

# Landscape changes in the Cordillera Real, Andes detected from satellite images

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Strong glacier recession was observed worldwide during the last decades. Among all, glaciers in tropical Andes have been showing the large negative specific mass changes which strongly limit the water resources available in the downstream area. A lot of research has been conducted on the study of glaciers changes, however, less focus has been given to the change of landscapes such as lakes and vegetation, although they are essential for water resources and have a significant meaning to the livelihood of local people because of the potential water storage provided by new or growing lakes and water storage in vegetated area by preserving meltwater and precipitation.

However, the Cordillera Real, Bolivia, has not been drawing much attention compared to the mountain ranges in Peru because of less large glaciers, although the glaciers are playing an important role in the water supply for several big cities in Bolivia, including its capital cities, La Paz and El Alto. Considering the important role of various landscapes that are playing in the water supply, this study is aimed at identifying the long-term change of landscape in the Cordillera Real, Andes.

In this study, a model was designed to identify five types of landscapes including glacier, lakes, wetland, vegetation and gravel using four normalized difference indexes which are calculated from Landsat-5 and Landsat-8 atmospheric corrected satellite images in the dry season (May to Oct) from 1991 to 2019, with the help of other data sources including ASTER GDEM, STRM water body data, ArcGIS world imagery and Google Earth map.

With this model, different types of landscapes were automatically identified, thus it is more efficient than previous studies and avoids errors brought by manual operation.

The result revealed the spatial changes of each type of landscape from 1991 to 2019. Overall, vegetation and gravel take most of the area, and their areas are relatively stable. The area of glacier shows a decreasing trend during the study period and the decreasing rate is consistent with the result of previous studies. It was found that the area of wetlands fluctuates with seasonal changes, and it normally reached the highest in May and early June, and the lowest area often shows in August and September. Five-year average of the wetland area showed an increase in the most recent periods. The area of lakes is slowly increasing, and new lakes have been detected near the retreated glacier.

The areal increase of wetland and lakes indicates the improvement of water storage capacity and possible increase of water resources in Cordillera Real. Although the retreated glaciers will temporarily provide sufficient meltwater runoff but the long-term sustainability of water resources is highly uncertain due to the influence of other landscapes and uncertainty in the remaining mass of glaciers.

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