Water and Soil Chemistry Interactions in the Khumbu Valley, Nepal

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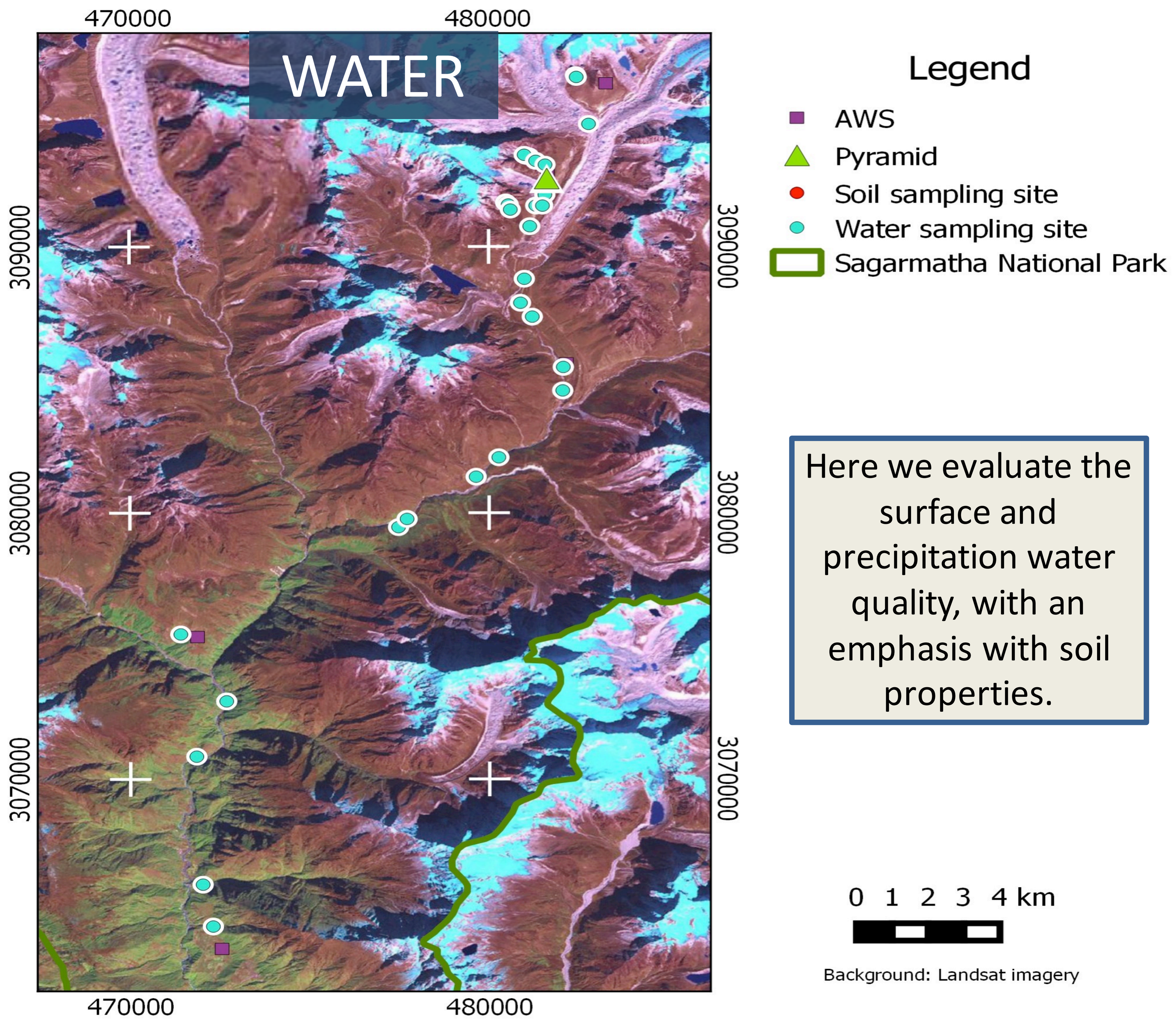
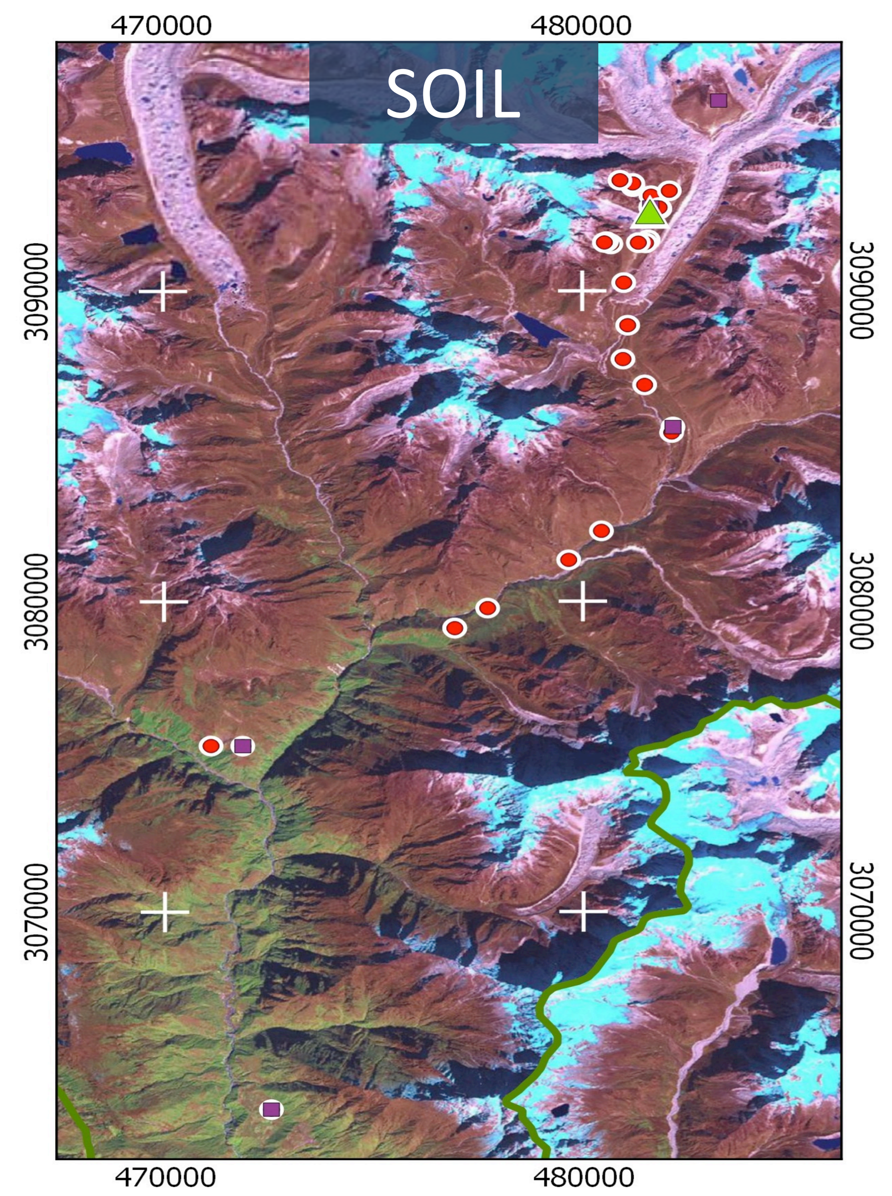
MOUNTAINS: GLOBALLY IMPORTANT ECOSYSTEMS

Nearly 20% of the Earth surface is comprised of mountains that provide a valuable surface water storage reservoir for millions of humans, including the Tibetans and Nepalis living below Mount Everest (Yeo and Langley-Turnbaugh, 2010). Climate change and retreating Himalayan glaciers have raised questions about water security in Himalayan countries because these changes may also affect water quality.



Here we evaluate the surface and precipitation water quality, with an emphasis with soil properties.



The Study Area is the Khumbu Valley region in the Sagarmatha National Park (27.75° to 28.11° N; 85.98° to 86.51° E) in the southern part of the central Himalaya. Altitudinal gradient: from 3570 to 5320 m asl.

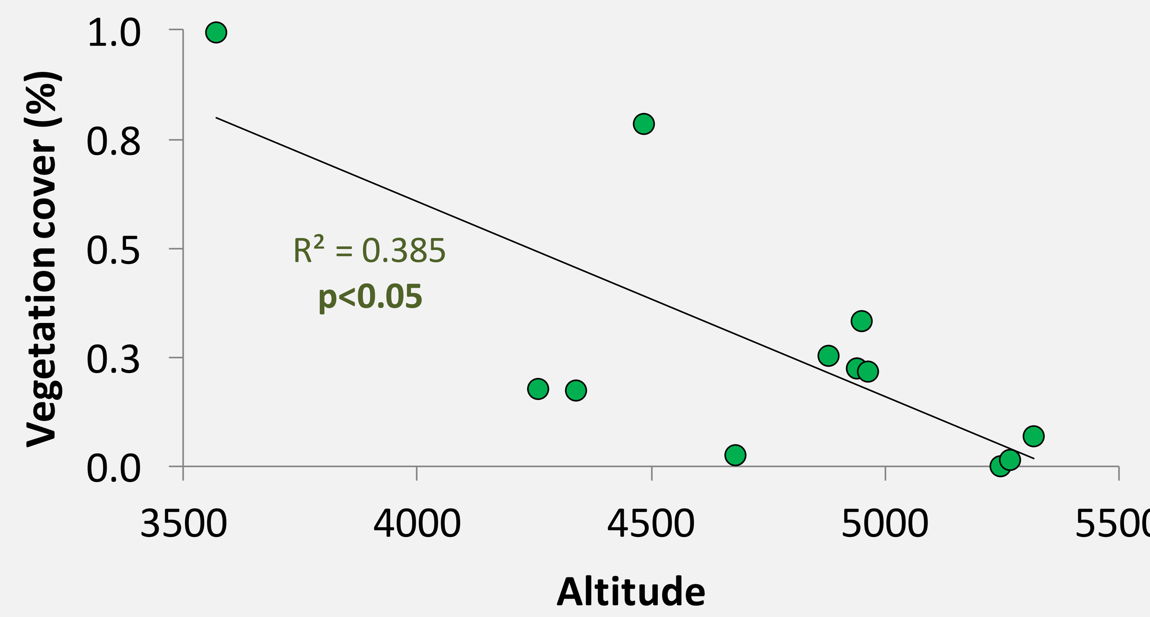
	Ca^{2+} (μeq l-1)	Mg^{2+} (μeq l-1)	Na^{+} (μeq l-1)	K^{+} (μeq l-1)	Cl^{-} (μeq l-1)	N-NO_3^- (μeq l-1)	SO_4^{-2} (μeq l-1)
Precipitation	1.1 – 9.3	0.1 – 1.4	1.0 – 2.4	0.2 – 6.4	0.8 – 2.5	0.05 – 0.48	0.2 – 3.5
Surface water	197 - 548	13 – 120	18 – 126	7 – 45	3 – 31	5 – 72	49 – 383

Differences in the ranges of measured ion concentrations between precipitation and surface waters are generally one to two orders of magnitude for samples collected at the same elevation. Higher concentrations in surface waters (3570 m to 5320 m) relative to liquid precipitation (5050 m) are clear indicators that both lake waters and glacier outflow waters are strongly influenced by subsurface routing and residence time. Future work to acquire and analyze groundwater and soil moisture samples will provide greater insight into the magnitude of groundwater contributions to river discharge.

Soil C stock (t ha^{-1})	
min	1.3
mean	26
max	44

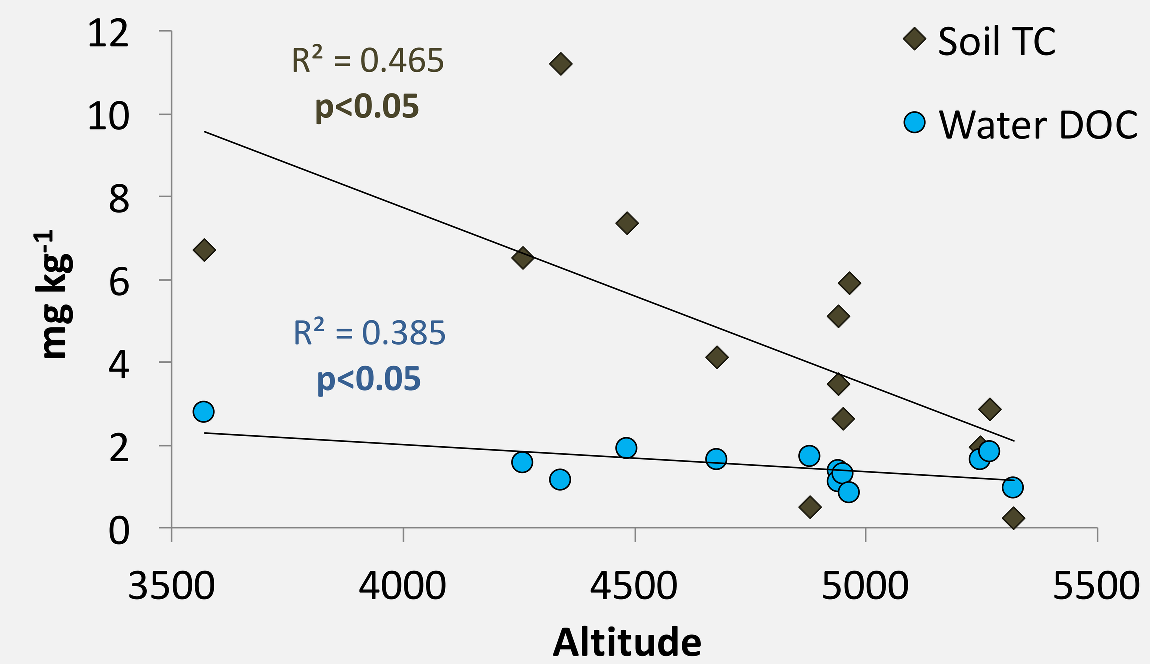
Lower values compared with Hoffman et al. (2014) in the Swiss Alps, which had minimum, mean and maximum of 3.1, 40.9 and 158.8 t ha^{-1}, respectively.

Sampling sites in the Khumbu Valley include the entire range of possible vegetation cover. This influences soil chemistry since vegetation is a source of carbon and can fix nitrogen.



Water DOC, soil TC and soil TN had a similar trend with significant negative correlations with altitude.

Harsh climate, short growing seasons, snowfall for more than five months, prolonged physiological dry conditions (that caused reduction in plant growth, litter production and microbial activity) at high elevations limit net primary production and C inputs to the soil. This may lead to decreasing SOC stocks with increasing elevation, as observed by Djukic et al. (2010) in the Austrian Alps at elevations higher than 1500 m asl and by Sing et al. (2011) in the Western Himalaya.



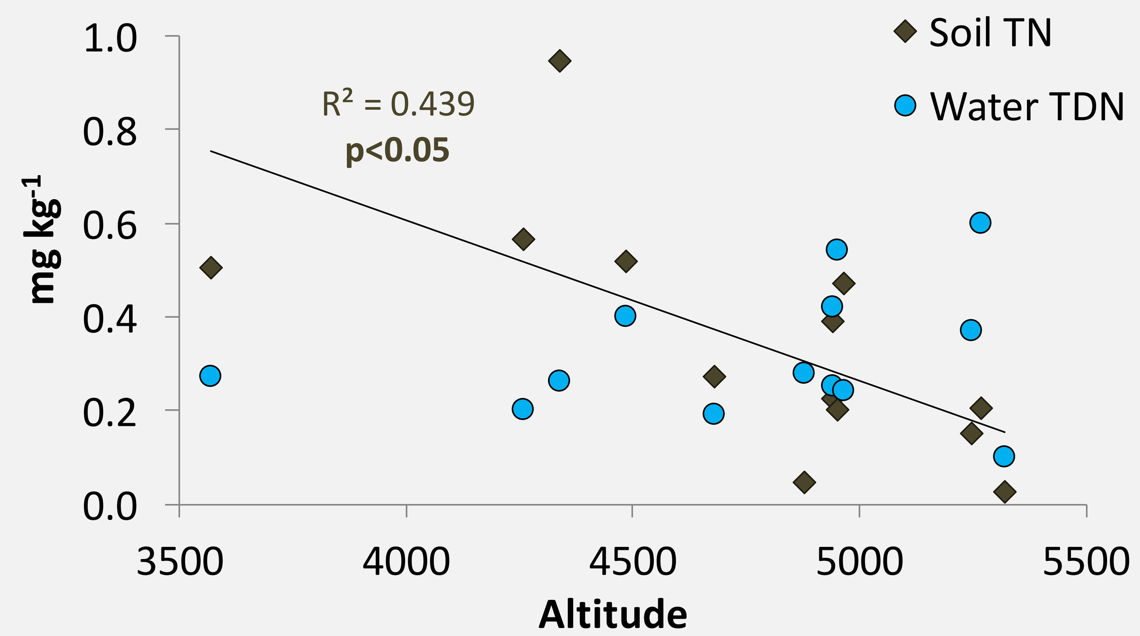
SIGNIFICANT CORRELATIONS IN THE SOIL

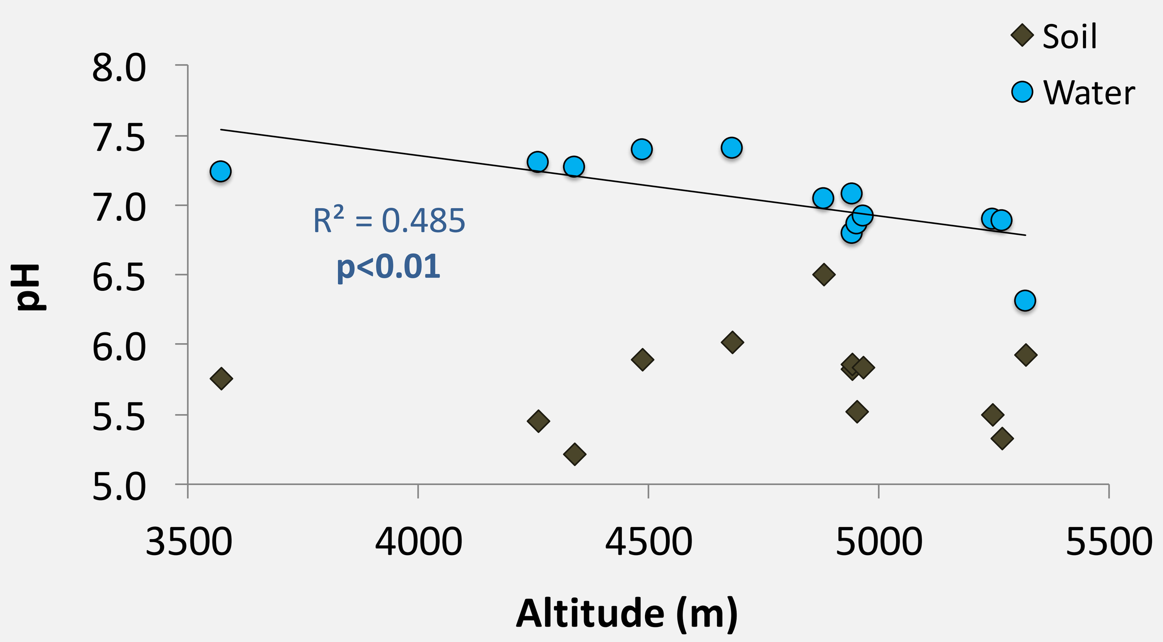
NEGATIVE

- TC and altitude ($p<0.05$)
- TN and altitude ($p<0.05$)
- Stock C and altitude ($p<0.05$)
- TC with pH ($p<0.05$)

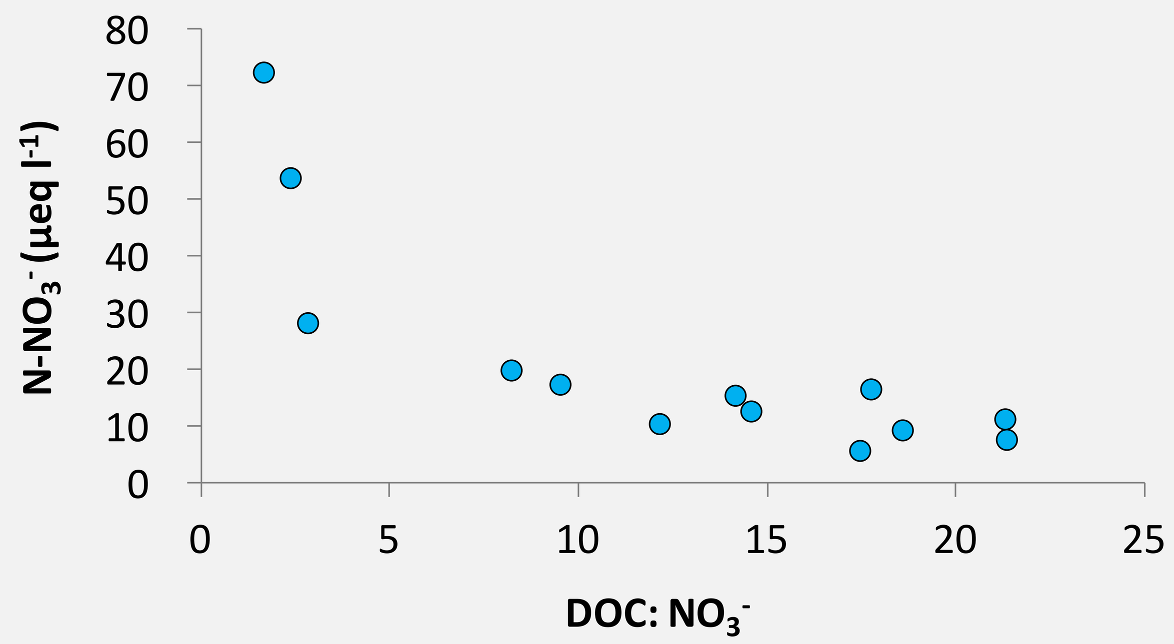
POSITIVE

- TC with TN ($p<0.01$)
- C: N ratio with C stock ($p<0.05$)





Soil pH did not vary with altitude, reaching acidic values around 5.5. Water showed a significant decreasing trend with the altitude probably caused by the increasing of SO_4 with the elevation.



Nitrate accumulations were typically associated with a DOC: NO_3^- ratio less than 10 (Williams et al., 2011). Stoichiometric results provided by the DOC: NO_3^- ratio shed light on why the quality of DOM changes with elevation in headwater catchments.

pH	Soil	Water
min	5.2	6.3
mean	5.7	7.0
max	6.5	7.4

Soil C: N ratio	
min	8.8
mean	12.9
max	15.5

➔ Ratios less than 25 ➔

Soil C: N ratios less than 25 in the alpine tundra are consistent with a system moving toward net nitrification, resulting in nitrate leaching, decreasing the DOC: NO_3^- ratio in stream water (Williams et al., 2011).

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