1ST LIAISE CONFERENCE AND DETERMINING EVAPOTRANSPIRATION CROSSCUT WORKSHOP

MAR 27 - 29, 2023 | LLEIDA, SPAIN

Classification of Different Irrigation Systems at Field Scale Using Annual Time-Series of Remote Sensing Data

Giovanni Paolini[1,3], Maria Jose Escorihuela[1], Olivier Merlin[2], Magí Pamies-Sans[3], Joaquim Bellvert[3]

[1]isardSAT, Barcelona, Spain / [2]CESBIO, Toulouse, France / [3] IRTA, Lleida, Spain

isardSAT®

IRTA Institute of Agrifood Research and Technology

Introduction

Why obtaining classification maps of irrigation systems?
Mitigating water demands

1. Currently there is no precise/reliable information regarding irrigated area and irrigation systems in Catalonia
2. Replace the simplistic assumption of irrigation scenarios used in many Land Surface Models (LSM). -> reduce uncertainty.
3. Promote and supervise the shift towards more sustainable and efficient irrigation methods. -> optimize water use.

FLOOD

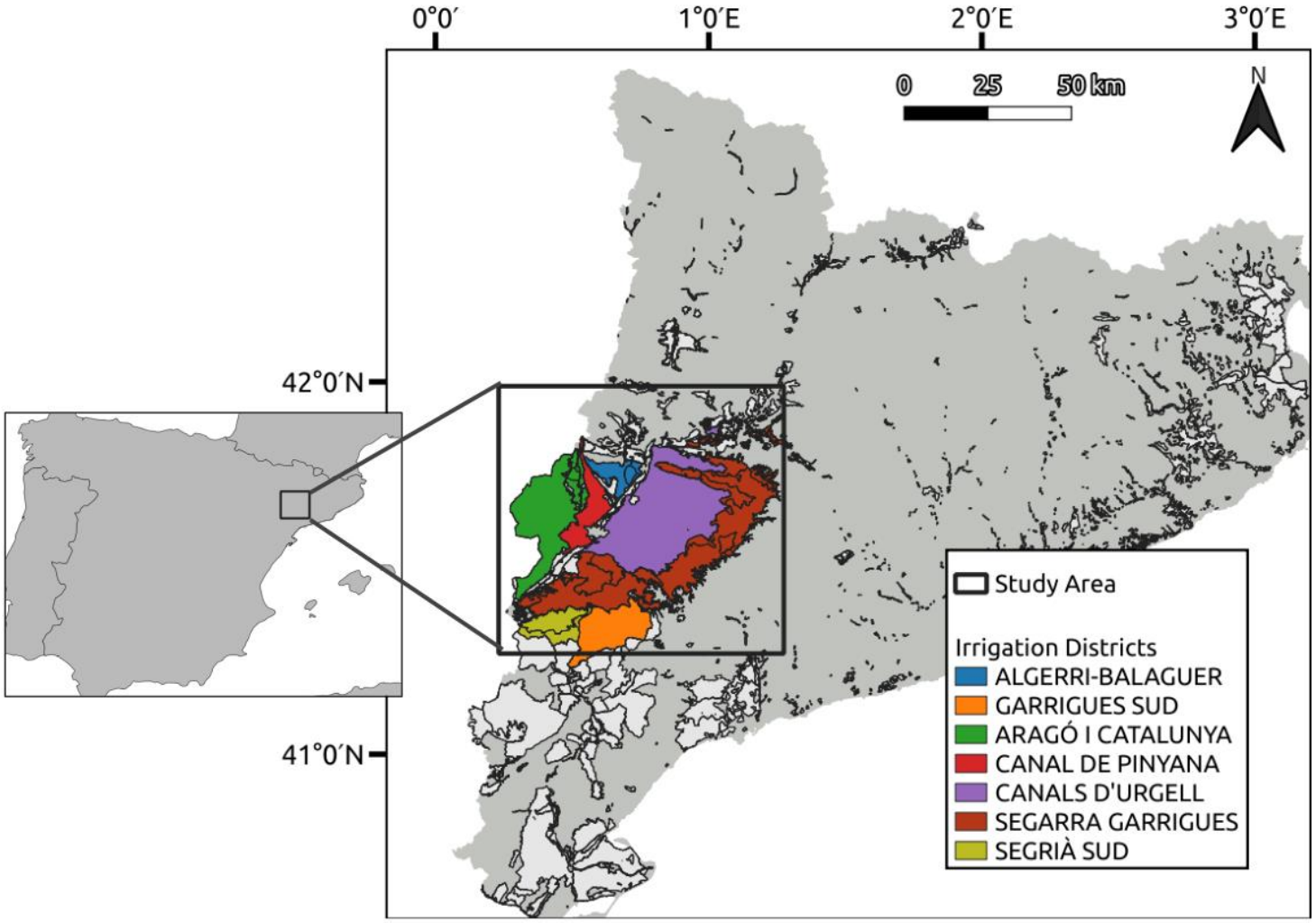
SPRINKLER

DRIP

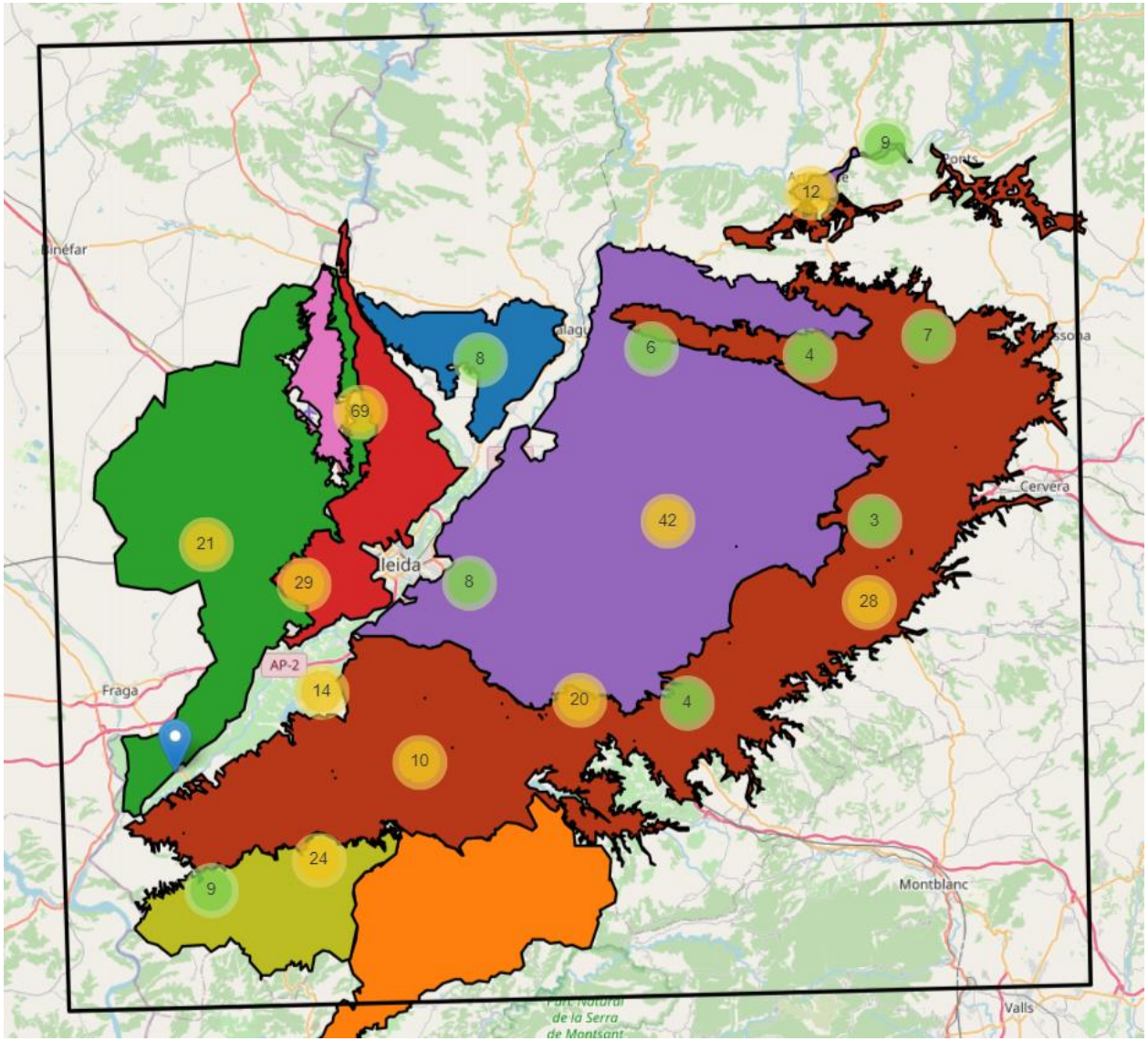
Hypothesis of Study

Temporal series of actual crop evapotranspiration, and surface soil moisture (estimated from remote sensing) should vary among parcels of different irrigation systems

Study Area

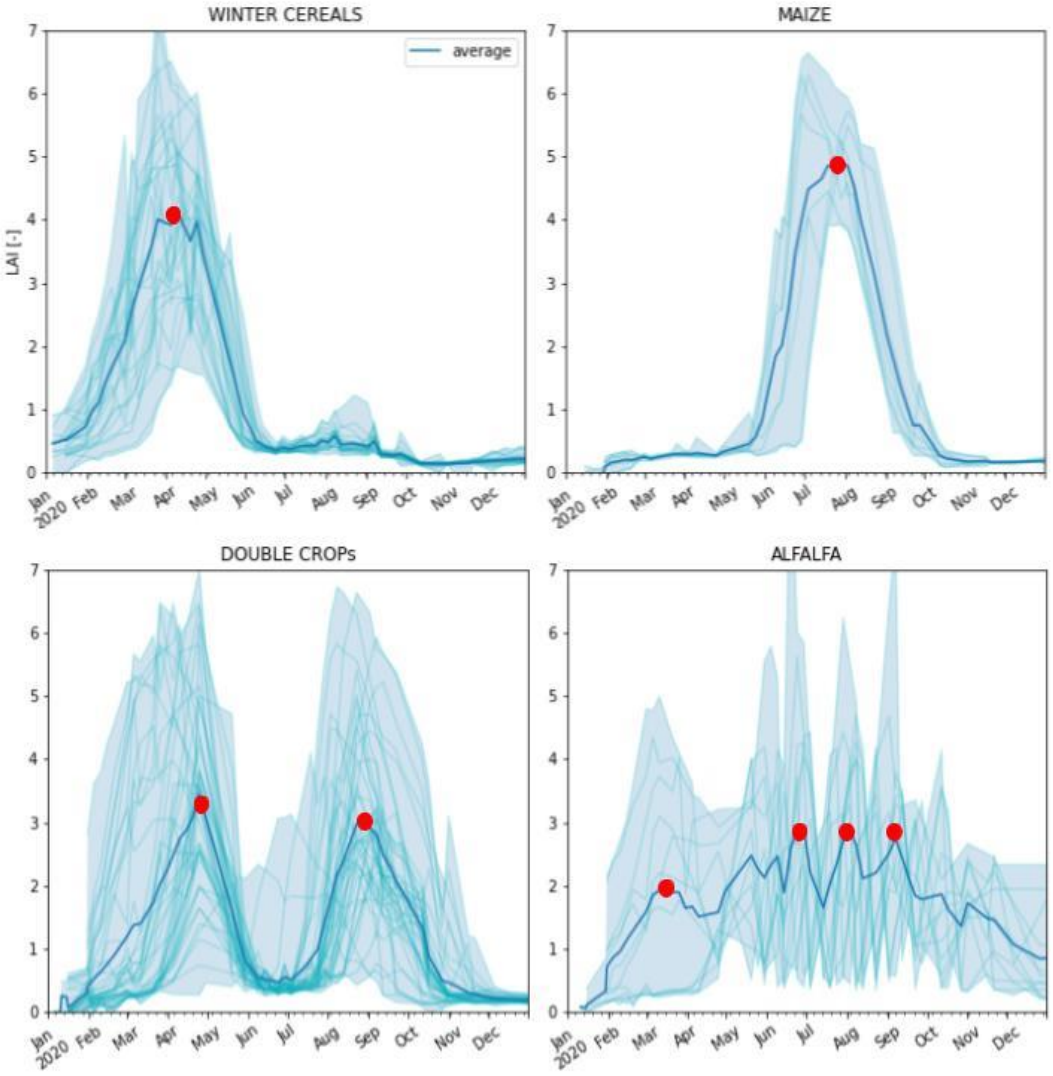

0°0′
1°0′E
2°0′E
3°0′E
42°0′N
41°0′N
0
25
50 km
N
Study Area
Irrigation Districts
ALGERRI-BALAGUER
GARRIGUES SUD
ARAGÓ I CATALUNYA
CANAL DE PINYANA
CANALS D'URGELL
SEGARRA GARRIGUES
SEGRIÀ SUD

Field Campaign - Distribution of Fields



> 300 fields

Field Campaign - Crop Detection



Field Campaign - Number of Fields

IRRIGATION SYSTEM	CROP TYPE	Number of Fields			FIELD LEVEL	PIXEL LEVEL
		2018	2019	2020		
DRIP	FRUIT and NUT TREES	78	78	78	234	24201
	VINEYARD	12	12	12	36	4599
	OLIVE	11	11	11	33	3201
SPRINKLER	MAIZE	8	8	8	24	10950
	DOUBLE CROPS	55	56	56	167	43849
	ALFALFA	7	7	7	21	3777
FLOOD	WINTER CEREALS	9	9	9	27	444
	MAIZE	14	14	13	41	1322
	DOUBLE CROPS	32	33	33	98	5859
	ALFALFA	9	9	9	27	2733
	FRUIT and NUT TREES	18	18	18	54	1734
NOT IRRIGATED	WINTER CEREALS	40	36	40	116	27584
	FRUIT and NUT TREES	13	13	13	39	1578
	VINEYARD	7	7	7	21	867
	OLIVE	17	17	17	51	6231
TOTAL		330	328	331	989	138929

Input ETact

Thermal data: S3 SLSTR

Optical data: S2 MSI

DMS (Data Mining Sharpening with and ensemble of Decision Trees) technique to produce 20m LST from S3 1Km LST and S2 20m VIS channels. Gao et al., 2012

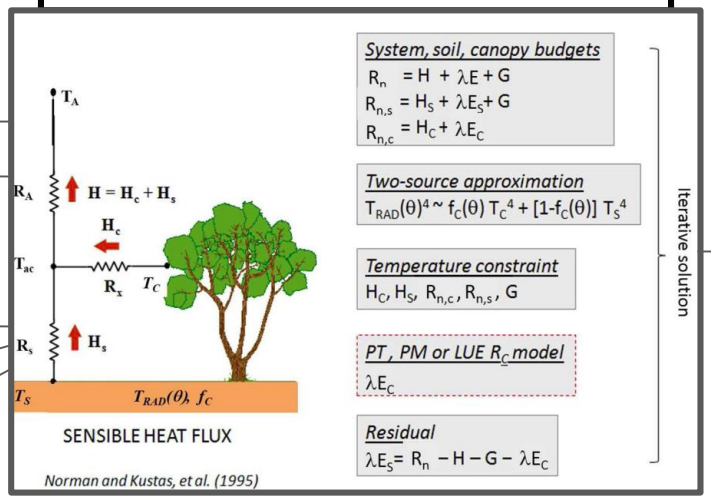
Sharpened 20m LST (S3 + S2)

Meteo Data: ECMWF ERA-5 reanalysis dataset

Land Cover: ESA's Climate Change Initiative land cover map

Elevation: 30m STRM DEM product

Two-source Energy Balance method using Priestley Taylor (PT) model
Kustas and Norman et al., 1995



Actual Instantaneous ET TSEB-PT

Actual Daily ET*

*The ET product is produced by IRTA, in the context of the sen4ET project, with the methodology explained in Guzinski et al., 2020.

Product

Process

Input ETact

Actual daily ET
With GAPS

K_c
Crop coefficient Time-series

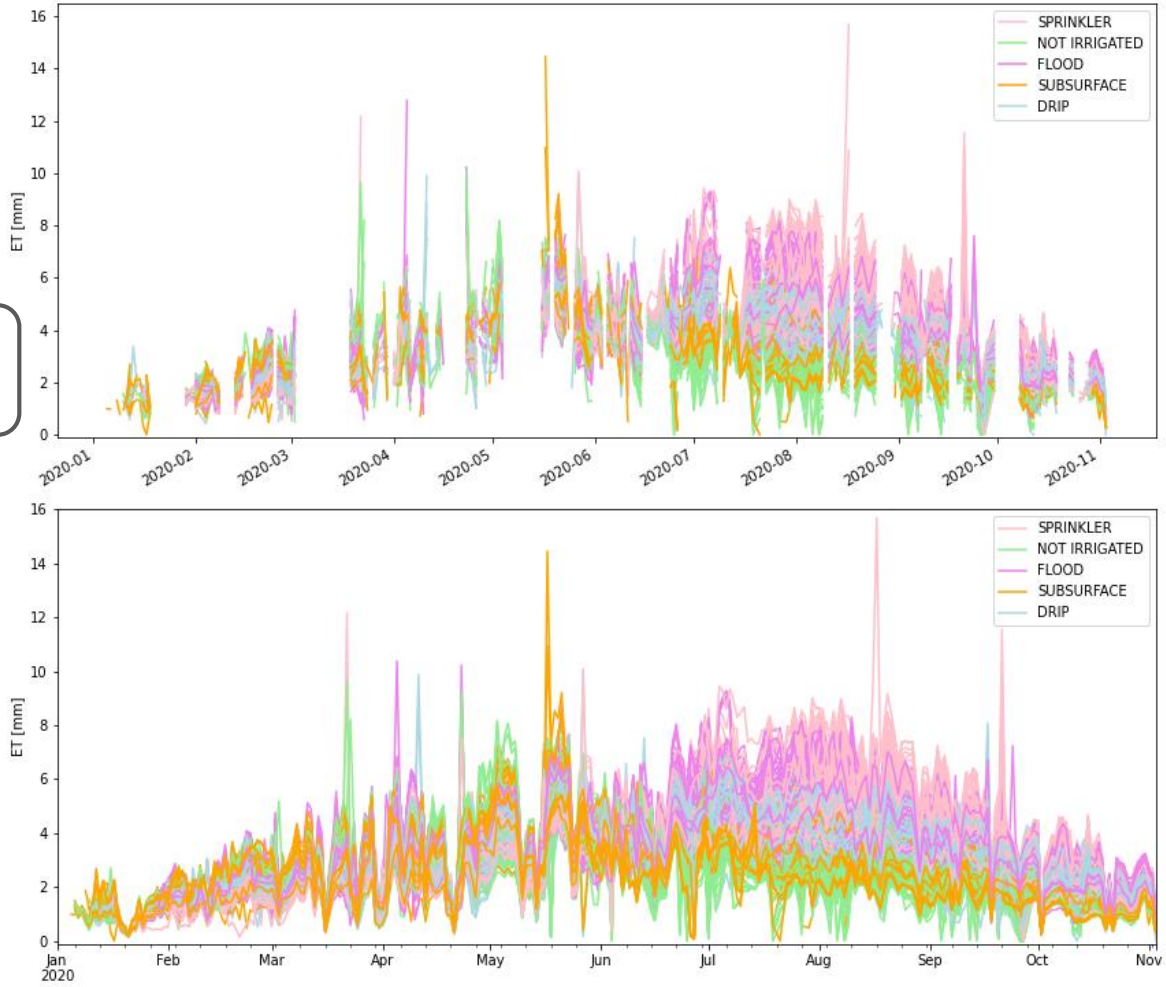
Linear Interpolation of missing days

K_s
Water Stress coefficient Time-series

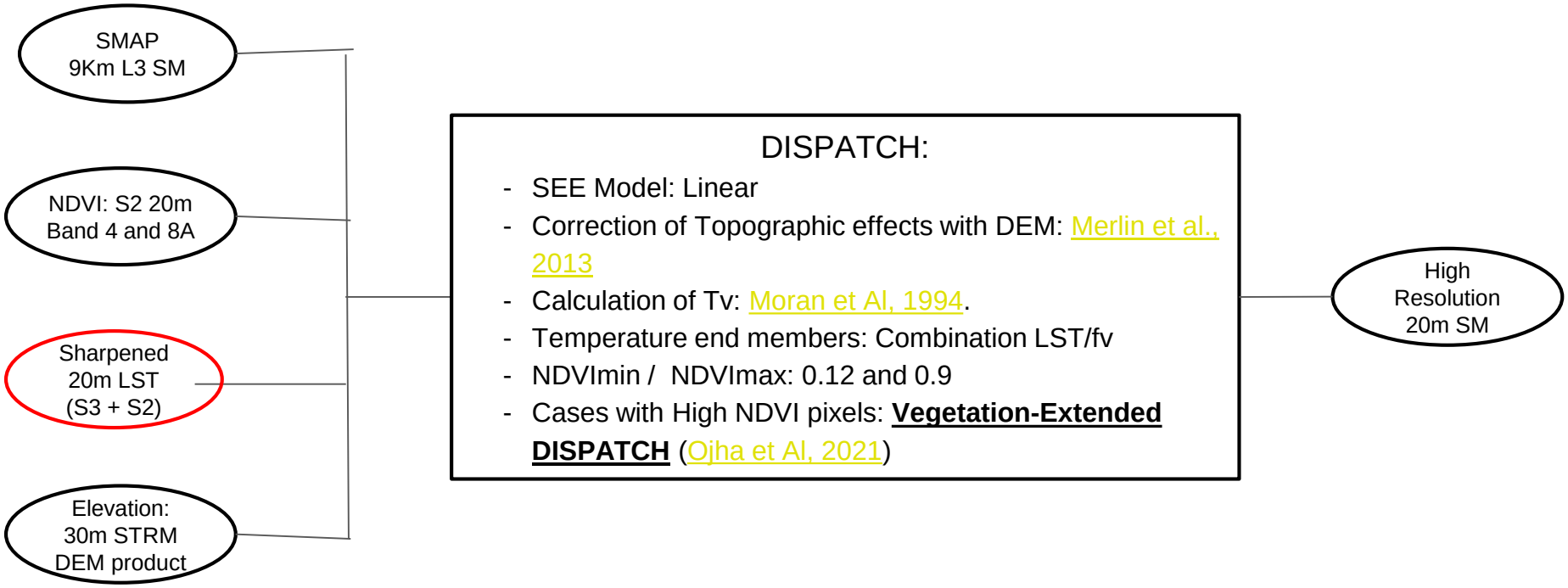
Linear Interpolation of missing days

Daily Reference ET_o:
ECMWF ERA-5 reanalysis dataset

Daily actual ET
Filled



Input Dispatch SM



On going validation of the product with in-situ SM values in different sites in the area...

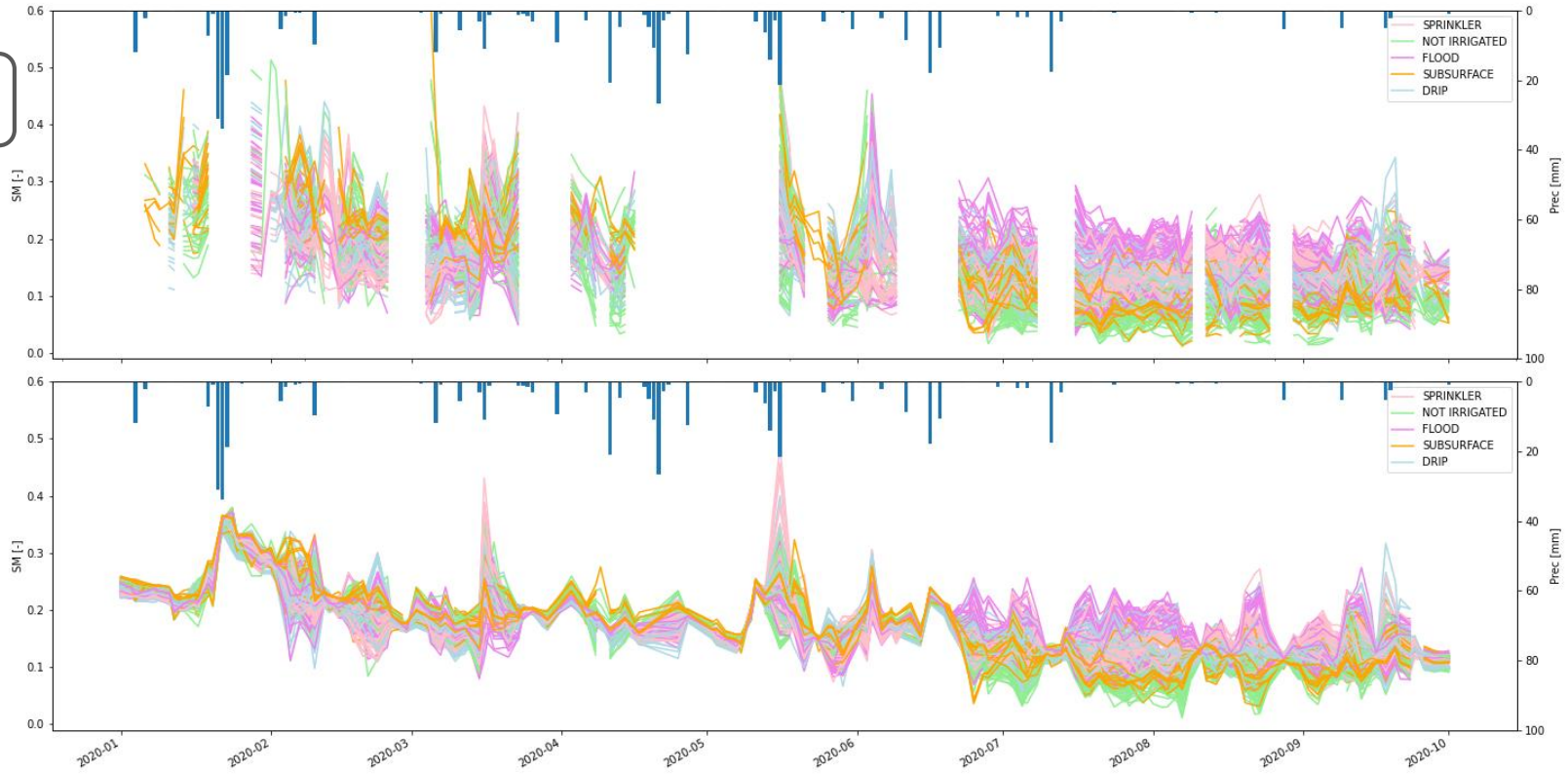
Product
Process

Input Dispatch SM

Dispatch 20m SM
With GAPS

SMAP 9 Km SM

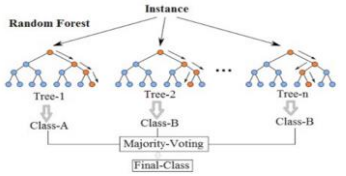
Dispatch 20m SM
Filled



AI models tested

TABLE IV
OVERVIEW OF THE MODELS USED IN THIS STUDY

MODELS	Reason for selection
Time Series Forest	Random forest is widely used in similar research [14]. Used as a benchmark.
ROCKET	State-of-the-art accuracy [39] with low computational requirements.
ResNet	Deep neural network with flexible structure, it outperforms other models in general reviews [40].



ROCKET	
length	$\{7, 9, 11\}$
weights	$\mathcal{N}(0, 1)$
bias	$\mathcal{U}(-1, 1)$
dilation	random
padding	random

Convolutional neural network

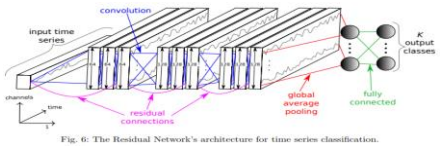


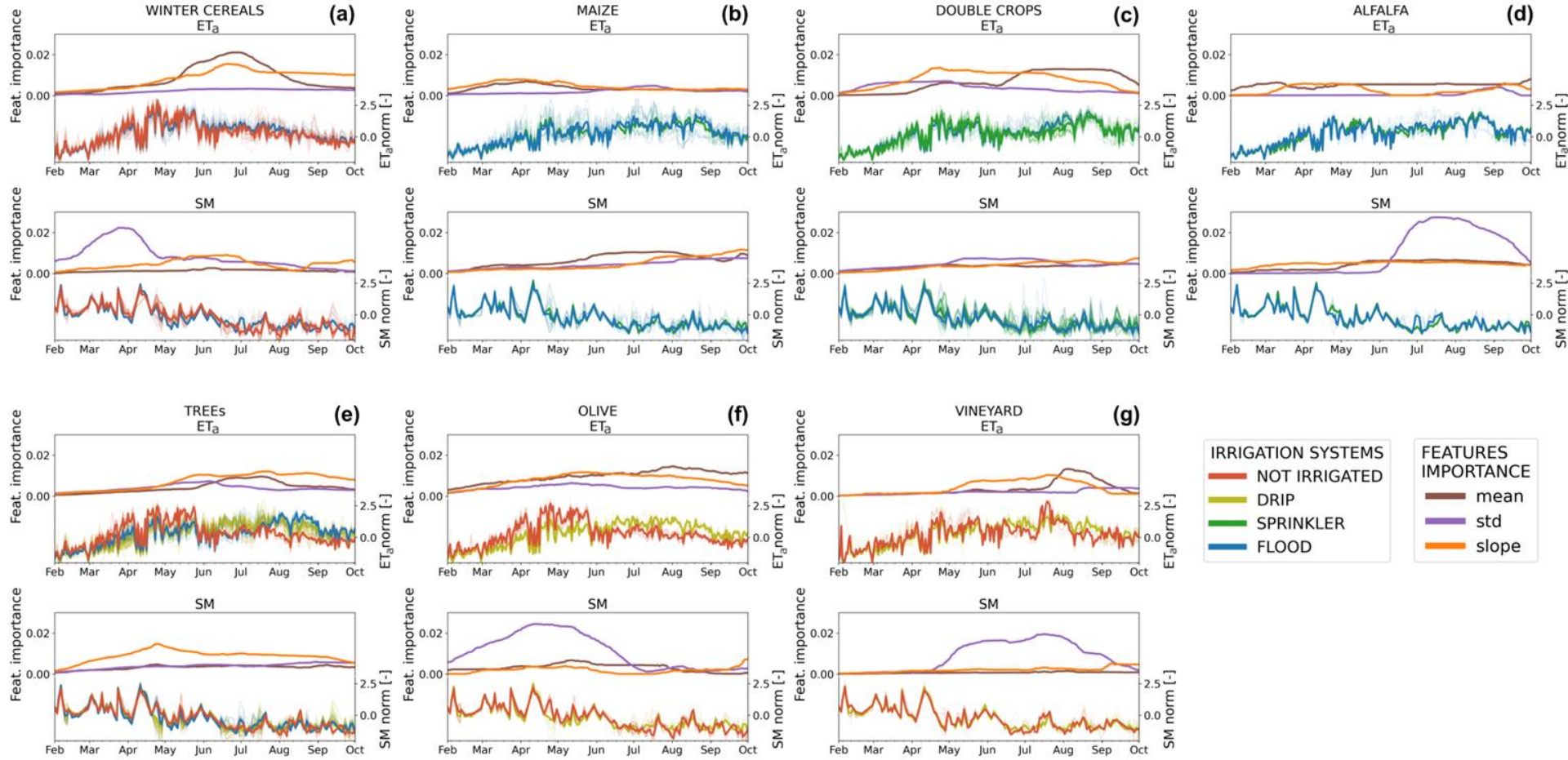
Fig. 6: The Residual Network's architecture for time series classification.

Results I

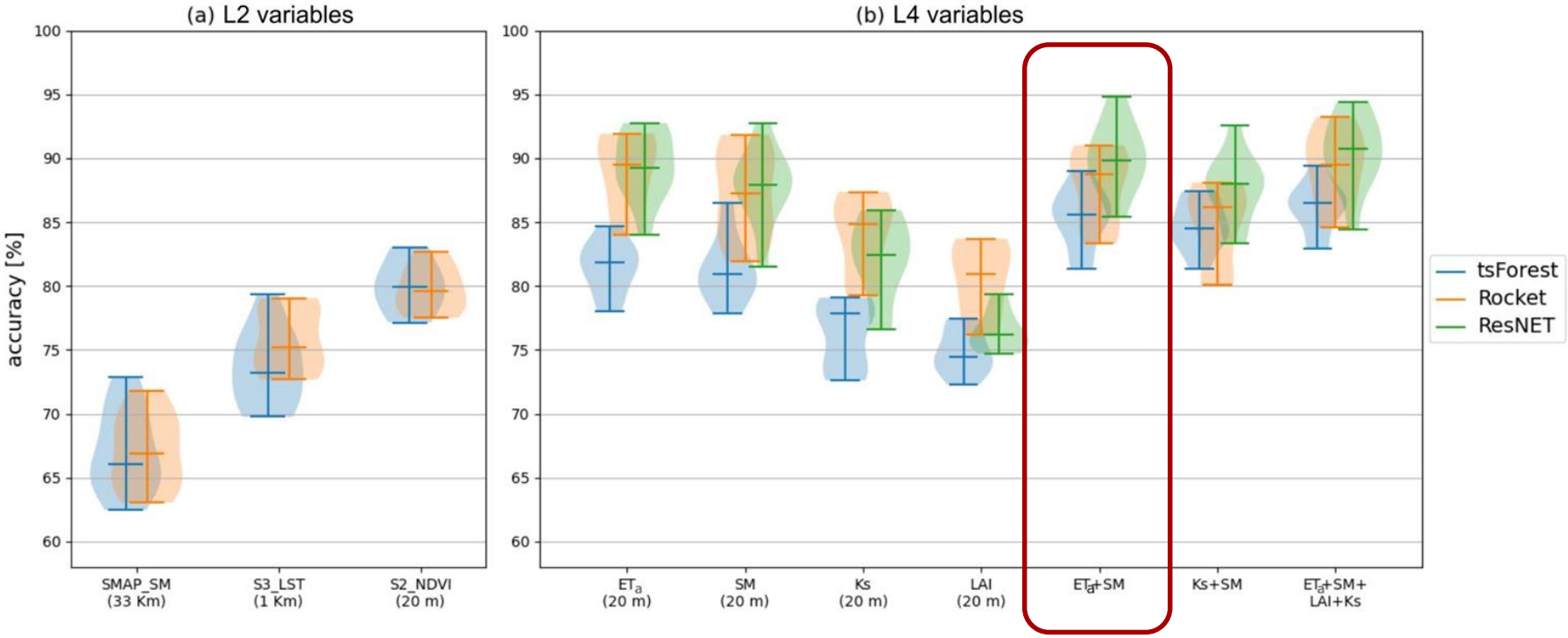
Is the irrigation system only explained by the crop type?

Variables	Crop types							RESULTS	
	Winter Cereals	Maize	Double Crops	Alfalfa	Fruit & Nut Trees	Olives	Vineyards	Aggregated Models	General Model
ET_a-TSEB	81.25%	48.82%	91.67%	72.00%	74.88%	**74.33%**	96.19%	78.15%	79.33%
SM Dispatch	88.75%	**76.47%**	91.67%	66.67%	73.18%	73.33%	80.95%	78.36%	74.25%
ET_a+*SM*	**90.62%**	70.00%	**93.75%**	**73.33%**	**81.71%**	69.67%	96.67%	**83.39%**	**81.89%**

Results II

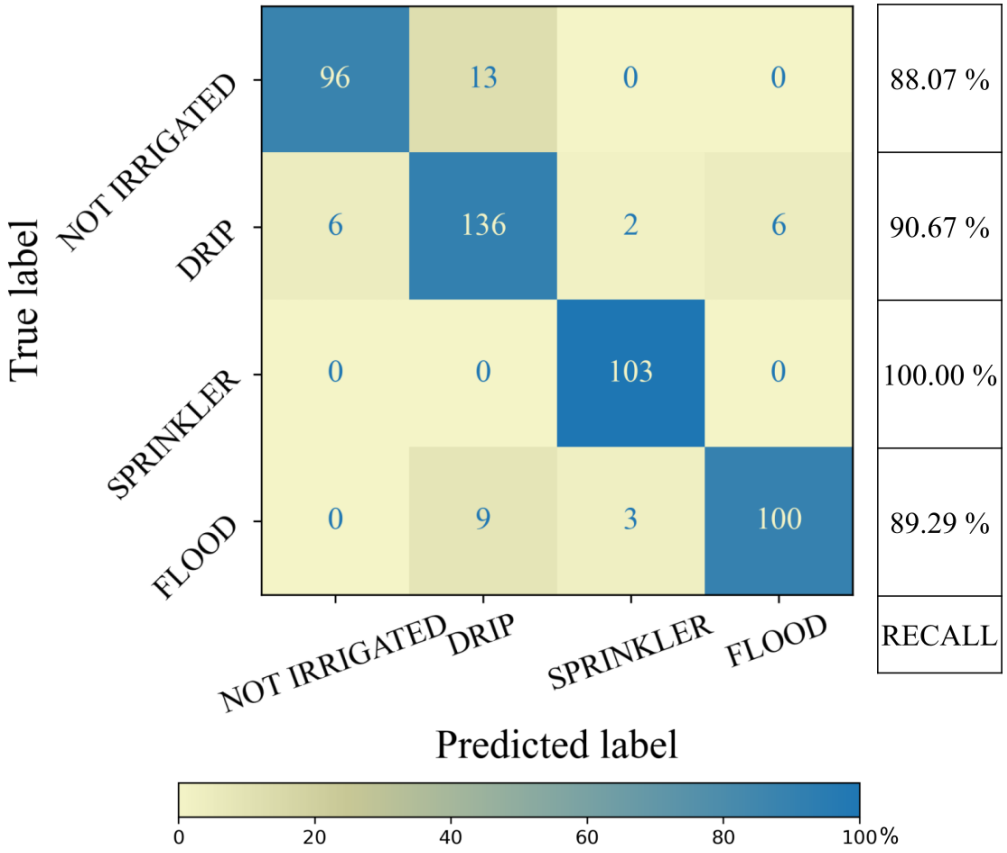

WINTER CEREALS
ETa
(a)
MAIZE
ETa
(b)
DOUBLE CROPS
ETa
(c)
ALFALFA
ETa
(d)
TREEs
ETa
(e)
OLIVE
ETa
(f)
VINEYARD
ETa
(g)
SM
Feat. importance
ETa norm [-]
SM norm [-]
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
IRRIGATION SYSTEMS
NOT IRRIGATED
DRIP
SPRINKLER
FLOOD
FEATURES IMPORTANCE
mean
std
slope

Results III


(a) L2 variables
(b) L4 variables
accuracy [%]
100
95
90
85
80
75
70
65
60
SMAP_SM (33 Km)
S3_LST (1 Km)
S2_NDVI (20 m)
ET$_a$ (20 m)
SM (20 m)
Ks (20 m)
LAI (20 m)
ET$_a$+SM
Ks+SM
ET$_a$+SM+ LAI+Ks
tsForest
Rocket
ResNET

Results IV

PRECISION	94.12 %	86.08 %	95.37 %	94.34 %



	MODELS		
METRICS (%)	tsForest	ROCKET	ResNET
Accuracy	85.29 ± 2.41	87.56 ± 2.95	**90.10** ± 2.70
Average Precision	85.43 ± 2.53	88.80 ± 3.12	**90.33** ± 2.78
Average Recall	84.76 ± 2.51	86.81 ± 3.17	**90.02** ± 2.76

Maps irrigation systems

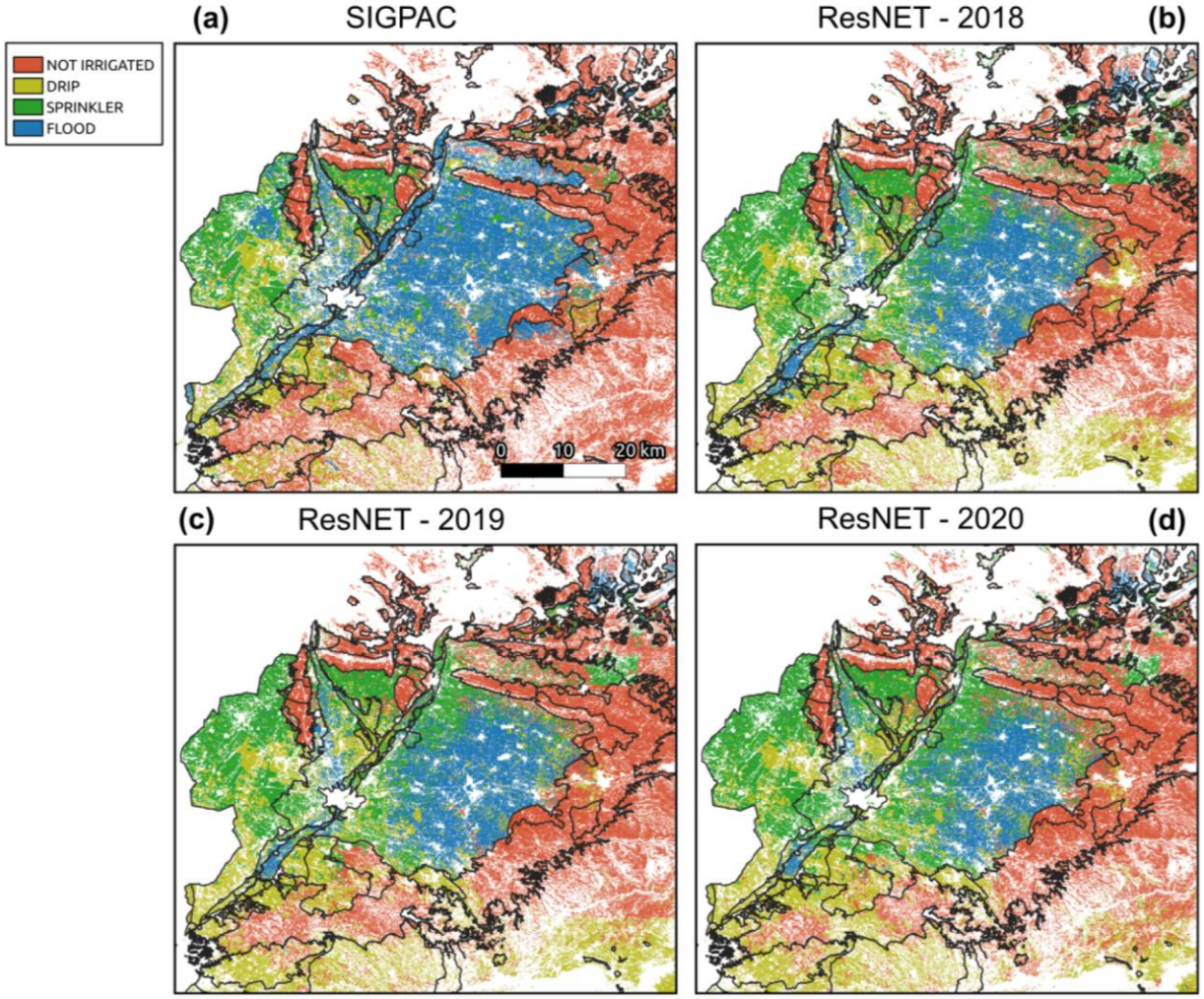
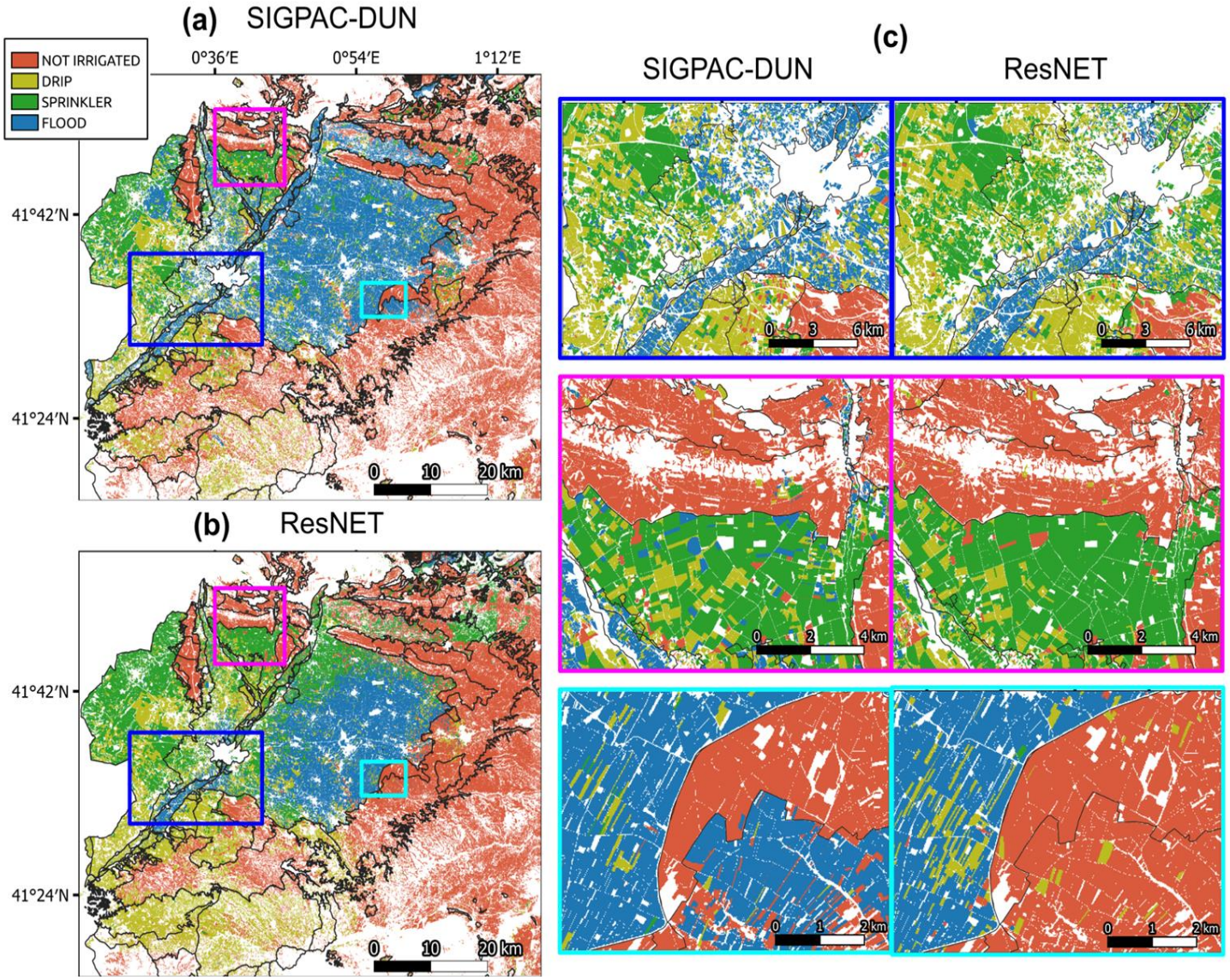
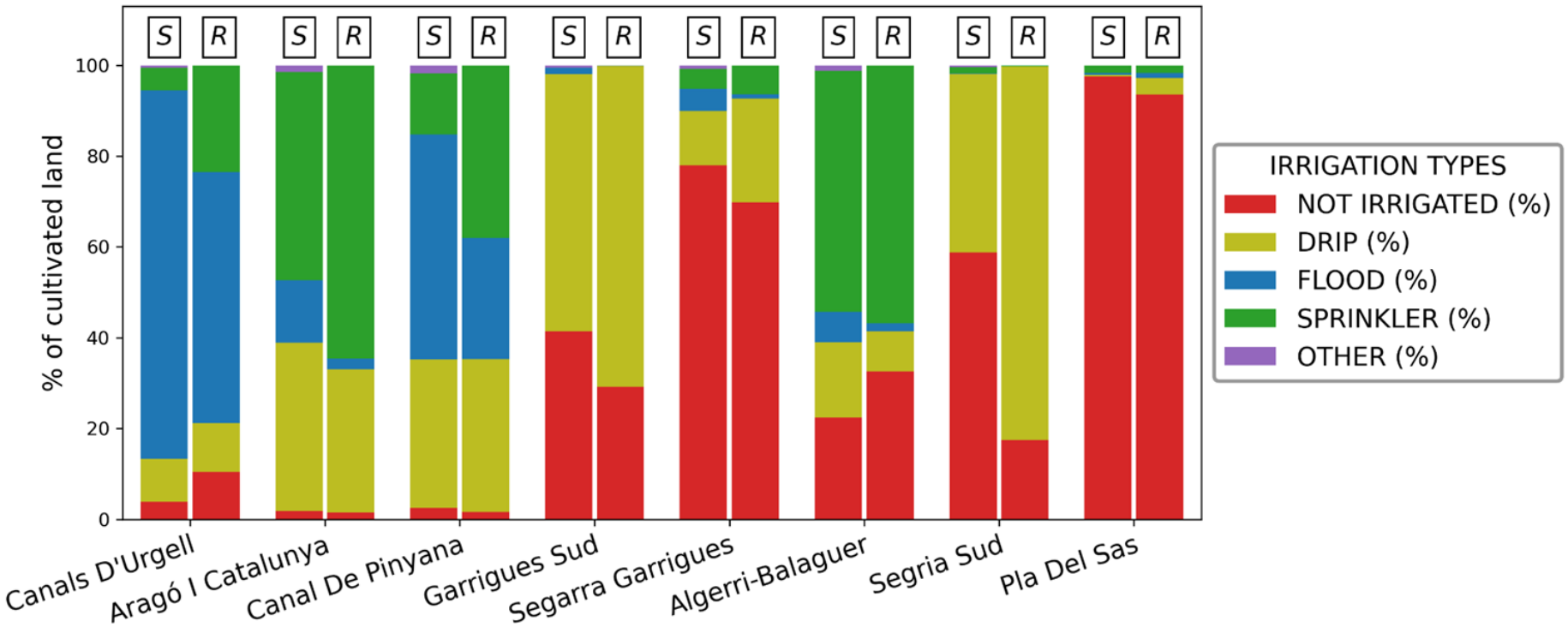


Figure 7: Irrigation Types map (**a**) as delivered by SIGPAC [34] and as created by the ResNET model with ET_a and SM time-series for 2018 (**b**) , 2019 (**c**) and 2020 (**d**).

Comparison: SIGPAC 2021



Comparison: SIGPAC 2021



Summary: Framework

IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 15, 2022 10055

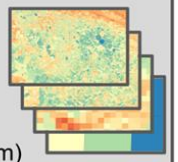
Classification of Different Irrigation Systems at Field Scale Using Time-Series of Remote Sensing Data

Giovanni Paolini, Maria Jose Escorihuela, Olivier Merlin, Magí Pamies Sans, and Joaquim Bellvert

a) Input Data

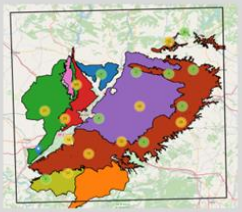
1. HYDROLOGICAL VARIABLES

Level 4 Data:
- ET (20m)
- SM (20m)
- LAI (20m)
- K_s (20m)



Level 2 Data:
- NDVI (20 m)
- SMAP SM (33 km)
- LST (1 km)

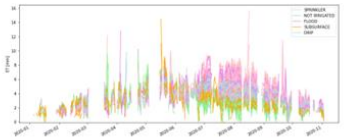
2. GROUND TRUTH IRRIGATION SYSTEMS DATASET



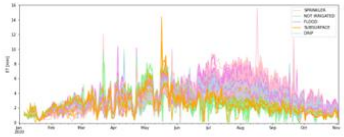
b) Processing

3. GROUND TRUTH FIELD SHAPE EXTRACTION

4. ANNUAL TIME-SERIES EXTRACTION



5. GAP FILLING



c) Classification

6. AI MODELS SELECTION:
- Time series Forest
- ROCKET
- ResNET (Deep Learning)

7. TRAIN + TEST DATASET

> 300 fields collected for 3 different years (total of around 900 time-series samples).

8. PREDICTION

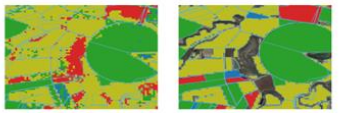
Classification of time-series to create annual Irrigation types maps for the entire study area.

9. OUTPUTS
- Not Irrigated
- Drip
- Sprinkler
- Flood

d) Post-processing

10. LABEL AGGREGATION

All pixels contained in the same field get same irrigation type (from majority of prediction). One field = One irrigation type.



11. TEMPORAL POST-PROCESSING

Comparison of all years: correct unrealistic irrigation types when a single year is different.

Thank you!

Any questions?

isardSAT®

IRTA Institute of Agrifood Research and Technology