

The environmental impact of mountaineering in the Mt. Manaslu region

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Manaslu is one of the 8,000-meter peaks ranking as the 8th highest peak in the world, located 130 km northwest of Kathmandu, the capital of Nepal. Since Manaslu's normal route (general climbing route) is relatively less difficult, the number of Manaslu's climbers have increased rapidly over the last 10 years. Sixty years have passed since Manaslu was first conquered by a Japanese expedition. The popularity of its scaling and the rapidly growing tourism in the Nepal Himalayas after 1970 are noticeably affecting natural, social, and cultural environments in the area. This in turn, is creating serious environmental issues at the Manaslu Base Camp (4,800 m above mean sea level), the entry point for climbing Mt. Manaslu. In this research, we aim to develop a system that can combine high resolution imagery and Digital Surface Model (DSM) in the base camp and simple monitoring into one method in order to estimate the environmental burden associated with the climbing activities in the Manaslu Base Camp. We performed aerial photography of the base camp using Unmanned Aerial Vehicle (UAV) and created DSM from Structure from Motion (SfM) of the obtained images. At the same time, positioning data of the feature was acquired through a Differential Global Positioning System (DGPS) survey, and a 3D topographic map was created.

The geographical area covered in this study is the Manaslu Base Camp in the Manaslu Conservation Area's, Gorkha District which is located in Northwest Nepal. In order to elucidate the actual usage of the Manaslu Base Camp, a field survey was carried out in August, 2016 at and around the Manaslu Base Camp using UAV. We conducted the following investigations at the Manaslu Base Camp: survey of the Base Camp, questionnaires to all the mountaineering parties at the Base Camp. We monitored the actual usage of the Manaslu Base Camp in order to clarify the number of tents and their locations by photointerpretation using high resolution satellite images. In the survey of the Base Camp using UAV, we acquired a high resolution image using Phantom 4 of DJI. Using the obtained high resolution image, 3D terrain data and an ortho mosaic image was generated from the SfM, and a map of the Manaslu base camp was created. In the DGPS base camp survey, we recorded location information of features such as tents, toilets and routes in the Manaslu base camp.

A topographical survey of the Base Camp was conducted to pinpoint the location of each tent and to grasp the topographical features of the area. We were probably the first in the world to create a topographical map of the Manaslu Base Camp that shows detailed positioning of the campsite. There were 32 kitchen tents, 58 toilet tents, 42 altars (places to pray for safe climbs) in the post-monsoon season. The resolution of the obtained high-resolution image was 0.009 m.

Inquiries were made to every party staying at the Manaslu Base Camp in 2016 August. The questionnaires enquired about the following information: Number of members in each party; number of belongings brought in and out; number of donkeys used to carry equipment; and environmental considerations taken by each party.

A few of the findings of this study in August 2016 at and around the Manaslu Base Camp are as follows. (1) A topographical map of Base Camp was prepared pinpointing the location of each and every tent of the area. We are the first in the world to prepare such topographical map of the Manaslu Base Camp using UAV. (2) The results of the questionnaires show that during the pre-monsoon period in 2016 an astounding 46 tons of goods were brought into the Base Camp. Furthermore, over 780 donkeys were used for transportation. (3) Water quality research was also conducted at water collection points of the

Base Camp. The water was found to be badly contaminated because of the urine and excrement of donkeys that were found scattered over the Base Camp.

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