GIS for Vertical Takeoff and Landing Site Selection

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Abstract

This research paper addresses the GIS analysis approach to the investigation of suitable sites for a vertical takeoff and landing drone. The study manipulated GIS and terrain layers and turned them into proper input before the spatial analysis that included slope, reclassify, classify and buffer was applied to the individual layers. The output layers were weighted and multi-criteria analyzed before those patches failing to comply with filtering out criteria were discarded. Field survey for each suitable candidate site was conducted to cross-check the proposed approach with the real world. Conclusion was extracted for the VTOL takeoff and landing sites and discussion was provided with further study being suggested on the mission simulation of selected takeoff and landing sites.

Keywords : GIS approach, Site selection, VTOL, Takeoff and landing

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1. Introduction

Surveying for drone launch sites is troublesome when the study areas are under constraints of mountainous terrain. Even though it is plausible to use a sensor capable of an aerial survey system to help identify the areas of interest with growing research in machine and computer vision [1], there is also a question of satellite navigation signal coverage and a requirement to help researchers to plot on a large scale map or other open sources such as Google Earth for flight mission planning. It can be seen from Figure 1 that in aerial photography over Pua district, Nan province in the Northern part of Thailand, of an area of more than 300 km^2, it is easier by exploring the target areas with unmanned aerial surveying system. That will help in planning for drone image acquisition more quickly. Those areas will also be locations of the ground-based survey to assess the accuracy of digital terrain models in the final phase of accuracy assessment. Therefore, flat and level sites are needed for vertical takeoff and landing (VTOL) drone in general for example DJI Phantom Drone.

In this current study, prior to launching a survey drone for VTOL site selection, it can be more economical to investigate the terrain nature of potential candidates for the launching site. Geographical Information System (GIS) technology was used to assess the criteria requested to define the suitability of land for housing [2]. The study in [3] was to develop a spatial model for land suitability assessment for wheat crop integrated with GIS techniques. The proposed model allowed obtaining results that corresponded with the current conditions in the area. The land evaluation procedure has also been applied by a GIS – based methodology. Integrating information with crop and soil requirements, the authors in [4] edited and managed land suitability maps for specific purposes by means of matching tables. With the final output aimed at creating military training scenarios to be included in a fire-arms training simulator of the Royal Thai Army, GIS data was prepared and used for the Potential Surface Analysis (PSA) in form of suitability map that revealed the potential of GIS vector layers that suited drug-trafficking routes [5]. However, the GIS-based approach has been barely applied to the survey of takeoff and landing site selection for VTOL drone mapping.

Figure 1 The study area with mountainous terrain

The results of the study in [6] showed that using an unmanned aerial system for topographic mapping and calculating volumes was more time and cost efficient than land surveying, with no loss in accuracy, but only when performed over bare earth terrain, suggesting that care be taken for the topographic mapping of the densely covered terrain. This current study was expected to further extend the cost efficiency of VTOL drone mapping by proposing a GIS – based approach for VTOL takeoff and landing site selection. The selection was performed prior to the still needed field survey. The significance of the study lied in the commercial mission planner that was conducted using available QGroundControl or Google Earth terrain data that was inadequate to meet the standard required for fine/small scale digital terrain model for very precise engineering study [7]. With updated GIS data of the study within GIS functionality before further spatial analysis and multi-criteria analysis being applied. Upon obtaining a suitability map for VTOL takeoff and landing sites, the field survey was conducted for every selected site to ensure proper distribution over the 300 km^2 study area.

2. Data Preparation

2.1 Geospatial Data

GIS layers included 2016 road and land use vector layers and 2020 satellite raster layer. The road network was manually updated using GIS basemap available online. The land use data were of 2016 product whose rural study area underwent some urbanization. The 30 m Landsat 8 imagery was of 2020 acquisition and selected to contain a few cloud-covered patches. The 1:50,000 topographic map covering the study area was in elevated ranges for an overall understanding of selected terrain of the study area (see Figure 2). The Digital Elevation Model or DEM of 12.5 m was a product of Advanced Land Observing Satellite (ALOS) in Phased Array type L-band Synthetic Aperture Radar (PALSAR).

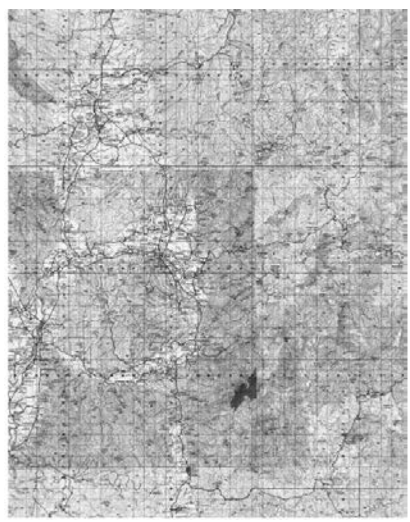

Figure 2 Topographic representation of the study area

2.2 Vertical Takeoff and Landing Requirements

As indicated in [6], the mission path must be free of obstructions for at least 200 m in each horizontal direction. The takeoff and land sites must consist of a level, flat surface that is free of obstructions for at least 5 x 5 m

2.3 Data Manipulation and Class Weighting

DEM was applied with slope creation to create a slope map. From [8], standard slope descriptors are provided where level to nearly level at slope of 0 - 2% or at approximate degree of 0 – 1.1 is used as the most suitable for the selection in Table 1 and the slope results in degree of Figure 3 left.

Land use map was manipulated as shown in Figure 3 middle with reclassify function to rank Miscellaneous class to Most suitable with Weight 3, Agriculture and Forest to Suitable with Weight 2, Residence to Least suitable with Weight 1, and Water to Unsuitable with Weight 0. Rationale under this rating was that the Miscellaneous class contained abandoned and unused areas that were the most suitable for site selection. Agriculture and Forest was a Suitable candidate for site selection with subject to field survey. Residential and urban areas were a compromising issue best validated on site. Water bodies could cause severe damage to the drone if unfortunate takeoff and landing took place.

Table 1 Slope suitability guidance.*

Slope (%)	Approximate degrees	Terminology	Slope suitability	Weight
0 - 2	0 - 1.1	Level - Nearly level	Most suitable	3
2 - 9	1.1 - 5	Very gentle – gentle slope	Suitable	2
9 - 15	5 - 8.5	Moderate slope	Least suitable	1
>15	>8.5	Strong slope	Unsuitable	0

* Adapted from [8]

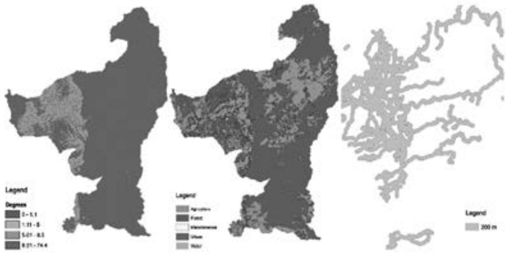

Figure 3 Results of the manipulation and class weighting

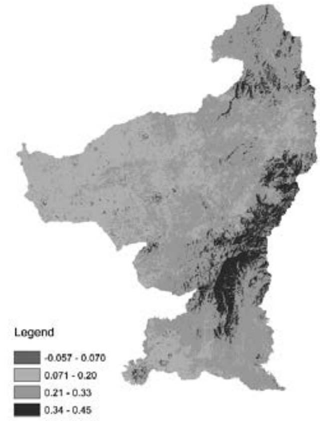

Figure 4 NDVI map derived from Landsat 8 imagery

In Figure 3 right, the road network layer was buffered based on the accessibility of a grownup man to carry the VTOL drone gear to a launch site and to create 200 m interval from either side of the road based on the 200 m horizontal clearance requirement as the Most suitable with Weight 3, from 200 to 300 m either side of the road center as the Suitable with Weight 2, from 300 m to 400 m as the Least suitable with Weight 1, and from 400 m and beyond as the Unsuitable with Weight 0. Satellite imagery was analyzed to obtain Normalized Difference Vegetation Index or NDVI and categorized into 4 classes with the lowest NDVI range from -0.057 to 0.070 as the Most suitable and Weight 3 based on the notion that low NDVI values resulted from non- to the less- forest cover of the studied patch. The NDVI range from 0.071 to 0.20 was rated Suitable and Weight 2, from 0.21 to 0.33 was rated Least suitable and Weight 1, and from 0.34 to 0.45 was rated Unsuitable and Weight 0. The NDVI map was shown in Figure 4.

2.4 Rasterization and Data Resampling

The reclassified Land use and Road maps were tabulated with suitability and weighting columns, the latter of which were numerical values of the rasterization process. The weighting column was for algebraic operation during the raster overlay step. A rasterization process was applied to the reclassified Land use and buffer Road vectors. The final pixel size at 15 m was arrived to maintain as much close accuracy as possible to the 12.5 m DEM resolution. This size was plausible for the original 30 m Landsat of the NDVI map product.

The weighted NDVI and Slope raster layers were applied by revaluing the pixel with the value of the Class Weighting. The revalued NDVI and Slope maps were resampled to 15 m pixel size appropriate to the final overlay step and matching with the previous rasterized layers. Figure 5 illustrates the Slope (far left), Land use (left), Road (right), and NDVI (far right) raster layers.

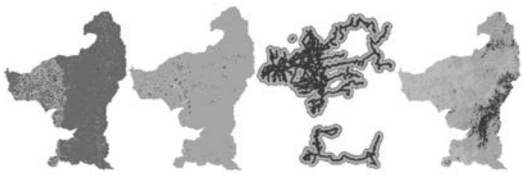

Figure 5 Raster layers for suitability

3. Research Methodology

The proposed research methodology as shown in Figure 6 consisted of 3 steps that were related to geospatial analysis and performed mainly down the left side flow of methodology. The VTOL mission simulation was discussed for further studies. The data preparation that involved the manipulation of geospatial data to an analysis ready format. The results were further weighted and multicriteria-analyzed to obtain potential candidates of launching site in the suitability map. Practicality, transportation, expenditure and safety were decisive criteria for the selection of suitable VTOL takeoff and landing sites.

The weighted layers were ranked according to their significance to the site selection criteria. The slope suitability and land use suitability were equally ranked the more influential factor on site selection than the road buffer and NDVI layers because they involved technical requirements and local safety, respectively. The road buffer and NDVI layers shared equal percentage weight to the analysis. The suitability map from multi-criteria analysis was calculated by;

$$\textit{Suitability map} = \frac{(Slope * 3.5) + (Land\ use * 3.5) + (Road * 1.5) + (NDVI * 1.5)}{10} \quad (1)$$

where Suitability map is the multi-criteria analysis result, Slope is the weighted slope map, Land use is the weighted land use map, Road is the buffered and weighted road layer map, and NDVI is the weighted NDVI map. Field Surveys were conducted following the calculation results whose selected areas were visited for observation and photographic evidence.

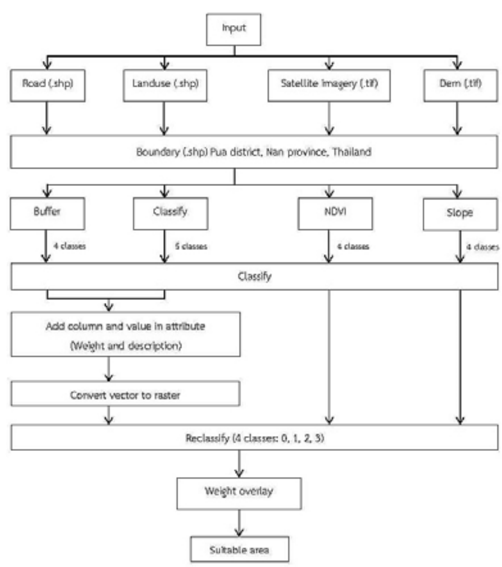

Figure 6 The proposed research methodology

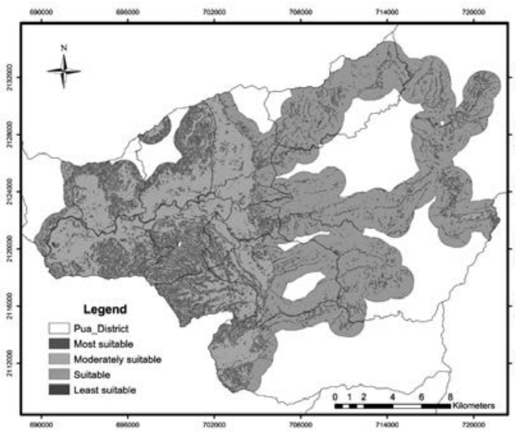

Figure 7 The weighted overlay map

4. Results and Discussion

Approximately 64.31% of the calculated result hardly visible on Figure 7 was categorized as Suitable sites illustrated in orange. The second largest areas were Moderately suitable and accounted for 35.45%. The Most and Least suitable areas shared almost respectively. Where safety to researcher lives and equipment was concerned, only the Most suitable areas as shown in scattered blue patches of Figure 8 were adopted as candidates for takeoff and landing sites. The Most suitable at 0.11% of the calculated result hardly visible on Figure 7 was found exclusively on residential areas that had been dictated since the Data Manipulation and Class Weighting process was embraced. These areas were further sampled for field surveys. Some illustration of Most suitable areas in blue of Figure 8 gave an idea of spatial distribution that could be exploited for the survey operation without the need to visit every patch for photographic and positional collection.

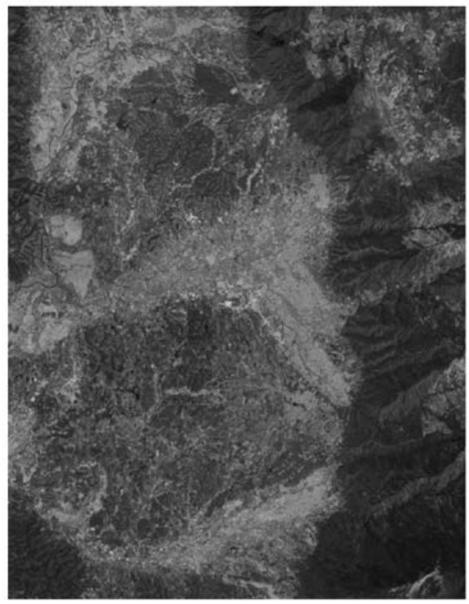

Figure 8 The weighted Most suitable patches overlay map

A spatial statistical method was applied to determine a selected series of suitable patches for the field survey where a standard distance was measured from the distribution of data around the center of all data, see Figure 9.

There were 29 sites selected for the survey and the distribution was within 8.3 km in radius. Time and fuel consumption were much saved from the survey according to the adopted spatial distribution that yielded only 29 sampled points to perform the survey.

Twenty-nine photos as shown in Figure 10 were taken with easy access to the locations resulted from the 200 m buffering data manipulation. Some of the sites fell within private properties but were accessible by vehicle for photography. Together with high reliability from the Land use layer, the photos revealed the high suitability for the VTOL takeoff and landing sites that responded to the objective of the proposed approach. Of all the 29 sites, there were 19 perfect sites for the VTOL takeoff and landing mission, whereas 10 other sites were blended with construction, water bodies and sparse vegetation considered dangerous for the mission.

The topographic features found upon the survey illustrated in Figure 10 were summarized in Table 2. There were two discussion points worth consideration from the topographic features in the table. The Land use layer with weighting percentage of 35% played a significant role in some discrepancies between the adopted approach and the real world. The survey summary revealed that most of the sites had withstood rare changes since 2016, the year of land use production. However, the fact that Pua district was one of Thailand tourism destinations during the winter had undergone Land use changes in most of the rest features with Residential category and manmade Construction among others.

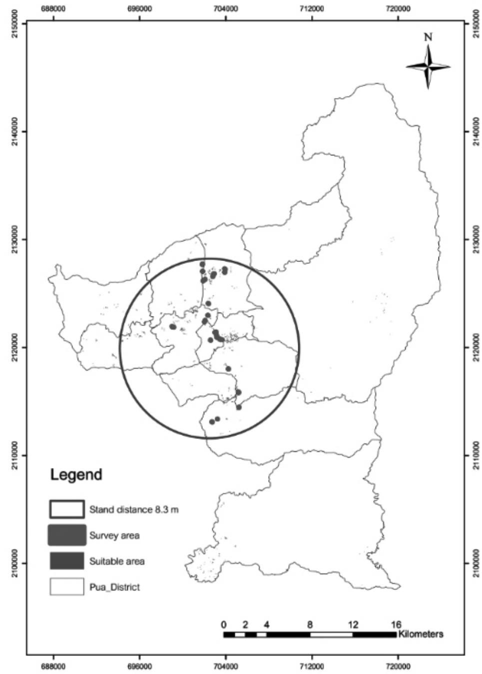

Figure 9 The epicycle representing the center of the patches

Figure 10 Photos taken upon field surveys

5. Conclusion and Further study

The research that adopted the GIS-based approach for the VTOL takeoff and landing site selection had achieved the objective by obtaining the flat and level sites. Four GIS and terrain layers included 2016 road and land use vector layers and 2020 satellite raster layer were manipulated prior to further spatial analysis

Table 2 Topographic features from the survey mission

No.	Topographic Feature	Survey Position in UTM (X,Y)	
1	Flat area and road in residential area	701823.2932	2127715.090
2	Abandoned and evenly vegetated area	703918.4949	2127259.551
3	Flat and unoccupied area	701830.2831	2127059.955
4	Flat area and paddy field	703893.8665	2126989.708
5	Vegetated and tree covered area	702884.6611	2126807.529
6	Sparse forest and scattered tree area	702799.9381	2126592.710
7	Flat area and paddy field	702066.6224	2126321.802
8	Flat and abandoned with tree and grassland	701892.2623	2126176.064
9	Flat and abandoned area	702379.5967	2124070.401
10	Flat and abandoned area	702330.9545	2122995.157
11	Flat and residential area	702073.3215	2122513.832
12	Flat and unoccupied area	702011.2941	2122382.184
13	Building and construction area	699032.0483	2121925.429
14	Flat area with tree and transmission pole	699145.9556	2121888.493
15	Flat area and road in residential area	703038.0582	2121421.105

and multi-criteria analysis. The Most suitable areas accounted for 0.11% of the suitable areas. After obtaining the suitability map for VTOL takeoff and landing sites, the necessary field survey was conducted for every selected site to ensure proper distribution over the 300 km^2 study area. There were 29 sites selected for the survey and the distribution was within 8.3 km, 19 sites of which were less influenced by urbanization. The VTOL nature of drone in general i.e., DJI Phantom Drone can be of use with the results of this study.

A simulation of the sites on mission planner platform of the used VTOL drone is under investigation during the time of publication of the article.

6. Acknowledgments

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