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Interactive comment on "The importance of plant water use on evapotranspiration covers in semi-arid Australia" *by* A. Schneider et al.

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General Commentary:

We (the Authors) thank the anonymous referee for their significant commentary and suggestions. Some of the comments were found to be crucial in improving our work for potential publication (e.g., regarding the description and novelty of our experimental design, and subsequent implications for the design of evapotranspiration cover systems). In contrast, other comments were deemed to be less relevant with regard to the scope of the study.

Overall, the referee's genuine concern over the limited availability of replicates for evap-

oration measurements on bare soil appears to require the most care and justification − which we address below and in the revised manuscript.

First, the limited availability of replicates for the bare soil treatment represented an unavoidable component of the field trial. In spite of this, the size of the sample plot was considered to be adequately representative of the broader cover treatment and the pooled sub-samples (within the plot) accounted for potential heterogeneity therein. Also, we minimised any uncertainty involved in the ET measurements using an open-top chamber through a laboratory calibration (page 11917, lines 5-7) and applied these findings to actively correct any measurements on-site. While the open top chamber underestimated gravimetrically determined evaporation from a water tray, a sound correlation between OTC and tray were found (Fig. 1). All field measurements were corrected based on the laboratory findings.

Furthermore, during the 10 min of field measurements, readings were taken every minute inside and outside of the chamber alternatively, which occurred on all locations throughout the day. The shorter timeframe readings over the field campaign showed the same patterns as presented in the manuscript. While we cannot exclude systematic errors, we can conclude that the presented trends reflect the behaviour of the system. We recognise the inherent uncertainty regarding each individual measurement. However, systematic procedures were applied to minimise errors which may have occurred during sampling and we consider our findings to be robust and reliable. This is shown by the qualitatively similar and comparable axis-scales and diurnal courses of ET (Fig. 5) measured among all locations over every day of sampling (Fig. 5).

Given these important comments, we believe that the revised manuscript will certainly benefit from a more detailed description of the uncertainty analysis (Comment: PAGE 11915, LINE10-30: There must be adequate quantification of errors and uncertainties. The statistical error must be reported and plotted in all figures and values in the text. An assessment of uncertainty must also be undertaken.)

Further responses to the referees' queries:

Comment: The title could be made more meaningful especially given the of the word 'evapotranspiration covers' which I had not come across before. Regardless the title didn't make sense to me anyway. Response: We have revised the title to better reflect the content of our study: "The limited role of vegetation in the water balance of mine waste cover systems in semi-arid Australia". Nevertheless, we would like to point out, that the term 'evapotranspiration cover' is a commonly used term in technical disciplines, but recognise that it is less known in environmental/biological sciences.

Comment: PAGE 11914, LINE12: Given the scope of the paper in the semi arid landscape I would like to see more detail on the climate of the region. Distributions of temperature, precipitation, relative humidity and vapour pressure deficit would be useful to illustrate where the study fits into that climate regime. Response: In the revised manuscript we will provide more information on climatic metrics such as daily evaporation, relative humidity at 9 am and 3 pm and mean monthly temperatures, data which are available from the Australian Bureau of Meteorology for this location. Furthermore, VPD can be calculated for 9am and 3pm.

Comment: PAGE 11914, LINE18: Report the soil bulk density and soil characteristics such as particle sizes if available. Response: The water retention curve of the topsoil, modelled with the program RETC (van Genuchten et al, 1991), was similar to a clay loam with a bulk density of 1.46 g/cm3. This information will be added to the manuscript.

Comment: PAGE 11914, LINE22: Please elaborate on the establishment of the evapotranspi- ration covers. How were they established, by natural seeding or planting? What was the species composition? What fraction of it was native vs. invasive species? Response: The plots were initially seeded with a mix of native grasses (Themeda triandra, Digitaria brownii, Bothriochloa macra, Chloris truncata) with approximately 3kg seed per hectare applied by hand. Furthermore, planting of Atriplex

nummularia was carried out. While seeded and planted species were present in the plant community on the ET cover, the majority of plants comprised volunteer pioneer species. No invasive species were recorded in notable numbers. We will add this information for the revised manuscript.

Comment: PAGE 11915, LINE18: The sentence is a little bit confusing, were the plants sampled for soil moisture or for biomass or leaf area? Comment: PAGE 11915, LINE24: What do you mean by this? How much is markedly? What measurements of soil water were undertaken? How was root zone soil moisture quantified? Response: Soil moisture was sampled from the upper 5 cm. Soil moisture in this layer was increased from 0.02 m3 m-3 to 0.14 m3 m-3 in average after the simulated rain event. The root zone was quantified visually by examining the soil profiles: "Root excavations examined for the two plant species after the field campaign confirmed the hypothesis of a deeper root zone for Sclerolaena birchii. [..] most of the root biomass was located between 0.1 and 1.0 m depth. Most of the Senna artemisioides root biomass was found to be in the upper 0.1 m of soil while no roots occurred below a depth of 1.1 m." (page 11923, lines 11-16)

Comment: PAGE 11915, LINE21: Please provide a justification for the 17mm event. Compare this to the longer term rainfall rate distribution. How was this applied? Over what area? Response: During the review progress we realised that we provided a faulty number for the simulated rainfall event. A total of 54L was applied per location, was using a 9L watering-can over a ground area slightly larger than the open top chamber (0.79m2). This equates to a simulated rainfall event of 42 mm, representing a major storm event in the area.

Comment: PAGE 11918, LINE8: Reporting of simple R2 is inadequate here. A thorough as- sessment of the error and uncertainty is required for the measurement system. A plot of test data would be beneficial here. What is your statistical conference in the chamber observations? Response: Empirical data (i.e., gravimetric water loss from a tray vs. evaporational water loss measured by using the open top chamber) will be provided (see Fig. 1 of this response) along with evidence of statistical significance (statistical test, p-values, significance level).

Comment: PAGE 11917, LINE07: Description of the OTC method is inadequate. Response: The purpose of this study was to apply the OTC method rather than testing it. Furthermore, the OTC chamber has been previously described in the literature (Hutley et al., 2000, Zeppel et al, 2006), which is cited in the manuscript (pg 11917 Line 8). Therefore, we would prefer to maintain the current brief description of the OTC method in the main body of the manuscript. At the discretion of the Editor, a more detailed description can be presented as Supplementary Info.

Comment: PAGE 11917, LINE17: You need to report the sensor specifications including accu- racy and response time. Is the use of the HMP155 appropriate for the task? Please justify the choice of sensor and suitability. Response: The chosen sensors were very appropriate for the measurements. The HPM155 has an accuracy of ± 1 %RH between +15 and + 25 °C between 0 to 90 % RH and ± 1 %RH + 0.008*reading %RH at -20 to +40 °C for relative humidity. The response time of the relative humidity sensors lies between 20 and 60 s, therefore our measurement periods of 1 min was appropriate to allow for establishing an equilibrium between the sensors and the ambient humidity. The accuracy of the HPM155 temperature sensor is given as ± (0.226-0.0028*temperature) °C between -20 and + 80 °C and as ± (0.055+0.0057*temperature) °C between +20 and + 60 °C. The temperature response time lies below 35 s (manufacturers manual for HPM155). The performance of this sensor, based on the manufacturer's operating manual, is better than sensors which have been used in other studies (e.g. the HMP45A in the publication: Isa A.M. Yunusa, Sigfredo Fuentes, Anthony R. Palmer, Catriona M.O. Macinnis-Ng, Melanie J.B. Zeppel, Derek Eamus, Latent heat fluxes during two contrasting years from a juvenile plantation established over a waste disposal landscape, Journal of Hydrology, Volume 399, Issues 1–2, 8 March 2011, Pages 48-56, ISSN 0022-1694, 10.1016/j.jhydrol.2010.12.033). We therefore conclude that the sensor is appropriate for the task.

The Li-190 is accurate to ±5% traceable to National Institute of Standards and Technology (USA) and the response time is 10 microseconds [http://www.licor.com/env/products/light/quantum_sensors/190specs.html]. The Li-190 sensor was stationary during the 10 min of chamber measurements with readings being taken every minute. The readings were stable under clear skies and only changed due to clouds as could be expected. The response time of the Li-190 was suited for the measurement method. This information will be provided in the revised manuscript – either in the main body or as supplementary information.

Comment: PAGE 11920, LINE5: Are these 'significant'? Response: Yes, these results are significant. Statistical evidence will be provided (statistical test, p-values, significance level).

Comment: PAGE 11920, LINE22: The aspect of 'theoretical' scenarios for plant cover are un- realistic as they are based on a small sample size and are extended beyond what could be reasonably expected from the measured dataset. The rationale for this unrealistic scenario is not apparent. The assertion regarding plant cover at 50 and 80% is mis- leading. There is not really any magic threshold at which the plant cover is 'critical'. In fact it is simply a linear function of plant and there is no rationale for any thresholds in cover. As a result this aspect of the manuscript many is tenuous. Response: We agree with the referee's comment and will address the rationale of these scenarios in the revised manuscript (see response the referee's last comment below).

Comment: PAGE 11920, LINE8: Measurements of evapotranspiration and vapor pressure deficit are overly simplistic . Response: This comment is not clear to us. Equations used in the manuscript are widely accepted in the literature. While the FAO 56 Penman-Monteith equation does simplify evapotranspiration measurements, it is generally accepted in scientific literature and has been shown to be one of the most accurate equations in semi-arid regions (Lopez-Urrea et al. 2006). The calculation of vapor pressure defict as the difference between saturation water vapor and actual water vapor is as well an accepted method (Monteith and Unsworth, 1990). We are therefore of the opinion that, while the choosen equations are simplistic they are still meaningful and serve the purpose of the manuscript. The point of these data is that there are consistent relationships between ET and VPD in both the morning and afternoon that indicate higher vegetation conductance in the morning than in the afternoon. Without much more detailed measurements of leaf and soil surface temperatures, vapour pressures and wind speeds, and measurements of soil moisture gradients, it is considered that the approximations of the FAO 56 Penman-Monteith method are reasonable.

Comment: PAGE 11920, LINE29: No. It just happens to be the same value. It is not predictive. Response: We agree. The original intention was to highlight that pET not necessarely reflects ETplot rather than being its predictor.

Comment: PAGE 11921, LINE8: I would expect 'after watering' for this to maybe not be the case. Can you show this data in figure four. Response: This comment is not quite clear. We assume that the reviewer referred to Line 7. Figure 3 of the manuscript showed soil moisture conditions before watering and three, five and seven days after watering. Figure 4 only shows data for the days after watering, as the pre-watering ET data is not available due to instrumental problems on that day. We included the pre-watering soil data to demonstrate the influence of watering and higher soil moisture was still present seven days after watering. During the course of the field campaign a clear decrease of ET was observed, correlating to decreasing soil moisture in 5 cm. Therefore, we inferred that ET prior to watering was lilkely very low in accordance with the very low soil moisture conditions.

Comment: PAGE 11921, LINE17: At what point do these plants reach their wilting point? Measurements over further days would have been useful here. Response: Unfortunately, these plant physiological attributes were not directly collected within our experimental design, yet putative range values are now provided in the Methods based on available literature values.

Comment: PAGE 11922, LINE4: Not just soil water but rather soil – route – plant – atmosphere continuum. Also there are other different drivers including net radiation and wind speed that are crucial. Differences in evapotranspiration, and hence the difference between the evapotranspiration versus vapor pressure deficit relationship in the morning and afternoon could be due to radiation and/or wind speed. Discuss. Response: We agree that evapotranspiration is driven by complex interactions between climatic metrics such as radiation, wind speed, and vapor pressure deficit. The revised manuscript will address these interactions based on the soil-root-plant-atmosphere continuum.

Comment: PAGE 11922, LINE10: Importantly plant stomatal conductance is likely to be a major driver. Measures of plant physiology and stomatal conductance would have added significant value to the study. At the moment the discussion used mainly hand waving and inconclusive given the lack of measurements. Comment: PAGE 11922, LINE5: Additional sap flow measurements may have added value here. Comment: PAGE 11922, LINE16: Isn't what you of observe just stomatal closure? Do you have any evidence for stomatal closure? Physiological measurements of leaf, soil and root water potentials would be invaluable. Response: The investigative aim of this study was to measure evapo-transpiration/evaporation effects of key native species at an alternative and reconstructed landfill cover. Our study, which is the first of its kind within this challenging arid and post-mining landscape, sought to identify the role of plants in minimising drainage as compared to bare soils. We see the point of revising the Introduction accordingly. We recognise the significant role of sap flow, stomatal closure, etc. when assessing the ecophysiological mechanisms underlying evapotranspiration among functionally diverse plants, but this was not the purpose of our study and these parameters likely exceed the scope of our investigative aims. Nevertheless, we see the point of discussing these issues and will revise sections of the discussion by identifying further avenues and opportunities for research.

Comment: PAGE 11922, LINE17-20: This section is speculative and not robust. More-over it is based on the slopes of evapotranspiration versus VPD which are problematic. This is because evapotranspiration covaries during the day as a function of net radiation, wind speed and soil moisture. Therefore an independent relationship is not assured. At the very least evapotranspiration should be normalised by net radiation to produce an evaporative fraction. A multivariate analysis would be appropriate here to break this down, however the authors do not have enough data to perform this. Response: The pourpose of these graphs is to show that a major component of ET can be explained by the variation in VPD. It is not claimed that VPD is independent from net radiation, but that is not necessary. VPD is the resultant of interactions between net radiation, the specific heat of the air (and humidity). There is no need to normalise ET by net radiation because we are interested in identifying whether ET can be explained by VPD. In the morning, it can be explained by a simple and consistent relationship, which suggests that the supply of water to the evaporative surfaces is not the limiting factor. In the afternoon, there is a different relationship thayt indicates a reduced rate of supply of water to the evaporative surfaces. This allows the conclusion that the supply of water from the soil to the evaporative surfaces is limited in the afternoon.

Comment: PAGE 11922, LINE18-30: There is no evidence in the data set for hydraulic redistri- bution. Response: We did not measure hydraulic redistribution as this was not the aim of this study. We rather used hydraulic redistribution from moister layers at depth to surface near areas as a potential explanation why the bare ground showed a strongly VPD driven evaporation in the mornings. This phenomenon has been described in the literature (Yamanaka and Yonetani, 1999) and is cited in the manuscript (pg 11922 Line 26).

Comment: PAGE 11923, LINE10-15: Some of measurement of plant biomass, root biomass and leaf area index would be useful to interpret the results. Were the differences observed in this study really due to differences in transpiring leaf area? Response: Data of plant biomass and leaf area index was collected and will be provided accordingly. The length of all branches of all species were measured in the laboratory

and the relationship between branch length and leaf biomass as well as leaf biomass and leaf area was experimentally determined under controlled conditions. Fig. 3 and Fig. 4 demonstrate the sound relationship between branch length and leaf biomass (Fig. 3) as well as leaf biomass and leaf area (Fig. 4). Total calculated leaf area (cm2) and leaf drymass (g) will be presented in the reviewed manuscript.

Comment: PAGE 11923, LINE20 to PAGE 11922 , LINE 12: The scenario here is arbitrary and not viable. The author also states on mine sites the plant cover is rarely greater than 50 per cent so extrapolating plant cover to 100% is meaningless. Measurements of evapo-transpiration over different plant covers across the range of natural compositions would have been a useful to actually elucidate the interaction between cover, evapo-transpiration and soil moisture balance rather than just some arbitrary and simplistic scenario that also has no physical basis and we know a priori that the changes in cover will not scale linearly and that changes in cover will have non-linear interactions with radiation (via shading and albedo), soil moisture (through competition between plants), and nutrient cycling. These scenarios cannot be justified. Response: The strategy of linearising relationships between vegetation coverage and plot evapotranspiration was used to depict the most conservative relationship regarding maximum possible evapotranspiration. For ecosystems with vegetation cover smaller than 50%, our data set provided a valuable projection of vegetation/species composition coverage. Indeed, at certain scales of resolution, the incorporation of further parameters (i.e., accounting for increased shading, albedo, plant competition for water) would likely result in the mentioned non-linear relationships. However, the inclusion of the various parameters impacting on the transpiration rate of plants leading to such non-linear relationship would project lower ET rates and hence provide further support to our critical conclusion that “relatively large vegetation coverage [. . .] is required to make plant community composition a critical determinant of water loss through evapotranspiration” (page 11926, lines 12-14) – a conclusion based on projections rather than predictive models. These aspects will be revised and clarified in the discussion.

References Hutley, L. B., O'Grady, A. P., and Eamus, D.: Evapotranspiration from eucalypt open-forest savanna of northern Australia, Funct. Ecol., 14, 183–194, 2000. Lopez-Urrea, R., Marin de Santa Olalla, M., Fabeiro, C., and Moratalla, A.: Testing evapotranspiration equations using lysimeter observations in a semiarid climate, Agricultural Water Management, 85, 15-26, 2006. Monteith, J. L. and Unsworth, M. H.: Principles of environmental physics, 2nd ed., Edward Arnold, London, 1990. van Genuchten, M. Th., F. J. Leij, and S. R. Yates:The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils, Version 1.0. EPA Report 600/2-91/065, U.S. Salinity Laboratory, USDA, ARS, Riverside, California, 1991. Yamanaka, T. and Yonetani, T.: Dynamics of the evaporation zone in dry sandy soils, J. Hydrol., 217, 135–148, doi:10.1016/s0022-1694(99)00021-9, 1999. Zeppel, M.J.B., Yunusa, I.A.M. and Eamus, D.: Daily, seasonal and annual patterns of transpiration from a stand of remnant vegetation dominated by a coniferous Callitris species and a broad-leaved Eucalyptus species, Physiologia Plantarum,127:3, 413-422, 2006.

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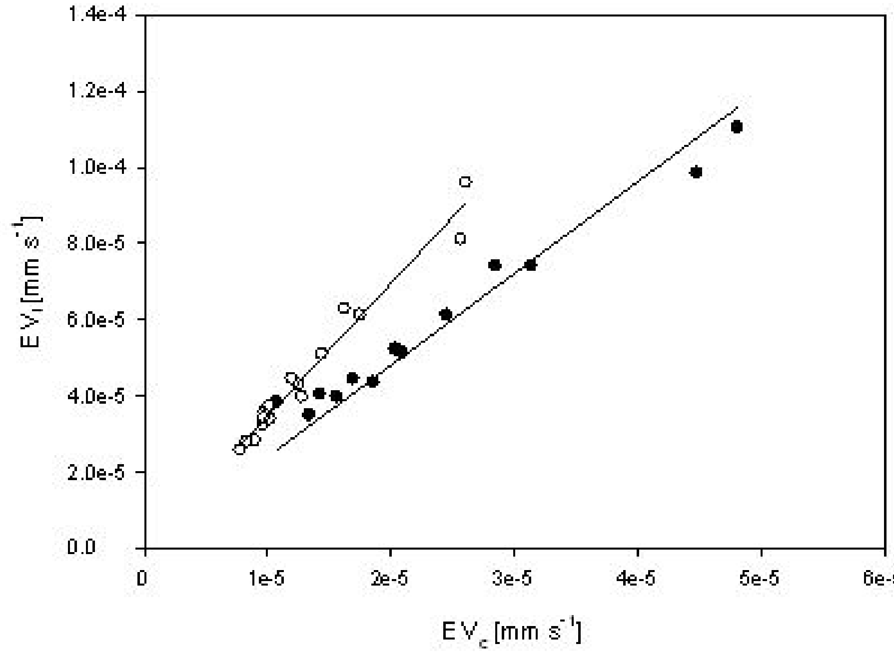

Fig. 1. Relationships between evaporation measured by the open top chamber (EVc) and gravimetrical water losses from a tray (EVt) for 0.4 m s-1 (open circles) and 0.8 m s-1 (solid circles). R2 for 0.4 m-2: 0.

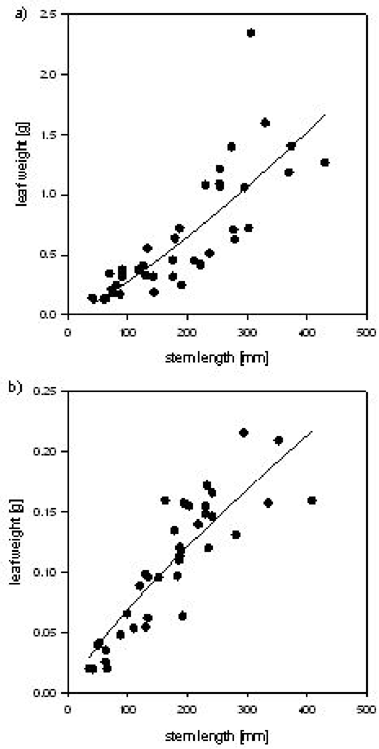

Fig. 2. Relationships between stem length and leaf weight for Senna artemisioides (a) and Sclerolaena birchii (b).

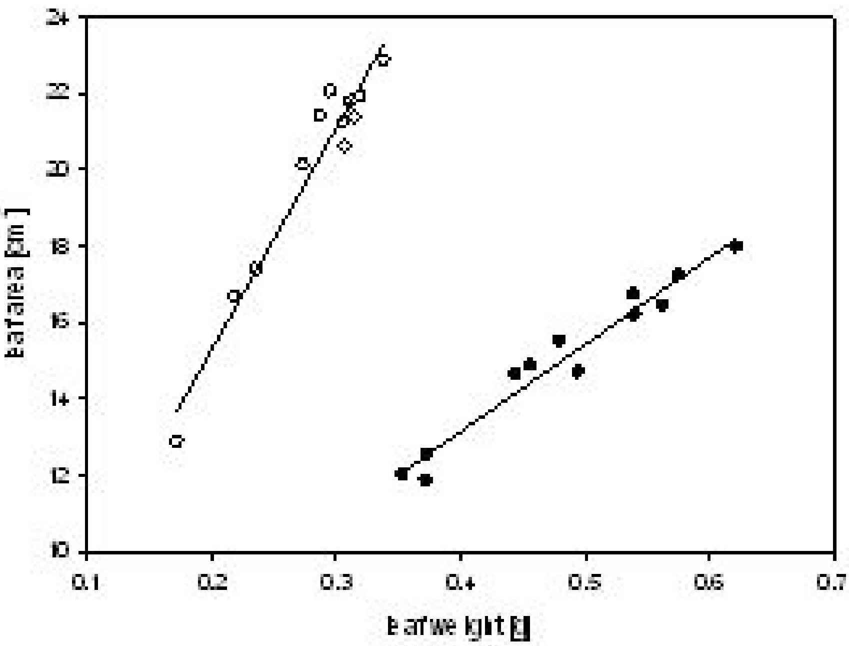

Fig. 3. Relationships between leaf area and leaf dry weight for Senna artemisioides (solid circles) and Sclerolaena birchii (open circles)