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Smart adaptation activities and measures against urban flood disasters

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ABSTRACT

Frequent inundation has become a serious problem in urban areas. It is necessary to improve rainwater retention/infiltration in the urban watershed. The purpose of this study is to report how private rainwater-retention/harvesting facilities can be spread gradually but steadily in the city by citizen-initiated activities. Rainwater harvesting tanks were installed intensively and a rainwater harvesting house was constructed in the city of Fukuoka, Japan after the city experienced a flood disaster. The former enhanced users' daily preparedness for emergency, and the latter inspired construction of a rainwater-harvesting housing complex. A public elementary school is in use from April 2016, which is inspired by these facilities. The school premises are located on the land reclaimed from an old irrigation pond. Thus the school needs to be adapted to this condition. 3000 m^3 of rainwater can be retained within the premises. The amounts of retention and discharge are monitored, and the data is utilized for science education. In big cities, people tend to depend too much on the top-down, mega-system, which invites more impervious surfaces in urban areas. Bottom-up, individual/collaborative approaches should be adopted in order to achieve multiple purposes of preventing/mitigating disasters, preserving/conserving ecosystems and nurturing/rebuilding communities in the city.

1. Introduction

A river is indispensable for sustaining a quality environment for diverse forms of life whereas it becomes a source of trouble with the overabundance of water. Frequent inundation has become a serious problem in urban areas all over the world (WMO/GWP, 2008). This is because the impervious surface covers most of the city area, and rainfall in the city tends to intensify due to heat-island effect and global warming. Measures such as dredging rivers, strengthening drainage systems and constructing flood walls are needed (Muller, Biswas, Martin-Hurtado, & Tortajada, 2015); however, they drastically change the urban riverine ecosystem (Palmer, Liu, Matthews, & Mumba D'Odorico, 2015). Moreover, these public works are insufficient as the urban-flood disaster inevitably deteriorates without decreasing runoff per se. It is necessary to devise and implement effective measures for rainwater retention and infiltration within the entire urban watershed where there are usually a huge number of private properties and enterprises situated. Furthermore, restoring the hydrologic cycle by utilizing the green infrastructure can be cost-effective and lead to a relevant policy change even in a metropolis like New York (NYC, 2014).

In order to promote green infrastructure effectively, it is crucial to use a wide range of combinations of innovative rainwater-harvesting measures, rather than focusing on single innovations (Marsalek and Schreier, 2009). Moreover, accurate design and configuration, simulation, localization and imposing proper maintenance schemes are indispensable in executing the rainwater harvesting system (GhaffarianHoseini, Tookey, GhaffarianHoseini, Yusoff, & Hassan, 2015).

This study reports private, small- to mid-sized rainwater harvesting tools/facilities installed in urban watersheds and their impacts on the public, flood-disaster mitigation. It also shows a large-sized facility constructed in another watershed. The facility has not only a rainwater-retention function but also ecological and educational roles. This study compares the facilities' functions with each other and examines their effectiveness as rainwater harvesting systems.

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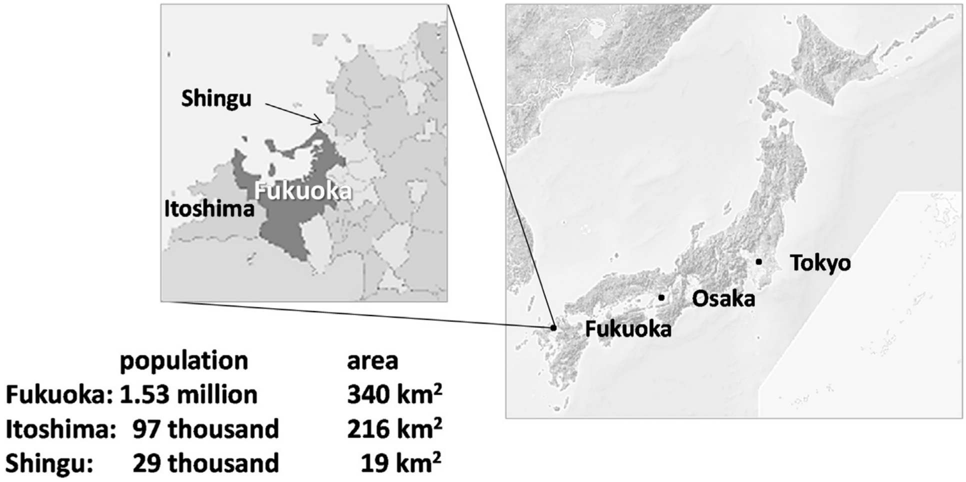

Fig. 1. Study sites.

The purpose of this study is to report how private rainwater-retention/harvesting activities can be spread gradually but steadily in the city, as a citizen-initiated, smart way to responding to urban flood-disaster risks in Japan.

2. Scope

In this study, we deal with rainwater retention/harvesting tools/facilities in the city of Fukuoka (population: 1.53 mil.; area: 340 km^2), Japan and its suburbs: Itoshima (97,000; 216,km^2) and Shingu (29 000; 19 km^2).

First, we are focused on the Hii River Basin located within Fukuoka (Fig. 1). The lower areas in the watershed have experienced inundations three times since 1960. The latest took place in 2009, and just after this event, a citizens' alliance for flood-disaster management was established (Yamashita et al., 2013). This group consists of a wide variety of stakeholders including victims of the disaster, residents in general, academics and college students studying watershed management, NPO members involved in water resources management, construction engineers, local government officials, etc. They have been trying to come up with ideas to tackle urban water challenges and practice what they can do together for a comprehensive flood control.

Second, we move onto Itoshima and Shingu, both of which need to respond to a growing population as suburbs of Fukuoka (Fig. 1). In association with the activities for the Hii River Basin, an apartment complex featuring rainwater-harvesting facility was built in 2012 in Itoshima, and a public elementary school with rainwater retention/harvesting functions is in use from April 2016 in Shingu.

In this study, we explain what the philosophy of these facilities is and how they are relevant to one another.

3. Citizens' alliance for the Hii River Basin management

3.1. Hii River Basin and flood disaster in 2009

The watershed area of the Hii River is included within the Fukuoka city area (population: 1.53 mil.), which is located in the north of Kyushu, one of the main islands of Japan (Fig. 1). The area of the watershed is relatively small; it is only 29 km^2, and the length of the main channel is 13 km. The urbanized areas account for about 70% of the watershed area, and about 180,000 people live there.

Three areas close to the Hii River were inundated due to heavy rainfall on July 24th, 2009. The rainfall was so intense; its amount reached about 100 mm/h. As the drainage system of the area is designed to manage the rainfall intensity of up to 52 mm/h, it was naturally overwhelmed. The rapid and concentrated runoff due to urbanization made the inundation even worse; 410 houses were flooded within this small watershed (Fig. 2).

3.2. Citizens' alliance

In response, we decided to provide a new forum for citizens including local residents, local officials, businesses, engineers, students, academics, etc. to share views regarding floods and flood prevention/mitigation. As there are many kinds of stakeholders involved in this endeavor, all they need is to put aside their differences and work together to solve the problem. The group call themselves "Citizens' Alliance for the Hii River Basin Management."

In order to share views and come up with voluntary runoff-control measures, the group carries out forums and fieldworks by themselves. The forums have been held 43 times from October 4, 2009 up until May 25, 2015. Around 100 people have participated in each forum.

The 43 forums can be classified into six phases: 1) Introduction, 2) Development, 3) Technical recommendations, 4) Actions, 5) Involvement in drawing up the river development project, and 5) Safety plan for 100 mm/h-rainfall.

3.2.1. From introduction to technical recommendations

During the period from the *Introduction* to *Technical recommendations* phases, the Alliance tried to build consensus and come up with ideas for comprehensive flood control.

In the *Introduction* phase (Oct. 2009–Jan. 2010), the Alliance discussed and compiled recommendations and proposals for the comprehensive flood control and watershed management of the Hii River and submitted them to the mayor and governor of Fukuoka. In the *Development* phase (Feb.–Dec. 2010), NPO and student members of the Alliance took advantage of the prefectural monitoring system for rainwater harvesting and started to install rainwater retention/harvesting tanks (0.2 m^3) to households willing to use one for free. The activity led most participants, including those who had experienced inundation and demanded immediate preventive measures, to agree to incorporate multiple rainwater retentions into flood control as an essential measure. In *Technical recommendations* phase (Jan.–May 2011), experts proposed redesigns of a closed schoolyard and an irrigation pond for effective rainwater retention/infiltration in the watershed and explored the possibility of constructing a rainwater harvesting house as a model housing

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