

Roles of natural levees in the Ara River alluvial fan on flood management

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Abstract The Ara River alluvial fan has a lot of natural levees. It is considered that the natural levees effect flood inundation flow, but there are few studies about the roles of natural levees from the point of view of flood control and management. In this study, by plotting positions of the remains of communities (from BC20 000 to AD1192) on the topographical classification map, it is clarified that many remains of communities in the Ara River alluvial fan were developed on the natural levees. Roads and railways in the Ara River alluvial fan were constructed in order to connect the natural levees in the Meiji-period. From the Ara River hazard map, flood depths on the natural levees are shallow compared with surrounding areas. The embankments of roads and railways on the natural levees are useful measures for preventing spread of inundation flow.

Key words alluvial fan; natural levee; development of communities' flood management

INTRODUCTION

A lot of alluvial fans exist in Japan. The geological condition of alluvial fans is well-drained and stable compared with those of plains. Because of global warming the probability of flood inundation is predicted to increase. How to reduce damage from flood inundation in the alluvial fan should be considered. On the Ara River alluvial fan, micro-topographies (such as natural levees) were developed by river flooding. Figure 1 shows an example of the natural levees seen in the Ara River alluvial fan. The elevation of the natural levees is more than 0.5 m higher than the surrounding area. It is important to understand the role of the micro-topographies for confining spread of inundation water. Many studies about alluvial fans have been conducted in the geology (Saito, 1988) and topography (Saotome, 2005) fields. Processes of formation and deposition of alluvial fans have been focused on the engineering field (Takahashi, 1979). However, there are few studies about the role of micro-topographies on alluvial fans on flood management. In this study, an investigation is made on the role of natural levees in the Ara River alluvial fan for floods.

THE ARA RIVER ALLUVIAL FAN

The Ara River alluvial fan is located at the northwest of Saitama Prefecture in Japan (see Fig. 2). There are two types of alluvial fans in this region. These are the new Ara River alluvial fan and the old Ara River alluvial fan. The new Ara River alluvial fan and the old Ara River alluvial fan were developed in alluvial and diluvial epochs, respectively, from the standpoint of geological age.

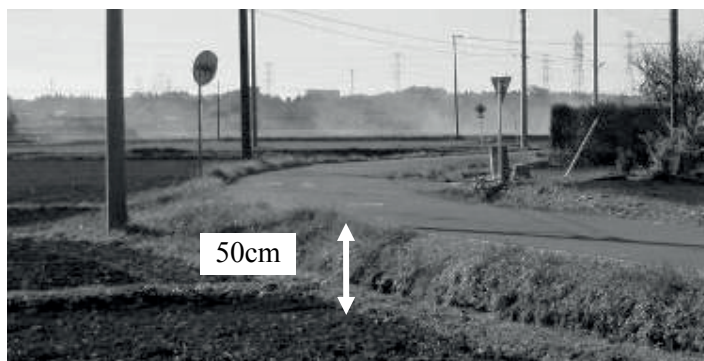


Fig. 1 A natural levee in the Ara River Alluvial Fan.

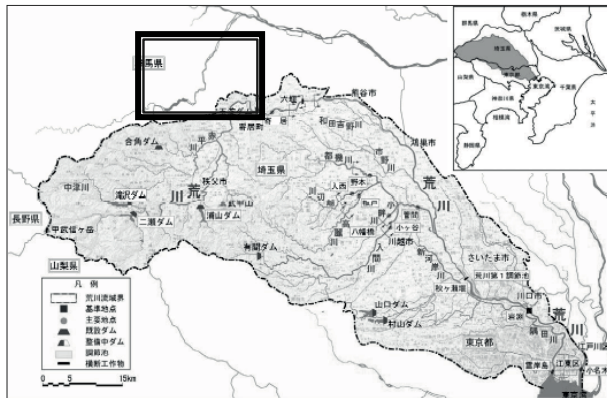


Fig. 2 Position of the Ara River alluvial fan.

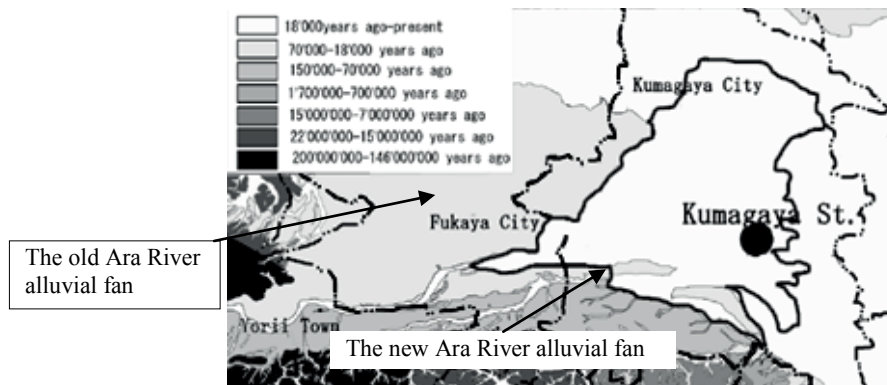


Fig.3 Depositional age of the Ara River alluvial fan.

The new Ara River alluvial fan is inside the continuous line in Fig. 3 (Oya, 1996). In this paper we define the new Ara River alluvial fan as “the Ara River alluvial fan”. This alluvial fan has mild slope (about 1/300), and a large area compared with other alluvial fans in Japan (Kagose, 1975).

In 1629, the Ara River was artificially shifted west to protect people who lived in Edo (Tokyo) from the flooding. The present plan form of the Ara River was made in that time. Before that, the Ara River often changed channel positions and flowed into the Tone River, which runs through the northeast region of the Ara River (Kurita, 1959). On the alluvial fan, ground material of the surface layer consists chiefly of sand. Under the surface layer, the silt layer forms the basis of this alluvial fan (Rissho University, 2010).

THE RELATIONSHIPS BETWEEN NATURAL LEVEES AND REMAINS OF COMMUNITIES

A lot of remains of communities were found in the Ara River alluvial fan (Kumagaya City, Saitama Prefecture Investigation Committee of the Kagoharaura Remain, 2009; Kumagaya City, Saitama Prefecture Board Of Education, 2009; Fukaya City, 2011). The oldest remains were formed in the Paleolithic period. This section presents the positions of remains of communities in the Paleolithic period (BC20 000–BC14 000), the Jomon period (BC14 000–BC1000), the Yayoi period (BC1000–AD300), the Kofun period (300–700), the Nara period (710–794), and the Heian period (794–1192) on the topographical classification maps which were made by Geographical Survey Institute of Japan in 1972. This map draws the natural levees, diluvial uplands and old river channels in detail (Geographical Survey Institute, 1974). The relationships between the natural levees and the positions of remains of communities on each time are discussed in the following sections.

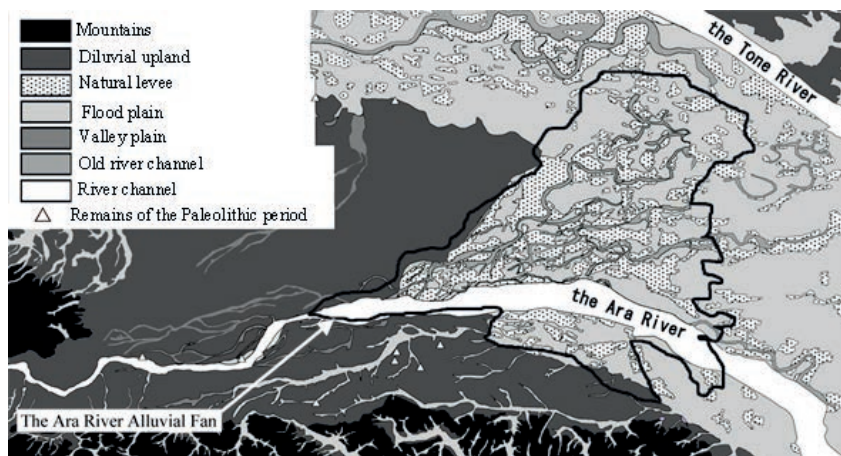


Fig.4 Positions of remains of the Paleolithic period.

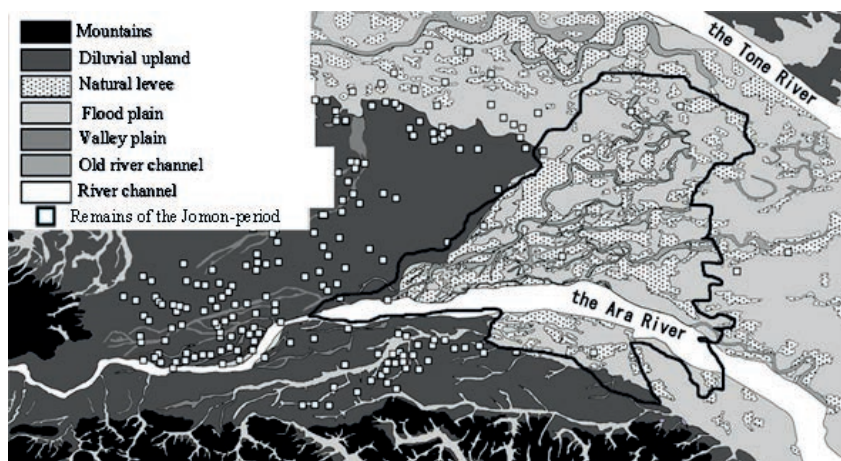


Fig. 5 Positions of remains of the Jomon period.

Natural levees and remains in the Paleolithic period (BC20 000–BC14 000)

Figure 4 shows the relationship between natural levees and the remains in the Paleolithic period (triangles). It is known that the Ara River alluvial fan was not yet formed in the Paleolithic-period. The remains were therefore limited in the diluvial upland, and there were no remains on the Ara River alluvial fan.

Natural levees and remains in the Jomon period (BC14 000–BC1000)

Figure 5 shows the relationship between the natural levees and the remains of the Jomon period (quadrangles). There were no remains in the Ara River alluvial fan in the Paleolithic period (see Fig. 4). However, in the Jomon period, many remains can be found in the diluvial upland, some can be found in the alluvial fan, and most of them are formed on the natural levees. It is considered that people have used natural levees as a base of community since the Jomon period.

Natural levees and remains in the Yayoi period (BC1000 AD300)

Figure 6 shows the relationship between the natural levees and the remains in the Yayoi period (quadrangles). The percentage of the remains on the natural levees in the Ara River alluvial fan of the Yayoi period (Fig. 6) increases in number compared with that of the Jomon period (Fig. 5). It is considered that Japanese paddy agriculture started in the Yayoi period, and people needed the ground where they could get water to produce rice. Therefore, people came down from the diluvial upland to the alluvial fan, and used the natural levees as a base of community.

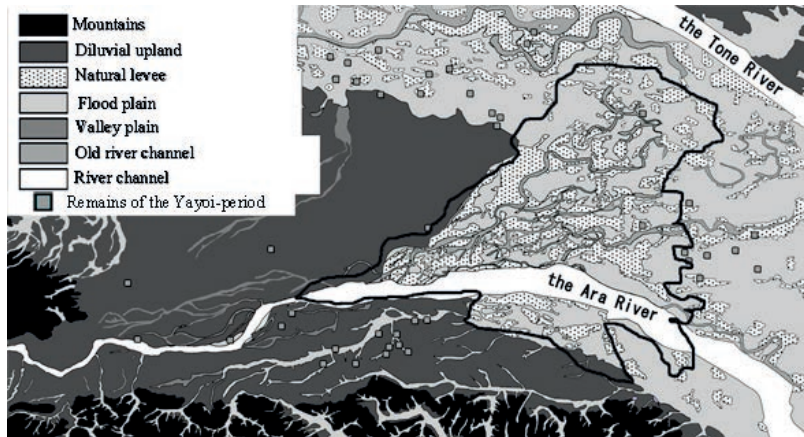


Fig. 6 Positions of remains of the Yayoi period.

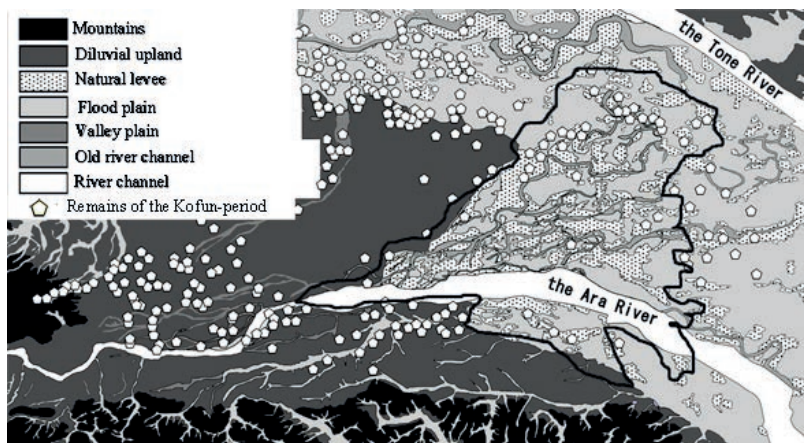


Fig. 7 Positions of remains of the Kofun period.

Natural levee and remains in the Kofun period (250–700)

Figure 7 shows the relationship between the natural levees and the remains in the Kofun period (pentagons). These pentagons include ancient burial mounds. By comparing with the distributions of the remains in the Yayoi period (Fig. 6) the number of remains in the Kofun period (Fig. 7) increases due to the increase of the population. Most remains in the Ara River alluvial fan in the Kofun period also occur on the natural levees in the Ara River alluvial fan.

Natural levees and remains of the Nara period and the Heian period (710–1192)

Figure 8 shows the relationship between distributions in the natural levees and the remains of the Nara period and the Heian period (pentagons). Many remains in the Ara River alluvial fan were found on the natural levees, and the remains were plotted on almost the same position as the Kofun period.

In this section, it is presented that people who lived in the Ara River alluvial fan used the natural levees as a base of livelihood since the Jomon period. The remains in the Ara River alluvial fan have increased over time. It is clarified that the development of communities were related to the natural levees since ancient times.

THE RELATIONSHIP BETWEEN NATURAL LEVEES AND COMMUNITIES IN THE MEIJI-PERIOD (1885–1912)

The relationship between temples and shrines in the Meiji-period and the natural levees in the Ara River alluvial fan is presented in Fig. 9. White points show positions of shrines, and black points show positions of temples. It is found that many shrines and temples are built on the natural levees.

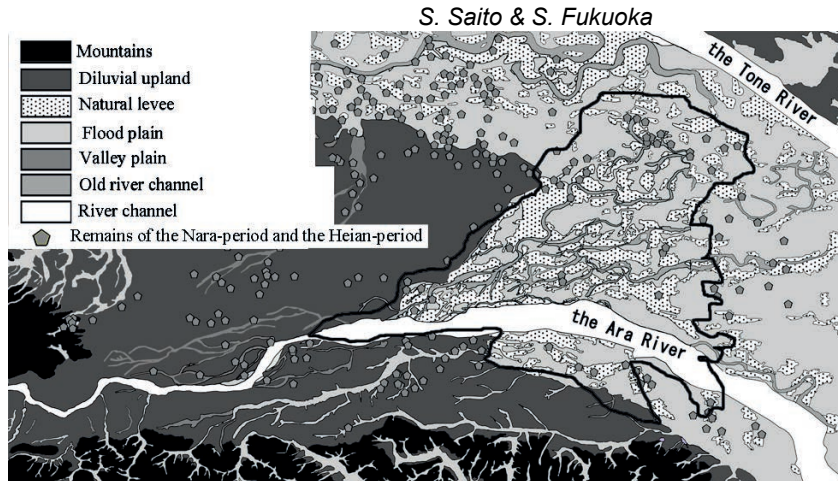


Fig. 8 Positions of remains of the Nara period and the Heian period.

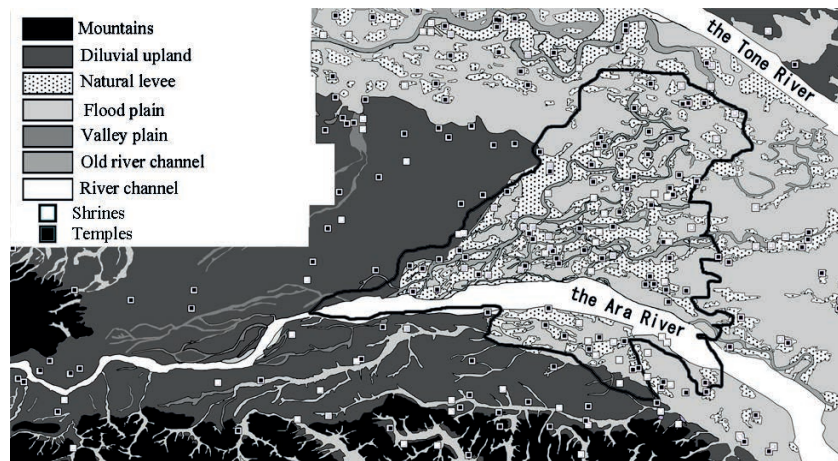


Fig. 9 Positions of shrines and temples.

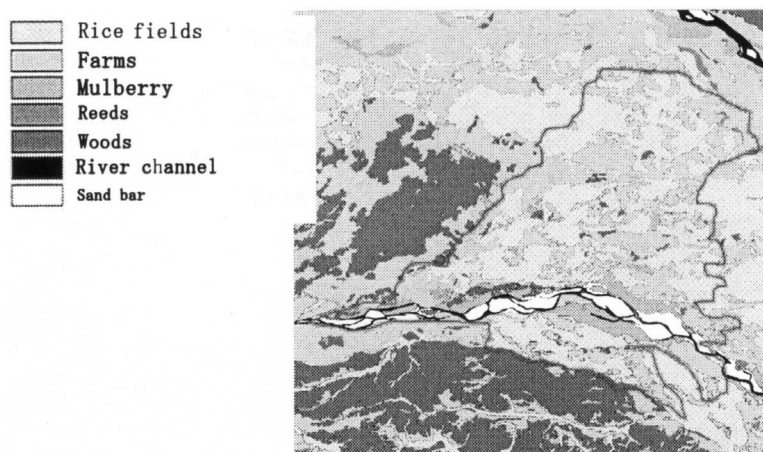


Fig. 10 Land use of the Ara River alluvial fan in the Meiji period.

Figure 10 shows the land use of the Ara River alluvial fan in the Meiji period (1885). The Ara River alluvial fan is inside the line on Fig. 10. The alluvial fan was covered mostly by fields and rice fields. To investigate the relationship between the natural levees and the fields, distribution of the natural levees is superposed on Fig. 10, as shown in Fig. 11. It is found that people used natural levees as the paddy fields.

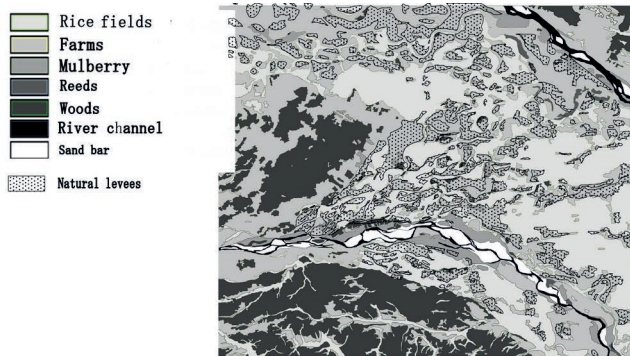


Fig. 11 Land use and natural levee.

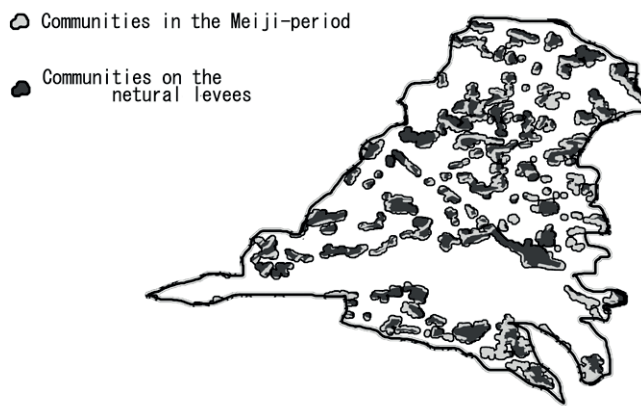


Fig. 12 Communities in Ara River alluvial fan in the Meiji period.

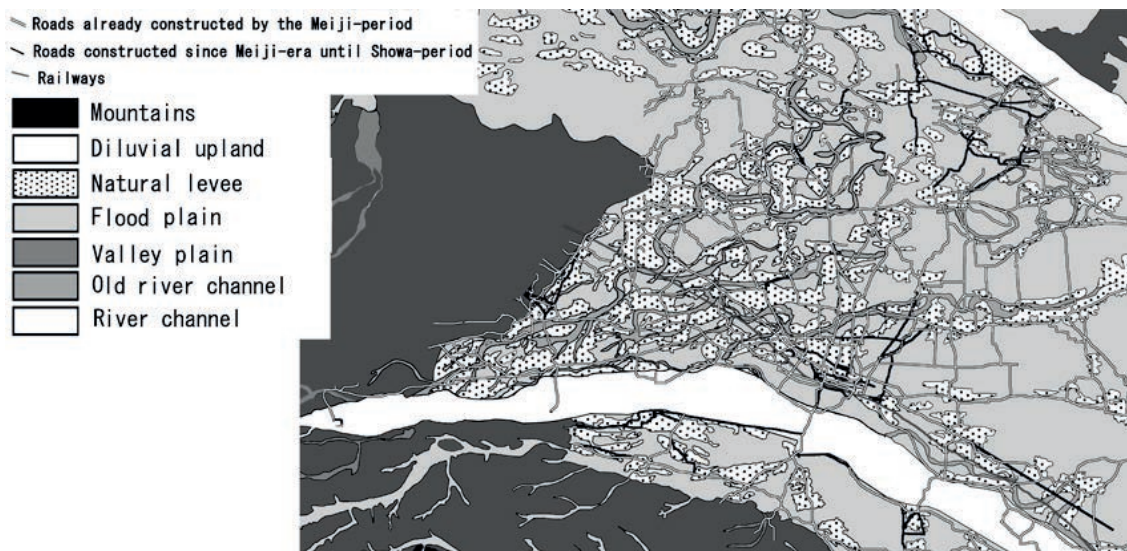


Fig. 13 Development of traffic network in the Ara River alluvial fan.

Figure 12 shows distribution of communities in the Meiji period (National Institute of Agro-Environmental Science) and the natural levees. It is found that most communities in the Ara River alluvial fan tended to develop on the natural levees. This is a similar tendency to that found in the

distribution of remains of communities in Ara River alluvial fan in the preceding section. Figure 13 shows the relationships between development of the traffic network and the natural levees in the Ara River alluvial fan. In the Meiji period, roads and railways were constructed so as to connect the natural levees in the Ara River alluvial fan. In the Showa period (1925–1989), it is confirmed that new roads are constructed on the natural levees. From the above discussions, we think the natural levees have roles for the development of communities and traffic.

THE ROLES OF NATURAL LEVEES ON FLOOD MANAGEMENT

Figures 14 and 15 superimpose the hazard map on the topographical classification map. The hazard maps in Figs 14 and 15 were made for an inundation by the 200-year flood on the Ara River (Upper Ara River Office, 2005) and the Tone River (Upper Tone River Office, 2006), respectively. The depth of inundation on the natural levees is relatively shallow, and the natural levees affect the surrounding inundation flow. It is considered that the natural levees are able to reduce the damage due to flood inundation.

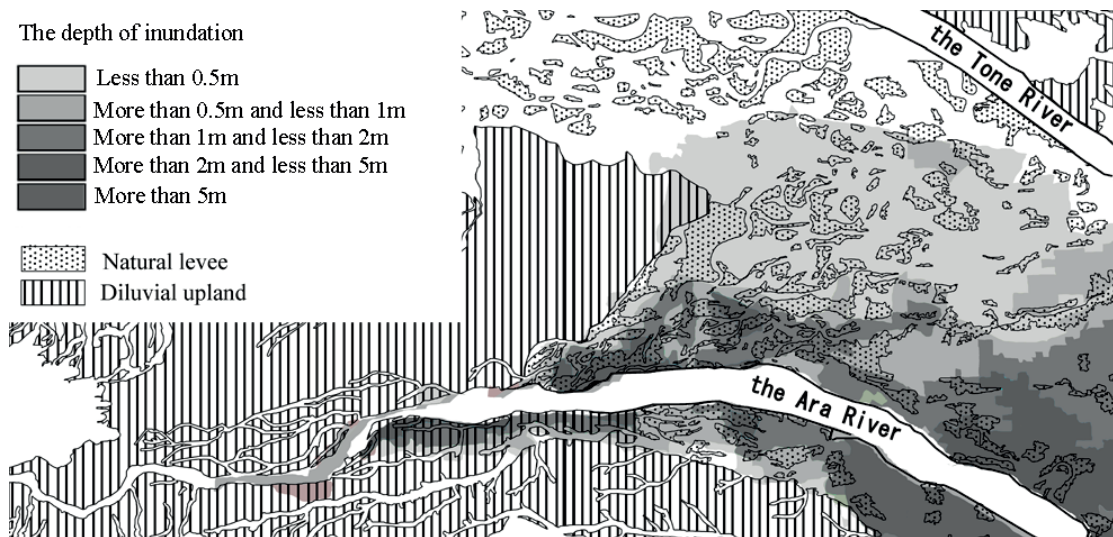


Fig. 14 Hazard map of the Ara River in the Ara River alluvial fan.

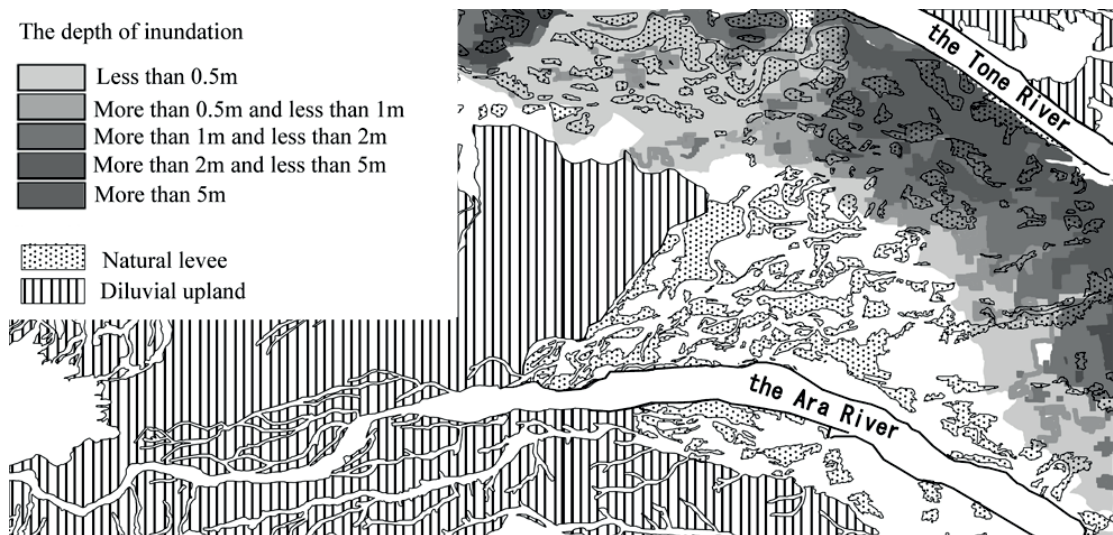


Fig. 15 Hazard map of the Tone River in the Ara River alluvial fan.

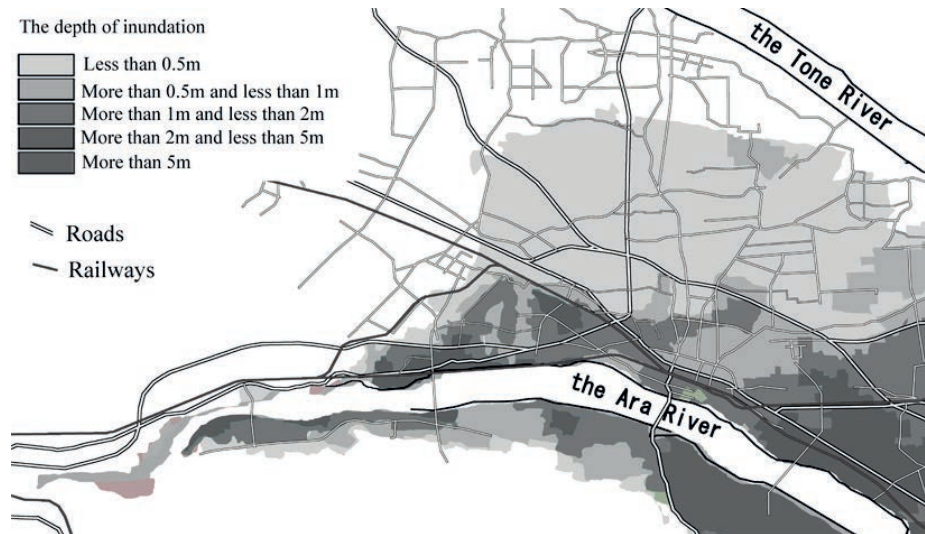


Fig. 16 Relationship between depth of inundation and traffic facility.

The locations of present roads and railways (Geographical Survey Institute, 2011) were superimposed on the hazard map of the Ara River (see Fig. 16). Inundation flows are blocked in front of the roads, and roads have the effect of reducing inundation depth. It is clarified that the natural levees with roads and railways have important roles for flood inundation control and management. It will be possible to create the safe city against flood damages by using natural levees with roads and railways.

CONCLUSIONS

In this study the roles of the natural levees in the Ara River alluvial fan are investigated by topographical classification maps, remains of the communities and field investigation. The primary conclusions are shown below:

- (a) By comparing the distributions of the remains of communities (from BC2000 to AD1192) and the natural levees in the alluvial fan, it was clarified that the people had moved from diluvial upland to the Ara River alluvial fan since the Jomon period and most of the remains of communities had developed on the natural levees in the alluvial fan.
- (b) Most of the communities, firms, temples and shrines indicated in the map which made in the Meiji period existed on the natural levees. Traffic networks in the Meiji period were constructed so as to connect the natural levees. It is assumed that the natural levees played a role as a foundation of development of communities.
- (c) The hazard map of 200-year flood of the Ara River and the Tone River, shows flood depths on the natural levees in the Ara River alluvial fan are shallow compared with surrounding areas and the inundation flows are blocked by the roads and railways on the natural levees. It is considered that the natural levees with roads and railways protect communities from flood inundation.

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