Methodology for Integrated Mapping of Radiation and Light Intensity in Power Transmission Lines

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***Abstract*—This study presents a methodology for mapping UltraViolet (UV) radiation and light intensity in vegetable gardens located within power transmission line easements. Using advanced sensors mounted on mobile robots, the system captures daily variations in UV radiation and luminosity. The collected data reveals differences in solar incidence across the easements, offering insights into their potential for sustainable agricultural practices.**

Keywords-UV Radiation Mapping; Light Intensity Monitoring; Transmission Line Easements; Mobile Robotic Sensing.

I. INTRODUCTION

Ultraviolet B (UV-B) radiation, a biologically active spectrum of sunlight (280–320 nm), has been extensively studied for its dual impact on human health and plant development. In humans, excessive exposure to UV-B is associated with increased risks of skin cancer and ocular disorders [1]. In plants, however, UV-B radiation influences anatomical and physiological traits, such as biomass allocation, leaf area, chlorophyll content, and secondary metabolite production, with effects varying by species and radiation dose [2][3]. For example, pigmented potatoes showed enhanced nutrient synthesis under controlled UV-B doses [3]. In the face of climate change and urban growth, transmission line easements emerge as potential sites for low-height, sustainable agriculture. However, their viability depends on understanding local environmental factors, especially solar radiation and light intensity.

This study proposes a Methodology for Integrated Mapping of Radiation and Light Intensity, combining fixed sensors and modular units mounted on mobile robotic platforms. By enabling spatially distributed and scalable data acquisition, this approach supports the identification of microzones with distinct agricultural potential. In line with recent advances in innovative sensor technologies and data-driven agriculture [4], the proposed system aims to inform sustainable cultivation strategies in non-traditional farming areas, promoting more efficient land.

The rest of the paper is structured as follows. In Section II, we present the measurement and sensor evaluation, describing the environment where the experiment was conducted. In Section III, we show the results originating from the fixed sensor mapping. We conclude the work in Section IV.

II. MEASUREMENT AND SENSOR EVALUATION

The project is designed to follow a structured set of stages, as outlined in Figure 1. A system is being developed to provide comprehensive analytical support throughout each workflow phase. Initially, the results were evaluated through measurements obtained using a fixed system to understand better how the variables interact and behave under controlled conditions. Data collection will subsequently be conducted using both ground and aerial mobile robotic platforms to evaluate scalability, optimize mapping strategies, and increase the efficiency of detailed local data acquisition.

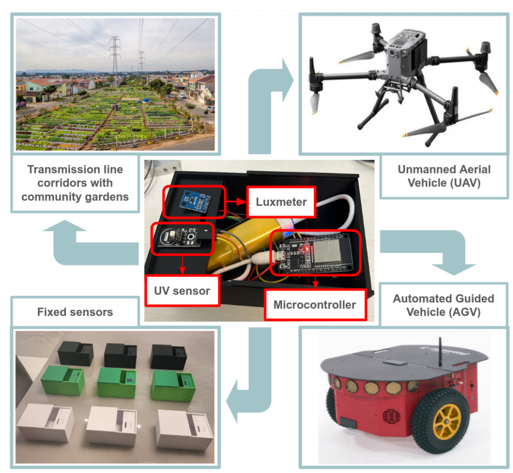


Figure 1. Project workflow and development of the measurement system using fixed and mobile robotic platforms.

The experiment was conducted in the vegetable garden at the Polytechnic Center of UFPR (Universidade Federal do Paraná), in Curitiba, Brazil. The city of Curitiba is located in coordinates -25.441105, -49.276855, characterized by a subtropical climate (well defined seasons). This site was chosen for its easy access, 200 m² area, and varying solar exposure throughout the day. Nearby 13.8 kV power lines also provide environmental conditions similar to those in typical utility easement areas. The measurement locations are shown in Figure 2.

Figure 2. Points of data collection.

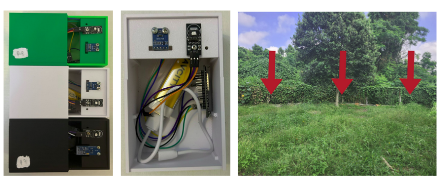
Measurements were carried out at nine fixed points within a vegetable garden from 7:30 AM to 5:30 PM, with data collected every second. Each unit consisted of an ESP32, a UV sensor (UVM30A or LTR390), and a light intensity sensor (BH1750), all enclosed in 3D-printed boxes of varying colors (black, white, and green) to evaluate the effect of housing color on sensor readings.

Sensor specifications are shown in Table I.

TABLE I. UV Sensor Specifications (Alternative)

Sensor	UV Detection Range	Temperature Range
UVM30A	200-370 nm	-40°C to 85°C
LTR390	300-350 nm	-40°C to 85°C

Data was collected over two days to assess this influence more accurately. Figure 3 illustrates the data acquisition architecture designed for detailed local mapping of light intensity and UV radiation levels.



(a) (b) (c)

Figure 3. (a) Color spectrum variations in the sensor housing. (b) Detailed view of the data acquisition circuit. (c) Location of 3 out of 9 measurements.

III. Results from Fixed Sensor Mapping

The sensors measure UV Radiation in mV, but provide a table of conversion to the UV Index. Table II shows the conversions from mV measurement to UV Index.

Given Table I, the charts in Figures 4 and 5 show the information of UV radiation (in UV index) and light intensity (in lux) overtime.

Figure 4 shows the data collected in the same point, P2, both by a black box (February 17th) and a white box (March 20th), in two distinct days.

Although data were collected on different days—March 20 having higher solar incidence—the waveforms remained similar due to consistent sensor placement. Notably, the black box reached higher internal temperatures on a less sunny day.

TABLE II. UV Index and mV measurements correspondence.

UV Index	Vout(mV)
0	<50
1	227
2	318
3	408
4	503
5	606
6	696
7	795
8	881
9	976
10	1079
11+	1170+

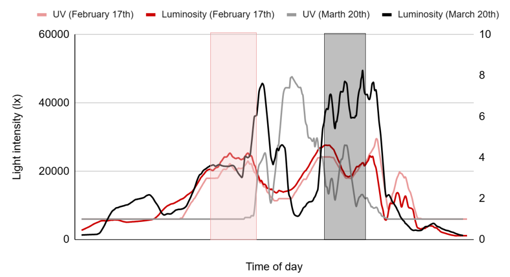


Figure 4. Data collected in P2.

Figure 5 shows data from point P9 using boxes of the same color on different dates. The highlighted regions illustrate stable diurnal patterns, suggesting that high-frequency sampling may be unnecessary, as significant variations occur over 10 to 60 minutes.

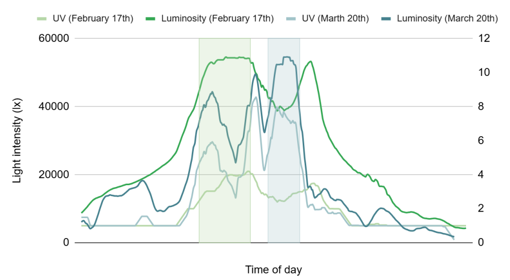


Figure 5. Data collected in P9.

IV. Conclusion and Future Work

This work had the objective of developing a methodology for integrated mapping sunlight-related variables, utilizing fixed sensors.

The collected data indicate that light intensity and UV radiation exhibited similar patterns across measurement points, primarily influenced by environmental factors, such as vegetation and shading from nearby obstacles. The color of the boxes had little effect on external sensor readings, highlighting the dominant role of ambient shading. However, box color did affect internal temperatures, which could impact the performance of electronic components.

Ground and aerial mobile robotic platforms will be employed in the following phases to assess scalability, refine mapping strategies, and increase the efficiency of localized measurements. This approach is expected to increase the accuracy of site-specific analyses and enable more context-aware solutions, as well as allowing longer-term data collection. Future work will also focus on expanding the sensor network and incorporating additional environmental variables, such as air and soil humidity and internal and external temperatures, to support detailed mapping further and informed decision-making. The goal is to achieve more accurate mapping to assess the true potential for sustainable crop cultivation in these areas.

Acknowledgments

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