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Title	Watershed Management and Hydrological Effects in Laoshan Experimental Station, Northeast China
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Citation	Eurasian Journal of Forest Research, 5(2), 107-112
Issue Date	2002-12
Doc URL	http://hdl.handle.net/2115/22156
Type	bulletin (article)
File Information	5(2)_P107-112.pdf

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Eurasian J. For. Res. 5-2: 107-112 , 2002 © Hokkaido University Forests, EFRC

Watershed Management and Hydrological Effects in Laoshan Experimental Station, Northeast China

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Abstract

On the basis of the watershed classification and according to the land types such as the forest, grassland, farm land, wetland, and the characteristics of the heterogeneous tendency of natural environment, we have determined four types of the natural secondary forest in the Northeastern China as cultivated, reformed, preserved, and utilized types with taking the second-class watershed as a research unit. Through the systematic management strategy such as planting, cultivation of man-made and natural mixed stand, terraced felling and different-layer tending treatments, we have made every land type in optimal arrangement state, so as to achieve the aim of increasing the quantity and quality of the vegetation. Meanwhile, the effect of soil utilization and the change of vegetation in the trial watershed on the hydrologic process during last 40 years could have been discussed. Results show: The forestry land area has heightened from 254.2 ha in 1958 to 484.3 ha in 1997, and increased 90.5% relatively. The area of the forestland has elevated 117.8%, especially the area of plantation has been increased sharply by 222.9 ha and 642.7% relatively. Meanwhile, the area of non-forest land such as sparse forestland and barren land decreases greatly. The forest coverage increases from 36.60% in 1958 to 79.72% in 1997 in the trial watershed. The stand average volume per hectare in 1997 was 125.59m^3 ha^{-1}, which has raised 107.79m^3 per hectare more than that in 1958. Changes in the distribution of stand volume on different age-grade have taken place too. As a result of the improvement of forest quantity and quality, the surface runoff gets decreased significantly, and the through flow gets decreased gently too. But the percolation changes little and shows a tendency to increase. For the evapotranspiration has become the main form of water output in the trial watershed, which takes up about 65.8% of the total water input.

Keywords: Watershed management, Forest management types, Forest community structure, Stand volume, Stand increment, Hydrological effects

Introduction

For a long time however the traditional forest management has done, it has only carried out the control and management of the forest itself, but has rarely made researches on ecological function influences and produced environmental effects of the forest (Wu *et al.* 1991). Therefore, this led to the forest management separated from the construction of the forest's ecological environment. However this results from the pattern of management (Li 1994, Xu 1994). It must be solved as soon as possible.

A project of Natural Forest Resource Protection, which is now being carried out widely in china. The aims are at increasing the quantity and quality of forest resources, improving ecological environment and realizing sustainable development of the forestry by changing the way of forest management and adjusting the forestry industrial structure. In this project, existing forests have been divided into such function types as ecological forest and commercial forest. And then the classified management has been taken in practice (Yong 1992, Wang 1998). But it still conduced forest management separated from the ecological environment protection. There is a shortage of systematic and efficient techniques of forest management.

In order to study the effect of soil utilization and the change of vegetation on the hydrologic process, the No.4 Class-Ⅱ watershed had been being taken as the trial spot in the Laoshan Experimental Station (LES) attached to Northeast Forestry University. All the changes such as the land utilization, quality and quantity of forest stand, as well as hydrological effect have been investigated and observed termly for nearly 40 years. This paper is only a brief of the researches on restoration and cultivation of forest resources, as well as construction of the ecological environment. We hope that it could provide the reference for the regions where there is similar condition in the days to come.

(Accepted; July 19, 2002)

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Study sites and Methods

Study sites

All trials and researches were carried out in No.4 watershed in LEF. It is located on Shangzhi county of Heilongjiang province, subordinated to the branches of Xiaoling, west slope of Zhangguangcailing Hill of Changbai mountains, 127° 30′ ~ 34′ in longitude and 45° 20′ ~ 25′ in latitude. The mean elevation is about 300mm. The slope in this region is ranges from 10° to 15° , and the terrain is a chain of undulated hills. The zonal vegetation in this area had been broad-leaved and Korean pine mixed forest. But original forest cannot be found now. The existent vegetation types are mainly secondary forests such as birch (*Betula platyphylla*) and poplar (*Populus davidiana*) forest, mongolian oak (*Quercus mongolica*) forest, hardwood forest and brushes, which regenerated from original zonal vegetation. From this, a large area of plantations of Dahurian larch (*Larix gmelinii*), Korean pine (*Pinus koraiensis*) and mongolian scots pine (*Pinus sylvestris* var. *mongolica*) etc, have been established. The landscape of this region is now a compound forest ecosystem of plantations and natural secondary forests. The dark brown soil is the main soil type, which takes about more than 60% of the total area. Others are such soil types as meadow soil, swamp soil and Bleached soil, which take up nearly 40% of the total area. The character of climate is middle temperate and humid. The mean annual temperature is 2.8℃, and about 700~800mm for the precipitation.

In this area, some elements of terrain resulted in the formation of water-influx units surrounded by ridges. Therefore, different grades and size of watershed are formed. From this, the No.4 Class-Ⅱ watershed was selected as the trials spot, which is located on the headstream of the Ashihe River and Mayanhe River which are the branches of Songhuajiang River. It provided suitable field conditions for researching on watershed management.

Method

Form 1958, A great deal of trials and researches have been carried out by taking No.4 watershed as trial site and establishing experimental blocks, with total area is about 600 ha. According to the natural ecological succession regulation, many treatments such as promoting natural regeneration, artificial adjusting, reforestation of fast growth and high yield plantation, as well as man-made and natural mixed forest cultivation, have been taken in practice through simulating the nature. Meanwhile, watershed management of forest ecosystem has been carried out in the researching spot. Till 1997, as soon as the quantity and quality of forest get increased, the ecological function, especially the hydrological effects of the watershed gets improved significantly.

The surface runoff, through flow and the percolation can be determined and gathered, when precipitation takes place, by establishing the rectangular sample compartment in size of $100m^2$, which was desolated around and 1.2m under ground with plastic boards. About 6 compartments was established separately in different forest types, such as hardwood forest, birch and poplar forest, Mongolian oak forest, as well as plantations of Korean pine, Mongolian scots pine and dahurian larch.

The methods to determine the evapotranspiration are as follows. First of all, the transpiration must be calculated on the basis of determination on leaf area and the intensity of transpiration (Ma, 1993). That is,

$T=A\times I\times t\times d$

Note: (T) Transpiration; (A) Leaf area per hectare; (I) Intensity of transpiration; (t) Mean hours of transpiration a day; (d) days of transpiration during growing season.

The evaporation of stand canopy is nearly equal to the amount of canopy interception. The evaporation of forest ground can be determined directly by using Lysimeter (Xu, 1989).

In the end, the total evapotranspiration of forest stands can be calculated from the sum of the transpiration, evaporation of stand canopy and the evaporation of forest ground (Xu, 1989 Kang, 1992).

Classification of forest management types

According to the division method of R. E. Horlon and A. N. Strahler, the grade of watershed can be divided as follows. The class- Ⅰ watershed is referred to as the water-conception area of the minimum river without branches or beheaded ditches. The class-Ⅱ one is as the water–concentration area of the second class rivers formed two or more first class rivers concentrating. The class-Ⅲ one refers to the area of the produced by two or more second class rivers' concentrating. Conclude so the forth, and then divided. At last, LEF is divided into 9 class-Ⅱ watershed regions and 36 class-Ⅰ watershed areas. The No.4 class-Ⅱ watershed is one of the class-Ⅱ watershed regions with much more researching establishment. In each class-Ⅱ watershed, the function types of the forests can be divided, that is, forests flunking the ridge, around the reservoir, at the bank of the river, regenerating difficult, eroding secondly and with great slope are divided as ecological forests. But the stands which in gently slope, are of high site index and are also with scarce ecological disasters, can be determined as commercial forests.

Secondly, the secondary forests can be divided into different management types of cultivated, reformed, set apart and cultivated, and utilized types according to the current state and the management treatments. The type of cultivated forest refers to the stand of cultivated future and value, through structure adjusted, management strengthened, ecological environment improved, growth accelerated, and branch shape cultivated, its quality and production can be raised. The improved is the natural secondary

forest, which has no cultivated future, little economic value, low production and ecological function and serious pest. The set apart and cultivated is the stand which lies on the slope more than 36° , and in the location of thin soil, bare stones isolated place, scarce manpower, and difficult regeneration or serious destroy, and has the capacity of multi-generation. The utilized is the one whose the stand or some tree individuals get matured technologically, and then need to be cut and regenerated.

Management techniques and strategy

Generally, natural secondary forest has unreasonable structure like low density, uneven distribution, with many empty niche etc. In this case, we resort to the strategy of planting conifers and protecting hardwood, that is, establishing conifer and broad-leaved mixed forest by introducing the suitable conifer trees into natural forest. It can shorten the succession period, and accelerate the restoration speed of the natural forest. Therefore, it not only increased the amount of forest, but also improved the quantity of forest stands. Especially, the productivity on unit area got significantly increased.

There are many gaps in different size distributed under the natural secondary forest. For theirs suitable ecological environment, it can be restored depends on the natural regeneration. Main tree species are *Fraxinus mandshurica*, *Juglans mandshurica*, *Quercus mongolica* and such pioneer trees as *Populus sp.* and *Betula platyphylla* etc, which form the multiple-story and different-age mixed forest by treatments of tending. Besides, on the edge of the forest, due to the protection of the stand, the ecological environment is better. Its natural reproduction depends on the trees whose seeds are spread by wind, that is, *Fraxinus mandshurica*, *Juglans mandshurica*, *Tilia amurensis* and so on. They have formed young and middle-aged forests.

For the seedlings and young trees taken place from natural regeneration, they not only need to undergo the selection by environment boult, but also need 2-3 seed-years to complete the whole process. However, it has great biological significance to shorten the regeneration period by artificial promotion. Expectedly, the seedlings and young trees coming from natural regeneration have higher density generally, which has surpassed the territory environment, so it is difficult for them to become forest. Thus significant effects can be obtained by applying systematic management of making certain tree individuals to be cultivated for younger stands and thinning for middle-aged stands.

Effect belts are usually opened up in barren hills suitable for forest, abandon-plough fields and bush lands. As soon as plantations are planted, natural broad-leaved trees are introduced. In the end, mixed forest of natural broad leaf and man-made coniferous will be formed. This is efficient measure for forest management to amplify the boundary of the edge, increase utilization rate of light energy and promote the increment of woods.

Besides, the techniques of gradient cutting and hierarchical tending can be carried out in the mature stand or the stand with the upper story being reached technological mature. That is, treatments like thinning for growth in sub-main forest story and released tending in succession story must be carried out, while cut the upper story of the forest.

Dynamics of the quantity of forest resources

From Table 1, it can be found that the quantity of forest resources in total experimental spot gets obviously increased through long-term scientific management. It is concretely illustrated as follows: The forestry land area has heightened from 254.2 ha in 1958 to 484.3 ha in 1997, and increased 90.5% relatively. The area of the forestland has elevated

Table 1. Dynamics of different land types in experimental regions

Year	Item	Area	Forest land area			Non-forest land area			Total forest land area	Non-forestry Land area	Forest coverage (%)
			Natural forest	Plantation	Total	Thin forest	Barren land	Total			
1958	Area (ha)	600.0	184.8	34.8	219.6	20.4	14.2	34.6	254.2	345.8	36.60
	%	100	30.80	5.80	36.60	3.40	2.37	5.77	42.37	57.63	
1983	Area (ha)	600.0	192.4	204.4	396.8	52.7	7.6	60.3	457.2	142.8	66.15
	%	100	32.07	34.07	66.13	8.78	1.27	10.05	76.20	23.80	
1997	Area (ha)	600.0	220.6	257.7	478.3	6.0	0	6.0	484.3	115.7	79.72
	%	100	36.77	42.95	79.72	1.00	0.00	1.00	80.72	19.28	

117.8%. The area of natural secondary forest in 1997 gets increased gently only 19.4% more than that in 1958. But the area of plantation has been increased sharply by 222.9 ha and 642.7% relatively. Meanwhile, the area of non-forest land such as sparse forestland and barren land decreases greatly. The forest coverage increases from 36.60% in 1958 to 79.72% in 1997 in the trial watershed.

Dynamics of the quality of forest resources

Through recent 40-year systematic management, following with the forest quantity increases remarkably, the stand quality of the whole trial region has also been improved greatly (See Table 2). On one hand, the stand average volume per hectare in 1997 was 125.59m^3 ha^{-1}, which has raised 107.79m^3 per hectare more than that in 1958. The other hand, the stand volume distribution was mainly concentrated on the young stands of first and second age grades, which covers 93.9% of the total volume in 1958. But the volume of the third age-grade stand is 44.04% of the total in 1983. Till 1997, not only the third age-grade stand volume covered 41.97%, but also the fourth and fifth age-grade stands volume has reached 41.69% of the total. These results have something to do with self-growth and development of the stand, but they do have intimate relationship with efficient management treatments.

Hydrological effects of the trial watershed

It is shown that the whole water storage function gets strengthened remarkably with the increasing and improving of the forest resources' quantity and quality in the trial watershed by fixed observation on the No. 4 grade- II watershed. Water storage in watershed mainly includes vegetation interception, litter storage and soil storage (Maulloch *et al.* 1993, Schaap *et al.* 1997). The dynamic of each ponderance of water storage is obvious, what's more, has unanimous regulations, that is each has the tendency to elevate with the increasing of the forest quality and quality. The amount of vegetation interception and litter storage mainly depends on the improvement of forest quantity and the adjustment of community structure. But the increase of soil storage is mainly due to the improvement of soil physical character (Chen *et al.* 1998). So it gives the advantageous proof of the improvement of the watershed ecological environment.

It can be found, from Table 3, that it has caused obvious change in watershed water balance through forest management, as the water surplus in 1958 became the water shortage in 1983 and 1997. The water shortage is mainly because of the forest large transpiration. As a whole, the evapotranspiration has become the main form of the watershed water output with the increase of the forest quantity and quality. Meanwhile, each item of the runoff shows obvious decrease tendency, but the percolation changes little or remains stable proportion. Decrease of surface runoff, while it turns into through-flow and percolation, is very important for containing water-source, conserving soil and keep watershed ecosystem.

Table 2. Dynamics of stand volume and distribution according to age grade

Year	Total volume		Grade I		Grade II		Grade III		Grade IV		Grade V		m^3 ha^{-1}
	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	m^3	%	
1958	4620.0	100	952.0	20.60	3386	73.30	282	6.10					17.80
1983	26598.2	100	2542.9	9.56	8437.1	31.72	11714.6	44.04	3903.6	14.68			67.01
1997	60070.0	100	394.0	0.66	9421	15.68	25209	41.97	15558	25.90	9488	15.79	125.59

Table 3. Dynamics of water balance in the watershed

Year	Watershed area (ha)	Water input (km^3)	Water output (km^3)					Water Balance (km^3)
			Evapotranspiration (km^3)	Runoff				
				Surface runoff	Through flow	Percolation	Total	
1958	600	4130.0	1592.115	798.742	469.994	1129.555	2398.291	139.594
1983	600	4173.6	2671.939	34.641	316.359	1206.170	1557.170	-55.509
1997	600	4342.8	2857.100	13.040	306.944	1355.822	1675.806	-190.106

Conclusion

ccording to the terrain features and the ridge trend, the whole experimental region has been divided into 9 second-class and 36 first-class watersheds by the theory and methods of landscape ecology. And then forest watershed management have been systematically carried out for more than 40 years by using forest management map. It is originally presented that the second-class watershed should be taken as management unit. The intensity of thinning and the area of cutting must determined according to the growth, ecosystem's function index and soil erosion standard of different forest types divided. This results in the watershed management and environmental construction becoming a whole. It is theoretical and realistic significance for protecting environment, cultivating forest, developing management and achieving the sustainable development of forestry.

The quantity and quality of forest get significantly increased and improved for about 40 years systematic management. The forestland area and the volume of stand per hectare get relatively increased 117.8% and 642.7% respectively, and the forest coverage amounts to 79.72%. So this not only improves the land utilization structure of the experimental region, but also raises the site productivity and at the same tine the watershed ecological function gets improved and elevated.

With the increase of forest quantity and quality, evapotranspiration has become the main form of the water output in the watershed. The surface runoff gets decreased significantly, and the through flow gets decreased gently too. But the percolation changes little and shows a tendency to increase. The reasons making for such regulation mainly are the through flow maybe influenced easily by the conditions of forest stand such as stand density, canopy, litters, mechanical character of forest soil as well as even the storage of forest. Especially, the roots of the tree can absorb some of the through flow. So, the through flow gets decreased, although the percolation gets increased, along with the increasing of the evapotranspiration

During the course of the watershed forest development deviation from management aim often occurs. This restrains the increase of forest resources. Adjustment and control should be carried out so as to strengthen the resistance of the ecosystem and keep the ecological balance of high efficiency.

In a watershed, the rotten substance and soil nutrient on the ridge and the upper slope, flow downward from the upper because of the runoff and the gravity. This shows erosion process, and the soil nutrient gravity expense zone is formed. On the middle slope, it not only receives the expense substance from the upper, but also exports them to the lower, thus the soil nutrient gravity transition zone is formed. On the plain down the slope, it receives them horizontally, and forms the soil nutrient gravity process concentration zone. During the ecological gravity process, the water takes very important effect. The water washes the soil, what 's more, washes away stone and disintegrated materials, at last destroyed ecological equilibrium. As a result, the natural environment and forest land productivity become poor and poor. Therefore, water is the dominant element in the watershed, which keeps the good ecological environment. Forest can store and keep water, so only when forest gets well adjusted, with high volume and good structure, the watershed can be kept in benign circulation. In order to achieve the aim to heighten stand quality and strengthen stand ecological function, we must carry out the management according to different zones and types. Seen from the above analyses, the watershed is a complete system, which has complex structure. So, watershed management has a bright and broad foreground.

Acknowledgements

The first author expresses thanks to Prof. T. Koike (FSC for Northern Biosphere of Hokkaido University, Japan) and staff of the forepassed Hokkaido University Forests, for their kind advice and support.

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