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Short communication

Modeling herbaceous productivity considering tree-grass interactions in drylands savannah: The case study of Yatir farm in the Negev drylands

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ABSTRACT

Savanization is an efficient strategy to confront desertification by increasing herbaceous productivity in drylands providing income to local population relying on grazing. Hence, to assess successful savanization herbaceous production must be estimated accurately. The conventional technique uses random sampling, which might misestimate productivity underneath the canopies due to tree-grass interactions. Here we present an improved model to assess biomass production accounting for tree-grass effects using a stratified sampling technique. Our model calculates biomass underneath the canopy in two configurations: (a) a cone shape, accounting for gradual changes along the bole-to-drip line with radiuses representing topographic aspects, and (b) a cylindrical shape, accounting for biomass underneath the canopy not affected by the tree. We tested our model in the *Acacia victoriae* savannah of Yatir at the Northern Negev drylands, Israel. Results showed that biomass underneath the canopy were up to 3-fold higher than the measured in between trees. Although the total canopied area was only 4.4% of the savannah, biomass underneath canopies constituted 7% of the total savannah production. Thus, conventional sampling might significantly underestimate biomass production in denser savannah. Our model was adjusted to multi-species savannah and different geographic aspects and could be used in drylands systems elsewhere.

1. Introduction

Savanization (i.e. planting of less than 200 trees ha^{-1}) is an efficient way for increasing the biomass of native herbaceous vegetation in arid and semiarid drylands (MAP < 550 mm y^{-1}) (Helman et al., 2014a,b; Malagnoux et al., 2008). It provides sustainable supply of forage for grazing management that the local population in these areas rely upon (Asner et al., 2004; Oba et al., 2000; Verwijmeren et al., 2014). Hence, to assess successful savanization herbaceous production must be estimated accurately without damaging the low-productivity ecosystem. Therefor, usually random sampling is conducted (Belsky et al., 1993).

Former studies have treated the area underneath the trees as one unit and as such suggested to simply sample it randomly in order to assess its contribution to total herbaceous biomass (Ludwig et al., 2004). However, herbaceous vegetation seems to be affected by trees in dry and temperate savannah sites, showing gradual changes in herbaceous biomass from the tree bole to the canopy edges (Dohn et al., 2013; Moustakas et al., 2013).

In general, trees interact with grasses through positive (facilitative) or negative (competition) mechanisms. The net effect will be facilitative or competitive depending on many factors that are difficult to model (Scholes and Archer, 1997). Specific environmental conditions regulate such interactions. For example, in semiarid regions (MAP < 550 mm y^{-1}) trees were found to have net facilitative effects on the local herbaceous vegetation (Moustakas et al., 2013). Dense herbaceous layers would develop underneath the canopy benefiting from the tree shade and water uplift in these dry places. Such interactions become competitive in more mesic sites (550 ≤ MAP < 750 mm y^{-1}) (Dohn et al., 2013).

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Because of these tree-grass interactions, using conventional random sampling technique (i.e. unstratified sampling) might misestimate the total herbaceous production of the savannah. The magnitude of under/over-estimation will depend on the intensity of the net facilitative/competitive effect and the stand density of the savannah.

Here we present a model to estimate biomass accounting for tree-grass interactions using a stratified sampling approach with minimum damage to the ecosystem. We present our model as mathematical equations suitable for single and multi-tree species savannah elsewhere and compare it with the conventional random technique in a drylands savannah at the Northern Negev. For that purpose, we chose the Yatir farm *Acacia victoriae* savannah (Fig. 1). A net facilitative effect was previously observed in this area (Helman et al., 2014a,b; Mor-Mussery et al., 2013) (Fig. 1). We examined the constancy of these observations and present the way it should be used to assess total productivity in drylands savannah elsewhere.

2. Model description

To properly estimate herbaceous biomass (*HB*) underneath the canopy we used a stratified sampling technique in two distinct configurations: (i) as a constant configuration that calculates total production underneath the tree (in g) assuming no tree-grass interactions, and (ii) as a gradual one, accounting for *HB* added due to facilitative effects (Fig. 2).

(i) The constant configuration (cylinder type):

The constant configuration was modelled as the volume of a cylinder. The base of the cylinder represents the projected area of the canopy perpendicular to the ground (Tr_{Area} and black lines in Fig. 2). Its height is the assumed *HB* (g m^{-2}) if no tree-grass interactions occurs, which is equal to the *HB* between the trees in open areas (HB_{Open}). Accordingly, Tr_{Area} (m^2) was calculated from the canopy radiuses measured in downhill, (Tr^{D}_{Rad}), uphill (Tr^{U}_{Rad}) and perpendicular to slope directions (Tr^{P}_{Rad}- i.e. the average of the right and left directions) (Fig. 2):

$$Tr_{Area} = \pi\left(\frac{Tr^{D}_{Rad} + Tr^{U}_{Rad}}{2}\right)Tr^{P}_{Rad} \quad [1]$$

Then, the total *HB* underneath the canopy area for the constant configuration (HB_{Cons}) is:

$$HB_{Cons} = HB_{Open} \cdot Tr_{Area} \quad [2]$$

Note that HB_{Cons} is in grams for the canopied area of a single tree.

(ii) The gradual configuration (cone type):

The gradual configuration was modelled as the volume of an elliptical cone with the centre at the bole (red lines in Fig. 2) (in the web version). Here, the area of the cone represents the area where *HB* changes gradually from the bole and is different from that of between the trees. The radiuses of the cone are the distances from the bole to where *HB* equals to that of between the trees (Fig. 2). These distances will be referred here as 'changing points'. Changing points are measured from the bole in downhill, (Tr^{D}_{Effect}), uphill (Tr^{U}_{Effect}) and perpendicular to slope directions (Tr^{P}_{Effect} – i.e. the average of the right and left directions), and the area is:

$$Tr_{Effect} = \pi\left(\frac{Tr^{D}_{Effect} + Tr^{U}_{Effect}}{2}\right)Tr^{P}_{Effect} \quad [3]$$

HB in the area underneath a single canopy where gradual changes occur (HB_{Grad}, in g) is calculated from *HB* measured at the

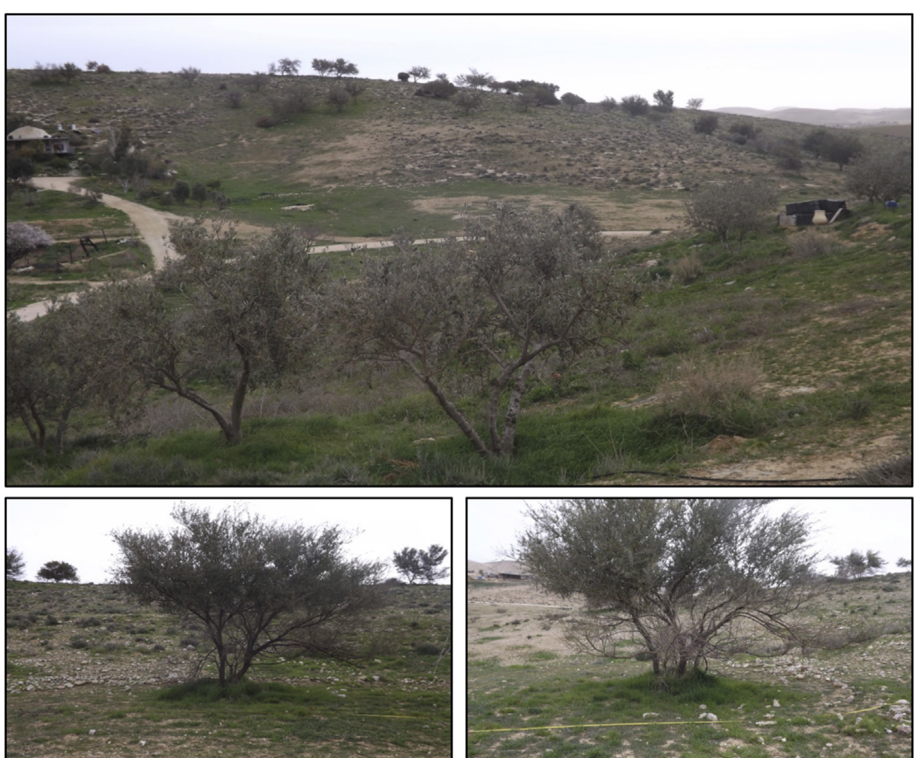

Fig. 1. A general view of Yatir farm (Upper), and the gradual change in herbaceous biomass from tree bole to drip line (Lower). Photos credit: A. Mor-Mussery (Febraury, 2014).