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The brief analysis of contribution of landscape design on low carbon ecological urban construction

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ABSTRACT

The topic of how to achieve the low carbon transition of society is becoming more and more popular in the present society. Researchers are concerning more about how to reduce carbon emissions. Plant landscaping design is of great potential in the low carbon project. In this work, some suggestions and comments were proposed in the landscaping design research area expecting the contribution on low carbon ecological urban construction. We hoped it would be a valuable reference for the sustainable development of improving the urban environment.

KEYWORDS

Low-carbon life; Plant landscape design; Sustainable development.

INTRODUCTION

The low carbon ecological urban needs to develop low carbon economy, as well as take low carbon industry as the developing direction with the urban construction object of low carbon plan. The methods for building low carbon ecological urban can be concluded as the following ones. Firstly, industry developing structure should be adjusted. Secondly, every building in human society should be constructed with the goal of energy conservation. Finally, low carbon should be achieved in human life consumption. Thus the environment temperature can be reduced further and the carbon sink can be increased as wel[1]. Our country is located at a contradictory developing stage, and it is hard to realize a uniform choice between the economic development and low carbon environment construction at this primary developing stage. However, one of the most feasible method so far is to carry out large quantity of plant landscape design and construction in the urban. This method can enhance the adsorption of CO_2 gas obviously. In other words, in order to achieve low carbon ecological construction of a city, one necessary measure is to plant green plants[2-3].

ARTISTIC OVERVIEW OF PLANT LANDSCAPE

Plants landscape is referred to the complete play of natural beauty in plants characteristic including line, form, and color, using shrubs, arbor, vegetation, and vine as plants materials with technological artistic performance, and thus the landscape design and creation is achieved. The modern theory concerning plant landscape is largely different with the traditional one. The modern theory desires not only a certain visual performing effect, but also a realization of sense of beauty in the corresponding form. Moreover, the benefit after landscape should be paid special attention to for the entire ecology whether the category and ornamental features of plants, or their form, ecological habit, and community constitution. The corresponding designers should research carefully on how to configure the plants according to the former characteristic and features with the basis of every plants' ecological habit and the demand of low carbon urban, and their ecological function and ornamental value should be played by the largest extent.

INFLUENCE FACTOR OF PLANT LANDSCAPE CARBON EFFECT

Plant structure

Plant structure can be divided into parallel, vertical, and density, etc. The carbon effects caused by different structures are also very different[2]. The efficiency of carbon sequestration in a unit area of composite multilevel structure is relative high, and its beautiful and active functional demands can be satisfied by the largest extent. When some plants can play a role of space division after landscape design, the corresponding carbon sink effect can be realized for the best. The grassland can be separated into dense and open ones, which are corresponding to different carbon sink function. Therefore, it is necessary to measure different categories and structures for different plants on the basis of the specific application environment. The main acceptable and welcome structures in plant landscape design are open and dense grasslands. The most application of specific forest structure is usually composite multilevel structure. The arbor structure level is dominantly composed of the order of high-middle-low with additional plants of corresponding shrub and ground cover plant. This structure mode is analyzed to possess larger leaf area index obviously, indicating higher photosynthesis efficiency on the other hand. Because the higher proportion of arbor in this kind of structure, the corresponding time period for carbon fixation is relatively longer. The dense forest has stronger landscape structure design in the carbon sink function.

Planting form of plants

Landscape design of plants with different forms and design styles is different in carbon sink efficiency. For example, the natural plants landscape design is totally different with that of artificial plants. The carbon sink efficiency expressed by natural landscape design is obviously higher than that of artificial landscape design. The carbon fixation efficiency of artificial landscape design is much lower and its photosynthesis efficiency is also relatively lower. And strong conservation is needed during this period, so its corresponding carbon emission is very large.

Category of plants

The carbon sink effect of different kinds of plants is also very different. Take arbor and shrub as an example, the carbon sink effect of arbor is relatively high while that of shrub is lower. Arbor is longer in lifetime and expresses larger carbon fixation in the long growing period. Shrub grows faster so that the carbon fixation time preserving inside the plants is relatively shorter during the carbon fixation process. Because the low carbon ecological demand in urban construction nowadays, plants with higher carbon fixation efficiency should must be chosen. In other words, the plants with better carbon fixation speed and period are just needed in landscape design. However, even if these former demand can be satisfied, if CO_2 gas is released in a very short time (plants are clipped by mankind or plants are dead), this kind of plants is obviously not suitable for the particle application. If they are must be used, strict control should be carried out in the application process. It can be seen that a proper category of plant constructs a large extent for the modern low carbon ecologic urban goal.

Plants characteristic

(1) Ability to adapt the environment. Plants with stronger ability to adapt the environment will need fewer requirements in specific conservation and management, even need no conservation and management. This characteristic indicates that plants can adsorb large quantity of CO_2 during photosynthesis and they exhibit strong adsorption ability, thus it reveals the carbon emission is relatively lower.

(2) Plants mass. The plant mass in itself is different for carbon fixation ability. The woodiness part is an obviously important part of plant. If it is larger, the carbon fixation ability is stronger correspondingly.

(3) Grow speed and lifetime. Take banana and gingko as an example to specify. The carbon convergence effect of banana is not stronger than that of gingko. But the carbon fixation ability of banana is stronger. The key problem is that when the carbon is fixed by banana, CO_2 will be released in a very short time. Long time carbon fixation cannot be realized by banana. Although the carbon fixation ability of gingko is not stronger than banana, the lifetime of gingko is extremely long, which can exceed 3000 years and its radius can reach four meters. The carbon fixation period of gingko can be realized to be several thousand years. It is very necessary to choose this kind of plant for low carbon ecologic urban construction to realize long time carbon convergence effect. That is to say these plants with fast grow speed and relatively long lifetime can exhibit strong carbon convergence effect.

(4) Plants structure. The proportion structures of plants themselves are also different from each other in the aspect of carbon convergence. The structures of plants can be analyzed as branches and leaves, limbs, and roots, etc. The corresponding proportion composition is very important for carbon convergence. The most stable carbon converge degree is limbs and roots. While some small branches show relatively less stability for carbon convergence. The most unstable is branches and leaves. The lifetime of plants leaves is the shortest, with several months or not longer than twenty months. After this time period, the leaves fall down from the plant and rot, finally release large quantity of CO_2 due to chemical reaction. It can be indicated that the proportion of woodiness part in the whole plant can affect largely on the CO_2 fixation time and efficiency[3].

Planting density and specification of plants

The planting density of plants should neither be very high nor very low. If the density is too high, the carbon convergence effect will be reduced. While if it is too low, the effect will also be reduced. This is caused by the bad phenomenon during the plants' growing process and large emission of CO_2. The usage efficiency of sunlight will be reduced. If the plants are transplanted using larger specification of plants, their CO_2 emission will be also larger and the corresponding carbon fixation ability will reduce faster.

LANDSCAPE DESIGN METHODS FOR LOW CARBON PLANTS

Choice of carbon fixing and drought resisting plants

Design of low carbon ecological urban can be realized by improving green quality and enhancing green coverage, and in this way the carbon fixing ability can be reached by the most degree. Different kinds of plants exhibit different carbon fixation and oxygen release ability. Based on the experiment results of researchers in different countries[4], plants of strong carbon fixation and oxygen release ability contain: bamboo, southern magnolia, Chinese tallow tree, cottonrose hibiscus, crape myrtle, and camptotheca acuminate, et al. Besides, plants of leguminosae, rosaceae, magnoliaceae, and aquifoliaceae also exhibit strong carbon fixation and oxygen release ability. The results are summarized in TABLE 1.

TABLE 1 : Plant carbon fixation and oxygen release classification index[5]

Carbon fixation and oxygen release ability	Mass of carbon fixation and oxygen release	
	Carbon dioxide	Oxygen
Very strong	>12	>8.7
Strong	10-12	7.3-8.7
Medium	6-10	4.4-7.3
Weak	4-6	<4
Very weak	2.9-4.4	<2.9

The plants choice of low carbon design should be considered from the view of water conservation. It is better to choose the plants with lower transpiration capacity and less water consumption. Therefore, waterproof and drought-resistant ability is an important indicator. Based on the researchers' reports, evaluation indicators of different kinds of plants are also very different, as shown in TABLE 2.

Configuration of high carbon sink plants is benefit for realizing low carbon ecological urban and low carbon society. It should be based on the premise of certain green mass within the whole area. Green mass means the space area taken by branches and leaves of plants during their growth process. The ecological effect of plants caused by interaction between carbon fixation and the environment should use green mass as a standard, which determines the carbon sink ability of plants by a certain extent[6]. In the urban green systematic program, carbon sink ability of urban can be effectively enhanced by increasing the green mass of unit area via reasonable plants configuration. The carbon fixation of green space system can be ensured and the water requirement can be reduced by reasonable configuration, meeting the goal of water-saving and emission reduction.

TABLE 2 : Plant water drought resistance evaluation form[5]

Evaluation index	Index content
Morphological index	Leaf size, leaf thickness, lamellar seta, wax, and pore are taken as evaluate criterion. For example, plants with deep roots are more drought-resistant than those with shallow roots.
Growing index	Plants growth is very sensitive to water lack. In the statistical growth, the indexes such as plants height, leaf area, growth amount, and dry mass accumulation can evaluate the difference of plants drought-resistance ability effectively.
Physical index	Water condition, leaf shadow pressure, water utilization, and some other indicators influencing plants water conditions such as photosynthesis rate, leaf water conservation ability, and transpiration rate are all included.

Systematic design of low carbon energy

Low carbon energy design should started with energy gather, energy transformation, and energy consumption. The diagram is shown in Figure 1.

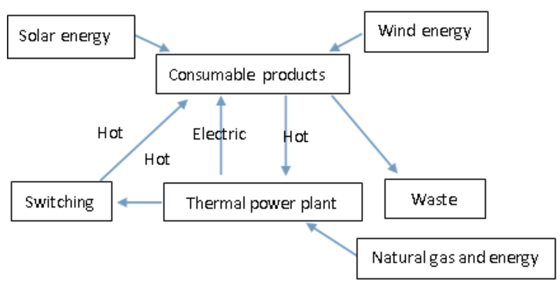

Figure 1 : Usage process of clean energy

Solar energy is a kind of general reproducible energy. Device of gathering solar energy can be conveniently set on the top of buildings, on the drain water well covers along the roads, and on the street lamps. Wind energy is also a kind of clean energy. Wind power generation can be artfully set for providing continuous energy of plants landscape and ecological urban, and be a unique ornamental sight. Biological energy distributes very widely, which is a kind of easily obtained energy. Biological energy can be derived from waste fermentation, and transform to usable electric and hot energy after purification and transformation.

REALIZATION AND EVALUATION OF LOW CARBON PLANTS LANDSCAPE

Methods for low carbon plants landscape realization

In order to realize the low carbon and emission reduction, methods for plants landscape are concluded as the five ways in reducing the energy demand and improving the energy usage efficiency. In other words, the reproducible energy should be used, the energy and resource should be cyclic utilized, and thus the carbon sequestration can be increased for the landscape plants. The five points are concluded as CLEAR principle as shown in (1)[7].

$$\Delta C = C + L + E + A + R \quad (1)$$

Where ΔC is the reduced carbon emission, C is carbon sequestration, L is the carbon emission reduction due to energy loop, E is carbon emission reduction due to reducing the energy demand and improving the energy utilization efficiency, A is carbon emission reduction outside the landscape area, R is carbon emission reduction due to utilization of reproducible energy. Based on these CLEAR principle, evaluation and quantification of low carbon program of plants landscape can be carried out.

Design methods for low carbon landscape plants

In order to reduce the energy consumption during plants landscape construction, it is quite necessary to consider low carbon design. The following aspects can be considered for contributing, maintaining, and dismantling the plant landscape, and thus the energy consumption can be largely reduced.

Firstly, the low carbon local materials should be chosen as landscape raw materials in order to reduce the energy consumption during raw materials transportation, and then the total energy consumption will be reduced. The low carbon materials instead of traditional high carbon materials are low energy consumption, low pollution, reproducible, and long lifetime plants. For example, some landscapes can choose the local natural materials to build and design. Vertical configuration should be used when dealing with the building outside walls, which can adsorb greenhouse gases effectively. Meanwhile, high technological durable materials is able to be chosen for better and longer usage during plant landscape.

Secondly, energy consumption during the plants lifetime should be further reduced. Reproducible energy is of great advantage. Street lamps can be designed as self-powered ones using natural energy to generate electric and popularizing extreme low energy consumption technology. The traffic in low carbon landscape should be energy-saving cars and the carbon emissions due to transportation system could be reduced in a certain extent. When configuring the plants, low carbon principle should be considered as the top principle. Energy consumed in plant protection should be reduced. Plants morphologies which need to be clipped usually such as spherical, hedgerow, color lump, and lawn should be reduced as much as possible.

Finally, water recycling system should be designed and the goal of rainwater cyclic utilization and water conservation and emission reduction will be realized. For example, the waste water can be converted into renewable water by a new technology, and then recycled as irrigation water for plants landscape. The rainwater can also be collected in the wet land by water purification technology for building artificial wet land, and the water is purified level by level to reach the natural purification by the effect of plants.

CASE ANALYSIS

Assimilation amount case study of plants photosynthesis

This work researches the objects of katus - Japanese maple and rhododendron vellereum in a botanic garden in a city. The lower side height of Japanese maple is very low due to existence of branches. Their large branches are open and flat, while small ones are fine and close with great number of leaves. So the sunlight is not easy to shine under the canopy when there is sunshine. Thus some rhododendron vellereum under their canopy are possibly dead, especially near their branches of backbones. It is indicated that the photosynthesis abilities of plants groups composed with these two kinds of plants are very different with each other. If the rhododendron vellereum is located under the phoebe sheareri forest, the obtained sunlight for photosynthesis effect is only 3% of the whole day sunshine, and they are all dead as a result. If they are located under the crown of big tree such as sycamore, the sunlight near the trunk is only 8% of the whole day sunshine, that is 20001×′250001× without blossom. If it stays far away from the trunk, the sunlight can reach 20%-30%, that is 5000-8001×′250001× with the place of increasing blossom obviously. If it get further close to the projection place, the sunlight strength value can exceed 80001× with lush flowers in this way. When the rhododendron vellereum is located under different plants forming different communities[8], the sunlight strength is also very different. For example, the sunlight strength under golden sugarbush can reach 20001×′300001× and 70001×′300001×, while that under triangle sugarbush reaches can be 2600-22001×′, 350001× and 5200-70001×′350001×. Sunlight strength of michelia, camellia, filamental flowering crab, and flowering peach in botanic garden are 901×, 200-12001×, 6001×, and 20001×, respectively.

In the day variation curves of plants under photosynthesis[9], the assimilation amount is represented by the shadow area formed by the photosynthesis net rate curve and time axis, as shown in Figure 2. On the basis of these diagram, when the assimilating net amount is set as q, a formula can be obtained for calculating day assimilating net amount in the measuring day for different kinds of plants, as shown in (2).

$$q = \sum_{i=1}^{j} \left[\left(q_{i+1} + q_i \right) \div 2 \times \left(t_{i+1} - t_i \right) \times 3600 \div 1000 \right] \quad \textbf{(2)}$$

Where q is the total assimilating amount in this measuring day (mmol•m^{-2}•s^{-1}), q_i is the instantaneous photosynthesis rate of the starting measuring time point. q_{i+1} is the instantaneous photosynthesis rate of the next measuring time point (μmol•m^{-2}•s^{-1}). t_i is the instantaneous time of starting measuring point. t_{i+1} is the instantaneous time of the next measuring point. j is the measuring time.

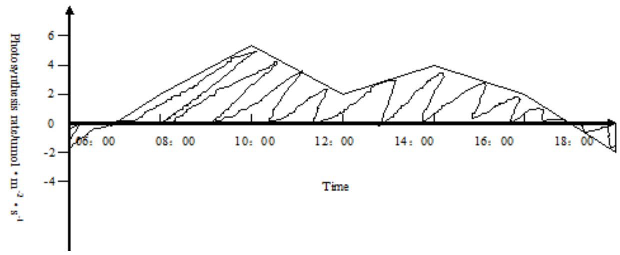

Figure 2 : Diagram of assimilation amount of plants day photosynthesis

Day fixed CO_2 amount is calculated by measuring the total assimilating amount on that day, as shown in (3).

$$W_{CO_2} = q44/1000 \quad \textbf{(3)}$$

Where 44 is molar weight of CO_2, W_{CO2} is the CO_2 weight fixed on the unit leaf area ($g•m^{-2}•d^{-1}$). Oxygen release amount of plant on that measuring day can be obtained according to photosynthesis reaction equation, as shown in (4)[10].

$$W_{O_2} = q32/1000 \quad \textbf{(4)}$$

Case analysis of plants carbon sequestration

In this study, carbon sequestration of a certain low carbon park is calculated and analyzed by measuring the carbon sequestration of plants system and estimating the carbon sequestration condition of the whole park in order to evaluate the low carbon characteristic on a better base.

Carbon sequestration of plants in park (H) is calculated by the carbon preservation amount of forest vegetation system multiply by 44/12[11]. While the estimation method of carbon preservation amount in vegetation system is the biomass (S) of vegetation multiply by carbon element content (T), as shown in (5).

$$H = S \times T \times 44/12 \quad \textbf{(5)}$$

The calculation of biomass is based on volume derived biomass calculation method, in which the biomass index continuous function method is applied the most widely. The formula is as shown in (6-7).

$$BEF = b/V + a \quad \textbf{(6)}$$

$$B = BEF \times V = aV + b \quad \textbf{(7)}$$

Where a and b are transformation functions. According to the published reports, the biomass per unit hectare in the park is 82.4 t/hm^2. The average biomass per unit hectare of shrub forest is 19.76 t/hm^2. If the park is located at hilly land, its specific surface area is calculated by Maogis grid method[12]. After referring to the corresponding data, the synthesized carbon content of this park is 0.44-0.53 with little carbon content difference between each plant. So in this study the carbon content is fixed as 0.5 for convenient calculation and comparison with other research results[13-14]. Carbon sequestration of vegetation in the park is estimated and calculated and the results are listed in TABLE 3.

TABLE 3 : Vegetation carbon sequestration

Classify	Area/hm^2	Total biomass/t	Total carbon preservation	Total carbon sequestration/t
Aggregate	31.58	2021.71	1010.85	275.69
Cedar	4.74	213.36	106.68	29.09
Deodar, coniferous species	1.58	230.91	115.46	31.49
Camphor tree, ligustrum, broadleaf evergreen trees	4.11	289.41	144.71	39.47
Koelreuteria, broussonetieae, deciduous species	6.32	290.1	145.05	39.56
Bamboo	11.37	936.9	468.45	127.76
Shrub	2.21	43.69	21.84	5.96
Open forest	1.26	17.33	8.67	2.36

After comparison from these data, it is concluded that bamboo contribute the most on carbon sequestration. The total CO_2 adsorption amount of this park is 275.69 t, which is a great contribution for low carbon urban construction. It is measured that the carbon sequestration amount per hectare in this park is 11.019 t/hm^2. As reported by researchers[15], carbon sequestration amount per hectare of 10 t/hm^2 is already a high level of carbon sequestration for the forest. This indicates that the park will show a high carbon sequestration ability after building completed.

CONCLUSIONS

In this work, plant landscape design combined with practical characteristic can realize low carbon objective application and contribute to low carbon ecological development. Fine photosynthesis effect of plants play a great role in carbon fixation and collection, further reducing the CO_2 content of the urban.

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