Management of Water Conservation Forests for Over 100 Years

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Summary

Tokyo Waterworks has been managing its water conservation forests for more than 100 years in order to secure stable river flow of the Tama River and to conserve Ogouchi Reservoir. Currently, total area of the forests is approximately 23,000ha, which is the largest scale owned by a single domestic water supplier. Although the water resource area was devastated at the start of the management, it is now covered by green forests through planned reforestation to activate multiple functions of the forests such as water conservation and prevention of soil erosion as well as restoration of the forests. On the other hand, devastation of privately owned forests, spreading in the same scale as the water conservation forests in our coverage area, is becoming serious. To improve and maintain these forests for the purpose of conservation of the water resource area, Tokyo Waterworks is engaged in forest maintenance through direct purchase of forests and utilization of volunteers. In addition, we are also promoting exchange activities with water users and others to let them deeply understand our projects. Tokyo waterworks will continue to nurture and manage our water conservation forests to maximize the forests' functions as well as conduct private forest regeneration and promote communication with the society at the water resources area.

Keywords:
Multiple functions of the forest, Tama River Water Resources Forest Team, familiarity on water conservation forests

1. Position of Water Conservation Forests

The water resources of the Tokyo metropolitan area are mainly divided into the Tone /Arakawa River system and the Tama River system. The history of waterworks utilizing the Tama River that across Tokyo Metropolis and Yamanashi Prefecture can be traced back to Tamagawa Josui (Aqueduct) (1654) of the Edo Era. Since then, the Tama River had been taking an active role as the water resource of the capital of Tokyo for 310 years until the time when water of the Tone River system became available in 1965. Nowadays, the dependency on the Tama River system goes down to 19% of the total water demand. However, the system has the Ogouchi Reservoir that can store water for approx. 45 days for approx. 13 million citizens, and continues to hold an important position as Tokyo's own backup water resource in case of droughts or accidents of other river systems (Figure 1).

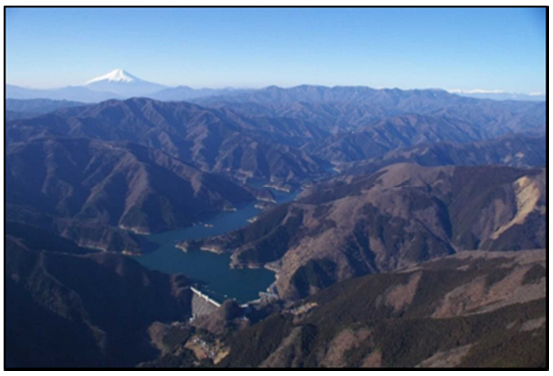

Figure 1 Water Jar of Tokyo, "Ogouchi Reservoir" and "Water Conservation Forests" Spreading its Upstream

Water Conservation Forests are the forests that have been managed systematically for over 100 years in order to ensure stable river flow of the Tama River system and conserve Ogouchi Reservoir. The total area of the forests is currently approx. 23,000 ha, which is equivalent to 47% of the water intake area or one tenth of the entire Tokyo area, and it is the largest scale owned by a single domestic water supplier.

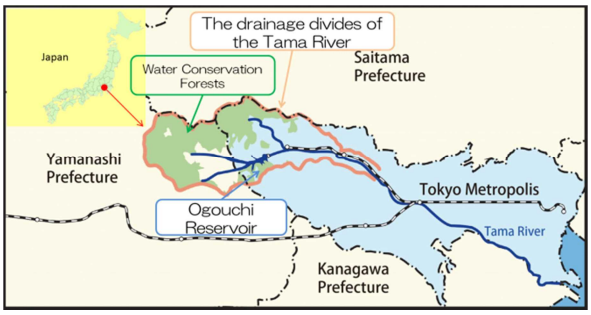

Figure 2 Location of Water Conservation Forests

Figure 2 shows the location of the water conservation forests.

2. Transition of the Management of Water Conservation Forests

The history of the management of water conservation forests dates back about 120 years ago. The forests in the upstream of the Tama River had been managed generally well by Edo Shogunate until the end of the Edo Era (1603-1867). However, they became devastated by the expansion of slash-and-burn fields, natural disasters, etc. in the Meiji Era (1868-1912), and deterioration of the river water quality and reduction of water quantity became serious problems. Devastation of the water resource area was a crucial issue for Tokyo which depended mostly on the Tama River system as its source of water at that time. To break through such situation, Tokyo Prefecture requested forestry professors of Tokyo Imperial University (the current University of Tokyo) to conduct forest survey around the Tama River upstream. The survey result indicated, "The situation of the forests in water resource area is seriously in danger, and Tokyo City will be immediately suffering from shortage of drinking water if forest management is neglected. It is an urgent task to start managing the forests at the water resource area of the Tama River directly by Tokyo Prefecture or Tokyo City." Upon receiving this survey result, Tokyo Prefecture decided to manage the forests by itself, and it received the transfer of the Imperial Forest at the eastern part of Yamanashi Prefecture in 1901. This is the start of water conservation forests.

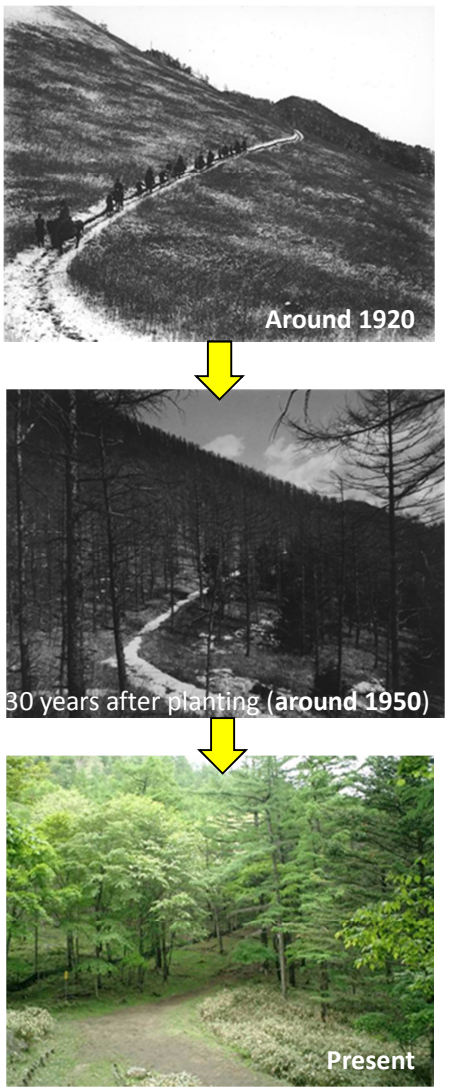

Figure 3 Restoration of Forests

After that, Tokyo City, which was then responsible for urban waterworks, conducted several inspections and survey, took over forest management in 1910, and have started full-scale forests restoration projects.

The forests are currently fostered and managed by focusing on strengthening forests' multiple

functions such as water conservation and prevention of soil erosion, and green forests are spreading in the upper stream of the Tama River as a result of our efforts nowadays.

Figure 3 shows the change of forests around the headwaters of the Tama River. You can see the place that was close to the wilderness about 100 years ago has now turned into a lush forest.

3. Functions Required to Water Conservation Forests

Forests have multiple functions such as water conservation, land conservation, prevention of global warming, supply of wood and so on. Among those, the following three functions are especially important as forests to conserve water resources:

① Water conservation function (Figure 4): a function to store rain fallen in the forest soil, turn it into ground water or intermediate water and let it flow slowly to rivers and thus, stabilize the river flow.

② Prevention of soil erosion function : a function to prevent soil erosion by branches and leaves of trees which protect surface soil from being directly hit by rain and to prevent soil run-off due to landslide by roots of trees which hold the soil firmly

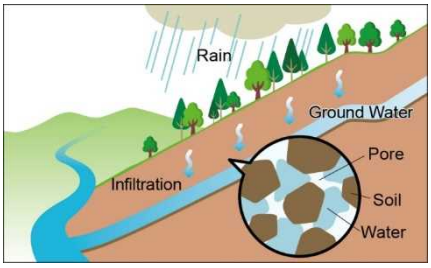

Figure 4 Water Conservation Function

③ Purification of water quality function: a function to filter, absorb and decompose dust in rain water fallen in the forest while percolating into the ground and to flow clean water to rivers

The function of water conservation is particularly important for securing stable river flow rate. In addition to this, it has been required to prevent sediment inflow into reservoir and water quality maintenance of reservoir since Ogouchi Reservoir was constructed in 1957 and thus, the "prevention of soil erosion function" and the "purification of water quality function" are also regarded as important functions for the forest management.

The current sedimentation rate of the Ogouchi Reservoir is approximately 3%, which is a very low rate compared to other reservoirs completed in the same period (Table 1). It can be concluded that the amount of sediment flowing into the Ogouchi Reservoir is small due to the reason that the water conservation forests located in the upstream part is properly managed and the prevention of soil erosion function works effectively.

Table 1 Comparison of Sedimentation Rates of Dams

Watershed area	Dam	Completion year	Years of Service	Storage (10,000 m^3)	Sedimentation rate	Remarks
Ara river	Futase	1961	55	2,690	17%	Result in 2009
Tone river	Shimokubo	1968	48	13,000	7%	Result in 2009
Tenryu river	Sakuma	1956	60	3,269	Approx. 36%	Result in 2006
Tama river	Ogouchi	1957	59	18,910	**3.3%**	Result in 2015

[Sources] Website of Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism (for Futase and Shimokubo Dams)
Website of Chubu Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism (for Sakuma Dam)

4. Proper Management of Water Conservation Forests

4.1. Direction of Forest Management

Water conservation forests are roughly categorized as “natural forests” and “plantations,” and the former covers approximately 70 % and the latter covers approximately 30% of the total area.

Most of the natural forests are forests that grow naturally from the past. In principle, we are aiming for the most stable forest in the area by leaving them to natural succession (Figure 5).

Figure 5 Natural Forests

Artificial forests are forests that seedlings were planted and raised by human hands at places that used to be almost wasteland. At present, in order to make full use of the work as water resource forests, we aim for forests consisting of various kinds of tree species by introducing broadleaf trees etc., and manage them in a planned matter by classifying them into the following two types.

One is “multi-layered forest update-type” (Figures 6). Forests of this type consist mainly of planted conifers of two or more generations while raising naturally grown broadleaf trees as well, and we aim for “multi-layered forests with mixture of conifers and broadleaf trees” ultimately. Generally, in the case of forestry of which the main purpose is to harvest wood, it is often composed only one generation of planted trees. This is because it is efficient to cut all trees when harvesting timber and then plant new trees all at once. However, in such forests, as the size of the trees and the spread of the roots within the soil are almost the same, the resistance against mountain disaster may be weakened. In addition, since almost all the trees are cut down before planting next-generation seedlings, there will be a situation, though temporarily, that there is no tree at all. If heavy rain hits under such situation, soil run-off and other problems are likely to occur. Therefore, when planting the next-generation seedlings, Tokyo Waterworks leave some trees of first-generation and plant seedlings of the next-generation in empty spaces so that forest conditions can be maintained at all times. The artificial forets of which the planted trees grow well and located at the places suitable for taking out cut trees such as being near a forest road is mainly categoraized as “Multi-layerd forest update- type”. 42% of our plantations fall under this type.

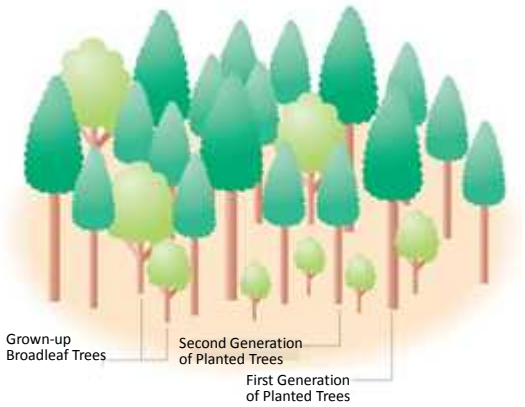

Figure 6 Multi-layered Forest Update-type

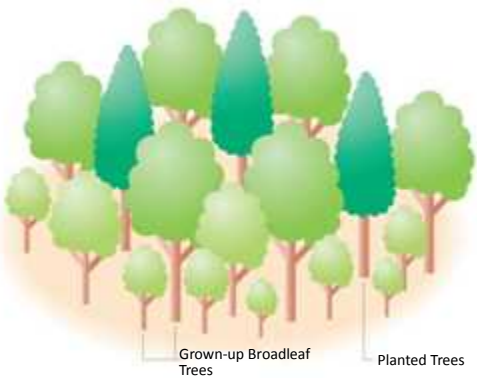

Figure 7 Natural Forest Induction-type

The other one is “natural forests induction-type” (Figure 7). For this type of forests, we aim to make them

become "forests extremely similar to natural forests" by appropriately thinning the planted coniferous trees, putting light in the forest, encouraging germination of broadleaf trees and growing them. Forests of this type mainly refer to the artificial forests where terrain and geological conditions are bad and there is a concern about the collapse of mountains due to cutting for forest regenerating works and plantations where it is difficult to carry out logged trees. 58% of our artificial forests fall under this type.

4.2 Management of Forests

Forests where trees were planted by human are required to be properly maintained afterwards by human as well. As the area is humid and temperate, rampancy of other plants such as herbaceous plants often inhibit the growth of planted trees. For this reason, we carry out "weeding" which helps the growth of the seedlings by removing weeds and shrubs continuously carried out in summer for around 7 years after planting. Thereafter, when seedlings grow and competition between planted trees begins, we conduct "thinning" as appropriate to achieve sound growth of trees by properly maintaining the interval between adjacent trees and securing the growth range of the planted trees. Thinning is an important task in cultivating water conservation forests. The effects of thinning are as follows:

Figure 8 Forest Maintenance Work

① As the growing space for each planted tree becomes wider, the canopy becomes larger and hypertrophic growth progresses. The roots can also develop widely and deeply.

② The clearing of the growing space of the logged trees improves the light environment in the forest, encourages germination of broadleaf trees, etc., and thus the undergrowth in the forest develops and the diversity of the forest increases.

Besides, in order to further improve the light environment in addition to thinning, "pruning" to cut off a part of the branches of the planted trees as appropriate is carried out as necessary.

By carrying out these forest maintenance works (Figure 8) for a long period of time in a planned manner, we are cultivating sound forests highly resistant to various damage.

4.3. Recovery of Mountain Disasters

Even though we make every effort to conserve and manage forests, mountain disasters sometimes happen due to typhoons, heavy rains and the like. In the event of a landslide, we do our mountain conservation work using the civil engineering method, etc. for restoration (forest regeneration). Figure 9 shows the recovery process of the area of landslide that occurred around 90 years ago. You can understand that the terracing works etc. were carried out to the collapsed land, and it regenerated to the forest after approximately 50 years.

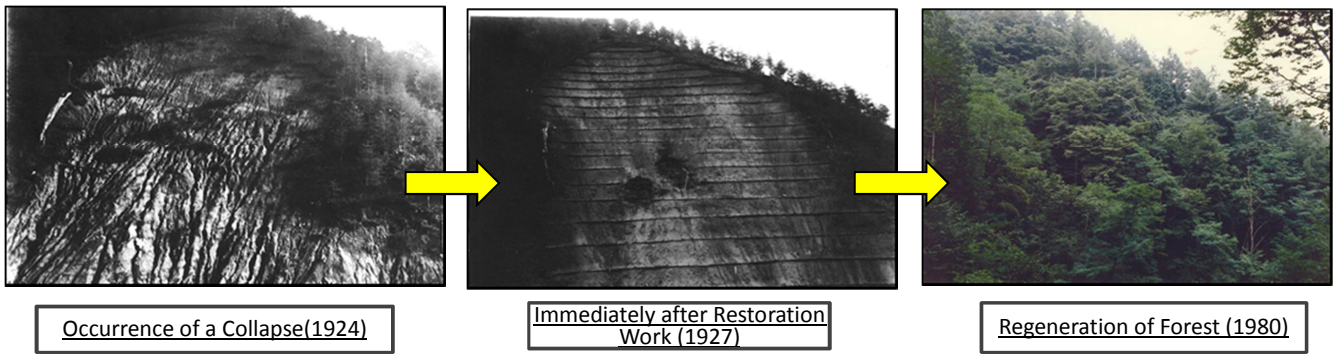

Figure 9 Restoration of Collapsed Site

4.4. Development of Forest Management Infrastructure

In order to efficiently and safely carry out forest conservation work and restoration of landslide areas inside vast water conservation forests, it is essential to establish an access route to the site. We have started to develop forest roads (roadways) in 1946, and up to now, 12 routes with the total length of 76 km have been completed. From these forest roads etc. 265 lines of trails or paths with the length of 785 km are extending in the forests. In addition, we have begun to construct "Single-track railway" in order to improve the efficiency of access within the forests. Since this facility requires almost no alteration of the topography when it's installed and it can be laid on steep slopes up to around 45 degrees, we could select the shortest route with high cost efficiency such as ridge, and we have completed 11 routes with the length of approximately 21 km so far (Figure 10).

Figure 10 Single-track Railway

5. Challenges and Responses

5.1. Regeneration of Private Forests

As for water conservation forests, as a result of maintenance and management for more than one century through the above-mentioned measures, they remain in good conditions. On the other hand, there are forests beyond the control of the authorities (private forests) spreading with the almost same area of water conservation forests in the upstream of the Tama River (Figure 11). As the owners of those private forests are less motivated in forest management including thinning and pruning due to such reasons as long term timber price slump, poorly managed forests are increasing. Figure 12 shows the trend in the stumpage price of "Japanese cedars" per cubic meter, which is a typical tree species planted in artificial forests. It shows that the price continues to decrease drastically with the peak in

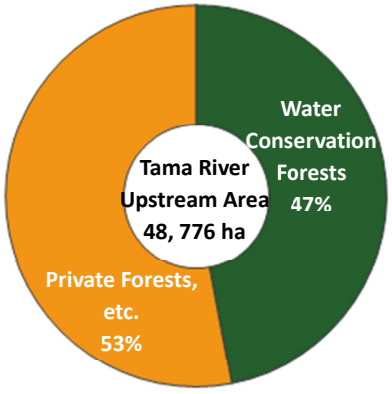

Figure 11 Proportions of Water Conservation Forests and Private Forests, etc.

1980 and that it went down to around 2,800 yen in 2015, roughly 10% of the peak price (about 23,000 yen). In abandoned forests, underbrush does not grow and topsoil erodes, and the multiple functions of forests such as water conservation and prevention of soil erosion are decreasing (Fig. 13).

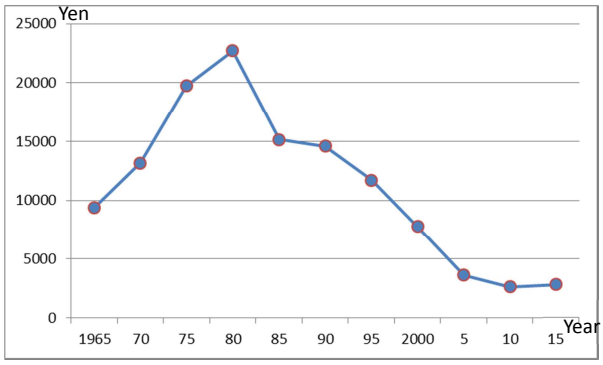

Figure 12 Transition of Stumpage (Cedar) Price per 1 m^3

[Source] created based on Annual Report on Forest and Forestry in Japan (2016), Reference p.14

Figure 13 Private Forest where the Fallen Tree is Scattered and the Surface is Exposed

5.1.1. Purchase and Conservation of Private Forests

As a drastic measure, we decided to purchase the forest so that direct management is possible forever. Under this project, we, by public offering, purchase private forests mainly located in the upstream area of Ogouchi Reservoir of which the owners cannot manage and intend to relinquish, and regenerate them into appropriate water conservation forests in a planned manner after purchase. We have purchased 1,865 ha of forests in seven years since starting our business in 2010.

Figure 14 After making a path and thinning

In developing the purchased forests , we implement improvement of footpaths in advance ,after that, thinning and pruning will be carried out as appropriate to cultivate healthy forests (Figure 14).

5.1.2. Conservation of Water Resources Area by Utilizing Volunteers (Tama River Water Resources Forest Team)

For the forest owners who do not intend to relinquish their forests, Tokyo Waterworks, upon consent of the owners, carry out forest conservation activities including thinning free of charge with the help of volunteers (Figure 15).

Figure 15 Team Activity (Thinning)

This project was launched as the "Tama River Water Resources Forest Team" under the initiative of the authority in 2002. The characteristic of this organization is that local guidance of team members (volunteers) is entrusted to a local forestry union which is a forest management professional group. This

system secures the safety of volunteers. As a result, there has been no major accident for 15 years since the start of activities, and the team has gained good reputation on the team's work completed carefully at the sites from many owners. As such, this project has been run smoothly, and as of the end of 2016, the number of volunteers reaches 1,227 of both sexes in total, and since the beginning, activities have been held around 1,900 times with approximately 24,000 participants and around. 200ha of forests have been regenerated. This initiative won the PIA 2014 East Asian Region Award of the International Water Association, and has been highly regarded from home and abroad (Figure 24).

5.2. Measures towards Water Conservation Forest being popular among People (*Fureai* walking in water conservation forests)

In order to steadily implement the projects related to the water conservation forests, it is indispensable to promote understanding of the importance of water and the role of water conservation forests, etc. among many people such as water users. For this purpose, we have set up three areas (*Suigenchi-fureai-no-michi*) that a wide range of age groups can visit, and arranged facilities such as footpaths, signposts, explanatory signboards, etc. We have also organized "*Fureai* walking in water conservation forests", in which staff members of Tokyo Waterworks directly guide water users chosen from among applicants, since 2006. In the program of *Fureai* walking in water conservation forests, staff members of Tokyo Waterworks explain the functions and roles of the water conservation forests that cultivate water, the names and characteristics of the trees, management of the water conservation forests, etc. while participants are strolling in forest. Participants can also enjoy various natural experiences such as feeling scents of barks and leaves of trees, touching mountain run-off water (Fig. 16).

Figure 16 *Fureai* Walking in Water Conservation Forests

Approximately 1,100 people have participated in the walk since its commencement and deepened their understanding of conservation of water resources area.

6. Conclusion

In our water conservation forests, from the consistent viewpoint that the water utility entity itself should protect the water resources, we have been making our efforts in forest conservation and maintenance in a planned manner in order to seek for effectuation of functions of forests for the public benefit such as water conservation for over 100 years. As a result, forests in the upstream of the Tama River have been regenerated as green forests, and the Tama River water resource including Ogouchi Reservoir has generally maintained its good condition. We will continue to grow and manage the water conservation forests appropriately so that we can maximize their functions and promote the regeneration of private forests and exchange /collaboration at the water resources area. With these efforts, Tokyo Waterworks will supply steadily potable delicious water of high quality over the future.