Title: The utility of visual estimation in the rapid assessment of grass abundance for studies of foraging

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Abstract

The collection of detailed forage abundance data for studies of herbivore foraging behavior is important but often logistically demanding. Rapid sampling measures may help, but it is essential to assess the utility of such methods in specific habitats. We examined the relationship between visually estimated cover of grass species and their measured biomass in Nagarahole National Park. We found that grass cover was an excellent predictor of biomass within species, and additional height measurements did not improve biomass estimation. Species-level covers were more reliable than total covers and can be used for rapid assessment of proportional forage abundance.

Keywords

Visual estimation, grass abundance, biomass, species cover, forage.

Introduction

Estimating forage abundance is a basic requirement for studying ecological and behavioral aspects of foraging in animals. However, the collection of detailed forage abundance data may be demanding in terms of effort, time, and resources, which are limitations for most field biologists. Therefore, rapid assessment methods rather than intensive approaches may need to be explored for on-site quantification of vegetation (Lavorel *et al*. 2008). Biomass measurements (for example, Noyce and Coy 1990, Sivaganesan 1991, Guo and Rundel 1997, Chiarucci *et al*. 1999, Henschel *et al*. 2005, Baskaran *et al*. 2010), count/density of individuals (for example, Noyce and Coy 1990, Guo and Rundel 1997, Blake 2002), and cover or rank (for example, Noyce and Coy 1990, Guo and Rundel 1997, Chiarucci *et al*. 1999, Blake 2002, Henschel *et al*. 2005, Rebello *et al*. 2013, Iversen *et al*. 2014) have been used for estimating vegetation abundance in field studies. Measurement of biomass involves harvesting vegetation in plots and weighing these samples. In terms of time-effectiveness, overall biomass measurement of a plot is not time consuming, while species-level measurements are, as they involve segregation of individuals of different species before weighing. Counts of individuals are practical for assessing tree abundance but not the abundance of lower strata vegetation such as herbs or grasses, for which cover is often used. Cover is estimated either visually (Guo and Rundel 1997) or by following the point quadrat method, in which the number of contacts with a fixed number of pins passed through the vegetation to the ground is used to estimate cover (for example, Goodall 1952, Jonasson 1988, Chiarucci *et al*. 1999).

Measurement of biomass would be ideal for assessing the quantity of forage available for consumption, but it may not be logistically possible (because of permits) or advisable to measure biomass on a large scale because it requires harvesting all the vegetation of the sampling plots. Therefore, there have been previous attempts to examine whether cover can be used as a surrogate for biomass. While Jonasson (1988) found strong correlations between cover and biomass, Guo and Rundel (1997) found that cover did not detect differences between plant communities the way biomass did, and Chiarucci *et al*. (1999) and Lavorel *et al*. (2008) clarified that inferences about community structure or functional trait values based on cover and biomass could be concordant or not depending upon the ecological feature being examined. Further, discordance between the measures of abundance was primarily seen in subtle aspects of community structure (Chiarucci *et al*. 1999). We, therefore, thought that visual estimation of cover may still potentially be a reliable, time-effective method for estimating forage abundance for herbivores, as one is generally looking for broader patterns in abundance rather than subtle differences in this case. Visual estimations of abundance have been used previously to assess spatio-temporal distributions of food resources (for example, Noyce and Coy 1990, Rebollo *et al*. 2013, Iversen *et al*. 2014), although the reliability of the method has seldom been assessed (but see Noyce and Coy 1990 for fruit abundance) in areas other than paddocks or simple, open ecosystems (for example, Waite 1994, Guo and Rundel 1997, Henschel *et al*. 2005).

We undertook the current study with the objective of assessing the utility of visual estimation as a time-effective method of on-site assessment of grasses in a tropical forest comprising multiple vegetation strata. This is important for characterizing forage distribution in elephants, which show a high proportion of grass in their diet (Owen-Smith 1988, Sukumar 1990, Baskaran *et al*. 2010, Roy and Chowdhary 2014), and grazing ungulates. The two questions that we address here are the following:

1. How do visual estimates of grass cover of individual species relate to their respective biomass measurements?
2. What is the relationship between the total grass cover estimated and the total grass biomass, and is the sum of species-level visual estimates better than the total grass cover visual estimate in predicting total grass biomass?

For the purpose of this study, grasses include sedges also (although they are from different families) because they are ecologically similar and because the number of sedges in the area was very small.

Methods

The study was carried out at the end of the wet season, from November to December 2013, in Nagarahole National Park (area: 644 km^2, 11.85°-12.26° N, 76.00°-76.28° E), which lies in the Nilgiris-Eastern Ghats landscape in southern India (Figure 1). The vegetation is characteristically tropical deciduous forest comprising several strata and is home to several herbivores, including Asian elephants, on which a long-term project based on uniquely identified individuals is currently ongoing (see Vidya *et al*. 2014). Based on a forest type classification map of the region developed by Pascal (1982), Nagarahole National Park was divided into the three major forest types: dry deciduous forest, moist deciduous forest, and teak plantations. We had previously divided the area into 2 km x 2 km grids, with 60 1-km line transects generated in randomly selected grids. During the present study, 23 transects in the southern part of the park were sampled because of logistical constraints in sampling the northern parts. To improve the sample size, 17 additional sites, at least half a km away from the random transects and at least 100 m away from forest roads, were chosen for sampling, resulting in a total of 40 sampling sites. Care was taken to adequately represent all three forest types (based on their availability) in the sampling sites. Sampled locations are mapped in Figure 1.

Sampling was carried out in 20 m x 5 m plots at the starting point or the end point of the transect. In all but one of the plots, three 1 m x 1 m quadrats were sampled, equidistant along a straight diagonal line (in one plot, only two quadrats could be sampled). Measurements on grass abundance were made in these 119 quadrats at two levels. First, total grass cover (union of all grass species cover) was visually estimated by a single observer (HG) as the percentage of quadrat area covered by all grasses. Second, grass cover for each grass species was visually estimated, independent of the cover of other species. Cover was usually estimated to the closest 5% or in interval bins of 5%, in which case, the middle value of the interval was chosen as the cover value. Values of less than 5% were entered in the case of rare species that were represented by only one or two individuals in the quadrat. Grass height was also measured since it could possibly improve the estimation of biomass along with visually estimated cover. Four individuals (except in the case of rare species, in which fewer than 4 individuals were available) of each species were arbitrarily selected, their natural standing heights (i.e. without straightening the plant) measured with a scale, and the average of these taken as the height for that species. The total grass (wet) biomass was measured using a digital weighing balance (to the closest gram) after harvesting all the grass from the ground level. Individuals were then hand-sorted into the respective species, and the biomass for each species was measured.

The unit of analysis was the 20 m x 5 m plot. Values of different variables in 1 m x 1 m quadrats were averaged to obtain values for the plots. Apart from total grass cover, overall grass cover was also measured as the sum of individual grass species' covers (which could exceed 100 since each species was assessed independently). Total grass cover, sum of grass species' cover, and total biomass were normally distributed, while cover, biomass, and height for individual species were not. The latter variables were, therefore, log transformed for the analyses, although the analyses were also performed on untransformed data to examine how different the results were. We first carried out a test for the homogeneity of slopes to inspect the effect of habitat type on the relationship between biomass and grass cover. Since there was no effect of habitat type on this relationship (see Results), we used simple regressions of biomass on overall grass covers (total grass cover and sum of grass species' covers) to assess the usability of the latter measure. The same analyses were also carried out using individual grass species' covers in 10 species (the other species were present in fewer than 10 plots). At the level of individual species, we also checked whether multiple regressions that included species heights, in addition to individual grass species' covers, were better able to explain variation in individual species' biomass compared to regressions without height included. Data were analyzed using Statistica 8 (StatSoft Inc. 2007).

Results

Based on the 40 plots (119 quadrats) sampled in three habitat types, we found no effect of habitat type on the relationship between total biomass and total grass cover (Homogeneity of slopes: Effect of habitat: $F[2,34]=0.219$, $P=0.805$; Effect of total grass cover: $F[1,34]=30.192$, $P<0.001$) or on the relationship between total biomass and the sum of grass species' covers (Homogeneity of slopes: Effect of habitat: $F[2,34]=0.448$, $P=0.643$; Effect of sum of grass species' covers: $F[1,34]=57.291$, $P<0.001$). Therefore, we ignored habitat as a factor and analyzed data from all the plots together. We found that while both total grass cover and the sum of grass species' covers were able to explain total biomass to a reasonable extent, the sum of grass species' covers had better explanatory power than total grass cover (total grass cover: $F[1,38]=54.669$, *Adjusted* $R^2=0.579$, $P<0.000$; sum of grass species' covers: $F[1,38]=81.673$, *Adjusted* $R^2=0.674$, $P<0.000$, Figure 2).

Species-level analyses showed strong relationships between biomass and visually estimated cover in all the common grass species (which were present in 10 or more plots) analyzed (Table 1). The adjusted R^2 values for the untransformed data were also almost as high as those for log transformed data (Table 1). Multiple regression of species biomass on species cover and species' average height also yielded high R^2 values (Table 1), but average height did not have a significant effect in any species other than *Oplismenus compositus* ($\beta=0.180$, $P=0.031$). Overall, adjusted R^2 values from the simple regression and multiple regression were not different from one another (Wilcoxon matched pairs test: $T=18.0$, $Z=0.968$, $P=0.333$).

Discussion

These results show that the simple method of visually assessing grass cover works well as a proxy for biomass of individual species, as well as total biomass, in the more complex habitat that we examined. The area that we examined had trees and dense non-grass understorey vegetation, unlike the pasture land and open areas without multiple vegetational strata that were examined in previous studies. At the level of individual species, all the species examined showed high R^2 values in the regressions of species biomass on species cover and there was no clear advantage of including grass height, in addition to species cover, in predicting species biomass. This is probably because all our plots were in forested areas that did not have many tall grasses as seen in some other forests and areas around swamps. Since there was no advantage of including grass height in addition to species cover in predicting biomass, this would further reduce the time and effort required to assess forage abundance in our study area.

We found, surprisingly, that the relationship between the sum of grass species' covers and total green biomass was stronger than that between total grass cover and total green biomass. Normally, one would not expect the sum of species' covers to be a useful measure as it exceeds 100% and there is no particular reason to include between-species leaf overlaps but not within-species overlaps (Wilson 2011). However, the sum of grass species' covers probably performs better than total grass cover when the within-species leaf overlap is smaller than the between-species leaf overlap. This might be true of forests with multiple strata, in which individuals in the lower strata avoid self-shading and individuals of the same species are not very close to one another in order to reduce competition. Thus, collecting data on species cover is important in this situation and mere total cover estimation will not suffice. Since the sum of grass species' cover better represents total biomass compared to total cover, one can also estimate the proportional abundance of foods by dividing the sum of food species covers by the sum of all species' covers. This would be useful because it is much simpler to assess individual species' covers in the field and calculate the proportional abundance of foods later on, than to visually judge what proportion of grass cover is represented by all the food species combined. The latter would entail remembering all the food species in the field and making a combined estimation of only those species present in each plot.

We thus find that the visual estimation method performs very well in assessing forage availability in a tropical forest, which can be used in studies on elephant habitat and forage selection. This will save time and allow for sampling a greater number of sites. We do not, however, imply that such relationships are transferable to other forests and suggest independent assessments before using the visual estimation method.

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Tables

Table 1. Results of regressions of species biomass on visually estimated species cover and of species biomass on visually estimated species cover and measured average species height. All species except *Cyrtococcum patens* in this table are food species. *Grass 57 was an unidentified species.

Species Name	**Regression of species biomass on species cover (*Adj.* R^2 for untransformed data in parentheses; all *P* values for these are <0.001)**	**Multiple regression of species biomass on species cover and average species height (*Adj.* R^2 for untransformed data in parentheses; all *P* values for these are <0.001)**
Axonopus compressus	*F*[1,19]=80.542, *Adj*. R^2=0.799 (*Adj*. R^2=0.653), *P*<0.001.	*F*[2,16]=22.917, *Adj*. R^2=0.709 (*Adj*. R^2=0.610), *P*<0.001.
Chloris dolichostachya	*F*[1,19]=188.490, *Adj*. R^2=0.904 (*Adj*. R^2=0.901), *P*<0.001.	*F*[2,16]=68.670, *Adj*. R^2=0.883 (*Adj*. R^2=0.899), *P*<0.001.
Cynodon dactylon	*F*[1,16]=226.440, *Adj*. R^2=0.930 (*Adj*. R^2=0.826), *P*<0.001.	*F*[2,11]=82.611, *Adj*. R^2=0.926 (*Adj*. R^2=0.818), *P*<0.001.
Cyrtococcum accrescens	*F*[1,26]=104.500, *Adj*. R^2= 0.793 (*Adj*. R^2= 0.590), *P*<0.001.	*F*[2,23]=55.981, *Adj*. R^2=0.815 (*Adj*. R^2=0.620), *P*<0.001.
Cyrtococcum oxyphyllum	*F*[1,19]=191.950, *Adj*. R^2=0.905 (*Adj*. R^2=0.854), *P*<0.001.	*F*[2,17]=69.831, *Adj*. R^2=0.879 (*Adj*. R^2=0.861), *P*<0.001.
Cyrtococcum patens	*F*[1,10]=401.410, *Adj*. R^2=0.973 (*Adj*. R^2=0.867), *P*<0.001.	*F*[2,9]=186.820, *Adj*. R^2=0.971 (*Adj*. R^2=0.874), *P*<0.001.
*Grass 57**	*F*[1,12]=63.451, *Adj*. R^2=0.828,	*F*[2,8]=8.387, *Adj*. R^2=0.596

	(*Adj*. $R^2=0.732$), $P<0.001$.	(*Adj*. $R^2=0.846$), $P=0.011$.
Kyllinga monocephala	$F[1,21]=334.110$, *Adj*. $R^2=0.938$ (*Adj*. $R^2=0.770$), $P<0.001$.	$F[2,16]=130.930$, *Adj*. $R^2=0.935$ (*Adj*. $R^2=0.875$), $P<0.001$.
Oplismenus compositus	$F[1,36]=240.340$, *Adj*. $R^2= 0.866$ (*Adj*. $R^2=0.777$), $P<0.001$.	$F[2,34]=133.800$, *Adj*. $R^2=0.881$ (*Adj*. $R^2=0.815$), $P<0.001$.
Oryza sativa	$F[1,14]=54.713$, *Adj*. $R^2= 0.782$ (*Adj*. $R^2=0.852$), $P<0.001$.	$F[2,11]=37.930$, *Adj*. $R^2=0.850$ (*Adj*. $R^2=0.834$), $P<0.001$.

Figure legends

Figure 1. Locations of sampling sites in the study area. The forest type classification is based on Pascal (1982).

Figure 2. Relationships between a) total grass cover and total biomass and b) the sum of grass species' covers and total grass biomass.

Figure 1

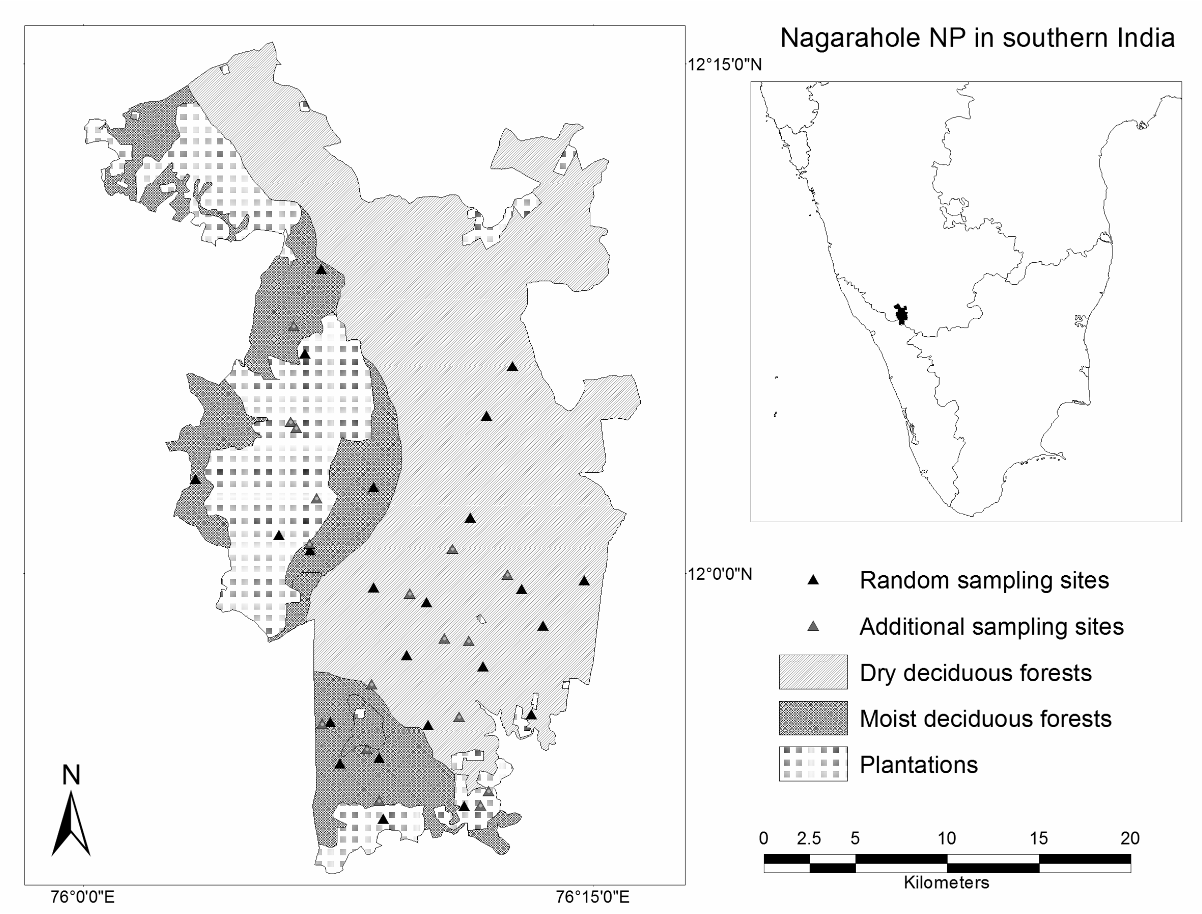
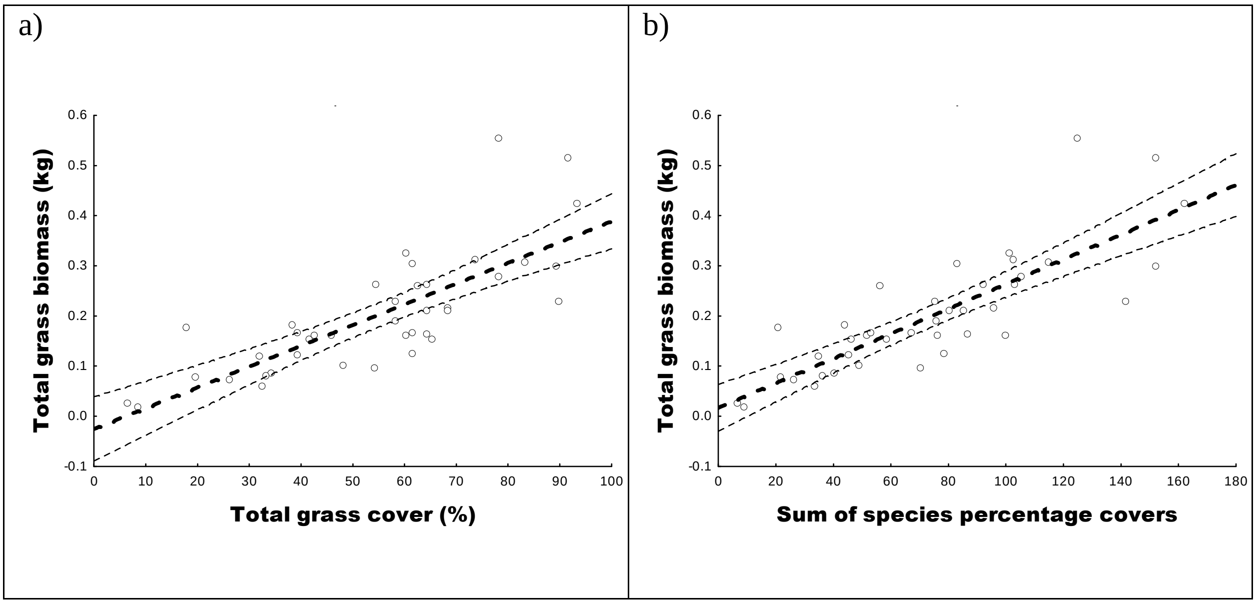

Nagarahole NP in southern India
12°15'0"N
12°0'0"N
76°0'0"E
76°15'0"E
N
▲ Random sampling sites
▲ Additional sampling sites
▨ Dry deciduous forests
▩ Moist deciduous forests
▦ Plantations
0
2.5
5
10
15
20
Kilometers

Figure 2


a)
Total grass biomass (kg)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
10
20
30
40
50
60
70
80
90
100
Total grass cover (%)
b)
Total grass biomass (kg)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
20
40
60
80
100
120
140
160
180
Sum of species percentage covers