



中國水稻研究所
China National Rice Research Institute

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The 1st China-Australia Symposium on Crop Stress Physiology and Climate Adaptation

Research on rice yield prediction based on long-time series UAV multispectral data



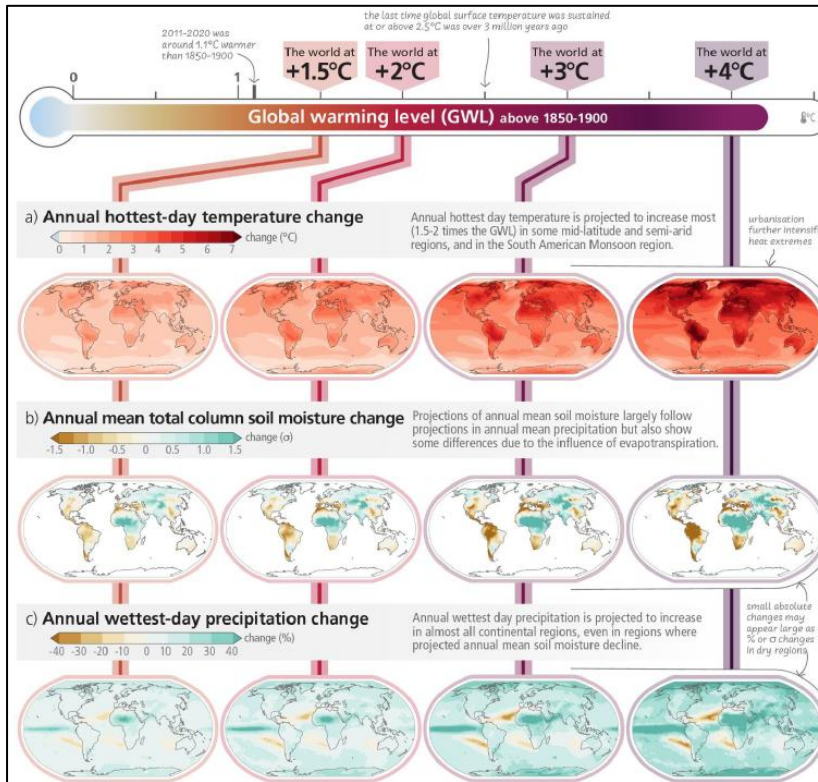
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China National Rice Research Institute, Hangzhou
Tasmanian Institute of Agriculture, University of Tasmania

Launceston March 2026

RESEARCH BACKGROUND

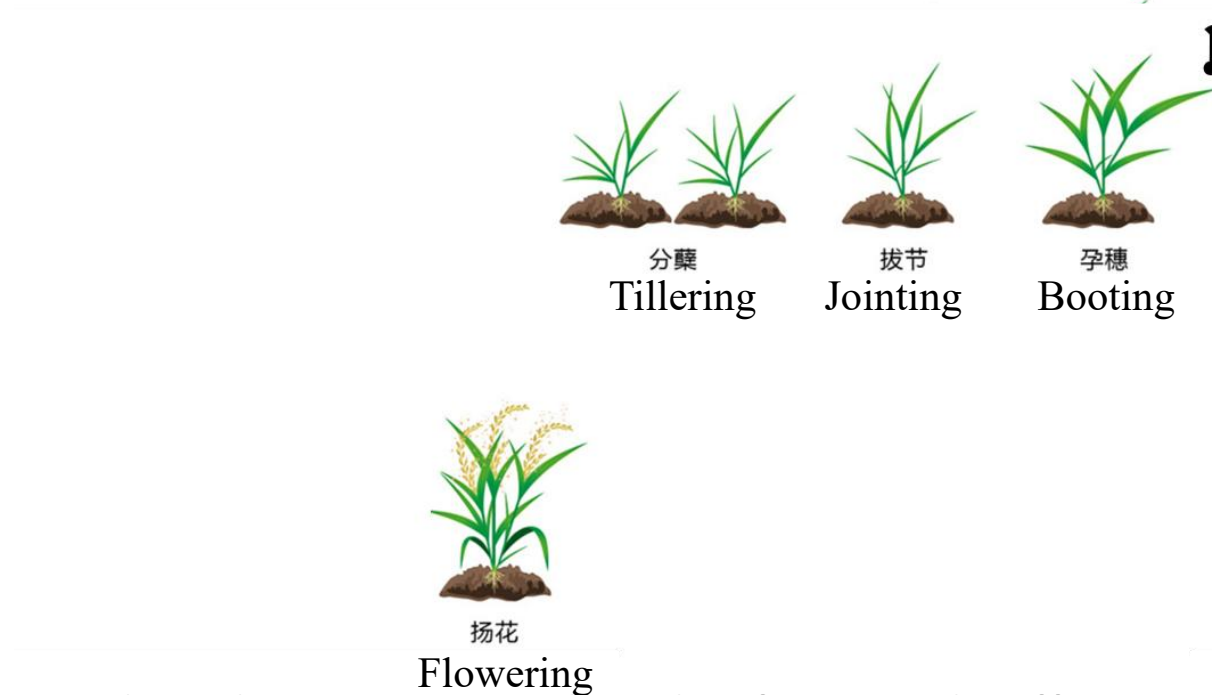


- *With global warming and the increasing impact of extreme weather events, rice yield prediction is facing greater **uncertainty**.*
- ***Accurate yield estimation** is not only essential for food security but also critical for promoting improved **cultivar breeding** and conservation tillage.*

RESEARCH BACKGROUND

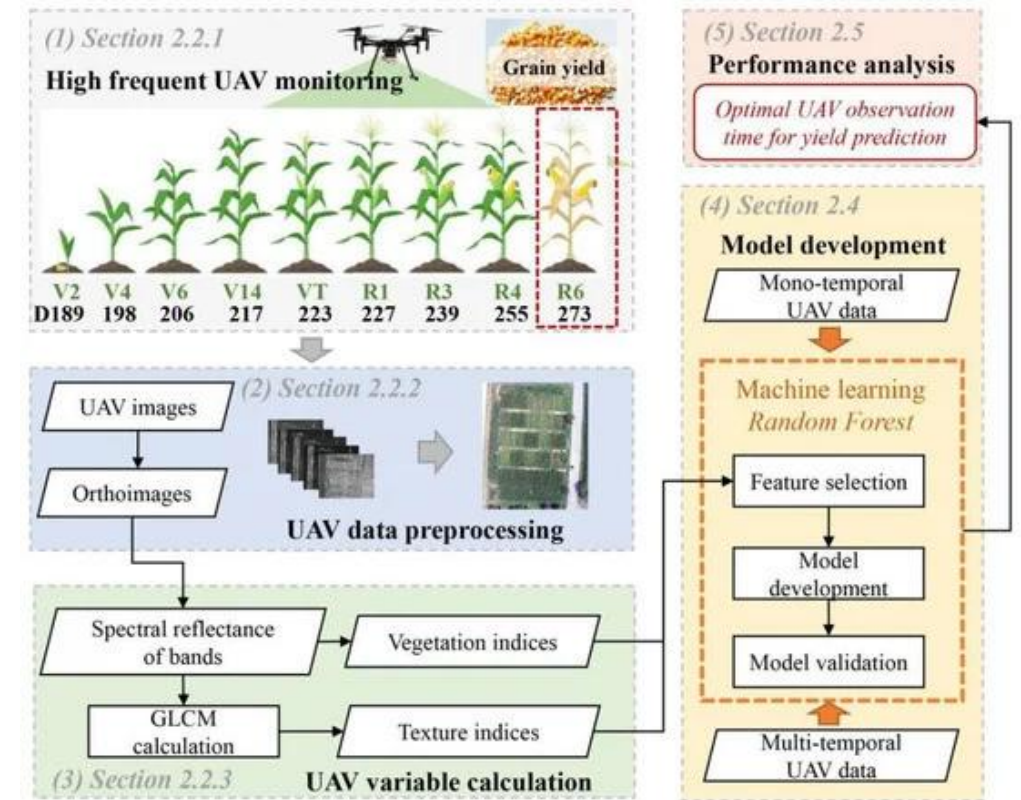
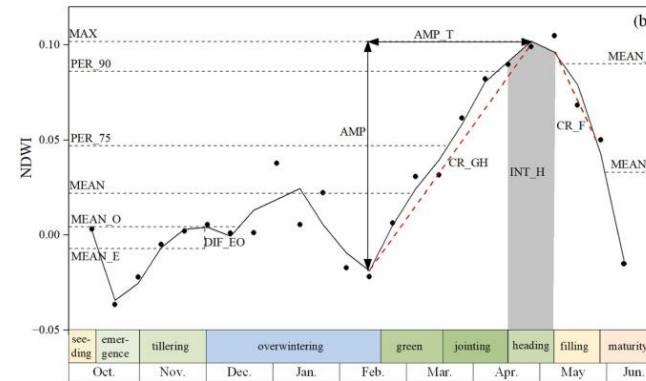
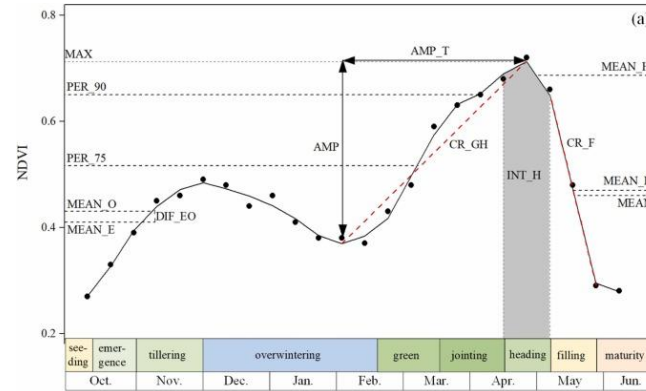
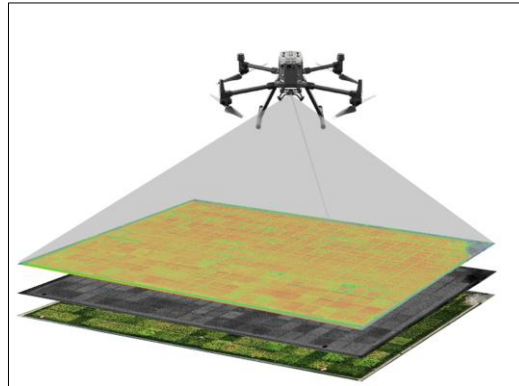
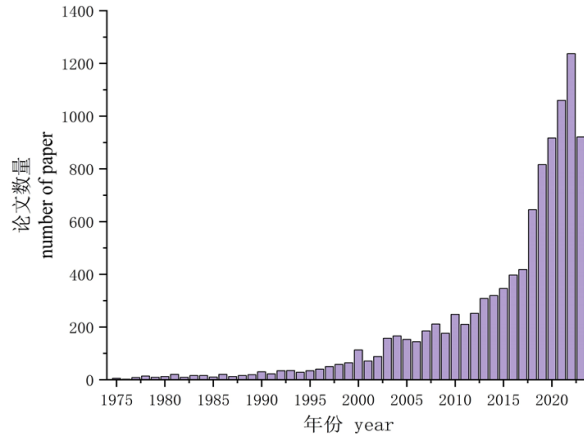


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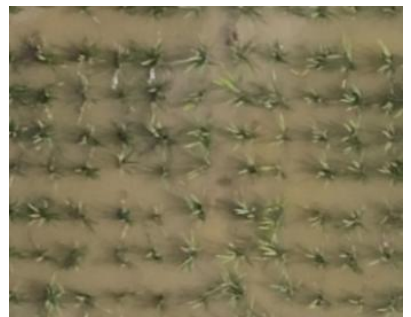
- Rice yield formation involves the entire growth cycle of rice, with different yield components interacting and constraining each other.
- Optimizing **planting density**, controlling **tiller fertility**, and improving **photosynthetic capacity** and assimilate **conversion efficiency** are key practices in rice production.
- Therefore, rice yield estimation is a **comprehensive temporal study** that combines rice physiological conditions with environmental variables.

RESEARCH BACKGROUND



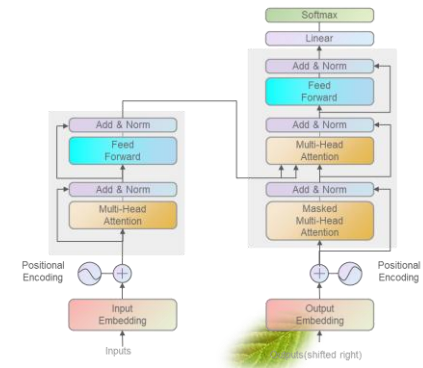
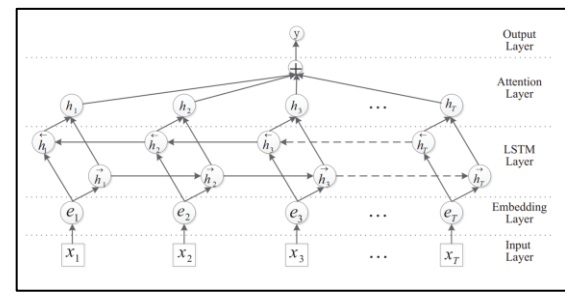
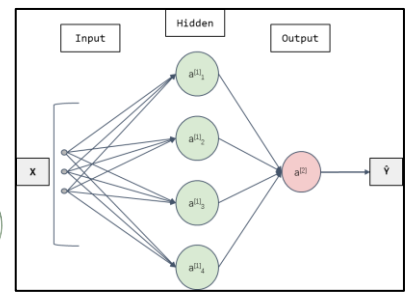
- In recent years, with the updation of UAV technology, remote sensing now offers higher spatiotemporal resolution. The ability to monitor crop growth in real-time through **long-term time-series data** has led to its rapid adoption in yield prediction.
- *BUT, how to efficiently acquire it? how to effectively use it?*

TARGET



01

How to accurately extract multi-temporal UAV data?



02

How to effectively construct multi-variety yield prediction models?

How to extract data ?



Experimental Design

EXP1 Nitrogen-Potassium Interaction Experiment

V: Huanghuazhan、xiushui134

N: N0:0、N1:4.5、N2:9、N3:13.5 kg/667m²

K: K0:0、K1:3.6、K2:7.2、K3:10.8 kg/667m²

EXP2 Dynamic Top-dressing Experiment Based on SPAD Thresholds

V: Huanghuazhan、xiushui134

N: Four nitrogen application models were developed, utilizing SPAD thresholds of 34, 37, and 40, in addition to an RTNM (Real-Time Nitrogen Management) decision-making framework.



Fig1-1. Study Site and Field Experimental Layout

How to extract data ?

preprocessing architecture

Threshold segmentation techniques

- ◆ Otsu
- ◆ MLT based on ricePSO (particle swarm optimization)

Time-series data smoothing techniques

- ◆ Non-smoothing (CK)
- ◆ Seven smoothing method (linear and spline double sigmoidal (Dsig), double logistic (Dlogistic), asymmetric Gaussian (Gauss), Gaussian Mixture Model (GaussMIX) and (Growth)) .

Model Evaluation

- ◆ ML model (RF/SVM/XGBoost)
- ◆ Time-series model (LSTM/Bi-LSTM)

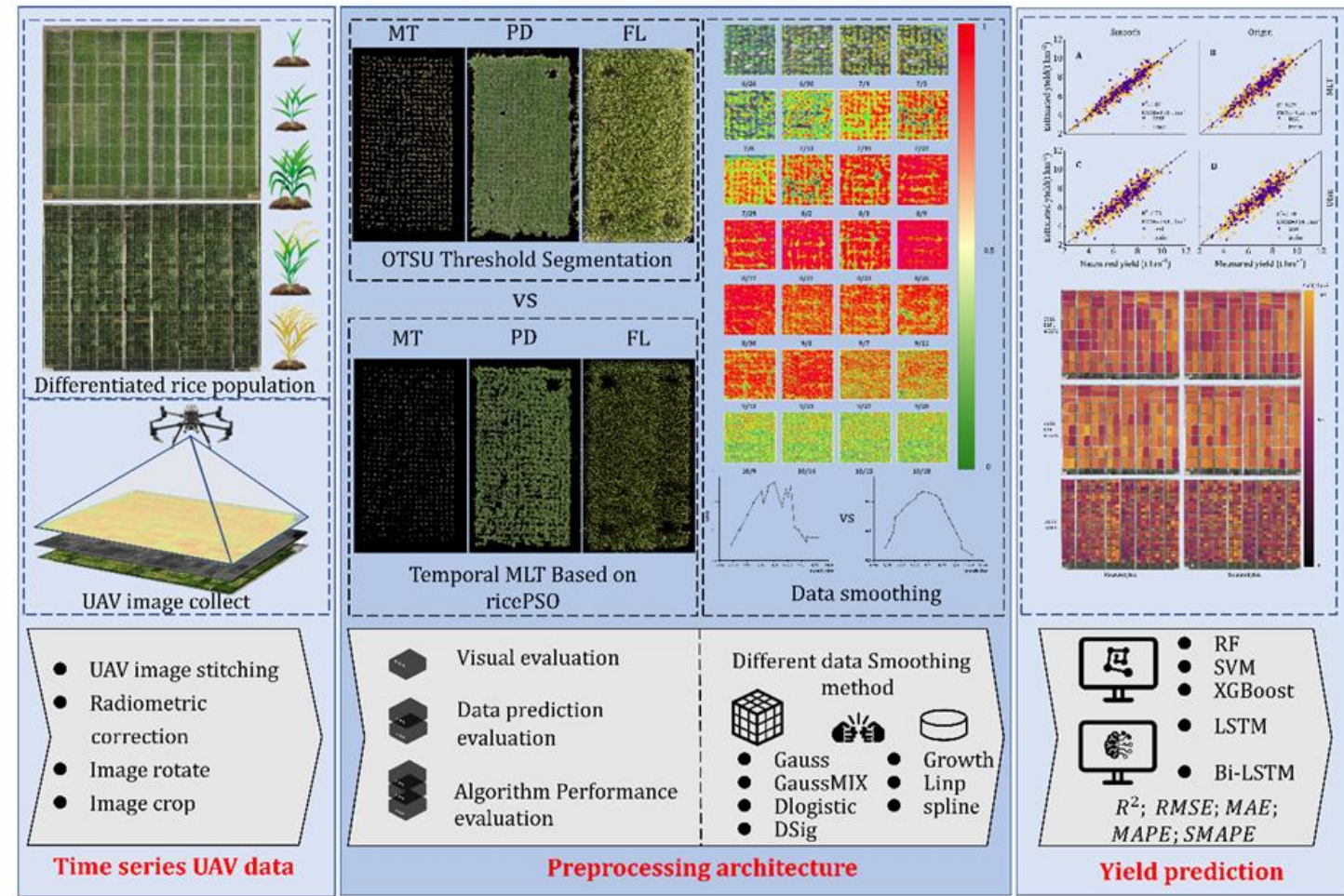


Fig1-2. WORKFLOW

How to extract data ?



Threshold segmentation

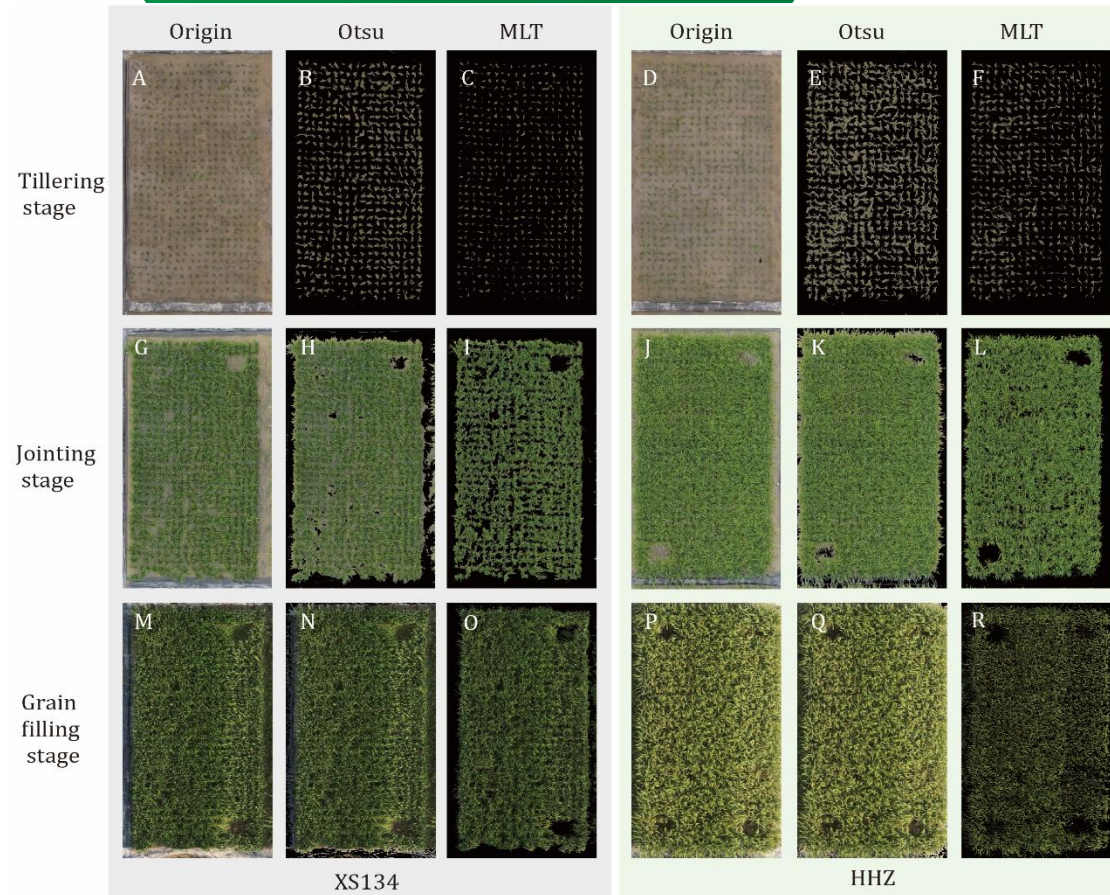


Fig 1-3 The segmentation effects of two threshold segmentation strategies

- ◆ The **MLT** method demonstrates **superior performance** in image segmentation across different growth stages
- ◆ The MLT method also outperforms the Otsu method in terms of yield forecast accuracy (>1-11%).

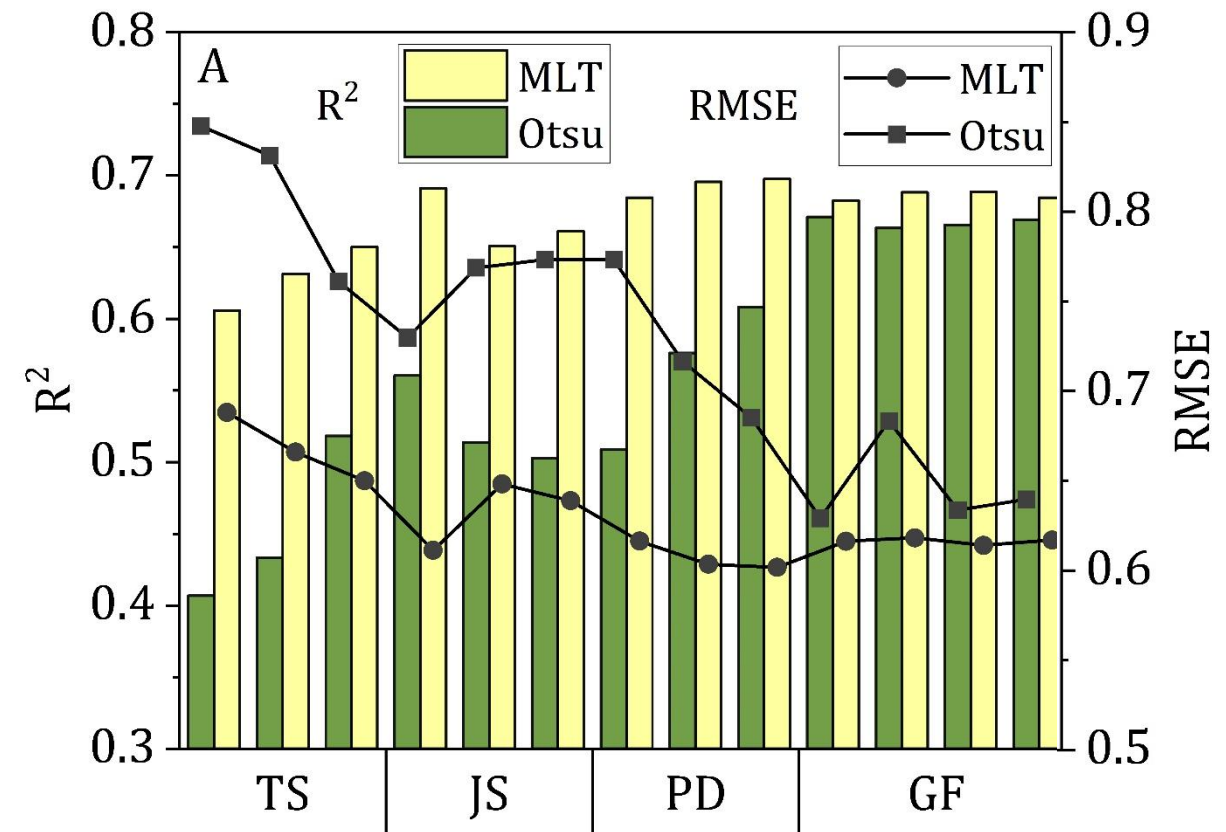


Fig1-4. Yield prediction performance under two different threshold segmentation strategies

How to extract data ?



Temporal filter smoothing

Table1-1. The effects of different filtering smoothing functions on the time series data

Method	R ²	MAE	RMSE	RRMSE
Gauss	0.82	0.05	0.06	0.12
GaussMIX	0.81	0.05	0.06	0.13
DLogistic	0.75	0.06	0.07	0.15
DSig	0.77	0.06	0.07	0.14
growth	0.72	0.08	0.1	0.19
Linp	0.63	0.06	0.1	0.19
spline	0.63	0.06	0.1	0.19

Table1-2. Impact of diverse preprocessing strategies on the yield prediction performance

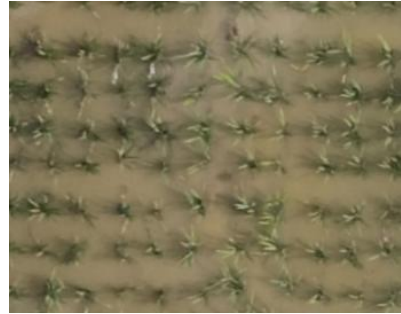
Data correction	Model	R ²	RMSE	MAE	MAPE	SMAPE
		(%)	(t hm ⁻²)	(t hm ⁻²)	(%)	(%)
MLT+Smooth (Gauss)	RF	80.16	0.52	0.43	5.76	5.70
	SVM	79.61	0.53	0.41	5.25	5.30
	XGBoost	81.29	0.51	0.41	5.53	5.44
	LSTM	81.59	0.51	0.38	5.01	4.98
	Bi-LSTM	87.52	0.35	0.25	3.29	3.29
MLT + Origin	RF	75.17	0.58	0.46	6.04	6.03
	SVM	74.34	0.59	0.48	6.30	6.28
	XGBoost	73.71	0.60	0.47	5.92	5.96
	LSTM	73.89	0.60	0.49	6.49	6.40
	Bi-LSTM	75.35	0.58	0.45	5.78	5.82
Otsu+Smooth (Gauss)	RF	72.42	0.62	0.51	6.90	6.74
	SVM	70.23	0.64	0.51	6.47	6.51
	XGBoost	71.65	0.63	0.51	6.81	6.80
	LSTM	72.56	0.61	0.51	6.91	6.81
	Bi-LSTM	73.26	0.61	0.47	5.96	6.00
Otsu + Origin	RF	68.05	0.66	0.53	6.73	6.82
	SVM	67.70	0.67	0.52	6.81	6.86
	XGBoost	68.01	0.66	0.53	7.13	6.99
	LSTM	68.66	0.65	0.52	6.78	6.80
	Bi-LSTM	70.06	0.64	0.50	6.36	6.48

- ◆ the Gaussian method demonstrates superior performance across multiple evaluation metrics.
- ◆ Combining MLT and Gaussian smoothing significantly improves the accuracy of crop yield prediction.

• SUMMARY •



01



How to accurately extract multi-temporal UAV data?

- **MLT and data smoothing techniques** have significantly improved the accuracy of rice yield prediction based on UAV multispectral remote sensing data.
- This method provides a practical preprocessing strategy, but it still needs further research for **multi-variety breeding** scenarios with large differences in growth period.

How to use data ?



Experimental Design

V: 550 rice varieties

(landraces, commercial varieties, rice germplasm resources)

Index: Yield and yield composition; drone data from transplanting to maturity.

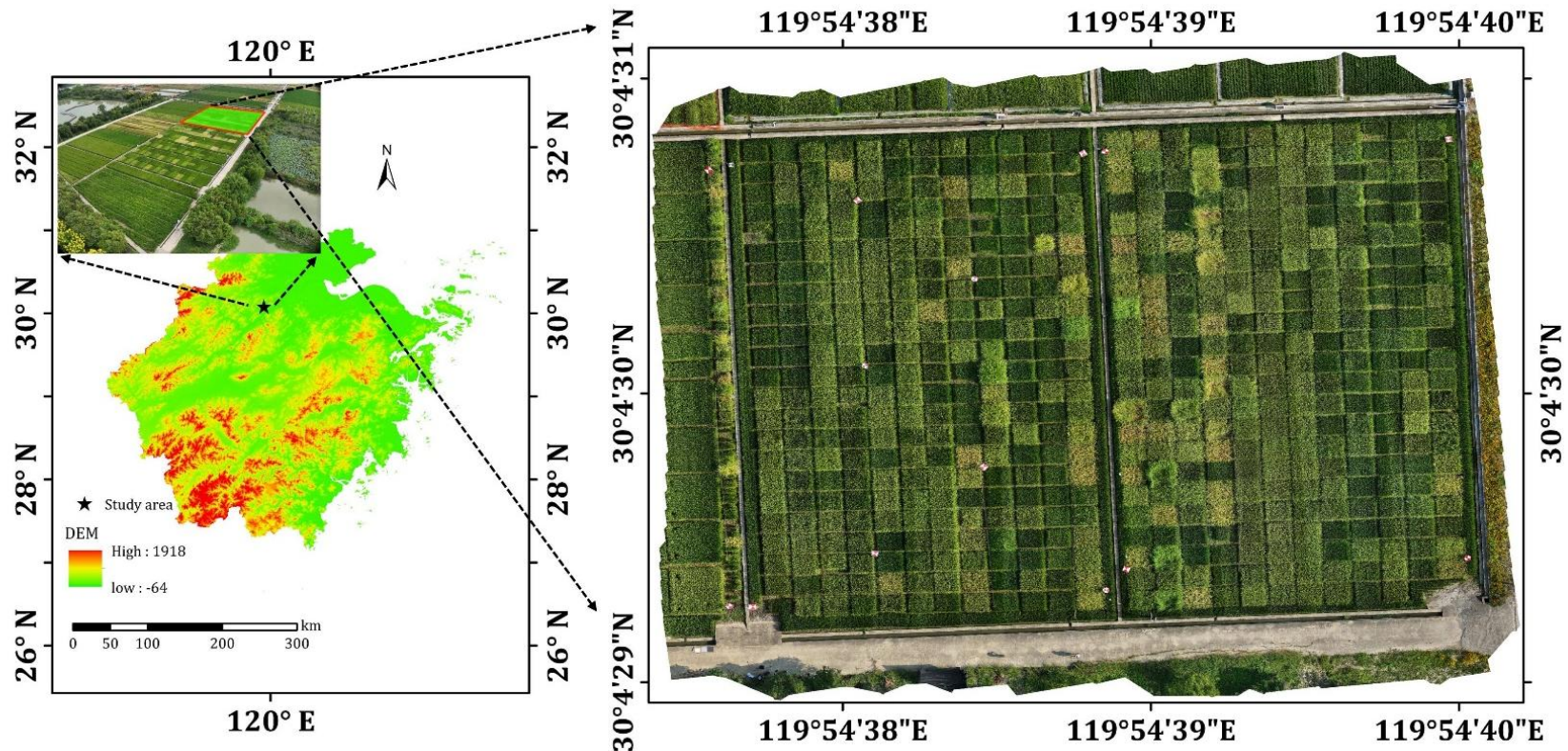


Fig 2-1. Study Site and Field Experimental Layout

How to use data ?



A Time-Series Yield Prediction Framework for Diverse Rice Varieties

Time-Series Alignment

Algorithm Strategy

- ◆ LINE
- ◆ DTW
- ◆ Seg-DTW

Growth-Stage Alignment Strategy

- ◆ Rice phenology prediction model
- ◆ aligned by key growth stages

Deep learning

- ◆ An improved Transformer model, named the Rice Cross-Period Attention Transformer (**riceCPAT**). and three widely used architectures were adopted as benchmarks.

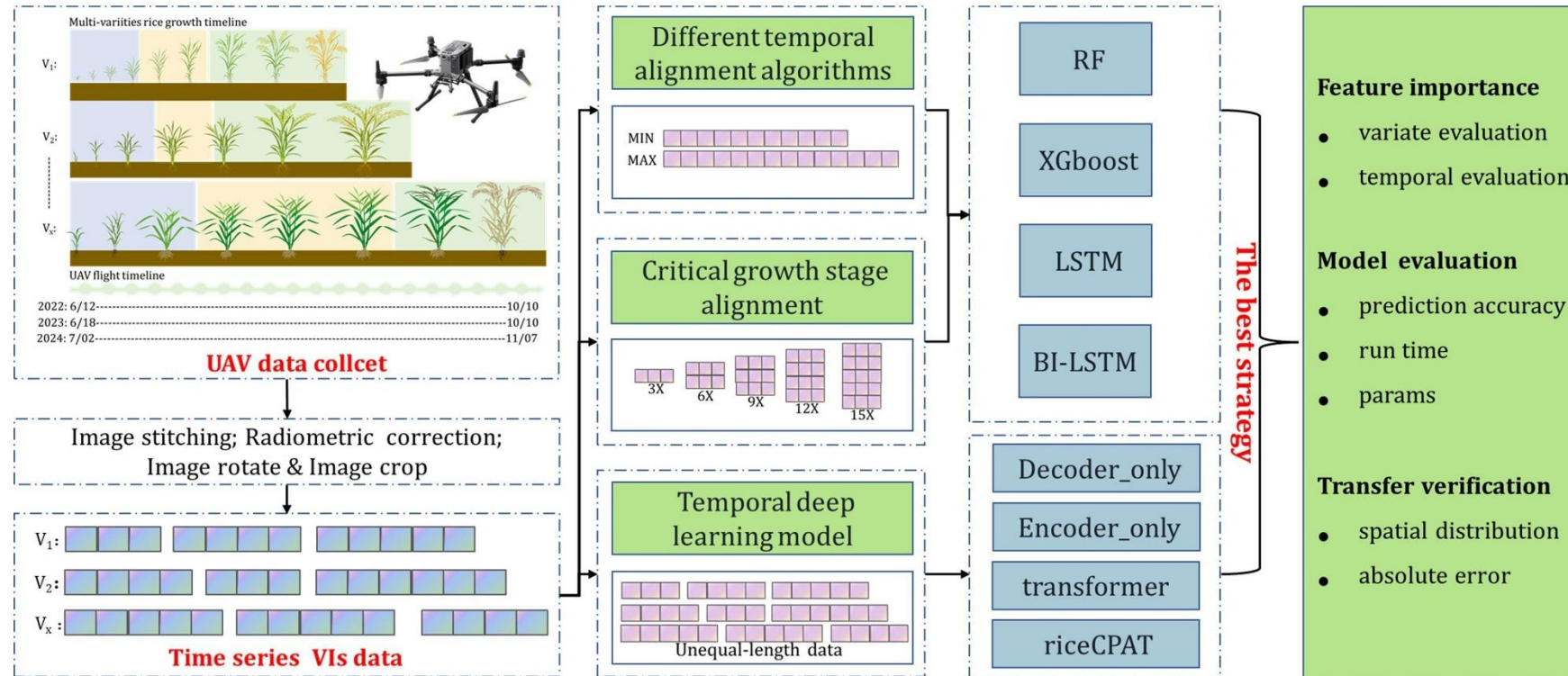


Fig 2-2. Conceptual design of the study

How to use data ?



Time-Series Alignment Algorithm

Table 2-1. Effects of three time-series alignment methods on yield prediction performance

Alignment algorithm	Model	Min reference sequence			Max reference sequence		
		R ²	RMSE	MAE	R ²	RMSE	MAE
DTW	RF	41.64	71.54	36.31	42.82	72.92	51.67
	XGboost	38.85	74.43	56.03	40.02	74.46	56.51
	LSTM	41.59	75.99	47.44	41.63	71.54	36.82
	Bi-LSTM	44.19	69.95	47.93	47.1	69.18	51.14
LINE	RF	30.01	79.29	58.18	25.56	85.79	56.39
	XGboost	24.55	82.21	60.86	23.45	81.93	51.68
	LSTM	33.69	80.98	52.35	31.96	82.01	53.37
	Bi-LSTM	36.58	74.58	52.80	29.51	78.64	57.12
Seg-DTW	RF	43.92	72.21	52.29	47.97	69.89	50.68
	XGboost	42.61	71.80	52.62	43.71	70.93	53.90
	LSTM	45.03	69.43	43.07	48.87	66.96	40.23
	Bi-LSTM	48.58	69.71	49.61	47.72	67.71	50.68

- ◆ **Seg-DTW** achieved the best performance when using the longest reference sequence. Combined with the **LSTM model**, it produced the highest prediction accuracy, with an R² of 48.87%, an RMSE of 66.96 g m⁻², and an MAE of 40.23 g m⁻². This represents an improvement of 17.4% over conventional DTW and 52.8% over linear interpolation.

How to use data ?

Growth-Stage Alignment Strategy

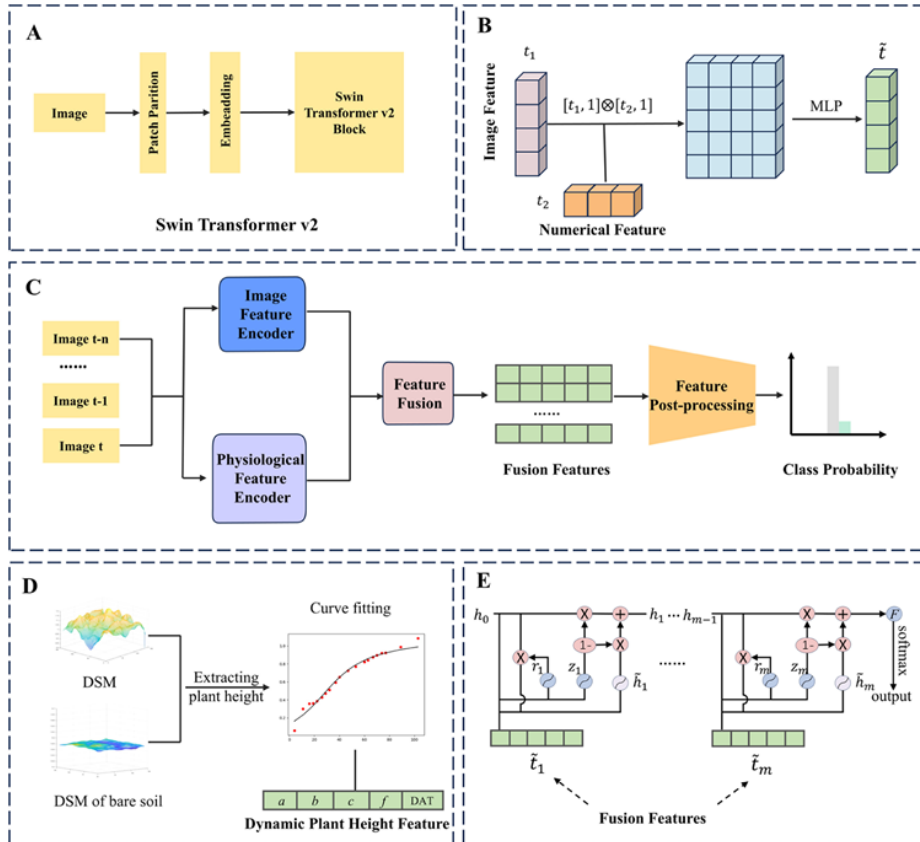


Fig 2-3. GrowAI(multimodal fertility extraction model)

- ◆ The GrowAI recognition model achieves an average accuracy rate of up to 96%
- ◆ Increasing the time series length improved model performance, with the average R^2 of all models increasing from 40% to 61%, and the 15X & Bi-LSTM achieving the highest R^2 (65%).

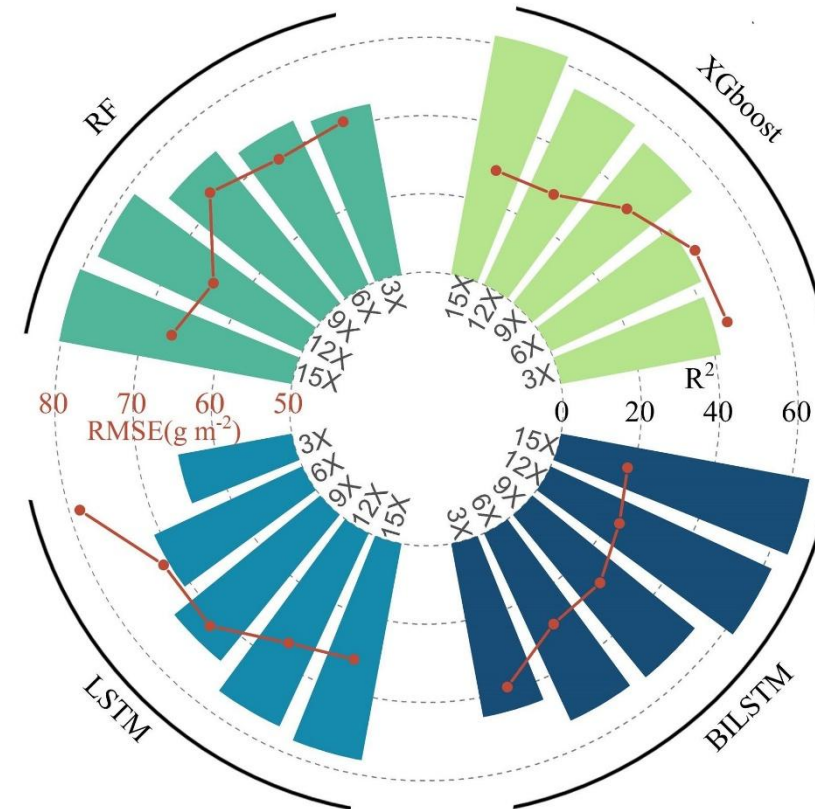


Fig2-4. Yield forecasting results based on the critical fertility period alignment strategy

How to use data ?



Deep learning

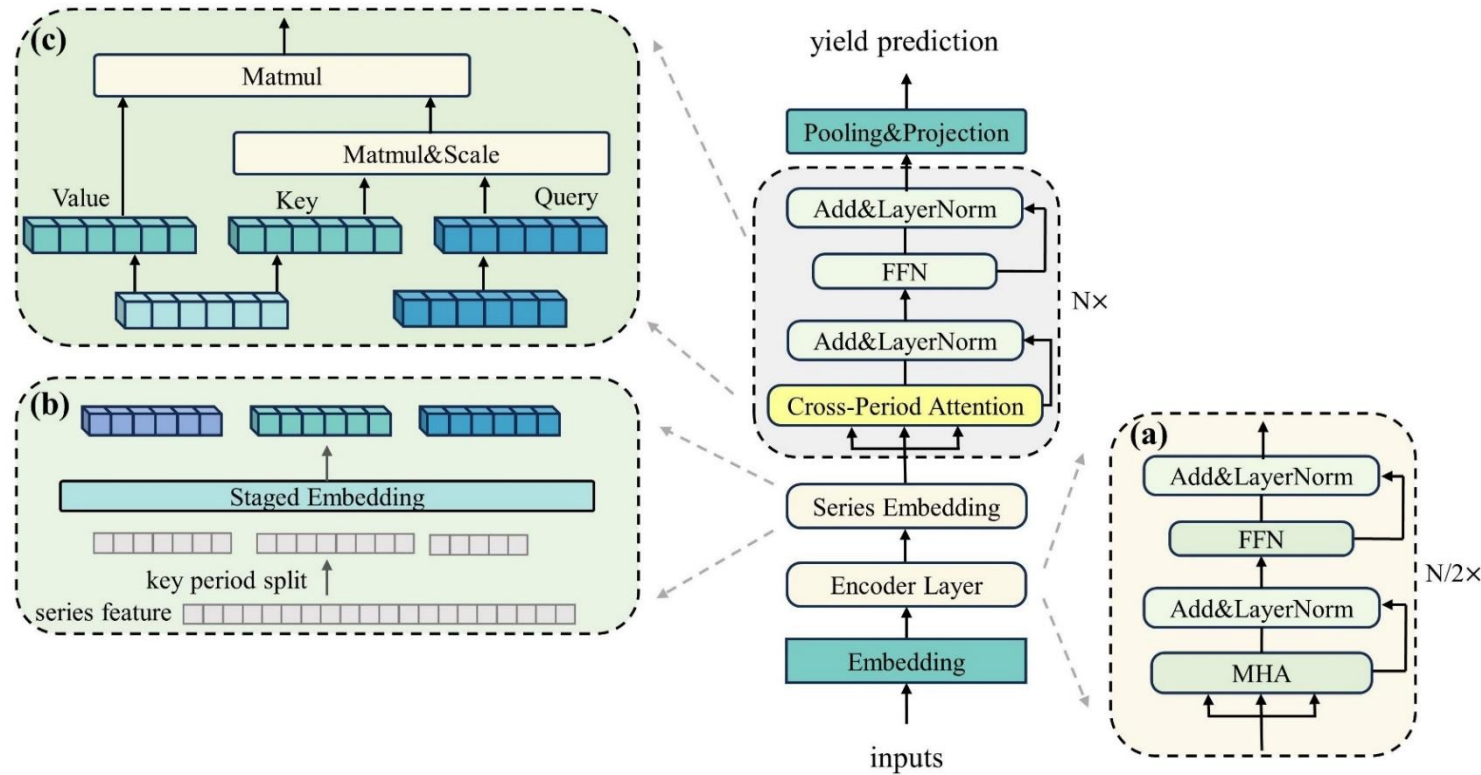


Fig 2-5. The architecture of Cross-Period Attention Transformer for Rice

riceCPAT employs a hierarchical processing strategy. First, it extracts shallow features using a standard Transformer encoder (a) to preserve complete time-series information. Then, based on an adaptive segmentation strategy for key reproductive period nodes (b), it compresses heterogeneous length segments into fixed-dimensional vectors using average pooling. After intra-segment encoding and pooling, it obtains the segment embedding matrix and performs cross-period attention calculation (c).

How to use data ?



Research result

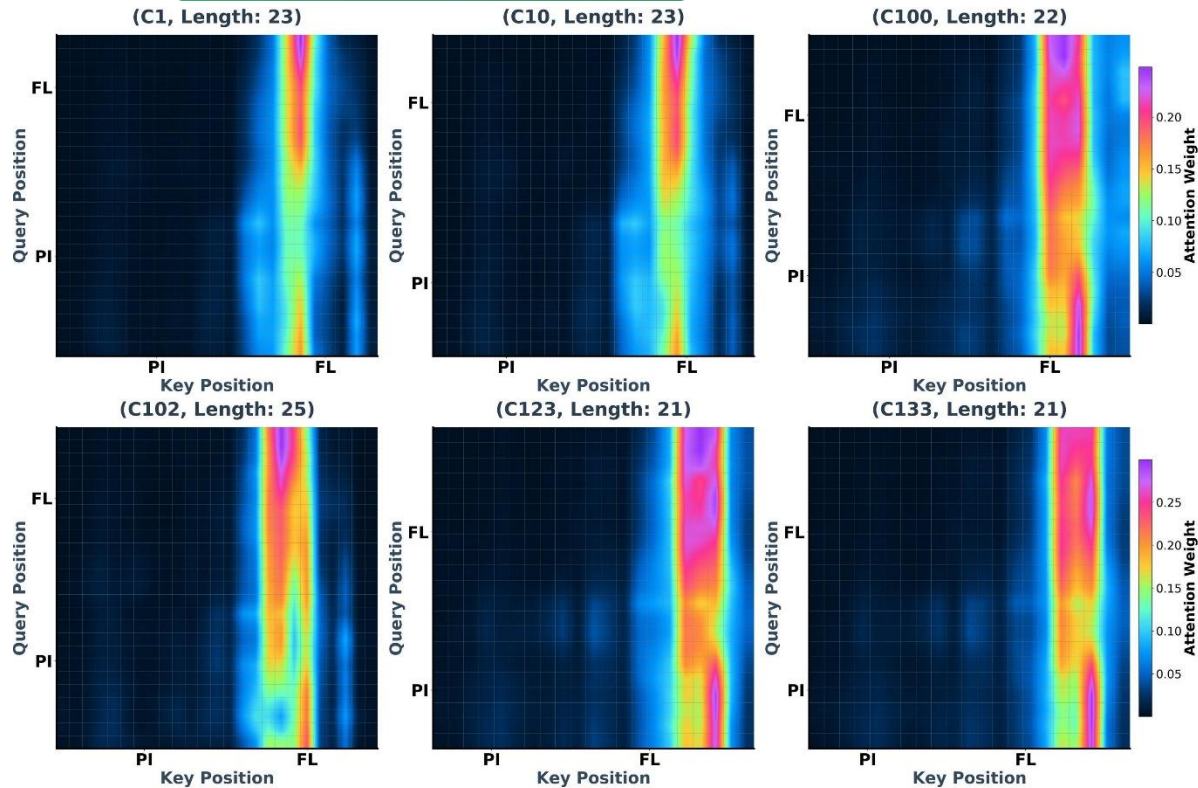


Fig 2-6 Shallow Feature Extraction

- ◆ Shallow Feature characteristics indicate that the period around the **heading stage** is the critical period for rice yield prediction.
- ◆ riceCPAT achieved the highest R^2 (**74.18**) among all evaluated models, significantly reducing the root mean square error (45.73 g m^{-2}) and mean absolute error (36.19 g m^{-2}), while using the fewest parameters (72,561), reducing computational complexity and the number of parameters.

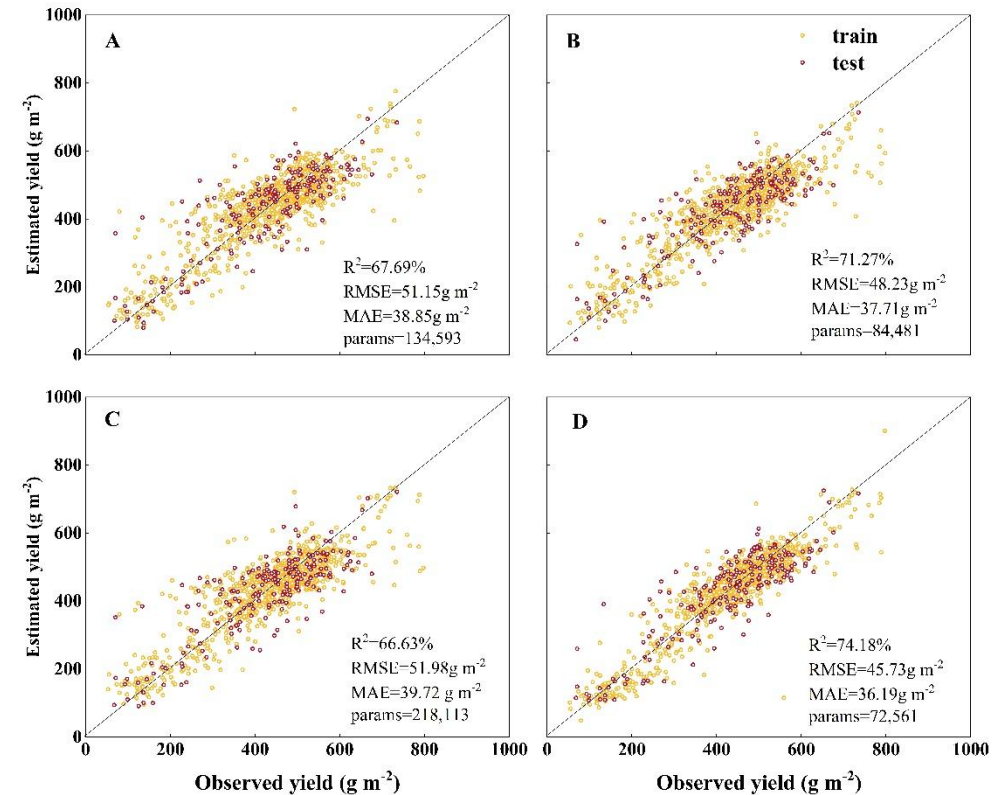


Fig 2-7. Yield prediction results based on four transformer. (A) decoder_only; (B) encoder_only; (C) Transformer; and (D) riceCPAT.

How to use data ?



Transfer verification

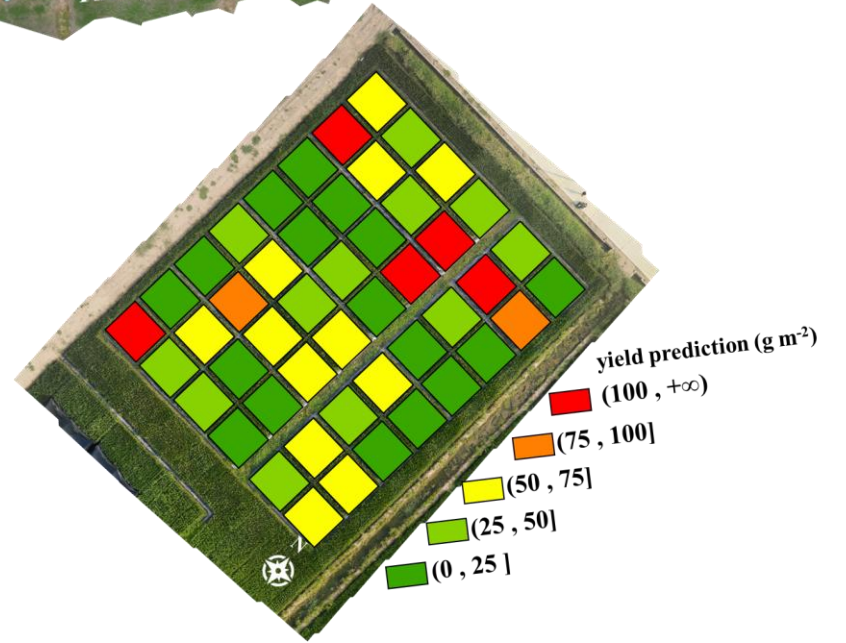
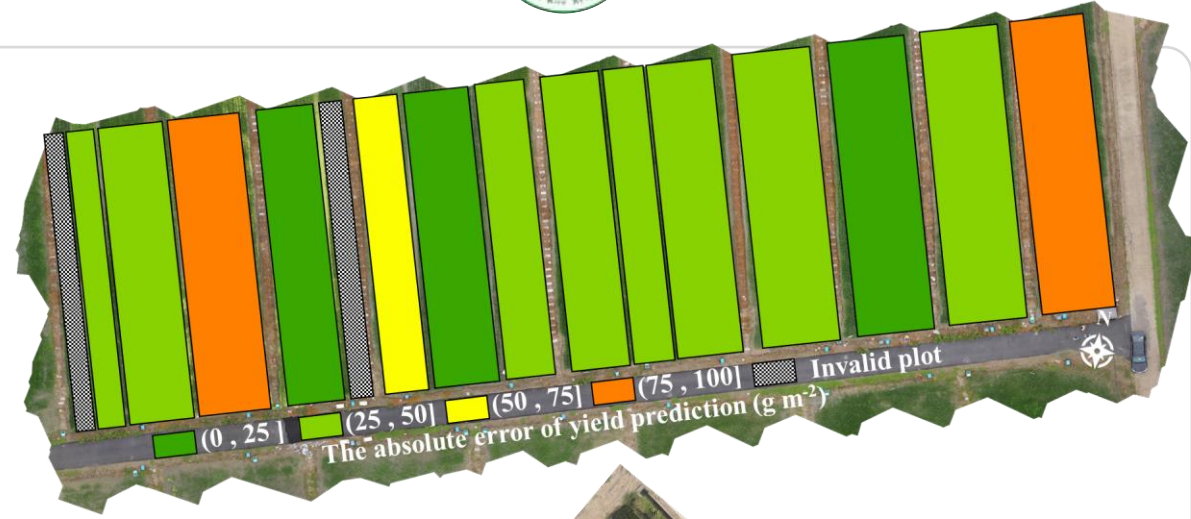
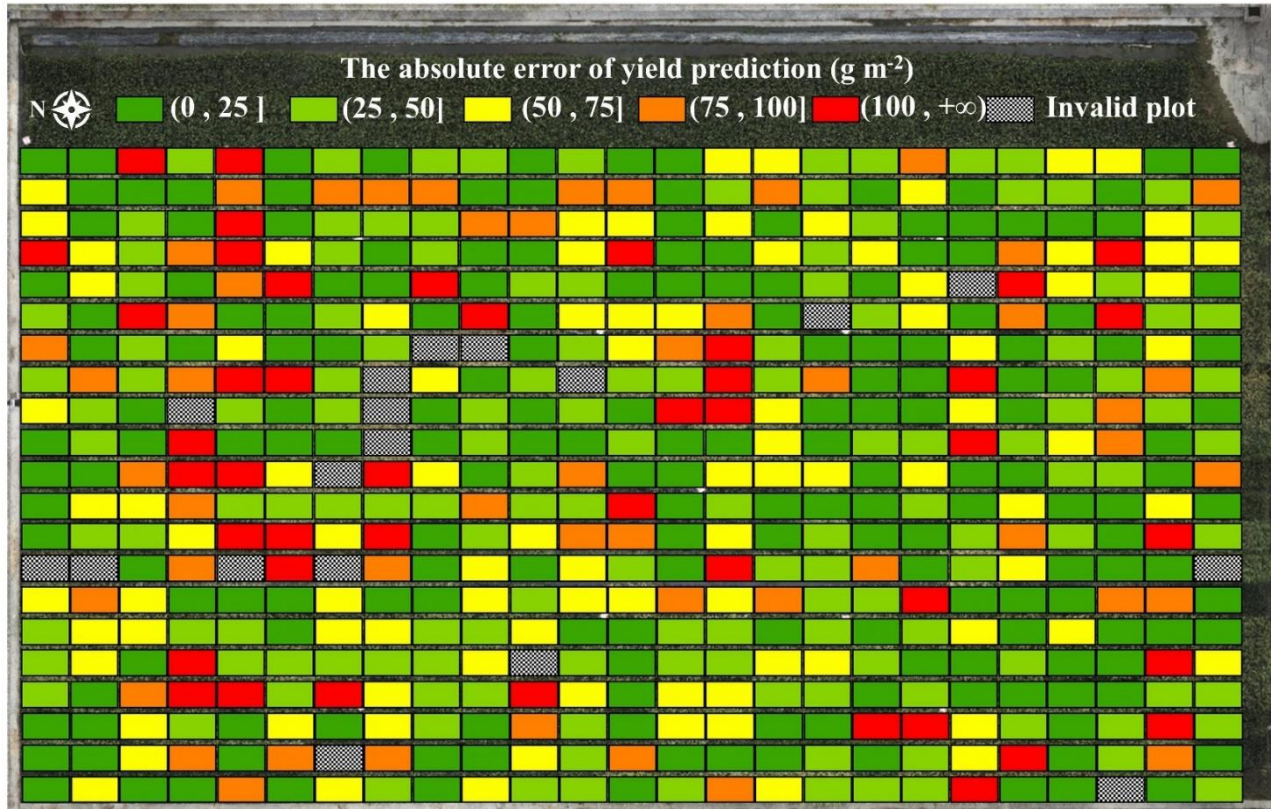
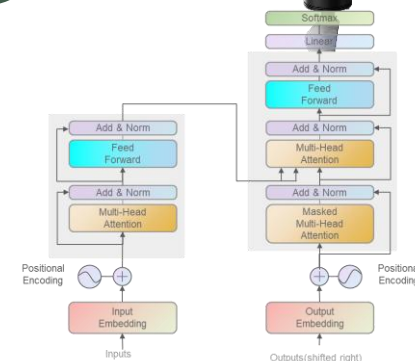
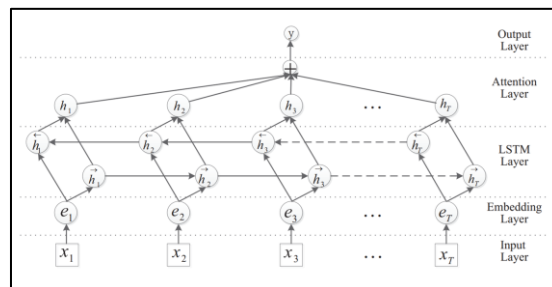
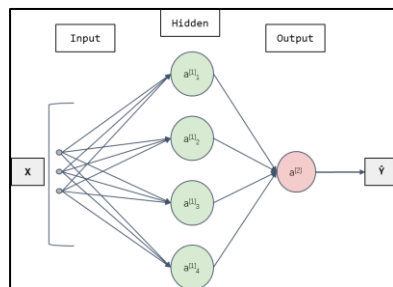


Fig 2-8. Transfer verification

- ◆ Model validation accuracy on unknown datasets: $R^2 = 66.90 \pm 1.64\%$
- ◆ For most breeding plots, yield prediction errors were within acceptable limits (absolute difference $< 50 \text{ g m}^{-2}$), accounting for 63% of effective plots.

SUMMARY



02 How to effectively construct multi-variety yield prediction models?

- ◆ Long-term UAV time-series data significantly improves rice yield prediction.
- ◆ MLT segmentation and Gaussian smoothing improve feature extraction accuracy.
- ◆ And most importantly, the proposed cross-attention Transformer model provides superior performance for multi-variety yield prediction.



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THANKS

Questions and discussions are welcome

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