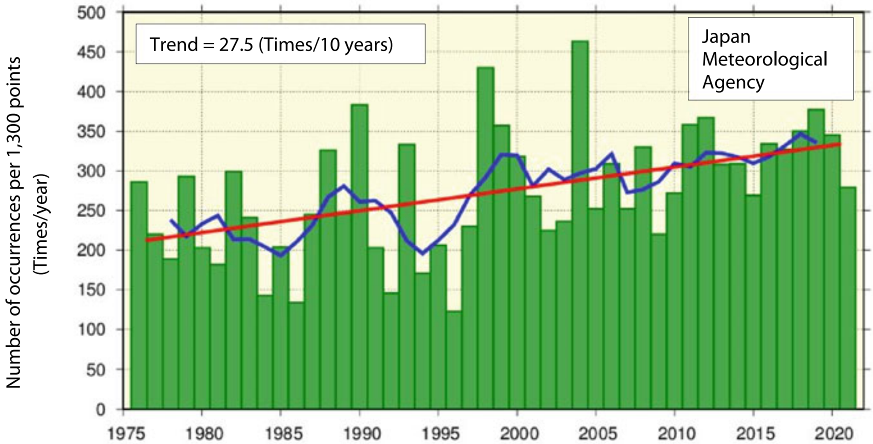


**Fig. 1.6** Number of rainfall events exceeding 50 mm/h per year. *Note* The blue line shows the 5 year moving average, and the red line shows the long-term change trend. *Source* Modified from the Japan Meteorological Agency, https://www.data.jma.go.jp/cpdinfo/extreme/extreme_p.html, Accessed May 18, 2022 (in Japanese)

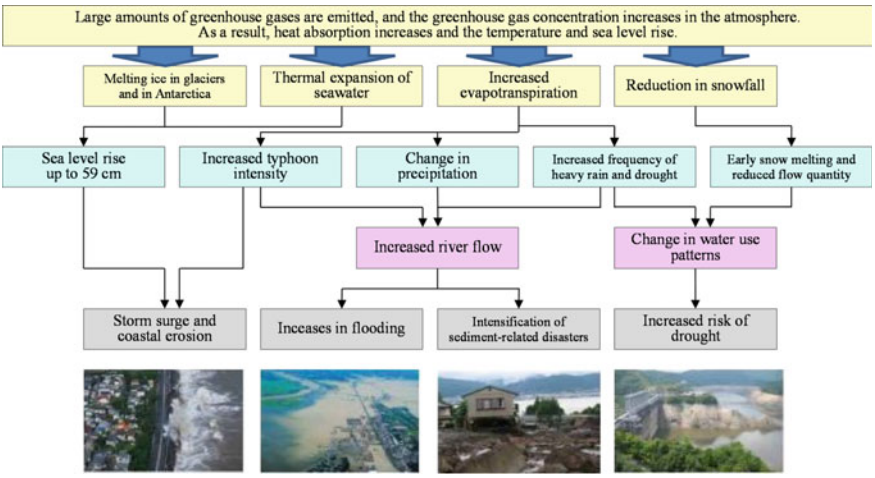


**Fig. 1.7** Disasters caused by global warming. *Source* Modified from the Shinano River Ohkouzu Bosai Center (2009), http://www.hrr.mlit.go.jp/shinano/ohkouzu/bousaic/0912mizukanren/0912mizukanren.htm, Accessed October 30, 2021 (in Japanese)

**Box 1.1 United Nations Designates 2021–2030 as Decade of Ecosystem Restoration**

The General Assembly of the United Nations has announced that 2021 to 2030 will be designated as the decade of UN ecosystem restoration. Ecosystem restoration is the process of restoring degraded ecosystem functions, such as those of land, lakes and oceans, and increasing the productivity of ecosystems to the levels required by human society.

Deterioration of land and marine ecosystems has a negative impact on the well-being of 3.2 billion people, and the loss of biodiversity and ecosystem services accounts for approximately 10% of global gross domestic product. Approximately, 20% of the planted surface is eroded, depleted and polluted, reducing productivity by 2050, with global crop yields likely to decline by 10% and up to 50% in certain areas. Restoring 350 million hectares of degraded land by 2030 will generate $9 trillion in ecosystem services and remove 13–26 gigatons of greenhouse gases from the atmosphere.

This decade of ecosystem recovery will bring together political, scientific and financial support globally and lead to large-scale recovery from successful pilot efforts. The implementation of this effort will be led by the United Nations Environment Program (UNEP) and the Food and Agriculture Organization of the United Nations (FAO).

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IPCC (2021) Climate Change 2021 the physical science basis summary for policymakers. In: Working group I contribution to the sixth assessment report of the intergovernmental panel on climate change

Winkler K, Fuchs R, Rounsevell M, Herold M (2021) Global land use changes are four times greater than previously estimated. Nat Commun 12:2501. https://doi.org/10.1038/s41467-021-22702-2

# Chapter 2
# Flood Control Methods

**Abstract** There are various flood control methods used in Japan. Because Japan has implemented modern hydraulic technology, to date, flood control methods have been used based on the concept that not even a drop of water will overflow from the outer bank to the inner bank. However, due to the effects of recent global warming, flood-related disasters have become more severe, and conventional flood control methods are no longer able to protect human lives and properties. Therefore, flood control methods must be changed to minimize damage from overflowing water from the outer bank to the inner bank. Thus, watershed control, open levees and paddy field dams should be implemented. An open levee is a traditional river construction method. Watershed control and paddy field dams are intended to be used as flood control methods in not only rivers but also the entire region.

**Keywords** Flood control · Modern hydraulic technology · Open levee · Paddy field dam · Traditional river construction method · Watershed control

## 2.1 Flood Control Methods

Flood control methods are shown in Fig. 2.1. These methods include the following: excavating a river channel to increase the cross section of water and lower the water level (Fig. 2.1a), building an embankment and enlarging the cross section of water (Fig. 2.1b), increasing the height of an embankment and enlarging the cross section of water (Fig. 2.1c), setting back the embankment to enlarge the cross section of water and lower the water level (Fig. 2.1d), constructing a dam to reduce the amount of water flowing to downstream rivers and lower the water level (Fig. 2.1e) and temporarily holding the floodwater at the detention basin when the water is about to overflow due to flooding (Fig. 2.1f).

While methods A to E are based on the idea that even a single drop of water should not overflow from the outer bank to the inner bank, method F assumes that water overflows from the outer bank to the inner bank. In comparison with the other methods, method F represents a substantial difference in flood control method, and method F is very important.



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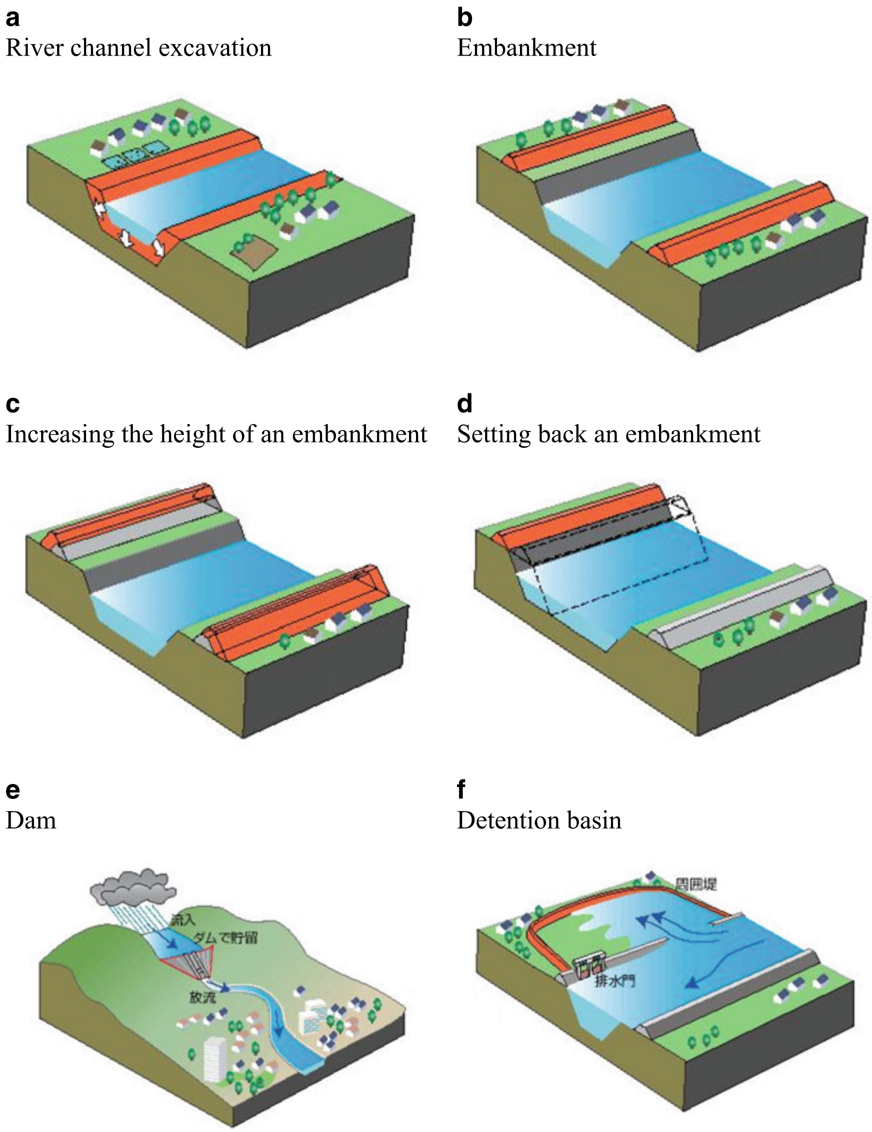


**Fig. 2.1** Flood control methods. *Source* Modified from the Ministry of Land, Infrastructure, Transport and Tourism of Japan, https://www.mlit.go.jp/river/pamphlet_jirei/bousai/saigai/kiroku/suigai/suigai_4-5-ref2.html, Accessed October 30, 2021 (in Japanese)

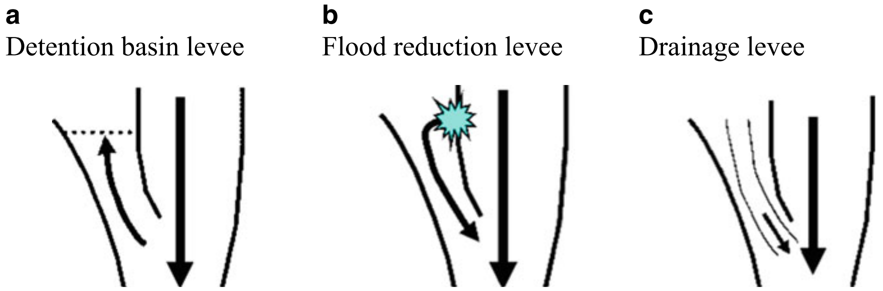


**Fig. 2.2** Types of open levees. *Source* Modified from Teramura and Okuma (2005). Copyright 2005 Japan Society of Civil Engineers

## 2.2 Open Levee

An open levee is a form of river embankment with break in it (Fig. 2.2). As an open levee is discontinuous, water will overflow at the open part during a flood. However, the levees are constructed to overlap and contain the gaps; thus, flood-related disasters are limited to a certain area (Okuma 1987).

Open levees are classified into three types depending on their location and purpose. A detention effect can be obtained by temporarily causing the floodwaters at the opening to flow back into the levee (Fig. 2.3a). This levee type is used in gently sloping rivers. The flood reduction and drainage levee types are often used in steep rivers. The flood reduction levee type is designed on the assumption that there may be an upstream bank breakage (Fig. 2.3b). The drainage levee type is intended to remove inland water from tributaries (Fig. 2.3c).

An open levee is an autonomous structure created on the assumption that a flood will occur. However, flood control using a continuous embankment does not require a community to implement self-protection efforts, so local residents lose their ability to function autonomously (Teramura and Okuma 2005).

## 2.3 Paddy Field Dam

Runoff control devices are installed at the drainage outlets of paddy field plots to intentionally and temporarily store rainwater in paddy fields during intense rainfall events (Yoshikawa 2014). This measure is called a paddy field dam (Fig. 2.4). Paddy fields act as dams. Since there are many paddy fields in Japan, the dam effect of paddy fields is substantial.

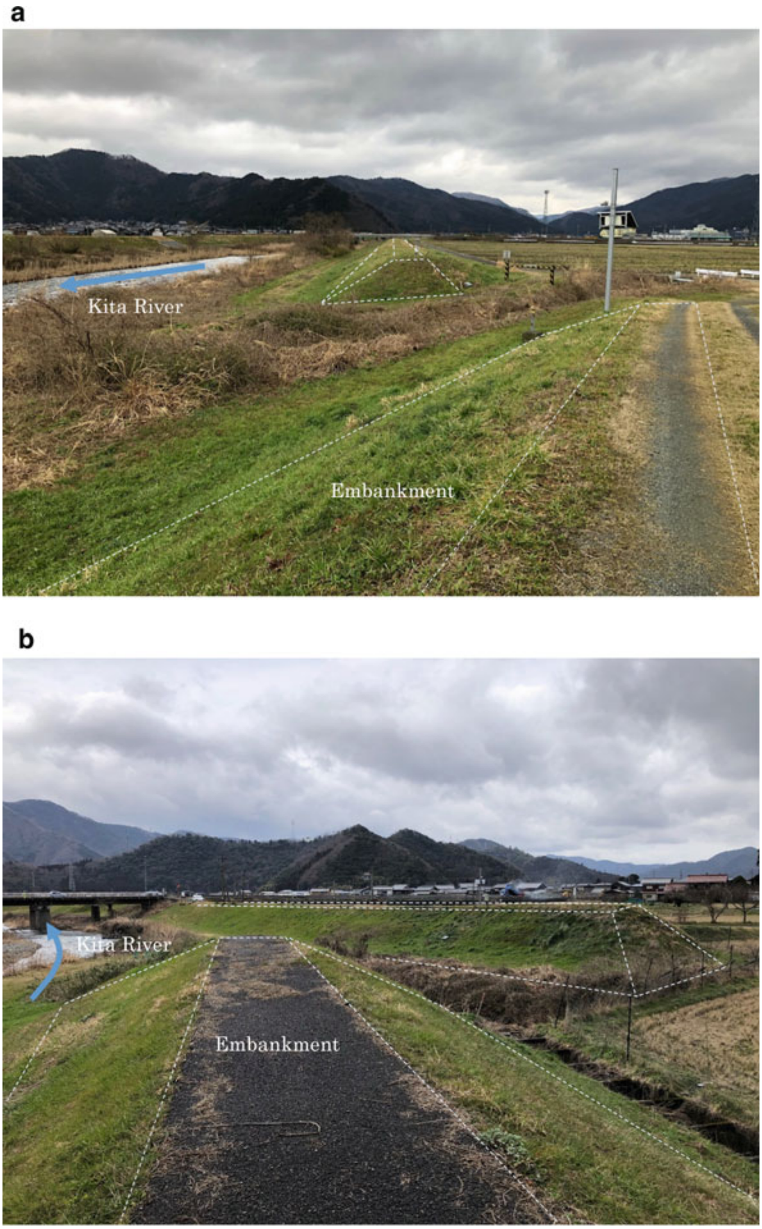


**Fig. 2.3** Open levee (*Photos* by Akira Matsui). *Notes* **a** Open levee 10 in Fig. 7.1. **b** Open levee 11 in Fig. 7.1. Photo date: February 26, 2021

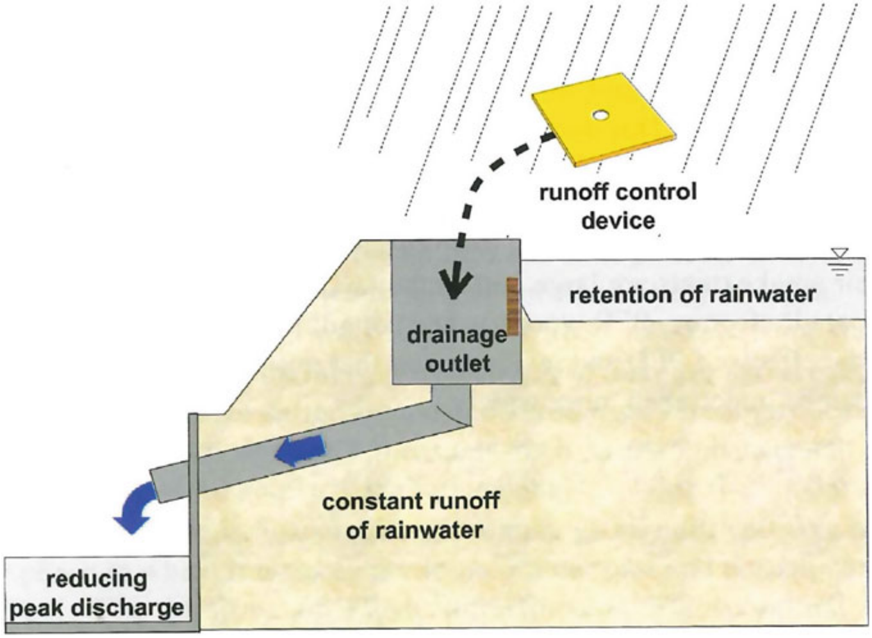


**Fig. 2.4** Schematic of a paddy field dam. *Source* Reprinted with permission from Springer: Springer. Social-ecological restoration in paddy-dominated landscapes by Nishikawa Usio and Tadashi Miyashita 2014

## 2.4 Watershed Control

Watershed control involves embankment maintenance, dam construction/regeneration, etc. The concept of watershed control is that everyone in the catchment area of the basin where inundation is expected due to river flooding will take measures against flood-related disasters (Fig. 2.5).

As part of watershed control, sediment accumulated in rivers is removed to increase flow capacity (Figs. 2.6 and 2.7). In addition, embankments and slopes are strengthened (Fig. 2.8). To determine the water level that corresponds to flood risk, a water-level gauge is installed, and the river water level is observed (Fig. 2.9).

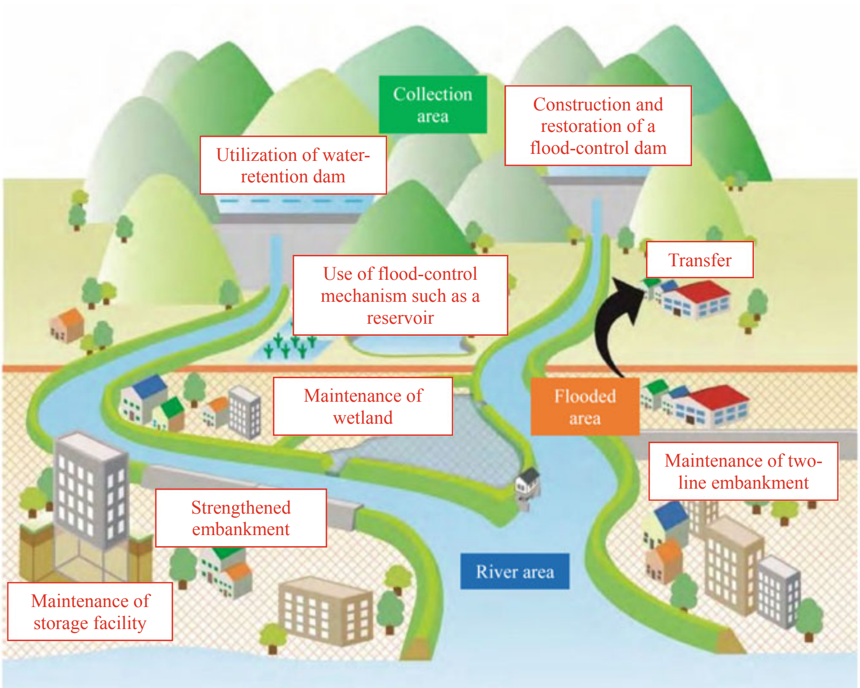


**Fig. 2.5** Watershed control. *Source* Modified from the Ministry of Land, Infrastructure, Transport and Tourism of Japan, https://www.mlit.go.jp/report/press/content/001370162.pdf, Accessed October 30, 2021 (in Japanese)