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Effects of Thinning on Litterfall Production and Leaf Litter Decomposition Rates of Karacabey Forested Wetlands, Bursa, Turkiye[1]

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Abstract

The contribution of litterfall (dead leaves, twigs, etc., fallen to the ground) and forest floor (organic residues such as leaves, twigs, etc., in various stages of decomposition, on the top of the mineral soil) is fundamental in both forest ecosystem sustainability and soil greenhouse gases (GHG) exchange system with the atmosphere. A focus on forested wetlands is particularly important, as these systems account for a disproportionate amount of global carbon flux relative to their spatial coverage, and the decomposition of leaf litter is a major contributor. In this study, we aimed to investigate the effects of two different thinning treatments (low thinning-canopy closure 41-70% and intense thinning-canopy closure 10-40%) on litterfall, forest floor litter and leaf litter decomposition rates of alder (*Alnus glutinosa*) stands in Karacabey forested wetlands. The litterfall was monthly collected using open litterfall traps for 2 years from 2021 to 2022. The forest floor litter was also sampled 50 x 50 cm^2 quadrates of 5 points in research plots of 20×20 m. The differences in leaf litter decomposition rates between the low and intense thinning stands were investigated using the litterbag method in the field for 18 months. The results indicated that the intense thinning significantly reduced the total litterfall production (7.24 ± 0.384 Mg ha^{-1}) and the forest floor litter (2.78 ± 0.41 Mg ha^{-1}) compared to the low thinning stand (10.8 ± 0.527 Mg ha^{-1} and (4.38 ± 0.82 Mg ha^{-1} respectively). Lower leaf litter decomposition rates were also seen in the intense thinning stands than in the lower thinning stands. At the end of the 18 months, the leaf litter mass loss was 83.6% in the intense thinning stands compared to the lower thinning stands (88.3%).

Keywords: Forested Wetlands, Thinning, Litterfall, Decomposition, Turkiye.

1. Introduction

Litterfall is one of the most important and dynamic components of nutrient cycling in terrestrial and forested wetland ecosystems (Attiwill and Adams 1993; Metcalfe et al. 2011). Studies have shown that for both the sustainability of forest ecosystems and soil greenhouse gases (GHG) exchange system with the atmosphere, the contributions of litterfall and forest floor litters are essential. Any alteration in the forest litterfall and litter layers can have an important impact on the soil's GHG seasonal variation (Leitner et al. 2016).

It is generally considered that the quantity and quality of litter fall are mainly influenced by climate and latitude (Berg and Meentemeyer, 2001). However, these impacts can be varied by altitude, exposure, soil type, climatic variability, pests, and diseases (Martinez-Alonso et al., 2007). In addition, forest types, stand properties, and silvicultural activities such as thinning (natural or artificial) may also vary litterfall production (Blanco et al., 2006; Navarro et al., 2013). Silvicultural practice including thinning has been actively used in Turkish forest plantations for a long time (Çömez et al., 2019). Tree growth and productivity, higher nitrogen mineralization rate, and protection to trees against insect attack can be achieved at the forest stands by the thinning (Liu et al., 1992; Coyea and Margolis, 1994; Thibodeau et al., 2000). Soil environments, the aboveground and belowground productivity, root density and turnover can be also varied by the thinning (Bowden et al., 2004).

The effects of thinning on foliage and forest floor properties, on litter fall, litter decay and nutrient cycling, and on rainfall interception, tree transpiration and hydrological connectivity were previously investigated by authors (Wollum and Schubert, 1975; Lado-Monserrat et al., 2016; Lopez-Vicente et al., 2017). All these studies of the effects of thinning on litterfall have found conflicting results, with thinning leading to changes in litterfall in some cases and no differences in others, implying that the impacts of silvicultural management on litter dynamics are complicated by factors such as stand age, species, climate patterns, and

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the management intervention used (Segura et al., 2017; Çömez et al., 2019).

Litter fall production in forested wetland ecosystems are higher than in terrestrial forest ecosystems, and this may result in significant dissolved organic matter production in coastal ecosystems (Kathiresan and Bingham, 2001). In forested wetland ecosystems (mainly mangroves), leaf production is the main part of the litter fall and essentials for animals and microbial organisms. Many studies are carried out in mangrove ecosystems to investigate mean litter fall production and decomposition rates (Sharma et al., 2012; Kamruzzaman et al., 2016). However, no study is available on litterfall, forest floor litter weight and decomposition rates of Turkish forested wetland ecosystems.

In Turkiye, unfortunately about 12000 ha forested wetlands are left. Several riverine and some forested wetlands in Turkiye have already been investigated for their ecology, biology (Çiçek, 2002), soil and root carbon and total nitrogen stocks (Sariyildiz et al., 2022, 2023). This study aimed (1) to determine monthly variation in litterfall production of alder after low and intense thinning, (2) to investigate litter fall production and forest floor litter weight between low thinning plots and intense thinning plots, and (3) study the litter decomposition processes between low thinning plots and intense thinning plots.

2. Material and Methods

The study site is located at the forested wetlands of Karacabey (40º23 38´´- 40º21 43´´N, 28º23 02´´- 28º34 21´´E) which is the third-largest wetland in Turkiye (Figure 1). The Karacabey floodplain ecosystem is formed by the accumulation of sediments deposited by creeks and streams flowing into the sea. The water level varies based on the rise and fall of groundwater during certain periods throughout the year. Total size of the Karacabey floodplain is approximately 3800 ha. (Akay et al., 2017). It includes a variety of habitats; sand dunes (623 ha), swamp (532 ha), lakes (760 ha), grasslands (390 ha), croplands (545 ha) and floodplain forests (950 ha). A semi humid climate is generally characteristics to the study region. According to previous year's meteorological data (2007–2020), mean annual precipitation was 719 mm and mean temperature was 15.5 ^{0}C.

The low and intense thinning sites were chosen according to the canopy closure (low thinning-canopy closure 41-70% and intense thinning-canopy closure 10-40%) and the information from the District Forestry Directorate. Litterfall consisted of leaf litterfall, branch litterfall mainly small twigs and branches, reproductive parts, and other woody parts collected using litter traps. In each site (low and intense thinning), three sampling plots (20 m × 20 m) located approximately 300 m. apart were identified (total of six plots). Within each of the six plots, five traps (50 x 50 x 30 cm) were randomly put under the trees (total of 30 traps). The fall litters were collected monthly on a similar date in 2021 and 2022. The litter was passed from the traps to the numbered paper bags. Forest floor litter samples were collected in October, January, March using a wooden frame (total 30 samples). Both litterfall and forest floor litter samples were dried at 80 ^{0}C in an oven for 48 h and then their dry weight was measured.

Litter decomposition experiment was carried out in the field using litterbag method. The bags were 20x20 cm with a mesh size of 1.5 mm. In each bag, 3 g leaf litter was put. Some leaf samples were also used to calculate the initial oven dry mass of the material at 85 ^{0}C.

Total 90 litter bags (6 plots x 3 removal dates x 5 replicate litterbags = 90 bags) was used in the field experiment. The bags were placed on the ground of the corresponding sites (low and intense thinning) with metal nails. Five litter bags at 9, 12 and 18 months were collected to follow the continuum of litter decay over time. Mass loss rates at each collecting period was calculated after drying samples at 85 ^{0}C.

The decay rate coefficient (k) estimates the disappearance of leaf litter on a annual basis, using the negative exponential decay function $Xt/X0=e-kt$, where X0 is the original amount of litter and Xt is the amount of litter remaining at time t (Olson, 1963). The k value was used to calculate turnover time (1/k) and the time required for 50% decomposition or the half-life of litter on the ground, $t_{1/2}$, calculated as 0.693/k and the time required for 95% and 99% decomposition, calculated as 3/k and 5/k.

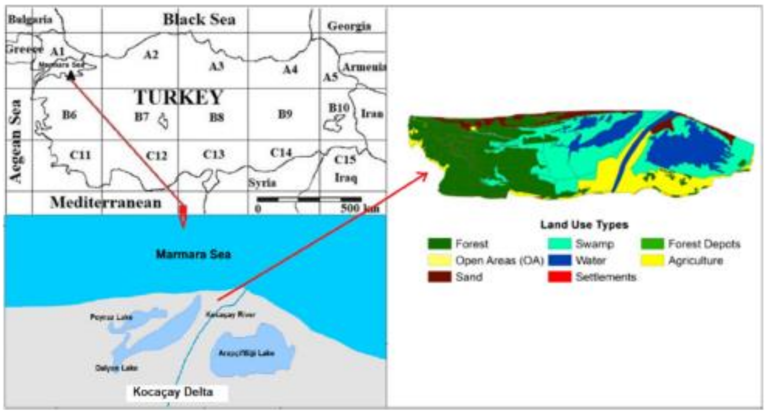

Figure 1. Location of the research area according to the grid system of Turkiye (Henderson, 1961) and land use type (Akay et al., 2017).

3. Results

Figure 2 shows the monthly patterns of litter fall (leaves, twigs, reproductive parts, other woody parts and total litter fall) during the study years of 2021 and 2022. Leaf litter fall was higher in summer, fall (October, November, December) and lower in winter, spring (January, February, March, April). However, excessive leaf falls occurred in October because of strong wind which generally occurs in this month in the region. In October and following two months, the low thinning sites produced higher leaf litterfall than the intensive thinning sites (Figure 2a).

Branch litterfall, including small twigs and branches showed an increase from winter-spring seasons towards summer-autumn seasons (Figure 2b). In February, branch litterfall was the lowest, while it was the highest in October. The differences in branch litterfall between the low and intense thinning sites were clearly seen, with higher values in the low thinning sites than in the intense thinning sites. In general, reproductive components were higher in the low thinning stands than in the intense thinning stands. Both low and intense thinning sites, the reproductive parts showed an increase from winter to spring, and then decreased in summer and autumn (Figure 2c). As seen for leaf and branch litterfalls, the productive production was also higher in the low thinning stands than in the intense thinning stands. As for the other woody litterfall, they showed a sharp increase in spring, with a pick in April and then decreased during summer (Figure 2d). As for total litter fall, the low thinning sites had higher litterfall (10.8 Mg/ha/year) than the intense thinning sites (7.24 Mg/ha/year) because of high density of trees (Figure 2e, Table 1). Forest floor litter weight was also higher in the low thinning site (4.38 Mg/ha) than in the intense thinning sites (2.78 Mg/ha) (Table 1).

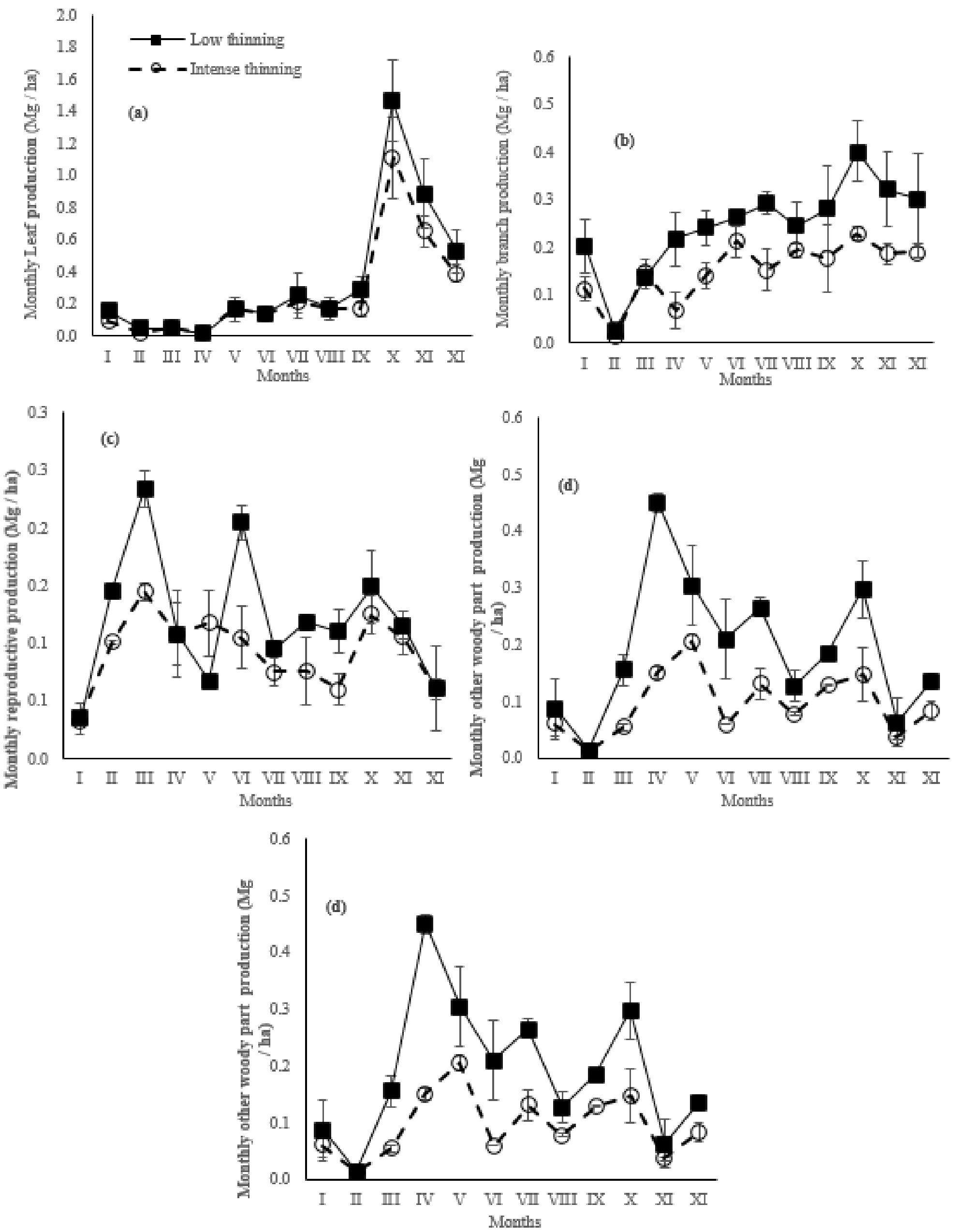

Figure 2. Monthly pattern of leaves, twigs, reproductive parts-seeds, others and total litterfall of the studied low and intense thinning plots (Mg / ha).

Table 1. Forest floor litters of alder at the low and intense thinning sites (Mg / ha).

	Litterfall	Forest Floor Litter (Mg / ha) mean ±S.D.	Litterfall: Forest floor litter weight ratio
Low thinning	10.8^b ±0.53	4.38^b ± 0.82	2,47
Intense thinning	7.24^a ± 0.38	2.78^a ± 0.41	2,60

The mass remaining of alder leaf litter during litter decomposition process is shown in Figure 3. The alder leaf litter mass loss was the highest at the end of the decomposition process (summer-autumn) and the lowest during winter and spring. Alder leaves decomposed faster in the low thinning site (k = -1.0289) than in the intense thinning stands (k= -1.091) (Table 2). The differences in leaf litter mass loss between the low and intense thinning site decreased from 9.8% to 4.7% during time (Table 2). After 18 months of decomposition, the leaf mass remaining in decomposing litter was 11.7% in the low thinning site and 16.4% in the intense thinning site (Table 2). T_{50}, T_{95} and T_{99} values for alder leaves were lower in the low thinning stands than in the intense thinning stands, indicating that mass loss was faster in the low thinning stands (Table 2).

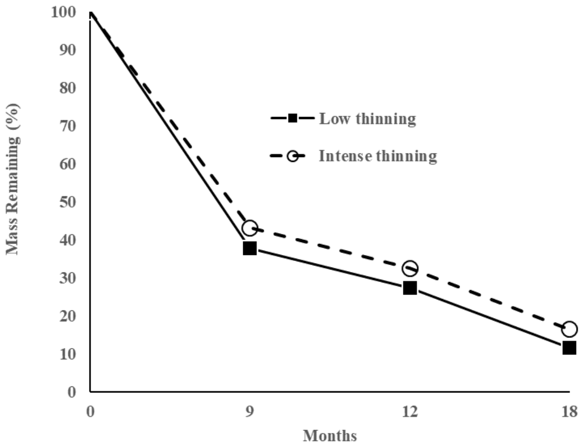

Figure 3. Mass remaining (%) of alder leaves at the low and intense thinning sites after 9, 12 and 18 months.

Table 2. Mass loss rates (%) of alder leaves in the low and intense thinning sites after 9, 12 and 18 months and also mean annual decay rate coefficient and time required for 50%, 95% and 99% decomposition (years).

	Mass loss (%)			Annual decay rate coefficient (k)	T_{50} (year)	T_{95} (year)	T_{99} (year)
	9 months	12 months	18 months				
Low thinning	62.2	72.7	88.3	-1.289	0.54	2.33	3.88
Intense thinning	56.8	67.5	83.6	-1.091	0.64	2.75	4.58
Differences	9.8	5.2	4.7				

4. Discussion

Mean annual litterfall production, forest floor litter weight and leaf litter decomposition rates of alder stands were studied in the low and intense thinning stands during 2021 and 2022. The results showed that the low thinning stands produced more litterfall and had higher litter on the forest floor. Litter decomposition rates were also faster in the low thinning stands compared to the intense thinning stands.

Litter fall result corroborates with similar studies focusing on the effects of thinning intensity on litterfall biomass (Harrington and Edwards, 1999; Roig et al., 2005). Roig et al. (2005) reported that the mean litter fall was lower in the heavy thinning stands than the moderate thinning, indicating that thinning can reduce the amount of litterfall. The authors have argued that the amount of litterfall reduces after thinning mainly due to the reduction of stand basal area, which provides the rest of the trees more growing space and resources (e.g., Kunhamu et al., 2009; Navarro et al., 2013; Lado-Monserrat et al., 2016). annual litter fall production decreased with increasing thinning intensity in *Pinus halepensis* stands in Spain (Navarro et al., 2013). Kunhamu et al. (2009) reported that the annual litter fall varied from 5.73 Mg h^{-1} (intense) to 11.18 Mg ha^{-1} (unthinned plot). However, just after the thinning operation, they showed that the control plot produced more litterfall in all months; this was because the control plot was denser compared with the other thinned plots (30% and15% cut), where the stands were more open. It is generally stated "that thinning can increase biomass productivity of any remaining trees and results in a decrease in litterfall production and thus in nutrient inputs to the soil, immediately following thinning (Blanco et al. 2006). This is mainly due to the reduction of tree density, canopy coverage or stocking levels after thinning (Jung et al., 2008).

Annual litter fall of alder in the low (10.8 Mg/ha/year) and intense (7.24 Mg/ha/year) thinning stands of the forested wetlands were higher compared to Mediterranean riparian forests and rivers of Iberian (mean = 5.51 Mg/ha/year, by Gonzalez et al. 2010; Gonzalez, 2012), and also in a floodplain forest on the upper coastal plain of South Carolina (average annual litterfall ranged from 5.70 - 6.67 Mg/ha/year by Donald and Gottschalk, 1985). In our study, we observed high amount of litter fall. This could be an indicator of regular nutrient return to the soil or to the reserve of nutrients. Naiman et al. (2005) stated that at early successional stage in riparian zones litter production was higher than in older forests since the young plant ecosystems continually produce in growth.

Annual litter fall of alder in the forested wetlands were higher than that found in various *Alnus* spp. stands in different terrestrial conditions. Estimates of annual litterfall in various *Alnus* spp. stands in different parts of the world were as follows: *Alnus crispa* 2.6 Mg/ha/year in Alaska (Crocker and Major 1955); *Alnus glutinosa* 3.3 Mg/ha/year in Hungary (Jaro-cited by Bray and Gorham 1964); *Alnus hirsuta* 2 - 6 Mg/ha/year in Japan (Tadaki and Shidei 1960); *Alnus nepalensis* 3.2 - 5.8 Mg/ha/year in the Eastern Himalaya (Sharma and Ambasht, 1987); *Alnus rugosa* in Canada (5.5 Mg/ha/year) (Daly 1966); and *Alnus rubra* in Oregon (4.5-9.9 Mg/ha/year) (Zavitkovski and Newton 1971). In our study site, seasonal rainfall and temperature were higher at the present study sites than for most of these *Alnus* forests, and consequently the litterfall estimates were also higher.

Annual litter fall in our study had a low proportion of leaves (39 % at the low thinning site, 44% at the intense thinning site). The average annual litter fall in deciduous riparian forests was reported to be 70 % (Meentemeyer et al. 1982), 57% in the Mediterranean and Iberian rivers (Gonzalez et al. 2010) and 73-84% under the floodplain forests (Donald and Gottschalk, 1985). The lower leaf production in the litter fall for the floodplain level could be due to the canopy dieback (Rood et al. 2000). This was also noted in the present study. The canopy dieback is generally considered due to a lack of hydrogeomorphic dynamism, abrupt and long low-water periods during winter and spring (Gonzalez et al., 2010; Gonzalez, 2012).

In our study, annual reproductive and woody part inputs were 13% (1.44 Mg/ha/year) and 27% (2.93 Mg/ha/year) and at the low thinning site respectively, while they were 15% (1.08 Mg/ha/year) and 25% (1.82 Mg/ha/year) at the intense thinning site respectively. These results were higher than found by Donald and Gottschalk (1985) who reported that annual reproductive inputs averaged 0.34 - 0.39 Mg/ha/year and 5-6.5% of total litter fall, while annual wood parts (branch and twigs) averaged 1.33-0.90 Mg/ha/year and 13-21% of total litter fall.

In general, in our study, litterfall of alder was higher summer-autumn (October-November-December) and lower in winter-spring (January-February- March-April). Similar monthly patterns were also recorded by a number of authors who stated that litterfall production was highest with maximum temperature and rainfall (e.g. Coupland et al., 2005; Kamruzzaman et al., 2013). Under tropical climate conditions, a number of authors (Sundarapandian and Swamy, 1999) found higher litter fall in spring, summer and autumn. The highest litterfall in summer could be in relation with leaf senescence. Rapp (1984) stated that the early leaf senescence was accelerated by the dry period. Jenson (1974) noted that the litter fall increased with the dry period in summer.

In our study, we found that forest floor litter weight was lower in the intense thinning site (2.78 Mg/ha) than in the intense thinning sites (4.38 Mg/ha) Lower forest floor quantity in the intense thinned treatments may be explained by lower litter inputs and also higher abiotic decomposition in the intense thinning stands. In this sense, Almagro and Martinez-Mena (2012), when comparing two Mediterranean ecosystems with different tree densities of Aleppo pine trees, observed higher decomposition in the plot with lower aboveground biomass but also with lower basal respiration in the forest floor. The authors explained this fact by the effects that a higher canopy cover may have when decreasing physical decomposition processes such as photodegradation or fragmentation of litter by raindrop impact and splash.

In our study, the rate of decomposition was higher in the low thinning site than in the intense thinning site. Similarly, Bravo-Oviedo et al. (2017) found that removal of 40% of basal area delayed decomposition rates in a mixed *Quercus pyrenaica-Pinus pinaster* forest whereas removal of 25% of basal area accelerated needle litter decomposition rates which was similar decay rates to that of oak leaves. Blanco et al. (2011) found a reduction effect of thinning on decomposition that vanished after 4 years in the intermediate thinning treatment in a pure Scots pine forest growing on Continental climate with a dry period. Leaf litter mass loss showed a peak at end of the decomposition experiment (summer-autumn), while it was lowest in winter and spring. Higher decomposition in the low thinning stands during the summer-autumn seasons could be attributed to better microbial activity under better temperature conditions. Gupta and Singh (1977) also showed highest disappearance rate, 36 – 53% during rainy season, while a weight loss of 15 – 26% was recorded in winter season.

The decay rate coefficient (k) was higher in the low thinning site (-1.298) than in the intense thinning stands (-1.091). The k values for temperate hardwood species range from 0.08 to 0.47 (Melillo et al., 1982), from 0.66 to 1.09 for subtropical forest (Alhamd et al., 2004) and rfrom 0.30 to 0.75 for Mediterranean ecosystem (Fioretto et al., 2005). Alvarez et al. (1992) reported that, k values of tropical forests were often higher than 1.0, showing that leaf-litter turnover was in a year or less than a year. The varying k value could be due to the leaves nutrient content (Songwe et al., 1995) or season.

5. Conclusion

The present study showed that the thinning operations can have a significant seasonal effect on both forest floor and litterfall production in the forested wetlands. The observed litter fall decrease may not be seen in long term due to the increment of litterfall from the surviving trees, and thus long-term in situ research is essential in order to evaluate the annual variability of litterfall and the forest floor layers. In addition, the intense thinning significantly reduced the leaf litter decomposition of alder stands. It seems the decomposition rate increase with increasing canopy cover. It is suggested that heavy thinning might have negatively affecting the decomposition process in the forested wetlands. This hypothesis must be further explored.

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