The Ecological-Hydrological Characteristics of the Three Manmade Forest Communities in the Central Yunnan Province*

***Wang Zhenhong*[1,2], *Duan Changqun*[1], *Chen Ming*[3] and *Wang Keqing*[2]**

[1]Environment Science Department, Yunnan University,Kunming,650091,China
E-mail: zhhwang@ynmail.com or dengsongmail@163.com
[2]Envinronment Science and Engineering Department , Southwest Forestry College, Kunming,650224, China
[3]Office of Soil and Water conservation, Yunnan province, Kunming, 675500, China

Abstract: In present work, we studied the ecological-hydrological law of three manmade forest communities at a located site of the central Yunnan province from 1998 to 2000. The finding indicated that the interception of canopy, stem-flow, through-fall of *E.maideni-A.mearnsii*, *E.maideni*, *P.Yunnanensis* took respectively up 35.21%, 0.65%, 64.14%; 30.10%, 0.88%, 67.56%; 27.8%, 4.64%, 69.25% of total precipitation. The canopy interception was up to maximum when precipitation per day was 70 mm for *P.yunnanensis* and *E.maideni* and 90 mm—95 mm for *E.maideni*, after exploiting moving variance analysis, a new analysis way. Surface runoff in the contrast restored naturally were 3—4 times more than the ones in manmade forest. Among the following factors influencing the ecological hydrology of forest, i.e., plant diversity, the dominance of the arbor layer, percentage of soil organism, through-fall, minimum water-holding capacity of soil, soil bulk, the canopy interception , non-capillary porosity of soil, number of litters per year, Si /V of soil, maximum holding-water capacity of soil, total porosity of soil, average timber of arbor, stem-flow, capillary porositybut, bio-diversity is the key factors that act on other factors and influenced the capacity of surface runoff control directly and indirectly. The bio-diversity characteristics of forests and the biological nature of edificators influence much significantly ecological- hydrological effects and law of ecosystem.
Keywords: the central Yunnan province, man-made forest ecosystem, hydrological-ecological law, bio-diversity

1 Introduction

Human activities have destroyed much of the world's forests (Burgess, 1993; Saxena & Nautiyal, 1997). The causes of deforestation are multifaceted but are driven by population growth, politics, and patterns of economic development (Paulson 1994;Ruder & Roper 1996; Gretchen C.Daily,1995). In Jinsha river basin of China, the above-mentioned causes were more typical than in other areas of the world. Moreover, Jinsha river area was also an ecological ectone and difficulty areas to forest recovery (Ma Shijing,1995; Li Kun,1995).As a result, soil and erosion became more and more serious. Bio-diversity was allso subject to great loss with deforestation. The area became one of the most serious areas about soil and water erosion problem in the west of China (Zhou Yu, 2000). From the 1980s, some organizations or establishments begun to get a clear understanding of the importance of forest preservation and recovery. Family planning begun and up to now, population have been controlled basically. Some forest recovery engineering, "the comprehensive harness of soil and water erosion in Jinsha river basin", "the shelter-forest engineering in Jinsha river basin" were carried out since 1988 in partial areas of the areas. People took mainly the measures of afforestation with natives or by the introduction of exotic quick-growing tree species in the process of these engineering carried (Wang Zhenhong,1992).These forest recovery measures were sure to be helpful to recover forest, but the quantitative effects of them keep still unknown, esp., the ecological hydrology of the different manmade forests and the relationship between the factors influencing ecological hydrology. It is very demanding for

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us to use the corresponding finding of the ecological hydrology in the forest recovery process to guide the afforestation.

In present work these respects are considered and the forest recovery effects about the ecological hydrology were researched in an experiment plant communities at a site of in Jinsha river basin of China. We addressed the following the questions: (1) what were the ecological hydrological characteristics and mechanism of the different man-made forest in forest recovery? (2) In forest recovery, how was relationship between the factors influencing the forest hydrology, in that the factors include the factors of rain distribution in forest, vegetation factors, soil factors, and so on? To answer the questions, we engaged in comparison experiments from 1998—2000.

2 Method

2.1 Site description

Fieldwork was carried out in the ecological observation station of soil and water conservation office of Muding county from March 1997 to March 2000 near Gonghe city (25º24' 09",N; 101º28' 18",E),approximately 200 km west of Kunming, capital of Yunnan province in China. The average annual rainfall in the area is 846 mm (mid-subtropical climate zone). Rainy season lasts from May to October per year. The average annual temperature is 16°C. The soil of the area is red earth. The original vegetation was subtropical even-green broad-leave forest, which has been almost all destroyed in the area. There are four sorts of experimental vegetation, *Pinus Yunnanensis* forest, *Eucalyptus maidenii* forest, mixed *Eucalyptus maideni-Acacia mearnsii* forest, that were recovered artificially with same transplantation density and soil preparation in 1990, and the restored naturally vegetation closed as contrast, on an abandoned farmland due to serious erosion in study site. There were not the impacts of people after afforestation. Nowadays, manmade experimental forests have been complex ecosystems in which there are many other species. We assumed that there was the same condition of vegetation, soil, macroclimate at study site before the recovery experiment of forests and carried out the research.

2.2 Forest hydrology

Daily precipitation (P) was recorded by two auto-rain-gauges and two standard rain-gauges within the bare plot in the open area. 10 sample trees were chosen in every forest. A spiral ditch was cut at 1.3 m height of every tree and a separated plastic tube from its head was nailed in the small ditch. The stitch between the edge of the separated plastic tube and the wall of small ditch was sealed by mixture of emulsion and plasticine so that all stemflow(S_f) flew into the plastic tubes and lead to the tank of stemflow. Under canopy, a global collector that its diameter was equal to the diameter of canopy was installed for the collecting of the fallthrough (T_f). Interception was calculated on the basis of the data of stemflow and throughfall as the formula:

$$Ic=P-S_f-T_F$$

where Ic = interception; P = precipitation; S_f = stemflow; T_f = throughfall. Canopy interception, throughfall ,stemflow of forests were conversed in proportion of woody plant coverage (Richard Lee, 1981).Four standard runoff plots (5.49 m×22.1 m) were laid out in the representative habit of forests. The boundary of the plots was built by concrete, which extended to the depth of 0.5 m under the surface of soil and the part above soil surface was 0.5 m high. The volume of the collective tank of soil surface runoff was designed according to the frequency of the storm that happens one time in one hundred years. The volume of surface runoff was measured after every rain with auto-fluviograph (Morgan R P C., 1996; Hudson N W, 1981).

2.3 Transects

In the habitat where runoff plots were laid out, seven transects (1m×50m) were parallel laid out and marked permanently with pvc tubes. Each of transects crossed two of standard runoff plot and was parallel to the long boundary of runoff plots. Every woody stem was identified along parallel transects and herbage was also identified in totally 35 sampling plots (1 m^2) at 10 m intervals. Alpha diversity was assessed by the description of Shannon-wiener diversity index, ecological dominance, community evenness, and community similarity by the description of Jaccard index (Appendix 1). We measured the height and diameter at breast height, of every woody stem height > 1.5 m. Timber volume of every woody stem height > 1.5 m was calculated as the formula:

$$Tv = Da \times H \times C.$$

where Tv = timber volume of every woody plant; Da = diameter at breast height of the woody plant height >1.5 m; C = coefficient (Sun shixian,1991).The covering presence of herbage and woody plants (height >1.5 m) were recorded at 0.25 m intervals along transects. Woody plant and herbage coverage was the percentage that the covering point number occupied total recorded point number. At the point of No.25 m of each transect, we arranged a litter collector, which collective area was 1 m^2. Litters of different forests were aired, weighed in October per year. The aboveground herbage bio-mass of 1 m^2 was harvested, aired, and weighed with an electronic balance at 10 m intervals along the transects as well. After sampling the aboveground herbage bio-mass, soil samples were taken at 0—10 cm, 10—25 cm, 25—50 cm depth at each point respectively with cutting ring of 100 cm diameter (three replicas per layer per points, 35 sample points in all) for the analysis of soil physical and chemical nature (Zhan Wanru. 1981).

2.4 Statistical analysis

About forest hydrology, Moving variance function was used to analyses the variation of canopy interception, stemflow, throughfall with the increasing precipitation that was outcome of the ordination of all precipitation data from great to little value in observation period. We assumed that there was the limit value of canopy interception, stemflow with the increasing precipitation when the branch, leaves, stems amount and spatial distribution of different trees or forests keeps constant in a certain period. When moving variances of canopy interception, stemflow keep constant or decreasing with the increasing precipitation, the precipitation the turning point of vario-grams corresponds to on the x axis should be the greatest precipitation of canopy interception or stemflow. Moving variance (MV (Δp_i)) for a certain Δp_i ($\Delta p_i = p_i - p_{i-1}$) was calculated as the average of squared differences of pairs of neighboring observations: Where: $Ni(\Delta p_i)$ is the total number of pairs of neighboring observations from 1 to i; $Y(p_{i-1})$ and $y(p_i)$ were the neighboring value of some variable.

$$MV(\Delta p_i) = \frac{1}{N_i(\Delta p_i)} \sum_{i=1}^{N_i(\Delta p_i)} [y(p_{i+1}) - y(p_i)]^2$$

The variations among the factors influencing ecological hydrology in the different forests were compared pair-wise using F-test. If there were significant difference, multi-variable linear correlation analysis was used to analyses the relationship between the factor variables in that we assumed that the difference of forests was determined, directly or indirectly, by the gradient variation of the variables.

3 Results

3.1 Forest hydrology

The observation indicated that different forests were different about canopy interception, stemflow, throughfall. The canopy interception of *E.maideni-A.mearnsii* forest was highest (35.21%) because of canopy interception ratio of *A.mearnsii* and high coverage of arbor layer. *E.maideni* forest and *P.yunnansis* forest were listed secondly (30.10%) and thirdly(27.8%) (ANOVA $F_{B\text{–}D}$=1.8, n=95, p<0.001; $F_{C\text{–}D}$=1.5, n=95, p<0.001; $F_{B\text{–}C}$=1.1, n=95, p>0.05, not significant; the capital letter, B=*P.yunnanensis* forest,C=*E.maideni* forest,D=*A.mearnsii* forest, the letters represent the same experimental materials in following paragraph). There was the greatest stemflow on the stems of arbor in *P.yunnansis* forest (4.64%),but less than 1% of stemflow in *E.maideni* forest and *A.mearnsii-E.maideni* forest (0.88%, 0.65%)(ANOVA $F_{B–D}$=4.5, n=95, p<0.0001; $F_{C–D}$=1.5, n=95, p<0.001, $F_{B–C}$=3.8, n=95, p<0.0001). For throughfall, there were high value in *E.maideni* and *P.yunnansis* forests (67.56%,69.25%), only slightly low in *E.maideni-A.mearnsii* forest(64.14%) (p<0.001, $F_{B–D}$=1.91. n=95; $F_{C–D}$=1.26, p<0.005, n=95; $F_{B–C}$=1.1, n=95, p>0.05, not, siginificant). We further found that there was a different canopy hydrological law among three tree species after the moving variance analysis of canopy interception, stemflow, throughfall of them. We assumed that when all leaves and branch of plant were saturated by rain water, canopy interception and stemflow would trend to zero and throughfall would equal to precipitation. After observation, we verified the assumption that there was a maximum of canopy interception. Canopy interception of *P.yunnanasis* was up to the maximum when precipitation increased to 70 mm, and the variogram shows the turning after 70 mm of precipitation. The maximum of the canopy interception of *E.maideni* showed up at about 70 mm precipitation as well. The canopy interception of *A.mearnsii* was the greatest among three species because when precipitation was up to 90mm—95mm,the variogram just turned. For stemflow, the assumption that there was a maximum of stemflow was not verified. Perhaps all rains in the period did not include the precipitation of the maximum of stemflow. The variance of the stemflow of *P.yunnanensis* varied greatlier than that of *E.maideni* and *A.mearsi*i,and there was generally a trend that the variance of stemflow of three tree species increased endlessly with the increasing of precipitation.The variances of throughfall varied greatest for *A.mearnsii*, intermediate for *E.maideni*, and least for *P.yunnanensii*. Overall, moving variogram of interception appeared “S” type and that of stemflow and throughfall did “J” type.

The soil surface runoff modulus of contrast, *P.yunnanesis* forest, *E.maideni* and *E.maideni-A.mearnsii* forest differed most significantly among all forest recovery variables (ANOVA $F_{A–B}$=5.4, n=62, p<0.00001; $F_{A–C}$=6.3, n=62, p<0.0001; $F_{A–D}$=11.88, n=62, p<0.00001; $F_{B–D}$=2.22, n=62, p<0.00011; $F_{C–D}$=1.87, n=62, p<0.0022; not significant between B and C).The different significance between contrast and manmade forest was higher than the one between manmade forests. The runoff modules of contrast,*P.yunnanensis* forest,*E.maideni* and *E.maideni-A.mearnsii* forest were respectively 333 114 $m^3 \cdot km^{-2} \cdot a^{-1}$, 63 463 $m^3 \cdot km^{-2} \cdot a^{-1}$, 84 562 $m^3 \cdot km^{-2} \cdot a^{-1}$, 159 671 $m^3 \cdot km^{-2} \cdot a^{-1}$. Overall, the runoff modules of contrast was 4—5 times more than that of manmade forests.

3.2 Transect

Plant diversity showed to certain extent difference among the contrast, *P.yunnanensis* forest, *E.miaidensii* forest, and *A.mearnsii-E.miaidensii* forest. The development of the species diversity as a whole could be considered quite quick compared with the zonal climax community, considering the fact that the man-made forests grew only for ten years. *P.yunnansis* forest had the most species (total,38). *E.maideni-A.mearnsii* forest and *E.maideni* forest had the similar number of species (total,24, 27 respectively). The contrast had the least species (total 17). The number of species wa Shanon-Wienner index was lowest in contrast (1.36), highest in *P.yunnanensis* and *E.maidenii-A.mearnsii* forests (1.92,1.89 respectively) and intermediate in *E.maideni* forest(1.82)(Figure 1 a).For community evenness, manmade forests were more even than the contrast(community evenness indices of the contrast, *E.maideni, P.yunnanensis, A.mearnsii-E.maideni* forests: 1.26,2.16,1.96,2.06 respectively),which was because in manmade forests there were not fairly dominant species(Figure 1 d). The explanation was verified by the data of ecological dominance of different forests (Figure 1 c). Ecological dominance of community was highest in contrast (0.11), lowest in *P.yuannensis* forest and *E.maidenii* forests (0.06 equally), and intermediate in *E.naidenii-A.mearnsii* forest (0.08). Jaccard index in term of the beta diversity was highest between the contrast and *E.maideni* forest (0.20), the contrast and *P.yunnasis*(0.18), lowest between the contrast and *E.maideni-A.mearnsii* forest(0.11), intermediate between *P.yunnanensis* and *E.maideni* forests(0.15), *P.yunnansis* and *E.maideni-A.mearsi* forests(0.14), *E.maideni* and *E.maideni-A.mearsi* forests(0.16)(Figure 1 b). However, Jaccard indices were all quite low between the experimental materials and the zonal climax community (0.03,0.06,0.06,0.05 respectively) (Figure 1 e). The data suggested that community similarity was high between the contrast and *P.yunnanensis* forest, *E.maideni* forest, between the zonal climax community and the manmade forests, but fairly low between the zonal climax community and the contrast restored naturally. There was statistically a significant difference on the mean value of coverage of arbor and herbage layer, litters, timber volume of woody plant and herbage biomass between manmade forests and the contrast except for few pairs. The mean coverage of arbor layers was highest in *E.maidenii-A.mearnsii* forest. The mean coverage of herbage layers was highest in contrast. *P.yunnansis* forest had the most litters and contrast had the lowest ones. The mean timber volume of woody plant was highest in *E.maideni-A.mearnsii.* In three forests and contrast, the highest biomass of herbage was of contrast, and the lowest was of *E.maideni-A.mearnsii.* The recovery variables of soil system differed as well among the contrast, *P.yunnanesis* forest,*E.maideni* and *E.maideni-A.mearnsii* forest except for the minority of pairs of the variables. For soil chemical property, organic matter, pH, total N, and available K, of soil were more significantly different than other variables among the experimental materials. The different significance was lowest for total P and available P, of soil and intermediate for available N, total K, of soil. The different significance between

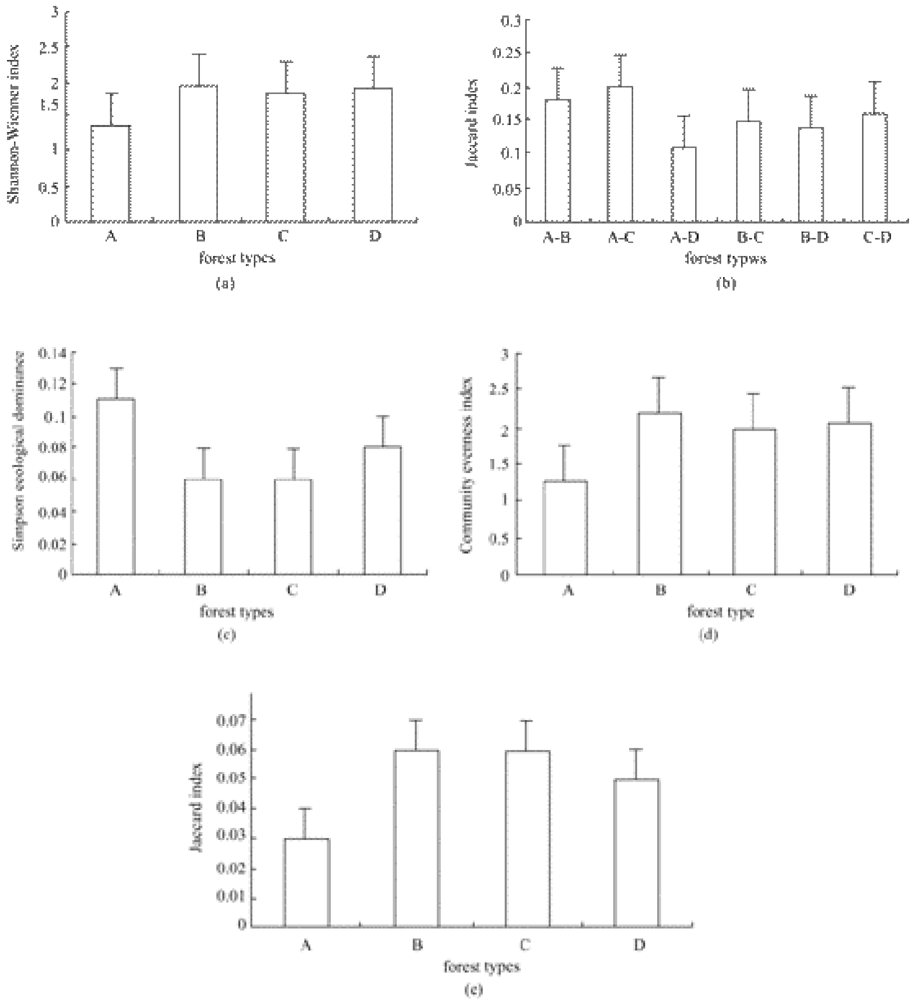

Fig. 1 Alpha diversity and Jaccard index in term of the beta diversity. In figure, A=the contrast, B=*P.yunnanensis* forest, C=*E.miaidensii* forest, D = *A.mearnsii-E.miaidensii* forest and the letters in following figures and tables represents the same experimental forests as the Figure. (a) Shannon-Wiener index of a,b,c,d. (b) Jaccard index among A,B,C,D; (c) Ecological dominance of community of A,B,C,D; (d) Community evenness index of A,B,C,D; (e) Jaccard index between A,B,C,D and the zonal climax community.

the contrast and the manmade forests was highest with all recovery variables, which demonstrated that manmade forest acted markedly on the forest soil. The difference of soil physical property was also obvious among the experimental materials except for the fairly minority of pairs of the variables. The finding indicates that the manmade forests made the gradient recovery effects of soil system.

3.3 Correlation structure

The correlation among the forest recovery variables was fairly high in that the correlation coefficient of the majority of pairs of recovery variables was more than 0.5(Table 1). This showed that there were quantitatively some natural connections among manmade forests about plant diversity, forest hydrological characteristics, surface runoff and soil erosion, soil property and forest characteristics. Among all recovery variables, there were the tightest relationship.

Among community evenness, Shannon-Wiener index, Jaccard index, ecological dominance, soil surface runoff and erosion, canopy interception, organic matter, available N, available P, minimum water-holding capacity, of soil, woody plant layer coverage, bio-mass of herbage (correlation coefficient> ±0.8, Table 1).

4 Discussion

4.1 Forest hydrological characteristics

With canopy hydrology, there were significant difference among tree species, manmade forests, because of the different biological characteristics and forest structures. We found that *A.maideni* can grow much of branch and leaves and there are many layers of branch in its canopy, which form heavy and great canopy. Its leaves are very small and the distance between small leaves is short. There is the down on the small leaves. Moreover, there is high coverage of arbor layer due to *A.mearnsii* growing many layers of branch and leaves in *E.maisensii*-*A.mearnsii* forest, and leaves are often under the small opening of the upper layers of canopy. These structures are in favor of canopy intercepting greatly and decrease throughfall. There are a large angle between small leaves and compound petiole, compound leaves and small branch, branch and stem, and it is difficult for intercepted rain drop to move from small leaves to compound petiole, compound petiole to small branch, small branch to stem. So, less stemflow of *A.mearnsii* was collected when it rains. For *P.yunnanensis* and *E.maideni*, there are much larger openings of middle and upper part of canopy and little branch and leaves in the downer part of canopy. The precipitation can not be intercepted repeatedly. There are the cuticles that reject water drop on the leaves of the two tree species, which are in favor against the adsorption of raining drop and it is easy to slide down from leaves. But there are little angles between leaves and branch for *P.yunnanensis*, rain drop move quickly from the tip to the base of leaves with young leaves and flow to the stem as rain drops drop down to touch the tip of leaves. Stemflow happens easily and the supplement of it is quite large. If leaves are old, the tip of leaves aims at the surface of the earth. When it rains, the raining water on the leaves becomes throughfall. So the interception rate of canopy of the two tree species was very low. There were elsewhere similar results for other tree species as well (Jiang Youxu, 1996; Liu Shirong, 1995; Liu Wenyao).Due to the different biological characteristics and forest structures, the three tree species showed unique hydrological laws of canopy when precipitation increased continually basing on the moving variance analysis.

The research indicated also that surface runoff were greatly different among experimental plots, and there was the same case in other manmade forests (Zhou Yu, 1999; Zhou Guoyu, 1995; Max Rietkerk, 2000). It is because there are high interception of rain as being mentioned, species diversity that can give rise into rain interception of many layers of community, much litter, and good soil construction in the forests that surface runoff can be controlled efficiently in forests compared to rare land control. Among the experimental forests, surface runoff control was different else. *E.maideni*-*A.mearnsii* forest and *P.yunnanensis* forest was quite efficient to control of surface runoff because they have more excellent and heterogeneous community construction such as high species richness, heterogeneous form characteristics of branch, leaves, or effect on soil by some physiological function. We found out the evidences that the different introduction of tree species for reforestation changed the species composition and species

Table 1 Correlation matrix between all restoration variables. Correlation values>0.58 (absolute value) are significant with $p< 0.05$; correlation value>0.70 are significant with $p< 0.01$, $n=12$

variables	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	ab	ac	ad	ae
a*	1.00																													
b	1.00	1.00																												
c	−0.90	−0.89	1.00																											
d	0.92	0.92	−1.00	1.00																										
e	−0.98	−0.99	0.86	−0.89	1.00																									
f	−0.95	−0.96	0.85	−0.88	0.98	1.00																								
g	−0.86	−0.87	0.79	−0.81	0.90	0.92	1.00																							
h	0.61	0.57	−0.60	0.58	−0.51	−0.45	−0.41	1.00																						
i	0.89	0.90	−0.81	0.84	−0.86	−0.81	−0.68	0.40	1.00																					
j	0.61	0.56	−0.68	0.66	−0.51	−0.46	−0.44	0.97	0.38	1.00																				
k	0.94	0.94	−0.97	0.99	−0.93	−0.92	−0.84	0.47	0.89	0.53	1.00																			
l	−0.49	−0.44	0.49	−0.47	0.39	0.33	0.31	−0.98	−0.23	−0.97	−0.34	1.00																		
m	0.99	0.99	−0.93	0.95	−0.98	−0.96	−0.87	0.53	0.91	0.55	0.98	−0.40	1.00																	
n	0.78	0.80	−0.48	0.54	−0.82	−0.80	−0.70	0.11	0.77	0.03	0.66	0.02	0.76	1.00																
o	0.97	0.98	−0.81	0.85	−0.98	−0.96	−0.86	0.42	0.91	0.40	0.91	−0.28	0.97	0.90	1.00															
p	−0.85	−0.83	0.94	−0.93	0.79	0.75	0.71	−0.83	−0.69	−0.89	−0.86	0.76	−0.84	−0.33	−0.70	1.00														
q	0.84	0.82	−0.57	0.60	−0.80	−0.74	−0.66	0.74	0.65	0.64	0.60	−0.66	0.75	0.72	0.79	−0.67	1.00													
r	−0.85	−0.85	0.99	−0.99	0.83	0.83	0.77	−0.49	−0.80	−0.59	−0.97	0.38	−0.91	−0.46	−0.79	0.89	−0.46	1.00												
s	−0.15	−0.10	0.20	−0.16	0.05	−0.01	0.01	−0.87	0.09	−0.85	−0.01	0.94	−0.06	0.34	0.07	0.52	−0.41	0.08	1.00											
t	0.65	0.69	−0.61	0.64	−0.71	−0.74	−0.66	−0.19	0.76	−0.14	0.76	0.33	0.73	0.78	0.78	−0.31	0.25	−0.67	0.64	1.00										
u	0.33	0.38	−0.29	0.33	−0.42	−0.47	−0.41	−0.53	0.52	−0.50	0.47	0.65	0.43	0.65	0.52	0.05	−0.04	−0.38	0.88	0.93	1.00									
v	0.32	0.37	−0.34	0.37	−0.41	−0.45	−0.40	−0.52	0.51	−0.46	0.50	0.64	0.43	0.57	0.49	0.01	−0.11	−0.44	0.86	0.93	0.99	1.00								
w	0.59	0.62	−0.68	0.70	−0.64	−0.67	−0.61	−0.17	0.71	−0.07	0.78	0.30	0.69	0.58	0.67	−0.39	0.09	−0.76	0.58	0.96	0.87	0.91	1.00							
x	−0.92	−0.94	0.70	−0.74	0.94	0.92	0.81	−0.36	-0.87	−0.30	−0.82	0.22	−0.91	−0.96	−0.98	0.59	−0.82	0.66	−0.12	−0.75	−0.53	−0.47	−0.60	1.00						
y	0.77	0.77	−0.45	0.49	−0.75	−0.69	−0.61	0.64	0.60	0.51	0.51	−0.56	0.68	0.76	0.77	−0.54	0.99	−0.34	−0.32	0.25	0.00	−0.09	0.05	−0.82	1.00					
z	0.95	0.97	−0.80	0.84	−0.97	−0.95	−0.85	0.36	0.91	0.34	0.91	−0.22	0.96	0.91	1.00	−0.67	0.75	−0.78	0.13	0.81	0.57	0.54	0.71	−0.98	0.73	1.00				
ab	−0.57	−0.54	0.36	−0.37	0.50	0.45	0.38	−0.85	−0.30	−0.76	−0.31	0.85	−0.45	−0.33	−0.45	0.59	−0.87	0.23	0.73	0.19	0.47	0.52	0.30	0.47	−0.84	−0.40	1.00			
ac	0.84	0.81	−0.71	0.72	−0.77	−0.69	−0.59	0.89	0.69	0.82	0.68	−0.80	0.77	0.51	0.73	−0.84	0.90	−0.61	−0.57	0.18	−0.16	−0.18	0.12	−0.70	0.84	0.68	−0.83	1.00		
ad	0.39	0.43	−0.01	0.08	−0.47	−0.46	−0.37	−0.21	0.43	−0.35	0.22	0.31	0.37	0.88	0.58	0.14	0.50	0.01	0.51	0.57	0.60	0.48	0.30	−0.71	0.62	0.60	−0.16	0.18	1.00	
ae	−0.95	−0.96	0.74	−0.79	0.96	0.94	0.83	−0.43	−0.89	−0.38	−0.85	0.29	−0.93	−0.93	−0.99	0.65	−0.84	0.70	−0.05	−0.73	−0.48	−0.43	−0.59	0.99	−0.83	−0.98	0.51	−0.74	−0.65	1.00

* a=Community evenness; b=Shannon-Wiener index; c= Ecological dominance; d= Jaccard index; e=Surface soil erosion; f=Surface runoff; g=Throughfall;h=Stemflow; i=Interception; j=pH;k=Soil organic matter; l=Total P; m=Available P; n=Total N; o=Available N; p=Total K; q=Available K; r=Bulk density; s=Capillary ; t=Non-capillary; u=Total porosity; v=Capillary absorbed water; w=Maximum moisture water; x=Minimum holding water; ySi/V ratio; z=Coverage of woody plant; ab=Coverage of herbage; ac=Litters; ad=Timber of arbor; ae=Biomass of herbage.

diversity of forests in forest recovery, which improve the ecological hydrology of forests. Moreover, the native species for reforestation promoted the plant diversity, like other work (Butterfield,R.P. ,1995). The result may be because of the complex inter-specific relationship, say, there may be high affinity between the native species, and they were easy to co-exist, when the native species invaded forests. The native species could improve habitat for the ecesis of other natives as well. So native species is useful to the realization of runoff control in forest ecosystem. We can call the mechanism as native effect about ecological hydrology.

4.2 Correlation between the factors influencing ecological hydrology of forests

We found that there was the positive relationship between surface run and respectively the factors dealing with plant diversity, soil improvement, bio-mass, forest interception rain, soil capillary, but the negative relationship between ecological dominance, through-fall, bulk density, minimum water-holding capacity, of soil, bio-mass of herbage, and so on (Table 1). For all factors, the factors about soil improvement promoted to form good soil construction, which was useful to the penetration of surface run as well as they ware useful to increase the primary production and bio-mass, based on which interception rain of forests increased. As a result of interception rain increases over land and penetration increases under land, surface run of forest was efficiently controlled. However, the natural plant community is generally not fertilized by man long, which mainly depends on matter cycle of ecosystem and the improvement of plant function group. The matter cycle of ecosystem need many organisms to realize the pass of matter ecosystem needs (Tilman.D., 1996; Naeem, S, 1994; Karieva, P, 1994; Tilman.D., 1994; SariPitkanen, 2000; Jiang Youxu, 1996). So, diversity is the base of matter cycle of ecosystem, soil improvement, which is the key of surface run control at last. In the experimental lands the factors influencing ecological hydrology changed after afforestation and with forest rcovery, but what was paid close attention was which of the factors changed at first in all the factors. We presumed that the diversity among all factors changed in the first place, in that the basis of the change should had been credited with the introduction of the different tree species for forest recovery. This was also the form of diversity increase. Moreover, the forest recovery effects of the different tree species would beget further diversity, as would mean good performance of ecosystem (Tilman. D, 1996; Naeem, S, 1994). Canopy interception would increase as soon as diversity and performance of ecosystem were improved, because which would give rise to the multi-story community structures, a amount of interception matters such as branch, leaves, litters and so on, the base of a large amount of rain intercepted again and again. A large amount of interception was helpful to surface runoff control and this would diminish the loss of nutrient elements and improve the soil system. Therefore, diversity would be located at the pioneer of surface run control of natural ecosystem directly and indirectly like “a fuse” and by which, other factors that promote are “ignited”.

We acknowledge that in our experiment, biomass and coverage of herbage were negatively relative to diversity. It might be evidences that there was difference between forest and prairies (Tilman.D., 1996). In forests, arbor tree species got high biomass, coverage, which made the competition over herbage, and therefore, bio-mass and coverage of herbage were not high. But the great values were some variables like species diversity, litters, interception, related positively to coverage and timber volume of arbor, as formed the negative trend to herbage bio-mass and coverage, even soil erosion, runoff.

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