J Bangladesh Agril Univ 18(3): 751–759, 2020 https://doi.org/10.5455/JBAU.101583

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Evaluation of Harvesting Speed and Idle Time of Mini-combine Harvester using GIS Mapping

Md. Shadhin Ibn Ali Pathan, Md. Rostom Ali✉, Md. Kamrul Hasan, Chayan Kumer Saha, Md. Monjurul Alam

Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

ARTICLE INFO

Article history
Received: 24 Apr 2020
Accepted: 04 Jul 2020
Published online: 10 Jul 2020

Keywords
GPS, GIS, Precision agriculture, Paddy harvester, Machine idling

Correspondence
Md. Rostom Ali
✉: rostomfpm@bau.edu.bd

OPEN ACCESS

ABSTRACT

With a view to implementing Precision Agriculture (PA) technologies like Global Positioning System (GPS) and Geographic Information System (GIS) in mechanized harvesting this study was carried out in southern Bangladesh. In this study, the harvesting speed and machine idle time of a mini combine harvester were evaluated from geo-referenced data through visual inspection which was created using a GIS software. The linear speed trendline obtained from the GPS data indicated an average harvesting speed slightly above 2 km/h and GIS mapping showed that the harvester was idle for as long as 15 seconds or more on some occasions. In addition, an attempt was also taken to build a relationship between harvesting speed and heading changes. The results revealed that no significant relationship existed between harvesting speed and heading changes. In the case of machine idle time, from the developed map it could be easily identified where on the field and how much time the machine was idle during the harvesting operation. Application of GPS technology in farm machinery management might create some opportunity to obtain spatial data regarding machine operation. Again, machine data with geo coordinates can enable farmers and farm managers to identify the causes of inadequate machine performance and take actions to increase farm productivity.

Introduction

The Global Positioning System (GPS) is a set of earth-orbiting satellites that provides signals to a GPS receiver giving location and exact time information to users (Buick, 1997). Almost all precision agriculture activities now use GPS receivers to provide the spatial coordinates required to generate mapped information (Sudduth, 1999). By assigning a GPS coordinate to each line of data, researchers can observe and analyze how machine performance changes due to spatial aspects of agricultural fields (Adamchuk *et al*., 2004; Darr, 2012). As GPS coordinates are recorded alongside every line of machine data collected, machine performance data can be input into specialized software programs and analyzed to learn the details about the specific operation that was conducted (Taylor *et al*., 2002). On the other hand, Geographic Information Systems (GIS) are computer assisted systems for the capture, storage, retrieval, analysis and display of spatial data or geographic data (Clarke, 1986). The coordination between GPS and GIS allows the GPS receiver to collect field information from Differential Global Positioning System (DGPS) satellites and the GIS to store, display and interpret the field data at the time of collection (Buick, 1997; Earl *et al*., 2000). The primary tasks of GPS data analysis include determination of the distance, travel speed and heading based on the coordinates of two points (Adamchuk, 2001). With the use of software programs such as ArcGIS™, spatial aspects of agricultural fields such as field shape and topography, can be viewed (Buick, 1997). Due to the large amount of data that is often collected, the analysis has the potential to be tedious. However, the integration of a program such as Microsoft Excel™ and its associated functions into the data analysis process, has the potential to streamline the process substantially (Crisler, *et al*., 2002).

Adamchuk *et al*. (2004) mentioned that in every case, the efficiency of farm machinery operation can be affected by three factors: i) travel speed, ii) effective swath width, and iii) field traffic pattern. Renoll (1972) examined the influence of implement width and travel speed on productivity. Pathan *et al*. (2020) mentioned that harvesting patterns and heading changes of paddy harvesters may affect harvesting efficiency. GPS technology can be used effectively to determine mini-combine harvester's speed throughout the field operation. Machine idle time is another very important factor that reduces machine efficiency. Time when the

Cite This Article
Pathan, M.S.I.A., Ali, M.R., Hasan, M.K., Saha, C.K., Alam, M.M. 2020. Evaluation of Harvesting Speed and Idle Time of Mini-combine Harvester using GIS Mapping. *Journal of Bangladesh Agricultural University*, 18(3): 751–759. https://doi.org/10.5455/JBAU.101583

operator is in the machine and not actually working at the field should be counted as lost time (Hunt, 1995). Machine idling during harvesting can occur for many reasons such as operator's problem, clogging of the machine, any disturbances in the field, etc. Idling of machine contributes to the ineffective time of field operation thus reduces field efficiency which increases operating cost and it is essential for farm operators to have an accurate idea of the operating costs of their machinery if they are to make informed economic decisions (Hassan and Larson, 1978). From knowing how decisions are made information systems can be developed to aid farm managers in real-time decision making (Sorensen *et al.*, 2010). By using GPS tool to record geo-referenced machine data and GIS softwares to analyze such data, precise machine idling can be determined.

Manual harvesting of paddy is a laborious, time-consuming and costly operation which requires about 100-150 persons hr labor to harvest 1 ha of paddy field (Alizadeh and Allameh, 2013). In Bangladesh, the importance of mechanized harvesting by the combine or mini combine harvester is greatly felt as the shortage of labor during harvesting period is becoming acute throughout the country. Ali *et al.* (2018) reported that total labor required for harvesting of paddy was 21man-day/ha, 29 man-day/ha and 61 man-day/ha for using mini-combine harvester, reaper and manual system, respectively. The high labor requirement in manual harvesting results in increased production cost in the forms of high labor cost, losses due to manual harvesting, and untimely agricultural operations. It is even more significant in southern Bangladesh where land productivity is decreasing due to salt accumulation. Moreover, sudden flood or natural calamities regularly threat the yield. In such cases, combine or mini combine harvester will facilitate timely harvesting of paddy and increase profit by reducing harvesting cost and various losses associated with agricultural operations. Amponsah *et al.* (2017) reported that the mini combine produced low mechanical grain damage with total grain loss ranging from 1.43% to 4.43% and 1.85% to 5.6% for the IR841 and Nerica L20 rice varieties, respectively. Hossain *et al.* (2015) showed that average time, cost and grain that could be saved by using combine harvester over manual methods are 97.50%, 35.00% and 2.75%, respectively.

The advent of real-time geo-referenced data logging has made data collection easier, and often the data can be reviewed off-site to examine traffic patterns, field practices, and other operational issues (Grisso *et al.*, 2004). Machines can be tracked very easily with positioning systems and yield and machinery performance monitoring enables farm operators and managers to acquire large amounts of site-specific data that can be used to enhance decision making (Blackmore, 2000; Fountas *et al.*, 2006). Precision Agriculture technologies like GPS and GIS are still not adopted in Bangladesh. Farmers lack proper knowledge and access to such knowledge is also limited. Complexity of these technologies and high cost of adoption are the limiting factors. But identifying the utilization scopes and advantages of these technologies from Bangladesh perspective may encourage farmers and farm managers to adopt such technologies. Studies like this one may pave the way to these opportunities. By using precision agriculture technology like GPS, the accuracy of machine performance evaluation can be increased. At the same time, visual analysis of the machine data can provide great scope of machine management. Considering the above matters, the main objective of the study was to visually represent the GPS based harvesting speed and machine idle time of mini combine harvester by a GIS software.

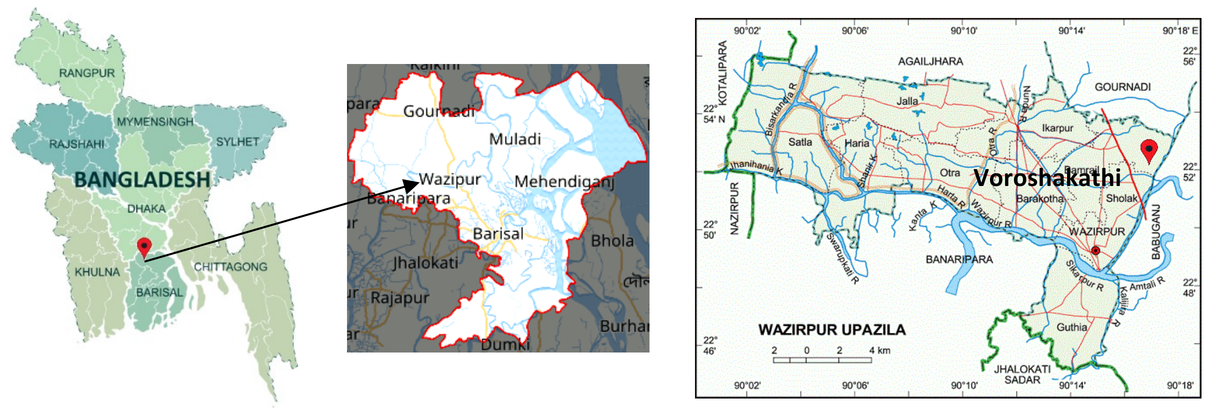
Materials and Methods

Study location

To evaluate the harvesting speed and machine idle time of a mini combine harvester, data were collected by a GPS receiver during the harvesting operations. Data for mini combine harvester were collected from fields of *Voroshakathi* village (Latitude: 22.868440⁰ N, Longitude: 90.279176⁰ E) of Wazirpur Upazila in Barishal district. Study location on Bangladesh map is shown in Fig. 1. The harvesting data were collected in May, 2018. The rice variety in these fields were BRRI dhan 29. The fields were muddy and there was about one inch of stagnant water in the fields.

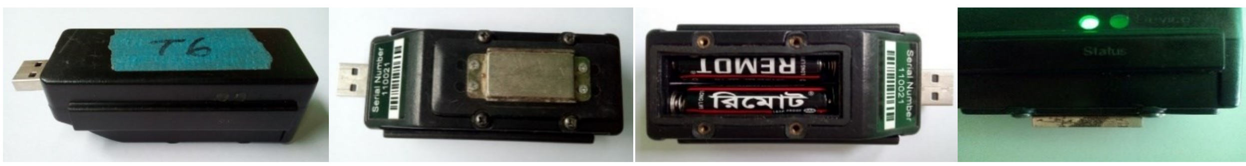
Devices used

The data generated by the mini combine harvester (ACI™ 4LBZ-120) during the harvesting operations were collected and recorded by a small GPS device named Tracking Key2™. The device is manufactured and marketed by Land Air Sea Systems, Inc. of the United States of America and the specifications are shown in Table 1. This GPS device was small, light weight and very easy to move and use. The GPS receiver was installed on the mini combine harvester. Before installing the device fresh "AAA" sized 1.5 V alkaline batteries were inserted and it was made sure that the GPS receiver was connected to the GNSS satellites. An indicator light indicates the battery level by brightness of the light, another light indicates the connection of the device to the satellites. Different views of the GPS device are shown in Fig. 2. The GPS receiver was left mounted on the harvesters during the whole harvesting operation to collect all the necessary data like time, position of the machine (coordinates), elevation from sea level, speed, heading, etc. After completion of the harvesting operations, the device was removed from the harvester



(a) (b) (c)

Figure 1. Location of the study site on map. (a) Bangladesh map, (b) Barishal district map, (c) Wazirpur upazila map



(a) (b) (c) (d)

Figure 2. Different views of the GPS device. (a) Upside of the GPS device, (b) Downside of the GPS device, (c) Batteries are inserted in the device, (d) Lights to indicate the power and status of the device

Table 1. Specifications of the GPS device

Items		Specifications
Name and model	:	Tracking Key II GPS tracker
Compatible	:	Mac and PC
Mounting System	:	Magnetic, water resistant
Power	:	2 AAA baterries, stores 100 hrs of data, power saving sensor, 30 hrs battery life in motion
Capturing data	:	Automatically
Accuracy	:	GPS position accuracy within 6 ft, records location every sec

(a) (b)

Figure 3. GPS receiver recorded data during mini combine harvester operation. (a) Installing GPS receiver on mini combine harvester, (b) Harvesting paddy with mini combine harvester

and connected to a computer via its USB 2.0 interface. It was needed to sign in to the service provider's dedicated server via the user's registered account. After uploading the GPS receiver's recorded files to the server, the harvester's data could be seen on the map. Data was exported as .CSV file for analyzing purposes. These files were then imported in the GIS software separately and various customized maps regarding different sets of data were created. The GPS receiver could produce data at one second interval and was able to record speed as low as one kilometer per hr (1 km/h). The main inconvenience of this GPS receiver was that it could not record speed precisely which was necessary for some important evaluations. The device was not able to record all the necessary parameters to fully estimate machine performance. However, this is a finding that will help in taking decisions about the suitability of such devices for evaluating certain operations.

Data collection

Geospatial data for the mini-combine harvester were collected from fields of *Voroshakathi* village of Wazirpur Upazila in Barishal district during the *Boro* harvesting season (January-May, 2018). The GPS receiver was installed on the mini combine harvester during the harvesting operation and it recorded data generated by the harvester (Fig. 3). Data collection procedure has also been mentioned in Fig. 4.

Data processing

Paddy of 4 sides (2 feet wide) of the identified field was harvested manually for smooth operation of mini-combine harvester initially. Then batteries were inserted in the GPS receiver and it was installed on the harvester. The GPS receiver recorded the geospatial data of machine operation. The recorded data were processed and analyzed later. The whole process of the study can be illustrated by a flow diagram (Fig. 4).

Data analysis

After the harvesting operation, it was necessary to access, process and analyze the data generated by the mini combine harvester and recorded by the GPS receiver. Several tools such as LandAirSea™ web application, Microsoft Excel™ and ArcGIS™ (free web version) were used to access, process and analyze the data. The GPS receiver recorded the data as .LAS file which was needed to be processed on the server of LandAirSea. After accessing the server and uploading the .LAS file it was converted to .CSV file which is a compatible file format for ArcGIS. CSV files can also be processed by Microsoft Excel. The GPS receiver records time, heading, speed and elevation along with coordinates. Only the desired columns were chosen for this study. Speed, time and coordinates columns were of interest for this particular study. From the geo-referenced data harvesting speed and machine idle time of mini combine harvester were analyzed and visually represented by the GIS tool.

Development of maps in GIS software

GIS is a useful tool to visualize the machine operation aspects on maps. It can give visual representation of any variable corresponding to its coordinates. When a compatible file was imported in the program, various variables present in the data file were analyzed and visually represented on maps. The general data processing and analysis in the GIS program has been shown by a flow diagram presented in Fig. 5. There is a free web based version of ArcGIS that also offers some of the very useful and important functionalities. After reviewing both the ArcGIS 10.5 and ArcGIS web version it was decided that the web version was sufficient to process and analyze the data for this study.

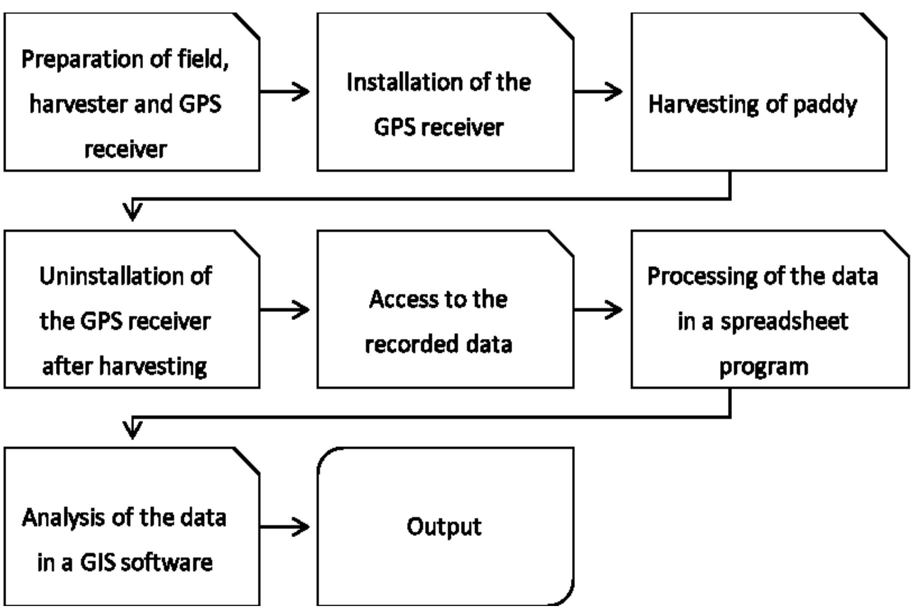


Figure 4. Flow diagram of the data collection and processing

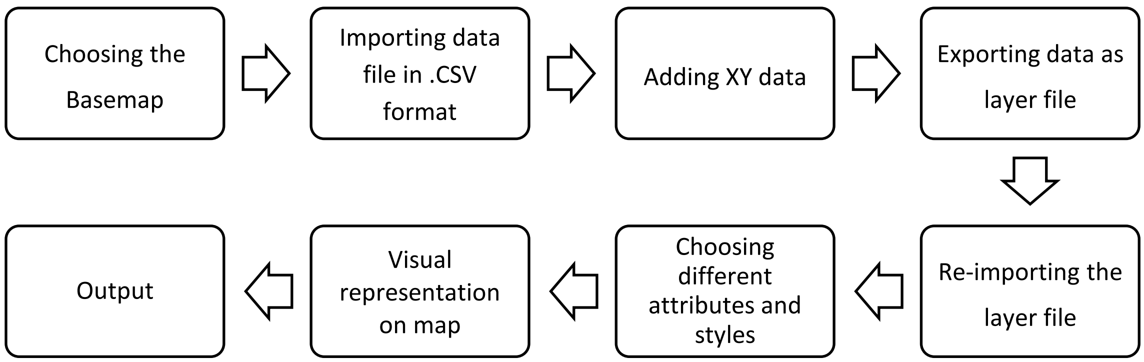


Figure 5. Flow diagram of creating a map using a GIS program

Results and Discussion

Harvesting speed of mini-combine during harvesting of paddy

On field and off field speed of mini combine harvester varies significantly. The GPS receiver used for this study recorded speed of the mini combine harvester every second but could not record speed below 1 km/h. The GPS receiver also could not record speed precisely and always showed integers and no fractions. But by assuming the speed to be correct, the speed changes of the mini combine harvester was observed in the study. Microsoft Excel was used to represent the speed as graph shown in Fig. 6. Data processing of a .csv file in an excel spreadsheet has been mentioned in Fig. 4. From Fig. 6 it can be seen that the average speed of the mini combine harvester during harvesting was well below 4 km/h. The linear speed trendline indicates that the average harvesting speed was above 2 km/h but less than 3 km/h. The theoretical operating speed of the mini combine was 1.6 to 2.8 km/h. By manual calculation the average forward speed of the harvester was found about 2 km/h. The GPS device used in this study was not very precise, a more precise GPS receiver like RTK GPS could record harvesting speed more precisely.

Speed change pattern of mini-combine harvester

A graph (Fig. 7) has been developed to show the changes of speed between data points during the harvesting operation. From Fig. 7 it can be seen that the speed almost remained constant during the harvesting operation. The fluctuations in the graph are mainly due to off field speed. The recorded off-field speed change was as high as 15 km/h. A sudden change of speed during the harvesting operation can be noticed from the figure. The change was about 3 km/h at best. This sudden change happened at the end of the harvesting operation. The operator increased the speed as he finished off the harvesting. To produce more precise speed change pattern, a high accuracy GPS device will be required.

Observing harvesting speed change at different points using GIS tool

The harvesting speed of the mini combine was observed with the help of the GIS software. Two maps were obtained from the data: one with the original speed as recorded by the GPS receiver during the harvesting operation and another one with the changes of speed between two sequential data points which were shown in Fig. 8. From Fig. 8, it can be seen that the harvesting speed of the mini combine harvester was mostly constant throughout the harvesting operation. Considerable higher speeds were mostly off-field speeds. The figure also shows that the locations where the speed was higher are also the locations with higher speed changes.

Relation between speed and heading change

To see whether the speed of the mini combine harvester changes during the turnings, speed and heading changes were plotted in the same graph and it is shown in Fig. 9. It could not be concluded appropriately from the graph (Fig. 9) whether there was any relationship between speed and heading change during harvesting by mini combine harvester. A highly precise GPS receiver might help in identifying any relationship between speed and heading change. A map created by the GIS software showing the relationship between speed and heading changes as shown in Fig. 10 also did not reveal anything significantly different from the above graph. In Fig. 10 'blue' dots represent the locations where heading changes were relatively high but speed was low. 'Light orange' dots represent the locations where both the heading changes and speed were low.

Machine idle time

To see if there was any machine idling occurring during harvesting operation a map was created in the GIS program. The map shown in Fig. 11 visually represents the locations in the field where the machine was idle. In Fig. 11 black pointers indicate the locations on the field where the machine was idle or the GPS receiver did not record any machine data for more than five seconds. Another map representing machine idle time was prepared where machine idle time was classified in seconds and presented on map with different colors. This map is shown in Fig. 12. In Fig. 12 the 'white' dots represent the locations on field where the harvester was fully operational. When the harvester was idle for one to five seconds (1-5s) it is shown with 'green' dots. The 'blue' dots represent the machine idle time between six to ten seconds (6-10s) and the 'orange' dots represent the machine idle time between eleven to fourteen seconds (11-14s). When the harvester was idle for fifteen seconds or more (≥15s) it is shown with 'red' dots. The reasons for these machine idle time could not be identified properly from the GPS receiver data as there were no such provisions. The GPS receiver's limitations, machine clogging, operator's issue, handling the bag during grain collection may be considered as potential reasons. Whatever was the cause it certainly affected machine efficiency.

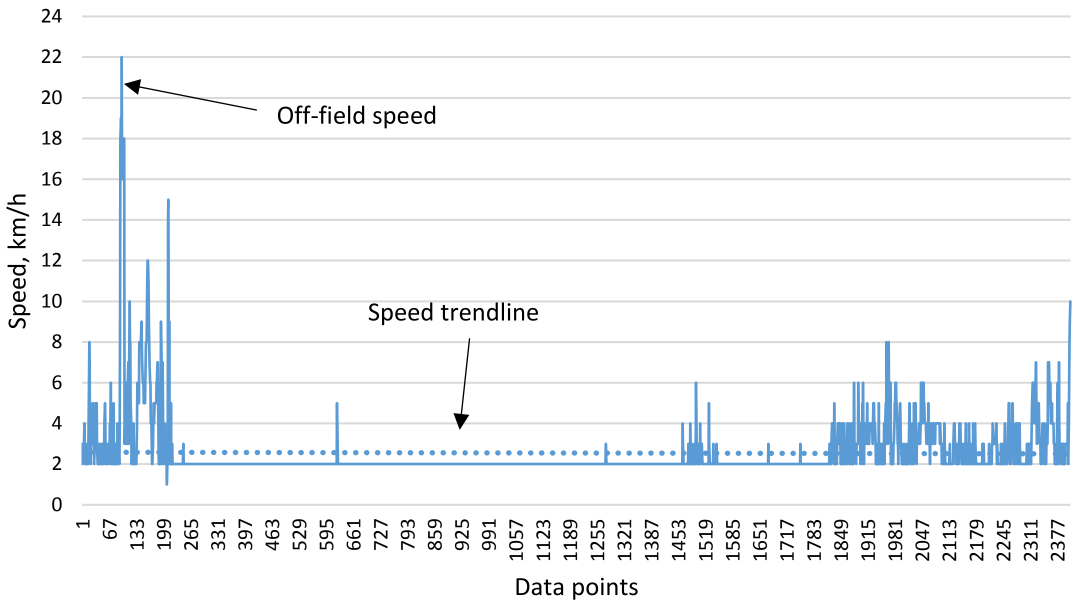


Figure 6. Speed of the mini combine at different point during harvesting

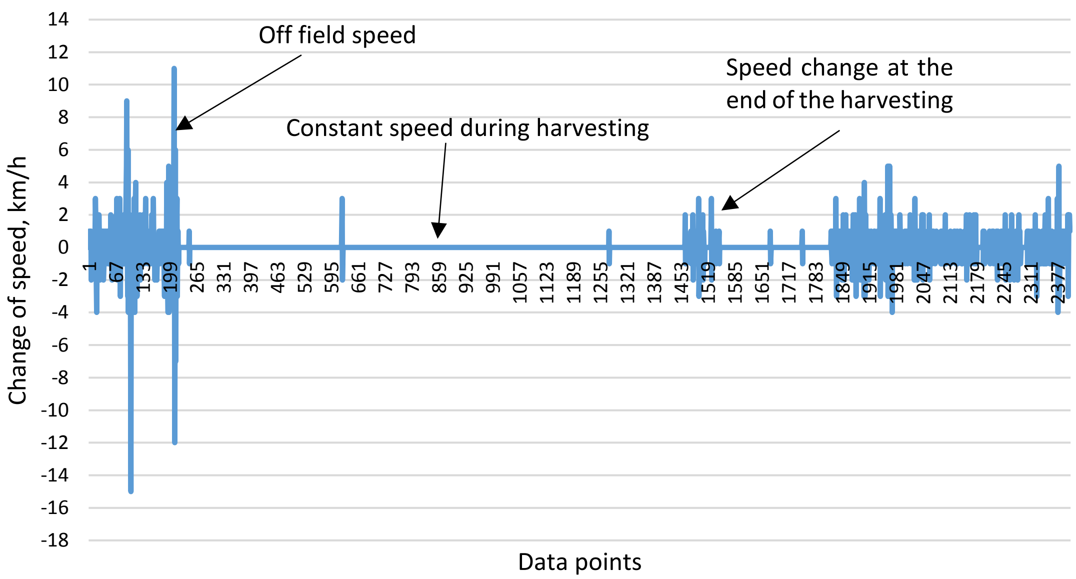


Figure 7. Speed change pattern of the mini-combine at different points during harvesting

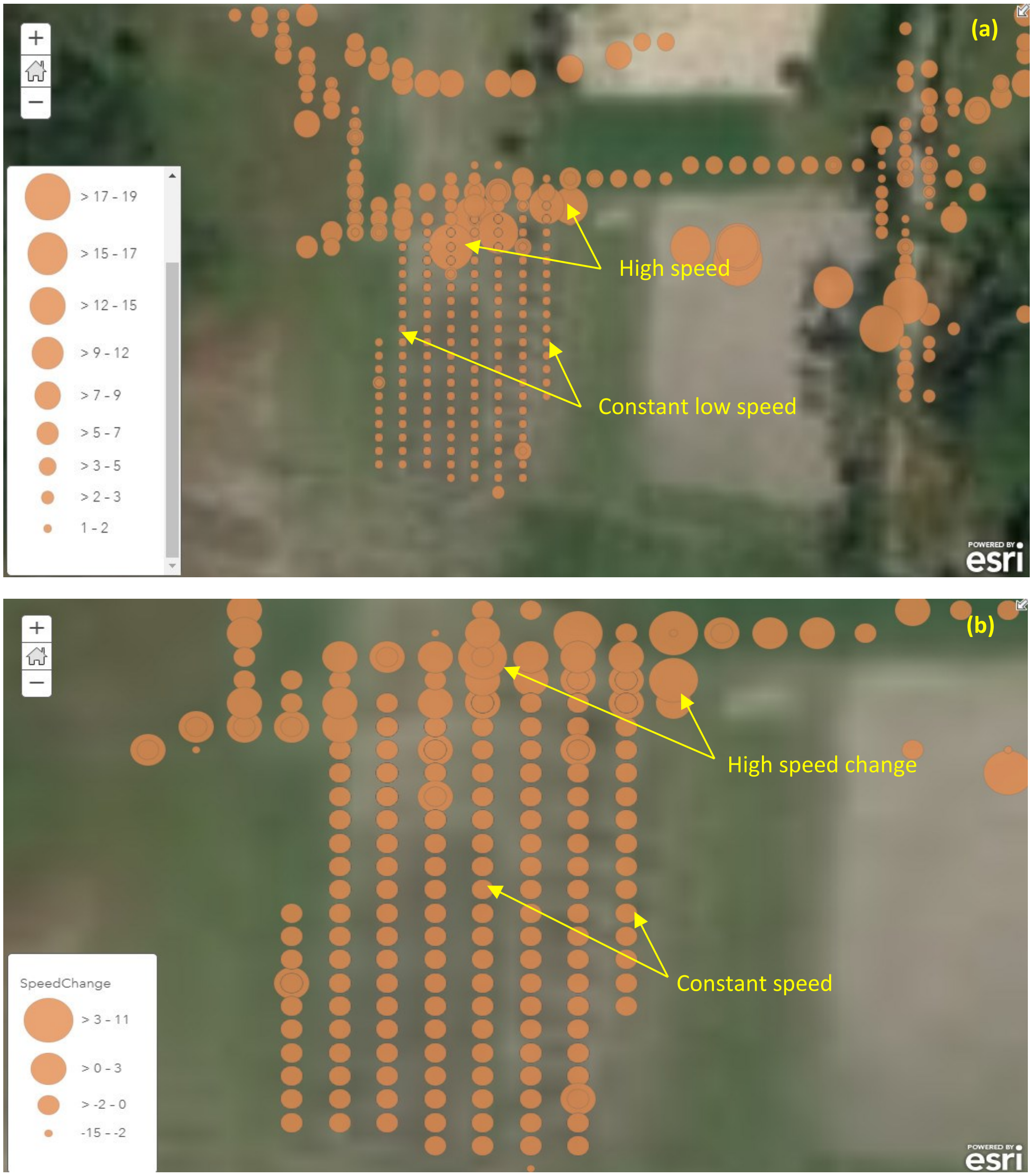


Figure 8. (a) Harvesting speed, and (b) speed change pattern of the mini-combine during harvesting

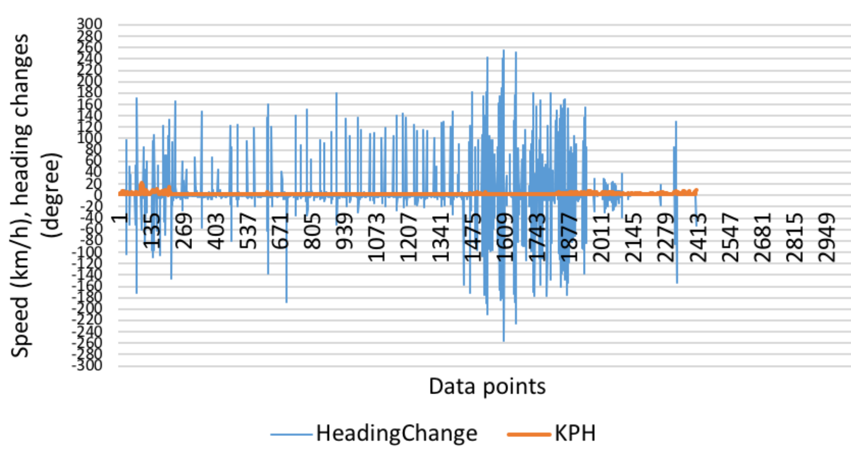


Figure 9. Relation between speed and heading change

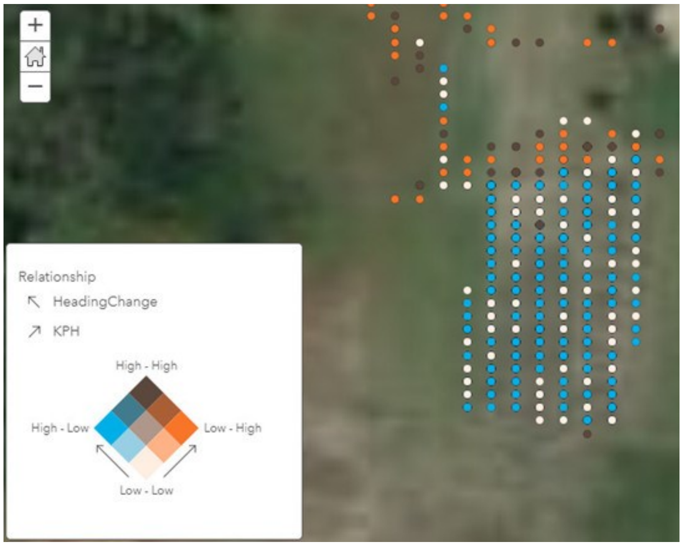


Figure 10. A map showing the relationship between speed and heading change

Figure 11. A map showing mini-combine idle time during harvesting

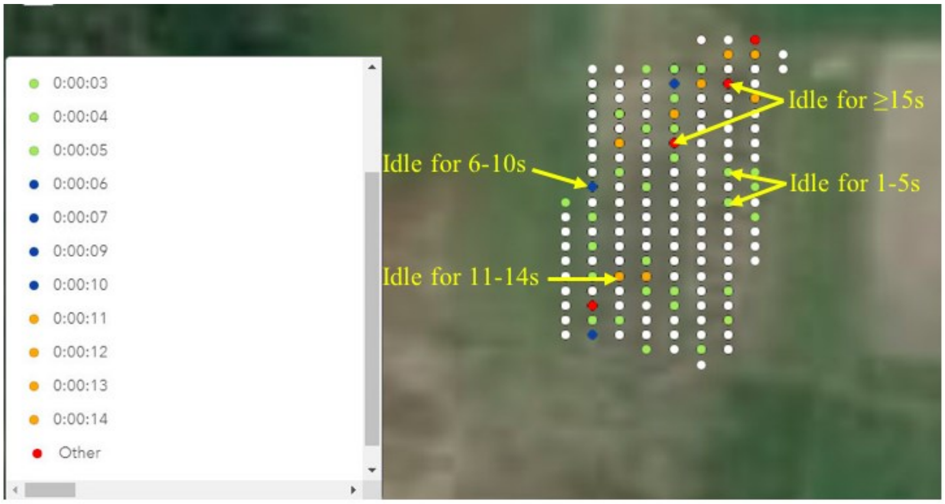


Figure 12. Classified idle time of mini-combine during harvesting

Conclusion

GPS and GIS tools can be used effectively to visually represent machine attributes such as harvesting speed and machine idle time. The average speed of the mini combine harvester during harvesting was found slightly above 2 km/h which was close to the speed calculated manually. The relationship between speed and heading changes was also investigated, but no significant conclusion could be made from the graph and the map. The limitations of the GPS receiver was a factor in this case. Visual representation of machine idle time gave an overview of where on field and how long the machine was idle. Knowing machine idle time will let the farmers know how much excess time it may require to complete a certain amount of field operation and it may also allow them to identify and reduce such time losses. At the same time, visual analysis of the machine data can provide great scopes of machine management and decision making.

Acknowledgement

This study as part of Appropriate Scale Mechanization Consortium (ASMC) project ''Appropriate Scale Mechanization Innovation Hub (ASMIH) - Bangladesh'' is made possible by the support of the American People provided to the Feed the Future Innovation Lab for Sustainable Intensification through the United States Agency for International Development (USAID) and University of Illinois at Urbana-Champaign, USA (Subaward Number: 2015 -06391 -06, Grant code: AB078). The contents are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government. First author would also like to acknowledge the Ministry of Science and Technology (MoST) of Government of the People's Republic of Bangladesh for National Science and Technology (NST) fellowship.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Adamchuk, V.I. 2001. Precision Agriculture: Untangling the GPS Data String. Historical Materials from University of Nebraska-Lincoln Extension. Paper 707. EC01-157. https://digitalcommons.unl.edu/extensionhist/707

Adamchuk, V.I., Grisso, R.D. and Kocher, M. 2004. Machinery performance assessment based on records of geographic position. Proceedings of the 2004 ASAE/CSAE Annual International Meeting, Ottawa, Ontario, Canada, ASABE. 11 p. https://doi.org/10.13031/2013.17067

Ali, M.R., Hasan, M.K., Saha, C.K., Alam, M.M., Hossain, M.M., Kalita, P.K., and Hansen, A.C. 2018. Role of Mechanical Rice Harvesting in Socio-Economic Development of Bangladesh. Proceedings of the 2018 ASABE Annual International Meeting. ASABE. 1 p. https://doi.org/10.13031/aim.201700596

Alizadeh, M.R., and Allameh, A. 2013. Evaluating rice losses in various harvesting practices. Int. Res. J. Appl. Basic Sciences, 4(4): 894-901.

Amponsah, S.K., Addo, A., Dzisi, K.A., Moreira, J., and Ndindeng, S.A. 2017. Performance evaluation and field characterization of the Sifang mini rice combine harvester. Applied Engineering in Agriculture, 33(4): 479-489. https://doi.org/10.13031/aea.11876

Blackmore, B.S. 2000. Using information technology to improve crop management. Weather and Agro-Environmental Management. AgMet Millennium Conferences, 29th February 2000, pp.30-38.

Buick, R. 1997. Precision agriculture: An integration of information technologies with farming. Proceedings of the New Zealand Plant Protection Conference, 18–21 August 1997. pp. 176-184.

Clarke, K.C. 1986. Advances in geographic information systems. Computers, environment and urban systems, 10(3-4): 175–184. https://doi.org/10.1016/0198-9715(86)90006-2

Crisler, M.T., Strickland, R.M., Ess, D.R. and Parsons, S.D. 2002. Data mining methods for use with geo-referenced field crop data. Proceedings of the World Congress of Computers in Agriculture and Natural Resources, Iguacu Falls, Brazil, 13-15 March 2002. pp. 265-271. https://doi.org/10.13031/2013.8340

Darr, M. 2012. CAN bus technology enables advanced machinery management. Transactions of the ASABE, 19(5): 10-11. https://doi.org/10.13031/2013.42312

Earl, R., Thomas, G., and Blackmore, B.S. 2000. The Potential Role of GIS in Autonomous Field Operations. Computers and Electronics in Agriculture, 25(1-2): 107–120. https://doi.org/10.1016/s0168-1699(99)00058-7

Fountas, S., Wulfsohn, D., Blackmore, B.S., Jacobsen, H.L., and Pedersen, S.M. 2006. A model of decision-making and information flows for information-intensive agriculture. Agricultural Systems, 87(2): 192-210. https://doi.org/10.1016/j.agsy.2004.12.003

Grisso, R.D., Kocher, M.F., Adamchuk, V.I., Jasa, P.J., and Schroeder, M.A. 2004. Field efficiency determination using traffic pattern indices. Applied Engineering in Agriculture, 20(5): 563-572. https://doi.org/10.13031/2013.17456

Hassan, G.I., and Larson, D.L. 1978. Combine capacity and costs. Transactions of the ASABE, 21(6): 1068-1070. https://doi.org/10.13031/2013.35442

Hossain, M.A., Hoque, M.A., Wohab, M.A., Miah, M.A.M. and Hassan, M.S. 2015. Technical and economic performance of combined harvester in farmers' field. Bangladesh J. Agril. Res. 40(2): 291–304. https://doi.org/10.3329/bjar.v40i2.24569

Hunt, D. 1995. Farm power and machinery management, Cost determination, 9th edition, Iowa State University Press, Ames, Iowa, USA.

Pathan, M. S. I. A., Ali, M.R., Hasan, M.K., Saha, C.K., Alam, M.M. 2020. Investigation of harvesting track and heading change of paddy harvester using geo-referenced data. Agricultural Engineering International: CIGR Journal, 22(2): 235-243.

Renoll, E.S. 1972. Concept for predicting capacity of row-crop machines. Transactions of the ASAE. 15(5): 1025-1030.

Sørensen, C.G., Fountas, S., Nash, E., Pesonen, L., Bochtis, D., Pedersen, S.M., Blackmore, B.S. 2010. Conceptual model of a future farm management information system. Computers and Electronics in Agriculture, 72(1): 37-47. https://doi.org/10.1016/j.compag. 2010.02.003

Sudduth, K.A. 1999. Engineering technologies for precision farming. International Seminar on Agricultural Mechanization Technology for Precision Farming, pp.5-27.

Taylor, R.K., Schrock, M.D., and Staggenborg, S.A. 2002. Extracting machinery management information from GPS data. ASAE Annual International Meeting, Hyatt Regency, Chicago, Illinois, USA. https://doi.org/10.13031/2013.13933