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Study of Grain Harvester Operating Speed Modes Based on GIS and GNSS Data

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SUMMARY

Navigation data obtained during the operation of agricultural machinery are used for the analysis of field operations and the investigation of the characteristics of technological processes. One of the sources of such information is GNSS monitoring, which provides real-time recording of machine coordinates and movement parameters. The aim of this study is to investigate the movement of a grain harvester based on GIS and GNSS monitoring data. The study was conducted in a production field with an area of 117 ha located in the Ternopil region of Ukraine. Navigation data were processed using the ArcGIS geographic information system. Based on GNSS observations, harvester movement trajectories were reconstructed and classified according to speed intervals. For each class, the number of passes and the total trajectory length were determined. The analysis revealed an uneven distribution of passes among individual speed classes. The highest number of passes and the greatest total trajectory length were recorded within the speed interval of 9.1–11.4 km/h, corresponding to the main operating mode of the harvester during harvesting operations. The developed cartographic models illustrate the spatial distribution of machinery speed and the characteristics of passes within the study area. It was established that most harvester passes were performed within the speed interval of 9.1–11.4 km/h, which was characterized by the highest number of passes and the greatest total trajectory length.

Keywords: Global Navigation Satellite Systems (GNSS); Precision agriculture; Geographic Information Systems (GIS); Speed modes; Movement trajectories; Spatial analysis.

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Introduction

Navigation technologies are an important component of modern precision agriculture. The use of multi-constellation GNSS solutions ensures high accuracy in determining the coordinates of agricultural machinery during field operations (Guo et al., 2018).

In recent years, navigation systems have become widely adopted in precision agriculture technologies. GNSS data are used to track machinery routes, monitor the field operations, and assess machinery efficiency (Radočaj et al., 2023). Trajectory analysis enables identifying operational characteristics of machinery within a field, determining areas of reduced speed, and evaluating operating modes (Chen et al., 2023; Bettucci et a., 2026).

Domestic studies have also focused on the application of geographic information systems, satellite navigation, and remote sensing technologies for solving agricultural production tasks (Zatserkovnyi et al., 2025).

The aim of this study is to analyze the speed modes of a grain harvester based on GNSS monitoring data and to assess the distribution of passes among speed classes.

Method

The study utilized GNSS monitoring data on agricultural machinery movement, including machinery positioning coordinates and time stamps obtained during field operations. The navigation information was used to reconstruct machinery movement trajectories and to further analyze the speed modes of its operation.

Data processing was performed in the ArcGIS geographic information system. Based on a sequence of GNSS observations, linear trajectory segments were generated, allowing the actual routes of machinery movement within the study area to be represented (Li et al., 2023). For each segment, the movement speed was determined through analysis of the spatial positions of points and the time intervals between them.

The obtained speed values were grouped into predefined intervals, after which the passes were classified according to speed modes. For each class, the number of passes and the total trajectory length were calculated, making it possible to assess the distribution characteristics of speed modes during harvesting operations.

The analysis of navigation data incorporated approaches to GNSS trajectory interpretation and agricultural machinery operating mode classification presented in the studies of Guo et al. (2018), Radočaj et al. (2023), Chen et al. (2023), and Bettucci et al. (2026).

The results were visualized and interpreted via thematic mapping, statistical summarization, and graphical analysis techniques. The classification results of speed modes were presented as thematic maps, making it possible to trace their spatial distribution within individual passes and evaluate the movement patterns of the harvester during harvesting operations. This approach enabled the assessment of the spatial distribution of machinery speed modes and the identification of operational characteristics within the study field.

The study was conducted in a production field covering an area of 117 ha, located near the village of Shypivtsi, Zalishchyky District, Ternopil Region, Ukraine (Fig. 1). The soil cover of the territory is predominantly represented by typical low-humus Chernozems and their degraded light loam varieties. The study area is characterized by spatial variability of soil properties, microrelief features, and varying field operation conditions, which makes it suitable for investigating the spatial characteristics of machinery movement.

Figure. 1. *Geographic location of the study area within Zalishchyky District, Ternopil Region (based on Google Earth data)*

Relief features and soil cover heterogeneity influence field operation conditions, making the area suitable for analyzing the spatial characteristics of machinery movement.

Results

To analyze the spatial characteristics of machinery movement, the initial GNSS dataset was reduced to 5,000 uniformly distributed points while preserving the overall trajectory configuration. Based on the obtained navigation data, movement trajectories of a John Deere S770 grain harvester were reconstructed within the study field (Figure 2).

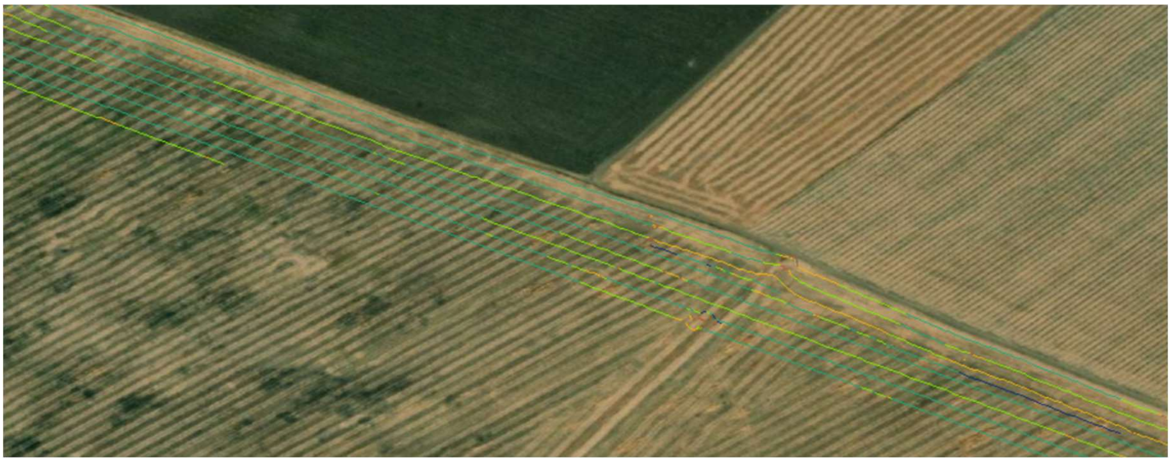

Figure. 2. *Fragment of grain harvester movement trajectories based on GNSS monitoring data*

The developed cartographic model reflects the spatial characteristics of harvester movement and the nature of passes within the study area. The color coding of the trajectories represents different speed modes and allows tracing their spatial distribution across the study area (Figure 3).

The unidirectional nature of most passes indicates the organized implementation of harvesting operations according to the field configuration, whereas changes in movement direction are associated with machinery turning maneuvers at the field boundaries. At the same time, variations in color along individual trajectories indicate fluctuations in movement speed during operation. Local speed variations are observed both within turning zones and along individual working passes, indicating heterogeneity in harvesting conditions across different parts of the field.

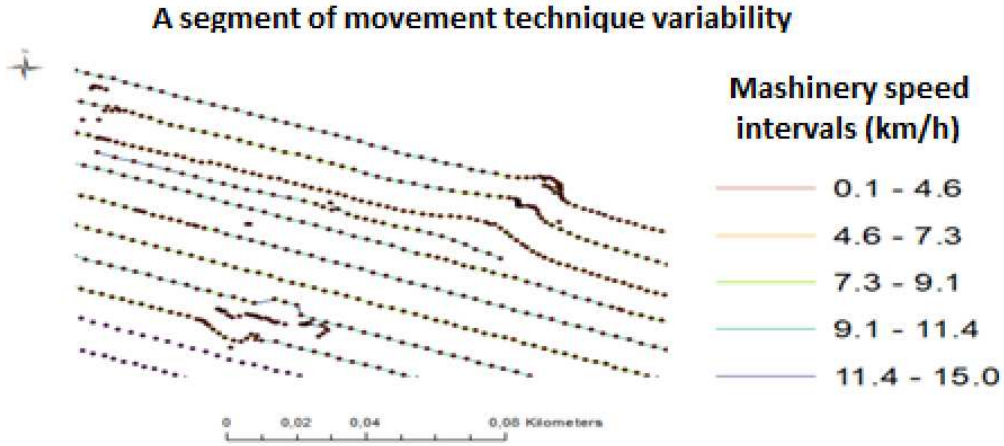

Figure. 3. *Spatial distribution of grain harvester speed modes based on GNSS monitoring data*

For further analysis, the passes were classified according to speed modes. The grouping results are presented in Table 1.

Table 1. *Distribution of harvester passes by speed classes*

Speed Class	Speed Interval, km/h	Number of Passes
1	0.1–4.6	171
2	4.6–7.3	484
3	7.3–9.1	1134
4	9.1–11.4	3067
5	11.4–15.0	52

The analysis revealed a pronounced unevenness in the distribution of passes among individual speed classes. The highest number of passes was recorded within the speed interval of 9.1–11.4 km/h, accounting for approximately 62.4% of all registered harvester passes. This indicates that the specified range corresponds to the primary operating mode during harvesting operations.

To evaluate the intensity of individual speed modes, the total length of passes within each speed class was additionally analyzed (Figure 4).

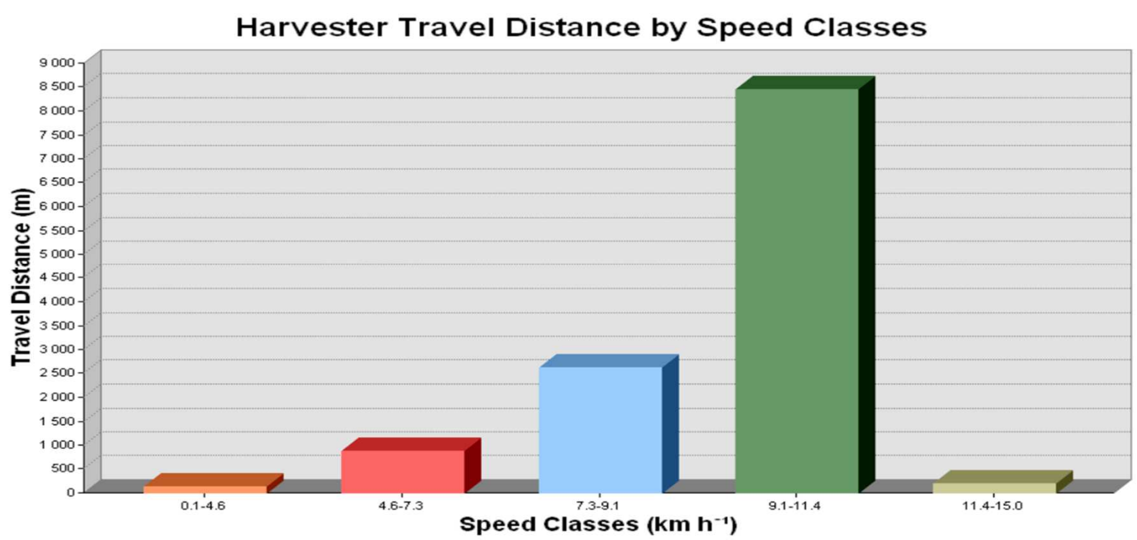

Figure. 4. *Distribution of harvester pass lengths by speed classes*

The analysis of pass distribution showed that the greatest total pass length also corresponds to the speed interval of 9.1–11.4 km/h, amounting to 8,452.8 m. For the 7.3–9.1 km/h class, this indicator equals 2619.2 m, whereas for the 4.6–7.3 km/h interval it amounts to 863.4 m. The lowest values were recorded within the 0.1–4.6 km/h and 11.4–15.0 km/h intervals, where the total pass lengths were 133.0 m and 187.2 m, respectively.

It was established that most harvester passes were performed within the speed range of 9.1–11.4 km/h, which accounts for both the highest number of passes and the greatest total trajectory length. The results obtained can be used to evaluate the operating modes of harvesting machinery and to analyze the efficiency of field operations.

Conclusions

Based on GNSS data, an analysis of grain harvester movement was carried out and the spatial distribution of its speed modes within a production field was investigated. The application of geoinformation technologies made it possible to reconstruct the actual movement trajectories of the machinery and to analyze the spatial structure of its movement within the study area.

During the study, the passes were classified according to speed modes, and their spatial distribution was assessed. It was established that both the highest number of passes and the greatest total trajectory length correspond to the speed interval of 9.1–11.4 km/h.

The integration of GNSS data with GIS tools enables the assessment of harvesting machinery operating modes and the spatial characteristics of field operations. The obtained results can be applied for machinery performance monitoring and for evaluating the efficiency of harvesting processes.

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