TOWARDS PRECISION AGRICULTURE: VLC-ENABLED UAVS

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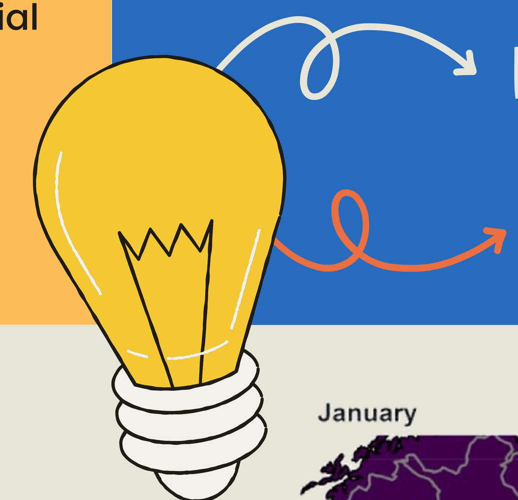
INTRODUCTION

- Precision agriculture (PA) is a farming management strategy that utilizes information technology to monitor, measure and respond to the spatial and temporal variability of crops and soil in order to enhance agricultural production sustainability.
- PA depends on the collaboration between robots to execute various agricultural operations, such as weed detection and treatment, crop monitoring and spraying.
- Unmanned aerial vehicles (UAVs) are emerging as a promising technology for PA by providing data such as plant growth data and crop health data, owing to the ability of the UAVs to fly at high altitudes and the potential to equip them with cameras.
- These data can assist farmers in making informed decisions on crop management, thus optimizing the farming outcomes while minimizing the used resources.

VISIBLE LIGHT COMMUNICATION (VLC)

- Visible light communication (VLC) is an emerging technology that employs light-emitting diodes (LEDs) for both illumination and data transmission.
- VLC offers larger bandwidth, free spectrum, high data rate, enhanced security and privacy, and more energy efficiency, as it combines illumination and communication functions in a single device.
- VLC-enabled UAVs offer a flexible solution for providing on-demand communications, which is essential for supporting wireless coverage in remote and hard-to-reach areas.



DATA COMMUNICATION

ILLUMINATION

SYSTEM OVERVIEW

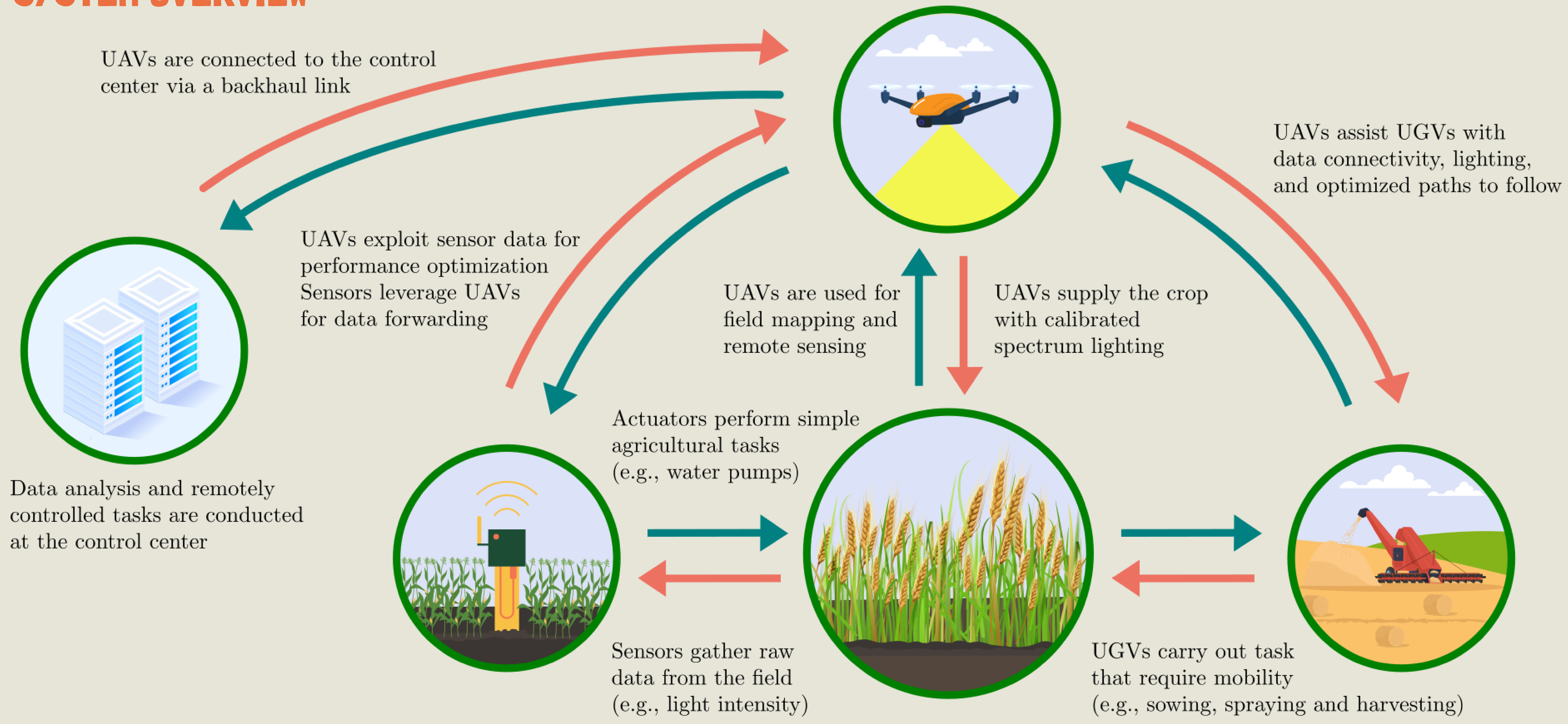


Figure 3. A detailed illustration of the interaction between the components of the proposed PA system.

LED-BASED GROW LIGHTS

- LED-based grow lights are artificial light sources that use LEDs to emit the optimal wavelengths and intensity of light for plant photosynthesis and growth.
- By equipping the UAVs with LED-based grow lights, they can enhance plant growth if the emitted light fulfils three criteria: light quality, light quantity, and light duration.
  a. Light quality refers to the spectral distribution of the absorbed light. The general effects of different wavelengths on plants are as follows:
    i. Ultraviolet: detrimental.
    ii. Violet and blue: photosynthesis and vegetative growth.
    iii. Green and yellow: reflected due to their minimal impact.
    iv. Red: flowering and budding.
    v. Infrared: converted into heat.
  b. Light quantity measures the amount of intensity received by plants due to the solar flux incident on them.
  c. Light duration is the length of time that plants receive illumination each day.
- Some regions experience a low light duration due to the limited number of daylight hours (see Figure 1).

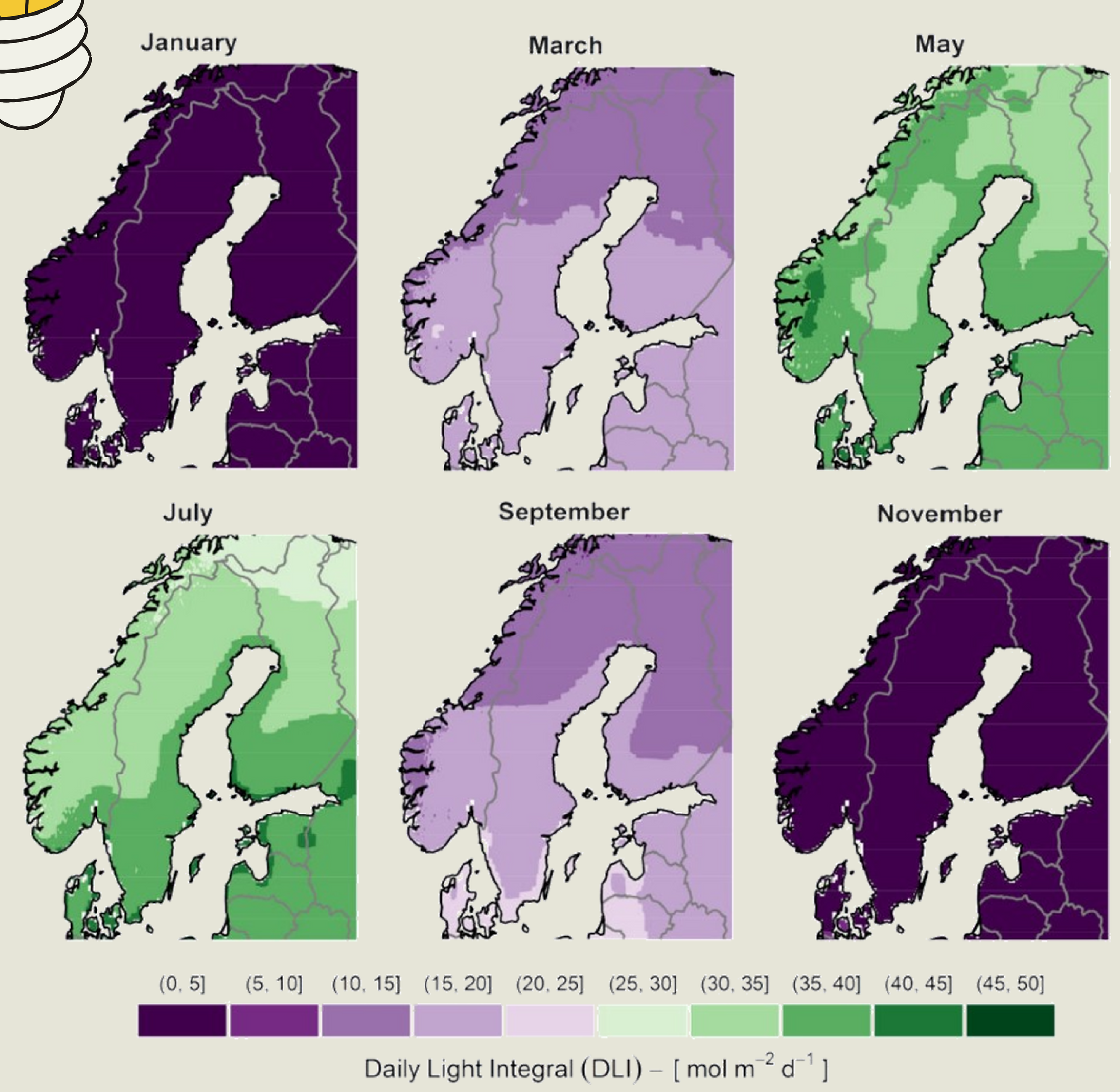
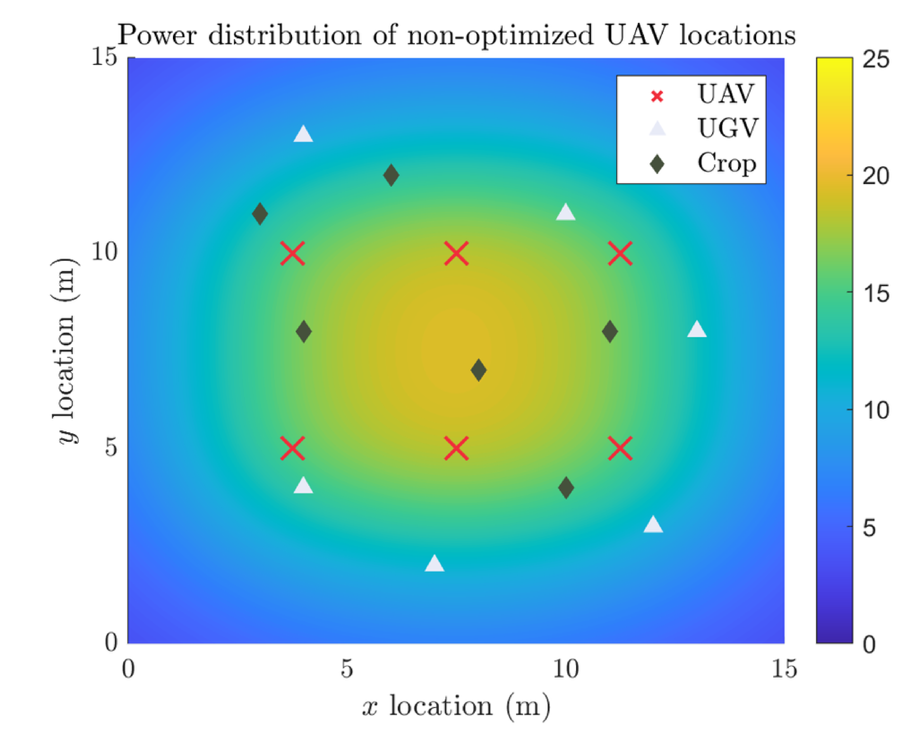


Figure 1. Daily light integral (DLI) distribution in Sweden throughout the year. This figure is from [1]. DLI is a measure of the total amount of light that plants receive in a day.

PERFORMANCE EVALUATION

- To highlight the viability and workability of the proposed system, we investigate a system of six UAVs that provide both illumination and data communication for plant growth and user devices.
- The system consists of six plants with a predefined illumination threshold and six user devices with communication requirements.
- We optimize the UAV locations to maximize the total power density received by plants and user devices while meeting their illumination and communication needs.
- The results (see Figure 4) demonstrate the importance of UAV location optimization for PA systems in terms of sustainability and performance.



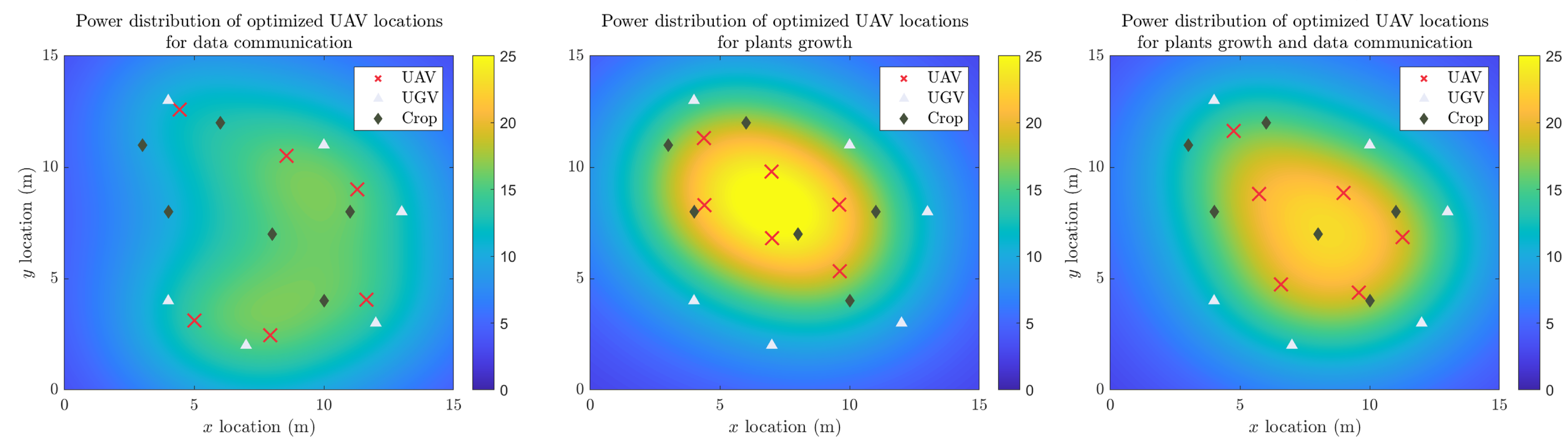


Figure 4. Comparison of received power density for different UAV locations.

LONG-DAY & SHORT-DAY PLANTS

- Light duration affects the flowering and blooming of plants by regulating their photoperiodism.
- Plants can be categorized into different types based on their photoperiodic response (see Figure 2):
  a. Long-day plants require a day length that exceeds a critical threshold to initiate flowering (e.g., Iris).
  b. Short-day plants require a night length that exceeds a critical threshold to initiate flowering (e.g., Chrysanthemum).

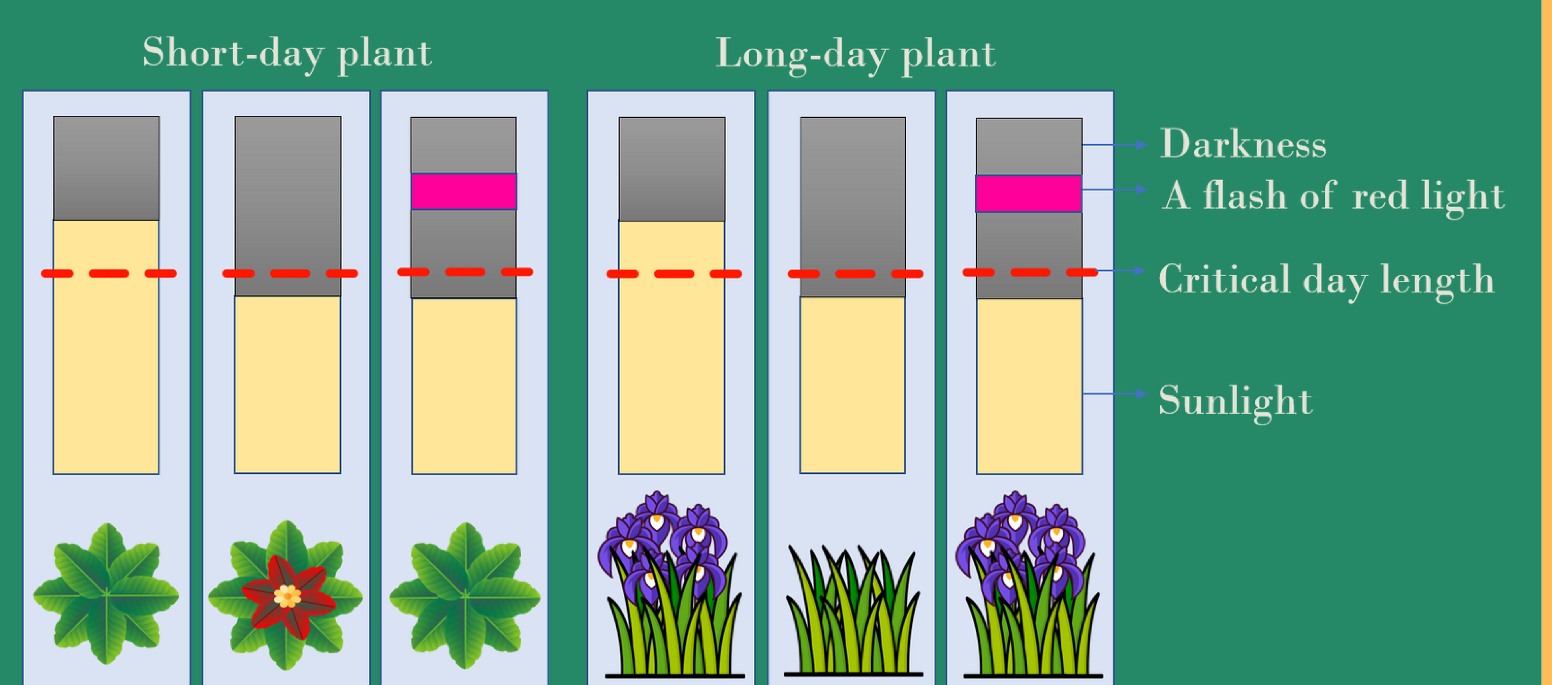


Figure 2. The effect of different photoperiods on the growth of long-day and short-day plants.

SUSTAINABILITY BENEFITS

- Using VLC-enabled UAVs as outdoor grow lights prevents blocking natural light and reduces energy consumption and cost compared to conventional grow lights.
- Optimize system performance and resource utilization by using VLC-enabled UAVs as mobile and adaptive grow lights that can adjust their positions.
- Employing VLC-enabled UAVs as reliable data hubs facilitates resource management and productivity optimization by collecting and delivering data from sensors.
- Avoiding interference and environmental impact of electromagnetic field exposure by deploying VLC technology.
- Combining illumination and communication functions in VLC-enabled UAVs enhances energy efficiency and performance.

Refrences

1. Hernandez Velasco, M. (2021). Enabling Year-round Cultivation in the Nordics-Agrivoltaics and Adaptive LED Lighting Control of Daily Light Integral. Agriculture, 11(12), 1255.

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