ACTIVITY REPORT

Build4People

Enhancing Urban Resilience through Thermal UAV Technology: A Case Study of Green Space Monitoring in Phnom Penh, Cambodia

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This activity report describes the use of thermal Unmanned Aerial Vehicle (UAV) for monitoring urban land cover (i.e., green spaces), focusing on the potential to monitor urban ecosystems of the rapidly urbanising Phnom Penh. By employing a transdisciplinary approach, the Build4People project trained local partners on using thermal UAVs to collect high-resolution RGB and thermal images. Results revealed distinct thermal footprints of different land covers, highlighting the cooling effects of water bodies and vegetation in an urban area. This activity demonstrates how thermal UAV technology can advance urban environmental monitoring. The empirical results from the activity are useful in fostering sustainable urban transformation because local decision-makers received clear visual hints about thermal footprint of different infrastructures inspiring measures to combat urban heat island (UHI) effects, among others. Generally, applying such innovative technologies in the field of sustainable urban transformation is regarded as essential to enhancing environmental sustainability and urban liveability.

Deutsch
Dieser Tätigkeitsbericht beschreibt den Einsatz von thermischen unbemannten Luftfahrzeugen (UAV) zur Überwachung der städtischen Bodenbedeckung (d. h. Grünflächen) mit Schwerpunkt auf dem Potenzial zur Überwachung städtischer Ökosysteme in der sich rasch urbanisierenden Stadt Phnom Penh. Mit einem transdisziplinären Ansatz schulte das Projekt Build4People lokale Partner in der Verwendung thermischer UAV zur Erfassung hochauflösender RGB- und Wärmebilder. Die Ergebnisse zeigten deutliche thermische Fußabdrücke verschiedener Landbedeckungen und verdeutlichten die kühlenden Effekte von Gewässern und Vegetation in einem städtischen Gebiet. Diese Übung zeigt, wie thermische UAV-Technologie die städtische Umweltüberwachung verbessern kann. Die empirischen Ergebnisse der Übung sind nützlich für die Förderung einer nachhaltigen städtischen Transformation, da lokale Entscheidungsträger klare visuelle Hinweise auf die thermischen Fußabdrücke verschiedener Infrastrukturen erhielten, die unter anderem zu Maßnahmen zur Bekämpfung des städtischen Wärmeinseleffekts (UHI) inspirierten. Generell wird der Einsatz solcher innovativen Technologien im Bereich der nachhaltigen Stadtumgestaltung als wesentlich für die Verbesserung der ökologischen Nachhaltigkeit und der Lebensqualität in Städten angesehen.

Cover photo:
Phnom Penh, Cambodia (photo credit: Katharina M. Borgmann).

Street Landscape in Phnom Penh, Cambodia (photo credit: Katharina M. Borgmann).

ខ្មែរ

របាយការណ៍សកម្មភាពនេះបានពិពណ៌នាអំពីការប្រើប្រាស់ ឧបករណ៍ដ្រូនដែរមានបំពាក់កាមេរ៉ារង្វាស់កម្តៅ (Thermal UAV) សម្រាប់ការតាមដានលំហាបៃតងនៅក្នុងទីក្រុង និងផ្តោតលើសក្តានុពលដើម្បីពង្រឹងប្រព័ន្ធអេកូឡូស៊ីទីក្រុងភ្នំពេញ ដែលកំពុងរីកចម្រើនយ៉ាងឆាប់រហ័ស។ តាមរយៈការប្រើប្រាស់វិធីសាស្រ្តទំនើប គម្រោងBuild4People បានបណ្តុះបណ្តាលដៃគូក្នុងស្រុកឱ្យចេះប្រើបច្ចេកវិទ្យាកម្រិតខ្ពស់ទាំងនេះ។

យើងក៏បានប្រើប្រាស់ឧបករណ៍ដ្រូនដើម្បីប្រមូលរូបភាព(RGB) និងរូបភាពកម្តៅដែលមានគុណភាពកំរិតខ្ពស់ ។ លទ្ធផលបានបង្ហាញអំពីលក្ខខណ្ឌកម្តៅខុសៗគ្នាទៅតាមប្រភេទគម្របដីនីមួយៗ ផ្ទៃទឹកនិងរុក្ខជាតិមានឥទ្ធិពលក្នុងការកាត់បន្ថយកម្តៅក្នុងទីក្រុង។ ការសិក្សានេះក៏បានបង្ហាញអំពីរបៀបដែល ឧបករណ៍ដ្រូនមានបំពាក់កាមេរ៉ារង្វាស់កម្តៅ(Thermal UAV)អាចតាមដាន និងប្រមូលទិន្នន័យពាក់ព័ន្ធជាមួយនឹងបរិស្ថាន

ទីក្រុងបានទូលំទូលាយ និងប្រកបដោយប្រសិទ្ធភាព។ ព័ត៌មានដែលទទួលបានដោយការសិក្សាបានប្រែក្លាយជាឧបករណ៍ដ៏សំខាន់ក្នុងការប្រើប្រាស់សម្រាប់ការជម្រុញកែលម្អទីក្រុងប្រកបដោយចីរភាព ព្រោះអ្នកអនុវត្តអាចទទួលបានការបង្ហាញយ៉ាងច្បាស់អំពីទីតាំងដែលគួរសម្រេចចិត្តក្នុងការបន្ថែមផ្ទៃបៃតងដើម្បីទប់ទល់នឹងឥទ្ធិពលកោះកម្ត(Urban Heat Island)។ ជាទូទៅ ការអនុវត្តបច្ចេកវិទ្យាដែលប្រកបដោយភាពច្នៃប្រឌិតក្នុងការកែប្រែទីក្រុងប្រកបដោយចីរភាពត្រូវបានចាត់ទុកថាជាកត្តាចាំបាច់ក្នុងការលើកកម្ពស់ដល់និរន្តរភាពបរិស្ថាន និងគុណភាពនៃការរស់នៅរបស់ប្រជាជនក្នុងទីក្រុង។

(Automated translation)

Introduction

Urban green spaces (such as parks, community gardens, and tree-lined boulevards) are not merely aesthetic enhancements in our cities but are vital to urban ecosystems. They provide many benefits: mitigating urban heat island effects, improving air quality, supporting biodiversity, and offering recreational opportunities for city dwellers (Bowler et al., 2010). These areas serve as natural oases in concrete jungles, contributing significantly to the physical and mental well-being of the population (Hartig et al., 2014). However, effectively monitoring and managing these spaces is a complex task, often heavily resource-consuming to address the challenging dynamics of urban environments. Traditional monitoring methods can be labour-intensive and time-consuming (Haaland et al., 2015).

In this context, thermal UAVs equipped with advanced sensors and thermal imaging capabilities provide a unique vantage point to study urban green spaces. By capturing high-resolution thermal images from above, they offer detailed insights into the thermal properties of an urban area (Berni et al., 2009). This technology enables researchers and urban planners to monitor land surface of skin temperature variations of urban structures, assess vegetation health, and understand different surfaces' heat absorption and radiation patterns (Zarco-Tejada et al., 2012). The data gathered is invaluable for planning and monitoring urban green spaces, contributing to strategies that combat the UHI effect, thus safeguarding the sustainability and resilience of our cities. Mapping the thermal footprints of urban structures can thus serve as a powerful approach for studying the spatial physical pattern of the urban heat island in tropical cities.

As we seek solutions for sustainable urban development, integrating advanced technologies like thermal UAVs in environmental monitoring of urban structures represents a significant leap forward in using sophisticated technologies. In this report, we delve into the one of the activities of the Build4People project, an exemplary initiative that leveraged thermal UAV technology to monitor urban green spaces.

Build4People Project Overview

The overall aim of the inter- and trans-disciplinary Build4People project is to support and analyse the transformative shift in Phnom Penh’s current business-as-usual urban development pathway towards a pathway with higher sustainability and liveability levels. The entry points for the research are initially the building and in further course of the project increasingly the more comprehensive neighbourhood planning sectors. Methods, tools and key instruments to achieve the Build4People's objectives are collaborative planning workshops, strategic niche management approaches, transition management approaches such as living labs and subsequent experimental implementation. Thereby, the constant transfer of knowledge between stakeholders from science, politics, civil society and the corporate sector is being regarded as essential for sustainable urban transformation. All of these measures are expected to generate applied knowledge, the development of sustainable practices and consequently to serve as a basis for evidence-based decision-making for local stakeholders in line with the UN Sustainable Development Goals (SDGs).

Approach

Thermal infrared (TIR) remote sensing using unmanned aerial vehicles (UAVs) is an important means of obtaining the temperature of the land surface (LST) with high spatial resolution. In this effort, the Build4People project adopted a collaborative and hands-on approach. Key to this initiative was the training of local research partners, young academic staff of the Royal University of Agriculture (RUA) in Phnom Penh in using the thermal UAVs for data collection. Marking a significant milestone in capacity building, the UAV was formally handed over to RUA in a ceremony, symbolising the project's commitment to sustainable research practices and continuing this vital work in the future (Build4People, 2022).

Necessary thermal image data processing was a joint effort between RUA and Eberswalde University for Sustainable Development (HNEE), ensuring a comprehensive analysis incorporating local

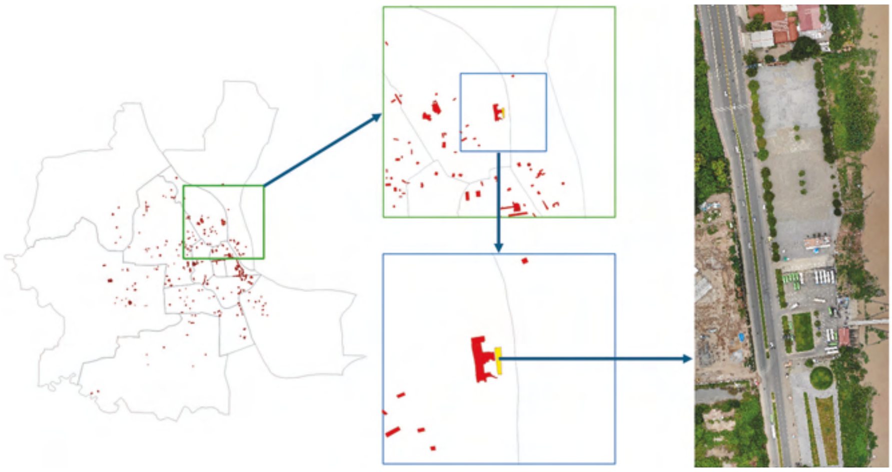

Fig.1: Location of the study area.

knowledge and technical experience combined with international perspectives. The University of Hamburg, as the project consortium leader, played a pivotal role in facilitating the overall task and in disseminating the results at project events.

Data and Methods

The image data presenting urban structures' LST was collected from an urban green space in the eastern part of Phnom Penh city, close to the Riverfront area at the Mekong River (Figure 1). We used a DJI Mavic Air 2 Enterprise Dual sensor UAV to collect the thermal image data on selected flight parameters (Figure 2). 180 UAV images (90 RGB and 90 thermal images) were collected to build RGB (visible wavelengths in red, green, blue) and thermal orthomosaics (a collection of UAV images joined in a single geometrically corrected large image).

An example of the raw (unprocessed) RGB and thermal image is given in Figure 3. Each RGB and thermal image were spatially aligned to build the dense (point) cloud (a collection of points generated from the images representing the flight area), a digital elevation model (DEM), a surface model (DSM), and RGB and thermal orthomosaics. After obtaining the orthomosaics, distinct features (i.e., trees, roads, bare soil) were identified visually from the RGB orthomosaics. Then, thermal

Flight parameters	
Flying altitude:	33.5 m
Overlaps (front and side):	85%
Maximum speed:	10 km / hour
Camera angle:	Nadir
Flight pattern:	Normal
Pixel size (RGB):	1.6 x 1.6 µm
Pixel size (thermal):	3 x 3 µm

Fig.2: Project UAV and flight parameters.

RGB image (raw/unprocessed) **Thermal image (raw/unprocessed)**

Fig.3: Example of RGB and thermal images.

orthomosaics were used to extract the surface temperature of selected features.

Results and Discussion

Different features are identified visually in the study area to identify the thermal footprint within four primary land use land cover (LULC) categories; the categories and sub-categories are given in Table 1.

The calculated overall range of LST was about 28 to 60°C, with water being the lowest LST and an ongoing car engine on the road being the highest LST (Figure 4). Tree crowns and other vegetation surface temperatures range from 30 to 33 °C, built-up and sealed surface areas range from 40 to 45°C, and the surface temperature of bare soil is 40°C.

Water bodies and trees show lower LST than other features in the study area. Larger tree canopies appear to have lower surface temperatures than smaller tree canopies. However, even the smaller canopy also has a visual lower LST buffer around them; similar findings were observed in a previous study by Akbari et al., (2001). In the grass cover case, the grass patch's size influences LST and the lower LST buffer around them. A combination of grass and trees appears to have larger, lower LST buffer areas. In the built-up area category, the concrete pavement appears warm regarding emitted heat

Table 1: Identified major LULC categories and sub-categories.

LULC category	Sub-category
Trees and vegetation	Large canopy
	Smaller canopy
	Grass
Built-up areas	Road
	Pavement
	Red roof building
	White roof building
	Concrete road divider (without vegetation)
	Concrete road divider (with vegetation)
Bare soil	Bare soil
Water	Water

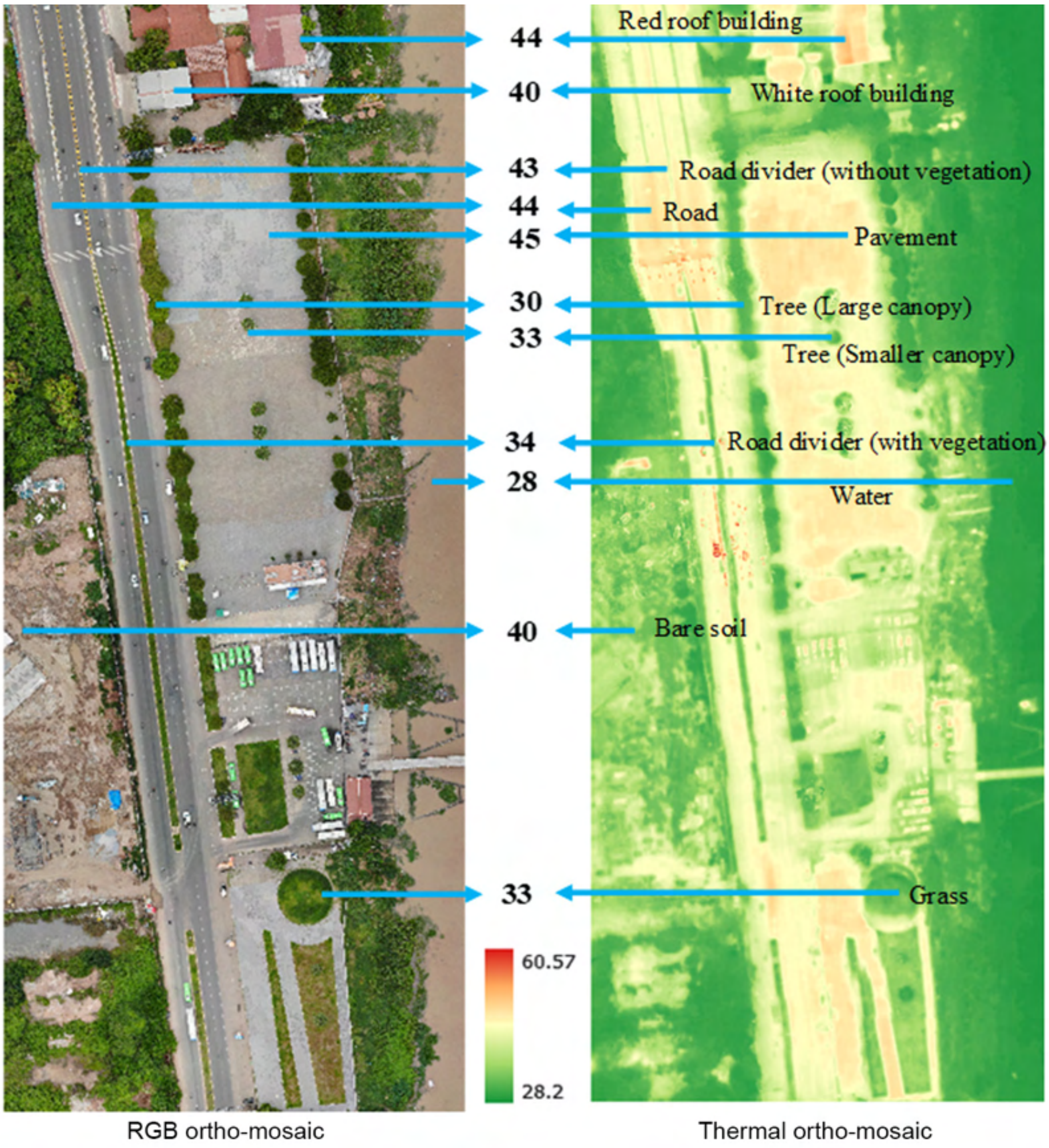

Fig.4: Surface temperature of LULC subcategories.

fluxes and LST in the image. In the case of the road, both the road and the concrete road divider appear to be comparatively warmer areas. However, the concrete road divider with vegetation cover on its top seems to have noticeably lower LST (up to 9°C). This finding echoes the observation of a previous study (Tan & Sia, 2005). Also, white-roof buildings seem to emit lower surface temperatures than red-roof buildings. While it requires further investigation of building materials, construction types, volumes and uses to make concluding remarks, it appears that the colour of the roof influences the LST, which is also argued by Santamouris (2014). Bare soil mainly shows LST similar to that of the built-up areas.

The results demonstrate how different materials and surfaces have distinct thermal signatures. This insight is helpful for urban planning, particularly in designing and enhancing green spaces or vegetation islands or a technical combination or integration of vegetation into the physical built-up

Constant transfer of knowledge between international stakeholders from science, urban citizens and the corporate sector is being regarded as essential for sustainable urban transformation."

structure of urban areas. By understanding the thermal behaviour of different surfaces, urban planners can strategically position green spaces to mitigate urban heat island effects, thereby creating more environmentally sustainable and comfortable urban areas. Using thermal UAV sensor technology marks an advancement in urban environmental monitoring. Thermal UAVs offer greater efficiency, comprehensive coverage, and in-depth data collection than traditional methods and allow for a more detailed analysis of urban green spaces, facilitating informed urban planning and environmental management decisions. The findings from the study can inform policy decisions related to urban development and sustainability. This might include strategies for urban cooling, air quality improvement, and biodiversity enhancement (Gómez-Baggethun & Barton, 2013).

The approach to this activity from the Build4People Project includes collaboration between scientists and capacity building for young academic staff of the research partners. This is required to create a sustainable impact in the project area and enables the learning to be transferred and spread to a larger audience through the research partners.

The data was collected during the wet season, and the LST is influenced by seasonal variability, air temperature and other environmental variables. So, the absolute temperature values are not to be taken generally for the area. In addition, the results and interpretation relied on visual observation; hence, the precise information about the size of grass patches, tree canopies and material of the built-up areas, including roads and building roofs, is not considered. The study presented here includes one green space, an example from Phnom Penh city. Hence, the findings cannot be generalized for all green spaces. The next step is to carry out similar investigations in different green spaces and transfer results to identify potential common patterns emerging or not, including different scenarios in different urban spaces and physical built-up structures. Moreover, a future experiment can include the cooling effect of different surfaces considering the material, size of the specific surface, and proximity to the nearest vegetation and water.

Conclusions

The method and findings potentially apply to various urban areas in other projects with similar, broader goals. Future projects should consider different climatic and urban contexts to adapt and scale these methods globally. Furthermore, the subjective experience of the quality of urban green spaces should be explored by citizen science approaches to grasp the essential perspective of the urban residents. In this way participatory bottom-up approaches go hand in hand with the integration of technologies. Integrating such technologies in urban planning can be helpful for the sustainable transformation of urban areas, thus contributing to sustainable development goals (SDGs) in urban planning. Such initiatives contribute significantly to creating more resilient and liveable cities, underscoring the importance of innovative technology in urban environmental management.