Validation of remotely sensed soil moisture using crowdsourced measurements

Mel Woods / DJCAD, University of Dundee, UK

Luca Zappa, Angelika Xaver, Wouter Dorigo / Department of Geodesy and Geoinformation, TU Wien, Austria

Drew Hemment / University of Edinburgh, UK


GROW
OBSERVATORY

GROW Observatory

To support a movement of citizens generating, sharing and using data and information on growing and land practices.

To address urgent climate challenges for science and society.

Background / Soil Moisture

- Soil moisture is a pivotal element regulating water, energy and carbon fluxes
- Key for land use and food production
- Monitoring soil moisture is challenging because of its high spatial and temporal variability
- In the last decades, microwave sensors onboard satellites have proven capable to estimate soil moisture globally

Background / Validation

- Validation of remotely sensed products is a crucial step to ensure their reliability

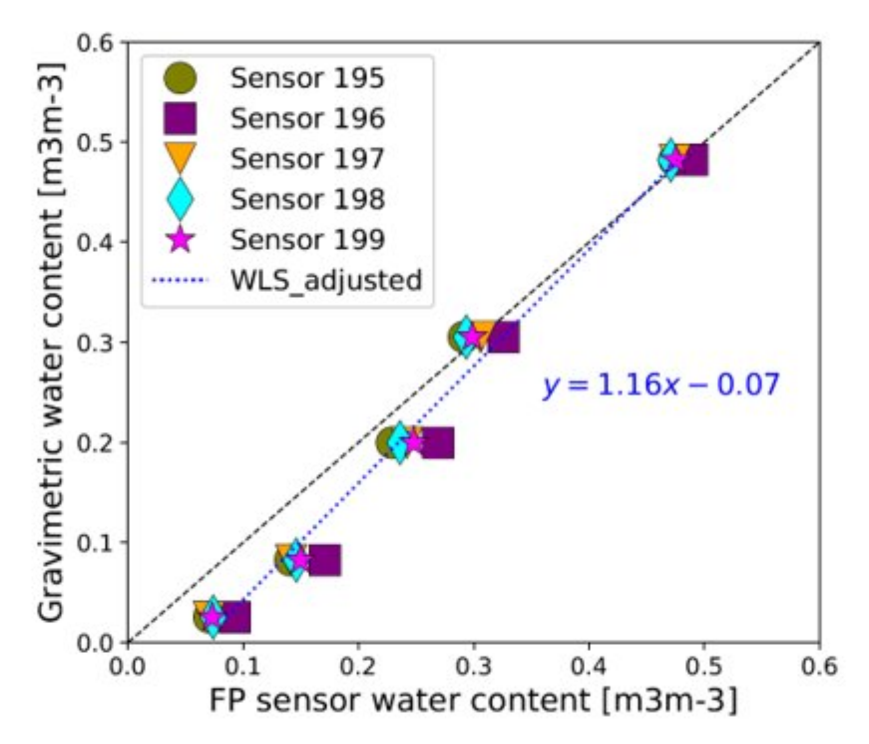
- The most accurate reference data for validation purposes are in-situ measurements

- However, installing and maintaning ground sensors is expensive and time-consuming

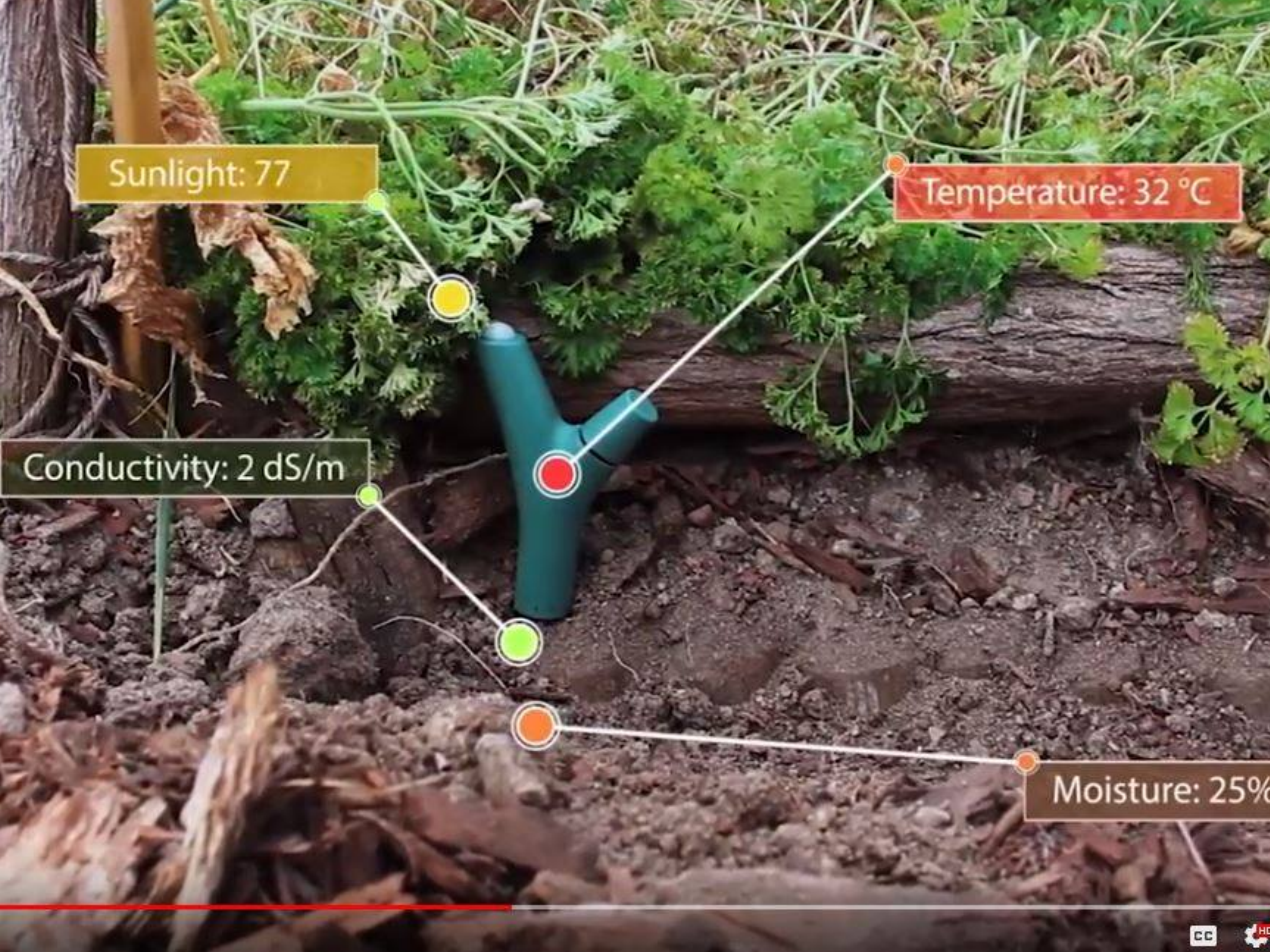
- Few sensors available globally, unevenly distributed

Background / Low-Cost Sensor Parrot Flower Power

- Readily available consumer sensor, 15,000 purchased
- Performances of the sensors thoroughly investigated in the lab and in the field [1]
- Strong consistency with gravimetric sam ples
- Inter-sensor variability negligible
- High correlation against professional pro bes in field conditions



- [1] Xaver et al., 2019


Sunlight: 77
Temperature: 32 °C
Conductivity: 2 dS/m
Moisture: 25%

Data and Methods / The GROW Approach and Model

Data and Methods / The GROW Vision

TURN DATA INTO KNOWLEDGE FOR CHANGE

How do we support people to move from data to meaning towards changes in practice?

Data and Methods / Site Definition

24 GROW Places

Data and Methods / Site Definition Scientific Criteria

- Meaningful geographic coverage (across a breadth of climate, soil, and land-use types, and agro-technology approaches)
- An area of approximately 50x50 km described with a distribution density of about 1000 sensors
- Soil, terrain and land-use variability, with relatively homogenous characteristics around each sensor (20-30 meter radius)
- Good quality of environmental data (terrain, soil, and land-use)

Data and Methods / Definition of Social Criteria

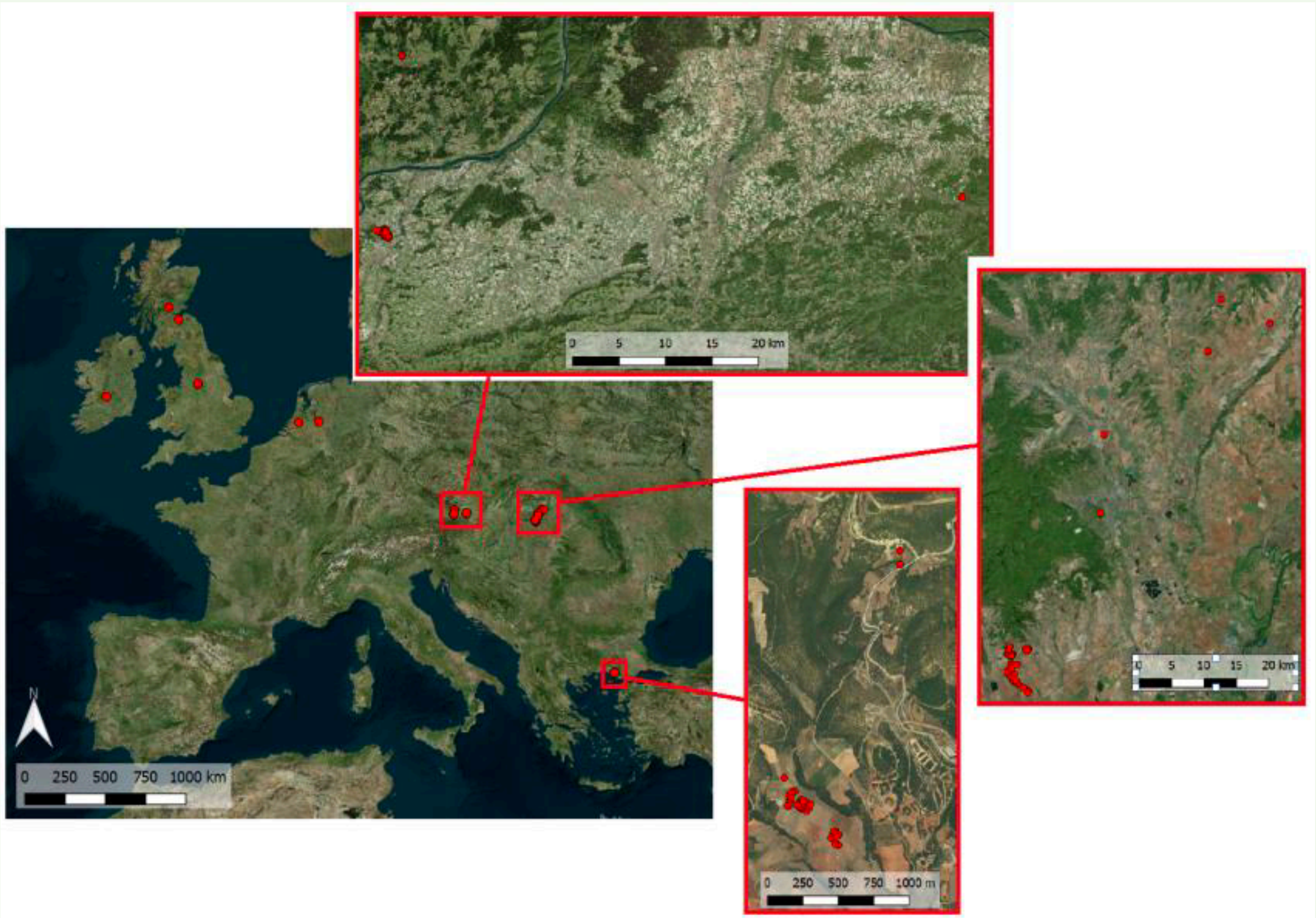
- Having a scientific institution capable of supervising the process
- A local organization with established connections to maintain and extend the network
- An identified Community Champion with
    - competencies for leadership, education and ability test the engagement, awareness-raising strategies, and toolsets

Data and Methods / Low-Cost Sensor

A subset of all available crowdsourced data was employed, critieria:

- Minimum observation period of 1 year
  - Ensure good temporal overlap with satellite observations, and wide ran ge of moisture levels
- Sensors located urban areas, forests, or in close proximity to water were excluded
  - unreliable remotely sensed data
- Measurements flagged as “good“ (ISMN quality control)
- Measurements taken with air temperature < 4°C were disregarded

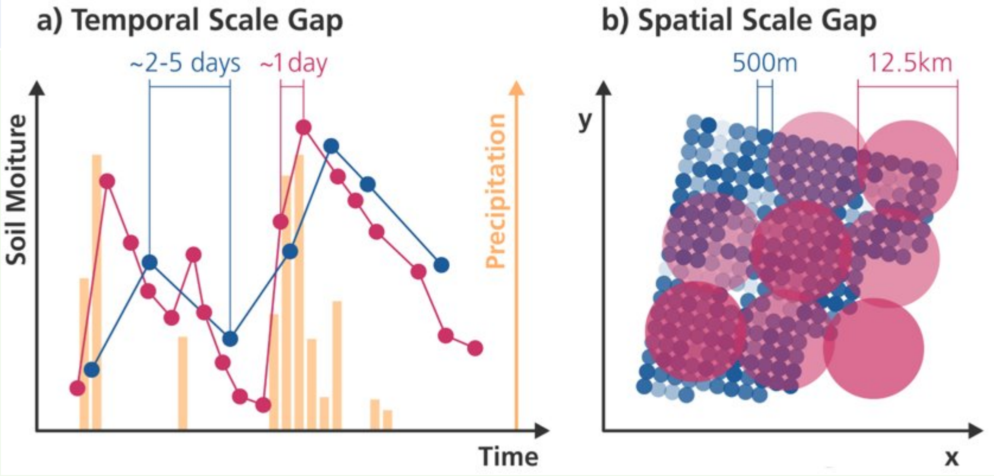
Data and Methods / In-situ soil moisture measurements



Distribution of the in-situ sensors employed for the temporal analysis

Data and Methods / Satellite soil moisture products

	Spatial resolution	Revisit time	Unit	Ref
SMAP	36 km	1-2days	m^3/m^3	[1]
ASCAT	25 km	1-2days	% sat	[2]
CCI-SM	0.25°	1 day	m^3/m^3	[3]
Sentinel -1	1 km	2-6days	% sat	[4]



Data and Methods / Preprocessing & analysis

- Temporal matching
  - in-situ observations closest to satellite overpass (for each individual product) was considered

- Scaling
  - satellite observations rescaled to mean-std of in-situ measurements, to account for systematic representativeness error, different depth sensed, and different measurement unit

- Statistical metrics
  - Pearson correlation (R) and unbiased root mean sqaure deviation (RMSD)

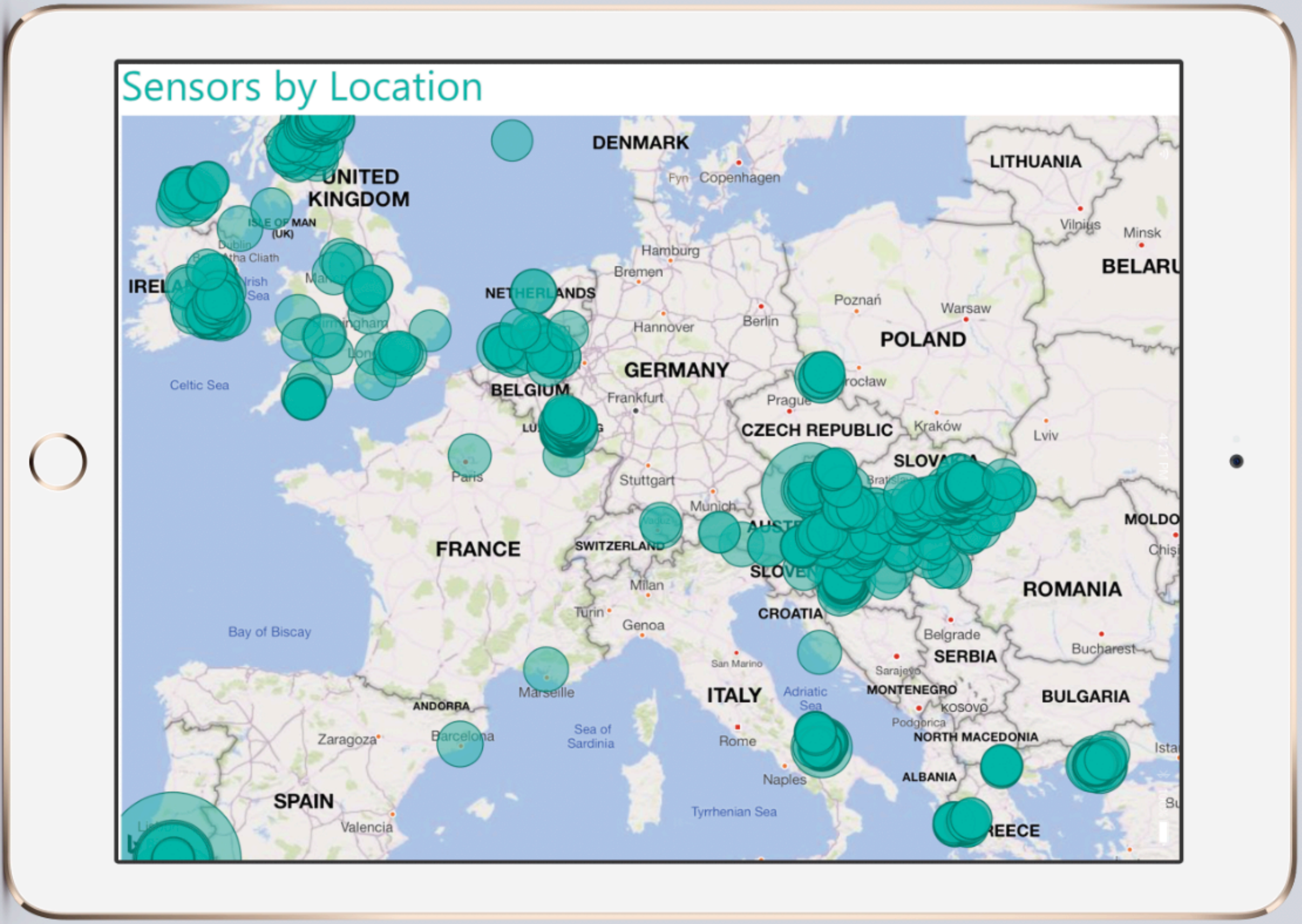
Crowdsourced Remote Sensing

- We analyzed and inter-compared the temporal consistency of ASCAT, SMAP, ESA CCI SM, and Sentinel-1 products

- Employing data from 154 ground sensors covering different climatic and environmental conditions across Europe.

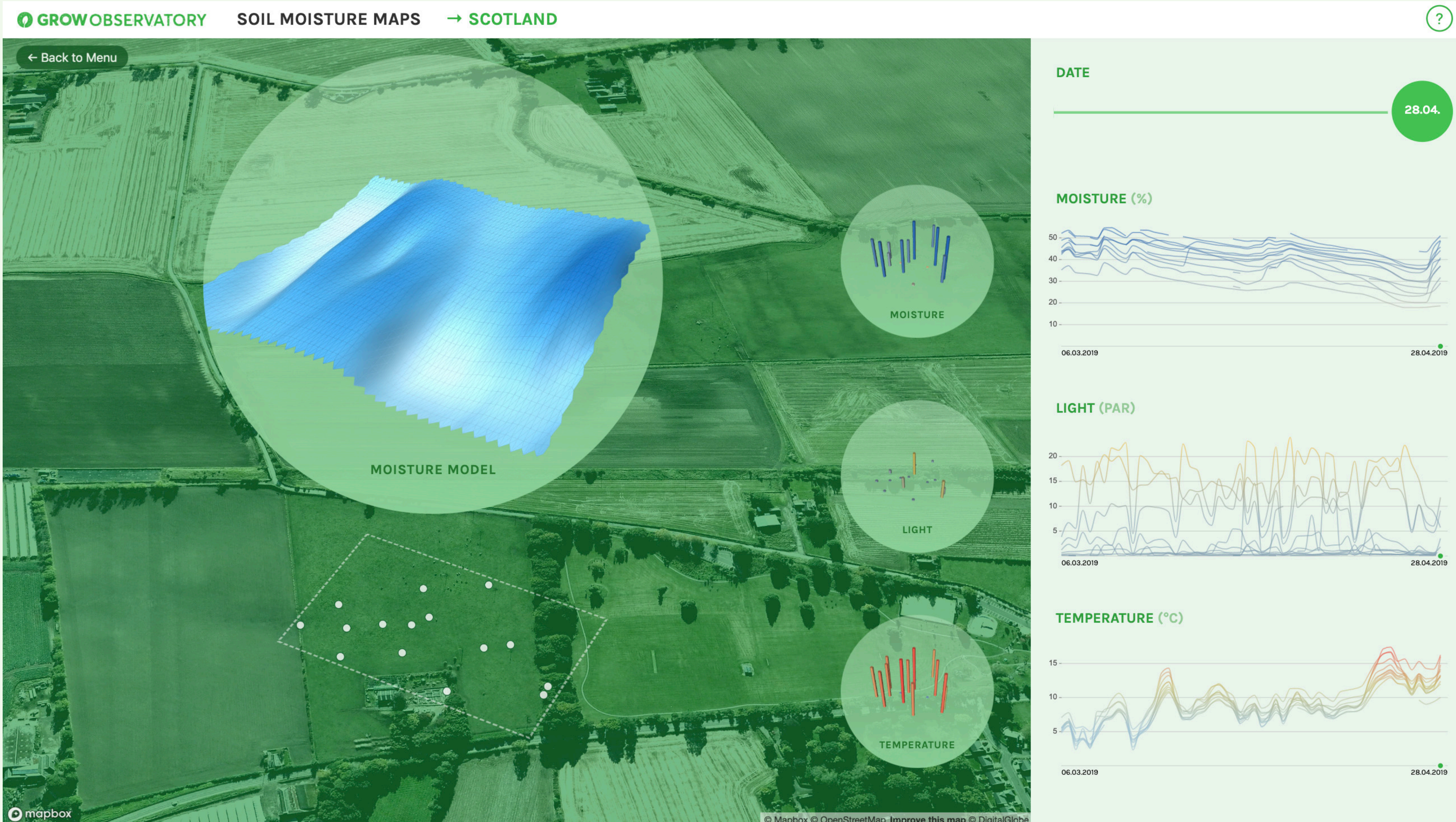
- The sample dataset now available on ISMN database for further interrogation.

Results / Full Sensor Distribution



Map showing 6,500 sensors returning data, Oct 2019

Results / Soil Moisture Visualisation



Results / GROW Places Greece, Spain and Portugal

Community Using Sensors and Open Soil Moisture Data for themselves to inform:

- **Wetland monitoring** for migratory birds in Evros basin, Greece
- **Water Resource** reduced by 30% in a banana farm on El Hierro, Spain
- **Wild Fire mitigation** for managing Land and Soil Moisture in Portugal
- **Disease monitoring** in Olive groves in Greece
- **Growing Practices** for regeneration of soils and increase in yields

Results / Remote Sensing

- Analyzed and inter-compared the temporal consistency of ASCAT, SMAP, ESA CCI SM, and Sentinel-1 products

- Confirmed that SMAP and ESA CCI SM performances are comparable and they are generally able to better capture the soil moisture dynamics of soil moisture compared to other products.
-
- In well-represented satellite pixels, i.e. places with a high number of in-situ sensors, found a wide range of satellite products' accuracy depending on the individual sensor used as a reference

Results / Remote Sensing

- For well-represented satellite pixels, i.e. high number of in-situ sensors, we found a wide range of satellite products’ accuracy depending on the individual sensor used as a reference.

- This is more prominent for coarse scale products, however, the same behaviour was observed also for high-resolution soil moisture product (Sentinel-1).

Note: single point location as a reference to evaluate coarse-scale products (20-40 km) generates high uncertainties in the results because it is extremely difficult to estimate the representativeness of an in-situ measurement for such satellite footprints.

Results / Remote Sensing

Our results suggest that at the kilometric scale one single in-situ sensor might not be representative of the overall soil moisture dynamics.

- Valid for highly fragmented landscapes, the presence of various land cover types, e.g. summer and winter crops, broadleaf and evergreen forest, leads to a great variability of soil moisture spatio-temporal patterns.

- The use of crowdsourced observations, is of utmost importance because it allows to monitor soil moisture intensively at the sub-pixel scale, reducing the representativeness errors and uncertainties generally associated to conventional networks.

Results / Design of CO’s for Remote Sensing

Highly encouraging, implications for both the design of future COs and the integration of COs for EO as follows.

The social aspects play an important role in creating opportunities with the remote sensing community for environmental monitoring.

- CO continuous monitoring, should be determined and design to achieve an extended period of time (e.g. months or years).
- Ongoing need for strategic approaches both to the development of scientific protocols and criteria, engagement of resilient communities of practice and place.
- Finding a balance between, scientific requirements, selection of sites, interests and locations of citizen scientists, and varying technical and social competencies with needs for training and support.

Conclusions: Remote Sensing

- Demonstrated the first experience using crowsourced measurements for validation of remotely sensed soil moisture
- Even within the same satellite pixel, a high variability in the satellite skill was found (possible thanks to the unprecedented high density of crowdsourced data).
- Consistent for coarse scale (SMAP, ASCAT, ESA CCI) and high resolution (Sentinel-1) products
- The spatial consistency of Sentinel-1 against crowdsourced data is poor, but needs further investigation

Full Paper (Forthcoming) SPIE

Zappa., L, Woods., M, Hemment., D, Xaver., A, Dorigo., W, (2020) Evaluation of Remotely Sensed Soil Moisture Products using Crowdsourced Measurements

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THANK YOU!

Any Questions?

Mel Woods

Professor of Creative Inteligence,
University of Dundee

@i_serena / m.j.woods@dundee.ac.uk

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