A study on carbon sequestration capacity and benefit evaluation of different modes of plant disposition in Karst Peak-Cluster Depression Areas

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Abstract. In order to integrate increasing carbon sequestration of plants into vegetation restoration and reconstruction project in Guizhou karst area, the carbon storage, spatial distribution characteristics and carbon sequestration benefits of five kinds of disposition modes were studied in Karst Peak-Cluster Depression Areas. The result showed that: Disposition model of each vegetation carbon storage and increment is characterized by vine layer > shrub layer > tree layer > herb layer. In the vegetation layer vine layer and the shrub layer carbon increment of vegetation carbon density has no significant difference, respectively accounting for 56.06%, 48.31%, which are in the dominant, but far higher than other vegetation layer. In addition, the carbon increment of different mode of herb layer and soil layer has small differences, and carbon storage appeared lower than that of control. Based on five disposition model of carbon increment and economic benefit analysis, we concluded that different disposition model in the 10 and 20 years later, both carbon increment and economic benefit are characterized by Mode 3(*Zenia insignis* Forest) > Mode 1(*Ligustrum lucidum* Forest) >Mode 5(*Broussonetia papyrifera* Forest) > Mode 4(*Zenia insignis* Forest) > Mode 2(*Sophora japonica* Forest). The trends are the same, which fully prove and illustrate the accuracy of estimation model. The disposition model 3 of *Zenia insignis* forest has the highest economic value of respectively 16823 USD/hm^2 ten year later, 32735 USD/hm^2 after twenty Years later. This research will provide scientific basis and practical methods for the comprehensive treatment of rocky desertification in Karst to obtain maximum economic benefit of carbon fixation**.**

Introduction

With the rapid development of global industrialization, concentration of CO_2 in the atmospheric continues to rise, which triggered a series of environmental problems having become the focus of attention worldwide [1]. Forests are the largest terrestrial ecosystem carbon pool, accounting for 86% of global carbon storage, and 73% of total soil carbon pool [2], which play an important role in the global carbon cycle [3-4]. At present, domestic and foreign scholars have attached great importance to carbon sink function of forest. Their research focused on the carbon storage capacity and distribution pattern of forest ecosystems, etc. [5-7], but others studied on the ecosystem carbon cycling characteristics of the forest [8]. As we all know, Karst area's unique microclimate, one of

China's major carbon pools, gave birth to a wide variety of ecosystems, having a extremely rich biodiversity, which play an important role in maintaining the ecological balance, conservation of water and soil and water. At the present stage, trends of degradation of the fragile ecosystem in Guizhou have serious impact on its carbon sink function serious influence the carbon sink function. Vegetation restoration and reconstruction is an important measure to deal with the ecological degradation of Guizhou and many scholars have carried out extensive research [9-12]. But all the research do no integrate increasing carbon sequestration of plants into vegetation restoration and reconstruction project so that the tree species selection and collocation of carbon sequestration effect is not obvious, which cause a lot of the ecological effect of afforestation project can not fully reflect [13]. Therefore, different modes of suitable plant disposition in Karst Peak-Cluster Depression Areas were taken as the research object. This research will discuss carbon storage and its Spatial distribution characteristics, and carbon sequestration benefits of study different modes of suitable plant disposition, On the basis of this study, karst area was revealed carbon sequestration ability in different vegetation configuration mode and its benefit, which is not only beneficial to the management of rocky desertification of karst area, but also to provide a scientific basis and practical methods for the vegetation restoration and reconstruction works in karst areas by maximize the effects of increasing carbon sequestration.

Study Area

Pingtang County in Guizhou Province is selected as the study area. Samples are taken at Liujiawan Village in Kedu Town of Pingtang County, which is 15 km away from the town and 2.5 km from the location of Five-hundred-meter Aperture Spherical Telescope Project (FAST). The region is a typical Karst peak cluster depressions, with an relative height of peak cluster depressions ranges 841.2 ~ 1 193.8m, featured by abundant heat and rainfalls, 17˚C of average air temperature, -3.5˚C of extreme low temperature, 1259 mm of mean annual precipitation, 77.3 % of annual precipitation from April to August, about 700 mm of annual evaporation capacity and 278 frost-free days. No winter cold here and summer heat free [14] . The arboreal vegetation of the area is mainly dominated by pine; rhamnose, acutissima pistache, and shrub vegetation are mainly Pyracantha, Cotoneaster, small fruit roses, viburnum.

Material and Methods

At the beginning of 2011, according to evaluation Basis of investigation of Karst adaptability of locally grown variety of plan, we select the plants that are well adapted. to construct five modes of suitable plant disposition like the Solid Collocation of arbors-frutex-liana-grass in Karst Peak-Cluster Depression Areas at Liu jiawan Village in December 2012. Five modes are as follows: *Ligustrum lucidum-Amorpha fruticosa-Lonicera macranthoides*(Mode 1,*Ligustrum lucidum*);*Sophora japonica- Amorpha fruticosa - Lonicera macranthoides*(Mode 2,*Sophora japonica*); *Zenia insignis- Amorpha fruticosa -Argyreia seguinii*(Mode 3,*Zenia insignis*); *Fraxinus chinensis- Magnolia multiflora- Illigera grandiflora*(Mode 4,*Fraxinus chinensis*); *Broussonetia papyrifera- Amorpha fruticosa - Illigera grandiflora*(Mode 5,*Broussonetia papyrifera*).Under each mode, arbors-frutex-liana substantially in accordance with the actual situation in certain spacing (arbors 3 m * 4 m, frutex 2 m *2 m, rattans 2 m * 2 m) were digging point for planting .Planting pit should be shift when faced uncovered Rock appropriate place; Herbs are natural growth after we stop farming out weeds. All the plants of arbors-frutex-liana are open-air rearing of one-year-old seedlings at the beginning of 2011. All the plants are seedlings except that *Lonicera macranthoides* are ***grafted*** seedlings (Yulei No.1) and *Argyreia seguinii* is Vegetative propagation seedling. All the plants of arbors-frutex-liana are open-air rearing of one-year-old seedlings at the beginning of 2011. All the plants are seedlings except that *Lonicera macranthoides* are ***grafted*** seedlings (YuleiNo.1) and *Argyreia seguinii* is Vegetative propagation seedling.

Sample setting and Investigation

In September 2014, in the testing ground of five modes of suitable plant disposition, we respectively set up a typical sample plots 20 m * 20 m (Be shown in table 1), and a control plot with the same area in the similar and adjacent land (after the beginning of the experiment stopped farming, and do not take any artificial measures). Through observation of height, diameter, and crown of arbors-frutex- liana, we select three standard woods in each mode; Three herb samples 1 square metre respectively is set in the middle and two Angle along the diagonal in each sample .In view of the testing ground of soil layers only about 20 cm, soil investigation were divided into two layers by 0 ~ 10, 10 ~ 20 cm.

Table 1 basic Overview of typical sample area

disposition model	Community characteristics
Mode 1 *Ligustrum lucidum* Forest	height 1.5m, diameter 3.5cm of arbors;shrub coverage 22%;liana coverage 30%;grass coverage 60%;canopy density 0.22
Mode 2 *Sophora japonica* Forest	height 1.6m, diameter 2.1cm of arbors;shrub coverage 10%;liana coverage 40%;grass coverage 55%;canopy density 0.20
Mode 3 *Zenia insignis* Forest	height 2.2m, diameter 3.1cm of arbors;shrub coverage 15%;liana coverage 80%;grass coverage 65%;canopy density 0.25
Mode 4 *Fraxinus chinensis* Forest	height 1.5m, diameter 3.5cm of arbors;shrub coverage 22%;liana coverage 30%;grass coverage 60%;canopy density 0.15
Mode 5 *Broussonetia papyrifera* Forest	height 1.5m, diameter 3.5cm of arbors;shrub coverage 22%;liana coverage 30%;grass coverage 60%;canopy density 0.18
the control group	grass coverage 70%

Sample Collection and Measurement Indicators

Determination of Vegetation layer biomass and the carbon content . All the standard woods were weight the fresh weight of organs respectively by the method of whole digging sampling ,while Grass were by the way of the fresh weight of the ground and underground according to different parts. We take the fresh sample back to the lab dry (or editing) in the constant temperature oven 90 ~ 100 ˚C under short-term (50 min), then 80 ˚C constant temperature in the oven heatdrying to constant weight 48 h, then weigh and dry weight of the sample. The weight is the biomass.

Soil sampling and analysis. In the various disposition model and the control group using 5 cm inner diameter soil drill press 0 ~ 10, 10 ~ 20 cm stratified sampling. The same set of three random sampling points, each layer of each sampling point drill three mixed soil samples respectively, three samples of the same level of the soil sample level mixed soil samples, and then by potassium dichromate volumetric method (heat of hydration method) to determine soil organic carbon [15]. In addition, in the research representative area was selected, to excavate section, depth to 20 cm, along the profile in 0 ~ 10, 10 ~ 20 cm take undisturbed soil stratification with cutting ring, in sealed bags, back to the laboratory to determine the soil bulk density

Statistical analyses

Seedling Carbon. In growing stage, we measured each carbon per plant nursery stock standard strains (each seedling selection three standard strains, individual carbon averaging), and then calculated each seedling of carbon per hectare according to the planting patterns.

Vegetation Carbon and Its Increment. Vegetation biomass multiplied by the carbon content can be used to calculate carbon reserves, and vegetation carbon increment is equal to the harvest time of vegetation carbon minus the carbon of seedling and control group.

Soil Carbon Storage. The calculation method of Soil Carbon Storage was as follow:

$$SOC = 0.1\sum_{i=1}^{n} D_i q_i C_i \quad (1)$$

In Eq.1, '*SOC*' represent of soil organic carbon density (t/hm^2); '*n*' is for the number of soil, this article 2; 'D_i', 'Q_i', 'C_i', respectively refers to different soil layer thickness (cm), soil bulk density (g/cm^3) and different soil organic carbon content (g/kg). Soil carbon increment is equal to the harvest time of soil carbon reserves minus carbon.

Different Modes to Calculate Carbon Storage in 10 and 20 years. With the increase of forest age, the biomass and carbon sequestration of forest will gradually increase, and the arbor in the heart of the forest biomass accounts for absolute advantage [17]. Therefore, to estimate the different patterns of carbon increment in 10 and 20 years is the carbon Storage of tree layer, while the shrubs, vines, herbs and soil shall be calculated at the current level. According to each species of field survey and the social survey results in the same area of Ping Tang county, combining with the enforcement of the Guizhou province of binary stocking list of different tree species and binary scale of local standards (DB52T 821-832,2013), we could determine the standard plant biomass and carbon Storage of the different pattern of tree species, further calculate carbon increment per unit area according to density in 10 and 20 s.

Economic benefit of carbon fixation. In the world, the value of CO_2 is evaluated by carbon tax law and afforestation cost method. Carbon tax law is based on the government to limit the amount of CO_2 emissions to the atmosphere, through the collection of tax and fee standards for the CO_2 of forest plants to calculate the economic value of fixed CO_2, the Swedish carbon taxes in the academic community has been recognized by many people. Afforestation cost method is based on the afforestation in the number of points to absorb CO_2 from the atmosphere and the relationship between the costs of afforestation to calculate the value of forest CO_2 fixation, but regional afforestation cost comparison is not high. Therefore, in this paper, the economic value of a fixed CO_2 is calculated, with the method of Swedish carbon taxes (0.15 USD / kg carbon).

PASW Statistics 18.0, Microsoft Excel 2010 were used to analyze the data.

Results

Carbon storage and its Spatial distribution characteristics the under different disposition model. After deducting seedlings carbon and compared with the control, we obtained different level corresponding carbon increment under the five kinds of plant disposition mode. The table 2 shows that the tree layer carbon increment under different configuration mode in 0.05 ~ 0.15t/hm^2, and the overall difference is small, except that Mode 5 with other model is extremely significant difference

(P < 0.01, the same below). Carbon increment of shrub layer is 0.36 ~ 0.68 t/hm^2, among that mode 1 and mode 2, 3 is relatively high, mode 4 and 5 and with other model poses a significant difference (P < 0.05, the same below). The carbon increment of different mode of vine layer has large differences (0.26 ~ 0.92 t/hm^2), and almost all exist significant differences between each other. In addition, the carbon increment of different mode of herb layer and soil layer has small differences, and carbon storage appeared lower than that of control. Main reason is that the control group is the herb community with large growth space compare with experimental group whose growth space is limited because of trees, shrubs, vine growth occupy certain resources and space. Usually, layers of carbon has smaller change in the short term, therefore, the absolute value of carbon increment of soil layers are smaller. Overall, the increment of carbon storage Model 1(1.04 t/hm^2), Model 2(1.22 t/hm^2), and Model 3(1.36 t/hm^2) are higher, Mode 4(0.71 t/hm^2)and Model 5 (0.70 t/hm^2) are low.

Table 2 carbon storage and its Spatial distribution characteristics under different disposition model (t/hm^2)

disposition model	tree layer	shrub layer	liana layer	herb layer	soil layer	total
Mode 1	0.12±0.02bA	0.51±0.06bA	0.63±0.04cB	-0.20±0.02cB	-0.02±0.02bAB	1.04
Mode 2	0.15±0.02aA	0.68±0.04aA	0.74±0.05bB	-0.26±0.03cB	-0.09±0.02cdC	1.22
Mode 3	0.10±0.03bA	0.48±0.03bAB	0.92±0.07aA	-0.09±0.02aA	-0.05±0.03cB	1.36
Mode 4	0.10±0.01bA	0.40±0.01cBC	0.27±0.02dC	-0.13±0.04abA	0.07±0.01aA	0.71
Mode 5	0.05±0.01cB	0.36±0.04cC	0.26±0.01dC	-0.06±0.02aA	0.09±0.02aA	0.70

Note: data in the table column with different small letters differ significantly (P < 0.05), between different capital letters differ significantly (P < 0.01), Pearson coefficient of double side inspection.

Incremental carbon storage of different disposition model after 10 years. Estimation results in the table 3 show that under different disposition mode, the carbon increment of tree layer will reach 31.65 ~ 97.10 t/hm^{2}and total carbon increment 45.21 ~ 112.15 t/hm^2 and increasing carbon sequestration efficiency of different disposition mode are high. Total carbon increment of Mode 3 which is markedly higher than that of several other models, which reveal sequestration efficiency of Model 3 is very obvious in Karst Peak-Cluster Depression Areas.

Table 3 incremental carbon storage of different disposition model after 10 years(t/hm^2)

disposition model	tree age /a	tree layer	Total carbon storage
Mode 1	13	54.98	67.34
Mode 2	13	31.65	45.21
Mode 3	13	97.10	112.15
Mode 4	13	37.67	50.69
Mode 5	13	51.35	64.54

Incremental carbon storage of different disposition model after 20 years. The table 4 shows that after 20 years incremental carbon storage of different disposition model appear more obvious differentiation. The carbon increment of tree layer in the range of 81.61 ~ 203.18 t/hm^2, and different mode of total carbon increment will reach 95.17 ~ 95.17 t/hm^{2,} ,and tree layer accounts for over 85% of the total carbon increment. Among them, tree layer carbon increment of the model 3 reached 1.64 ~ 2.49 times the rest models and the total carbon increment reached 1.60 ~ 2.29 times, which indicate that increasing carbon sequestration efficiency of model 3 is significantly higher than the rest of the several modes.

Economic benefit evaluation of carbon fixation under different disposition model

The estimation results in the table 5 indicated that the economic benefit of carbon fixation under different disposition model in Karst Peak-Cluster Depression Areas show the carbon economic benefits in 105 ~ 204 USD/hm^2. As the growth of the stand age, carbon sequestration can achieve economic benefit of 6782 ~ 16823 USD/hm^2 after 10 years, grew by an average of 678 ~ 1682 USD/hm$^{2;}$.After 20 years, economic benefit of carbon fixation can reach 14276 ~ 32735 USD/hm^{2,} grew by an average of 1428 ~ 3274 USD/hm^2. Therefore, along with the continuously vegetation restoration and reconstruction project was implement in Guizhou Karst Mountain, We firmly believe that it will not only bring huge economic benefits and social benefits, but also bring huge economic benefits.

Table 4 incremental carbon storage of different disposition model after 20 years(t/hm^2)

disposition model	tree age /a	tree layer	Total carbon storage
Mode 1	23	123.89	136.25
Mode 2	23	81.61	95.17
Mode 3	23	203.18	218.23
Mode 4	23	94.18	107.20
Mode 5	23	118.47	131.66

Table 5 economic benefit of carbon fixation under different disposition model (USD/hm^2)

disposition model	Present	10 years	20 years
Mode 1	156	10101	20438
Mode 2	183	6782	14276
Mode 3	204	16823	32735
Mode 4	107	7604	16080
Mode 5	105	9681	19749

Conclusions

The research results show that disposition model of each vegetation carbon storage and increment is characterized by vine layer > shrub layer > tree layer > herb layer. In the vegetation layer vine layer and the shrub layer carbon increment of vegetation carbon density has no significant difference, respectively accounting for 56.06%, 48.31%, which are in the dominant, but far higher than other vegetation layer. The result is different from the conclusions of other scholars that the vegetation layer depends mainly on the conclusion of tree layer [18].

Based on five disposition model of carbon increment and economic benefit analysis, we concluded that different disposition model in the 10 and 20 years later, both carbon increment and economic benefit are characterized by Mode 3>Mode 1>Mode 5>Mode 4>Mode 2. The trends are the same, which fully prove and illustrate the accuracy of estimation model. The disposition model 3 of *Zenia insignis* forest has the highest economic value of respectively 16823 USD/hm^2 ten year later, 32735 USD/hm^{2}after twenty Years later .Therefore, to integrate increasing carbon sequestration of plants into vegetation restoration and reconstruction project in Guizhou karst area will not only bring huge economic benefits and social benefits, but also bring huge economic benefits.

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