Studies on the Optimum Model of Forest for Soil and Water Conservation

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Abstract: This paper dealt with the soil and water conservation benefits on different kinds of vegetation along the Yangtze River valley in Xixia county, Henan Province. The four kinds of vegetation are dense trees with middle-dense shrub and loose grass(DMDL), loose trees with middle-dense shrub and dense grass(LMDD), dense shrub and middle-dense grass(DMD) and gradient farmland(GF). The results show that the annual surface runoff and soil erosion were 33.94 mm and 3.603 t • hm^{-2} on DMDM; 2.885 mm and no soil erosion on LMDD; 21.035 mm and 0.384 t • hm^{-2} on DMD; 36.110 mm and 32.657 t • hm^{-2} on GF. The soil and water conservation benefits on the four types of vegetation were in the following order(from high to low): LMDD > DMD > DMDL > GF. And also the soil and water conservation benefits have the following order, grass > shrub > tree, based on the comprehensive analysis of the height between canopies and ground, and the force of rain dropping on the soil. LMDD was suggested to be the optimum structure model for obtaining the ideal soil and water conservation benefits and the best usage of different vegetation.

Keyword: forest, soil and water conservation, optimum model, vegetation

The effects of forest on soil and water was a important problem for sustainable development. The study of forest ecology now put much emphasis on the forest effects on decreasing soil erosion and the change of soil characteristics. Forest can not only affect soil physic and chemistry traits, but also regulate rainfall's distribution and water flow process. The study on these effects of four main-types vegetations was carried on in 1999—2000 in shuanglong in Xixia county, Henan province. The amount of direct runoff, soil erosion were observed in the fixed field.

1 Study site outlines

The study site is lying in the shuanglong in Xixia county, Henan province, locating at 111º01' E and 33º05'. The altitude is from 300 m to 1,045 m, having a northwest slope of 20º more. The soil is brown with the depth of 40 cm. The site's yearly average air temperature is 11.6℃—15.4℃, and the precipitation is 860 mm—935 mm. The collecting water area was 750 hm^2.

Runoff fields were setup in Four kinds of vegetation, which are dense trees with middle-dense shrub and loose grass(DMDL), loose trees with middle-dense shrub and dense grass(LMDD), dense shrub and middle-dense grass(DMD) and gradient farmland(GF). The outline of each field area seen the Table 1.

Table 1 The outline of four kinds of vegetation

Type	gradient	area/m^2	Trees coverage %	shrub coverage %	glass coverage %	vegetation coverage %
DMDL	30	81.74	58	20	3.5	70.5
LMDD	29	87.46	41	18	91.5	100
DMD	27	91.43	0	60.65	28.45	83.9
GF	28	90.69	0	0	0	50

2 Study method

2.1 The measurement of direct flow-off

The measurement was carried out in blocked field using bricks and cement lowly banked at the upper and two lateral sides; the bank being isolated with field belt. The lower side was dyked to have runoff channels and its collecting pool with asphalt felt on them to avoid rainfalls. The runoff was measured when it appears after rainfall. The pool bottom was washed with clean water after the measurement for the later use.

2.2 The measurement of soil erosion

The sediment method was used to measure the soil erosion amount. The silt in the pool bottom was disturbed and well mixed with upper water. mixture was immediately scooped out into plastic bucket. The upper water was poured out after natural settlement, while the silt was natural dried and weighted. The unit is kg • m^{-3}.

2.3 The measurement of soil physic traits

The weight and ring cutting methods were used to measure the soil water content, unit weight, gravity, capillary porosity, non-capillary porosity, and maximum moisture capacity. The double ring casing tube and the circle infiltration measurement were used to measure soil permeable speed and amount.

3 Results and discussion

3.1 The physic traits of soil

The four vegetations obviously affected the physic traits of soil according to the observation (Table 1): The unit weight of soil varied in 0.13 g/cm^3—1.54 g/cm^3, and kept the same change trend as that of soil gravity in different vegetations. The greatest of soil non-capillary porosity was in DMD , the second ,in DMDL , the third, in LMDD and the smallest, inGF; while its changing value showed the inverse ratio to that of the soil unit weight. The capillary porosity a showed the same trend. Therefore, DMD preparation can promote water storage capacity of soil, which benefits to the soil and water conservation.

Table 2 Effect of different vegetation on soil physic traits

Vegetation types	layer(cm)	Unit weight of soil (g • cm^{-3})	Soil gravity (g • cm^{-3})	Non-capillary porosity (%)	Capillary porosity (%)	Total porosity (%)
DMDL	0—10	1.45	2.49	6.5	34.46	40.96
LMDD	0—10	1.30	2.50	8.07	40.13	48.20
	10—20	1.35	2.55	7.86	39.20	47.06
	20—30	1.45	2.60	7.76	36.47	44.23
DMD	0—10	1.54	2.62	7.95	33.27	41.22
GF	0—10	1.33	2.47	7.68	38.47	46.15

3.2 The infiltration characteristic of soil

The soil infiltration mainly depends on soil porosity, especially on non-capillary porosity, but porosity depends in a great content on soil physic traits, precipitation and its intensity. According to the soil infiltration observation in different site preparation field (Table 3), the greatest amount of soil beginning infiltration was LMDD(24.7 mm/min), the second was in DMD(23.18 mm/min), while the smallest, the DMDL(13.64 mm/min). The change of amount of stable infiltration showed the same as that of the beginning one. Therefore, according to local precipitation, much of the rainfall can be absorbed by soil, while only a little became direct runoff, especially in LMDD. Therefore, the LMDD has obvious effect on decreasing the surface runoff.

Table 3 Relationship between soil site preparation and soil infiltration

Vegetation types	Layer (cm)	Beginning Infiltration speed (mm/min)	Stable Infiltration speed (mm/min)	The average infiltration speed(mm/min)
DMDL	0—10	13.64	6.55	7.44
LMDD	0—10	24.70	7.98	10.85
	10—20	21.60	7.42	8.95
	20—30	18.52	6.94	8.03
DMD	0—10	23.18	7.25	9.71
GF	0—10	15.99	7.23	8.59

3.3 The effect of different vegetation on the runoff and soil erosion

There was much change of soil physic traits and soil infiltration characteristics because of the different vegetations. Therefore, the different vegetation have much difference in regulating direct runoff and decreasing soil erosion (Table 4).

Table 4 Effect of various vegetations on the amount of runoff

Precipitation (mm)	GF		DMD		DMDL		LMDD	
	Runoff (mm)	Runoff coefficient (%)	Runoff (mm)	Runoff coefficient (%)	Runoff (mm)	Runoff coefficient (%)	Runoff (mm)	Runoff coefficient (%)
21.8	1.25	5.37	0.58	2.67	1.54	7.07	0	0
26.0	1.26	4.85	0.41	1.56	1.20	4.64	0.11	0.44
19.5	0.42	2.15	1.20	6.17	0.12	0.63	0	0
29.6	1.98	6.69	0.43	1.48	2.23	7.25	0	0
28.7	0.41	1.43	0.12	0.43	0.55	1.94	0.06	0.2
13.7	3.25	23.72	0.89	6.49	1.16	8.54	0.29	2.14
39.4	2.92	7.41	0.72	1.84	3.09	7.87	0.08	0.21
13.5	0.19	1.41	0.10	0.77	0.43	3.24	0	0
62.8	8.82	14.02	6.45	10.28	9.17	14.61	1.81	2.89
13.6	0.07	0.51	0.00	0.05	0.10	0.73	0	0
50.2	2.53	5.04	0.43	0.87	2.63	5.25	0	0
74.4	12.41	16.68	9.79	13.17	9.73	13.08	0.51	0.7
total	36.11	8.55	21.03	4.98	33.93	8.03	2.88	0.68

According to Table 4, the following principal can be seen: The amount of runoff and runoff coefficient varied among 2.88 mm—36.11 mm 0.68—8.55 in four vegetation runoff fields respectively. The Runoff coefficient was 8.55; In the DMDL, the value was 33.93 mm, 8.03%, in DMD, was 21.03 mm,4.98%,in LMDD,was 2.88 mm,0.68%,respectively. However, in the GF, the observation was

36.11 mm, 8.55%, respectively. The amount of runoff on the four types of vegetation were in the following order(from high to low): GF> DMDL >DMD>LMDD.

In this study, the corresponding direct runoff and soil erosion observation of four different vegetations was calculated. Table 5 had showed the relationship between vegetation and Precipitation (Table 5).

Table 5 Effect of various vegetations on the amount of soil erosion

data	Precipitation (mm)	GF	DMD	DMDL	LMDD
7.16	21.8	0.123	0	0.229	0
7.24	26.0	1.338	0.016	0.217	0
7.28	19.5	0.055	0	0	0
7.30	29.6	1.459	0	0.383	0
8.5	28.7	1.397	0	0.007	0
8.6	13.7	4.585	0.016	0.072	0
8.10	39.4	3.988	0	0.934	0
8.14	13.5	0.059	0	0.057	0
8.15	62.8	2.815	0.35	0.585	0
8.27	50.2	0.170	0	0.091	0
9.15	74.4	16.680	0	0.698	0
total		32.656	0.384	3.603	0

According to Table 5, The amount of soil erosion has a near relationship with the rainfall intensity, the precipitation intensity will become the main factor. These figures showed that when the rainfall intensity increased, the amount of runoff and silt sharply increased. The amount of soil erosion on the four types of vegetation were in the following order (from high to low): GF>DMDL > DMD >LMDD. And this show that the vegetation was the main factor on the amount of soil erosion.

4 Conclusions

(1) The vegetation has obvious effect on decreasing runoff, in which the LMDD showed the greatest effect, DMD, the second, DMDL, the third and all of them are better than GF.

(2) the vegetation can promote soil capillary porosity, and thus to soil infiltration obviously. The beginning and stable infiltration speed in DMDL, DMD and LMDD is higher than that of GF. Therefore, vegetation is benefit to decrease soil erosion.

(3) The soil and water conservation benefits on the four types of vegetation were in the following order (from high to low): LMDD > DMD > DMDL > GF. LMDD was suggested to be the optimum structure model for soil and water conservation benefits.

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