Reviewer asked which site?

Authors: Thanks for the crucial question, we have clarified in the abstract that the study validated ETa at the field scale and extrapolated to irrigation scheme scale.

Reviewer asked: meaning "values extrapolated from lysimeter"?

Authors: We appreciate the comment, we clarified to: extrapolated ETa values from the field lysimeter and weather station.

The reviewer stated: This is overstated, given the findings mentioned previously only stops at which model perform best. Maybe explain how you see the findings contribute “reduce the overuse of water in agriculture”.

Authors: We appreciate the comment, we have revised the abstract to clarify that the study demonstrates the potential of accurate ETa estimation to support better irrigation scheduling, which may lead to reduced water overuse, particularly in water-scarce arid environments.

Reviewer asked: what do you mean? which direction?

Authors: Thanks for the question, we have revised to: Revised to: combination.

Reviewer asked: what about evaporation from canopy interception?

Authors: Thanks for this, canopy interception included.

Reviewer commented: ETa is crop water use, not crop water requirement. Requirement depends also on yield target.

Authors: Thanks for this, we have revised to distinguish ETa as actual crop water use.

Reviewer highlighted: lost through the process of ET.

Authors: Revised.

Reviewer commented: all previous sentences are referenced, but this one is not. Is there a reason? Is this statement based on empirical studies on farmers' practices?

Authors: Thanks for the comment, citations have been included.

Reviewer asked where citations are?

Authors: Thanks for the comment, we have included citations.

Reviewer asked, which device specifically?

Authors: Specified the device as smart field weighing lysimeters and eddy covariance systems.

Reviewer recommended: You need to define ETc like how you define ETa.

Authors: Thanks, we have defined ETc.

Reviewer has asked, by whom? where? why cite a German article from 1926?

Authors: Thanks for this comment, we have included a more local study: Moeletsi et al. (2013).

Reviewer commented: ETc = Kc * ETo. And Kc = ETa/ETo. This means ETa = ETc. So why do you use two different terms? Please explain clearer

Authors: Thanks for this comment, we have clarified this point. The difference between ETc and ETa is that ETa is influenced by the actual field conditions which are determined through actual field measurements while ETc is based on estimations based on standard Kc values. ETa and ETc can be equal under non-stressed, well-watered conditions, but they diverge when stress is present. While ETc represents how much water the crop would use ideally, ETa tells us how much water the crop used, making ETa more dynamic and field-condition specific.

Reviewer commented: "I think you should cite the two FLUXNET datasets instead of this paper".

Authors: Thanks for the suggestion, we have included the two papers citations, by Baldocchi et al. (2001) and Pastorello et al. (2020).

Reviewer has commented: This makes the sentence very long and difficult to follow.

Authors: Thanks for this, we have revised to: Remote sensing offers a practical way to estimate ET over large areas, given the cost and logistical challenges of ground-based measurements across diverse vegetation.

Reviewer asked: Do you mean ground-based measurement lack temporal resolution required? I think it's the other way, RS lack temporal resolution since satellites only capture a snapshot once every few days.

Authors: We have revised this section.

Reviewer has asked for a revision.

Authors have revised as requested.

The **Reviewer** asked: which scales? Landsat provide 30m scale (optical) and 100m (thermal)?

Authors: Thanks for the comment, we have revised this.

The **Reviewer** commented: not clear. please revise.

Authors: We have revised this section.

The **Reviewer** has asked: 85% of what?

Authors: We have revised and made this clearer.

The **Reviewer**commented: this does not follow the previous sentence (about SEBAL high accuracy) well

Authors: Thanks for this, we have made a clear link.

The **Reviewer**has asked: do you mean that there is no water scarcity issue for this scheme?

Authors: Thanks for the comment: We have revised for a clear understanding: This is because the scheme lacks its own source of water to sustain productivity, however; the scheme depends on water from areas such as the Vaal River through the Bloemhof dam.

The **Reviewer**commented: if the billing is based on flow meters, why do people need to know the amount of water used by crops?

Authors: Thanks for this, more information added: These amounts are crucial in irrigation water management particularly for regional water accounting, understanding the crop water demand helps with allocation and long-term sustainability planning.

The **Reviewer**commented: whose need? irrigation scheme manager?

Authors: Thanks for this question: we added: to support informed decision-making by researchers, irrigation water managers and policymakers

The **Reviewer**asked: which locations exactly?

Authors: We added: to extrapolate ETa from lysimetric measurements to other fields within the irrigation scheme that are equipped with weather stations.

Reviewer made a highlight.

Authors: We made revisions.

The **Reviewer**commented: so there are multiple types of crops in the scheme. I would expect that NDVI-Kc relationship varies for different crops. While you only have one lysimeter (did not mention which crop grown in the field), how can you extrapolate that relationship to other types of crops?

Authors: Thanks for this, we revised for clarity: The study was conducted from September 2019 until May 2021 capturing different seasons and crops. In 2019, winter barley was planted in the experimental field, while in 2019-2020 summer season, maize was planted. During the 2020 winter season, barley was planted again while in 2020-2021 summer season soybean was planted.

Reviewer commented: Missing station names in Figure 1.

Authors: We have included station names in Figure 1.

Reviewer commented: legend: Blue color is reservoir, not dam. where is the experimental farm located in Vaalharts irrigation scheme? Where is the lysimeter located in the experimental farm? I don't really understand the figure 1b. you need to add more description in the caption. what are we seeing here? why is the shape ?

Authors: We have revised from dam to reservoir. We indicated that the experimental farm is located where SABBI station is located. Figure 1b is the experimental farm where ground measurements are installed demarcated by the red boundary. The shape shows a pivot irrigated field which is now indicated on the manuscript figure caption.

Reviewer commented: Is this within the scheme? it's not indicated in panel (a)

Authors: We have indicated on the study area figure.

The **Reviewer** commented: incomplete sentence.

Authors: We have completed the sentence.

The **Reviewer** commented: which scale exactly?

Authors: Thanks for the comment: we have revised with “an irrigation scheme”.

The **Reviewer** asked: how exactly?

Authors: Thanks for the comment, we have revised, with the following additions: The atmospheric correction was done using the Dark Object Subtraction 1 (DOS1) method. The method assumes that some pixels in the image such as water bodies or shadows should have very low or zero reflectance in some bands, especially in the visible range. These pixels represent dark objects, because of atmospheric scattering; these pixels appear brighter than they should. The DOS1 method subtracts a constant value, which is the assumed atmospheric path radiance from all pixels in each band to correct this atmospheric effect and improve surface reflectance accuracy.

Reviewer commented: using which method?

Authors: Thanks for the question. We included: using the raster calculator and bilinear resampling method in QGIS to align with the 30 m resolution of multispectral bands.

Reviewer commented: you mentioned the bands used in this table. But nowhere else these bands are mentioned again.

Authors: Thanks for the comment, the bands have been mentioned on model input variables such as NDVI, SEBAL, CWSI.

The Reviewer commented: not mentioned barley in the text, only in figure 2

Authors: We have included barley in text relating to lysimeter data capturing.

Reviewer commented: what does this mean exactly? did the filter replace the spikes with certain values or what?

Authors: We have made this clearer as in what the filter does.

The Reviewer commented: should have the same unit as deltaD and deltaS? what is the unit of ETa?

Authors: Thanks for this, however this is solved on the follow-up derived equation and this is why: Irrigation is measured as mm from an irrigation gauge, however equation 1 derives equation 2 based on the principle of zero-irrigation which result in ’’I’’ being negligible.

The Reviewer suggested the removal of ETa.

Authors: Thanks for the error suggestion, we removed ETa.

Reviewer commented: time instead of tine.

Authors: We have revised tine to time.

The Reviewer asked: which variables specifically?

Authors: Thanks for this, we have revised to, “These variables included air temperature, relative humidity, solar radiation, wind speed, wind direction, rainfall and barometric pressure”.

The Reviewer asked: specify the method used to derive them.

Authors: We have revised this to: These indices were derived using spectral band ratio and combination methods where reflectance values from specific multispectral bands such as red and near infrared are mathematically combined to represent vegetation properties like health, canopy density and greenness using vegetation index formulas directly to the satellite spectral bands.

The Reviewer asked: How exactly?

Authors: Thanks for the question: We clarified this with: “The vegetation indices serve as proxies for the fractional vegetation cover and leaf area index, which both of which influence transpiration rates. On the other hand, the values of ETo represents the evaporative demand of a hypothetical reference crop under optimal water conditions. The Kc relates actual crop water use to the atmospheric demand. Since the Kc values differ over the crop growth stages reflecting changes in canopy development, vegetation indices derived from remote sensing are used to estimate Kc values. The empirical or semi-empirical models establish relationships between vegetation indices and Kc values by calibrating observed ETa from the lysimeter against vegetation index values”.

Reviewer commented: all remote sensing-based algorithm can do this. so what's the real advantage of this algorithm?

Authors: We have revised this with: This algorithm was selected because it links the VIs to Kc values, which removes the complexity of physical modelling or detailed parameterization required by energy balance or surface temperature-based models, which rely on high-quality thermal data and complex calibration. The approach relies on multispectral data to represent the spatial distribution of crop water use. Moreover, this algorithm provides a simple scalable ETa estimates with relatively low computational demand, enabling effective monitoring over large areas with frequent temporal coverage. It is also easier to customize and calibrate the algorithm to specific crop types or land covers using ground data, which can improve its accuracy.

The Reviewer commented: Missing unit.

Authors: Thanks, unit included (W m^{-2}).

Reviewer: you mentioned weather station was installed at 1.2m. So how did you get windspeed at 2m?

Authors: We have revised this to 1.2 m.

The Reviewer asked: what are the values of these constants that you used?

Authors: For this study we included: Cn=900 and Cd=0.38.

Reviewer asked: you mean ETa measured by lysimeter?

Authors: Thanks for the comment, yes, we included it on text.

The Reviewer commented: can that one farm be representative of the entire irrigation scheme? (e.g., in terms of crop type, agriculture practice, crop conditions)

Authors: Thanks for this question. One lysimeter cannot be representative, this is why we extrapolated ETa using NDVI to have a spatial representation.

The Reviewer commented: I understand the limit, but it's not an excuse to extrapolate one single farm to the entire scheme.

Authors: The extrapolation is not only based on a lysimeter, but this uses a relationship between ETa and ETo under less stressed conditions developed at farm scale. Then this relationship is applied on all weather stations.

The Reviewer picked a typo: NDVI?

Authors: We have fixed to NDVI.

The Reviewer commented: This is only an implementation of SEBAL algorithms as described by Bastiaanssen (1998). You need to explain in detail how the formula in Bastiaanssen is applied in this plugin.

Authors: We have included: he SEBCS plugin in QGIS implements the SEBAL algorithm as described by Bastiaanssen (1998), allowing for the estimation of ETa using satellite thermal and multispectral data. The SEBAL algorithm is based on the surface energy balance equation, where ETa is calculated as the residual of Rn, G, and H. The plugin automates the derivation of each component wherein: Rn is computed using incoming and outgoing shortwave and longwave radiation, with albedo derived from multispectral reflectance bands. The component, G is estimated empirically using NDVI and surface temperature, while H is calculated through the near-surface temperature gradient and aerodynamic resistance derived from the selection of hot and cold anchor pixels. The plugin uses an iterative approach to link surface temperature to temperature differences and applies default or user-supplied wind data to estimate H. Lastly, the latent heat flux is obtained as the residual energy of Rn – G – H, which is converted to ETa in mm per day using the latent heat of vaporization.

The Reviewer commented explain how SEBCS compute Rn, G, and H.

Authors: We have added more information on the paragraph.

The Reviewer commented: include equation of deltaT

Authors: We have added the deltaT equation.

Reviewer commented: LST is land surface temperature, then what is LST_air?

Authors: Thanks for this comment: We revised to T_air, which is air temperature

Reviewer highlighted numbering error, suggesting 2.4.4.

Authors: Thanks for this key aspect, we have revised the numbering accordingly throughout the document.

Reviewer highlighted that: Missing full name of SEBS

Authors: Surface Energy Balance System added.

Reviewer commented: In equation 7, there's also soil heat flux. what's the difference between two models exactly?

Authors: SEBAL is empirical and relies on anchor pixels while SEBS is a physically-based model which uses atmospheric theory and requires more weather data.

Reviewer commented: it's not clear how these variables were calculated based on your description

Authors: Thanks for the comment, we have demonstrated how the variables were calculated.

The Reviewer commented: in equation 5, you use gamma (γ) to denote psychrometric constant. I suggest you use the same here to be consistent.

Authors: Thanks for the comment, the one mentioned in eq.5 is a standard atmospheric property that relates the partial pressure of water vapor to the air temperature and pressure. The ones defined here separate soil and air.

Reviewer highlighted errors in numbering 2.5 and 2.5.1.

Authors: Thanks a lot for this, we have fixed the numbering.

Reviewer commented: revise this long sentence. it's cumbersome to follow

Authors: Thanks for the comment, we have revised the sentence as: The ETa estimates from the four evaluated algorithms were validated by directly comparing them with daily ETa measurements from a smart field weighing lysimeter over 22 days across different cropping seasons at field scale.

The Reviewer commented: which relationship? how to you develop it?

Authors: Kc=ETa/ETo, therefore ETa=Kc*ETo, this relationship was used.

Reviewer commented: numbering error: 2.5.2.

Authors: The numbering was fixed as recommended.

The Reviewer highlighted SE: to be, RMSE

Authors: Thanks for this, we have fixed the error to RMSE.

The Reviewer highlighted: this is standard error, so it does not evaluate systematic over- or underestimation.

Authors: Thanks for the comment, we have fixed this, the values of SE reflects the variability of the error distribution between the algorithm-estimated ETa and the lysimeter-measured ETa. A lower SE indicates that the estimates are consistently close to the actual measured values which suggests higher precision.

The Reviewer asked: at which locations? lysimeter?

Authors: Thanks for this. Yes, at lysimeter location, we have added this information for clarity.

The Reviewer suggested the usage of a small letter on Seasons to seasons.

Authors: Thanks for the comment, we have fixed this to lower case.

The Reviewer suggested including maps of mean and coefficient of variation (CoV) of ETa values from 4 models to demonstrate this point.

Authors: We appreciate the **Reviewer**'s suggestion to include maps of the mean and coefficient of variation (CoV) of ETa values from the four models. However, our study already includes maps of the spatial distribution of ETa, which played a key role in identifying correlation pixels for evaluating the model estimates against lysimeter measurements. We recognize that CoV maps can be useful in highlighting spatial variability over time. However, given the focus of this study on operational applicability in irrigation scheduling, our emphasis was on preserving temporal detail, especially at daily time steps. The lysimeter provides real-time, high-resolution ETa data that is essential for daily irrigation management. Averaging ETa values across time to produce mean or CoV maps would risk masking short-term fluctuations that are critical for detecting irrigation events, crop water uptake, and stress responses. Furthermore, we maintain that direct pixel-to-lysimeter comparisons performed on a daily basis offer a more meaningful and actionable evaluation of model performance, especially in precision agriculture where day-to-day ETa variation directly informs irrigation decisions.

The Reviewer suggested: Please use the same range of colorbar of each sub figure, so it's easier to see the spatial difference between these models.

Authors: Thanks a lot for this comment, to improve visual comparability, as suggested, we have standardized the color bar ranges across all spatial distribution maps.

The Reviewer suggested: you need to back this observation with actual results (e.g., MAE)

Authors: Thanks for this, to back up the above mentioned, we included this: SEBAL had the lowest average MAE of 0.46 mm d^{-1} across the four validation sites, compared to 0.52 mm d^{-1} for the VI-based ETa and 1.17 mm d^{-1} for SEBS.

The Reviewer commented: by how much? what is the bias value?

Authors: Thanks for this question, we have included more information on this. Across the four validation stations, SEBAL exhibited an average bias of approximately 0.22 mm d^{-1}, indicating a slight tendency to overestimate ETa. In comparison, VI-based ETa had a slightly higher average bias of 0.26 mm d^{-1}, while SEBS showed a more pronounced overestimation bias of 0.89 mm d^{-1}.

The Reviewer asked, what does this mean?

Authors: Thanks for the comment, we meant high variability of estimated ETa to field ETa, we have fixed this in text.

The Reviewer noted that there is no Figure (S7) as indicated in text.

Authors: Thanks for this comment, we have fixed the error to (S1) which is on supplementary material.

The Reviewer commented: From the figure VI seems to perform best. why did you conclude that SEBAL perform best?

Authors: We appreciate this comment. However, among the evaluated algorithms, both SEBAL and VI-based ETa showed strong agreement with lysimeter measurements; however, SEBAL demonstrated slightly higher correlation and more consistent performance across multiple validation sites, indicating its robustness for broader spatial application within the Vaalharts Irrigation Scheme.

The Reviewer commented: in 3.3 you say field scale. Either field scale or farm scale, be consistent.

Authors: Thanks for this comment, we have revised the section to field scale.

The Reviewer commented: why multi-stations?. In L363, you says this figure compare with the lysimeter (one single station)

Authors: Thanks for this, we have revised this error. We meant at the experimental site.

The **Reviewer** commented: how many days exactly?

Authors: Thanks for the question, we have included the number of days as 22 days cloud-free.

The **Reviewer** commented: total means over the entire irrigation scheme or what? if it's total ETa at the experimental farm, it should be subsection in 3.3

Authors: We thank the reviewer for pointing this out. The "total ETa" referenced in the manuscript refers specifically to the experimental farm area, not the entire irrigation scheme. We agree with the reviewer that this should be made clearer in the manuscript. We have moved it to Section 3.3, as suggested, to ensure it aligns with the structure and focus of that subsection.

The **Reviewer** commented: so is this enough to make a conclusion for the scheme in general.

Authors: We appreciate this important question. We appreciate the reviewer’s important question. Our analysis and conclusions are specifically based on the experimental farm area, which served as the validation site due to the availability of lysimeter-derived ETa and supporting data. While this area represents only a portion of the broader irrigation scheme, it was selected to ensure high-quality ground-truth data for accurate model evaluation. The extrapolation and testing of ETa extrapolated using weather stations makes the conclusions more sound in such data scarce environments.

The **Reviewer** commented: Total ETa. When you aggregate, the under-/overestimation from different days are cancelled out, which results in lower error in the total estimates. But it does not mean all estimates are accurate

Authors: We appreciate the reviewer's observation. We do acknowledge that aggregating ETa over time such as summing daily ETa to compute a seasonal or total value can lead to an apparent reduction in error due to compensating biases where overestimations on certain days offset underestimations on others.

The **Reviewer** commented: you extrapolated ETa, not measured it at these locations.

Authors: Thanks for this comment, we have fixed this to extrapolated on the manuscript.

The reviewer asked: could it be that SEBS is less well calibrated than SEBAL? The performance of these algorithms depending on how you calibrate them

Authors: We appreciate the reviewer's observation. We do acknowledge that SEBS may be more sensitive to certain input parameters such as atmospheric stability, roughness length, or surface resistance than SEBAL, and this could partially explain the observed differences in performance. SEBS includes a more physically explicit representation of the surface energy balance and turbulent heat fluxes, which can increase its sensitivity to uncertainties in meteorological inputs or surface characteristics.

The **Reviewer** commented: is this p-value of r? how many data points were used?

Authors: We appreciate the reviewer's comment. Yes, the reported p-values represent the statistical significance of the Pearson correlation coefficients, testing the null hypothesis that there is no linear correlation between the estimated ETa and the measured or extrapolated ETa values. The number of data points used for each correlation analysis corresponds to the number of satellite overpass days with cloud-free imagery and available lysimeter or weather station data which is 22 days.

The **reviewer** commented: his section can be combined with 3.5 since it presents the same results (in scatterplots instead of tabular statistics): Comparison of modelled ETa with extrapolated ETa at weather stations

Authors: Thanks for the suggestion, we have combined the two sections.

The **Reviewer** highlighted that the first paragraph of the discussion is not a discussion.

Authors: We revised the section to provide a brief start about the study outcomes as: This study focused on the evaluation of multiple remote sensing-based ETa algorithms against lysimeter observations and extrapolated ETa values using weather stations. The main findings of this study were the observed differences in model performance. The findings demonstrated that, SEBAL consistently showed the most accurate estimates, which were followed by VI-ETa and SEBS. However, the CWSI-ETa demonstrated limited reliability. The study findings

demonstrate the strengths and limitations of each algorithm as well as their implications for operational water management in irrigated agriculture.

The **Reviewer** commented: but you based on regression of NDVI and ETa at one single lysimeter representing only barley. How can you conclude that it is reliable over the entire irrigation scheme with diverse crops?

Authors, we acknowledge that details about other crops were limited. We did the regression based on three different crops although barley was done twice. We included barley, maize, barley and soybean seasons.

The **Reviewer** asked: which results support this statement?

Authors: We appreciate this question. The Kc ensemble model on supplementary material is based on the four cropping seasons including barley in 2019, maize in 2019-2020, barley in 2020 winter and soybean in 2020-2021 seasons.

The reviewer commented: ground-derived Kc is for barley crop at the location of lysimeter, not representative of all crops

Authors: We included barley in 2019, maize in 2019-2020, barley in 2020 winter and soybean in 2020-2021 seasons, we added this information for clarity.

The reviewer suggested: at least include lysimeter measurement of other crops before concluding this.

Authors: We appreciate the comments we have included the crop information which was missing.

The **reviewer** suggested: his is key results, but not mentioned in abstract

Authors: We have included the section on the abstract.

The reviewer commented: but how are these representatives of the entire scheme? what assumptions must hold?

Authors: We appreciate this comment; we have included more information: The ETa estimates in this study were extrapolated across the irrigation scheme using remote sensing algorithms parameterized with meteorological data from a weather station located within the experimental field. This approach assumes that atmospheric and surface conditions across the scheme are sufficiently homogeneous for the station data to be representative of the broader area. These assumptions are reasonable in the study area due to the relatively uniform topography, similar cropping patterns and consistent irrigation practices throughout the scheme. However, the local variability in microclimate, soil moisture and crop conditions could influence ETa estimates at finer spatial scales.

The reviewer commented: why do you cite FAO56 paper here for a statement on SEBAL?

Authors: Thanks for this comment, we have revised the citation.

The **reviewer** commented: this is the key limitation of the method, but authors don't seem to have outlined in detail how they mitigate this limitation. This makes the overall method sounds lack of rigour. For example, the authors could have considered errors in extrapolation, errors in measurements and propagate them to the validation results to show how sensitive the results (and conclusion) are.

Authors: Thanks for this valuable comment, to clarify this. We included a sensitivity analysis in our methodology, results, discussion and conclusions of the manuscript.

The **Reviewer** commented: this is not well supported by the results. based on what do you conclude this potential?

Authors: Thanks for the comments, we have added a section: Revised to, The SEBAL algorithm provided highly accurate ETa estimates when evaluated against the smart field weighing lysimeter data at the experimental site within the Vaalharts Irrigation Scheme. This was indicated by the high R^2 value > 0.90 and RMSE which was as low as 0.31 mm d^{-1}, This shows that, SEBAL has the capability for capturing spatial and temporal ETa variability. These results indicates that SEBAL-derived ETa estimates may serve as a reliable biophysical input for informing irrigation scheduling in data-scarce.

The reviewer commented: This also undermines the conclusion and contribution of this paper. Instead of relying on satellite optical data for precision irrigation, other approaches for agricultural water management should be considered (e.g., low-cost soil moisture measurement, crop and moisture protection)

Authors: Thanks for the comment, we revised the this to: Optical satellite data can be constrained by cloud cover, revisit frequency and limited soil moisture sensitivity. Therefore, integrating satellite ETa estimates with ground tools such as soil moisture sensors with practical farm management methods including mulching and crop protection strategies can enhance water management outcomes, these hybrid approaches can allow for a more localized, real-time decision-making that responds to climate variation and farm-specific conditions.

The **reviewer** commented: I don't think the priority should be improving algorithms if the goal is to improve agriculture water management. the authors could have problematized this assumption: "more precise and accurate data lead to better decisions".

Authors: Thanks for the comment, we have revised the future recommendations section.