

Measures for vegetation restoration on modification sites at Takizawa dam

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ABSTRACT: Takizawa Dam is located in Chichibu-Tama-Kai National Park in Saitama Prefecture, Japan. Since the national park is rich in nature, it was aimed to reduce impact on ecosystem in the area and downstream during the construction of the dam. Measures for vegetation restoration were taken on all modification sites as the quarry site, cut slopes of the road, and cut slopes near the dam body generated by the dam construction projects. The total area of vegetation restoration is about 130,000 m². The materials used for the restoration were the surface soil near modified sites and purchased soil, seeds gathered near the modification sites, seedlings grown from the gathered seeds, and trees going to be underwater by the appearance of the dam lake. Especially, in the quarry site, the seeds of pioneer trees were sprayed with soil on slopes by seeding work (double layer spraying and seed spraying, etc.), and the seedlings of native species were planted on the berms and platforms. Measures for vegetation restoration began in 2001 and completed in 2007. The monitoring survey has been carried out at regular intervals to investigate the degree of germination and restoration. This report shows the present states of vegetation restoration and the imported alien species on the quarry site among the measures of vegetation restoration at Takizawa Dam.

1 INTRODUCTION

In Japan, a lot of legal systems and measures have been enacted for the conservation of the biological diversity which has been taken into considerations in a variety of discussions and suggestions on re-vegetation matter as well (Fukunaga et al. 2008, JSORT 2002, Kobayashi and Kuramoto 2006, MOTEIJ et al. 2006). However, in Japan, design and construction of re-vegetation to conserve biological diversity have been carried out without a collective view of concrete method (DMOROS 2004). In order to solve this problem, an accumulation of data on survey, design, construction, and monitoring regarding to re-vegetation, data sharing and an appropriate evaluation of those data are essential. In addition to an improvement of present situation by making up a gap between the policy and on site technical capability, an immediate countermeasure against negative influence on local ecosystem by alien species should be carried out at each site.

Located in Chichibu in Ara River System in Japan, Takizawa Dam is a multipurpose dam constructed and completed by Japan Water Agency in 2008. Vegetation restoration has been executed since 2001 based on a policy of natural recovery without alien species that have negative influence in the area and downstream but with native species collected near the dam sites (Inaba et al. 2004). Vegetation restoration, whose area is approximately 130,000 m², is carried out in such modification sites due to dam project as the quarry site, cut slopes of the road and cut slopes near the dam body. Vegetation restoration used the seeds collected around the dam and seedlings grown from them, trees grown up in the area that was going

to be underwater because of the dam lake, and materials available in the basin such as soils of modification sites (Inaba et al. 2004). In the quarry site, the seeds of pioneer trees were sprayed with soil on slopes by seeding work (double layer spraying and seed spraying, etc.), and the native seeds and seedlings were planted on the berms and platforms by planting work. Vegetation restoration was completed in 2007. The monitoring survey has been carried out at regular intervals to investigate the degree of vegetation growth.

In measures for vegetation restoration using native species in Takizawa dam, we report the present states on the quarry site. And we discuss the factors of difference of states of vegetation restoration and imported alien species on both slopes sprayed with soils by seeding work and piled with the surface soil.

2 OVERVIEW OF TAKIZAWA DAM

Takizawa Dam is a concrete gravity dam located at the upstream part of Ara River System in Chichibu, Saitama Prefecture, Japan. Ara River System, whose basin area is approximately 3,000 km², has Tokyo Metropolis in its downstream area, leaving it one of Japan's major river systems in terms of population and assets in estimated flood area. The river water is used in a highly complicated way. Figure 1 shows the location and Picture 1 shows a bird's-eye view of Takizawa Dam.

The upstream area of Takizawa Dam is located in the rich natural region designated as Chichibu-Tama-Kai National Park. Since the region is inland and high in elevation, it's cool all year around. The average annual temperature is approximately 11 degrees Celsius and the average annual rainfall is 1,370 mm (Average value from 1999 to 2003).

3 THE EXECUTION OF VEGETATION RESTORATION ON THE QUARRY SITE

The aggregates of concrete of Takizawa Dam were collected from the quarry site around the dam from May, 2001 to June, 2004. The quarry site is located in the left bank of Nakatsu River, a branch of Ara River. Its elevation is in between approximately 930 and 1,100 meters.

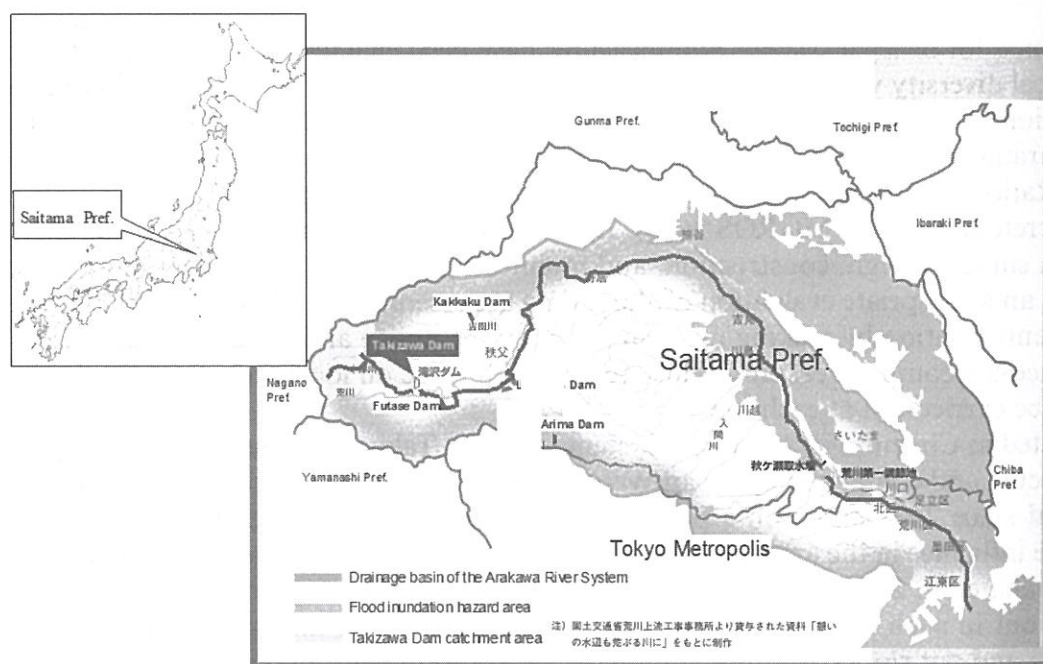
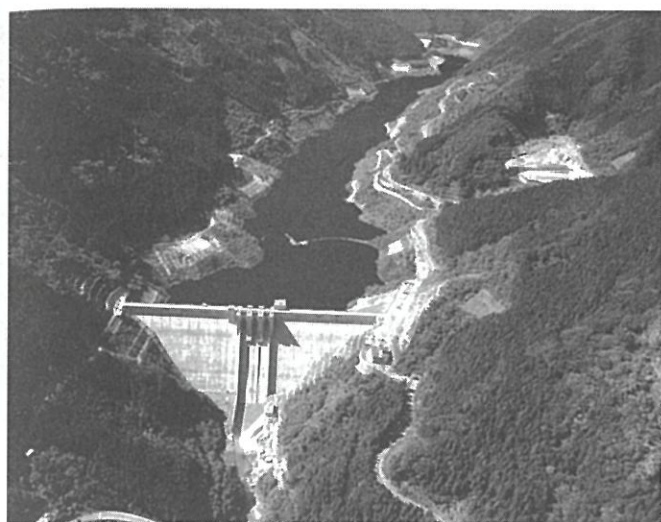


Figure 1. The location of Takizawa Dam.



Dam type	: Concrete gravity dam
Dam body volume	: Approximately 1,670,000 m ³
Dam height	: 132 m
Crest length	: 424 m
Catchment area	: 108.6 km ² (reservoir area: 1.45 km ²)
Reservoir capacity	: 63,000,000 m ³
Effective capacity	: 58,000,000 m ³

Picture 1. A bird's-eye view of Takizawa Dam.

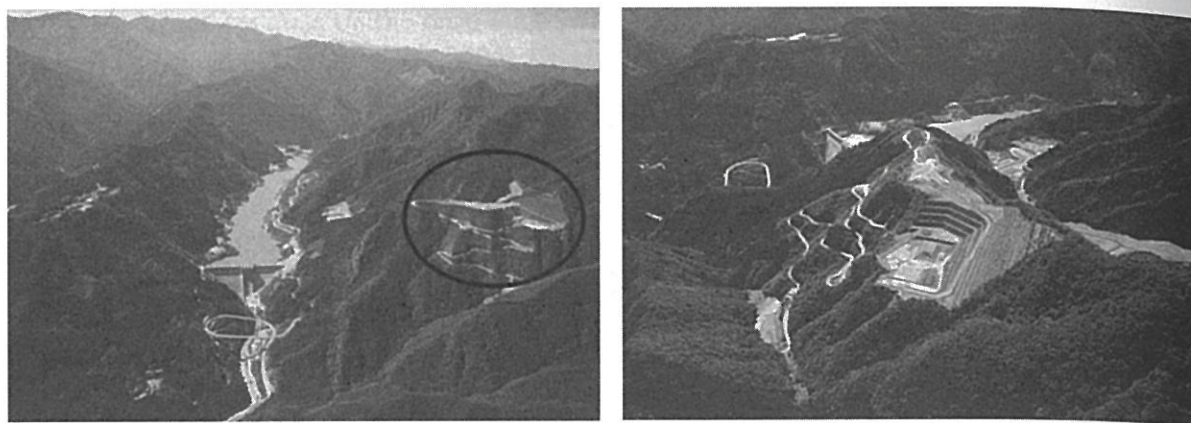


Figure 2. The location of the quarry site.

It consists of cut slopes of approximately 29,000 m² facing to southeast and berms and a platform of approximately 60,000 m². Figure 2 and Picture 2 show the location of the quarry site. Picture 3 shows a bird's-eye view of quarry site.

Two types of soil for vegetation restoration were used. On mild gradient (1:1.2) slopes, the surface soil of the quarry site was piled to aim at restore vegetation by buried seeds (referred to as "surface soil area"). On steep gradient (1:0.8) slopes, purchased soil, brought from out of the region, and seeds of native pioneer trees, gathered near the modification sites, were mixed and sprayed by seeding work called double layer spraying (referred to as "double layer spraying area"). The compound of seeds used in the double layer spraying area was reviewed since the number of collected species and amount differed every year. Table 1 shows the compound of seeds on the double layer spraying area. On the berm and the platform, the surface soil was also piled and native seeds and seedlings, and seedlings of native trees were planted. The native seeds and seedlings were raised in a premeditated way since 2001 (Inaba et al. 2004).

As a result of these executions, the following transitions are expected; the formation of pioneer tree communities (e.g. *Rhus javanica* var. *chinensis* (Sumac)) in the first step, followed by the growth of deciduous broad-leaved forest (e.g. *Quercus mongolica* ssp. *crispula*), which is common in the region, in the end of the process of succession.



Picture 2. A bird's-eye view of the quarry site & Picture 3. A bird's-eye view of quarry site.

Table 1. The compound of seeds on the double layer spraying area.

Execution	1,2,3		4,5		6,7,8,9		10,11,12,13,14,15,16	
Slope No.	3-1	3-2	5-1	5-2	6	8-1	12	13
Quadrat No.	3-1	3-2	5-1	5-2	6	8-1	12	13
Execution Period	Nov.2001	Nov.2001	Apr.2002	Apr.2002	Dec.2002	Apr.2003	Feb.2004	Apr.2004
Slope Direction	SE	SE	SE	SE	SE	SE	SE	NE
Slope Gradient	1:1.2	1:1.2	1:0.8	1:0.8	1:0.8	1:0.8	1:0.8	1:0.8
Soil type (Soil Depth)	Surface soil of quarry site (30cm)	Surface soil of quarry site (30cm)	Mixture of purchased soil and seeds of native pioneer trees	Mixture of purchased soil and seeds of native pioneer trees	Mixture of purchased soil and seeds of native pioneer trees	Mixture of purchased soil and seeds of native pioneer trees	Mixture of purchased soil and seeds of native pioneer trees	Mixture of purchased soil and seeds of native pioneer trees (5cm)
Execution Method	Piling	Piling	Double layer spraying	Double layer spraying	Double layer spraying	Double layer spraying	Double layer spraying	Double layer spraying
Species of seed								
<i>Miscanthus sinensis</i>			0.239	0.239				
<i>Ahus firma</i>						0.072	0.016	0.041
<i>Betula platyphylla</i> var. <i>japonica</i>							0.022	0.038
<i>Deutzia crenata</i>					0.062	0.188	0.059	0.066
<i>Deutzia scabra</i>						0.033	0.023	0.026
<i>Mallotus japonicus</i>					0.118	0.042	0.078	0.134
<i>Rhus javanica</i> var. <i>chinensis</i>			0.078	0.078	1.875	3.125	0.364	0.63
<i>Stachyurus praecox</i>			0.079	0.079	0.167			0.042
<i>Aralia elata</i>			0.009	0.009	0.1	0.075	0.007	0.011
<i>Clethra barbinervis</i>			0.019	0.019	0.187	0.125	0.08	0.09
<i>Clerodendrum trichotomum</i>					0.141	0.05	0.081	
<i>Buddleja japonica</i>						0.008		
<i>Weigela decora</i>						0.006		
Total weight(g/m ²)			0.424	0.424	2.65	3.724	0.73	1.078
No. of species	0	0	5	5	7	10	9	9

4 MONITORING SURVEY

4.1 Survey area

8 quadrates, divided depending on execution method and year, were set on slopes in the quarry site (Table 1) to record the growth of plants in each quadrate. Figure 3 shows the survey area.

4.2 Method

Main monitoring survey items were the composition of plant species, the percentage of vegetative covers, cover degree, sociability, and the height of plants in the quadrates. Within the first three years after the execution (until 2005), the size of quadrate was one square meter (1 m × 1 m) to record the germination mainly. After three years from the execution (on and after 2006), the quadrates were expanded to 25 square meters (5 m × 5 m) because of the growth of plant communities, and vegetation was recorded by Braun-Blanquet method (Suzuki 1971) (referred to as "detailed survey"). In addition to "detailed survey",



site.

10,11,12,13,14,15,16	
12	13
2004	Apr.2004
SE	NE
0.8	1:0.8
of	Mixture of
and soil	purchased soil and
of	seeds of native
of pioneer	pioneer trees
	(5cm)
layer	Double layer
	spraying
016	0.041
022	0.038
059	0.066
023	0.026
078	0.134
364	0.63
	0.042
007	0.011
008	0.09
081	
1.73	1.078
9	9

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× 5 m) because
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tailed survey”,

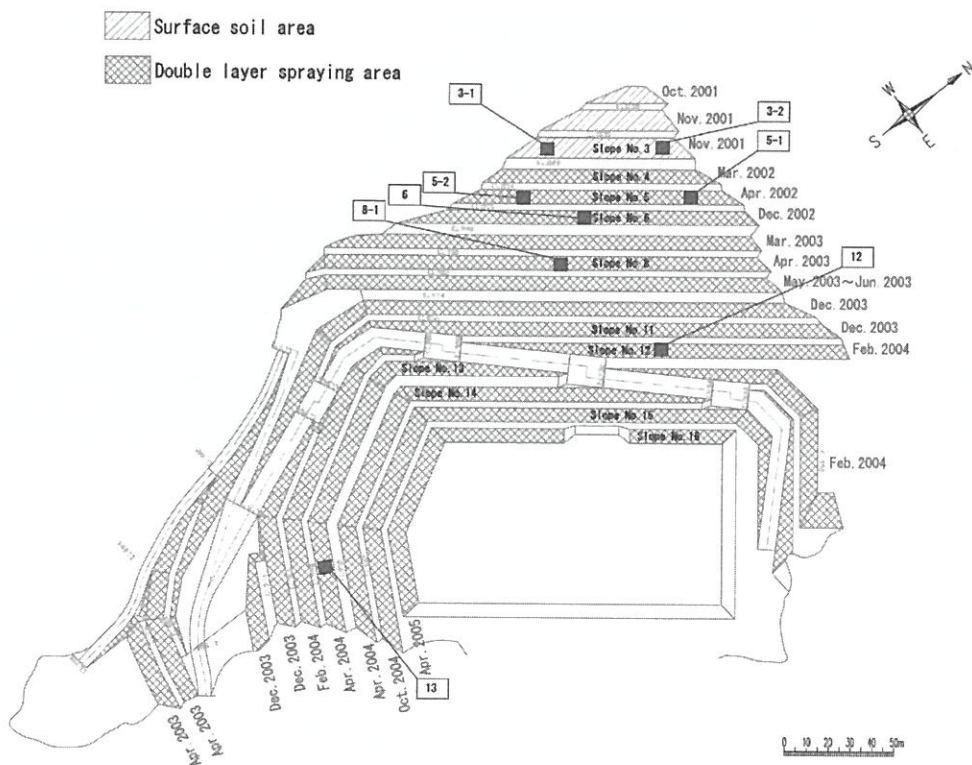


Figure 3. The survey area of quarry site.

the percentage of vegetative covers, the height of plant communities and dominant species were recorded on each slope (referred to as “wide survey”).

5 RESULTS

5.1 The percentage of vegetative covers, the height of plant communities, dominant species

Picture 4 and Picture 5 show the view of the quarry site in August, 2003 and August, 2010. From these pictures, it is confirmed that all slopes were getting covered with plants, and vegetation restoration occurred.

Figure 4a, Figure 4b and Table 2 show changes in the percentage of vegetative covers, the height of plant communities and dominant species in each quadrat over the years. The percentage of vegetative covers increased in every quadrat. In the double layer spraying area, the percentage of vegetative covers reached 60 to 80% in the first 3 or 4 years after the execution. Later on it kept over 80% although there was a period when the percentage was slightly low. In the surface soil area, the percentage of vegetative covers was as low as 50% in the first 5 or 6 years after the execution, but it finally reached 80% after 8 years. The height of plant communities increased in every quadrat over the years. In the double layer spraying area, where grasses such as *Miscanthus sinensis* (Eulalia) were dominants, the height of plant communities was around 1 to 2 meters. The dominant species differed depending on quadrates. In the double layer spraying area, species such as *Miscanthus sinensis* (Eulalia), *Rhus javanica var. chinensis* (Sumac) and *Buddleja japonica* (Japanese buddleja) sprayed by seeding work grew and became dominants just after execution. In the surface soil area, species such as *Miscanthus sinensis* (Eulalia) and *Weigela decora* finally became dominants after a short period when *Macleaya cordata* (Plume poppy) was a dominant.

5.2 Secular changes of number of species and the percentage of alien species

Figure 4c and Figure 4d show changes in number of species and the percentage of alien species in each quadrat over the years. The definitions of alien species (species, subspecies or



Picture 4. The view of the quarry site in Aug. 2003. & Picture 5. The view of the quarry site in Aug. 2010.

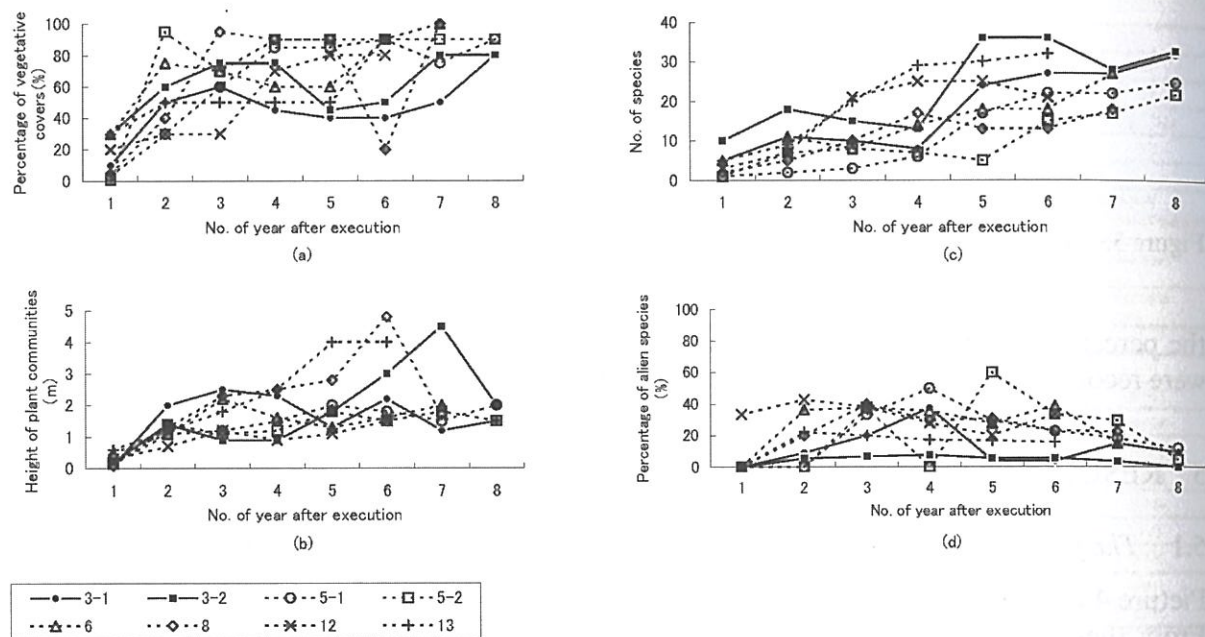


Figure 4. Changes in the percentage of vegetative covers, the height of plant communities, number of species and the percentage of alien species in each quadrat.

Table 2. Changes in dominant species in each quadrat.

Quadrat No.	No. of year after execution							
	1	2	3	4	5	6	7	8
3-1	-	<i>Macleaya cordata</i>	<i>Macleaya cordata</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Alnus firma</i> var. <i>hirtella</i>	<i>Miscanthus sinensis</i>
3-2	<i>Youngia denticulata</i>	<i>Reynoutria japonica</i>	<i>Weigela decora</i>	<i>Weigela decora</i>	<i>Weigela decora</i>	<i>Weigela decora</i>	<i>Weigela decora</i>	<i>Miscanthus sinensis</i>
5-1	-	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>
5-2	-	<i>Buddleja japonica</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>
6	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	-
8	-	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Rhus javanica</i> var. <i>chinensis</i>	<i>Miscanthus sinensis</i>	-
12	-	<i>Digitaria ciliaris</i>	<i>Oenothera biennis</i>	<i>Artemisia indica</i> var. <i>maximowiczii</i>	<i>Miscanthus sinensis</i>	<i>Miscanthus sinensis</i>	-	-
13	-	<i>Buddleja japonica</i>	<i>Alnus firma</i> var. <i>hirtella</i>	<i>Alnus firma</i> var. <i>hirtella</i>	<i>Alnus firma</i> var. <i>hirtella</i>	<i>Alnus firma</i> var. <i>hirtella</i>	-	-

Table 3. The list of alien species confirmed.

Species	Surface soil area	double layer spraying area	Selected as reminded species in	Habitat
<i>Pleuropterus multiflorus</i>		○		Urban area
<i>Phytolacca americana</i>	○			Low land, uncultivated land
<i>Stellaria media</i>				Low land, cultivated land
<i>Chenopodium ambrosioides</i>				shoulder of road, uncultivated land
<i>Trifolium repens</i>				Low land, shoulder of road, grassland, farmland
<i>Oenothera biennis</i>	○	○	●	shore
<i>Symphytum x uplandicum</i>				Shoulder of road, grass land
<i>Solanum nigrum</i>				uncultivated land
<i>Buddleja davidii</i>		○		Shore
<i>Verbascum thapsus</i>				Shore, uncultivated land, shoulder of road
<i>Veronica persica</i>		○		Low land, cultivated land, shoulder of road
<i>Bidens frondosa</i>	○	○	●	uncultivated land, wetland
<i>Bidens pilosa</i>	○	○	●	Urban area, uncultivated land, shore
<i>Conyza sumatrensis</i>	○	○	●	uncultivated land, shoulder of road
<i>Cosmos bipinnatus</i>				Bare ground, shore
<i>Crassocephalum crepidioides</i>				Low land, cleared section of forest
<i>Erechtites hieracifolia</i>	○	○		cleared section of forest, shoulder of road, uncultivated land, landfill
<i>Erigeron canadensis</i>	○	○	●	cultivated land, uncultivated land, shoulder of road
<i>Erigeron philadelphicus</i>	○	○	●	cultivated land, shoulder of road, urban area
<i>Gnaphalium pensylvanicum</i>		○		cultivated land
<i>Solidago altissima</i>			●	Low land, Excessively fertilized land
<i>Sonchus asper</i>	○	○		cultivated land, shoulder of road
<i>Stenactis annuus</i>	○	○	●	cultivated land, shoulder of road
<i>Taraxacum officinale</i>	○	○		Urban land, cultivated land
<i>Agrostis alba</i>		○		Shoulder of road, grassland
<i>Eragrostis curvula</i>		○	●	Farmland, shoulder of road, uncultivated land, shore
<i>Festuca arundinacea</i>			●	playground, house garden, shoulder of road, cultivated land, uncultivated land
<i>Panicum dichotomiflorum</i>				Low land

any taxonomic unit introduced to outer area of natural distribution and carrying any organs, gametes, seeds, eggs capable of sexual and/or asexual reproduction) followed the handbook of alien species (ESoj 2002). Table 3 shows the list of alien species confirmed. The number of species increased over the years in almost all the quadrates. The number of species in the double layer spraying area was less than 10 in the first 1 or 2 years after the execution. On and after 5th year, the number of species differed from 5 to 30 depending on quadrates; the quadrate with 32 species was confirmed on the north-east slope on and after 6th year. The number of species in the surface soil area was 10 to 20 in the first 4 years after execution, and then increased to 25 to 40 on and after 5th year. The percentage of alien species differed depending on execution method. In the double layer spraying area, the percentage of alien species was low just after execution, but then it shifted to around 20 to 60%. In the surface soil area, that was lower than 20%, even though that recorded 40% in the 4th year. 19 alien species such as *Oenothera biennis* (Evening primrose) were found in the survey area. They were commonly seen in areas as cultivated land and shoulder of road. Even though invasive alien species was not found, 9 species designated as dangerous alien species in Japan were found.

6 CONCLUSIONS

Conclusions based on the results of survey and states on the quarry sites are shown below.

- In the double layer spraying area, native pioneer tree communities of 2 to 3 m in height were formed in the first 3 to 4 years after execution. The percentage of vegetative covers was 60 to 80%. However, the area where *Miscanthus sinensis* (Eulalia) was mixed in to be a dominant had slower formation of pioneer tree communities.
- The number of species or diversity, and the dominant species in the double layer spraying area seemed to be strongly related to the species and amount of seeds mixed in.
- Since the seeds of alien species were not distributed in the double layer spraying area, they could have been originally contained in the purchased soil material.
- In the surface soil area, because of the buried seeds, the number of species was larger while the percentage of alien species was lower than those in the double layer spraying area. From this reason, native pioneer tree communities were formed in the first 3 to 4 years after execution.

The soil materials need to be treated carefully before seeding work (double layer spraying) since the number of collected species and amount differ every year and also there is a high percentage of alien species mixed in. Role of vegetation restoration is to make a chance to put a natural ecological succession on track (DMOROS 2004).⁶ At Takizawa Dam, the formation of pioneer tree communities such as *Rhus javanica* var. *chinensis* (Sumac) was expected as the first step of the vegetation restoration. It was confirmed that this step was achieved within 3 to 5 years after execution by using the surface soil. The “ecological succession” seemed to be continued at Takizawa Dam since invasive alien species, such as *Pueraria lobata* (Kudzu-vine), have not been found yet. The monitoring survey will be continued to confirm an indication of formation of a deciduous broad-leaved forest, a common forest type in the region, which is the final step.

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