Using Remote Sensing and Geospatial Systems to Support Decision-making for Sustainable Agriculture and Food Security in Rwanda

AfricaGIS 2019

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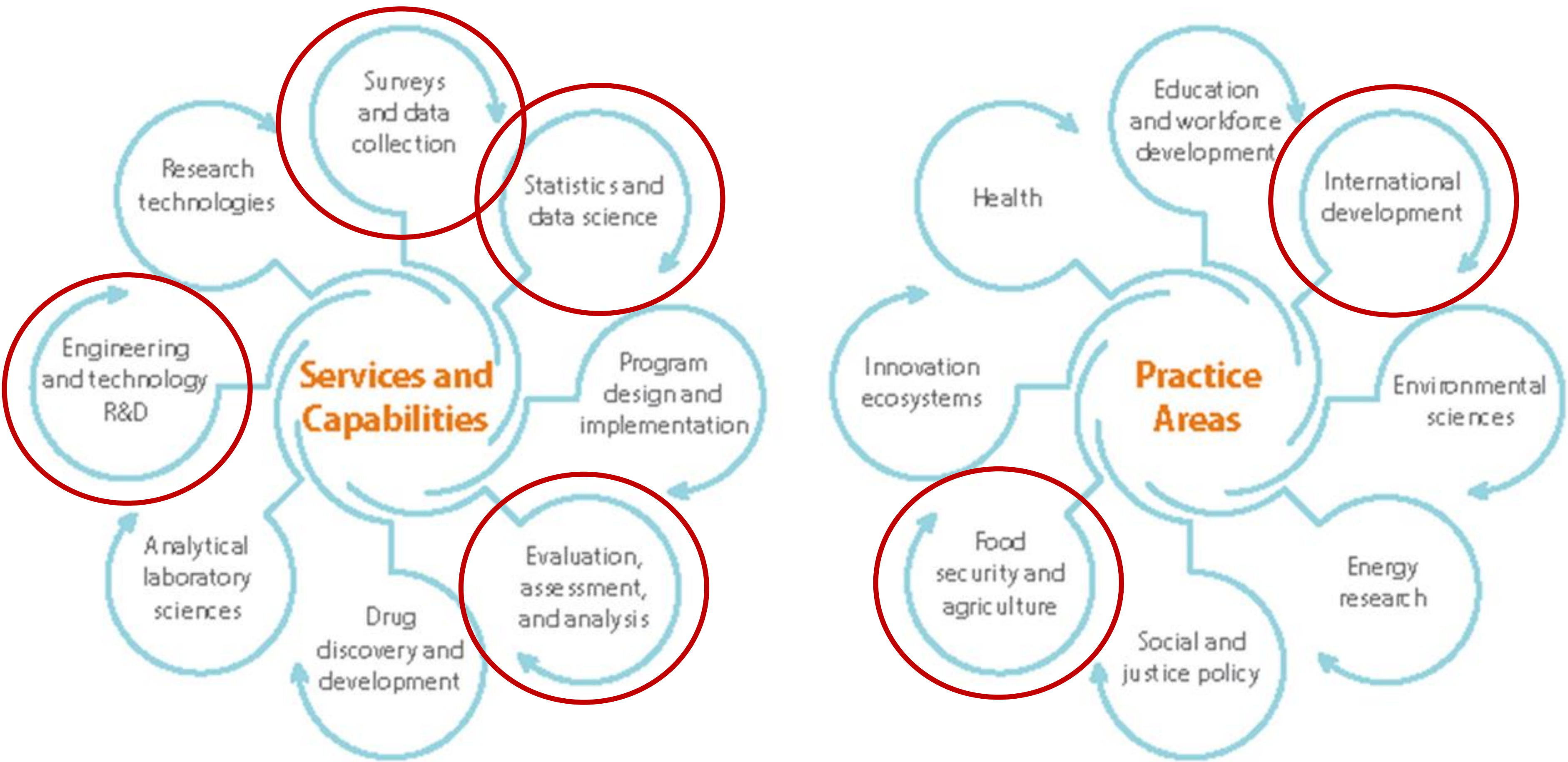
RTI International

- RTI International is a non-profit independent research institute headquartered in the Research Triangle Park in North Carolina, USA.
- Our mission is to improve the human condition by turning knowledge into practice.
- We explore new ideas and seek solutions to critical issues facing people around the globe.

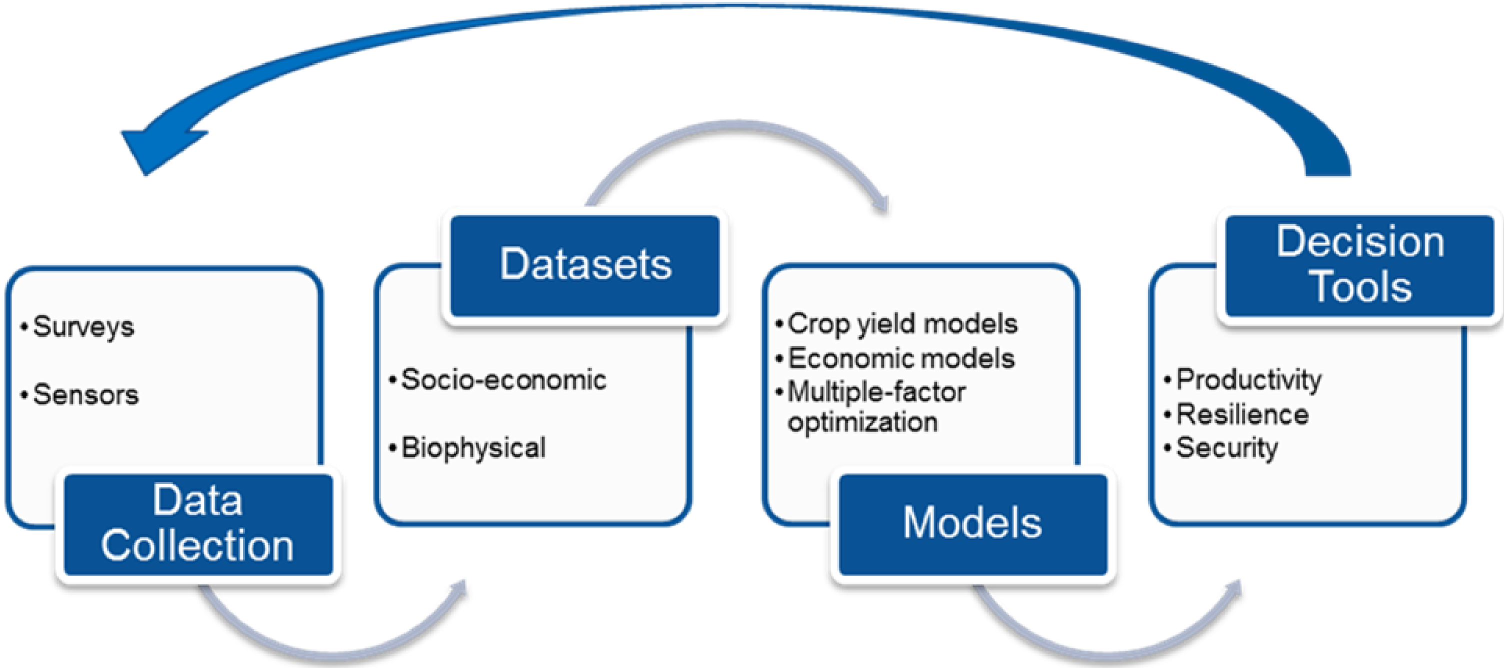
Multidisciplinary Research

- RTI International is a multidisciplinary research organization.
- We apply a diverse set of services and capabilities across key practice areas to contribute to solving critical issues.



Project Background

In its strategic focus area of Food Security and Agriculture, RTI funded a research project to explore methodologies for analyzing big **datasets** to **extract information** to support **decision making** for agriculture.



Other presentations at AfricaGIS 2019

- Rineer et al. "Using UAV-Collected Ground-Truth Data and Computer Vision for Identification of Crop Type for Sustainable Agriculture and Food Security in Rwanda" – this session
- Robert Beach et al. "Evaluating the Effects of Alternative Management Strategies on Rwandan Agriculture" – session 3C

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
- Our project is developing methods and tools for Rwanda, though will be more broadly applicable

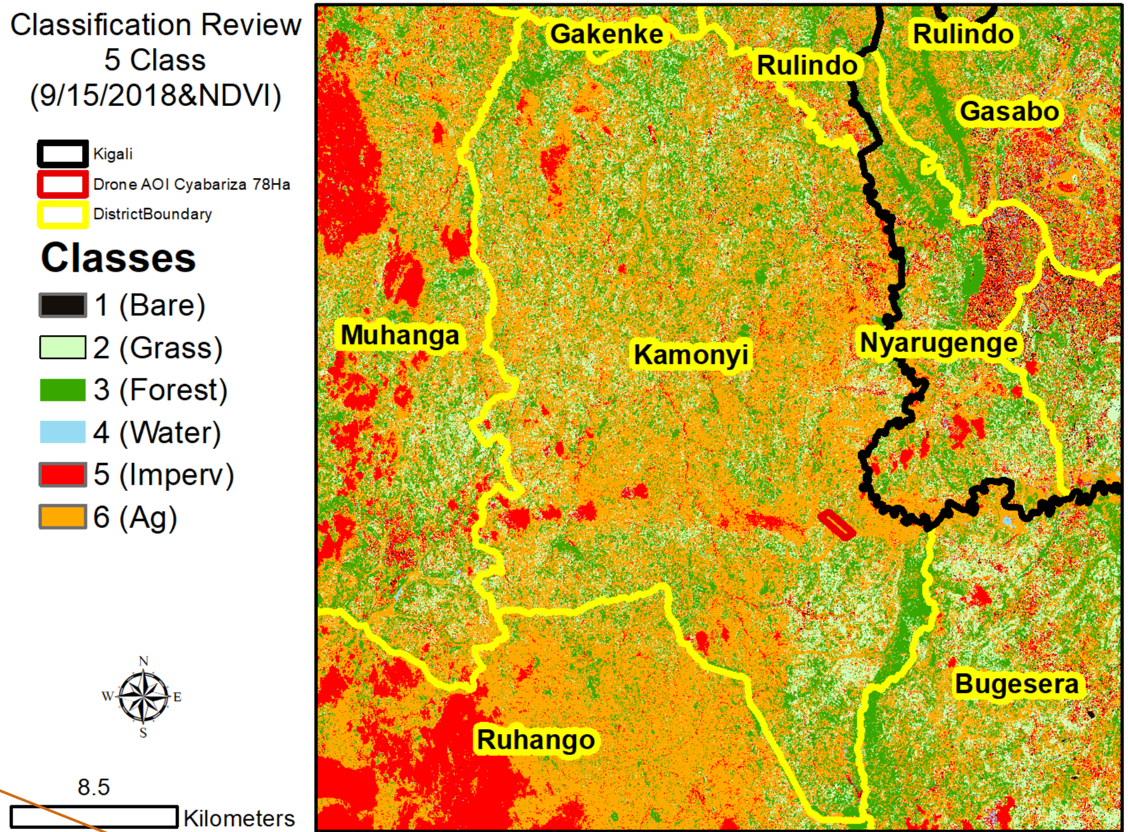
Overview

- Flew drones 3 times during 2019 Season A in each of 6 different locations representing different agroecological zones
- Used high resolution drone images to calibrate freely available satellite data (Sentinel-1 and Sentinel-2) for crop analytics
- Tracking changes in normalized differentiated vegetation index (NDVI) over the growing seasons to estimate:
  - Timing of land clearing for planting crops
  - Changes in NDVI of crops during the growing season
  - Timing of crop harvest
- Classifying land cover/land use type (8-class) at 10m x 10m resolution at the national level
- Combining spatial data on soils, weather, and other biophysical factors and NISR survey data to estimate suitability, simulated productivity, and effects of management practices

Characterizing Current Situation

Using satellite data to characterize land cover

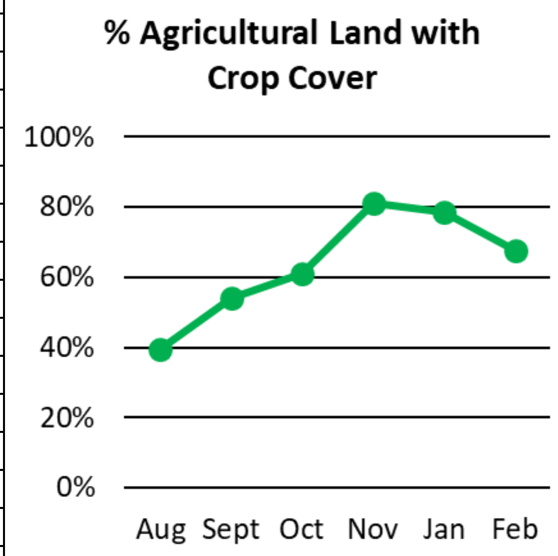
- We used machine learning techniques to classify land cover into 6 classes
- We used training data from satellite imagery and pre-existing land cover classes
- Results close to NISR official data from 2017 Season A



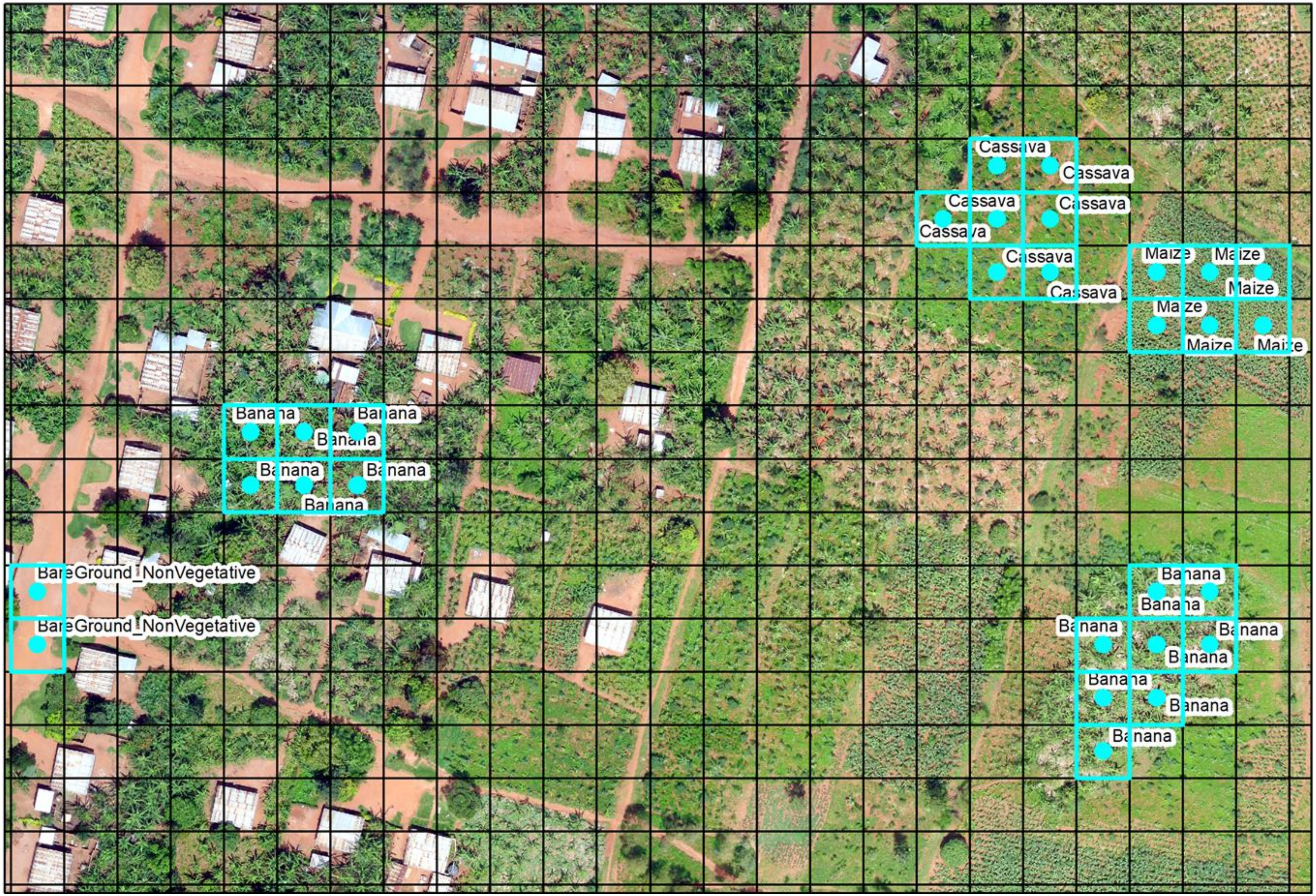
Source	Bare	Grass	Forest	Water	Impervious	Agriculture	Total Area
RTI (6 – class)	2	108	156	3	36	357	**661**
Source		**Fallow**	**Non-Ag**			**Cultivated**	**Total Area**
NISR (3-class)	N/A	99	114	N/A	N/A	364	**577**

Share of agricultural land with visible crops, 2019A

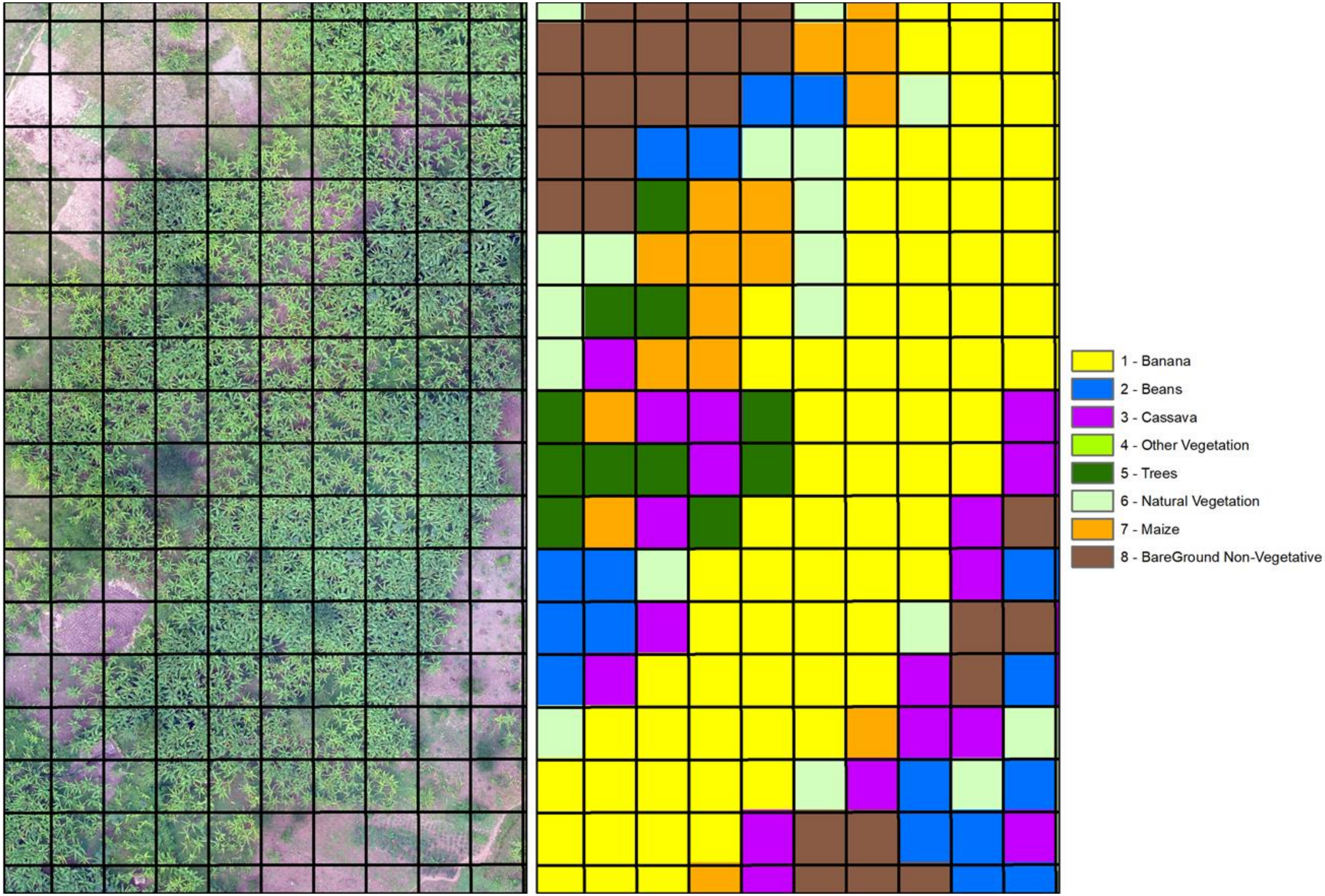
District	In Production (%)					
	Aug	Sept	Oct	Nov	Jan	Feb
Nyarugenge	**0.463**	0.608	0.560	0.843	0.858	0.672
Gasabo	0.439	0.755	0.542	0.830	0.818	0.702
Kicukiro	0.348	0.505	0.213	0.584	0.813	0.719
Nyanza	0.263	0.608	0.627	0.734	0.682	0.660
Gisagara	0.251	0.589	0.670	0.866	0.831	0.755
Nyaruguru	0.412	0.480	0.601	0.771	0.826	0.783
Huye	0.282	0.501	0.629	0.823	0.494	0.728
Nyamagabe	0.463	0.527	0.560	0.756	0.698	0.757
Ruhango	0.310	0.522	0.553	0.734	0.421	0.456
Muhanga	0.431	0.605	0.547	0.731	0.634	0.742
Kamonyi	0.328	0.590	0.644	0.755	0.636	0.452
Karongi	0.520	0.512	0.597	0.838	0.648	0.677
Rutsiro	0.632	0.578	0.641	0.884	0.723	0.758
Rubavu	0.535	0.541	0.694	0.832	0.619	0.456
Nyabihu	0.459	0.535	0.477	0.899	0.855	0.684
Ngororero	0.437	0.480	0.291	0.807	0.801	0.752
Rusizi	0.508	0.590	0.877	0.939	0.878	0.884
Rulindo	0.443	0.724	0.720	0.836	0.843	0.716
Gakenke	0.450	0.628	0.263	0.877	0.877	0.834
Musanze	0.348	0.545	0.599	0.915	0.866	0.617
Burera	0.466	0.517	0.467	0.904	0.811	0.571
Gicumbi	0.532	0.674	0.528	0.927	0.807	0.584
Rwamagana	0.445	0.607	0.730	0.880	0.903	0.792
Nyagatare	0.249	0.326	0.523	0.901	0.902	0.391
Gatsibo	0.384	0.413	0.631	0.921	0.916	0.605
Kayonza	0.275	0.379	0.502	0.711	0.792	0.610
Kirehe	0.236	0.480	0.582	0.709	0.847	0.809
Ngoma	0.286	0.536	0.654	0.839	0.924	0.798
Bugesera	0.235	0.380	0.348	0.504	0.710	0.492
Nyamasheke	0.636	0.589	0.810	0.919	0.789	0.862
NATIONAL	0.396	0.542	0.611	0.810	0.784	0.677



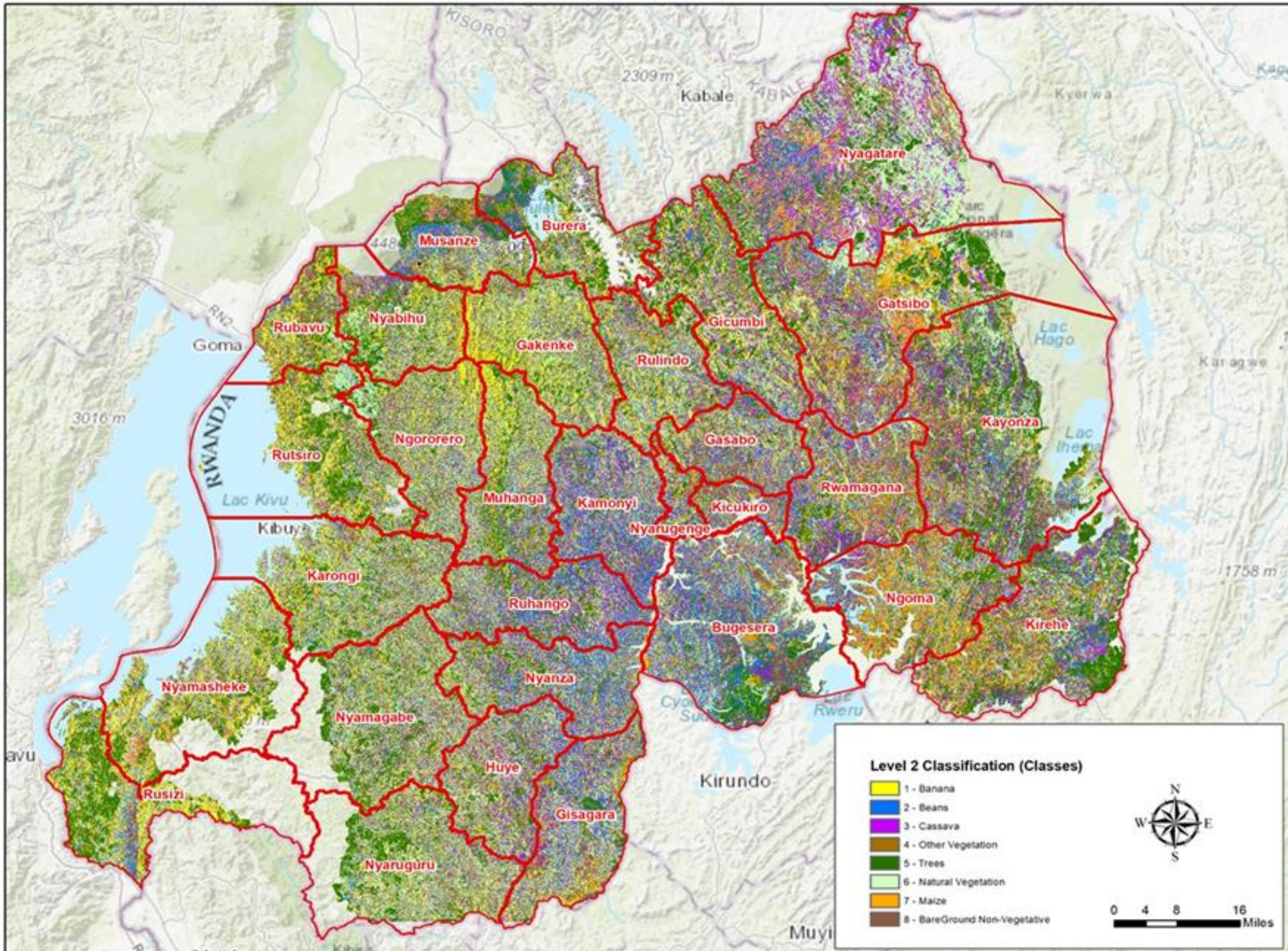
Labeling satellite grid cells from drone image

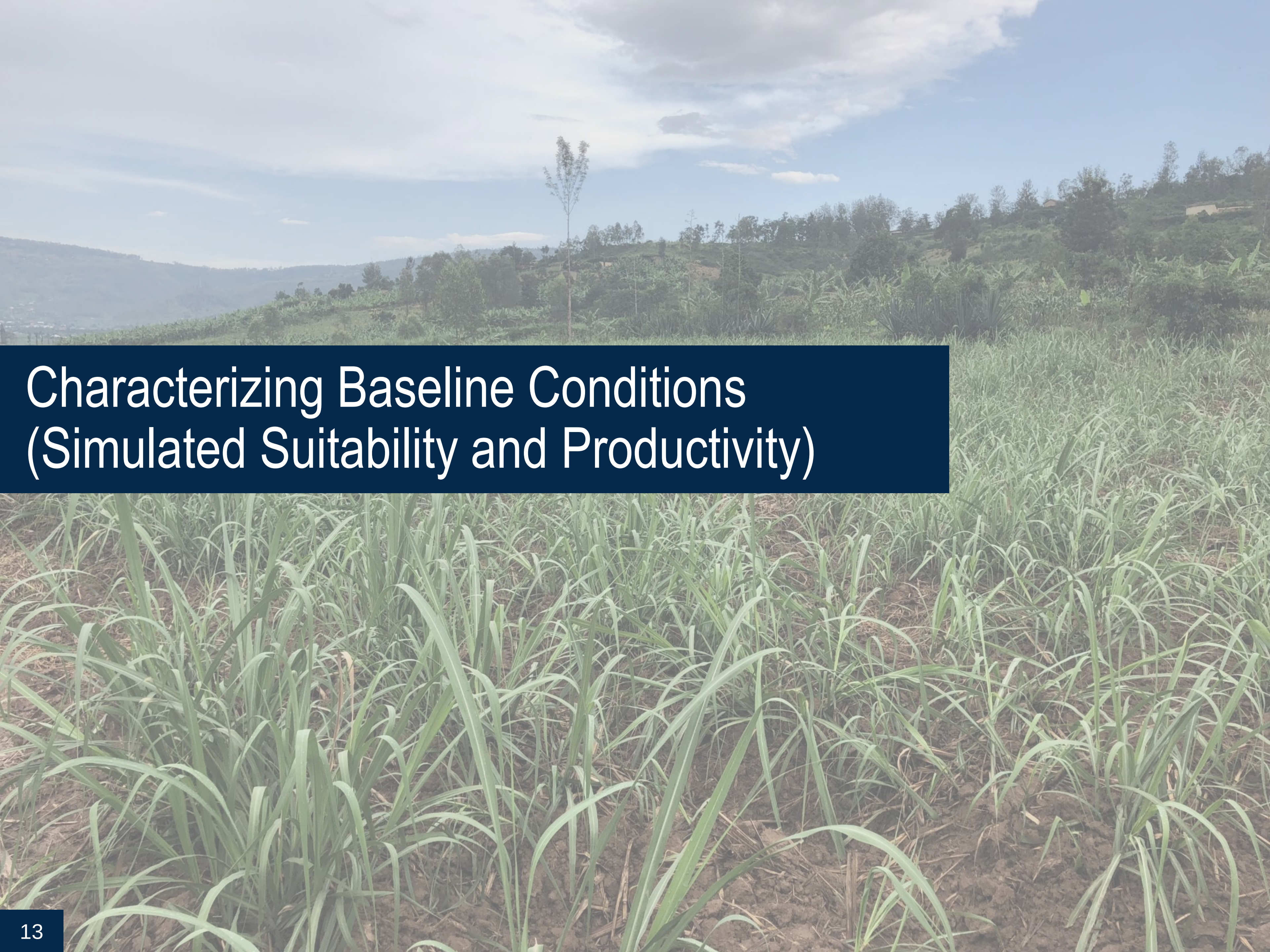


Application of calibrated machine-learning algorithms for classification



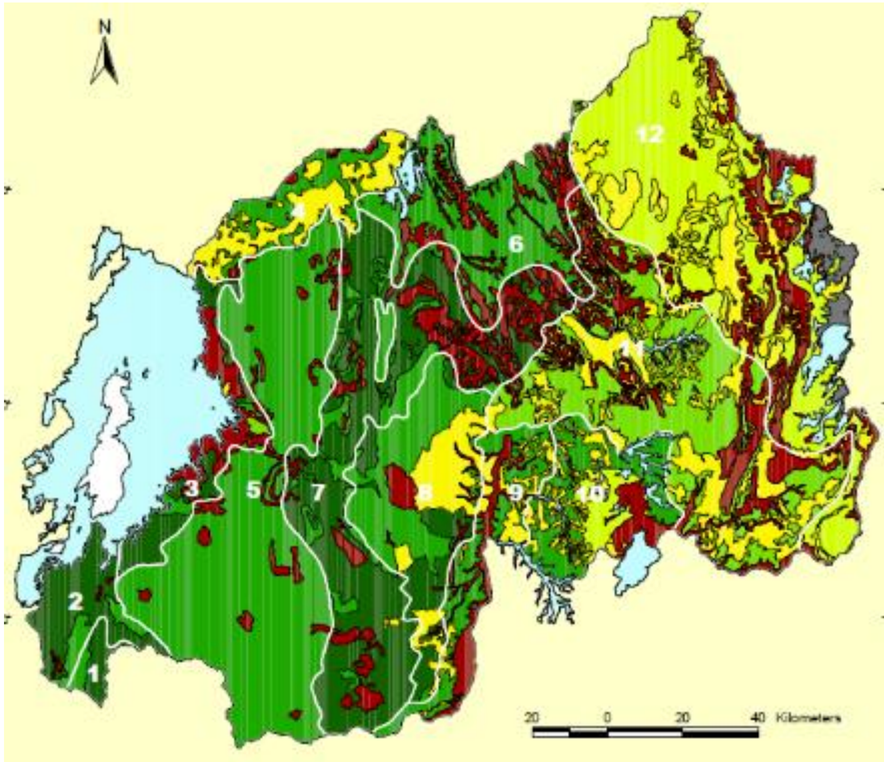
Identification of land cover/land use at the national level



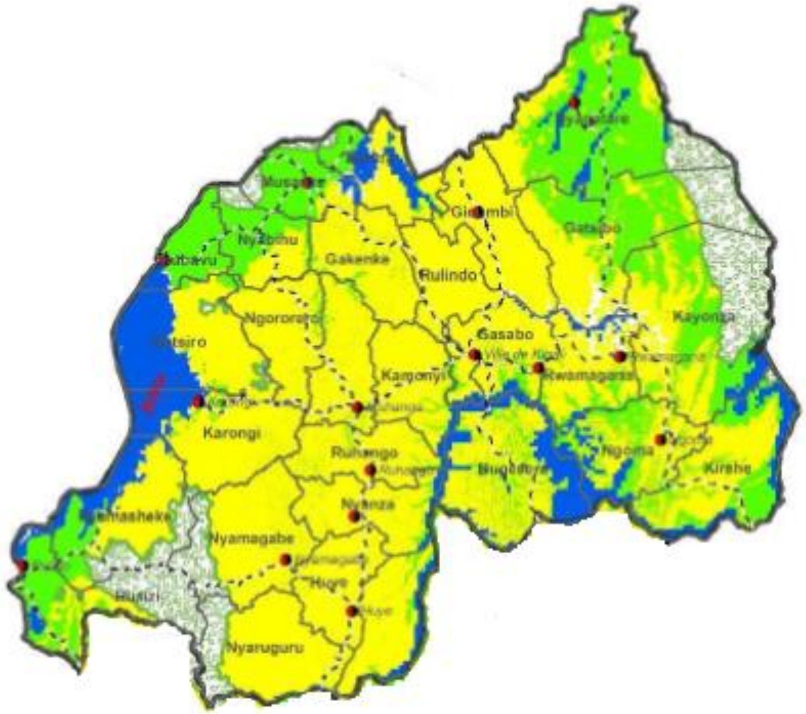


Characterizing Baseline Conditions (Simulated Suitability and Productivity)

Previous Maps of Crop Suitability for Maize



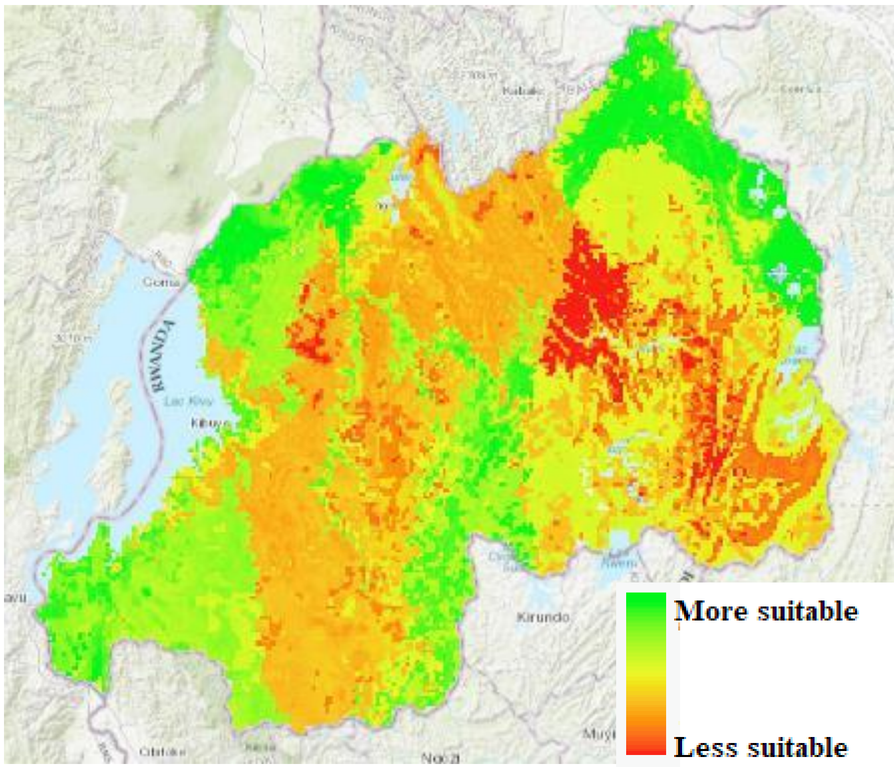
Verdoot et al., 2006 (Ghent University)



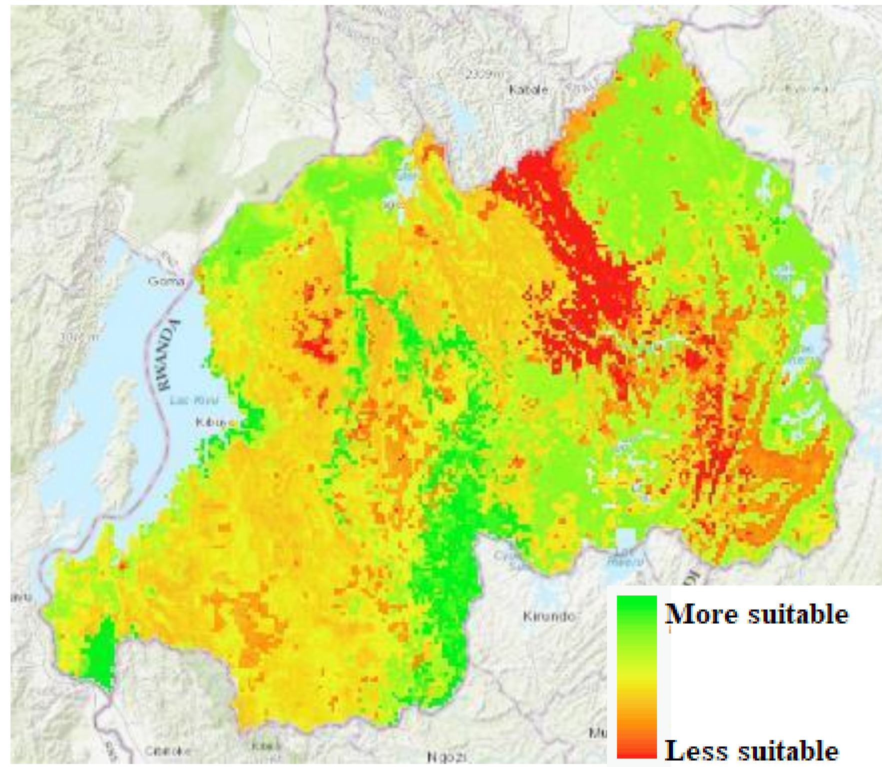
CGIAR, 2016

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

Season A (September – February)



Season B (March – June)

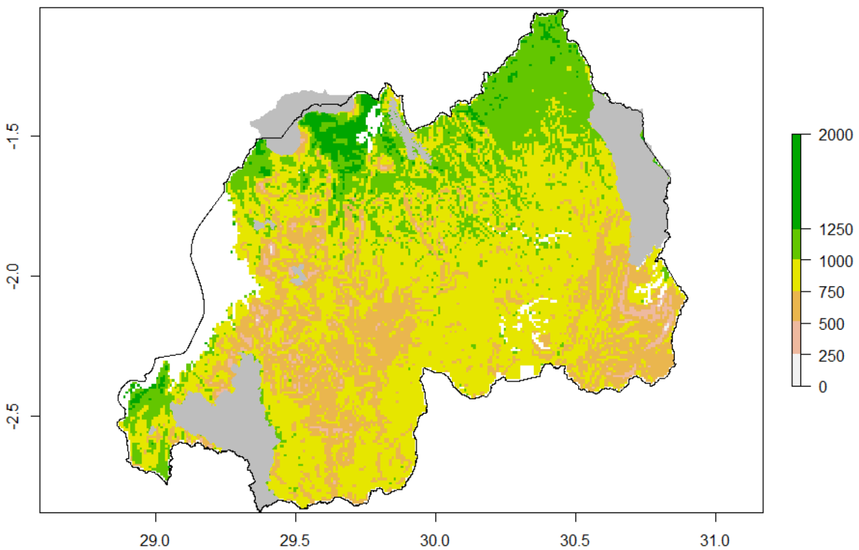


RTI International (2018)

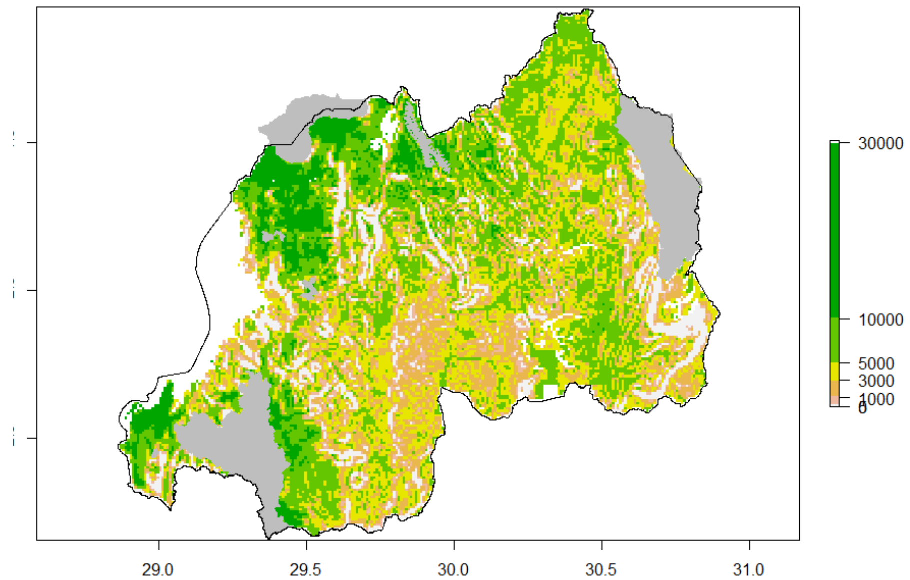
Parameters include: Precipitation, temperature, slope, elevation, soil drainage, soil clay, soil depth, soil cation exchange capacity, soil carbon, soil pH. Data Sources: Climate Data, Worldclim … MeteoRwanda; Soil data from ISRIC SoilGrids and MINAGRI; Elevation data, SRTM

Simulated Productivity Maps for Season A – 1 km resolution

Avg. Climbing Bean Productivity (kg/ha)



Avg. Irish Potato Productivity (kg/ha)

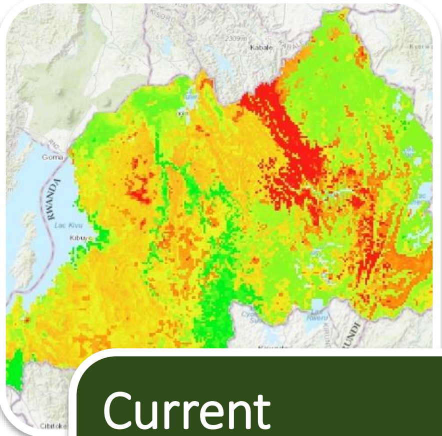


Developed by correlating historical yields (NISR) with global gridded environmental variables (1 km resolution). Parameters include: Precipitation, temperature, slope, elevation, soil drainage, soil clay, soil depth, soil cation exchange capacity, soil carbon, soil pH. Data Sources: Climate Data, Worldclim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

Scenario Modeling: Projecting Future Impacts

Assessing impacts on agriculture

Step 1: Characterize current situation



Current Situation

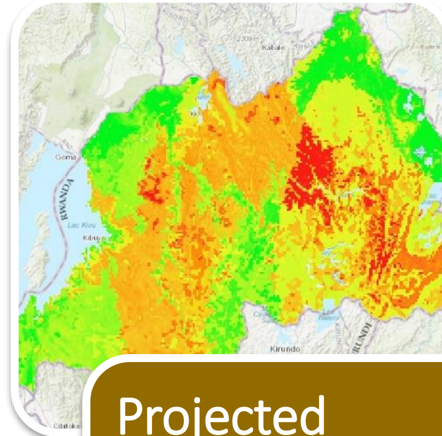
- Productivity
- Profitability (e.g. income)
- Nutrition

Step 2: Project how things will change

Effect of Programs

- Changing inputs or management practices
- Diversification
- Climate change

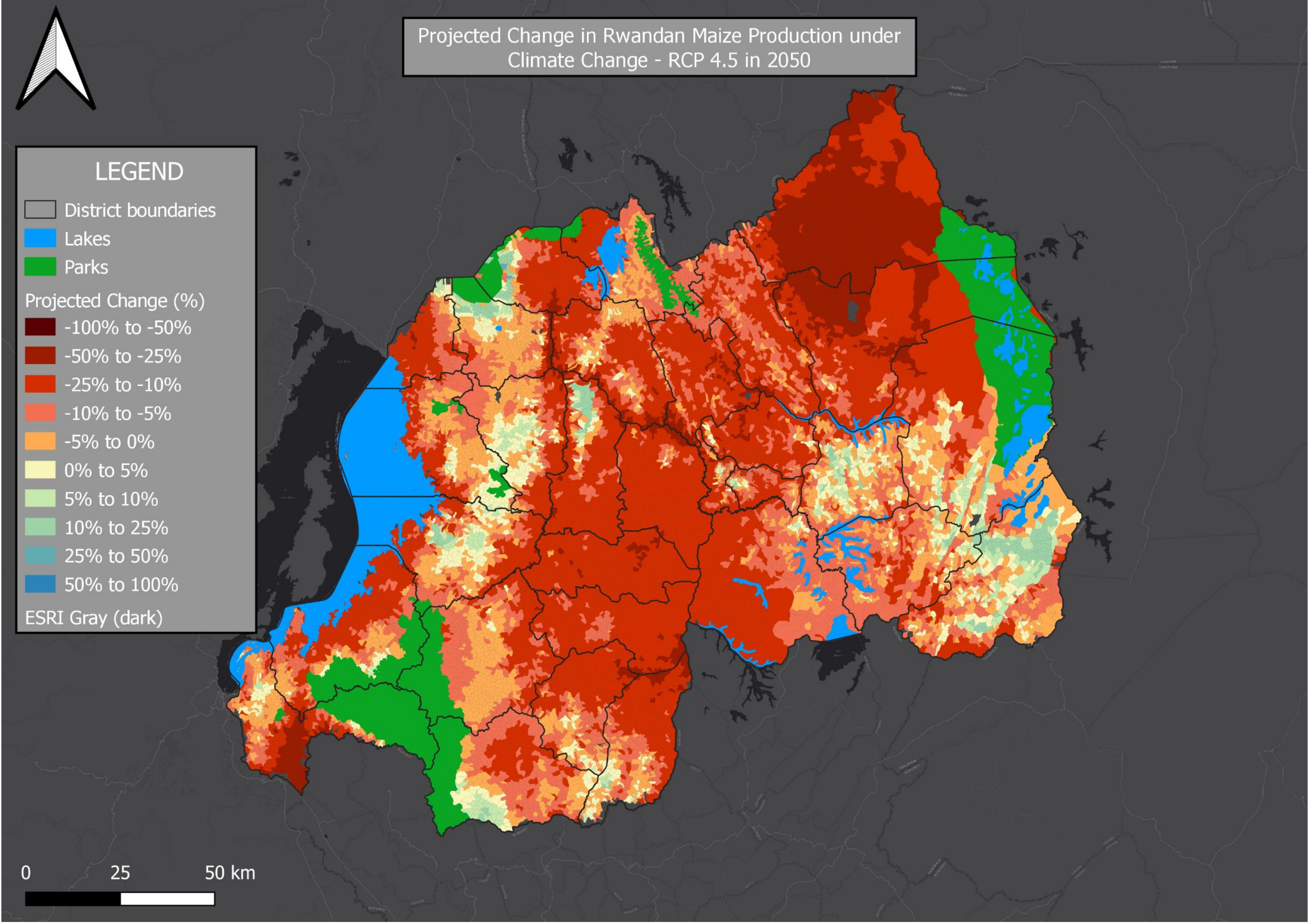
Step 3: Identify impacts



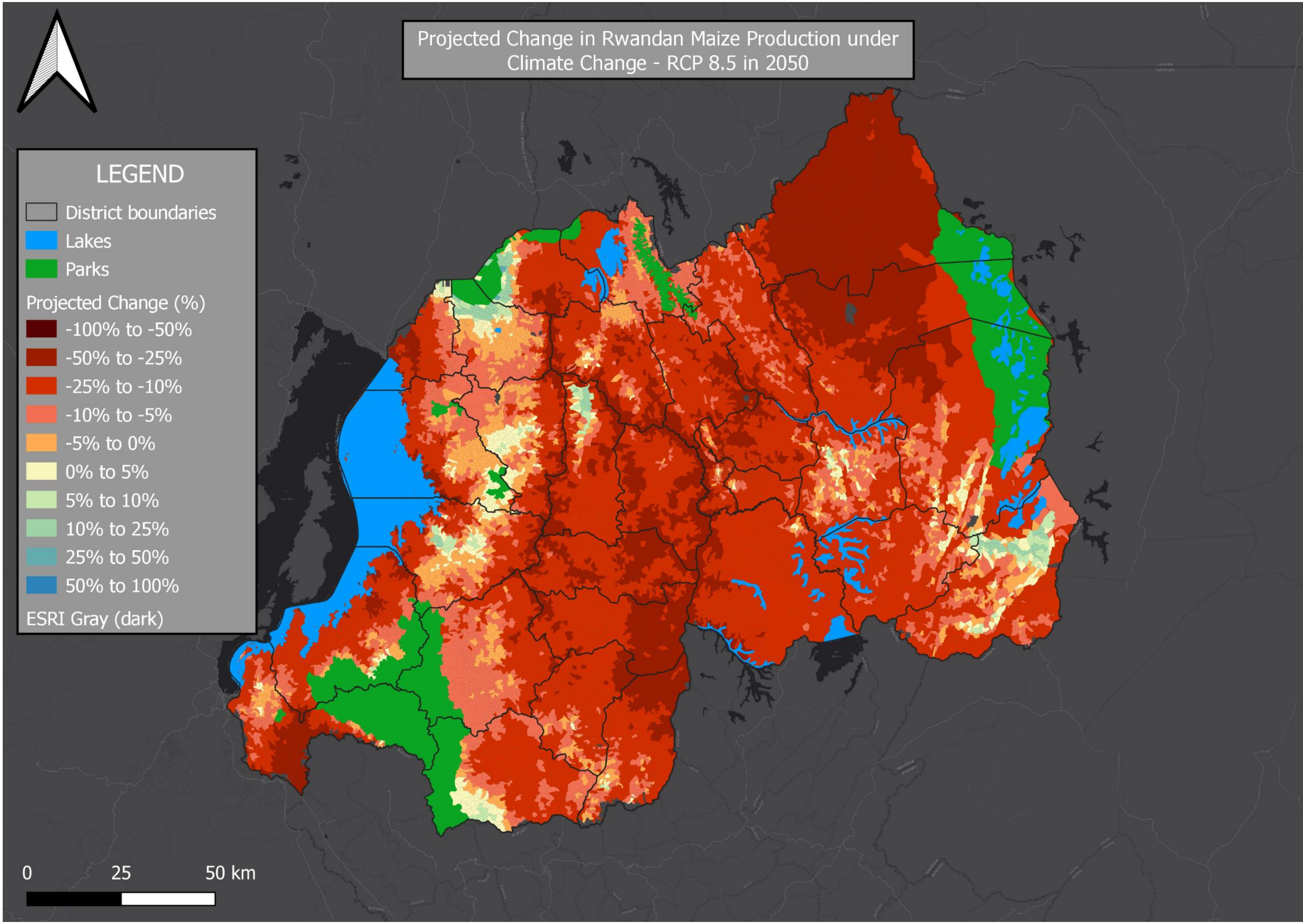
Projected Impacts

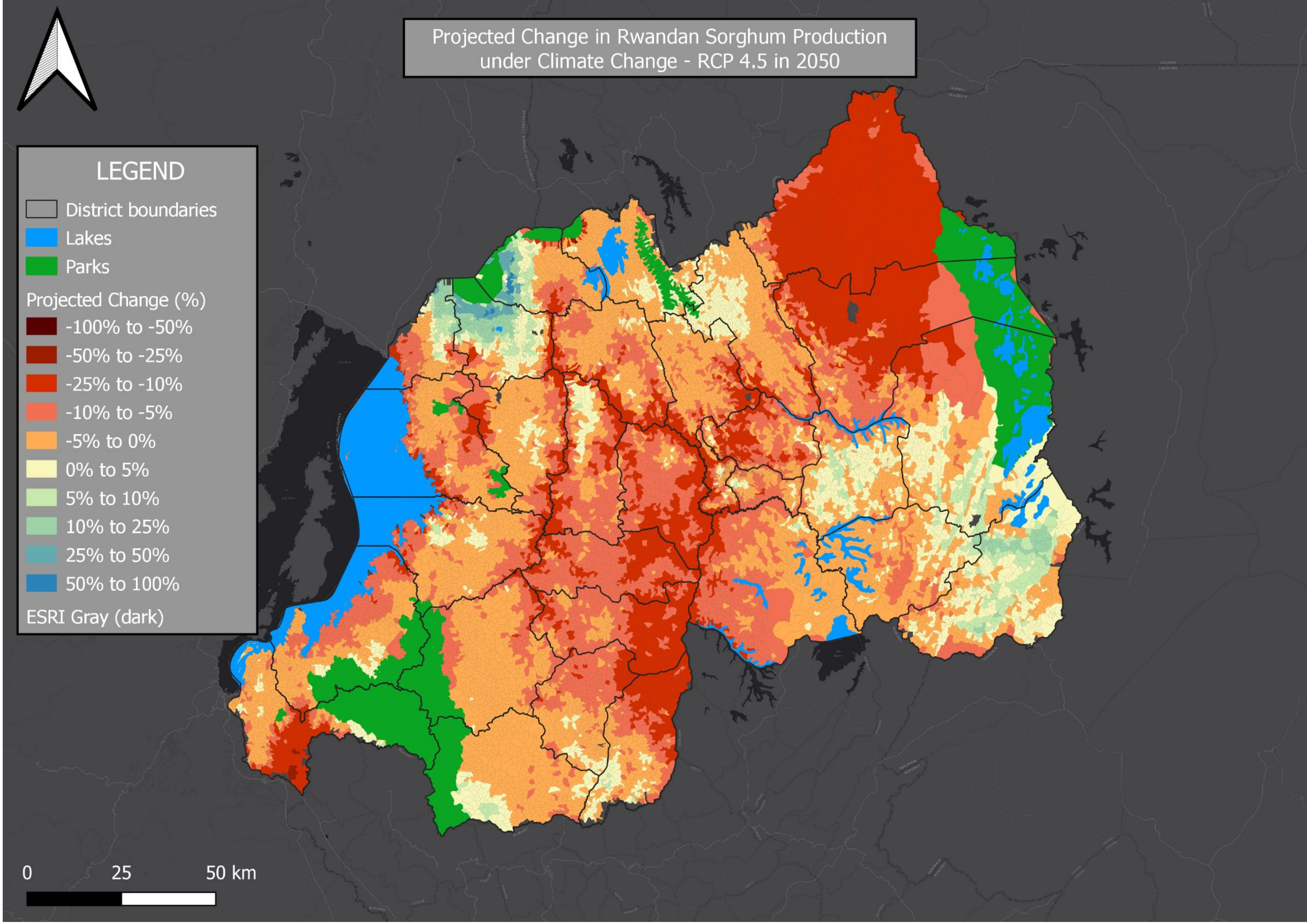
- Productivity
- Profitability (e.g., income)
- Nutrition

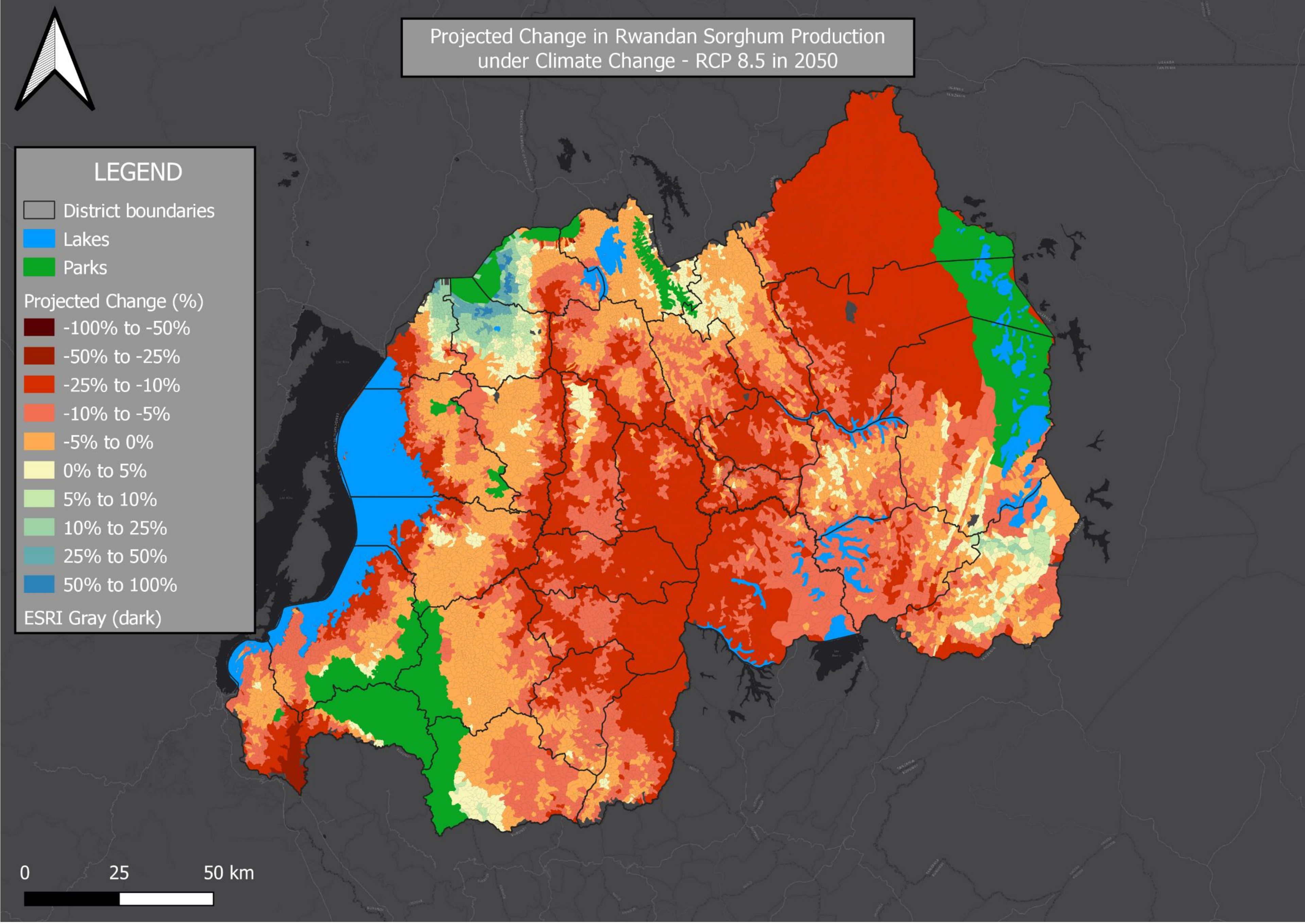
Example: How does irrigation affect the productivity and profitability of different crops, according to season and geography? Where would the benefits be the greatest for different crops?



Projected Change in Rwandan Maize Production under Climate Change - RCP 4.5 in 2050
LEGEND
District boundaries
Lakes
Parks
Projected Change (%)
-100% to -50%
-50% to -25%
-25% to -10%
-10% to -5%
-5% to 0%
0% to 5%
5% to 10%
10% to 25%
25% to 50%
50% to 100%
ESRI Gray (dark)
0
25
50 km


Projected Change in Rwandan Maize Production under Climate Change - RCP 8.5 in 2050
LEGEND
District boundaries
Lakes
Parks
Projected Change (%)
-100% to -50%
-50% to -25%
-25% to -10%
-10% to -5%
-5% to 0%
0% to 5%
5% to 10%
10% to 25%
25% to 50%
50% to 100%
ESRI Gray (dark)
0
25
50 km


Projected Change in Rwandan Sorghum Production
under Climate Change - RCP 4.5 in 2050
LEGEND
District boundaries
Lakes
Parks
Projected Change (%)
-100% to -50%
-50% to -25%
-25% to -10%
-10% to -5%
-5% to 0%
0% to 5%
5% to 10%
10% to 25%
25% to 50%
50% to 100%
ESRI Gray (dark)
0
25
50 km


Projected Change in Rwandan Sorghum Production
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Projected Change (%)
-100% to -50%
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-25% to -10%
-10% to -5%
-5% to 0%
0% to 5%
5% to 10%
10% to 25%
25% to 50%
50% to 100%
ESRI Gray (dark)
0
25
50 km

Next steps

- Model enhancements
  - Continue expanding labeled ground-truthing dataset
    - Hand-labeling of additional satellite grid cells overlaid with drone images
    - Applying computer vision machine learning techniques to our drone images to expand area of labeled data for calibration of satellite images
  - Further testing of alternative model specifications
    - Implement cross-validation and other robustness checks
    - Improved reflection of growing season dynamics
  - Exploration of utilizing higher-resolution satellite data
  - Incorporate estimation of crop yields
- Ongoing analysis of 2020 Season A (September 2019 – February 2020) development in Rwanda
- Scenario analyses
  - Adoption of improved management practices
  - Climate change adaptation scenarios
- Application of techniques developed for an impact evaluation of an agricultural development project in Niger

More Information

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