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Exploring the emergence and changing dynamics of a new integrated ricecrawfish farming system in China

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6 Supplementary Material

7 Landsat data

8 We used Landsat 8 OLI as the major data source and took Landsat 7 ETM+ as supplementary data when 9 Operational Land Imager (OLI) images have bad quality, e.g., with high cloud coverage. Landsat 5 TM 10 images were not used in this study. Both Landsat 7 and Landsat 8 have a 30-m spatial resolution and 16-11 day revisit rate. Previous studies show that Landsat 7 and Landsat 8 have good consistency and can complement each other for mapping land use/covers (Chen & Zhu, 2022). We first selected OLI images 12 with cloud cover lower than 30% within two periods, respectively. We then respectively selected ETM+ 13 14 images for regions where OLI images are lacking within two periods. To make sure the spectral bands 15 from the two satellite sensors are compatible, we selected the visible bands, NIR band, and SWIR bands. 16 Then we spatially created a mosaic based on the two images from Landsat 7 and Landsat 8. Specifically, 17 we use pixels from Landsat 7 to replace the pixels affected by clouds in Landsat 8 images. We finally 18 obtained two images in two cultivation periods and used them for further classification. All the 19 preprocessing work was conducted with Google Earth Engine (GEE), including interpolation, cloud masking, and mosaicing (Foga et al., 2017). 20

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22 Training and assessment samples

Samples were collected based on intra-annual time series graphs of spectral indices and custom visualizations of Google Earth VHR images (Fig. S1). Integrated rice-crawfish farming system (IRC) has a typical spatial structure, characterized by crawfish rearing trenches surrounding the paddy fields (Fig. S2). Non-IRC samples indicate samples of other land use types, including normal croplands, buildings, forests, and water. All 1,300 IRC samples and 1,138 non-IRC samples are used to assess the accuracies of maps. Moreover, water samples included in non-IRC samples were used in CART algorithm to extract the distribution of water in two periods of rice-crawfish farming system.



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Fig. S1 Distribution of field samples. IRC samples indicate samples of the integrated rice-crawfish
 system. Non-IRC samples indicate samples of other land use types, including normal croplands,
 buildings, forests, and water

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A. Rice-crawfish farming field



Fig. S2 Example high-resolution images of rice-crawfish farming fields and traditional cropland. ImageA and B are captured with Google Earth Pro software, with the date of 2022-7-25 and 2022-12-11.

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39 Method for rice-crawfish mapping

The classification method used in this study is based on object-based water difference method (OWDM) (Wei et al., 2021). OWDM first maps the water distribution of two cultivation periods by Automated Water Extraction Index (AWEI_{sh}), and takes the increased water area in the rice-fallow period compared with the rice-planting period as rice-crawfish pixels. To avoid pixel noise, segmented land parcels have been introduced, and the final outputs are rice-crawfish farming parcels. OWDM has been verified and validated with good performance and has been used to map ricecrawfish distribution in other regions (Chen et al., 2022).

48 Two improvements of OWDM have been made in this study. One is in water distribution mapping.

49 OWDM used the mean value and the minimum and maximum values of water samples to determine 50 the suitable AWEIsh thresholds. In this study, we used CART algorithms to map the water distribution in two periods. As a tree-based machine learning algorithm, CART used a split criterion 51 to perform binary recursive classification (Li et al., 2023; Timofeev, 2004). After inputting water 52 samples, Gini index was calculated to determine the best threshold of AWEIsh and finally obtained 53 54 the water spatial distribution (Lewis, 2000). The other improvement is in image segmentation. Instead of using eCognition software, we utilized simple non-iterative clustering algorithm (SNIC) 55 to segment Landsat images. Main parameters required in SNIC include: "seeds" to create elements 56 57 and initialize a priority queue Q, "compactness" influences the cluster shape (a higher value results 58 in more compact superpixels), "connectivity" (4 or 8) to populate the priority queue, 59 "neighborhoodSize" to avoid tile boundary artifacts (Achanta & Susstrunk, 2017). Considering the study area characteristics, we did the code test and assessment, and finally set the suitable 60 61 parameters as follows: seeds: size = 6, gridType = hexagon, compactness = 1, connectivity = 8, and neighborhoodSize = 256 (Li et al., 2020; Tassi & Vizzari, 2020; Xue et al., 2023). CART 62 63 classification was conducted in R and SNIC was conducted on GEE.



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Fig. S3 Workflow of mapping integrated rice-crawfish farming.

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68 Accuracy assessment

We produced a confusion matrix by using validation samples to assess the performances of rice-crawfish maps. We used overall accuracy (OA) and Kappa coefficient to reflect the global accuracies of resulted maps. User's accuracy (UA) and producer's accuracy (PA) refer to the commission error and omission error, respectively. These accuracy metrics were calculated by using the following equations:

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$$OA = \frac{\sum_{k=1}^{n} P_{kk}}{N}$$

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$$UA = \frac{P_{kk}}{P_{k+1}}$$

$$PA = \frac{P_{kk}}{P_{+k}}$$

Where N represents the sum of all validation samples; P_{kk} represent the sum of diagonal elements. P_{k+} and P_{+k} denote the sum of elements in the kth line and kth column.

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Table S1 Accuracy assessment of rice-crawfish cultivation maps.

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	2013	2014	2015	2016	2017	2018	2019	2020	2021
OA (%)	96.21	95.57	94.03	94.07	93.79	92.87	93.19	94.97	94.62
PA (%)	85.19	84.48	80.61	81.81	83.14	81.27	83.54	88.43	88.10
UA (%)	95.96	95.65	96.71	97.70	96.94	97.29	96.38	95.24	96.16

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