The Soil Moisture Condition of the Different Topographic Positions in Loess Plateau and Construction of Plantations

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Abstract: The soil moisture conditions in loess plateau were analyzed. Differences of soil moistures in different landforms and slope direction were discovered. Research results showed that soil moistures in more than 15 years old plantations, which grew in south slope of the small plain and gully region, were deficit. In the hilly and gully region, soil moisture deficits of plantations were serious and the dry layer within soil profile was formed due to strong transpiration of trees. Densities of plantations in loess plateau were big which was the main one of reasons for soil moisture deficits of plantations. Therefore, in construction of plantations, tree species, especially lower water consumption species, are selected for the suitable sites, where soil moistures have to meet the growth of trees. Trees in relatively lower density should be planted on other places except for high density of shrubs on steep slopes where soil erosion is severe, and area of the mixed forest should be increased. In addition, methods by pruning, thinning and rainwater harvesting adjust soil moisture and relieve the moisture deficit of stands.
Keywords: soil moisture, plantation, Loess plateau

Loess Plateau is the largest loess region all over the world, where the ecological environment become worse and soil erosion is the heavier due to destruction of vegetation in the past. Precipitation in the area is relatively less (300mm—600mm) and underground water is so deep that it cannot provide for tree growth. Soil moisture is the most important factor impacting the survival and growth of trees. Therefore, researches on soil moistures of different landform and exist plantations have very significant meaning for the construction of plantations in the area.

1 Variation of soil moistures in different landforms in loess plateau

On the basis of its geomorphic types, loess plateau is divided into two regions, i.e. hilly and gully, and small plain and gully region. Different slope directions, runoff and winds due to complex topographies (Table 1) affected soil moistures in the hill and gully region. Results in the beginning of Spring showed that in the hilly and gully region, soil moisture in the bottom of gully, where runoffs from slopes were harvested, was the highest. Soil moisture in the north slope of hill and gully was higher than that in the south slope of hill and gully. Soil moisture in the top of hill was the lowest due to strong evaporation caused by wind and no runoff from other places. Soil moistures in the small plain and gully region also were different (Table 2). Soil moisture in the north slope of gully was higher than that of the south slope. Soil moisture in down slope was great than that of medium slope and soil moisture in medium slope was higher than that of upper slope.

Table 1 Soil moisture contents in different sites in the hilly and gully region

Depth of soil (cm)	The bottom of gully	North slope of hill (27°)	South slope of hill (28°)	North slope of gully (30°)	South slope of gully (29°)	The top of hill
0—100	15.3%	12.4%	10.4%	12.9%	10.7%	9.8%
100—200	17.4%	14.2%	11.9%	14.7%	12.2%	11.9%
0—200	16.4%	13.3%	11.7%	13.6%	11.5%	10.9%

Table 2 Soil moistures in different places of slopes in the small plain and gully region

The depth of soil (cm)	The north slope of gully			The south slope of gully		
	Upper	Medium	Down	Upper	Medium	Down
0—160	16.6%	17.9%	18.7%	13.7%	16.9%	17.6%
160—350	17.2%	18.4%	19.5%	10.0%	16.2%	18.0%
0—350	16.9%	18.2%	19.1%	11.7%	16.5%	17.8%

Because soil moistures in different topography were different, sites should be divided on the basis of soil moistures in different topographies, slope directions and slope gradients, then different tree species will be chosen for the suitable sites when trees are planted.

2 Soil moistures of plantation lands in loess plateau

2.1 Soil moisture of plantation land in small and gully area of loess plateau

In the same climate condition, sites played very important role in soil moisture of plantation. Precipitation from May to October in more rain year was 598.3 mm. The mean soil moisture of *Robinia prseudoacacia* stands within 160 cm in the north slope of gully was 17.52%, which was 83.4% of field capacity, while that in the south slope was 10.2% which was only 48.3% of field capacity. The mean soil moisture from 160 cm to 350 cm in the north slope was 11.8% whereas that in the south slope was 7.0%, which was only 33.3% of field capacity. Rainfall from May to October in less rain year was 278.4mm. The mean soil moisture within 160 cm in the north slope of gully was 13.4%, which was 63.8% of field capacity, while that in the south slope was 8.8% which was only 41.9% of field capacity. The mean soil moisture from 160 cm to 350 cm in the north slope was 12.9% whereas that in the south slope was 7.1%, which was nearly same as that in more rain year (Table 3). Results from above showed that soil moisture deficit of the plantation in south slope occurred whether in more or less rain year. There were some similar results for *Robinia prseudoacacia* and *Pinus tabulaeformis* plantations from Wei (1999) and Sun *et al.* (1998).

Table 3 Dynamics of soil moisture of *Robinia prseudoacacia* plantations in the gully slope (%)

Soil	The north slope in more rain year						The south slope in more rain year					
depth(cm)	May	June	July	Aug.	Sep.	Oct.	May	June	July	Aug.	Sep.	Oct.
0—160	14.6	12.7	20.4	18.4	19.3	19.7	10.0	7.6	10.7	11.0	10.5	11.0
160—350	12.3	11.6	12.5	11.2	11.6	11.8	7.4	6.8	6.9	7.0	7.0	7.1
Soil	The north slope in less rain year						The south slope in less rain year					
depth(cm)	May	June	July	Aug.	Sep.	Oct.	May	June	July	Aug.	Sep.	Oct.
0—160	20.9	14.1	11.9	11.7	10.9	11.0	10.5	8.3	7.7	9.6	7.8	8.7
160—350	15.1	13.1	12.7	11.9	11.6	12.9	7.1	7.2	7.0	7.0	7.2	7.0

Note: trees were 16 years old, density of stands in the north and south slopes were 2,280 and 2,300 trees/ha, slope gradients of the north and south slopes were 27° and 28° .

In the same site, soil moistures in different densities of stands were different. In the root zone (within 200 cm) during tree growth season, soil moistures decreased with densities of 16 years old *Robinia prseudoacacia* stands increasing (Table 4). Soil moistures in 2,300 trees/ha stand were deficit because of high transpiration of trees. Therefore, density of the stand in west slope can not exceed 1,750 trees/ha. It is noted that density of the stand in drought south slope of gully should be smaller. Result of research from Sun *et al.* (1998) indicated that soil moisture deficits of

plantations in the region were also caused by higher densities of stands and over-extensive management. Soil moistures from lower density of *Prunus armeniaca* plantation in the south slope were great than those of *Robinia prseudoacacia* plantation in the north slope. So decreasing density of plantation in the region is an very important way to relieve the deficit of soil moisture.

Table 4 Soil moistures of different densities of *Robinia prseudoacacia* plantations in west slope of gully (%)

Density (trees/ha)	Soil depth (cm)	May	June	July	Aug.	Sep.	Oct.
2,300	0—200	11.1	9.9	11.8	11.7	11.9	12.0
1,750	0—200	14.6	12.1	15.7	16.4	15.3	15.7
1,250	0—200	15.1	13.8	16.3	17.2	16.4	16.6

2.2 Soil moisture of plantation land in hill and gully loess plateau

Many researches showed that soil moisture environment of plantations in hill and gully region were worse (Yang and Han 1985, Li *et al.*, 1990, Wang and Li 1992). Soil moistures in plantations from above authors are listed in Table 5. Soil moistures in shrub plantations were serious deficit except for within 100 cm soil layer while those in arbor plantations were nearly up to wilting coefficient and completely deficit. Dry soil layers within 300 cm in arbor plantations and in shrub plantations below 100 cm were formed due to the water absorption by roots of trees and shrubs. Therefore, plantations are situated under an unfavorable soil water environment.

Table 5 Soil moistures of different plantations in hilly and gully region of loess plateau

Soil depth (cm)	*Robinia prseudoacacia*	*Populus hopeiensis*	*Hippophae rhamnoides*	*Caragana korshinskii*
0—100	6.4	7.6	11.4	11.3
100—200	5.2	6.2	4.7	4.6
200—300	5.0	5.5	4.6	4.3

3 Construction of plantations in loess plateau

3.1 Tree species selected for the suitable sites

Because of soil moisture differences in different topographies, soil moistures in different sites should be analyzed before plantations in loess plateau are established. On the basis of soil moisture conditions in different sites, planning of plantations is worked out and tree species are chosen for suitable sites where soil moistures meet tree growth. In the hilly and gully region of loess plateau, some shrub species such as *Caragana korshinskii*, *Amorpha fruticosa* and *Hippophae rhamnoides* are planted in tops of hills and mounds, and steep slopes in gully due to the lowest sol moistures. *Salix matsudana* and some *populus species* planted in the bottoms of gully. *Prunus armeniaca var. Ansu* and *Prunus dividiana* are planted in the gentle sunny slopes of hills and mounds. Mixed forests of arbor and shrub species with line mixture are planted in the regular slopes of hills and mounds and group mixture of arbor and bush species are planted in the irregular slopes of gullies. At the same time, the share of shrub species should be increased.

In the small plain and gully region of loess plateau, shrub species are planted in the steep slopes of gully. Arbor species are planted in the relatively gentle slopes of gully and slopes of the small plain because of steep slopes in the most of gully. Area of mixture of arbor species with line and group mixture should be increased so as to control soil erosion. To obtain income, some economic tree species such as *Prunus armenica*, *Prunus persica* and *Pyrus bretschneideri* should be planted in the gentle sunny slopes

of the small plain.

3.2 Controlling density of stands

On the basis of our investigation from loess plateau, densities of trees, which of conifer were from 5,000trees/ha to 10,000 trees/ha and of deciduous trees were from 2,500 trees/ha to 5,000 trees/ha, were obviously big when trees were planted. With trees' ages increasing and their growth, transpiration of trees to consume soil moisture increased, which lead to decrease of soil moisture, even in the moisture deficit. Soil moistures in high densities of arbor stands over 15 years old formed a dry soil layer. It is very clear that high density of arbor plantation was the main of reasons for soil moisture deficit. Therefore, the suitable densities of plantations, 1,200 trees/ha—2,000 trees/ha for conifer and 800 trees/ha–1,500 trees/ha for deciduous trees, should be adopted. Soil moistures of plantations are improved by decreasing densities of plantations.

3.3 Strengthening tending and management for existing stands

In the past decades, tending and management for plantations in loess plateau were very extensive. In some places, plantations have not been tended and managed. Tending and management for plantations are very important way to adjust water environment of stands. For examples, lopping and pruning for branches of trees, removal cutting, sanitation cutting and tending felling can not only decline water consumption and relieve water deficit of stands but also improve growth of trees. Therefore, tending and management for plantations should be strengthen so as to relieve worse water environment of plantations.

3.4 Developing rain water harvesting for trees from row spaces in plantations

In loess plateau, source of soil moisture in plantations only depends on rainfall. Rainwater harvesting for plantations is a good method, which can harvest runoff from upper row spaces by setting up terraces and ditches in slopes, and improve water environment of stands and trees' growth. Results of research from Wang (2000) showed that rain water harvested from raw spaces in *Robinia prseudoacacia* plantations were from 349.1 mm to 838.6 mm under 462.9mm rainfall in growth season with density of the stand decreasing to 840 trees/ha from 3,330 trees/ha. Water harvested in lower density of the plantation was 1.8 times as much as rainfall and meet tree growth while water harvested in high density of stand was less than rainfall so as to impact tree growth. It is clear that developing rain harvesting and decreasing stand density are very available ways to improve soil water environment of plantations. These methods should be extended vigorously in loess plateau.

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