Dear editor and reviewer,

please find below our point-by-point reply to the comments made by the reviewer. References to line numbers refer to the revised manuscript including track changes.

Reviewer #2 comments:
After discarding those controversial or unclear analyses in the original submission, the revised MS has been greatly improved. Most of my following comments are editorial.

We thank the reviewer for the evaluation of our manuscript, the insightful comments and the reviewer's interest in our manuscript.

Line 26: change "increasingly" to "significantly".

Changed.

Line 101: the now deleted words state water availability in the region does not match time series of rain-gauge data. I am curious why rain gauge data is not correct?

The deleted sentence refers to the previously published analyses of weather station data in the "context of perceived changes by local farmers". As stated in the Introduction section, Gurgiser et al. (2016) found in interviews that farmers report detrimental effects to their agriculture in the past decades. Their analysis of available rain-gauge data however did not show any meteorological trends or an increase in extreme events as reported by the farmers. The argument we originally wanted to make here (and still do in the revised manuscript from l. 43 and discussed from l.301) is that to date it remains unclear whether the mismatch of farmers' reports is due to incorrect rain gauge data or their perception not meeting actual changes (or not-changes).

Line 171: Are there any references to the extraction of SOS/EOS, especially the threshold of "30%"? rather than the generally used 50%?

We used 30 % as this is the default setting in the DATimeS software (Belda et al., 2020). We reformulated the sentence to clarify (see l. 150).

Line 176: How do you define "POS"?

Good point, in contrast to SOS and EOS it is undefined in the current version. POS (Peak Of Season) is defined as the day of season where the maximum NDVI value occurs. Added to the revised manuscript (see l. 150).

Line 181: suggest to delete "variability in"

Deleted.

Section 3.1: I did not quite understand the rationale of introducing soil moisture data here. (1) Soil moisture agrees better with NDVI in monthly scale, and such a advantage is not clear at annual scale. (2) There is no sufficient proof showing precipitation is a better indicator than soil moisture. Then, why soil moisture is not included in the following analysis?

The rationale of introducing soil moisture (SM) data was to show the relationship between NDVI and different components of the hydrology following the reviewers' comment iii) and iv) and the discussion with the editor.

Regarding (1): Yes, SM data shows higher agreement with NDVI than rainfall on monthly scale (Fig 2a). We did not perform the analysis for the annual scale (Fig 2b) as the SM data is unfortunately only available since 2015 and we do not consider correlations based on five data points to be sufficiently robust.

Regarding (2): We do not argue that precipitation is a better indicator than SM, in fact we state the opposite (from l. 173). SM is not included in the subsequent analysis as we focus on the near-climatological MODIS era 2000-2020 and the SMAP data is only available from 2015 onwards.

Line 221-222: This statement may be unfair; why soil moisture data is not presented in Fig. 2b?

See also the previous answer. On a monthly basis for 2015-2020, SM yields higher explained variance than CHIRPS but on an annual scale 2000-2020 (where comparison with SMAP is not applicable) CHIRPS reaches a relatively high explained variance.

Line 223: Fig 2b should be Fig 2d??

Correct, changed.

3.2 subtitle: and "their consistencies?

Changed.

Line 239: any "significant" changes? no changes != no significant changes

Added.

Line 253-256: The KDEs in Fig. 5 is inferred from two specific regions (e.g., Cordillera Negra and Blanca), respectively. (1) RSB is the combination of Cordillera Negra and Blanca? (2) To be straightforward, please provide the KDE map of phenology over RSB during the study year.

Regarding (1): Yes both regions together are the complete RSB watershed. In the manuscript (l. 100) we state where the eastern (Blanca) and western (Negra) parts of the RSB watershed are located and it is shown in Fig.1. However, we agree that this might be confusing.

Regarding (2): We added a direct reference to Fig.1 in the caption of Fig.5. to clarify.

Line 290: Please clarify the "mean seasonal precipitation" here. Does it refer to the averaged precipitation during the period 2000-2020 or the neutral years??

Reformulated. It refers to the sum of the mean monthly precipitation sums for the period 2000-2020 and not to the neutral years.

Line 322: NDVI changes: Note that both NDVI and CHIRPS precipitation data are detrended there. NDVI changes should be NDVI variabilities?

Yes, agreed and changed.

Line 343-345: I do not suggest to add these sentences (from “they cannot explain” to “land-cover change.” here, since the authors have excluded regions with land-cover changes, see lines: 188-191

To clarify, we think that we rather accounted for land-use effects (such as irrigation which decouples NDVI and water availability) but we did not account for land-cover change (l. 168: “We did not account for land-cover change during…..”). We therefore would prefer to keep these statements as we believe our analysis is more reputable if we discuss potential weaknesses and limitations.

Line 377: We cannot find a significant advance in SOS ...SOS in RSB is featured with "high interannual variability but no significant trend"

Reformulated.

Line 394: “water availability” should be "plant water availability" ?

Added.

Fig.1: (1) Why these cities (or sites) are not included in the main figure? (2). There is no obvious East-West gradient in precipitation among these cities (sites).

Regarding (1): The reason is simply the map scale and aesthetics. On the scale of the full RSB the locations of the observations would be hard to distinguish.

Regarding (2): We agree, that pattern might be relatively hard to identify in that plot. In fact, we find the highest seasonal precipitation in the easternmost plot (Carachuco), while Llupa and Paquishca show a very similar amount (they are in sight of each other). Similarly, the two western rain gauges show a very similar signal while the rain-gauge Universidad, located at the valley floor has the lowest values which might be an altitudinal effect. To be more precise, we changed the plot from monthly precipitation sums to cumulative precipitation sums (see below for a large version) and reformulated the caption to “Lower right panel roughly illustrates the East-West precipitation gradient…”. Although the data shows not a strict East-West gradient at all stations, it captures that rainfall sums at the eastern Coordillera Blanca range are roughly 1000mm/season while the Coordillera Negra rain gauges receive approximately 300mm less per season.

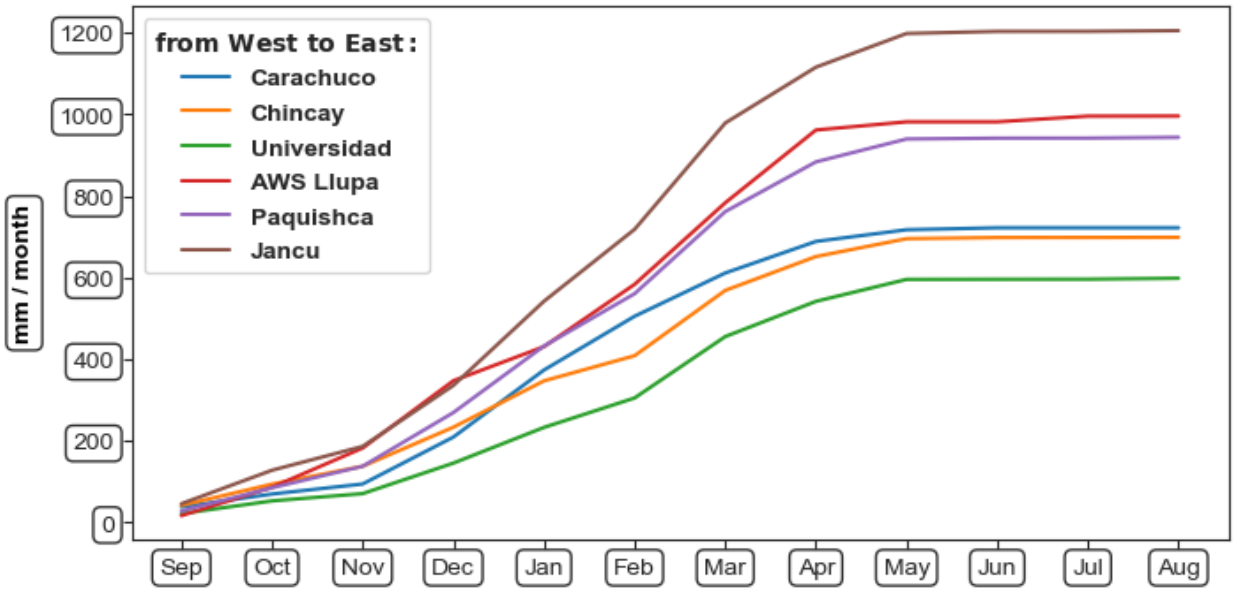

Fig.2: (1). Better correlation between NDVI and soil moisture is found there. (2) why soil moisture is not included in Figure 2b? Then, it is unfair to say precipitation agrees better with NDVI. (3) Why the correlation between precipitation and NDVI differs across different timescale? Time lag effect??

Regarding (1): Correct.

Regarding (2): See our previous reply to the same question above.

Regarding (3): On a monthly basis, the correlation of NDVI and precipitation is comparably low. In Fig. 2a this correlation is based on the data of 2015-2020 due to the availability of the SM data. It yields a coefficient of determination of 0.11. For 2000-2020 this value is slightly improved but still similarly low (see plot below). In contrast, on an annual scale this correlation drastically improves. The reviewer is correct that this is related to a time-lag effect but we would rather describe it as NDVI being a cumulative indicator of water availability which in turn is governed by inputs into the hydrological system (i.e. precipitation). Consequently, anomalously wet seasons yield anomalously green vegetation and vice versa. The near-immediate response as interpreted through monthly anomalies is less clear for several reasons: 1) in the wet months we do not expect a direct response of vegetation to additional rainfall inputs but this additional moisture might be beneficial after the retreat of the seasonal rainfalls, 2) similarly, this might be the case for the driest time of the year and 3) the time lag between NDVI and precipitation is varying dynamically over the season as schematically presented in Fig. 2c.

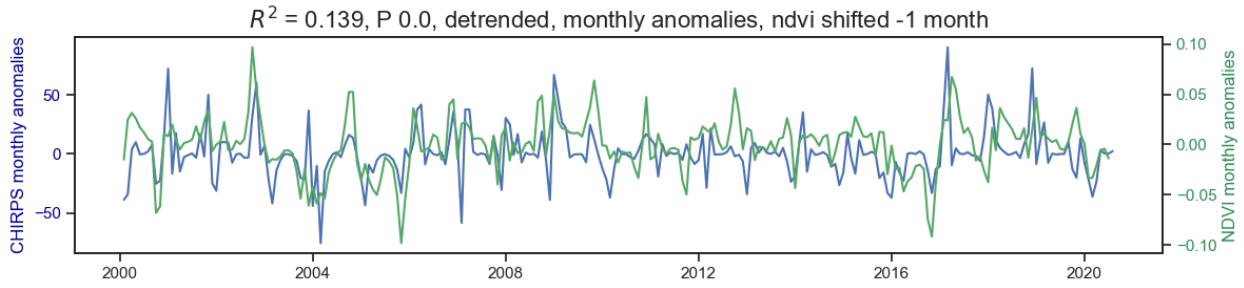

Fig.3: How about providing a map showing the day season changes in NDVI and precipitations?

We apologise that we do not understand what the reviewer means with “day season changes in NDVI and precipitations”.

Fig.4: I do not think it is wise to only take pixels with significant changes in NDVI into consideration. For example, the average NDVI trends, Mar (4g) vs. May (4i).

We are not completely sure what the reviewer is suggesting here. The data availability differs between the rainy (e.g. March) and the drier months (e.g. May). The idea about showing these maps is to transparently show where and when trends occur and data availability issues due to cloud cover (grey in the map) during the rainy season. We do not use average monthly trends of NDVI in any plot or sentence throughout the manuscript. In case the reviewer is referring to the inset plots: These are monthly domain average CHIRPS data as stated in the caption: “Small panels show domain mean CHIRPS rainfall data for the respective month and additionally decadal slope (m) and linear regression statistics for significant ($p < 0.05$)”. We added a few words to the figure caption to clarify.

Fig.6: LOS is mainly determined by EOS

We believe the reviewer mixed up SOS and EOS. We mentioned in the text (l 205) that LOS is mainly governed by SOS. It has a high variability over the period of observation with a variability range of up to 60 days while EOS only varies up to 34 days (compare e.g. Section 3.3 or Fig. 5). We added a sentence in the text (l. 212), explaining the effect of the EOS trend on LOS in the context of the SOS variability.