RESEARCH ON HEAT EXPOSURE CHARACTERISTICS IN ACCESSIBLE PARK SPACES BASED ON MULTISPECTRAL UAV IMAGES

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Abstract. Radiation and high temperatures during hot seasons significantly affect the health of outdoor activity enthusiasts. Fractional Vegetation Cover (FVC) in accessible spaces provides shading and cooling functions, reducing the risk of heat exposure for the public, and serves as an indicative measure of outdoor heat exposure conditions. Analyzing the FVC and its variations in accessible park spaces can provide a basis for optimizing park vegetation, effectively reducing the risk of heat exposure for visitors. This study takes Harmony Park in Xinxiang City as an example, focusing on the period from May to September as the hot season, and uses multispectral UAV images as the data source to analyze the FVC and its variations in accessible spaces within the park. The results indicate that the overall average FVC in the park during the hot season is relatively low, with only 0.191 as the lowest coverage level, leading to a high risk of heat exposure for visitors. In the monthly FVC levels during the hot season, the proportion of bare area is around 70%, indicating that the majority of areas have no vegetation cover, yet the areas most frequented by visitors have the highest risk of heat exposure, warranting significant attention. The monthly variations in other FVC levels are relatively small, with lowest, lower, and middle coverage levels typically peaking in May, June, or September, while higher and highest coverage levels typically peak in July or August. Pixel-scale analysis shows that the FVC in accessible park spaces during the hot season primarily improves from May to August and gradually degrades from August to September. The vegetation in accessible park spaces should consider requirements such as large tree canopies, high Leaf Area Index (LAI), rapid growth, moderate density, and proper positioning. Methods such as changing tree species, increasing planting, and adjusting positioning can be employed to reduce the risk of heat exposure.
Keywords: *heat exposure, FVC, park, accessible spaces, multispectral, hot season*

Introduction

Many cities around the world are experiencing record-breaking summer temperatures. Urban environments exacerbate extreme heat, leading to the phenomenon of urban heat islands and increased heat exposure within cities (Yin et al., 2023). The high summer temperatures in cities pose a serious threat to the health of outdoor activity enthusiasts and have a significant impact on the outdoor activities of residents (Cheval et al., 2023). Prolonged exposure to high temperatures can place stress on the temperature regulation of the human body, leading to heat stress-related illnesses, with symptoms ranging from mild heat cramps to fatal heatstroke (Hu et al., 2019). This is especially concerning for the elderly, as the temperature regulating ability of the body diminishes with age, resulting in a decreased overall sensitivity to heat. Even if they subjectively feel comfortable, older individuals may inadvertently subject themselves to heat stress (Li et al., 2023). Research has shown that increasing tree and vegetation cover can reduce the adverse effects of direct sunlight exposure and extreme heat on health, contributing to a decrease in the incidence and mortality rates associated with heat stress in outdoor spaces, while also enhancing thermal comfort levels (Wolf et al., 2020). Generally, the higher the tree coverage, the lower the frequency of severe heat stress (Sheridan et al., 2024). Tree shade can reduce heat-related illness by approximately 80% and significantly lower mortality rates on extremely hot days, thereby helping to mitigate the impact of heatwaves (Graham et al., 2016; Sinha et al., 2022). Urban ecological infrastructure is a promising strategic solution for addressing urban overheating issues, as vegetation provides cooling through transpiration and shading, greatly reducing the likelihood of heat exposure and gaining public acceptance in urban areas (Winbourne et al., 2020). Numerous studies have demonstrated a close relationship between vegetation coverage and heat exposure. Vegetation coverage refers to the degree to which the ground is covered by vegetation, typically expressed as a percentage, reflecting the proportion of the land surface covered by vegetation to the total area.

Parks serve a diverse range of functions and come in various types. However, from a physical composition perspective, all parks consist of four main elements: wooded areas, lawns, water bodies, and hard paving. Parks are usually large in size with abundant vegetation and seem very suitable for summer use, but this might not be the case. In reality, the accessible space within parks may be relatively small, and for larger green spaces and parks, much of the area may be inaccessible (Petrunoff et al., 2021). Apart from a few open lawns and water bodies, the majority of the accessible space to visitors consists of hard paving. Hard paving is further divided into roads and squares, where roads serve the primary function of transportation, including main roads, secondary roads, and walkways, while squares primarily serve as areas for activities and viewing, including gathering squares, rest nodes, viewing platforms, and activity squares, among others. Therefore, studying the vegetation coverage of accessible spaces is helpful in evaluating visitors' heat exposure during park activities. A wealth of research has demonstrated the significant role of FVC in reducing public heat exposure and increasing willingness to engage in park activities. However, there is a lack of research on the FVC of accessible park spaces during hot seasons, which may exaggerate the true experience of park usage in summer for visitors. The issue of vegetation coverage in accessible park spaces during hot seasons deserves sufficient attention in order to provide a relatively comfortable outdoor environment for the public.

The ecological land in urban areas plays an important role in mitigating resident heat exposure by providing shade and reducing human exposure to heat and ultraviolet radiation (Feng et al., 2023). Urban parks are an essential component of urban ecological infrastructure, not only meeting the leisure needs of urban residents but also functioning as urban cool islands. During hot summers, parks, due to their relatively suitable microclimate, become the primary outdoor spaces for residents to take walks, relax, and engage in social activities. The FVC also influences the willingness of park residents to engage in activities; the thermal comfort of outdoor spaces significantly affects people's usage (Hwang et al., 2010). The vegetation cover and size of green spaces in the community can influence residents' willingness to participate in sports activities, thus impacting their health (Perry et al., 2011). Favorable vegetation conditions often accompany higher usage frequency, longer park visits, increased physical activity, and greater life satisfaction (Chiang et al., 2023).

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At the urban scale, there is a strong nonlinear relationship between canopy coverage and surface temperature (Wang et al., 2023; Wei et al., 2023). Differences in vegetation cover play a dominant role in influencing the urban thermal environment and comfort. Studies indicate that cooling effects are primarily driven by FVC (Gillerot et al., 2024), with higher FVC providing better cooling effects (Meili et al., 2021; Horváthová et al., 2021). Of course, the size, shape, and type of green spaces, as well as the coverage of trees and grass (Bowler et al., 2010), the Normalized Difference Vegetation Index, tree height, and other factors, all influence cooling effects (Gao et al., 2022; Guo et al., 2023). During the day, plants can lower temperatures through transpiration, provide shade, and create cool breezes (Alawadhi, 2022). Additionally, tree shade significantly reduces average radiation temperature and physiological equivalent temperature, thus providing a more comfortable microclimate for the city and enhancing public thermal comfort (Tan et al., 2016; Lai et al., 2023). Thermal comfort, of course, is influenced by physiological, psychological, and social/behavioral factors (Xu et al., 2019). Whether individuals feel comfortable in the microclimate they encounter depends on the complex interaction of physiological, behavioral, and psychological factors (Nikolopoulou and Steemers, 2003). Tree shade is the optimal design measure to meet the requirements of a thermally comfortable environment (Xu et al., 2019). Trees are highly effective in reducing the Universal Thermal Climate Index during summer days, primarily by lowering the average radiation temperature in shaded areas (Coutts et al., 2016). The cooling effect of tree canopies is particularly important in summer, as high temperatures pose health risks to urban residents and workers (Mishra et al., 2015). Shading is crucial for alleviating daytime heat stress in summer. If urban environments are possessed with more tree cover and higher albedo (Aleksandrowicz and Pearlmutter, 2023), the severe heat stress events can be significantly reduced (Li et al., 2024).

This study, based on multispectral UAV images and focusing on the hot season, analyzes the characteristics of heat exposure in accessible park spaces, providing a basis for vegetation renewal and design in these areas. According to the usual seasonal division method, June to August is considered summer. However, this may not align perfectly with actual seasonal perceptions. In 1934, the renowned Chinese climatologist Zhang Baokun established a standard for dividing the four seasons based on phenological phenomena, i.e., dividing the natural seasons based on the changes in local natural characteristics and phenological landscapes. Xinxiang City has a warm temperate continental monsoon climate, with distinct seasons and cold winters and hot summers. The period from May to September is the hot season in Xinxiang City, with strong daytime solar radiation and high perceived temperatures among the public. This study considers the period from May to September as the research timeframe for heat exposure.

The framework of this study is shown in *Fig. 1*.

Materials and methods

Study area

Xinxiang City is located in the northern part of Henan Province, with the Yellow River to the south. It serves as the central city of northern Henan and is designated as a national garden city, boasting numerous parks of varying sizes within the city. Among these, Harmony Park, located in the Hongqi District, is representative and typical. The park, with an open design, covers an area of approximately 11 hectares (*Fig. 2*). This study selects Harmony Park as the research sample for the following reasons: (1) It is one of

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the few comprehensive parks in Xinxiang City, equipped with a well-developed road traffic system and leisure square system to meet the public's sightseeing and leisure needs; (2) Established in 2008, it is one of the earliest parks in Xinxiang City with modern landscape design features; (3) The park boasts rich vegetation, diverse configuration types, substantial green coverage, and relatively mature development; (4) It attracts a large number of visitors and is one of the most popular parks in Xinxiang City.

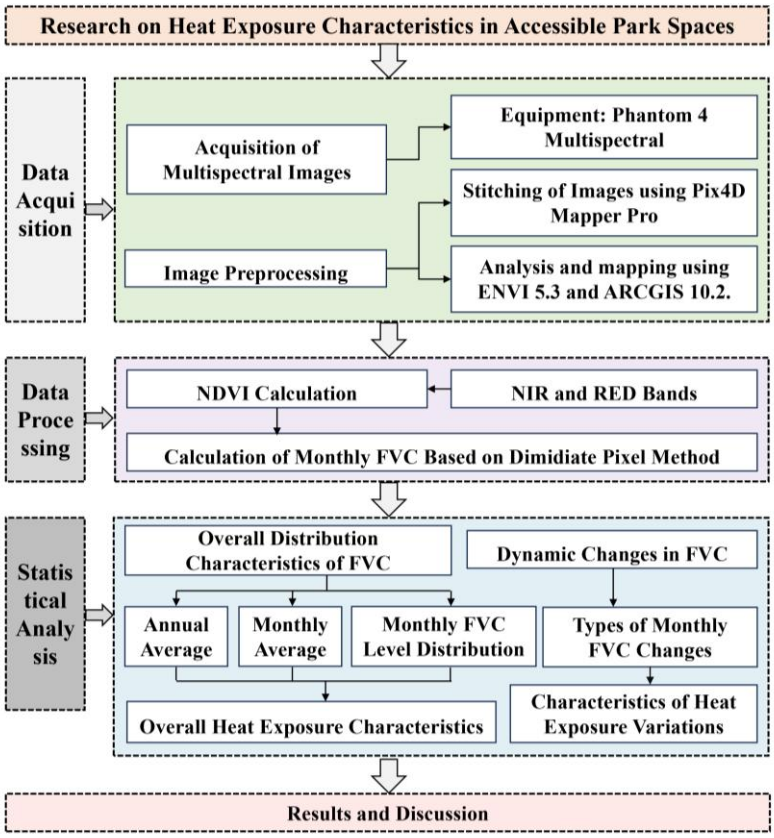

Figure 1. *Schematic Diagram of the Research Framework*

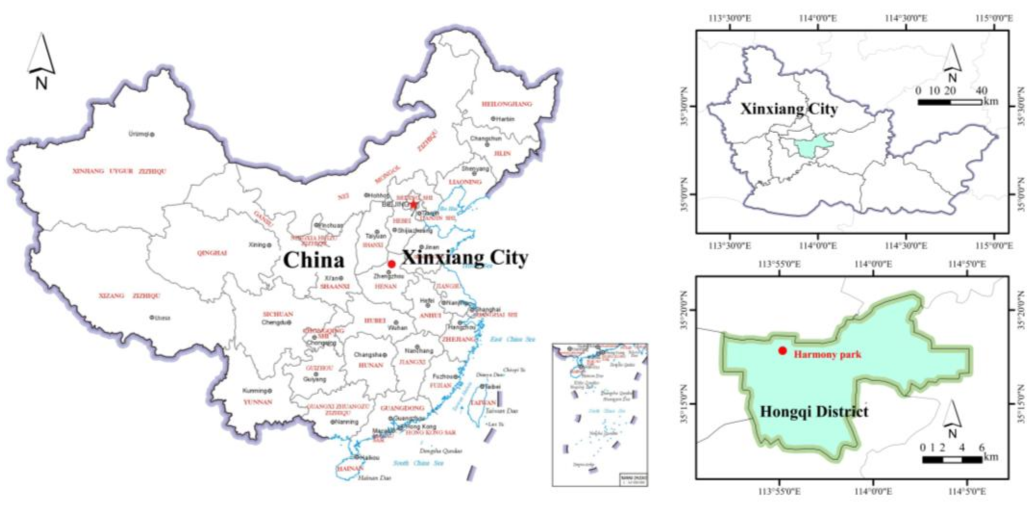

Figure 2. *Schematic map of Harmony Park (Map source: http://bzdt.ch.mnr.gov.cn/, Cartographic License Number: GS 2019 1676)*

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Data collection

A DJI Phantom 4 Multispectral (P4M) UAV, equipped with an integrated multispectral imaging system, was used to capture monthly time-series images of the parks around the 25th of each month from May to September 2021 (*Table 1*). The P4M sensors undergo strict calibration at the factory, with calibration parameters embedded in the image metadata for distortion adjustment during post-processing. Before each flight, sensor calibration, including compass and lens alignment, is performed according to DJI's control software guidelines to ensure data consistency across different months. The DJI TimeSync system ensures accurate positioning during image capture through microsecond-level synchronization of the flight control, camera, and RTK clocks (Li et al., 2020).

Table 1*. Parameters for multispectral image acquisition*

Parameter	**Month**				
	May	**June**	**July**	**August**	**September**
Date	25	25	26	26	27
Coordinate System	WGS84 /UTMzone 49N				
Flight Altitude	150m				
Forward Overlap	80%				
Side Overlap	80%				
Main Line Angle	0°				
Weather Condition	No Wind and Clouds				
Camera Model Name(s)	FC6360_5.7_1600x1300				
Average Ground Sampling Distance (GSD)	7.97 cm/3.14 in	7.94 cm/3.13 in	7.92 cm/3.12 in	7.93 cm/3.12 in	7.96 cm /3.13 in
Dataset	230 images				
Kappa	Mean(0.003), Sigma(0.001)	Mean(0.003), Sigma(0.001)	Mean(0.003), Sigma(0.001)	Mean(0.003), Sigma(0.001)	Mean(0.003), Sigma(0.001)

The image data was processed using Pix4Dmapper software for single-band image stitching, and further analysis and mapping were conducted using ENVI 5.3 and ArcGIS 10.8 software. The P4M integrates one visible light sensor and five multispectral sensors, utilizing DJI's integrated Network Real-Time Kinematic (RTK) system to ensure spatial accuracy. The Network RTK system provides positioning capabilities with a horizontal accuracy of 1 cm + 1 ppm and a vertical accuracy of 1.5 cm + 1 ppm. This level of precision is sufficient to meet experimental requirements, enabling high-precision positioning without the need for ground control points (Suomalainen et al., 2018; Smith and Harris, 2019). Additionally, the integrated multispectral light intensity sensor on the top of the device captures solar irradiance and records it in the image files. During post-processing, solar irradiance data was used for radiometric correction to eliminate environmental light interference, enhancing the accuracy and consistency of data collected at different times. Radiometric correction is performed using the Quick Atmospheric Correction tool in ENVI 5.3 software.

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Research methods

Designation of accessible spaces for park visitors

In park management in China, to minimize damage to vegetation and lawns from human trampling, public access is restricted to most green spaces, with only a few lawn areas being accessible. Therefore, accessible spaces are primarily concentrated in paved areas like roads and squares.

Since the majority of plants in parks are deciduous, the impact of the leaf-off season on visual judgment is minimal. This study selects RGB images of the park from January and uses visual interpretation in ENVI 5.3 to delineate the boundaries between green spaces and hard surfaces, validating the accuracy of these boundaries through field surveys conducted in the park.

A Region of Interest (ROI) was established for data analysis (*Fig. 3*). For spatial description, the accessible space was categorized into two types: roads and squares.

Figure 3. *Schematic diagram of ROI in accessible park spaces (Squares and roads serve as accessible spaces, while green areas and water bodies are designated as non-accessible spaces)*

FVC calculation

The NDVI is a commonly used vegetation cover index, indicating the density and dynamic changes of vegetation. It is often used to monitor the growth and health of vegetation. However, NDVI tends to compress in areas with low vegetation cover and expand in areas with high vegetation cover. Therefore, the FVC estimated based on NDVI becomes an important indicator for measuring the vegetation condition of the land surface. FVC is based on the Dimidiate pixel model (Mohammed and Algarni, 2020), which assumes that the land surface of a pixel consists of green vegetation and bare area. FVC represents the ratio of vegetation in the pixel. The formula is as follows (Gutman and Ignatov, 1998):

$$FVC = (NDVI - NDVI_{\text{soil}})/(NDVI_{veg} - NDVI_{\text{soil}}) \quad \text{(Eq.1)}$$

where $NDVI_{soil}$ represents the NDVI value of a pixel covered purely by bare area under ideal conditions, and $NDVI_{veg}$ represents the NDVI value of a pixel covered purely by vegetation under ideal conditions (Dong et al., 2023). In theory, both values should

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approach 0 and 1 under ideal conditions. However, due to various factors, the minimum and maximum values of NDVI are not necessarily $NDVI_{soil}$ and $NDVI_{veg}$. Combining previous research (Tong et al., 2016), the NDVI values corresponding to 5% and 95% are taken as the NDVI values for pure bare area and pure vegetation-covered pixels, respectively.

NDVI is computed from the red and near-infrared bands using the following formula (Singla et al., 2023):

$$NDVI = (NIR - R)/(NIR + R) \quad \text{(Eq.2)}$$

An NDVI value greater than 0 indicates the presence of vegetation cover, while an NDVI value of 0 signifies the absence of vegetation. However, it is not possible for vegetation cover to yield a negative value. To ensure that the estimation of FVC accurately reflects actual vegetation coverage, it is necessary to set the values for roads, paved squares, and water surfaces to zero. This study utilized the Band Math tool in ENVI 5.3 software to zero out negative NDVI values.

$$0>B1 \quad \text{(Eq.3)}$$

where B1 represents the NDVI raster.

FVC classification

According to the SL190-2007 Standards for Classification and Gradation of Soil Erosion issued by the Ministry of Water Resources of China, the FVC is classified into six levels: bare area (FVC ≤ 10%), lowest coverage area (10% < FVC ≤ 30%), lower coverage area (30% < FVC ≤ 45%), middle coverage area (45% < FVC ≤ 60%), higher coverage area (60% < FVC ≤ 75%), and highest coverage area (FVC > 75%).

Analysis of spatial and temporal dynamic changes of FVC at the pixel scale

To visually represent the improvement or degradation of FVC at the pixel scale between months, a differential method was employed for analysis. After calculating the differences, density segmentation was conducted using ENVI 5.3 software. Based on previous research and on-site vegetation conditions, different levels were assigned to the vegetation changes. The differential calculation was obtained using the layer stacking and band arithmetic tools in ENVI 5.3. The formula is as follows (Liu et al., 2024):

$$\Delta FVC = FVC_i - FVC_{i-1} \quad \text{(Eq.4)}$$

where, ΔFVC represents the FVC delta index, where ΔFVC >0 indicates an increase in FVC, and ΔFVC <0 indicates a decrease; and FVC_i FVC_{i-1} represent the pixel values of FVC on the images from two consecutive months. Using the Raster Color Slices tool under the Classification menu in ENVI software, segmentation results can be obtained after setting the relevant parameters. Based on this, the dynamic changes in FVC were divided into 5 levels: significant degradation (less than -30%), slight degradation (-30% to -5%), basic stability (-5% to 5%), slight improvement (5% to 30%), and significant improvement (greater than 30%) (Yang et al., 2016).

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Results and analysis

Overall heat exposure characteristics of accessible park spaces

The overall average of the FVC for the accessible space in the Harmony Park during the hot season is 0.191, which is at an extremely low level. The average FVC values from May to September are 0.181, 0.188, 0.189, 0.206, and 0.193, respectively. There is only a slight increase from May to July, with the highest value reached in August, followed by a decline (*Fig. 4*, *Fig. 5*). The park faces a significant risk of heat exposure during the hot season, which will significantly impact the public's willingness and duration of visits.

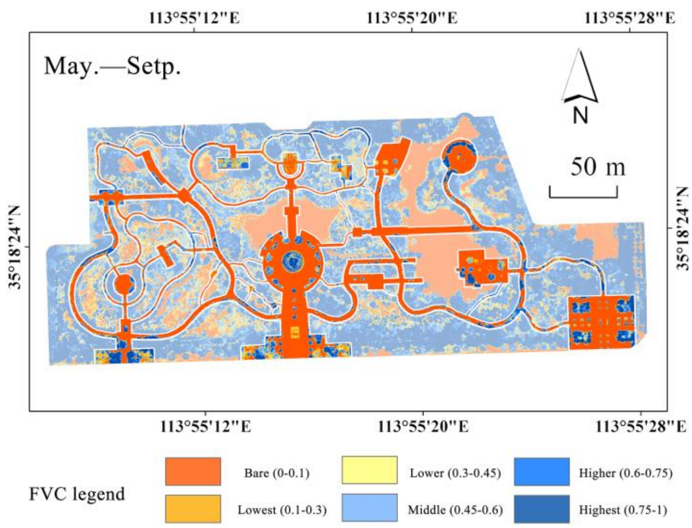

Figure 4. *Overall average of the FVC for the accessible space in the Harmony Park during the hot season*

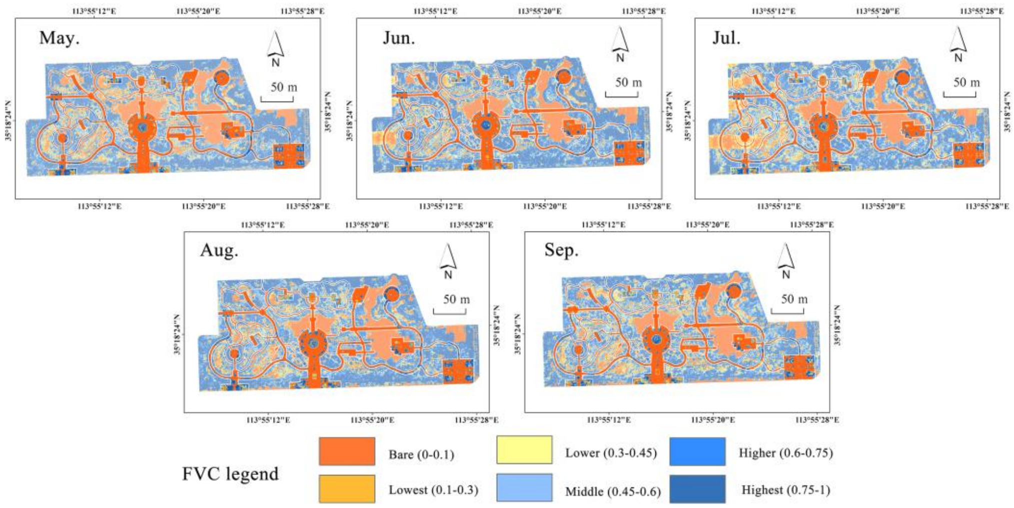

Figure 5. *Monthly spatial distribution of FVC in accessible park spaces during the hot season*

In terms of spatial distribution, the FVC on roads is mainly concentrated on the northern side roads and the main east-west roads. Since trees are generally planted at a distance of over 0.5m from the curb, narrower roads tend to receive more shading. The

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FVC on the squares is mainly distributed at the southern and southeastern entrance squares, with some distribution in the northeastern corner and the central square. This indicates that the accessible park spaces during the hot season are almost unsuitable for visitor use during the day, exposing them to serious heat exposure risks.

In the hot season, the spatial distribution of various FVC levels in Harmony Park's accessible spaces ranks consistently on a monthly basis as follows: bare area, highest, higher, middle, lowest, and lower (*Table 2*). The proportion of bare land is close to 70% in each month and shows a monthly decreasing trend. This reflects a rather serious issue: the majority of accessible spaces lack vegetation cover, resulting in the highest heat exposure risk in the areas most frequented by visitors. The proportions of lowest, lower, and middle coverage gradually increase, but there is a significant decrease in August, which is due to the conversion of some vegetated areas to higher coverage categories. The proportion of higher coverage increases monthly, reaching its peak in August before decreasing. Highest coverage remains relatively stable from May to June, decreases in July, and then suddenly rises to its peak in August before decreasing again. In theory, according to phenological norms, the proportion of highest coverage in July should increase. However, in this study, extreme heavy rainfall in July led to prolonged waterlogging, causing damage to some plants and influencing the FVC values.

Table 2. *Proportions of various FVC levels in accessible park spaces during the hot season (%)*

	Bare Area	Lowest Coverage Area	Lower Coverage Area	Middle Coverage Area	Higher Coverage Area	Highest Coverage Area	Total Area(hm)
May	71.17	4.21	3.56	4.34	5.64	11.08	2.43
June	69.08	4.83	4.13	5.11	6.38	10.43	2.43
July	67.69	5.48	4.95	5.85	6.63	9.41	2.43
August	67.40	4.34	4.09	5.11	6.83	12.19	2.43
September	67.20	5.64	5.07	5.85	6.22	10.02	2.43

Analysis of spatiotemporal dynamic changes in FVC at the pixel scale

Generally, an increase in FVC implies a decrease in Heat Exposure. Plants can provide better shading and cooling effects. The dynamic changes in FVC at the pixel scale in the park during the hot season are shown in *Fig. 6*, and the proportions of different change types are presented in *Table 3*. The proportion of areas with no significant change is highest from May to June and lowest from July to August. The proportion of improved areas is highest from May to June and from July to August, mainly characterized by moderate improvement. This period corresponds to the peak growth period for plants, where leaf area gradually reaches its annual peak. However, the proportion of degraded areas from June to July is higher compared to May to June and July to August, indicating an extremely anomalous phenomenon. This is mainly attributed to the impact of heavy rainfall in July, leading to significant damage to vegetation due to prolonged water logging. From August to September, influenced by the phenological changes of vegetation, the proportion of degraded areas gradually increases, while the proportion of improved areas decreases. Additionally, the proportion of improved areas is lower than that of degraded areas.

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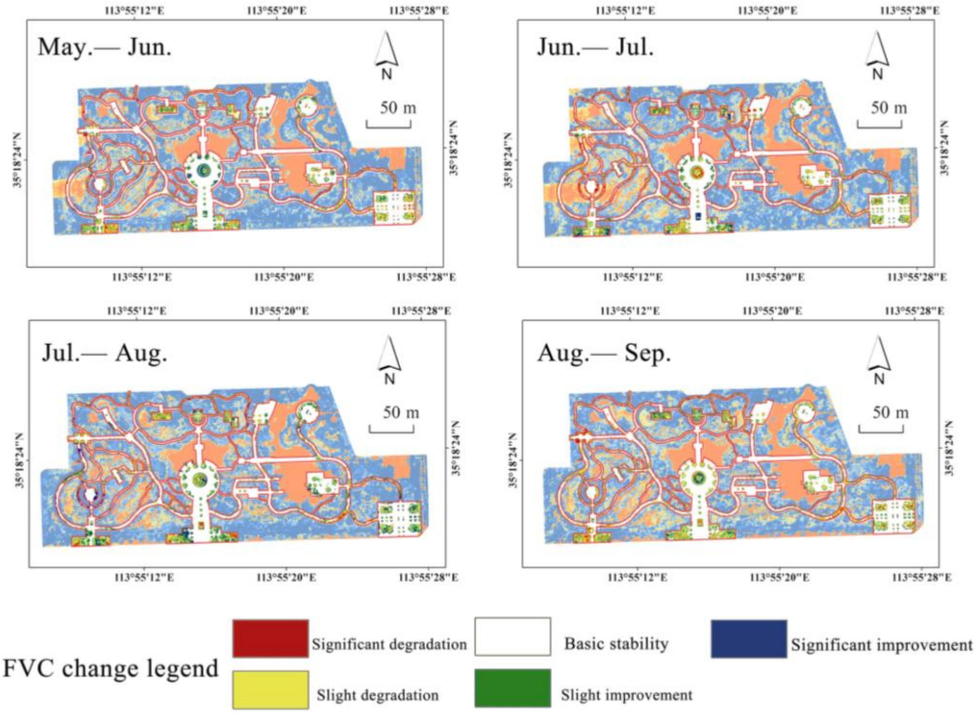

Figure 6. *Dynamic Changes in FVC at the Pixel Scale for Adjacent Months in the Accessible Park Spaces during the Hot Season*

Table 3. *Proportions of different types of FVC changes at the pixel scale for adjacent months in the accessible park spaces during the hot season (in %)*

	May-June	June-July	July-August	August-September
Significant degradation	3.03	4.00	3.14	4.37
Moderate degradation	9.86	11.25	8.92	12.60
Basic stability	73.34	70.20	69.58	70.24
Moderate improvement	11.18	9.54	12.12	9.60
Significant improvement	4.01	4.57	5.50	2.70

Discussion

Influence of urban green space design standards

Parks play a crucial role as the “green lungs” or “green cores” in urban areas and are important public recreational spaces, especially during the summer. A survey indicated that over 70% of respondents support prioritizing the establishment of more parks and shaded green spaces, while over 80% support planting more trees along streets as a strategy to alleviate and adapt to heat. Currently, in urban green space design standards and park design guidelines, most regulations focus on functionality, facilities, and other aspects. However, there is a lack of mandatory regulations for FVC, especially the accessible space FVC, leading designers to rely largely on subjective judgments in park vegetation design, often neglecting the shading requirements during the summer.

With climate change exacerbating, it becomes crucial for urban planners, policy makers, and emergency management personnel to incorporate FVC considerations into the decision-making process (Sousa-Silva and Zanocco, 2024). In urban planning and

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design, increasing green coverage, afforestation, and other methods can effectively reduce the urban heat island effect, enhance urban environmental comfort and suitability, and mitigate the impact of heat exposure on residents' health. Therefore, relevant standards should not only regulate green space ratios but also establish FVC standards (Li et al., 2023). Guiding the types of accessible space plants in parks, their canopy width, height, and planting methods can effectively reduce the heat exposure risk for park visitors during the summer. For example, urban climatologists have proposed that planting trees with wide canopies and tall trunks can enhance the cooling effect of microenvironments (Nan et al., 2023). Even distribution of trees on sun-exposed sidewalks can avoid mutual shading, thus optimizing the shading effect of each tree (Lachapelle et al., 2023). Planting mature trees with large canopies becomes a simple and effective method to reduce urban heat and avoid direct sunlight (Zamponi et al., 2023).

Influence of design aesthetics on heat exposure in accessible park spaces

In park vegetation arrangement, designers typically focus on two factors: space and aesthetics. Spatial design emphasizes a combination of openness and enclosure to create a well-balanced landscape effect. Therefore, as the main viewing areas for visitors, pathways are often left without tree planting to create an ultimate spatial visual effect. squares, being open spaces, need to provide convenient activity areas for visitors, and planting vegetation can hinder the activities on the square, thus leading to lower FVC in these areas. Shading requires dense foliage, yet in park design, aesthetics play a crucial role in plant selection, which might lead to the exclusion of densely foliaged plants.

Impact of plant characteristics on heat exposure in accessible park spaces

The vegetation in accessible park spaces should meet requirements such as having large tree canopies, high LAI, rapid growth, and proper positioning (Hami et al., 2019; Lee et al., 2020). Structural features such as LAI, tree height, and planting density affect transpiration and latent heat, thereby reducing heat stress. Leaf Area Density (LAD) and canopy diameter significantly influence thermal comfort, and street trees should provide a good balance between shading and air circulation (Speak et al., 2020; Xiao et al., 2024). The extent of air and surface temperature reduction due to tree shading is significantly positively correlated with LAI (Sharmin et al., 2023; Chen et al., 2023). Street trees with high LAD and closer spacing between trees contribute to improving cooling effects in roadside environments (Kong et al., 2017; Jayasinghe et al., 2024). There is considerable variation in LAI among plants, and the changes in LAI due to phenological variations are complex (Jia and Zhang, 2022). In the long term, planting fast-growing, dense-leaf trees can more effectively reduce heat in the area (Jia and Zhang, 2022), and using mature trees with large canopies is a simple and effective method to reduce urban heat and avoid direct sunlight (Zamponi et al., 2023). Proper placement of trees in the right locations can provide optimal shading for pedestrians, making the optimization of tree planting locations crucial (Langenheim et al., 2020; Hao et al., 2023).

Impact of extreme heavy rainfall on FVC in accessible park spaces

July is a period of vigorous plant growth, theoretically indicating a higher proportion of highest vegetation coverage. However, in this study, the proportion of highest vegetation coverage in July was relatively low, primarily due to the influence of extreme weather. On July 9, 2021, Xinxiang City experienced extremely heavy rainfall, with the

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highest recorded precipitation reaching 907mm, resulting in severe urban waterlogging. Due to the flood persisting for nearly two weeks before gradually receding, the vegetation in lower-lying areas of the park was significantly affected by inundation, leading to a notable decrease in FVC values. The UAV imagery was captured on the 21st of that month, directly documenting the impact of this extreme weather on the vegetation (Xu et al., 2023). By analyzing changes in FVC, urban managers can identify affected areas after flooding and timely assess the condition of damaged vegetation. In the park design and vegetation renewal of these areas, priority should be given to flood-tolerant plants and resilient native species to enhance vegetation survival and recovery in extreme weather, thereby reducing the negative impact of future floods on FVC.

Conclusion

The average FVC of accessible park spaces during the hot season is 0.191. This indicates a high risk of heat exposure in the park during this season, making it unsuitable for daytime visitor use. Optimizing roadside vegetation should involve increasing the planting of street trees to enhance the FVC of the roads. Additionally, there should be an increase in planting vegetation in open spaces to provide more comfortable shaded areas without impeding activities.

The distribution of FVC levels in accessible park spaces from May to September remains consistent, with the order being bare area, highest, higher, middle, lowest, and lower, respectively. Bare area accounts for approximately 70% of FVC in each month, with minimal variation. This suggests that the majority of accessible spaces lack vegetation cover, yet these areas with the highest visitor usage have the highest heat exposure risk. The variation in other FVC levels from month to month is relatively small, with lowest, lower, and middle FVC levels typically peaking in May, June, or September, while higher and highest FVC levels usually peak in July or August. Optimizing the vegetation in accessible spaces should involve increasing planting density and selecting plant species with dense foliage. Simultaneously, while considering visual aesthetics, park street trees should be evenly distributed.

At the pixel scale, the dynamic changes in park FVC during the hot season, except for July affected by heavy rainfall, generally show improvement from May to August, gradually declining from August to September. Vegetation in accessible park spaces should prioritize plant species with high LAI, large canopy, and substantial size.

(4) Urban managers should establish guidelines or regulations to set minimum values for the FVC of hard spaces like roads and squares in urban green areas, aiming to reduce the heat exposure risk for visitors during hot seasons. In planning and design, trees, especially tall canopy trees, should be planted along main roads and squares to create continuous shaded areas, which help lower surface temperatures and enhance human comfort.

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