JECAM @ Koutiala (Mali) – VHR imagery to quantify crop response to fertilizer and develop business services for smallholders

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Rationale

Food needs arising from the demographic explosion of sub-Saharan Africa can only be met through agricultural intensification. Smallholder systems feature enormous yield gaps, which may be reduced through ISFM and other sustainable intensification practices. However, today's huge variability in farming practices and returns on investments is likely to exacerbate in the future. Monitoring changes in productivity across scales is a significant challenge in heterogeneous systems, where overall low SOM and nutrient deficiencies prevail. Fortunately, remote sensing can help monitor crop performance at levels of granularity increasingly compatible with smallholder farming. This opens support applications for precision agriculture, allowing the exploitation – rather than the mitigation – of spatial heterogeneity, and the demonstration that enhanced productivity and livelihoods are possible in complex cropping systems.

Purpose

Goal: accelerate on-the-fly yield gap assessments with imagery to release pent-up demand for critical inputs, improve agricultural productivity and rural livelihoods in heterogeneous smallholder production systems. **Objective:** measure the sensitivity of the satellite signal to on-farm fertility treatments applied on five key local crops: cotton, maize, peanut, pearl millet, sorghum

Methods

Site: Sukumba (Koutiala, Mali), 50 farms distributed across 3 catena strata (10 farms per species). **Satellite imagery:** 30+ DigitalGlobe® scenes (May-Nov. 2014/2015), 2m multispectral ortho-rectified at centimetric accuracy, converted to TOA reflectances. **Fertility trials:** farmer practice + 5 fertility windows on cotton, maize, peanut (millet, sorghum: 6 levels). **Sample size:** 540 environments; 2,700 quadrats; 13,500 plants. **Ground measurements:** biweekly BBCH, weed %, plant height, ground cover fraction, light interception (AccuPAR), chlorophyll content. **Aerial remote sensing:** UAV SenseFly eBee 10cm with CANON S110 NIR: NDVI, canopy height. **Farming practices:** sowing, fertilization, weeding, harvest dates, field history. **Data capture:** full digital with custom JotBi™ (MANOBI) and ODK forms. **Analysis (2014):** ANOVA to separate fertilization (plot effect) from crop type and other management (field effect) from environment (stratum effect).

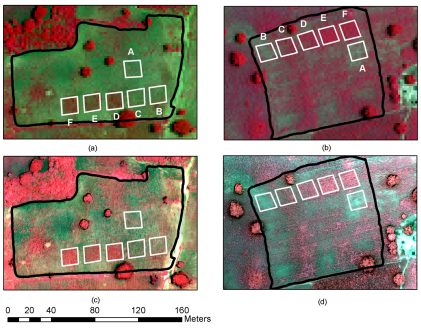
Learnings

1. Most of African smallholder (SH) systems heterogeneity is due to **variability in management** 2. Satellite imagery can **resolve heterogeneity**, monitor crop response to fertilizer, etc. 3. The strongly negative yield-heterogeneity relation is not a result of sub-optimal resource management by farmers. It stems from **lack of (affordable) inputs**. 4. Precision agriculture in SH systems is **not about optimizing** within-field/farm management of existing resources. It is about lifting bottlenecks to new resources. 5. **Monitoring farm management, performance** is key to reduce risk for input providers and to industrialize PA. 6. Until sufficient big (+RS) data has accumulated, characterizing SH management at scale is **easiest done from ground** (wireless) data networks

2017 plans

1. Re-run analyses on larger 2016 sample of farm management conditions. 2. Assess potential of Sen2agri data for bringing yield / fertilizer gap estimates to scale. 3. Assimilate sen2agri data from individual parcel to region with CRAFT and AgMIP

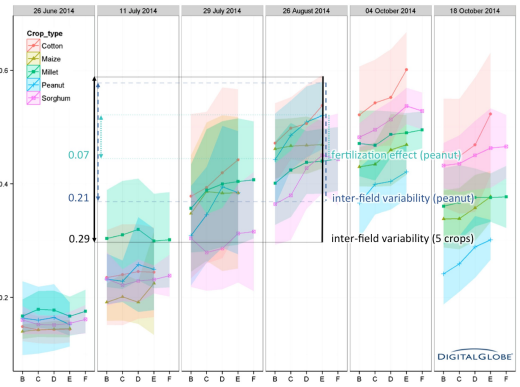
Intra-field variability



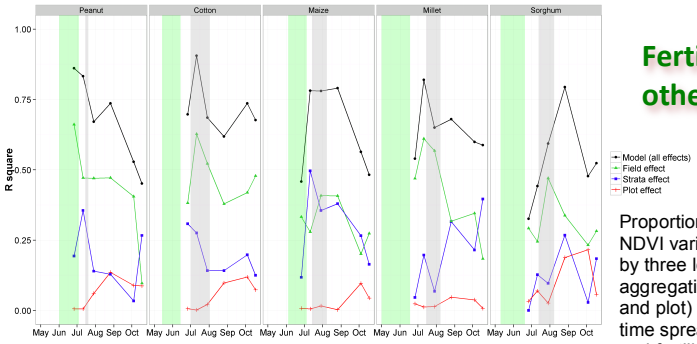
Variable fertilizer rates were applied on a sample of smallholder fields for dominant crops (Mali) and mixed cropping systems (Nigeria). Fertilizer application rates were specific for each crop species and elaborated in consultation with farmers and extension services. VHR imagery captures the crop canopy response to these treatments: here a late August GeoEye image at 2m resolution (a-b) & synchronous UAV image at 0.1 m resolution (c-d) for millet field on sandy soil (a-c) & sorghum field on loamy soil (b-d). However multiple other factors contribute to canopy heterogeneity as illustrated by similar canopy conditions elsewhere within the target fields.

Inter-field variability

Regional average and standard deviation (colored shading) of the temporal NDVI profile for each fertilization treatment, per crop type. For any single date during the season, fertilization impact on NDVI is dwarfed by the range of NDVI across environments and management levels. It also shows that NDVI alone is a poor discriminant of crop types, and highlights the significant challenge of automating smallholder crop recognition.

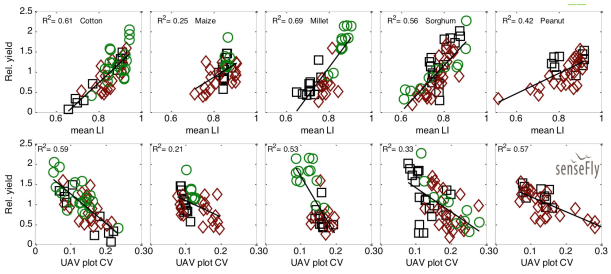


Fertility vs. other factors

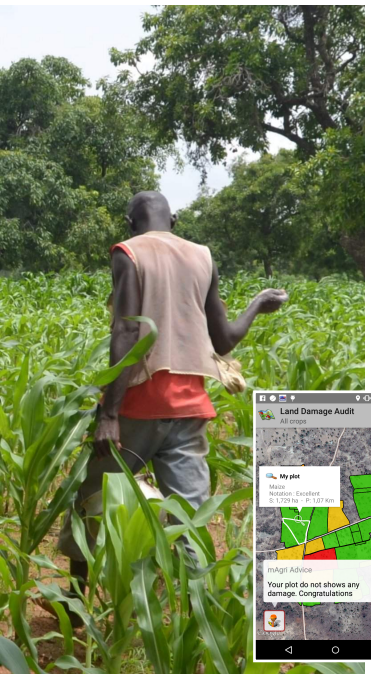


Proportion of the total NDVI variance explained by three levels of spatial aggregation (strata, field and plot) for 5 crops. The time spread of sowing and fertilization applications are shown for each crop as green and grey windows, respectively. At a landscape scale, drawing inferences about fertilization gaps from crop response (~yield gaps) is only possible after (i) other management factors have been documented (e.g. dates of sowing, fertilizer applications, weeding, etc.) and (ii) crop types have been documented. In other words, remote sensing cannot directly attribute crop response (and resulting yield gaps) to fertility management until other factors of variability have been resolved.

Heterogeneity and yield



The top row illustrates the expected positive correlation between light interception (LI) as estimated from quadrat-level measurements using AccuPAR-LP80 and vertical f-cover photos. The bottom row displays a negative correlation between canopy heterogeneity at the plot scale, as represented by the coefficient of variation (CV) of the NDVI computed from UAV (SenseFly eBee) multispectral imagery. Fields whose crop canopies are heterogeneous tend to yield less. This is consistent with a production system characterized by large yield gaps – i.e. where management (including fertilization) is far from recommended practice and where the main source of variability is due to management.



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