Using remote sensing, machine learning, and analytics to inform cost-effective and sustainable agriculture and food security policy in Rwanda

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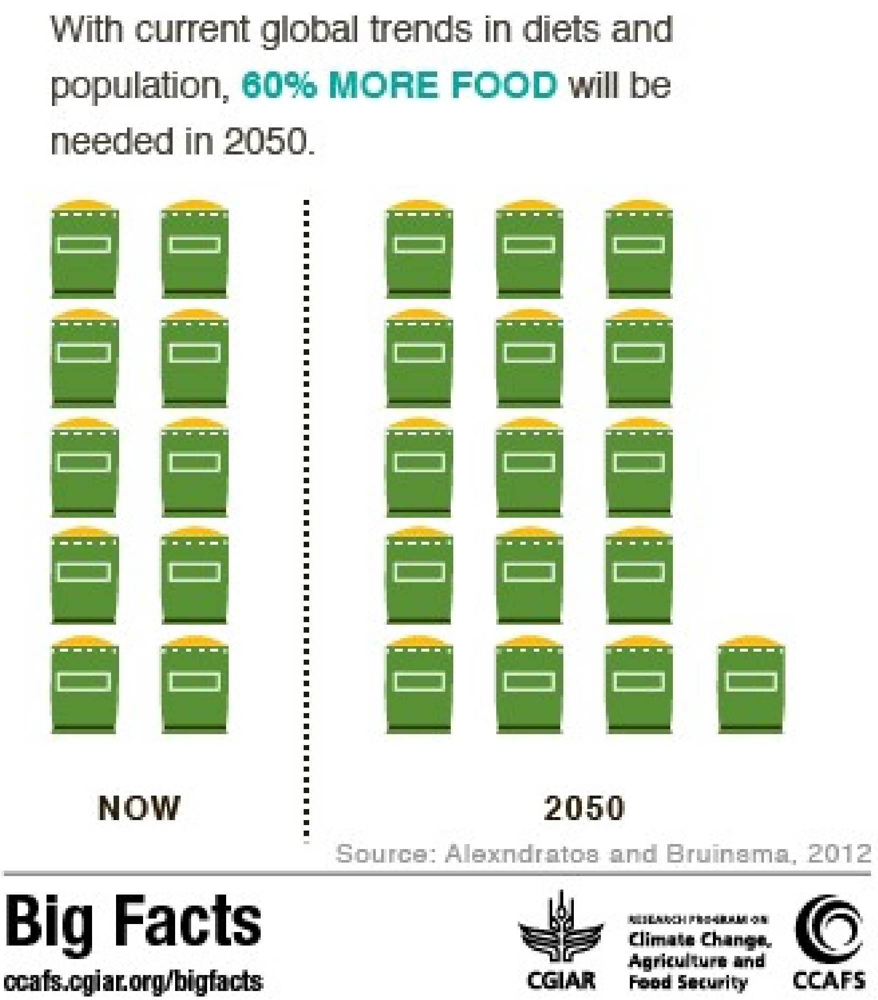
Background

- Achieving global food security and resilience within the agricultural sector is a major and growing challenge requiring significant advances in production efficiency and sustainability

- Despite substantial reductions in the rate of global food insecurity and undernutrition over the past few decades, about 1 in 9 people in the world are currently undernourished



Need for improved data

Short-term Challenges:

- How much land has been planted with which crops and where?
- What is the status of the crops during the growing season and expected production?

Medium to Longer Term Challenges:

- How to prioritize investments (e.g. improved seeds, erosion control, irrigation)?
- What is the impact of climate change on crops?

Stakeholders want more timely and actionable information to address food security

- In many regions, governments, farmers, and other stakeholders need better information to make data-driven, evidence-based decisions
- Numerous efforts making use of remote sensing, big data, and analytics underway but few cases where these efforts are informing policy in low- and middle-income countries to date
- RTI Grand Challenge is developing methods and tools for Rwanda, though will be broadly applicable

Remote sensing

- Remote sensing refers to acquisition of information about an object or phenomenon without making physical contact with the object
  - Used in numerous fields, including geography, surveying, and most earth sciences and has military, intelligence, planning, commercial and humanitarian applications
  - Typically used to refer to the use of satellite- or aircraft-based (including unmanned aerial vehicles, or drones) sensor technologies that are used to detect and classify objects on earth
- Selected agricultural applications
  - Soil and water resource mapping
  - *Planting dates/progress of growing season*
  - *Acreage estimation*
  - *Crop type identification*
  - *Yield forecasting*
  - Crop condition tracking
  - Precision farming

Why now?

- Interest in applying these technologies is not new

Table 4.--Potential applications of remote sensing from space platforms: estimated feasibility

Application area	Resolution requirements 1/		Interpretation capabilities		Estimated feasibility
	Photographic	Multispectral	Photographic	Multispectral	
Inventories of major land uses	Minimal	Minimal	Developed	Undeveloped	Feasible
Soils surveys	Minimal	Minimal	Developed	Undeveloped	Feasible
Water resources surveys	Minimal	Minimal	Developed	Undeveloped	Feasible
Bases for mapping	Minimal	Not applicable	Developed	Not applicable	Feasible
Range conditions surveys	Minimal	Minimal	Partially developed	Undeveloped	Feasible
Agronomic surveys	Minimal	Minimal	Partially developed	Undeveloped	Feasible
Crop species identification	Stringent	Minimal	Partially developed	Undeveloped	Possibly feasible
Crop vigor analysis	Minimal	Minimal	Partially developed	Undeveloped	Possibly feasible
Crop production estimates	Minimal	Minimal	Partially developed	Undeveloped	Possibly feasible
Livestock and wildlife surveys	Maximal	Maximal	Undeveloped	Undeveloped	Not feasible

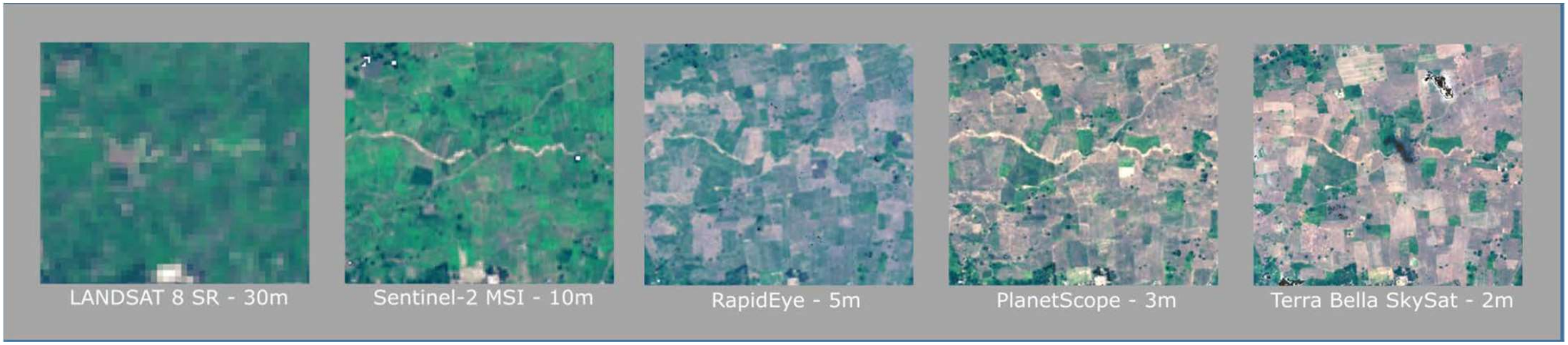
1/ Resolution required to obtain usable or reconnaissance-type data relative to the maximum resolution theoretically obtainable. Resolution requirements for the detailed informational objectives associated with some specific applications within broad application areas will normally be greater than those indicated.

Source: USDA, 1967

- Improvements in image resolution, establishment of open-access infrastructure for data acquisition, and development of machine learning algorithms for processing make it feasible to obtain and process high-frequency data at low cost

Feasibility of using remote sensing for smallholders

- Comparison of the same site in Morogoro, Tanzania (Lobell, 2016)



- NASA LANDSAT data have been available for over 40 years (LANDSAT9 launch date is scheduled for December 2020)
- European Space Agency's Sentinel-2 was launched in 2015
- Numerous private companies have been launching high-resolution satellites over the last few years
  - Greatly expanding availability and resolution
  - Can be relatively costly to access

The RTI Grand Challenge Project: Promoting Agricultural Resilience and Enhancing Food Security in Rwanda

RTI Food Security Grand Challenge Vision

Our food security and agriculture visualization and analysis toolkit brings together new and improved data sources and analytical methods in unique ways to help decision makers improve food security and build agricultural resilience in the face of climate change.

RTI Food Security Grand Challenge Rationale

Problem

- Lack of actionable information to address food security

Solution

- Food security and agriculture data visualization and analysis toolkit
- Builds on existing ALIS and SAIS platforms

Users

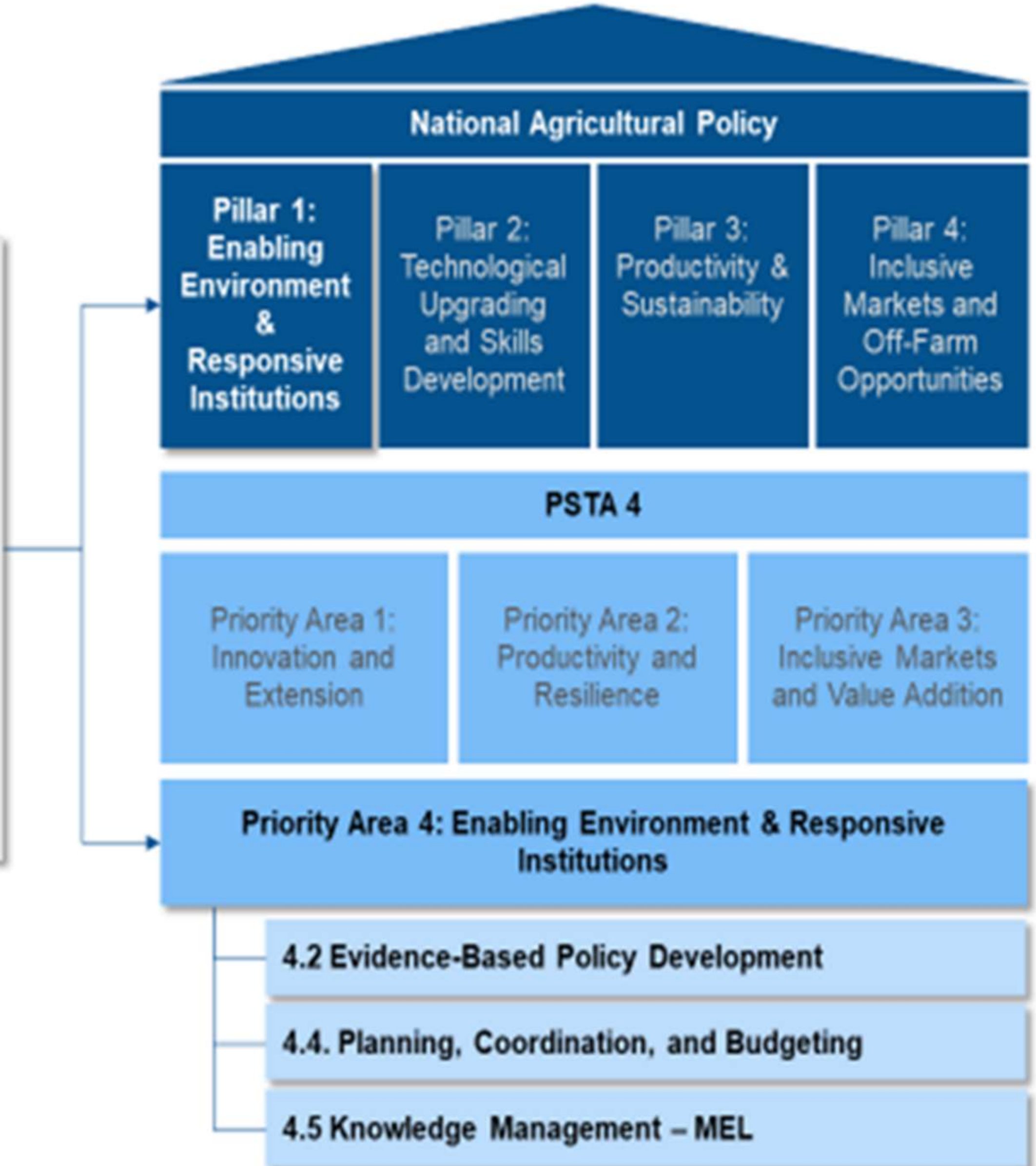
- National and subnational decision-makers
- Researchers

Benefits

- Improved ability to make informed decisions and take actions to improve food security and agricultural resilience (in the face of climate change)

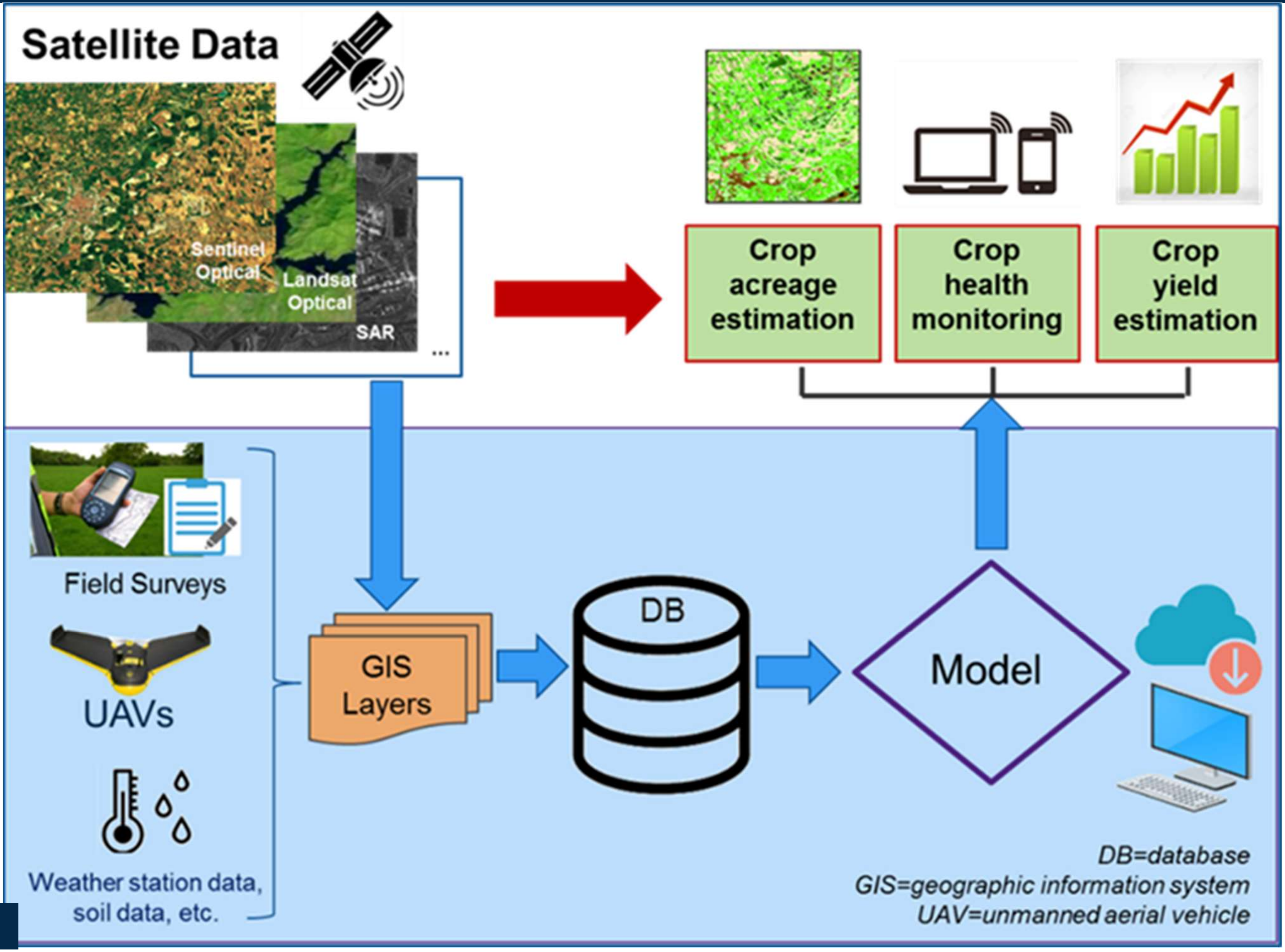
Alignment with NAP and PSTA 4

Our toolkit will build on existing platforms to help decision-makers more effectively identify policies and interventions that will achieve desired outcomes for food security and agricultural resilience.



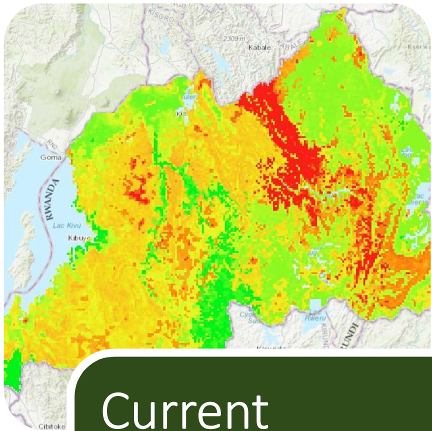
Approach

Development of spatial database



Assessing impacts on agriculture

Step 1: Characterize current situation



Current Situation

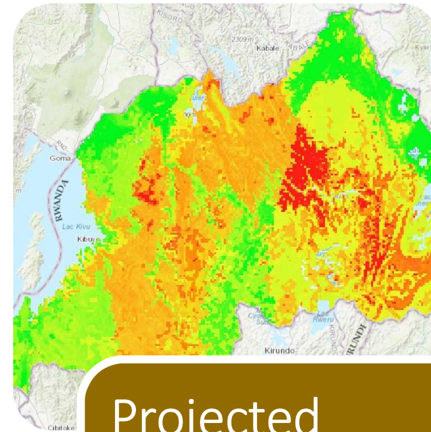
- Productivity
- Profitability (e.g. income)
- Nutrition

Step 2: Project how things will change

Effect of Programs

- Changing inputs or management practices
- Diversification
- Climate change

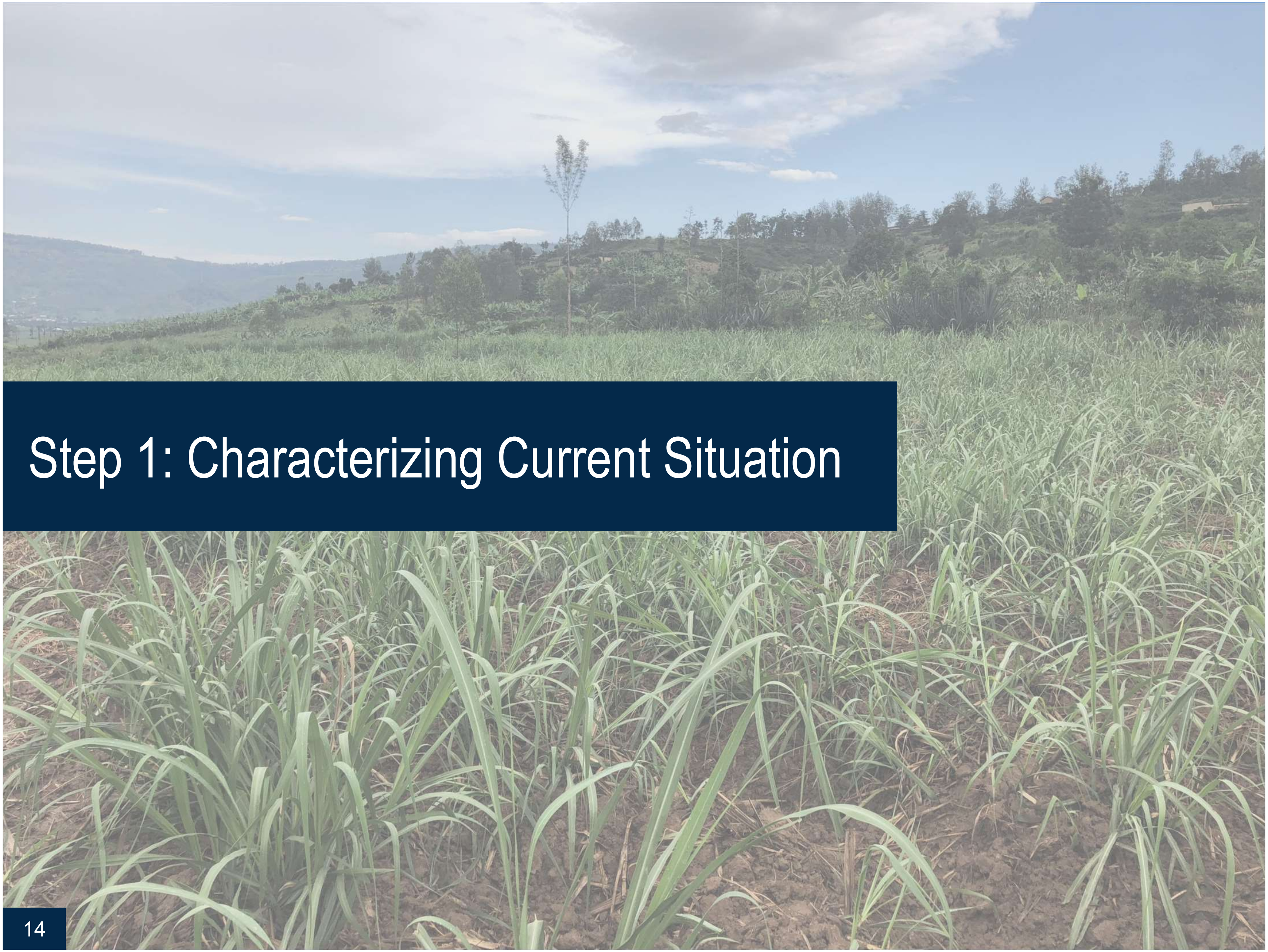
Step 3: Identify impacts



Projected Impacts

- Productivity
- Profitability (e.g., income)
- Nutrition

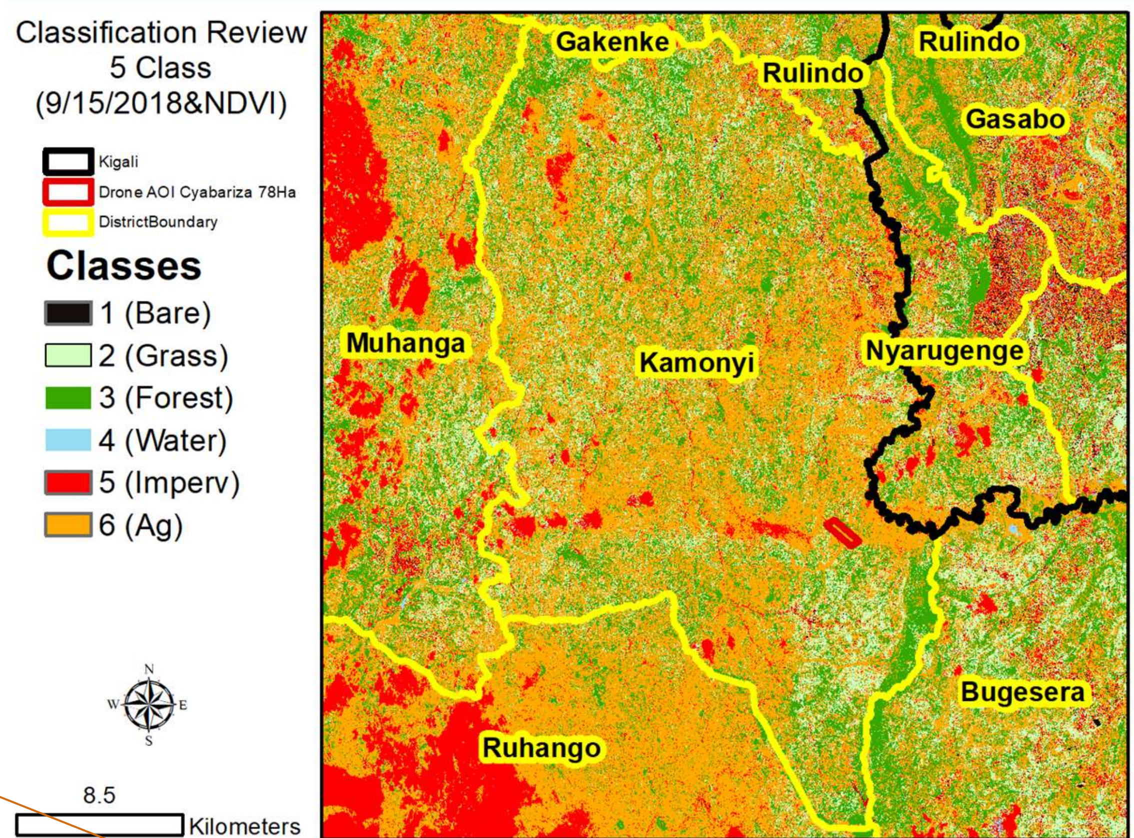
Example: How does irrigation affect the productivity and profitability of different crops, according to season and geography? Where would the benefits be the greatest for different crops?



Step 1: Characterizing Current Situation

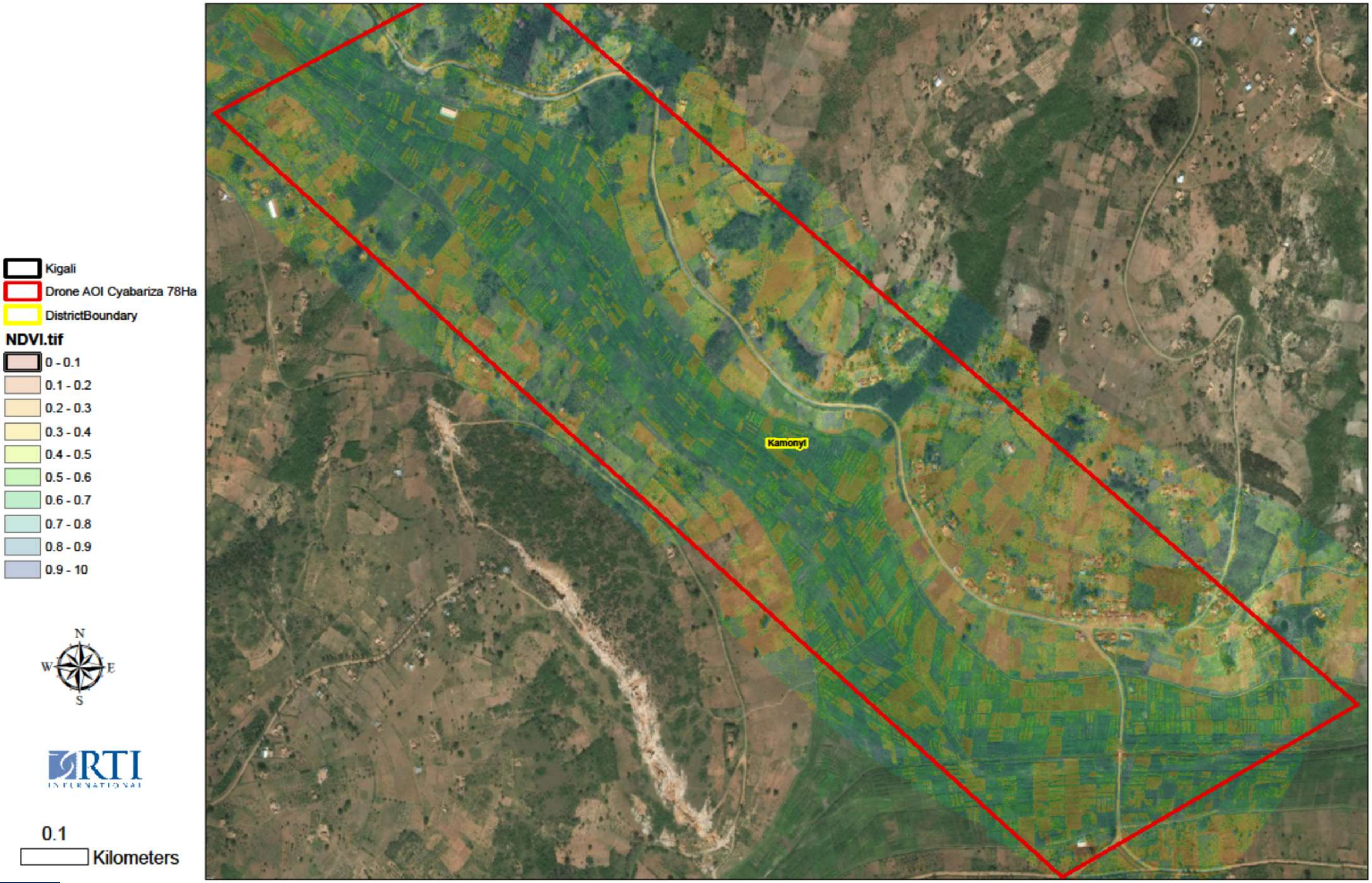
Using satellite data to characterize land cover

- We used machine learning techniques to classify land cover into 6 classes
- We used training data from satellite imagery and pre-existing land cover classes
- Results close to NISR official data from 2017 Season A

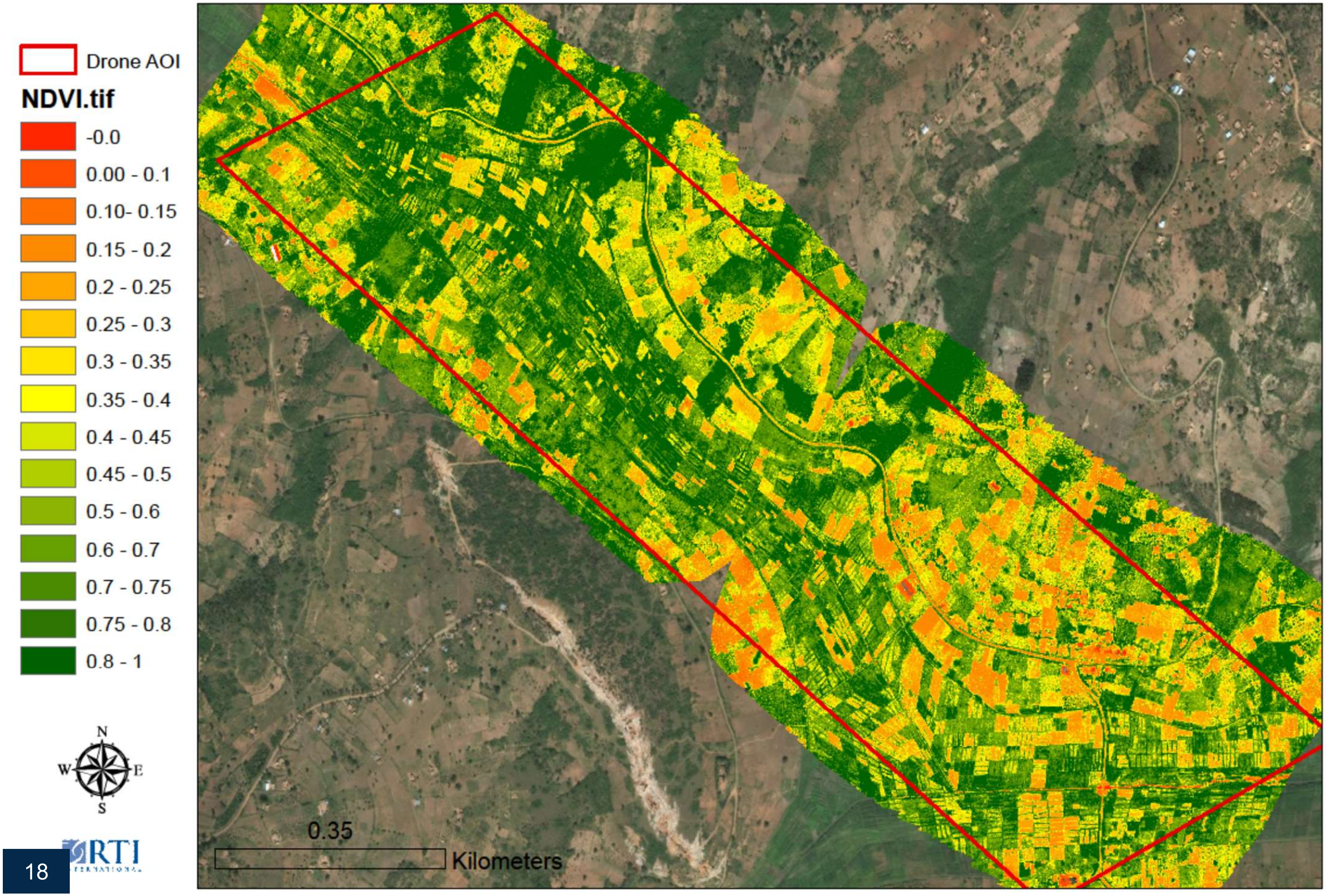


Source	Bare	Grass	Forest	Water	Impervious	Agriculture	Total Area
RTI (6 – class)	2	108	156	3	36	357	**661**
Source		**Fallow**	**Non-Ag**			**Cultivated**	**Total Area**
NISR (3-class)	N/A	99	114	N/A	N/A	364	**577**

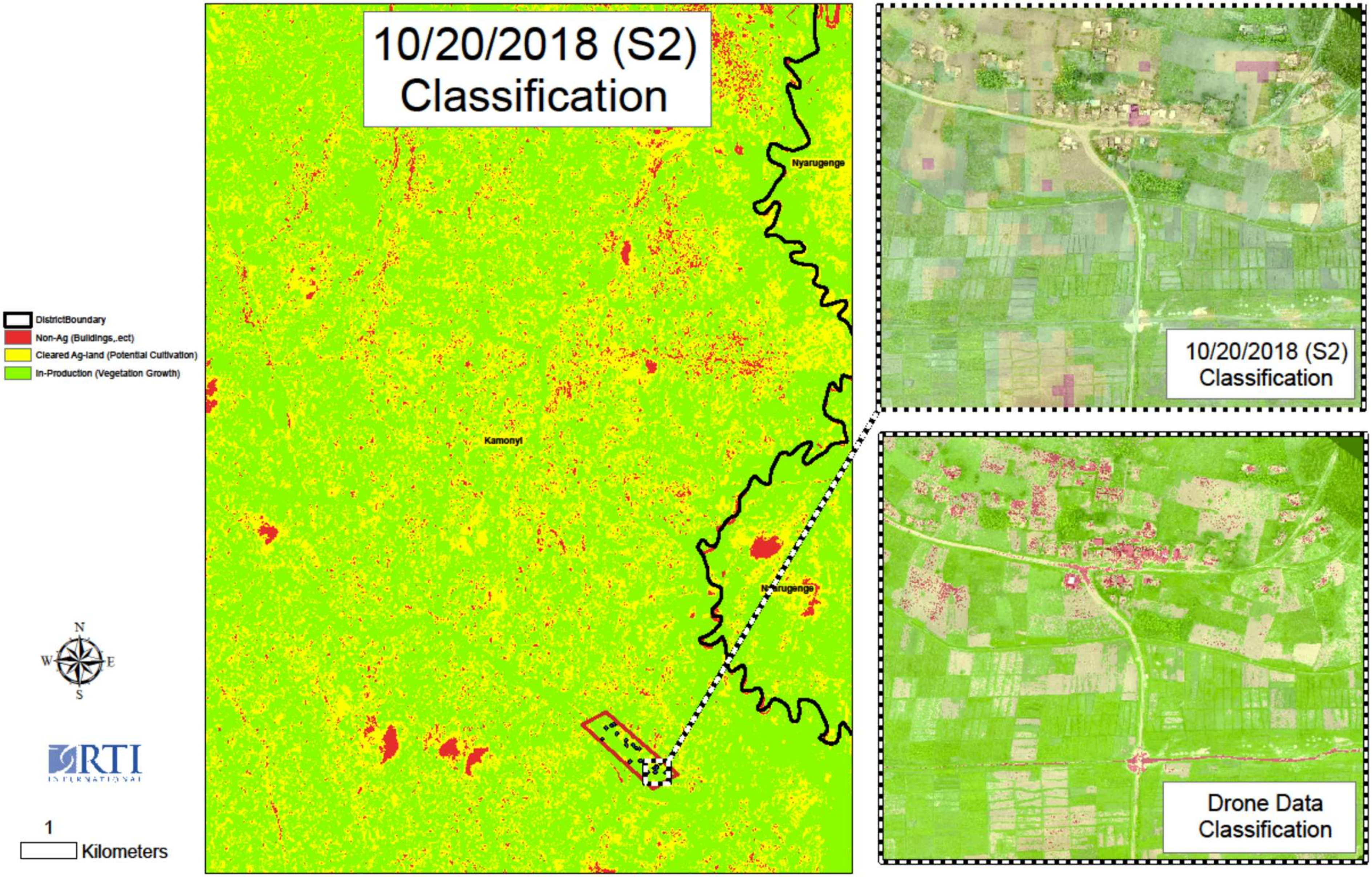
Using drone imagery to assess agricultural land



NDVI from drone image



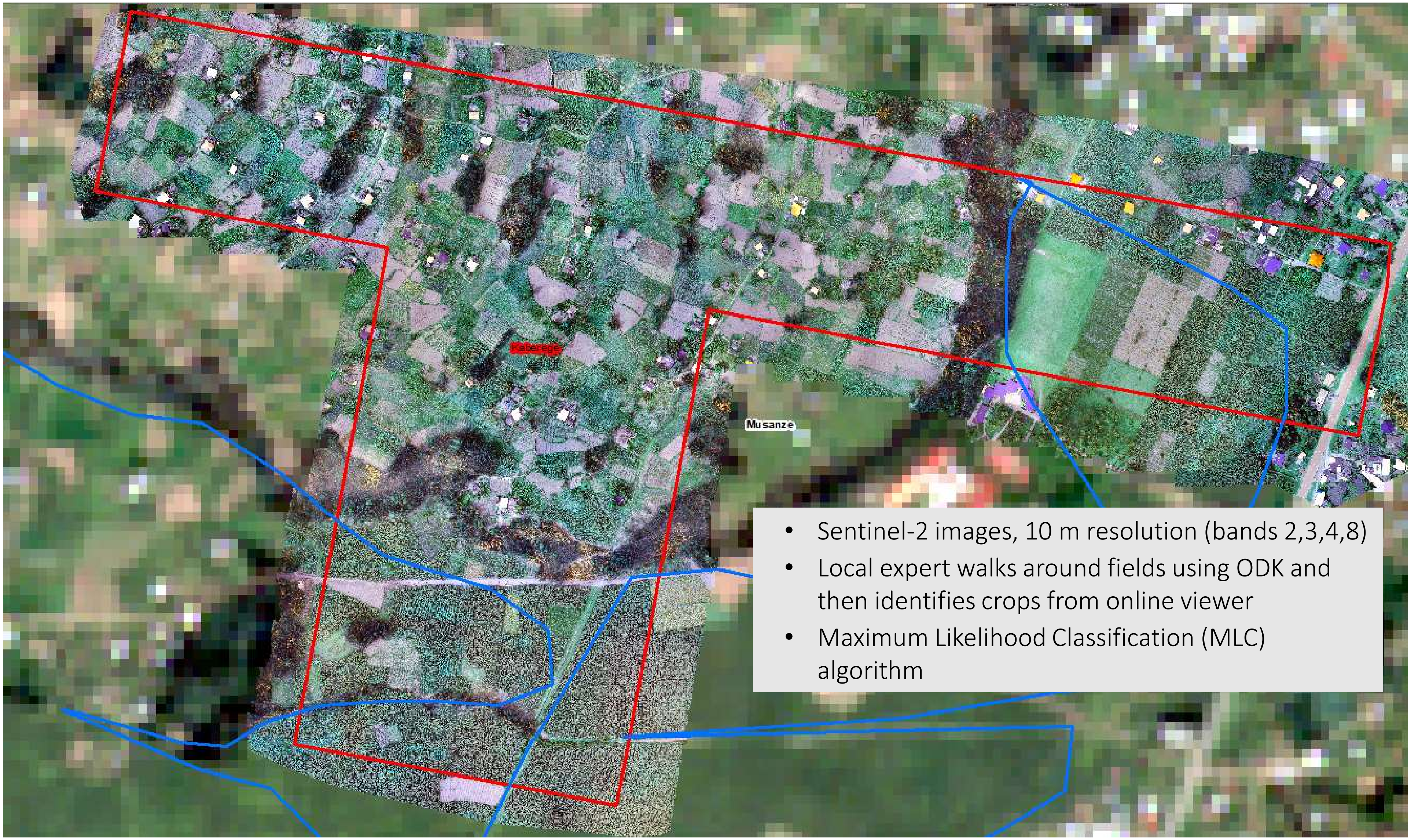
Using remote sensing to characterize planted area



Using drone data to characterize crops

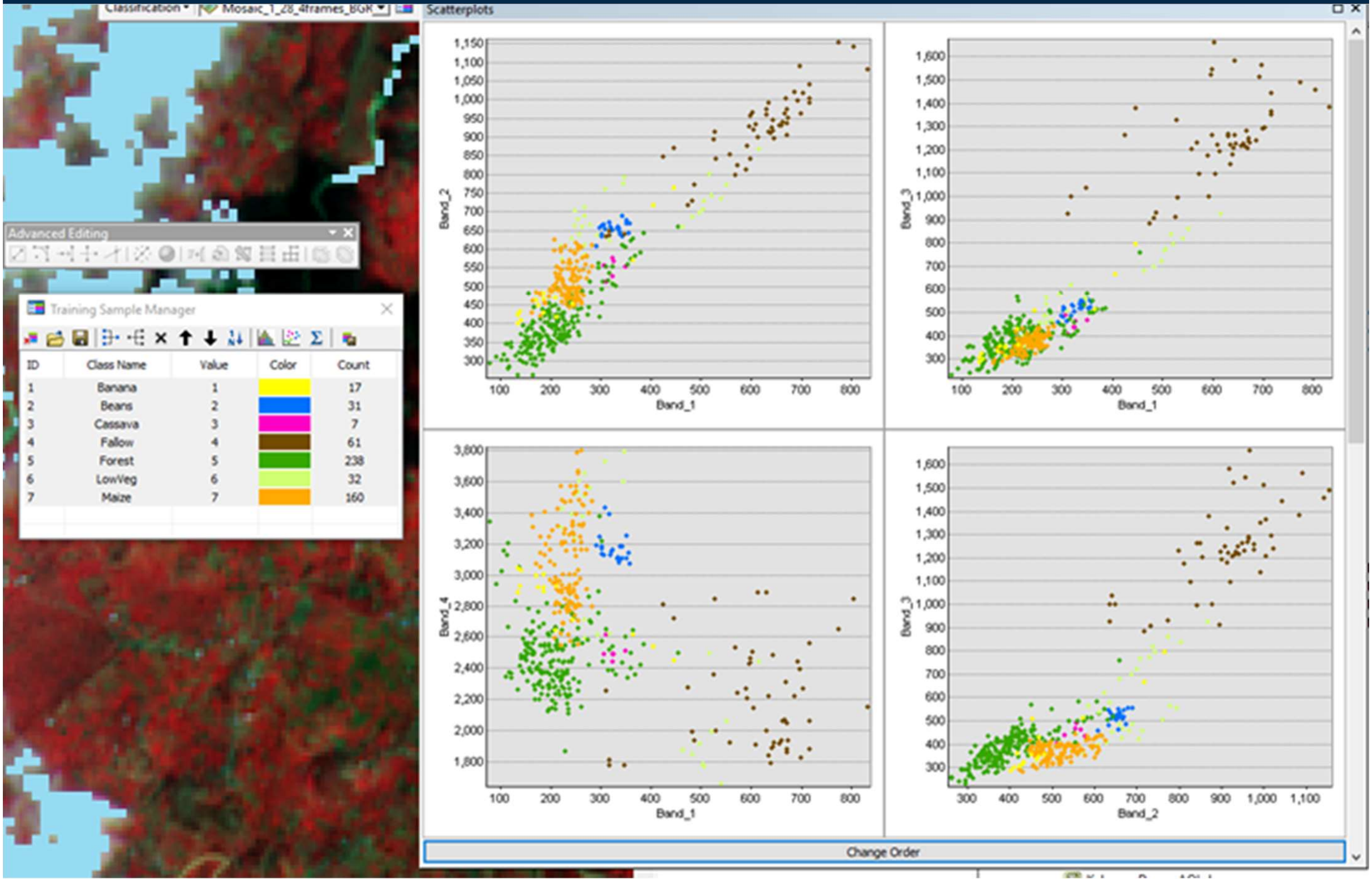
Developing training dataset from drone images

Drone RGB image from Musanze, Rwanda

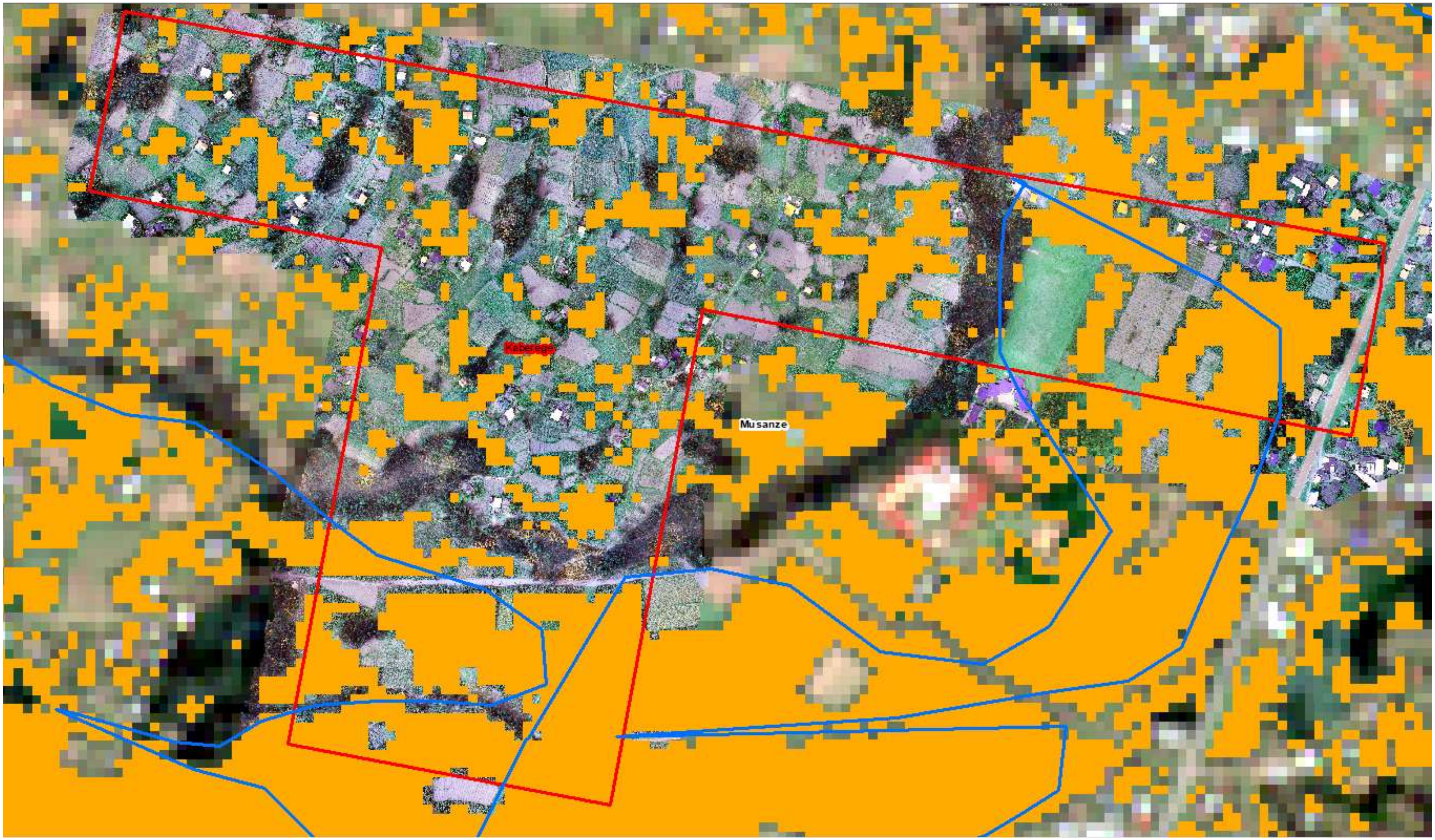


- Sentinel-2 images, 10 m resolution (bands 2,3,4,8)
- Local expert walks around fields using ODK and then identifies crops from online viewer
- Maximum Likelihood Classification (MLC) algorithm

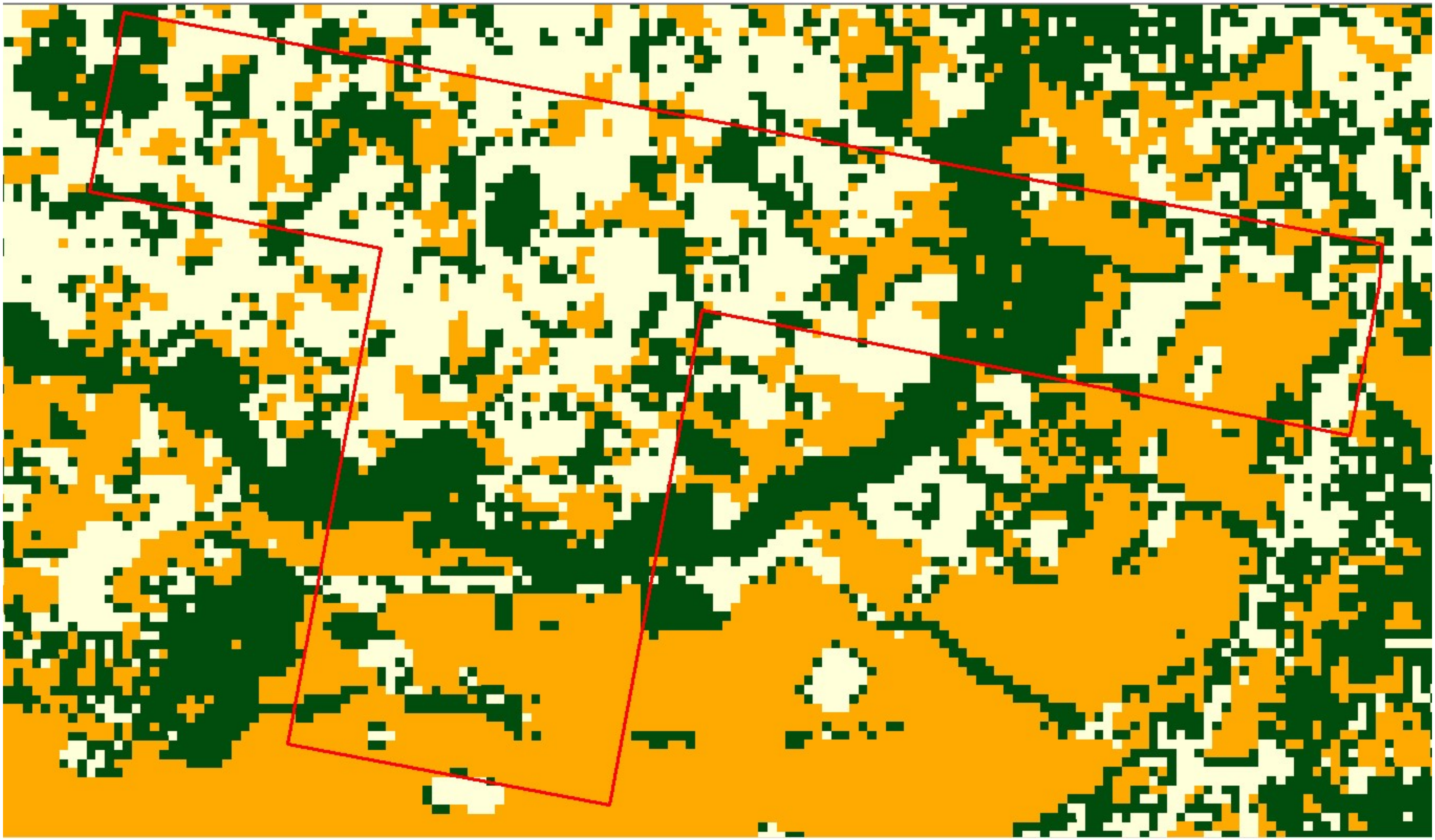
Assessing separability of land use classes



Maize classification on Sentinel 2 imagery (10m)

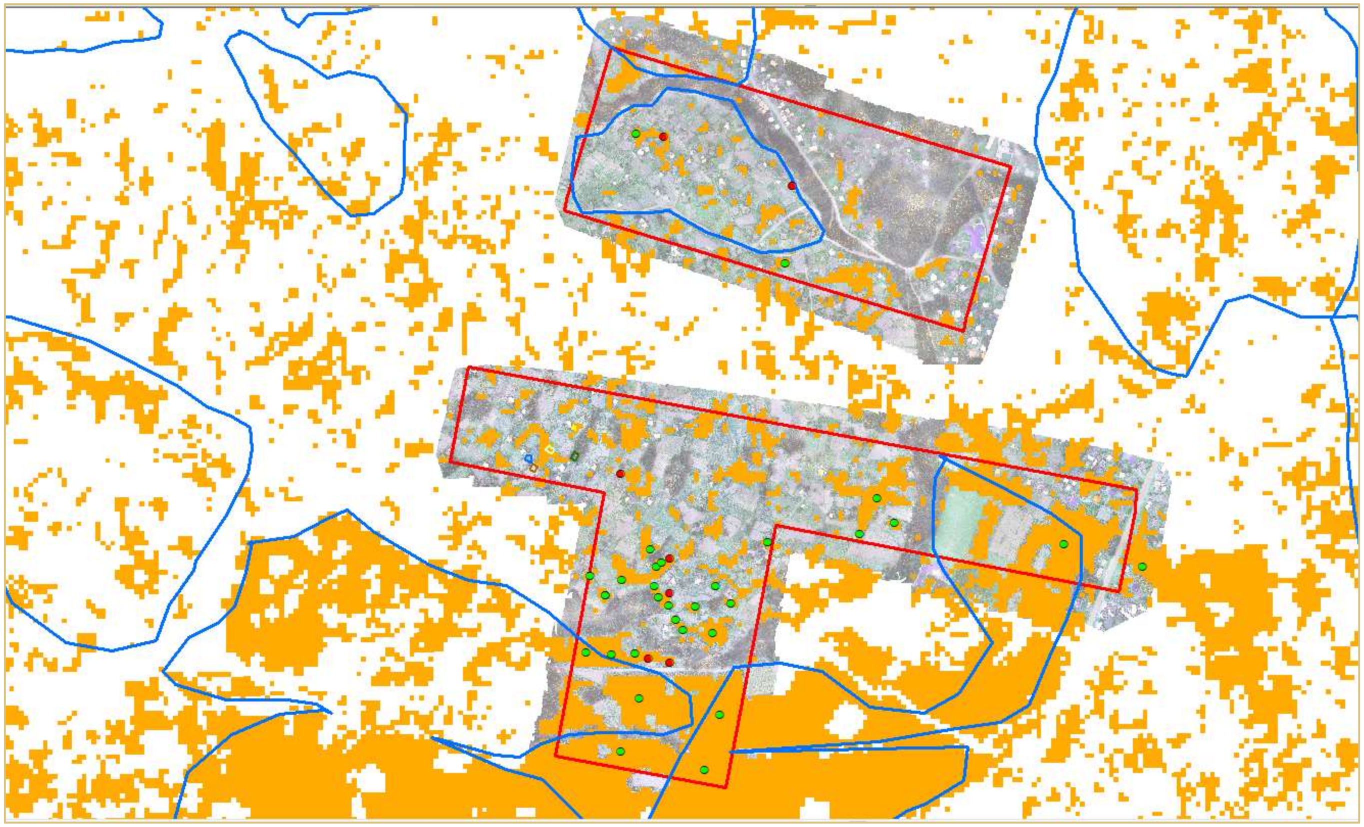


Maize, forest, and other classification on Sentinel 2



Preliminary testing of accuracy of maize classification

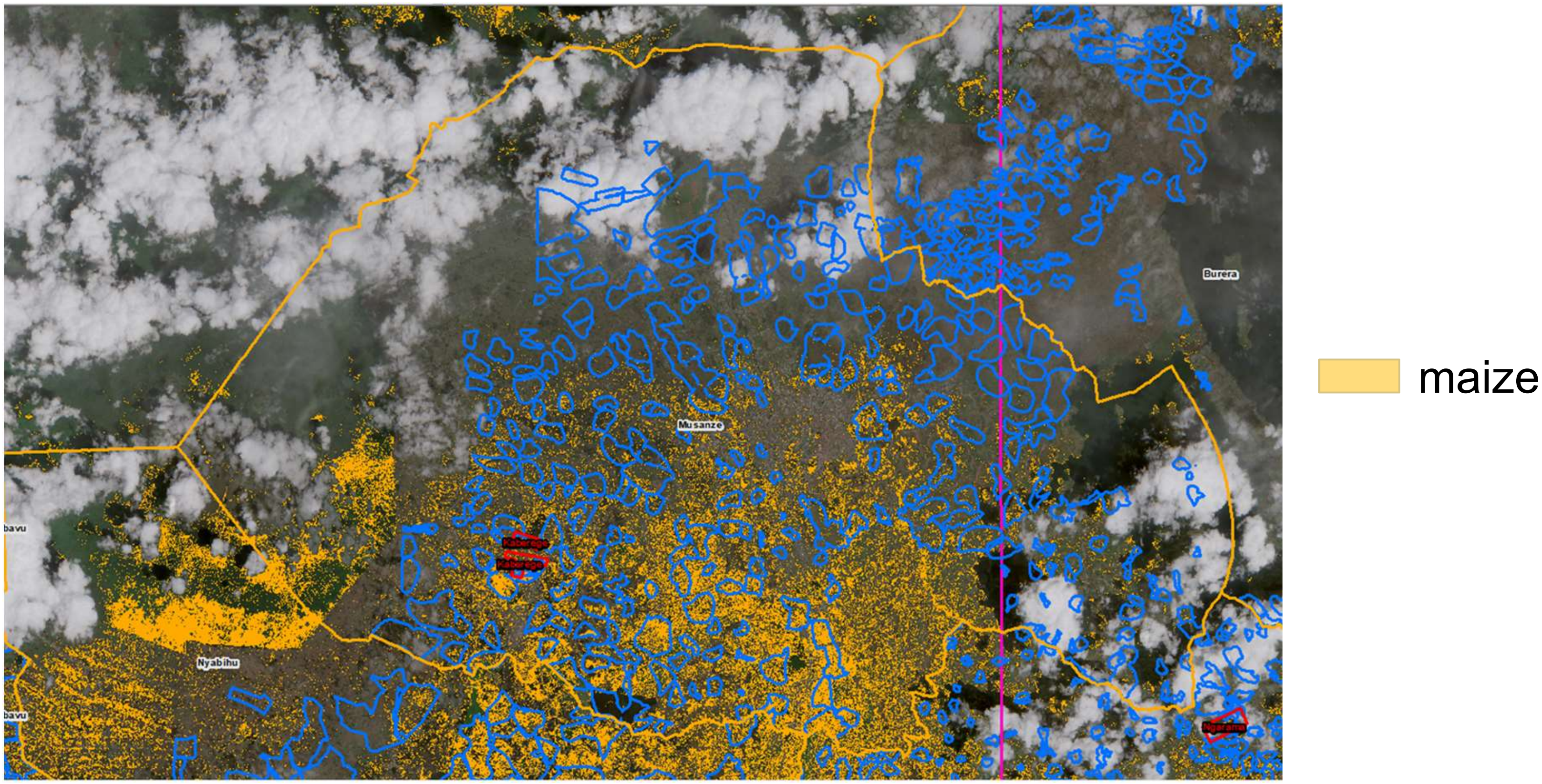
To test accuracy of maize classification, we used classification from UAV images that was set aside for testing (not used for training dataset).



Comparison with classification based on UAV Images			
Incorrect	Correct	% Incorrect	% Correct
7	38	18%	82%

Crop Classification for Musanze District

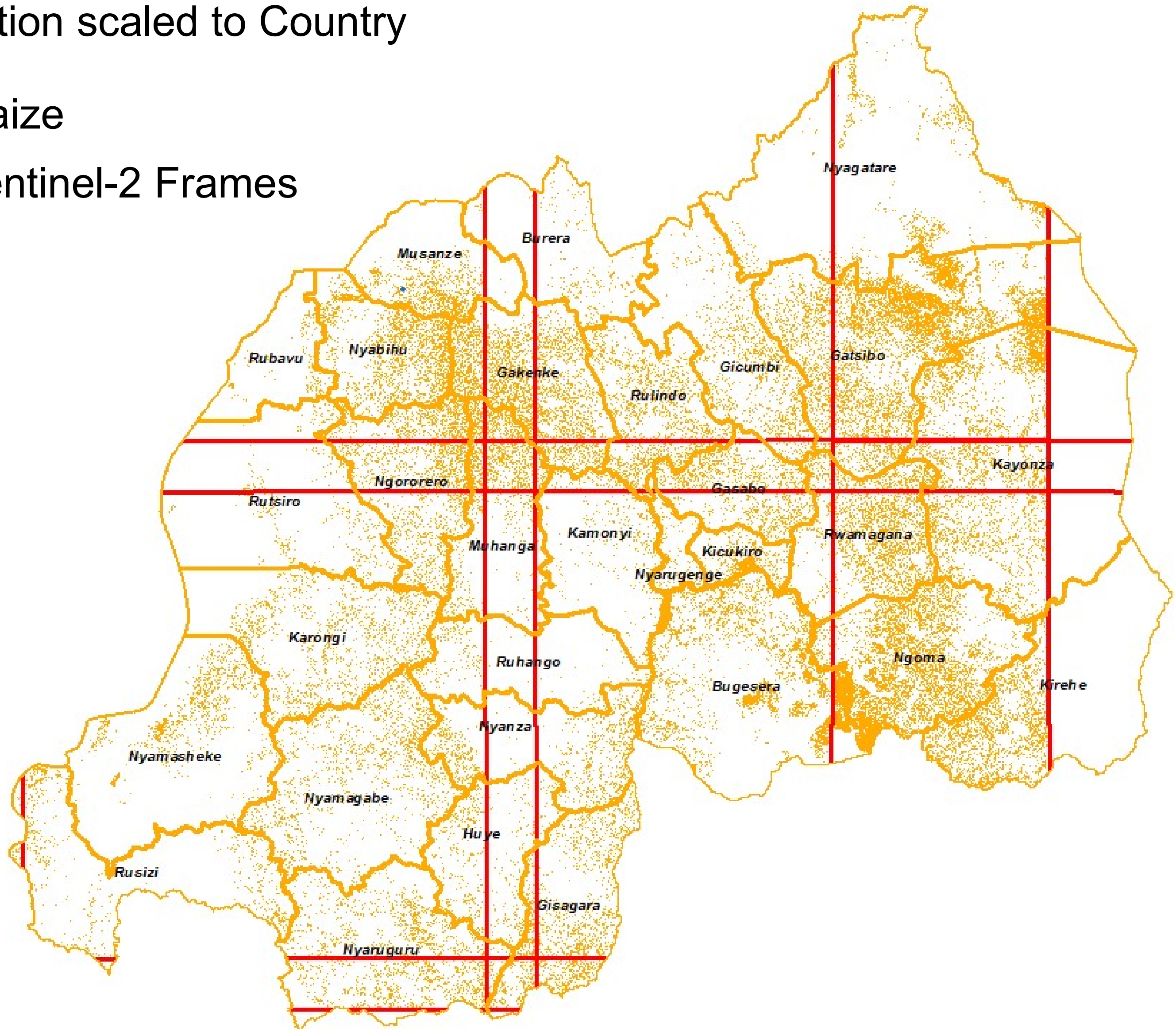
Sentinel-2 satellite image (10 m resolution) from 1/29/2019: Musanze District



Musanze District		
Area of Maize from Computer Model	Area of Maize from 2017 NISR Survey	Difference
6,200 Ha	6,404 ha (includes sorghum)	3%

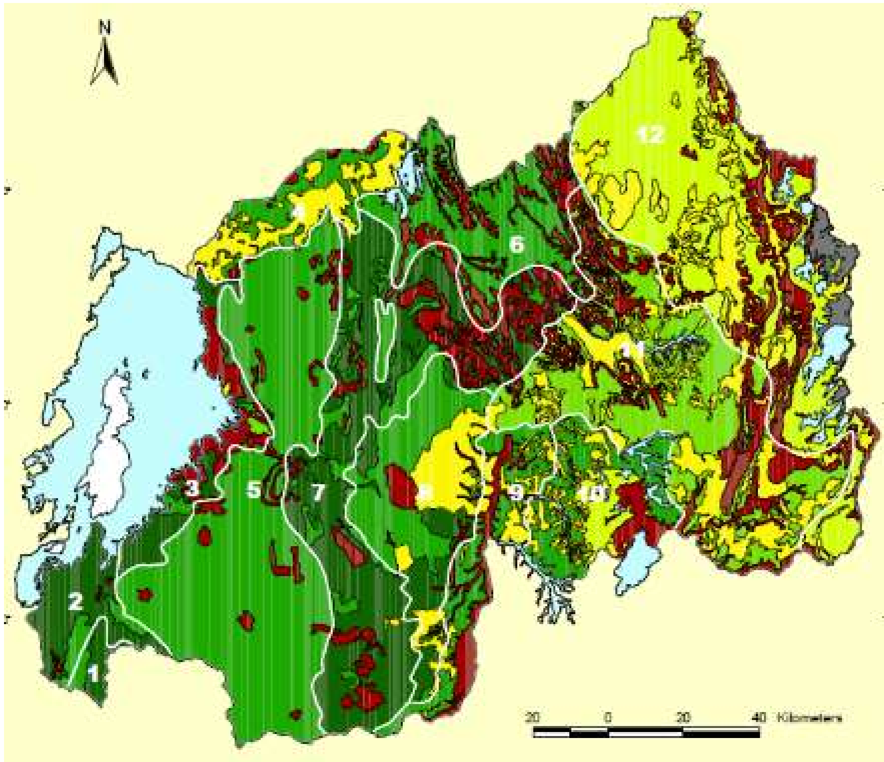
Maize classification: Scaled up to Country Level

Classification scaled to Country

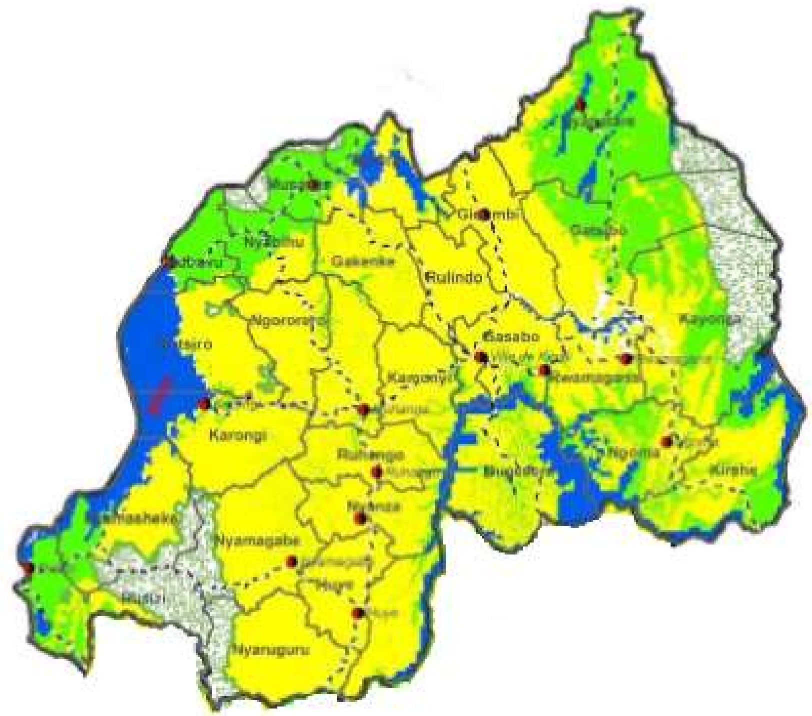


Step 2: Characterizing Baseline Conditions (Average Suitability and Productivity)

Previous Maps of Crop Suitability for Maize



Verdoot et al., 2006 (Ghent University)

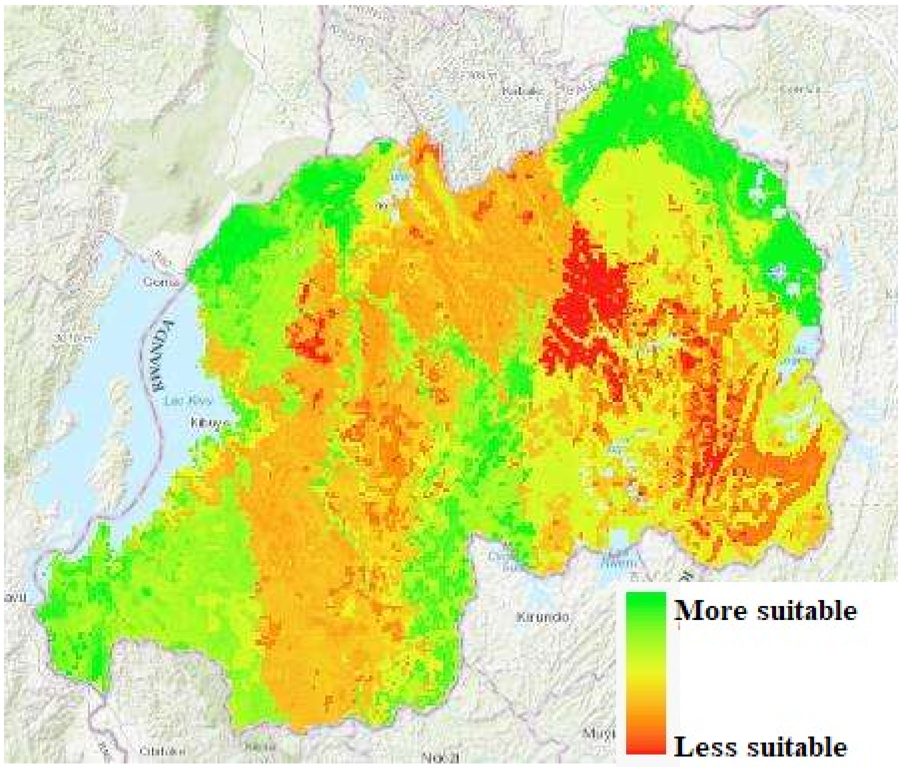


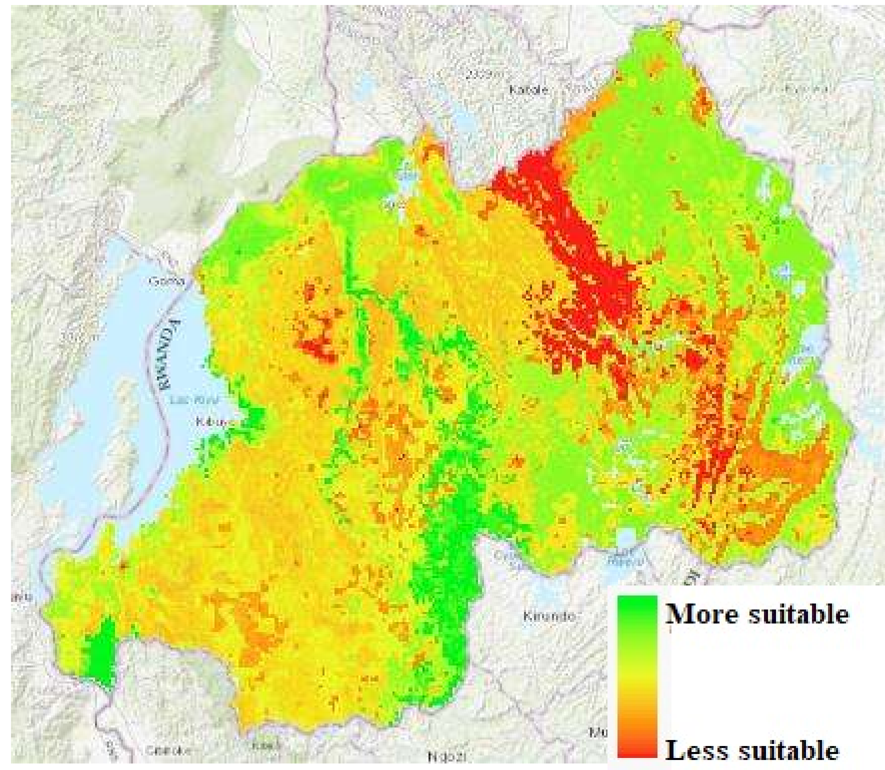
CGIAR, 2016

Seasonal Crop Suitability Map for Maize by Season – 1 km resolution

Season A (September – February)

Season B (March – June)



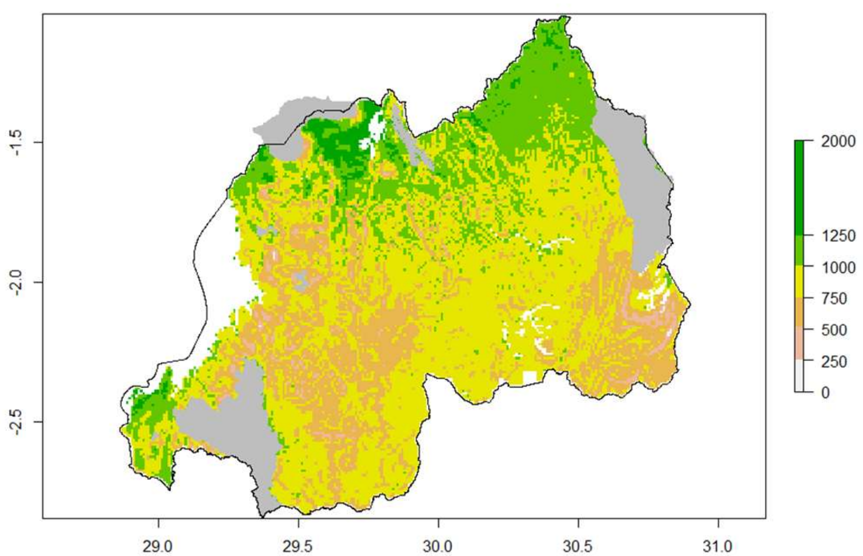


RTI International (2018)

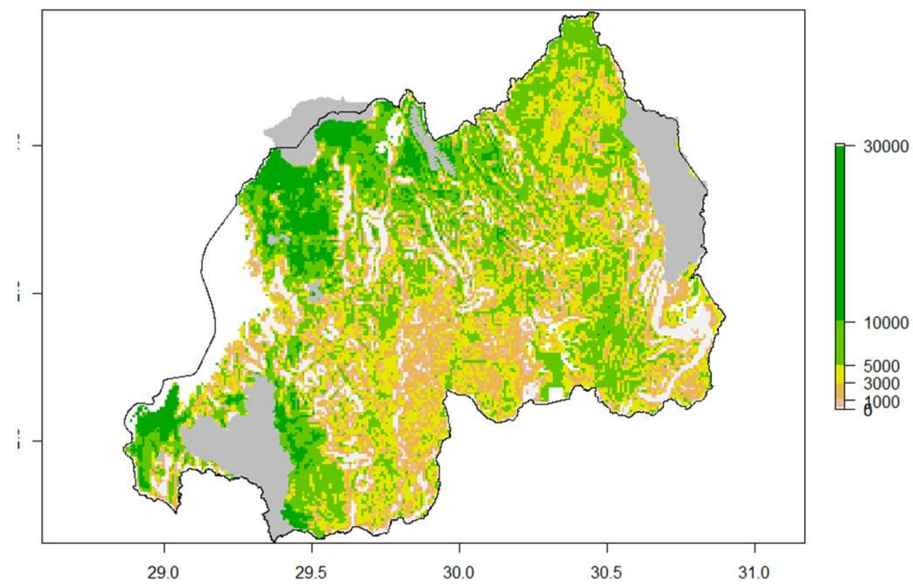
Parameters include: Precipitation, temperature, slope, elevation, soil drainage, soil clay, soil depth, soil cation exchange capacity, soil carbon, soil pH. Data Sources: Climate Data, Worldclim and MeteoRwanda; Soil data from ISRIC SoilGrids and MINAGRI; Elevation data, SRTM

Potential Productivity Maps for Season A – 1 km resolution

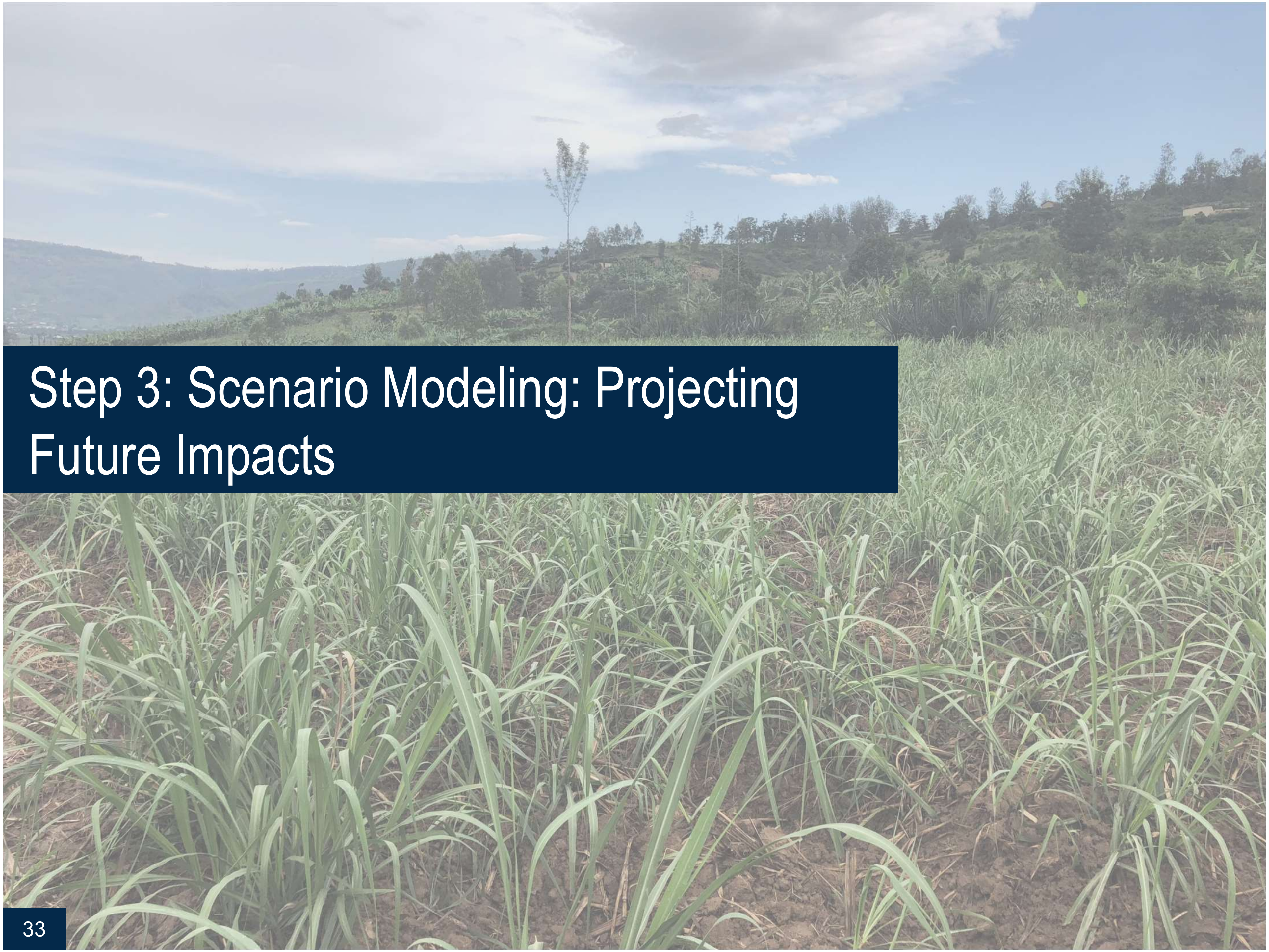
Avg. Climbing Bean Productivity (kg/ha)



Avg. Irish Potato Productivity (kg/ha)



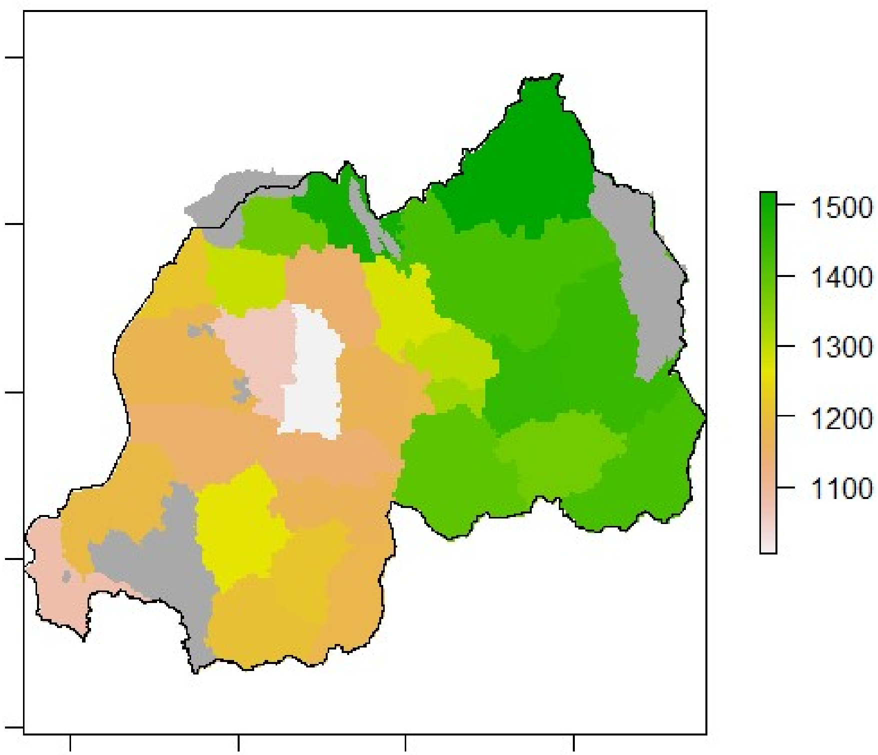
Developed by correlating historical yields (NISR) with global gridded environmental variables (1 km resolution). Parameters include: Precipitation, temperature, slope, elevation, soil drainage, soil clay, soil depth, soil cation exchange capacity, soil carbon, soil pH. Data Sources: Climate Data, Worldclim and MeteoRwanda; Soil data from ISRIC SoilGrids and MINAGRI; Elevation data, SRTM

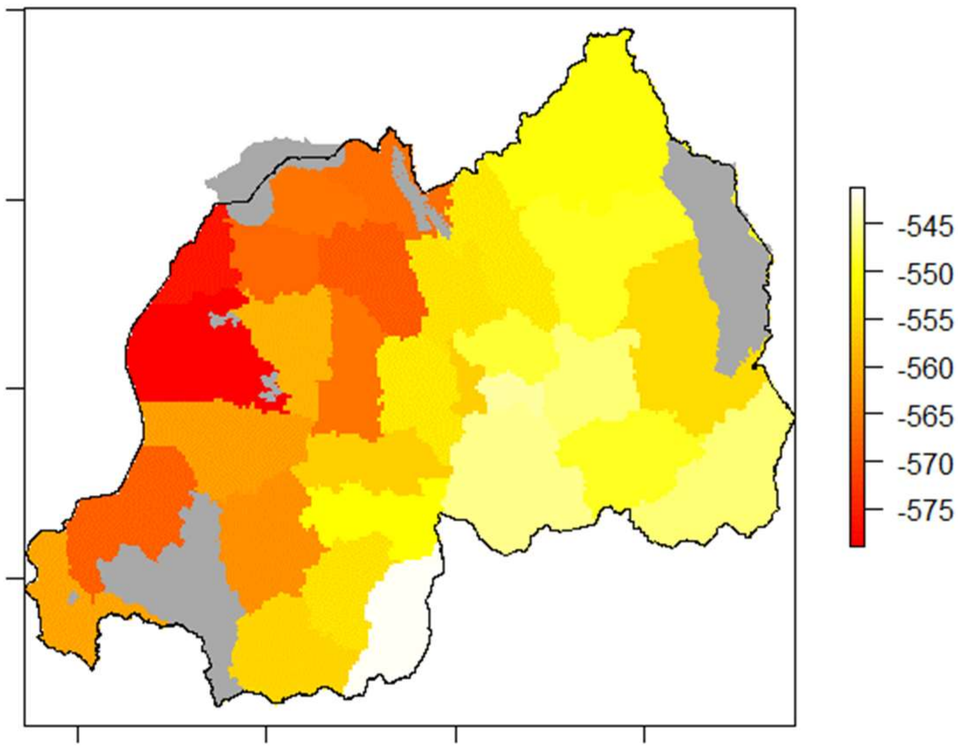


Step 3: Scenario Modeling: Projecting Future Impacts

Preliminary productivity mapping and climate change impacts – District level

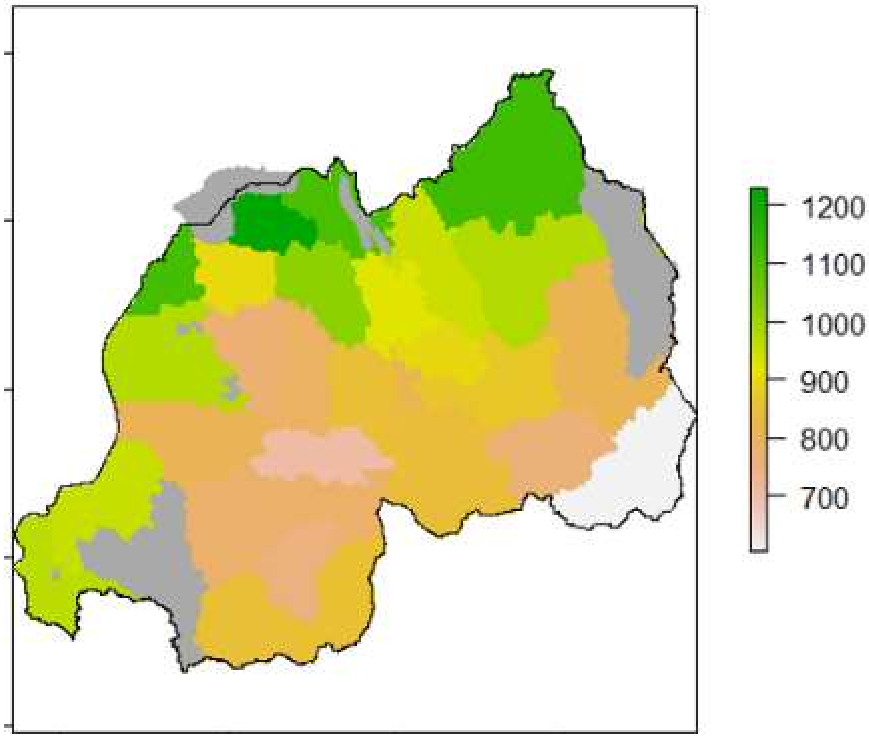
Maize Yield, Current Climate (left) and Simulated Change in Yield under Future Climate (right) (kg/ha)

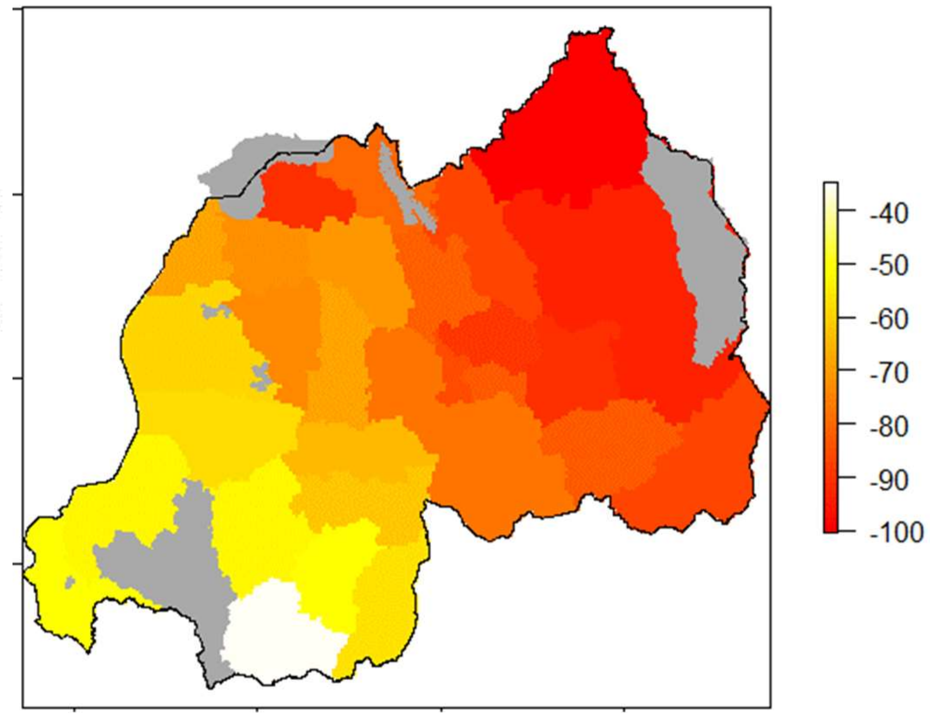




Preliminary productivity mapping and climate change impacts – District level

Climbing Bean Production, Current Climate (left) and Simulated Change in Yield under Future Climate (right) (kg/ha)

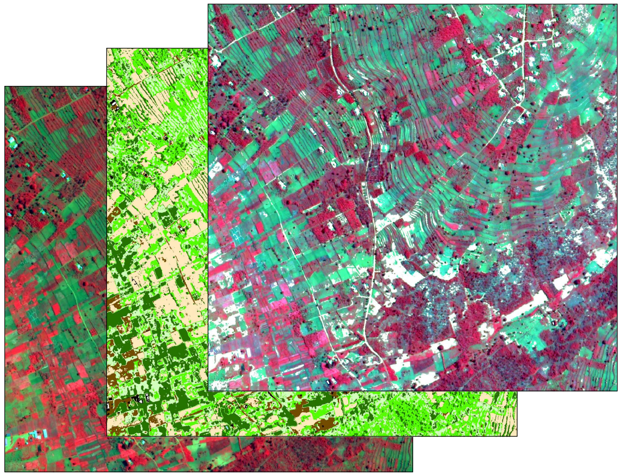




Future Outputs and Sustainability

Illustrative future spatial products

- Improved suitability and potential productivity maps
- Historical and current crop locations
- Historical and projected crop productivity
- Historical and projected crop profitability
- Historical and projected nutrient availability
- Impacts of climate change on crop productivity



Rwanda spatial imagery

Example of a synthetic population (each point represents a household)

Sustainability: Who could use these tools and how?

	Users of the Toolkit	Uses of the Toolkit
	University of Rwanda, AfriCultureRes Project (http://www.africultures.eu/project)	Agricultural monitoring and early warning system that will support decision making in food security
	Ministry of Agriculture and Animal Resources	Support monitoring and evaluation of agricultural strategy as well as investment planning.
	Local Organizations/Consultants (e.g. Vanguard Economics, ESRI Rwanda)	As part of their suite of tools to inform the GoR
	Private Sector for-profit (e.g. BK Techouse, https://bktechouse.rw/)	Where to maximize return on investment and stimulate growth with different interventions

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