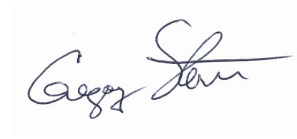


April 1, 2019

Dear Dr. Still

Please find enclosed our second set of revisions for manuscript, mss# bg-2018-322, "Quantifying energy use efficiency via entropy production: A case study from longleaf pine ecosystems." We have completed all revisions per the Reviewer's' comments and suggestion. Below are the Reviewer's' comments in normal black font and our responses to the comments in blue. We have included in our online submission both a marked and clean copy of the revised manuscript. Please contact me if you have any questions regarding the manuscript.

Sincerely,



Gregory Starr, Ph.D.
Professor of Global Change Biology
University of Alabama

1. The entropy production by solar radiation is calculated by Eq. 4.6, and I agree with this formulation. Solar radiation carries the imprints of the solar emission temperature, and is absorbed and produces heat that is associated with the surface temperature, so the expression for entropy production includes the temperatures as it is commonly done. However, later on page 7 the authors use a metric called “Empirical MEP”, where instead of the temperature at which solar radiation is being absorbed they use air temperature. I see no physical justification for using air temperature. Solar radiation is absorbed at the surface, not in the air.

Author’s Response: Thank you for this comment and you are absolutely correct. We have changed this error in our calculation of MEP for shortwave radiation and are now calculating

$$\text{MEP}_{\text{RS}} = R_{\text{s,in}} \left(\frac{1}{T_{\text{srf}}} - \frac{1}{T_{\text{sun}}} \right)$$
 We have updated the results and figures. The results and tests of statistical significance for eff_{rad} did not change.

2. The radiation efficiency they define in eq. 5.4 appears arbitrary to me. In thermodynamics, efficiencies relate to how much meaningful work can be derived out a flux, e.g., for a power plant, how much electricity can be generated out of a heat flux. With entropy fluxes, this actually loses the point. I want to illustrate this with two cases. Imagine case A of a power plant that derives no work out of a flux. Its entropy production by some irreversible processes within the plant is given by the flux and the difference between the inverses of the temperatures at which heat comes in with combustion and goes out of the cooling tower. Case 2 is a power plant that derives the maximum of work out of the flux, which is eventually dissipated into heat. As it turns out, both power plants will actually produce entropy at exactly the same rate, and the only difference is that in case B work is performed, while in case A no work is performed. For such a situation, efficiency has a real meaning, as it allows us to distinguish whether energy is being used to perform work or whether it is wasted. The current paper does not do this kind of analysis, but only focuses on efficiencies based on entropy fluxes. I see no justification for doing so. I do not see a motivation why this should tell us something about why an ecosystem is more or less efficient.

Author’s Response: In this study we assumed that a system which would produce more work from incoming energy, would also remain at a lower temperature. In fact, the xeric and intermediate sites had higher surface and air temperatures compared to the mesic site. Similarly, both sites had lower ratios of eff_{rad} , thus implying a lower efficiency to convert incoming energy into useful work. More precisely, this may indicate that exergy at these sites was greater, given that all sites receive the same amount of radiation (due to their close proximity to one another). So, for our ecosystems of interest, this relates to radiative entropy and the carbon efficiency. When assuming that an ecosystem would use more incoming energy to produce LE, rather than H, air and soil temperature would be lower, which would maintain a larger gradient to surface temperature. This was further indicated by greater eff_{rad} when SWC and VPD increased, which could be related to greater LE and thus lower surface temperatures. In fact, that is what we see at the mesic site (lower temperatures), suggesting a greater efficiency to convert incoming energy into work; in contrast, the temperature gradient between soil temperature and T_{srf} at the intermediate and xeric sites is much lower, as a consequence of lower efficiency. This may be compared to a solar power system, which becomes more efficient when the solar panels are cooler. Additionally, outgoing shortwave radiation was much greater at the xeric and intermediate sites, indicating lower absorption of solar radiation.

So rather than thinking about this problem in terms of a specific quantity of efficiency, here we are looking at the systems and their thermodynamic environment as a whole.

3. I still disagree with using NEE to infer entropy fluxes. Photosynthesis creates chemical free energy out of sunlight. Hence, the absorption of solar radiation does not quite produce as much entropy as a green plate that has the same albedo as a leaf, because some of the radiation is not turned into heat, but rather ends up in the chemical free energy associated with carbohydrates and oxygen. Only when these carbohydrates are being respired is heat being generated and entropy being produced. When you use the combined flux NEE, you would diagnose negative entropy fluxes during the day, and positive during the night. But no process produces negative entropy. So these fluxes need to be separated to make sense, and the entropy production by solar radiation would need to be adjusted to account for the fraction of radiation that is not converted into heat.

Author's Response: We have adjusted the section on metabolic entropy production using absorbed photosynthetic active radiation (page 7, equations 2.16-2.22). The results and discussion sections and figure 7 were edited accordingly.

There is still a sentence on page 8, L1 that claims that “under ideal conditions, an ecosystem maximizes its entropy production when it converts all incoming R_s and R_l into work”. No, all incoming radiation cannot be converted into work as it would violate the second law of thermodynamics. I think I already explained this in my last review.

Author's Response: We have deleted the sentence in the revised document.