Application of Solar Radiation Analysis Technology in the Optimization of Campus Planting Design

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Abstract. In recent years, the slogans and concepts of sustainable campus, eco-campus, and environmental protection campus have been continually put forward, but there is little ink about the maintenance and management of the most important plants on campus. However, landscape designers often neglect the requirements of plants for the growth conditions of sunlight, or the impact of surrounding buildings on the living environment of plants, resulting in an irreversible situation. To this end, this research hopes to use environmental analysis aided design software to simulate the solar radiation environment and provide references for campus planting design and suggestions for plant selection. The results show that sciophytes are suitable for planting in areas where solar radiation energy is less than 2.90 MJ/m²d; Heliophytes are suitable for planting in areas where solar radiation energy is greater than 5.40 MJ/m²d, and the area in between is suitable for planting mesophytes.

1. Introduction
Energy saving, carbon reduction, and building a sustainable environment have become hot topics in today’s society. To reduce waste of resources and reduce environmental pollution, a landscape architect has an important responsibility. Therefore, how to improve the overall urban climate conditions and natural ventilation, reduce the heat island effect and, summer surface temperature, the first step to establish is the use of plant greening. As Taiwan’s urban green space resources are very limited, campus green spaces with a large greening ratio and a large number have become the best green space compensation from the city. However, most of the campus landscape design, out of considerations of funding and ease of transplantation, ignores the requirements of plants for their own growth conditions and the impact of surrounding buildings on the living environment, causing campus plants to grow slowly and even die. Intangible increases in labor costs and waste of resources, and there is no guarantee that the replanting will conform to the original design intent. Therefore, ensuring the rational use of sunlight by plants is directly related to the quality of the landscape environment [1]. The energy created by solar radiation has advantages and disadvantages for the growth of plants. The rational use of solar radiation energy is a favorable channel to improve plant growth and a means to assure that plant resources are not wasted. It can be understood that the growth habits of plants and the entire campus solar radiation environment play a really important role in landscape planting design.

1.1 The influence of solar radiation spectrum for plant growth
The solar radiation spectrum can be in the visible light band (380-780nm), ultraviolet band (below 400nm), and infrared band (700-10000nm) according to the wavelength. The visible spectrum is the energy source for green plants to produce organic matter through photosynthesis, that is, plants can...
grow and develop normally under white light, which plays an important role in plant growth. In white light, different wavelengths of light have different effects on plants. For example, red light (620~690nm) prevents the decomposition of chlorophyll in plants, promotes the decomposition of carbon dioxide and the synthesis of carbohydrates, so that it remains green in spring and summer, and also affects plant flowering and seed formation. Blue light (400~500nm) contributes to the synthesis of organic acids and proteins, increases metabolism, and therefore accelerates plant growth and development [2]. Therefore, the growth rate of landscape plants in different areas can be adjusted according to the distribution of solar radiation, so as to reduce the cost of maintenance and protection of personnel in the later period.

1.2 The influence of light intensity and weakness on plant growth
The intensity and weakness of light have a direct effect on the growth and development of plants. In general, the intensity of plant photosynthesis will increase with the increase of light intensity. When the light intensity is weak, the organic matter produced by plant photosynthesis cannot reach the amount that the plant wants to absorb, which will affect the life of the plant. When the light intensity reaches a certain value, the intensity of plant photosynthesis will no longer increase with the increase of light intensity. When the light intensity exceeds the saturation, it will destroy the protoplasm of the plant, cause the decomposition of chlorophyll, or cause excessive loss of plant water, resulting in weakening or stopping of photosynthesis [3]. According to the different needs of different plants for light intensity and weakness, they are divided into three types: positive plants, negative plants, and neutral plants. The smallest amount of solar radiation can also distinguish suitable living areas for these three types of plants. Sciophytes are suitable for planting in areas where solar radiation energy is less than 3MJ/m²d; Heliophytes are suitable for planting in areas where solar radiation energy is greater than 6MJ/m²d, and the area in between is suitable for planting mesophytes.

2. Research method
With the promotion of the international trend of sustainable development, people pay more attention to environmental factors, and the era of adding environmental analysis to landscape design has arrived. The traditional evaluation based on experience, manual calculation, production of scale models or on-site measurement methods, etc. require a lot of time, manpower and money, and it is easy to cause irreparable errors [4]. Therefore, this research uses numerical simulation technology and appropriate design aids to create terrain models and building models using Rhinoceros 3D, and then inputs physical information of the building and the environment through Ecotect Analysis to create an energy model to analyze the building and the surrounding environment at a specific time Section of the solar radiation situation, and according to the physiological characteristics of plants, evaluate different planting design options.

2.1 Study area
Simulation area selection Chaoyang University of Science and Technology first campus in Taiwan situated in Wufeng District of Taichung with Administration Building (6 floors), Science and Engineering Building (7 floors), Information Building (5 floors), Humanities and Technology Building (10 floors), Design Building (9 floors), Teaching Building (8 floors), Management Building (10 floors), Library (7 floors), Kindergarten (2 floors). CYUT is a place for environmental education and actively promotes green universities and moves towards a low-carbon campus. Therefore, this research analysis can be used as a reference for the selection of campus landscape plants.

2.2 Analysis software
Ecotect Analysis is a comprehensive, easy-to-use, and user-friendly ecological building aided design software. It has built-in analysis modules for building thermal environment, light environment, sound environment, sunlight and shadow, solar radiation, economy, and environmental impact. User can build a numerical model in an intuitive three-dimensional drawing environment. Through the compilation of numerical model volume and various parameters, you can evaluate the impact of
different design methods on the physical environment or energy consumption and achieve ecological simulation analysis [5].

2.3 Numerical terrain model and building information model data
The numerical terrain model is a numerical terrain model with a grid spacing of 20 meters from the Ministry of the Interior. The data is used to show the three-dimensional spatial terrain fluctuations in a numerical way. The building information model is calculated based on the actual floor height. This research uses Rhinoceros 3D Lands design module to perform terrain modeling and simplified building simulation to improve the efficiency of Ecotect Analysis calculations, as shown in Figure 1.

![Figure 1. Numerical terrain model and building information model data.](image)

2.4 Meteorological data
The meteorological data are the TMY3 standard meteorological year data compiled by the Institute of Construction of the Ministry of the Interior. The data cover a whole year of meteorological data, based on actual observation data from the first-level station of the Central Meteorological Bureau in Taiwan for 15 years (1998-2012). Developed with reference to the Sandia Method standard process in the United States, and its data include temperature, relative humidity, direct sunlight, diffuse radiation intensity, wind speed and direction, cloud cover and rainfall, reflecting the long-term changes in Taiwan’s outdoor climate. This research was imported through the conversion of Ecotect Analysis's weather analysis tool. It can rapidly understand the solar path, solar radiation and other climatic features of the base site, so as to summarize the key directions or principles of the plan.

2.5 Solar radiation calculation
In order to understand the influence of buildings on the solar radiation of the base, this study uses the time-averaged radiation and solar access analysis of Ecotect Analysis to simulate and analyze the solar radiation illuminance around the building. Most plants grow in the summer, so the annual calculation interval is set from June to September. The daily calculation time is set from 9:00 am to 5:00 pm. The different plant types lead to different heights. For the convenience of calculation, the radiation height received by trees is set to 3.5m, shrubs are set to 0.6m, and the ground is set to 0.1m. The standard value of average daily photosynthetically active radiation n in this area is calculated by Ecotect Analysis software, and the area with different standard values of daily average radiation can be obtained, which can provide corresponding basis for the selection and boundary of different types of landscape plants.

3. Result & Discussion
Based on the data results simulated by Ecotect Analysis software, and according to the influence of solar radiation on the growth of plants and the campus planting database, we have a certain understanding of the area where landscape plants are planted in the campus. It is suitable for the area of 4.90 MJ/m²d ~ 6.0 MJ/m²d planting heliophytes, suitable for planting sciophytes in the 0 MJ/m²d ~ 2.90 MJ/m²d area, and suitable for planting mesophytes in the 2.90 MJ/m²d ~ 4.90 MJ/m²d area. (see Figure 2 and Table 1).

![Insolation Analysis](image)

**Figure 2.** Solar radiation analysis.

| Insolation Analysis | Average Daily PAR |
|---------------------|------------------|
| Confidence Range: 3.45~5.40 MJ/m²d | Annual Value: 4.63 MJ/m²d |
| Visible Nodes: 6400 | |

**Table 1.** Recommended plant species.

|                | Heliophytes                                                                 | Mesophytes                                                           | Sciophytes                        |
|----------------|------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Arbor          | Golden shower, Common Crepe Myrtle, Golden Trumpet Tree, Lapacho, Bishop Wood, Lemon gum, Madagascar Almond, Burmese Rosewood | Ring-cupped oak, Formosan michelia, Taiwan nato tree, Common elaecarpus, Honduras mahogany | Common garcina, Taiwan Spruce     |
| Shrub          | Common Lantan, Golden Dewdrop, Drawf Ixora, Cigar Flower, Common jasmine orange, Brazil bougainvillea | Chinese pagoda tree, Tobira Pittosporum, Japanese Maple, Tatarian Dogwood | African, Asparagus, Nandina, Azalea |
| Ground cover   | Trilobate Wedelia, Coleus blumei Benth, Cosmos, Gladiolus                    | Hollyhock, Annual Phlox, China Rose, Chinese Pink                   | Climbing fig, peony              |
From Table 1, we can see that positive plants and neutral plants have more options in planting design, whether they are trees, shrubs or ground cover plants, they have more options than shade-loving plants. According to the analysis results, in the campus, low shrubs and ground cover plants can be planted within the planting area of specific plants. There are more plant species with these two attributes than arbor plants, and there are more plant species to choose from. There are more ways to match plants. When landscape architects choose plant species, they will be restricted due to the difference in regional climate and environment. But when designing landscape planting, in fact, the designer’s first consideration is not to determine the specific name of the plant in the design, but to choose the suitable planting range according to the growth habit of the plant, and then choose the plant that can grow within this certain growth range. Attribute type, then select the appropriate plant species in this type of plant to match the plants and determine the name of the plant to be planted. Such reverse design can help us realize the rational use of resources and achieve the effect of energy saving and emission reduction.

4. Conclusion
This research is a pioneering research. The computation of solar radiation is all simulated by meteorological data, which may be slightly different from actual conditions. Subsequent experiments will assess the radiation from the sun and the sky by setting up pyranometers, and look into the light and thermal effects of solar radiation on plants, in order to offer more objective suggestions. The environmental analysis auxiliary software simulation brings some visual effects to the design. Before the implementation of the plan, the landscape architect began to combine the software to analyze all aspects of the landscape design, and preview the planting design and configuration. The purpose of using environmental analysis to assist design is to provide an application in campus planting design, and to provide an intuitive and valuable analysis for landscape architects in the process of landscape design analysis. Design is no longer just relying on past experience design, but can also make a scientific evaluation and analysis of the landscape environment to make the landscape design itself more clear, energy-saving, emission-reduction, and rational use of resources are the responsibility of contemporary society.

5. References
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