Open Journal of Forestry, 2015, 5, 28-37
Published Online January 2015 in SciRes. http://www.scirp.org/journal/ojf
http://dx.doi.org/10.4236/ojf.2015.51004

Influence of Some Soil Characteristics on Defoliation of *Cryptomeria japonica*

Kunio Ueda

School of Environmental Science, The University of Shiga Prefecture, Hikone City, Japan
Email: ueda@ses.usp.ac.jp

Received 7 December 2014; revised 26 December 2014; accepted 5 January 2015

Abstract

The defoliation of *Cryptomeria japonica* is observed in shrine forests around Hikone, Japan. Here, moisture content, soil pH, exchangeable Mg, Ca and Al of soil in shrine forests of *C. japonica* were examined in order to assess the relationship between these factors and defoliation. There was no relationship between soil pH, exchangeable Mg and Ca in soil and the degree of defoliation in shrine forests. Exchangeable Al in the soil of shrine forests increased with decreasing soil pH below pH 5.0, but there was no relationship between exchangeable Al and degree of defoliation in shrine forests. Soil moisture content differed between severely defoliated forests and forests with no defoliation. Soil moisture is thought to play a large role in inducing defoliation of *C. japonica*. Based on results from previous studies, the declining forests in the basin of the Kuzuryu River in Fukui Prefecture and in the basin of the Koito River in Chiba Prefecture reported by Yambe (1973) were considered to have been caused by the construction of dams. On these rivers, dams were constructed several years before the forest decline researched by Yambe. Dam construction is thought to have caused the low moisture content in the basins.

Keywords

Declining Forest, Soil Nutrients, Soil Moisture, River, Reservoir, Water, Biodiversity

1. Introduction

In Europe, declining forests are becoming more widespread, and factors that induce the defoliation of trees need to be elucidated in order to guide preservation efforts (Ozolincius & Stakenas, 1996; Mehlhorn et al., 1988; Kandler & Miller, 1990/1991; Cronan, 1991; Kandler, 1992; Klap et al., 2000; De Vries et al., 2003; Dobbertin, 2005; Drobyshev et al., 2007; Jonard et al., 2011). Air pollution characterized by the marked increase in the discharge of NO_x, SO_2, and ozone through industrial activities was the first factor to be widely investigated.

How to cite this paper: Ueda, K. (2015). Influence of Some Soil Characteristics on Defoliation of *Cryptomeria japonica*. *Open Journal of Forestry, 5,* 28-37. http://dx.doi.org/10.4236/ojf.2015.51004

Next, soil acidification resulting from the transfer of pollutants from the air by precipitation was considered.

Acid precipitation is not considered to be a likely mechanism for soil acidification, which causes damage to trees. Acid precipitation causes the elution of aluminum, which is very toxic to plants, from soil. Acid precipitation is also considered to elute nutrient elements, such as Mg and Ca, and to leach elements from the soil, which may result in the nutritional deficiency of trees. Drought and increasingly dry weather patterns are also considered to be possible cause contributing to the decline of forests.

In Japan, forest decline was observed in the Kanto Plain in the 1960s and was reported by Yambe (1973). Forest decline was later observed in many other areas of Japan. Many species of trees were reported to be defoliated, but this phenomenon was reported most commonly and most widely with *Cryptomeria japonica* (Yambe, 1973 & 1978; Takahashi et al., 1986; Nashimoto & Takahashi, 1991). Similar factors were researched and discussed to identify the causes of forest declining in Japan but the main factors are unresolved.

Around Hikone, Japan, the defoliation of *C. japonica* was observed, and I researched several factors which were considered to possibly induce forest decline. Exchangeable Mg, Ca and Al content in soil and their relationships to soil pH, defoliation of *C. japonica* and past and current drought conditions in areas with *C. japonica* were examined. In this paper, I tried to find the most important factor to induce the forest decline in these soil characteristics.

2. Materials and Methods

Extant shrine forests in the eastern part of Shiga Prefecture having more than 10 trees and at least one *C. japonica* tree were selected for study along with other areas with forest decline (**Figures 1-3**). The degree of *C. japonica* defoliation was observed, and surface soil samples were collected at 1- to 2-m intervals from *C. japonica* from 24 May to 12 November 2002. In forests with defoliation, soil was collected around defoliated and non-defoliated trees. **Figure 2** shows the location of shrine forests where the research was conducted on the relationship between soil pH, exchangeable Mg, exchangeable Ca, and the forest decline. **Figure 2** shows the location of shrine forests where research was conducted on the relationship between soil pH, exchangeable Al and the forest decline. The degree of *C. japonica* decline was determined based on the standard described by Yambe (Yambe, 1973). In this standard, severe decline was assigned as Yambe's degree 1, moderate decline was assigned as Yambe's degree 2 and 3 and no decline was assigned as Yambe's degree 4 and 5.

Figure 1. Locations of research sites from which data were reported or discussed in this paper. A is the Hikone area in Shiga Prefecture, B is the basin of the Kuzuryu River in Fukui Prefecture and C is the basin of the Koito River on the Boso Peninsula of Chiba Prefecture.

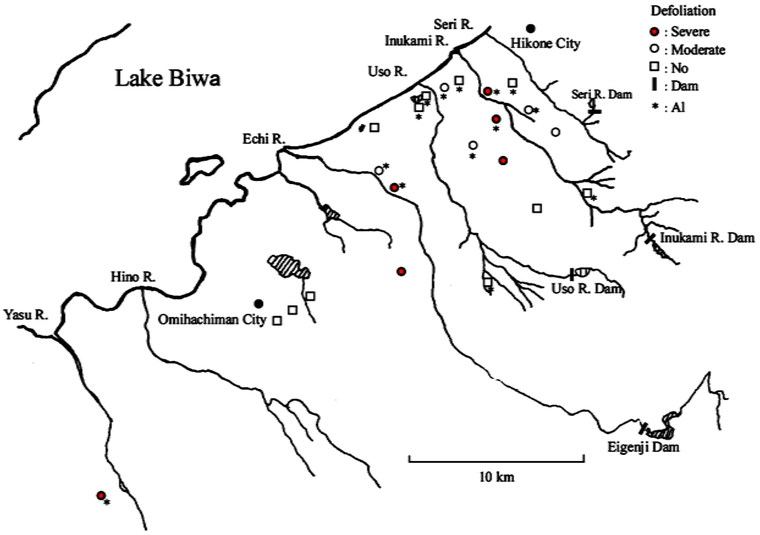

Figure 2. Locations of shrine forests with investigation sites for soil pH, exchangeable Ca, exchangeable Mg and defoliation of *C. japonica* in the Hikone area.

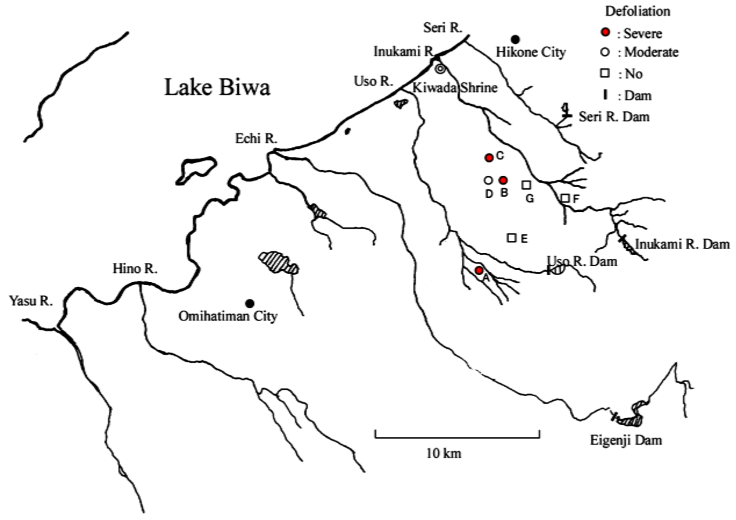

Figure 3. Locations of shrine forests investigated for soil moisture and degree of defoliation of *C. japonica* in the shrine forests of the Hikone area.

Soil pH was measured using a glass electrode after mixing 50 ml of distilled water to 20 g of soil in a 100 ml polyethylene bottle and stirring for 30 min. Exchangeable Mg, Ca and Al in soil were determined as follows. Exchangeable Mg and Ca were determined by adding 25 ml of 1 N NH_4OAc to 2 g of air-dried soil in a 50 ml centrifuge tube and shaking for 30 min. The tubes were centrifuged at 2000 g for 10 min. The supernatant was poured into a 50 ml volumetric flask. In the case that the supernatant was turbid due to fine particles in the soil, the supernatant was filtered through a Bűchner funnel fitted with No. 2 Toyo filter paper. The procedure was repeated with additional 25 ml of 1 N NH_4OAc, and the 50 ml volumetric flask was brought up to a volume of 50 ml with 1 N NH_4OAc. The obtained extracted solution was diluted to reach 1000 ppm $SrCl_2$. The solution was analyzed by atomic absorption spectrometry (SOLAAR 929, UNICAM Ltd.). To determine the exchangeable Al in soil, 10 g of soil was mixed in a 100 ml beaker with 25 ml 1 N KCl, stirred for 2 min, and allowed to stand for 30 min. The mixture of soil and 1 N KCl was filtered through a Bűchner funnel fitted with No. 2 Toyo filter paper. After the filtration, 25 ml of 1 N KCl was poured onto the soil on the filter paper and filtered again. The rinse and filtration were performed once more. The filtrate was used to determine Al concentration by inductively coupled plasma atomic absorption spectroscopy (ICP; IRIS AA ICAP, Nippon Jarrell-Ash Co., Ltd.).

Soil moisture was measured *in situ* for soil at the shrines (**Figure 3**) by an instrument based on the principle of amplitude domain reflectometry (ADR; Daiki Rika Kogyo Co., Ltd.) on 29 October and 16 November in 2008, which were the days after a period of 3 consecutive clear or cloudy days. When there were one part with damaged trees and other part with no damaged trees within one forest shrine, the soil moisture was measured at points located at 2- to 3-m intervals from the damaged or not damaged tree. The soil moisture was measured a few of times at one site within a 1 m radius circle in the shrine forest.

In the Kiwada Shrine (**Figure 3**), soil moisture was measured at four sites during 2009. Soil moisture was measured at least three times for each measurement by the ADR instrument.

Information on dams in Japan was obtained from The Japan Dam Foundation website (The Japan Dam Foundation).

3. Results and Discussion

The distribution and degree of defoliation of *C. japonica* in the eastern part of Shiga Prefecture is shown in **Figure 2**. Defoliation was observed over the entire eastern part of Shiga Prefecture. There was no clear tendency in the location of shrine forests showing defoliation of *C. japonica*.

Figure 4 and **Figure 5** show the relationships between soil pH, exchangeable Ca and exchangeable Mg. The single, genaral correlation between soil pH and exchangeable Ca (**Figure 4**) is that for higher soil pH, the concentration of exchangeable Ca in the soil increases. This phenomenon depends on the well established fact that pH becomes greater as the concentration of exchangeable Ca in soil increases. However, there was no clear relationship between the concentration of exchangeable Ca and the degree of defoliation in *C. japonica*.

There was no clear correlation between soil pH and exchangeable Mg (**Figure 5**). In addition, there was no clear correlation between soil pH, exchangeable Mg and defoliation degree of *C. japonica*.

There was a clear correlation between soil pH and exchangeable Al (**Figure 6**). As soil pH becomes lower, exchangeable Al increases. However, the severe degree of defoliation was only observed at the location with soil pH of 5 to 7 and a low concentration of exchangeable Al. Thus, the defoliation of *C. japonica* is not thought to be induced by Al toxicity.

The relationship between soil moisture and defoliation of *C. japonica* is shown in **Figure 6** and **Figure 7**. The result indicates that there is a clear tendency for higher soil moisture content near a tree with foliage than near a defoliated tree. Based on this result, defoliation of *C. japonica* is thought to be caused by a deficiency of moisture.

Based on the period of lower soil moisture content in Kiwada Shrine from September to October consistently observed at the four sites (**Figure 8**), soil moisture content was considered to be the lowest in autumn and at a

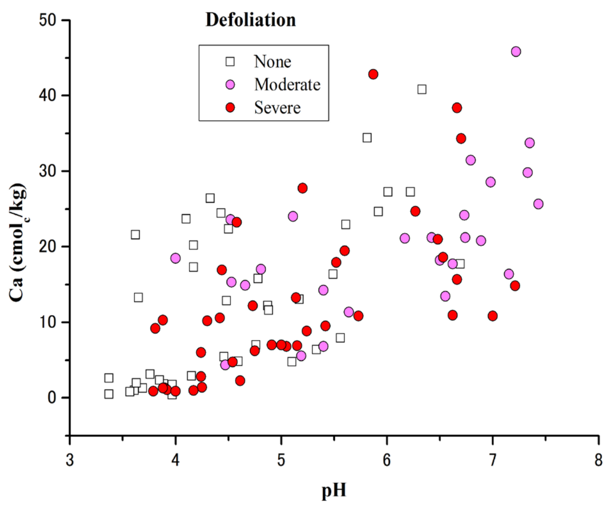

Figure 4. Relationship between soil pH, concentration of exchangeable Ca in the soil and the degree of defoliation in *C. japonica* in the shrine forests of the Hikone area.

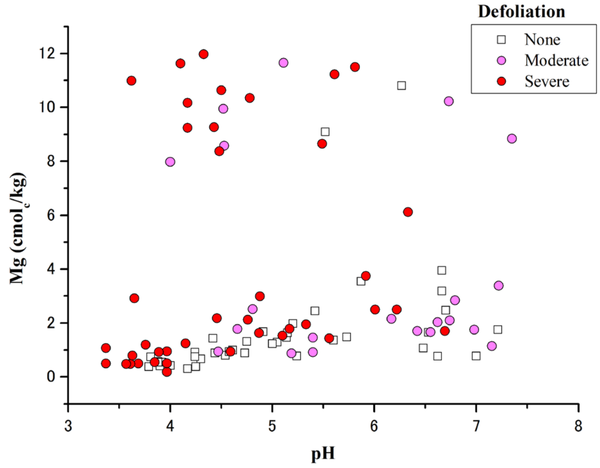

Figure 5. Relationship between soil pH, concentration of exchangeable Mg in the soil and degree of defoliation of *C. japonica* in the shrine forests of the Hikone area.

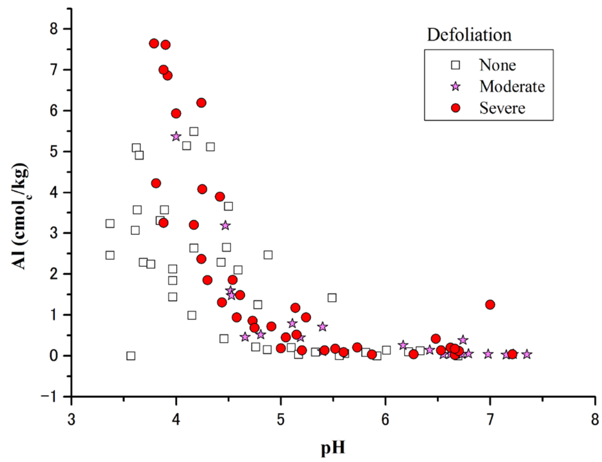

Figure 6. Relationship between soil pH, concentration of exchangeable Al in soil and degree of defoliation of *C. japonica* in the shrine forests of the Hikone area.

level that likely represents a deficiency in soil moisture that is needed to support trees. When soil moisture content drops below the level necessary to support *C. japonica* throughout the season, *C. japonica* is expected to become brown and defoliated, starting with the crown of the tree. *C. japonica* in Kiwada Shrine was thought to be part of a severely damaged shrine forest because there were no *C. japonica* taller than 10 m and all *C. Japonica* taller than 7 m were defoliated.

Based on the results shown in **Figures 1-8**, it is estimated that the decline of trees was brought about mainly by a deficiency in moisture. The decline of *C. japonica* in the eastern part of Shiga Prefecture had already been identified and reported by Nashimoto and Takahashi based on defoliation of *C. japonica* (Nashimoto & Takahashi, 1991). This research was started at least 10 years after the beginning of the tree decline. Wilted trees or trees with some crown defoliation were likely to have already have been cut down at the start of this study. Based on these considerations and obtained results (**Figures 1-8**), relationships between tree defoliation and soil composition could not be clarified. The observations obtained at the beginning of the declining of *C. japonica* in Japan were considered to be important for understanding the relationship between forest decline and the soil composition, especially soil moisture.

Figure 4 and **Figure 5** show the relationships between soil pH, exchangeable Ca and exchangeable Mg. The single, genaral correlation between soil pH and exchangeable Ca (**Figure 4**) is that for higher soil pH, the con-

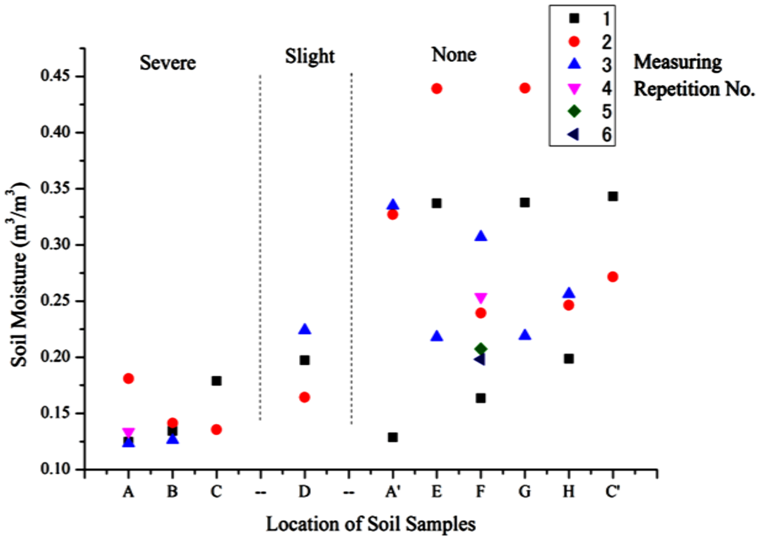

Figure 7. Relationship between soil moisture and degree of defoliation in shrine forests of the Hikone area. The defoliation of *C. japonica* was observed in one area of Goryo Shrine (A) but no defoliation was observed in the other area (A'). B, C, D, E and F indicate Hatiman Shrine, Koura Shrine, Yuuki Shrine, Otaki Shrine and Karuno Shrine, respectively. Within the Koura Shrine, there was an area of defoliation in one area (C) but not in another area (C').

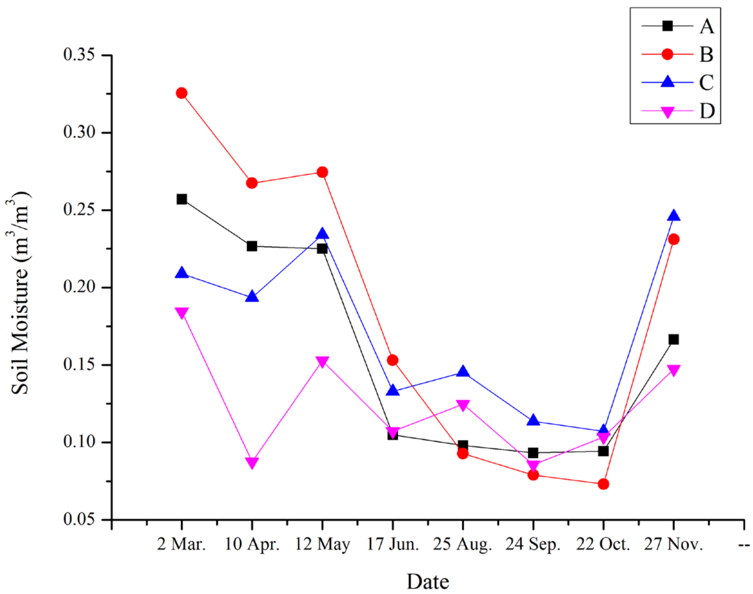

Figure 8. Soil moisture was measured throughout 2009 at four sites in the Kiwada Shrine that is located near the estuary of the Inukami River and is shown in **Figure 3**. Soil moisture was measured at sites A to D in the Kiwada Shrine.

centration of exchangeable Ca in the soil increases. This phenomenon depends on the well established fact that pH becomes greater as the concentration of exchangeable Ca in soil increases. However, there was no clear relationship between the concentration of exchangeable Ca and the degree of defoliation in *C. japonica*.

There was no clear correlation between soil pH and exchangeable Mg (**Figure 5**). In addition, there was no clear correlation between soil pH, exchangeable Mg and defoliation degree of *C. japonica*.

There was a clear correlation between soil pH and exchangeable Al (**Figure 6**). As soil pH becomes lower, exchangeable Al increases. However, the severe degree of defoliation was only observed at the location with soil pH of 5 to 7 and a low concentration of exchangeable Al. Thus, the defoliation of *C. japonica* is not thought to be induced by Al toxicity.

The relationship between soil moisture and defoliation of *C. japonica* is shown in **Figure 3** and **Figure 7**. The result indicates that there is a clear tendency for higher soil moisture content near a tree with foliage than near a defoliated tree. Based on this result, defoliation of *C. japonica* is thought to be caused by a deficiency of moisture.

Based on the period of lower soil moisture content in Kiwada Shrine from September to October consistently observed at the four sites (**Figure 8**), soil moisture content was considered to be the lowest in autumn and at a level that likely represents a deficiency in soil moisture that is needed to support trees. When soil moisture content drops below the level necessary to support *C. japonica* throughout the season, *C. japonica* is expected to become brown and defoliated, starting with the crown of the tree. *C. japonica* in Kiwada Shrine was thought to be part of a severely damaged shrine forest because there were no *C. japonica* taller than 10 m and all *C. Japonica* taller than 7 m were defoliated.

Based on the results shown in **Figures 1-8**, it is estimated that the decline of trees was brought about mainly by a deficiency in moisture. The decline of *C. japonica* in the eastern part of Shiga Prefecture had already been identified and reported by Nashimoto and Takahashi based on defoliation of *C. japonica* (Nashimoto & Takahashi, 1991). This research was started at least 10 years after the beginning of the tree decline. Wilted trees or trees with some crown defoliation were likely to have already have been cut down at the start of this study. Based on these considerations and obtained results (**Figures 1-8**), relationships between tree defoliation and soil composition could not be clarified. The observations obtained at the beginning of the declining of *C. japonica* in Japan were considered to be important for understanding the relationship between forest decline and the soil composition, especially soil moisture.

When dams are constructed, water is reserved in the dam and the flow of the river becomes restricted. The amount of water in the basin of the lower reaches of the river becomes smaller, making it easier for plants in the basin to become deprived of water, especially *C. japonica*, which has a requirement for high moisture soil. Yambe researched the distribution of forest decline in four areas of Japan and discussed the relationship between forest decline and the distribution of soil and foliar microbes (1973). However, soil moisture in relation to the declining trees was not discussed. **Figure 9** shows the distribution of defoliated trees in the Fukui Plain as reported by Yambe (1973). Here, the Kuzuryu River, dams constructed on the river and the main mountains around the Kuzuryu River are described. Kuzuryu Dam, Washi Dam and Futuhara Dam were constructed on the main branch of the Kuzuryu River and were completed in 1968. Yambe researched the decline of *C. japonica* in 1975, and Yambe's research was completed 7 years after the dam construction. Defoliation of the trees was estimated to have begun 2 or 3 years after the completion of the dams. The main branch of the Kuzuryu River and the two big tributaries of the Kuzuryu River, the Asuwa and Hino rivers, were located within the contour of defoliated trees at the upper reaches of the rivers (**Figure 9**).

Along the Kuzuryu River, especially near the mouth, there is a distribution of sand and gravel. The coarse particle sizes were distributed in the area west of the Hukui Plain that is the center of the sand and gravel distribution area. Soil with a high content of sand and gravel is known to have low water retention, and plants in this type of soil are considered to easily become short of water.

In contrast to these examples, declining *C. Japonica* was observed along the tributaries of the Kuzuryu River although there was no construction of dams on Asuwa River and Hino River until 1975 when Yambe (1973) researched the declining of *C. Japonica* (**Figure 9**). It is supposed that the construction of Kuzuryu Dam,Washi Dam and Futuhara Dam influenced on the declining *C. Japonica* along the Asuwa River and Hino River. The reason for the phenomenon is considered to be the low water content along the tributaries following dams constructed on the Kuzuryu River and lowered water level in the basin of the Kuzuryu River.

Yambe (1973) also reported the decline of *C. japonica* on the Boso Peninsula of Chiba Prefecture. **Figure 10** shows the distribution of declining *C. japonica* along with the location of the Koito River, dams constructed on the river (Mishima Dam in 1955, Toyohusa Dam in 1969 and Koori Dam in 1972) and main mountains.

The Koito River flows through the middle of the contour of declining trees. Yambe researched the decline in the distribution of *C. japonica* in 1975.

The Koito River became narrow after the construction of the dams because the dams restricted the flow of the

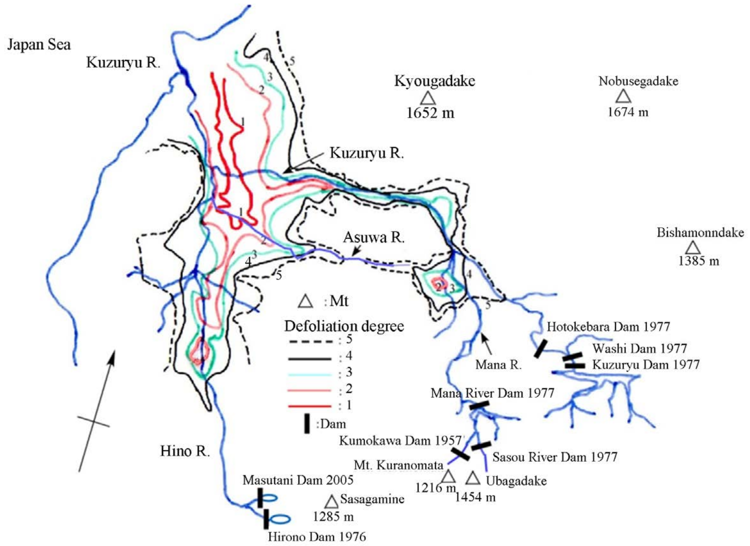

Figure 9. Relationship between the Kuzuryu River, the locations of constructed dams, the contour of degree of defoliation of *C. japonica* and mountains in the Fukui Plain. This figure was adapted from Yambe, and the Kuzuryu R., constructed dams and mountains were added. The highest degree of defoliation is defined as follows: (1), (2) is severe, (4) indicates moderate damage and (5) indicates slight damage.

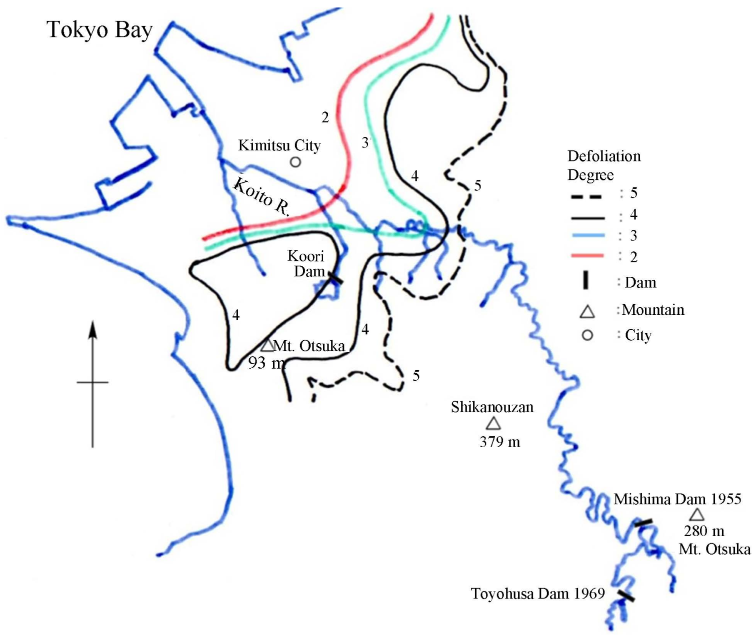

Figure 10. Relationship between the locations of the Koito River, constructed dams, contours of degrees of defoliation of *C. japonica* and mountains on the Boso Peninsula, Chiba Prefecture. Figure adapted from the work of Yambe and revised to add the Koito River, constructed dams and mountains. The defoliation degree key is the same as shown in **Figure 9**.

river. From the results obtained from **Figure 9** and **Figure 10**, not only did the river stream become narrow but also the ground water was thought to become restricted (**Figure 10**). Water content in the soil next to the river becomes less and is expected to have caused the defoliation of *C. japonica* (**Figure 11**).

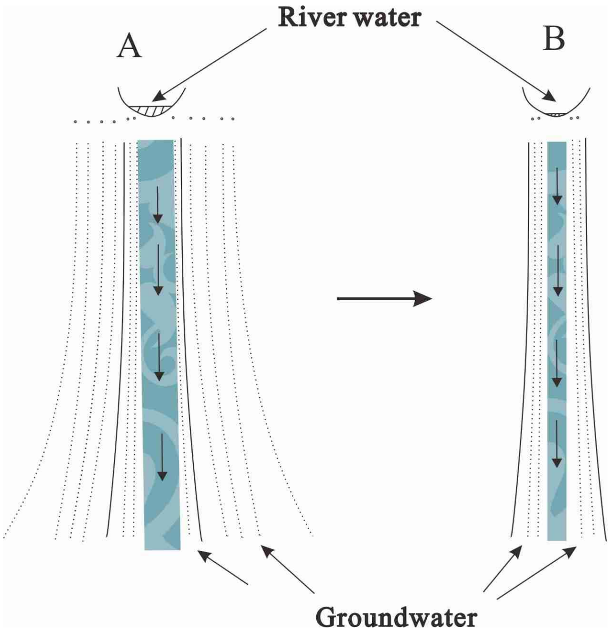

Figure 11. Change of river flow after dam construction. After dam construction (B), the river flow becomes less than before dam construction (A). The breadth of the underground water flow around the river also becomes smaller after dam construction.

Research of the factors affecting forest decline (Klap et al., 2000) in Europe based on the Pan-European sys-tematic 16 km × 16 km forest condition monitoring grid showed that drought stress is an important predictor for the decline of most tree species. Europe is an arid region, and the air and soil are easily dried when dams are constructed, as happened in the 20th Century. Drought is mainly caused by a lack in precipitation, but drought conditions are readily induced by dam constructions on rivers as the flow of water becomes restricted.

But, until now there is no research paper that deals with the influence of dam construction on the drought in the basins where forest declines are observed. In future the influence of dam constructions on the drought in the basins should be researched.

4. Conclusion

The defoliation of *C. japonica* in shrine forests was observed in the Hikone area of Japan. Investigation of pH, exchangeable Mg, Ca, Al and moisture content in the soil of the shrine forests showed the relationship between moisture content and defoliation degrees of *C. japonica* in shrine forests. Drought conditions caused by lack of precipitation and dams constructed on the upper reaches of the river were thought to be the best explanation of this decline.

Yambe reported declining forests in the basin of the Kuzuryu River in Fukui Prefecture and Koito River in Chiba Prefecture (Yambe, 1973), and these findings suggested that dam construction was related to the defolia-tion of *C. japonica*.

Klap reported that declining forest is spreading in Europe and drought stress due to lack of precipitation is an important predictor for the decline (Klap et al., 2000). Many dams are constructed on the main branches and tributaries of Rhine River and Danube in central Europe. The influence of dam constructions on forest declining should be investigated in Europe.

References

Cronan, C. S. (1991). Differential Adsorption of Al, Ca, and Mg by Roots of Red Spruce (*Picea rubens* Sarg.). *Tree Physiology*, *8*, 227-237. http://dx.doi.org/10.1093/treephys/8.3.227

De Vries, W., Vel, E., Reinds, G. J., Deelstra, H., Klap, J. M., Leeters, E. E. J. M., Hendriks, C. M. A., Kerkvoorden, M., Landmann, G., Herkendell, J., Haussmann, T., & Erisman, J. W. (2003). Intensive Monitoring of Forest Ecosystems in Europe 1. Objectives, Set-Up and Evaluation Strategy. *Forest Ecology and Management, 174,* 77-95. http://dx.doi.org/10.1016/S0378-1127(02)00029-4

Dobbertin, M. (2005). Tree Growth as Indicator of Tree Vitality and of Tree Reaction to Environmental Stress: A Review. *European Journal of Forest Research, 124*, 319-333. http://dx.doi.org/10.1007/s10342-005-0085-3

Drobyshev, I., Anderson, S., & Sonesson, K. (2007). Crown Condition Dynamics of Oak in Southern Sweden 1988-1999. *Environmental Monitoring and Assessment, 134,* 199-210. http://dx.doi.org/10.1007/s10661-007-9610-9

Jonard, M., Legout, A., Nicolas, M., Dambrine, E., Ulrich, C. N. E., van der Perre, R., & Ponette, Q. (2011). Deterioration of Norway Spruce Vitality Despite a Sharp Decline in Acid Deposition: A Long-Term Integrated Perspective. *Global Change Biology, 18,* 711-725. http://dx.doi.org/10.1111/j.1365-2486.2011.02550.x

Kandler, O. (1992). Historical Declines and Diebacks of Central European Forests and Present Conditions. *Environmental Toxicology and Chemistry, 11,* 1077-1093. http://dx.doi.org/10.1002/etc.5620110805

Kandler, O., & Miller, W. (1990/1991). Dynamics of "Acute Yellowing" in Spruce Connected with Mg Deficiency. *Water, Air, and Soil Pollution, 54,* 21-34. http://dx.doi.org/10.1007/BF00298650

Klap, J. N., Voshaar, J. H. O., Vries, W. D., & Erisman, J. W. (2000). Effects of Environmental Stress on Forest Crown Condition in Europe. Part IV: Statistical Analysis of Relationships. *Water, Air, and Soil Pollution, 119,* 387-420. http://dx.doi.org/10.1023/A:1005157208701

Mehlhorn, H., Francis, B. J., & Wellburn, A. R. (1988). Prediction of the Probability of Forest Decline Damage to Norway Spruce Using Three Simple Site-Independent Diagnostic Parameters. *New Phytologist, 110,* 525-534. http://dx.doi.org/10.1111/j.1469-8137.1988.tb00292.x

Nashimoto, M., & Takahashi, K. (1991). Decline of Japanese Cedar (*Cryptomeria japonica* D. Don) Trees in the Kanto-Koshin and Kansai-Setouchi District. *Japanese Journal for Environ, 32,* 70-78.

Ozolincius, R., & Stakenas, V. (1996). Tree Crown Defoliation: Influencing Factors. *Baltic Forestry, 2,* 48-55.

Takahashi, K., Okitsu, S., & Ueda, H. (1986). Acid Deposition and Japanese Cedar Decline in Kanto Region, Japan. *Japanese Journal for Environ, 28,* 11-17.

The Japan Dam Foundation (2014). Dams in Japan. http://damnet.or.jp/Dambinran/binran/TopIndex_en.html

Yambe, Y. (1973). Declining of Trees in Tokyo. *Bulletin of FFPRI, 257,* 101-107. http://www.ffpri.affrc.go.jp/labs/kanko/257-4.pdf

Yambe, Y. (1978). Declining of Trees and Microbial Florae as the Index of Pollution in Some Urban Areas. *Bulletin of FFPRI, 301,* 119-129. http://www.ffpri.affrc.go.jp/labs/kanko/301-4.pdf