Catena 172 (2019) 501–508

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Links between slope aspect and rate of litter decomposition on inland dunes

Justyna Jasińska*, Piotr Sewerniak, Maciej Markiewicz

Department of Soil Science and Landscape Management, Nicolaus Copernicus University in Toruń, Lwowska 1, 87-100 Toruń, Poland

ARTICLE INFO

Keywords:
Litter decomposition
Release of nutrient
Slope aspect
Topography
Inland dunes
Pine forest

ABSTRACT

Litter decomposition has been widely studied and described in literature; however, so far rate of the process has not been investigated and described in detail with regard to inland dunes, despite them being common landforms in many regions of the world. The aim of our study was to show links between the topographically-induced variation in some main drivers of litter decomposition (microclimatic parameters, soil properties, vegetation) and the rate of the process on inland dunes. Our 3-year experiment was conducted on contrasting slope aspects (north- and south-facing slopes) of dunes representing the early and mature stages of pine forest development. On each slope the rate of litterfall decomposition (mineralisation and humification) was investigated using the litterbag method. The materials used for the experiment were the dominant category of litterfall for each plot and these were placed in 15 × 15-cm nylon mesh bags with 2 × 2-mm mesh. Litterbags were placed on the soil surface in the middle of each of the studied slopes. The chemical composition (C, N, P, K, Mg, Mn, Ca, Fe, Al) of initial litterfalls and of materials representing subsequent stages of decomposition was analyzed. The results were linked to topographically-induced variations in microclimatic parameters (air temperature and relative air humidity automatically recorded with HOBO U23-001 loggers) soil temperature and moisture (TDR method). In a mature pine stand, the rate of litterfall decomposition was faster on north- than south-facing slopes, while for the early stage of forest development the relationship was the opposite. The main agent of the differences for the mature stand was soil moisture and subsequent higher density of microbial decomposers, while for the early stage it was the difference in the initial chemical properties of the litterfall. Our results indicate that slope aspect significantly affects the rate of litter decomposition on the dunes by spatially differentiating the main drivers of the process.

1. Introduction

Slope aspect plays an important role in the spatial differentiation of many environmental processes. In the northern hemisphere, south-facing slopes receive more solar radiation than north-facing exposures. Consequently, slope aspect strongly affects microclimatic conditions such as temperature, humidity and evaporation. Specifically, in the northern hemisphere, north-facing slopes are commonly reported as cooler and wetter than south-facing slopes. Differences in microclimates entail dissimilarities in vegetation (Shreve, 1924; Cantlon, 1953) and soil microorganism populations (Chu et al., 2016).

The combined effect of the abiotic and biotic factors mentioned above is reflected in the spatial pattern of soil attributes, which follows topography. Relief is a soil-forming factor which strongly affects soil type as well as soil properties (Jenny, 1941). It has been commonly reported that, in the northern hemisphere, the soils of north-facing slopes are characterised by higher contents of organic matter (Kutiel, 1992), organic carbon (Liu et al., 2013; Sewerniak et al., 2017) and moisture (Liu et al., 2013; Chu et al., 2016; Sewerniak et al., 2017), and wider C/N ratio values (Chu et al., 2016) than pedons of south-facing exposures. Additionally, cation exchange capacity and base saturation were higher in soils located on north-facing slopes than south-facing slopes (Sariyildiz et al., 2005), whereas for soil temperature the topographically-induced relation was opposite (Liu et al., 2013; Sewerniak et al., 2017). Some researchers also reported that soil pH was higher on north-facing slopes than on south-facing slopes (Sariyildiz et al., 2005), but in other studies the opposite pattern was found (Chu et al., 2016; Sewerniak et al., 2017). The topographically-induced regular diversification of soil properties may result in a regular pattern of soil types (Sewerniak et al., 2017).

Slope aspect also affects litter decomposition, which is an extremely important process influencing the formation of both organic and humus horizons in a soil (Bot and Benites, 2015). This process is crucial in the undisturbed functioning of a natural ecosystem (Prescott et al., 2004) as well as in maintaining high productivity in forest plantations (Yang et al., 2004). Litter decomposition is a driver of the conversion of plant

* Corresponding author.
E-mail addresses: justynaj@doktorant.umk.pl (J. Jasińska), sewern@umk.pl (P. Sewerniak), mawicz@umk.pl (M. Markiewicz).

https://doi.org/10.1016/j.catena.2018.09.025
Received 30 January 2018; Received in revised form 17 August 2018; Accepted 11 September 2018

residues (which return to a soil mostly by litterfall) to soil organic matter. This phenomenon includes two complementary and simultaneous processes, namely mineralisation and humification (Bot and Benites, 2015). Elements within the decomposed material are released and become available for plant uptake (Swift et al., 1979; Prescott et al., 2004), constituting part of a nutrient cycle (Staaf and Berg, 1982). The rate of litter decomposition is determined by biotic and abiotic factors. The biotic factors include litter quality (e.g. content of lignin, N, P and other elements, C/N ratio, lignin/N ratio, Cobo et al., 2002; Berg and McClaugherty, 2008; Zhou et al., 2008) and decomposer communities (bacteria, fungi, protista and invertebrates; Swift et al., 1979; Joergensen et al., 2009). In turn, abiotic factors include soil properties (texture, porosity, moisture, temperature, pH, cation exchange capacity, Swift et al., 1979; Berg and McClaugherty, 2008) and (micro)climatic conditions (parameters related to humidity, temperature and actual evapotranspiration, McTiernan et al., 2003; Berg and McClaugherty, 2008; Zhou et al., 2008).

On account of its unquestionable impact on microclimates, as well as on soil properties and vegetation, topography is an important indirect factor affecting litter decomposition. The influence of relief on the process has been examined extensively for mountainous areas (Mudrick et al., 1994; Sariyildiz et al., 2005). However, so far, links between slope aspect and rate of litter decomposition have not been investigated with reference to inland dunes, despite the fact that these landforms occur commonly throughout the world, especially in Central and Eastern Europe (Zeeberg, 1998), North America (Forman et al., 2001) and northern Asia (Zhu et al., 2003). The dunes are built of well-sorted, nutrient-poor, quartz aeolian sands, usually with Podzols as the dominant soil type, which is especially relevant to inland dunes of Central Europe (Koster, 2009; Bednarek and Jankowski, 2006; Sewerniak et al., 2017). Inland dunes are characterised by homogenous parent material, however, in recent studies a clearly topographically-induced pattern of soils and microclimates (and subsequently also of vegetation) has been found for these landforms in Central Europe (Sewerniak et al., 2017; Sewerniak and Jankowski, 2017). These findings, as well as the lack of detailed knowledge in this field, encouraged us to examine links between the topographically-induced variation in some main drivers of litter decomposition (microclimatic parameters, soil properties, vegetation) and the rate of litter decomposition on inland dunes. Thus, the aim of this study was to determine these links with reference to inherent properties of decomposing plant material. Our secondary goal was to compare the above links in two different stages of pine forest development (early stage of succession and mature pine stand) on inland dunes. We based our study on the following hypotheses: (i) in the relatively dry environment of inland dunes, as a result of north-facing slopes potentially having higher moisture, the rate of litter decomposition could be faster for this aspect than on sunny slopes, (ii) as a result of differences in vegetation occurring between the two investigated stages of pine forest development, the topographically-induced variation in litter decomposition would differ between these stages.

2. Materials and methods

2.1. Study site

The research was conducted in the Toruń Basin (N Poland), which is one of the largest inland dune areas in Central Europe (Zeeberg, 1998). The investigated area has an average annual precipitation of 522.5 mm and a mean annual temperature of 7.9 °C (Wójcik and Marciniak, 2006). The dominant soils of the studied area are sandy and acidic Podzols (Bednarek and Jankowski, 2006) and the potential vegetation for the investigated dunes is subcontinental pine forest *Peucedano-Pinetum* (Chojnacka et al., 2010).

The research plots were located on the north- and south-facing slopes of two latitudinally situated dunes with a relative height of ca. 15 m. The dunes were representative of two vegetation types: 1) loose woodlands representing the early secondary succession stage of Scots pine (*Pinus sylvestris*) forest (hereafter referred to as "succession"), and 2) mature pine stand (Suppl. 1, hereafter referred to as "mature"). The two investigated ecosystems were divided into a total of four plots, representing both north- and south-facing slopes of each of the two stages (early and mature) of pine forest development on inland dunes, thus succession-N, succession-S, and mature-N, mature-S (Table 1).

Secondary plant encroachment at the succession site (52°56′09.40″N 18°39′06.74″E) was initiated by deforestation for military purposes ca. 65 years ago, due to its location within an artillery training area. This area has been excluded from forest management treatments, and vegetation strictly follows topography (Suppl. 1, Table 1). Furthermore, the density of pines and birches encroaching into the succession site is higher on north- than south-facing exposures (Sewerniak and Jankowski, 2017). The mature site (52°55′13.08″N 18°42′05.42″E) was located in a buffer zone of the artillery training area in which production forest stands have been subjected to standard forest management practices. The studied dune at the mature site was overgrown with 145-year-old, planted Scots pine stand.

On both investigated dunes acidic Podzols occur, although the soils of the north-facing slopes are more podzolised (Sewerniak et al., 2017). Also, on the south-facing slopes of the dunes at the succession area, soils are mostly eroded by denudation processes and consequently do not presently meet the criteria of Podzols and are classified as Arenosols (Sewerniak et al., 2017).

2.2. Sampling

Litter decomposition was examined for three years on contrasting slope aspects (north- and south-facing) at both study sites, using the litterbag method (Bocock et al., 1960). The samples used for the experiment were collected from study plots, where the material was freshly fallen senesced plant litter (materials used for the experiment were the dominant category of litterfall for each plot, Table 1), and then those materials were air-dried at ca. 20 °C to obtain constant weight. 8 g of needle litter and 5 g each of both heather stalks and grass blades were placed separately in 15 × 15 cm nylon mesh bags with 2 × 2 mm mesh size. Next, in December 2012, 25 litterbags with the plant material relevant to the vegetation type of each investigated slope were placed on the soil surface in the middle of each of the four studied slopes, with five litterbags at each of five subplots as replicates in each plot (in total 100 litterbags were studied). Subsequently, decomposing materials were collected at 5 time points (June and December 2013, June and December 2014, December 2015) for laboratory analyses. For each term, five litterbags were taken from each study plot. Some preliminary results on the first two years of litter decomposition at the mature site were presented in our previous paper (Sewerniak et al., 2015). This sampling design might be considered as pseudo-replicated by some researchers. Pseudoreplication is widely discussed in the literature (e.g. Freeberg and Lucas, 2009; Davies and Gray, 2015). The issue described in this paper requires more studies on other inland dunes to confirm the findings we show in this article.

2.3. Field methods

All field measurements described below were taken in the same place as the sampling described above. From April to November 2013 soil temperature and soil moisture were investigated every two weeks in each study plot (measurements were taken on 17 days in total). The measurements were taken at a depth of 3 cm. Soil temperature was measured using an electronic thermometer, whereas soil moisture content (in % v/v) was determined by Time Domain Reflectometry (TDR) in ten replicates on each slope on each measurement day. Before the measurements of soil moisture, the TDR probes were calibrated for sandy soils.