

## LANDFILL VEGETATION DEVELOPMENT NEAR SOFIA REVISITED

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**Abstract:** The study presents results of an analysis of the successional development of self-established vegetation for a period of more than 15 years on a landfill site near Dolni Bogrov (Sofia) and recommends tolerant species for rehabilitation of landfills and similar sites. The results allow the following inferences and conclusions:

The plant communities are transitional between the classes *Stellarietea mediae* and *Artemisietea vulgaris*. Syngeneses is completed, and clear processes of endo-ecogenesis are observed on the whole territory, which will lead to the development of meadow and pasture communities. Participation of turf-grass species in the plant cover results in successful control of erosion processes and has the positive effect of minimizing infiltration of pollutants after rainfall. In the future, phyto-remediation could be applied using both species that have proved their tolerance to landfill conditions and species that occur naturally in herbaceous communities in adjacent areas. The ratio of cool-season to warm-season species is still not effective enough and is far from the recommended 1:1 relationship. Thus, further measures are necessary to reach a better balance.

The results proved that the vegetation cover plays an important role in the reclamation of the site. The species composition indicates that the process of vegetation development is directed toward more sustainable plant communities, which will provide secure protection against erosion and will minimize or prevent infiltration of pollutants into the soil after heavy rainfall. It could be recommended to continue the study of successional development processes of the plant communities for better understanding of the potential and ecological effect of appropriate use of vegetation in reclamation of landfill waste.

**Keywords:** Landfill site, waste deposition, vegetation, succession

### **Introduction**

Landfilling continues to be the most common form of waste disposal in the EU and creates serious problems of contamination of the environment. One of the main problems and tasks in establishing landfills is their remediation, and plant species are considered as a particularly important tool to achieve this goal. Under favourable conditions the vegetation appears spontaneously on such kind of sites. Monitoring the development of self-generated vegetation in similar places could provide very useful information that can be used in remediation activities.

The solution for sustainable rehabilitation of landfill sites consists of using plants best adapted to denuded and destroyed lands or anthropogenic substrates, and the species exploit different niches left empty by the disturbance. The plant development causes modification of the soil substrate and creates preconditions for the development of the next vegetation types of the successional series [5, 18, 21].

The objective of the present study was to assess the current species composition and abundance on the landfill site near Dolni Bogrov, Sofia region, and to compare the results with previous inventories.

### Materials and Methods

The subject of the study is the landfill site near Dolni Bogrov, situated on the non-flooded terrace of the River Lesnovska, about 20 km northeast of Sofia. The exploitation of the landfill took place from 1972 to 1997 and waste materials had been deposited in abandoned sand-pit fields. As a result of limited technical rehabilitation the landfill is capped with a soil layer of depth between 0.20 m and 0.80 m. The soil is formed by material originating from different soil horizons mixed with waste from construction works and refuse and classified as the class Anthrosoils, type Urbogenic, kind Urbo-deposic [11].

The climate in the region is temperate. Average annual precipitation amounts to 636 mm, and the average annual temperature is 10 °C.

Floristic assessment was made in 2003 and 2013. The same experimental plots that were established during the first assessment [7] were studied. Additionally, eight typical sectors in the landfill were studied. Each relevé was performed in an area of homogeneous structure and species composition. The sizes of relevés were about 100 m<sup>2</sup>. Phytosociological descriptions were performed twice, in 2003–2004 and in 2012–2013 (in total, 16 descriptions). The species abundance was evaluated according to the scale of Braun-Blanquet [4]. The classification of plant communities was performed by means of the specialized software package SYN-TAX V [22]. Floristic affinity was calculated by mean of Horn's index [17].

Taxonomic nomenclature followed the Handbook for identification of higher plants in Bulgaria [16], and the syntaxonomic nomenclature followed the respective references [14, 15, 19]. The phytogeographical structure was studied according to Walter [8, 2].

The phenological morphotypes were determined according to Weaver [23], and the plants were classified into two groups: cool-season plants (renewing growth early in spring and reaching their maximum development and biomass accumulation until the beginning of summer) and warm-season plants (renewing their growth activities later in the spring and growing continuously until early fall).

### Results and Discussion

The total species diversity on the landfill amounted to 91 plant species involved in various micro-groups, covering 97% of the landfill. The species belong to 76 genera and 25 families. Most represented families are: Asteraceae - 21 species, Poaceae - 6 species, Lamiaceae - 6 species, Boraginaceae, Apiaceae and Brassicaceae - 4 species, and other families with at least 3 species. Results showed that landfill offers high species diversity, accommodating not only ruderal species but in some cases also rare species.

The species composition consisted in 2003 of 50% perennial, 40% annual and 10% biennial plants (Fig. 1) and in 2014 of 57% perennial, 32% annual and 11% biennial plants (Fig. 2). This composition indicates the direction of plant development to a more stable stage. *Elymus repens* was a dominant and constant species throughout the period of observation.

The descriptions of the same plant communities performed during two subsequent vegetation periods express high similarity. This indicates that over such a short time period no substantial changes occur in the species composition. There are fluctuations in the abundance of some species. Such fluctuation processes are typical for the herbaceous plant communities as a whole. The lack of substantial variation in the species composition and the relatively long period

after the closure of landfill indicate that the ecological niches are occupied and the plant communities had undergone the stage of syngeneses. The high percentage cover and participation of perennial plants, as well as the start of the soil-formation process are indicators of currently ongoing processes of endo-ecogenesis.

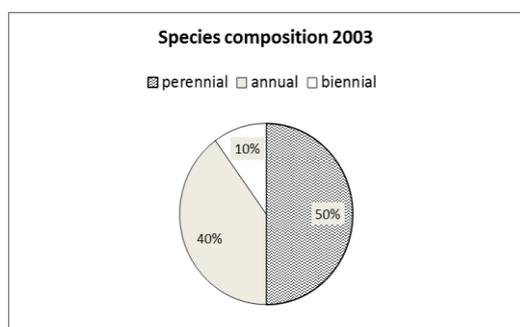


Fig. 1: Species composition on landfill, 2003

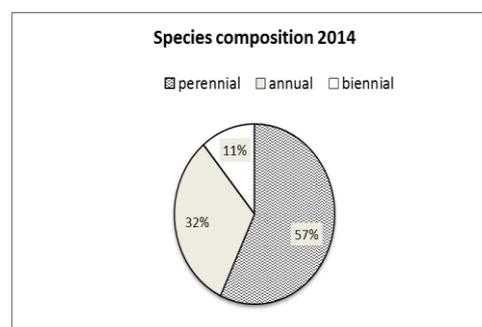


Fig. 2: Species composition on landfill, 2014

The main element of the plants in the communities developing on the landfill site near Dolni Bogrov are species that form long-term secondary mesophyte herbaceous communities in the region of Sofia plain – *Elymus repens*, *Alopecurus pratensis*, *Bromus sterillis*, *Trifolium repens*, *Lotus corniculatus*, *Plantago lanceolata*, *Cynodon dactylon*, *Poa pratensis*, etc. [3]. Some of these species play an important role in the formation of turf-grass cover, which is of substantial importance for minimizing pollution and preventing infiltration. Except the naturally colonizing species, in the further reclamation some other plants, mostly turf-grass grass species, naturally occurring in the herbaceous plant communities in the same region could be used - *Festuca pratensis*, *Arrhenatherum elatius*, *Lolium perenne*, *Cynosurus cristatus*, *Dactylis glomerata* etc. [15].

The analysis of the phytosociological structure showed that the predominant species in 2003 (Fig. 3) belonged to the classes *Stellarietea mediae* (31%) and *Polygono-Poetea annae* (5%) and relatively smaller number of perennial species are diagnostic for the classes *Artemisietea vulgaris* (19%) and *Molinio-Arrhenetheretea* (14%). This structure reflects the smaller age and the earlier stage of the successional development. The observations and studies have shown that the formation and development of the herbaceous plant communities on anthropogenic terrain undergo three main stages: weed-ruderal, cereal-ephemeral and turf grass-leguminous [10, 9]. The presence of the species typical for the first two stages expresses the dynamic status of the plant communities developing on the new part of the landfill site. Seven years after the landfill had been capped, the first weed-ruderal stage on this sector had already finished completely and the development of the next cereal-ephemeral stage has already started. The plant assemblage *Hordeum murinum-Poa annua* subcommunity has some floristic and physiognomic affinity with the association *Atriplexi tataricae-Hordeetum murinum* (Felf. 1942) Tx. 1950, belonging to the class *Stellarietea mediae*.

Class *Stellarietea mediae* includes ruderal plant communities dominating by annual species, developing on anthropogeneous substrates and in agricultural fields. In Bulgaria, similar plant communities have been described, developing on abandoned agricultural land and on anthropogeneous substrates – waste fields, abandoned manure sites, in settlements and mining embankments [14, 15, 20]. The comparative analysis revealed that the plant communities studied could be assigned to existing associations and plant assemblages. Their floristic affinity is closest to

the association *Echio-Melilotum albae* Tx.1942, widely distributed on the territory of Balkan Peninsula and having more limited distribution in Bulgaria [3, 12]. The plant group *Ballota nigra-Artemisia absinthium* [20] described on the territory of Melnik and Assenovgrad has similar species composition. The main differentiating features of the plant group established in the region of the landfill site is the dominating role of *Elymus repens*, which is almost absent in the above plant communities, and the constant presence of *Achillea pannonica*. The dynamic character of the plant communities under consideration and the local scale of the study do not provide enough evidence for describing a new association. At the current stage they could be regarded as an *Achillea pannonica-Elymus repens* community.

In 2014 the predominant species are perennials (57%) belonging mostly to the classes *Artemisietea vulgaris* (31%) and *Molinio-Arrhenetheretea* (16%), while the representatives of the classes *Stellarietea mediae* (18%) and *Polygono-Poetea annuae* (2%) are less represented (Fig. 3).

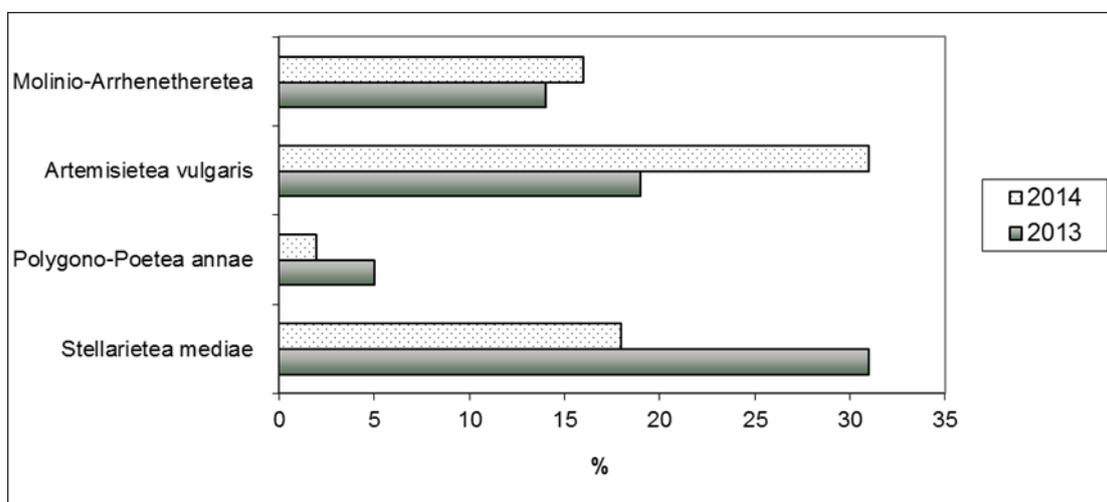


Fig. 3: Phytosociological structure of plant communities on landfill 2003-2014

The longer time period (20 years) results in the beginning of the next cereal-ephemeral successional stage. The occurrence of relatively large number of annual species indicates, on one hand, that the culmination of development of this stage is still not a fact. On the other hand, the presence of species typical for the next turf grass-leguminous stage indicates the direction of development. Depending on the management regime in the future we could expect formation of xero-mesophyte plant communities of class *Molinio-Arrhenatheretea* or xerophyte plant communities of class *Festuco-Brometea*. One of the four relevés is characterized by poor species composition. Main differentiating species in the other plant communities are *Dipsacus fullonum*, *Marrubium vulgare* and *Arctium lappa*. Two variants are distinguished: typicum and with *Dipsacus fullonum* (Table 1).

The analysis of the phytogeographical structure of *Achillea pannonica-Elymus repens* community (Fig. 4) shows that Euro-Asiatic elements predominate (about 25 %), followed by Euro-Mediterranean ones (about 19 %). The cosmopolitan and invasive alien species are less represented (about 14 %) and among them we could highlight *Ambrosia artemisifolia*, a species that has been recently recorded for a first time in the region of Sofia [6]. Recently, some sub-Mediterranean species have occurred in the locality, such as *Bromus commutatus* and some others.

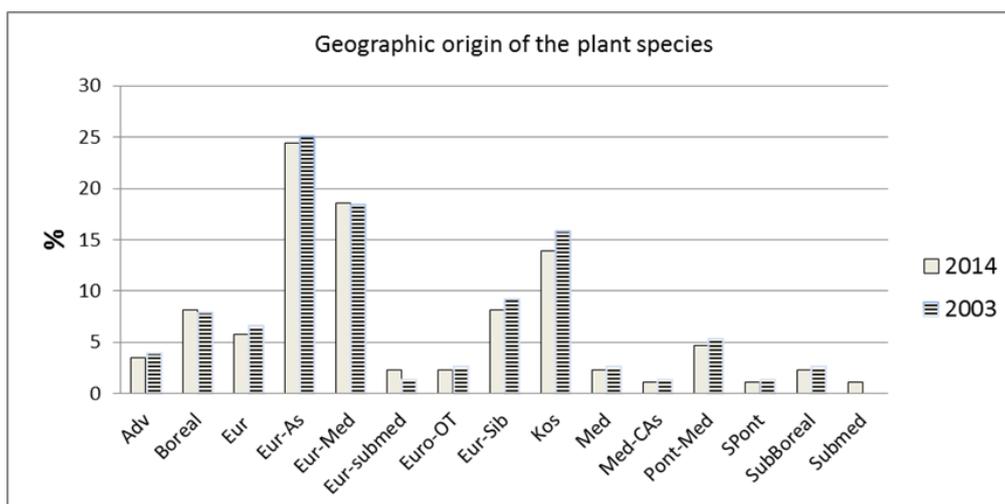


Fig. 4: Geographical origin of the plant species on the landfill, 2003–2014

The cool-season species on the landfill site are *c.*70 % of the total number of species present and the warm-season species comprise *c.*30 %. The cool-season plants reach their maximum development until the beginning of summer. These species become mostly senescent during the hot summer and then resume their growth, which continues until the first frosts. The warm-season plants renew their growth activities later in the spring, but grow continuously until early fall and thus produce maximum foliage in midsummer. They generally produce deep root systems that penetrate deep in the soil, especially during the summer, when the moisture is insufficient, while the cool-season plants have mostly shallow and branched root systems. The ratio between cool- and warm-season species is still not enough effective and is far from the recommended 1:1 ratio [13]. Hence, planning of future measures leading to better balance is necessary.

Analyses of long-term vegetation data from permanent relevés at the landfill indicate that areas having more species tend to maintain higher cover and fluctuate less in cover relative to the mean value, compared with areas supporting fewer species [1]. This depends also on the character of plant species. However, since the cereals already occupied most sites of the area, we believe that the existing stable cover will be maintained successfully. The plant diversity, including many species belonging to different functional and taxonomic groups, will ensure the functional integrity of a protective cap under threats from contamination in the environment.

### Conclusion

The results of the study performed in the waste landfill site, Dolni Bogrov village near Sofia, allow the following inferences and conclusions:

The plant species composition changed during the period of study. The plant cover is of patchy structure and different dominant species exhibit peculiar variation of life history;

The relatively long period after the closing of landfill indicate that the ecological niches are occupied and the plant communities had undergone the stage of syngeneses, which is completed in the older part of the landfill, while the newer part reached its final stage; plant communities are of transitional character between the classes *Stellarietea mediae* and *Artemisietea vulgaris*; it is

predicted that the processes of endo-ecogenesis observed on the whole territory will lead to change of vegetation and to formation of plant communities of meadow- and pasture-type;

The majority of plants in the communities studied are species forming long-term secondary mesophyte herbaceous communities in the region of the Sofia plain. Participation of turf-grass species in the plant cover results in successful control of the erosion processes and has a positive effect on the minimizing of infiltration after the rainfalls.

We believe the results of the study could be used in restoration and management of disturbed nature areas.

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## O RECONSIDERARE A DINAMICII VEGETAȚIEI PE HALDELE DE DEȘURI MENAJERE DE LÂNGĂ ORAȘUL SOFIA

### (Rezumat)

Studiul prezintă rezultatele analizei dezvoltării succesionale a vegetației pe o perioadă de 15 ani de pe depozitele menajere de lângă Dolni Bogrov (Sofia) și recomandă speciile tolerante pentru reabilitarea unor astfel de zone.

Rezultatele obținute permit formularea următoarelor concluzii:

Asociațiile vegetale sunt în tranziție între clasele *Stellarietea mediae* și *Artemisietea vulgaris*. Singeneza este completă, iar procesele de degajare endo-ecogenetice se observă pe întreg teritoriul, ceea ce va duce la dezvoltarea comunităților de pajiște și pășune. Prezența speciilor de gazon în comunitățile vegetale va avea un efect pozitiv asupra ținerii sub control a proceselor de eroziune și a minimalizării infiltrării agenților poluanți după ploi. Pe viitor, fitoremedierea ar trebui făcută prin utilizarea atât a speciilor care tolerează condițiile respective, cât și a celor care apar în mod natural în comunitățile ierboase adiacente. Raportul dintre speciile care se dezvoltă în perioadele reci față de cele care se dezvoltă în perioadele calde nu este încă destul de eficient și este departe de valoarea recomandată 1:1. De aceea, sunt necesare măsuri viitoare suplimentare pentru a ajunge la această balanță.

Rezultatele au arătat importanța covorului vegetal în recuperarea zonei. Compoziția specifică indică faptul că dezvoltarea vegetației se face înspre comunități vegetale mai sustenabile, care vor asigura protecția necesară față de eroziune și vor minimaliza infiltrarea în sol a agenților poluanți după ploi abundente. Se recomandă continuarea studiului proceselor de dezvoltare succesională a comunităților vegetale pentru a înțelege mai bine potențialul și efectului ecologic al utilizării adecvate a vegetației în recuperarea zonelor cu depozite menajere.

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