

Interactive comment on “Assessing vegetation structure and ANPP dynamics in a grassland-shrubland Chihuahuan ecotone using NDVI-rainfall relationships” by M. Moreno-de las Heras et al.

M. Moreno-de las Heras et al.

mariano.moreno-de-las-heras@durham.ac.uk

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We would like to thank Reviewer 2 for his/her interest in our study and helpful comments, which have largely contributed to improve our manuscript. We detail below a point-by-point response to all his/her comments/suggestions. Modifications to adapt the paper to Referee2's comments can be tracked in the marked MS submitted as supporting information for this response.

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Point-by-point reply:

General comment 1: “Vegetation structure and the associated dynamics in recent years is key to the understanding of terrestrial carbon cycle and prediction of future climate change. In an arid/semi-arid environment, it is particularly important, as land degradation is phenomenal and largely irreversible. In this paper, the authors used the latest satellite data derived from the MODIS sensor, as well as field-based measurements of climate and vegetation characteristics, and performed a theoretically correct, but empirically complex analysis over the study area in the Chihuahuan Desert in New Mexico, USA. It clearly shows the linkage between the vegetation change and one major environmental driver in this region – precipitation. In my opinion, the paper is well written in the introduction part and the theoretical basis, with a complete set of references and a simplified but clear process-based model description. That means, the paper lays out the question quite well. However, the methodology and consequently the results have quite a few confusing points, and that limits my understanding of this paper. Overall, I recommend reconsider the paper after major revisions. The authors need to make more efforts on clearly explain the methods, use simple and concise words, with the help of equations and diagrams”.

Response to General comment 1:

We really appreciate the positive evaluation of the scope and contents of our study. We have carried out important modifications in the manuscript with the purpose to make points more succinct, simplify concepts and clarify all the confusing points indicated by Referee 2 in the below detailed comments and responses to the comments.

General comment 2: “Concepts should be concise instead of wordy descriptions. For example, what are the reference NDVI-rainfall signatures (section 3.3)? Even after

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reading the entire paper, I was still confused by this concept. Is this the optimal RaL (in days) that maximizes Pearson's R (NDVI vs antecedent total rainfall for observations from 2000 to 2013)? I suppose it should be a simple variable and probably is 57 days for herbs and 145 days for shrubs as shown in Figure 3b. Why not use a simple term, such as ORaL (for optimal length of rainfall accumulation)? Or a symbol?"

Response to General comment 2:

We have made every effort to simplify concepts and avoid wordy descriptions. Referee 2 is right, the concept "NDVI-rainfall signature" (or RaL) resulted confusing and uninformative. Following his/her recommendations, we have excised the term "NDVI rainfall signature" from the text, which has been replaced by Olr (for optimal length of rainfall accumulation). Olr is now defined in the introduction (Page 4 lines 7-9: "The length (or number of days) of antecedent rainfall that best explains the NDVI (or green biomass) dynamics of dryland vegetation (hereafter optimal length of rainfall accumulation, Olr) appears to. . .") and used consistently in our conceptual model and the rest of the paper (for example, in figures 1 and 3).

General comment 3: "Figures and methods should be linked to explain the concepts better. Still in section 3.3, terms ARain_hv and ARain_s appear for the first time. But I did not understand what it was, until I saw it again in Figure 4. So are these in fact the green and red lines in Fig. 3b (for empirical results), and theoretically it should be the curves in Fig. 1b? Once the terminology is created, please use them consistently in the paper. Why not use them starting from Fig. 1?"

Response to General comment 3:

We have added direct links between our concepts and the figures displayed in the study. For example, the Olr term is defined in the introduction, and further determinations of Olr values for herbaceous and shrub vegetation (i.e. Olr_hv and Olr_s,

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respectively) are graphically detailed for both the theoretical model simulations (Fig. 1) and the empirical results (Fig. 3). Unlike Olr, ARain is not a single value but a temporal series of values (i.e. a temporal series of antecedent precipitation with Olr rainfall accumulation length). Now the ARain_hv and ARain_s series are detailed in both the modelling section and the empirical results of the study with graphical representation in figures 1 and 3. Concept definitions for ARain_hv and ARain_s now appear for the first time in the modelling section, and are directly linked to Fig. 1 (Page 7, lines 1-3): "Here, ARain_hv and ARain_s are defined as the antecedent rainfall series that optimize those vegetation-type specific relationships (i.e. time series of precedent rainfall with accumulation lengths Olr_hv for herbaceous vegetation and Olr_s for shrubs, Fig. 1a)".

General comment 4: "One of the major flaws I found in this paper is the decomposition of NDVI (section 3.5). It is true that the signal can be partitioned into several contributions from pure pixels. However, I do not agree that the soil background contribution can be subtracted as a constant value. If the authors did not account for the contribution of soil underneath vegetation, the contribution of soil should be a linear function of vegetation cover. For example, if a pure pixel of soil has an NDVI value of 0.12, then the contribution of soil for a pixel covered by 80% vegetation should be only $0.12 \times 0.2 = 0.024$ ".

Response to General comment 4:

C_bs(t) in equation 3 of the NDVI decomposition method describes the whole soil background contribution to the NDVI signal and not just the bare soil component. We erroneously transcribed this term in our study (as bare soil) from the original description of the equation by Lu et al. (2003), who defined the term as "the baseline or contribution from the background soil" and applied a constant value across time to remove the soil NDVI signal. Similarly, Montandon and Small (2008) in their field study determined for

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our site “soil background NDVI values” (rather than bare soil contributions). We apologize for the misunderstanding we could have caused with our wrong reproduction of the equation and concepts. We have modified the text to correct the errors: “Time series of NDVI at any specific location reflects additive contributions of background soil and the herbaceous and woody shrub components of vegetation (C_{bs} , C_{hv} , and C_s , respectively) for that particular site (Lu et al., 2003)” (Page 12, lines 1-5), “Montandon and Small (2008) carried out in situ measurements of field spectra convolved by the MODIS bands to determine the background soil contribution to NDVI in the SNWR. They obtained a soil NDVI value of 0.12 for Turney sandy loam soils, which are broadly distributed across the McKenzie Flats” (Page 12, lines 7-10), and “Therefore, a constant value of 0.12 was applied to subtract the background soil baseline (C_{bs}) from the NDVI time series, obtaining a new set of soil-free series (NDVIO)” (Page 12, lines 19-21).

Our approach is consistent with the standardization method proposed by Carlson and Ripley (1997), which probably constitutes the most common NDVI normalization technique for the estimation of vegetation biophysical properties (e.g. cover, LAI, NPP). Carlson & Ripley’s NDVI normalization method consists on the re-scaling of NDVI values as a function of local maximum values of NDVI time-series (usually obtained at peak vegetation growth in irrigated agricultural fields for the region) after removing the soil background contribution as a constant value (e.g. generally estimated as the minimum value of the time series of NDVI or determined in the field using in situ NDVI measurements). Provided that soil NDVI does not change importantly with soil moisture levels (this is only true for bright sandy and sandy-loam soils as the desert soils found in our study site, Huete et al. 1985) and that spatial variations in soil characteristics (i.e. soil texture and chiefly colour) are not very important (in our sites and at the scale of analysis the soils are homogeneous Turney sandy loams; see page 8, lines 19-20), the application of a unique and constant soil NDVI value offers an efficient approach for removing the background soil contribution (Huete et al. 1985, Montandon and Small 2008, Choler et al. 2010). In fact, some of the most popular NDVI decom-

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position methods apply a constant value to remove the background soil NDVI baseline (for example, Roderick et al. 1999, Lu et al. 2003). Coherency with those studies is now detailed in the text (Page 12, lines 12-15): “Application of reference soil values in NDVI decomposition and normalization methodologies provides an efficient standardization approach for characterizing the background soil baseline, particularly in areas with homogeneous soils (Carlson and Ripley, 1997; Roderick et al., 1999; Lu et al., 2003; Choler et al. 2010)”.

Specific comment 1: “Abstract: “We use these relationships to (a) classify landscape types as a function of the spatial distribution of dominant vegetation, and to (b) decompose the NDVI signal into partial primary production components for herbaceous vegetation and shrubs across the study site.” I cannot understand this sentence. Overall, I think the authors need to put more results in the abstract rather than lots of introduction”.

Response to Specific comment 1:

We have reworded the abstract, reducing the introductory information and extending the results (Pages 1-2, lines 12-9): “Climate change and the widespread alteration of natural habitats are major drivers of vegetation change in drylands. In the Chihuahuan Desert, large areas of grasslands dominated by perennial grass species have transitioned over the last 150 years to shrublands dominated by woody species, accompanied by accelerated water and wind erosion. Multiple mechanisms drive the shrub-encroachment process, including precipitation variations, land-use change, and soil erosion-vegetation feedbacks. In this study, using a simple ecohydrological modelling framework, we show that herbaceous (grasses and forbs) and shrub vegetation in drylands have different responses to antecedent precipitation due to functional differences in plant growth and water-use patterns. Therefore shrub encroachment may be reflected in the analysis of landscape-scale vegetation-rainfall relationships. We

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analyze the structure and dynamics of vegetation at an 18 km² grassland-shrubland ecotone in the northern edge of the Chihuahuan Desert (McKenzie Flats, Sevilleta National Wildlife Refuge, NM, USA) by investigating the relationship between decade-scale (2000-13) records of remotely sensed vegetation greenness (MODIS NDVI) and antecedent rainfall. NDVI-rainfall relationships show a high sensitivity to spatial variations on dominant vegetation types across the grassland-shrubland ecotone, and provide ready biophysical criteria to (a) classify landscape types as a function of the spatial distribution of dominant vegetation, and to (b) decompose the NDVI signal into partial components of annual net primary production (ANPP) for herbaceous vegetation and shrubs. Analysis of remote-sensed ANPP dynamics across the study site indicates that plant growth for herbaceous vegetation is particularly synchronized with monsoonal summer rainfall. For shrubs, ANPP is better explained by winter plus summer precipitation, overlapping the monsoonal period (June to September) of rain concentration. Our results suggest that shrub encroachment has not been particularly active in this Chihuahuan ecotone for 2000-13. However, future changes in the amount and temporal pattern of precipitation (i.e. reductions in monsoonal summer rainfall and/or increases in winter precipitation) may enhance the shrub-encroachment process, particularly in the face of expected upcoming increases in aridity for desert grasslands of the American Southwest”.

Specific comment 2: “Page 58, Line 13: “a set of plausible parameters obtained from literature”. Why are these parameters not dependent on vegetation type? In particular W_0 and k ?”

Response to Specific comment 2:

We retrieved parameter values from previous studies that have applied theoretical modelling frameworks with a similar structure (e.g. one-layer models) to explore shrub-herbaceous dry ecosystems (for example, Rietkerk et al., 2002; Ogle and Reynolds,

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2004; Gilad et al., 2007; Saco and Moreno-de las Heras, 2013). Those studies indicated very important differences between herbaceous and shrub vegetation types for the plant growth and mortality rates (g_{max} and m parameters), although in general they did not apply clear differences for the other parameters. Consequently, we preferred to keep other parameter values constant for the simulations of both the herbaceous and shrub dynamics.

In order to test whether variations in the values of model parameters W_0 , k_w , c , k_i , i_0 and r_w can impact the simulated Olr values (and therefore our interpretations of the modelled herbaceous and shrub dynamics) we have applied a model sensitivity analysis that is now available in the supporting information for the revised paper (Supplementary Fig. 1). Most parameters, and particularly W_0 and k_w , have a negligible effect on simulated Olr_{hv} and Olr_s values. The only two parameters that can impact Olr values significantly are i_0 (infiltration rate in bare soil) and r_w (loss of soil moisture by direct evaporation and/or deep drainage) that, in any case, do not depend on vegetation density or vegetation type. Reductions in bare soil infiltration and increases in evaporation/deep drainage can increase Olr . This effect is more important for simulated Olr_s values than for Olr_{hv} . Therefore, variations in i_0 and r_w can ultimately amplify the Olr differences we obtained for herbaceous and shrub vegetation (i.e. the difference between Olr_{hv} and Olr_s).

The main results of our model sensitivity analysis are now summarized in the text (Page 7, lines 7-11): “Sensitivity analysis of Olr to other model parameters (Supplementary Fig.1 in the online supporting information of this study) indicates that W_0 , k_w , k_i , and c have negligible effects on simulated Olr values. Reductions on bare soil infiltration (i_0) and increases on water loss by direct evaporation and/or deep drainage (r_w) can impact Olr_{hv} and Olr_s values, ultimately amplifying the differences we obtained between vegetation types”.

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Specific comment 3: “Page 59, Line 3: “These modelling results illustrate conceptually the distinct dependence of the relationship between plant biomass and antecedent precipitation on vegetation type”. This is the major contribution from the simplified model, and serves the purpose of this study pretty well. It would be even better to emphasize with one or two sentences describing the particular circumstances/assumptions where the “simplified” version can be applied”.

Response to Specific comment 3:

We are very pleased with the positive evaluation of our model simulations and the conceptual set-up of our study. We have expanded the model information with the above discussed model sensitivity analysis (please, see our response to the Specific comment 2), and we have added also some details on the potential limitations of the model and how these limitations can affect our simulated results (Page 7, 11-14): “Other factors not explicitly considered in our simple model, such as differences in root structure, may also reinforce herbaceous and shrub differences in time-scale plant responses to antecedent precipitation (Reynolds et al., 2004; Collins et al., 2014)”.

We have added also a sentence to emphasize the utility of the model for the study of dryland systems (Page 7, lines 15-19): “The simple model presented in this study provides a good starting point for addressing general differences in plant responses to antecedent precipitation for different vegetation types in drylands. Overall, our modelling results illustrate conceptually the distinct dependence of the relationship between plant biomass and antecedent precipitation on vegetation type, particularly when comparing the dynamics of dryland herbaceous and shrub vegetation”.

Specific comment 4: “Page 63, Line 15 and 19: “Exploratory data analysis. . .” and “Preliminary analysis”. Why not put these analyses as supplementary materials?”

Response to Specific comment 4:

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Those analyses are already integrated in the results section. For example, linearity between NDVI, NPP and precipitation is explicit in Figs. 5b and 7. Similarly, the emergence of secondary Olr_hv values for the Creosotebush Core Site during wet years with strong herbaceous production is detailed in Fig. 3 and Supplementary Fig. 2, both cited in the results section (Page 15, lines 5-17). Citation of those analyses in the methods is unnecessary and probably quite confusing for the readers. Therefore, we have deleted those citations in the Methods.

Specific comment 5: “Page 63, Line 23: “In order to avoid confounding effects (i.e. the mixing of the dominant-shrub and non-dominant herbaceous responses to precipitation) on the identification of the local NDVI-rainfall signatures, correlations between NDVI and antecedent precipitation series (of different rainfall accumulation lengths) were determined independently for each annual cycle of vegetation growth (April–March).” Wordy, and no cause-and-effect relationship”.

Response to Specific comment 5:

We agree with Referee 2 that that sentence is wordy and confusing. We have reworded the whole paragraph to simplify the text and improve description of cause-and-effect relationship (Page 10, lines 26-31): “Growth of non-dominant herbaceous vegetation in arid shrublands can make the detection of the shrub-specific NDVI-rainfall metrics (i.e. Olr_s) difficult due to the emergence of secondary Olr_hv values, particularly in wet years with strong herbaceous production (Moreno-de las Heras et al., 2012). We applied detailed analysis of the NDVI-rainfall relationships in the Core Sites for each annual cycle of vegetation growth to facilitate discrimination of the Olr_hv and Olr_s metrics”.

Specific comment 6: “Page 64, Line 2: “The reference vegetation-type characteris-

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tic antecedent rainfall series (ARain_hv and ARain_s for herbaceous vegetation and shrubs, respectively)". Please refer to figures here".

Response to Specific comment 6:

Following the recommendations, ARain_hv and ARain_s are now referenced to figures 1 and 3 for the modelling and empirical results sections, respectively (see also the above response to General comment 3 for more details).

Specific comment 7: "Page 64, Line 15: "Conversely, a low strength on the NDVI-rainfall relationship consistently obtained across the 2000–2013 cycles of vegetation growth for a specific vegetation-characteristic antecedent rainfall series will locally evidence a low activity of the analyzed vegetation type for the study period." Not a necessary sentence, and hard to understand".

Response to Specific comment 7:

Following the recommendations, we have deleted that sentence.

Specific comment 8: "Page 64, starting from Line 20: This paragraph is hard to understand. I suppose that the authors have used PCA due to high dimensionality (28 variables). However, PCA analysis makes the study scene-dependent. How could it be applied to other regions, when the 1st dimension of PCA is not dominated by herbaceous/shrub fractions?"

Response to Specific comment 8:

Referee 2 is right on the purpose of our PCA. We have applied PCA to reduce data dimensionality. We have simplified the paragraph to reflect correctly this point (Page 11, lines 23-26): "In order to reduce data dimensionality, we applied Principal Component Analysis (PCA) using the calculated correlation coefficients as variables for analysis

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(28 variables resulting from the two vegetation-specific antecedent rainfall series and the 14 growing cycles)".

PCA extracts data variability in a set of orthogonal components that are ordered in terms of absorbed or explained variance (i.e. the first component accounts for as much of the variability in data as possible). In our application, PCA summarizes the intensity of herbaceous and shrub activity (or growth) for all the MODIS pixels in our grassland-shrubland ecotone across 2000-13, and the first component reflects accurately the spatial distribution of herbaceous/shrub fractions across the ecotone. Applications in other simple grassland-shrubland ecotones (or other single ecotones between two vegetation types with contrasted plant growth patterns) will lay very similar results. As far as the plant-growth patterns of the two vegetation types are different, the first component will undoubtedly reflect those differences. The only case we can picture that probably will not offer a good discrimination of vegetation types in the first PCA component is a very large-scale application of this method in areas with a variety of vegetation types and ecotones. For example, in a very extent area where, instead of a single ecotone with two contrasted vegetation types, there are various transitions between multiple vegetation types (e.g. grasslands, evergreen shrublands, deciduous shrublands, and open forests) the information explained by the first component will probably not differentiate all the vegetation types. In this case, accurate discrimination of all the vegetation types will require the use of the first two or three PCA components (and not just the first component of the analysis).

Specific comment 9: "Page 67, Line 1: "Explorative comparisons revealed that this simple two-step procedure outperformed other more complex NDVI-decomposition methodologies". When this is being said, better to provide evidence (e.g., results of comparisons)".

Response to Specific comment 9:

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We applied and compared a variety of NDVI-decomposition methodologies with different levels of complexity. The simple method presented in our study outperformed, for example, the application of artificial neural network and autoregressive modeling, which notably inflated the error of the remote sensing ANPP estimations (see below the section “Comparison of NDVI-decomposition methodologies” for details). Those explorative comparisons facilitated the selection of a simple and efficient methodology for this paper, although we do not think that they provide any sort of critical information for the readers of this study. Actually, we believe that full presentation of those details in the paper would unnecessarily increase the complexity of our study, so we have decided to delete the reference in the text to the explorative work detailed below in this response letter.

Specific comment 10: “Figure 5: When the core sites were used as reference pure pixels for herbs/shrubs, how can the NDVI series in panel A still show 2 components?”

Response to Specific comment 10:

We did not use the Core Sites as pure pixels for herbs/shrubs, but as reference sites with dominant herbaceous/shrub vegetation. The Creosotebush and Black Grama Core Sites are dominated by shrubs and perennial grasses, respectively. However, they do not represent areas with pure herbaceous or shrub vegetation. Actually no MODIS pixel for the area (pixel size is 230 x 230 m²) represents just one pure vegetation type (nor would any pixel size beyond a few cm given the patchy nature of the vegetation). The ground pictures of the sites in Fig. 2 (bottom panels in figure 2) clearly show that in the Black Grama Core Site (right bottom panel) there are scattered shrubs (i.e. the scattered dark green plants in the picture), while in the Creosotebush Core Site (left bottom panel) there are also some perennial grasses and variable amounts of annual forbs and grasses (i.e. the standing dry plants/spikes and stubble in the picture). Accordingly, the decomposed NDVI series in Fig. 5a show: (i) for the Black Grama

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Core Site a dominant component of herbaceous vegetation and a non-dominant component of shrub vegetation, and (ii) for the Creosotebush Core Site a dominant shrub component and a non-dominant component of herbaceous vegetation.

To avoid misinterpretations, we have carefully checked (and corrected as necessary) vegetation descriptions in the manuscript. Both, dominant and non-dominant components of vegetation for the grassland and shrubland sites are explicitly described in the description of the study area (Page 8, lines 9-19: “This study area extends over two LTER core sites established in 1999 (Fig. 2c): a desert shrubland (Creosotebush SEV LTER Core Site) dominated by creosotebush, and a grassland (Black Grama SEV LTER Core Site) dominated by black grama (...). The abundance of creosotebush (*Larrea tridentata*) in the grasslands is generally low, although smaller shrubs and succulents (e.g. *Gutierrezia sarothrae*, *Ephedra torreyana*, *Yucca glauca*, *Opuntia phaeacantha*) can be common. The abundance of perennial grass species decreases to the southern and southwestern parts of the study area, where creosotebush stands are widely distributed with in general low (although variable in time) amounts of annual forbs and grasses”), and further emphasized in other parts of the manuscript (for example, Page 15, lines 10-11: “For the Creosotebush Core Site (with dominant shrub vegetation and subordinate forbs and grasses)...”).

Comparison of NDVI-decomposition methodologies:

Comparison of NDVI-decomposition methodologies, (i) Methods:

We applied and evaluated two variations of the simple NDVI decomposition method presented in the paper (Reference method) using two more complex approaches (SOLO and AutRes methods):

SOLO: This methodological variation consisted on the application of an artificial neural

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network (ANN) modelling algorithm (SOLO, Self-organizing Linear Output Map, Hsu et al. 2002) for refining the relationship between soil free NDVI (NDVI0) and the herbaceous and shrub optimal antecedent rainfall series ARain_hv and ARain_s (eq. 5 in the manuscript):

$$\text{NDVI0}(t) = h \text{ ARain_hv}(t) + s \text{ ARain_s}(t)$$

SOLO classifies input data (i.e. the NDVI0 temporal series) into different groups with similar temporal properties (e.g. homogeneous sections of the temporal series with increasing values, decreasing values, plateaus, etc.) and further applies first-order least-squares optimization of the target NDVI-rainfall equation independently for the different data groups established in the classification.

AutRes: This methodological variation consisted on the application of an autoregressive model instead of first-order optimization of the above simple equation. NDVI0 for any $t+\Delta t$ in the autoregressive model is expressed as the partial contribution of herbaceous and shrub vegetation (C_{hv} and C_s , respectively) in t plus their variation in time (to $t+\Delta t$) in response to changes on antecedent precipitation:

$$\text{NDVI0}(t+\Delta t) = C_{hv}(t) + h \Delta \text{ARain_hv}(\text{from } t \text{ to } \Delta t) + C_s(t) + s \text{ ARain_s}(\text{from } t \text{ to } \Delta t)$$

where, h and s represent vegetation-type specific rainfall-NDVI conversion coefficients for the herbaceous and shrub components.

This autoregressive approach requires reference information on the contribution of shrub and herbaceous vegetation to NDVI in, at least, a discrete t to propagate the relationships along the NDVI temporal series. Evergreen shrubs in the area (e.g. creosotebush) permanently maintain green leaves during all seasons, while herbaceous vegetation generally does not show photosynthetic activity at the end of winter. We assumed that NDVI0 at the end of the cycles of vegetation growth (late March) was fully represented by shrubs, using these values as reference points to propagate the autoregressive model along the time series.

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Following the procedure detailed in the paper, we applied the estimated coefficients h and s to determine the weight of the herbaceous and shrub fractions on the time series. In order to preserve the observed seasonality of the original time series, the predicted weights (or percentage contributions) were reassigned to the input NDVI0 series obtaining the final components for herbaceous vegetation and shrubs (C_{hv} and C_s , respectively).

Comparison of NDVI-decomposition methodologies, (ii) Results:

NDVI partitions obtained using the reference decomposition method yield for the Black Grama Core Site a clearly dominant herbaceous component (below Fig. 1a). Conversely, the decomposed shrub NDVI signal strongly prevails over the decomposed herbaceous component in the shrub-dominated Creosotebush Core site. SOLO and AutRes decomposition methods, however, do not reproduce the expected dominances for the reference grassland and shrubland sites, particularly for the shrub-dominated Creosotebush Core Site where the decomposed signal for herbaceous vegetation exceeds the shrub component for a variety of periods (below Figs. 1d and g).

Agreement between field ANPP levels and the annual sums of the decomposed herbaceous/shrub NDVI series is markedly stronger for the reference NDVI decomposition method ($R^2 \geq 0.65$) than for SOLO and AutRes decomposition methods ($R^2 \leq 0.55$ and 0.53 , respectively; below Figs. 1b, e and h). Accordingly, SOLO and AutRes NDVI decomposition methods notably inflate the error of the remote sensing ANPP estimations, when compared with the results generated by the reference NDVI decomposition method applied in our study (normalized error is 12%, 18% and 26% for the reference, SOLO and AutRes methods, respectively; below Figs. 1c, f and i).

Overall these explorative results reveal that the simple NDVI decomposition procedure applied in our study (the reference method) outperforms other more complex methodologies based on artificial neural network and autoregressive modeling (SOLO and

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AutRes methods) for the decomposition and transformation of the NDVI signal into herbaceous and shrub NPP components.

Comparison of NDVI-decomposition methodologies, (iii) References:

Hsu, K., Gupta, H. V., Gao, X., Sorooshian, S., and Iman, B. 2002. Self-organizing linear output map (SOLO): an artificial neural network suitable for hydrologic modelling analysis, *Water Resources Research*, 38, 1302.

Comparison of NDVI-decomposition methodologies, (iv) Figure Caption:

Figure 1. NDVI decomposition comparisons between three methods: (a-c) Reference decomposition method applied in our study, (b) SOLO method, and (c) AutRes method. Plots (a, d, and g) show the decomposed NDVI time series of herbaceous and shrub vegetation for the Black Grama and Creosotebush Core sites. Plots (b, e, and h) show the agreement between the annual sums of decomposed herbaceous/shrub NDVI and field ANPP. Plots (c, f and i) show the root mean square error (RMSE) and normalized error (NRMSE) of the herbaceous and shrub ANPP estimates derived from the application of the different NDVI decomposition methods.

Please also note the supplement to this comment:

<http://www.biogeosciences-discuss.net/12/C801/2015/bgd-12-C801-2015-supplement.pdf>

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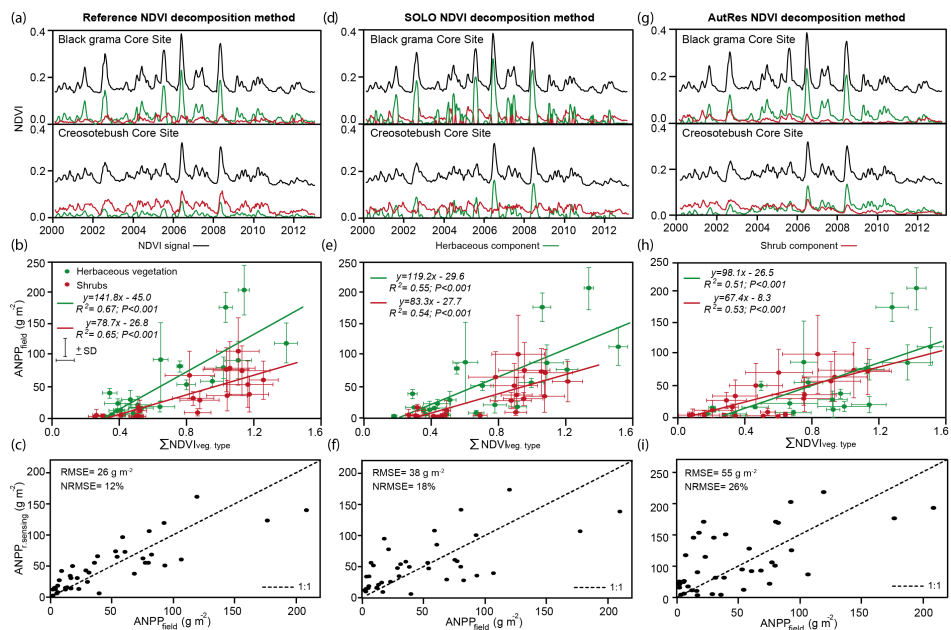


Fig. 1.

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