Monitoring of agricultural investment areas in Ethiopia based on remote sensing time-series data

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Introduction: Background and Rationale

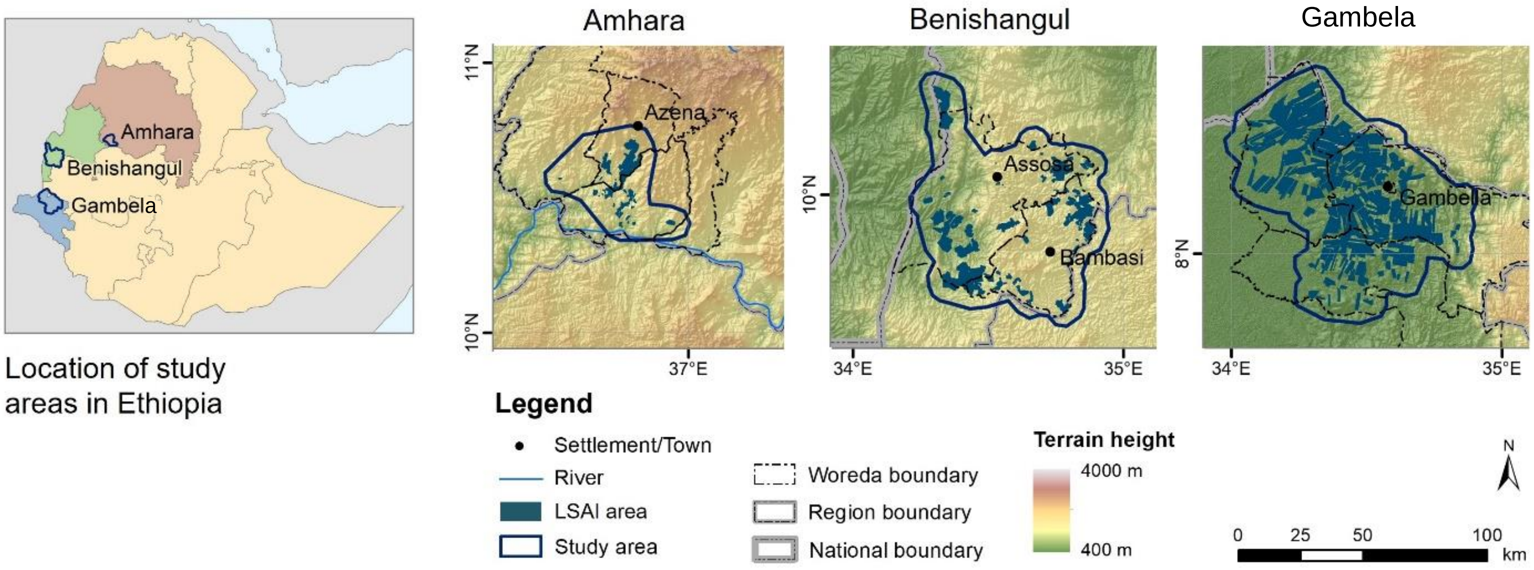
- Promotion of large-scale agricultural investments (LSAI) to transform the agricultural sector as part of the *Ethiopian Homegrown Economy Strategy*
- Albeit the agricultural sector being the major GDP contributor, investment and development has been slowly progressing
- A plethora of agricultural investors (land lessees) neither implements business plans nor complies with contractual agreements
- The GoE lacks capacities to efficiently and effectively monitor agricultural investments in land, and thus vast areas of land remain unproductive.

→ ***Remote sensing offers tremendous potential for decision-making and performance monitoring of agricultural investments.***

→ GIZ S2RAI entered a project cooperation with the German Aerospace Center (DLR) to develop a remote sensing monitoring method for LSAI in Ethiopia and build capacities accordingly.

Target Areas: Seven Woredas in three regions

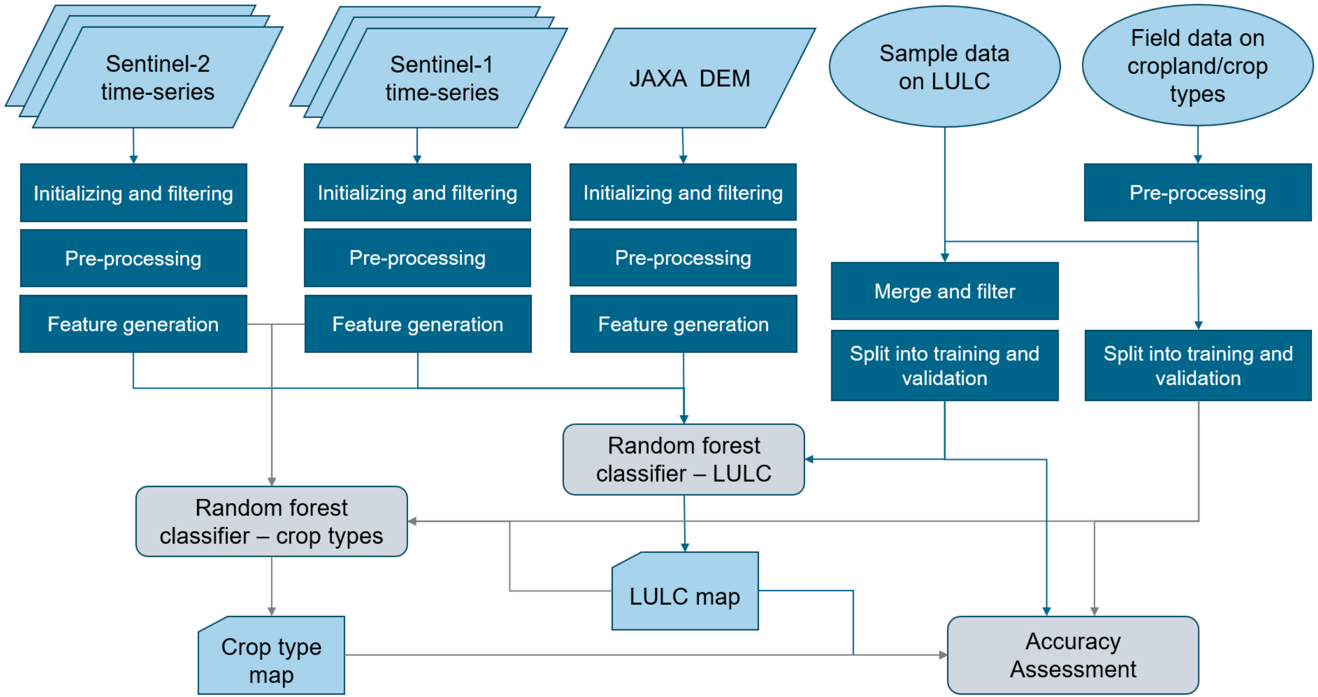
- Three study sites in Amhara, Benishangul-Gumuz and Gambela regions
- Sites include LSAI areas with a 5-km buffer



RS4AIM Project: Objectives

- RS4AIM: Remote Sensing for large-scale Agricultural Investment Monitoring in Ethiopia
- Objectives:
  - Development of classification methods for cropland and crop type classification using supervised image classification based on *in-situ* data and *open-source* high-resolution Earth observation data
  - Application of methods to derive information products on cropland and crop types for the years 2021 and 2022 for the three study areas in Ethiopia
  - Provision of training courses on remote sensing-based land cover and crop type classifications for GoE staff

Methodology: Classification Workflow



Source: Eisfelder et al. 2023

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Field data: *In-situ* data collection on crop types

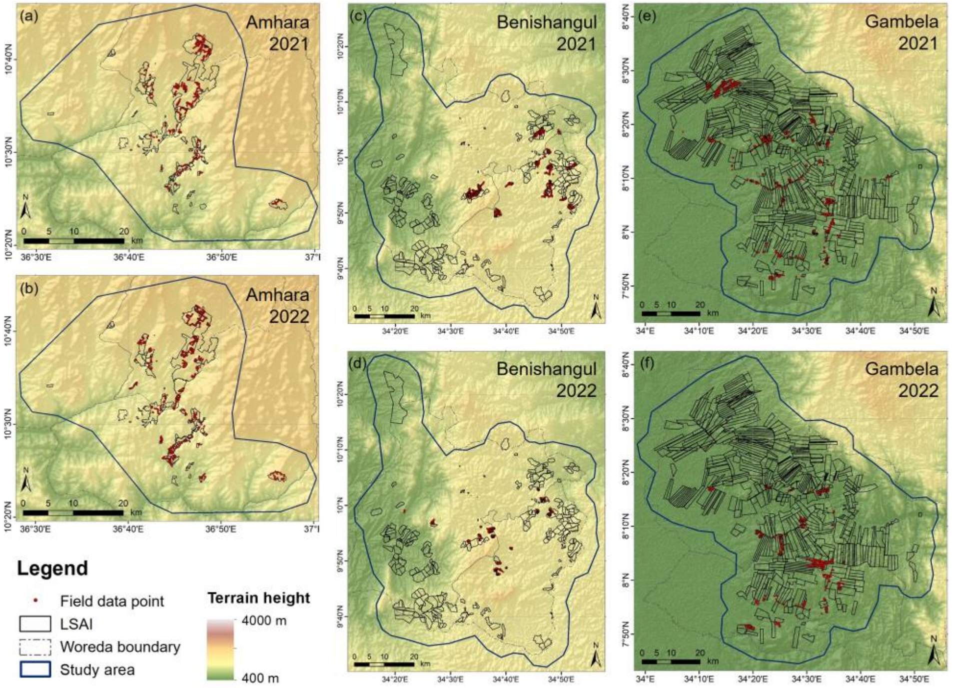
- Field surveys in 2021 and 2022
- Data on 21 different crop types collected

Reference data available for crop type classification in 2021 and 2022

Amhara		
Crop type	2021	2022
Maize	113	233
Sunflower	62	79
Sesame	20	21
Mung bean	27	53
Soy bean	75	128
Haricot bean	37	20
Pepper	29	22
Chickpea	25	-
Wheat	63	99
Coffee	74	92
Teff	16	22
Finger millet	21	13

Benishangul		
Crop type	2021	2022
Maize	169	180
Sorghum	293	183
Sesame	19	-
Mung bean	3	-
Soy bean	157	63
Groundnut	17	-
Haricot bean	2	-
Pepper	100	199
Mango tree	22	66
Teff	24	20
Niger seed	29	48
Flax seed	1	-

Gambela		
Crop type	2021	2022
Maize	39	102
Sorghum	25	36
Sesame	-	19
Mung bean	721	394
Soy bean	-	87
Cotton	350	215
Mango tree	-	23

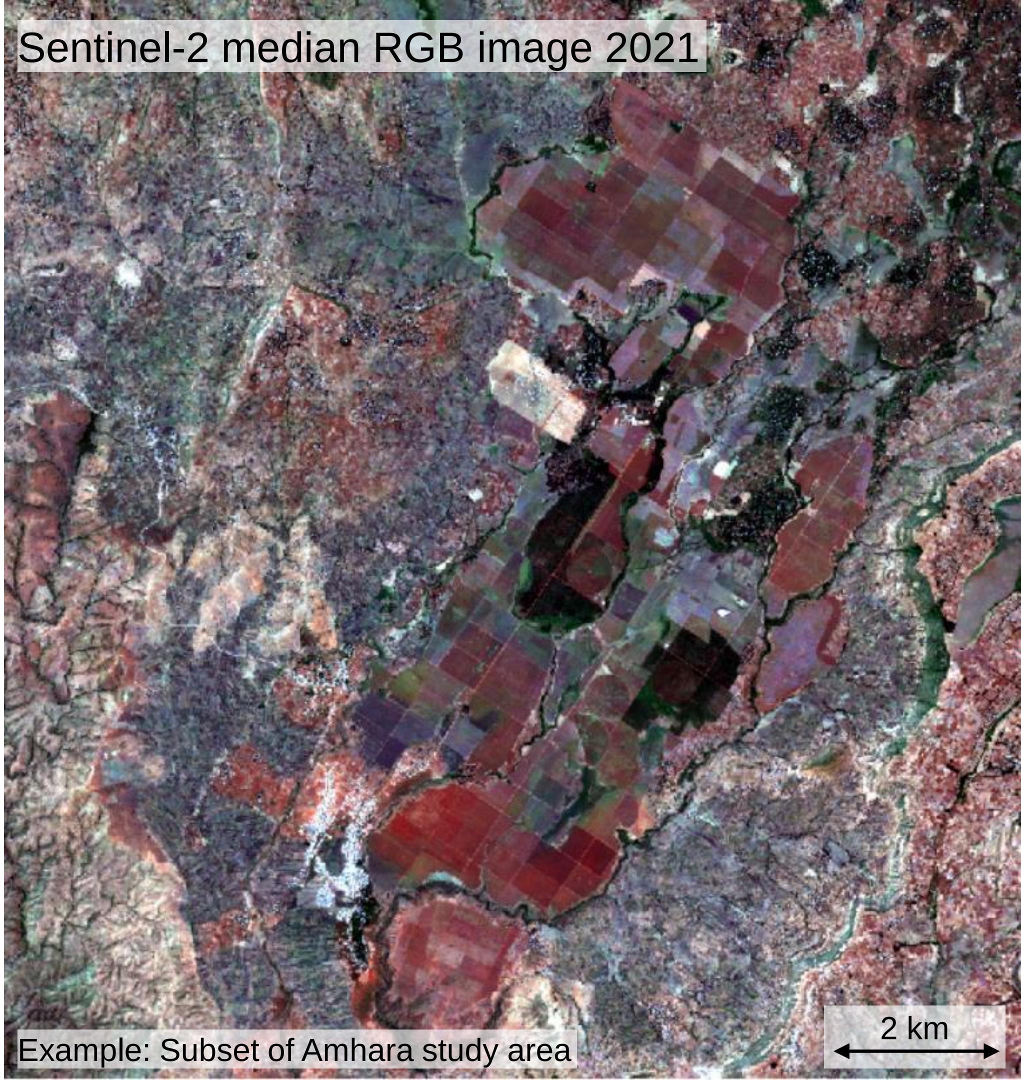


Locations of field data collected during the field campaigns in 2021 and 2022

Source: Eisfelder et al. 2024

Classification: Data base

- High-resolution remote sensing time-series data
  - Multispectral: Sentinel-2
  - Radar: Sentinel-1
- Slope information from elevation data
- Generation of selected spectral and temporal metrics
- Random forest classifier
- Classification results have spatial resolution of 10 m

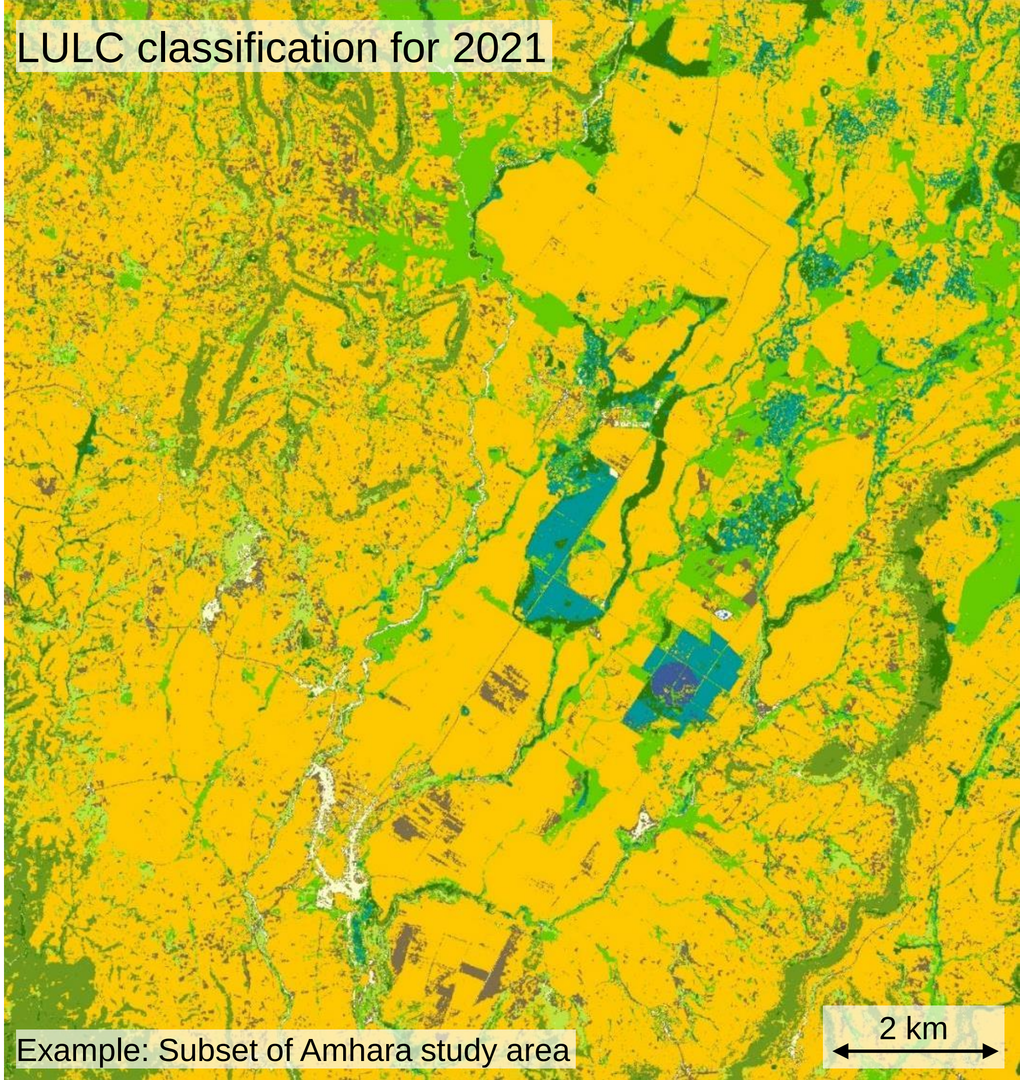


Classification: Cropland

- Classification of land use / land cover (LULC) classes
- Identification of cropland areas
- Mapping of tree plantations

Step 1: LULC

- Tree Cover
- Grassland or wetland
- Cropland
- Bare or built-up area
- Water
- Shrubland
- Sparse vegetation
- Fallow cropland
- Tree plantation
- Plantation



Classification: Crop Types

- Differentiation of crop types within cropland areas
- Field data on crop types required as input information

Step 1: LULC → **Step 2: Crop types**

Step 1: LULC

- Tree Cover
- Grassland or wetland
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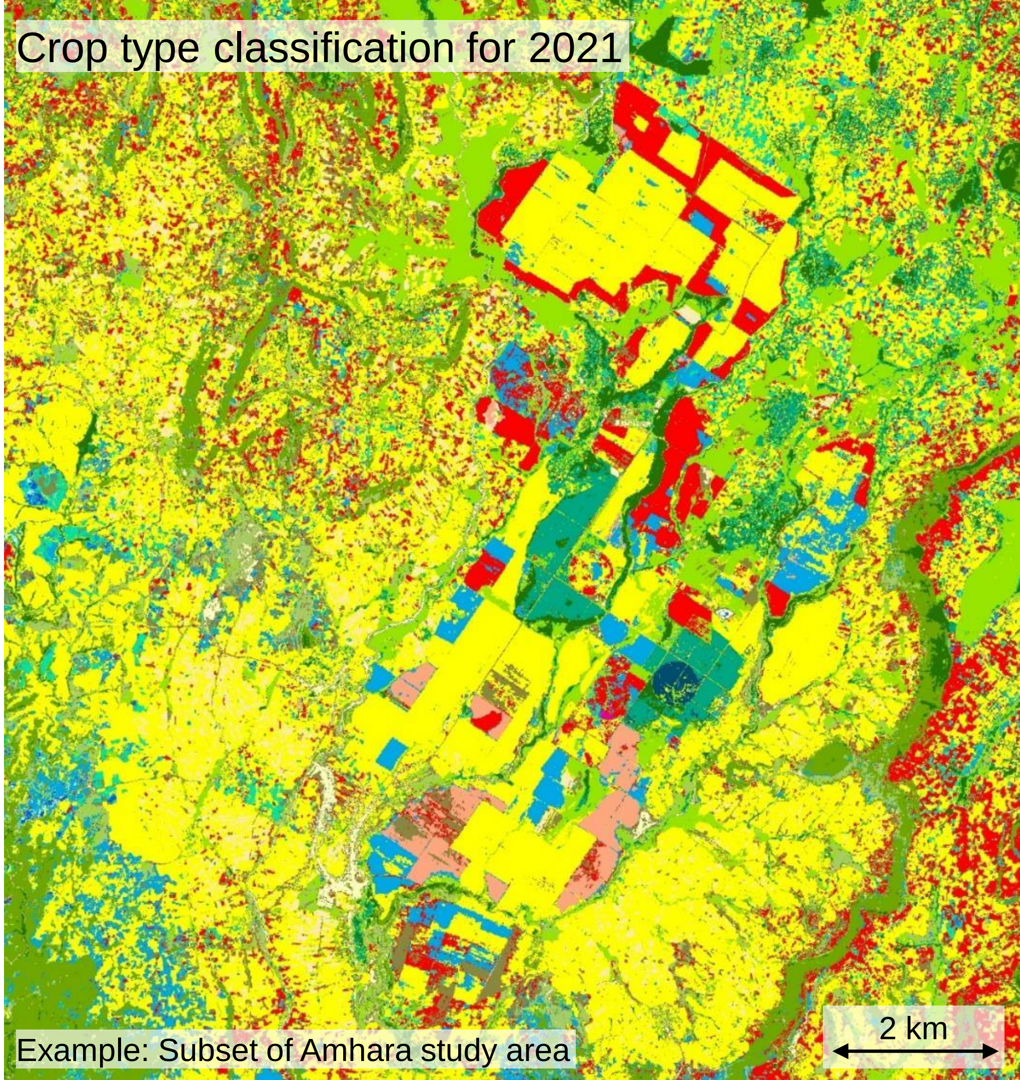
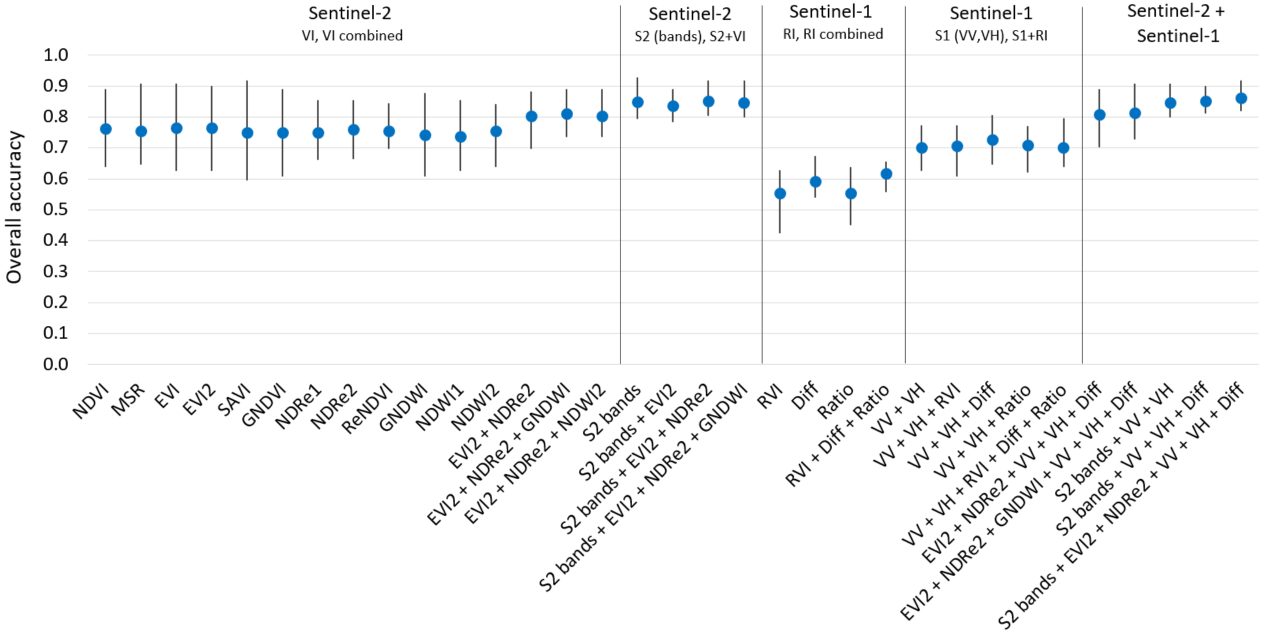
Step 2: Crop types

- Maize
- Sunflower
- Sesame
- Mung bean
- Soya bean
- Haricot bean
- Pepper
- Chickpea
- Wheat
- Teff
- Finger Millet



Results: Input data set comparison for crop type classification

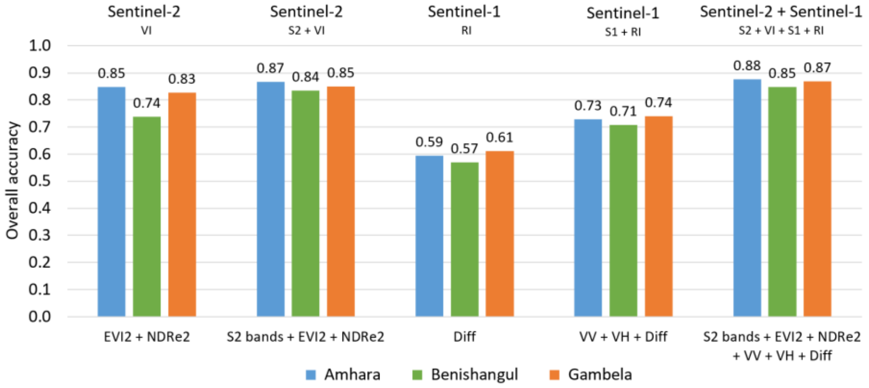
- 33 input data set variants tested for crop type classification for the three study areas and two years of investigation



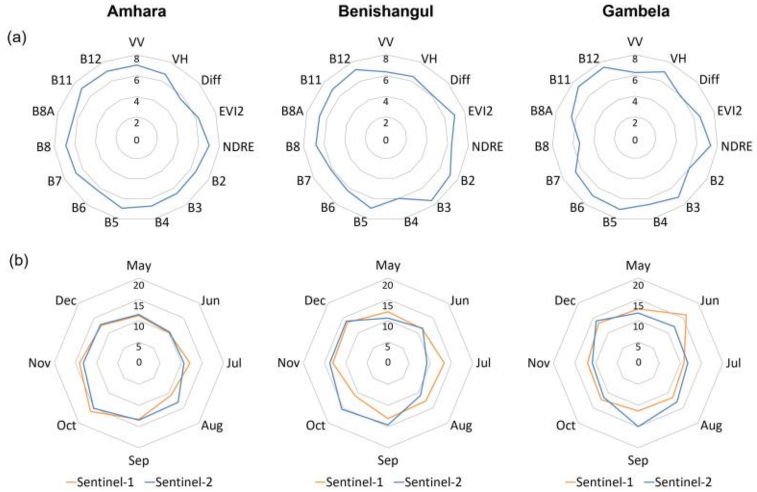
Source: Eisfelder et al. 2024

Results: Input data set comparison and parameter importance

- Sentinel-2 bands allow for high classification accuracy
- Overall highest accuracies for variant that combines Sentinel-2 and Sentinel-1 bands and parameters
- Most important parameters and months differ among study areas



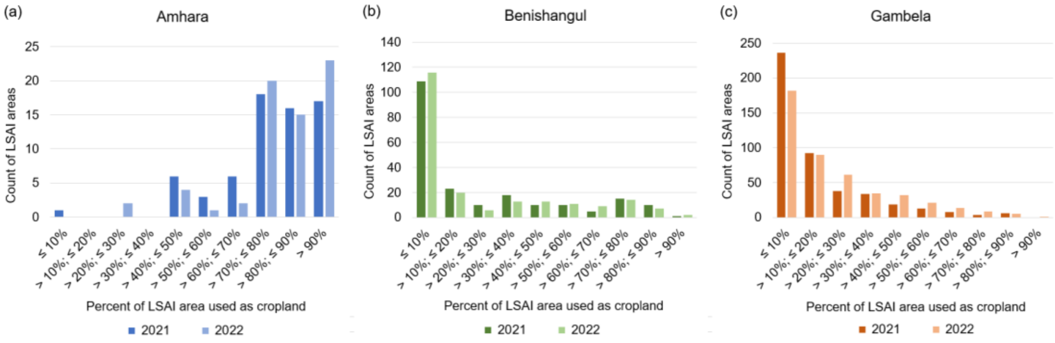
Average overall accuracy for each of the study areas derived with selected variants for the five categories of input features.



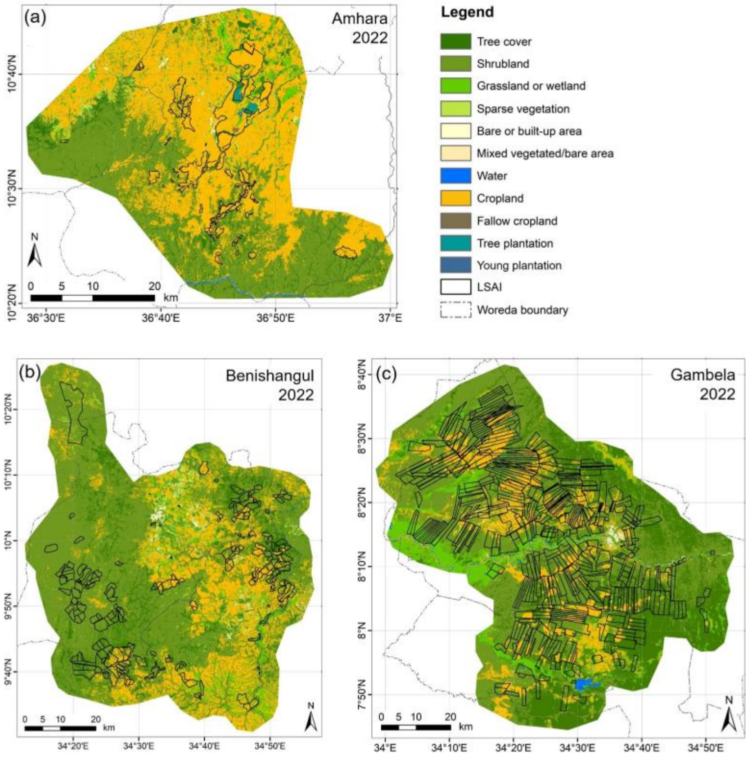
Summed variable importance for selected variant for (a) variables belonging to one band/index/parameter and (b) variables from the same month, separated for Sentinel-1 and Sentinel-2.

Results: Cropland classification

- Amhara: ~80% of land within LSAI areas used as cropland in 2021 and 2022
- Benishangul and Gambela: only 17-21% of land within LSAI areas used as cropland
- → Great potential for further cropland development in Benishangul and Gambela study areas



Count of LSAI areas with a defined percentage range of area used as cropland



LULC classification results for the year 2022

Accuracies for the cropland classifications

	Amhara		Benishangul		Gambela	
	2021	2022	2021	2022	2021	2022
Producer's accuracy [%] for cropland class	95.7	96.4	90.7	87.5	97.9	93.1
User's accuracy [%] for cropland class	90.1	92.6	91.9	90.7	89.5	84.8

Adapted from: Eisfelder et al. 2024

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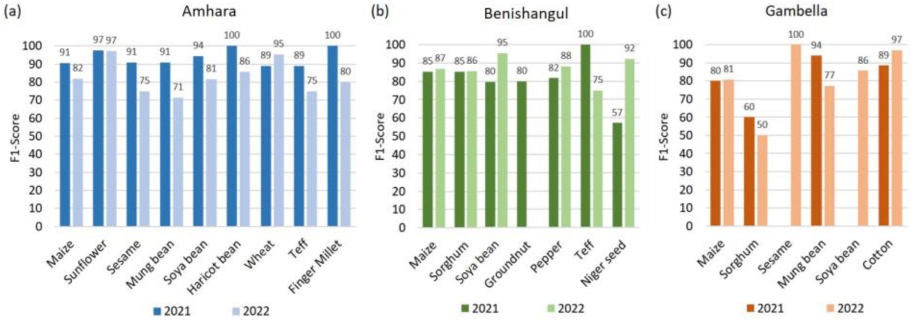
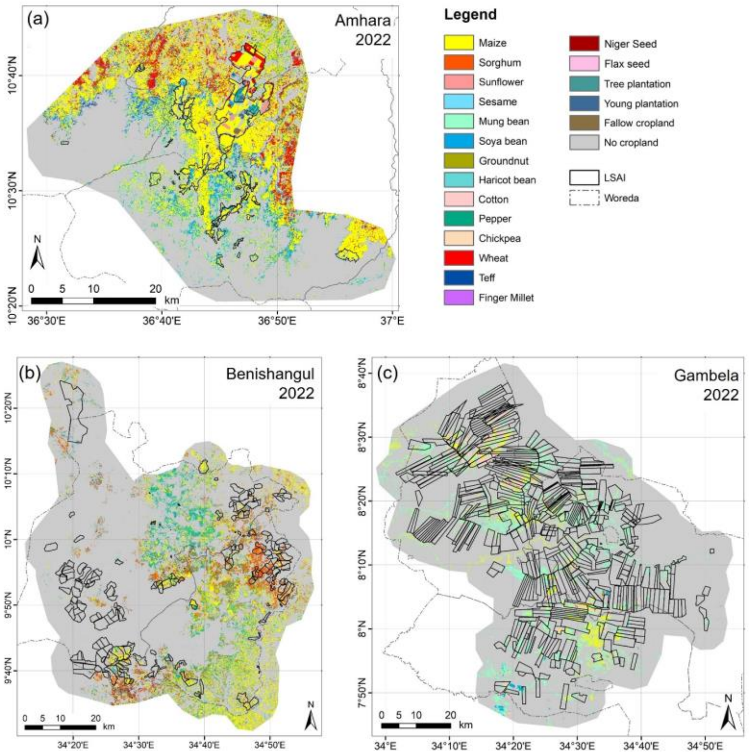
Results: Crop type classification

- Most important crops (cropland area within LSAI area on which crop is grown):
  - Amhara: Maize (~60%), soy bean (~10%), wheat (~8%)
  - Benishangul: Maize (~35-40%), sorghum (~35-40%), soy bean (~10-20%)
  - Gambela: Mung bean (~60%), cotton (~25%)



Class-specific accuracies for the crop type classifications



Crop type classification results for the year 2022

Adapted from:
Eisfelder et al. 2024

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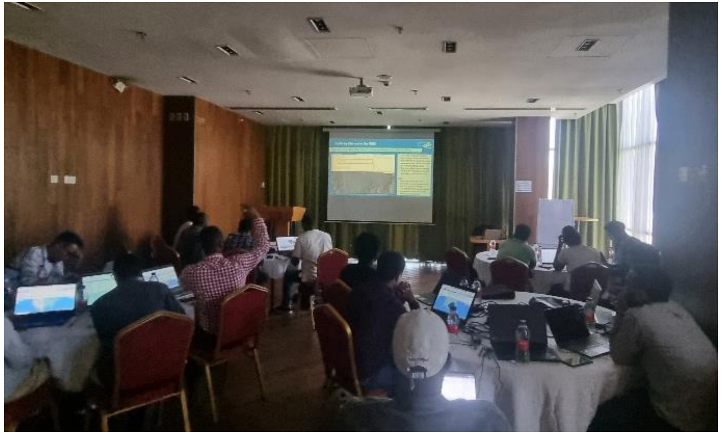
Capacity Building: Training Courses for Regional Experts

- Three days training in 2022 (18 participants from three regions) and in 2023 (23 participants from five regions)
- Principles of Remote Sensing, cloud processing via Google Earth Engine, applications of land use and crop type classifications



Summary: RS4AIM Project

- Method development for cropland and crop type classification in Ethiopia based on open-source remote sensing data
- Inclusion of Sentinel-2 multispectral and Sentinel-1 radar data time-series for classification
- Classification procedure can be easily adapted to be applied for additional study areas and years
- Cloud processing environment (GEE) allows application without own large computational power and software
- Mapping of cropland and crop types performed for 2021 and 2022 for three study areas in Ethiopia
- Capacity building on remote sensing-based classification for regional experts

Potential Application: Data-driven provision of valuable insights for decision making and optimizing resource management

- **Compliance and risk assessment:** Identification of non-compliance and implementing corrective measures
- **Identification of accurate crop planting distribution:** Basis for yield estimates, market predictions and agricultural revenue generation
- **Land use planning and water management:** Identification of suitable areas, optimizing land allocation and irrigation scheduling
- **Monitoring:** crop health (and pests), weather and farm infrastructure
- Optimization of **supply chain logistics**
- **Investment Decision Support:** Assessment of performance and potential risks

Outlook

- Investors and governments can gain a comprehensive understanding of operations, leading to improved productivity, sustainability, and informed decision-making throughout the investment lifecycle.
- Monitoring and evaluation tool under conditions of scarce resources (costly field visits, etc.)
- GEE source code is delivered to be utilized for further interventions
- RS data used is global and open source, and site-specific parameter can easily be adjusted

→ ***RS4AIM application in other geographical settings***

- Integration of RS4AIM with the Commercial Agriculture Management Information System (CAMIS)

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