Review report on “Soil-vegetation-water interactions controlling solute flow and transport in volcanic ash soils of the high Andes”

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The paper “Soil-vegetation-water interactions controlling solute flow and transport in volcanic ash soils of the high Andes” by Páez-Bimos et al. investigates the influence of two different types of vegetation (cushion plants and tussock grasses) on soil water balance, solute fluxes and chemical weathering in the high Andes ecosystem via fieldwork and numerical modelling. The cushion plants had lower water transmission below the A horizon and lower soil chemical weathering rates due to their shallower and coarser roots. The tussock grasses had steady water transmission throughout the soil profile and higher soil chemical weathering due to their deeper and finer roots. The paper concluded the soil water balance under the two vegetation types was different due to the root structure of the plants, which altered solute fluxes and soil chemical weathering throughout the depth of the soil.

Studies done in the past about the volcanic ash soils of the high Andes focused mostly on land use (Podwojewski et al., 2006; Buytaert et al., 2002; Buytaert et al. 2007) and on soil properties (Buytaert et al., 2005; Zehetner et al., 2003; Tonneijck et al., 2010; Tonneijck et al., 2010; Zehetner & Miller, 2006), while more recent studies in the area focused on its vegetation effects on hydraulic soil properties (Páez-Bimos et al., 2022), soil hydrology (Lahuatte et al., 2022), runoff processes (Minaya et al., 2021), and weathering (Barbosa et al., 2022). This paper is in line with these topics, since it focuses on vegetation, weathering, and hydrology. It is most comparable with Páez-Bimos et al. (2022) by also researching vegetation effects on hydraulic soil properties. Some of their conclusions were repeated in this paper, for example:

- Compared to tussock grasses, the higher water retention capacity at saturation under cushion-forming plants can enhance soil water storage during prolonged rainfall events, whilst the higher total available water results in higher water storage for plants and can promote evapotranspiration during the dry season.
- The saturated hydraulic conductivity in the top horizon is higher under cushion forming plants.
- Below the rooting zone, the saturated hydraulic conductivity drops remarkably, especially under cushion plants.

However, I think there are sufficient differences between the two papers. Páez-Bimos et al. (2022) touches upon the soil pore structure and the specific plant root characteristics that were found to be notably different between the two vegetation types, which is not included in this paper. This paper focuses on solute fluxes and chemical weathering, which is not discussed in the paper by Páez-Bimos et al. (2022).

According to the paper, vegetation effects on individual components of the soil water balance have been studied before. Furthermore, Molina et al. (2019) found that there are significant differences in soil chemical weathering between vegetation patterns. This paper aims to reveal the mechanics behind vegetation influencing soil weathering rates via its root system effects on soil water fluxes, since this has not been evidenced before. It adds knowledge about soil-vegetation-water interactions that may be relevant for soil hydrology, soil chemistry and ecology fields. Therefore, I think the paper addresses relevant scientific questions within the scope (advancing understanding of hydrological systems) of the journal Hydrology and Earth System Sciences well.

The paper is well written and uses understandable and precise language. It includes figures that support the understanding of, summarize, and add to the text well. Especially figure 10 helps to understand and summarize the text very well. The root diameter and deepness are visualized here, which puts their differences into perspective. The differences in arrow sizes are distinguishable and immediately show the results in a glance. However, I do have some issues – mostly with the methods and conclusions – that I would like the authors to address before publishing. Besides the strengths of the paper, I will elaborate on these issues below.

I think your introduction is well written and gives a good background and understanding for the topic of the paper. It also includes relevant references. I think it creates a nice funnel from a broad perspective (the relationship between soil hydrology and chemical weathering and how this has been researched before; the relationship between vegetation, soil hydrology and weathering; and the Andes ecosystem) to the research questions and problem statement. My personal preference would be to move the information on the Páramo ecosystem (line 99-109) from the introduction to the site description in the methods (paragraph 3.1), but this is entirely up to your own preferences.

From the methods section in your paper, I understood almost everything that you did. Everything was written down very clearly and most already existing methods were referenced properly (e.g: the undisturbed samples by the multi-step apparatus (van Dam et al., 1994) in line 157-158; "... by the Eijkelkamp pressure membrane apparatus (Klute, 1986)" in line 160; and "... using the two heads method (5 and 10 cm) (Reynolds and Elrick, 1985)" in line 165-166. Aso, figures 1d and 1e helped visualize the vegetation types and table 1 helped understand the text by visualizing what these sample locations look like. However, the reasoning behind some of your methods are not fully clear to me. For example:

- It is unclear from the text that you did not violate the assumption of independence between observations of the Mann Whitney U test since you took multiple samples from one location. Can you prove that you did not violate this assumption?
- Also, you write that the mean annual rainfall values (2019-2020) did not differ significantly between the two sites (line 375). You however do not show what statistical test is used to determine this significant difference. Can you include this in your methods?
- Furthermore, you write that, for preparing the soil samples for soil texture determinations, the carbonates and OM were removed. Bieganowski et al. (2018) writes that, while there is no uniform soil preparation standard compiled, the best known method describes that – besides OM – soluble and gypsum removal is obligatory, and besides carbonate, iron oxide removal is optional. Can you argue why you only removed the carbonate and OM and not these other components?
- In your introduction, you reference Molina et al. (2019): "*Here, we take advantage of the mosaic-like distribution of vegetation types in the high Andes ecosystem, changing over short distances and allowing other factors (i.e., climate, geology, soil age, and topography) to remain constant*". This sentence makes it seem like it is important for the topography to remain constant for this experiment. However, Molina et al. (2019) write "*High Andean tropical ecosystems provide a good opportunity to study the association between chemical weathering, local topography, and vegetation patterns: the climate, parent material, and soil age can be held constant at the landscape scale, while the vegetation and slope morphology*

can vary greatly from the hilltops to the valley bottoms.". Therefore the topography can vary between the two locations. Another paper done at your study sites (Páez-Bimos et al., 2022) concludes "*Soil hydraulic properties and soil pore structure changed in the uppermost horizons (A1 and A2) under cushion-forming plants and tussock grasses; whereas they did not change at topographic position.*". Can you specify whether the topography between the two sites is the same and if it was not, whether this influences your conclusions?

To conclude, while I think your scientific methods are clearly outlined and reproduceable. I think by elaborating more on these methods, your approach will have a more solid basis for the reader.

I like that you explain your results in the discussion with many references, e.g.: "The higher ETa under cushion-forming plants compared to tussock grasses is consistent with a recent study in the same sites based on water stable isotopes (Lahuatte et al., in rev.)" in line 483-484; and "The limitation of soil water transmission (e.g., by a reduction in vertical hydraulic conductivity) can result in saturation even at low rainfall intensities during prolonged precipitation events (Burt and Butcher, 1985). Thus, under tussock grass in the A horizon, the soil water storage capacity is limited by..." in line 497-499. However, your conclusion that a shallower and coarser root system is related to a more porous soil structure is not explained anywhere in the text. I think you should explain this in your discussion. I would recommend to reference to your previous paper Páez-Bimos (2022), possibly with some of the other results from there, like relating the strong decrease in saturated hydraulic conductivity with depth under cushion forming plants facilitating the soils to become saturated faster to the ash deposits.

In your paper, you make some conclusions that I could not find significant evidence for in your paper. I think this weakens the conclusions of the paper: right now I am not convinced that the conclusions are substantiated. For example:

- In the conclusion (line 669), you write "*Other solutes like DSi, Na, HCO_3^- are only minimally influenced by vegetation type.*". However, the highest HCO_3^- concentration was found at the greatest depth under tussock grass which, according to the you, cannot be explained by the root network or SOC and needs further investigation (line 596). Therefore it is unclear to me how you reach the conclusion that there is only a minimal influence from vegetation type on HCO_3^- if the highest found concentration cannot be explained by the root network or SOC and needs further investigation. You now only include sources about HCO_3^- (in line 595) that found "higher root and microbial respiration can enhance carbonic acid formation, which then dissociates into HCO_3^-". Can you reference a source that finds the deep high HCO_3^- concentration cannot be explained by the root network or SOC?
- You conclude "*In our study sites, we evidenced the role of root systems in regulating the soil water balance.*" (line 668-669). I did find statistical evidence that there were differences between the vegetation types in solute concentrations and fluxes, but I could not find statistical evidence that there were differences between vegetation types in the soil water balance or evidence for this causality. Can you explain how you proved the causality of vegetation root systems regulating the soil water balance?
- The annual solute fluxes of cations and DSi (taken as a proxy for weathering) are systematically higher in the TU-UP profile (line 449-451), but you write Na and DSi differences are not significant (line 589, although figure 8 shows Na differs significantly at 20 and 40 cm and DSi differs significantly at 40 cm) even though DSi was observed as one of the two dominant soil solute fluxes (line 538). Can you explain how you evidenced that there are chemical weathering differences between the vegetation types if this is the case?

- I cannot find statistical evidence for the causality relationship of the vegetation type affecting the contemporary soil chemical weathering (line 673-674). Can you prove that there is causality here?

In conclusion, I do not think the statistics and results you showed are sufficient to support your conclusions at this moment. I think including some sources for HCO_3^- and evidence of causality will prove you reached substantial conclusions, which would improve the paper remarkably.

I also have some minor issues, that are summed up below:

- I am not sure if the title clearly reflects the contents of the paper. First of all, it does not become clear in the paper what the difference between solute flow and transport is. Also, the title is only associated with research question ii. There is no mention of chemical weathering, which was addressed in research question iii.
- The abstract only mentions that the vertical distribution of soil properties associated with the root systems. It does not explain what the mechanism is here, while the role of the roots is explained in the conclusion quite well. I think this misses from the abstract. Also, the abstract does not mention the location of the measurements.
- Your paper aims to fill the knowledge gap of how vegetation can influence contemporary weathering rates through its effect on soil water fluxes and transport. It is unclear how this information can be applied, can you give an argument for why the knowledge gap needs to be filled?
- In figure 4, the dots are very hard to distinguish from the simulated line. Also, the legend colors are very hard to relate to the colors in the picture.
- I think the number and quality of your references is appropriate. When I checked some of your sources (e.g. Fan et al., 2017; Jiang et al., 2018), I could not find any incorrect interpretations and these sources seemed of high scientific quality. However, I noticed that you included two papers in your reference list that were under revision by the time you wrote the paper. When I checked them it appeared that they have been published already. I will include them (Lahuatte et al., 2022; Páez-Bimos et al., 2022) in my reference list for you to include them.
- Páez-Bimos (2022) quantifies the root abundance and diameter, is that what you used for the relative root sizes in figure 10? If so, can you reference this paper in your figure for that?
- The paper is inconsequent in the APA references in the text: when two authors are included, sometimes '&' is used, sometimes 'and' is used.
- P7, line 187 and p9, line 235 reference to figure 2e, which does not exist.
- P7, line 160 writes ""36 undisturbed and 18 undisturbed samples". I think one of these should be "disturbed".
- P26, line 619 says "0.4 times, respectively". However, I am not sure this is correct since the two transmissions do not both seem 0.4. When I did my own calculation it seemed more like "0.44 and 0.79 times respectively"?

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