Monitoring of orchard irrigation
by unmanned aerial systems and remotely-sensed imagery
(Drone and Artificial Intelligence to help saving water & producing high quality apples)

Magalie Delalande (INRAe) & Jean Luc Regnard (SupAgro)
History of experiments and selection of practice

Short overview of the experiments:

1- **Identify Indicators of response to tree’s water status**, from remotely-sensed imagery collected by drone (UAV) over a large collection of apple tree varieties,
   Indicators selected were reflectance data from the multispectral camera and canopy surface temperature collected by the thermal infrared camera

2- **Collect as many** multispectral and thermal images as possible from commercial orchard.
   From these images, we developed and trained an algorithm that aims at estimating the water status of the trees, which should, in theory, reflect the functioning or malfunctioning of the watering system

Why choosing a Digital-based orientation?

Agriculture ranks as a leading sector in digital-based decision support system (precision Ag).
   Farmers are one of the first professions to connect to the Internet and use online services.
   In the fields, digital technology is ubiquitous with GPS-guided tractors that use data from satellite images to develop parsimonious and sustainable practices,

Agriculture represent the largest part of civil drone use today,

With regard to fruit growing, two type of drone use are emerging today: data acquisition and actions

Our solution fits perfectly in the expectations of the farmers towards the contribution of digital in the sustainable farm of tomorrow : identify irrigation malfunctioning through fast data acquisition and users friendly application using free software
Description of the practice selected for the leaflet

What?
We flew the drone embedding a multispectral and a thermal camera over commercial orchards (apple) and collect as many images as possible,

The images were used to train a neural network (Artificial Intelligence) to detect the signal of trees experiencing water deficit (= clogging) and trees experiencing over watering (=leaks).

Why?
With parsimonious watering systems (drip irrigation monitored par soil moisture sensors), malfunctioning is difficult to detect, but are a real problem (lifetime of irrigation system, quality of fruits, lifetime of trees)

leaks => waste of water + loss of apple quality (↗ large fruit >75mm, ↘ firmness)
clogging => loss of apple quality (↗ small fruit <70mm, ↗ fruit <40% color, ↑ fruit >60% color, ↑ starch index and ↗ acidity => change in maturity

Status? Not so far from Ready-to-use, but the details take time!
Main steps to implement this practice

How should farmers proceed to implement this practice?

Two possibilities of implementation:
- farmer prefers to acquire data by its own
- farmer prefers to delegate the data acquisition (farmer advisor, service provider)

1. Install the application on a computer (laptop) (Internet required)

2. On a cloudless, little wind day, fly the drone with cameras = collect images => **about 18 min/ha**  
   *Ensure to be in compliance with local aerial regulation*

3. Copy the images from the SD card onto the laptop, and run the application

4. Once the map and file are edited, send someone on the spots to check and solve the problem

5. Regularly check the availability of updates (new combo of cameras, more precise application, faster application, ...)

Farmer Advisers’ most commonly used drones for data acquisition
Expected Key result / Message to take home

1- **It is possible** to **identify malfunctioning of** on the orchard’s **drip irrigation systems** *(without hail nets)* from **drone** embedding multispectral and thermal IR cameras

2- **Artificial Intelligence** may be of **great help** for rapid detection/localization of malfunctioning on orchard’s drip irrigation systems

3 - **A.I. application** is **close to** the **Ready-To-Use status**, **but**

Before releasing the AI based application we need to improve its robustness *(environmental conditions x agricultural practices –including other systems than drip irrigation, low cost cameras)*

Continuation of the project: **improving the robustness of A.I. algorithm**
- by training the algorithm on different orchards *(environmental conditions x agricultural practices)* **with** farmer and farmer advisers
- by using other cameras (most commonly used - low cost - cameras)
- Improving the application for by being more sharp in the data selection *(work on the algorithm)*
### Practice Performances

**AGRONOMY & ENVIRONMENT**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide reduction</td>
<td>Water use reduction</td>
</tr>
<tr>
<td>Energy for water pumping</td>
<td>Greenhouse gas reduction</td>
</tr>
<tr>
<td>This solution reduces the amount of water waste</td>
<td>Fruit production</td>
</tr>
<tr>
<td>This method permits a regular water supply, with more fruits for the fresh market, and limited quality loss due to irregularities in the water supply.</td>
<td>Ease to implement</td>
</tr>
<tr>
<td>The tool and software do not request any specific skills or knowledge. It is validated on-station.</td>
<td>Ready to use</td>
</tr>
</tbody>
</table>

**COSTS & BENEFITS**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>Specific investment to buy the drone. Benefits due to the water and time spared.</td>
</tr>
<tr>
<td>Time to set-up</td>
<td>Little time needed to fly the drone (= 18mn/ha).</td>
</tr>
<tr>
<td>Time to manage</td>
<td>Save time to monitor the leaks and clogging.</td>
</tr>
</tbody>
</table>

**OPERATIONALITY**

- Positive outcome
- Neutral to positive outcome
- Areas of improvement
- Critical points

**It allows low cost, simple and quick use, on a laptop, in the field, without internet.**

Robustness need to be improved before release.
Roadmap for transfer– Next steps

- First step before transfer: Improve the robustness of the algorithm (most currently used low cost cameras, more cultural design, improved accuracy)

- Practice on commercial orchard with farmers and farm advisers interested by digital technology and using already drones for their tips

- Promote the application to users (farm advisers and farmers), open days, communicate, demonstrate on orchards, ...

Meanwhile, continue to improve the robustness of the algorithm, to make it faster and more accurate, to adapt it to new technological developments of sensors, to other fruit species, and propose updates for the application.
Un gran agraïment a tots

Field and drone team

AI / informatic team
The interface: needs a better design

Step 1: re-sizing images

Step 2: layers stack

Step 3: preparing to search

Step 4: searching misfunctionning spots

GO + clogging + leaks
Overview of data treatment

Récupération des données

Traitement des données

Redimensionnement

Empilement des spectres

Découpage des images

Labelisation

Augmentation des données

Construction du modèle

Optimisation des hyperparamètres

Résultats du modèle

Mise en application
Model Building and optimization of hyperparameters

Convolutional Neural Network

Construction du modèle

Optimisation des hyperparamètres

=> To improve model accuracy

- Taux de Dropout
  - 0.00, 1.00

- Fonction d’optimisation
  - [1e⁻⁵, 1e⁻⁶, 1e⁻⁷]

- Fonction d’activation
  - [ReLU, LeakyReLU, ELU]

Training step:
inputs: images 160x128 pi et 7 channels
Partition of dataset:
Training / validation / test: 80/10/10
2 networks developed: Leaks + Clogging

Max JEAN – M2 student
Gala © Brookfield
2019: 5 days * 1 flight * 2 tracks
2020: 3 days * 3 flights/day * 3 tracks/flight
Gala ® Venus under grey hail-nets : analyse still on-going (2 days * 3 flights/day * 3 tracks/flight = 18 mosaics)
An Internet of Things (IoT) solution for improved irrigation scheduling

Joan Bonany (IRTA), Luca Corelli Grappadelli (UNIBO)

01.01.2018 to 31.12.2020

Supported by:

Climate-KIC is supported by the EIT, a body of the European Union
History of experiments and selection of practice

Write a short overview of the experiments that have been tested since the start of the project AND why this particular practice/experiment was retained as the most promising in terms of results and future transfer.

The experiments consisted in using capacitance soil water content sensors and volumetric meter in commercial apple orchards in Spain, France and Italy. The data from these probes have been collected and integrated in a web platform where the data was combined with weather forecast to provide an irrigation scheduled fitted to the conditions of each under test.

The system was tested in two different ways. In France and Italy, the system provided irrigation schedule in a weekly basis that was implemented by the grower in commercial orchard (DSS). The results of the DSS orchard were compared to a similar orchard of the same cultivar managed by the grower without using the DSS.

In Spain, the experiment consisted of comparing an irrigation scheduling based on using the platform and manually changing the irrigation controller, approximately once a week with the system changing automatically on a daily basis the water volume or time directly on the irrigation controller.
Description of the practice selected for the leaflet

What? An irrigation scheduling system combining on-site sensors to now-casting meteorological conditions to better fit irrigation water restitutions to actual crop needs.

Why? Under climate change, water availability can be a limiting factor for agriculture productivity. Better management of irrigation by use of soil sensors and weather data can lead to significant water savings without compromising production or quality.

Status? Ready to use with the appropriate training.
Main steps to implement this practice

<How should farmers proceed to implement this practice, describe the main steps (do not mention here the experimentation protocol)> 

A farmer or a group of farmers should:
• Install capacitance soil water content sensors at 20, 40, 60 cm depth
• Install water meter in the irrigation line
• Use a cloud platform that captures data from these probes and combines it with weather data forecast to calculate an irrigation schedule based on water budget method corrected by soil probes
• Use the irrigation schedule to change periodically (usually on a weekly basis) the irrigation controller
• Or link the web platform with the irrigation controller to change the schedule on a daily basis
The proper implementation of the practice should result in the majority of the occasions in a better irrigation management, including:

- Water savings in the order of 20-30% compared to utilization of water budget method alone or grower standard practice
- Further savings of irrigation water when a layer of automation is added to the system by which the irrigation schedule is automatically delivered to the irrigation controller in a daily basis
- No indication of production or quality losses
- If the water for irrigation is pumped, it is expected a logical reduction in energy
- Reduction of nutrient losses by lixiviation out of the root zone
Practice Performances

< If you have completed the Excel file for the Leaflet you can obtain your Performance Graph to be inserted here by contacting:

-> Aude Alaphilippe aude.alaphilippe@inrae.fr for Apple
-> Marion Casagrande marion.casagrande@inrae.fr for Strawberry

In any case please highlight the most positive outcome and the most negative outcome >
Roadmap for transfer – Next steps

The practice is ready to be used by growers. The web platform that collects and integrates soil water content and weather data forecast into irrigation schedule is ready available. Interested growers or fruit growing companies can contact either IRTA or UNIBO for commercial implemention of the practice.

On the other hand, recently, there it has been other initiatives that have made available similar solutions on a commercial basis. So there are diferent commercial solutions that can help to implement the practice in fruit orchards.
Optimization of the irrigation of strawberry field crops: Monitoring based on tensiometers

François Lecompte (INRAE), Fanny Thierry (Invenio), Soukaina EL Mrini (INRA Maroc), Ahlam Hamim (INRA Maroc), Sophie Bomel (INRAE), Marion Casagrande (INRAE), Douae Lamrahli (Messem), Hicham Essrifi (Messem), Ahmed Taleb (Danone), Aziz Didicheikh (GIZ)

01.01.2018 to 31.12.2020

Supported by:
History of experiments and selection of practice

- **Water related issues:** Water availability, water cost, leaching and pollution → Water management

- **Strategy:** Setting soil water tension thresholds for irrigation based on tensiometers = effective, fast and low cost.

- **Experiment:**
  5 farm labs (Morocco), first 6 months of the growing season 2019-2020
  1 experimental site (France), growing season 2019-2020
Practice description

What?
Irrigation management based on sensors which measure soil water tension, a component of the water potential, in strawberry field crops.

Why?
To preserve water resource by adjusting irrigation to the crop’s needs while maintaining yield level.

Status? Ready to use?
Practice implementation

1. **Install 3 to 5 pairs of sensors** (10 & 30 cm) on each homogeneous area.
2. **Check sensors** at least once a week during the growing season.
3. **Fractionate irrigation inputs** to maintain soil water tension between 10-15 cbar.

*Surface soil water tension (10 cm): trigger irrigation if > 15 cbar*

*Lower soil water tension (30 cm): manage irrigation duration (cf. Chart)*

<table>
<thead>
<tr>
<th>Lower soil water tension</th>
<th>Water amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10 cbar</td>
<td>Decrease amount</td>
</tr>
<tr>
<td>10 - 15 cbar</td>
<td>No change</td>
</tr>
<tr>
<td>&gt; 15 cbar</td>
<td>Increase amount</td>
</tr>
</tbody>
</table>
## Key results

<table>
<thead>
<tr>
<th>Results</th>
<th>« Experimental » plot</th>
<th>« Farm » plot</th>
<th>Difference between plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>October-March</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average water use (m³/ha)</td>
<td>2 889 ± 380</td>
<td>5 451 ± 705</td>
<td>- 46 ± 6 % (wilcoxon p-value = 0.032)</td>
</tr>
<tr>
<td>Average Water Use Efficiency (WUE)</td>
<td>0.13 ± 0.01</td>
<td>0.07 ± 0.01</td>
<td>+ 85 ± 17% (wilcoxon p-value = 0.008)</td>
</tr>
</tbody>
</table>

Key expected results (Morocco): - 30% water use, yield level maintained → Goals are achieved and even exceeded

Long and significant irrigation leads to soil saturation. **Fractionated irrigation and sensors use enable the reduction of water use.**
Practice Performances

AGRONOMY & ENVIRONMENT

Has not been studied
Reduction in the use of energy (water pumping)
High yield maintained
Water use reduction.

COSTS & BENEFITS

Investment cost
Time to set-up
Time to manage

Pesticides reduction
Climate change mitigation potential
Fruit production
Ease to implement
Ready to use
Fairly easy to set-up
Well-known practice

HUMAN ASPECTS & FEASIBILITY

Low investment cost
Low time required to settle and remove sensors.
Time required for monitoring is low
Reduction costs related to water use.
Dissemination

- **FRIENDLY FRUIT OUTPUT: Leaflet** (overall method and results)
- **Short report** (detailed method and results) to be distributed to the 5 partner farmers
- **Short training session** for the technical consulting staff
- **Berry School event** (Morocco)