UAVリモートセンシングと日射量データの統合による収量推定
Estimation of Rice Yield Based on the Integration of UAV Remote Sensing and Solar Radiation Data

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1. Introduction

Crop monitoring using Unmanned Aerial Vehicle (UAV) remote sensing is an important contributor to the improvement of yield and quality, based on precision agriculture. Besides, yield prediction information before harvest is important for farmers in planning harvesting work. In agricultural remote sensing, there are many studies about estimation of yield using satellite data. The most popular method for estimating yield is derivation of regression model between a vegetation index and measured yield. However, these model’s estimation accuracy depends on the geographic location. In other words, there is a problem in widespread applicability of the estimation model.
The main objective of this study was to investigate an alternative applicable model for estimation of yield of paddy rice based on UAV remote sensing and solar radiation datasets. A secondary objective was to explore the possibility of expanding the yield estimation method developed from UAV remote sensing to satellite remote sensing.

2. Methods and Materials

2.1. Field measurement

UAV remote sensing datasets for three rice varieties (*Koshihikari, Fusaotome, Fusakogane*) acquired in three locations (*Chiba, Niigata, Saitama*) were analyzed. In Chiba, we observed two fields which are located at the Chiba Prefectural Agriculture and Forestry Research Center. Two fields were subdivided into 48 compartments with different cultivation conditions (transplanting day, varieties, amount of fertilizer). Observation equipment were an electric-powered Multicopter (enRoute Zion QC630, MEDIX JABO H601G, DJI Phantom2) and digital camera (visible image: RICOH GR, green, red, near-infrared image: BIZWORKS Yubaflex). Flight altitude was 50m.

2.2. Data processing

Ortho photographs were generated using the SfM/MVS technique. The images taken with Yubaflex, after conversion to radiance, were used to create the ortho mosaic images using SfM / MVS software. After that, we calculated vegetation indexes (NDVI, etc.) using the ortho mosaic photos. At that time, we added NDVI $_{\text{pure vegetation}}$(NDVI$_{pv}$), where in pixels with NDVI value greater than 0 are taken to be vegetation, as one of the vegetation indexes.

2.3. Other data

Two types of solar radiation datasets were analyzed. One was the Daily Photosynthetically Active Radiation (PAR) data (JAXA) estimated from Aqua/MODIS while another was Global Solar Radiation (GSR)

from 1 km mesh agricultural weather data (NARO).
To apply the UAV method to satellite remote sensing, MODIS 8days composite data and crop survey data (Ministry of Agriculture, Forestry and Fisheries) in three prefectures (*Chiba, Ibaraki, Nagano*) were analyzed.

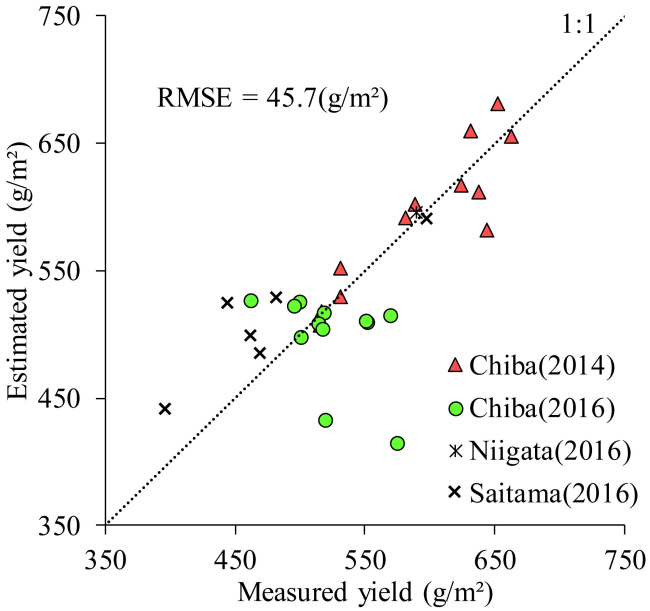
3. Results

(1) With respect to *Koshihikari*, the average solar radiation of the 20-day period from the heading stage was found to have the highest correlation to yield. With respect to *Fusaotome* and *Fusakogane*, the average solar radiation of the 30-day period from the heading stage had the highest correlation to yield.
(2) Applying the yield estimation models to another year or location resulted in a RMSE of PAR-based model of 45.7g/m². On the other hand, RMSE of GSR-based model was 24.8g/m². GSR-based model outperformed PAR-based model.
(3) As a result of application of the UAV method to satellite remote sensing in three prefectures, *Ibaraki* and *Nagano* yields were found to have higher correlation to solar radiation. In the percentage of *Koshihikari* in paddy fields in *Ibaraki* and *Nagano* was about 80%. On the other hands, it was less than 70% in *Chiba*. For this reason, the correlation between yield and solar radiation in *Chiba* was considered to be affected by varietal difference.

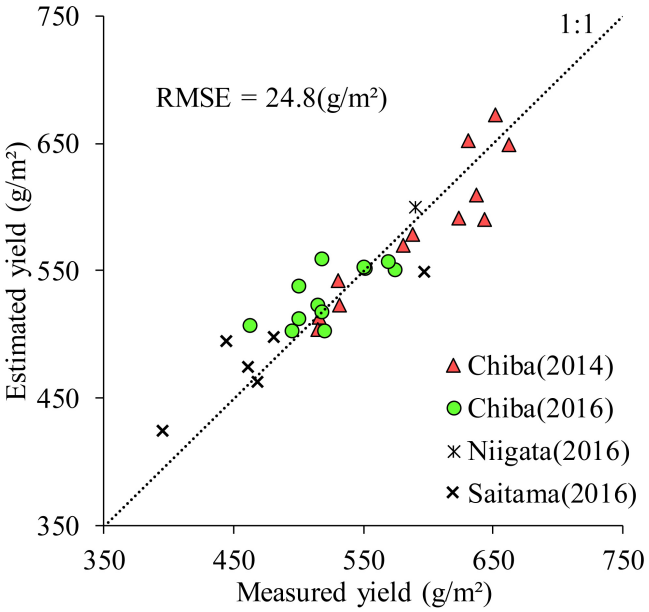
4. Discussion and Conclusion

The models in this study were considered to be evaluating the production of assimilation products by photosynthesis. Hence, we were able to apply the same models to other years and regions.
The models for estimation of yield of paddy rice provided in this study would work as applicable models for estimation of yield of paddy rice using the integration of UAV remote sensing and solar radiation.

キーワード：UAVリモートセンシング、日射量、品種
Keywords: UAV remote sensing, solar radiation, variety



a) Yield estimation using PAR



b) Yield estimation using global solar radiation

