

1- Introduction

Food and agriculture are key to African livelihoods and to the Water-Energy-Food-Ecosystem nexus. In the Senegal River Basin (SRB), the main challenge for water management and rural development lies in the Sahel Valley. Since 1960, irrigation has been developed in the valley to diversify agricultural livelihoods and to cope with the drought of the 1970s and 80s. With the future construction of dams and reservoirs in the coming decades, it is important to assess their impact on the WEFE nexus. As the SRB is a transboundary watershed, it is difficult to obtain official data on irrigated agricultural land. It should be noted that not all agricultural livelihoods are monitored by official services. This is particularly the case with flood recession agriculture (FRA), which is based on the use of floodwater as a resource.

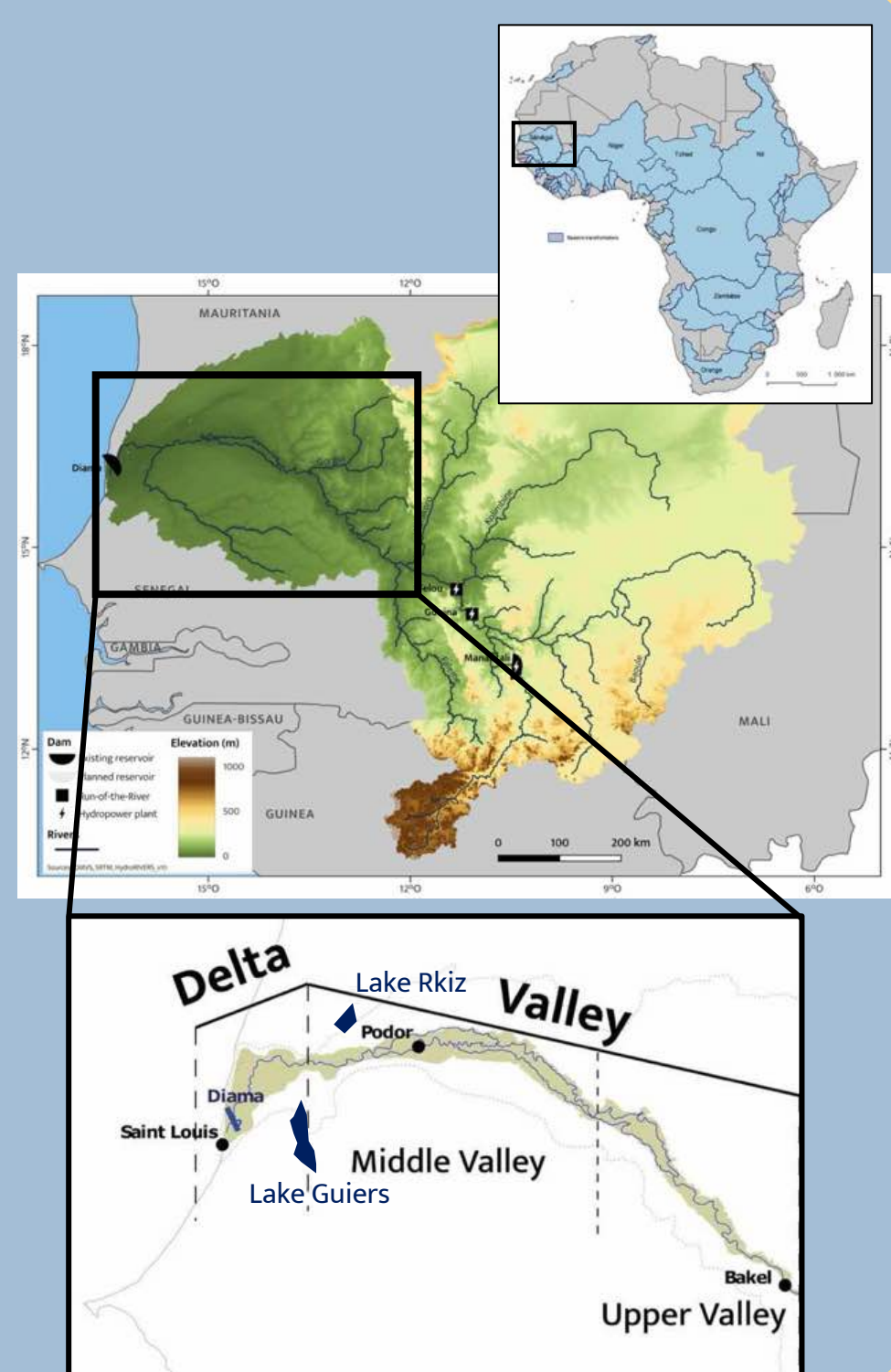
To fill this gap, it is necessary to monitor and map the diversity of agricultural systems, especially irrigated ones. To this end, we propose a reproducible framework for mapping seasonal irrigation and flood recession agriculture in the Senegal River valley and delta, based on EO data and the use of a deep learning algorithm.

2- Study area

The Senegal River Basin, located in West Africa, represents a critical watershed within the region. The valley and delta are situated downstream within a flat Sahelian floodplain, which covers an area of over one million hectares. The floodplain has supported food needs for centuries through fishing, farming, and grazing. The area is shared between Senegal and Mauritania, and numerous irrigated schemes, primarily for rice farming, have been established or are under development.

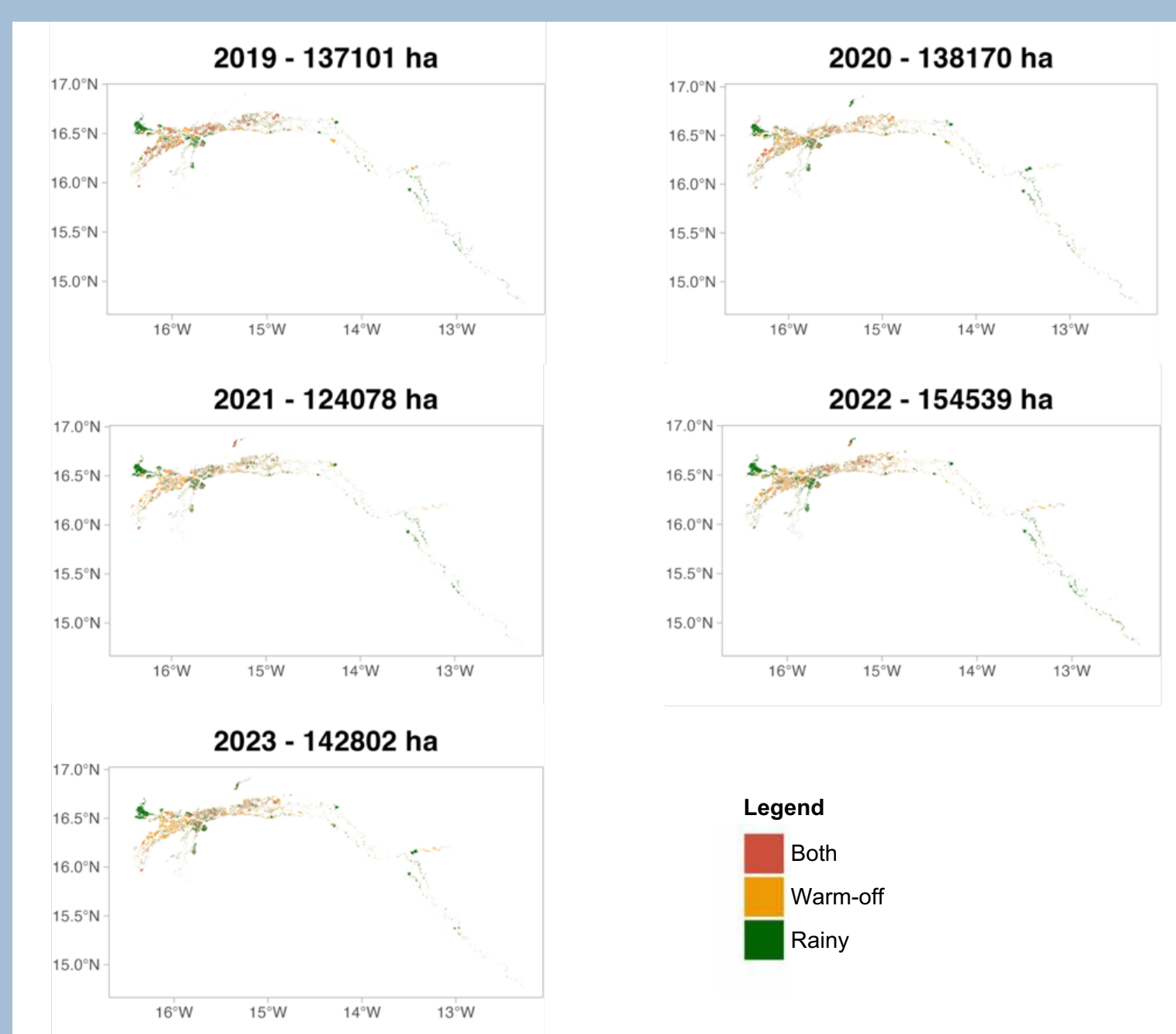
Flood recession farming has been the predominant agricultural system for centuries, with sorghum as the main crop. However, this system is now facing increasing constraints and is not found in the Delta.

The agricultural rainy and flood season occurs from August to February, while the warm-off (dry) season runs from March to June.

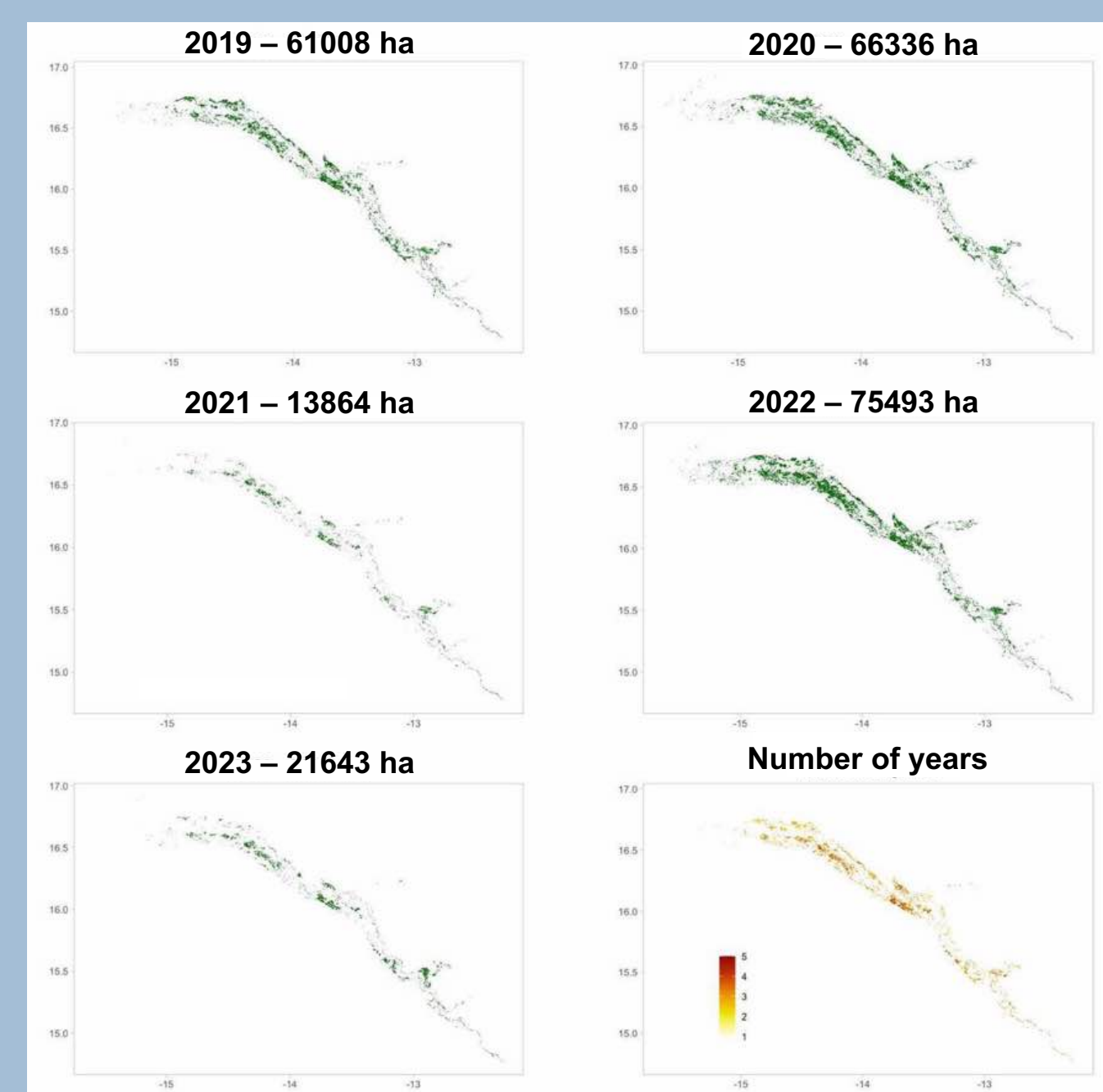


4- Results

Agricultural pattern over Senegal Valley and Delta



Irrigated agriculture in Senegal River Valley and Delta



Flood-recession agriculture in Senegal River Valley

3- Methods

Index images construction

- Mask clouding with GEE Sentinel-2 Cloud Probability product
- Sentinel-1 GRD is already preprocessed inside GEE
- Images available since 2019 for our study area

Optical and radar indices based on the detection of water, humidity, vegetation, soil and texture:

Index	Composante	Source
MNDWI	Water	Xu, 2006
NDMI	Moisture	Gao, 1996
BSI	Bare soil	Rikimaru et al. 2002
NDVI	Vegetation	Rouse et al., 1973
MSAVI	Adjusted Vegetation	Qi et al., 1994
NDRE	Red Edge	Barnes et al., 2000
VV/VH	Surface texture and roughness	Slatger et al., 2020



Analysis of Sentinel-1 GRD and Sentinel-2 MSI images on Google Earth Engine

Season 1
(Warm-off – March to July)

- Over 3600 optical index images
- Over 700 radar images

Season 2
(Rainy and Flood Recession – August to February)

- Over 4500 optical index images
- Over 1000 radar index images

Seasonal composite image

(Mean, Min, Max, StdDev, Skew, Kurtosis)
One seasonal image with 36 bands (9 indexes and 6 reducers)

ROIs dataset

3770 points over 8 land cover classes

Classification

Per season, per year

Regions of Interest Sampling

Based on high resolution images (Google Earth) and RGB Images from Sentinel-2 in 2019

Land cover	Number
Warm-off irrigation	450
Rainy season irrigation	600
Flood-recession agriculture	675
Forest	620
Other vegetation	160
Bare soil	675
Wetlands uncultivated	400
Water	190

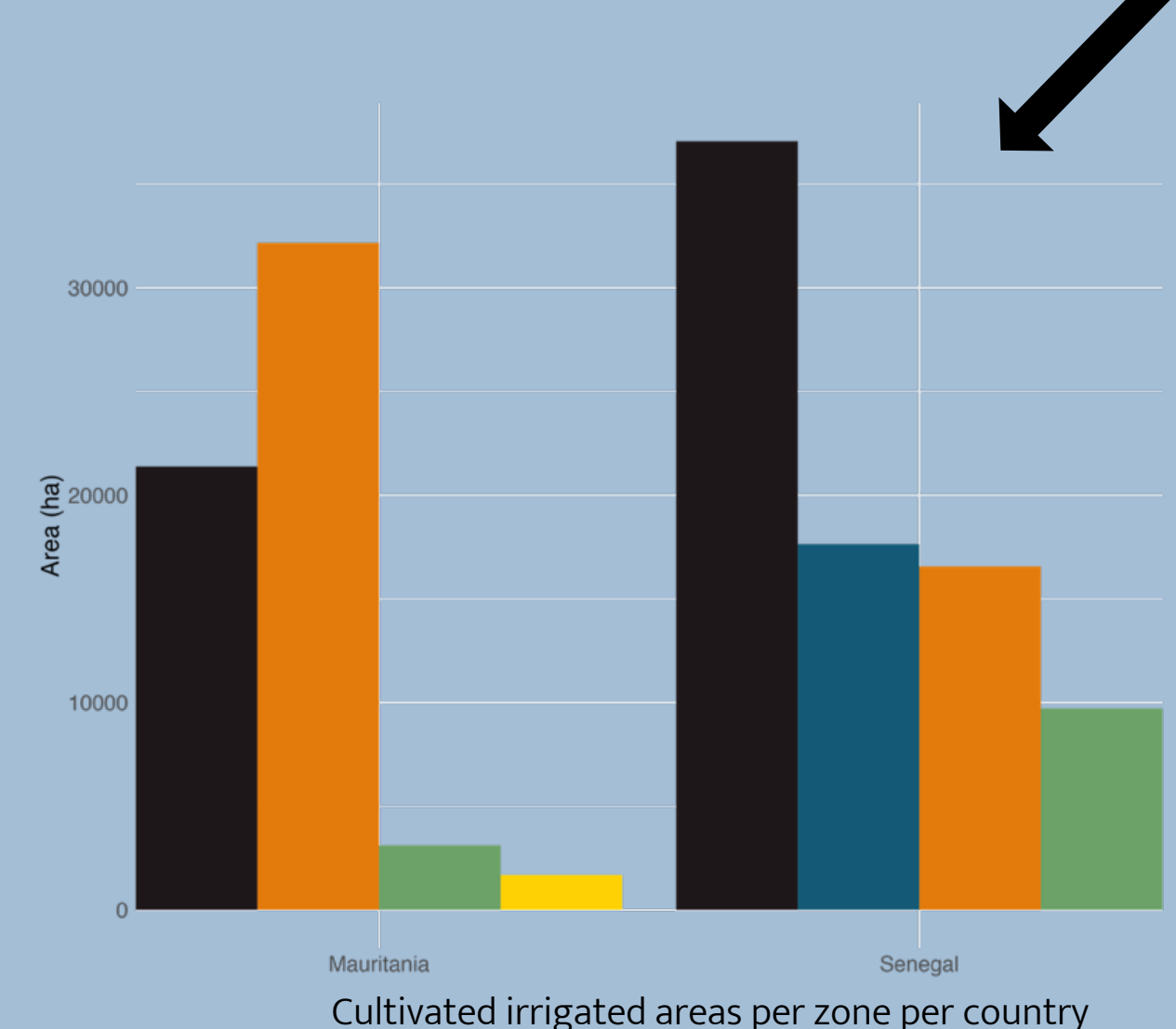
Random Forest Algorithm

Classification conducted for the year 2019 and subsequently applied to the years 2020 to 2023.

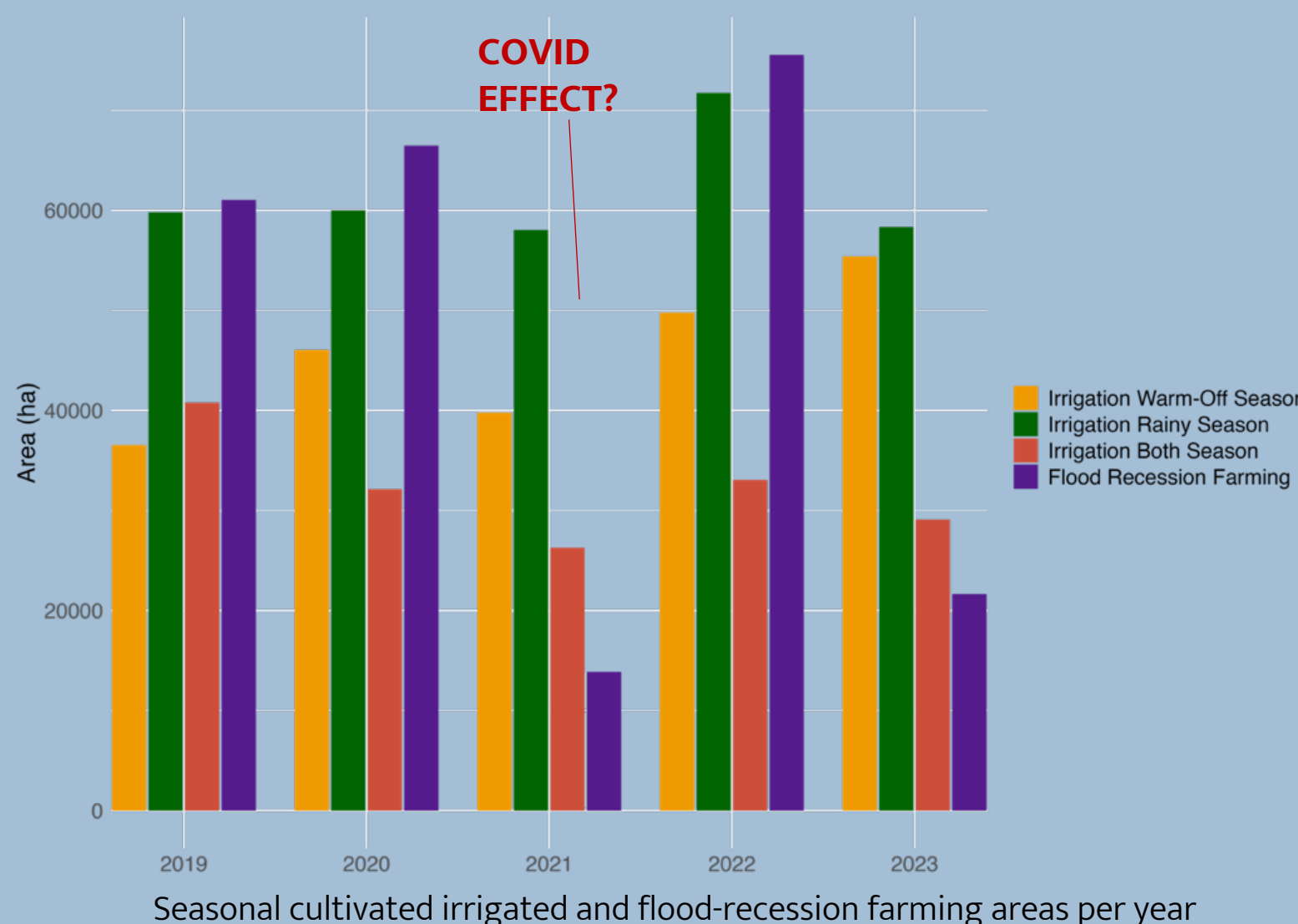
➔ Overall accuracy is good

➔ Accuracy is better during the warm-off season due to less diversified land cover, especially in terms of very sparse vegetation (except for forests and irrigated areas).

Accuracy	Warm-Off Season	Rainy and Flood Season
Training	99,7	99,6
Validation	94,4	90,9
Kappa	91,8	88,8



Cultivated irrigated areas per zone per country



Seasonal cultivated irrigated and flood-recession farming areas per year

➔ In Senegal, irrigated areas are mainly found in the delta and around Guiers Lake

➔ In Mauritania, irrigation is shared between the delta and the Kaedi area in the upper valley

➔ Irrigation is more important during the rainy season

➔ Flood-recession farming is highly variable depending on annual flood level

Irrigation in Senegal Valley and Delta versus official data

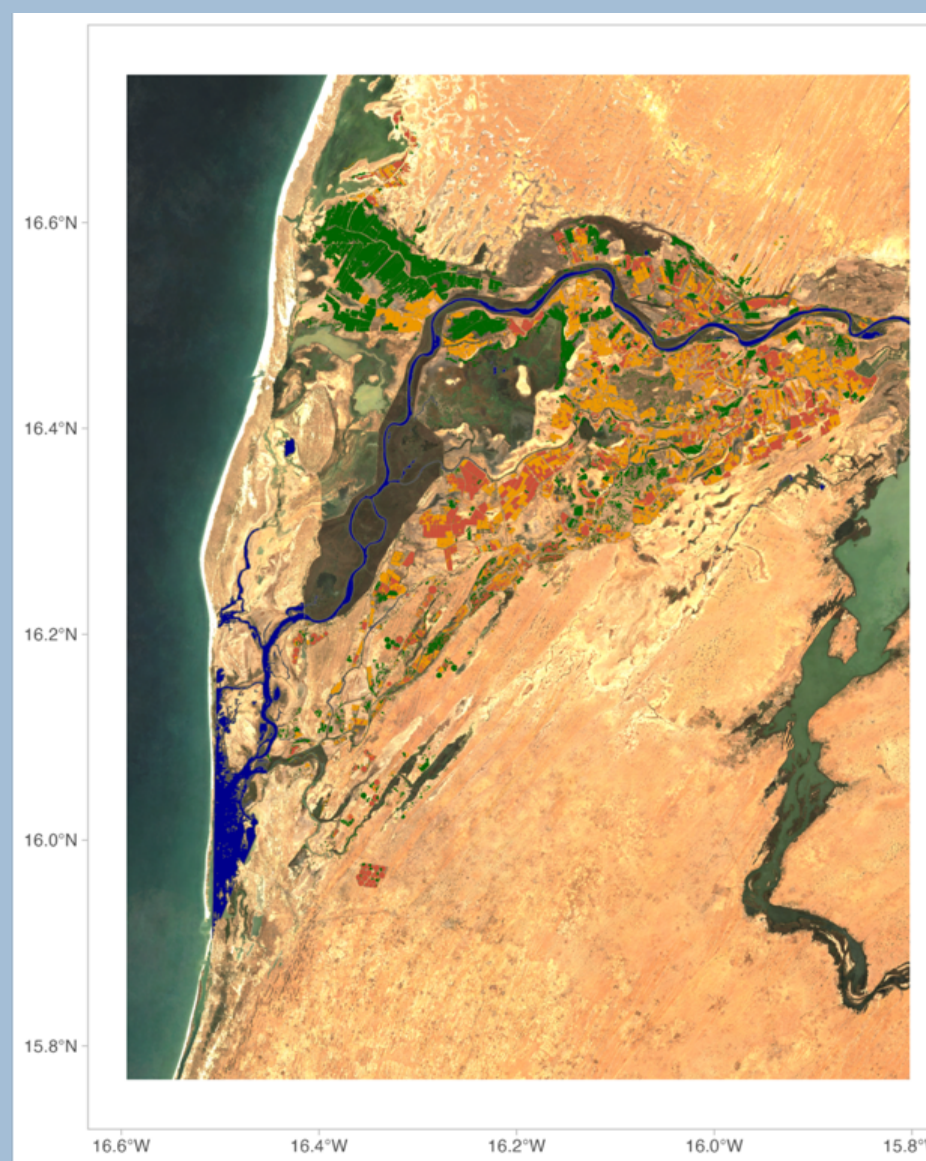
Year	Warm-Off Season cultivated areas (ha)	Official data for Senegal (SAED)	Rice production (kT)	Rainy Season cultivated areas (ha)	Official data for Senegal (SAED)	Rice production (kT)	Annual rice production (kT)
2019	45 333	46 500 (=)	240	56635	35 300 (-)	311	551
2020	48 895	50 400 (=)	268	55 037	36 497 (-)	302	570
2021	39 784	43 856 (+)	218	45 010	28 494 (-)	247	465
2022	47 977	No data	263	45 016	No data	247	510
2023	52 352	No data	287	47 745	No data	262	549

Comparison between EO data (this study) and official data in Senegal (data from SAED). Rice production estimation is based on an average yield of 5,5 t/ha

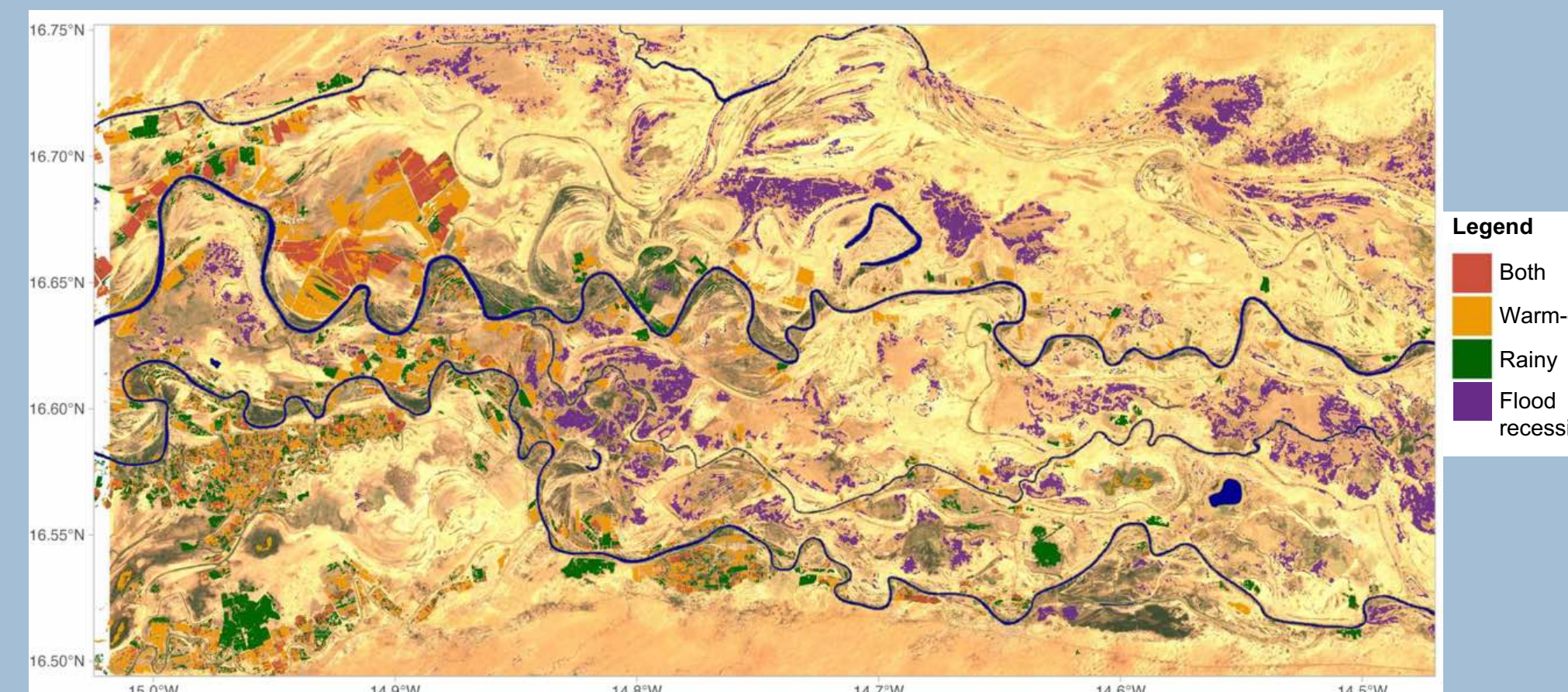
➔ Comparison is appropriate for the warm-off season, but EO data are higher than the official data for the rainy season

➔ Annual rice production of SRV and Delta is approximately 500kT

Agricultural land cover in two focus areas in 2020



Irrigated agriculture in Senegal Delta



Irrigated agriculture and flood-recession farming over Podor and Ndoum area in SRV

➔ Delta has larger irrigated perimeters
➔ Diversification of irrigated agriculture is more important in the Valley than Delta, with existence of FRA

5- Conclusion

- This is the first large-scale valley and delta map of seasonal irrigation, with a particular focus on flood-recession agriculture.
- EO data supports mapping and monitoring irrigation-related agricultural land cover in Sahel. Random Forest is an effective tool for spatial data on irrigation and FRA, with calibration data (ROIs) being a key step.
- Findings show varied development and use of irrigated areas, with a concentration in certain zones, like Delta or Guiers Lake. FRA surface area also fluctuates significantly year to year, due to hydrological variability.

