Journal of Arid Environments 124 (2016) 10–12

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Letter to the Editor

It is okay to be average when quantifying rangeland dynamics Comment on: Easdale, M.H & Bruzzone, O. 2015: Anchored in 'average thinking' in studies of arid rangeland dynamics – The need for a step forward from traditional measures of variability. J. Arid. Environ. 116: 77–81

Easdale and Bruzzone (2015) recently indicated that to better capture temporal patterns of rangeland dynamics, there is a need to move forward from simple measures of variability such as mean, standard deviation, and coefficient of variation (CV). They note that this is especially true in cases where long time series are available (e.g., ten or more years at a monthly resolution), as with remotely sensed data. To support this viewpoint, Easdale and Bruzzone (2015) presented multiple simulated time series datasets that had same mean and standard deviation, but different seasonal patterns. These seasonal pattern differences were only captured using Fourier analysis (i.e., power spectrum analysis, Chatfield, 1996), highlighting the utility of the method. Here, however, we show the opposite phenomenon, where multiple datasets can show similar temporal patterns from Fourier analysis, but have different and meaningful means, standard deviations, and CVs.

Using the methodology suggested by Easdale and Bruzzone (2015), we analyzed six different aboveground net primary production (ANPP) datasets. The data were gathered monthly from 2000 to 2015 in Northern Patagonia (Argentina) and were obtained from an Argentinian national forage tracking system (Grigera et al., 2007; http://larfile.agro.uba.ar/lab-sw/sw/gui/Inicial.page). This forage tracking system provides monthly ANPP estimations based on remote sensing, meteorological, and land use data (Piñeiro et al., 2006; Grigera et al., 2007 and Irisarri et al., 2012, 2013). More specifically, we focused on six different paddocks ranging in size from 300 to 2000 ha within a single ranch (LAT: −42°45′05″; LON: −71°00′38″). Mean annual precipitation at the study ranch is 341 mm. Three of the study sites were steppes (aerial vegetation cover up to 50%, dominated by cool season grasses and shrubs adapted to xerophytic conditions) and three sites were meadows (aerial cover up to 95%, dominated by cool season grasses adapted to flooding conditions). Time series data for the reported analyses represented mean ANPP values for each paddock, calculated from all pixels that were completely contained within each paddock (50–330 pixels/paddock). Power spectrum analysis was performed on de-trended time series data (i.e., negative temporal trend removed; Legendre and Legendre, 1998), and results are presented below as the relative power density (power spectrum coefficient/sum of power density coefficients) for visual comparative purposes (i.e., to use a common magnitude on the Y-axis).

ANPP showed a clear annual pattern for all six study paddocks, with peaks in early summer (December; Fig. 1A) and minimum values in winter (June; Fig. 1A). A negative trend across study years in summer ANPP peaks was also apparent (Fig. 1A, B) and consistent with the drought described worldwide for the last decade (Zhao and Running, 2010). However, these trends were different among study paddocks as shown by respective December ANPP anomalies, which represent the proportions above or below the average for each data point (Fig. 1B). For instance, when examining the meadow data, paddocks two and three had similar peak values at the beginning of the time series, but by the end of the first 10 years, paddock three had a much lower peak value and continued in a negative trend (Fig. 1A, B). This trend is even better captured by the December anomaly of meadow paddock three (Fig. 1B). However, even though this (and other) paddock differences existed both within and between steppes and meadows (Fig. 1A, B), power spectrum results were very similar for all steppe and meadow sites (Fig. 1C). The power spectrum analysis indicated that most of the variations within ANPP time series were associated with annual cycles, and to a lesser extent, a bi-annual cycle (Fig. 1C).

Although the power spectrum analysis showed similarities between all study paddocks, mean annual ANPP and inter-annual CV clearly differed in the six areas. For instance, within the steppe dominated paddocks, mean ANPP varied almost 1.5 times and its inter-annual CV varied 2.0 times (Fig. 2). As mean steppe ANPP increased, so it did its inter-annual CV (Fig. 2). Meadow paddocks had much higher mean annual ANPP than steppe paddocks, but similar inter-annual CV (Fig. 2). For both meadows and steppes, mean daily ANPP and intra-annual CV showed similar patterns to mean annual ANPP and inter-annual CV. However, note that intra-annual CV was much higher for meadows than steppes (Fig. 2 inset). These intra-annual data showcase that the power spectrum analysis did not detect important differences in CV between steppes and meadows. This lack of detection by power spectra was likely due to seasonal ANPP dynamics being similar in this part of Patagonia.

The approach proposed by Easdale and Bruzzone (2015) provides insights to describe and discuss temporal trends of arid rangeland areas. However, as demonstrated by the above example utilizing real data, it can still be wise to use "average thinking."

DOI of original article: http://dx.doi.org/10.1016/j.jaridenv.2015.02.006.

http://dx.doi.org/10.1016/j.jaridenv.2015.06.005

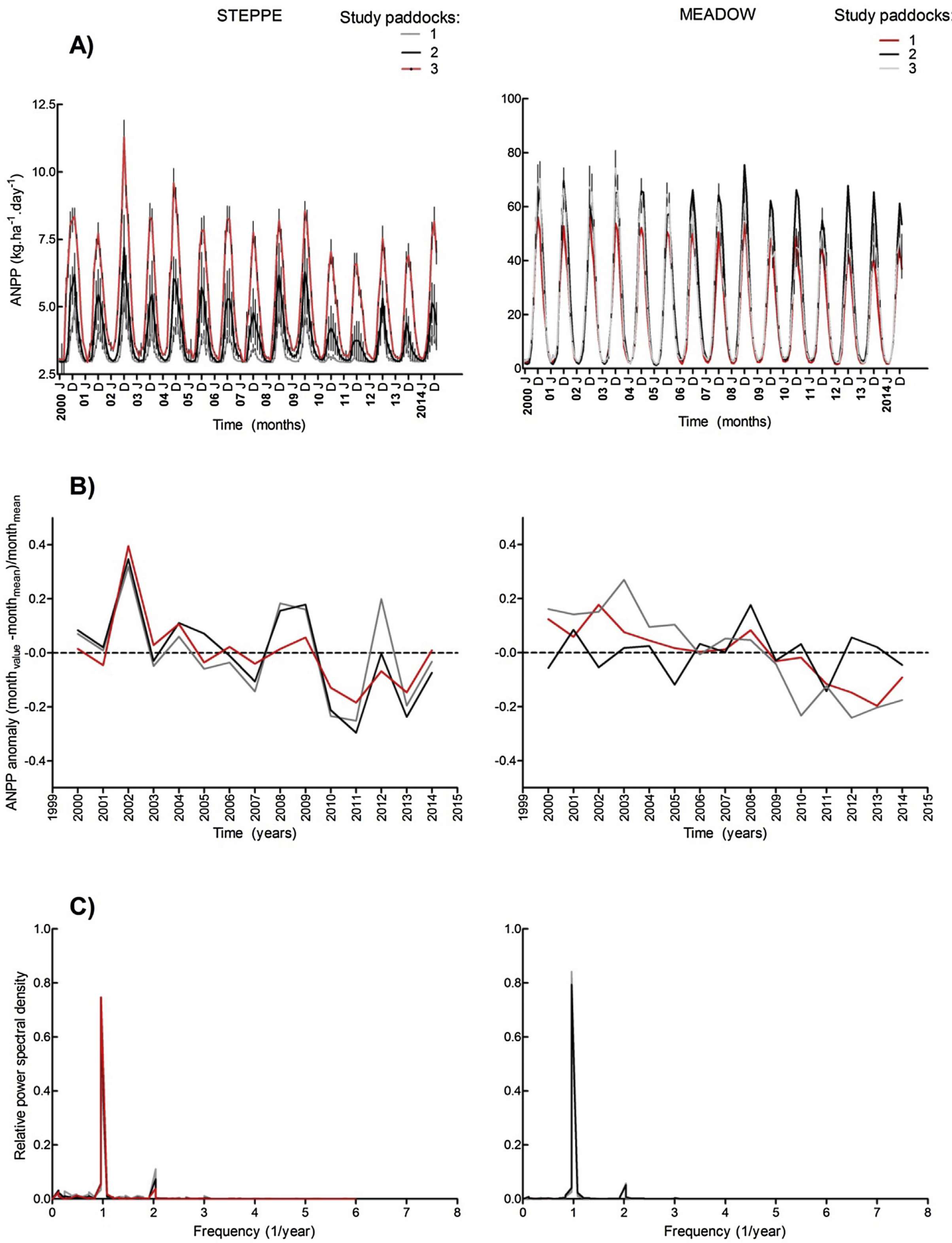

Fig. 1. Panel A: Mean monthly ANPP (±SE) from 2000 to 2015 for the six study paddocks (three steppes and three meadows). On the x-axis, "D" represents December and "J" represents June for each year. Panel B: December ANPP anomaly for the six study paddocks from 2000 to 2014. Panel C: power spectra of the 2000–2015 time series calculated from Fourier transformations.

We showed that it is clearly possible to have data with similar temporal patterns for ANPP (as revealed by power spectra analysis), but with very different (and meaningful) means, CVs, and anomalies. Thus, if future time series analyses only focus on power spectra or related techniques such as autocorrelation and partial autocorrelation functions, (e.g., Cowpertwait and Metcalfe, 2009), we will

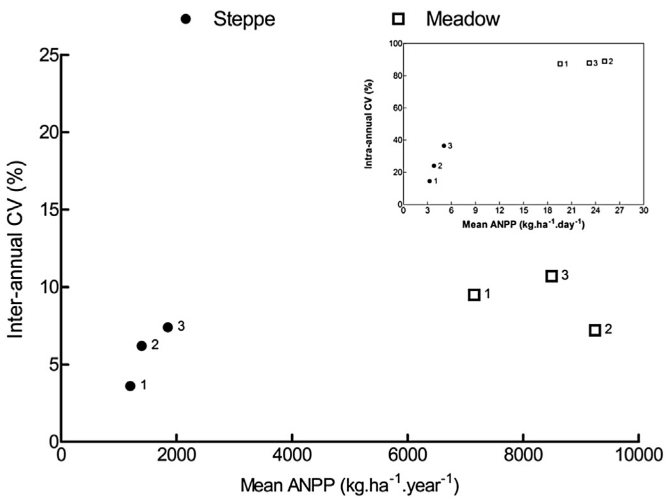

Fig. 2. Mean annual ANPP (x-axis) and inter-annual coefficient of variation (CV; y-axis) of the six study paddocks (three steppes and three meadows). Inset: Mean daily ANPP (x-axis) and intra-annual coefficient of variation (CV; y-axis) of the six study paddocks (three steppes and three meadows).

lose capability to describe fundamental and meaningful metrics of variability in forage production systems. The use of anomalies, also criticized by Easdale and Bruzzone (2015), provided above a quantitative description of the negative trend of peak ANPP. Furthermore, our "average thinking" provided a description of how different types of vegetation (i.e., steppes vs. meadows) responded to the reduction in annual rainfall experienced in all six study paddocks.

Our use of mean and inter-annual CV, as primarily criticized by Easdale and Bruzzone (2015), provided an essential description of the six paddocks. For example, steppe paddocks 1 and 2 used to be the same paddock, but were divided in half thirty years ago. Our analysis showed that both paddocks had similar mean annual ANPP, but paddock 2 had higher inter-annual variation. This higher variation has clear implications for ranching, but would not have been apparent if the data had only been examined using power spectra to examine cyclic patterns. Similarly, although both mean annual and daily ANPP was six times higher for meadows than steppes, the inter-annual CV was similar but the intra-annual CV was four times higher for meadows (Fig. 2). This non-proportional change between mean and intra-annual CVs also has critical implications for ranching, especially when planning seasonal paddock use.

Given the above results, it becomes difficult to wholly agree with the argument in Easdale and Bruzzone (2015) that CV is a poor measure of variability because it is confounded by the mean. Sometimes this confound can provide important insights, as above where means and CVs did not change proportionally. However, and as Easdale and Bruzzone (2015) describe, important information can be lost when only examining means and CV for rangeland studies. Our aim here was to show the same can indeed be said for their methodology. It is not our intention to dispute or discourage the use of the methods described in Easdale and Bruzzone (2015). Rather, we would simply like to point out that "averaging thinking" is still of value, and should perhaps be paired with time series analysis to best understand long-term rangeland forage production dynamics in future studies. As Easdale and Bruzzone (2015) describe, it is clearly important to avoid overlooking important patterns in long-term datasets. Given the examples provided both here and in Easdale and Bruzzone (2015), this is perhaps best accomplished by utilizing time series analyses and "average thinking" in conjunction instead of emphasizing that one method should be preferred over another. As evidenced above, either method alone can miss meaningful information, so results of either methodology may only be truly meaningful in the context of one-another.

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26 February 2015
Available online xxx