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CURRENT STATUS AND PROSPECTS OF RESEARCH ON UAV REMOTE SENSING INVERSION OF RICE AGRONOMIC PHYSICAL AND CHEMICAL PARAMETERS

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Abstract: In recent years, UAV remote sensing technology has been widely used in the inversion of physical and chemical parameters of rice, and has gradually developed into the main way to obtain remote sensing information at the plot scale of rice fields. one of the paths. In-depth analysis of the current status and existence of inversion research on rice agronomic physical and chemical parameters (referring to parameters that can determine certain physical and chemical properties in the agricultural field) based on UAV remote sensing In the problem, it is helpful to better grasp the future development trend of rice drone remote sensing. Review of UAV remote sensing technology in retrieving biochemical component content, structural parameters, productivity, etc. The current research status of the research, in which the inversion research on the content of biochemical components mainly focuses on the direction of nitrogen and chlorophyll and is still dominated by data-driven methods, such as for inversion of nitrogen Narrow band vegetation index NDRE, inversion of rice chlorophyll content by coupling extreme learning machine and partial least squares regression, etc. , and the inversion method based on physical model Fewer; the inversion research of structural parameters mainly includes leaf area index, biomass, etc. , and the method includes the radiation transfer mechanism model used to invert the leaf area index. PROSAIL, used to reverse Optimized Gaussian process regression method based on canopy spectral characteristics for evolving biomass; remote sensing of productivity focuses on rice yield estimation, disease and lodging detection, and the method is useful for water Rice estimation utilization RGB Image usage K- Means Fusion with kernel correlation filtering algorithm. A summary of UAV remote sensing platforms, equipment, and methods was conducted, and nearly 10 year rice farmer Research progress and results of UAV remote sensing inversion of physical and chemical parameters.

Keywords: Rice; UAV; Remote sensing; Inversion; Spectrum

1. OVERVIEW OF AGRICULTURAL UAV REMOTE SENSING PLATFORM

China's rice production accounts for about 1/3 of the grain production. 2/3 The population relies on rice as their staple food, and stable rice production is important for ensuring national food security. plays a crucial role [1]. In recent years, the trend of intensification and scale of rice production has become increasingly obvious. UAV remote sensing technology can be used to control rice in a timely manner Key information on growth during the growth period such as nutrition, diseases and insect pests can provide reliable data support for rice field management, variety selection, etc. promoted large-scale The detection and precise fertilization of model crops can help improve agricultural productivity, reduce environmental pollution and achieve sustainable development.

The main ways to obtain rice field growth information are: manual ground collection, satellite remote sensing collection and drone remote sensing collection. Among them, artificial ground mining The collection method is to select a certain number of rice plants for measurement, which mainly includes disease classification [2], chlorophyll content [3], nitrogen content [4], and photosynthetic rate. Acquisition of information such as rate [5]. Such methods are limited by factors such as measurement efficiency and labor costs, and are difficult to apply to large-scale rice production and commercial breeding. kind. The satellite remote sensing collection method is limited by the spatial resolution, return visit period, cost and other factors of current optical satellites, and is more suitable for provincial or national-scale rice yield estimation [6] and planting area extraction [7], disaster assessment, phenological analysis [8], species classification [9] and other fields, it is difficult to target Accurately monitor rice growth at the field scale. Compared with this, UAV remote sensing collection has fast response capability; high image resolution; application expansion It has strong capabilities and can replace a variety of small remote sensing sensors according to actual needs; it has the advantage of low operating costs and is very suitable for monitoring rice growth at the field scale. Accurate monitoring [10].

This study takes the relevant research results of UAV remote sensing in the inversion of rice physical and chemical parameters as the review object, sorting out and summarizing the current national research results in this field. Internal and external research progress and cutting-edge directions, in order to provide relevant theoretical basis for future quantitative UAV remote sensing research on rice based on UAV remote sensing methods. and technical support.

The UAV remote sensing platform is the necessary instrument and equipment to carry out quantitative remote sensing research on rice. It mainly includes two UAV flight platforms and remote sensing payloads. In part, different flying platforms correspond to different rice production scales, and the remote sensing load mainly determines the type of rice remote sensing data obtained.

1. 1 Overview of UAV Flying Platform

At present, in the research and application of agricultural UAV remote sensing, electric UAV platforms are mainly used [11- 12]. According to its wings and flight direction Different types of UAV flying platforms can be divided into multi-rotor, fixed wing and composite flying platforms. The multi-rotor can hover in the air for easy shooting and Monitoring tasks. The advantages of multi-rotor are good maneuverability, long hovering time and easy control. But their battery life is relatively poor. Advantages of fixed wing It can fly in the air for a long time, has strong endurance and fast speed, and is suitable for long-distance monitoring and reconnaissance missions. However, they are less maneuverable. The composite flying platform combines the advantages of multi-rotor and fixed wing, and has the ability to take off and land vertically and fly in the air for a long time. The advantage is that it can be used in narrow It can take off, land and operate in a small space, while being able to fly in the air for a long time, suitable for monitoring and reconnaissance missions. However, due to the complex flight platform Structure and complexity, higher cost. Overall, choosing between different types of drones depends on mission requirements and environmental conditions. Rice drone remote sensing Commonly used flight platforms in the field are shown in Table 1.

The UAV low-altitude remote sensing platform has greatly simplified the difficulty of flight control through continuous technological upgrades, especially for small areas. In terms of control of the multi-rotor flying platform, autonomous flight has been achieved to obtain remote sensing data, making the acquisition of UAV remote sensing data processable and standardized.

Table 1 Commonly used flying platforms for quantitative remote sensing of rice

category	Manufacturer / Model	Applicable scene	references
Category	Manufacturer/model	Applicable scenarios	References
Multi-rotor Multi - rotor	DJI / Phantom series Dji / Genie series	≤20 hm 2	[13]
Multi-rotor Multi - rotor	DJI / Jinwei series Dji / Warp series	≤40 hm 2	[14]
fixed wing Fixed - wing	EBee/RTK series EBee/RTK series	≤70 hm 2	[15]
fixed wing Fixed - wing	Three Airlin es /MTD100	≥70 hm 2	[16]
Composite- wing	Pegasus /v1000 Feima/ v1000	≥70 hm 2	[17]

1. 2 Common Loads for Agricultural UAV Remote Sensing

The remote sensing payload is the main instrument and equipment mounted on the UAV flying platform to obtain rice remote sensing information. According to the type of data acquisition, it mainly includes: data Code camera, multispectral camera, hyperspectral imager, thermal imager, lidar, sunlight-induced chlorophyll fluorescence meter, etc. Digital camera can obtain high-resolution images of rice canopy RGB Visible light imagery is also the most common and relatively low-cost type of UAV remote sensing. This kind of UAV remote sensing load has effective pixels up to tens of millions.

A multispectral camera, also called a multichannel spectrometer, is a remote sensing image collection device composed of specific wavelengths. Compared with visible light images, multispectral images The main purpose is to add near-infrared band and red-edge band information that are sensitive to changes in crop growth.

Hyperspectral imagers can obtain reflectivity information in continuous bands within a certain wavelength range. In the field of agricultural remote sensing, airborne hyperspectral imagers are mainly The band range is 400~ 1000nm _. Since the hyperspectral imager can obtain high-dimensional reflectance information of the rice canopy, compared with visible light and multi-light The information dimension of the spectrum has obvious advantages. However, its shortcoming is that when the drone is flying at the same height, the spatial resolution of hyperspectral images is significantly higher. Sub-visible and multispectral remote sensing imagery.

The main working principle of the thermal infrared imager is to use an infrared detector and an optical imaging mirror to receive the infrared radiation energy of the measured target. The photosensitive source of the infrared detector of the scientific system uses an electronic scanning circuit to scan the infrared thermal image of the object being measured, converting it into an electrical signal and passing it through the calibration algorithm. Convert it into temperature, and then convert the temperature of each pixel into a grayscale digital matrix, and add pseudo-color processing to form a hot red drone External remote sensing images [18].

LiDAR is an active remote sensing technology that mainly uses the principle of light reflection when encountering obstacles. LiDAR System sends It shoots laser light and reflects it back to LiDAR after encountering ground objects. CMOS in the system The sensor receives and calculates the distance from the drone to the ground object through the time difference.

Sunlight-induced chlorophyll fluorescence (SIF) is a spectral signal emitted by the photosynthetic center of plants under sunlight conditions, with red light and near-infrared light. The two wave peaks can directly reflect the dynamic changes of actual photosynthesis of plants. SIF Remote sensing is a vegetation remote sensing technology that has developed rapidly in recent years, making up for Inadequacy of current vegetation remote sensing observations.

1. 3 UAV Remote Sensing Data Processing Software and Prepossessing Methods

The UAV flight platform and remote sensing payload are the hardware foundation for quantitative remote sensing of rice UAVs, and obtaining high-quality UAV remote sensing data for rice fields is Quantitative analysis of data requires software support. At present, UAV flight platforms all come with their own autonomous flight control software, which can ensure that they are in accordance with standardized The route collects remote sensing data for the area to be analyzed, and there are also some highly integrated payloads such as Sequioa, RedEdge Images can be obtained independently. After obtaining the original data of remote sensing images, it is usually necessary to splice and preprocess the remote sensing images. Commonly used data splicing software includes: PIX 4 Dmap - per, Agisoft PhotoScan, RockyMapper, DJI Terra et al.

2. UAV REMOTE SENSING INVERSION OF RICE BIOCHEMICAL COMPONENT CONTENT

2. 1 UAV Remote Sensing Inversion of Rice Nitrogen Content

Nitrogen is the most important element that affects rice growth, development and final yield. Changes in nitrogen content will affect photosynthesis, protein synthesis, and carbon Nitrogen metabolism, so rice nitrogen is important information to characterize rice growth. Precise fertilization through nitrogen levels can improve rice productivity and is also At present, one of the most research directions in the field of rice UAV remote sensing is. Among them, UAV optical remote sensing is used to construct spectral index and establish statistical regression. Inversion model is the most commonly used method to invert rice nitrogen content. Based on the traditional broad-band vegetation index, the normalized vegetation index (normalized dif - reference vegetation index, NDVI), ratio vegetation index (relative volatility index, RVI), etc. , the accuracy of retrieving rice nitrogen content is not Very high. This is mainly because these vegetation indices can only roughly describe the overall growth of rice, but cannot make decisions based on specific biochemical component content information. Accurate prediction. Some researchers take advantage of the dimensionality of hyperspectral information to construct a narrow-band vegetation index to improve the retrieval accuracy of rice nitrogen content [36]. The form of index construction mostly draws on traditional NDVI, enhanced vegetation index (enhanced vegetation index, EVI) and other vegetation index methods, ZHENG et al. [37] constructed a narrow-band vegetation index through UAV hyperspectral remote sensing data. NDRE, and use regression analysis method to invert rice nitrogen content quantity, the results show that using NDRE The inversion effect is better than the inversion effect of traditional wide-band vegetation index. INOUE [38] used an airborne spectroscopic instrument Create a hyperspectral vegetation index RSI, which achieves good accuracy in retrieving rice nitrogen content on a regional scale. The UAV vegetation index is used as an input quantity to reflect The advantage of estimating the nitrogen content of rice is that it is simple and operable. However, because the mechanism of the influence of nitrogen content on the spectrum is relatively complex, it is difficult to simply use the vegetation index to estimate the nitrogen content of rice. It is often difficult to describe this complex relationship, which also makes the accuracy of nitrogen content retrieval using vegetation index susceptible to varying degrees of interference. for better Taking advantage of the data dimension of hyperspectral, researchers used feature extraction methods to reduce the dimensionality of the hyperspectral reflectance acquired by drones and extract high-resolution data. Spectral characteristics, and then combined with machine learning algorithms to establish a UAV remote sensing inversion model of rice nitrogen content. Yang Hongyun et al. [39] used principal component analysis (prin - cipal component analysis, PCA) and the continuous projection algorithm (successive projections algorithm, SPA) conducted on rice hyperspectral reflectance Feature extraction, the accuracy of the rice nitrogen machine learning diagnosis model established based on spectral features on both the training set and the prediction set exceeds 95%. in water Regarding UAV remote sensing modeling methods of rice nitrogen content, there are few inversion methods based on physical models, and data-driven methods are still the main ones at present. Commonly used machine learning models for UAV remote sensing inversion of rice nitrogen content include: GPR [40], PLSR [41], RF [42], NN [43], etc. How to improve rice nitrogen content without The mechanism of human-machine remote sensing inversion is the focus of UAV remote sensing inversion of rice nitrogen content.

2. 2 UAV Remote Sensing Inversion of Rice Chlorophyll Content

The pigment content of rice leaves mainly includes chlorophyll and carotenoids. The chlorophyll content can directly reflect the nutritional status of rice and is closely related to the rice. Leaf photosynthesis is closely related [44]. Research on UAV remote sensing modeling of rice chlorophyll content mainly includes : data-driven and mechanism model-driven methods Law. Cao Yingli et al. [45] aimed at the problem of unclear red edge position characteristics in the UAV hyperspectral retrieval of rice chlorophyll content in Northeast China. Based on the red-edge spectral response characteristics of chlorophyll content, five machine learning methods were used to establish a UAV remote sensing inversion model of rice chlorophyll content. Efficient monitoring of canopy chlorophyll content provides a reference. XU [46] combined with the mechanism of crop radiation transmission PROSAIL model, optimized Bayesian network model structure The structure improves the pathological inversion problem of UAV remote sensing of rice chlorophyll content and improves the inversion accuracy. LIU [47] used adaptive ant colony optimization algorithm (AU-ACO) extracts the hyperspectral features of rice UAVs, and couples the extreme learning machine (ELM) with the partial least squares regression (PLSR) to construct a water The rice chlorophyll content inversion model improves the UAV remote sensing prediction ability of rice chlorophyll content.

2. 3 UAV Remote Sensing Inversion of Other Rice Component Contents

In addition to nitrogen and chlorophyll, domestic and foreign researchers have also conducted relevant research on the inversion of other nutrient contents in rice using drone remote sensing technology. Ban Songtao et al. [48] used the continuous projection method to extract UAV hyperspectral characteristic bands that are highly correlated with phosphorus in rice leaves, using four machines The learning method constructs the inversion model of phosphorus content respectively. LU [49] studied the inversion of rice potassium with different spectral indexes and texture features based on UAV remote sensing. To determine the feasibility of the rice potassium content, an inversion model for rice potassium content was constructed that integrated texture features and vegetation index.

3. UAV REMOTE SENSING INVERSION OF RICE STRUCTURAL PARAMETERS

3. 1 Rice LAI UAV Remote Sensing Inversion

Leaf area index (LAI) is one of the important structural parameters of rice. LAI It is a dimensionless variable that describes the canopy structure and is related to vegetation photosynthetic activity and plant health. It can be regarded as a potential representative of crop biomass, harvest index and grain yield, and is useful for evaluating rice growth, It is of great significance to predict the final growth and agricultural production of rice. Calculation of rice using traditional agronomic methods LAI Although the calculation results are more accurate, However, destructive sampling is required, and the LAI It is often difficult to characterize the population status of rice. UAV low-altitude remote sensing means can pass Equipped with a variety of optical sensors, it uses data-driven, physical model-driven, data assimilation and other methods to invert the scale of rice fields. LAI. YAN etc. [50] for 48 For different rice varieties, UAV multispectral remote sensing images are used to calculate the vegetation index, and statistical analysis methods are used to establish the rice LAI inversion model, the research results show that the vegetation index during the entire growth period is related to LAI The correlation is weak, especially the vegetation index before heading and after heading and LAI There is a significant lag in the relationship. The integration of vegetation index and canopy height can improve the inversion accuracy. Hang Hongyan et al. [51] used different texture combinations to The texture index was optimized according to the formula, and a multi-index fusion rice was established using spectral characteristics, texture index and coverage as input quantities. LAI UAV remote sensing inversion model, the root mean square error of the model is 0. 3. Establishing UAV remote sensing of rice using a data-driven approach LAI Inversion model, inversion results and test conditions, There is a strong correlation between the data collection methods and the model’s universality is insufficient. LI [52] adopted a radiative transfer mechanism model PROSAIL, using drones Hyperspectral remote sensing images are used to retrieve rice by establishing a lookup table LAI, effectively improved the tillering stage of rice LAI The case where inversion is overestimated.

3. 2 Rice Biomass UAV Remote Sensing Inversion

Rice aboveground biomass is one of the key parameters for evaluating rice growth. Crop biomass is estimated through remote sensing. Among them, optical remote sensing and laser Lidar sensing is the main source of remote sensing data for rice biomass estimation, among which optical remote sensing inversion is the most widely used [53]. XU [54] based on UAV The spectrum, texture and other characteristics of the rice field canopy were obtained, and a rice biomass inversion model was established by optimizing the Gaussian process regression method to improve the rice biomass inversion model. Model inversion saturation problem when the quantity is high. DAISUKE [55] combined UAV low-altitude remote sensing data to obtain rice coverage and established a UAV remote sensing image The model relationship between rice biomass and quantitative trait locus (QTLs) improves UAV high-throughput phenotyping Obtain the application effect in rice assisted breeding.

3. 3 UAV Remote Sensing Detection of Other Structural Parameters of Rice

In addition to rice In addition to major structural parameters such as LAI and biomass, UAV remote sensing technology has been used to detect structural parameters such as rice plant height and rice ears. Researchers have conducted relevant studies. LU [56] extracted rice fields by obtaining multispectral and visible light remote sensing images of rice. NDVI and vegetation coverage, Rice plant height monitoring model established using multiple linear regression method, model R 2 for 0. 838.

4. UAV REMOTE SENSING MONITORING OF RICE PRODUCTIVITY

4. 1 UAV Remote Sensing Estimation of Rice Yield

Accurate remote sensing estimation of rice yield is of great significance for rice variety selection, insurance loss assessment, production management, etc. Commonly used remote drones The sensory yield estimation method is to establish a statistical model between vegetation index and yield in multiple growth periods. This method is widely used because of its simplicity and high efficiency. Application [57-58]. However, the natural conditions of the spectral information obtained at different time points must be different, and the extracted vegetation index must also have certain errors. Affects the yield inversion accuracy [59]. Studies have used "relative spectral variables" ” and “relative yield ” concept to carry out multi-temporal UAV rice yield remote sensing assessment Calculation, the absolute value of the average relative error reaches less than 5% [60]. DUAN [61] used UAV remote sensing to construct enhanced plants for rice under different phenological conditions. is indexed, and the rice yields of different regions and varieties are inverted through the multi-temporal inversion method. The error accuracy is within Within 7%, research results show that using UAV multi-temporal remote sensing can effectively retrieve rice yield. In addition to using vegetation index for yield monitoring, some researchers also use image-based Analytical methods for estimating rice yield, REZA et al. [62] used rice drones at low altitude RGB image, a method based on K- Means The method fused with the kernel correlation filter (KCF) algorithm is used to segment the rice ears, and then use agronomic formulas to estimate rice yields to estimate the yield of low-cost rice. provides a new method. At the same time, some researchers use the method of integrating hyperspectral information and texture features to construct rice breeding communities. The UAV remote sensing yield estimation model improves the accuracy of traditional machine learning methods in estimating rice yield [63-64]. HAYAT [65] proposed a basis Multivariate Gaussian mixture model (gaussian) based on unsupervised Bayesian learning method mixture model, GMM), used to identify the number of rice ears in rice drone remote sensing images. The accuracy of rice ear identification is More than 90% can provide decision-making basis for rice breeding and yield estimation. OGAWA etc. [66] designed A deep learning method that can use low-cost drone visible light cameras to accurately identify rice ear positions in rice fields to assist in rice variety selection and yield assessment.

4. 2 UAV Remote Sensing Monitoring of Rice Diseases

UAV remote sensing monitoring of rice diseases is of great significance in providing plant protection management decisions in rice fields and ensuring rice yield and quality. righteous. AN [67] used UAV multi-temporal hyperspectral data to establish rice smut disease detection using a method of coupling spectral features and time features. model, the recognition accuracy is 85%. Xiao Wen et al. [68] used split windows Gram - Schmidt Changes in feature extraction of UAV rice field hyperspectral remote sensing images, and use PSO - SVR Algorithm establishes rice sheath blight disease index detection model. Kong Fanchang et al. [69] used the UAV hyperspectral platform to obtain information on different diseases. Based on the canopy data of rice panicle blast with damage levels, a random forest was used to establish an identification model, and the characteristic correlation of each input quantity was added based on the rice physiological parameters. With the explanation, the accuracy of the prediction set reaches 90%, which can explain the comprehensive change process of the overall physiological parameters of the plant caused by panicle blast.

4. 3 UAV Remote Sensing Identification of Rice Lodging

Rice lodging is of great significance to rice yield and harvest as well as insurance loss assessment in the later period. Because lodging rice is different from normal rice in plant shape, There are large differences in structure, so image classification methods are often used for identification. YANG [70] combined with UAV remote sensing data to use lightweight depth Learning model EDANet achieves accurate identification of rice lodging in rice fields, with an identification accuracy exceeding 90%. TIAN [71] studied the multispectral images acquired by UAVs. Like constructing texture feature index, the established lodging detection model is more accurate than the corresponding image recognition model.

5. DISCUSSION AND PROSPECTS OF UAV REMOTE SENSING OF RICE PARAMETERS

The research on the inversion of physical and chemical parameters of rice based on UAV remote sensing has achieved certain research results. By summarizing the relevant research, the current difficulties and development suggestions in the field of rice UAV remote sensing are as follows:

UAV remote sensing inversion of rice physical and chemical parameters is mostly based on data-driven methods, and the physical meaning of the inversion model still has shortcomings. Machinery Algorithms such as learning and deep learning have developed rapidly in recent years, using data-driven methods to establish a correlation between UAV remote sensing information and rice physical and chemical parameters. The corresponding relationship greatly simplifies the modeling difficulty. It only needs to obtain a large number of sample data sets to complete the modeling, which improves the model efficiency, but the data The driving method has high requirements for data collection conditions and data sample size. At the same time, the model has many limiting conditions and the inversion model has insufficient universality [72]. Crop radiation transfer uses physical methods to accurately describe the response mechanism between solar radiation and crop spectra. It is a method of using drone remote sensing to carry out rice quantification. important theoretical basis of remote sensing, among which PROSPECT The model is currently the most commonly used radiation transfer mechanism model used to describe rice leaves and can simulate crop leaves Optical properties of 400~2 500 nm [73-74], 2021 Year PR OSPECT Latest upgrades to the model PROSPECT-PRO The model separates proteins from cellulose, lignin, hemicellulose and starch, optimizes the simulation process of leaf radiation transfer, and provides a method for inverting crop carbon through spectral information. Nitrogen content provides a certain basis [75]. Although the radiative transfer model has certain advantages in the physical sense of the model, the rice parameters it inverts are The quantities are limited to the input parameters of the radiative transfer model. The inversion methods are mainly lookup table methods and numerical optimization methods [76]. There are problems with low inversion efficiency. question.

Parameters such as rice nitrogen content and disease level are currently the main agronomic parameters used in rice drone remote sensing. However, how to use drone remote sensing to guide water conservation? There are still deficiencies in the practical application of precise operation prescription maps for top dressing and pesticide application in rice fields, including the lack of reference remote sensing information for decision-making. is one of the keys to the problem. Some studies build standard rice fields through optimal cultivation models and obtain corresponding UAV remote sensing information as standard parameters. The remote sensing information is examined and compared with the UAV remote sensing data measured in the field to form a prescription map [77-78]. However, there are still many restrictions in the construction of rice standard fields. factors, including restrictions on varieties, phenology, cultivation modes, etc. , and the introduction of rice growth models as a reference for decision-making is a future development using drone remote sensing. An important method for rice field management decision-making [79-80].

There are deficiencies in rice drone remote sensing big data and rice research is concentrated in Asia, with insufficient global attention. The achievements of artificial intelligence in recent years has developed rapidly and has been widely used in the Internet field. Massive data is the prerequisite for carrying out artificial intelligence research. At present, rice physical and chemical ginseng The acquisition of quantitative and UAV remote sensing data mainly relies on the independent collection of each scientific research team, making it difficult to truly establish a large rice UAV remote sensing data set. Therefore, how to establish a nationwide rice drone remote sensing data collection standard and sharing mechanism will help scientific researchers to achieve breakthroughs in rice drones. The key technologies of computer-based quantitative remote sensing are of great significance.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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