Detection of nitrogen in winter wheat based on Sentinel-2 data

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АГРОТЕХНОЛОГИИ БУДУЩЕГО

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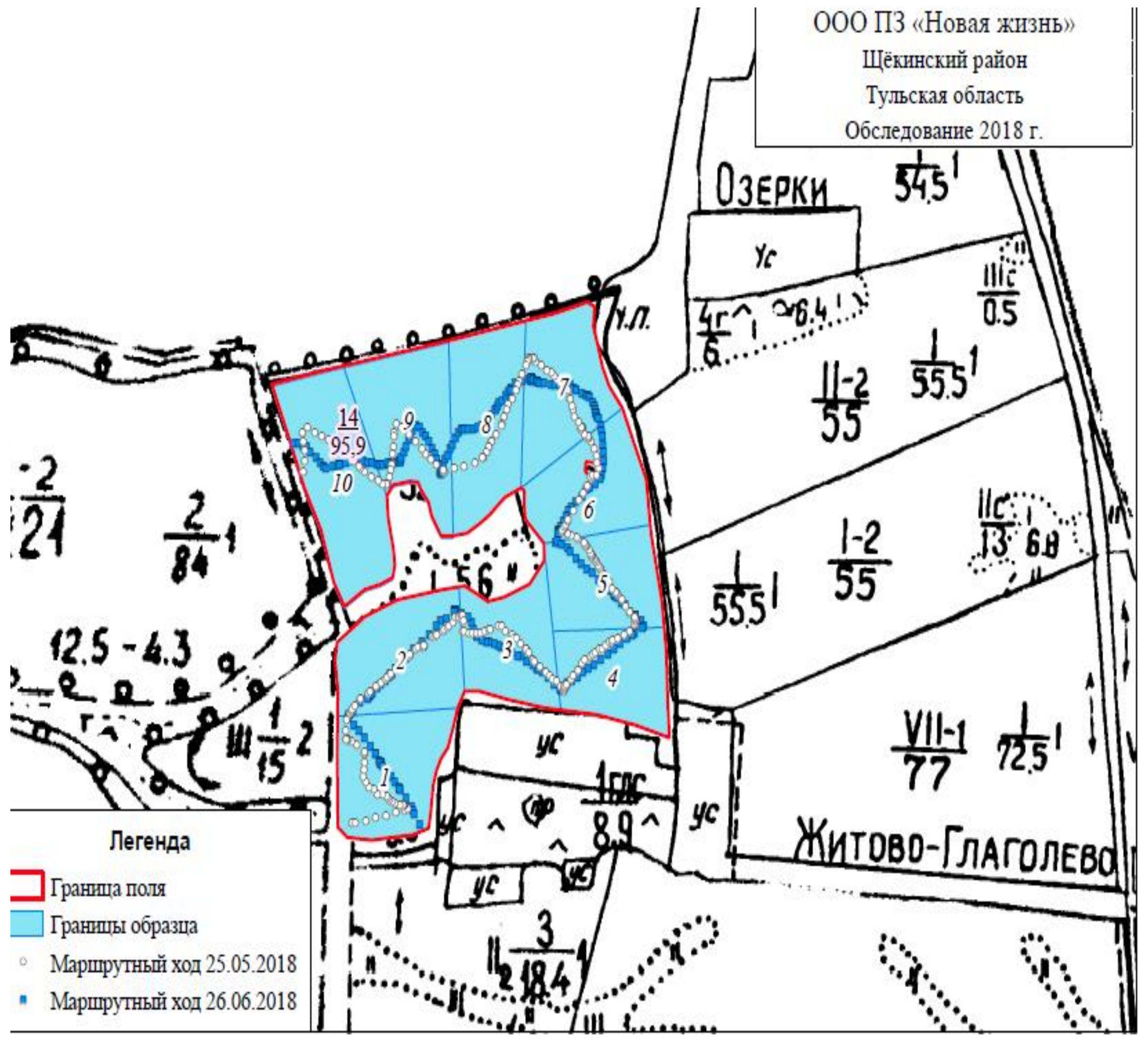
Leaf nitrogen content is highly dynamic and variable within every winter wheat plot. Thus, quick and precise determination of nitrogen is required as accurately as possible. The objective is to find the correlation between winter wheat leaf nitrogen content and Sentinel-2 data and predict the amount of available nitrogen using regression modeling. The best model was developed based on vegetation indices, calculated using 4, 9, 10 and 11 bands of the Sentinel-2.

Introduction

Since nitrogen is one of the most essential elements for plant nutrition, nitrogen shortage can affect crop productivity. Excess nitrogen application harms on plant health and environmental situation.Therefore, real-time information about nitrogen crop content is crucial. However, conventional laboratory methods are laborious and take a long time. Using satellite data is a good alternative for operative crop nitrogen monitoring.



Figue1.Test agricultural field with winter wheat

Materials and methods

The nitrogen content was measured using the SPAD 502 Plus N-tester on two dates (25.05.2018 and 26.06.2018). The measurement points in the field (LLC "Novaya Zhizn", Tula region, Russia) were recorded using GPS (accuracy 5 meters). The field area includes ten sites, each with an area of about 10 hectares. Each site has 30 measurements of nitrogen in upper winter wheat leaves which were averaged and compared with atmospherically corrected (DOSI method) Sentinel-2 satellite data (Table 1). For all field measurement points we extracted the reflection values for each pixel in all spectral bands. Different vegetation indices were calculated that can be used to determine nitrogen in wheat leaves (Table 2). Regression analysis allowed to find the highest quality models for predicting nitrogen content.

Band number	Resolution (meters)	Central wavelength (nm)	Bandwidth (nm)
B01	60	443	20
B02	10	490	65
B03	10	560	35
B04	10	665	30
B05	20	705	15
B06	20	740	15
B07	20	783	20
B08	10	842	115
B08A	20	865	20
B09	60	945	20
B10	60	1375	30
B11	20	1610	90
B12	20	2190	180

Table 1. Band characterization of Sentinel-2A

Vegetation indices	Formula
NDVI =(NIR-RED)/(NIR+RED)	$NDVI_1$ =(B08-B04)/(B08+B04)
	$NDVI_2$ =(B07-B04)/(B07+B04)
RVI=NIR/RED	RVI=B08/B04
NDRE=(NIR-RE)/(NIR+RE)	NDRE=(B08-B05)/(B08+B05)
IPVI=(NDVI+1)/2	IPVI=(B08+1)/2
CCI	CCI=B09/B04
NI1	NI1=B02/B03
NTVI1	NTVI1=(B10-B11)/(B10+B11)
NTVI2	NTVI2=(B08-B11A)/(B08+B11A)
NI2	NI2=B01/B12
NI3	NI3=B08A/B04

Table 2. Vegetation indices and spectral band ratios

Results and discussion

The best linear regression obtained model, characterizing the link between spectral data of Sentinel-2A and nitrogen content, is:

N = 3977,10-3787,63* NTVI1 - 42,51*CCI,

where NTVI1=(Band10-Band11)/(Band10+Band11) and CCI= Band09/Band04

Adjusted R2 = 0.65. Indicators are statistically significant at p-level <0.05.

The model was validated based on obtained linear regression and the estimated sample of field measurements.

	b	Std.Err. - of b	t(5)	p-value
Intercept	3977,10	724,2421	5,49140	0,000384
NTVI1	-3787,63	827,1992	-4,57886	0,001330
CCI	-42,51	12,7820	-3,32556	0,008861

This regression model was used for rapid mapping of the nitrogen content in wheat leaves throughout the plots (Fig.2).

Studies have shown good prospects of using Sentinel-2 satellite data to rapidly assess the nitrogen content in wheat leaves. The most informative data were received for the explored region from 4, 9, 10 and 11 bands of Sentinel-2 as indices NTVI1 and CCI.

The limited number of points used for both model construction and validation does not allow us to believe that the model is stable as it requires additional field data. The resulting model can hardly be used in other regions or for other wheat varieties. Nevertheless, similar models can be built up for each individual plot and then used in subsequent years to monitor the nitrogen content in wheat without additional field work. In this case the use of data from Unmanned Aircraft Systems could be more perspective with comparison to satellite data.

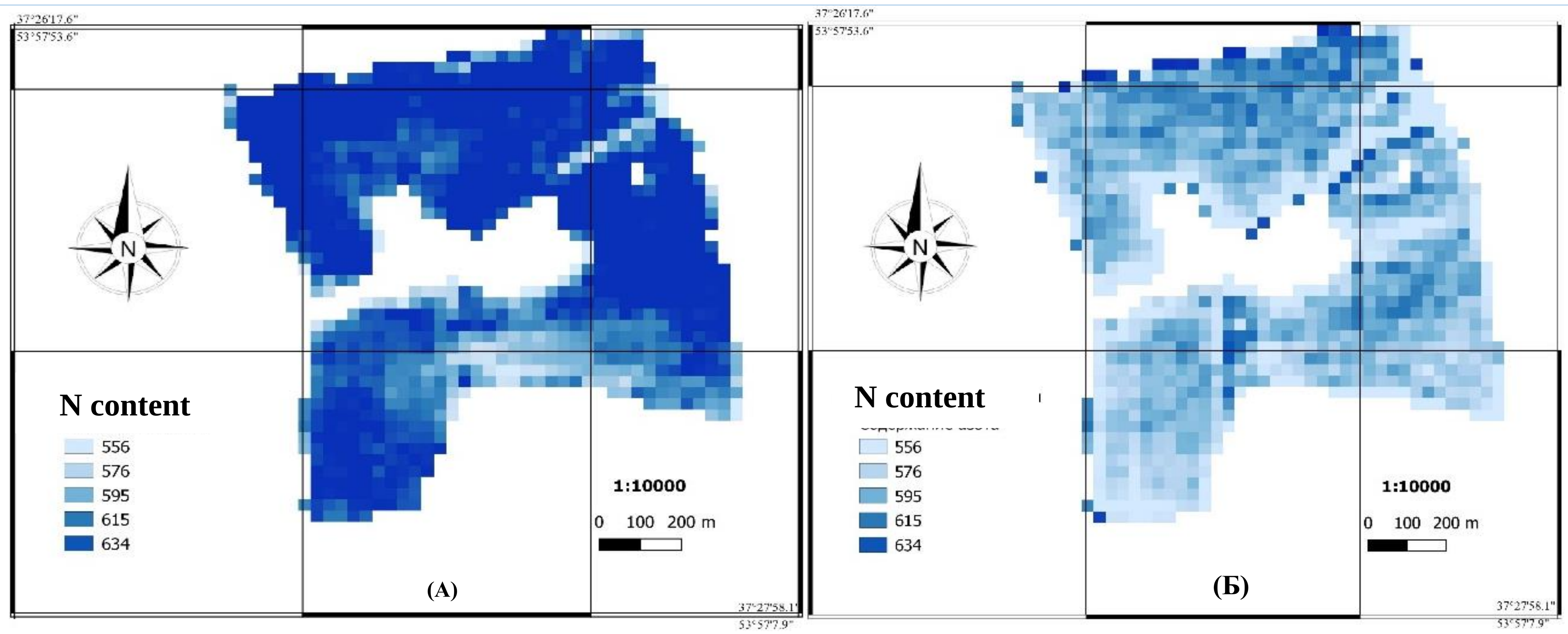


Figure 2. Nitrogen Predicted Maps for (A) 25.05.2018 и (Б) 26.06.2018

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