Investigation of harvesting track and heading change of paddy harvester using geo-referenced data

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Abstract: Global Positioning System (GPS) is a global navigation satellite system that provides geo-location and time information to a GPS receiver anywhere on or near the Earth. Many parameters, such as machine operation track, turning pattern, effective time of field operation, field capacity, field efficiency, machine idle time, etc. can be evaluated precisely by using geo-referenced data recorded by a GPS receiver during field operations. Highly precise GPS receivers are expensive and unaffordable for farmers and farm operators in Bangladesh. Keeping this in mind, the scope of an affordable and easy to handle GPS receiver was explored in the study. A GPS receiver was used to record the data generated by combine harvester and mini combine harvester during harvesting. Data were recorded during the harvesting period of *Boro* season (April-May, 2018) at Bangladesh Agricultural University farms and at fields of *Voroshakathi* village of Wazirpur upazila in Barisal district. Data recorded by GPS receiver were processed by Microsoft Excel and analyzed by ArcGIS. Heading change analysis of combine harvester and mini combine harvester made it clear that turning of mini combine harvester was easier than combine harvester. It was also visible that change of heading was more frequent and extreme in combine harvester than in mini combine harvester. ArcGIS was used to show the findings on map. Using GPS receiver on harvesting machines can help in decision on making for appropriate farm management.

Keywords: GPS, combine harvester, mini combine harvester, harvesting, harvesting track, heading changes.

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1 Introduction

Mechanization of agriculture in Bangladesh started late than many parts of the world. Over time the process got pace due to several strategic approaches among which popularization of mechanization by extension programs and government's incentives as subsidy towards machine purchase are crucial. Adoption of machines for various agricultural operations increased over time but some operations are still mostly dependent on physical labors and harvesting is one of them. Harvesting operation alone consumes 20% of labor requirement which includes harvesting by sickles and bundle making (Datt and Prasad, 2002).

Harvesting is the first and major post-harvest operation and it is an important part of mechanized agriculture. Ali et al. (2018) reported that total labor required for harvesting of paddy was 21 man-day ha^{-1}, 29 man-day ha^{-1} and 61 man-day ha^{-1} for using mini-combine harvester, reaper and manual system, respectively.

A considerable amount of paddy is lost in each stage of production especially in harvesting, processing and

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storage. Bala et al. (2010) reported that post-harvest losses of rice at farm level were 9.49%, 10.51% and 10.59% for *Aman*, *Boro* and *Aus* season, respectively. Other studies showed that the losses of paddy in post-harvest operations in Bangladesh were more than 13% (Abedin et al., 2012). Due to industrialization, labors are shifting towards mills and factories thus creating shortage of labor for agricultural operations. This shortage is most felt during the harvesting period of paddy. Non-availability or shortage of labors often lead to delaying harvesting of paddy which results in losses. The losses may occur in the form of shattering, exposure to natural calamities such as flood, storms, etc. or in the form of reduced grain quality. Samson and Duff (1973) reported that 5, 7 and 10 days delayed harvest, which resulted in 3%, 6% and 11% decrease in paddy yield, respectively. In addition to these losses it also hampers the seed bed preparation and sowing operations for next crop. Thus, both farmers and policy makers are realizing the necessity of mechanized harvesting operations.

Ali et al. (2018) found that the field efficiency of mini combine harvester for *Aman*, 2016 season was 56.38% ± 1.59% and for *Boro*, 2017 season it was 55.24% ± 0.41%. The results were obtained using traditional methods of machine performance evaluation. Heading change of harvesting machines during field operation is one of the aspects of machine operation that goes unnoticed most of the time. The travel path itself reveals valuable information about machinery performance (Adamchuk et al., 2004). By using precision agriculture technology like global positioning system (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.

Precision Agriculture is a farm management approach that uses information technology, satellite positioning data, remote sensing and proximal data gathering to optimize returns on inputs whilst potentially reducing environmental impacts (Zarco-Tejada et al., 2014). Most people associate precision farming or site-specific management with the GPS (Adamchuk, 2001).

The 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 the spatial aspects of agricultural fields (Adamchuk et al., 2004; Darr, 2012). GPS provides the opportunity to record a set of geographic coordinates that specify a particular field location. Therefore, field data collected using GPS technology is geo-referenced (Adamchuk, 2001). Different types of GPS receivers are now commercially available in the market. These GPS receivers record various spatial data which can be further analyzed to evaluate machine performance. 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). By entering geo-referenced data into software, machine performance can be viewed and evaluated in relation to two spatial aspects of agricultural fields. 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: 1) travel speed, 2) effective swath width, and 3) field traffic pattern. Taylor et al. (2002) observed that harvest efficiency showed a stronger relationship with turning time than field efficiency and both were negative. Efficiencies decrease with increasing turning time per acre. More than 60 percent of the variability in harvest efficiency was captured with turning time which is substantially better than that obtained with unloading time. Pandey and Devnani (1987) evaluated two harvest patterns and concluded that field efficiency could be improved by optimizing harvest patterns.

Geo-referenced data can play an important role in the management and operation of farm equipment (Grisso et al., 2004). Taylor et al. (2002) suggested that given the stronger relationship with turning time and harvest efficiency, it appeared that farm managers should focus more effort on reducing the time spent turning during harvest rather than unloading on the go. Farm managers could more quickly improve harvest efficiency by modifying harvest patterns to minimize turning than by unloading grain on-the-go. There is no GPS based available study to evaluate/track the harvesting operation of mechanical harvesters in Bangladesh. The GPS based evaluation of heading changes and harvesting track can be considered one of the methods for utilizing harvesting machines more efficiently. This method is simple and easy to handle for conducting experiment. Considering the above matters, the main objective of the study was to evaluate the harvesting track and heading change pattern of combine harvester and mini combine harvester by using geo-referenced data.

2 Materials and methods

2.1 Study site

To evaluate the harvesting track and pattern of heading change of a combine harvester and a mini combine harvester, data were collected by a GPS receiver during the harvesting operations of these machines. Data for combine harvester were collected from Bangladesh Agricultural University farms (Latitude: 24.719710°N, Longitude: 90.432845°E) and data for mini combine harvester were collected from fields of *Voroshakathi* village (Latitude: 22.868440°N, Longitude: 90.279176°E) of Wazirpur upazila in Barishal district. In Figure 1 study locations are shown on Bangladesh map.

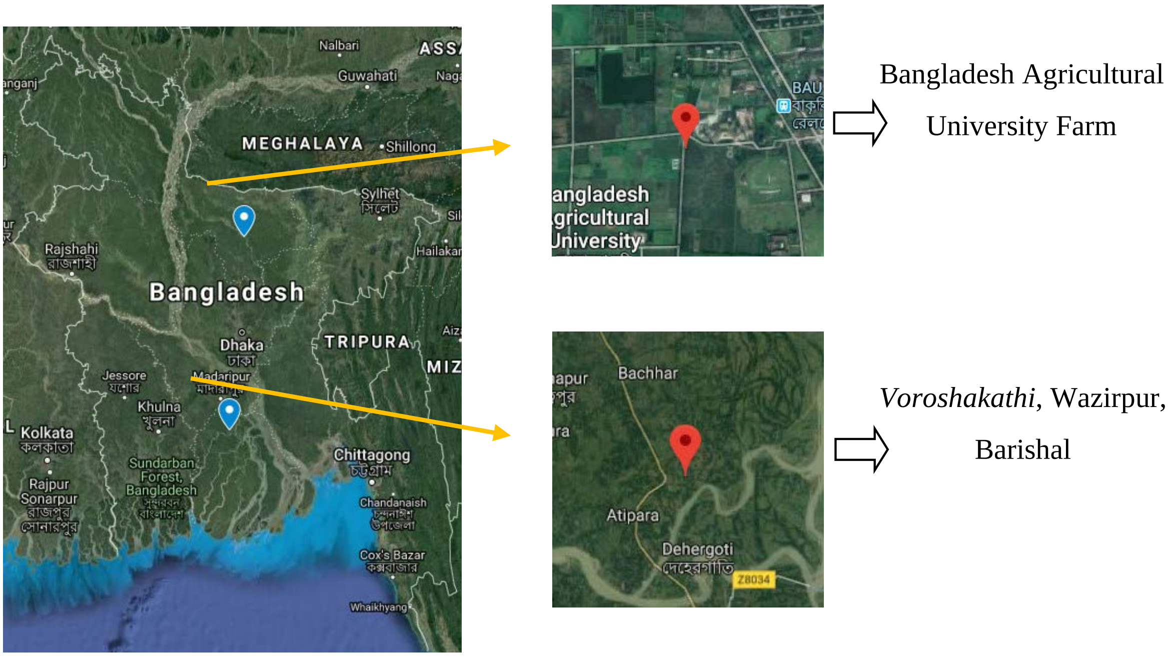


Figure 1 Study locations on map

2.2 Data collection device

The data generated by the combine harvester and mini combine harvester during the harvesting operations were collected and recorded by a small on-board GPS device. This GPS device was cheap, light weight, small and very easy to move and use. The primary objective of this study was to assess the feasibility and extend of such a small, low profile GPS device in mechanized harvesting operations. The GPS device is named Tracking Key2 which is a successor of its previous version. Different views of the GPS device are shown in Figure 2. The device is manufactured and marketed by Land Air Sea Systems, Inc. of United States of America.

The device is powered by two “AAA” sized 1.5 V alkaline batteries. An indicator light indicates the battery level by brightness of the light, another light indicates the connection of the device to the satellites as shown in Figure 2.

(a) Upside of the GPS device

(b) Downside of the GPS device

(c) Batteries are inserted in the device

(d) Two lights indicate the power and status of the device

Figure 2 Different views of GPS device

The TrackingKey2 GPS receiver was installed on the combine and mini combine harvester. Before installing the device fresh “AAA” sized 1.5 V alkaline batteries were inserted in the GPS device and it was made sure that the GPS receiver was connected to the Global Navigation Satellite System (GNSS). The GPS receiver was left mounted on the harvesters during the whole harvesting operation. It collected all the necessary data like time, position of the machine (co-ordinates), elevation from sea level, speed, heading, etc. After completion of the harvesting operations, the device was removed from the harvesters and connected to a computer via its Universal Serial Bus (USB) 2.0 interface. It was needed to sign into the service provider’s dedicated server via the user’s registered account. A standard internet connection was mandatory for this operation. After uploading the GPS receiver’s recorded files to the server, the harvesters’ data could be seen on the map. Data was exported as comma separated values or .CSV file for analyzing purposes.

These files were then imported in ArcGIS 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^{-1}). 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.

2.3 Data collection of combine harvester

At Bangladesh Agricultural University farms, World Jielong (4LZ-4.5L) combine harvester was used for the harvesting of paddy during the *Boro* season (April-May) 2018. The GPS receiver was used to record data generated by World Jielong combine harvester (Figure 3).

Figure 3 GPS receiver recorded data during combine harvester operation

2.4 Data collection of mini combine harvester

Geospatial data for ACI (4LBZ-120) mini-combine harvester were collected from fields of *Voroshakathi* village of Wazirpur upazila in Barisal district during the *Boro* season (April-May) 2018. The GPS receiver was installed on the mini combine harvester during the harvesting operation and it recorded data generated by the harvester (Figure 4).

Figure 4 GPS receiver recorded data during mini combine harvester operation

2.5 Flow diagram of operation

After preparation of the field and harvesting machine, 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. Same procedure was followed for both combine harvester and mini combine harvester. The whole process of the study can be illustrated by a flow diagram (Figure 5).

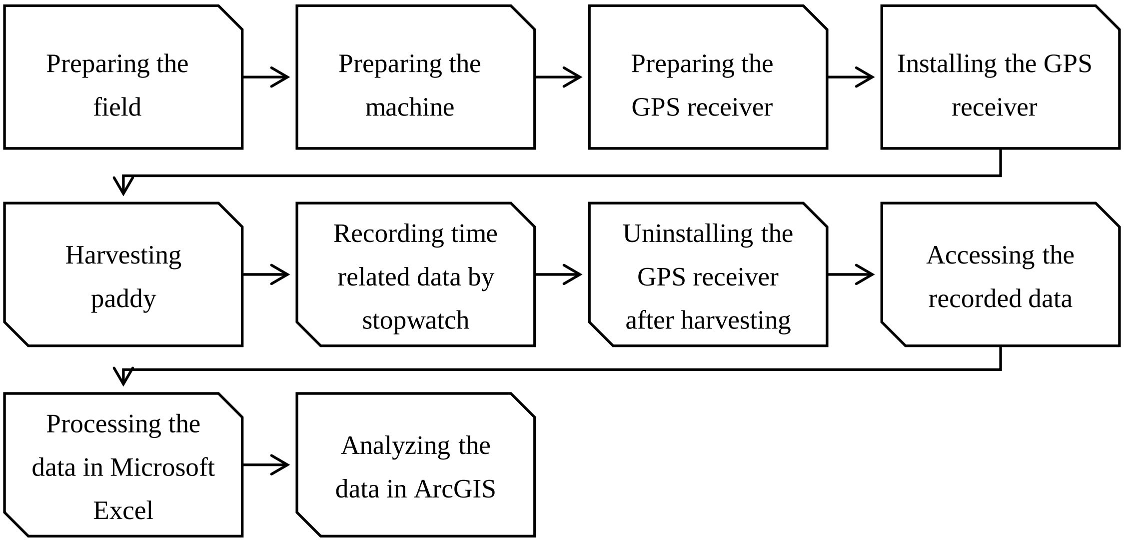
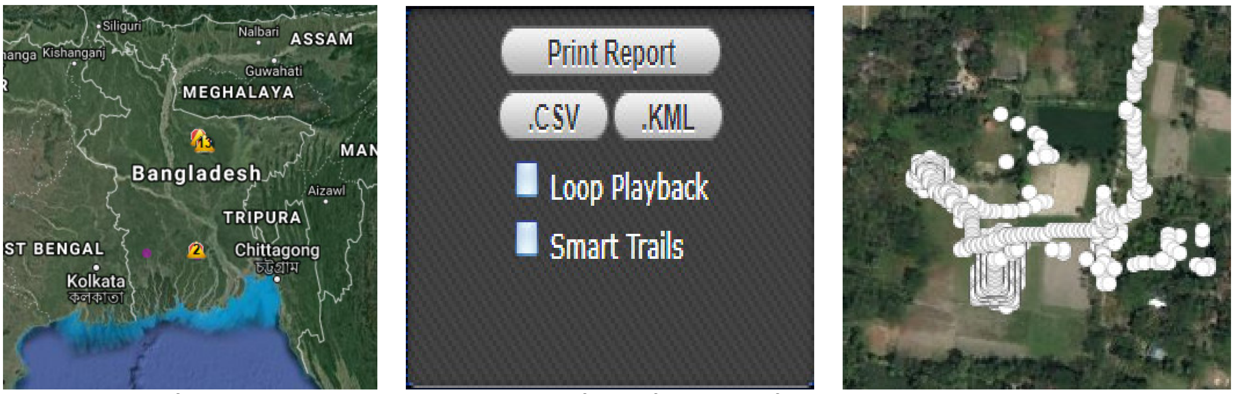


Figure 5 Flow diagram of the operation

2.6 Data processing

After the harvesting operation it was necessary to access, process and analyze the data generated by the combine harvester and mini combine harvester and recorded by the GPS receiver. Several tools such as LandAirSea web application, Microsoft Excel and ArcGIS were used to access, process and analyze the data. The GPS receiver records the data as .LAS file which was needed to be processed on the server of LandAirSea as shown in Figure 6.



(a) Location of machine on map (b) Conversion of .LAS file to .CSV file (c) Data points shown in ArcGIS

Figure 6 Processing of data

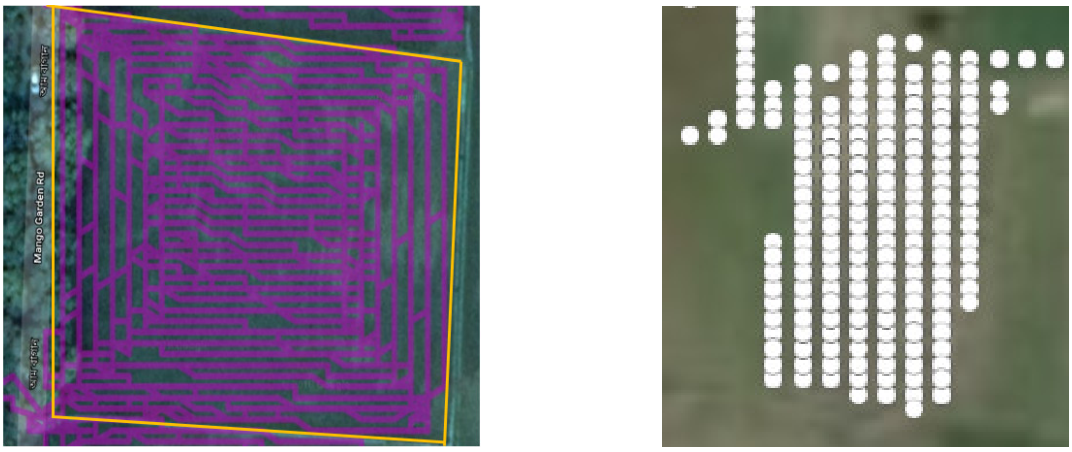
After accessing the server and uploading the .LAS file, it was converted to .CSV file which was a compatible file format for ArcGIS. CSV files can also be processed by Microsoft Excel. The GPS receiver records time, heading, speed and elevation along with coordinates. Only the desired columns were chosen for this study. Heading and coordinates columns were of interest for this particular study. From the geo-referenced data harvesting track, heading and heading change between data points of combine harvester and mini combine harvester were analyzed and visually represented.

3 Results and discussion

3.1 Harvesting track of combine and mini combine harvester

Harvesting tracks of combine harvester and mini combine harvester were shown on map by uploading the

.LAS file to LandAirSea server. Harvesting tracks of the harvesters on map gave a visual overview of the whole harvesting operation. Figure 7(a) shows the harvesting track of combine harvester and Figure 7(b) shows the harvesting track of mini combine harvester.



(a) Combine harvester (b) Mini combine harvester

Figure 7 Harvesting track

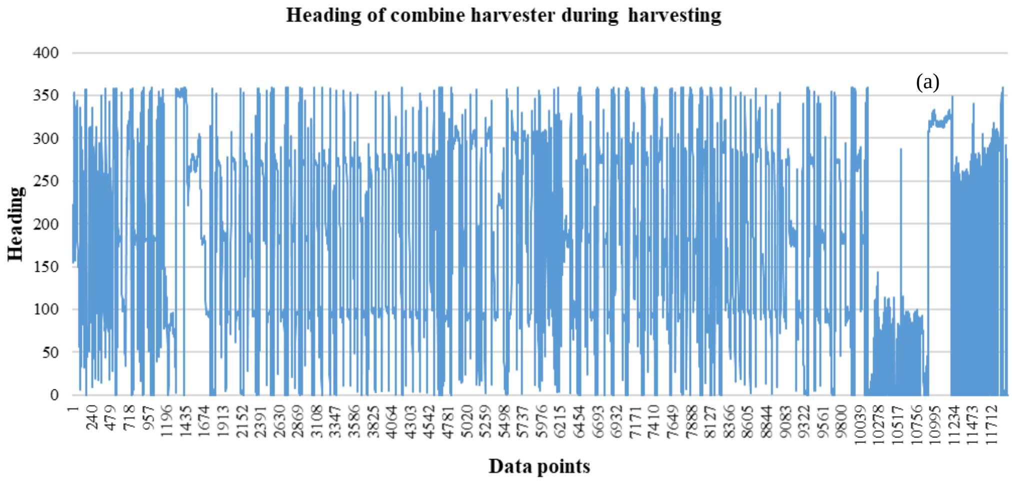
From Figure 7(a) and 7(b), it is found that the harvesting track of mini combine harvester was much cleaner than that of combine harvester. This happened because the unloading of grain was not carried out ‘on-the-go’ in case of combine harvester whereas the unloading was done ‘on-the-go’ in case of mini combine harvester. Every time the grain tank was full in the combine harvester travelled to a certain place to unload the grain but it did not follow any certain path to travel to that place and the GPS receiver recorded these tracks within the harvesting operation.

3.2 Heading change during harvesting

One of the harvesting operation parameters recorded by the GPS receiver was heading of the harvesters during harvesting. The recorded data were further processed in Microsoft Excel and graphs were produced. Figure 8 shows the heading graphs of combine and mini combine during the harvesting operation.

From Figure 8(a) it is found that the heading of the combine harvester changed often and the time gap between two heading change was also found small. Figure 8(b) illustrates that for mini combine harvester the time gap between two heading change was comparatively longer than that of combine harvester. It also showed that the heading changes were comparatively lower for mini combine harvester.

Figure 8 illustrates that the headings of combine harvester changed frequently and to a higher degree than that of mini combine harvester. This might be happened because the combine harvester was outside of its harvesting course when it travelled for unloading and it also moved a lot when the turnings were made.



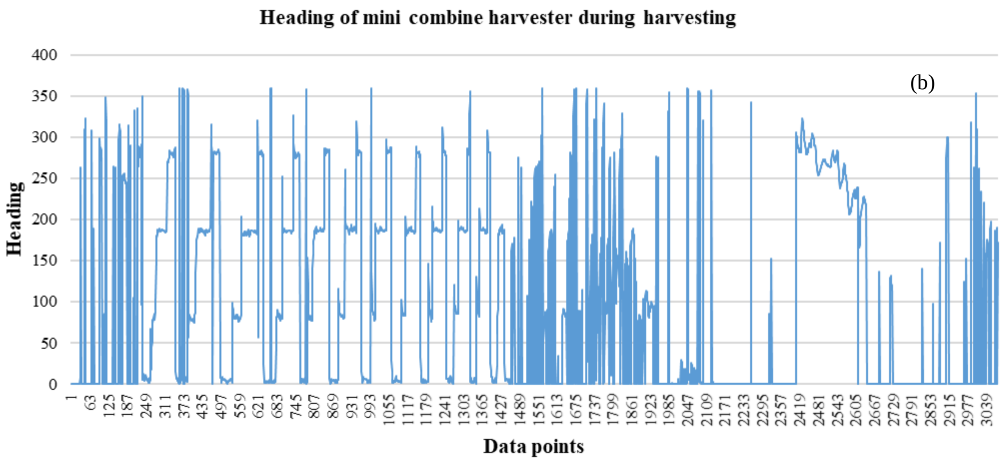


Figure 8 Heading graphs of (a) combine harvester (b) mini combine harvester

3.3 Heading change between data points

From the GPS receiver recorded data, the change between two sequential headings was observed for combine harvester and mini combine harvester. Again, Microsoft Excel was used to determine the differences between two headings. Heading changes were plotted against data points to obtain graphs as shown in Figure 9.

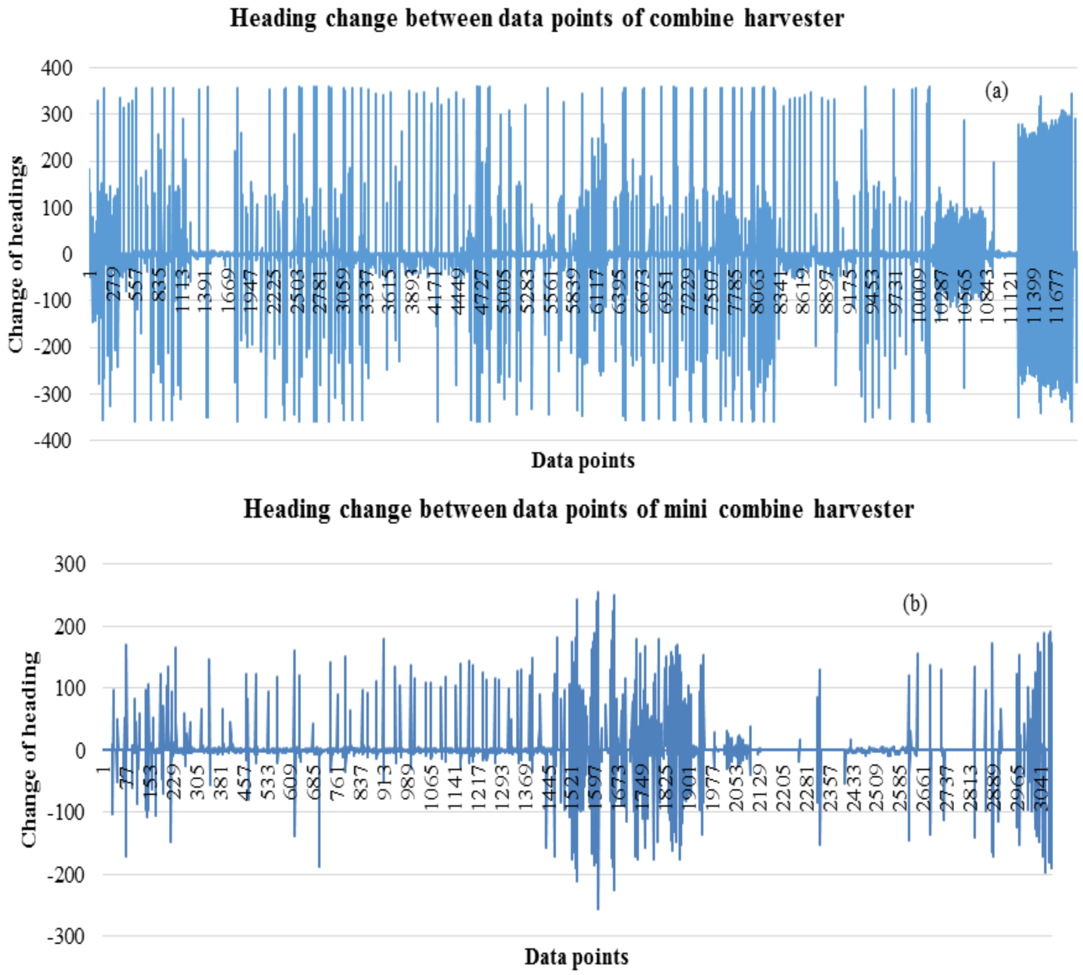


Figure 9 Heading change between data points (a) combine harvester (b) mini combine harvester

It is seen from Figure 9(a) that for combine harvester the heading changes between data points were very high and it happened frequently. On the other hand, Figure 9(b) shows that for mini combine harvester the heading changes between data points were comparatively lower and time gaps between such changes are longer.

Turning of a harvester is directly associated with the heading changes. Higher, more frequent and nonpatterned heading changes of combine harvester during harvesting and turning compared to mini combine harvester made it clear that turning of mini combine harvester was easier than combine harvester. The small structure, lower forward speed and easier maneuverability make it possible for mini combine harvester to harvest paddy with less variation in headings compared to combine harvester. For combine harvester, the higher and frequent heading changes might be happened because of operator's skill, travelling for unloading of the paddy, unnecessary movement for making room during turning as no dedicated headlands were available.

4 Conclusions

Geo-referenced data can be used effectively to determine various aspects of machine performance such as machine efficiency, machine idle time, turning patterns, etc. It can also be used to create maps for visual analysis. Here, the heading changes of combine harvester and mini combine harvester indicate that turning maneuver of mini combine harvester is easier and quicker than that of combine harvester. Moreover, the deviation from the harvesting path during turning is more prominent in combine harvester than mini combine harvester. Less variation in heading change during harvesting means there would be less overlapping of the harvesting track and ineffective operating time would be reduced. This will eventually increase harvesting efficiency.

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