

## ИСПОЛЬЗОВАНИЕ ДАННЫХ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ ДЛЯ ОЦЕНКИ ПРОДУКТИВНОСТИ ОЗИМОЙ ПШЕНИЦЫ В УСЛОВИЯХ ЖИТОМИРСКОГО ПОЛЕСЬЯ

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На основании собственных экспериментальных исследований выполнен анализ эффективности использования данных дистанционного зондирования для оценки продуктивности озимой пшеницы в условиях Житомирского Полесья. Разработан алгоритм применения методов дистанционного зондирования для прогнозирования урожайности, предусматривающий определение взаимосвязи между энергетическими параметрами многоспектральных снимков и продуктивностью озимой пшеницы на разных типах почв. Экспериментальные исследования проведены с применением полевых и камеральных методов с последующей статистической обработкой результатов, их геоинформационным анализом и представлением в виде карт, созданных методом количественного фона. Получены функциональные зависимости между урожайностью зерна и соломы озимой пшеницы и отражающей способностью спектральнональных растровых изображений и вегетационных индексов. Установлено наличие высоких ( $r=0,82-0,90$ ) коэффициентов корреляции между величиной отражающей способности для каналов 11, 12, вегетационного индекса NDSI и урожайностью основной и побочной продукции озимой пшеницы. Практическое значение результатов исследований заключается в разработке технологии дистанционного зондирования продуктивности озимой пшеницы на территории с мозаичным неоднородным почвенным покровом с использованием общедоступных бесплатных сцен Sentinel-2A MSI L1C и оупенсорного программного обеспечения QGIS.

**Ключевые слова:** дистанционное зондирование, продуктивность, озимая пшеница, прогнозирование, оценка, точность.

On the basis of our own experimental studies, we have conducted analysis of the effectiveness of remote sensing data use to evaluate the productivity of winter wheat in Zhytomyr Polesia. An algorithm for applying remote sensing methods for forecasting yields has been developed, which provides for the determination of relationship between the energy parameters of multispectral shots and winter wheat productivity on different types of soils. Experimental studies were carried out using field and cameral methods with subsequent statistical processing of results, their geo-information analysis and representation in the form of maps created by the quantitative background method. We have obtained functional dependencies between the yield of grain and straw of winter wheat and the reflective capacity of spectrozonal raster images and vegetative indices. We have established the presence of high ( $r = 0.82-0.90$ ) correlation coefficients between the reflectivity for channels 11, 12, the NDSI vegetation index and the yield of the main and secondary production of winter wheat. The practical significance of research results is the development of technology for remote sensing of winter wheat productivity in a territory with a mosaic heterogeneous soil cover using the free public scenes Sentinel-2A MSI L1C and open source software QGIS.

**Key words:** remote sensing, productivity, winter wheat, forecasting, estimation, accuracy.

### Введение

>bklZgpbggh\_ ihemq\_gb\_ Zgguo h[ h[t\_fZo gZa\_fgbc [bhfZkku k\_evkdohayckl\gguo dmevlmj k bkihevahZgb\_f kimlgbdh\k bfbdh\yey\_lky gZb[he\_\_wdhghfbq\_kdb \j]h\uf f\_lh\hf Z]j hfhgblhjbg]Z IjbdeZgh\_ agZq\_gb\_ hp\_gdb khklhygby b ijh]ghabjhZgby mjhZcghklb k\_evkdohay ckl\gguo dmevlmj \u^e\_gh \jy^ f\_\ngZ jh\guo b gZpbhgZevguo ijh]jZff [13, 23]. MdjZbg\_kbkl\_fZ fhgblhjbg]Z khklhygby k\_evkdohayckl\gguo dmevlmj b ijh]ghabjhZgby mjhZcghklb gZ hkgh\ kimlgbdh\ Zgguo jZajZ[Z luZ\_lky \jZfdZo ijh]jZffu @jhdhkfbq\_kdb\_b gZa\_fgu\_ gZ[ex^gby \bgl\_j\_kZo mklhcqb\j]h jZa\lby b [\_ah]Zkghklb^ \*(28\$nhjfbjm\_fhc ih j\_r\_gbx khf\_klgh]h aZk\_Zgby Ij\_ab\mfZ GZpbhgZevghc ZdZ^fbb gZmd MdjZbgu G:GM b Dhee\_]bb GZpbhgZevgh]h dhkfbq\_k dh]h Z]\_gklZMdjZbguGD:Mhl ]. [5].

[7], hkh[mx agZqbfhklv ijbh[j\_LZ\_l jZajZ[hldZ Ze]hjbFZ dZq\_kl\_ggh]h ðklZgpbhggh]h ðZ]ghklbj hZgby mjhZcghklb bo a\_jgZ b khehfu HgZdh g Z lhqghklv ijh^gby ðklZgpbhggh]h ðZ]ghkl bjhZgby eby\_l p\_euc jy^ h[t\_dlbguo b km[t\_dlbguo nZdlhj h] hij^eyx sbo mjhZcghklv lhc beb bghc k\_evkdohayckl\_gghc dmevlmju g\_hghjhghklv ihq\ggh]h ihdjhZ baf\_gqbhklv debfZlb q\_kdbo mkehbc jZaeqby \ wnn\_dlbghklv ijb\_fy\_fuo Z]jhl\_ogheh]bc b khjlh\ hc kljmdlmj\_ ihk\_h\ . Bkohy ba wlh]h a gZqbl\_evgh\_dhebq\_klh bkke\_hZl\_e\_c > 11, 22@ndZauZ\_l gZ g\_h[oh^ bfhklv jZajZ[hldb dhfie\_dkguo ijh]ghaguo fh^e\_c mqbluZxsbo lbi ihqu b^a\_fe\_ivevah\ Zgby jZaghh[jZab\_dmevlmj debfZlbq\_kdb\_mkehby HgZdh ihemq\_gb\_lZdbo fh^e\_c ij\_fheZ]Z\_l kehuc ijhp\_kk dhjj\_dlg]h bgl\_ljbhZgby jZaghdZq\_kl\_gguo Zgguo dhlhju \dhg \_qghf blh]\_ fh\_l ijb\_klb d kgb\_gbx lhqghklv ðklZgpbhggh]h a hgðjhZgby b h[\_kp\_gbZgb x b^b dhf ie\_dkghklb

Ih gZr\_fm fg\_gbx ey dZq\_kl\_gghc jZajZ[hldb fh^eb ðklZgpbhggh]h ðZ]ghklbjhZgby mjhZcghklb habfhc ir\_gbpu g\_h[ohðfh q\_ldh ihgbfZlv oZjZdl\_j \_\_ h[mkeh\_e\_gghklb ey Z]jhwdeh]bq\_kdbo mkehbc khfbjkdh ]h lhc\_kv lZdbfb nZdlhjZfb ke\_fm\_l kqblZlv lbi ihq\gg h]h ihdjh\ Z ihkdhevdm kms\_klm\_l [hevrZy\_]h fhaZbqghklv b khjlh\ mx kljmdlmj\_m ihk\_h\ ljbq\_f b gnjhjZpby h khjlh\ hc kljmdlmj\_ ihk\_h\fh\_l [ulv bkihevahZgZ dZd ðiehgbl\_evZy b mlh qgyxsZy kemqZ\_ g\_h[ohðfhklv ihemq\_gby Zgguo h gZdhie\_gbb fZkku khehfu eyblv b aZnb dkbjhZlv wlb nZdlhju b ihemqblv dZq\_kl\_gguc b gZ^guc ijh]gha hafghk ihfsvx kimlgbdhükgbfdh\ \khdhfjZaj\_r\_gb\_f dZdhufbyeyxky kp\_gu Sentinel-2A.

kijhkZf hp\_gdb wnn\_dlbghklv bkihevahZgby Zgguo ðklZgpbhggh]h ahgðjhZgby ey ij h]ghaZ mjhZcghklv k\_evkdohayckl\_gguo dmevlmj ihkys\_g p\_euc jy^bkke\_hZgbc dZd hl\_q\_kl\_gguolZdbaZjm[\_guomq\_guo . GZk\_lhgrygbc^gvfgh]bfbkke\_hZl\_eyf mZehkv jZajZ[ hlZlv kh[kl \_ggu\_ ijh]ghagu\_ fh^eb mjhZcghklv dmevlmj mqbluZxsbo\_dhgdj\_lgu\_ ehdZevgu\_ mkehby nhjfbjhZgby ijhmdlbghklv dhlhju\_ h[\_ki\_qbeb mh\_e\_lhjb\_l\_evngx lhqghklv hij^ \_e\_gby h gZdh gb hgZ ba ij\_èh\_gguo fh^e\_c g\_fh\_l \iheghc f\_j\_ ij\_l\_ghZlv gZ mg b\ jkZevghklv >ey hij^\_e\_gby mjhZcghklv dmevlmj k bkihevahZgb\_f Zgguo ðklZgpbhggh]h ahg^ bjhZgby bkihevamxl g\_kdhevdh ijbgbibZevguo ihðhh\ ðZ]ghklbjhZgb\_mjhZcghklv ih ki\_ dljZevghc bgnjhjZpbpb \hij^\_e\_ggu\_wlZiu\_i\_jbhð \\_l\_Zpbpb dmevlmj > 6, 21] i hkljh\_gb\_ ij h]ghaguo fh^e\_c mjhZ cghklv ih Zgguf ihe\_üo baf\_j\_gbc gZ jZaguo wZiZo hj]Zgh]\_g aZ dmevl nju k bkihevahZgb\_f\_f\_lh\ZiijhdkbfZpbpb [17, 26] hp\_gdm ijhmdlbghklv nblhfZkku k\_evkdho hayckl\_gguo dmevlmj k bkihevahZgb\_f \\_l\_Zpbhgguo bg^dkh\ihemq\_gguo \oh^ dhf[bgZpbpb jZaeqguo ki\_dljZevguo dZgZeh\ kimlgbdhükokp\_g [8, 10, 15, 22 b^ ] .

< qZklghklv \bkke\_hZgbyo [21@[gZjm`\_g lj\_g^\\_l\_Zpbhggh]h bg^dkZ 59, dZd hlghr\_gb \_ dZgZeh\fg]hki\_dljZevguo kgbfdh\ /DQGVDW 70 b mjhZ\_ \habfhc ir\_gbpu ZjbZpby mjhZ\_gZ mjhg\_fZeh]h ohaycklZ\_n\_jfu gZ kh]eZkhüZeZkv k\ebqbgZfb Zggh]h \\_l\_Zpbhggh]h b g^dkZ b Z]jhf\_l\_hjeh]bq\_kd hc bgnjhjZpb\_c Ih Zgguf > 26], \ebqbgZ Zddmfmeypbb Z[khexlgh kmoh]h \s\_klZ nblhfZkku gZ h[ tykgy\_lky agZq\_gbyfb bg^dkZ1'9,lh]ZdZd ihq\ggu\_ bih]hgu\_nZdlhju[mke ZebZxl hklZevgu\_j\_lj\_kkbb ðklZlhqgh bgnjhjZlbgu\_f hdZaZeky ihðh^d ihkljh\_gbx dhjj\_eypbhgguo ijh]ghaguo fh^e\_cmjhZcghklba\_jghüodmevlmjgZhkggh\ kimlgbdhükgbfdh\ khkj\_ðbfjZaj\_r\_gb\_f 02',6 12\$+55 6327 k bkihevahZgb\_f mkj\_è\_gguo Zgguo mjhZcghklv jZaj\_a\_hl^evguo h[eZkl\_c b ijhbgpbc > 2, 4, 5, 11@ZkkqblZggu\_\ebqbg b g^dkZ 1'9, ohjhrh kh]eZkhüZebkv k mjhZcghklv k\_evkdohayckl\_gguo dmevlmj ij\_bfms\_kl\_ggh ir\_gbpuhabfhcgZih qZoe\_khkl\_ibbKl\_ibMdjZbgu> 4, 5@i\_kljhZihq\ggh]hihdjhZ g\_agZqbl\_evZ ljb wlfh fZdkbfZevgu\_ agZq\_gby bg^dkZ [ueb ijbmjhg\_gu d hij^\_e\_gguf ZlZf \\_l\_Zpbpb BkihevahZgb\_gZ dZrlZghüo b k\leh -dZrlZghüo ihqZö kj\_è\_lh aZ \\_l\_Zpbhgguo i\_jbh\habfhc ir\_gbpu b g^dkZ 1'9, lZd\_ h[\_ki\_qbeh mh\_e\_lhjb\_l\_evgu\_j\_amevlZluj\_lj\_kkbhgghcaZpbkbfhklb5 ^2 = 0,78) [2].

Ijh]ghamjhZcghklv bhkgghZgguc gZ bkihevahZgby kgbfdh\kbgøjhgabjhZgguo o k nZaZfb jZab]by ir\_gbpu yjhç gZ km]ebgbkluo b kmi\_kqZguo ihqZö k mq\_lhf k\_ahggc dhebq\_klZ hkZ\_dh\hdZaZe ðklZlhqgh\_ h[hkgghZgghklv b wnn\_dlbghklv lZdh]h ijh]ghabjhZgby > 11]. Ihoh` bc ihðh^ d ðZ]ghklbd \_ mjhZy habfhc ir\_gbpu gZ ihqZö i\_j\_ohghe ahgu hl lZjh[\_j\_gh]h lhc \_kvy d E\_khkl\_ib MdjZbgu hibkZg b jZ[hl\_ [6@mfZjguc 1'9, aZ



, dhlhjuç \j\_b f\_

gZb)Zpbhgghc kt\_fdb h[\_ki\_qb Z e ðnn\_j\_gpbZevgmX lhqghklv :\$( \*126 f \

]\_hljZnbq\_kdhckbkl\_f\_dhhjðgZl:\*6mgb\jkZevgZyijh\_dpbyF\_jdZlhjZ

Ihe\_u\_bkke\_hZgby ùihegyebkv \nZam gZklmie\_gby iheghc ki\_ehklb habfhc ir\_gbpu

khjZ @]ZgZ<sup>a</sup> (1-y^dZZZ\mklZ ] b ij\_ñkfZljbZeb hl[hjZklbl\_evguoh[jZaph\ \

khhl\lk lbb k j\_dhf\_gZpbyfb > 1] < dZhc lhqd\_ gZ[ex^gbc kiehsZð f <sup>2</sup> \ -djZlghe

ihlhjghklb kj\_aZeZkvky gZa\_fgZyfZkkZir\_gbpu b\ hlh[jZgguoh[jZapZokèZghklvx %

hij\_eyebkvfZkkZa\_jgZbkhehf> 1, 3].

**1. Номенклатура почв в пределах исследуемой территории и количество точек наблюдений**

GZaZgb_brnjZjhjhbah\l_gghe\jmiuihq\	GZaZgb_brnjihqih deZkkbnbdZpbb)§	Dhehq_klh lhq_drl
K\leh -k_ju_bk_ju_hihåhe_ggu_kmi_kqZgu_ihq\	Eutric podzoluvisols (Pde)	15
K\leh -k_ju_bk_ju_e_]dhkm]ebgbklu_hihåhe_ggu_je_]Zlu_	Gleic Greyzems (GRg)	4
ih_q\		
L_fgh -k_ju_e_]dhkm]ebgbklu_hihåhe_ggu_bq_jgha_fu	Haplic Greyzems (GRh)	4
hihåhe_ggu_ih\joghklgh -]e_]Zlu_]		
L_fgh -k_ju_e_]dhkm]ebgbklu_hihåhe_ggu_bq_jgha_fu	Haplic Greyzems (GRh)	6
hihåhe_ggu_ih\joghklgh -]e_]Zlu_]		
K\leh -k_ju_bk_ju_hihåhe_ggu_kmi_kqZgu_ ]e_]Zlu_ihq\	Gleic Greyzems (GRg)	±*
≥jghh -ihåhebklb_bihåhebklh -]jghu_kmi_kqZgu_je_u_	Eutric podzoluvisols (Pde)	±*
ih_q\		
≥jghh -ihåhebklb_bihåhebklh -]jghu_kyagh -i_kqZgu_	Eutric podzoluvisols (Pde)	±*
ih\j_oghklgh -]e_]Zlu_ihq\]		
≥jghh -ihåhebklb_bihåhebklh -]jghu_kmi_kqZgu_	Eutric podzoluvisols (Pde)	±*
ih\joghk_lgh -]e_]Zlu_ihq\]		
Em]hh -[hehlg_u_behZlh -[hehlg_u_blhjnhZlh -[hehlg_u_	Mollic Gleysols (GLm)	±*
g_hkmr_ggu_ihq\		
≥jghu_e_]dhkm]ebgbklu_ ]em[hdb_je_u_ihq\ubbo	Eutric Planosols (PLe)	±*
hihåhe_ggu_jZaghklb]		

gZ[ex^gbyùihegyebkv\hevðhij\_åeZoZj\_ZehgZb[he\_jZkijhkljZg\_gguoihq\

Fmevlbki\_dljZevgZy kp\_gZ Sentinel-: MSI L1C k jZðhf\_ljbq\_kdbf jZaj\_r\_gb\_f

[blibdk\_evbiyhkljZgkl\ggufjZaj\_r\_gb\_f ±fibdk\_evbkihevam\_fZy\ðZq\_kl\Zgguo

ðklZgpbhggh]h ahgbjhZgby [ueZihemq\_gZba Zjob\ Z kimlgbdhuoZgguo 86\*6(526'DWD

&HQWHU=\_heh]h\Zykem[ZKR: ,gZohÿs\_]hkykh[hghfhklmi\_ (lZ[e\_ ).

**LZ[ebpZ . Характеристика мультиспектральной сцены Sentinel-2A MSI L1C**

	S2A_OPER_MSI_L1C_TL_MPS_20170804T111320_A011058_T35UPR
	1
	12
	10
	0,490
	0,560
	0,665
	0,842
	20
	0,705
	0,740
	0,783
	0,865
	0,1610
	0,2190
	60
	0,443
	0,940
	0,1375

g\_ gmZebkv \jZðhf\_ljbq\_kdhc b ]\_hf\_ljbq\_kdhc dhjj\_dpbb agZq\_gbc

ibdk\_e\_cbhjhljZgknjhfbjhZgb b bkh^jZeb bgnhjfZpbx h [ hljZZl\_evghc kihkh[ghklb !

TOA (Top of Atmosphere Reflectance) ih\joghklb . Bah[jZ\_gb\_ ]jZgpb Zj\_Zeh\ ihq\

kp\_ghc g Zihemq\_ggmx hkghmgZghkbebkv lhqdbhl[hjZ  
 h[jZaph\ b bgl\_ljbhZebkv \\_bgmx [Zam ]\_hijhkljZgkl\gguo Zgguo JZ[hIZ k  
 ]\_hijhkljZgkl\ggufb Zggufb uihегyeZkv k ihfsvx hmi\_gkhjkghc ]\_hbgnhjfZpbhgghc  
 kbkl\_fu Quantum GIS \jkb b 2.18.

I h h[s\_ba\klguf nhjfmeZfZZilbjhZgguf d khhl\lklmxsbf dZgZeZf bkihevahZgghc  
 kp\_gu Sentinel-2: MSI L1C [uebjZkkqblZgu ke\_fmxsb\_\\_]\_lZpbhggu\_bihq\ggu\_bg^dku  
 ghjf ZebahZgguchlgkbl\_evгucbg^dkjZklbl\_evghklb1'9,1RUPDOLJHG'LIIHUHQ ce Vegetation  
 Index) [20@hjfZebahZgguc bnn\_j\_gpbjhZgguc ihq\gguc bg^dk 1'6, 1RUPDOLJHG  
 Difference Soil Index) [25@\_lZpbhgгucbg^dkkmq\_lhfihq\69,6RLO6MXVWHG9HJHWDWLRQ  
 Index) [16@h^ bnbpbjhZgguc ihq\ggh -dhjj\_dlbjhZgguc bg^dk 0 SAVI (Modified Soil  
 Adjusted Vegetation Index) [9, 27@hjfZebahZgguc bgnjZdjZkгuc bg^dk 1', 1RUPDOLJHG  
 Difference Infrared Index) [14@h jfZebahZgguc bg^dk kh^jZgby eZ]b \ihq\ NDWI  
 (Normalized Difference Water Index) [12@h jfZebahZgguc bg^dk my^c jZklbl\_evghklb  
 NDSVI (Normalized Difference Senescent Vegetation Index) [19].

I hemq\_ggu\_bg^dku [uebdexq\_gu \bkoгmx dhjj\_eypbhgmx fzljbpм éy ijh^gby  
 dhj\_j\_eypbhggh -j\_lj\_kkbhggh]hZgZebaZijh]Zff\_ éy klZlklbq\_kdhch[jZ[hldb6W atistica 12.0.  
 KlZlklbq\_kdZy h[jZ[hldZ Zgguo uihегyeZkv \g\_kdhevдh wlZih\GZ i\_jhf wlZi\_ iml\_f  
 jZkq\_lZ i h]\_rghklb Z[khexlghe ZiijhdkbfZpb - kj\_g\_h hldheг\_gby jZkq\_lguo agZq\_gbc hl  
 nZdlbq\_kdbo 0\$(b kj\_g\_dZjZlбq\_kdh]h hldheг\_gby jZkq\_lguo ag Zq\_gbc hl nZdlbq\_kdbo  
 (RMSE) [ueh hp\_g\_gh dZq\_klh ihemq\_gguo mjZg\_gbc\_j\_lj\_kkbb > 24@Z\_ljhjf wlZi\_ [ueZ  
 ijh^gZ hp\_gdZ hkl h\_ljghklb ihemq\_gguo dhjj\_eypbhggh-j\_lj\_kkbhgguo fh^e\_c dhlhjZy  
 ij\_fmkfZljbZeZ \jbnbd ZpbxkZfhc fh^ebdjhkk -ZebZpb x), ZIZd\_kjZg\_gb\_ijh]ghaguo  
 \ebqbg ihemq\_gguo gZ hkg h\_l\_jZajZ[hIZgghe fh^eb , k\_j\_Zevgh baf\_j\_ggu fb agZq\_gbyfb.  
 MdZaZggu\_f\_lhúijbf\_gyebkvéyhp\_gdbfh^e\_cihemq\_gguoéyhfbgbjmxs\_cihiehsZb  
 ihq\ k\leh -k\_jhcbk\_jhchih^ he\_gghcihq\ .

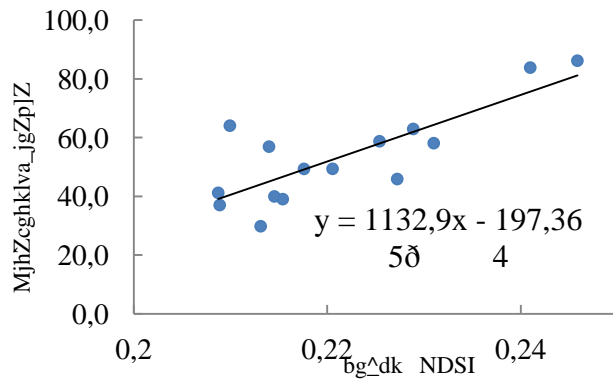
**Основная часть**

**ih** x \Zbfhkyab f\_m hljZl\_evghc kihkh[ghklvx  
 i h\joghklb b \ebqbg hc mjhZcghklb habfhc ir\_gbpu [ue uihег\_g dhjj\_eypbhggh -  
 j\_lj\_kkbhgгuc ZgZeba Ijb wlhf [ueh mql\_gh qlh lhqghklv \klZgpbhggh]h bZ]ghklbjhZgby  
 ijhndlbghklb g Za\_fghe [bhfZkku ir\_gbpu \agZqbl\_evghc f\_j\_h[mkeh\_gZ kehghklvx  
 ihq\ggh]h ihdjZ\_dhl hjZy hij^ey\_lky\_g\_lhevдh dhebq\_klf lbih\ ihq\gh b \Zbfгuf  
 jZkiheh`gb\_f bo Zj\_Zeh\ij^eZo l\_jjblhjbb bkke\_hZgbc ey mq\_lZ ijhkljZgkl\gghe  
 g\_hghjhghklbjZkij^e\_gby gZa\_fghecfZkkuhabfhc ir\_gbpu [uehjZajZ[hIZghljbp\_gZjby  
 ih^hlhjfuf ihgbfZeb khq\_lZgby [ebadbo ih ]\_g\_abkm b khcklZf ihq\ahg\_gZ[ex^gbc  
 Q\_l\_jluc kp\_gZjbc bkihevahZeky éy kjZ\ g\_gby b g\_mqbluZe ihq\gghe g\_hghjhghklb  
 ihkdhevдm\_g\_h [uebdexq\_gu Zj\_Zeuk\_oгZb[he\_jZkijhkljZg\_gguo ihq\Z[e LZdhc  
 ijb\_f ihahebe dhk\ggh mq\_klv hkghgu\_j\_bfu nmгdpbhgbjhZgby ihq\ iblZl\_evгuc  
 l\_fi\_jZlmjguc eZghklb hafmguc h[mke Z\_ebZxsб\_ \ebqbgm mjhZcghklb Z\_lZd`  
 agZqbl\_evgh jZkrbj blv hafhghklb hkms\_klè\_gby ijhkljZgkl\ ggh]h ]\_hklZlklbq\_kdh]h  
 ZgZebaZ h[ki\_qbZy hij^e\_ggmx dhf[bgZlhjghklv ihq\Ijb wlhf fZ dkbZevgh lhqgh  
 hkijhba\lkykljmdlmjZihq\ggh]h ihdjZ\_oZjZdl\_jgZyékhh\lklmxs\_cl\_jjblhjbb <  
 j\_amevlZl\_ [ueb mklZghè\_gu \ebqbgу dhwnnbpb\_glh\dhjj\_eypbб f\_m ijh^m dlbghklvx  
 habfhc ir\_gbpu b hljZl\_evghc kihkh[ghklvx ih\joghklb ihjZaguf ihq\gguf kp\_gZjbyf  
 éyZkljhqZgZehkp\_gu Sentinel-: MSI L1C lZ[e

**Коэффициенты корреляции для показателей продуктивности озимой пшеницы и качественных характеристик каналов сены Sentinel-2A MSI L1C для различных сценариев**

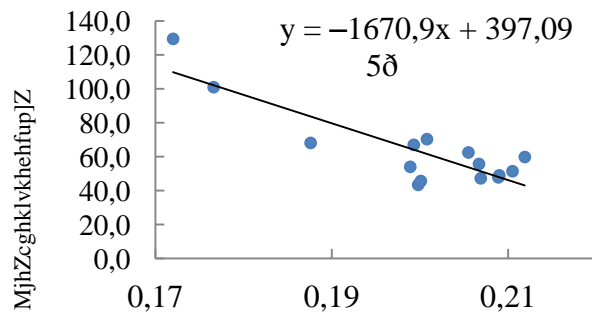
№ сценария	Показатель	Сценарий		
		Сценарий 1	Сценарий 2	Сценарий 3
1	NDVI	0,41	0,41	0,41
2	NDWI	0,82	0,82	0,82

3	- FAO Pde	9	- 1 - 11 - 12 - 6 0,80 NDSI	- 11 - 12 - 6 0,77 NDSI
4	-	9	- 1 -	



Jbk AZbkbfbhklvf\_fmjhzcgkklvxa\_jgzhabfhcir\_gbpub\_ebqbgchcbg^dkZ NDSI ljZgbpZo3GH

Kj\_gyy ihlj\_rghklv ZiihdkbfZpbb ihe\_hc mjhzcgkklb a\_jgz khklZbeZ - a\_jgh = 14,5 %  
 (RMSE<sub>a\_jgh</sub> = 9,47 p]ZKhh\lklmxsb\_\ebqbgueymjhzcgkklb kkehfu khklZbeb - kkehZ =  
 15,3% (RMSE<sub>a\_jgh</sub> = 11,79 p]Z Dhwnnbpb\_glu^l\_jfbgzpbb ey mjhzcgkklb a\_jgz b kkehfu  
 khklZbebkhhl\lkl\ggh



Jbk AZbkbfbhklvf\_fmjhzcgkklvkhhehfuhabfhcir\_gbpub\_ebqbgchcbg^dkZ NDSI ljZgbpZo3GH

J\_amevlZlu ijbf\_g\_gby f\_lhh\djhkk -ZebZpbb b\_l\_klhuo mqZkldh\k^l\_evklm\_xl h  
 him klbfhf mjhg\_ ihlj\_rghkl\_c jZajZ[hlgguo ijh]ghaguo fh^ e\_c qlh mdZauZ\_l gZ  
 hklZlhqgmx dh j\_j\_dlgkklv\ijh^gguo ihe\_\uobklZl\_bklbq\_kdbobkke\_hZgbc  
 K p\_evx bamZebaZpbb j\_amevlZlh\bkke\_hZgb c gZ hkgh\ jZajZ[hlgguo ijh]ghaguo  
 fh^e\_c k bkihevahZgb\_fmngdpbhgZevguo hafhgkkl\_c=BK QGIS f\_lhhfdhehq\_kl\ggh]h  
 nhgZ[ueb khaZgudZjl u ijhkljZgkl\ggh]h jZkij\_^e\_gb ymjhzcgkklba\_jgz bkkehfu habfhc  
 ir\_gbpu gZ kx bkke\_fm\_fm\_x l\_jjblhjb\_x . Ij\_klZ\_e\_ggZy gZ dZjlZo ]\_hijhkljZgkl\ggZy  
 bgnhjfZpby hkl Zhqghcf\_j\_kh]eZkm\_lky khkh[\_gghklyfb l\_jjblhjbZevgh]h jZkijhkljZg\_gby  
 Zj\_Zeh\ihqLZd g Zjbf\_j ijb u iheg\_gbb ihe\_uo bkke\_hZgbc gZ ihqZo k gZebqb\_f \  
 ijhnbe\_ ]e\_h ]h ]hjbahgZ \*5J \ ] mjhzcgkklv ir\_gbpu [ueZ gb\_ qlh  
 ih\jZ\_lky b j\_amevlZlZfb ]\_hklZl bklbq\_kdh]h fh^ ebjhZgby Ijb ihibdk\_evghf ihRq\_l  
 h[sZyfZkkZa\_jgz ij\_^eZo l\_jjblhjb bkke\_hZgby khklZbeZpZkhhl\lklmxsZy  
 fZkkZkhehfup

**Заключение**

**В** klZ\_gguf -:06,/ &kijhkljZgkl\gguf  
 jZaj\_r\_gb\_f b f ijb]hgu ey bZ]ghklbjhZgby mjhzcgkklb a\_jgz b kkehfu habfhc  
 ir\_gbpu mklZghe\_gh qlh dZgZeu [ebg\_ ]h bgnjZdjZkgh]h bZiZahgZ 6:5 b  
 \ ]\_lZpbhguc b g^dk l'69, jZkkqblZgguc k bo bkihevahZgb\_f fh]ml ijbf\_gylvky ey  
 bZ]ghklbjhZgby ijhfm dlbgkklb habfhc ir\_gbpu \nZa\_ iheghe ki\_ekklb \mkehpyo  
 g\_hghjhghkkl ihq\ggh]h ihdjhZ ijh]ghagu\_ fh^eb mjhzcgkklb a\_jgz b kkehfu  
 khaZg gu\_k bkihevahZgb\_fZgguo bklZgp bhggh]h ahgdbjhZgby h[\_ki\_qbZxl himklbfuc  
 mjh\gv ihlj\_rghklv Z ijb djhkk -ZebZpbb d hwnnbpb\_gl dhjj\_eypb b\_fm baf\_j\_gguf b  
 ijh]ghaguf\ebqbgZfb khklZey\_l - ijb mkehbb fhaZbqghklb ihq\ggh]h ihdjh\ Z  
 bZ]ghklbjhZgb\_ ijhfm dlbgkklb ir\_gbpu ke\_fm\_l \ u ihegylv ij\_^eZo ihq\gguo Zj\_Zeh\  
 kohguo ih ]\_g\_abkm b khcklZf ihkdhevdm ij\_g\_lj\_gb\_Zgguf nZdlhf\_uauZ\_l ihl\_jx  
 lhqghklb ijh]ghaghe fh^eb dhllhjZy Z[khexlguo\_\ebqbgZo k khklZbeZ p]Z ey a\_jgz b

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1. ħki\_oh \ , ; : F\_lhĥdZihe\_h]hhiulZbaĤ\_j\_jZ[bĥi;ĥki\_oh\ . ± F , ± k
2. ?jhr\_gdh , N < J\_lj\_kkbhggu\_fh^eb hp\_gdb mjhZcghklb habfhc ir\_gbpu \KlZ]hihevkdhf djZ\_k  
bkihe vahZgb\_f NDVI N?jhr\_gdh B=Q\_j\_gbg\_gdh ;xe KlZ]hihevkdhf]hgZmqgh -bkke\_ĥg -lZk\_evkdh]h  
ohaycklZ ± 2013. ± < ± K ± 64.
3. A\_gq\_gdh , H 1 Jhkegggplĥ iĥmqgbd H 1 A\_gq\_gdh G KZeZl\_gdh F : ;ehghĥ AZ\_j\_H 1  
A\_gq\_gdZ:l]jZj gZhkĥZ , 2001. ± k
4. J\_lj\_kkbhggu\_fh^ebhp\_gdbmjhZcghklb\_k\_evkdohayckl\gguodmevlmjihZgguf MODIS G GDmkkmev [b  
Ĥ ] // Khj\_f\_ggu\_ijh[e\_fuĥklZgpbhggh]hahgĥjhZgbyA\_febbadĥkĥkZ ± 2012. ± L ± < ± K ± 107.
5. Dmkkmev G G Hp\_gdZkhklhygbyjZklb\_evghklb\_ijh]ghabjhZgb\_mjhZcghklb habfuo dmevlmjMdjZgbu  
ih kimgbdĥuf Zgguf GZlZevy Dmkkmev GbdheZc BevbG K\_j\_c KdZdmg :eZ EZj\_gxd XIVth International  
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MdjZbg\_B Eyevdh [bĤ ] Khj\_f\_ggu\_ijh[e\_fuĥklZgpbhggh]hahgĥjhZgbyA\_febbadĥkĥkZ ± Bgklblml  
dhkfbq\_kdbobkĕ ĥZgbcJhkkbckdĥcZdZ^fbbgZmdFĥkdZ ± 2010. ± Lhf ± < ± K ± 28.
7. KlZlklbgqbc[xe\_l\_gv]ĥkĕieĥskĕvkvdh]ĥkihZjkvdodmevlmjijĥjhZ c\_jhdm ĥaZĥimkd ±  
^bj\_dlĥj ^lZjZf\_glm klZlklbdb ĕevkvdh]h ]ĥkihZjkZ IZ gZĥhebrgvh]h k\_j\_ĥĥsZ >jZghĕkemfb  
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