

**A method for assessing multiples ecosystem services from grasslands based on vegetation characteristics.
– An example from Norwegian semi-natural grasslands**

Taugourdeau Simon^{1*}, Line Johansen², Sølvi Wehn²

^{1*}CIRAD, Montpellier, France

²Bioforsk, STJØRDAL, Norvège

*Corresponding author e-mail: s.taugourdeau@gmail.com

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Introduction

Ecosystem services are human benefits provided by ecosystems and related to the characteristics of the vegetation (de Bello *et al.*, 2010). Semi-natural grasslands provide a large set of ecosystem services and are thus important ecosystems in boreal landscapes. The vegetation of semi-natural grasslands differ regarding land use, soil and climate. Consequently, also provision of ecosystem services from semi-natural grasslands will vary among various types of semi-natural grasslands. Here, we propose a method to develop indicators of ecosystem services from semi-natural grassland using the DEXI® software (Bohanec and Raikovic, 1990).

Materials and Methods

We developed indicators from four ecosystem services: 1) forage provision (quantity and quality), 2) genetic resources diversity, 3) pollination and 4) aesthetic value. Based on literature and expertise, we defined several characteristic of the vegetation relating to each of these ecosystem services (Table 1). The example is based on a vegetation surveys from 14 sites in Mid-Norway. In each site, one plot was semi-natural grassland grazed by sheep and one plot was abandoned (n = 28 plots). In each plot, surveys were made in four quadrats of 2m x 2m and species composition and abundance, cover of bare soil and ground-, field-, understory- and canopy-layer were recorded. Trait values from the TRY (www.try-db.org) and BRC (www.brc.ac.uk) databases were extracted and combined with the species data to calculate variables of vegetation characteristics.

For each of the four ecosystem services, the defined vegetation characteristics were then aggregated using the DEXI® Software using a stepwise procedure:

1) The DEXI® software only uses categorical value as inputs. Therefore, we transformed the continuous variables into categorical variables. For the number of species and the canopy cover, we defined a threshold to transform the variables (Table 1). For the other vegetation characteristics, the thresholds used were the quantiles (33% and 66%) of the values: low (below the $Q_{33\%}$), medium (between the two quantiles) and high (above the $Q_{66\%}$).

2) To aggregate the vegetation variables and propose a notation of the ecosystem services (from 1: very low, to 5: very high) we had to propose decision rules. An example of decision rule is: if a variable A is low and a variable B is medium we choose that in this case the services would be low. For illustrating the method, we chose for most cases, to apply the same weight to each of the variables, but some variables were weighted based on expertise (Table 1). We then compared ecosystem services provided in semi-natural grasslands under various land-uses, soil and climates by drawing charts using the DEXI® Software.

Results and Discussion

Here, we will present the choices made for the evaluation of forage quantity. We included four vegetation characteristics in the evaluation of the provision of forage quality; cover of field layer, cover of grass species, community weighted mean (the mean value in a community summed over all plant species present) of leaf dry matter content (CWM LDMC) and the functional diversity (dispersion of the value in a community summed over all species present) of specific leaf area (FD SLA). Some of the plots were influenced by a low cover of the field layer (due to high canopy-, ground- or bare soil-cover) which is negative for sheep grazing; only the vegetation in the field layer is used as forage. Therefore, we considered cover of field layer as the most important vegetation characteristic (weight: 50%). The other three vegetation characteristics were given the same weights (17%). They were included as they are related to the capacity of the vegetation to grow. Grass species produce more forage than forbs species (Baumont *et al.* 2011) and Low CWM LDMC is shown to correlate positively with productivity (Pontes *et al.* 2007). The functional diversity of specific leaf area SLA is

related to the seasonality of the fodder production. A community of high FD SLA has production throughout the grazing season and so high seasonal production (Klump and Soussana, 2009).

Table 1: Vegetation characteristic variables used in the evaluation of five ecosystem services, the threshold used to transform the variables into categorical variables (low below the first threshold, medium between the two thresholds, high above the second threshold) and the weight of the variables in the DEXI® tree. The thresholds in italic were chosen by expertise and the other based on quantiles. The sign correspond to the direction of the relationships between vegetation and ecosystem services.

Ecosystem Service	Vegetation characteristic variable		Thresholds		Weight
Genetic resources	Number of species	+	25	<i>50</i>	100%
Pollination	Cover of species with Diptera pollination	+	48%	<i>62%</i>	33%
	Cover of species with Hymenoptera pollination	+	32%	<i>46%</i>	33%
	Cover of species with Lepidoptera pollination	+	59%	<i>69%</i>	33%
Aesthetic appreciation	Number of Flowers colors	+	6	<i>8</i>	30%
	Forbs/grass	+	0.66	<i>0.99</i>	20%
	% of canopy layer	-	<i>5%</i>	<i>15%</i>	50%
Forage quality	CWM LNC of the field layer	+	23.6	<i>24.8</i>	25%
	CWM Leaf palatability of the field layer	+	3.4	<i>4.1</i>	50%
Forage quantity	FD SLA of the field layer	+	50.4	<i>95.9</i>	17%
	CWM LDMC	+	235	<i>271</i>	17%
	Cover of grass	+	25%	<i>50%</i>	17%
	Cover of field layer	+	66%	<i>86%</i>	50%

As an example, we will show that precipitation and land-use have impact on ecosystem services provided by semi-natural grasslands in Mid-Norway (Figure 1). From this example, we see that grazed plots provide more ecosystems services compared to abandoned plots, but this varies along gradients of precipitation. The driest (850 mm of precipitation) grazed plots had a higher provision of ecosystem services than the wetter (2000 mm of precipitation) grazed plots.

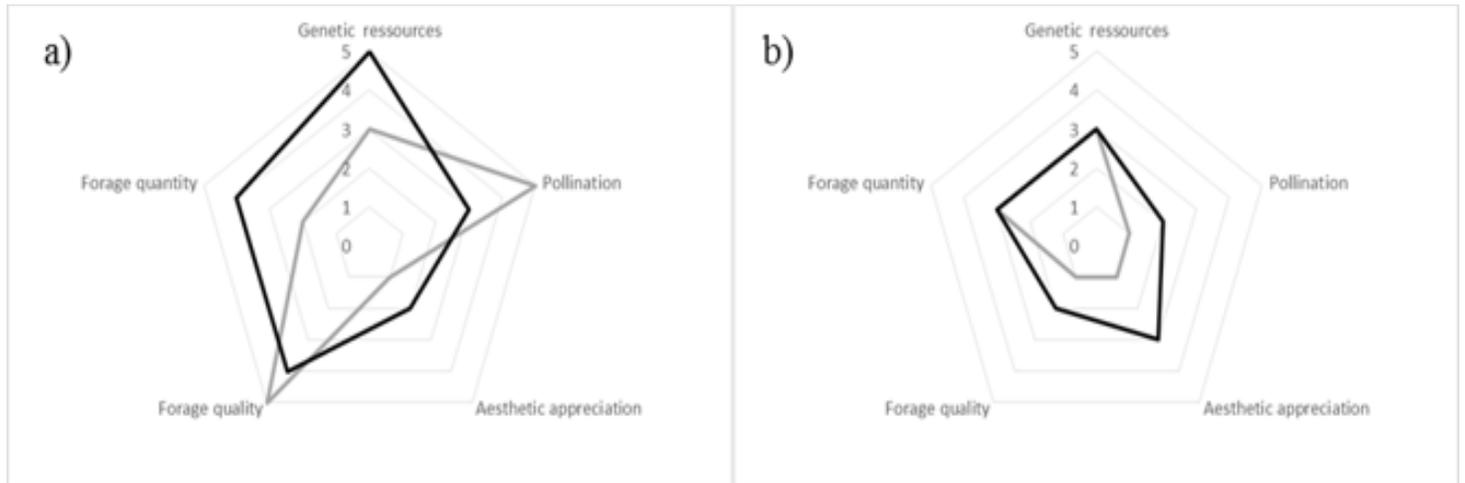


Figure 1: Example of the evaluation of ecosystem services from semi-natural grasslands in Norway in a) a dryer site (850 mm) and b) a wetter site (2000 mm) and grazed plots (black) and abandoned plots (grey).

Conclusion

We presented here a method that can be used to develop indicators of multiples ecosystem services using vegetation characteristics as input variables. These indicators are tools to be discussed and modified. Thresholds and weightings have to be validated based on real data. When this has been done, these indicators can be used to evaluate influence of land use, soil, climate as well as other environmental impacts on the provision of multiples ecosystem services.

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