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ACTIVITIES OF WHEAT PHENOTYPING THROUGH REMOTE SENSING TECHNOLOGIES IN RUSSIAN FEDERATION

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Annotation: *Crop phenotyping is a valuable method for retrieving important crop traits that inform agronomic decisions and the crop development process. Remote sensing technologies offer a way to collect surface properties from a distance, making them an increasingly important tool in agronomic research. In this context, a recent search was conducted on wheat phenotyping using remote sensing technologies in the Russian Federation. Although some innovative studies have been identified, more extensive research is needed. Given Russia's extensive history with remote sensing technologies, it is likely that further advancements will be made in wheat phenotyping studies using remote sensing technologies. However, due to language barriers, some of the research may be challenging for English readers to fully comprehend.*

Key words: *wheat, wheat phenotyping, remote sensing, UAV*

Crop phenotyping are the methods to retrieve the biophysical and biochemical traits of the crops for the proper evaluation of the growth of the plants. The retrieved traits (which can be morphological, physiological, biochemical and molecular) are important in understanding as well as analysing the growth of the crops in the given environment for the crop development and agronomic strategies. General approaches in crop phenotyping include visual observation, spectroscopy (using sensors for measuring reflectance), imaging (using camera sensors for the images of the crop), molecular phenotyping and remote sensing technologies.

Current innovations seen in the remote sensing technologies have been the added advantage in the crop remote sensing due to the newer development and increasing number of the satellite, aerial, UAVs, and ground based sensors. Remote sensing provides the non-destructive ways to observe the crops at the near real time basis in a larger spatial area effectively and accurately. The collected spectral information can be interpreted quantitatively that can be empirically related with the crop growth parameters. The remote sensing technologies have been further polished with the applications of machine learning and deep learning algorithms for the interpretation of the quantitative information eventually assisting in the crop phenotyping.

Remote sensing technologies utilise different parts of the electromagnetic information or the wavelengths reflected from any surface without being near to the

object. The ways of using these wavelengths vary and also depend on where the sensors are mounted or placed, which are distinguishably called optical or multispectral, Synthetic Aperture Radar (SAR), hyperspectral, thermal and LiDAR in remote sensing technologies. The utilisation of remote sensing technologies are ultimately to reduce any intensive process of the crop phenotyping while essentially enhancing the accuracy of the process.

Whatever the innovations are, challenges are still in the application of these technologies on a larger scale not being limited to the scopes of the research. Being the major crop of the globe, the applicability should be true for the wheat. As of 2016, Russia has been the global leader of the wheat exporter in the world and Russia's involvement in the remote sensing technologies has been extensive. This demands the need to observe any research or any activities conducted within Russia Federation in wheat phenotyping using remote sensing technologies. Broadly, observing the updates related to crop phenotyping within Russia would also lead to understanding of the wheat phenotyping overlapping remote sensing techniques.

Search of the information. To get the grasp of the current activities of crop phenotyping, search of the related terms were done in google scholar and google. Search terms in Russian and English were searched after 2015 as shown in Table 1. The Russian terms indicate the wheat phenotyping and remote sensing. All the searches were scanned briefly to get the overall gist as the introductory observation.

Таблица 1

Site	no.	Search Terms	Time Period
Google Scholar	i.	Фенотипирование пшеницы	2015 - 2022
	ii.	дистанционное зондирование пшеницы	
Google	iii.	Фенотипирование пшеницы site:.ru	2015 - April 2023
	iv.	wheat phenotyping in russia site:.ru	
	v.	UAV technologies in russia site:.ru	
	vi.	ground remote sensing technologies in russia site:.ru	
	vii.	crop remote sensing technologies in russia site:.ru	
	viii.	Фенотипирование пшеницы с помощью дистанционного зондирования в России	

	ix.	Фенотипирование пшеницы на основе беспилотных летательных аппаратов site:.ru	

Discussions. First two searches (i and ii) resulted in extensive works being done in wheat phenotyping and wheat remote sensing. Research works in wheat phenotyping can be seen extensively conducted within Russia. Key areas relate to high throughput phenotyping (done for the large number of plants rapidly), grain quality and disease resistance using image analysis. Remote sensing based studies can be seen being applied for wheat yield estimation, observation of the status of nitrogen and grain quality of the crops and productivity of the wheat crops. As the text is in Russian, it can be difficult for the general readers to grasp the main methodological approach which can be unclear only through the provided abstract in english. In most cases, the abstracts are not available in the English language, adding difficulty in understanding the overall approach. As a general applicative rule, vegetation indices (NDVI) are seen as being related to the yield and the wheat growth status. Search ii does not reveal if the remote sensing related works have exhaustively either used any European or the USA satellites such as Sentinel -1, Sentinel-2 and Landsat which does not necessarily mean there has been no use of data from those satellites, although few cases may have.

Search iii results the cases of the digital phenotyping being initiated within Russia using digital cameras and scanners. The opening of the new research lab as of 2022 in All-Russian Research Institute of Agricultural Biotechnology is noteworthy activity. This includes the preparation of the 3-dimensional point cloud as less as 1 mm in each dimension in blue, green, red and far red range of spectrum collecting phenotyping information as the crop grows.

The search iv resulted in the development of the information system for the storage and access of the wheat phenotyping data [1]. Searches v and ix helped in the observational uses of UAV in crop phenotyping process. Drone technologies are innovative within Russia with organisations eager to develop the uses of the drones in different applicable areas. Activities from Lobachevsky State University of Nizhny, Novgorod can be noted specialising the use of multispectral images captured from the drones in different crop stages for the selection process. Search vi specifically did not result in any suggestive results to be included but more selective key words could be helpful in resulting better results.

Searches vii and viii further revealed the remote sensing activities of the crop remote sensing in different directions performed in agricultural contexts. Developing hyper-spectrometer for nanosatellites from Samara University and the RAS Image Processing System Institute (ISOI), capturing hyperspectral data can result in exploratory works in field based phenotyping process, and are sure to be assistive in different crop remote sensing studies.

The observed searches have helped in some overview of the crop phenotyping research within Russia Federation, and the country can surely exploit different phenotypic sensors [2]. Remote sensing technologies based methods in the observation of the wheat crop can be distinctly visible. Institutions are seen working

in drone based remote sensing, developing digital phenotyping methods and innovating methods in the crop phenotyping process. The Russian atmosphere is itself rich with different organisations and startups specialising in crop remote sensing such as GeoScan and ScanEx whose activities have not been discussed here. Innovations of these startups and their innovations in remote sensing based crop phenotyping is still worth exploring. The searchability of the wheat phenotyping activities can also be limited by Russian language which can hinder the process of searching the resources for the english language speaker. For instance, the searched terms used in this observation might not have been able to result in the related works as desired in this preliminary work which can be further developed, searched and refined.

The general observation however reveals the upcoming potential of the crop phenotyping process that includes wheat. The workability of how only satellites are used in the wheat phenotyping or how only drones are used in the process are ambiguous from this article itself. Certain observations also point to the limited capabilities of the remote sensing technologies of satellite based remote sensing but these are understandable and depend more on the functionalities of how satellites perform [3]. But, the future will see more sophisticated research activities in the areas of wheat phenotyping using remote sensing technologies both in field and laboratory based work.

Conclusion. Crop phenotyping is the process of observing the crops closely in their growth status for crop development process and agronomic management. The remote sensing technologies will surely assist in the crop phenotyping process. Innovations particularly in wheat phenotyping can be observed in the Russian Federation. The full understanding of the conducted research can be hindered by the language skills for the English reader, however the activities are generally visible through general search. Russia can be concluded as the country moving towards the innovative methods of the wheat phenotyping process where remote sensing technologies will get the chance to explore in coming years ahead.

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