Yield mapping for different crops in Sudano-Sahelian small holder farming systems

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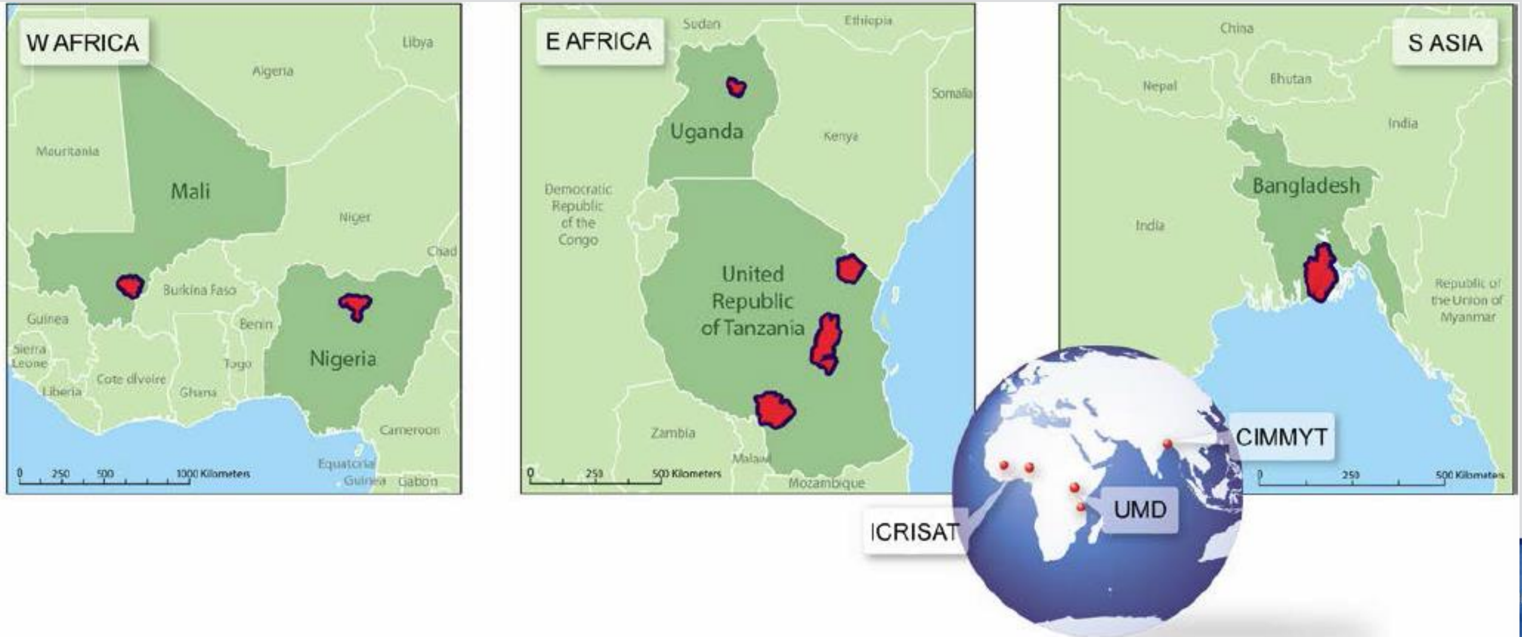
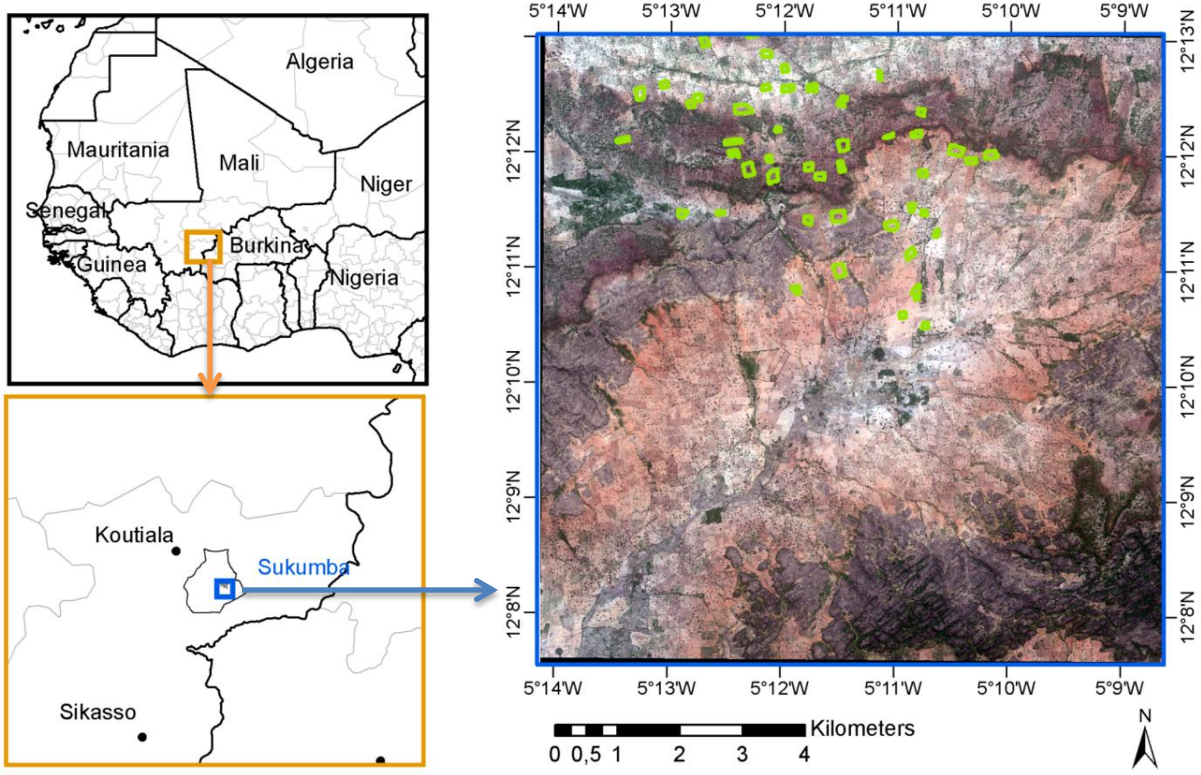
Spurring Transformations in Agriculture through Remote Sensing

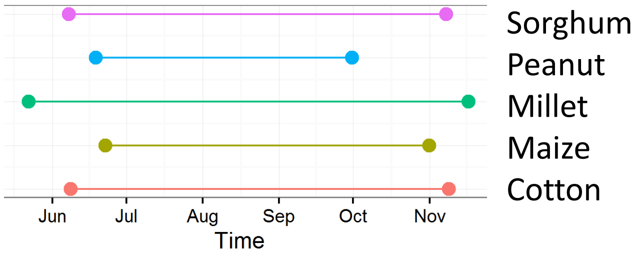
- BMGF funded project, ITC-leads
- Mali/Nigeria + Tanzania + Bangladesh



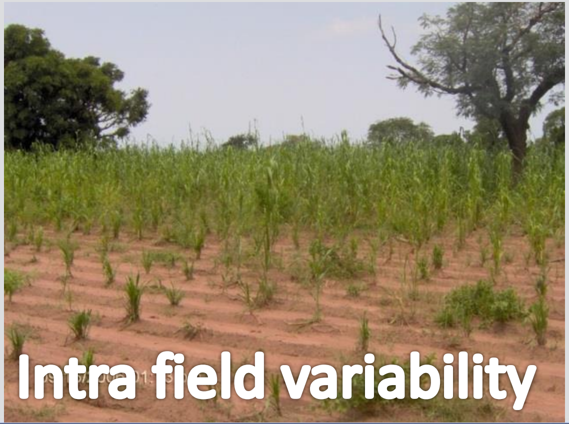
Mali site



- Small holder cropping
- Field size: 1.45 ha
- Low fertilization
- Low yield
- 5 main crop types



Many sources of heterogeneity



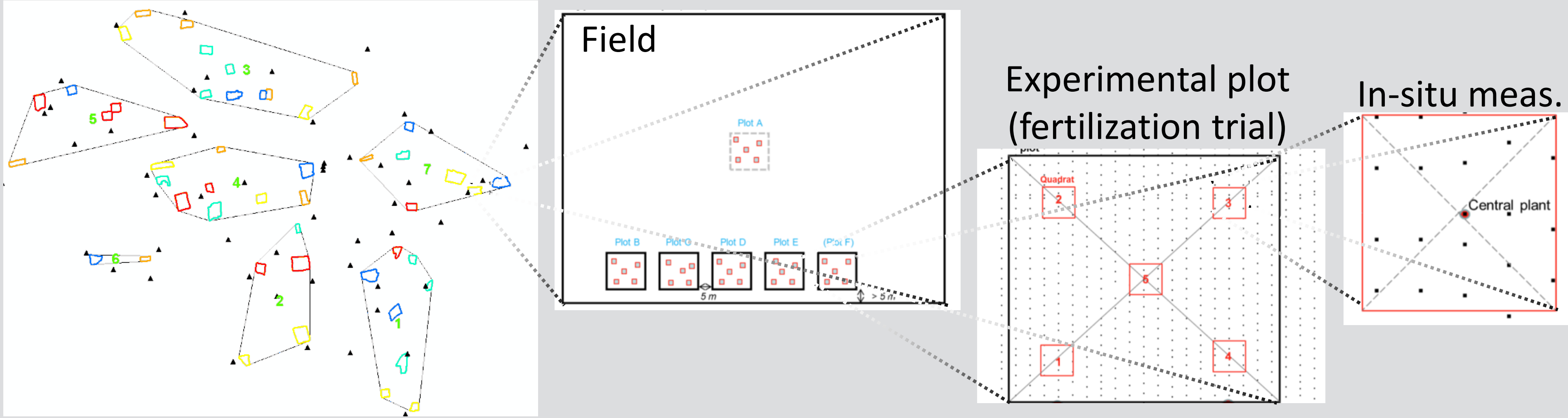
Objectives

Yield estimation in heterogeneous landscape

- Decametric SPOT-5 Take5 compatible with fragmented landscape?
- Metric WorldView time-series?
  1. Trees inside the fields?
  2. Mixed pixels at the field border?

Unprecedented in-situ datasets

- 5 crop types - 50 fields - 2 growing seasons (2014-2015)
- Biweekly: LAI, f-cover, Plant height, Chlorophyll, Devpt. stage, …
- Fertility trial & biomass measurement (destructive end of season)

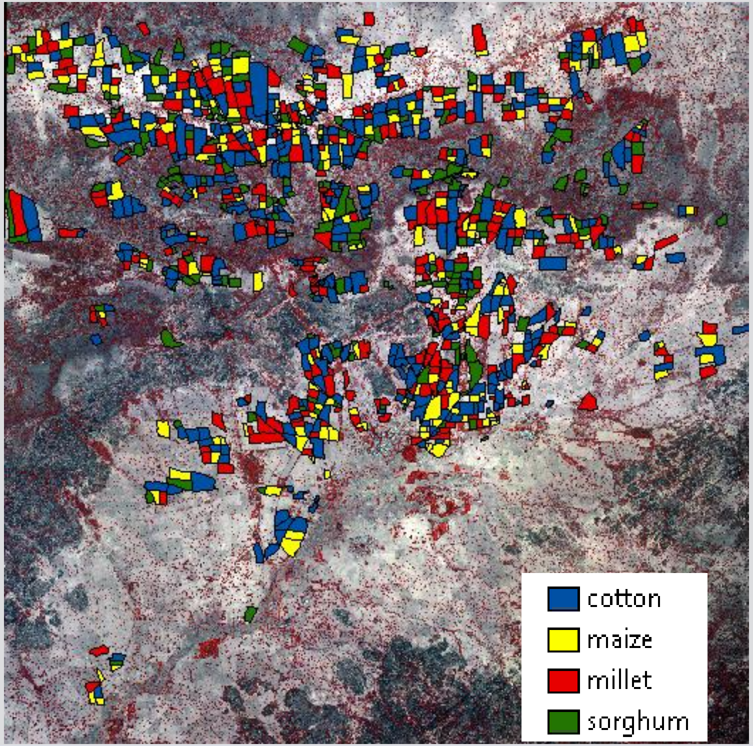


Fertilization to represent landscape heterogeneity

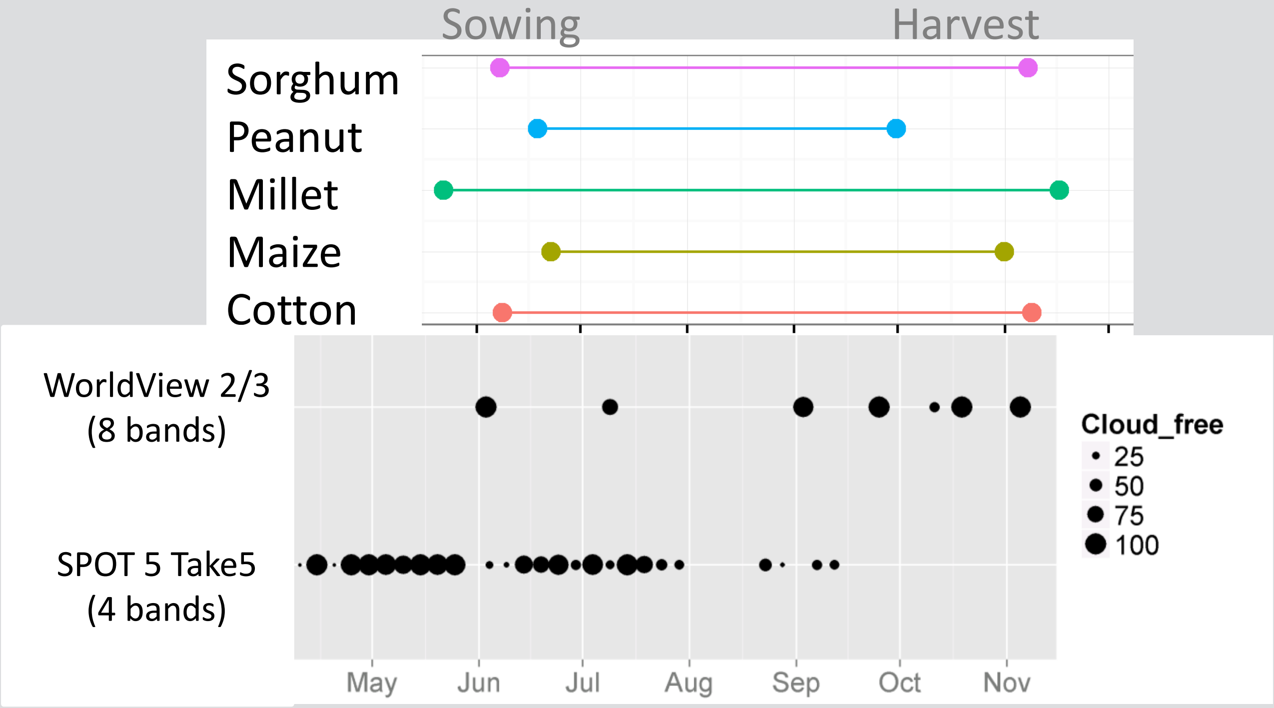
Crop type map

4 crop types for 1023 fields

- Field deliniated on VHR image
- Crop type identification by field visits

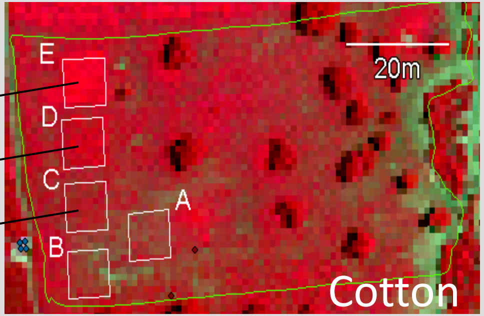


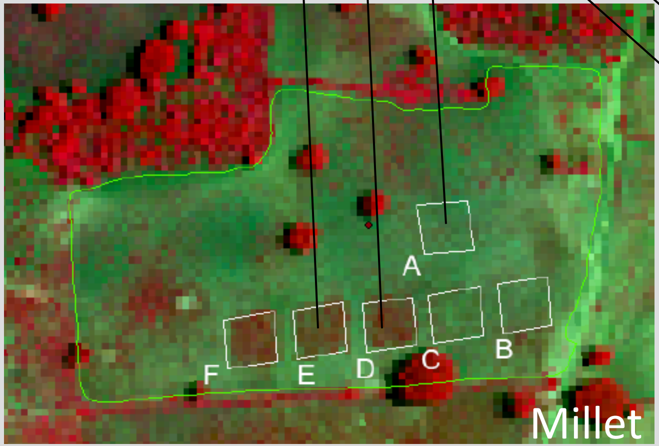
RS time series for 2015 growing season

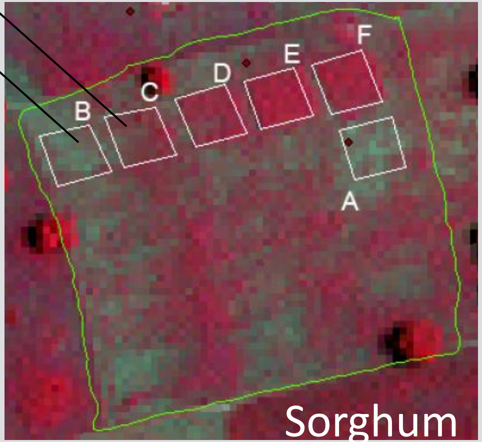


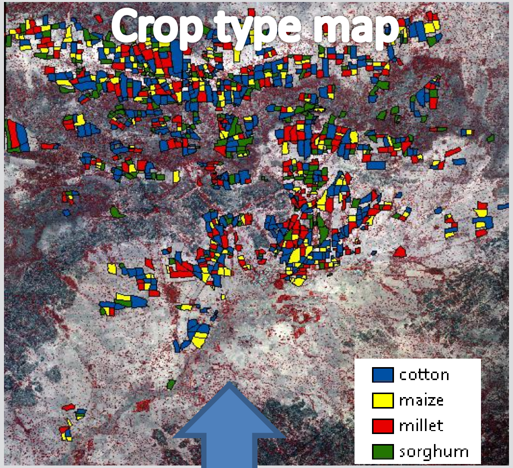
Linear regressions to estimate biomass

1. Model definition for each crop type with experimental plots







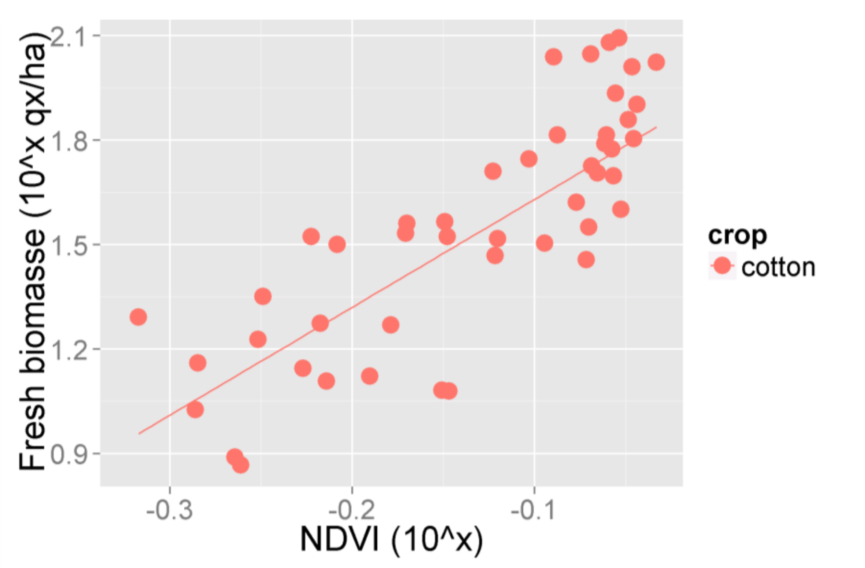


2. Biomass estimation for all the fields in the crop type map (n=1023)

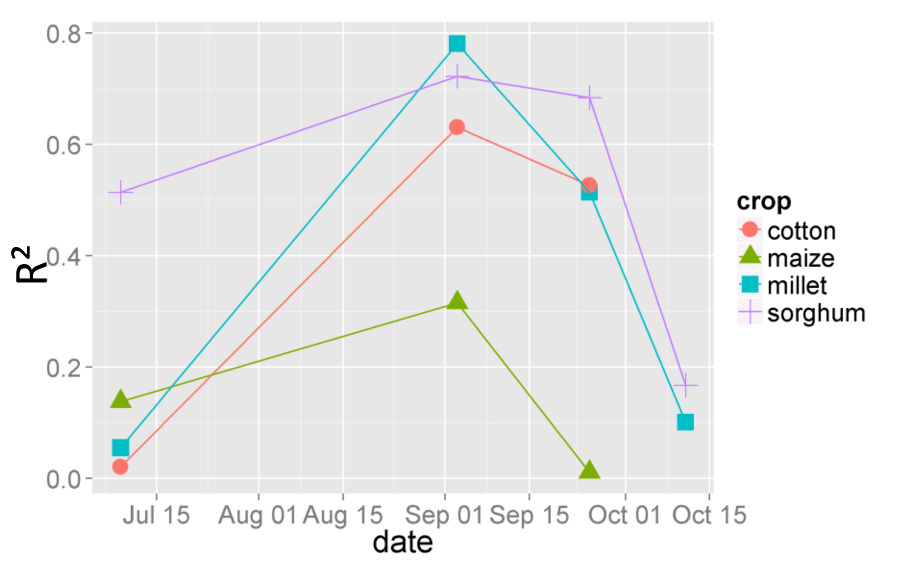
Linear regressions to estimate biomass

1. Model definition with experimental plots

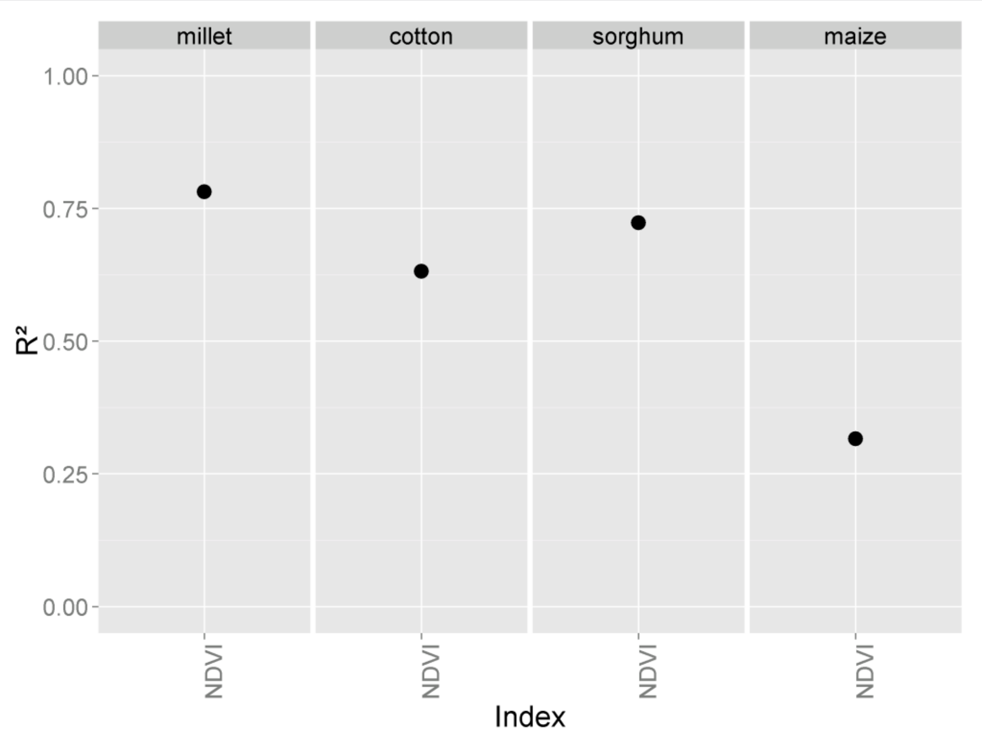
2015-09-03 (R^2=0.63)



Temporal evolution of the correlation coefficient (R^2)



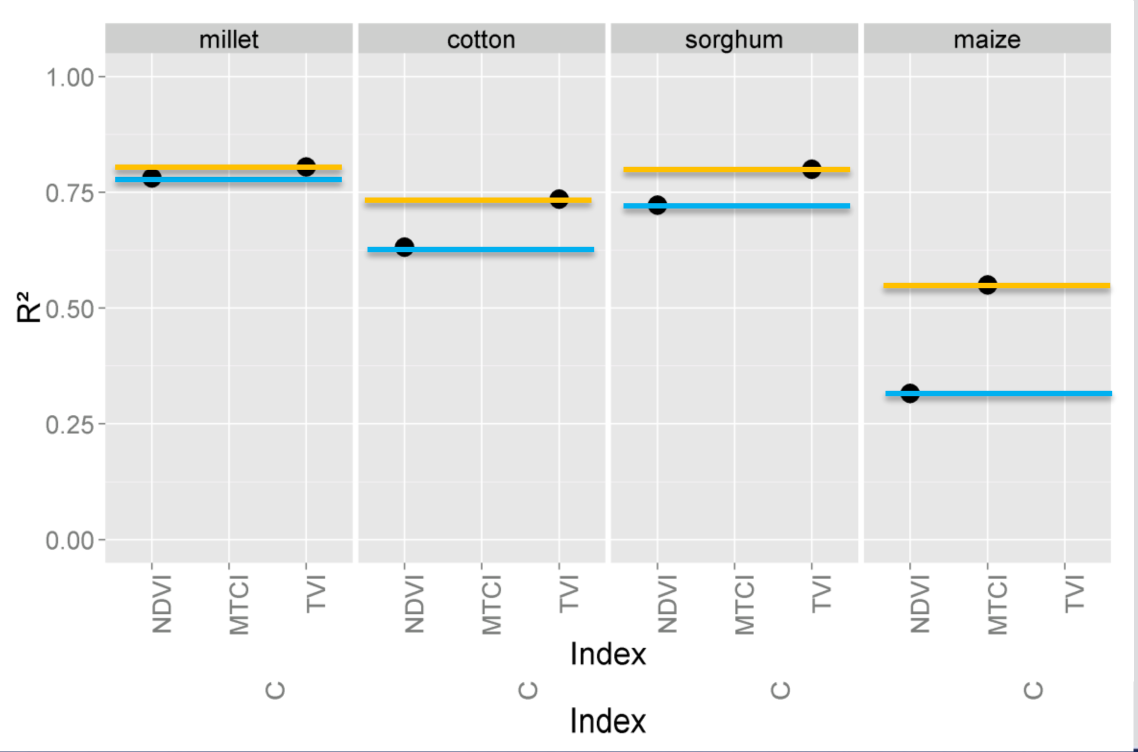
Selection best veg. index for each crop



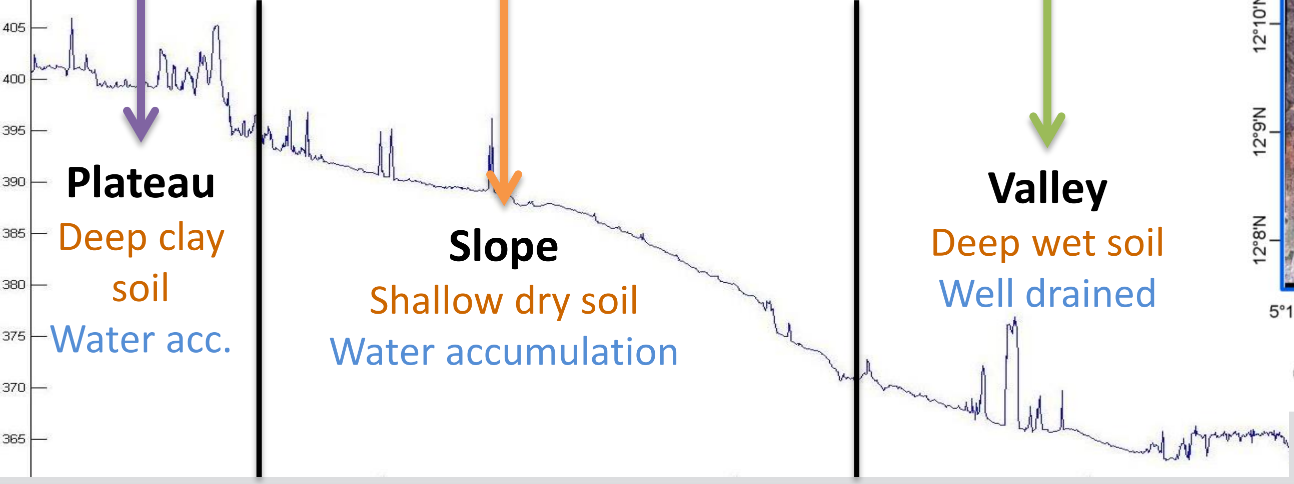
Selection best veg. index for each crop

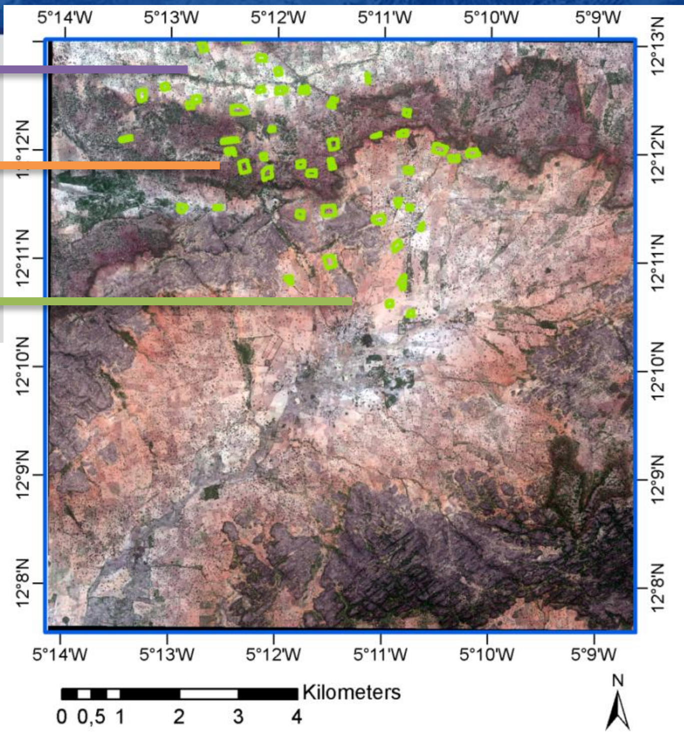
Normalized Difference Vegetation Index	$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$
Green NDVI	$gNDVI = \frac{\rho_{NIR} - \rho_{GREEN}}{\rho_{NIR} + \rho_{GREEN}}$
Red-edge NDVI	$NDVIre = \frac{\rho_{NIR} - \rho_{RED-EDGE}}{\rho_{NIR} + \rho_{RED-EDGE}}$
Modified Chlorophyll Absorption Ratio Index	$MCARI = [(\rho_{rededge} - \rho_{red}) - 0.2(\rho_{rededge} - \rho_{Green})] \frac{\rho_{rededge}}{\rho_{red}}$
Modified Chlorophyll Absorption Ratio Index	$MCARI2 = \frac{1.5[2.5*(\rho_{NIR} - \rho_{red}) - 1.3(\rho_{NIR} - \rho_{Green})]}{\sqrt{(2\rho_{NIR}+1)^2 - (6\rho_{NIR} - 5\sqrt{\rho_{red}}) - 0.5}}$
Triangular Vegetation Index	$TVI = 0.5\,[120(\rho_{750} - \rho_{Green}) - 200(\rho_{red} - \rho_{Green})]$
Modified Triangular Vegetation Index	$MTVI2 = \frac{1.5[1.2*(\rho_{NIR} - \rho_{Green}) - 2.5(\rho_{red} - \rho_{Green})]}{\sqrt{(2\rho_{NIR}+1)^2 - (6\rho_{NIR} - 5\sqrt{\rho_{red}}) - 0.5}}$
Green Chlorophyll Index	$Cl_{Green} = \frac{\rho_{NIR}}{\rho_{Green}} - 1$
Red-edge Chlorophyll Index	$Cl_{Red-edge} = \frac{\rho_{Red-edge}}{\rho_{Green}} - 1$
MERIS Terrestrial Chlorophyll Index	$MTCI = \frac{\rho_{NIR} - \rho_{Red-edge}}{\rho_{Red-edge} - \rho_{Red}}$

Selection best veg. index for each crop



Different agro conditions through the catena

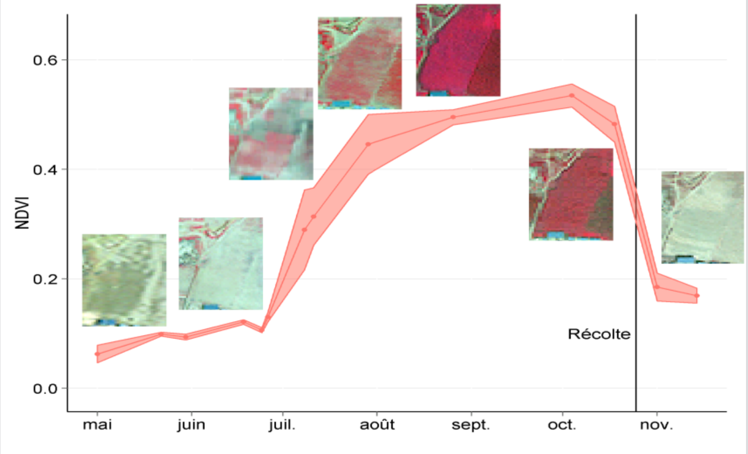




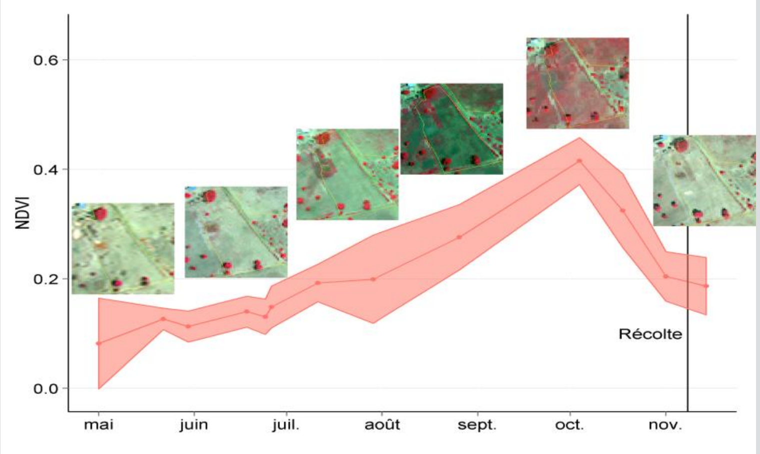
Different agro conditions through the catena

➢ Different growing conditions

Sorghum (valley)

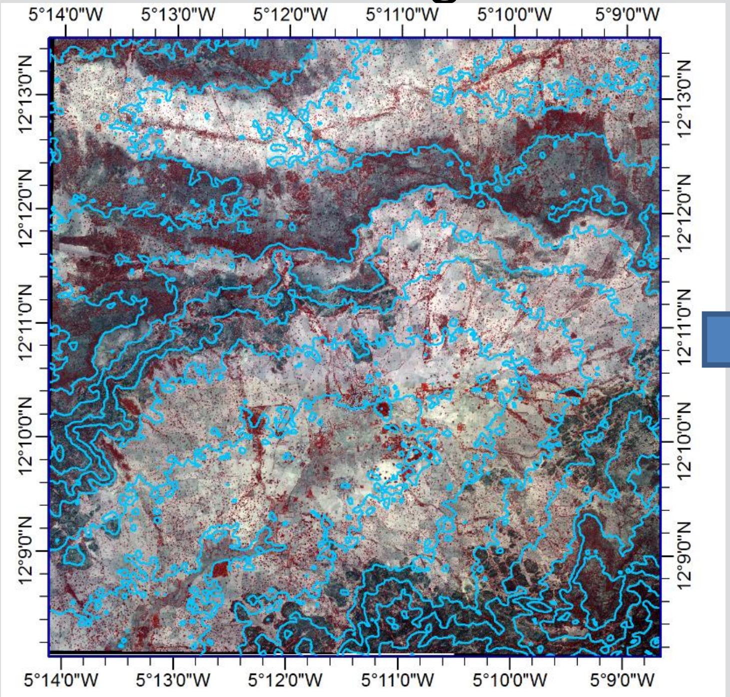


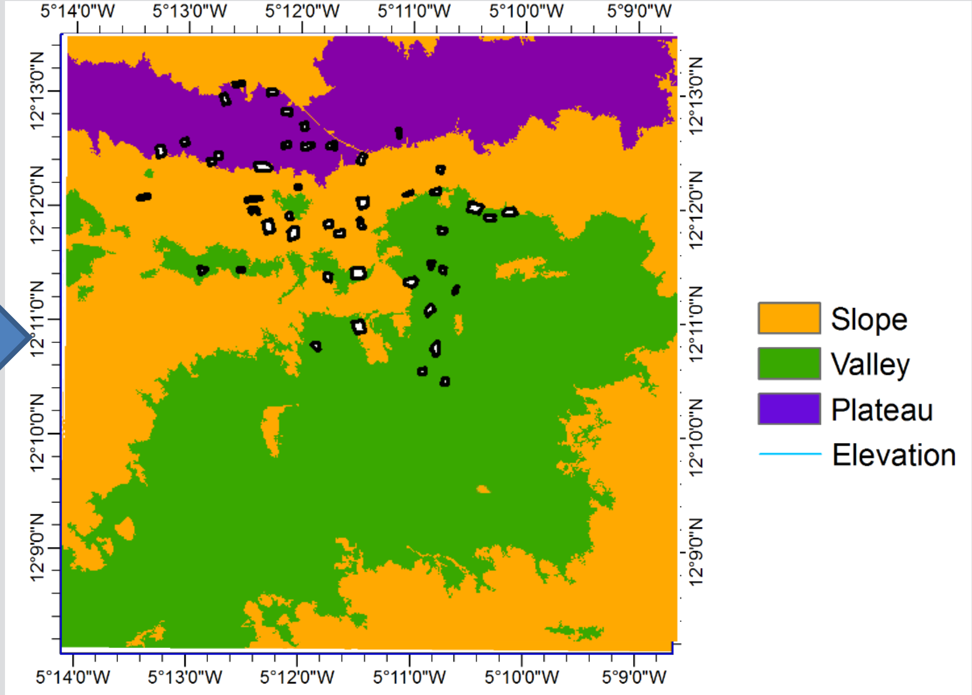
Sorghum (slope)



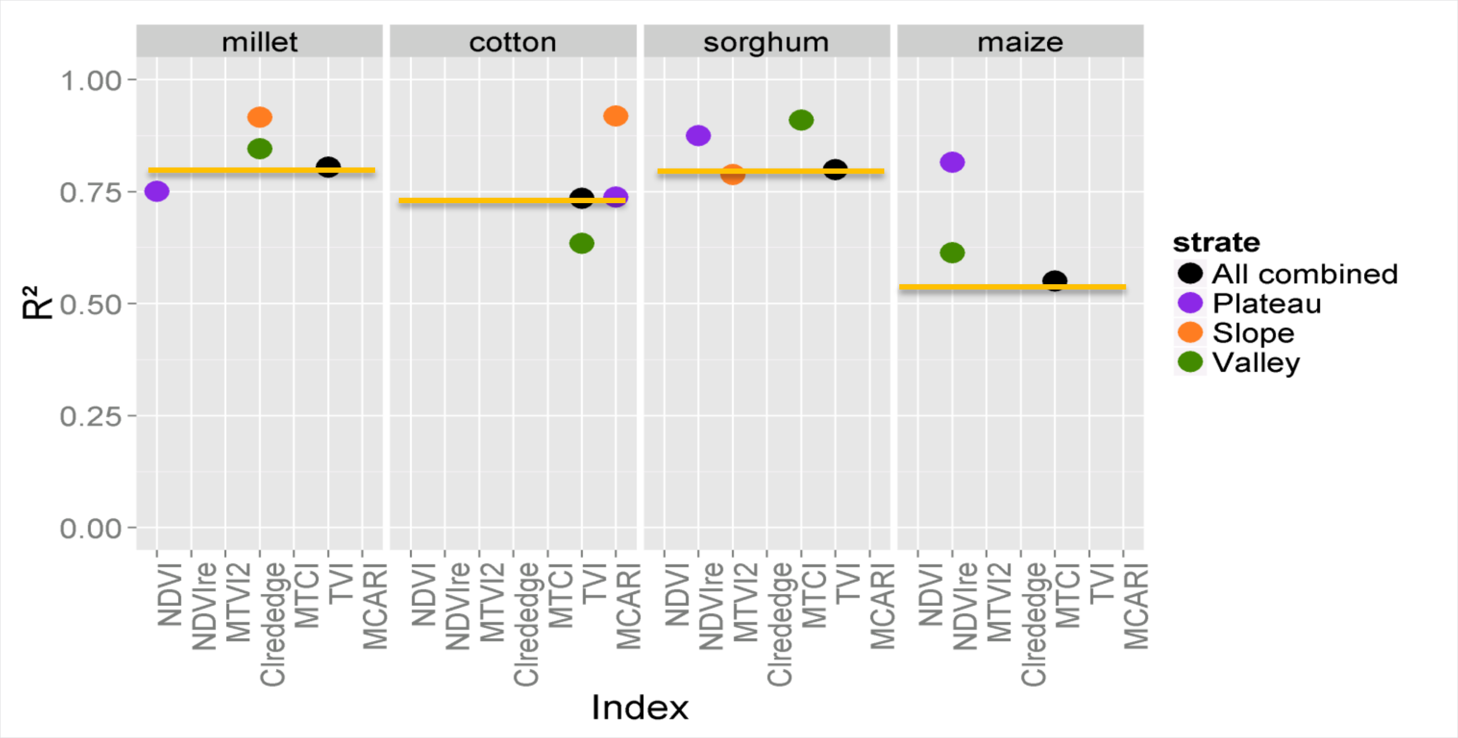
Landscape stratification

Altitude & brighness





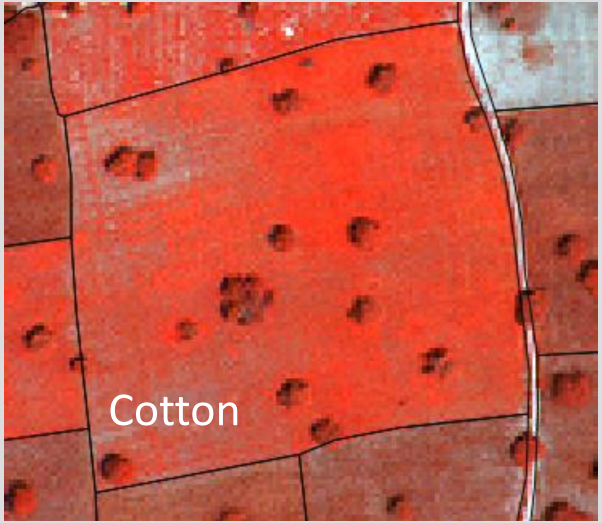
Best model selection for each strata

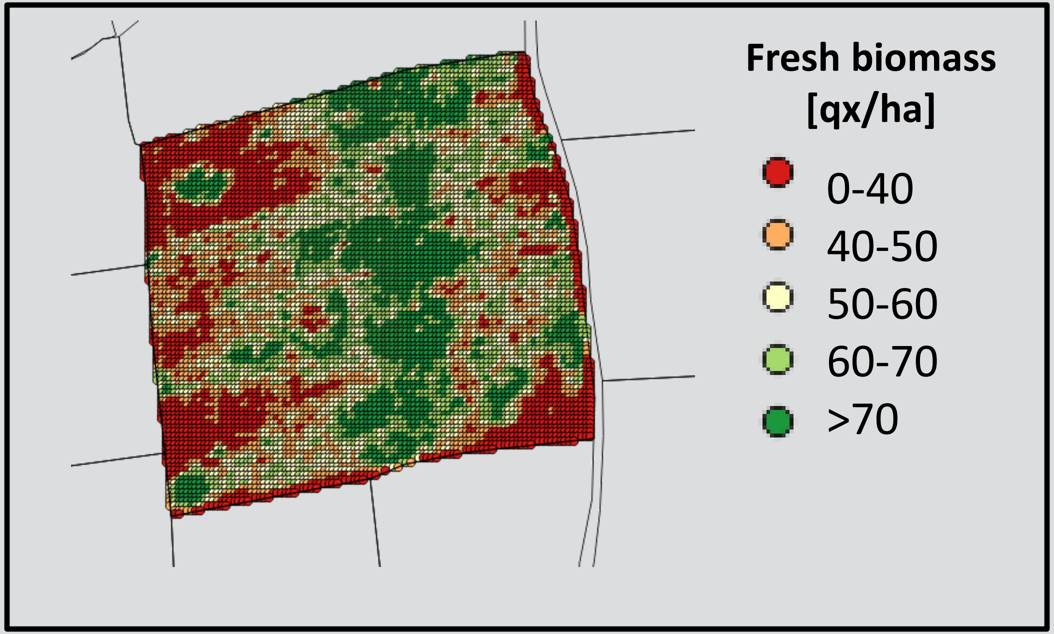


Model inversion for biomass estimation

DigitalGlobe

Estimation at pixel level

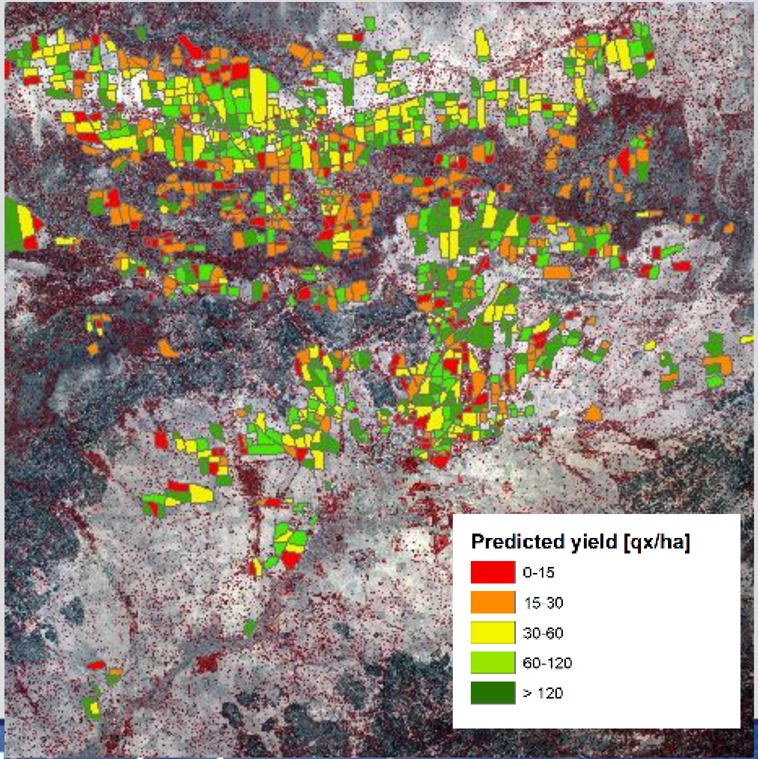




RBM: Reference Biomass Map (field avg.)

DigitalGlobe

Estimation for the 1023 fields

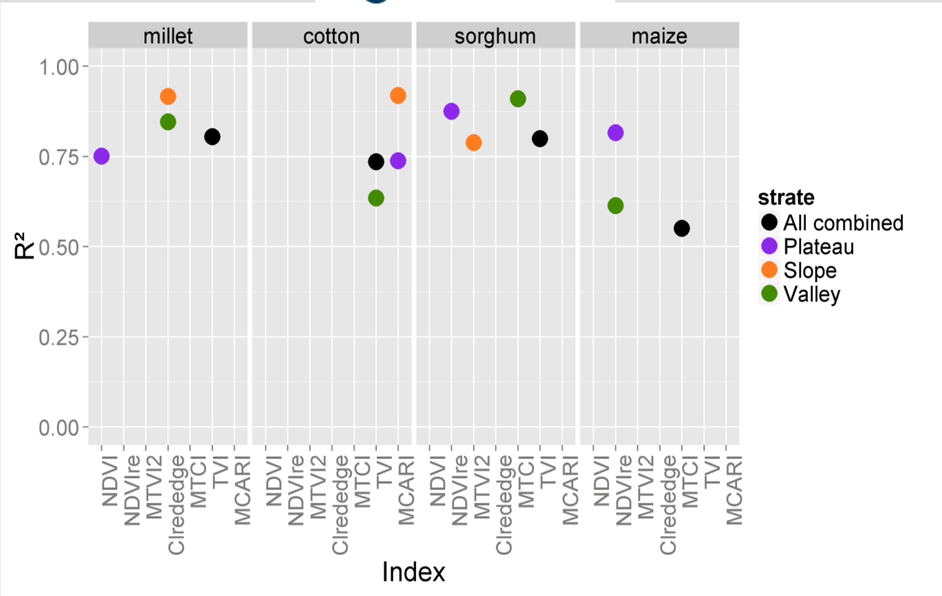


Normalized mean abs. err. (MAE) wrt in-situ measured biomass

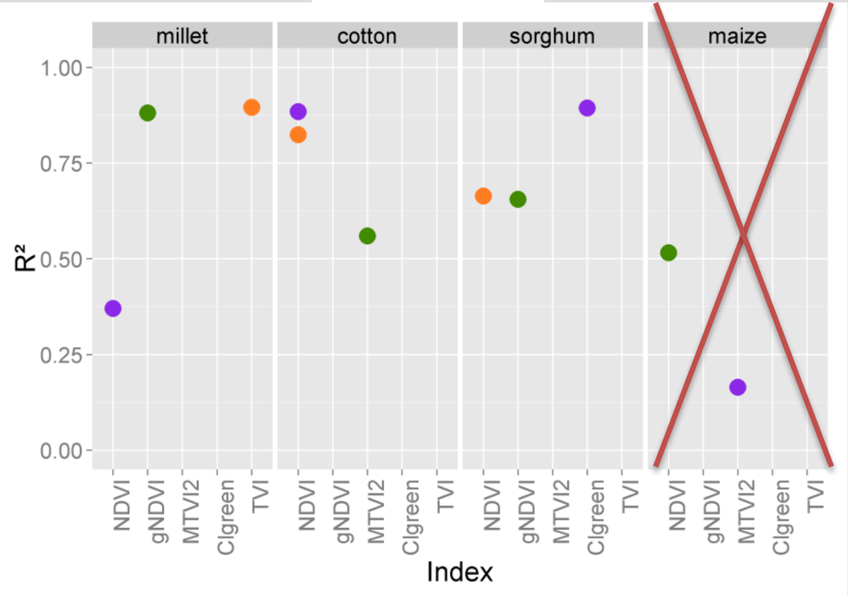
Crop type	MAE (%)
Sorghum	21.42
Cotton	25.4
Maize	21.06
Millet	11.03

Relatively good R^2 with SPOT (except Maize)

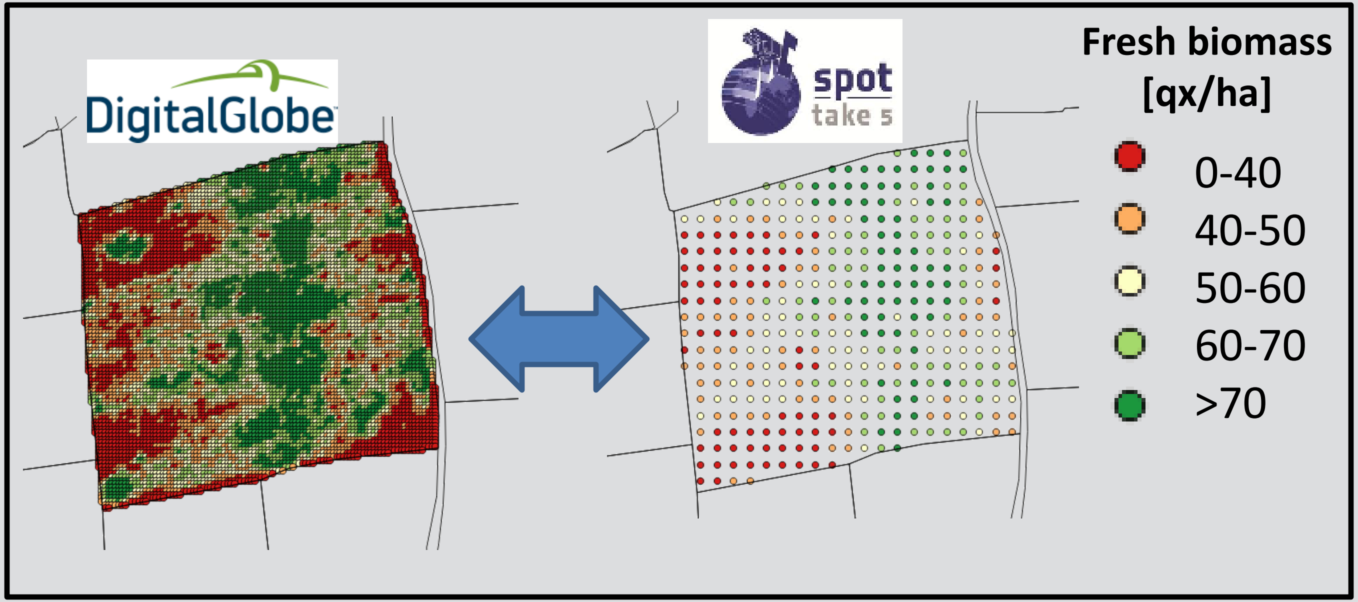
DigitalGlobe



spot take 5



10-m resolution still catches spatial pattern



Impact of resolutions on biomass estimation

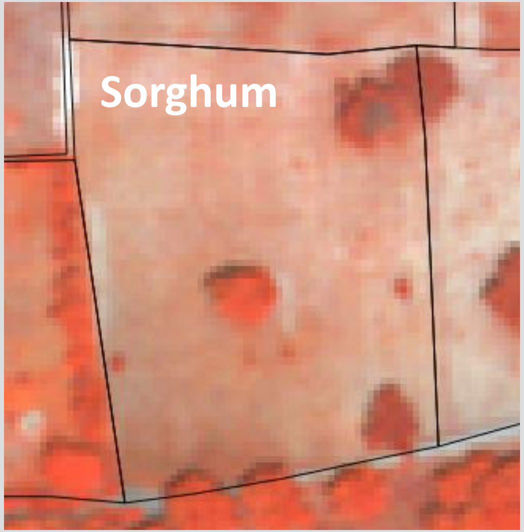
spot take 5

Crop type	MAE* 2-m res. (%)	MAE* 10-m res. (%)
Sorghum	21.42	27.82
Cotton	25.4	29.16
Maize	21.06	/
Millet	11.03	20.84

Larger error
at 10-m resolution

*MAE = Normalized mean abs. err. (wrt in-situ measured biomass)

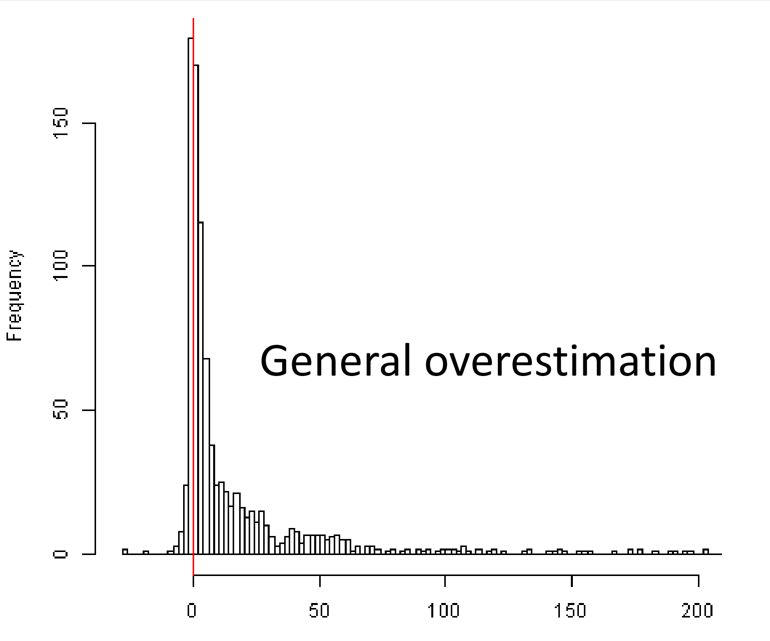
Impact of trees on biomass estimation

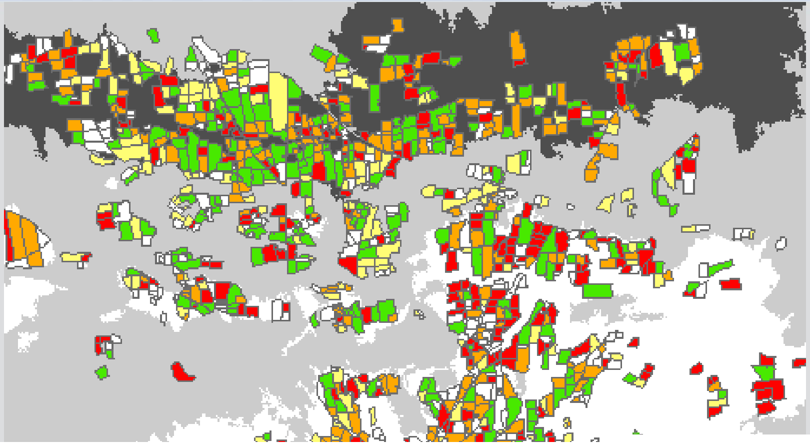


+20 qx/ha due to the trees

Impact of trees on biomass estimation

Biomass difference wrt RBM



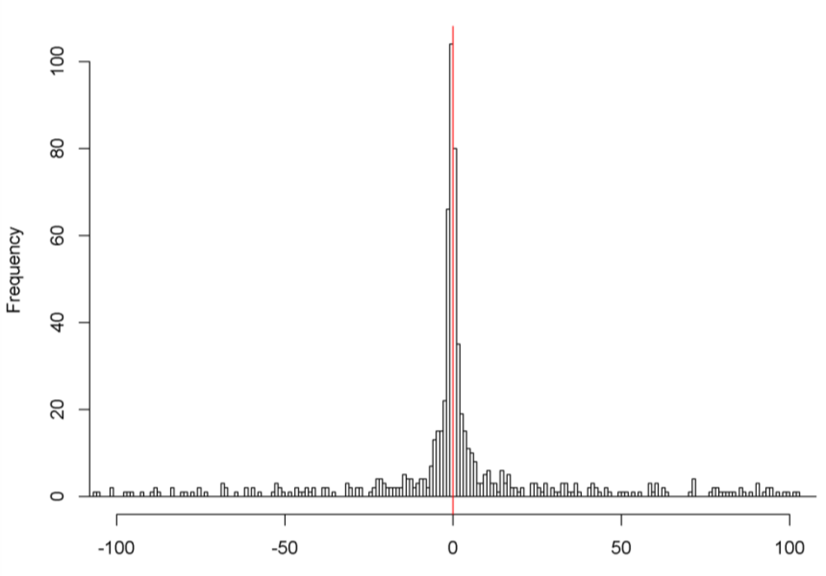


Significant impact for Maize and Millet

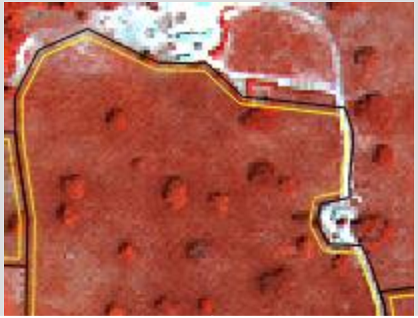
Crop type	p-value	overestimation
Sorghum	0.106	
Cotton	0.311	
Maize	0.002	29 %
Millet	3.6e-11	20 %

Impact of field border on biomass estimation

Border mixels introduce noise in biomass estimation



Field average biomass difference (qx/ha)



Crop type	p-value
Sorghum	0.306
Cotton	0.162
Maize	0.774
Millet	0.0002

Significant impact for Millet

Conclusions

- Unprecedented in-situ data & RS time series for 2 crop seasons
- **Linear regression** models allow good biomass estimation (11-25% error at 2-m res., 20-29% error at 10-m res.)
- **Acquistion date is important** - linked to crop calendar (crop & year specific)
- **Stratification** improves regression models (in heterogeneous landscape)
- **Specific vegetation index** per crop type & strata
- **Biomass overestimated by trees** in the field for millet-maize (20-29% resp.)
- Pixels in the field's border do impact biomass estimate only for millet