GUIDELINES ON DEVELOPMENT AND MANAGEMENT OF PRECISION PROTECTION SYSTEMS

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Table of Contents

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GUIDELINES ON PRECISION PROTECTION SYSTEMS

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1. Introduction

1.1 Precision protection systems

With rapid developments in artificial intelligence, the application of drone technology has been emerging in agriculture, especially in field surveys for plant disorders and precision farming [1]. Drone technologies are more cost-effective and capable of providing unmanned platforms adaptable to small or large fields than more conventional remote imaging sensing methods using satellites and manned aircraft [2].

In recent years, the use of drone systems coupled with high-resolution cameras and specialized sensors has made it possible to create scenes with extremely small pixels less than one inch. This technology has opened up significant prospects for geosciences applications and more efficient management techniques in agriculture and forestry [3].

More specifically, such systems have been used globally for the following tasks: surveying for and mapping soil properties, estimating vineyard canopy leaf area index, detecting and mapping sunflower nitrogen status, detecting weeds, detecting missing or dead plants in vegetable fields, estimating crop biomass with nutrient levels, surveying for plant diseases, spraying agrichemicals, evaluating drip irrigation efficiency [4].

The choice of the type of drone and the sensor system determine the possibilities of using the technology in agriculture. In addition to the electromagnetic spectrum visible to the human eye, from 400 nm to 700 nm, some sensors are capable to capture invisible light, particularly in the near-infrared (NIR) window, of which the wavelength is greater than 700 nm. However, with the deployment of remote sensing technologies including UAVs, ground verification is still essential to verify the reality on the ground and to calibrate the results from UAV technology, thus reducing the costs of repetitive field surveys and saving a lot of time.

1.2 Objectives and description of the innovation

Objectives: This work aims to implement a drone equipped with a multi-spectral camera system in a field study on the potato late blight disease in the region of Meknes. The objective is to provide farmers in the area with accurate and timely information on the incidence and distribution of the disease that will allow for labor savings in phytosanitary treatments through timely decision making to limit yield losses and avoid wasting resources. The recommendations to the partners and the professionals of the agricultural advice concerning the diffusion of the useful information will be diffused through an application on smartphone allowing to manage efficiently the interventions for the phytosanitary treatment of the crop (information and notifications).

Plant diseases can cause considerable damage to agricultural production. Late blight of potato plants, is one of major diseases that could harmful the potato yield and then destroy tens of thousands of hectares when the disease is not controlled at early stage of its development. Traditional management practices for this disease often assume that the inoculum propagates

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homogeneously over the growing areas. The use of fungicides by farmers can often be untargeted and suboptimal.

However, the targeted use of pesticides is likely to reduce the amounts required for the control of late blight as well as the number of chemical treatments and therefore the costs and the ecological impact in the agricultural production systems. In addition to such practice reduce the probability the appearance of resistant strains to active substances available in the market. Remote sensing has been largely used to detect, monitor and quantify a wide range of diseases on different crops.

Therefore, the main objective is to develop an early warning system for the management of late blight, caused by Phytophthora infestans, on potato crops based on the multispectral aerial images taken by drones equipped with multispectral camera sensors.

2. Description of procedure, trials, materials and results

2.1 Operative procedure

2.1.1 General procedure

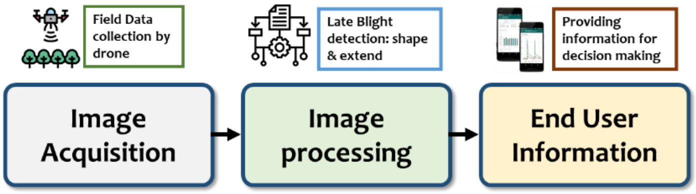

Figure 1: early detection and management of Late blight disease

2.1.2 Specific procedure and data processing

During this study, we will be focused on the use of multispectral wavebands (red-edge) and near-infrared) and spectral vegetation indices (e.g., green/red ratio) as relevant features predictors of general stress in plants. The most popular vegetation index is NDVI (Normalized Difference Vegetation Index). In order to easily separate the multispectral bands of infected leaves from those of uninfected by late blight, the experimental design will consist of different potato growing sites with different program- based treatments, including treated and untreated sites for this disease. Incidence and severity of late blight symptoms will be assessed in different experimental plots by visual observation of foliar symptoms in each individual plant by using an appropriate sampling technique and late blight disease rating scale. Both multispectral imaging and disease rating will be conducted with respect to growth Stages of potatoes. The recorded datasets will be analysed and relevant vegetation indices will be estimated based on acquired multispectral bands. These vegetation indices will be correlated with disease severity to identify which is the best vegetation index to use for early detection of downy mildew on potato crops.

To detect the incidence and spatial extent of the disease and to monitor its spread, farmers usually walk through their fields to check and count the plants infected by the pathogen and to assess the severity of the disease in order to decide on the phytosanitary treatments to be planned. This usually requires periodic monitoring of the crop fields and accurate assessment of the disease incidence, which requires an expert eye and a lot of time, especially when the crop area is large.

Farmers are always concerned about saving resources (money and time) and are eager to get help and advice from local agricultural development and advisory professionals in order to decide and plan the necessary interventions in a timely manner to save resources and maintain yield levels.

The steps associated with conventional approaches to detecting crop diseases and infections often lead to delays in interventions that generate additional costs for producers.

In this activity, we describe the implementation of a drone system in a field survey aimed at assessing the incidence and distribution of the disease caused by Late blight pathogen in order to help potatoes producers in the Meknes region to control the disease quickly and effectively. The approach and information obtained and the results of the research can be directly made available to producers and used by agricultural advisory professionals in order to implement such an approach to help agricultural producers implement an intervention for the treatment of diseases and infections regardless of the crop practiced.

The potato is a product of high economic importance in the Sais region (North Central Morocco). Thanks to the favorable semi-arid climate and especially to the possibilities of irrigation, the potato is well developed throughout the spring season between March and July but also in autumn. Infection of the potato with late blight can cause irreparable damage to the farmer and can eventually spread to other neighboring areas.

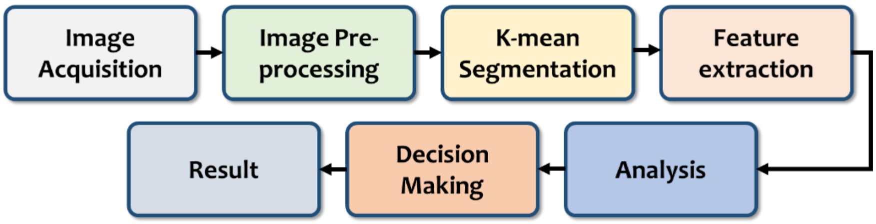

Figure 2: Data acquisition and processing of Late blight disease management

The implementation of drone technology can provide a rapid and practical approach to monitoring the incidence and determining the distribution of a crop pest disease. In the majority of situations, using the conventional approach of visually monitoring crop fields, one person will only be able to cover about 2-5 acres in a day. However, it only takes 2-3 minutes to cover more than 2 acres per drone flight and only 3-4 hours to generate mosaic images and identify intervention areas, implying great time-saving benefits from implementing this technology. The cost of drones is still quite high for small farmers even though prices are tending to decrease. The application of this technology at the scale of a homogeneous agricultural area for the early detection of diseases and infections of crops and subsequently the dissemination of useful information for all farmers, especially small farmers, will be an important measure that professionals in extension and agricultural advice can use to help farmers better manage interventions of phytosanitary treatments in a timely manner and preserve crop yields.

Field trial of early late blight detection on potatoes by using drones:

- Trial installation and crop development was normal, but there was no appearance of any signs of the disease. (Drought 2021-2022). The trials are reconducted during autumn and winter seasons (2022-2023), which are more suitable for the development of the disease (humidity requirement).

- Development of algorithm for early detection of the disease will be based on scenes collected by the drone. The same mobile application developed for precision irrigation can be used for notification to farmers regarding the risk related to the disease.

Stakeholders and regional partners:

- National School of Agriculture of Meknes (ENAM);
- Provincial Directorate of Agriculture (DPA El Hajeb);
- Association of vegetables producers in Ait Ouallal Bittit;
- National Office of the Agricultural Council (ONCA).

The tasks focus on four main pillars namely:

1. Conduct agronomic experimentation on detection by drones of late blight on potato;
2. Development and implementation of algorithm for early detection of the disease based on scenes collected by the drone;
3. Support and training of farmers on the use of mobile application for disease management by using the information provided.

2.2 Results

2.2.1 Trials on potatoes

The experimental trial is carried out on a plot of 1 acre with potato (Solanum tuberosum, two varieties: Barcelona & Synergy) planted in early October 2022 in raised lines. Prior to planting, we applied organic compost, carried out by spreading on the soil ridges, placed drip lines for irrigation. Farm workers carried out the manual sowing of healthy seeds in line with a spacing between the lines of 80cm and between the sowing points of 16 cm.

Irrigation is applied regularly according to the needs of the plant in relation to the state of moisture of the soil and the climatic conditions.

A potassium fertilizer was applied at the 3 leaf stage with a quantity of 25Kg for the whole test plot.

Once the flight of the drone is completed (during January 2023), the data will be transferred to a computer. We will be able to process the data with a data retrieval software, assemble the images and analyses the data with the specialized software (Feb. 2023).

To verify the results, a plant pathologist will carry out a conventional ground survey on the same day as the drone visit. The survey will allow the proper assessment of the incidence (severity) of the disease by counting the number of healthy and infected plants. We will compare these data with the results obtained from the drone system by using statistical tests to evaluate the accuracy of disease detection by the UAV and will be performed by applying Fisher's Least Significant Difference test at $p<0.05$.

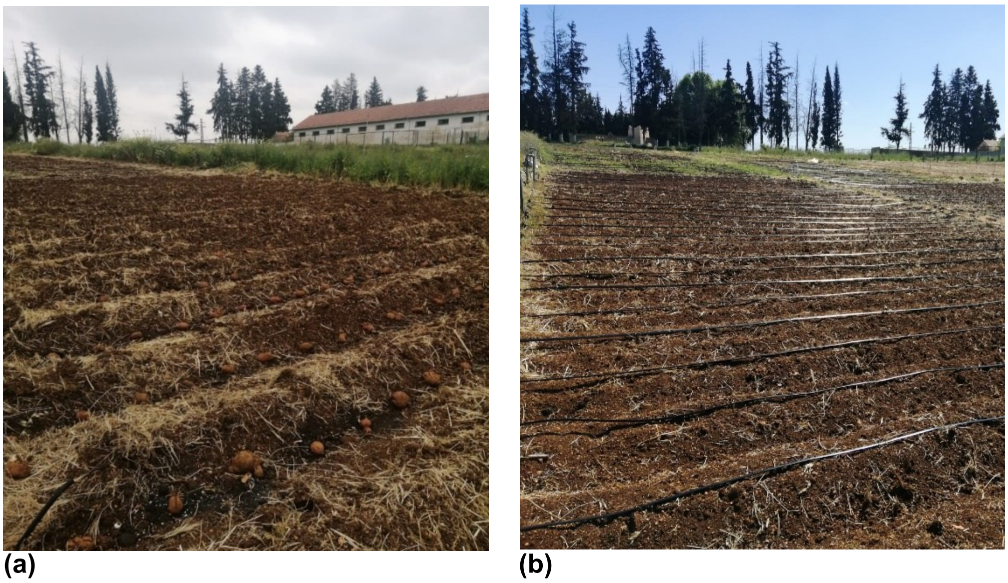
(a) (b)

Figure 3: Sowing potatoes tubers (a) drip irrigation system installation (b)

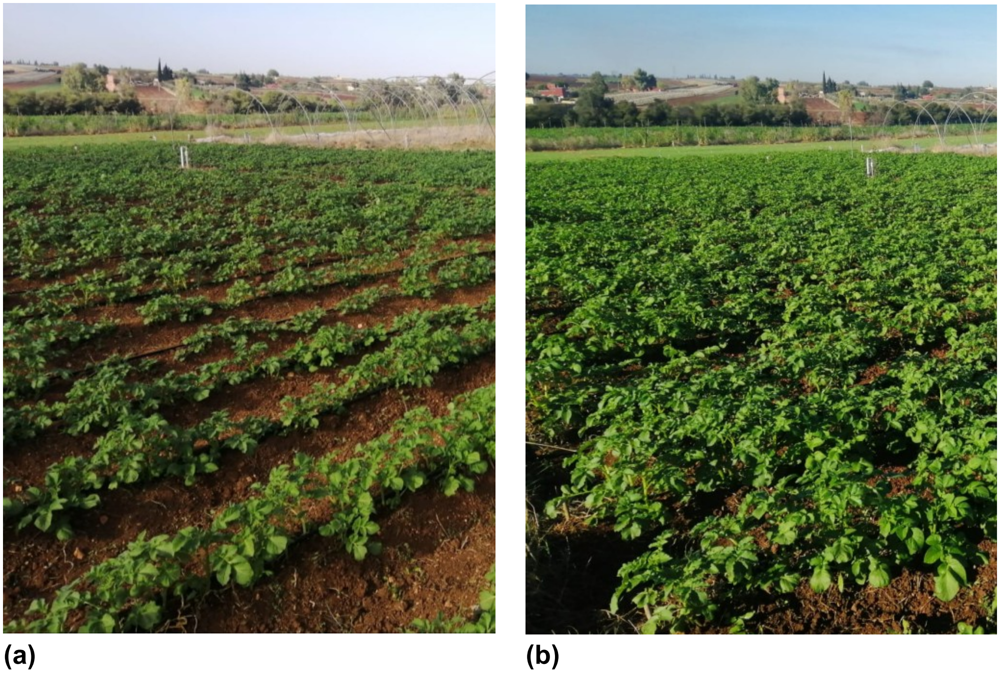
(a) (b)

Figure 4: potato plants at 4 weeks old (a) and at 6 weeks old (b)

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Figure 5: potato trial field at 9 weeks.

2.2.2 Drone description

- Phantom 4 Pro multispectral RTK

Technical specifications:

- Diagonal (without helix): 350 mm
- Max. Ascent Speed: 6 m/s (automatic flight); 5 m/s (manual control)
- Max. speed 50 km/h (31mph) (P-mode); 58 km/h (36mph) (A-mode)
- Operating temperature: 0 to 40°C (32 to 104°F)
- Transmitter power (EIRP): 2.4 GHz: < 20 dBm (CE/MIC/KCC): 5.8 GHz: < 26 dBm (FCC/SRRC/NCC)
- Image Position Compensation: The relative positions of the CMOS center of the six cameras and the phase center of the integrated D-RTK antenna calibrated and recorded in the EXIF data of each image.

Camera:

- Format(s): JPEG photo (visible light imagery) + TIFF (multi-spectral Imagery).
- Operating Temperature: 0 to 40°C (32 to 104°F)
- Max image size: 1600x1300 (4:3.25)
- Shutter speed 1/100 -1/20000 s (visible light imagery): 1/100 -1/10000 s (multi-spectral imagery)

2.2.3 Pathogenicity tests on potato leaves

Preparation of the sporal suspension

The P. infestans strain was maintained at 18 °C in the complete darkness on CornMeal Agar, prepared by cooking cornmeal in 500 ml water for 1 hour at 60 °C and then by adding agar, peptone and dextrose and filter cornmeal mix afterwards through a cheesecloth. To prepare the spore inoculum, 10 mL of sterilized distilled water was added to each plate of P. infestans. The culture plates were placed at 4 °C for 24 hours to release zoo spores from sporangia and then filtered through two layers of filter.

Inoculation of fungus

To compare the pathogenicity of 8 isolates, plant leaflets were washed with deionized water and dried in a laminar flow hood. The leaflets were inoculated with one 20 µL droplet (5.104 sporangia mL-1) of each genotype and incubated at 18°C in Petri dishes lined with wet, sterilized filter paper.

The isolate was generally considered virulent if at least two of the four inoculated leaflets had significant lesions (1cm). An avirulent interaction was indicated by lesions with a diameter of 1 cm or less. A large lesion was considered inconclusive.

Figure 6: Inoculation of fungus in potato leaves

2.3 Expected results

a. Reduction of the use of phytosanitary products for the treatment of late blight in the area by 20% compared to the current situation thanks to a better programming of applications at the appropriate time. This will also reduce time interventions and decrease farmers' expenses accordingly.

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b. Cost reduction of the production and more sustainability of regional agriculture considering best use of phytosanitary products (less quantity with early interventions). Increase of farmer's income.

3. Guidelines for the Development and Management

3.1. System Setup and Deployment

- Select appropriate drone models with multispectral imaging capabilities.
- Calibrate sensors regularly to ensure accurate data capture.
- Establish predefined flight paths for consistent field coverage.
- Ensure compliance with local aviation regulations for drone operations.

3.2. Data Collection and Processing

- Schedule automated drone flights for periodic disease monitoring.
- Implement cloud-based storage for large-scale image datasets.
- Use deep learning algorithms for real-time disease classification.
- Incorporate vegetation indices (NDVI, NDRE) for enhanced early detection.

3.3. User Interface and Accessibility

- Develop a mobile application for farmers and agricultural stakeholders.
- Ensure real-time notifications on disease detection and severity.
- Provide an interactive dashboard and infection trends.

3.4. Maintenance and Model Updates

- Regularly update AI models with new datasets for improved accuracy.
- Optimize software to enhance image processing speed and accuracy.

3.5. User Training and Support

- Offer trainings for farmers on disease identification and for using the mobile app
- Encourage feedback from end users to refine system usability and performance.

3.6. Risk Management and Sustainability

- Address digital literacy challenges by developing intuitive and local language user interfaces in the mobile app.
- Foster collaborations with agricultural institutions and policymakers for long-term impact.

4. Technology and production key performance indicators

The guidelines presented here and the work carried out so far contribute to the achievement of the following key performance indicators, foreseen in the project grant agreement:

- Reduction of the consumption of phytosanitary products by 10 to 30% and decrease in production costs for farmers: as far as the technology applied is concerned, it is expected that the knowledge and capacity of farmers to better manage interventions and to foresee them in time in relation to early warnings on the state and evolution of the disease at the scale of the area will be improved. Improved farmer income (while contributing to environmental conservation).

On the overall scale of the region, it is expected that the sustainability of agriculture will be improved given the improved environmental quality. In addition, down the production chain, end consumers should be able to purchase healthier products.

- PPI-ST: 10% reduction of production losses.

- PPI-LT: 10% increase of small farmers and SMEs' income through reduced production costs and improved product quality (average).

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