<u>Area and mass balance for tropical glaciers in Peru in the period 1985-2008 using ASTER and Landsat data.</u>

<u>An estimation of glacial water storage and its impact on the water supply of Lima.</u>

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<u>Abstract</u>

Lima, (12°1'S, 77°6'W), Capital of Peru, faces new challenges for the water supply of its inhabitants as a result of Climate Change. The city is surrounded by desert and is characterized by extremely high water stress, with continually increasing population as well as limited and unequal distribution of water resources. Lima is highly dependent on the *Río Rímac*, which brings melt- and rainwater from the Central Andes.

This diploma thesis investigates one of the outer tropical glaciated regions of the Western Cordillera (Central Andes) that is drained by the *Rímac*. Using remote sensing satellite data from ASTER and Landsat, changes of the "*Glaciers of Shullcon*" region (5758 m asl, 11°88'S, 76°05'W) have been identified in a multi-temporal time series from 1985-2008. Therefore methods of remote sensing and GIS (Geographic Information Systems) were applied, as the NDSI (Normalized Difference Snow Index) for detecting glaciated areas. I also present comparisons with additional climate data.

In this investigation, three main periods of variability of the glaciated areas could be identified. The first period ranges from **1985-1998**, and is characterized by relatively strong and eventually very strong ablation. The second period ranges from **1998-2002** and is characterized by strong accumulation, while the third period from **2002-2008** again shows patterns of quite strong ablation.

Monthly averaged precipitation data from 1995 to 2002 are compared to the long-term average of 1947-2008 for three nearby climate stations (*Casapalca*, *Milloc*, *San José de Parac*). This reveals pronounced patterns of partially low precipitation from 1997-1998, and extremely high precipitation from 1999-2001. These patterns correlate well with the SOI (*Southern Oscillation Index*) and with the most recent ENSO-events – the ***El Niño*** of **1997-1998** and three ***La Niñas*** from **1998-2001.**

The three observed main periods of variability of glaciated areas may be explained by this phenomenon. The glaciated area decreased strongly with the last *El Niño,* while it was increasing following the three *La Niña* events, and has again been decreasing since 2002.

The **total absolute area lost** by the glacier from 1985 to 2008 could be identified as **~ 14 km^2**, which corresponds to an **annually melting rate** of **1,24 % a^{-1}**. According to scaling-theory this translates into a **total absolute volume loss** of ~ **554·10^6 m^3** and a **total absolute mass loss** of ~ **499·10^6 t** (with the assumption of a constant ice-density of 900 kg/m^3). From this a **total averaged thickness loss** of **~ 12 m** is calculated, which corresponds to an **annually water equivalent** of **~ 472 mm a^{-1}.**

Assuming **linear or exponential trends**, it was found that, under the same climatic conditions as during the investigated time period, the glacier may completely disappear within **70-186 years**.

Against this backdrop of possible trends, the sustainability of water supply for Lima must be discussed and questioned. An initially increasing water supply due to melting could change to lower discharge within a few decades. It is necessary to address the complex system of water supply in its totality, including precipitation and ground water, as well as melt water and dammed-up lakes. It may be possible that dammed-up lakes, such as lake *Yuracmayo* in the area of interest, could provide long-term storage for the draining melt water and future rain water. Further it must be investigated to what extent climate parameters may change under Climate Change conditions, including e. g. the superficial temperature, precipitation, atmospheric humidity and cloudiness. For future estimates of glacier melting, a special focus should be placed on the energy budget, relevant for sublimation and melting processes, as well as for the ENSO-events with *El Niño* and *La Niña*.

An adaptation of Lima's water supply to the trends indicated above is unavoidable. It seems inevitable that both **social adaptation** (an economically and infrastructurally fair distribution of water throughout the city and its poor suburbs) and **technical adaptation** (damming up of more lakes, constructing more water-tunnels, improving efficiency of water consumption) must be carried out and supported by the government, the communities, and in particular the people.