# <u>Comments from reviewer 1 and response by authors to reviewer 1</u>

## General comments by reviewer 1

**Reviewer's comment:** The author needs to update the title in the manuscript. The current manuscript title is "Evaluation of remote sensing algorithms for estimating actual evapotranspiration in agricultural environments". However, in the authors' response, you mentioned that the title has been revised to "Evaluation of Remote Sensing Algorithms for Estimating Actual Evapotranspiration in Irrigated Agricultural Environments: Insights from the Vaalharts Scheme, South Africa". I would also suggest the title to be more specific "Evaluation of Four Remote Sensing Algorithms…", since it evaluates SEBAL, SEBS, VI, and CWSI algorithms, and not all existing algorithms.

**Authors' response:** Dear reviewer, thanks for raising this comment, we have revised the title as: "*Evaluation of Four Remote Sensing Algorithms in Estimating Actual Evapotranspiration in Agricultural Environments". See lines 1-3.*

## Main comments by reviewer 1

**Reviewer:** it's not clear. do you mean 'estimates at the scale of irrigation scheme'?

**Authors' response:** Thanks for requesting clarity, we have revised the sentences to a clearer version: "field-scale ETa estimates were validated using a smart field weighing lysimeter and the algorithms estimates were evaluated at irrigation-scheme scale using weather-station-based extrapolation". See lines 25-27.

**Reviewer:** why is this the most important?

**Authors' response:** Dear reviewer thanks for picking this up, we have removed the statement to make the manuscript smooth. See line 34.

**Reviewer:** if SEBAL is the best-performing algorithm, why specifically mention the reliability of this one? why not highlight its strengths?

**Authors' response**: Thanks for requiring clarity on this, we have revised to: While SEBAL is the second-best performing algorithm, the validation of VI-ETa approach in estimating ETa against lysimeter measurements demonstrated its reliability with strong correlations and low error metrics, as a result, the VI-ETa algorithm is a computationally efficient alternative. The uncertainty analysis indicated that extrapolated ETa estimates were reliable within ±7–12%. The study demonstrates the potential of accurate ETa estimation to support better irrigation scheduling, which may lead to reduced water overuse, in water-scarce environments. See lines 34-38.

**Reviewer:** suggest removing this

**Authors' response:** We appreciate the suggestion; we have removed the statement. See lines 43-44

**Reviewer:** what kind of measurements? Can we really measure ETa, or we can only estimate through proxy, such as changes in soil moisture content in lysimeter?

**Authors' response**: Thanks for requiring clarity, we clarified that ETa is derived from lysimeter mass balance measurements which include changes of mass due to changes in soil moisture variability. See lines 44-45.

**Reviewer:** This reference proposes a method for irrigation scheduling, not supporting the statement "farmers will either over-irrigate or under-irrigate".

**Authors' response**: We have revised the citation to: (Abd Elbasit and Ratshiedana, 2024). See line 48.

**Reviewer**: Include reference Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. Fao, Rome, 300(9), p.D05109.

**Authors' response:** We appreciate the suggestion; we have included Allen et al. (1998). See line 57.

**Reviewer**: From Allen et al. (1998): ETc is "the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions"

**Authors' response:** We appreciate the reviewer's comment, we have revised: 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. ETc represents how much water the crop would ideally use, whereas ETa represents the actual amount of water that the crop has used. See lines 57-60.

**Reviewer:** Tells was removed by reviewer

**Authors' response**: Thanks for noting the typing error, we have removed tells. See line 62.

**Reviewer:** remove. use abbreviation after defined

**Authors' response**: Thanks for the suggestion, we have considered using the abbreviation. See line 63.

**Reviewer**: enough for what. How many is enough?

**Authors' response:** Thanks for requesting clarity, we have revised this and explained more: These stations are still not enough in most parts of South African agricultural landscapes to be representative of field-scale ETc estimation with high accuracy (Ncoyini et al., 2022). According to Ramoelo et al. (2014) South Africa currently has only two open-access FLUXNET eddy covariance stations, insufficient for national-scale ET validation across heterogeneous agricultural landscapes. See lines 66-68.

**Reviewer:** Since you used the definition of ETc from Allen (1998), this Kc determination is only true if ETa is measured for crops under optimal management conditions. You still need to edit this sentence to clarify the difference

**Authors' response**: Thanks for suggesting this; we have revised this into: ETc represents evapotranspiration from disease-free crops grown under optimal soil water and management conditions (Allen et al., 1998), whereas ETa reflects actual field conditions including water stress. See lines 75-77.

**Reviewer:** ETa under standard conditions (i.e. "from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions")

**Authors' response:** Thanks for suggesting more details, we have revised as recommended to: ETa estimated under standard conditions such disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production under the given climatic conditions. See lines 82-83.

**Reviewer:** Suggested ETa not ET

**Authors' response**: Thanks for noting the typing error, we have changed from ET to ETa see line 91.

**Reviewer:** Reviewer deleted the reference: Blatchford et al., 2020

**Authors' response**: The removal of citation was accepted, See line 89.

**Reviewer:** Surface Energy Balance System Su, Z., 2002. The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes. Hydrology and earth system sciences, 6(1), pp.85-100.

**Authors' response**: Thanks for suggesting, we have revised to: model developed by Su (2002) was implemented, see line 104.

**Reviewer**: Suggested at seasonal scale

**Authors' response**: Thanks for the suggestion, we have included "at seasonal scale", see line 111.

**Reviewer:** you mean SEBS model by Su (2002) or SEB models in general, including SEBAL?

**Authors' response**: Thanks for asking; yes, we meant SEBS by Su (2002), see line 112.

**Reviewer:** Suggested the use of and Not however

**Authors' response**: Thanks for the suggestion, 'and" included in the manuscript, see line 134.

**Reviewer**: Suggested the use of from sources not from areas

**Authors' response**: Thanks for the suggestion, we have included ''from sources", see line 134.

**Reviewer**: Suggested inclusion of were used to developed

**Authors' response**: Thanks for the suggestion, we included '' were used to developed'', see line 186.

**Reviewer**: Some sections were circled for removal

**Authors' response**: We removed all the marked areas on the map, see line 177.

**Reviewer**: Error on map: irrogation

**Authors' response**: Thanks for noting the typing error, we have revised to ''irrigation'', see map on line 177.

**Reviewer**: You indicate in the first panel that the peak in load cell is due to irrigation event. Could you say something about rainfall events during the experimental period? Was there any rainfall? Was rainfall amount considered in the water balance?

**Authors' response**: Thanks for requiring clarity, we have included something on rainfall on the text and demonstrated the exclusion of such days in the formulas. Rainfall depth (mm) was aggregated to daily totals and incorporated into the water balance equation alongside irrigation inputs, see lines 257-258.

**Reviewer:** Suggested adding reference

**Authors' response**: Thanks for the suggestion, we have added the reference: (Chakouri et al., 2020), see line 202.

**Reviewer**: Use where not were

**Authors' response**: Thanks for the suggestion, we revised to "were used to develop", see line 186.

**Reviewer:** Suggested adding ''were done'

**Authors' response**: Thanks for the suggestion, we added "were done", see line 244.

**Reviewer:** is precipitation also negligible during zero-irrigation days? Did you measure precipitation?

**Authors' response**: Thanks for requesting clarity, yes; precipitation was measured using a tipping bucket rain gauge as indicated in Figure 2, top right. Also see inclusion in line 269-270.

**Reviewer:** if 1 kg of water in lysimeter equals 14 mm, then in equation (1), it should be 14.14 * (deltaD - deltaS) to convert kg to mm. Because this is an equation, both sides should have the same unit. I assume the unit of ETa on the left side is in mm like in equation 2. You cannot substract kg from mm without conversion even if it's negligible mm

**Authors' response:** Thanks for the comment requiring revision, we have revised the equations, see line 251 through to 256.

**Reviewer:** check the font type to follow authors' guide. ETa, should be regular, not italic since it's multi-letter variable. Lm and Dm should have 'm' in subscript

**Authors' response**: Thanks for the comment, we have revised this part in the manuscript, see line 259

**Reviewer:** Include index equations

**Authors' response:** Thanks for the request, we have included the NDVI formula in supplementary material Equation (S7), see supplementary table.

**Reviewer:** which models exactly?

**Authors' response**: Thanks for the question, we meant the linear model, see lines 295.

**Reviewer:** what kind of relationships? do you refer to linear relationship in Equation 6? **Authors' response:** Thanks for the question, yes; we meant linear relationships, see lines 295.

**Reviewer:** o must be subscript, same in equation 5 and 7

**Authors' response:** Thanks for the suggestion ''o'' has been standardized, see equations 5 and 7.

**Reviewer:** U_2 in FAO56 ETo formula strictly means windspeed measured at 2 m. If you measured windspeed at 1.2m, you must convert to 2m windspeed using wind profile relationship (see equation 47 in Allen et al., 1998). This will increase your windspeed by 12% and affect your results

**Authors' response:** Thanks for picking the error, all measurements were done at 2 m as indicated on Moeletsi et al. (2022), see lines 276-277.

**Reviewer:** why this and not 0.34 as in Allen et al., 1998?

**Authors' response:** Thanks for picking up the typing error, we corrected the typo of 0.38 to 0.34 for daily timestep grass reference crop as per Allen et al. (1998). See line 322.

**Reviewer:** refer to Table S2

**Authors' response**: Thanks for the suggestion, we have referred to Table S2 in the manuscript, see lines 340-342.

**Reviewer:** consider using consistent variable, either LST or Ts, not both

**Authors' response:** Thanks for the suggestion, we changed to LST consistently throughout the manuscript. See an example in line 384.

**Reviewer:** how were these anchors pixels selected?

**Authors' response:** Thanks for the suggestion to clarify, we have explained how the pixels were selected as: the hot pixels were identified over dry, bare soil surfaces characterized by high LST and low NDVI values, representing conditions of minimal ET. Cold pixels were selected over dense vegetation areas exhibiting high NDVI and low LST which are indicative of maximum ETa under well-watered conditions. The anchor pixels were selected manually following the standard SEBAL methodology to ensure that they represented the extreme energy balance conditions within each satellite scene.

**Reviewer:** either 'The SEBS approach' here or full form. Also, the same for 2.4.2

**Authors' response**: Thanks for the suggestion, we have used SEBS, see line 388.

**Reviewer:** which theory?

**Authors' response**: Thanks for this concern, we have removed this part, see line 392.

**Reviewer:** which variables specifically?

**Authors' response**: Thanks for requiring clarity, variables including air temperature, wind speed, relative humidity, incoming solar radiation and incoming longwave radiation, see lines 392-393.

**Reviewer**: what are NDVImin and NDVImax? are they min and max of a scene or constant values for every scene?

**Authors' response**: Thanks for requiring clarity, NDVImin is the minimum NDVI and NDVImax is NDVI maximum, see line 401.

**Reviewer:** Reviewer suggested selective

**Authors' response**: Thanks for the suggestion, we have included selective, see line 445.

**Reviewer**: should also include LST

**Authors' response**: Thanks for the suggestion, we included LST, see Table S3. On supplementary material.

**Reviewer**: Add labels of crop type

**Authors' response**: Thanks for the suggestion, we have added the labels of crop type, see Figure 4.

**Reviewer:** what strikes me is that day159-255, the NDVI-Kc relationship is different from day 255 onwards.

**Authors' response**: Thanks for the comment, we understand the reviewer's observation. However, during DOY 159–255, the crop was in the vegetative to mid-season growth stage, where canopy development was increasing NDVI reflecting green biomass and leaf area, Kc increased consistently with NDVI due to rising transpiration dominance. In this phase, the NDVI–Kc relationship was strong and nearly linear as ET was being largely controlled by canopy transpiration. However, after DOY 255, the crop entered the late season where leaf chlorophyll declined while some structural biomass remained. As a result, NDVI may remained relatively high due to residual canopy structure, as a result; Kc declined due to reduced transpiration and stomatal activity This led to a decoupling between NDVI and Kc where NDVI no longer represented crop water use accurately.

**Reviewer:** In previous review, I suggested averaging ETa values across all 4 models to produce mean or CoV maps of 4 models, and not "averaging across time" like authors interpreted. This is to show how 4 models agree and disagree spatially. Please include as requested.

**Authors' response**: Thanks for the suggestion, we have included maps of mean ETa, see Figure 8 and those on supplementary materials.

**Reviewer:** Although the labels of colormap seem homogenized across all models, the maps themselve look exactly the same as in previous version. For example, in CWSI (27October2019), the range was 2.31 to 6.8 in the previous version. I would expect that when you change the range to 0-9.5, the color of the map would be closer to yellow since you decreases the minimum and increase the maximum. However, the new map looks exactly the same as before. Please double-check that you have changed visualization range, not only the labels

**Authors' response**: Thanks for the suggestion, we have revised the maps as suggested, see Figure 8 and those on supplementary materials.

**Reviewer**: this is not "minimal". For on-farm irrigation application, <1mm/day MAE is only acceptable

**Authors' response**: Thanks for noting this, we have revised this section, see the whole of section 3.2.

**Reviewer:** You mean "seasonal ETa"? In fig6, SEBS actually does not perform well in terms of daily ETa (MAE is 1.17 mm/d, bias of 0.89 mm/d)

**Authors' response**: Thanks for noting this, we have revised this section.

**Reviewer:** the table missing the result of CWSI

**Authors' response**: Thanks for noting this, we have added CWSI on Table S4 on supplementary material.

# Comments from reviewer 2 and response by authors to reviewer 2

### General comments by reviewer 2

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**Reviewer:** For microlysimeters, information about installation and crop management is required to ensure that soil and crop conditions match inside and outside the lysimeter. The limitation of using a single measurement from a very small surface area with a variety of crops remains and should be more clearly acknowledged in the discussion and conclusions.

**Authors' response:** Thanks for requesting clarity, yes, Figure 1. of the manuscript shows the location of ground measurements which is the location of the lysimeter. Figure 1.b shows the location of measurements in the red boundary, outside the box is the continuity of the uniform crop representing the same crop in the lysimeter, see description on line 175. Moreover, Figure 2. Also shows the lysimeter core with the crop and the crop surrounding it being the same across the four measurement seasons. The limitations of using a single measurement have been acknowledged on the discussion and the conclusion section. We have added a supplementary figure S7 which shows the field condition relating the crop in the lysimeter and the field crop.

We have added details on the installation of the lysimeter. This include the following: "*During the installation of the lysimeter, a fresh soil sample core was sampled from the tilled field. The soil monolith hosted the field cultivated crop of each season replicating the soil, environmental and treatment conditions of the surrounding field with the crop matching the one planted in the entire farm. Retrieving the soil monolith core from the lysimeter involved the use of three rope straps which were fixed to steel hook anchors embedded in the ground. These straps were used to secure a jack positioned on top of the cylinder which effectively drove the cylinder into the soil. The process continued until a sufficient volume of soil was filled reaching the bottom level within the cylinders. At the base of the lysimeters cylinder the closing process was achieved using gypsum-filled ceramic caps, which contributed to effective sealing. These caps played a significant role in establishing a suitable boundary between the external field environment and the controlled internal environment within the lysimeter. Within the gypsum filled caps, two pumps were secured to maintain the balance in conditions of wetness between the lysimeter and the field condition. Preventive measures against potential leakage included the incorporation of a rubber seal between the cylinder walls and the contact point of the ceramic cap which were further reinforced by a metallic strap to ensure a secure connection. A weighing balance platform was positioned below these caps, secured using metal fasteners and tensioned nut and bolts.*"

**Reviewer:** Several concerns arise from applying the Crop Water Stress Index (CWSI) in this study that may influence the results. The first issue is the lack of clarity regarding the selection of Twet and Tdry. This is crucial because the index was initially developed to measure plant-foliage temperatures, not for remote sensing, and selecting the extremes of crop resistance as originally intended is not straightforward.

**Authors' response:** The ΔT_m= minimum LST-T_air (proxy for Twet) while ΔT_x= maximum LST-T_air (proxy for Tdry). Twet is approximated by the lowest observed canopy-air temperature difference while Tdry is approximated by the highest observed difference. The hot pixels were identified over dry, bare soil surfaces characterized by high LST and low NDVI values, representing conditions of minimal ET. Cold pixels were selected over dense vegetation areas exhibiting high NDVI and low LST which are indicative of maximum ETa under well-watered conditions. The anchor pixels were selected manually following the standard SEBAL methodology to ensure that they represented the extreme energy balance conditions within each satellite scene.

**Reviewer:** The second, more significant concern is that the CWSI is only valid for fully covered canopies. For a fair comparison, only dates that meet this criterion should be considered. However, Fig. 4 shows that several days at the beginning of the growing cycles do not fulfil this requirement, leading to significant discrepancies, as shown in Fig. 6c. An interesting alternative is to use the Water Deficit Index (WDI), developed by Moran et al. in 1994, which is specifically designed to apply the CWSI under both partial and full canopy cover conditions. The authors might consider including Table S2 in the main paper, as these relationships may be of interest to readers interested in Kc-NDVI applications (see Pocas et al., 2020; https://doi.org/10.1016/j.agwat.2020.106081).The statistics presented in sections 3. 3.3 and 3. 3. 3.3.1 do not align. For example, the MAE and bias reported in lines 466-473 differ from those shown in Fig. 8. If I am not mistaken, these values should be consistent. Fig. 8 indicates that the VI- ETa model achieves the lowest errors across all metrics (MAE, RMSE, bias, and SE) and high R 2. Furthermore, Fig. 6(a and b) shows that this model's performance is superior. However, throughout the results and discussion section, the text clearly states that SEBAL is the best-performing model (e.g., line 576). Please clarify this discrepancy Please, reference in the manuscript the WRC Report No. 3163/1/24, where part of this work is presented.

**Authors' response:** Thanks for this concern, the reviewer indicates that the index was developed to work on a fully canopy covered area, that is correct, we did not use bare ground for estimates, the 30 m Landsat 8 image covers a bigger portion with crops, the cropping style in the farm was of dense population which allowed for more vegetation visibility in one pixel across the selected dates. We have acknowledged the limitations of the algorithm in the discussion section, see lines 738-742. The reviewer further suggests that the table be brought back into the main document, this table with other tables were proposed to be on the supplementary material. The errors in statistical presentations have been rectified, see the results section.The WRC Report No. 3163/1/24 has been included on the citation, this is cited as: Abd Elbasit, M.A.M. and Ratshiedana, P.E., 2024. SMART FIELD WEIGHING LYSIMETER FOR VALIDATION OF SATELLITE-BASED EVAPOTRANSPIRATION UNDER ARID ENVIRONMENTS. WRC Report No. 3163/1/24.https://www.wrc.org.za

**Main comments by reviewer 2**

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**Reviewer:** This title does not match the one included in the response to reviewers

**Authors' response**: Dear reviewer, thanks for raising this comment, we have revised the title as: **"***Evaluation of Four Remote Sensing Algorithms in Estimating Actual Evapotranspiration in Agricultural Environments". See lines 1-3.*

**Reviewer:** The information in this table is not necessary to follow and can be easily accessed by readers from multiple sources.

**Authors' response**: Thanks for the reviewer's concern, however; we understand the table is very short and makes it easier for readers or those reproducing the methods using these bands.

**Reviewer:** This selection deserves an explanation

**Authors' response**: Thanks for noting this missing part on the manuscript, the anchor pixel selection has been well described, see lines 384-387.

**Reviewer:** Change farm to field

**Authors' response**: Thanks for the suggestion, we have changed farm to field, see line 411.

**Reviewer:** Reviewer suggested: and would not comply with the requirements of some modeling schemes, as the CWSI

**Authors' response**: Thanks for the suggestion, we have added "and would not comply with the requirements of some modelling schemes, as the CWSI". See lines 420-421.

**Reviewer:** It is more logical to present the validation of the methods at the point scale using lysimeter measurements first and then perform a scale-up to analyze the irrigation district.

**Authors' response**: Thanks for this comment, we have revised the presentation of the results, see the results section.

**Reviewer:** These values does not agree with figures in Fig.8

**Authors' response**: Thanks for noting this, we have revised this section, see the text before the figure.

**Reviewer:** The figure demonstrates that the adjustment of VI is superior to SEBAL, which tends to both overestimate and underestimate measurements, similarly, leading to a reduction in bias. This should be acknowledged in the text, including a discussion of the RMSD difference, as the current text suggests the opposite of what is illustrated in Figure 6.

**Authors' response**: Thanks for noting this, we have revised this section, before figure 6. We have revised this section as picked by the reviewer, see section 3.2 through 3.3.

**Reviewer:** Unless Figure 8 is mistaken, this conclusion is very surprising, as the results in both Fig. 6 and 8 indicate that VI-ETa performs better than SEBAL.

**Authors' response**: Thanks for this, we have revised the errors, see section 3.2 through 3.3.

**Reviewer:** What implications does the comment refer to?

**Authors' response**: Thanks for this, we have revised the discussion to: 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 indicate that the VI-based ETa algorithm produced the most accurate estimates, followed closely by SEBAL, while SEBS showed comparatively lower accuracy. In contrast, the CWSI-based ETa algorithm 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.

**Reviewer:** This observation was done and demonstrated by several authors (see one of the references below) since the 80', more than 30 years before Niu et al. Please, check more apropiatte citation from the review paper by Pocas et al. 2020

- Bausch, W.C. and C.M.U. Neale. 1987. Crop coefficients derived from reflected canopy radiation: A concept. Transactions of

the ASAE 30(3):703-709.

- Pocas et al. 2020: https://doi.org/10.1016/j.agwat.2020.106081

**Authors' response**: Thanks for the suggestion, we have included Bausch and Neale (1987), Niu et al. (2020) and Pocas et al. (2020). See line 657.