Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

Construction of Multifunction Forest Management Demonstration Sites

Phase II

ECOLOGICAL MONITORING REPORT for SAMPLE PLOTS in PHASE I

Wang Shusen

December 20, 2016

Contents

1 Aim and significance

The monitoring works were carried out in 2016. The monitoring sites included 72 round sample plots, which include 8 forest types (the young, middle-aged and near-mature *Pinus tabulaeformis* planted forest, the young, middle-aged and near-mature *Larix principis-rupprechtii* planted forest and the middle-aged and near-mature *Betula platyphylla* natural forest), 3 management methods (the conventional management, close-to-natural management and the no treatment) , 3 duplication (at the upper slope, middle slope, lower slope respectively). Then, we studied the plant species diversity under tree layer, the forest carbon storage, the water conservation, the forest recreation and demonstrated the influence of the close-to-natural forest management on them. This study could provide the support for the good forest management decision for the local forestry leaders and the forestry leaders in Chinese warm temperate region.

2. Project area

2.1 Natural condition

(1) Location

The project area is located at the Wangyedian Forest Farm (E118°9′-118°30′, N41°21′-41°39′). The Wangyedian Forest Farm is at the southwest part of the Harqin Banner of the Chifeng city, Inner Monglia. Its northeast is the Wangyefu town, its southwest the Weichang county and the Longhua county, and its southeast Heilihe Forest Farm of Ningcheng county. Its area is 5, 4700 ha.

(2) Geology and topography

Wangyedian Forest Farm belongs to Qilaotu branch of the northern Yan mountain. Its average altitude is 1,300 m and its southwest, whose highest peak is 1,890.6 m, is higher than the northeast. The relative height of Wangyedian Forest Farm is 200-400 m and its slope is between 15°～35°. Its southern part has a gently slope and many narrow gullies and its ridge belong to the plateau-dam land; on the contrary, the northern slope, which is the birthplace of Xibo river, has a steep slope and the broad gullies. On the other hand, the bedrocks of the Wangyedian region are mainly granite and gneiss.

(3) Climate and soil

Wangyedian Forest Farm belongs to the transitional land of the Northern China plain and the Mongolian plateau, and the transitional climate region of the maritime climate to continental climate. Because of mountain raise and forest existence, it has high humidity, because of 49% of the average relative humidity and the plentiful rainfall. According to the records of the local meteorological department, its mean annual precipitation was 520.4 mm, which mainly felt from June to August. Its mean annual temperature was 4.2℃(-31-36℃). Its ≥10℃ accumulated temperature was 2390.6℃. In summary, the period of high rainfall and high temperature was at the same season. Moreover, the annual sunshine hours was long and was up to 2,361.5 hours. Its growing season was short and was about 117 days, and the frost appearance was about at September 9, and the last day was at May14. The soils of Wangyedian Forest Farm is mainly meadow, brown forest soil, rocky soil and alluvial soil.

(4) Forest resource

The total area of the Wangyedian Forest Farm is 24,668.2 ha. Among them, forest land area is 22,397.1 ha, accounting for 90.79% of the total area. The total forest volume is 1.437 million m^3. Forest farm mainly has 12 tree species, for exxample, *Larix principis-rupprechtii*, *Pinus tabulaeformis*, *Betula platyphlla*, *Pinus sylvestris var. mongolica*, *Pinus koraiensis*, *Ulmus pumila*, *Quercus mongolica*, *Betula dahurica*, *Populus davidiana*, *Juglans mandshurica*. Among them, the forest of *Larix principis-rupprechtii* has 4,835.4 ha, 21.61% of the total forest land; the forest of *Pinus tabulaeformis* has 5,906.4 ha, 26.37% of the total forest land; the forest of *Betula platyphlla* has 6,355.0 ha, 28.37% of the total forest land. Shrub lands has 1,057 ha, the main shrub species are *Armeniaca sibirica* and *Corylus heterophylla*.

(5) Plant resource

There were total of 88 families, 326 genera and 627 species of the higher plants at the Wangyedian Forest Farm. , At the wild fungus resources investigation in 2012, the 2 phyla , 4 classes ,12 orders, 41 families, 79 genera, 162 species, were found. Among them, the *Basidiomycota* had 1 class, 8 orders, 35 families, 69 genera, 152 species; and the *Ascomycetes* had 3 classes, 4orders ,6 families, 10 genera, 10 species..

2.2 Social condition

The region of Wangyedian Forest Farm has 18 villages, 33,000 people. It belong to the Harqin Banner and is location of Meilingu town. The S206 road passes through. The total output value of the Wangyedian Forest Farm was 6.65 million yuan in 2012, among them, the timber sales income was 6.03 million yuan. The annual average income was 48,000 yuan per workers.

3 Monitoring Contents

(1) The plant species diversity under trees

According to the characteristic of this project, we set up the quadrats at sample plots and investigated the number of plant species under trees, number of individual of every plant species, plant coverage, and so on. We analyzed the Shannon-Wiener diversity Index, Simpson Dominance Index, the Margalef Richness Index and Pielou Evenness Index of shrubs and herbs. We compared these plant species diversity of different forest types, different forest ages, different forest management methods, and make clear the influence of close-to-natural forest management methods on the plant species diversity.

(2) Forest carbon storage

Without fertilizing, the soil's carbon storage is stable. The change of forest carbon is mainly reflected by the carbon storage of vegetation and ground litter. We investigated the number of tree species, the number of individual and their DBH, then we weighed the shrubs, herbs and litters of every quadrats. According to the related equations, we calculated the carbon storage of the tree layers, shrub layers, herb layers and litter layers. Through comparing these carbon storage of the different forest types, different forest ages, different forest management methods, we make clear the influence of close-to-natural forest management on the forest carbon storage .

(3) Water conservation

Because of the high vegetation coverage, there was not soil and water loss. Therefore, only the water conservation was chiefly monitored in our research. We have monitored the soil capillary porosity, the maximum soil water storage, the Maximum water holding capacity and the water conservation capacity of litter. Through analyzing the water conservation abilities of soil and litter at the different forest type,s forest ages, forest management methods, we demonstrated the influence of forest management method change on the forest water conservation of soil and litter.

(4) Forest recreation

Local tourism economy have developed for the implement of this project. We distributed the questionnaire to tourists randomly and visited local travel agencies in August to November, 2016. We analyzed the visitors' composition, travel times and travel expenses, then calculated the total annual travel expenses in this beautiful forest site.

4 Investigating Methods

4.1 General information about the sample plots and the monitoring works

We had constructed a 466.67 ha close-to-natural demonstration forest in the first phase of this project. The 72 round sample plots had been set up, which include 8 forest types (the young, middle-aged and near-mature *Pinus tabulaeformis* planted forest, the young, middle-aged and near-mature *Larix principis-rupprechtii* planted forest, and the middle-aged and near-mature *Betula platyphylla* natural forest), 3 forest management methods (the conventional management, the close-to-natural management and the no treatment) and 3 duplications. The radius of sample plots was 13.82 m and each plot area was 600 m^2. In these sample plots, all trees has been measured. The target trees and the interfering trees has been marked.

We have finished our field study in August, our experiment in September, our questionnaires at Natinoal days, our data analysis until November, our report at December, 2016.

4.2 Field investigation

(1) Plant investigation

In each tree sample plot, set a rectangle shrub quadrat with the size of 5 × 5 m, and set 1 quadrat with the size of 1×1 m in each shrub quadrat. Recorded the name of the trees, shrubs and herbs and take pictures. Pressed plant specimens and labeled (the collection of plants did not was carried out within the sample plots, and was done at the sites near to the sample plot in order to avoiding affecting the vegetation of the sample plot). As for the tree sample plots, recorded the name, number, DBH and canopy density of trees; and recorded the names, number, heights and coverage of the shrub and herb in the shrub and herb quadrats.

(2) Vegetation investigation

Selected the similar vegetation near to each sample plot, set randomly 3 shrub quadrats with the size of 5 × 5 m, and 3 herbal quadrats of 1m×1 m. Cut the branches and leafs of the shrubs and the herbs and weighed. Took some the branches and leafs as the sample, nearly 500 g for shrub, and 250 g for herb, labeled and weighed, then brought them back to the laboratory.

(3) Litter investigation

We selected the similar vegetation near to each sample plot, and set 3 litter quadrats of 50 × 50 cm. Measured the total depth, the depth of the no decomposed layers, the semi-decomposed layers, collected with gauze and labeled, then weighed.

(4) Soil investigation

Selected the similar vegetation near to each sample plot, dug 3 soil profiles randomly. Trimmed the profiles by soil-trimming knife, took the 2 samples at each 0-10 cm, 10-20 cm and 20-40 cm below ground using the ring-knife methods. Labeled, recorded and weighed.

(5) Survey of Forest Recreation

We have gotten the average annual number of the tourists who visited Wangyedian National Forest Park from local travel agencies. Moreover, 500 questionnaires have been filled by visitors.

4.3 Experiments

After the investigation, we have identified the pressed plant species using the local plant species name list and the Flora of Inner Mongolia for the plant species diversity research. Then placed the samples of branches, leaves and litter into the 65℃ oven for 24 hours. Then weighed them. Then the dry litter samples were immersed into water, then were taken out repeatedly from water after immersed for 0.5, 1, 2, 4, 8, 12 and 24 hours and placed them statically at a dry plate for 15 min until the litter does not drop water, then weighed and put them back again.

Put one of two sets of soil samples into the 105℃ oven for 12 hours , and weighed. Then took off the upper covers of the ring-knife of another set of soil samples, changed the bottom cover with the filter paper and cover with the mesh. Put it into a basin, which contains water at 2-3 mm depth, for 12 hours. Weighed. Then, put them into a basin, Whose contained water surface just reached the top of the ring-knife, for 12 hours. Then added the upper cover. Turned over and weighed. Put into oven at the temperature of 105℃ for 12 hours. Then Weighed.

4.4 Calculation methods

(1) Plant species diversity

Relative coverage = coverage of a species / coverage of all species

Relative height = height of a species / height of all species

Relative abundance = abundance of a species / abundance of all species

Importance value of shrub or herb (P_i) = (relative coverage + relative height + relative abundance) / 3

Margalef richness index： $D = \frac{S-1}{\text{Ln N}}$

Shannon-wiener diversity index： $H' = -\sum_{i=1}^{s} PiLnPi$

Pielou evenness index： $E = H' / LnS$

Simpson dominance index： $P = 1 - \sum_{i=1}^{S} Pi^2$

S - Species number in each sample plot.

N - individual number in each sample plot.

(2) Carbon storage of vegetation and litter

According to the DBH and height of trees, using local Single Entry Volume Table, calculated the tree timber volumes and stock volumes, and then calculated the tree carbon storage based on the wood density, ratio of root and stem, biomass expansion factor and carbon contents of different tree species (Table 1).

Table 1 The parameter of trees for carbon storage

Tree	Equation of stock volume	CF	R	D	BEF
Larix principis-rupprechtii	$y=0.0001x^{2.5317}$	0.521	0.212	0.49	1.416
Pinus tabulaeformis (planted)	$y=0.00009x^{2.5062}$	0.521	0.251	0.36	1.589
Betula platyphlla	$y=0.0001x^{2.4838}$	0.491	0.248	0.541	1.424
Populus davidiana	$y=0.0001x^{2.542}$	0.496	0.227	0.378	1.446
Quercus mongolica	$y=0.0001x^{2.3818}$	0.5	0.292	0.676	1.355
Betula dahurica	$y=0.00009x^{2.5028}$	0.491	0.248	0.541	1.424
Pinus tabulaeformis (natural)	$y=0.0001x^{2.4421}$	0.521	0.251	0.36	1.589

note: y - timber volume, m^3; x - DBH, diameter at breast height, cm; CF - carbon content of a tree species; R - ratio of root and stem; D - wood density of a tree species, t dm m^{-3}; BEF - biomass expansion factor for transforming trunk biomass to above-ground biomass.

CS = V×D×BEF×(1+R) ×CF×44/12

CS - forest carbon storage of a tree species, tCO_2 ha^{-1};

V - timber volume of a tree species, m^3 ha^{-1};

D - wood density of a tree species, t dm m^{-3};

BEF - biomass expansion factor;

R - ratio of root and stem;

CF - carbon content of a tree species.

Based on generally accepted carbon content of shrub, herb and litter (0.47, 0.45 and 0.45) and ratio of root to stem (0.4) , calculated carbon storage of shrub, herb and litter.

(3) Water conservation capacity of litter

$W= (0.85\times R_m-R_o) \times M$

W - water conservation capacity of litter (t/ha);

R_m - maximum water holding capacity (%), which is the water holding rate that litter is soaked for 24h;

R_o - average natural water holding capacity (%), which adopted the average water holding rate of the natural litter of sample plot;

M - litter amount (t/ha).

(4) Water conservation capacity of soil

Soil bulk density:

$dv=m / v$

dv - soil bulk density (g/cm3);

m - weight of dry soil (g);

v - volume of ring-knife (cm3).

Capillary porosity of soil：$P = A/V\times 100$

P - capillary porosity of soil (%);

A - weight of soil in ring-knife (g);

V - volume of ring-knife (cm^3).

Soil maximum water storage：$S = \sum (1000\times h_i\times p_i)$

S - maximum water storage of soil (t/ha);

h_i - soil thickness of the i layer (m);

p_i - maximum water storage of the i layer (t/ha).

(5) Forest recreation benefit

According to the result of statistical data from travel agencies and the filled questionnaires, calculated the annual tourist numbers, average travel expenses, average travel times. Then, figured up the travel expense per year at Wangyedian National Forest Park.

5 Result

5.1 The influence of close-to-natural management on the plant species diversity

5.1.1 Composition of Shrubs and herbs

(1) Composition of Shrubs

According to the results of investigation, 12 shrub species were investigated, which belong to 7 families, 11 genera. Three species among them belonged to *Rosaceae* and *Caprifoliaceae*, accounting for 50% of the total number of species, follows by the *Betulaceae* (2 species), accounting for 16.7%, other families, such as *Leguminosae*, *Saxifragaceae*, *Berberidaceae* and *Araliaceae* (1 species), accounting for 8.3% respectively (Table 2).

Table 2 Shrub species composition

No.	Species	Families	Genera
1	*Spiraea pubescens* Turcz.	*Rosaceae*	*Spiraea*
2	*Rosa davurica* Pall.	*Rosaceae*	*Rosa*
3	*Rubus sachalinensis* Leveille	*Rosaceae*	*Rubus*
4	*Weigela florida* A. DC.	*Caprifoliaceae*	*Weigela*
5	*Abelia biflora* Turcz.	*Caprifoliaceae*	*Abelia*
6	*Lonicera chrysantha* Turcz.	*Caprifoliaceae*	*Lonicera*
7	*Corylus heterophylla* Fisch. ex Trautv.	*Betulaceae*	*Corylus*
8	*Corylus mandshurica* Maxim. et Rupr.	*Betulaceae*	*Corylus*
9	*Lespedeza bicolor* Turcz.	*Leguminosae*	*Lespedeza*
10	*Hydrangea bretschneideri* Dippel	*Saxifragaceae*	*Hydrangea*
11	*Berberis amurensis* Rupr.	*Berberidaceae*	*Berberis*
12	*Eleutherococcus senticosus* Maxim.	*Araliaceae*	*Eleutherococcus*

(2) Composition of herbs

According to the field study in summer, there were 60 herb species, belonging to 24 families, 48 genera. The species of *Compositae* (11 species) accounted for 18.3% of the total number of species; follows by *Rosaceae* (7 species), accounting for 11.7%; *Leguminosae, Violaceae, Ranunculaceae* (5 species), accounting for 25%; *Liliaceae*, *Polygonaceae* (3 species), accounting for 5%; *Cyperaceae*, *Caryophyllaceae*, *Umbelliferae*, *Rubiaceae* (2 species), accounting for 13.3% (Table 3).

Table 3 Herb species composition

No.	Species	Families	Genera
1	*Dendranthema chanetii* Shih	*Compositae*	*Dendranthema*
2	*Artemisia sacrorum* Ledeb.	*Compositae*	*Artemisia*
3	*Artemisia argyi* Levl. et Van.	*Compositae*	*Artemisia*
4	*Saussurea nivea* Turcz.	*Compositae*	*Saussurea*
5	*Heteropappus altaicus* Novopokr	*Asteraceae*	*Heteropappus*
6	*Taraxacum mongolicum* Hand-Mazz.	*Asteraceae*	*Taraxacum*
7	*Bidens parviflora* Willd.	*Asteraceae*	*Bidena*
8	*Picris hieracioides* Linn.	*Asteraceae*	*Picris*
9	*Saussurea Japonica* DC.	*Asteraceae*	*Saussurea*
10	*Saussurea parviflora* DC.	*Asteraceae*	*Saussurea*
11	*Parasenecio hastatus* H. Koyama	*Asteraceae*	*Cacalia*
12	*Sanguisorba officinalis* L.	*Rosaceae*	*Sanguisorba*
13	*Geum aleppicum* Jacq.	*Rosaceae*	*Geum*
14	*Agrimonia pilosa* Ledeb.	*Rosaceae*	*Agrimonia*
15	*Rubus saxatilis* L.	*Rosaceae*	*Rubus*
16	*Potentilla tanacetiflolia* Willd. ex Schlecht.	*Rosaceae*	*Potentilla*
17	*Potentilla simulatrix* Wolf.	*Rosaceae*	*Potentilla*

18	*Filipendula palmata* Maxim.	*Rosaceae*	*Filipendula*
19	*Vicia unijuga* R. Br.	*Leguminosae*	*Vicia*
20	*Vicia amoena* Fisch. ex DC.	*Leguminosae*	*Vicia*
21	*Melilotus suaveolens* Ledeb.	*Leguminosae*	*Melilotus*
22	*Melissitus ruthenica* C. W. Chang.	*Leguminosae*	*Melilotoides*
23	*Trifolium lupinaster* L.	*Leguminosae*	*Trifolium*
24	*Viola dactyloides* Roem. et Schult.	*Violaceae*	*Viola*
25	*Viola variegata* Fisch ex Link.	*Violaceae*	*Viola*
26	*Viola mandshurica* W.Beck.	*Violaceae*	*Viola*
27	*Viola patrinii* DC. ex Ging.	*Violaceae*	*Viola*
28	*Viola acuminata* Ledeb.	*Violaceae*	*Viola*
29	*Ranunculus japonicus* Thunb.	*Ranunculaceae*	*Ranunculus*
30	*Aconitum Wangyedianense* Y. Z. Zhao	*Ranunculaceae*	*Aconitum*
31	*Clematis heracleifolia* DC.	*Ranunculaceae*	*Clematis*
32	*Thalictrum aquilegifolium var.* sibiricum Regel et Tiling	*Ranunculaceae*	*Thalictrum*
33	*Aquilegia viridifolia* Pall.	*Ranunculaceae*	*Aaquilegia*
34	*Polygonatum odoratum* Druce	*Liliaceae*	*Polygonatum*
35	*Veratrum nigrum* L.	*Liliaceae*	*Veratrum*
36	*Maianthemum bifolium* F. W .Schmidt	*Liliaceae*	*Maianthemum*
37	*Plantago asiatica* L.	*Plantaginaceae*	*Plantago*

38	*Rumex acetosa* L.	*Polygonaceae*	*Polygonum*
39	*Polygonum manshuriense* V. Petr. ex Kom.	*Polygonaceae*	*Polygonum*
40	*Carex siderosticta* Hance	*Cyperaceae*	*Carex*
41	*Carex angare* Steud.	*Cyperaceae*	*Carex*
42	*Dianthus chinensis* L.	*Caryophyllaceae*	*Dianthus*
43	*Stellaria discolor* Turcz. ex Fenzl	*Caryophyllaceae*	*Stellaria*
44	*Bupleurum chinense* DC.	*Umbelliferae*	*Bupleurum*
45	*Peucedanum terebinthaceum* Fisch. ex Turcz.	*Umbelliferae*	*Saposhnikovia*
46	*G.boreale* L.	*Rubiaceae*	*Galium*
47	*Galium verum* L.	*Rubiaceae*	*Galium*
48	*Polygonum aviculare* L.	*Polygonaceae*	*Polygonum*
49	*Iris tigridia* Bunge	*Iridaceae*	*Iris*
50	*Leymus chinensis* Tzvel.	*Gramineae*	*Leymus*
51	*Polemonium chinensis* Brand	*Polemoniaceae*	*Polemonium*
52	*Geranium wlassowianum* Fisch. ex Link	*Geraniaceae*	*Geranium*
53	*Phlomis umbrosa* Turcz.	*Labiatae*	*Phlomis*
54	*Equisetum arvense* L.	*Equisetaceae*	*Equisetum*
55	*Sedum aizoon* L.	*Crassulaceae*	*Sedum*
56	*Pteridium aquilinum* var. Latiusculum Underw. ex Heller	*Pteridiaceae*	*Pteridium*

57	*Adenophora borealis* Hong et Y. Z. Zhao	*Campanulaceae*	*Adenophora*
58	*Dioscorea nipponica* Makino	*Dioscoreaceae*	*Dioscorea*
59	*Gentiana macrophylla* Pall.	*Gentianaceae*	*Gentiana*
60	*Valeriana alternifolia* Bunge	*Valerianaceae*	*Valeriana*

5.1.2 The influence on the shrub species diversity

Because shrubs had few species and number, shrubs species diversity indexes were not calculated, only the number of species and the number of their individuals was counted. Because the middle-aged *Pinus tabulaeformis* planted forest has no shrubs, there was no data about it here.

(1) The influence on the shrub species diversity of the young forest.

The table 4 and table 5 show that there were few number of shrub species at the young forests of *Pinus tabulaeformis* planted forest and the *Larix principis-rupprechtii* planted forest. The young *Pinus tabulaeformis* forest of the conventional forest management had *Spiraea pubescens, Rosa davurica* and *Rubus sachalinensis,* and the average individuals was 8.1. There was only *Spiraea pubescens* under the no treatment and the close-to-natural management, and 4.3, 2.0 individuals respectively. Therefore, the shrub species diversity of under the conventional management is greatest. In contrast, the shrub species diversities of the young *Larix principis-rupprechtii* forest under the close-to-natural management and the no treatment were greater than conventional management. The species number and individual number under these three forest managements were 5, 15.6; 4, 15.3; and 1, 6.3 respectively; In a word, there was not any trends that could be gotten form our study about the shrub species diversity of young forest under different forest managements.

Table 4 The shrubs of the young *Pinus tabulaeformis* forest

Management	Species	Number
Close-to-natural	*Spiraea pubescens* Turcz.	2.0
Conventional	*Spiraea pubescens* Turcz.	6.7

	Rosa davurica Pall.	0.7
	Rubus sachalinensis Leveille	0.7
No treatment	*Spiraea pubescens* Turcz.	4.3

Table 5 The shrubs of the young *Larix principis-rupprechtii* forest

Management	Species	Number
Close-to-natural	*Spiraea pubescens* Turcz.	7.3
	Rubus sachalinensis Leveille	6.7
	Lespedeza bicolor Turcz.	1.0
	Corylus heterophylla Fisch. ex Trautv.	0.3
	Weigela florid A.DC.	0.3
Conventional	*Spiraea pubescens* Turcz.	6.3
No treatment	*Spiraea pubescens* Turcz.	13
	Rosa davurica Pall.	0.7
	Lespedeza bicolor Turcz.	0.3
	Corylus heterophylla Fisch. ex Trautv.	1.3

(2) The influence on shrub species diversity of the middle-aged forest

Because the *Pinus tabulaeformis* planted forest has not shrubs, we have only analyzed the shrubs species diversity of the *Larix principis-rupprechtii* planted forest and the *Betula platyphlla* natural forest. Shrubs species number and individual number of the middle-aged *Larix principis-rupprechtii* planted forest under the close-to-natural forest management (3, 72), > those under the conventional forest management (3, 6) > those under the no treatment (2, 3). The shrubs species of the *Betula platyphlla* forest under the close-to-natural forest management (6) > that under the no treatment (5) > that under the conventional management (4), and the number of individuals at the conventional forest management (46) > that under the close-to-natural forest management (31.2) > that under the no treatment (17). In summary, the close-to-natural forest management is possible more beneficial to the shrub species diversity of middle-aged forest (Table 6-7).

Table 6 The shrubs of the middle-aged *Larix principis-rupprechtii* forest

Management	Species	Number
Close-to-natural	*Spiraea pubescens* Turcz.	4.0
	Corylus heterophylla Fisch. Ex Trautv.	1.0
	Corylus mandshurica Maxim. et Rupr.	67
Conventional	*Spiraea pubescens* Turcz.	2.3
	Hydrangea bretschneideri Dippel	1.7
	Corylus heterophylla Fisch. Ex Trautv.	2.0
No treatment	*Spiraea pubescens* Turcz.	2.0
	Corylus heterophylla Fisch. Ex Trautv.	1.0

Table 7 The shrubs of the middle-aged *Betula platyphlla* forest

Management	Species	Number
Close-to-natural	*Spiraea pubescens* Turcz.	7.3
	Hydrangea bretschneideri Dippel	3.7
	Corylus heterophylla Fisch. ex Trautv.	8.3
	Weigela florida A. DC.	8.3
	Abelia biflora Turcz.	3.3
	Lonicera chrysantha Turcz.	0.3
Conventional	*Spiraea pubescens* Turcz.	1
	Hydrangea bretschneideri Dippel	1
	Corylus heterophylla Fisch. ex Trautv.	43.3
	Eleutherococcus senticosus Maxim.	0.7
No treatment	*Hydrangea bretschneideri* Dippel	2
	Corylus heterophylla Fisch. ex Trautv.	10
	Corylus mandshurica Maxim. et Rupr.	4
	Abelia biflora Turcz.	0.3

	Berberis amurensis Rupr.	0.7

(3) The influence on shrub species diversity of the near-mature forest

The table 8-10 show in the near-mature *Pinus tabulaeformis* planted forest, species number under the close-to-natural forest management (3) > that under the conventional forest management (1) and the no treatment (1). Average number of shrubs individual under the conventional management (40) > that under the close-to-natural management (23.3) > that under the no treatment (5.7). In the *Larix principis-rupprechtii* and *Betula platyphlla* forest, species numbers of shrubs under the no treatment (5, 2) > those under the close-to-natural management (4, 1) and the conventional management (4, 1). Average number of shrubs individuals of the *Larix principis-rupprechtii* forest under the conventional management (48.3) > that under the no treatment (32.4) > that under the close-to-natural management (9.7). Average number of shrubs of the *Betula platyphlla* forest under the conventional management (4.6) > that under the close-to-natural management (3.7) > that under the no treatment (3.3). In summary, the conventional management is mostly beneficial to shrub diversity in the near-mature forest.

Table 8 The shrubs of the near-mature *Pinus tabulaeformis* forest

Management	Species	Number
Close -to- nature	*Spiraea pubescens* Turcz.	22
	Lespedeza bicolor Turcz.	1.0
	Hydrangea bretschneideri Dippel	0.3
Conventional	*Spiraea pubescens* Turcz.	40
No treatment	*Spiraea pubescens* Turcz.	5.7

Table 9 Shrubs of the near-mature *Larix principis-rupprechtii* forest

Management	Species	Number
Close- to- nature	*Spiraea pubescens* Turcz.	2.7
	Rubus sachalinensis Leveille	4.3
	Lespedeza bicolor Turcz.	1.0
	Weigela florida A. DC.	1.7
Conventional	*Spiraea pubescens* Turcz.	37.7
	Corylus heterophylla Fisch. ex Trautv.	0.3
	Corylus mandshurica Maxim. et Rupr.	9.3

	Weigela florida A. DC.	1
No treatment	*Spiraea pubescens* Turcz.	18.3
	Rosa davurica Pall.	0.7
	Corylus heterophylla Fisch. ex Trautv.	4.7
	Corylus mandshurica Maxim. et Rupr.	6
	Weigela florida A. DC.	2.7

Table 10 The shrubs of the near-mature *Betula platyphlla* forest

Management	Species	Number
Close- to -nature	*Spiraea pubescens* Turcz.	3.7
Conventional	*Spiraea pubescens* Turcz.	4.3
No treatment	*Spiraea pubescens* Turcz.	3.3
	Corylus heterophylla Fisch. ex Trautv.	0.3

5.1.3 The influence on the herb species diversity

(1) The influence on herb species diversity of young forest

According Fig. 1, Shannon-Wiener indexes, Simpson indexes and Margalef indexes in young *Pinus tabulaeformis* forest under the close-to-natural management (1.94, 0.80, 2.35) > those under the no treatment (1.81, 0.79, 1.73) > those under the conventional management (1.58, 0.73.1.41). Pielou index under the no treatment (0.88) > that under the conventional management (0.85) > that under the close-to-natural forest management (0.83). The close-to-natural forest management could improve herb species diversity, dominance and richness, but the highest species evenness was under the no treatment. The differences of four indexes under different forest managements was not significant (P>0.05).

According Fig. 2, Shannon-Wiener indexes, Margalef indexes in young *Larix principis-rupprechtii* forest under the close-to-natural management (1.89, 1.93) > those under the conventional management (1.81, 1.52)> those under the no treatment (1.60, 1.22), Pielou index under the conventional management (0.85) > that under the no treatment (0.85) > that under the close-to-natural management (0.82). Simpson index under the conventional management (0.79) > that under the close-to-natural management (0.77) > that under the no treatment (0.75). While the differences of four indexes under different forest managements was not significant in statistics (P>0.05).

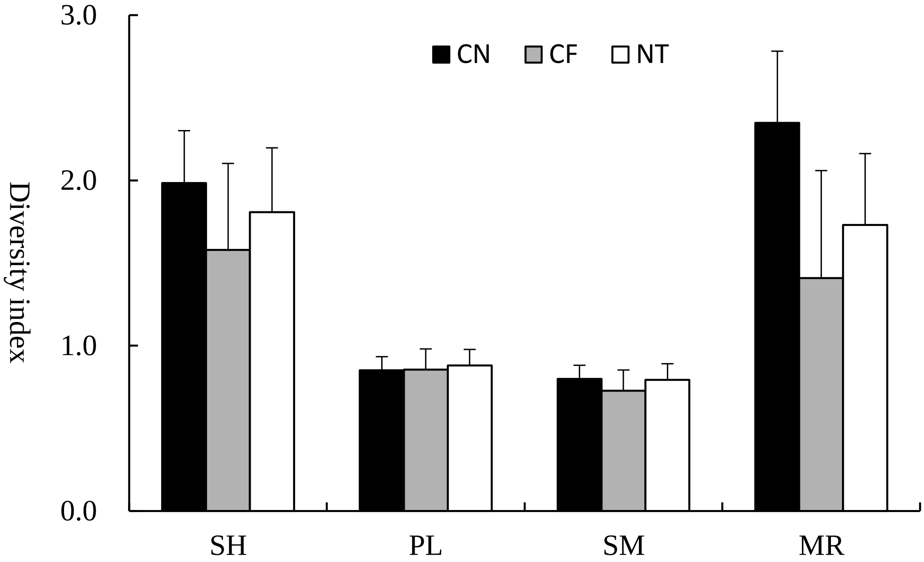

Fig. 1 Herb species diversity of the young *Pinus tabulaeformis* forest

Note: CN is the close-to natural forest management, CF is the conventional forest management, and NT is the no treatment. SH is the Shannon-Wiener index, PL is the Pielou index, SM is the Simpson index and MR is Margalef index.

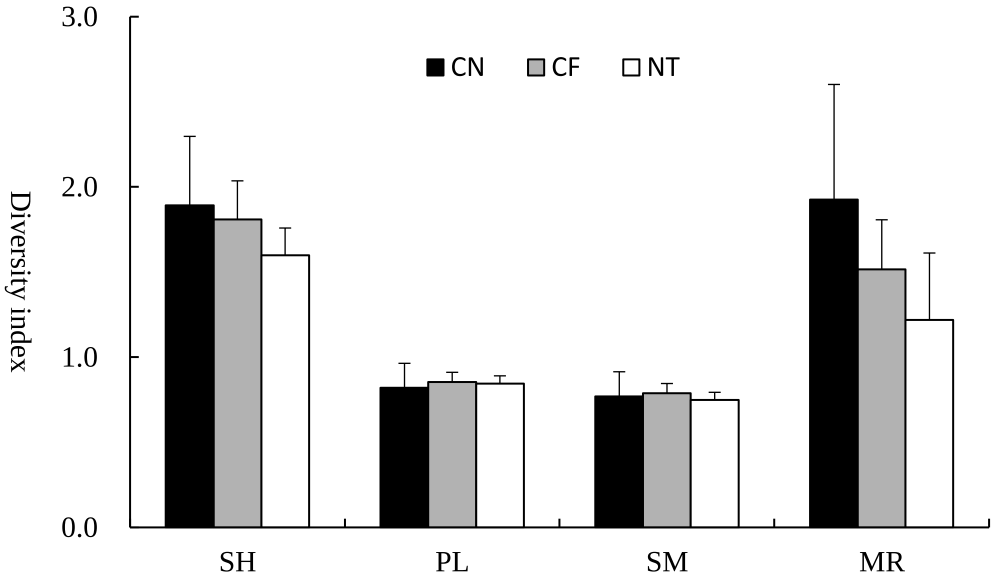

Fig. 2 Herb species diversity of the young *Larix principis-rupprechtii* forest

In summary, the close-to-natural forest management improved the herb species diversity and richness in young forest and decreases their evenness inconspicuous. However, all differences was not significant (P>0.05).

(2) The influence on herb species diversity at the middle-aged forest

According to Fig. 3, Shannon Wiener indexes, Simpson indexes, and Margalef indexes of the middle-aged *Pinus tabulaeformis* planted forest had same trends, these indexes under the close-to-natural management (1.95, 0.81 2.12) > those under the conventional management (1.45, 0.66, 1.33) > those under the no treatment (1.18, 0.57, 0.99). The difference of Shannon-Wiener index under the no treatment and the close-to-natural management was significant in middle-aged *Pinus tabulaeformis* planted forest (P < 0.05).

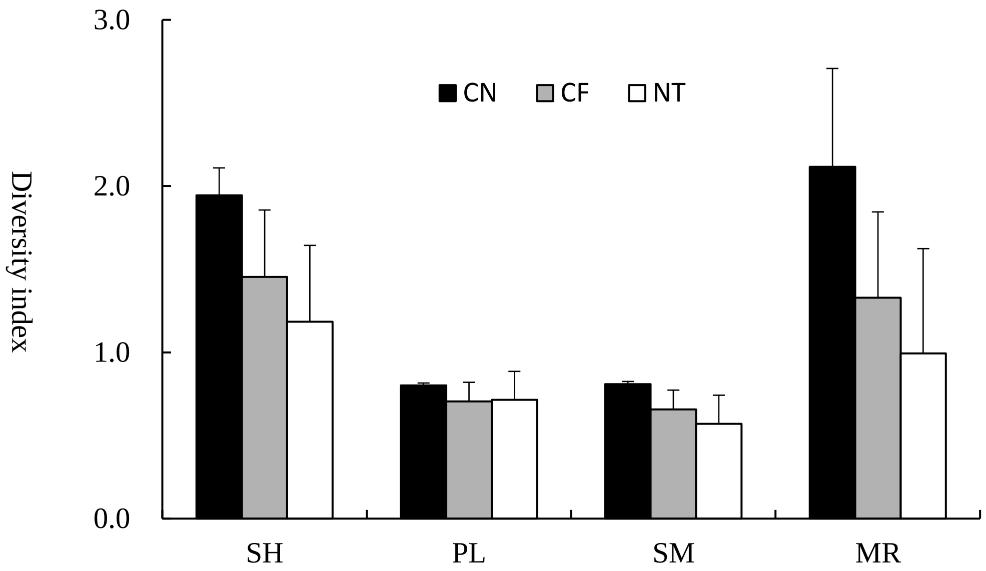

Fig. 3 Herb species diversity of the middle-aged *Pinus tabulaeformis* forest

According to Fig. 4, Shannon-Wiener indexes, Simpson indexes, Margalef indexes of *Larix principis-rupprechtii* planted forest had same trends, these indexes under the close-to-natural management (1.95, 0.80, 2.26) > those under the conventional management (1.90, 0.79, 1.92)> those under the no treatment (1.29, 0.60, 1.37). Pielou evenness index under the conventional management (0.84) > that under close-to-natural management (0.82)> that under the no treatment (0.68). The difference of the Margalef indexes under the no treatment and the close-to-natural management was significant (P > 0.05).

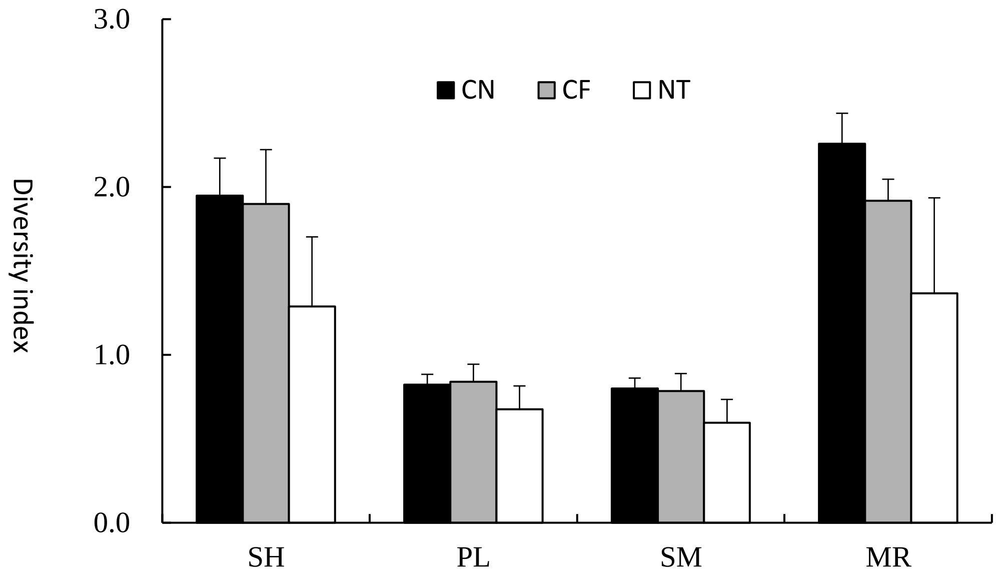

Fig .4 Herb species diversity of the middle-aged *Larix principis-rupprechtii* forest

According to Fig. 5, the order of Shannon-Wiener indexes and Simpson indexes in the *Betula platyphylla natural* forest were: the close-to-natural management (1.91, 0.80) > the conventional management (1.80, 0.78) > the no treatment (1.68, 0.76). The order of Pielou evenness indexes was: the no treatment (0.83) > the close-to-natural management (0.82) > the conventional management (0.82), The order of Margalef richness indexes was the conventional forest management (2.02) > the close-to-natural management (2.00) > the no treatment (1.54), but the difference of indexes was not significantly (P>0.05).

In summary, the close-to-natural forest management often improved the herb species diversity and richness in middle-aged forest.

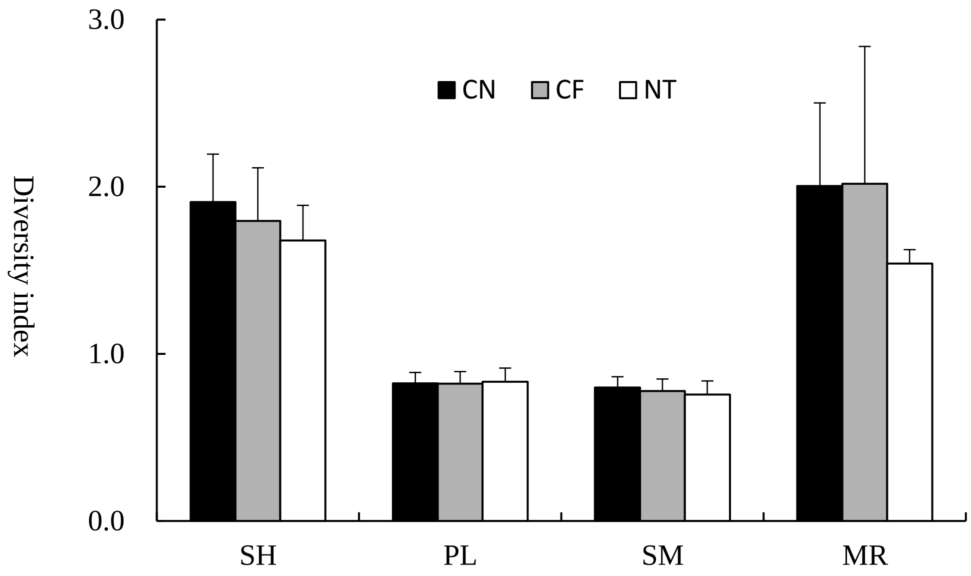

Fig. 5 Herb species diversity of the middle-aged *Betula platyphylla* forest

(3) The influence on the herb species diversity of the near-mature forest

According to Fig. 6, the order of Shannon-Wiener indexes, Margalef indexes, Simpson indexes in *Pinus tabulaeformis* planted forest were: the no treatment (2.09, 0.84, 2.05) > the conventional management (1.98, 0.83, 1.62) > the close-to-natural management (1.64, 0.72, 1.51). The order of Pielou evenness indexes was: the conventional management (0.89) > the no treatment (0.88)> the close-to-natural management (0.78). Shannon-Wiener indexes under the no treatment and close-to-natural forest management had significantly difference (P>0.05).

According to Fig. 7, Shannon-Wiener index and Margalef index in near-mature *Larix principis-rupprechtii planted* forest had different trend: the close-to-natural management (1.74, 1.56) > the conventional management (1.66, 1.38) > the no treatment (1.46, 1.19). the order of Simpson indexes was: the conventional management (0.76) > the close-to-natural management (0.75) > the no treatment (0.72). The order of Pielou evenness indexes was: the no treatment (0.87) > the close-to-natural management (0.83) > the conventional management (0.80), but any indexes had no significantly difference (P>0.05).

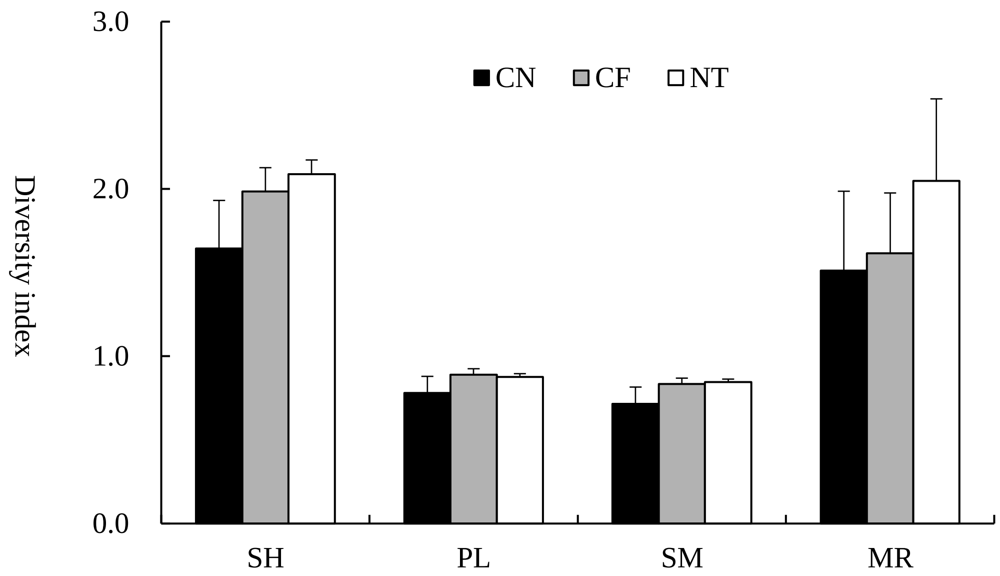

Fig. 6 Herb species diversity of the near-mature *Pinus tabulaeformis* forest

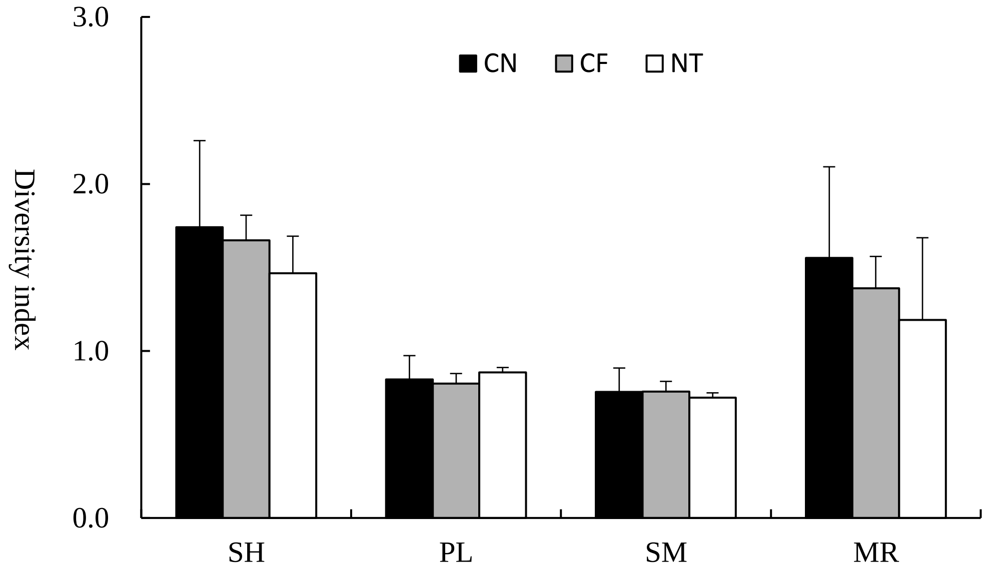

Fig.7 Herb species diversity of the near-mature *Larix rincipis-rupprechtii* forest

According to Fig. 8, the order of Shannon-Wiener indexes in near-mature *Betula platyphylla natural fores*t was: the close-to-natural management (1.66) > the no treatment (1.50)> the conventional management (1.31). The order of Margalef richness indexes was: the close-to-natural management (1.98) > the conventional management (1.12) > the no treatment (1.04). The order of Pielou evenness indexes was: the no treatment (0.94) > the conventional management (0.78) > the close-to-natural management (0.73). The order of Simpson indexes was: the no treatment (0.76) > the close-to-natural management (0.69) > the conventional management (0.64). The difference of Pielou evenness index between the no treatment and close-to-natural management, the conventional management was significant ($P<0.05$).

In summary, the closr-to-natural forest management increased herb species diversity and richness in near-mature forest.

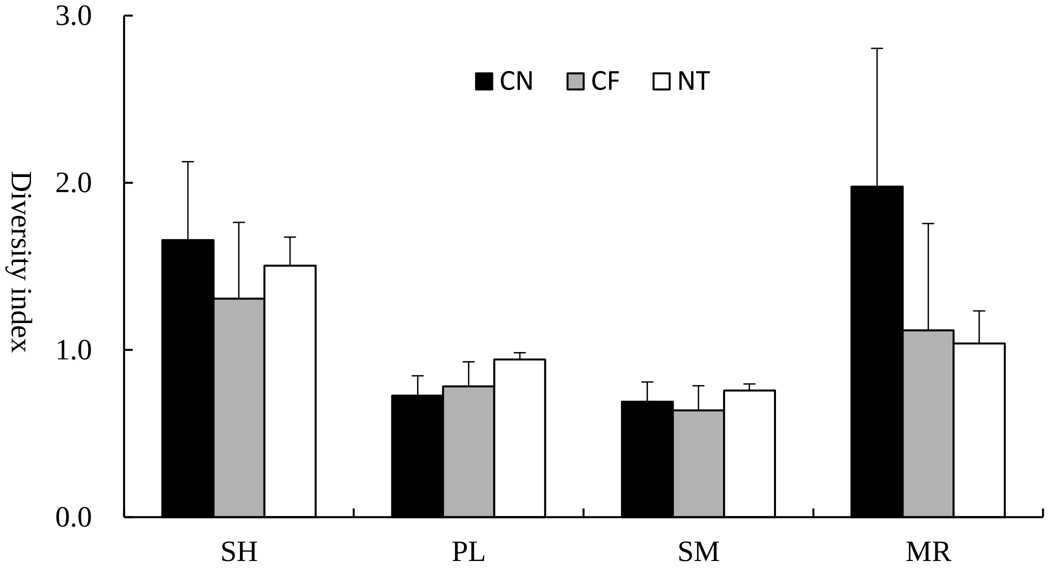

Fig.8 Herb species diversity of the near-mature *Betula platyphylla* forest

5.1.4 Summary

According to analysis of shrubs and herb species diversity of the *Pinus tabulaeformis* planted forest, *Larix principis-rupprechtii* planted forest, and *Betula platyphylla* natural forest, the results are as follow.

General speaking, the close-to-natural forest management could increase herb species diversity and richness in three forests, but, in the statistics, the difference mostly was not significant.

As for shrub species diversity, the close-to-natural forest management could increase shrub species number and individual number in middle-aged forest, and the conventional forest management was beneficial to shrub species diversity in near-mature forest, while shrub species diversity of the young forest had no obviously trend.

5.2 The influence of the close-to-natural management on the carbon storage

5.2.1The influence on the forest carbon storage of tree layer

According to Fig. 9, the carbon storage of tree layers of the *Pinus tabulaeformis* plantated forest was as follow: the no treatment (166.81 tCO_2 ha^{-1}) > the close-to-natural management (154.34 tCO_2 ha^{-1}) > the conventional management (138.17 tCO_2 ha^{-1}). The carbon storage of tree layers of the middle-aged and near-mature *Pinus tabulaeformis* planted forest under three different managements was as follows: the no treatment (293.42 tCO_2 ha^{-1}, 191.88 tCO_2 ha^{-1}) > the close-to-natural management ((262.14 tCO_2 ha^{-1}, 185.69 tCO_2 ha^{-1}) > the conventional management (227.79 tCO_2 ha^{-1}, 172.95 tCO_2 ha^{-1}). The carbon storage difference of the conventional management and the no treatment were significant ($P<0.05$). The carbon storage of tree layers of the young *Pinus tabulaeformis* forest was as follow: the close-to-natural management (15.19 tCO_2 ha^{-1})> the no treatment (15.13 tCO_2 ha^{-1}) > the conventional management (13.78 tCO_2 ha^{-1}), and the carbon storage difference of these three managements were not significant ($P<0.05$).

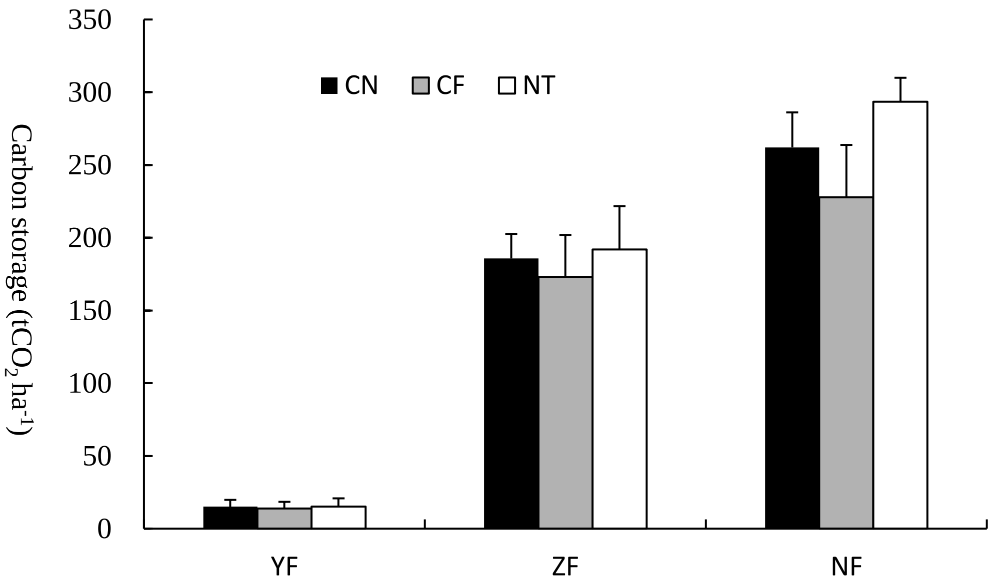

Fig.9 The carbon storage of tree layers of the *Pinus tabulaeformis* forest

Note: YF is the young forest, ZF is the middle-aged forest and NF is the near-mature forest.

According to Fig. 10, the carbon storage of tree layer in *Larix principis-rupprechtii* planted forest has shown: the no treatment (189.24 tCO_2 ha^{-1}) > the close-to-natural management (175.58 tCO_2 ha^{-1}) > the conventional management (166.97 tCO_2 ha^{-1}). In the different forest age, the order of the carbon storage of tree layer in the young, middle-aged and near-mature *Larix principis-rupprechtii planted* was the no treatment (108.44 tCO_2 ha^{-1}, 184.41 tCO_2 ha^{-1}, 274.86 tCO_2 ha^{-1}) > the close-to-natural management (99.92 tCO_2 ha^{-1}, 181.33 tCO_2 ha^{-1}, 245.48 tCO_2 ha^{-1}) > the conventional management (93.75 tCO_2 ha^{-1}, 176.52 tCO_2 ha^{-1}, 230.64 tCO_2 ha^{-1}), and the carbon storage difference of the three managements were not significant (P<0.05).

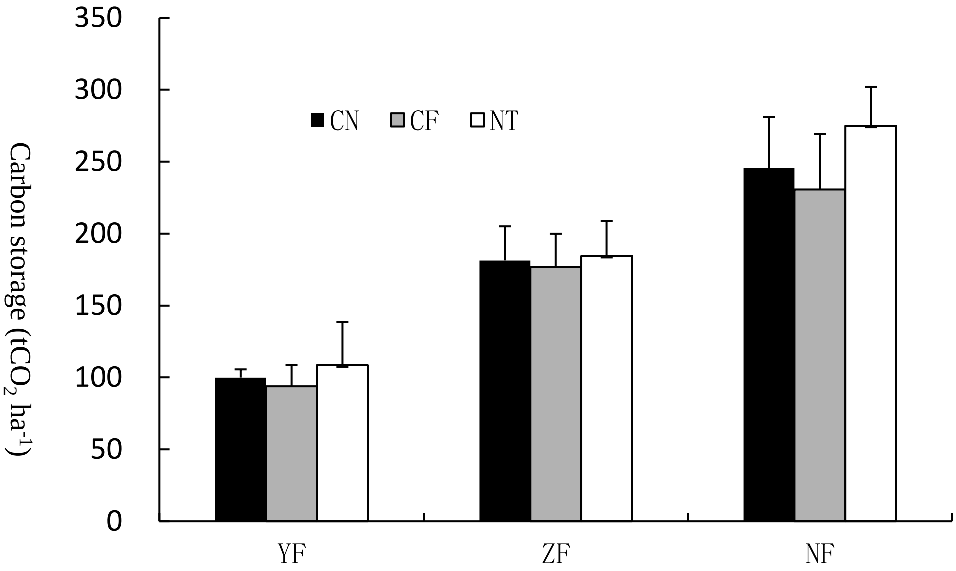

Fig.10 The carbon storage of tree layers of the *Larix principis-rupprechtii* forest

According to Fig. 11, the carbon storage of tree layer of the *Betula platyphylla* natural forest under three different forest managements were as follows: the no treatment (266.16 tCO_2 ha^{-1}) > the close-to-natural management (228.75 tCO_2 ha^{-1}) > the conventional management (181.38 tCO_2 ha^{-1}). In the different forest age, the carbon storage of tree layer in the middle-aged and near-mature was shown: the no treatment (288.03 tCO_2 ha^{-1}, 244.29 tCO_2 ha^{-1}) > the close-to-natural management (226.00 tCO_2 ha^{-1}, 231.50 tCO_2 ha^{-1}) > the conventional management (158.37 tCO_2 ha^{-1}, 204.39 tCO_2 ha^{-1}), The carbon storage difference between the no treatment and the conventional management, the close-to-natural management in middle-aged forest were significant (P<0.05) .

In summary, the order of the trees carbon storage of three forests of different forest age was shown as follow: the no treatment (207.40 tCO_2 ha^{-1}) > the close-to-natural management (186.22 tCO_2 ha^{-1}) > the conventional management (162.18 tCO_2 ha^{-1}).

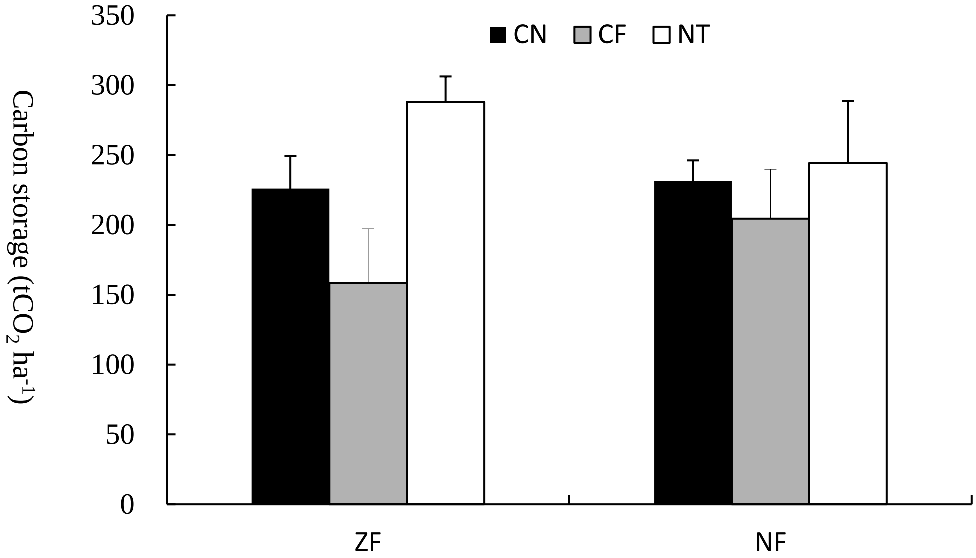

Fig.11 The carbon storage of tree layers of the *Betula platyphylla* natural forest

5.2.2 The influence on the forest carbon storage of shrub layer

According to Fig.12~14, because shrubs under three forests were few and were not regular, carbon storage of shrub layer of three forests in different forest age were not regular.

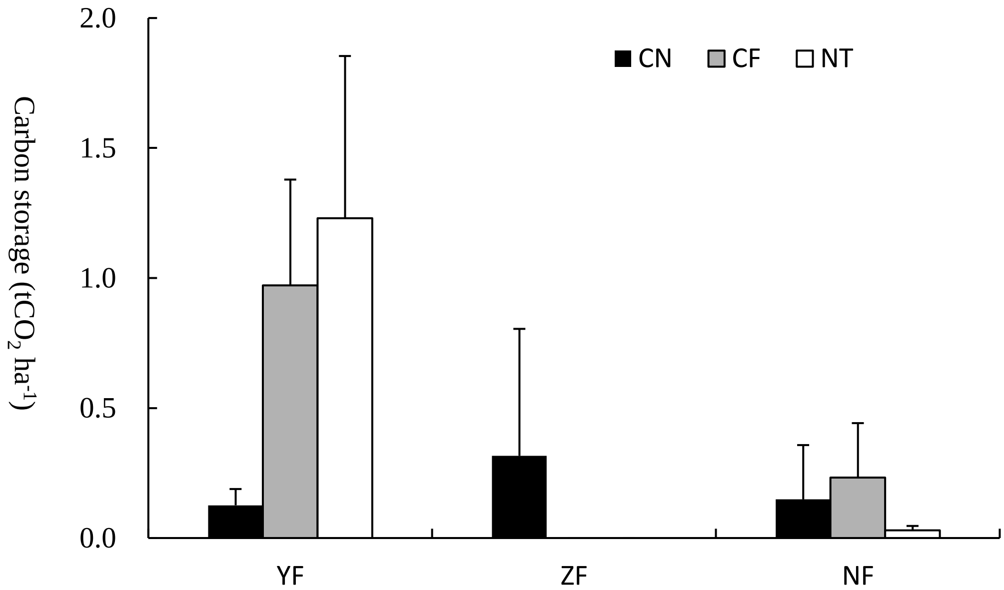

Fig.12 The carbon storage of shrub layers of the *Pinus tabulaeformis* forest

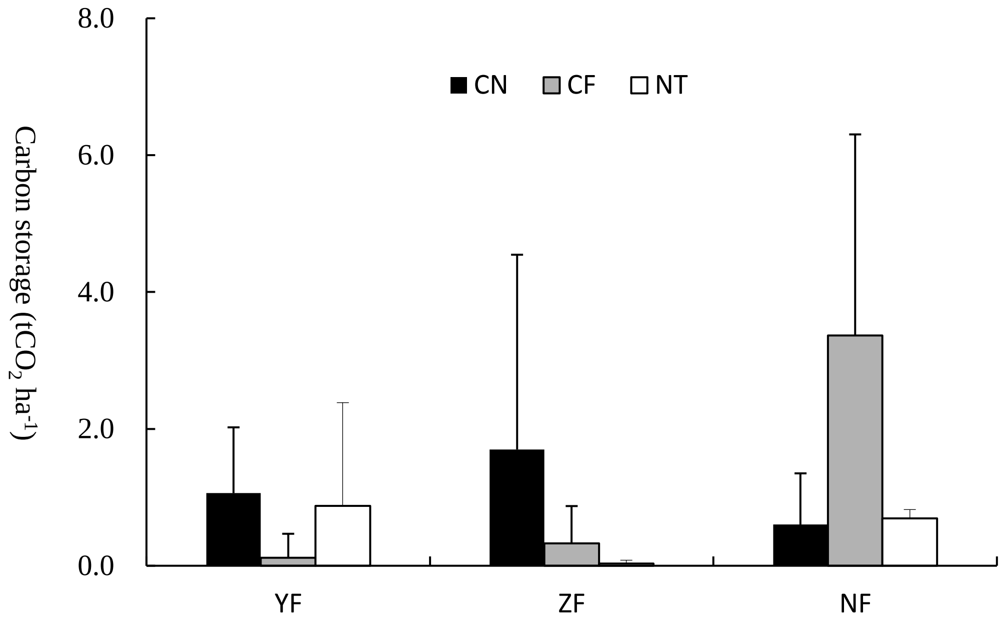

Fig. 13 The carbon storage of shrub layers of the *Larix principis-rupprechtii* forest

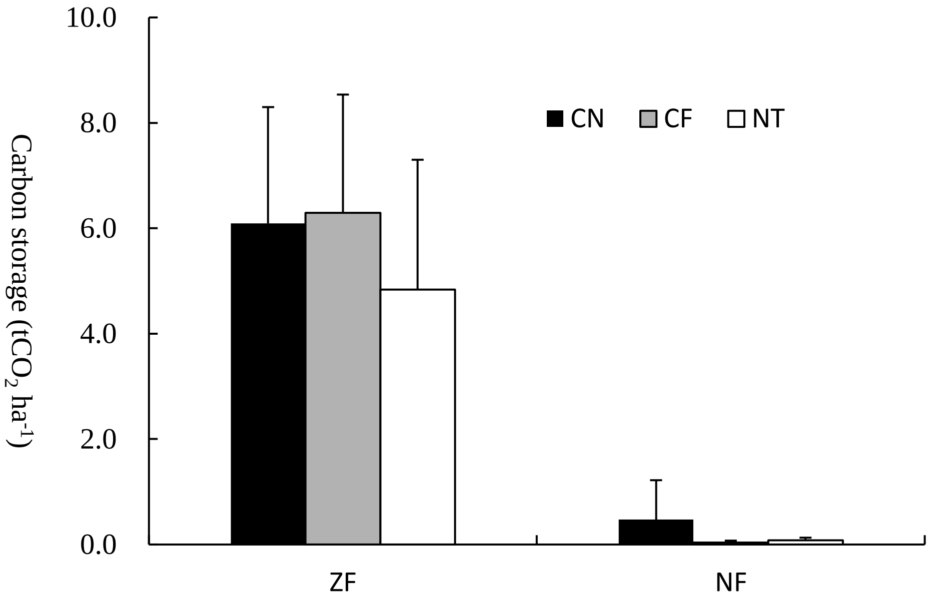

Fig. 14 The carbon storage of shrub layers of the *Betula platyphylla* natural forest

5.2.3 The influence on the forest carbon storage of herb layer

According to Fig. 15, the order of carbon storage of herb layer in middle-aged and near-mature *Pinus tabulaeformis* planed forest was as follow: the close-to-natural management (3.85 tCO_2 ha^{-1}, 1.74 tCO_2 ha^{-1}) > the conventional management (3.24 tCO_2 ha^{-1}, 1.56 tCO_2 ha^{-1}) > the no treatment (0.83 tCO_2 ha^{-1}, 0.58 tCO_2 ha^{-1}), but the order of carbon storage of herb layer in the young *Pinus* *tabulaeformis* planted forest was as follow: the conventional management (0.46 tCO_2 ha^{-1}) > the close-to-natural management (0.38 tCO_2 ha^{-1}) > the no treatment (0.30 tCO_2 ha^{-1}). In a word, the carbon storage of herb layer in the *Pinus tabulaeformis* forest is shown: the close-to-natural management (1.99 tCO_2 ha^{-1}) > the conventional management (1.75 tCO_2 ha^{-1}) > the no treatment (0.57 tCO_2 ha^{-1}), and the carbon storage difference of the three managements were not significant ($P<0.05$).

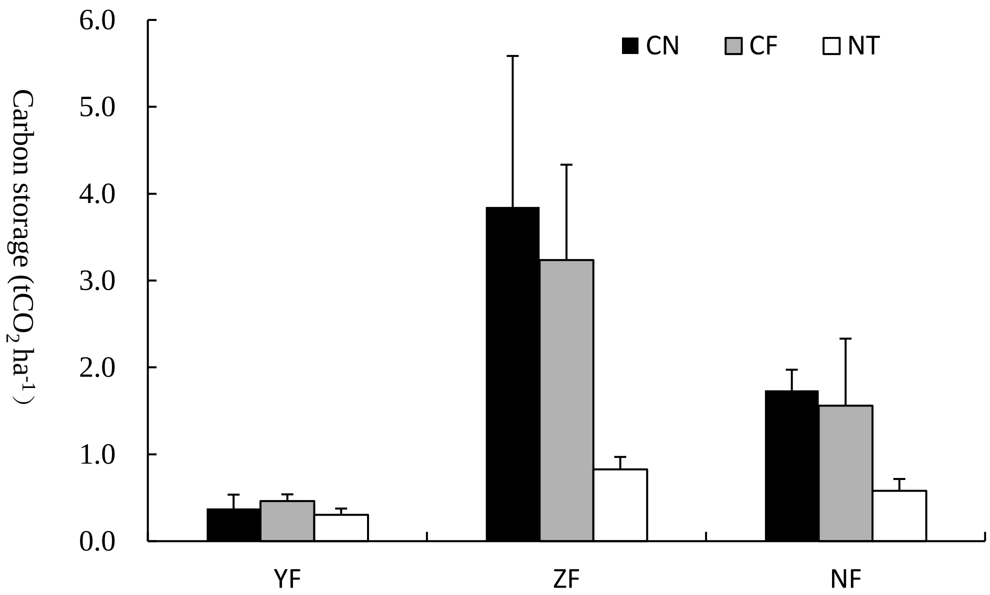

Fig.15 The carbon storage of herb layers of the *Pinus tabulaeformis* forest

According to Fig. 16, the orders of the carbon storage of herb layers in the middle-aged and near-mature *Larix principis-rupprechtii* planted forest were as follow: the close-to-natural management (1.86 tCO_2 ha^{-1}, 3.99 tCO_2 ha^{-1}) > the conventional management (1.26 tCO_2 ha^{-1}, 1.95 tCO_2 ha^{-1}) > the no treatment (0.38 tCO_2 ha^{-1}, 0.18 tCO_2 ha^{-1}). The herb carbon storage in the young *Larix principis-rupprechtii* planted forest was shown: the conventional management (1.19 tCO_2 ha^{-1}) > the close-to-natural management (0.67 tCO_2 ha^{-1}) > the no treatment (0.32 tCO_2 ha^{-1}). In summary, the carbon storage of herb layers of the *Larix principis-rupprechtii* planted forest was shown: the close-to-natural management (2.17 tCO_2 ha^{-1}) > the conventional management (1.47 tCO_2 ha^{-1}) > the no treatment (0.29 tCO_2 ha^{-1}), The carbon storage difference between the no treatment and the close-to-natural management in middle-aged and near-mature forest were significant ($P<0.05$).

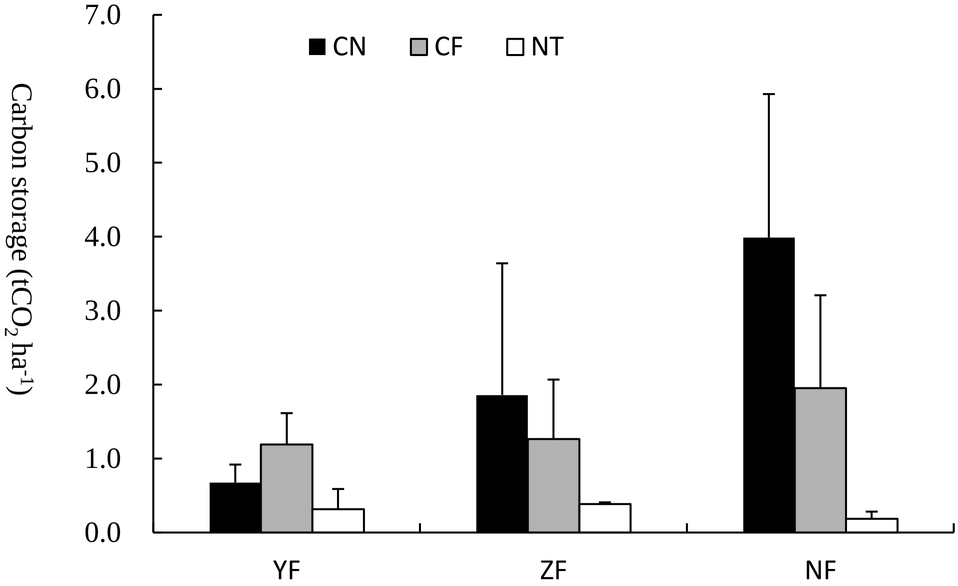

Fig.16 The carbon storage of herb layers of the *Larix principis-rupprechtii* forest

According to Fig. 17, the carbon storage of herb layer in the middle-aged *Betula platyphylla* natural forest was as follow: the close-to-natural management (1.33 tCO_2 ha^{-1}) > the conventional management (1.24 tCO_2 ha^{-1}) > the no treatment (0.67 tCO_2 ha^{-1}). the carbon storage of herb layer in the near-mature *Betula platyphylla* forest was as follow: the close-to-natural management (1.74 tCO_2 ha^{-1}) > the conventional management (1.56 tCO_2 ha^{-1}) > the no treatment (0.58 tCO_2 ha^{-1}). The carbon storage of herb layer in the *Betula platyphylla* natural forest was as follow: the close-to-natural management (1.32 tCO_2 ha^{-1}) > the conventional management (1.10 tCO_2 ha^{-1}) > the no treatment (0.67 tCO_2 ha^{-1}). The carbon storage difference between the no treatment and the close-to-natural management, the conventional management were significant ($P<0.05$).

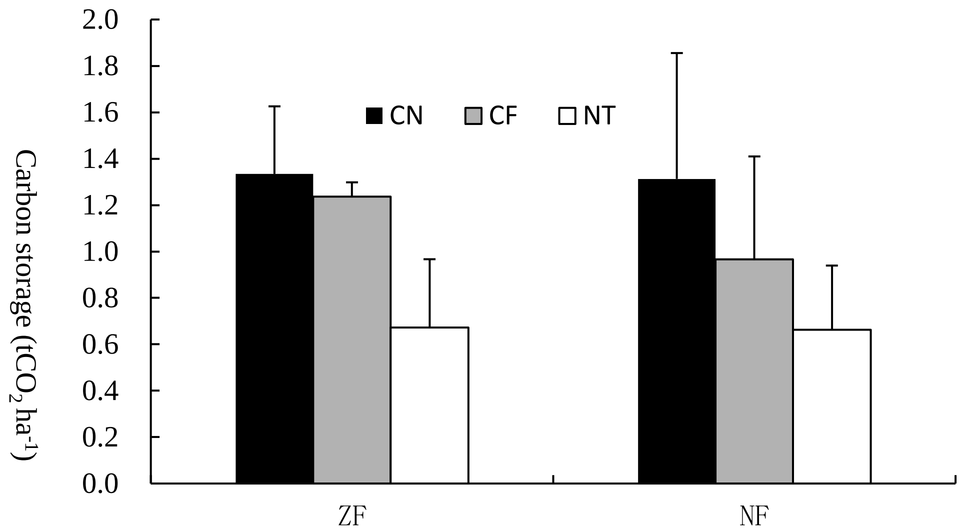

Fig.17 The carbon storage of herb layers of the *Betula platyphylla* natural forest

In summary, the order of carbon storage of herb layers in the *Pinus tabulaeformis* planted forest, the *Larix principis-rupprechtii* planted forest and the *Betula platyphylla* natural forest was as follow: the close-to-natural management (1.84 $tCO_2\ ha^{-1}$) > the conventional management (1.44 $tCO_2\ ha^{-1}$) > the no treatment (0.51 $tCO_2\ ha^{-1}$).

5.2.4 The influence on the forest carbon storage of vegetation layer

On the whole, the order of carbon storage of vegetation layer in the *Pinus tabulaeformis* planted forest was shown as follow: the no treatment (167.80 $tCO_2\ ha^{-1}$) > the close-to-natural management (155.64 $tCO_2\ ha^{-1}$) > the conventional management (140.33 $tCO_2\ ha^{-1}$). The carbon storage of vegetation layer in the young, middle-aged and near-mature *Pinus tabulaeformis* plantated forest were shown: the no treatment (16.66 $tCO_2\ ha^{-1}$, 192.7 $tCO_2\ ha^{-1}$, 294.03 $tCO_2\ ha^{-1}$) > the close-to-natural management (15.69 $tCO_2\ ha^{-1}$, 189.85 $tCO_2\ ha^{-1}$, 264.02 $tCO_2\ ha^{-1}$) > the conventional management (15.21 $tCO_2\ ha^{-1}$, 176.19 $tCO_2\ ha^{-1}$, 229.59 $tCO_2\ ha^{-1}$). The carbon storage difference between the no treatment and the conventional management in middle-aged and near-mature forest were significant ($P<0.05$).

.

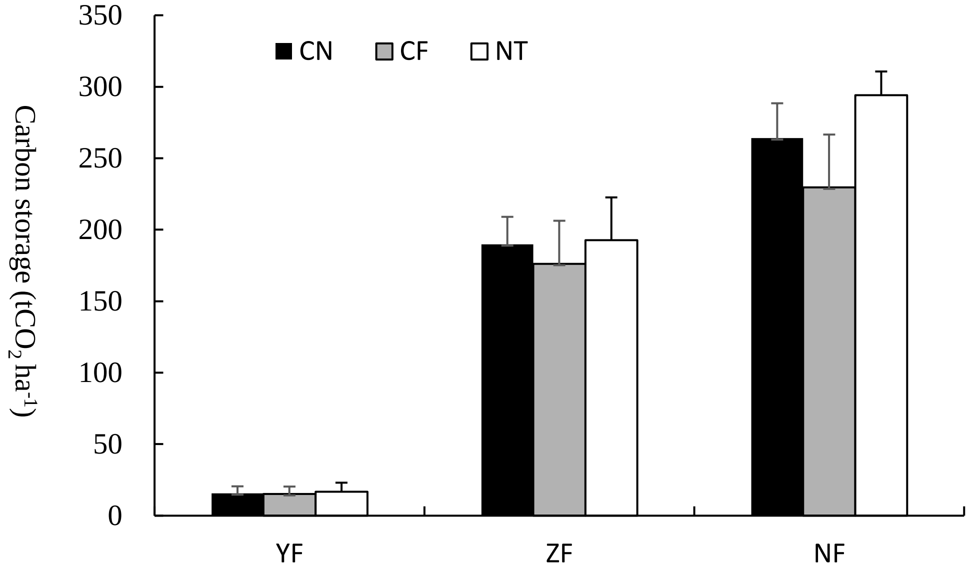

Fig. 18 The vegetation carbon storage of *the Pinus tabulaeformis* forest

According to Fig. 19, the carbon storage of vegetation layer in the young, middle-aged and near-mature *Larix principis-rupprechtii* plantated forest were shown: the no treatment (109.63 tCO_2 ha^{-1}, 184.82 tCO_2 ha^{-1}, 275.74 tCO_2 ha^{-1}) > the close-to-natural management (101.65 tCO_2 ha^{-1}, 184.89 tCO_2 ha^{-1}, 250.07 tCO_2 ha^{-1}) > the conventional management (95.06 tCO_2 ha^{-1}, 178.11 tCO_2 ha^{-1}, 235.96 tCO_2 ha^{-1}). On the whole, the order of carbon storages of vegetation layer was shown as follow: the no treatment (190.06tCO_2 ha^{-1}) > the close-to-natural management (178.587tCO_2 ha^{-1}）) > the conventional management (169.71tCO_2 ha^{-1}). and the carbon storage difference of the three managements were not significant ($P<0.05$).

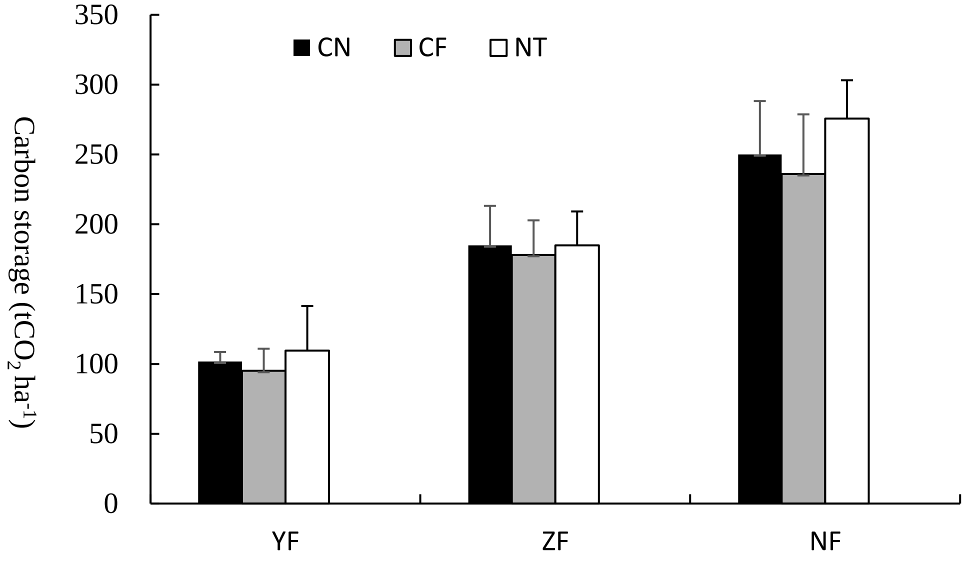

Fig. 19 The vegetation carbon storage of the *Larix principis-rupprechtii* forest

According to Fig. 20, the carbon storage of vegetation layer in the middle-aged and near-mature *Betula platyphylla* natural forest were shown: the no treatment (293.54 tCO_2 ha^{-1}, 245.03 tCO_2 ha^{-1}) > the close-to-natural management (233.44 tCO_2 ha^{-1}, 233.29 tCO_2 ha^{-1}) > the conventional management (165.90 tCO_2 ha^{-1}, 205.40 tCO_2 ha^{-1}). In general, the carbon storage vegetation layers in the *Betula platyphylla* natural forest were shown: the no treatment (269.28 tCO_2 ha^{-1}) > the close-to-natural management (231.36 tCO_2 ha^{-1}) > the conventional management (185.65 tCO_2 ha^{-1}). The carbon storage difference between the no treatment and the close-to-natural management, the conventional management in middle-aged forest were significant ($P<0.05$).

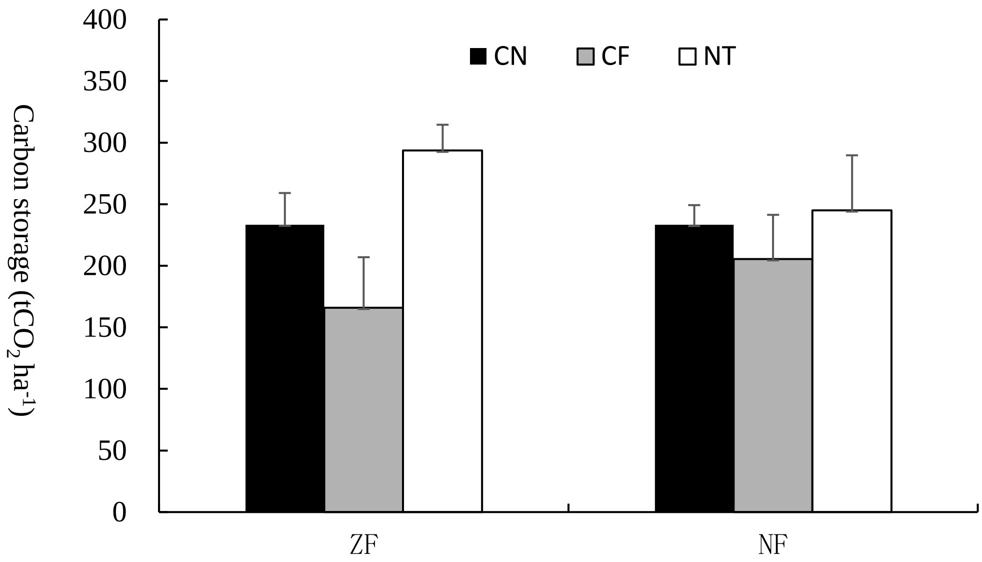

Fig. 20 The vegetation carbon storage of the *Betula platyphylla* natural forest

In summary, the carbon storage of vegetation layers in the *Pinus tabulaeformis* planted forest, *Larix principis-rupprechtii* planted forest and *Betula platyphylla* natural forest were shown: the no treatment (209.05 tCO_2 ha^{-1}) > the close-to-natural management (189.58 tCO_2 ha^{-1}) > the conventional management (165.23 tCO_2 ha^{-1}).

5.2.5 The influence on the forest carbon storage of the ground litter layer

According to Fig. 21, the carbon storage of the ground litter layer under the no treatment and close-to-natural management (4.51 tCO_2 ha^{-1}, 3.38 tCO_2 ha^{-1}) are more than the conventional management (3.26 tCO_2 ha^{-1}) in the young *Pinus tabulaeformis* planted forest. The ground litters carbon storage of the middle-aged *Pinus tabulaeformis* planted forest were shown: the no treatment (5.42 tCO_2 ha^{-1}) > the close-to-natural management (4.66 tCO_2 ha^{-1}) > the conventional management (4.62 tCO_2 ha^{-1}). The carbon storage of ground litters layer of the near-mature forest were as follow: the no treatment (7.84 tCO_2 ha^{-1}) > the close-to-natural management (7,79 tCO_2 ha^{-1}) > the conventional management (5.69 tCO_2 ha^{-1}). On the whole, the ground litters carbon storage of the *Pinus tabulaeformis* planted forest was shown: the no treatment (4.93 tCO_2 ha^{-1}) > the close-to-natural management (5.26 tCO_2 ha^{-1}) > the conventional management (4.52 tCO_2 ha^{-1}), and the carbon storage differences of the three managements were not significant ($P<0.05$).

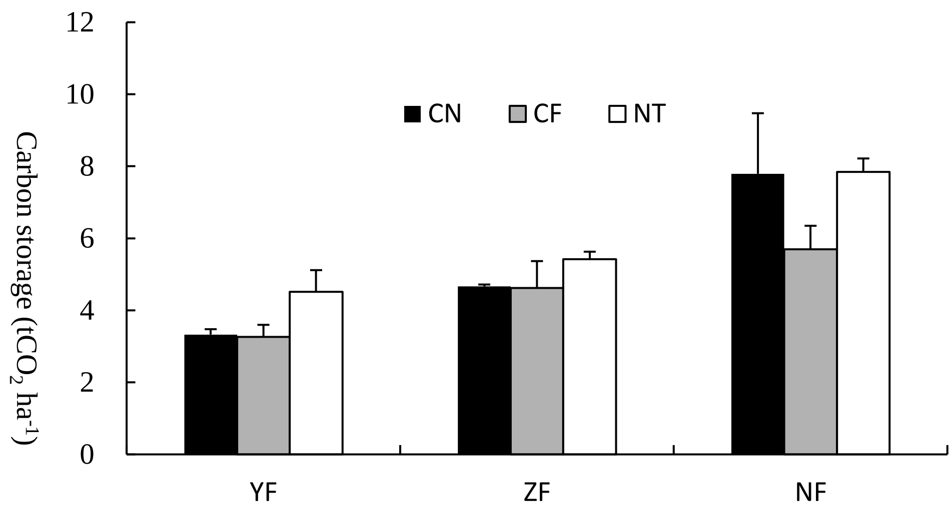

Fig. 21 The ground litter carbon storage of the *Pinus tabulaeformis* forest

According to Fig. 22, the carbon storage of ground litter layer in the young *Larix principis-rupprechtii* planted forest were as follow: the no treatment (4.20 tCO_2 ha^{-1}) > the close-to-natural management (3.64 tCO_2 ha^{-1}) > the conventional management (3.04 tCO_2 ha^{-1}), the carbon storage of ground litter layer in the middle-aged forest were shown: the no treatment (5.34 tCO_2 ha^{-1}) > the close-to-natural management (5.31 tCO_2 ha^{-1}) > the conventional management (4.63 tCO_2 ha^{-1}), the carbon storage of ground litter layer in the near-mature forest were as follow: the no treatment (7.14 tCO_2 ha^{-1}) > the close-to-natural management (5.42 tCO_2 ha^{-1}) > the conventional management (5.16 tCO_2 ha^{-1}), On the whole, the carbon storage of ground litter layer in the *Larix principis-rupprechtii* planted forest were shown: the no treatment (5.56 tCO_2 ha^{-1}) > the close-to-natural management (4.79 tCO_2 ha^{-1}) > the conventional management (4.28 tCO_2 ha^{-1}), and the carbon storage differences of the three managements were not significant ($P<0.05$).

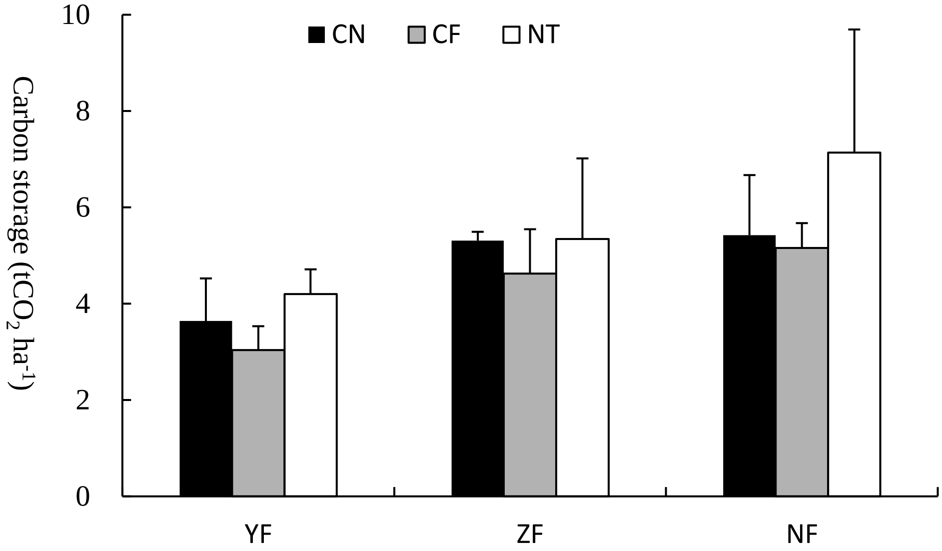

Fig. 22 The ground litter carbon storage of the *Larix principis-rupprechtii* forest

According to Fig. 23, the carbon storage of ground litter layer in the middle-aged *Betula platyphylla* natural forest were shown: the close-to-natural management (3.83 $tCO_2\ ha^{-1}$) > the no treatment (3.26 $tCO_2\ ha^{-1}$) > the conventional management (3.06 $tCO_2\ ha^{-1}$). The carbon storage of ground litter layer in the near-mature forest were shown: the no treatment (6.27 $tCO_2\ ha^{-1}$) > the close-to-natural management (4.16 $tCO_2\ ha^{-1}$) >the conventional management (3.42 $tCO_2\ ha^{-1}$). In general, the carbon storage of ground litter layer in the *Betula platyphylla* natural forest were as follow: the no treatment (4.77 $tCO_2\ ha^{-1}$) > the close-to-natural management (3.99 $tCO_2\ ha^{-1}$) > the conventional management (3.24 $tCO_2\ ha^{-1}$). The carbon storage difference between the no treatment and the conventional management in near-mature forest were significant ($P<0.05$).

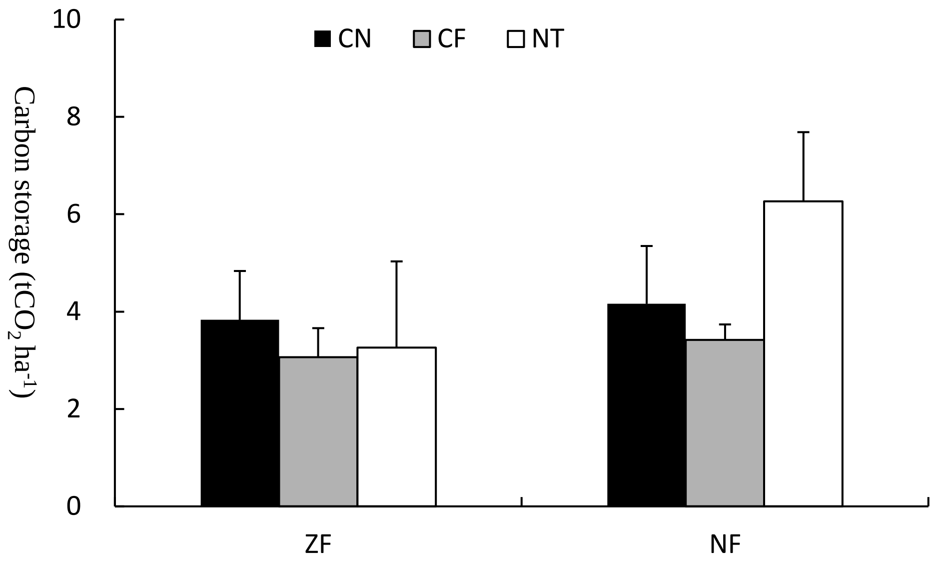

Fig. 23 The ground litter carbon storage of the *Betula platyphylla* natural forest

In summary, the carbon storage of the ground litter layer in the *Pinus tabulaeformis* planted forest, *Larix principis-rupprechtii* planted forest and *Betula platyphylla* natural forest were as follow: the no treatment (5.42 tCO_2 ha^{-1}) > the close-to-natural forest management (4.68 tCO_2 ha^{-1}) > the conventional forest management (4.01 tCO_2 ha^{-1}).

5.2.6 Summary

Through the study of the influence of close-to-natural forest management on forest carbon, the conclusion are as follow.

(1) The order of carbon storage of tree layer was as follow: the no treatment (207.40 tCO_2 ha^{-1}) > the close-to-natural forest management (186.22 tCO_2 ha^{-1}) > the conventional forest management (162.18 tCO_2 ha^{-1}). The change of carbon storage of tree layer is in opposite direction with forest cutting intensity.

(2) The change of carbon storage of shrub layer in three forest types was not regular, because of few species and low densities of shrubs.

(3) The carbon storage of herb layers were shown: the close-to-natural forest management (1.83 tCO_2 ha^{-1}) > the conventional forest management (1.44 tCO_2 ha^{-1}) > the no treatment (0.51 tCO_2 ha^{-1}). The close-to-natural forest management was beneficial to the carbon storage of herb layers.

(4) The carbon storage of vegetation layers were shown: the no treatment (209.05 tCO_2 ha^{-1}) > the close-to-natural forest management (189.58 tCO_2 ha^{-1}) > the

conventional forest management (165.23 tCO_2 ha^{-1}). The trend of carbon storage of vegetation layer is similar with that of tree layer.

(5) The carbon storage of ground litter layers were as follow: the no treatment (5.42 tCO_2 ha^{-1}) > the close-to-natural forest management (4.68 tCO_2 ha^{-1}) > the conventional forest management(4.01 tCO_2 ha^{-1}). More trees meant more carbon storage of ground litter.

5.3 The influence of the close-to-natural management on soil water conservation

5.3.1 The influence on the soil capacity of water conservation

(1) The influence in the *Pinus tabulaeformis* planted forest

According to Fig. 24, the order of soil bulk densities in the *Pinus tabulaeformis* planted forest was: the close-to-natural management (1.27 g/cm^3) < the no treatment (1.30 g/cm^3) < the conventional management (1.34 g/cm^3). The soil bulk densities in the young *Pinus tabulaeformias* planted forest were as follow: the close-to-natural management (1.27g/cm^3) < the no treatment (1.33 g/cm^3) < the conventional management (1.37 g/cm^3). In the middle-aged and near-mature forest, it had same trend that the close-to-natural management (1.37g/cm^3, 1.18 g/cm^3) < the no treatment (1.33 g/cm^3, 1.19 g/cm^3) < the conventional management (1.37 g/cm^3, 1.23 g/cm^3). Soil bulk densities under different forest management had no significantly difference ($P>0.05$).

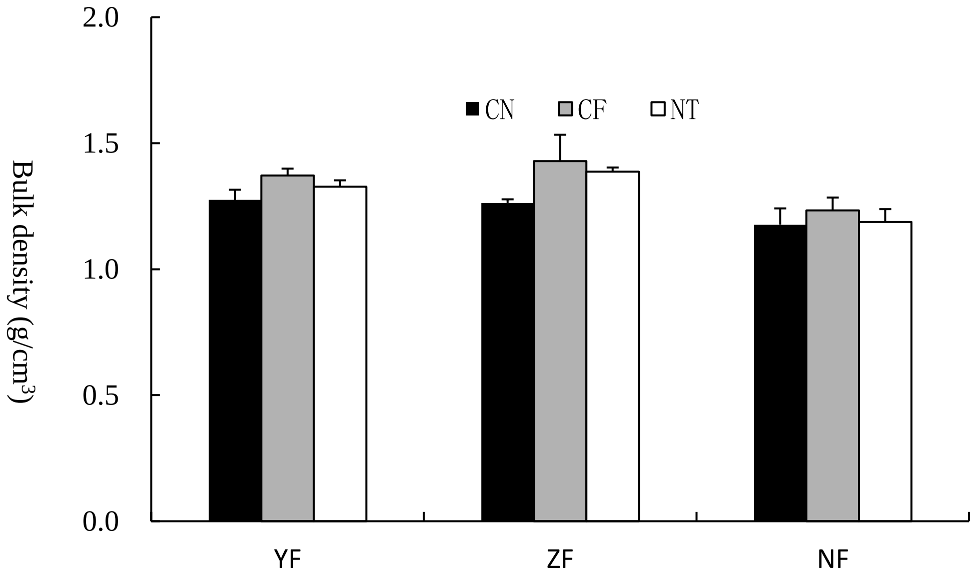

Fig. 24 The soil bulk densities of the *Pinus tabulaeformis* forest

According to Fig. 25, the capillary porosities of soil in the *Pinus tabulaeformis* planted forest was shown: the close-to-natural management (46.14%) > the no treatment (39.51%) > the conventional management (36.96%). Among them, the order of capillary porosities of soil in the young *Pinus tabulaeformis* planted forest was shown: the close-to-natural management (45.48%) > the no treatment (38.82%) > the conventional management (34.5%), the conventional management was significantly less than the close-to-natural management and the no treatment ($P<0.05$). In the middle-aged forest, that been shown: the close-to-natural management (39.45%) > the no treatment (36.44%) > the conventional management (34.82%). They had no significantly difference under 3 forest managements ($P>0.05$). In the near-mature forest, the close-to-natural management (54.49%) > the no treatment (43.27%) > the conventional management (41.56%), and capillary porosity of soil under the close-to-natural management was significantly more than that under the no treatment and the conventional management ($P>0.05$).

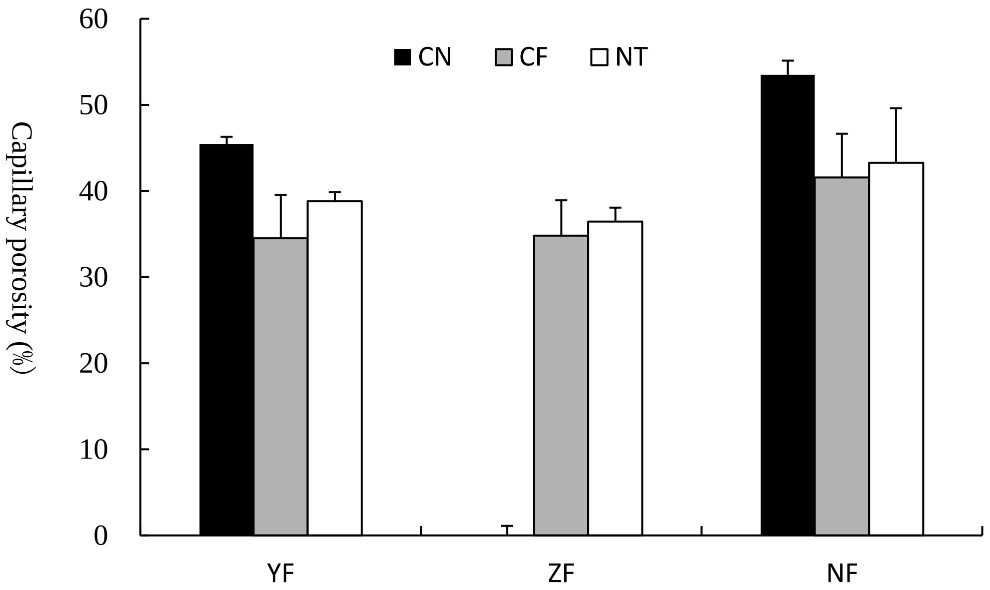

Fig. 25 The soil capillary porosity of the *Pinus tabulaeformis* forest

According to Fig. 26, the trend of soil maximum water storage in the *Pinus tabulaeformis* planted forest was shown: the close-to-natural management (1635.78t/ha) > the no treatment (1495.48 t/ha) > the conventional management (1357.54t/ha). The soil maximum water storage in the their young forest had the order: the soil maximum water storage of the close-to-natural management (1591.25t/ha) > those of the no treatment (1513.81t/ha) > those of the conventional management

(1280.17t/ha), In the middle-aged and near-mature *Pinus tabulaeformis* planted forest, they has same trend: the soil maximum water storage of the close-to-natural management, the no treatment and the conventional management were 1360.40t/ha, 1955.70t/ha; 1297.62t/ha, 1675.01t/ha; 1280.56t/ha, 1551.90t/ha respectively. soil maximum water storage under different forest management have significantly difference in the near-mature *Pinus tabulaeformis* planted forest (P<0.05).

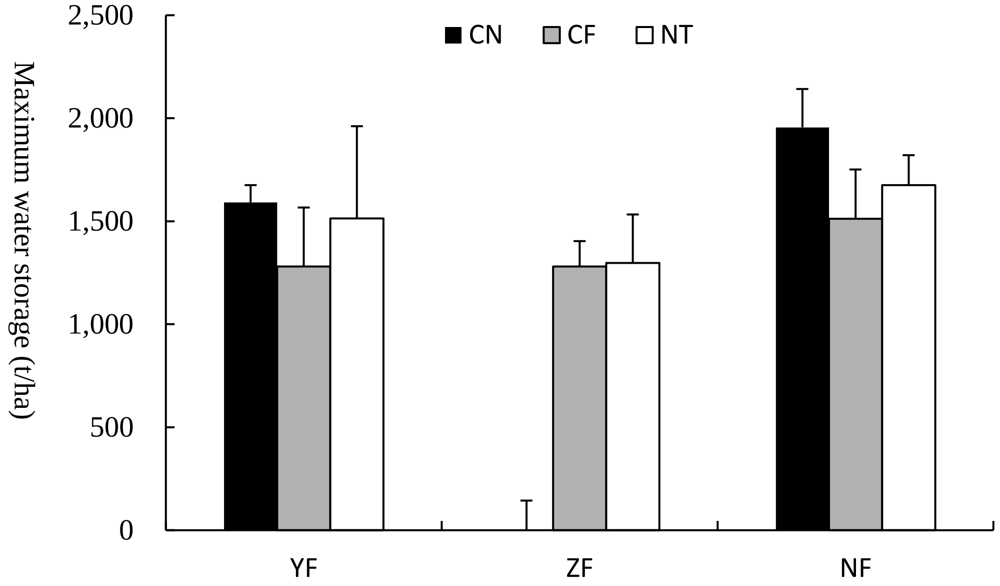

Fig. 26 The soil maximum water storage of the *Pinus tabulaeformis* forest

(2) The influence in the *Larix principwas-rupprechtii* planted forest

According to Fig. 27, the soil bulk density in the *Larix principwas-rupprechtii* planted forest had the trend: the close-to-natural management (1.16 g/cm^3) < the no treatment (1.20 g/cm^3) < the conventional management (1.24 g/cm^3). Soil bulk density of three different forest age were both as follow: the close-to-natural management > the no treatment > the conventional management. Soil bulk densities in the young *Larix principwas-rupprechtii* planted forest were 1.14 g/cm^3, 1.19 g/cm^3, 1.20 g/cm^3 respectively; 1.17 g/cm^3, 1.23 g/cm^3, 1.28 g/cm^3 in the middle-aged forest respectively; 1.18 g/cm^3, 1.18 g/cm^3, 1.23 g/cm^3 in the near-mature forest respectively. Their soil bulk densityvunder different forest management had no significantly difference (P>0.05).

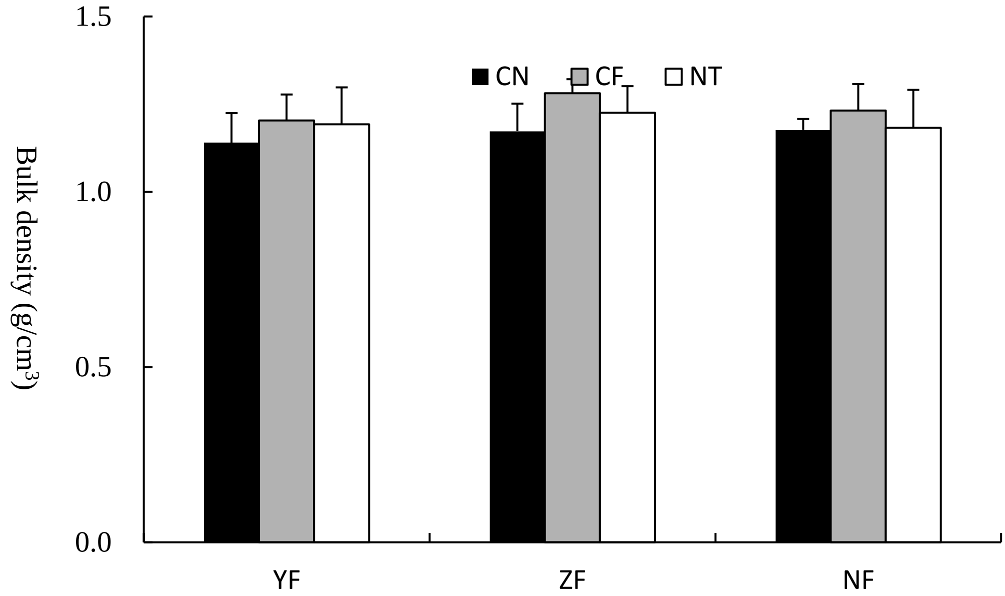

Fig. 27 The soil bulk densities of the *Larix principwas-rupprechtii* forest

According to Fig. 28, the order of the soil capillary porosity in the *Larix principwas-rupprechtii* planted forest was as follow: the close-to-natural management (43.81%) > the no treatment (42.20%) > the conventional management (40.58%). The order of capillary porosity of soil in the young *Larix principwas-rupprechtii* planted forest was: the close-to-natural management (43.01%) > the no treatment (42.77%) > the conventional management (39.53%). there were similar in the middle-aged and near-mature forest, they were 44.03%, 42.78%, 41.73% and 44.41%, 41.05%, 40.08% respectively. However, they had no significantly difference (P>0.05).

According to Fig. 29, soil maximum water storage in the *Larix principwas-rupprechtii* planted forest had the trend: the close-to-natural management (1758.73 t/ha) > the no treatment (1693.64 t/ha) > the conventional management (1568.84 t/ha). The soil maximum water storage under the conventional management was significantly less than the close-natural management (P<0.05). The soil maximum water storage were 1780.67 t/ha, 1727.76 t/ha, 1503.04 t/ha in the young *Larix principwas-rupprechtii* planted forest respectively;1704.0 t/ha, 1670.42 t/ha, 1645.63 t/ha in the middle-aged forest respectively; 1791.53 t/ha, 1682.73 t/ha, 1557.85 t/ha in the near-mature forest respectively. The soil maximum water storage in different age *Larix principwas-rupprechtii* planted forest under different forest management had no significantly difference (P>0.05).

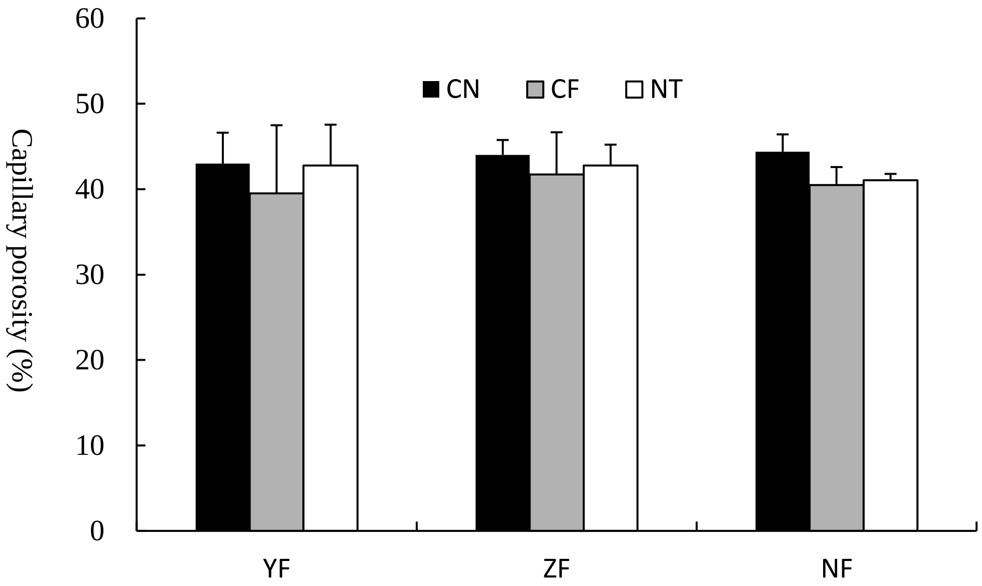

Fig. 28 The soil capillary porosity of the *Larix principwas-rupprechtii* forest

(3) The influence in the *Betula platyphylla* natural forest

According to Fig. 30, the trend of soil bulk densities in the *Betula platyphylla* natural forest was: the close-to-natural management (1.16 g/cm^3) < the no treatment (1.19 g/cm^3) < the conventional management (1.24 g/cm^3). Soil bulk density in the middle-aged and near-mature *Betula platyphylla* natural forest had same trend: 1.15 g/cm^3, 1.17 g/cm^3, 1.20 g/cm^3 and 1.28 g/cm^3, 1.20 g/cm^3, 1.18 g/cm^3 respectively. Soil bulk density in the different aged forest *Betula platyphylla* under different forest management had no significantly difference (P>0.05).

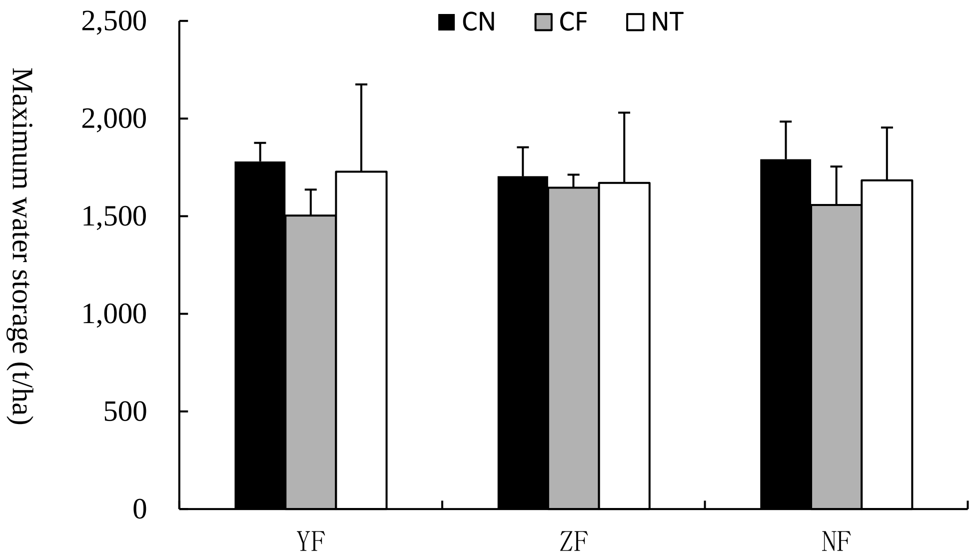

Fig. 29 The soil maximum water storage of the *Larix principwas-rupprechtii* forest

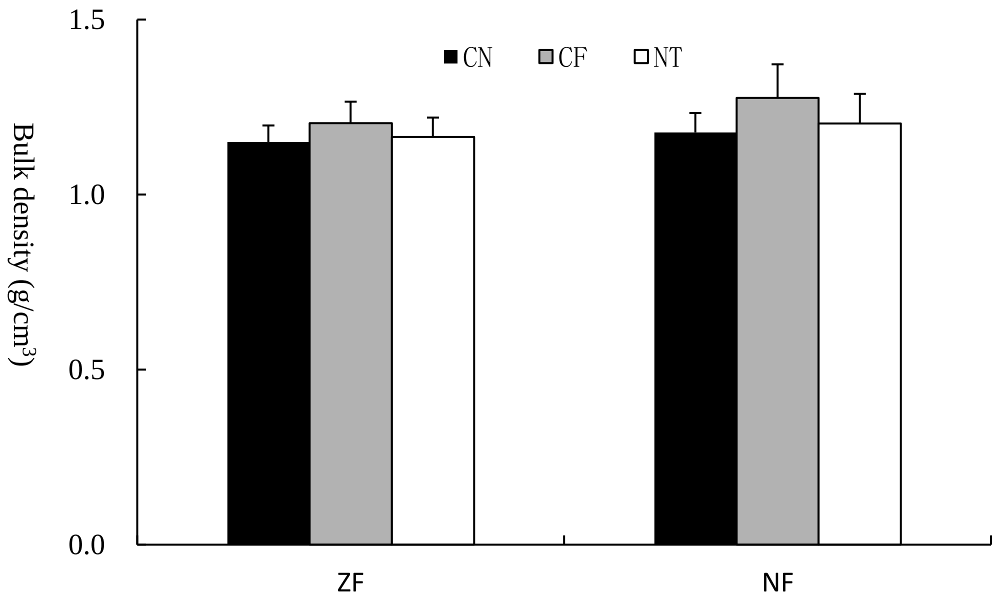

Fig. 30 The soil bulk densities of the *Betula platyphylla* natural forest

According to Fig. 31, the tend of soil capillary porosity in the *Betula platyphylla* natural forest was: the close-to-natural management (43.97%) > the no treatment (42.06%) > the conventional management (40.50%). in the middle-aged and near-mature forest, they were 44.21%, 42.69%, 40.10% and 43.90%, 41.28%, 40.83% respectively. Capillary porosity of soil in *Betula platyphylla* natural forest under different forest management had no significantly difference (P>0.05).

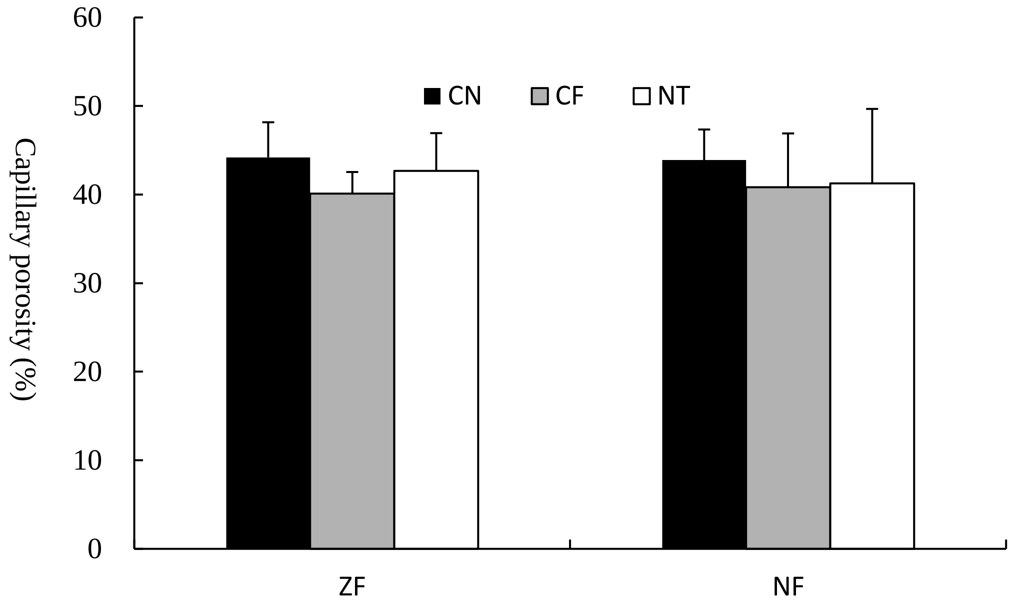

Fig. 31 The soil capillary porosity of the *Betula platyphylla* natural forest

According to Fig. 32, the order of soil maximum water storage in the *Betula platyphylla* natural forest was: the close-to-natural management (1767.91 t/ha) > the no treatment (1687.39 t/ha) > the conventional management (15718.39 t/ha). The soil maximum water storage in the middle-aged and near-mature *Betula platyphylla* natural forest had same trend that was: 1799.59 t/ha, 1738.29 t/ha, 1712.61 t/ha and 1745.40 t/ha, 1630.25 t/ha, 1433.93 t/ha respectively. The soil maximum water storage in *Betula platyphylla* natural forest under different forest management had no significantly difference (P>0.05).

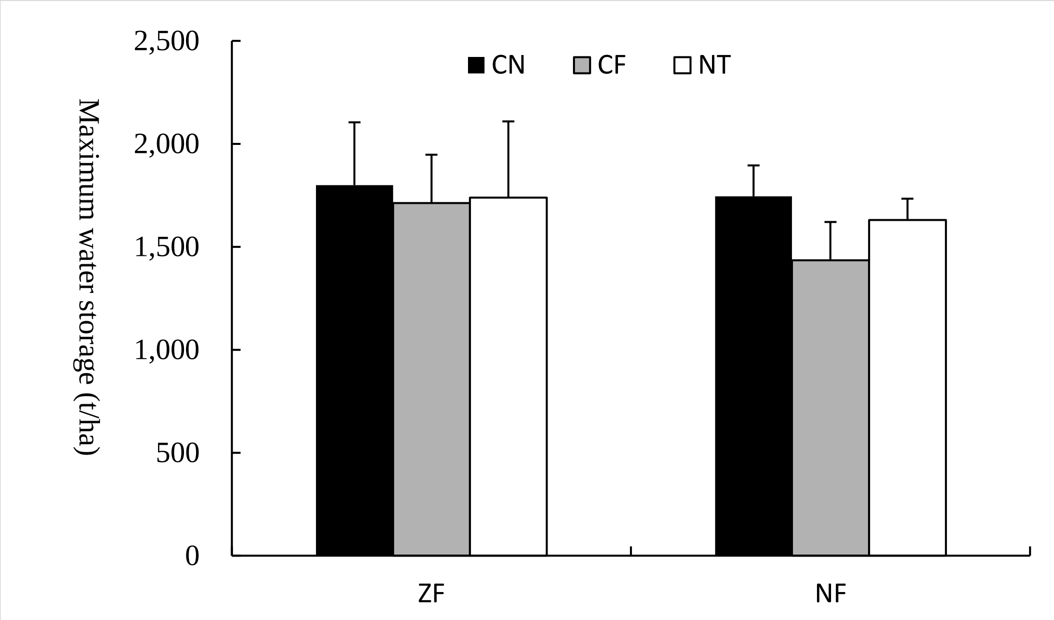

Fig. 32 The soil maximum water storage of the *Betula platyphylla* natural forest

(4) Summary

The soil bulk density in different kind of forest were shown as follow: the close-to-natural forest management (1.20 g/cm^3) < the no treatment (1.23 g/cm^3) < conventional forest management (1.20 g/cm^3), and there were no significantly difference (P>0.05) among them.

The capillary porosity of soil in different kind of forest were shown as follow: the close-to-natural forest management (44.64%) > the no treatment (41.26%) > conventional forest management (39.35%), and the close-to-natural forest management had significant difference with the no treatment and the conventional forest management (P<0.05).

The soil maximum water storage in different kind of forest were shown as follow: the close-to-natural forest management (1720.81 t/ha) > the no treatment (1625.50 t/ha) > the conventional forest management (1499.39 t/ha), and the soil maximum water storage of the close-to-natural forest management had significant difference with those of the conventional forest management (P<0.05).

5.3.2 The influence on litter capacity of water conservation

(1) The influence in the *Pinus tabulaeformis* planted forest

According to Fig. 33, the trend of litter amounts in the *Pinus tabulaeformis* planted forest was: the no treatment (14.37 t/ha) > the close-to-natural management (12.76 t/ha) > the conventional management (10.97 t/ha). The litter amount in the young, middle-aged and near-mature forest had similar rules. They were :10.94 t/ha, 13.15 t/ha, 19.02 t/ha; 8.07 t/ha, 11.31 t/ha, 18.89 t/ha and 7.91 t/ha, 11.19 t/ha, 13.80 t/ha respectively. The litter amount under the conventional management was significantly less than the no treatment and the close-to-natural management in the near-mature forest (P<0.05).

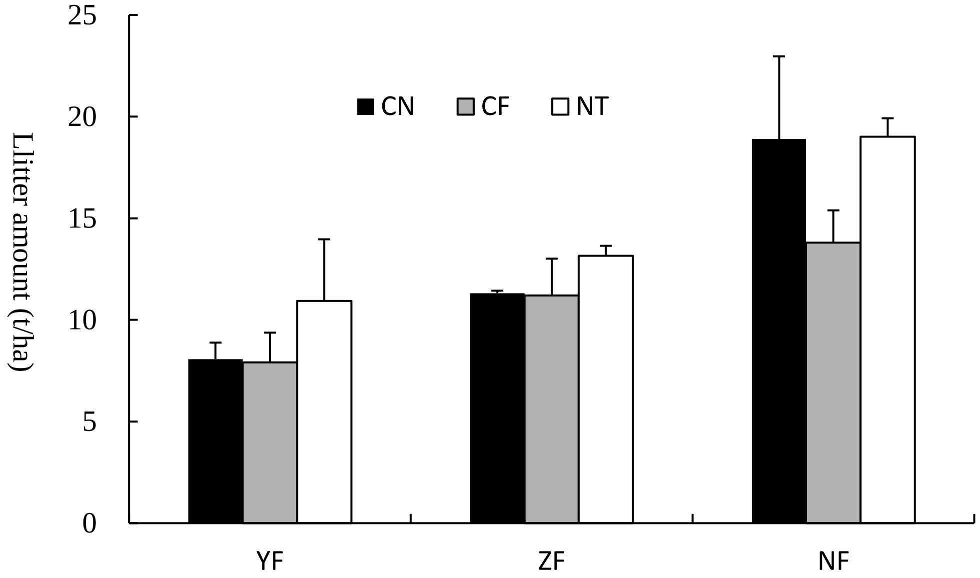

Fig. 33 The litter amounts of in the *Pinus tabulaeformis* forest

According to Fig.34, the maximum water holding capacity of litter in the *Pinus tabulaeformis* planted forest were shown: the no treatment (211.50%) > the close-to-natural management (203.18%) > the conventional management (196.46%). The maximum water holding capacity of litter were 216.37%, 201.53%, 188.33% in the young forest; 214.44%, 211.86%, 208.12% in the middle-aged forest and 203.70%, 196.14%, 192.91% in the near-mature forest respectively. The maximum water holding capacity of litter under different forest management had no significantly difference (P>0.05).

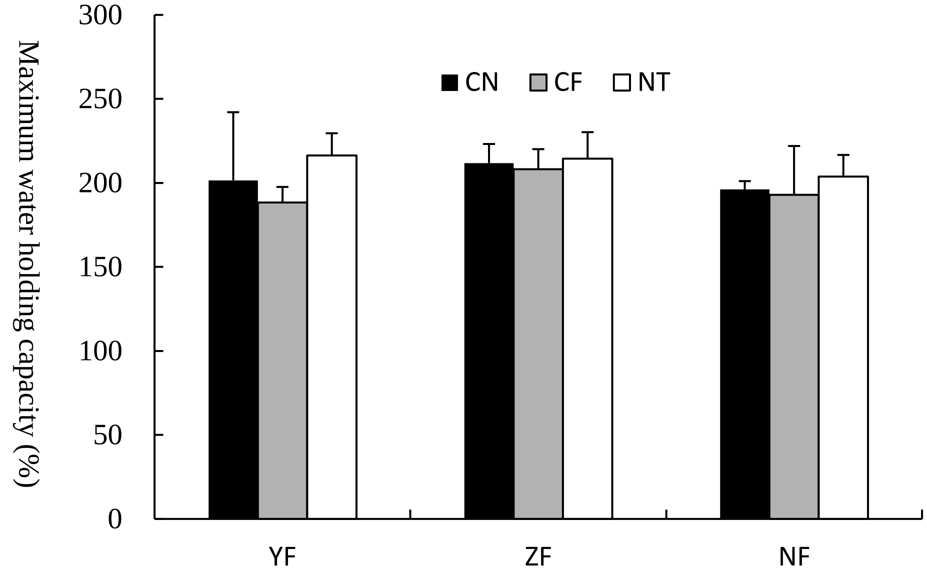

Fig. 34 The maximum water holding capacities in the *Pinus tabulaeformis* forest

According to Fig.35, the water conservation capacity of litter in the *Pinus tabulaeformis* planted forest were shown also as follow: the no treatment under (19.54 t/ha) > the close-to-natural management (16.88 t/ha) > the conventional management (13.42 t/ha). The water conservation capacity of litter were 14.91 t/ha, 10.26 /ha, 9.11 t/ha in the young forest; 18.53 t/ha, 15.52 t/ha, 14.79 t/ha in the middle-aged forest and 25.18 t/ha, 24.86 t/ha, 16.37 t/ha in the near-mature forest respectively. the water conservation capacity of litter under different forest management have no significantly difference (P>0.05).

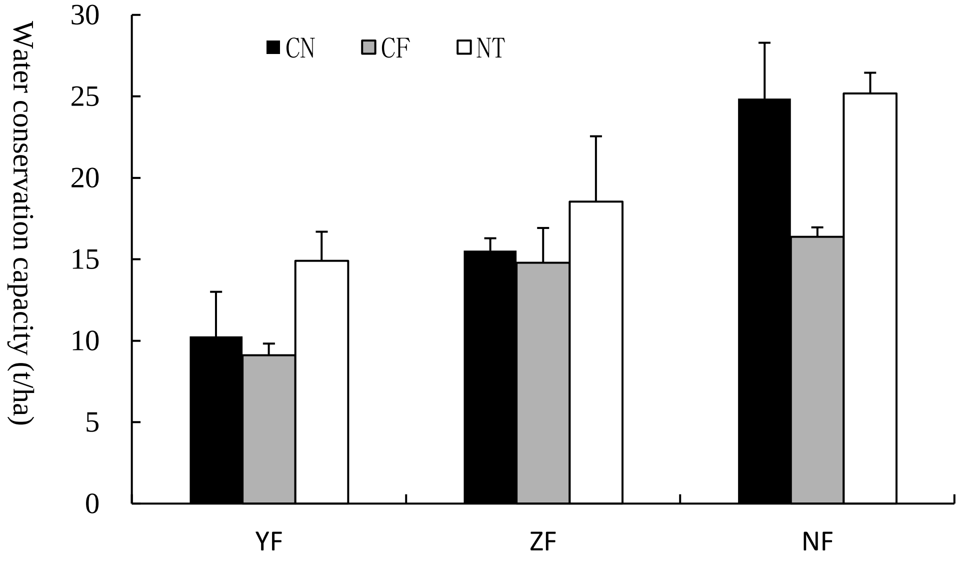

Fig. 35 The water conservation capacity of in the *Pinus tabulaeformis* forest

(2) The influence in the *Larix principwas-rupprechtii* planted forest

According to Fig. 36, the litter amount of the *Larix principwas-rupprechtii* planted forest have the trend: the no treatment (13.48 t/ha) > the close-to-natural management (11.6 t/ha) > the conventional management (10.36 t/ha). The litter amount in the young, middle-aged and near-mature forest had similar order:10.19 t/ha, 8.83 t/ha, 7.37 t/ha; 12.95 t/ha, 12.88 t/ha, 11.22 t/ha and 17.30 t/ha, 13.15 t/ha, 12.51 t/ha respectively. The litter amount in the near-mature *Larix principwas-rupprechtii* planted forest under the conventional management was significantly more than the no treatment (P<0.05).

According to Fig. 37 the maximum water holding capacity of litter in the *Larix principwas-rupprechtii* planted forest had a trend: the no treatment (285.15%) > the close-to-natural management (261.13%) > the conventional management (249.14%), and the no treatment was significantly more than the conventional management (P<0.05). The maximum water holding capacity of litter were 292.08%, 274.89%, 263.40% in the young forest; 290.48%, 257.44%, 252.93% in the middle-aged forest; and 272.88%, 251.07, 231.09% in the near-mature forest respectively. The maximum water holding capacity of litter under different forest management had no significantly difference (P>0.05).

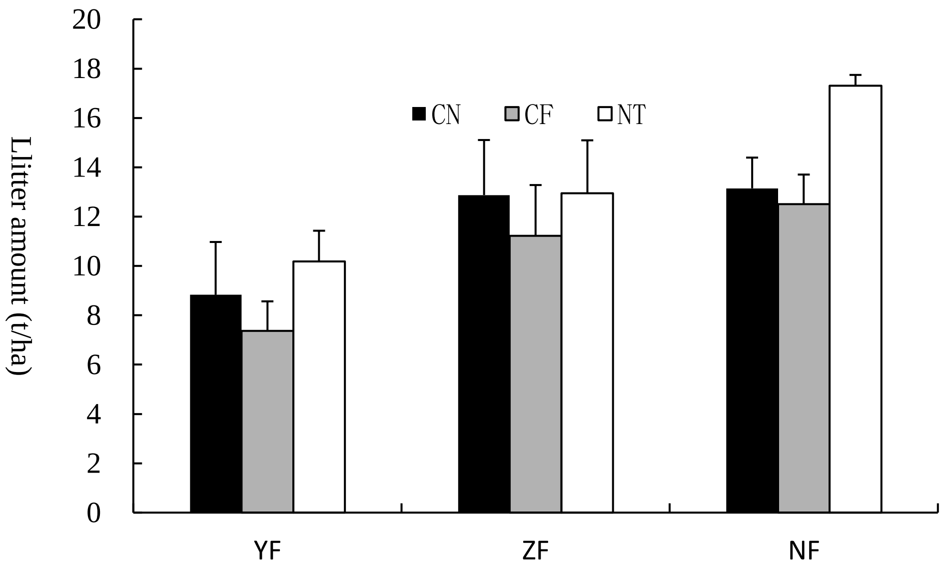

Fig. 36 The litter amount of in the *Larix principwas-rupprechtii* forest

According to Fig. 38, the water conservation capacity of litter in the *Larix principwas-rupprechtii* planted forest were also shown: the no treatment (23.54 t/ha) > the close-to-natural management (17.99 t/ha) > the conventional management (14.70 t/ha). The water conservation capacity of litter were 14.91 t/ha, 10.26 t/ha, 9.11 t/ha in the young forest; 18.53 t/ha, 15.52 t/ha, 14.79 t/ha in the middle-aged forest and 25.18 t/ha, 24.86 t/ha, 16.37 t/ha in the near-mature forest respectively. The water conservation capacity of litter under different forest management had no significantly difference (P>0.05).

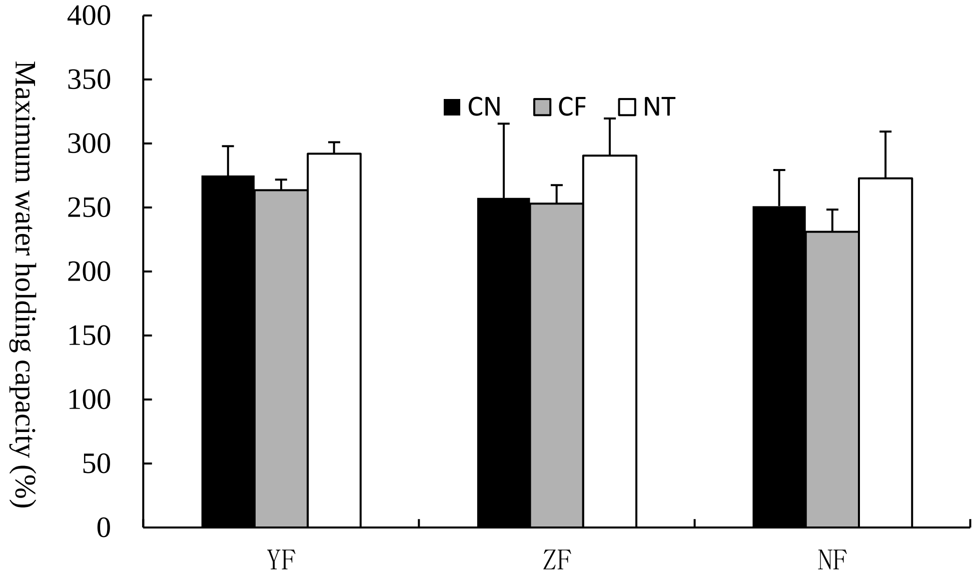

Fig. 37 The maximum water holding capacity in *Larix principwas-rupprechtii* forest

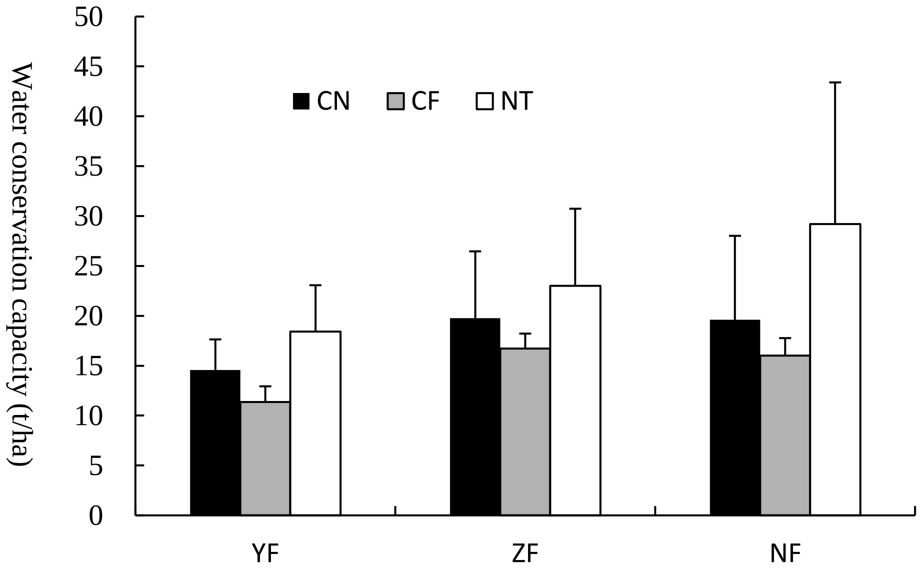

Fig. 38 The water conservation capacity in the *Larix principwas-rupprechtii* forest

(3) The influence in the *Betula platyphylla* natural forest

According to Fig. 39, the litter amount in the *Betula platyphylla* natural forest had the rule: the no treatment (12.28 t/ha) > the close-to-natural management (9.68 t/ha) > the conventional management (7.86 t/ha). The litter amount in the middle-aged and near-mature *Betula platyphylla* natural forest had similar trend: 10.41 t/ha, 9.29 t/ha, 7.43 t/ha and 15.20 t/ha, 10.08 t/ha, 8.28 t/ha respectively. The no treatment was significantly more than the conventional management ($P<0.05$).

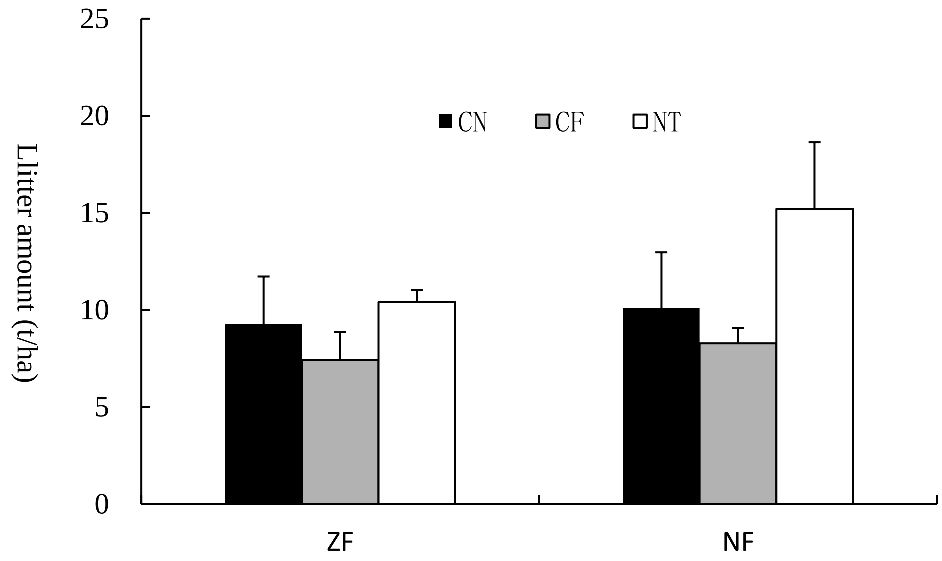

Fig. 39 The litter amount of in the *Betula platyphylla* forest

According to Fig. 40, the maximum water holding capacity of litter in the *Betula platyphylla* natural forest had shown: the no treatment (255.56%) > the close-to-natural management (251.37%) > the conventional management (247.28%). The maximum water holding capacity of litter in different forest age had similar trend: 256.21%, 253.15%, 247.29% in the middle-aged forest and 254.90%, 249.58%, 247.27% in the near-mature forest respectively. The maximum water holding capacity of litter under different forest management had no significantly different ($P>0.05$).

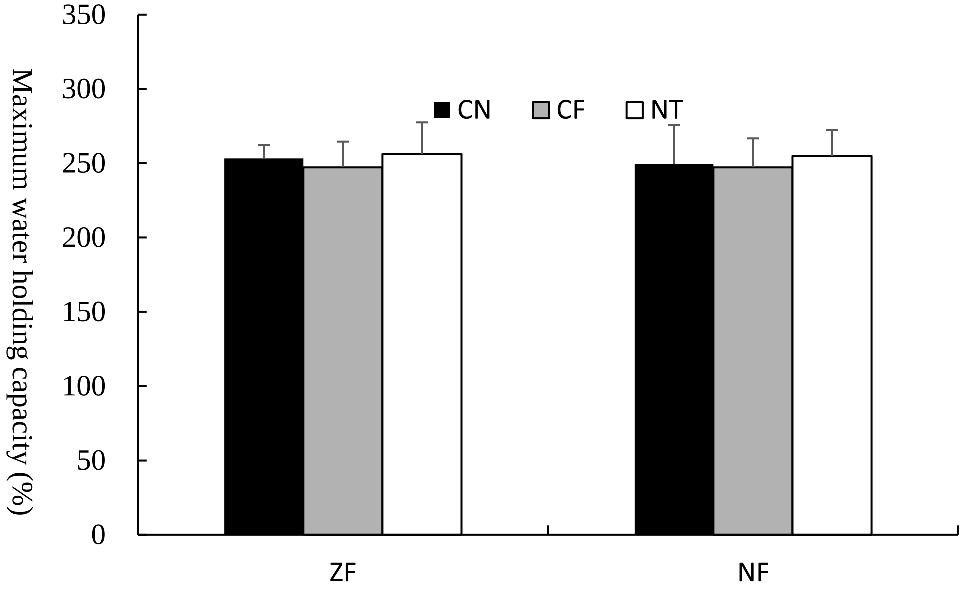

Fig. 40 The maximum water holding capacity of in the *Betula platyphylla* forest

According to Fig. 41, the water conservation capacity of litter in the *Betula platyphylla* natural forest were also shown as follow: the no treatment under (22.36 t/ha) > the close-to-natural management (16.27 t/ha) > the conventional management (13.00 t/ha). The water conservation capacity of litter in the middle-aged and near-mature *Betula platyphylla* natural forest were also shown: the no treatment (18.20t/ha, 26.52 t/ha) > the close-to-natural management (16.12 t/ha,16.43 t/ha) > the conventional management (12.31 t/ha, 13.70 t/ha). The water conservation capacity under the no treatment was significantly more than those under the conventional management in near-mature forest ($P>0.05$).

(4) Summary

The litter amount in three kinds of forest under different forest management were shown: the no treatment (13.55 t/ha) > the close-to-natural forest management (11.35 t/ha) > the conventional forest management (9.73 t/ha), and the conventional forest management was significantly less than the no treatment ($P<0.05$).

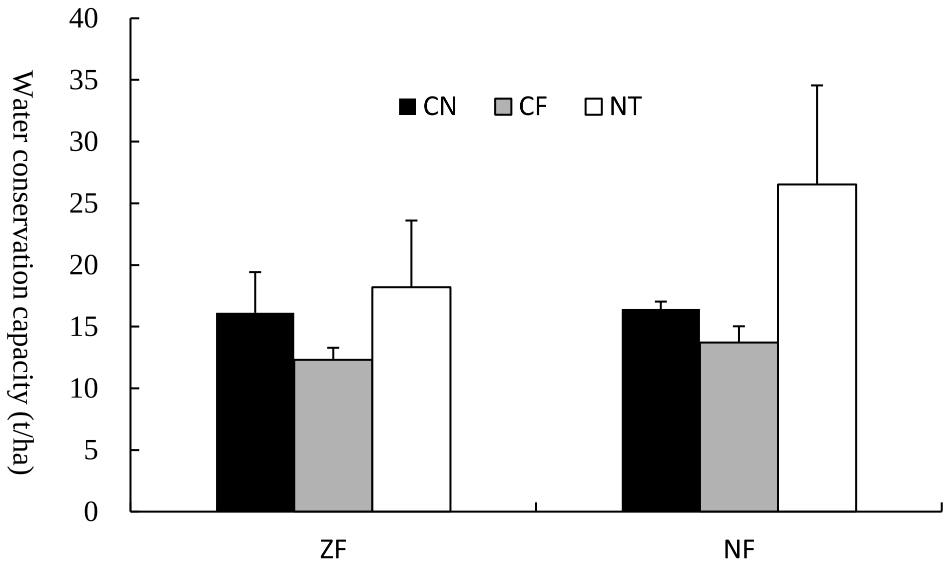

Fig. 41 The water conservation capacity of in the *Betula platyphylla* forest

The maximum water holding capacity of litter in three kinds of forest under different forest management were shown: the no treatment (250.74%) > the close-to-natural forest management (238.56%) > the conventional forest management (230.96%), and they had no significantly difference ($P>0.05$).

The water Conservation Capacity of litter in three kinds of forest under the no treatment, the close-to-nature forest management and the conventional forest management had same trend: 21.81 t/ha, 17.05 t/ha, 13.71 t/ha respectively, and they had significantly difference ($P<0.05$)

5.4 Forest recreation

5.4.1 Introduction of the Wangyedian National Forest Park

The Wangyedian National Forest Park, which is located at Wangyedian town of Chifeng city, Inner Mongolia, belongs to the transition part of the Great Xingan mountains and Yan mountains. Its forest land area is 23,200 ha with Chinese Pine, Larch, White birch and other tree species. It is beautiful place with a lot of gullies and hills and was a part of Mulan paddock at Qing Dynasty, where, Emperor Kangxi and Qianlong have hunted here for many times.

Fig. 42 Wangyedian National Forest Park

The Wangyedian National Forest Park has International Ski Field, Maojinba, Yunv peak, Sino-Japanese Friendship Forest and other sightseeing spots They has built cable-car, park, ring road, fishing place, reservoir and other basic facilities, and has taken the marathon and the mountain bike marathon in summer for attracting more visitors.

5.4.2 Characteristics of the personal information of visitors

In all 500 questionnaires, male and female accounted for 56%, 44% respectively. The male proportion was a little higher than the female. According to the regional distribution of visitors, they mainly from Chifeng city (38%). The second place was Beijng city (33%) and the people from Heibei province accounted for 20%. Therefore, the tourists who have gone to Wangyedian National Forest Park for forest recreation were mostly who come from surrounding area of this park.

Fig. 43 A International Ski Field; B Maojinba; C Yunv peak; D Sino-Japanese Friendship Forest

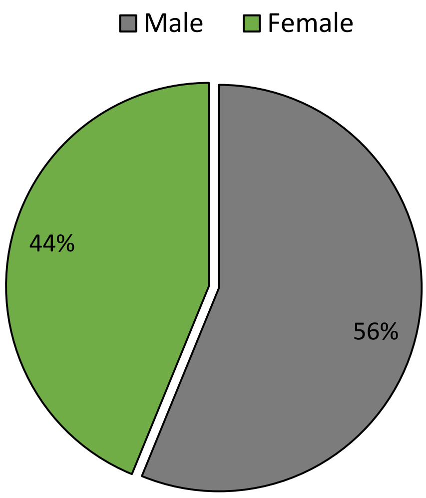

Fig. 44 Gender of visitor

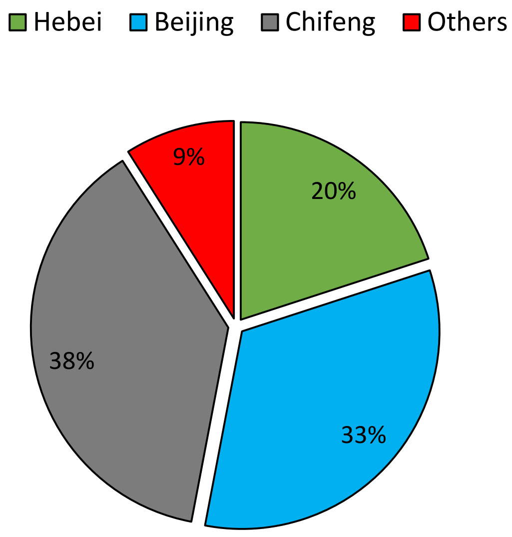

Fig. 45 Region of visitor

According to the age composition of visitors, the visitors of 21~50 years old accounted for 93%, and the visitors of 21~30 years old and 31~40 years old accounted for 46% and 31% respectively. The possible reasons is that the person in this age have enough money and energy support them. On the other hand, the forest recreation could attracted them.

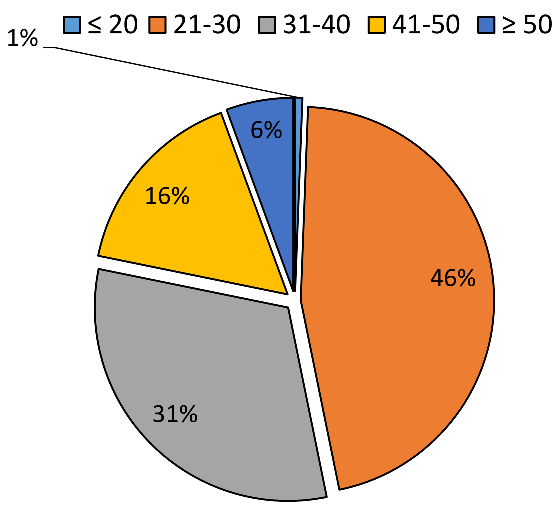

Fig. 46 Age of visitor

Education background, which represented visitor’s knowledge level, also had important effect on the forest recreation in this site. The visitors of the college level and above accounted more than 80%. This result means visitors, who had high education experience, liked forest recreation. On the other hand, family tour accounted for 71%, which possible imply that forest recreation fitted for family tour.

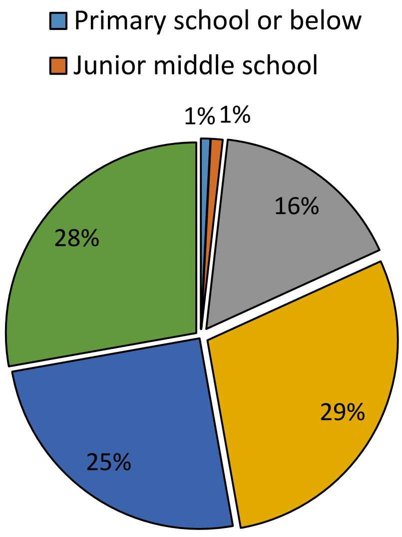

Fig. 47 Education of visitor

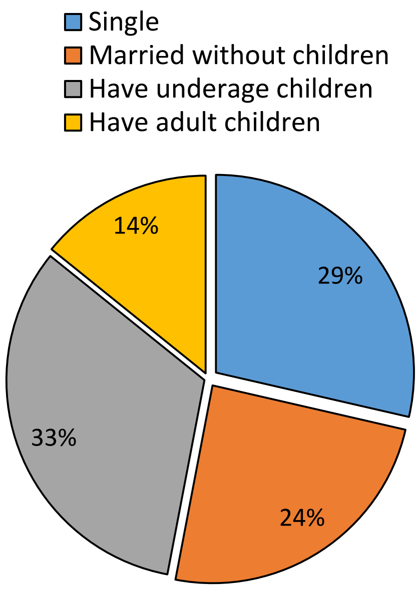

Fig. 48 Family structure of visitor

As for the visitor's profession, the questionnaire divided the profession into the person of governmental or public institutions, company employee, retired, housewife, peasant, student, soldier, freelancer. Among them, the company employees, persons of the governmental or public institutions and the freelancers accounted for 27%, 26% and 25% respectively. Because forest recreation could help them releasing the high work stress and change their environment.

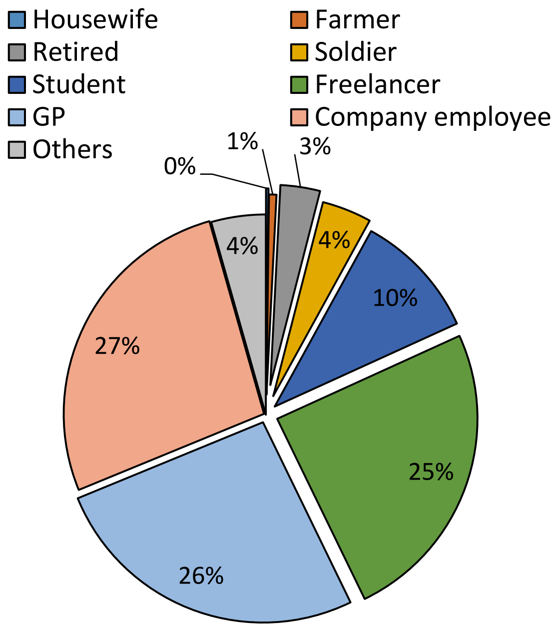

Fig. 49 Profession of visitor

Note: GP: person from the governmental or public institutions

In our study, the visitors, whose monthly incomes were between 3000~4000 RMB, were accounts for 39%. The visitors, whose monthly incomes were between 2000~3000 RMB and 4000~5000 RMB, were accounts for 27.6% and 16.2%. That means local tourism development is still at low level and have a lot work to do for attracting the high-income persons.

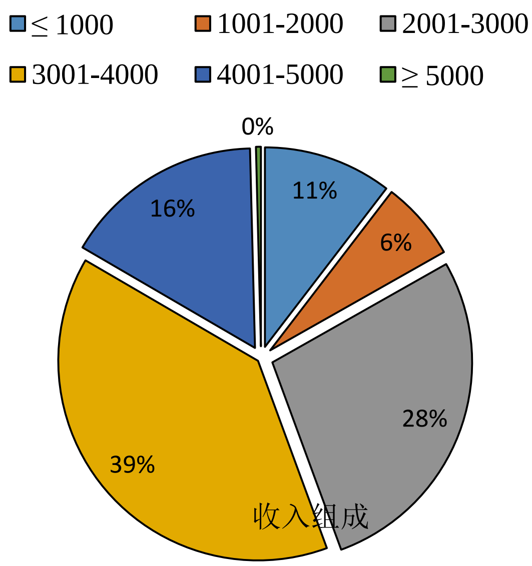

Fig. 50 Income of visitor

5.4.3 Visiting times, organization and channel of the information

The first, second and third visit times to the Wangyedian National Forest Park accounted for 47%, 39% and 14% respectively. This result means Wangyedian National Forest Park is well enough to attracting some visitors coming here more than once.

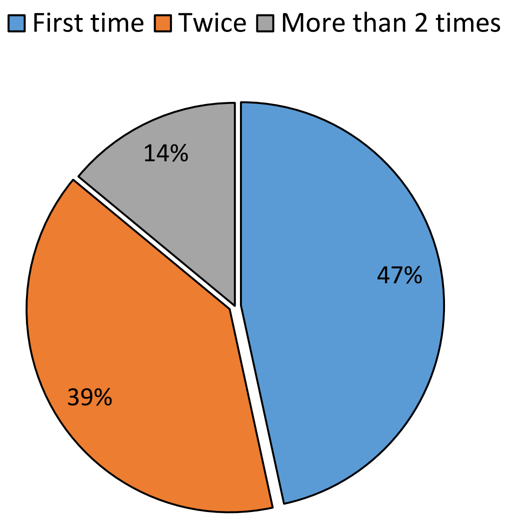

Fig. 51 Visiting times of visitor

In our study, free travelers accounted for 65% and family travel accounted for for 26%. That means the visitors here for forest recreation are mostly spontaneous and freely. On the other hand, most of people felt possibly the importance of forest recreation for the communication and emotion among family members.

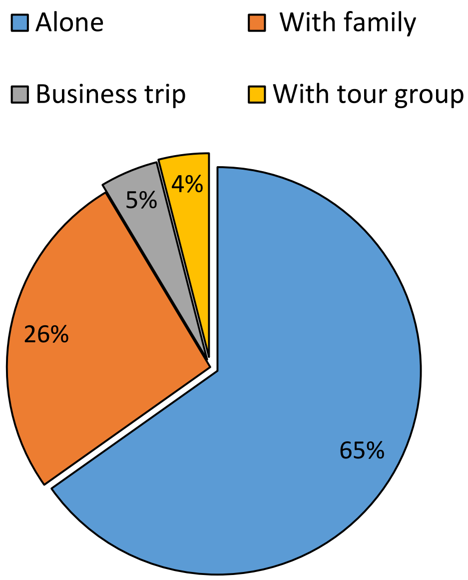

Fig. 52 The visiting way of visitor

The visiting information of Wangyedian National Forest Park was mainly form internet (26%). The travel agency only accounted for 8%, and the proportions of other 5 ways were similar. The possible reason is that the visitors were satisfied to the forest recreation of Wangyedian National Forest Park and displayed the information on internet.

5.4.4 Travel expense

In our study, we investigated the expense of entrance ticket, transportation, food, hotel and shopping of every randomly selected visitors.

According to Table 11, the visiting costs of the visitors with different jobs were different. Travel cost per visitor was 751.2RMB. Travel cost per visitor of soldier was most (900RMB), student was least (602.0RMB). Transportation (247.1RMB) accounted for 33% of total cost, the most travel cost, Shopping (121.7RMB) accounted for 16%, the least travel cost. Compared with other place, the consumption of the Wangyedian National Forest Park is low.

The total travel expense of the ticket, transportation, food, hotel and shopping was 751.2 RMB. Based on the provided data of the local travel agency, the visitors was about 30,000 every year therefore, the visitor’s travel expense in the Wangyedian National Forest Park was equal to 22,537,037 RMB.

5.4.4 Summary

According to the results of the questionnaires, we can conclude that: (1) visitors who visited Wangyedian National Forest Park, are mostly young adults who had the middle income level and high educational background. (2) visitors mainly lived around Wangyedian town and went to the Wangyedian National Forest Park with their family. (3) many visitors have gotten the visiting information of Wangyedian National Forest Park from Internet and like go there more than once. Average travel expense of everyone here is about 751.2 RMB.

According to the investigation and questionnaires, average shopping expense was only 121.7 RMB, which accounted for 16% of the average travel expense (753.3 RMB) and was lower than the expense of the fee of transportation, food, hotel charge. Wangyedian has rich mushrooms and many other wild food resources, but most of them have not been deeply processed and explored. If we could improve the quality of wild food resources, upgrade shopping environment, the regional tourism income of the Wangyedian National Forest Park will increase greatly.

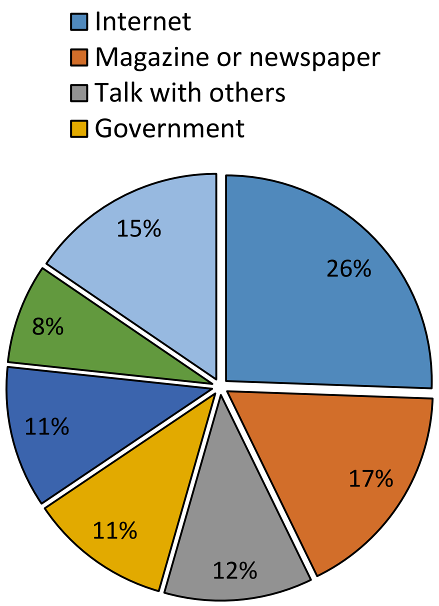

Fig. 53 Information Channel of visitor

Table 11 Travel cost of visitors unit: RMB

Occupation	No.	Travel expense	Ticket	Transportation	Food	Hotel charge	Shopping
Company	132	770.5	0.0	233.7	170.8	206.8	159.1

GP	127	834.6	0.0	289.8	226.0	174.0	144.9
Freelancer	120	645.8	0.0	196.3	201.7	167.9	80.0
Student	49	602.0	0.0	183.7	172.4	149.0	96.9
Others	25	832.0	0.0	340.0	208.0	176.0	108.0
Soldier	17	900.0	0.0	323.5	229.4	223.5	123.5
Retired	16	893.8	0.0	368.8	303.1	184.4	37.5
Total	486	751.2	0.0	247.1	201.3	181.1	121.7

Note: GP: person from the governmental or public institutions

6 Conclusion

According to analysis of the species diversity, carbon storage, soil water conservation ability and forest recreation of the *Pinus tabulaeformis* planted forest, *Larix principis-rupprechtii* planted forest, and *Betula platyphylla* natural forest, the results are as follow.

(1) The close-to-natural forest management could increase herb species diversity and richness in three kind of forests, and could increase shrub species number and individual number in middle-aged forest. However, the conventional forest management was beneficial to shrub species diversity in near-mature forest

(2) The carbon storage of vegetation layers, tree layer and ground litter layer were as follow: the no treatment > the close-to-natural forest management > the conventional forest management, but the carbon storage of herb layers were shown: the close-to-natural forest management > the conventional forest management > the no treatment.

(3) The soil bulk density was shown as follow: the close-to-natural forest management < the no treatment < the conventional forest management. The capillary porosity and the soil maximum water storage were shown as follow: the close-to-natural forest management > the no treatment > the conventional forest management. The litter amount, the maximum water holding capacity of litter and the water conservation capacity were shown: the no treatment > the close-to-natural forest management > the conventional forest management.

(4) The visitors per year in the Wangyedian National Forest Park are was about 30,000 and the total travel expense of visitors was 22,537,037 RMB.