Best Method in estimating the equilibrium-line altitude of late quaternary glaciers in Iran

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1. Introduction

Displacement of the equilibrium-line altitudes (ELAs) of Late Quaternary Glaciers in mountainous regions of Iran are mostly caused by climatic changes during Quaternary. It is vital to study surface landforms created by the inner and outer processes in this period (Yamani, 2007). Climate change in Quaternary has led to the emergence of glacial and inters glacial periods (Yamani, 2002). In Glaciology studies, the equilibrium line altitude (ELA) and the water and ice equilibrium line are the most important concepts (Ramesht et al. 2011). According to Porter (2005) "The equilibrium line is a place where snow accumulation is more dominant (Abtahi, 2013). Some national research examples are as follows: Evans (2006) in Wales, Sarikaya (2011) in Turkey, Mindrescu and Evans (2014) in Romania, Hendrickx et al. (2015) in Ethiopia, Jafari (2009), Moayeri et al. (2011) and Jafari (2014) in Iran. One of the most controversial issues in this regard is ELAs differences in different geographic latitudes and directions which is due to the variations along the slops which as a result made it difficult to discuss comprehensively.

2. Study Area

Iran, with an area of 1648195 square kilometers, is located between 25 to 40 degrees north latitude and 44 to 63 degrees east longitude. Iran is divided into 6 geomorphic units (Zagros, North, Central Iran, East, Northeast and Northwest unit) (Alaei Taleghani, 2012). Iran is divided into 6 first and 30 second grade catchments (Water statistical yearbook of Iran, 2011). Of the 30 second grade catchments, Quaternary glacier cirques (6 morphotectonic units) were identified in 21 sub-basins.

3. Materials and Methods

In order to estimate the ELAs, firstly an Iranian DEM with 30*30 meter resolution was prepared and merged and clipped for each basin. Merged topographic maps (1: 50000) were also extracted for each basin. Based on documents in topographic maps, 20-meter contour lines and the reflection of landforms in SRTM satellite images, cirques of each

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basin were identified. Secondly, according to the method of Terminus-to-Head Altitude Ratio (THAR), the identified cirques which didn't have concave longitudinal profile were not considered in the estimations. Based on this, out of 30 second-grade catchments, 21 catchments were considered as basins that had been influenced by the glacial process in cool Quaternary spans. The ELAs were estimated using Porter's cirque-floor altitude and Wright methods. The geographical directions of the cirques were classified into eight main and secondary directions. The ELAs were estimated using the following methods:

4. Results and Discussion

In the present paper, 11641 cirques were identified in Iran based on the shape and height of the contour lines, status of the waterway network and the height of the peaks dominating in cirques. The surface slope direction affects the abundance of the cirques, meanwhile more than 60% of the cirques are formed in slopes that are inclined toward north in the whole country. Such slopes are known as Nesar slopes due to the inclination of the solar angle. After all the cirque were determined, the above methods were used to estimate ELAs.

Comparison of the difference between the ELAs in different directions using Wright method revealed that the greatest difference was in salt lake (449 m) and Aras (440 m) catchments. The minimum elevation difference was observed in the Haraz-Gharehsu (-551 m) and Duranjir desert (-350 m) basins, and there were no differences in ELAs in different directions of three basins. Comparison of ELAs estimated by the cirque floor method in different directions indicates that Aras (761 m), Sefid-rud (602 m) and the central desert (350 m) basins had the greatest variations in different directions. In the morpho-tectonic unit of Central Iran, cirque-floor altitude and then the THAR methods (Wright) were more preferable, respectively considering the difference of estimated ELAs.

5. Conclusion

The ELA in the Zagros morphotectonic unit was about 2608 m during the Quaternary. With further expansion in latitude, ELA differences in this unit, was estimated to be 637 m. The ELA of southwest slopes was estimated to be 524 m above the ELA of the northeast slopes. In total, ELAs were decreased from south to north during the Quaternary, so that the difference between Karun (the southernmost basin) and Aras catchments (the northernmost basin) was 484 m. From a longitudinal perspective, ELA differences is more than 800 m between the western catchment in the west (with an estimated ELA of 2300 m), and Duranjir catchment in the central Iran (with an altitude of 3100 m). In conclusion, during the Quaternary, the ΔELA of Iran was more than 1065 m, and it varied between 2030 and 3100 m. The average ELA of Iran was about 2595 m. It can be concluded that in cirques landforms each latitudinal degree, could change the equilibrium-line altitude about 89 meters.

Keywords: Quaternary; Iran; ELA; direction; cirque; Wright; Porter.

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