# Effects of Forest Workings on Streamflow and Water Quality (Part 2)

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## Effects of forest workings on water quality

### 1) *Change in water quality following forest cutting*

The surface layer of forest soil accumulates organic matters and bases. When forest canopy is removed through cutting, the decomposition of organic matters is accelerated and inorganic elements released as a result begin to be leached out. However, in-depth investigation on this problem is still not sufficient enough.

A *Cryptomeria japonica* forest was cut over in a mountainous watershed underlain by paleozoic strata. In the next summer following the clearcutting, the streamflow carried off nitrogen, mostly $NO_3$-N, with the maximum of about 3.5 ppm. After that, however, the concentration of nitrogen in flow decreased gradually. In the next summer, the concentration increased again with the another maximum of 2.5 ppm. Since the third year, however, it decreased apparently and returned to the level before cutting within several years as the regrowth allowed on the cut-over area had developed.

The effects of forest cutting on water quality differ with forest type, cutting system, soil, geology, weather condition and so on. A large number of investigations will be necessary in the future.

### 2) *Change in water quality following herbicide spray*

Since 1962, various herbicides have been used in Japanese National Forests. Forest weeds important from the view point of timber management are many kinds of bamboo grass and fern and *Miscanthus sinensis*. These weeds, which grow vigorously everywhere over a wide range of conditions, act as an important obstacle for forest regeneration by oppressing the young growth.

According to researches at the Government Forest Experiment Station, sodium chlorate ($NaClO_3$) is very effective in killing the bamboo grass and 2,2. 3,3-tetrafluoro propionate natrium (TFP, $CHCF_4COONa$) is also useful in controling the growth of the grass and bamboo shoot. Ammonium sulfamate (AMS, $NH_4SO_4NH_2$) is considerably effective in killing the fern and TFP in controling *Miscanthus sinensis*. As the shortage of manpower in mountainous area is expected to become increasingly serious in future, the herbicide use will be compelled.

However, there is a serious problem that herbicide spread in forest must contaminate the stream water quality and damage the aquatic life. Investigations were already initiated, and some of the results will be given below[1].

A granular herbicide containing sodium chlorate by 50% was spread in a 70 ha broad-leaved forest watershed at the rate of 200 kg/ha by helicopter to kill a kind of bamboo grass—*Pseudosasa purpurascens*. The sample water was collected in stream at a way out of the watershed and their quality was examined. The concentration of chlorate ion reached the maximum of 45 ppm at three hours and a half after the beginning of spreading and after that quickly decreased. Stream discharge during the measurement period was about 60 $l$/sec. Alkalinity was also slightly increased and it was considered owing to the sodium bicarbonate mixed to make the grain. The changes in chlorine ion concentration were not recognized.

No changes were recognized in the numbers of individual and species of fish and aquatic insect. The pathological investigation of fish did not find out any abnormal symptom. But it was known that granular herbicide has a little worse effect on fish and other wildlife than that of sodium chlorate as a reagent, because of causing water turbidity owing to sodium bicarbonate and mineral matter used as an extender.

At present, it is considered that $NaClO_3$, TFP and AMS are of low toxicity, and if a great care is paid to the spreading method and quantity, they are almost out of the question of water quality. Anyway, a great many investigation should be made on the water pollution by herbicides for the future.

2, 4, 5-T is out of use by forestry at present.

*3) Change in water quality following forest fertilization*

In recent years, the fertilization has been practiced in a part of artificial forest. The total area of fertilized forest has amounted around 100,000 ha equivalent to about 1.1% of the total artificial forest area.

A popular method of fertilization is to apply a mixed material consists of nitrogen, phosphatic and potash fertilizers at the rate of 5:3:3. The forest is manured two or three times by the final cutting age of 40 to 55 years old. Generally the granular fertilizer is applied usually by manpower.

Only a few investigation was made on the effect of fertilization on water quality up to the present.

A water quality survey at the stream from about one ha fertilized stand detected the maximum concentration of nitrogen—mostly $NO_3$-N at 6 to 7 ppm in summer of the year fertilization done. The concentration was 3 or 4 times that of the neighboring non-fertilized watershed. The difference between both watersheds, however, disappeared in the following year[2].

Such a result was recognized on the young growth watershed right after planting. On the middle-aged forest watershed, holding the high absorbing power, the loss of nitrogen spread was of a very small quantity.

Other investigations on a relatively large watershed including many fertilized stands did not show changes in water quality.

Moreover, most of forest soils in Japan are acid soils which so often absorb phosphorus. That is why the loss of phosphatic compound into stream is a negligible small quantity. The loss of potassium manure is usually negligible too.

Many investigations are necessary before getting a final conclusion. As the case stands, however, as far as the fertilizers are applied by the method and in quantity as generally practiced the effect of fertilizer on water quality is presumed to be negligible, so that the water pollution following forest fertilization may not be a serious question. However, as the effect must differ with the method of fertilization, forest type, soil type, weather condition, etc., it is necessary to investigate the problem under all sorts of conditions.

## Conclusion and research subject in future

Research results at the Government Forest Experiment Station are summarized. Canopy interception loss with the principal coniferous forests ranged about 15–20% of annual precipitation, and 5–10% of the 100–200 mm storm. The maximum undergrowth and litter interception were about 1, 2–4 mm respectively with every rainfall. Annual water losses from forested watersheds ranged about 600–1,100 mm. Forest land has obviously higher infiltration capacity comparing with other land use area. Clearcutting caused the increase in annual runoff by 10–45% at the maximum. The cutting resulted in the increase in the total runoff in most months of the year, except the decrease in monthly runoff observed during high summer in little rain watershed and the decrease in monthly runoff during the second half of ordinary thawing period. After clearcutting, quickflow and peak discharge due to the 200–500 mm storm increased at the average of 1.30–1.65, 1.35–1.70 times that before cutting respectively. Low streamflow also increased with the clear-cutting on a small and little rain watershed. However, the average low streamflow from the watershed group with larger forest area percentage or the superior forest was larger than that from the other watershed group. Nitrogen content in streamflow increased by 3.5 ppm in next summer after clearcutting, but the increase ceased in later several years. Herbicide, sodium chlorate, application at the rate of 200 kg/ha caused such a high concentration of chlorate ion in streamflow as the maximum of 45 ppm, but the concentration quickly decreased later. Neither the changes in the numbers of individual and species of fish and aquatic insect nor the pathological symptom of fish occurred. Application of N-P-K mixed fertilizers increased the concentration of nitrogen in streamflow without the change of P and K concentration.

Forest hydrological study in Japan has its history over about 70 years. Both the scope covered and results obtained, however, are still far from satisfactory, remaining a lot of problems to be solved in future.

As stated above, the results on the relations between forest and low streamflow from the small watershed experiments was contrary to the one from the investigation with many relatively large watersheds. The reasons for this difference should be clarified. It should be paid attention that basically there might be some difference in the accuracy of hydrological measurement between both experiments. But, at present, it is difficult to say which one of the both results can be accepted as expressing an actual fact, because of the following reason. That is, the forest builts up the base flow from the relatively large watershed in much rain area. But, it is also possible that the forest decrease the base flow from the small watershed with scores of hectares in area and from the watershed in an extremely little rain area. It is by all means necessary to detect the fitness of the recognition to make clear the fact.

With regard to this subject, it is considered to be very important to have better understandings of the relation among the hydrological characters of upper layer geology—especially character of aquifer, the vertical distribution of tree root system and base flow, the behavior of gravitational water in the unsaturated soil layer and percolation of water from unsaturated zone into saturated one.

There are many unsolved technical problems which are directly required for establishing the desirable forest management system for water conservation.

Studies on the relation between runoff and area ratio of clearcutting or selective cutting system are also required and they are in progress at present.

The two-storied high forest system and contour belt cutting system are expected to be the desirable forest working systems for water conservation as presumed by the results of related researches. Watershed experiments will be, hereafter, essential to make clear the effects of both systems on runoff.

It will be also important to survey the water budget in the many stands of principal forest type. A trouble in the survey is the measurement of correct evapotranspiration. However, a good many of measured value of stand water budget, when it will be available, hereafter, will do much for solving the problem of selecting tree species, structure of stands, etc. desirable for water conservation.

Until comparatively recent days, the relation between forest workings and water quality has never been a matter of public concern. Therefore, the problems on the water pollution by forest cutting, road construction, herbicide spreading and forest fertilization should be throughly investigated. The water pollution by forest recreation activity is rapidly growing up into an especially important problem.

Effects of the conversion of forest land to golf course and villa land on water yield and quality are required anxiously to be clarified. Intensive investigations, however, have not been initiated yet.

Examinations are already begun, though in an initial stage, on the effect of forest grazing and the conversion of forest land into pastures.

About 70% of the total land acreage of Japan is the mountainous area. Almost all of the area are covered with forest land. The precipitation falling on the forest land constitutes water resources, but some times causes flood damages.

On the other hand, people's life in Japan depends highly on wood, so that the forest has been manipulated with first consideration for wood production from old times.

Accordingly, the adjustment is always required between the desirable forest management for the water conservation and that for the wood production. It gives an importance to the forest hydrological study in Japan.

Lately, the Forestry Agency is carrying out a project to determine the method for identifying the desirable forest type and workings for water conservation, and to designate the important areas to be preferentially arranged for desirable forest. The project is expected to give results which can be used as an important basis for the new forestry policy to improve and reinforce the existing protection forest system. And the Agency also has adopted a new guidance policy that the area of clearcutting to be practiced at one time should be limited less than 5 ha for the protection forest and 20 ha for the general commercial forest. The use of chemical substances in forests has also been brought under the regulation of the Agency.

Still more active forest hydrological studies are needed in future to establish desirable working systems for water conservation in the multiple use of forest. An emphasis will be laid on the investigation on the relation between practices of forest working and quality and quantity of water.

## References

1) Agriculture, Forestry and Fisheries Research Council: Effect of herbicide on forest ecosystem and its research method. Report No. 75, Agriculture, Forestry and Fisheries Research Council, pp. 209, (1974) [In Japanese].

2) Soil and Fertilizer Research Team: The movement of nitrogenous fertilizer in forest land. Annual Report of the Government Forest Experiment Station 1972, 44-46 (1973) [In Japanese].