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The use of functional plant leaves traits in the production ecosystem services assessment of grassland communities

Sergeevich Sautkin*, T. Vladimirovna Rogova, G. Adhatovna Shaykhutdinova

Department of General Ecology, Division of Ecology, Institute of Environmental Sciences, Kazan Federal University, Kazan, Republic of Tatarstan, Russia

** Corresponding author's E-mail: serebff@mail.ru*

ABSTRACT

The article investigates the experience of the ecosystem production services evaluation of grassland communities using the plant functional traits, leaf area, specific leaf area, and community weighted average specific leaf area (CWM SLA). The direct dependence of the communities' biomass on the values of the specific leaf area was revealed. Low values of the trait characterize the least productive degraded pasture meadow communities, and the most productive overgrown forest meadows have high values. The studies were conducted on the territory of Raifa forestry Volga-Kama State Natural Biosphere Reserve (VKGPBZ). Based on the outcomes, it is concluded that meadow communities' ecosystem production services can be successfully estimated using the calculation of the community- weighted specific leaf area (CWM SLA).

Keywords: Ecosystem services, Functional traits, LA, CWM SLA, Grassland communities.
Article type: Research Article.

INTRODUCTION

Evaluation of ecosystem services is currently an important element of ecosystem management policies. Ecosystem services depend on the well-being of people and their ability to cope and adapt to global changes (Daily *et al.* 2009; Perrings *et al.* 2011). An important component determining the delivery of ecosystem services is biodiversity (Díaz *et al.* 2006; Mace *et al.* 2012; Cardinale *et al.* 2012). Functional diversity (FD), broadly defined as the range and relative abundance of functional characteristics of plants and their contribution to the ecosystem (Dıaz & Cabido, 2001), has become key in assessing a variety of ecosystem services, including provision of feed and wood, carbon removal, and nutrient retention in the soil, pollination and many others (Díaz *et al.* 2006; De Bello *et al.* 2010; Kleiman *et al.* 2021). There are some studies about plant biology around the world (Ameri Siahouei, *et al.* 2020; Bagheri *et al.* 2020; Abolhasani *et al.* 2021; To assess ecosystem services, there is important to include not only the functional characteristics of plants, but also the characteristics of other organisms with which plants interact to provide ecosystem services (De Deyn *et al.* 2008; Reiss *et al.* 2009; De Bello *et al.* 2010). Most publications on ecosystem services still contain a quantitative assessment of one type of service or a very small number of them (Seppelt *et al.* 2011). A functional trait is defined as "any morphological, physiological or phenological inherited trait, measured at the level of an individual, starting from a cell and ending with the whole organism, without reference to the environment or any other level of organization" (Garnier *et al*. 2016). It has been established that, based on functional characteristics, one can view the key mechanisms by which individual species and groups of species (Lavorel & Garnier 2002; Diaz *et al.* 2004) affect the properties of ecosystems. It is known that the effectiveness of the net primary production of aboveground biomass can be directly depend on the specific leaf area (SLA) (Reich *et al.* 1992; Garnier *et al*. 2004). A high level of net primary production (NPP) directly affects the quantity and quality of cultivated plant feed (Lavorel & Grigulis 2012). NPP refers to provisioning and regulating ecosystem services. The ability of ecosystems to provide services to people depends on how

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these properties are distributed and which organisms or groups of organisms control them, providing a solution to economical or social tasks. Diaz *et al*. (2013) proposed a new methodological basis for the development of experimental tests for assessment of the relative role of community weighted mean (CWM) and functional diversity in ecosystem functioning. Conti & Díaz (2013) tested the contribution of CWM for a number of traits of leaves and stems and their functional diversity in the community. In the same year, Butterfield & Suding (2013) investigated the effect of these indicators on the quality of feed produced and carbon storage. Grigulis *et al*. (2013) investigated a number of ecosystem processes and services related to the nitrogen cycle, which demonstrate the relevance of the functional composition (CWM and FD) of plants for three European pasture lands. It was confirmed that the carbon and nutrient cycling processes are mainly caused by the traits of the most common (dominant) species (hypothesis on the ratio of biomass) (Grime 1998; Divsar 2018; Arzehgar 2019; Mirzaei 2019; Pansambal 2019; Ahwidi 2020). The main objective of this study is to develop a methodology for evaluating production services using the plant functional traits, as characteristics related to the leaf economic spectrum. To achieve this, we need to confirm the hypothesis on the ratio of biomass by Grime on own data and to reveal the presence of a relationship between functional traits and productivity. The following functional traits were selected for the study: specific leaf area (SLA) both for a one species and the community weighted mean (CWM SLA), leaf dry weight (LDW) and leaf area (LA). Using knowledge of the species functional traits and their role in biotic communities can greatly improve the assessment and management of ecosystem services.

MATERIALS AND METHODS

The studies were conducted: 1) on the territory of Raifa forestry Volga-Kama State Natural Biosphere Reserve (VKGPBZ); 2) in the suburbs of Kazan in the West Kazan terrace-valley landscape region of pine forests; 3) in the locality of the Anatysh village in the Prikamsky right-bank region of the semi humid midrussian-volga broad-leaved nemoral forests with the participation of forest-steppe species; and 4) in the locality of Mella-Tamak village in the Zai-Sheshminsky elevated plain region of the semi humid Volga-Zavolzhsky broad-leaved nemoral forests. A total number of plots, 100 m^2 each, were 17. Seven plots of forest communities included in the processing to increase statistical reliability of the sample: (Pinetum cladino-hylocomiosum, Pinetumvaccinioso- hylocomiosum, Pinetum shpagnosum, Pinetum convalariosum). Ten plots are represented by grassland communities located in a gradient of increasing anthropogenic load:

1) Forest overgrowing hay meadows: Raifa 77 and 79 quarter (R77 and R79).
2) Hay meadows: Gruzinskaya balka (G), Urnyak (U1, U2, U3, U4).
3) Pasture meadows: Ilyinskaya balka (I), Mella- Tamak (M), Anatysh (A).

Geobotanical descriptions were compiled on the plots, and species projective coverage was recorded. On each plot, ten Raunkier sites of 0.25 m2 each were laid, from which biomass was mowed. The collected biomass was divided into dominant species (*Aegopodium podagraria*, *Alchemilla* sp., *Pimpinella saxifraga*, *Centaurea jacea*, *Achillea millefolium*, *Geranium pratense*, *Geum rivale*), and graminoids, legumes and forbs fractions, dried and weighed. The species of the Poaceae and Cyperaceae families are assigned to the fraction of graminoids; legumes are represented by the genus *Lathyrus*, *Lotus*, *Medicago*, *Trifolium* and *Vicia*; all other species, characterized by a low individual contribution to the total biomass, were included in the forbs. Leaves were collected from dominant species and edificator species, in the amount of 10 leaves for each species. Samples were collected using existing methods and recommendations for the selection of plant leaves (Cornelissen *et al.* 2003; Perez-Harguindeguy *et al*. 2016). For the collected leaves LA and LDW were measured and SLA was calculated. Leaf area was measured and calculated using the Leaf Area Measurement v 1.3 program (Askew 2003). SLA was calculated using the following formula:

SLA = LA / LDW.

Based on the projective cover specific leave area of the dominated species community weighted average specific leaf area (CWM SLA) was calculated using the following formula:

$$CWM\ SLA = P_i \times SLA_i$$

where P_i is the projective cover of the i^{th} species; SLA_i - SLA of the i^{th} species.

The data were statistically processed in the R software (Team 2015). The sample test for normality was carried out using the Shapiro-Wilk test. The hypothesis about the similarity of meadow communities in terms of elevated biomass was tested using the t- test. A correlation analysis was used to evaluate the relationship

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between the CWM SLA and the aboveground biomass. The studied grassland communities were classified using the JUICE v7.0 program (Tichý 2002) according to habitat type (EUNIS) and vegetation class (Brown-Blanque).

RESULTS AND DISCUSSION

The studied grassland communities were assigned to three classes of vegetation: Molinio-Arrhenatheretea R. Tx. 1937, Festuco-Brometea Br.-Bl. et Tx. ex Sow 1947 (FES) and *Artemisietea vulgaris* Lohmeyer *et al*. Ex von Rochow 1951 (ART). According to the habitat types of EUNIS Habitat Classification (Davies *et al.* 2004), plots belong to low and medium altitude hay meadows (E22), wet or moist tall grass and fern meadows and fringes (E54), permanent mesotrofic pastures and grazed meadows after mowing (E21) and ruderal anthropogenic herb stands communities (IE51; Table 1).

Table 1. Classification of Grassland by Habitat Type and Vegetation Class.

Plot	Habitat type EUNIS	Vegetation class Braun-Blanke
R77, G, U1, U2, U3, U4	E22	MOL
R79	E54	MOL
I	E21	MOL
A	E21	FES
M	IE51	ART

In the overgrown hay grassland (Raifa VKGPBZ), dominate meadow species [*Alchemilla* sp., *Bromopsis inermis* (Leyss.) Holub, *Festuca pratensis* Huds., *Dactylis glomerata* L., *Poa trivialis* L. and *Centaurea pseudophrygia* (CA. L.) Maxim]. There is also a high proportion of forest (*Aegopodium podagraria* L. and *Carex pilosa* Scop.) and edge-meadow species (*Geum urbanum* L., *Geum rivale* L. and *Trollius europaeus* L.). The overgrowing process began in 2005, when active mowing stopped in the reserve. With a high abundance of forest and edge-meadow species, representatives of legumes (*Trifolium* pratense L. and *T. repens* L.) and plantains (*Plantago media* L. and *P. lanceolata* L.), characteristic of hayfields and pasture grassland almost completely disappeared. The undergrowth of oak, maple and birch appeared. For hay grassland (Urnyak, Gruzinskaya balka), meadow species [*Alchemilla* sp., *A. millefolium* L., *Centaurea jacea* L., *Dactylis glomerata* L., *Deschampsia cespitosa* (L.) Beauv., *Poa pratensis* L., *Festuca pratensis* Huds., *Phleum pratense* L., *Poa angustifolia* L., *Trifolium pratense* L. and *T. repens* L.], forest and edge- meadow species are practically absent. Meadow species (*Achillea millefolium* L., *Plantago media* L., *Trifolium pratense* L., *Galium mollugo* L., *Hypericum maculatum* Crantz., *Phleum pratense* L., *Poa angustifolia* L., *Ranunculus acris* L., *Trifolium repens* L., *Hieracium pilosella* L. and *Veronica chamaedrys* L.) and ruderal species (*Artemisia absinthium* L.) are characteristic of the pasture grass-forbs meadows (Ilyinskaya balka). Due to the high pasture load, trampling processes of vegetation are observed. In the pasture meadow grasses (*Agrostis tenuis* Sibth. and *Festuca rubra* L.), as well as *Fragaria viridis* (Duch.) Weston, *Plantago media* L. and *Trifolium pratense* L. are dominated. In the community of pasture grassland (Mella-Tamak) *Elytrigia repens* (L.) Nevski dominates, the following species are characteristic: *Achillea millefolium* L., *Artemisia absinthium* L., *Astragalus cicer* L., *Medicago romanica* Prod., *Odontites vulgaris* Moench, *Ononis arvensis* L., *Trifolium pratense* L. and *Trifolium repens* L. Table 2 shows the ecological and coenotic characteristics of grassland communities. The Jacquard coefficient was calculated and the similarity matrix of grassland communities was constructed (Table 3).

The aboveground biomass data is given in Table 4. The largest aboveground biomass is observed in forest overgrowing hay meadow in the reserve (R77), graminoids and herbs, as well as some dominant species, make a high contribution. The minimum biomass is observed in pasture meadow (I), where the greatest contribution belongs to ruderal forbs. As a result of testing the hypothesis about the similarity of grassland communities in terms of aboveground biomass, statistically significant differences in the compared samples were found. The largest difference (p-value = 1.808e-09) is typical of the pair “pasture grassland - overgrown meadow”, the smallest (p-value = 0.0001323) for the pair “forest overgrowing hay meadows - hay meadows” (Tables 4-5).

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Table 2. Ecological-Coenotic characteristic of grassland communities.

Plot	Number of Species	Proportion of Species (%)				
		Meadow	Forest	Edge-meadow	Ruderal	Steppe
R77	32	42	26	29	3	0
R79	26	62	15	19	4	0
G	34	74	0	23	3	0
U1	17	94	0	0	6	0
U2	28	81	4	11	4	0
U3	22	91	0	0	9	0
U4	26	92	4	4	0	0
I	27	63	0	15	22	0
A	29	70	0	7	20	3
M	16	44	0	13	37	6

Table 3. The similarity matrix of grassland communities (Jacquard Coefficient).

	R77	R79	G	U1	U2	U3	U4	I	M	A
R77	1	0.35	0.18	0.11	0.18	0.2	0.23	0.16	0	0.02
R79		1	0.16	0.16	0.26	0.2	0.33	0.14	0	0.06
G			1	0.24	0.24	0.19	0.32	0.3	0.08	0.11
U1				1	0.32	0.44	0.34	0.16	0.1	0.12
U2					1	0.39	0.5	0.23	0.16	0.12
U3						1	0.46	0.21	0.12	0.11
U4							1	0.25	0.11	0.1
I								1	0.08	0.12
M									1	0.13
A										1

Table 4. Plant Biomass, Divided into Fractions and Dominant Species**.**

Biomass (g m^{-2})	R77	G	I
Graminoids	263	241	45
Herbs	256	118	70
Legumes	1	3	20
Aegopodium podagraria	58	-	-
Alchemilla sp.	52	133	-
Pimpinella saxifraga	-	23	-
Centaurea jacea	-	71	-
Achillea milleifolium	-	-	22
Geranium pratense	172	-	-
Geum rivale	233	-	-
Total	1035	589	157

Samples of the obtained values were tested for normal distribution. According to the test results, all statistical sampling turned out to be normally distributed, histograms of the distribution are given in Fig. 1. Correlation analysis (Fig. 2) showed a strong positive correlation between the CWM SLA and the aboveground biomass (r = 0.875, p-value = 0.0009011). Grime's hypothesis about the ratio of biomass was confirmed, according to which the functioning of the ecosystem (in our case, this function is the production of biomass) is primarily due to signs of the most common (dominant) species in the community. The result confirms the existence of

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a relationship between functional traits and productivity. Thus, it is assumed that it is possible to use traits related to the economic spectrum of leaves to evaluate ecosystem production services. For meadow communities, a direct dependence of the amount of biomass on the size of the CWM SLA was found. The less functional trait - the less biomass. Thus, the least productive meadow communities (pasture) are characterized by low values of CWM SLA, and the most productive (overgrown hay meadows) are characterized by significantly larger values of the trait. The dynamics of CWM SLA changes in meadow communities is shown in Fig. 3.

It can be seen that the CWM SLA values of individual communities are arranged in decreasing order: forest overgrowing meadows are characterized by maximum values, while pasture ones are by minimum; all other meadow plots are located between them. The information obtained is precisely in our assumption that with the growth of CWM SLA, biomass will also increase. More productive communities of forest overgrown grassland are characterized by high values of CWM SLA, and less productive pasture communities - by low. Thus, based on only a few functional traits: LA, LDW, and CWM SLA, we can evaluate the of grassland communities without resorting to biomass mowing. The measured SLA values are shown in Table 5.

Table 5. Average SLA (cm^2 g^{-1}) of dominant plant species.

	SLA									
	R77	**R79**	**G**	**U1**	**U2**	**U3**	**U4**	**I**	**M**	**A**
Aegopodium podagraria	220	310								
Alchemilla sp.	215	291	141	113	152	181	156			
Asarum europaeum	257	315								
Bromopsis inermis		238								
Centaurea jacea			137	163	221		163	145		
Centaurea phrygia	185									
Centaurea scabiosa									80	
Dactylis glomerata	143	239	121	107	77	78	100	151		
Deschampsia cespitosa	102	117	108	82		122	107			
Festuca pratensis	146	297	163							
Geranium pratense	187									
Geum rivale	207	241	143	154						
Phleum pratense							150			
Pimpinella saxifraga			141		178				90	
Plantago lanceolata			157	141			125	194		
Plantago major								253		
Plantago media			171	173		287		172	104	101
Rumex acetosum			161							
Stellaria holostea	214									
Trifolium montanum									84	
Trifolium pratense				160	281	237	192	225	102	114
Trifolium repens				135				253	125	104
Veronica chamaedrys	209									

CONCLUSIONS

The studied meadows form a series depending on the anthropogenic load factor. In this regard, they are characterized by various indicators of species composition and abundance. Depending on the load, the productivity of meadow communities also changes. The least disturbed communities will be more productive, while communities with a greater burden of grazing and haying will be less productive. However, productive forest meadows without regular mowing tend to overgrow and form forest areas in their place. Using

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meadows as a valuable source of feed, one should avoid the complete stop of exploitation and overgrazing, due to the subsequent degradation of meadows and their possible disappearance from nature. The plant functional traits used in assessing productivity related to the economic spectrum of the leaf - LA, LDW, SLA, and CWM SLA - are informative. The correlation analysis revealed a strong positive, statistically significant relationship between the biomass and CWM SLA values. These results also confirm the Greim hypothesis on the ratio of biomass. So, it follows that the plant functional leaf traits can be successfully used to assess the productivity of communities.

For meadow communities a direct dependence of biomass on CWM SLA was found. The least productive pasture meadow communities are characterized by low values of CWM SLA, and the most productive by high values. Based on the values of CWM SLA, the examined meadows in accordance with their productivity form a series including the degree of impact on their vegetation cover and also the contribution to the assessment of ecosystem services can be successfully carried out according to the accounting of functional traits.

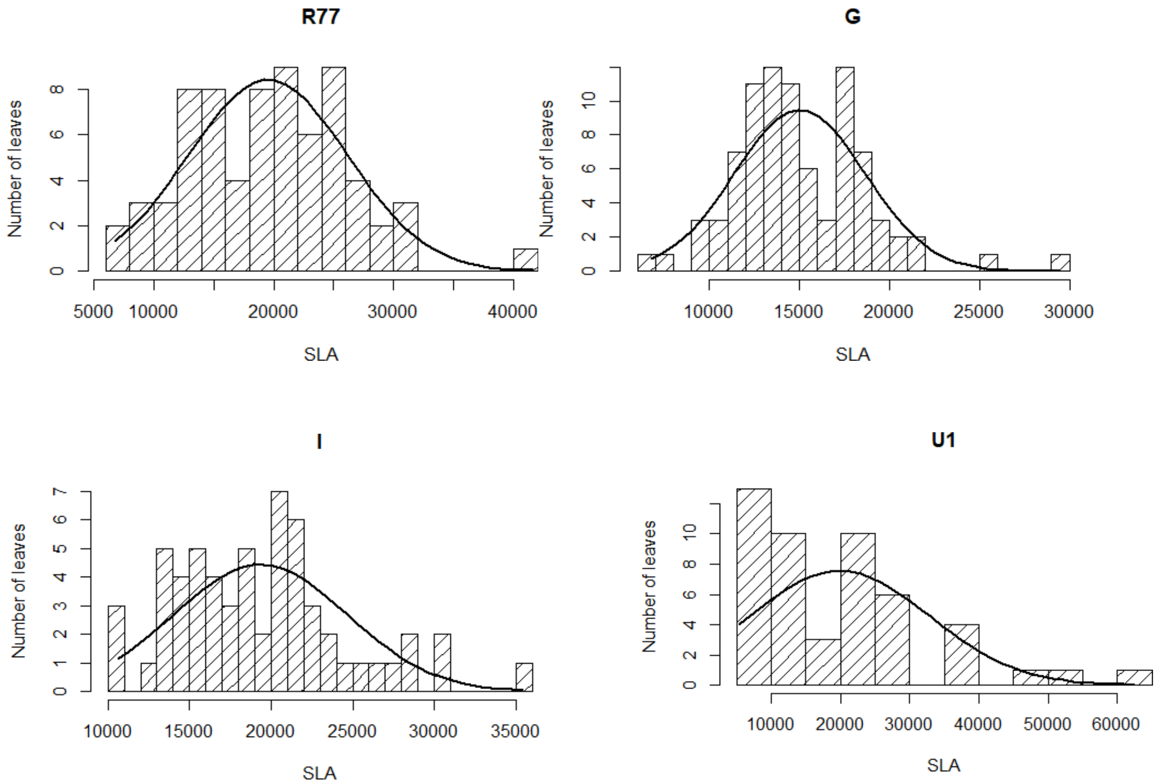

Fig. 1. Histograms showing the distribution of SLA values in the meadow communities (R77, G, I, U1).

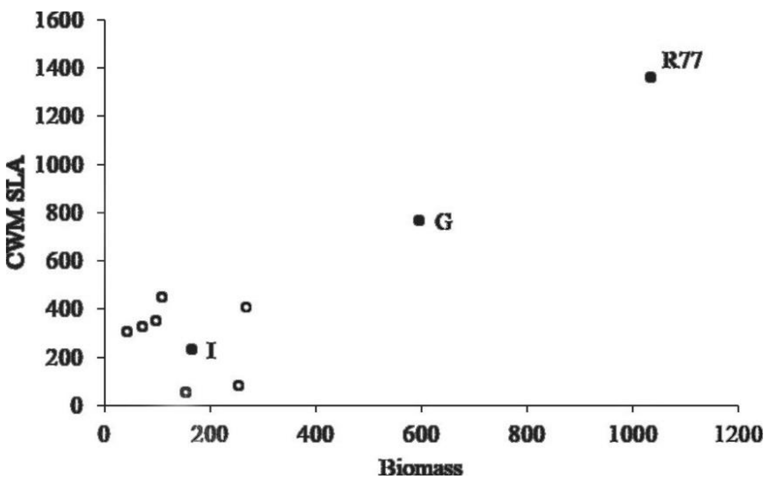

Fig. 2. The relationship between biomass and CWM SLA.

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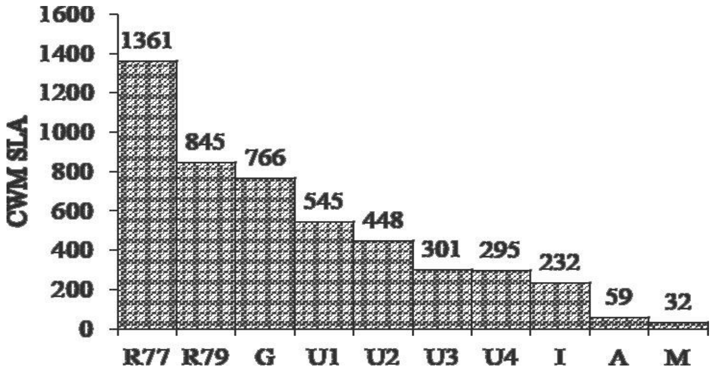

Fig. 3. CWM SLA values for meadow communities in the gradient of anthropogenic stress. Note: meadow communities (I - pasture, G - grassland and R77 - overgrown meadow); ○ - forest communities.

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