Operational High Resolution Soil Moisture for Agricultural Applications

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SMELLS project introduces the use of Soil Moisture to preventive management of Desert Locust.

Those plagues have threatened agricultural production in Africa, the Middle East and Asia for centuries and regularly affect up to one-tenth of the world’s human population.
Preventive management aims to prevent or to limit crop damage by controlling populations before they can reach high densities and form mass migrating swarms.
Surface to be monitored is immense latitudes 0 – 40 N, longitudes 20 W – 80 E.
moist sandy soil & green vegetation

rainfall

vegetation

Meteosat
ARTEMIS CCD
CMORPH RFE

GIMMS NASA GFSC
NOAA AVHRR
SPOT
LANDSAT
MODIS
SENTINEL
remote sensing evolution 1980s-2015

**VEG**
- 1980: GIMMS NASA GFSC
  - NOAA AVHRR NDVI
  - (1-7 km)
- 1990: Meteosat V+IR
  - (1st generation)
  - (hard BW copies)
- 2000: ARTEMIS CCD
  - (FAO RSC)
  - (hard colour copies)
- 2010: MODIS
  - (250 m)
- 2020: Sentinel
  - (10 m)

**RAIN**
- 1980: GIMMS NASA GFSC
  - NOAA AVHRR NDVI
  - (1-7 km)
- 1990: Meteosat V+IR
  - (1st generation)
  - (hard BW copies)
- 2000: ARTEMIS CCD
  - (FAO RSC)
  - (hard colour copies)
- 2010: MODIS
  - (250 m)
- 2020: Sentinel
  - (10 m)
1. The establishment of a dialogue between developers and Desert Locust monitoring users about their requirements related to Soil Moisture Remote Sensing.

2. Assessing the capacity of Soil Moisture to predict Desert Locust presence to be used in the framework of Desert Locust preventive management.

3. The development of an innovative approach to derive High Resolution Soil Moisture products from Sentinel-1 in synergy with SMOS data.
Users Requirements

In accordance with Requirements Baseline defined with Users, the SMELLS project has provided Soil Moisture (SM) estimations at two spatial resolutions:

• SM at a resolution of 1km for the entire AOI based on L-band passive MW every 10 days between 2010 to present and
• SM at a resolution of 100m for areas where and when Sentinel-1 acquisition is available for 2015-2016.
L-band Passive MW SMOS/SMAP/WCOM
- accuracy 0.04 m$^3$/m$^3$
- low spatial resolution 40 km
- high temporal 2 - 3 d

Medium Resolution O/T MODIS (1 km, 1 d)

SSM (1 km, 2 - 3 d)
SMELLS 1km

L-band Passive MW SMOS/SMAP/WCOM
- accuracy 0.04 m³/m³
- low spatial resolution 40 km
- high temporal 2 - 3 d

+ Medium Resolution O/T MODIS (1 km, 1 d)

Implemented and validated in Catalonia [Merlin et al., 2013, Escorihuela et al. 2016], Central Morocco (Merlin et al. 2015), South Eastern Australia (Malbeteau et al. 2016) and USA (Molero et al. 2016)
SMELLS 1km

SMELLS Soil Moisture Stations
SMELLS Soil Moisture Stations

**MOROCCO**
Fam el Hisn, province of Guelmim-Es Semara
(Lat N 29°00’58.8”, Lon W 8°50’29.9”)

**ALGERIA**
Abalessa, province of Tamanraset
(Lat N 22°47’33.0”, Lon E 4°14’41.0”)

**MAURITANIA**
42km South-east of Akjoujt, province of Adrar
(Lat N 19°38’07.4”, Lon W 14°02’03.3”)

**MALI**
Yékelmané, province of Kayes
(Lat N 15°07’11.8”, Lon W 10°33’14.8”)

Operational High Resolution Soil Moisture for Agricultural Applications
## SMELLS Soil Moisture Stations

<table>
<thead>
<tr>
<th>Location</th>
<th>R</th>
<th>RMSE</th>
<th>Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>FamHisn</td>
<td>0.69</td>
<td>0.021</td>
<td>-0.016</td>
</tr>
<tr>
<td>Abalessa</td>
<td>0.45</td>
<td>0.154</td>
<td>0.137</td>
</tr>
<tr>
<td>Yelimane</td>
<td>0.82</td>
<td>0.042</td>
<td>0.013</td>
</tr>
<tr>
<td>Akioujt</td>
<td>0.74</td>
<td>0.021</td>
<td>0.0161</td>
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### SMELLS Soil Moisture Stations

**SMELLS at 1km**

<table>
<thead>
<tr>
<th></th>
<th><strong>DAILY</strong></th>
<th></th>
<th><strong>DECADAL</strong></th>
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<tbody>
<tr>
<td></td>
<td>$R$</td>
<td>RMSE</td>
<td>$R$</td>
</tr>
<tr>
<td>Agoufou</td>
<td>0.81</td>
<td>0.046</td>
<td>0.89</td>
</tr>
<tr>
<td>Tondi</td>
<td>0.70</td>
<td>0.047</td>
<td>0.82</td>
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<tr>
<td>Wankama</td>
<td>0.63</td>
<td>0.046</td>
<td>0.71</td>
</tr>
<tr>
<td>Bani</td>
<td>0.61</td>
<td>0.048</td>
<td>0.70</td>
</tr>
</tbody>
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From Louvet et al. 2015

<table>
<thead>
<tr>
<th></th>
<th><strong>R</strong></th>
<th><strong>RMSE</strong></th>
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</thead>
<tbody>
<tr>
<td>SMOS</td>
<td>0.70</td>
<td>0.032</td>
</tr>
<tr>
<td>AMSR-E NSIDC</td>
<td>0.58</td>
<td>0.069</td>
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<tr>
<td>AMSR-E VUA</td>
<td>0.69</td>
<td>0.044</td>
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<tr>
<td>ASCAT</td>
<td>0.52</td>
<td>0.088</td>
</tr>
</tbody>
</table>
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SMELLS 1km 22 May 2015
Validation with survey data

- 2010-2016
- 36700 survey points
- 34800 points with satellite data
- 32563 points after synthesis per km² and decade

6262 INPV → 17.1% of presence
2770 CNCLP → 4.2% of presence
19192 CNLA → 59.9% of presence
4339 CNLAA → 46.3% of presence
Analysis for SM 1km – which dynamics is best?

Logit[Pr(p = presence)] = \( \alpha_0 + \alpha_1 \cdot SM + \alpha_2 \cdot SM^2 + \alpha_3 \cdot SM.2 + \alpha_4 \cdot SM.2^2 + \alpha_5 \cdot SM.3^2 + \alpha_6 \cdot SM.5^2 + \alpha_7 \cdot SM.7 + \alpha_8 \cdot SM.7^2 + \alpha_9 \cdot SM.8 + \alpha_{10} \cdot SM.8^2 + \alpha_{11} \cdot SM.10 + \alpha_{12} \cdot SM.10^2 \)

Optimum SM.2 \( \sim 0.07 \)
SM.7 \( \sim 0.125 \)
SM.8 \( \sim 0.125 \)
SM.10 \( \sim 0.05 \)
Building a prediction model

RandomForest model – only with SM adjusted on 2010-2015
November 2016 outbreak in Mauritania was concentrated on areas with Soil Moisture $>0.1$ seventy days before, as predicted by the analyses on 2010-2015 data.
Long-term high-resolution Soil Moisture dataset produced for the entire users area of interest at 1km spatial resolution for the period 2010-2017 (http://smells.isardsat.com/data-portal/)

SMELLS 1km product has been thoroughly validated, its accuracy is amongst the best soil moisture products but at a better spatial resolution (1km against typically 40km)

Correlation values are good (R> 0.70) and RMSE around 0.04 m3m3 and decadal

SMELLS 100m has room for improvement, Dramatic increase of data acquisitions since October 2016 (linked to S1B launch)
Results

Soil Moisture can explain presence/absence of Desert Locust with values significant to Desert Locust biology.

Soil Moisture allows to forecast locust presence 2–3 months ahead.

Current methodologies based on Vegetation Indices allow to predict presence only 1 month ahead.
Outlook

• The Soil Moisture products will be integrated into the national and global Desert Locust early warning systems in national locust centres and at FAO HQ, respectively.
• The Soil Moisture products should be extended to the entire Desert Locust recession area (0-40N/20W-80E).
• Integration of S3 LST in the SMELLS 1km algorithm
• Soil Moisture products at 100m and within root-zone to be investigated to provide further capacities of Desert Locust forecast.
Agriculture is an important pressure on water resources. Mediterranean countries agriculture uses 80% water available. The Mediterranean region is also one of the most sensitive areas to climate change.

Sustainable water use is a growing concern worldwide. Increasing water use efficiency in agriculture has been identified as one of the key themes relating to water scarcity and drought.

Irrigation performance assessments at the field scale show a mismatch between irrigation requirements and the amount of irrigation water that is actually applied. Optimize on-farm irrigation management.

Irrigation and fertilizer management improvements can help closing the crop yield gaps globally.
REC aims at develop an operational remote sensing algorithm dedicated to root zone soil moisture monitoring at the parcel scale.

REC will allow for the first time to:

1) to map root zone soil moisture on a daily basis at the field scale and
2) to quantitatively evaluate the different components of the water budget at the field scale from readily available remote sensing data.

These estimates will be integrated in an irrigation management system that will be used to trigger irrigation.
The approach is being implemented and validated in two sites in collaboration with their respective irrigation agencies:

- the modern irrigated area of Segarra-Garrigues in Lleida, Catalonia, Spain managed by ASG
- the irrigated perimeter of the Haouz Plain in the Tensift watershed, Morocco managed by the ORMVAH