EVALUATION OF THE CORRELATION BETWEEN THE COLOR OF DIFFERENT WHEAT VARIETIES AND WEATHER CONDITIONS USING RGN UAV-BASED IMAGES /

ОЦЕНКА НА ЗАВИСИМОСТТА МЕЖДУ ЦВЕТА ПРИ РАЗЛИЧНИ СОРТОВЕ ПШЕНИЦА И МЕТЕОРОЛОГИЧНИТЕ УСЛОВИЯ ИЗПОЛЗВАЙКИ RGN ИЗОБРАЖЕНИЯ БАЗИРАНИ НА UAV

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ABSTRACT

The present work investigates the dependences between weather conditions and the specific characteristics of nine wheat varieties and the reflection of light spectra. The obtained images captured with an unmanned aerial vehicle UAV model DJI Mavic 2 Pro and RGN camera reflect the state of vegetation of wheat varieties depending on environmental factors and the specific morphological features of each variety. The differences are analyzed and presented by variety, highlighting the relationship between the factors through reflected light and the condition of the investigated winter wheat varieties. The study provides valuable information for future research on the influence of meteorological conditions on the accuracy of the results obtained with UAV imaging.

РЕЗЮМЕ

Настоящата работа изследва зависимостите между метеорологичните условия и специфичните особености на девет сорта пшеница и отражението на спектри от светлината. Получените изображения заснети с безпилотен летателен апарат UAV модел DJI Mavic 2 Pro и RGN камера отразяват състоянието на вегетацията на сортовете пшеница зависимост от факторите на околната среда и специфичните морфологични особености на всеки сорт. Анализирани са разликите и е представено по сортове връзката между факторите посредством отразената светлина и състоянието на изследваните сортове зимна пшеница. Проучването дава ценна информация при бъдещи изследвания за влиянието на метеорологичните условия върху точността на получените резултати при заснемането с UAV.

INTRODUCTION

Reflective vegetation indices are keys in precision agriculture. The peculiarities of obtaining them significantly influence the correct reading of the received information and subsequent planning of agrotechnical activities. Proving dependencies between different factors is carried out using the methods of mathematical statistics for processing data from various practical and experimental studies. In precision agriculture, the study of the dependences between different dimensions of the environment and parameters of agricultural crops is the key. The process involves monitoring the entire life cycle of crops over an extended period of time. During this period, many of the factors have random values that are difficult to predict.

A basic approach in analysing data is the regression model, which characterizes the dependencies between the obtained data. In the article of *Jiang et al., (2020)*, a platform for remote sensing of unmanned aerial vehicles (UAV) is investigated, which creates a map of the monitored area of the normalized differential vegetation index (NDVI). An assessment of the influence of the parameters of the UAV operation modes on the correctness of the generated data is made. *Khabba et al., (2020),* proposes a method to determine the pattern when registering the reflected light. He analyses the data obtained during the vegetation of winter wheat grown in semi-arid conditions and the influence of irrigation.

The influence of the process in the processing of chickpeas by means of PFE was made by *Angelova et al. (2022)*. The study examines the relationship between 4 factors and 4 parameters and analyses the dependencies.

Through regression analysis (*Sellam et al., 2016*) establishes a relationship between a set of variables as area under cultivation, annual rainfall and food price index and their effects on rice yield. The study, through regression analysis, assesses environmental factors and their impact on crop yield. By means of multi-factorial analysis, it is determined which factors are important for decision-making. A 10-year sample period from 1990-2000 was examined for environmental factors. Linear regression was applied to establish a relationship between the independent variables and crop yield as the dependent variable. *Ganeva-Kiryakova, (2020),* uses a methodology to determine the condition of winter rape before and after wintering and to estimate the duration of flowering. The study was aimed to determine the states of culture and was conducted in the Python programming language. The factors: good, average and poor for each parameter, (duration of flowering) are determined by experts. The 10 variables used correspond to Sentinel-2 channels with 10 m and 20 m spatial resolution; all input data that were determined to be abnormal at the 5% significance level were excluded in post-treatments using a regression model for the process under consideration.

A study of the applicability and effectiveness of the methodology was done in *Atanasov et al., (2022)*. It confirms the validity of the obtained vegetation indices from the considered methodology compared with satellite data. Some authors (*Feng H. et. al., 2022*) investigate the performance of RGB imagery and hyperspectral data for monitoring crop growth based on multi-time estimation of the comprehensive growth index. Other authors *(Dong T. et. al., 2019*) explore the potential of vegetation indices for crop leaf area index estimation, with a focus on comparing red-edge reflectance based and the visible reflectance based.

The aim of the study is to determine how meteorological factors and the specificity of wheat varieties affect the accuracy of the data obtained for the recorded sunlight reflected by the crop in the visible and near infrared area.

MATERIALS AND METHODS

1. Study area

The experiment was conducted in the experimental field of the Dobrudja Agricultural Institute in the city of General Toshevo, Bulgaria during the economic year 2021-2022 on a field with coordinates: (43.657536 N, 28.021847 E) in the Dobrudja region, Bulgaria. The geography of the area is a plateau with an average altitude of about 230 m, (Fig. 1.). The climate is temperate, but the winter is harsh because of the incessantly blowing winds. The soils of the area are chernozem.

Fig. 1 - Location of the experimental plot

The seeding plan of the experimental trial field with designated cultivars is shown in Fig. 2. Each variety is sown in beds 1.25 m wide and 20 m long with two repetitions. Each variety is tested with two replicates to ensure the accuracy of the result. Roman numerals indicate the varieties as follows: I – Shibil; II - GT 7-190; III – Enola; IV – Chudomira; V – Fedora; VI – Annapurna; VII - Indje; VIII – Andronia; IX – Avenue.

	A				B				C	
1	Shibil	I		1	Chudomira	IV		1	Inje	VII
2	Shibil			2	Chudomira			2	Indje	
3	GT 7-190	II		3	Fedora	V		3	Andronia	VIII
4	GT 7-190			4	Fedora			4	Andronia	
5	Enola	III		5	Annapurna	VI		5	Avenue	IX
6	Enola			6	Annapurna			6	Avenue	

Fig. 2 - Planting plan of the individual varieties of the experiment

2. UAV Images acquisition

In the experiment was used MAPIR Survey3W Camera RGN (Company Peau Productions sub-brand of MAPIR) photosensor type: Sony Exmor R IMX117- 12 MP; photo 4000x3000, lens 41° HFOV, 47mm; external GPS/GHSS ublox UBX-G7020-KT. The camera is mounted on the DJI Mavic 2 Pro UAV shown in Fig. 3. The sensor matrix is a Bayer type. Each photocell converts the light falling on it in the spectrum it detects into an electric charge. The three colours correspond to reflections with different lengths of electromagnetic waves. Each of these colours have a different energy, a different frequency of propagation, which is the main reason they have a different reflection and a different amount of scattering in the atmosphere.

Fig. 2 - DJI Mavic 2 Pro with MAPIR Survey3W camera mounted

3. Data collection and processing

The input factors and their magnitudes on which the reflection from the leaf mass of the different varieties of winter wheat depends are analysed to obtain the dependencies by varieties. The factors considered are those on which the spectral reflectance of light is assumed to strongly depend and would directly change the result of remote spectral sensing. Disturbances (inaccuracies) in obtaining information about agricultural crops strongly depend on a group of factors depending on meteorological nature: E - illumination (lx), CCT - correlated colour temperature (K), Cloudiness (%).

There is a second group of factors related to morphological features of the investigated crops (in the specific case, winter wheat): the wax coating, plant flowers, and physiological signs such as the leaf area, which is determined by the parameter Flag leaf width (mm). The specified groups of factors directly determine the reflectance in the different spectral bands and influence the obtained vegetation indices. The measurement of light characteristics was performed with an HPCS-320 spectrometer, which uses an optical CCD sensor (Hangzhou Hopoo Light&Color Technology Co.Ltd). All measurements were taken during the flight missions.

The most common vegetation index is NDVI, which compares the difference in the reflected red spectrum of light (660 nm) and infrared (850 nm). The camera used for the MAPIR Survey3W-RGN experiment recorded the reflectance in the red – 660 nm, green – 550 nm, and infrared – 850 nm, and this channel was obtained after repositioning the blue. It is 20 nm wide as opposed to the other two which are 10 nm each. The speed of the UAV is much less than that of the diaphragm. By default, in flight with 10 ms^{-1} shutter speed is set to 1/500 s. These are factors that can be controlled, but they do not affect the results.

The considered factors form a large amount of information regarding the dependencies in obtaining vegetation indices, but in the present study only the most significant ones will be considered. With the set goals of the study, E - lighting (lx), CCT - correlated colour temperature (K), the wax coating were selected, and the investigated parameters were the colour values registered by the camera used.

Table 1 presents the natural data for the factors: lighting, colour temperature and wax deposit (scored: 1 absent, 5 medium, 9 strong) according to the dates in which the studies were made, as well as the digital data for the reflectance of red, green and infrared. Digital colour values were obtained after processing the RGN images with the Pix4D software product [Pix4D, 2024, https://www.pix4d.com/]. Due to the equal size of the investigated areas, the colour values are presented as an absolute value of the channel in the image.

Due to the equal size of the investigated areas, the colour values are presented as an absolute value of the channel in the image. On each of the observation dates marked as an experiment, it is a recording of the studied field with 300 separate photos, which are processed until they are compiled into one image with the program product Pix4D and a digital model of the surface is obtained. Then the area of each individual experiment (variety) was marked to determine the differences in reflectance and obtain vegetation indices such as NDVI, SAVI and others. For the presented study period, 3,600 photographs were obtained. Each of them contains information about an area of the experiment.

Table 1

Obtained data for the factors (Xi) and parameters (Yi) of the regression model for 2022

1. Wheat variety - Shibil

№ of trial	1	2	3	4	5	6	7	8	9	10	11	12
Date	26th of March	5th of April	26th of April	3rd of May	10th of May	17th of May	25th of May	31th of May	7th of June	21th of June	28th of June	5th of July
E - (κlx), X1	90.39	84.82	28.59	52.96	84.83	97.30	103.61	125.96	172.73	109.11	126.82	106.71
CCT (K), X2	5978	6087	6802	6409	6251	6089	6154	6012	5903	6004	6024	6036
Wax coating, X3	1	1	1	1	1	1	1	1	1	1	1	1
Red (R) Y1	2792.50	2932.27	1491.33	2802.84	3161.78	4127.28	4499.87	3860.67	3554.31	4316.57	2051.94	4573.80
Green (G) Y2	2477.20	2465.29	1070.29	1823.88	2306.19	3349.07	3703.05	3098.58	2834.01	3987.12	1678.66	4020.48
Nir (NIR) Y3	2744.46	3698.63	2329.50	4020.00	3649.35	4617.35	5410.29	3924.37	4635.60	4088.97	1574.95	3478.66

2 Wheat variety - GT 7-190

Wax coating, X3	3	3	3	3	3	3	3	3	5	5	5	5
Red (R) Y1	2761.01	3039.93	1763.92	3088.77	3689.34	4378.4	4403	4443.3	3504.84	4145.73	2281.74	4615.98
Green (G) Y2	2483.8	4132.06	1171.52	1946.83	2620.75	3659.46	3547.35	3492.43	2848.83	3885.8	1826.06	4071.97
Nir (NIR) Y3	2896.51	3961.36	3209.7	4421.41	4952.83	5277.89	5551.22	5649.97	4554.46	3605.02	1710.74	3478.33

3 Wheat variety -Enola

Wax coating, X3	1	1	1	1	1	1	1	1	1	3	3	3
Red (R) Y1	1515.96	3102.09	1449.31	2678.34	3670.8	4374.25	4144.62	4234.97	3278.34	3755.66	2306.25	4138
Green (G) Y2	1189.66	2695.73	1085.7	1781.94	2645.66	3636.42	3520.79	3253.8	2621.14	3281.55	1866.03	3706.34
Nir (NIR) Y3	2867.34	3965.25	2211.6	3728.54	4728.26	5232.11	4582.52	4789.5	4214.2	3402.53	1757.04	3012.23

4 Wheat variety - Chudomira

Wax coating, X3	1	1	1	1	1	1	1	1	1	7	7	7
Red (R) Y1	2607.34	3154.05	1380.9	2863.9	3325.65	4248	4303.42	2760.41	2590.56	4121.9	1533.53	4916.74
Green (G) Y2	2297.16	2568.26	1021.37	1925.34	2426.88	3378.61	3447.15	2084.37	2052.66	3851.35	1385.34	4388.36
Nir (NIR) Y3	3082.32	4082.15	2382.12	3890.49	3925.73	4957.77	5117.74	3903.15	3171.67	3759.33	1237.25	3757.12

5 Wheat variety - Fedora

Wax coating, X3	1	1	1	1	1	1	1	1	1	1	1	1
Red (R) Y1	2942.46	3185.56	1576.42	2712.21	3739.24	4578.08	4450.51	3305.78	3239	4115.59	2020.17	4875.29
Green (G) Y2	2685.99	2786.88	1176.5	1840.68	2799.08	3766.5	3565.96	2478.95	2597.79	3662.98	1696.25	4361.33
Nir (NIR) Y3	3255.19	4171.4	2700.81	3716.65	4961.87	5719.2	5598.86	4502.57	4334.1	4172.9	1628.92	3702.58

6 Wheat variety - Anapurna

Wax coating, X3	1	1	1	1	1	1	1	1	1	5	5	5
Red (R) Y1	3054.22	3419.77	1574.75	2445.95	3193.59	4234.93	4270.4	3295.17	2456.08	3620.09	2366.41	3783.52
Green (G) Y2	2891.94	3232.62	1169.46	1736	2326.88	3458.78	3569.54	2557.42	1925.47	3305.18	1915.44	3366.82
Nir (NIR) Y3	3202.97	4216.59	2625.54	3756.46	3726.4	5028.16	4959.43	4372	2948.09	3650.47	1720.79	2637.01

7 Wheat variety - Indje

Wax coating, X3	1	1	1	1	1	1	1	1	1	3	3	3
Red (R) Y1	2462.99	2988.33	1536.22	2606.83	2776.2	4300.49	4076.33	2178.02	2300.37	3952.12	1552.48	4742.07
Green (G) Y2	2241.82	2451.72	1054.71	1714.4	2076.13	3357.41	3086.98	1629.74	1769.63	3469.46	1289	4181.02
Nir (NIR) Y3	2951.68	3963.24	2779	3563.4	2923.42	5204.84	4843.25	2971.87	2837.72	3353.73	1197.11	3610.3

8 Wheat variety - Andronia

Wax coating, X3	1	1	1	1	1	1	1	1	1	7	7	7
Red (R) Y1	2842.37	2896.55	1562.37	2914.43	3392.21	4524.32	4333.98	3581.02	3198.75	4196.9	1566.21	4480.42
Green (G) Y2	2556.9	2478.46	1042.71	1792.37	2268.08	3841.41	3571.87	2674.91	2515.28	3800.43	1328.19	3998.89
Nir (NIR) Y3	2919.83	3810.36	2891.69	4141.21	4516.21	5651.67	5189.25	4635.68	4341.62	3969	1210.34	3260.39

9 Wheat variety - Avenu												
Wax coating, X3	1	1	1	1	1	1	1	1	1	9	9	9
Red (R) Y1	2751.58	3069.53	1451.99	2589.26	3363.95	4313.13	3498.1	3748.19	2611.72	3996.54	1986.68	4014.65
Green (G) Y2	2458.5	2666.62	1037.82	1613.94	2403.67	3628.55	2608.83	3113.77	2122.4	3712.48	1614.84	3520.77
Nir (NIR) Y3	2876.07	3850.61	2493.57	3657.12	4202.2	5067.37	3825.47	4218.64	3269.77	3791.92	1553.01	2849.27

The two factors $X1$ and $X2$ are the same for the entire experiment, therefore they will not be presented with numerical values in the following tables. Each of the varieties will be considered separately as a regression model.

The optimal values of the parameters $Yj, j = 1,2,3$ and the description of the echo surfaces for a larger area of the factor space require a regression model more complex than the linear one. This corresponds to a full factorial experiment – PFE of type 2^m and its derivatives. In this case, describing the optimum can be done with a polynomial of the second degree, (*Mitkov A., 2011*). The polynomial chosen for the experiment is of the form:

$$\hat{Y}_j = b_0 + \sum_{i=1}^{m} b_i \dot{x}_i + \sum_{\substack{i,k=1 \\ i<k}}^{m} b_{i,k} \dot{x}_i \dot{x}_k + \sum_{i=1}^{m} b_{ii} \dot{x}_i^2 \quad (1)$$

where: $\hat{Y}_j$ is estimation of parameter *Yj*; b_0 is a coefficient equal to 1; b_i coefficients of the regression equation; i is the index of factors 1 to 3; $\dot{x}_i$ coded values of the factors from Table 3; m – number of factors.

Finding the values for the quantities in the particular case is in a second-order polynomial. In it, the factors vary on three levels or more. Table 2 shows the variation and coding of the five-level factors.

Table 2

Levels of variation and factor coding of the regression model

Levels	E - (кlx), X1		CCT (K), X2		Wax coating, X3	
	Nature. values	Code. values	Nature. values	Code. values	Nature. values	Code. values
Low $X_{0i}+\alpha_i$	28.59	+1.682	5903	+1.682	1	+1.682
$X_{0i}+J$	65.63	+1	6231.125	+1	3	+1
Average X_{0j}	98.65	0	6145.75	0	5	0
$X_{0i}-J$	135.69	-1	6473.875	-1	7	-1
Above $X_{0i}-\alpha_i$	172.73	-1.682	6802	-1.682	9	-1.682
A step J	37.04	-	325.125	-	2	-

The area of the optimum is first described by a first-order plan, then the centre of the PFE or a fractional replica of it is chosen as the centre of the new plan. More appropriately selected key points are added to the plan. A rotatable central-composition plan is obtained - RCKP, (*Mitkov A., 2011; Andonova-Vakarelska T., 2017*). Added points lie on the coordinate axes at a distance α from the center of the plan.

Table 3

Rotatable central-composite plan in three factors

X1	0.000	0.000	1.682	1.000	0.000	0.000	0.000	-1.000	-1.682	0.000	-1.000	0.000
X2	1.682	1.682	-1.682	-1.000	0.000	1.682	0.000	1.682	1.682	1.682	1.682	1.682
X3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
X12	0.000	0.000	-2.829	-1.000	0.000	0.000	0.000	-1.682	-2.829	0.000	-1.682	0.000
X13	0.000	0.000	1.682	1.000	0.000	0.000	0.000	-1.000	-1.682	0.000	-1.000	0.000
X23	1.682	1.682	-1.682	-1.000	0.000	1.682	0.000	1.682	1.682	1.682	1.682	1.682
X11	0.000	0.000	3.364	2.000	0.000	0.000	0.000	-2.000	-3.364	0.000	-2.000	0.000
X22	3.364	3.364	-3.364	-2.000	0.000	3.364	0.000	3.364	3.364	3.364	3.364	3.364
X33	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Y1	2792.50	2932.27	1491.33	2802.84	3161.78	4127.28	4499.87	3860.67	3554.31	4316.57	2051.94	4573.80
Y2	2477.20	2465.29	1070.29	1823.88	2306.19	3349.07	3703.05	3098.58	2834.01	3987.12	1678.66	4020.48
Y3	2744.46	3698.63	2329.50	4020.00	3649.35	4617.35	5410.29	3924.37	4635.60	4088.97	1574.95	3478.66

This is how the star points are obtained, α is a star arm. The value of α=1.682 proposed by *Mitkov T., (2011)*, against the number of factors m=3 according to the formula $\boldsymbol{\alpha} = \mathbf{2}^{\frac{m}{4}}$. A symmetric plane is obtained, which is orthogonal to the central composition, as shown in Table 3.

The points of the rotatable plane are arranged so that when the coordinate axes are rotated, the dispersion distribution does not change. As a result of a proper choice of the number of replicates for observations in the centre of the plan, an almost uniform distribution of variance can be achieved throughout the area. This area does not depend on the distance to the centre of the plan. Such planning is called uniform-planning.

Statistical analysis was performed with the statistical processing software IBM SPSS Statistics (*www.ibm.com, 2024*) and quadratic model coefficients were determined.

RESULTS

The results of statistical processing are given in Table 4. The obtained values for the dependences between $Y1$ and the input parameters are presented in table 4. In table 5 the dependence between the input parameters and $Y2$ is presented and table 6 with the parameter $Y3$, which for variety 1 remains unity throughout the period.

Table 4

Results of regression analysis of factors against Y1 in variety 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.675[a]	0.456	0.252	849.64183

a. Predictors: (Constant), X22, X12, X11

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4845333.897	3	1615111.299	2.237	0.161[b]
	Residual	5775129.965	8	721891.246		
	Total	10620463.862	11			

a. Dependent Variable: Y1

b. Predictors: (Constant), X22, X12, X11

Table 5

Results of regression analysis of factors against Y2 in variety 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.708[a]	0.501	0.313	778.73592

a. Predictors: (Constant), X22, X12, X11

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4865354.853	3	1621784.951	2.674	0.118[b]
	Residual	4851437.028	8	606429.628		
	Total	9716791.880	11			

a. Dependent Variable: Y2

b. Predictors: (Constant), X22, X12, X11

Table 6

Results of regression analysis of factors against Y3 in variety 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.519[a]	0.270	-0.004	1059.61460

a. Predictors: (Constant), X22, X12, X11

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3318141.040	3	1106047.013	0.985	0.447[b]
	Residual	8982264.862	8	1122783.108		
	Total	12300405.902	11			

a. Dependent Variable: Y3

b. Predictors: (Constant), X22, X12, X11

The obtained high Fisher's criterion $F = 0.985$ for a significance level of 0.05 confirms that the null hypothesis is rejected and the criterion is significant. The coefficient of determination $R2$ for factors $Y1$ and $Y2$ is about 0.5, from which it follows that 50% of the change in parameters $Yj, j = 1,2,3$ are included in the model. For factor $Y3$, the coefficient is 0.27, which is expected for the specific case. In cultivar Shibil, the wax coating remained low throughout the study period.

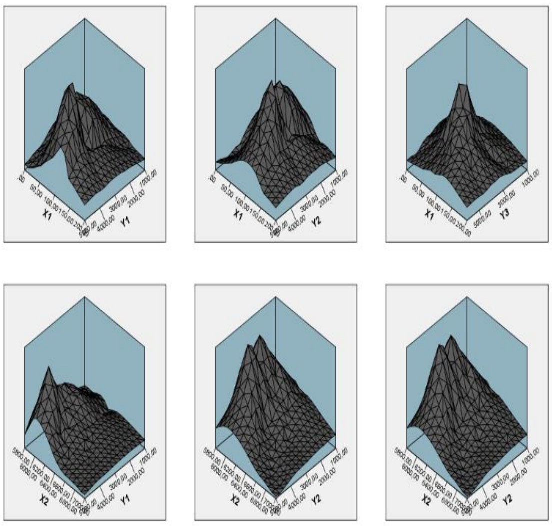
Evaluation of the significance of the factors compared to the obtained coefficients according to Student's criterion, for a significance level $\alpha = 0{,}05$, that is: $Y = 1,\ \alpha = 0.95$, with the number of degrees of freedom $k = n - 1 = 11$. Compared with the calculated coefficients B, it is seen which are the significant factors. Table 7 presents the significant coefficients with their values.

Table 7

Significance of coefficients

Model		B	t
Dependent Variable: Y1	(Constant)	3829.247	6.893
	X12	542.373	0.629
	X11	-281.983	-0.507
	X22	-42.422	-0.107
Dependent Variable: Y2	(Constant)	2929.690	5.754
	X12	435.264	1.676
	X11	-138.482	-0.559
	X22	80.879	0.443
Dependent Variable: Y3	(Constant)	4624.698	6.675
	X12	562.744	1.593
	X11	-475.646	-1.411
	X22	-307.951	-1.239

Fig. 4 shows the maximum values of the factors compared to each other for Shibil variety. The wax coating factor for the variety throughout the period is constant. A maximum of the values is seen where the factors $X1$ and $X2$ are involved.



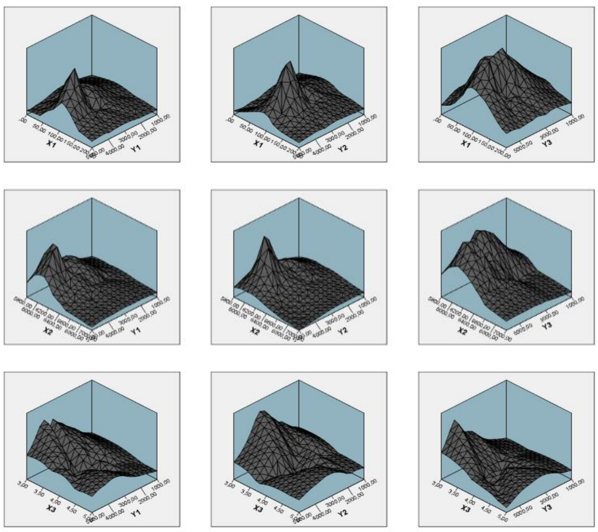


Fig. 4 - Dependencies of the factors in Shibil variety; **Fig. 5 -. Dependencies of the factors in variety GT 7-190**

The results obtained for variety GT 7-190 are presented in Fig. 5. In addition to the strong dependence on X2 colour temperature and the obtained values, the strong dependence on the wax coating X3 is also visible. For the Enola variety, the results have similar trends to the GT 7-190 variety.

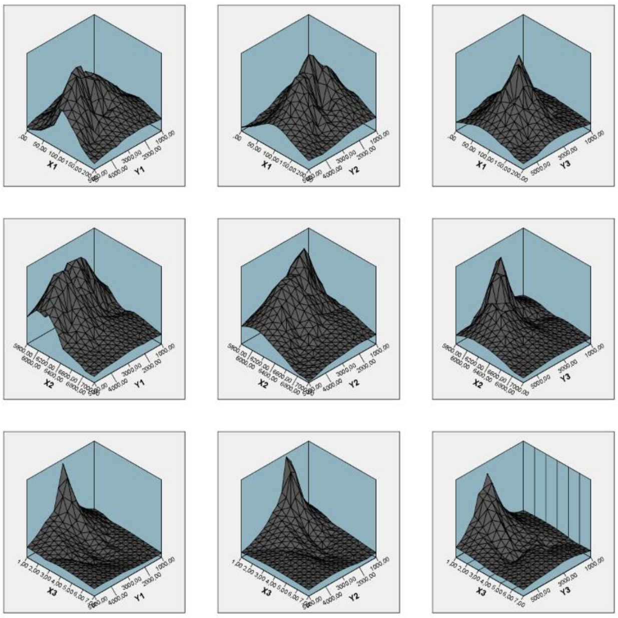


Fig. 6 - Dependencies of the factors in the Chudomira variety

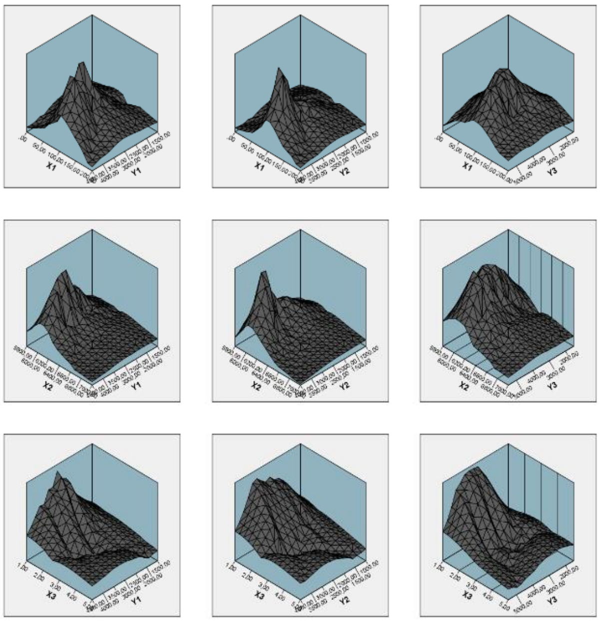


Fig. 7 - Dependencies of factors in variety Annapurna

In the case of the Chudomira variety (Fig. 7), the general tendency of the dependences is similar to the previous varieties, but there are sharper dependences. A very strong dependence to the reflection in the infrared range (Y3) is observed and a strong influence of the wax coating (X3), which in the variety increases significantly as the maturity stage approaches.

The Fedora variety, like Shibil, retains a constant value of the wax coating (X3), which is almost absent. This is the prerequisite for the two varieties to have similar trends. In the visible spectrum of the reflection, the Fedora variety in the conducted experiment has a lighter colour than Shibil. But the reflection in the infrared spectrum (Y3) is similar.

Factor dependencies for Annapurna cultivar are shown in Fig. 7. In this variety, it is characteristic that the X3 factor (wax coating) is absent at the beginning of development and then increases to average values. This can also be seen from the graph where there is a strong dependence. In the Inje variety, there is a close relationship, although the X3 wax coating is low, but the trend of change is similar to that of Annapurna.

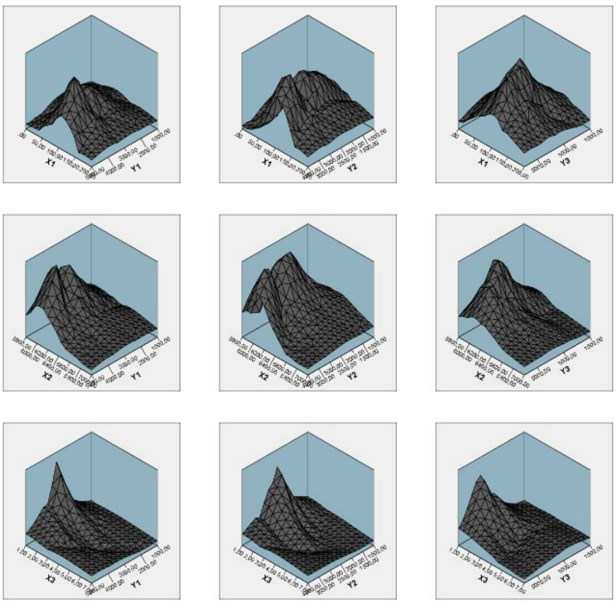


Fig. 8 - Dependencies of the factors in Andronia variety

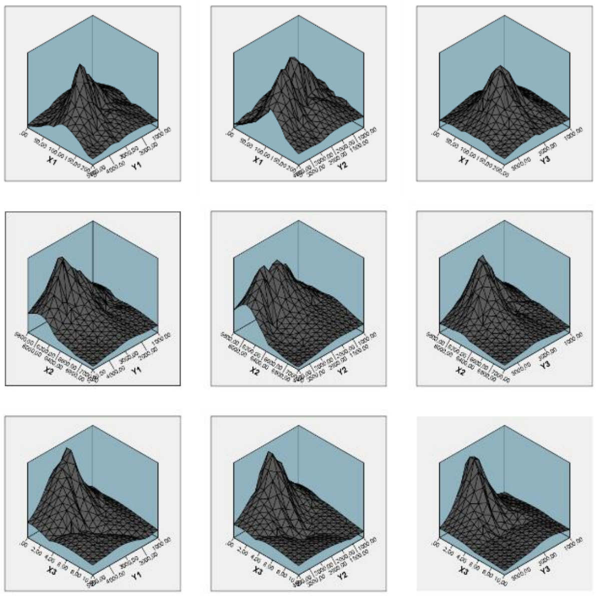


Fig. 9 - Dependencies of the factors in the Avenue variety

The varieties Andronia (Fig. 8) and Avenue (Fig. 9) do not have a wax coating in the initial stage of their development. In the grain formation stage, it increases to a medium value in the first and a high value in the second. In the visible spectrum, Andronia is dark green and Avenue is green in colour. These features are visible on the graphs reflecting the dependences of the factors between the two varieties.

The overall analysis of the dependencies shows a very strong dependence of the factor $X3$ (wax coating), which actually changes the amount of reflected light in all spectra. This greatly changes the reflective vegetation indices in remote spectral analysis. Factors $X1$ and $X2$ influence to a lesser extent. The influence of the $X3$ factor on the resulting NDVI reflectance index is shown in Table 8.

Table 8

Results of linear regression analysis for the dependence of X3 on NDVI

Regression Statistics	
Multiple R	0.844504113
R Square	0.713187197
Adjusted R Square	-1.2
Standard Error	2.032265819
Observations	1

ANOVA

	df	*SS*	*MS*	*F*
Regression	12	102.69896	8.558246	24.865947
Residual	10	41.301044	4.130104	
Total	22	144		

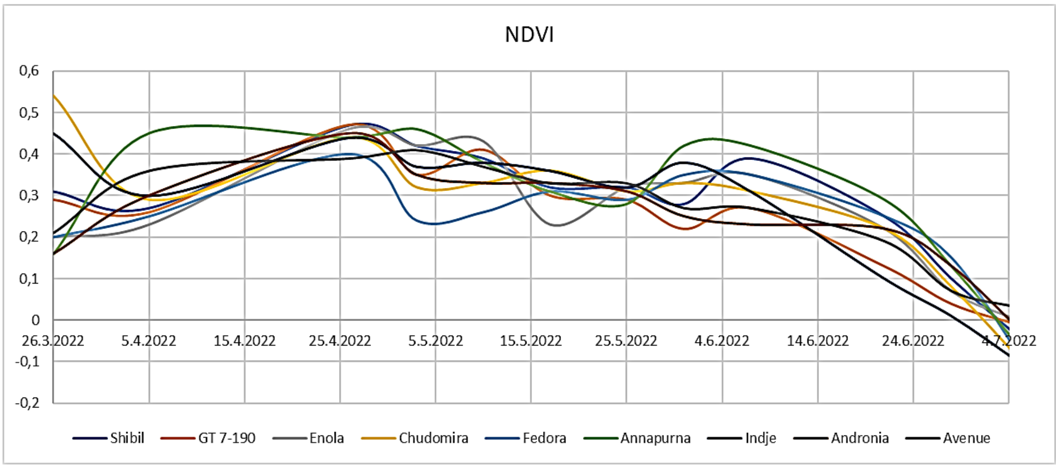


Fig. 10 - Obtained tendencies for changes in NDVI by varieties for the observed period

Fig. 10 summarizes the trends of changes in the reflective vegetation index NDVI by varieties for the considered period. The result was obtained by the program product Pix4D after processing the photographic material and marking the area with the corresponding variety. A calibration image for solar radiation intensity is introduced into the program. Which largely reduces factors X1 and X2 but is strongly influenced by X3. The wax coating directly changes the degree of reflection.

CONCLUSIONS

An active-passive experiment was conducted to investigate the correctness of obtaining reflective vegetation indices. A regression model was obtained that provides information on the influence of the three factors: E - lighting (lx), CCT - correlated colour temperature (K) and Wax coating (quantitative assessment) on the parameters of the model, which represent the digital values of the three colours: $Y1$ - red, $Y2$ - green and $Y3$ - near infrared.

The strong dependence of the parameters on the obtained reflective vegetation indices has been proven. The most significant influence is the factor wax coating, which changes the texture of the leaf mass, which changes the reflection in all spectra. It was found that as its value increases, the NDVI index does not reach large numerical values.

This gives us reason to reach the conclusion that: in agricultural crops (varieties) which during their growing season accumulate a wax coating, it is normal to lower the value of the reflective vegetation indices without it being related to crop stress. Differentiation of the dependencies between the factors and the development of trends in the change of the vegetation indices in the different varieties is the key for the correct interpretation of the data and the planning of the subsequent agrotechnical measures. The survey provides indispensable information for the breeding activity and aims to create a database of NDVI variation. It is planned to continue the research, with the main goal being the recognition of wheat varieties using photogrammetry data.

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