# SoilWatch

Remote Soil Monitoring Regenerate Soils Empower Land Users

#### Problem

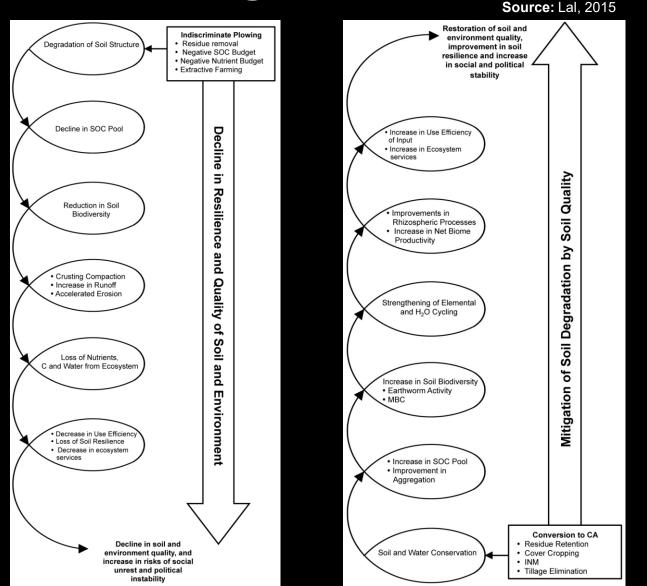
- **Degraded Soils** Worldwide Are a Threat to Global Food Security
  - Soil Erosion, or loss of soil organic carbon from topsoil, is the main cause of soil degradation globally
  - Soil erosion can decrease yield by up to 50%, if not provoke total loss of arable land, leads to Ecosystem Degradation, Reduces Water Supplies, Exacerbates natural disasters and Entails Loss of Livelihoods and Migration (FAO, 2018)

#### Opportunity

- The soil's carbon sink capacity (2500 GT) is larger than that of the atmosphere (800 GT) and vegetation combined (670 GT)
- 1/3 of World's arable land lost to land degradation in the period 1975-2015 (FAO, 2015)
- Over 90% of Earth's soils could become degraded by 2050 (FAO, 2018)
- Every ton of sequestered soil organic carbon (SOC) per hectare has the potential to boost yields by 32
   Mio Tons/year in developing countries and offset
   CO2 emissions at the rate of 500 Mio Tons C/yr (Lal, 2006)

#### How to Sequester Carbon through NBS?

- Mutual Environmental and Social Benefits of Sequestering Carbon in Soil besides climate change mitigation
- NBS to implement context-specific
  - Land Use (grassland or cropland?)
  - Agro-ecological conditions 
     SOM
     breakdown speed (actual removal, or
     prevention from further degradation?)
  - Soil conditions (loamy, sandy, etc?)



#### **Practical Pain Points**

Difficulty to measure soil carbon accurately in a cost-effective and scalable way

- Current Measurement Methodologies
  - Too expensive
  - Not scalable



- Measurement done in practice currently
  - "Cut corners"
  - Unreliable results
  - Accused of greenwashing



# Solution

 A satellite-based Monitoring, Reporting and Verification (MRV) system to link Land Users with Climate Financing and provide evidence for positive social and environmental benefits of Nature-based Solutions (NBS) projects

#### **Financial Incentive**

for land users who adopt regenerative management practices

#### **CO2** Sequestration

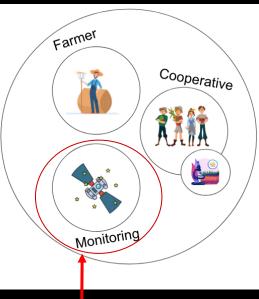
in the soil as a result of sustainable land management to mitigate climate change

#### **Food Security**

through regenerated soils, boosted yields and preserved livelihoods

#### **Project Consortium**

A multi-stakeholder consortium is formed to create a carbon credit



Consortium applies to a certification body



- . Regenerates soils & biodiversity
- 2. Positive impact on yields
- 3. Contributes in fight against global warming

**Certification Body** 

E.g. Gold

Standard.

VCS, CDM

Once certified the carbon credits are listed

3



CRS departments OR NGOs

**Carbon Marketplace** 

**OR Carbon Broker** 

SoilWatch as consortium partner or external MRV solution provider

Carbon credits implemented and monitored by the Consortium

2

Two types of carbon credits on sale:1)Carbon Offsetting: someonecompensates your footprint2)Carbon Removal: net negative emission

SoilWatch reduces the NbS project cost and chances of success by using its innovative MRV solution

# Product

#### **MRV** Tools

- Scoping Areas of High(est) Sequestration Potential
- Optimize Soil Field Sampling Locations
- Estimate Soil Organic Carbon Stocks
- Continuously Monitor Land Management Practices

#### **Technical Consulting**

- Onboard concerned land users and match them up with project developers and climate financing option(s)
- Support Project Proposal and Development

# **Process-based Models**

A Spatial Scale Disconnect

- Process-based models have potential for a broader range of applicability across gradients of soil, climate and management conditions
  - More complex and difficult to use than empirical models
  - Require many more data inputs
- <u>SoilsRevealed</u> used the <u>UNCCD</u> <u>modified Tier 1 method</u> to model global SOC stock change at 250m

| regional analyses of scenarios  Limitations  Dependent on specific soil fractionation method, difficult to link to dynamics at larger scales  Examples EnzModel, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, difficult to link to dynamics at larger scales  Examples EnzModel, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, difficult to link to dynamics at larger scales  EnzModel, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, difficult to link to dynamics at larger scales  EnzModel, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, difficult to link to dynamics at larger scales  EnzModel, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, difficult to link to dynamics at larger scales  Desendent on specific soil fractionation method, NICA, INDISIM DAYCENT, RothC, Ecosys CLM, IBIS, TEM  Desendent on specific soil fractionation method, Indifficult to link to dynamics  Plant growth Plant | Microsite  | Ecosystem  | Global   |
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| Modeling hypothesized mechanistic<br>relationships, predict short-term and<br>small-scale changes, predict dynamics of<br>measurable soil fractions       Hypotheses based on mechanistic or<br>empiric relationships, predict impacts of<br>site-specific changes, simulate site and<br>regional analyses of scenarios       Hypotheses for large-scale dynamics,<br>predict climate (hange with dynamic<br>soil feedback, simulate global scenario         Limitations       Dependent on specific soil fractionation<br>method, difficult to link to dynamics at<br>larger scales       Requires site-level data to drive and<br>evaluate model, cannot always represent<br>mechanistic relationships important at<br>smaller scales       Requires global-level data to drive and<br>evaluate model, model complexity<br>depends on computational capacity         Examples       DAYCENT, RothC, Ecosys       CLM, IBIS, TEM         Integrating the scale of the soil fractionation<br>mechanistic relationships important at<br>smaller scales       Human Activity<br>the scale of the scale of the soil of the scale o  |  |  |  |
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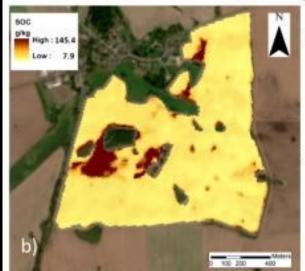
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# **Empirical Models**

Spatial Variability Described by Multi-Spectral Remote Sensing

- Empirical models through (machine learning) regression used in process-based models for calibrating certain model inputs
- Spatial distribution empirically modelled by sentinel-2 agrees with process-based models of comparable granularity (wrt. Piiki et al., 2019)
- Need for finer-grained spatial covariates to bring SOC estimates to the field level
  - Global elevation model
  - Multi-spectral sentinel-2 data
  - Land Use/Cover conversion information





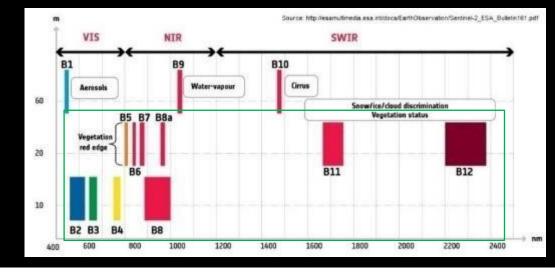
Source: Castaldi et al., 2019

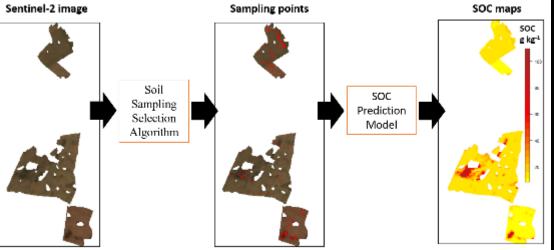
# **Input Data Source: Sentinel-2**

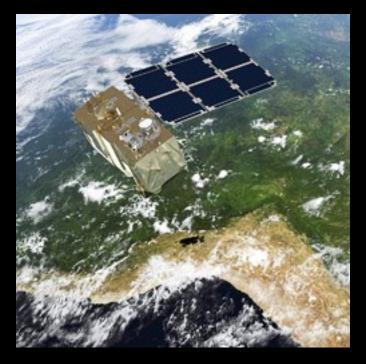
**Contextual Spatial Information measurable by Remote Sensing** 









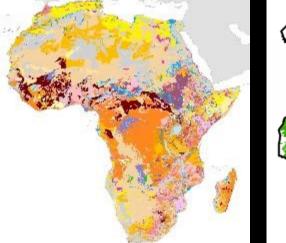


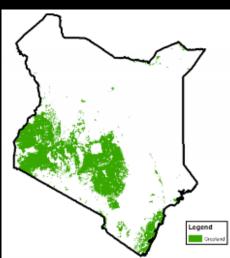
Sentinel-2A & B (Optical Multispectral) Resolution: 10/20/60 m Temporal revisit: 5 days Available since End 2016 for Africa Satellite mission with most potential for field-level yield

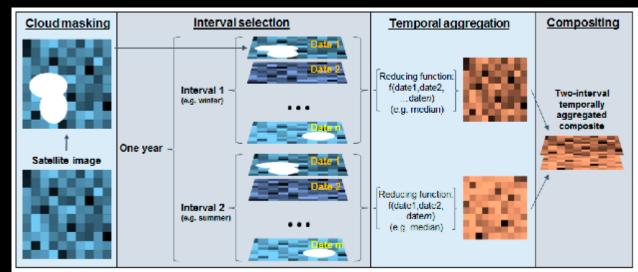
# "Laying" the Land

**Contextual Spatial Information measurable by Remote Sensing** 

- Identify plots at time of season when SOC  $\bullet$ estimation is least affected by external factors:
  - Crop and grasslands mask 1.
  - Sentinel-2 Seasonal Composites of the fields 2. when most bare
    - Reduce Crop Residues (tillage practices) effects
    - Reduce Soil Moisture effects (no preceding rainfall)
    - $\bullet$ **Reduce Surface roughness effects**
  - 3. Stratification According to "Soil Scapes"



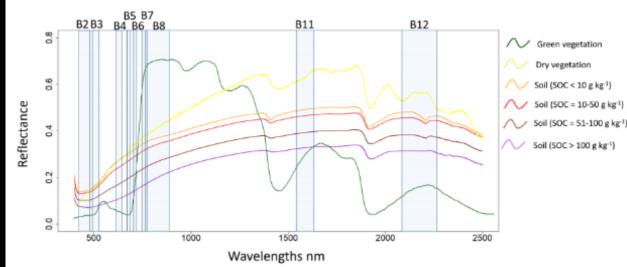




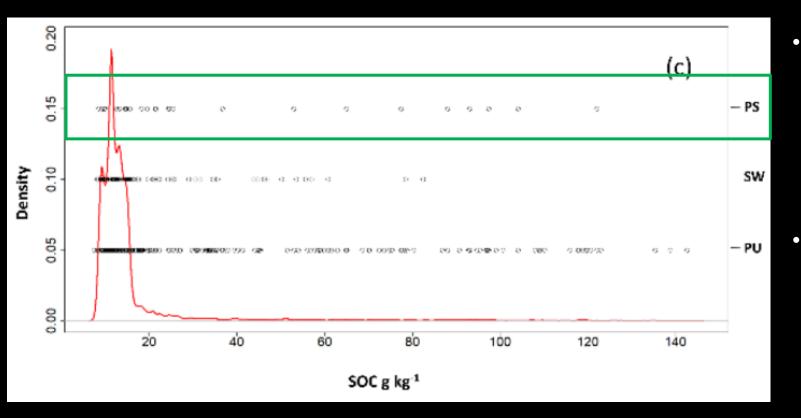
Dry vegetation

Soil (SOC < 10 g kg<sup>-1</sup>)

Soil (SOC = 10-50 g kg<sup>-1</sup>)



# **Qualitative Sampling vs Quantitative sampling**

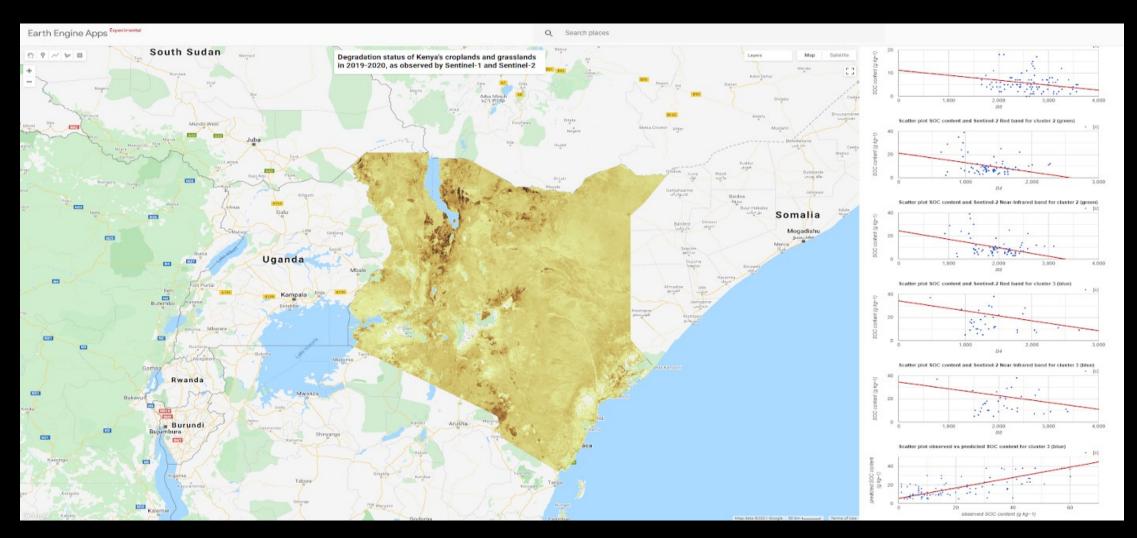


- More important to **sample the full range** of SOC variability in a given region than sampling a lot inconditionally
  - Smart sampling based on Sentinel-2 spectral feature space to generate regional spread of sampling locations
- Very high correlation coefficient between the Euclidian Distances between two
   Sentinel-2 spectra and the differences between corresponding two SOC measurements (Castaldi et al., 2019)

# **Operational Considerations**

- 1. Measured SOC changes more reliable when there is significant biomass and ground cover decay into topsoil (i.e. regenerative practices)
  - Yearly SOC change estimations of heavily tilled surfaces not statistically significant
  - Measurement intervals of approximately 5 years to obtain statistically significant results (Paustian et al., 2019)
- 2. Sample full range of SOC variability at the rate of ~**30 samples/1000 Ha** 
  - Spectral variability correlated with SOC variability  $\rightarrow$  Remotely assess optimal sampling locations
- 3. Re-sample at same locations to get yearly ground truth on SOC change
  - Using data from previous years (cross-year training) would require further research
- 4. An "ideal" (dry, bare, low roughness) cloud-free composite sentinel-2 image as input for SOC modelling and soil digital mapping
  - If "ideal" case not available, quantify the uncertainty of using sub-optimal (e.g. partially vegetated) input

#### **Google Earth Engine App Prototype**



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Monitoring of Soil Degradation Status and Management Practices

#### **Optimizing Soil Sampling Locations**



#### **Meet The Team**



William Ouellette: Earth Observation (EO) Data Scientist at FAO | Land Cover Specialist | Expert in cloud native EO data processing | Data crunching anything with coordinates



#### Eero Wahlstedt:

Monitoring, Evaluation & Learning Specialist | Expert in quantitative & qualitative data collection in challenging contexts in Sub-Saharan Africa | Aid sector reformer | Dad rock enthusiast



Joona Mikkola:

Former Manager for an Agribusiness Start-up | WFP M&E Consultant | Regenerative Agriculture Specialist | Hustler & environmentalist | Addicted to mountains



#### David Morrison:

Project manager | Former FAO Emergency Specialist | Consultant | Climate change and water conflict expert | Communications | Surfer

# SoilWatch Part of the Copernicus Accelerator

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A programme o

Implemented by

space-tec VERHAERT

- 12 months program, including:
  - Coaching
  - Bootcamps
  - Virtual Trainings
  - Access to Earth
     Observation Network
  - Meeting with Investors
  - Market Validation

# Harnessing satellite technology to provide affordable, scalable and up-to-date field-level assessment of soil quality conditions to reverse the trend of net carbon emissions and decreasing productivity in agriculture. Leveraging innovations in machine learning, future Copernicus missions and services to advocate for regenerative agricultural methods that foster soil carbon build-up while sustainably improving agricultural output and resilience in the face of climate change. Creating export revenue pathways for farmers by providing trusted data on verified increases in soil organic carbon and other soil quality indicators and linking communities to carbon credit markets.



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