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Analysis of the Slope Curvature in Flying Site Selection

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A B S T R A C T

Curvature of slope is a widely addressed problem in the domain of geotechnical planning. Flying site selection in steep terrain requires potential suitable slope. The main purpose of this study was to identify effects of the slope form in flying site selection. The geo-morphometric parameters were extracted from DEM using the ArcGIS, Surfer, Global Mapper and DiGeM software, respectively. The most effective parameters were slope and divergence-convergence index. The sport pilots should be concerned with details when preparing to take a flight. This study shows that the effect of environmental conditions is important to select the suitable flying site especially for take-off zone. Study area is Esfahan province that is located in Iran. Results indicated that planning too many flying sites at this regional scale are possible and the distribution of spaces is partly determined by landform curvature, such that conflation of the final maps obtained by this structure can produce a more accurate map.

1. Introduction

The constituents of landscape are slopes; "If the development of individual slopes is understood, the development of a landscape can be synthesized" (Scheidegger, 1961). However, land slope are little understood, though they have long been studied. One of the most basic kinds of land slope study is geometric (White, 1966).

Curvature of slope is a widely addressed problem in the domain of geotechnical planning. Although all geo-morphometric parameters relate to the morphology of the land surface, a number of them can be derived directly from a digital elevation model (DEM) without further knowledge of the area represented. They represent the raw shape of the land surface, regardless of how that surface relates to formational processes (Olaya, 2009).

Sparks (1960) goes so far as to say "There is a general consensus of opinion that slopes usually consist of a convex upper part and a concave lower part with, very often, a straight slope in between." Gilbert (1909) discussed concave and convex slopes, and Wood (1942) proposed four general basic slope elements which have been applied widely. King (1953), following Wood, lists the slope elements as: waxing slope (convex crest), f reef ace, talus or debris slope, and waning slope (concave)(White, 1966).

The main purpose of this study was to identify the effect of the form of slope and landform in flying site selection. Site selection in steep terrain requires that some excavation and regarding be carried out to building flying sites. The sport pilot should be concerned with details when preparing to take a flight. He or she must take into consideration both the land forms and the weather (Pagen, 1992). In paper, “The Soaring of Raptorial Birds”, Palmer has brought our attention to the fact that soaring is made possible by upward moving air currents (Bulletin, 1931).Toward, various shapes of terrain deflect the air different amounts (Pagen, 1992). The main contents in this paper include contour line, slope, aspect, plan and profile curvature as well as divergence-convergence index. A practical slope element has also been evaluated using the GIS system, the concave and convex slope was analyzed by DiGeM, and the results illustrated the convenience of data management.

2. The Research Methodology

However, several methods of analysis have been proposed in geo-mechanical literature, a practical slope curvature analysis method and related studies are still required. DiGeM is a small program specially designed for the extraction of hydrological land-surface parameters. DiGeM complemented the other software mainly for terrain parameters this software produced by Conrad (2002) of the Gottingen University. In this case the effect of space variation characteristics of the slope curvature factor to the flying site selection can be considered properly in the DiGeM analysis. The derived curvature maps and the techniques employed will be of interest to modelers.

In following stages, use DEM and their processing in DiGeM software. The extracted parameters from DEM are slope, aspect, and curvature, Divergence-Convergence Index (DCI), Plan Curvature (PL.C) and Profile Curvature (PR.C). (Moravej et al., 2012). Then extend data in this software with a statistical analysis framework. The paired analysis on the basis of statistical indicators enabled us to calculate the shape of slope which has been shown separately.

The Divergence-Convergence Index (DCI) is the deviation of the aspect of the eight neighboring grid cells from the direction to the central cell (Herbst et al., 2006).

3. Theoretical Background

Most slopes in nature, however, consist of complex landforms. Landform graded slopes on the other hand mimic stable natural slopes and are characterized by a variety of shapes, including convex and concave forms (Schor and Gray, 1995). Some basic land-surface parameters are analyzed locally,[1] while others — regional ones — also need to consider other or all parts of the DEM apart from the exact point where they are to be calculated.

In order to understand the principle it will be necessary to explain advantages of slope shapes for soaring. Concave shaped areas take on more heat than flat or convex areas (Pagen, 1992), which is made thermal condition. To the take-off and then to launch 1.5 to 6 m (5 to 20 ft) is fit enough to run. Also the ideal shape for ridge lift seems to be the concave shape that gradually gets steeper (Pagen, 1992). Figure 1 also illustrates how a concave shaped hill heats the air more readily than a convex shape. A concave bowl also shares this property.

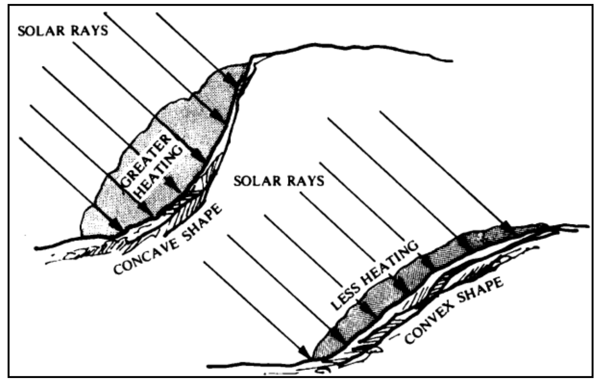

Figure 1: Heating on Concave and Convex Slope (Pagen, 1992)

Long, gradually sloping valleys will exhibit a daily cycle just like steeper slopes. The wind will tend to flow up these valleys during the day and down them at night. This valley flow is combined with the up and down slope flow in the manner shown in
Figure **2**.

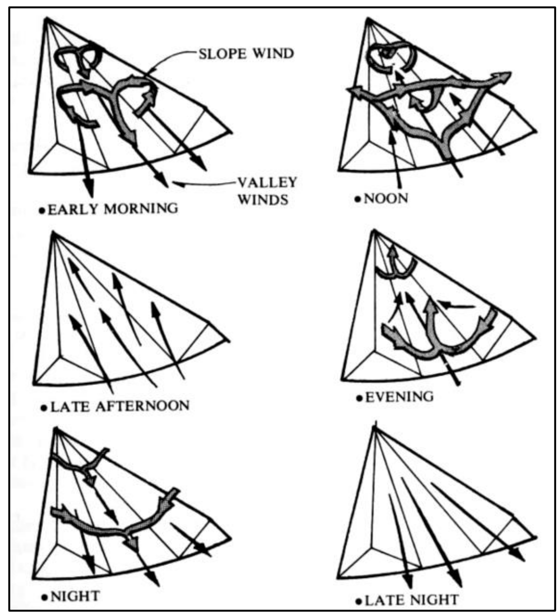

Figure 2: Daily Variations in Valley and Upslope Flow (Pagen, 1992)

To begin, the early morning sun initiates the upslope breezes while the down valley wind continues to drain the canyons and shadowed slopes. Soon the down valley wind stops and begins reversing by noon. By the late afternoon the up valley wind is powerful and even alters the upslope wind on the mountain sides. Towards evening the down slope winds begin while the up valley wind continues. Note the converging air in the middle of the valley. In a couple of hours the up valley wind has stopped and turned to become a down valley wind.

1 -Typically, these measures were meant to be computed within a small vicinity — e.g. 3×3 window.

This wind builds in strength into the night to alter even the downslope wind. In the morning the cycle begins anew.

The presence of uneven terrain, valley constrictions and general wind alters the neat plan outlined above. An overall wind can often prevent the flow up one side slope or even channel the wind for days in one direction along the valley (Pagen, 1992).

4. Case Study

As a case study Esfahan province was chosen where it is located almost in the middle of the Iranian plateau. It is a geologically well-studied area because of general interest in continental collision zones (

), and because of Iran's long history of research in geology.

Esfahan province height range is between 690 to 4394 MSL (Mean Sea Level) (
Figure **3**). The highest peak is Dena in the Zagros Mountains at 4390 m, located in Esfahan. Zayandeh-Rood or Zayanderood is the largest river in the central plateau of Iran. It starts in the Zagros Mountains and flows 400 kilometres eastward before ending in the Gavkhouni swamp, a seasonal salt lake, at the southeast of Esfahan province.

Table 1: Case Study Attributes- Esfahan Province

Range Type **Highest Point**	**Dena Mountains**
Area	107,025 km^2 Area may include lowland areas
Extent	422 km North-South 543 km East-West
Centre lat/lon	33° 15' N; 52° 15' E

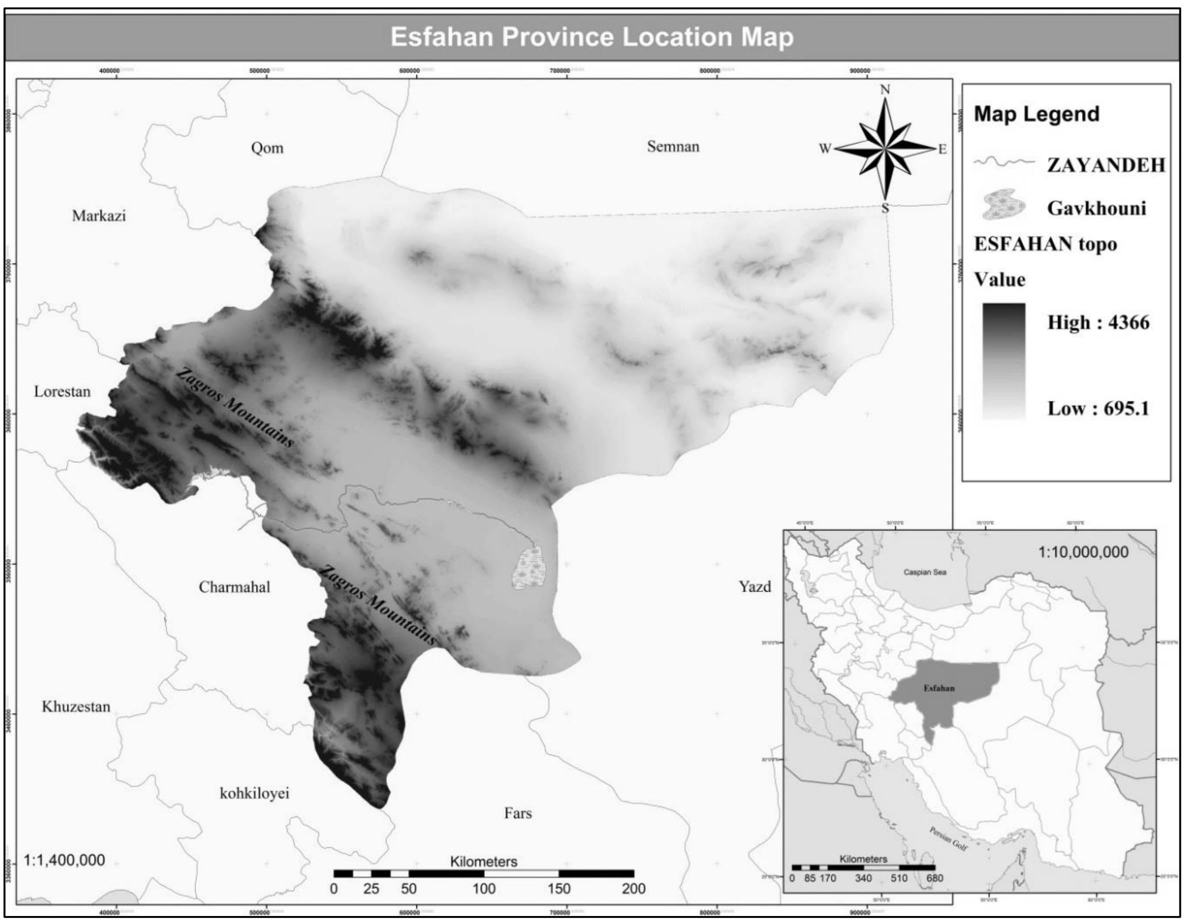

Figure 3: Location of Study Area in Esfahan Province, Iran

The climate, regarded by most investigators as an important factor in slope processes, is dry continental. The average annual precipitation is 116.9 mm, which is well distributed throughout the year. The average annual temperature is ranging between 40.6 °C and 10.6 °C on a cold day in the winter season. The average annual temperature has been recorded as 16.7 °C.

4.1 Analyzing Relief Database

Higher-order local surfaces (e.g. partial quartic) can fit more complex landform features, but are reliable only for very accurate data (Schmidt et al., 2003). Considering relief only, pilot at the top of a concave slope can observe the entire slope and the terrain at the bottom. But an observer at the top of a convex slope would have no observation of most of the slope or of the terrain at the bottom. In spite of that the climb farther up the convex slope would be easier (**Error! Reference source not found.**).

Figure 4: Shape of Slope

Table 2: Esfahan Province Slope Attributes

Slope degree	Area (km^2)	Percent
0 to15	98098.664	91.66
15 to 25	5813.608	5.43
25 to 35	2432.507	2.27
35 to 66	680.634	0.64

5. Mapping Results

GIS skills are very useful for fundamental studies of geomorphology such as slope analyses (Iwahashi et al., 2001). The slope (expressed as degree) and altitude information were obtained from the DEM using GIS software. The spatial resolution of data was set at 90 m per pixel. The analyzed sample is a 1:2,200,000-scale "Esfahan Province" map area. The most frequent slopes are less than 2 degree in the present case study. As indicated in Figure 5, Esfahan Province mainly has flat areas. The paired analysis on the basis of statistical indicators enabled us to calculate the shape of slope which has been shown separately.

For intermediate pilots the training slope is a cross section of training hill. 25°- to -35° slopes approximates the glide path enough that student pilots can avoid hard landings. Still, they can get off the ground. A stairway in the middle will facilitate walking up again. Hereby, mapping result was acquired especially in areas having suitable hill slope degree for flying site (2%) (Table 2).

Site selections in steep terrain have some requirements regarding building standard flying sites. The manner in which this grading is planned and executed and the nature of the resulting topography or landforms that are created affect not only the visual or aesthetic impact of the development but also the curvature of the slopes. The Divergence-Convergence Index (DCI), topo shape information and Profile Curvature (PR.C) were obtained from the digital elevation model using DiGeM software(Conrad, 2002). The typical 30 m by 30 m grid size is required to accurately resolve the hill slope/valley transition.

SlopeCurvature was calculated with DiGeM (Conrad,2002) using data from the DEM, case study areas grid result was between +90 to -90. Results are visually analyzed by draping them over Digital Terrain Models (DTMs) of study areas (Table 3). Then all grids were mosaic (average-kriging) by surfer application.

Table 3: Univariate Grid Statistics

	Average Z	Suitable Curvature
Minimum:	-84.1560287476	-30
Maximum:	85.3970718384	70

Those slopes which satisfied certain simplifying conditions were selected for study. In addition to the flat surface, suitable slope for flying site are convex slope about 25° to 35° degree which let pilot run and take off easily (Figure 6).

Various shapes of terrain deflect different air amounts; the concave slope (around -30) curve mostly has suitable thermal condition and will be commonly used during the flight. Even though convex shaped areas are more suitable for running than concave areas, both slope are useful and even elemental for selecting flying site, so the best potential sites are indicated in Figure 7. The results suggest that planning too many flying sites at this regional scale is possible and the distribution of spaces is partly determined by landform curvature.

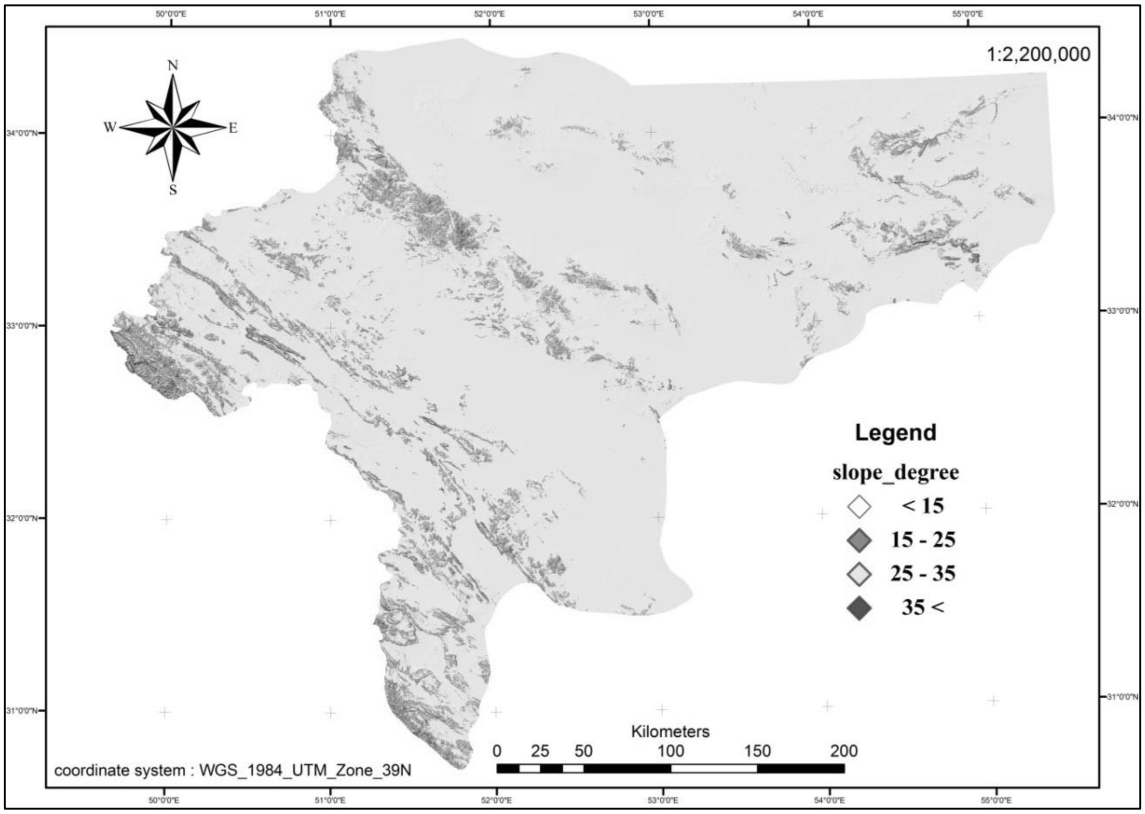

Figure 5: Esfahan Province Slope Map (GIS Export)

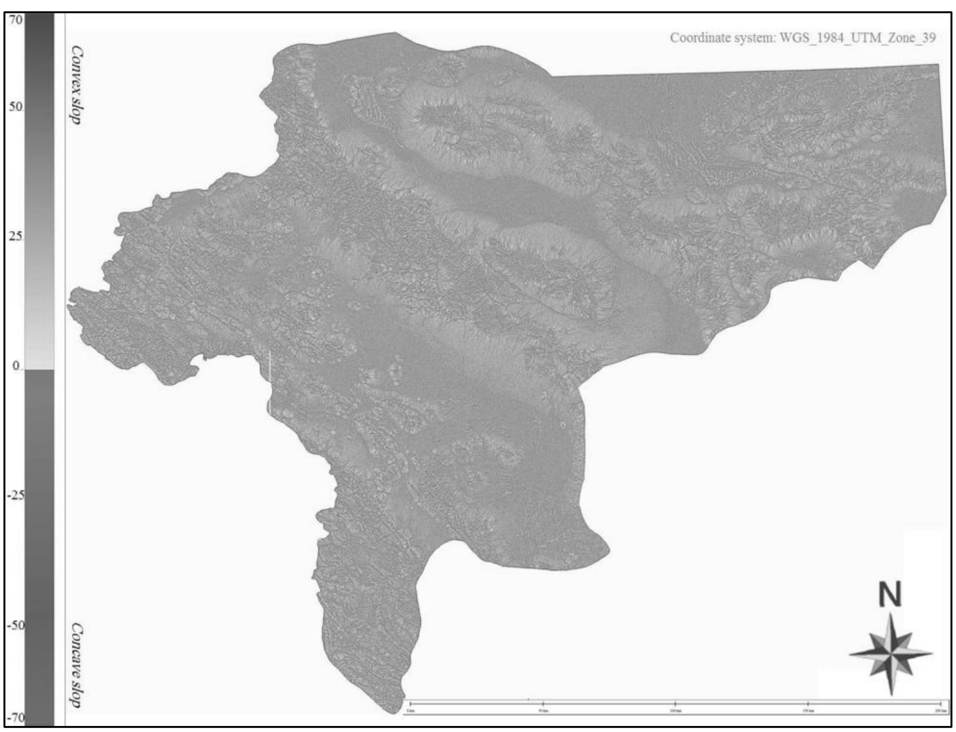

Figure 6: The Divergence-Convergence Index (Global Mapper Export)

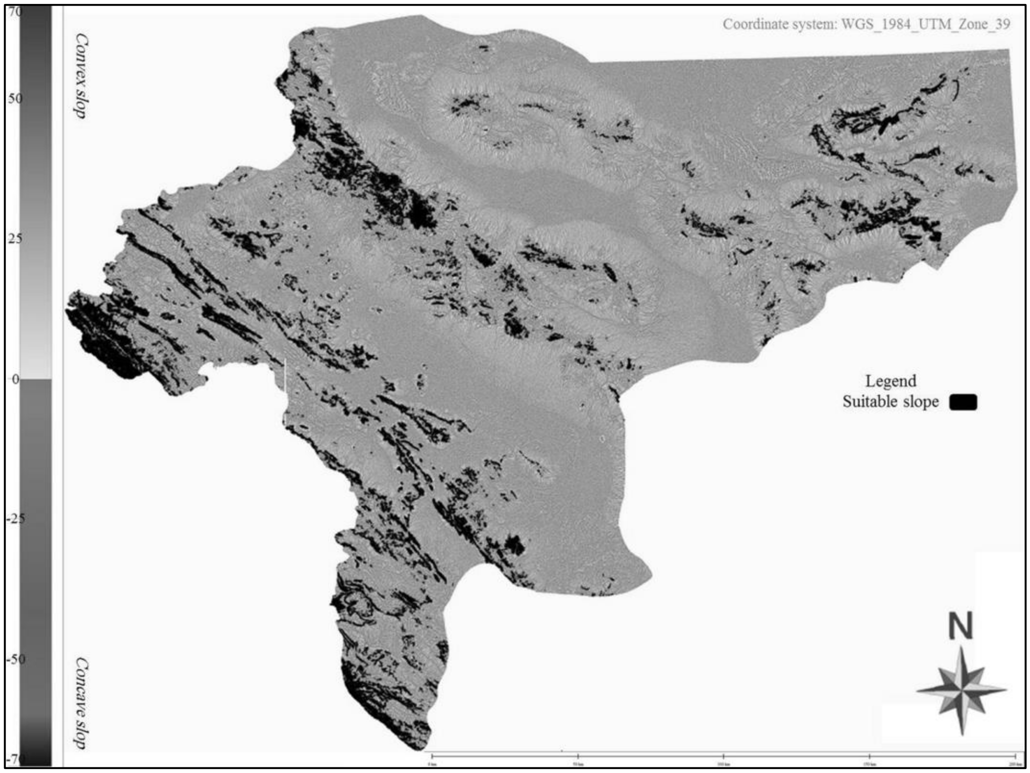

Figure 7: Concave/Convex Slope Suitable to Flying Site

6. Conclusion

Many existing geomorphometry approaches aim for the identification and/or extraction of discrete landforms, by focusing on specific surface shapes. Landform-graded slopes, on the other hand, are characterized by a variety of shapes including convex and concave forms that mimic stable natural slopes. Flying site selection in steep terrain requires potential suitable slope. By the way, there are mainly several kinds of possible slope forms for the flying site slope. The use of terrain attributes as co-variables was the focus in this study.

A number of authors have argued that selection process should utilize relevant available data and planners should arrive at results accepted by all key players in the selection process. In this case the effect of space variation characteristics of the slope curvature factor to the flying site selection is considered in the DiGeM analysis. The extracted parameters from DEM were slope, aspect, curvature, and Divergence-Convergence Index. The data was then extended in this software with a statistical analysis framework. The complicated geological structure can be accurately described by using DiGeM tools.

The sport pilots should be concerned with details when preparing to take a flight. They must take into consideration the land forms. This study shows that the effect of environmental conditions is important to select the suitable flying site especially for take-off zone.

Pilots at the top of a convex slope can run easier to take-off or landing and also, the climb farther up the convex slope would be easier. On the other hand, concave shaped areas take on more heat, which is made thermal condition. Therefore the ideal shape for ridge lift seems to be the concave shape that gradually gets steeper.

The calculation results can help us to better understand the slope's form state. In addition to information on zone selection, detailed knowledge of land use history, landscape structure and weather conditions is needed in order to understand the nature of area for standard flying site.

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