8 Current Issues and Research on Sediment Movement in the River Catchments of Japan

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INTRODUCTION

Prediction of sediment movement is one of the challenging tasks in water-related research. It is not only an interesting problem in terms of pure science but also a very urgent matter to solve in practical terms, especially in Japan, where sediment movement is active enough to cause severe human and physical damage. This chapter describes the situations surrounding sediment movement in river catchments in Japan and current topics and studies regarding sediment movement. The following section introduces the meteorological and geographical characteristics of Japan which have great impacts on sediment movement; these include the precipitation, topography and land use characteristics. Then the current issues in sediment movement in Japan are described. These are mainly engineering and environmental issues; research which addresses them is considered next. The concluding section summarizes the remaining academic challenges regarding sediment movement.

METEOROLOGICAL AND GEOGRAPHICAL CHARACTERISTICS OF JAPAN

Meteorological characteristics

The meteorological characteristic which has the greatest impact on sediment movement is precipitation. The annual precipitation average of Japan amounts to 1700 mm year^{-1}, considerably higher than the global annual average, i.e. 1000 mm, or that of Australia, 500 mm.

Figure 8.1 is a map of annual precipitation average for the past 30 years (1971–2000). It shows the regions of high precipitation (>2000 mm) in the centre and the southern part of the Japan Islands. The high precipitation mainly comes from a stationary front (the Baiu front), typhoons and/or snowfall.

Figure 8.2 shows the monthly precipitation of several cities in Japan. Most of the cities have much precipitation during the summer season (June–September). The spring and summer conditions are strongly affected by the Asian monsoon system which creates a stationary front, the Baiu front, which brings high precipitation, especially, in June and July. Also during the summer and autumn season, a considerable number of typhoons attack the Japan Islands, primarily in the southwest. Furthermore, there are often severe local rainstorms, which sometimes lead to flash floods.

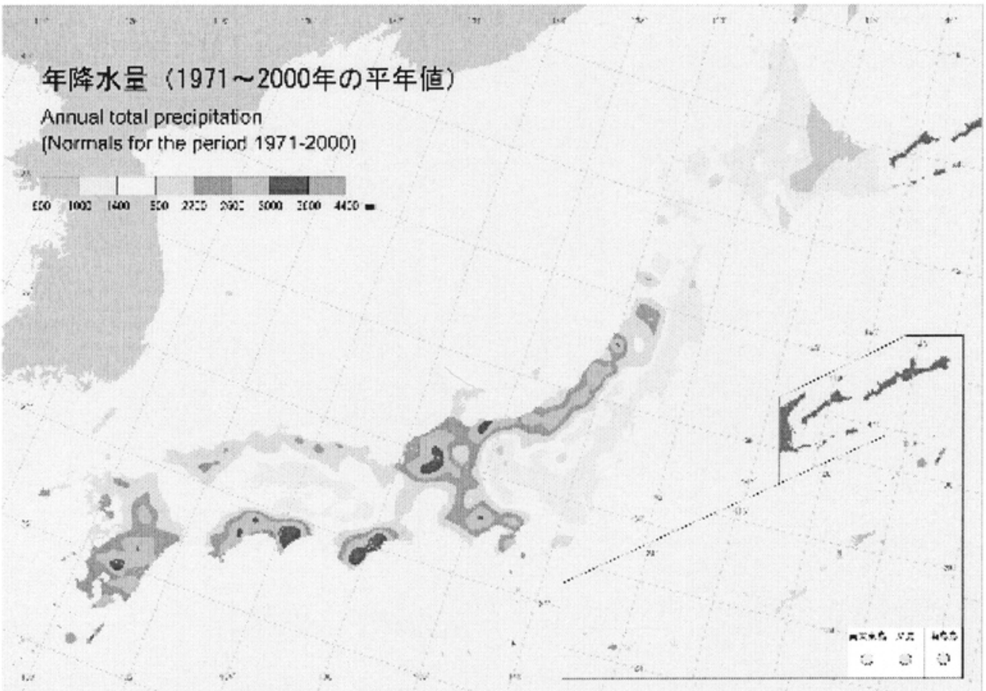


Fig. 8.1 *Map of annual precipitation average in Japan. (Source: Climatic Atlas of Japan for the period of 1971–2000).*

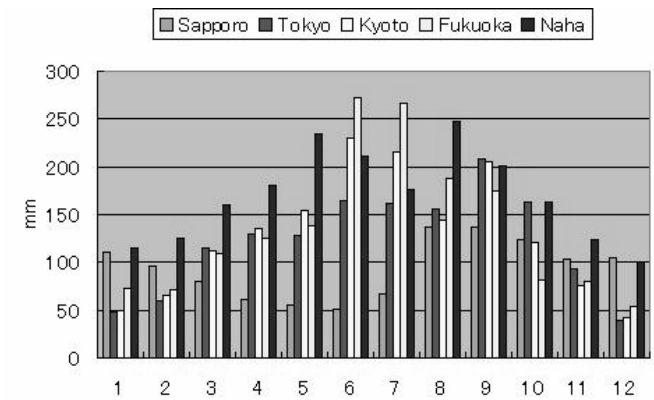


Fig. 8.2 *Monthly precipitation of several cities in Japan.*

Geographical characteristics

A distinctive feature of the Japan Islands is the high mountainous regions along the centre line of the islands and the alluvial fans and plains along the coasts. The topography is generally steep and a number of active volcanoes are distributed over the islands. Also, the islands have repeatedly experienced strong earthquakes which have made the geological structure fragile. Because of this, sediment activity in Japan is expected to be particularly high.

Fig. 8.3 *Urbanized area extending to hilly region.*

Another important characteristic is the high population density. The urbanized areas have been extending from the relatively flat coastal regions to the hilly regions as a result of the high population pressure (Fig. 8.3). The combination of severe precipitation and densely populated areas close to hilly and geologically fragile regions presents a high potential risk of sediment disasters.

CURRENT ISSUES ON SEDIMENT MOVEMENT IN JAPAN

The high activity of sediment movement leads to a wide range of practical problems. This section describes four current issues relating to sediment movement in Japan, including a serious one that can kill people and others that have engineering and/or environmental implications.

Debris flow disasters

The risk of sediment disasters is significantly high in Japan. Actually, we have experienced several severe sediment disasters in recent years. The most violent type of sediment-related disaster is a debris flow disaster, which can kill a large number of people and cause a huge amount of physical damage across a large area.

Figure 8.4 shows the site of a debris flow disaster at Kagoshima Prefecture in 1997. When the debris flow happened, the site had 200–300 mm precipitation per day, and 21 people were killed. Table 8.1 summarizes the numbers of deaths and houses affected by debris flow disasters from 1990 to 2002. We have been quite successful in reducing devastating damage due to flooding, but we still have a difficulty in reducing or mitigating debris flow disasters.

Sedimentation in dam reservoirs

Sedimentation in dam reservoirs is another problem. It reduces the dam’s capacity for controlling flood runoff and storing water resources. The worst sedimentation ratio of

Table 8.1 *Numbers of deaths and affected houses caused by debris flow disasters.*

Year	Deaths	Affected houses	Year	Deaths	Affected houses	Year	Deaths	Affected houses
1990	13	1091	1995	0	0	1999	28	230
1991	43	179	1996	14	0	2000	3	57
1992	0	0	1997	29	204	2001	0	212
1993	0	0	1998	9	96	2002	2	20
1994	0	0						

Fig. 8.4 *Site of a debris flow disaster at Kagoshima Prefecture in 1997. (Courtesy of The International Air Photo Inc.).*

dam reservoirs in Japan is about 98%. It means that the reservoir is almost filled with sediment transported from the upstream regions. However, this is an extreme case. The sedimentation ratio of dam reservoirs in Japan generally ranges from 5 to 30%.

Coastal erosion

A dam reservoir and sediment control facility can prevent the occurrence of sediment-related disasters by trapping and holding sediment transported from the upper region of a catchment. The consequence of preventing disasters, however, can be a major cause of another problem, coastal erosion. At the moment, it is not severe enough to cause any human and physical damage, but the problem receives much attention in terms of the environmental aspects.

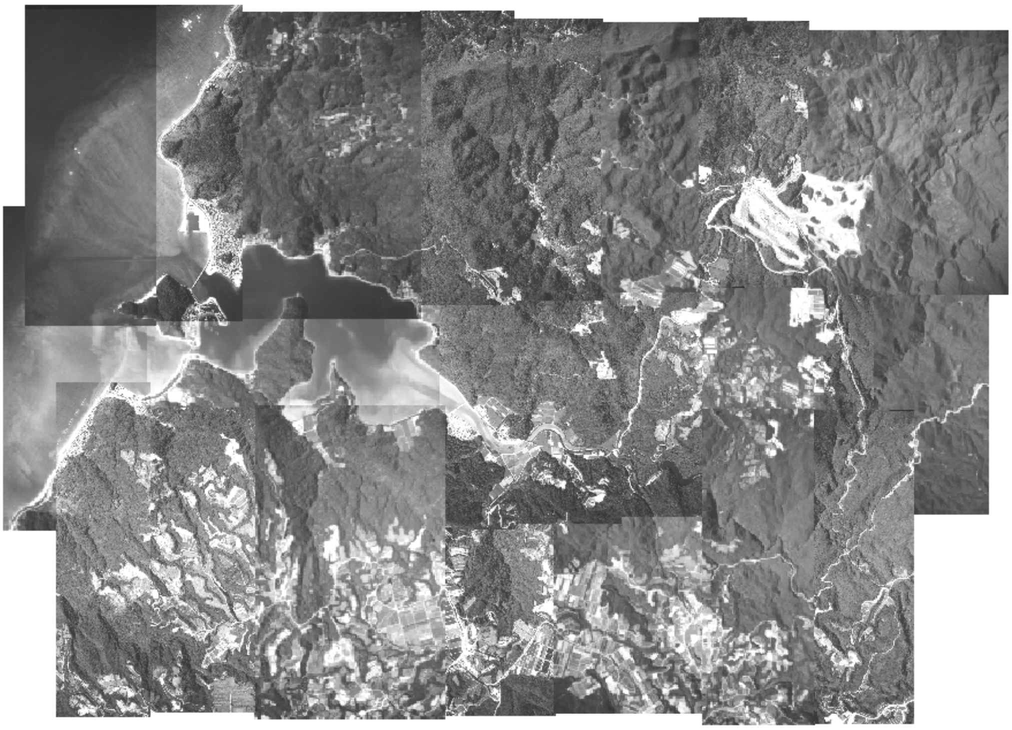


Fig. 8.5 *Aerial photo mosaic of a catchment with severe red soil erosion.*

Soil erosion

Soil erosion, especially of cultivated land, is not only an agricultural issue but also an environmental issue. The Okinawa region, located at the southern end of Japan, has been suffering from the problems caused by severe red soil erosion and runoff (Ichikawa *et al*., 2003). The red soil is distributed across the Okinawa region; the soil particles are so fine that the soil is quite erosive and the particles remain suspended once they are entrained by flowing water. Figure 8.5 shows the circumstances of a catchment where there is severe red soil erosion. The muddy water containing red soil particles (seen as white–light grey in the figure) pollutes the shores and coasts, and damages the ecosystems of the sea, and farming and tourism.

CURRENT RESEARCH ON SEDIMENT MOVEMENT

In Japan, the research activity on sediment movement is strongly motivated by engineering approaches that involve reduction of sediment disasters and environmental impact assessment.

Prediction of slope failures

Detailed and intensive field observations have revealed that spatial heterogeneity of soil structure plays an important role in rainfall–runoff and slope failure processes. Pipe flow in a hill slope is a typical process showing spatial heterogeneity of soil structure (Uchida *et al*., 2002). A number of researchers have focused on the process and investigating its characteristics and possible relation to slope failures using experiments and numerical simulations (Uchida & Mizuyama, 2002).

Numerical simulation of debris flow

Debris flow has been formulated as solid–water phase flow, being considered to be a continuum. However, recently, there have been attempts to model debris flow as an aggregate of particles using the distinct element method, which simulates the movement of each particle. One of the major advantages of the method is that a simulation result can be visualized so that one can easily understand it. Harada *et al.* (2003) developed a framework for simulating the processes forming a debris fan using the three-dimensional distinct element method. The distinct element method is also used for evaluating the attainment distance of soil blocks collapsed from a cliff (Wakai *et al*., 2004).

Evaluation of the effects of sabo facilities

Sedimentation in dam reservoirs not only reduces their water storage function but also can be a cause of coastal erosion. In order to solve or mitigate these problems, a number of new types of sediment control (sabo) facilities have been developed.

Figure 8.6(a) shows a slit-type sabo dam (Ougisawa sabo dam) which has a slit in the centre of the dam. This dam will trap relatively large rocks, which could be a cause of disasters, but relatively fine particles can go through the slit and are not accumulated in the dam reservoir. Figure 8.6(b) shows an open-type sabo dam (Shiramizutani sabo dam), built using a steel structure; the concept is the same as that of a slit-type dam.

Numerical simulation techniques can be helpful in designing these types of sabo facilities. There have been research investigations to establish a methodology for evaluating the effects of sabo facilities and the distinct element method, referred to above, has been used for simulating the sediment trapping/releasing effect of new-type sabo dams (Mizuno *et al*., 2000; Miyazawa *et al*., 2003).

REMAINING CHALLENGES

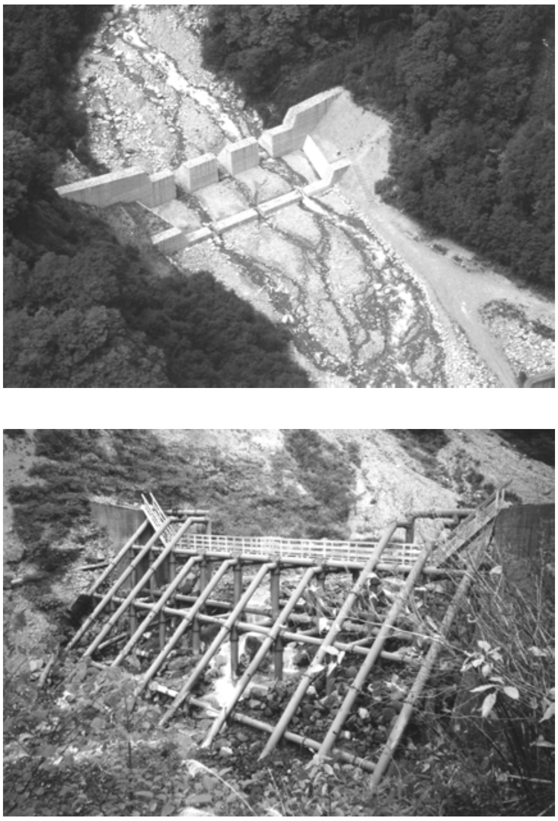
We still have a number of challenges remaining for studies on sediment movement.

The first is how to predict slope failures in real catchments. We are beginning to understand the detailed mechanism of slope failures but still have the problem of how we can predict where and when a failure will occur in real catchments.

The second challenge is to predict long-term sediment movement for 10- to 100-year periods. We have improved predictions of short-term sediment transport, but considerable uncertainty still remains in the prediction of long-term sediment movement, which is partly due to the uncertainty of climate.

The third challenge is the development of methods for gauging sediment discharge. We do not yet have an effective method for gauging sediment discharge.

Finally, prediction of sediment movement in ungauged basins is a challenge. Actually, the first and second challenges can be included in the PUB problem because we do not have any tools or methods to obtain precise information regarding soil structural properties across large areas or the long-term future climate impacts. We need to develop new techniques for measuring physical properties relating to sediment movement and also a new theory for describing sediment movement.



(a)

(b)

Fig. 8.6 *(a) Slit-type sabo dam. (Courtesy of Matsumoto Sabo Office, Ministry of Land, Infrastructure and Transport) (b) Open-type sabo dam.*

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