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GLOBAL SYMPOSIUM ON
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Incorporating cultivation features for soil salinity mapping in cropland

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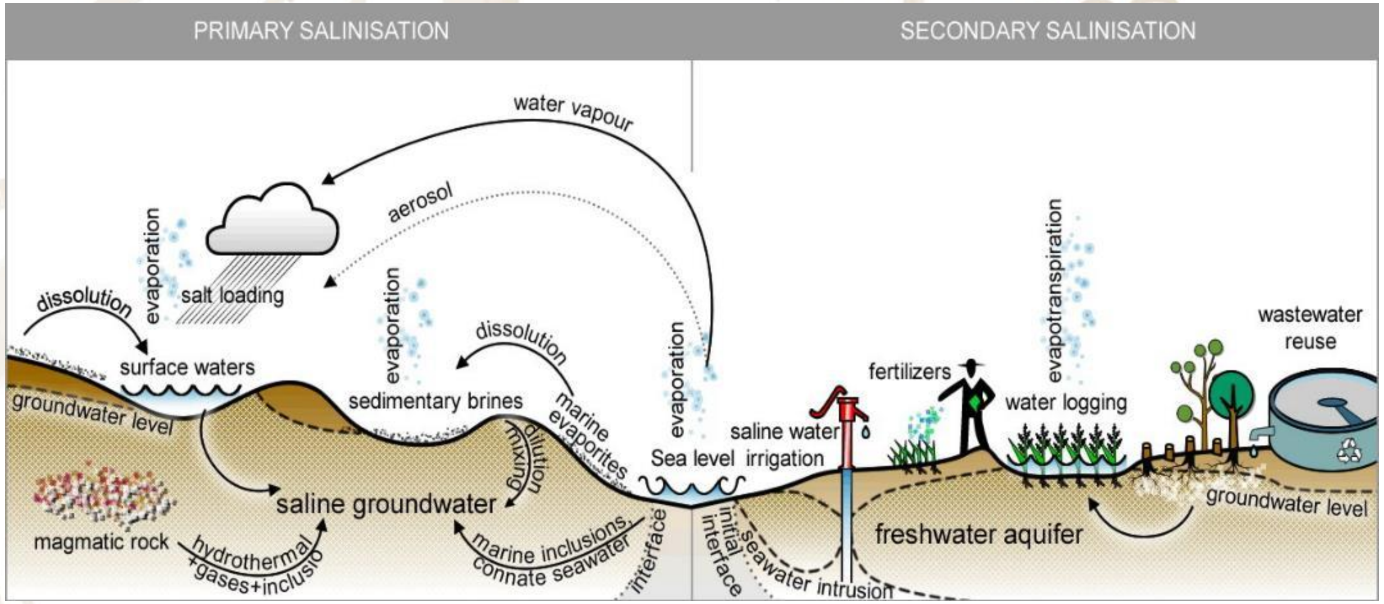
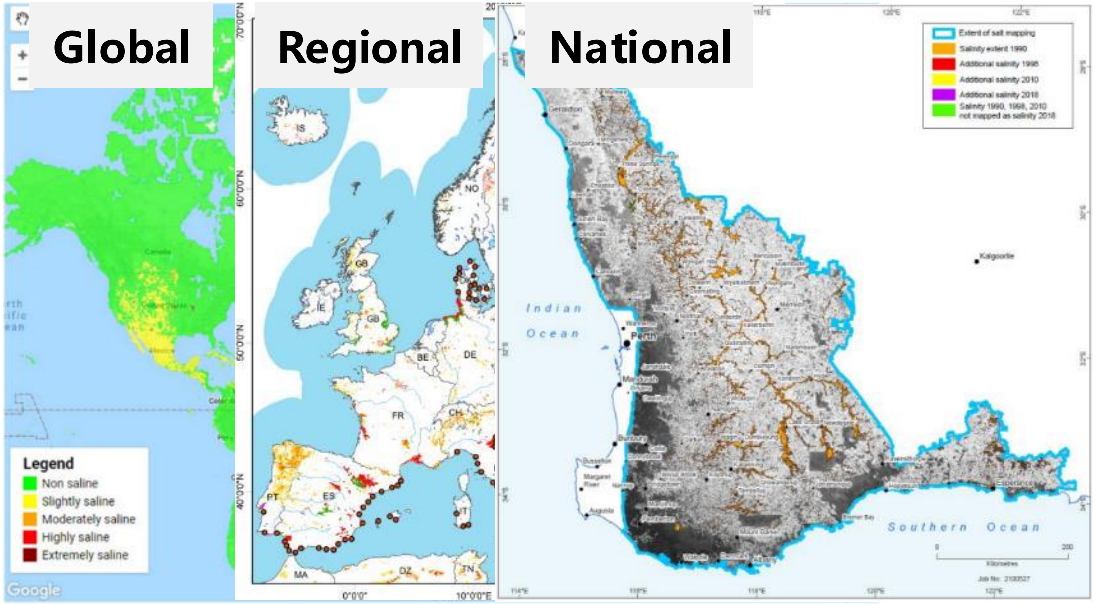
GLOBAL SOIL PARTNERSHIP

Content

Soil salinization is the main type of land degradations

- Soil salinization is one of the major hazards to global agricultural production, and is particularly prevalent in **arid and semi-arid regions**;
- **Soil salinity mapping** helps to support local agricultural management by providing predicted content and spatial distribution of soil salinity.

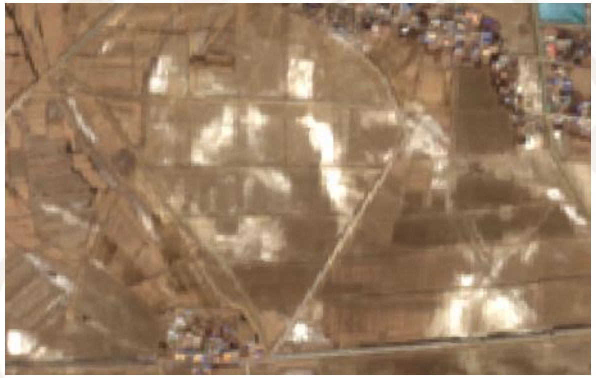
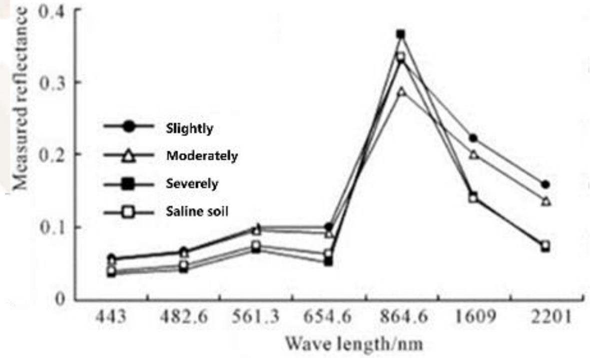


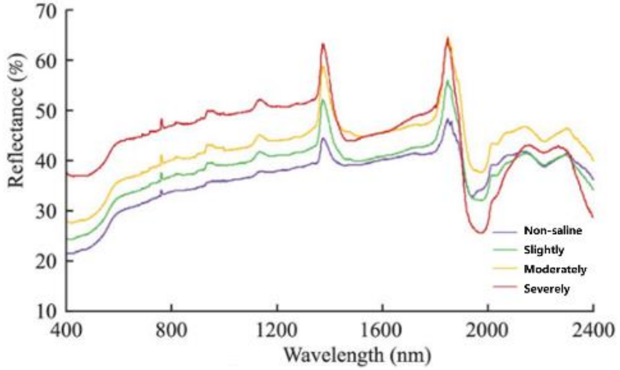


(Science of The Total Environment，2016) (RSE, 2019) (Science of The Total Environment，2016)

Remote sensing is an important tool on a large scale

- **Bare soil period:** As the salt content increases, the soil surface develops more features that are clearly different from healthy soil, which facilitates the application of remote sensing imagery.
- **Vegetation cover period:** crop growth condition under salinity stress has significant differences, which is also able to be acquired by remote sensing.

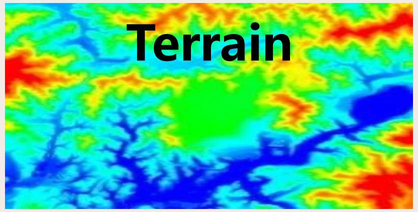



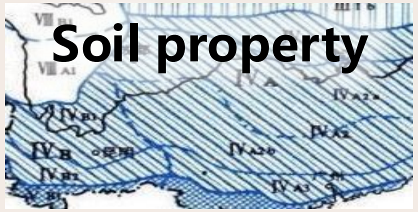



The selection of input variables is a critical step

- **Indices derived from remote sensing imagery are widely used in soil salinity mapping, including salinity indices (SIs) and vegetation indices (VIs).**

Environmental variables





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Spectral indices

NDSI	(B4 - B8)/(B4+B8)
CRSI	$\{[(B8\times B4) - (B3\times B2)]/[(B8\times B4) + (B3\times B2)]\}^{0.5}$
SI1	$(B2\times B4)^{0.5}$
SI2	$2\times B3 - (B4+B8)$
SI3	$(B2+B4)^{0.5}$
SI4	(B2 - B4)/(B2+B4)
SI5	$(B3\times B4)/B2$
SI6	$(B2\times B4)/B3$
SI7	$(B4\times B8)/B3$
SI8	B2/B4
SI9	$(B3\times B4)^{0.5}$
SI10	$(B4^2+B3^2)^{0.5}$
SI11	$(B3^2+B4^2+B8^2)^{0.5}$

NDVI	(B8 - B4)/(B8+B4)
NDRE	(B8 - B5)/(B8+B5)
EVI	$2.5 \times (B8 - B4)/(B8+6\times B4 - 7.5\times B2+1)$
RVI	B8/B4
CIre	B8/(B5 − 1)
BI	$(B4^2+B8^2)^{0.5}$
GI	B3/B4
TCARI	$3\times[(B5 - B4)-0.2 \times (B5 -B3) \times (B5/B4)]$
NAVI	1 - B4/B8
RG	B4/B3
GARI	$\{B8 - [B3 - (B2 - B4)]\}/\{B8+[B3 - (B2 - B4)]\}$
VARI	(B3 - B4)/(B3+B4 - B2)

Human activity information have great potential

Remote Sensing data

The accuracy of salt salinity mapping is still limited.

- ☒ Weak soil spectral information
- ☒ Cloudy and rainy weather
- ☒ Long periods of vegetative cover

More easier

?

Related

Soil salinity mapping

Improve!

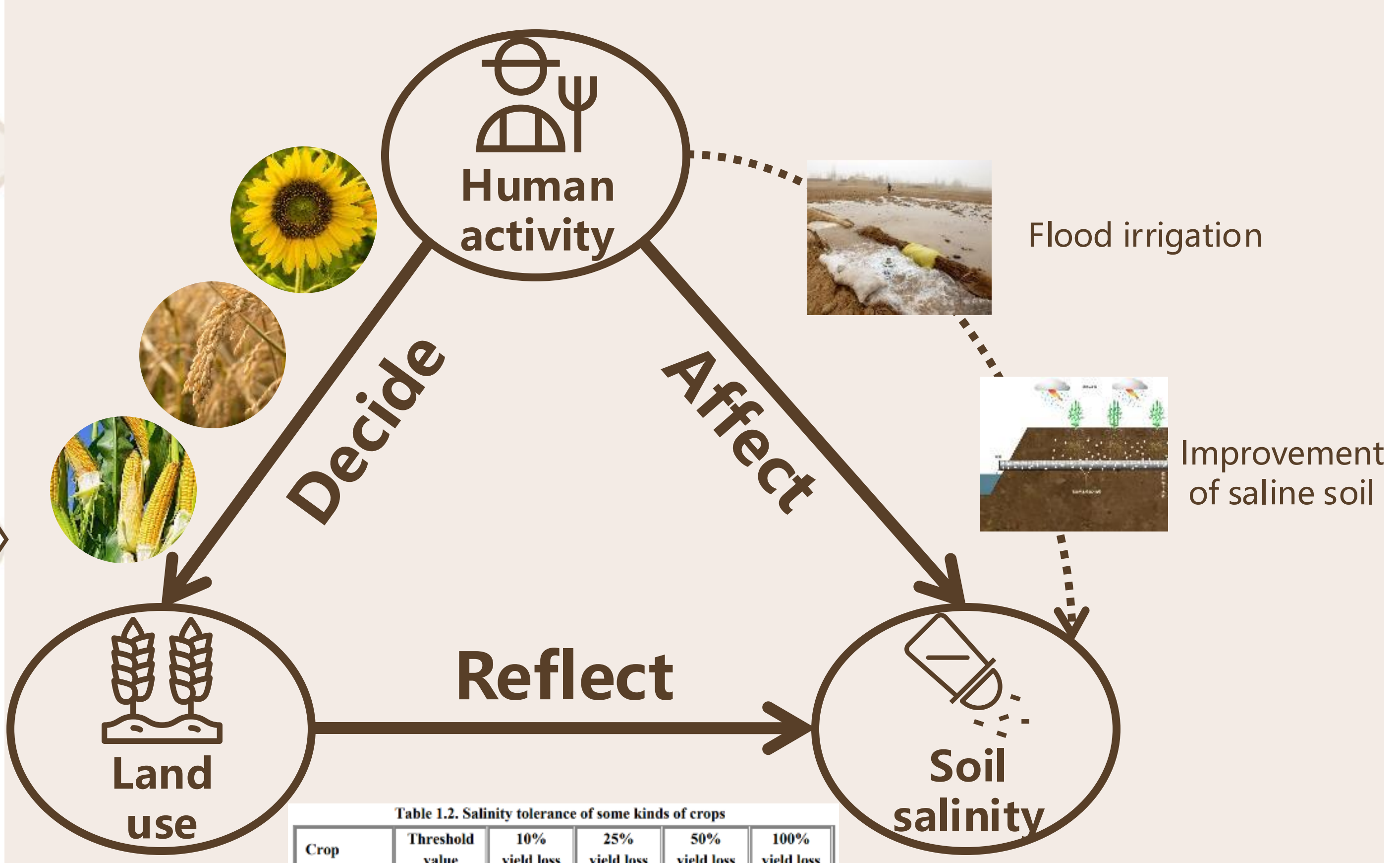

Table 1.2. Salinity tolerance of some kinds of crops

Crop	Threshold value	10% yield loss	25% yield loss	50% yield loss	100% yield loss
	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})
Beans (field)	1.0	1.5	2.3	3.6	6.5
Cotton	7.7	9.6	13.0	17.0	27.0
Maize	1.7	2.5	3.8	5.9	10.0
Sorghum	4.0	5.1	7.2	11.0	18.0
Sugar beets	7.0	8.7	11.0	15.0	24.0
Wheat	6.0	7.4	9.5	13.0	20.0

adapted from Doorenbos and Kassam (1979)

Cultivation features are extracted for soil salinity mapping

Continuous cropping year

Continuous cropping year ⬆

↓

Salt leaching ⬆

↓

Soil salt reduction ⬆

(Agriculture, Ecosystems & Environment，2024)

Crop type feature

- ☑ Crop classification tasks are **simpler** than salt prediction tasks
- ☑ Salinity tolerance varies among crops

Table 1.2. Salinity tolerance of some kinds of crops

Crop	Threshold value	10% yield loss	25% yield loss	50% yield loss	100% yield loss
	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})	EC_e (dS.m^{-1})
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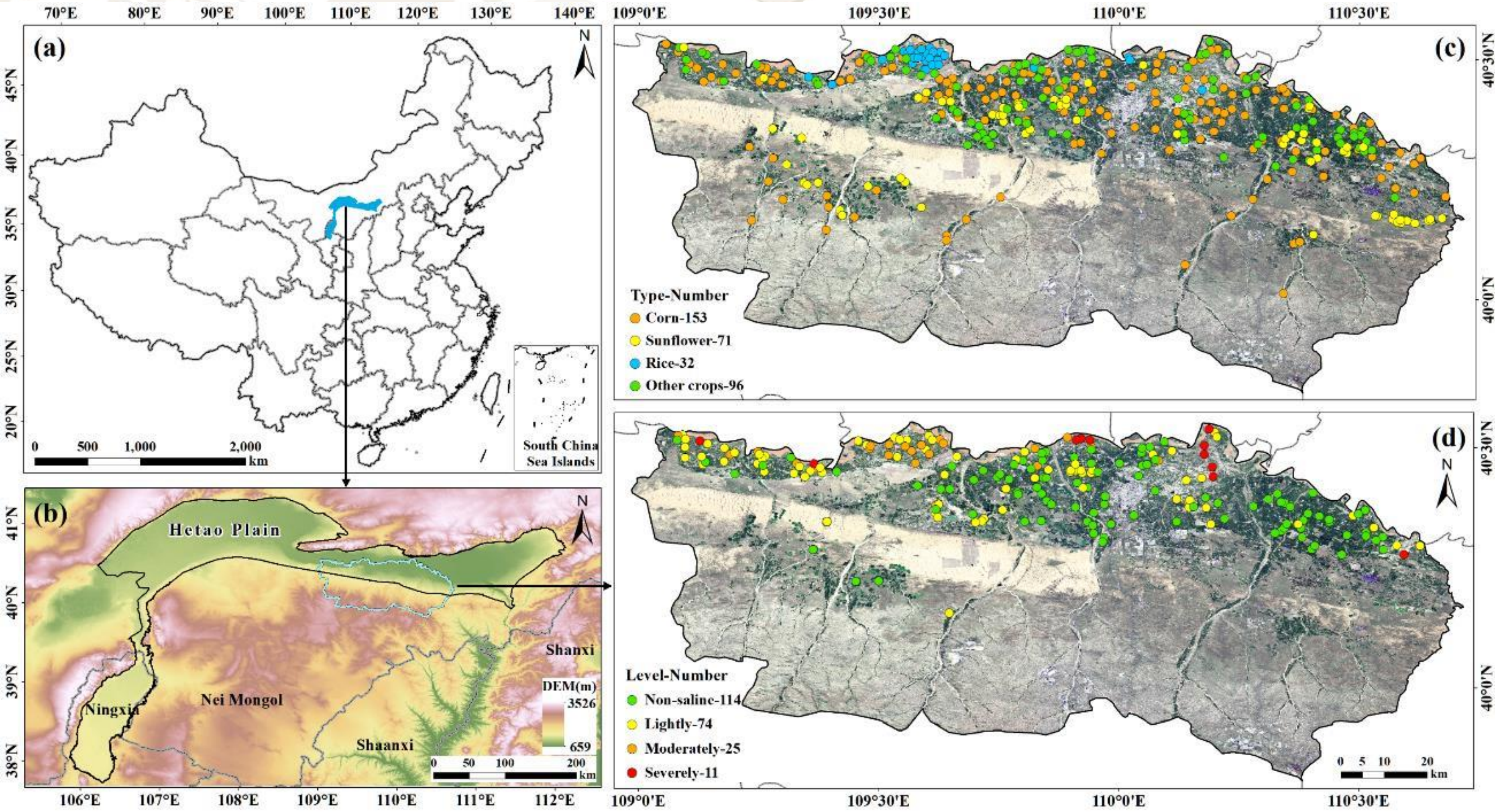
Content

Study area and ground samples



352 crop samples in 2022:

- Other crops include wheat, vegetable, and soybean with small planting areas and similar salt tolerance.

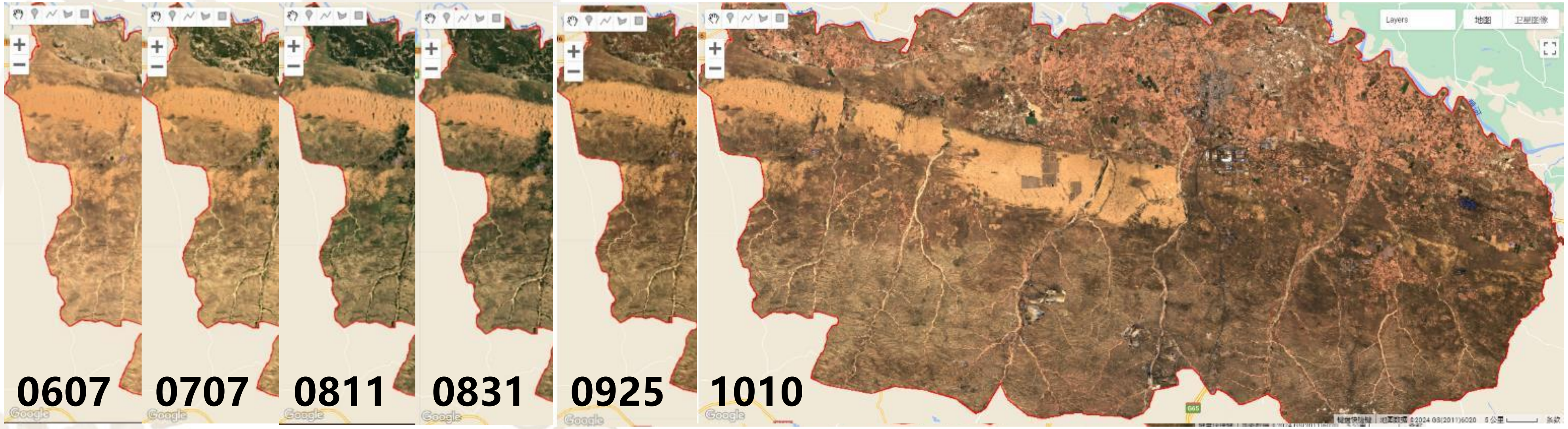
218 soil samples from 0-5cm in October 2022:

- Samples were divided into four levels, including non-saline (<1 g/kg), lightly (1-2 g/kg), moderately (2-4 g/kg), and severely saline (4-6 g/kg).

Data Source: Sentinel-2 in 2022

- Images **from June through October** were used to calculate SIs and VIs for crop classification and soil salinity inversion.

Month	April	May			June			July			August			September			October
Ten-day	last	first	middle	last	first	middle	last	first	middle	last	first	middle	last	first	middle	last	first
Corn	Sowing								Heading						Harvest		
Sunflower				Sowing							Anthesis					Harvest	
Rice		Sowing								Heading					Harvest		



Data Source: Environmental variables

- **All data were resampled to 10 m for consistent spatial resolution.**
- **The main applications of CLCD: (1) Masking croplands on images in 2022 for crop classification; (2) Calculating the cultivation feature using the spatial distribution information of cropland from 1990 to 2022.**

Feature type	Name	Spatial resolution	Time range
Terrain	ALOS PALSAR	12.5m	2006-2011
Soil property	Basic soil property dataset of high-resolution China Soil Information Grids (2010-2018)	90m	2010-2018
Land cover	China Land Cover Dataset (CLCD)	30m	1990-2022

Content

The flowchart of soil salinity mapping

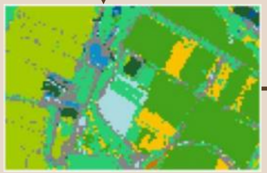
1 Continuous cropping year

1990	1991	…	2020	2021	2022
Cropland	Non-cropland	…	Non-cropland	Cropland	Cropland

CCY=2

2 Crop type feature

Random Forest



Quantification

Categorical feature

Corn	Sunflower	Rice	Other

Target Encoding

Crop type feature

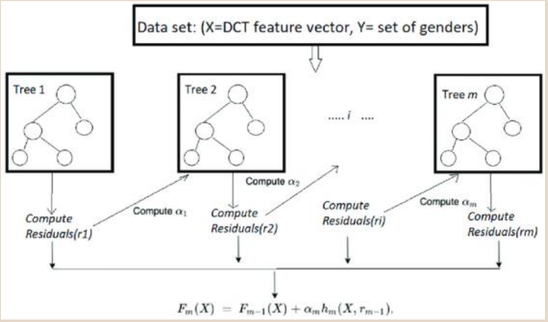
0.96	2.74	2.23	0.48

3 Soil salinity mapping

+ Continuous cropping year

+ Crop type feature

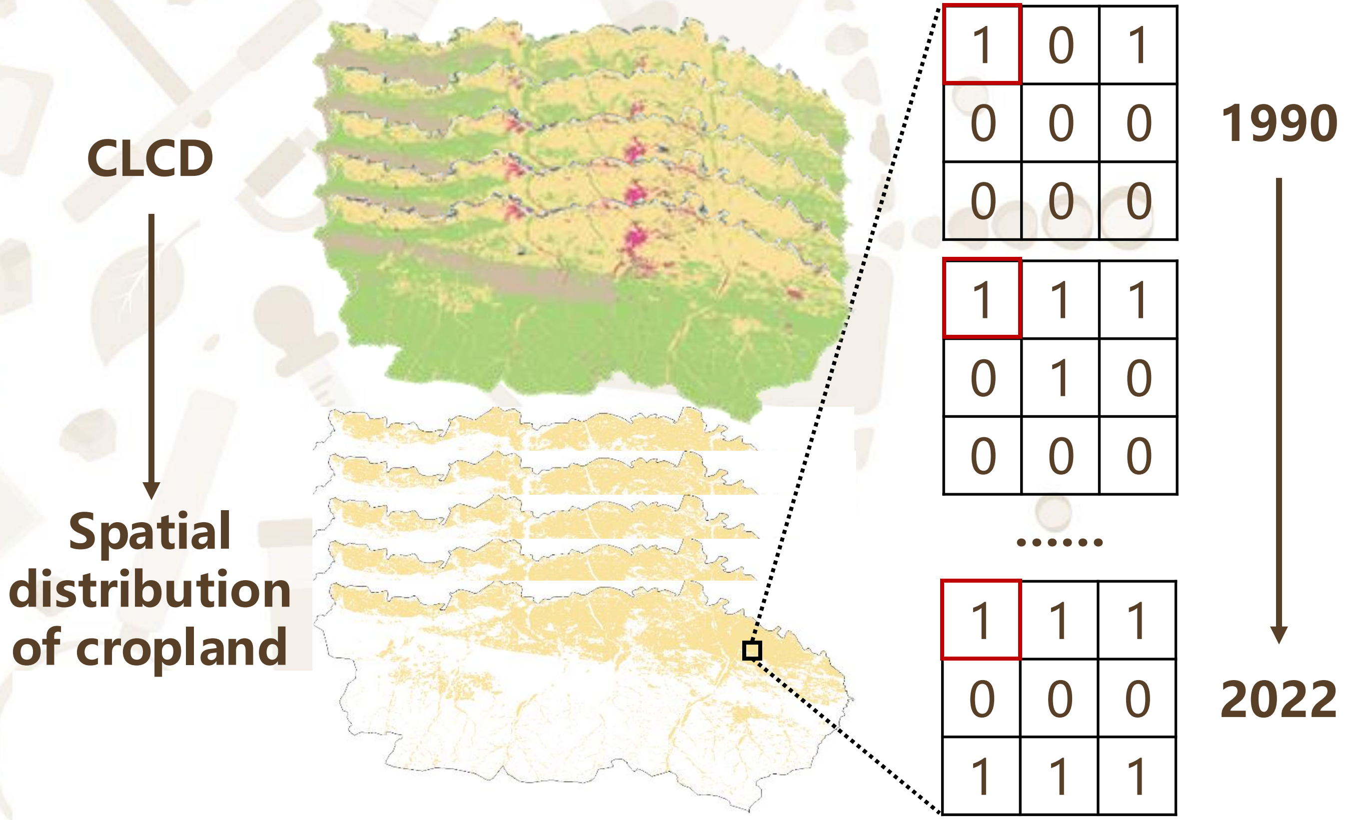
Salinity inversion model



Soil Salinity mapping

3.1 Continuous cropping year

- **Continuous cropping year (CCY) is the number of years of continuous agricultural production activities on cropland.**



'1' indicates cropland, '0' indicates non-cropland

1990-2022	CCY
11111 11111 11111 11111 11111 11111 111	33
11111 00000 00000 11000 00000 00011 111	5
00000 00000 00000 11111 00000 11100 000	0

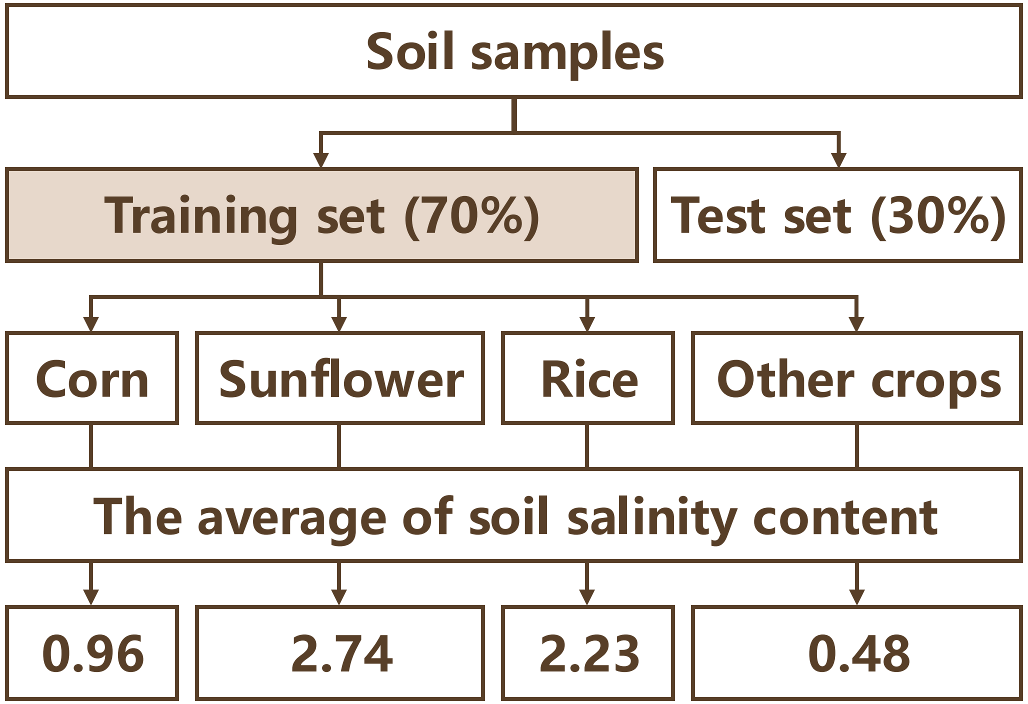
3.2 Crop type feature

- Features: spectral bands and VIs from June through October ;
- Classifier: RF;
- Evaluation metrics: OA, Kappa.

- Quantifying crop types based on the training set using **Target Encoding** (TE).

Name	Central wavelength (nm)
Blue (B)	496.6
Green (G)	560.0
Red (R)	664.5
Red Edge 1 (RE1)	703.9
Red Edge 2 (RE2)	740.2
Red Edge 3 (RE3)	782.5
Near infrared (NIR)	835.1
Red Edge 4 (RE4)	864.8
SWIR1	1613.7
SWIR2	2202.4

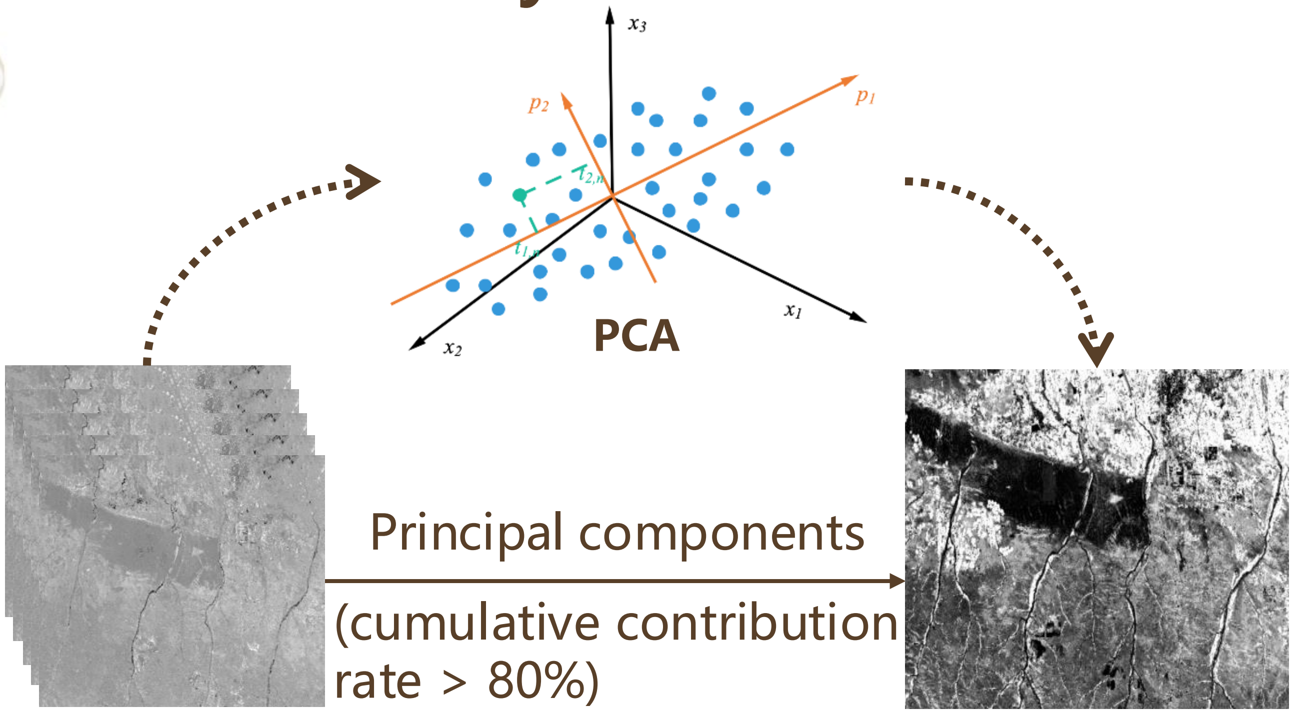
Vegetation index	Formula
VIgreen	$\frac{Green - Red}{Green + Red}$
NDVI	$\frac{NIR - Red}{NIR + Red}$
NDTI	$\frac{SWIR_1 - SWIR_2}{SWIR_1 + SWIR_2}$
NDSVI	$\frac{SWIR_1 - Red}{SWIR_1 + Red}$
LSWI	$\frac{NIR - SWIR_1}{NIR + SWIR_1}$
EVI	$2.5 \times \frac{NIR - Red}{NIR + 6 \times Red - 7.5 \times Blue + 1}$



3.3 Soil salinity modelling

- Besides environmental variables such as DEM and soil properties, **NDVI** was calculated **from June to October** and **salinity indices in October**;
- Feature dimension reduction was achieved using **principal component analysis (PCA)** to reduce information redundancy.

Type	Name	Formula
VI	NDVI	$\frac{NIR - R}{NIR + R}$
SI	SI_1	$\frac{NIR \times R}{G}$
	SI_2	$\frac{B - R}{B + R}$
	SI_3	$\sqrt{R^2 + G^2 + NIR^2}$
	SI_4	$\sqrt{NIR \times R}$
	CRSI	$\sqrt{(NIR \times R - G \times B) / (NIR \times R + G \times B)}$



3.4 Comparison designs and accuracy evaluation

- **Features: Terrain, soil property, pc_{SI}, pc_{NDVI}, Continuous cropping year, Crop type feature;**
- **Model: XGBoost;**
- **Evaluation metrics: R^2, MAE**

ID	Feature combination
S1	Terrain + Soil property
S2	S1 + pc_{SI}
S3	S2 + pc_{NDVI}
S4	S3 + Continuous cropping year
S5	S3 + Crop type feature
S6	S4 + Crop type feature

Evaluation metrics

R^2 (R-Square):

$$R^2 = 1 - \frac{\sum_i (\hat{y}_i - y_i)^2}{\sum_i (\bar{y} - y_i)^2}$$

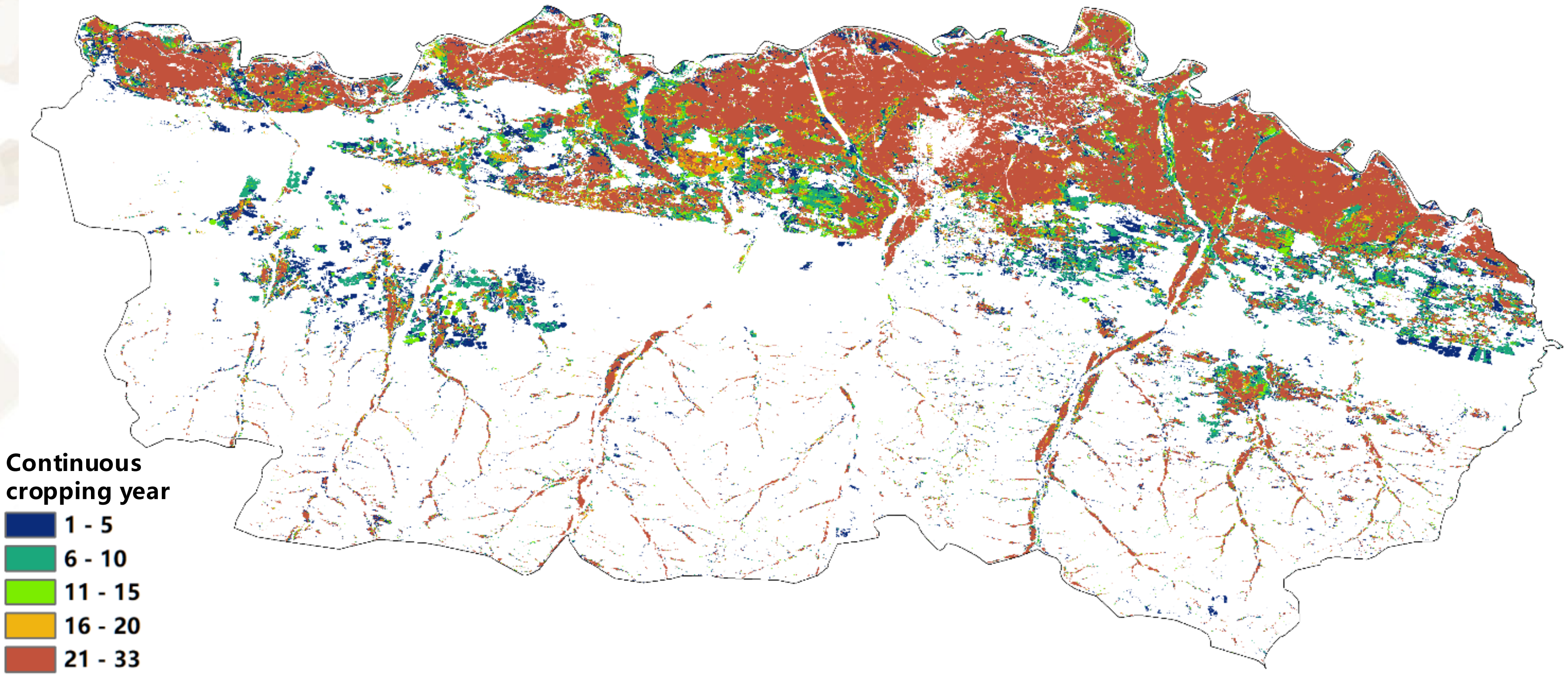
MAE (Mean Absolute Error):

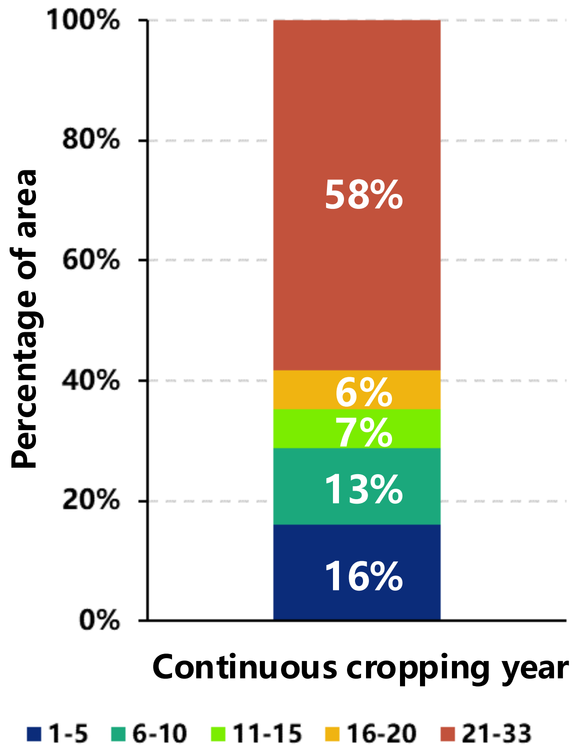
$$MAE = \frac{1}{m} \sum_{i=1}^{m} \left| (y_i - \hat{y}_i) \right|$$

Content

4.1 Continuous cropping year

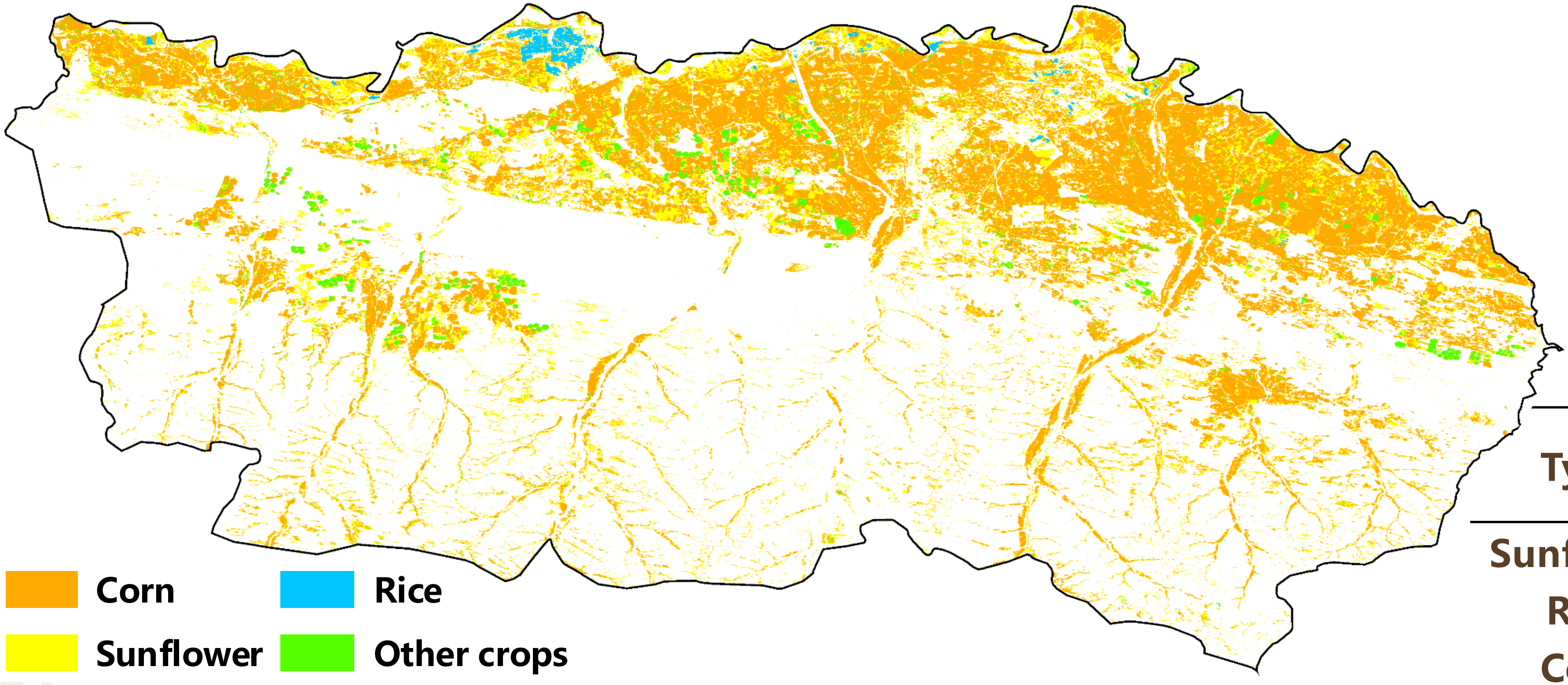
- Cropland that has been continuously cultivated for more than 20 years is mainly located in the northern plain;
- Newly reclaimed cropland is mainly located in the east.

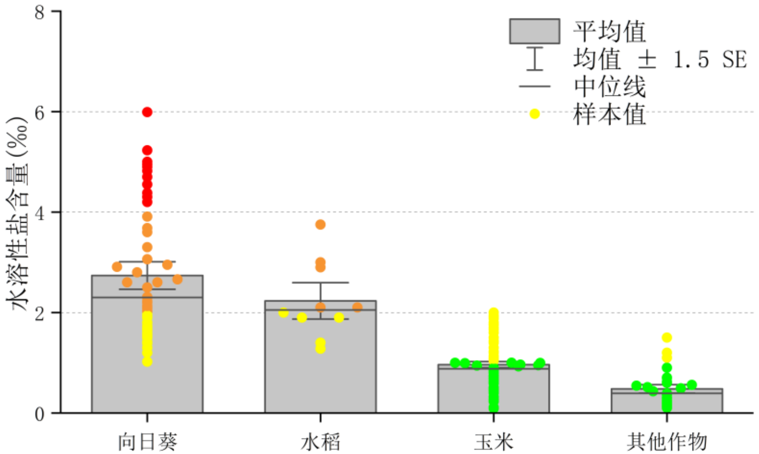




4.2 Crop classification result

- After extracting cropland using CLCD in 2022, the OA of crop classification was 97.17%, and Kappa was 0.96;
- The SSC of sunflower, rice, corn, and other crops gradually decreases.



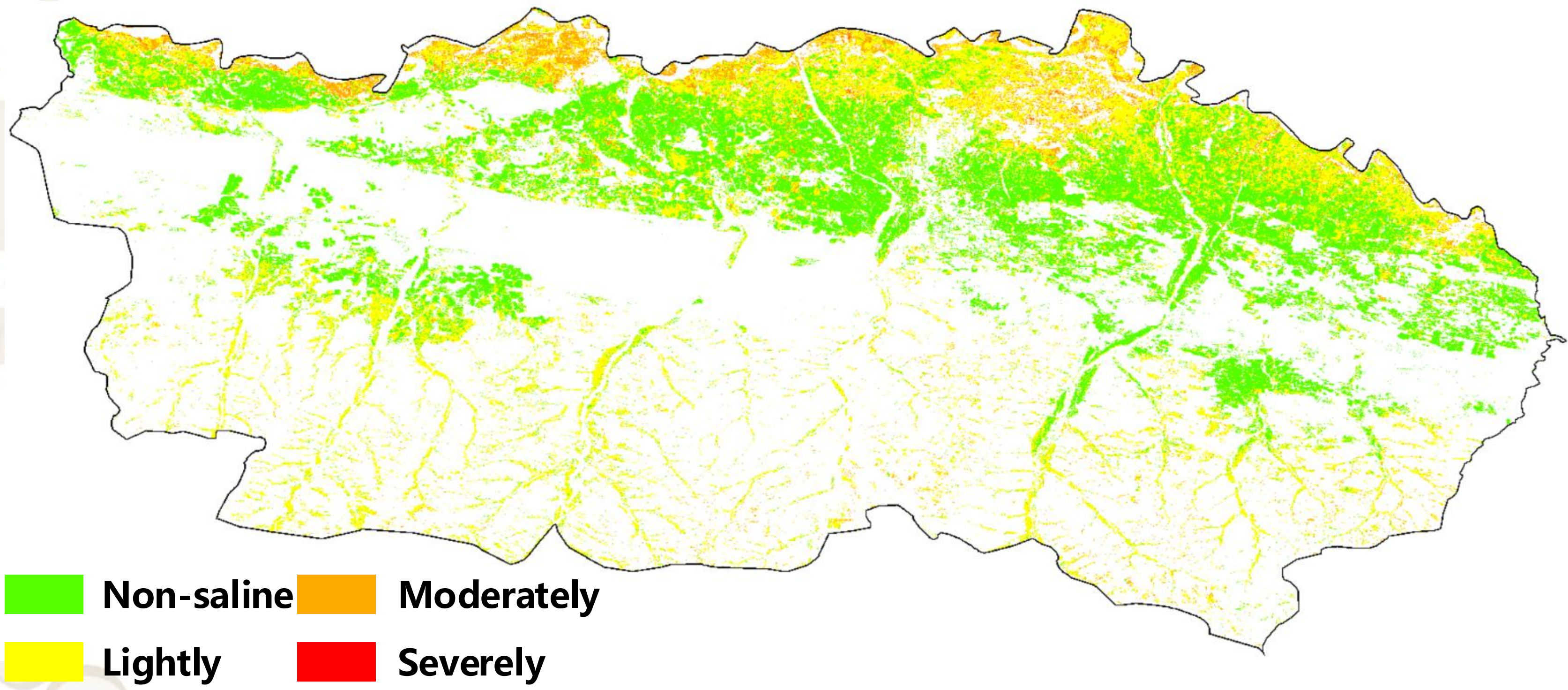


Type	Population		Training set
	Mean(‰)	Std	Mean(‰)
Sunflower	2.74	1.29	2.75
Rice	2.23	0.72	2.27
Corn	0.96	0.45	0.95
Other crops	0.48	0.32	0.45

4.3 Soil salinity mapping

- **Soil salinity inversion using DEM, 2 soil properties, 2 principal components of SIs, 1 principal component of NDVI, continuous cropping year and crop type feature had an R^2 of 0.74 and an MAE of 0.39。**

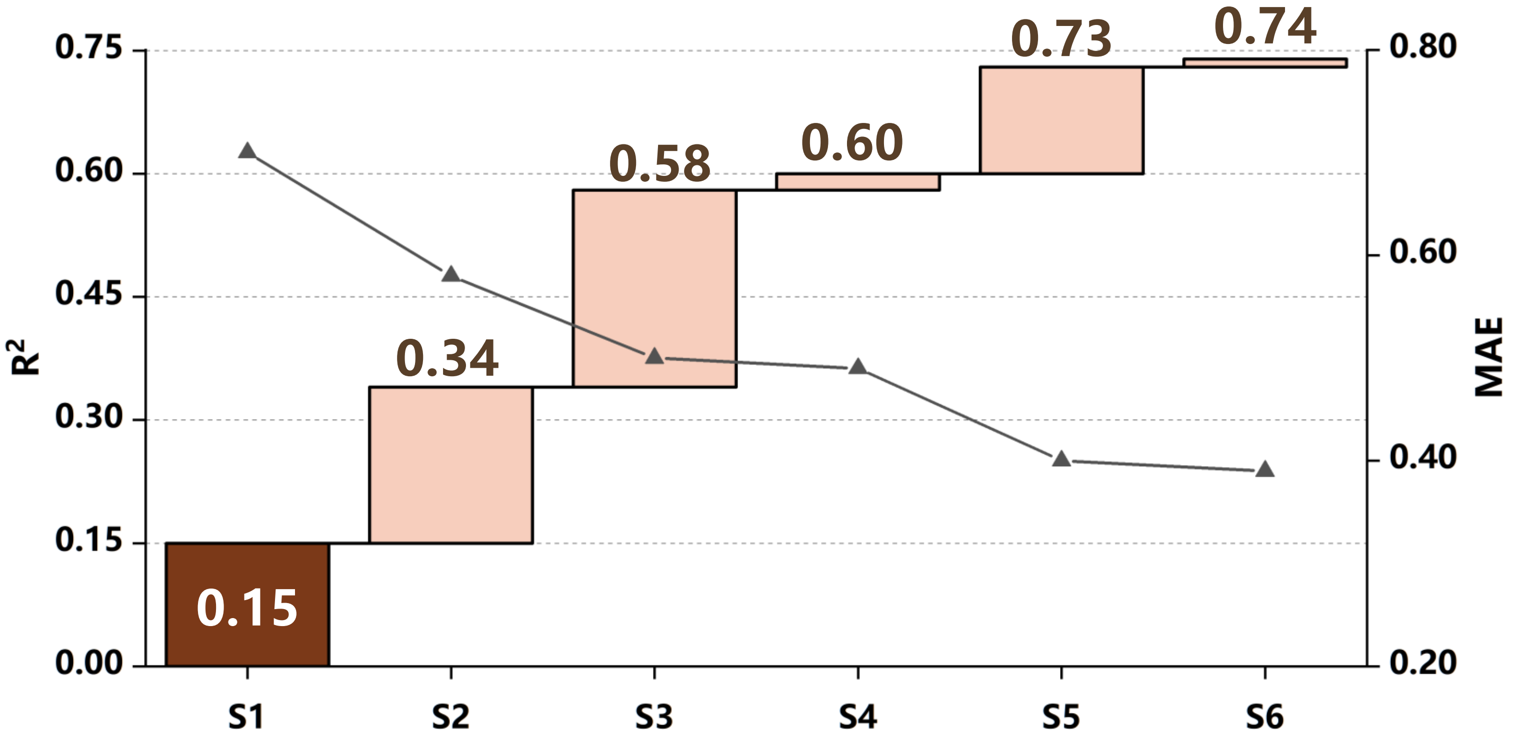
Feature	Cumulative contribution rate
$pc1_{SI}$	57.26
$pc2_{SI}$	37.92
$pc1_{NDVI}$	83.64



4.4 Comparison experiments

- Compared with the traditional feature combination of environmental variables and spectral features (S2, S3), the addition of cultivation features can further improve the inversion accuracy (S4-S6).

ID	Feature combination
S1	Terrain + Soil property
S2	S1 + pc_{SI}
S3	S2 + pc_{NDVI}
S4	S3 + Continuous cropping year
S5	S3 + Crop type feature
S6	S4 + Crop type feature



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THANK YOU

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