

Mapping Crop Types and Cropping Systems in Nigeria with Sentinel-2 Imagery

Esther Shupel Ibrahim 1,2,3,*, Philippe Rufin 1,4,7, Leon Nill 1, Bahareh Kamali 2,5, Claas Nendel 2,6,7 and Patrick Hostert 1,7

1 Geography Department, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany; philippe.rufin@geo.hu-berlin.de (P.R.); leon.nill@hu-berlin.de (L.N.); patrick.hostert@geo.hu-berlin.de (P.H.)

2 Leibniz Centre for Agricultural Landscape Research, Eberswalder Straße 84, 15374 Müncheberg, Germany; bkamali@uni-bonn.de (B.K.); Claas.Nendel@zalf.de (C.N.)

3 National Centre for Remote Sensing, Jos. Rizek Village Jos Eat LGA, P.M.B. 2136, Jos, Plateau state, Nigeria

4 Earth and Life Institute, Université catholique de Louvain, Place Pasteur 3, 1348 Louvain-la-Neuve, Belgium

5 Institute of Crop Science and Resource Conservation, University of Bonn, Katzenburgweg 5, 53115 Bonn, Germany

6 Institute of Biochemistry and Biology, University of Potsdam, Am Mühlenberg 3, 14476 Potsdam, Germany

7 Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany

Reliable crop type maps from satellite data are an essential prerequisite for quantifying crop growth, health, and yields. However, such maps do not exist for most parts of Africa, where smallholder farming is the dominant system. Prevalent cloud cover, small farm sizes, and mixed cropping systems pose substantial challenges when creating crop type maps for sub-Saharan Africa (SSA). In another vain, Africa has been underlined as one of the most vulnerable continents to climate change. In many regions of Africa, severe cases of pest and crop diseases are linked to the negative impacts of climate change such as rising average temperatures and changes in precipitation regimes. The problems are prominent in Nigeria, where rainfed subsistence farming dominates and even only slight changes in climate regimes may largely affect cropping systems.

Using remote sensing data and modeling techniques, related risks may be mitigated in the future, but a deep understanding of the mechanisms behind crop diseases or operational early-warning systems are not in place in Nigeria and most parts of SSA. There is accordingly the need to explore remote sensing data more rigorously and to develop methodologies for detecting and mapping crops affected by critical pest and disease. We here suggest a mapping scheme based on freely available Sentinel-2A/B (S2) time series and very high-resolution SkySat data to map the main crops—maize and potato—and intercropping systems including these two crops for the main crop production region of Nigeria, Jos Plateau. We analyzed the spectral-temporal behavior of mixed crop classes to improve our understanding of inter-class spectral mixing. Building on the Framework for Operational Radiometric Correction for Environmental monitoring (FORCE), we preprocessed S2 time series and derived spectral-temporal metrics (STM) from S2 spectral bands for the main temporal cropping windows. These STMs were used as input features in a hierarchical random forest classification. Secondly, we derived a spatial regression model to assess the distribution of fungal diseases in relation to weather and environmental variables. We assessed four environmental factors to explore spatial dependence, autocorrelation and significance of fungal diseases: elevation, slope, aspect, and land cover, coupled with three weather factors: relative humidity, rainfall and temperature, as well as the concentration densities of fields in the Jos Plateau cropland densities as a proxy for management practices. Increased risk of fungal disease infestations in areas where a susceptible crop densely present, is commonly assumed to occur with daily temperatures $> 21^{\circ}\text{C}$ and is favorable throughout the critical cropping season period (June-July) and frequent episodes of leaf wetness. The latter is a result of either high relative humidity ($>70\%$) or precipitation events, which we use both as proxies. Our crop type mapping resulted in the first wall-to-wall crop type map for this key agricultural region of Nigeria and achieved an overall accuracy of 84% for crop/non-crop discrimination, and 72% for the

five most relevant crop classes (including complex inter-cropping). Plot analyses based on a sample of 1,166 individual fields revealed largely homogeneous mapping patterns, demonstrating the effectiveness of our classification system also for intercropped classes, which are temporally and spatially heterogeneous. Moreover, we found that small field sizes (75% of fields smaller than 1 ha) were dominant in all crop types, regardless of whether or not intercropping was used. Our study offers guidance for creating crop type maps for smallholder-dominated systems with intercropping and underpins the importance of understanding critical temporal windows and related STMs for crop type differentiation and disease mapping. The study supports future smart agricultural practices related to food security, early warning systems, agricultural policies, and extension services.