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Crime Scene Mapping using Differential GPS and Geospatial Techniques for Simulated Outdoor Crime Scenes



رسم خرائط مسار الجريمة باستخدام نظام جي بي إس GPS والتقنيات الجغرافية المكانية بغرض عمل

مسار جريمة خارجية (مفتوحة) محاكية

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Abstract

Outdoor crime scene management is difficult to accomplish, especially when the crime transpired in a big area, uneven space, or an area with a lack of reference points. It is important to visualize the location of the evidence to get an idea of how the crime took place and in what manner.

In this research, two simulated outdoor crime scenes were created, where both manual tape measurement and Differential Global Positioning System (DGPS) unit were applied to see if the differential GPS offers an accurate and reliable alternative for mapping the scene over the baseline method. A Geographic Information System (GIS) was used to derive a map of the simulated outdoor scenes.

The result indicates that the DGPS unit provides a consistent reading when compared to manual tape measurement, giving an average reading difference of 0.06 cm and 0.13 cm.

The study concluded that the DGPS unit can be a viable alternative for mapping outdoor crime scenes.

المستخلص

إن إدارة أو التحكم في مسرح الجريمة الخارجي المفتوح أمر يصعب تحقيقه، خاصةً عندما تحدث الجريمة على مساحة كبيرة، متباعدة بشكل غير متساو، مع عدم وجود علامات مرجعية. من المهم تصور موقع الأدلة للحصول على فكرة عن كيفية وقوع الجريمة وبأي طريقة وقعت. في هذا البحث، تم إنشاء اثنين من مساح محاكاة الجريمة الخارجية المفتوحة، حيث تم تطبيق كل من قياس الشريط اليدوي ووحدة DGPS لمعرفة ما إذا كان نظام تحديد المواقع التفاضلي يوفر بديلاً دقيقاً وموثوقاً لرسم خريطة المشهد أفضل من الطريقة الأساسية. تم استخدام نظام المعلومات الجغرافية (GIS) لاشتقاق خريطة للمشاهد الخارجية المحاكاة.

تشير النتيجة إلى أن وحدة DGPS توفر قراءة ثابتة عند مقارنتها بقياس الشريط اليدوي، مما يعطي فرق قراءة متوسط يبلغ 0,06 سم و 0,13 سم.

وخلصت الدراسة إلى أن وحدة DGPS يمكن أن تكون بديلاً قابلاً للتطبيق لرسم خرائط مشاهد الجريمة الخارجية المفتوحة.

Keywords: Forensic Science, Crime Scene, Simulated, Differential Global Positioning System, ArcGIS

الكلمات المفتاحية: علوم الأدلة الجنائية، مسرح الجريمة، نظام جي بي إس GPS التفاضلي المحاكى، DGPS. نظام ArcGIS.



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1. Introduction

Crime scene investigation is a multi-phase exercise which involves not only gathering trace evidence but also scene recording, documentation, and scene reconstruction. In order to secure the chain of custody, all the pertinent observations and evidences need to have their exact location documented accurately. Outdoor crime scenes are the most difficult to explore, and to apply the traditional method for crime scene management on outdoor crime scenes can be taxing and challenging. This is especially the case when the evidence is scattered over a large area. It is clear that outdoor scenes are not processed with the same high standards as indoor scenes [1]. The photographic documentation of crime scenes is the foundation of any criminal investigation [2-3], but photography alone does not suffice the passive documentation. Common primary means of documentation are reports and note taking, photography, videography, mapping, and sketching [4]. Advanced techniques such as Unmanned Aerial Vehicles (UAV), 3D laser scanners, total stations, photogrammetry, and 360° photography have caught the attention of law enforcement agencies in many countries. However, these means need specific expertise and are not cost effective. Moreover, total stations are considered not viable as a mapping method because obstruction of the line site over long distances results in constant relocation of the transit point [5-7]. The exact location of the evidences cannot always be derived from photographs and 3D scans. This is where faults in crime scene documentation occur. The use of such methods are routinely applied in the field of archaeology fieldwork but only occasionally used in the forensic field [8].

In recent years, to record locational data of evidence at a forensic scene, technology has been constantly adapted to provide inclusive spatial components for analysis (9). However, standard global positioning system (GPS) units do not commonly offer the appropriate degree of accuracy for mapping the remains at a crime scene [6]. The enhanced unit, like the differential global positioning system (DGPS), has the potential to collect accurate positional information of objects and provide the location of the object on the earth's surface. In a more recent study, DGPS with

post processing was implemented in situations where scattered remains and scavenging patterns of human cadaver were extensively dispersed in a topographically varied area [10-11].

The DGPS unit conducted in past research has shown good results for artifacts found in open environments, but the accuracy limitation was covered only when the data were differentially corrected using post-processing against the closest base station. However, there is a limitation to post processing, as it requires additional work where the unprocessed data are transferred to a desktop computer and imported to Trimble Pathfinder to get the processed data. Furthermore, the use of DGPS (Trimble R1GNSS) without the need for post processing in crime scene management is under-researched as it is a relatively a new technology. It needs to be comprehensively employed in mapping the scene concerning the different aspects including uneven ground and lack of reference points, etc, to ascertain its effectiveness. It is expected that DGPS which does not need post processing further reduces potential sources of error, hence increasing accuracy. The present study focusses on utilizing a type of DGPS which does not require post processing to gauge its effectiveness by comparing it to traditional hand-drawn methods. Therefore, the purpose of this article is to examine the level of accuracy that can be achieved with the use of DGPS in outdoor crime scenes.

2. Materials and Methods

This research was conducted on campus at the Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India. For this study, a hand held standalone DGPS device (Trimble R1GNSS) was used along with TerraFlex software that can be connected to a mobile phone or tablet through bluetooth and provide highly accurate positional data (sub-meter). The conventional method was also utilized with tape measures and a compass. Results from the DGPS and hand-drawn methods were compared. In order to test the accuracy for outdoor scenes, two crime scenes were set up. The distances of various evidences were taken through DGPS and



compared with manual measurement.

Two scenarios were constructed to depict various examples that may be encountered in real-life situations. Scenario 1 represents the normal scene, and Scenario 2 represents uneven space or ground in an open environment. A baseline was developed or identified from where to conduct measurements that required two fixed points. X and Y coordinates were taken for the location of the evidences and measured with tape to get the exact position of the evidences. Measurements were taken from the baseline at an approximate 90 degree angle from the baseline to a point on the identified item or area of the crime scene. Most measurements were made either to the center mass of the item or to the nearest point of the item to the baseline.

The differential GPS data collection was done after

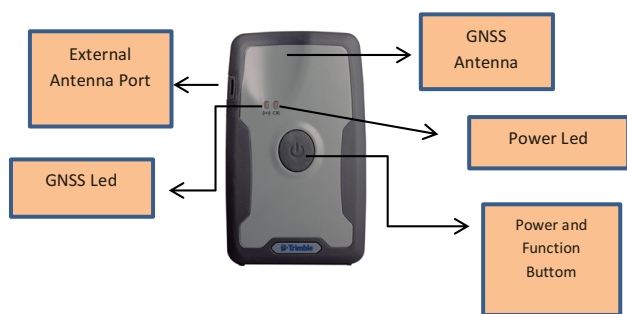


Figure 1- Trimble R1GNSS.

the manual measurement was completed. The R1GNSS device (Figure.1) was placed in a vertical position, as it was found to be more accurate than the horizontal position (10). Furthermore, while collecting the data, the device was positioned at a predetermined point adjacent or close to the evidences on the ground and remained stationary throughout the collection of each data point. The accuracy of the DGPS information for every area was checked and the length of time taken to finish the data collection of each scene was recorded.

This unit delivers GNSS positions in real-time without the need for post-processing, because correction sources such as SBAS and RTX networks are applied to suit the location, giving the desired accuracy in achieving reliable GNSS information anywhere in the world. Data collected

from the field were automatically synced; the plugin automatically pulls the data back from Terra Flex into the feature class without any intermediary file import or export steps, saving time and effort. The data were downloaded directly as CSV format that includes all the crime scene pictures and locations (latitude and longitude) of all the data, which was saved automatically on a Microsoft Excel sheet.

Finally, the collected data were exported to ArcGIS software with the point data for analysis. This created a map of the outdoor scene. The distances between the points of the corners, reference points and the evidences from the baseline were measured using the measuring tool in ArcGIS and were further compared with the manual measurement. The final map was created, and the base map (world imagery) was layered to give the geography of the crime location.

3. Statistical Data Analysis

In the present experiment, T-test was applied for drawing conclusions from the data. T test is used to compare two different set of values for comparison. The calculated value of T was compared with tabulated value at 5% level of probability for the appropriate degree of freedom (12). In this study, T-test was applied to see if the DGPS unit gave a reading consistent with the manual reading. The formula for T test is given below:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{x_1x_2} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where,

X_1 = Sample mean for first set of values.

X_2 = Sample mean for second set of values.

$S_{x_1x_2}$ = Standard Deviation.

n_1 = Total number of values in first set.

n_2 = Total number of values in second set.

4. Results of simulated scenarios

Scenario 1 consisted of six evidences in an open area. The accuracy of this location was 41 cm. (Figure-2 and 3) shows the overview of the scene and DGPS unit placed vertically near the evidence. The rough sketch was drawn to give the layout of the scene where E1-E4 consists of series of blood droplets, E5- knife with blood stains, and E6- hair clip (Figure 4). Measurement readings from both methods are shown in (Table-1) giving an absolute error of 2m and an average difference of 0.06 cm. T -test analysis is shown in (Table-2). From the table, it can be observed that the calculated value of ‘t’ is smaller than the table value

of ‘t’ on 20 degrees of freedom and at 5% level of significance, hence supporting the Null Hypothesis. Therefore, it can be concluded from the above data that there is no technical difference between the two methods. However, practically with the use of DGPS unit it is more accurate and reliable because human beings are liable to error especially when the area is big and objects are widely scattered [This seems to contradict the statement above “Therefore, it can be concluded from the above data that there is no technical difference between the two methods.”]. After analysis in ArcMap, it was determined that DGPS showed a reading consistent with the manual reading. The base maps were



Figure 2- Overview of Simulated Scene 1.



Figure 3- RIGNSS receiver near the evidence of scene 1.

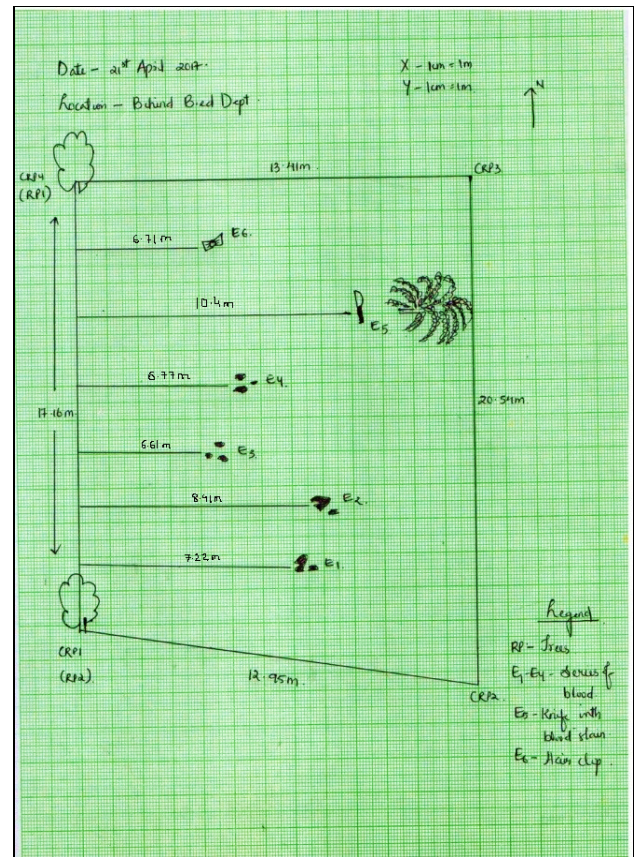


Figure 4- Hand drawn sketch of simulated scene 1.

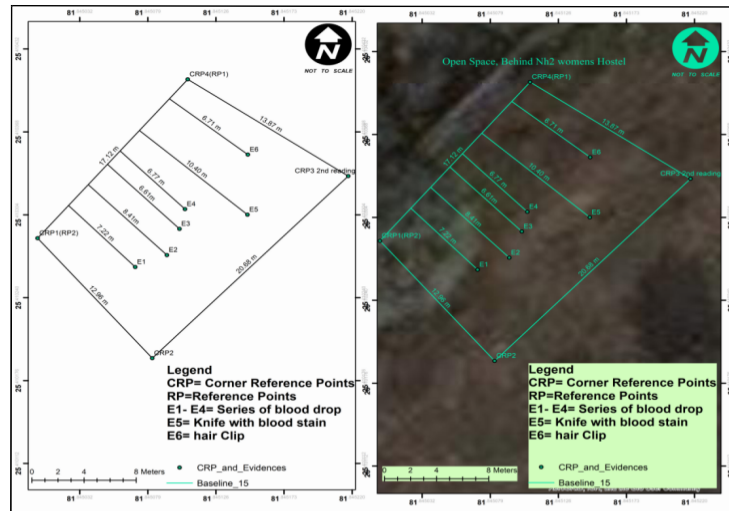


Figure 5- Final ArcMap and Base Map through ArcGIS of simulated scene 1.

Table 1- Measurements between Manual method and DGPS unit.

Sl.No	Code	Name of the Evidences	MM (M1) (In meter)	DGPS (M2) (In meter)	Absolute error between M1 and M2	Avg. diff. (cm)
1.	CRP1	CRP1-CRP2	42.5	42.53	0.03	-
2.	CRP2	CRP2-CRP3	67.4	67.86	0.46	-
3.	CRP3	CRP3-CRP4	44	45.52	1.5	-
4.	CRP4	CRP4-CRP5	56.3	56.18	0.12	-
5.	CRP5	CRP5-CRP2	56.3	56.18	0.12	-
6.	E1	Series of blood	23.7	22.62	1.1	0.06
7.	E2	-do-	27.6	26.19	1.4	-
8.	E3	-do-	21.7	24	2.3	-
9.	E4	-do-	22.2	21.7	0.5	-
10.	E5	Knife with blood stain	34.11	33.9	0.21	-
11.	E6	Hair clip	22	23.8	1.8	-

Table 2- Unpaired T-test for two samples assuming equal variance.

Category	Calculated value	Table Value	Degree of Freedom	Alternate Hypothesis	S/NS
Crime Scene 1	0.03	2.08	20	Rejected	NS

integrated/layered to give a better view about the geography of the scene (Fig 8). The time taken for the manual method was 30 min, and DGPS took 40 min.

Scenario 2 was created at a location where the ground was uneven (Figure-6 & 7). This caused a problem when using the conventional method measuring with tape. However, careful measurements were taken to be compared with the DGPS unit. The collection time taken by the traditional method was 30 min, and the DGPS unit took 25 min. The DGPS method was found to be quite accessible in places where the ground is uneven, because the only thing the investigator needs to do is put the device down at the vertical position for every point. The hand drawn map is shown in (Figure-8) consisting of two evidences: E1- blood stain on the brick and E2- wallet. The final base map was created through ArcGIS (Figure-9). The measurement readings of both methods are shown in (Table-3). The analysis shows the reading of the DGPS unit, which was found to be quite accurate when compared with the manual reading, giving a maximum absolute error of 0.82cm and average difference of only 0.13 cm (Table-4).



Figure 6- Overall view of simulated scene 2.



Figure 7- R1GNSS receiver near the evidence of scene 2.

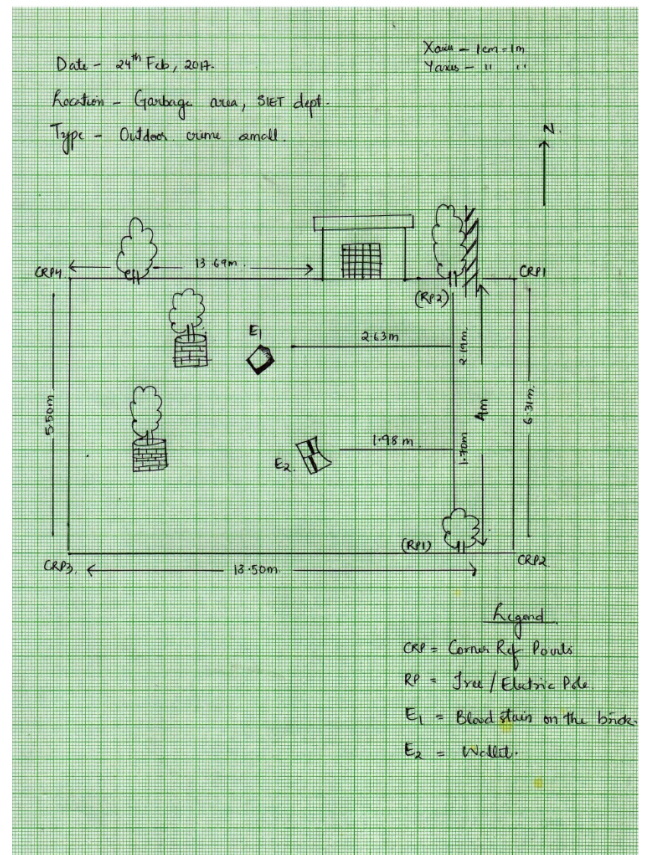


Figure 8- Hand drawn map of simulated scene 2.

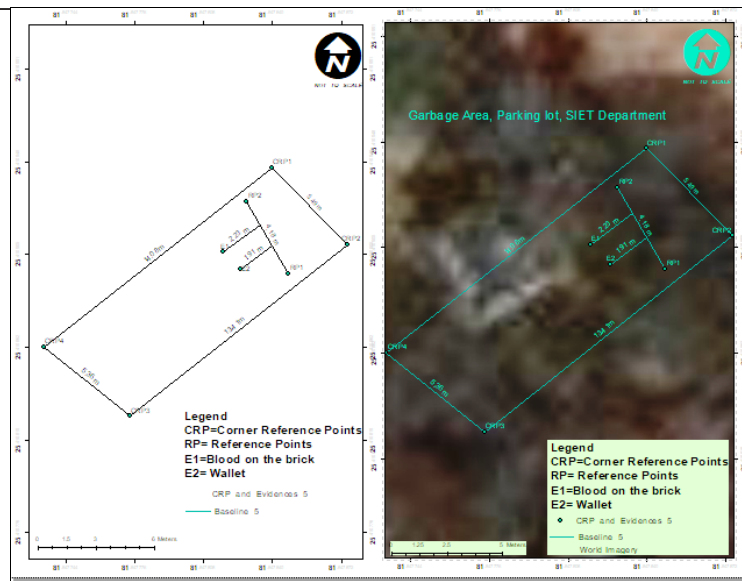


Figure 9- Final ArcMap and Base Map through ArcGIS of simulated scene 2.

Table 3- Measurements between Manual, DGPS unit and Recreation.

Sl.No	Code	Name of the Evidences	MM (M1) (In meter)	DGPS (M2) (In meter)	Absolute error between M1 and M2	Average diff.
1.	CRP1	CRP1-CRP2	6.31	5.49	0.82	-
2.	CRP2	CRP2-CRP3	13.50	13.41	0.09	-
3.	CRP3	CRP3-CRP4	5.50	5.36	0.14	-
4.	CRP4	CRP4-CRP1	13.69	14.08	0.39	0.13
5.	SRP1-SRP2	Trees (RP1-RP2)	4.00	4.18	0.18	-
6.	E1	Tablet cover	2.63	2.23	0.40	-
7.	E2	Watch	1.98	1.91	0.06	-

Table 4- Unpaired T-test for two samples assuming equal variance.

Category	Calculated value	Table Value	Degree of Freedom	Alternate Hypothesis	S/NS
Crime Scene 2	0.05	2.17	12	Rejected	NS

5. Discussion

The exact locations of the evidences in a crime scene are needed to analyze the spatial distribution of those evidences. This is necessary in order to reach a conclusion on activity level and reconstruct events that took place. For this reason, two different types of simulated crime scene were created to implement and compare manual and DGPS methods for mapping crime scenes and evidences in open environments. The manual method was conducted carefully without considering the time factor, although in an actual real crime scene, time becomes the factor and hence the tendency of human error may affect data. The DGPS method was reliable and efficient as it performs the work better with ease, even on uneven surfaces. Limited research has been conducted concerning the use of DGPS in crime scene mapping. In relation to forensic investigation, GPS and GIS have been used for geographic profiling and crime mapping (13-15). Studies conducted 12 years ago show an error level of 1.7m for a DGPS unit in an open environment (16), which clearly demonstrates that there has been rapid development in DGPS technology which has demonstrated centimeter level accuracy without the need for post processing, as determined from this study. The use of a mid-price receiver has been found to be less accurate than traditional mapping techniques because of various factors that hinder the accuracy such as the tree cover, position of satellite, and remains of a structure (5). A scene involving taphonomic research was conducted utilizing DGPS to analyze the dispersal of a body (10), and a study conducted by Walter and Shultz (11) demonstrated that DGPS after post-processing is a viable option for mapping dispersed human remains in an open environment.

The recording and visualizing of this spatial distribution is needed in order to reconstruct or recreate the crime scene (8). The DGPS without post-processing is a relatively new technology that has yet to be employed comprehensively in mapping outdoor crime scenes. In places where there are no reference points, uneven ground, and places where tree density cover effect the accuracy (5), the DGPS unit used for this study was quite convenient to handle compared to the manual method. The time taken by both the methods

in all the simulated scenes showed a difference from 5 to 10 min only. This research shows that the DGPS method can be implemented on documentation of outdoor crime scenes, as it has more advantages over the manual method since human beings are liable to error and these locations once taken can always relocate back even after decades passed.

The device used for this study was rugged, compact and does not have any issue with the environmental conditions as it is waterproof. Therefore, it is highly recommended, especially for outdoor crime scenes. The use of Geographical Information System (GIS) should be implemented to ensure successful combination of all the data and subsequent mapping of the distribution of the evidence and its context (8). Therefore, ArcGIS was utilized in this study to present the final map of the simulated outdoor crime scenes.

Both the manual method and DGPS unit have their own advantages and disadvantages. For the conventional method, it requires at least two to three people to conduct the measurements. However, a single person can operate the DGPS unit and complete the task. Both rough sketch and final sketch is mandatory to complete the documentation process, whereas with the use of the DGPS coordinates, a single ArcMap can be established which includes all the measurements as well giving a final map, in addition to world imagery, which gives much better information about the geography of the crime scene. Recreation/reconstruction is not possible at the actual crime scene after decades, due to changes in nature, development, and environmental factors. With the use of DGPS coordinates, recreation/reconstruction of crime scenes is possible for cold cases, as the coordinates once taken will never change. Humans are susceptible to mistakes, so manual measurements may contain errors. With the use of this device, an error could be reduced. Future research should be conducted to develop software that exports the DGPS coordinates and directly produces a 2D or 3D view of the crime scene. This will enhance crime scene investigation and give investigators more credibility and accuracy in presenting the facts surrounding a crime to the justice system.



6. Conclusion

The main aim of this research was to see if DGPS could be used for effective outdoor crime scene management, and to ultimately present or provide a map of the scene with the use of DGPS coordinates. Mapping an outdoor crime scene can be challenging because of long distances, limited manpower, and varied environments in which evidences are found scattered over a large area. Though several factors may influence the accuracy of the DGPS unit, the minimal error obtained for this unit in an open environment is appropriate for mapping outdoor crime scenes. The study concludes that the device used for this research (Trimble R1GNSS) along with the Trimble Tera Flex software could be a good alternative to implement for investigating outdoor crime scenes. This method shows a reading consistent with that of the manual method. The use of a Geographic Information System (GIS) is recommended to ensure the successful combination of all the data and the subsequent mapping of the distribution of the evidence and its context in an outdoor scene of any disaster site. The receiver used in this research can be applied effectively for areas where trees were present and the ground uneven. Getting one location reading is enough to know the position of each object, whereas in the case of the manual method, to know the exact location, X & Y coordinates must be measured. From this research, we can conclude that implementation of advanced technology like the DGPS unit in crime scene management will definitely refine the work of crime scene investigators. Similarly, the systematic recording of the exact location of crime scene documentation could lead to further benefits for investigations as analysis and reconstruct techniques even after decades, as the location once taken will never change. However, the use of DGPS for mapping indoor scenes was not feasible due to its indoor limitations.

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