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Changes in soil arthropods and litter nutrients after prescribed burn in a subtropical moist pastureland

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ABSTRACT

Plant litter decomposition is driven by soil biota and biophysiochemical conditions as well as substrate quality. Prescribed burns can affect the abundance and diversity of soil arthropods and the biophysiochemical conditions in terrestrial ecosystems. In this study, we examined the effects of a prescribed burn on soil arthropods and litter chemistry in decomposing litter during a total of 469-days field incubation using litter from two grasses, *Dichanthium annulatum* and *Megathyrsus maximus*, in a subtropical moist pastureland of Puerto Rico. We found the prescribed burn substantially elevated ultraviolet (UV) radiation and soil temperature; and significantly decreased the diversity of litter total arthropods, especially predators and Mesostigmata mites, during the initial 5 months after the burn. However, the prescribed burn had no effect on either the biophysical environment nor on arthropod abundance and diversity during the subsequent incubation period of >5 months after the burn. Furthermore, the prescribed burn substantially increased the immobilization of iron (Fe) and manganese (Mn), and decreased sulfur (S) concentration in the decomposing litter. Prescribed burn had no interactions with substrate quality for percent mass remaining (PMR) and elemental release or accumulation. Low substrate quality *D. annulatum* litter with a carbon to phosphorus (C/P) ratio of 614 was associated with higher microbivore diversity and higher predator density than higher substrate quality *M. maximus* litter with a C/P ratio of 266 during the entire incubation period. Lower initial concentration of litter P, magnesium (Mg) and calcium (Ca) in *D. annulatum* resulted in higher immobilization of these elements in decomposing litter than in *M. maximus*. Our study suggest that prescribed burn can impose short-term changes in biophysiochemical conditions and the diversity of arthropods in litter decomposition during the initial recovery period of about 5 months after a burn, thus highlighting a high resilience of the grassland ecosystem to fire disturbance, and that it can bring lasting changes in the cycling of Fe, Mn, and S in subtropical moist pastureland that can alter ecosystem productivity.

1. Introduction

Prescribed burn is used to remove young shrubs and trees and maintain pasturelands that were comforted from natural forests (Alcañiz et al., 2018; Girona-García et al., 2018). Burns can mediate changes in decomposition processes through altering soil organismal communities, the microclimate of the litter floor and soil, and the chemistry of decomposing litter (Koster et al., 2016; Podgaiski et al., 2015). Slowly moving detritivores and microbivores are vulnerable groups during pyrogenic ecosystem disturbances (Zaitsev et al., 2016). Predators have more advantages in escaping, and their hunting efficiency is greater in open habitats after fire (Malmström, 2010, Buckingham et al., 2019). However, Mesostigmata mites did not demonstrate any significant reduction of their numbers by fire in coniferous forest of central Sweden (Zaitsev et al., 2014). But predators would be controlled by detritivores through bottom-up effects (Kalinkat et al., 2013). Burns are shown to

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increase soil temperature and ultraviolet (UV) radiation, and reduced soil moisture, organic matter in O horizon, and shelter space for soil fauna (Butler et al., 2019; Liechty and Reinke, 2020). Reduced decay due to reduced arthropod abundance and diversity may be compensated by increased photodecomposition due to elevated solar and UV radiation within one year post-fire (Throop et al., 2017).

Pryke and Samways (2012) showed no significant differences in detritivore species richness or abundance between the burned and control sites in Fynbos of South Africa. Buckingham et al. (2015) reported that litter decomposition changed little with fewer arthropod species and individuals after burn, suggesting high litter arthropod functional redundancy. But other studies have indicated the critical role of microarthropods in transforming organic carbon (C), even without visible effects on mass loss (Soong et al., 2016; Tan et al., 2022). Detritivores prefer feeding on decomposing leaf litter that is well colonized by microorganisms rather than freshly fallen litter (Buckingham et al., 2019). Most previous studies have found loss of detritivores lead to reduced rates of leaf litter decomposition caused by burn (Throop et al., 2017). Microbivores and predators represent a separate energy channel (Buckingham et al., 2019), and their effect on litter decomposition and on litter element release is not well understood in tropical pasturelands.

The effect of burns on elemental release during litter decomposition varies among sites. Although there is abundant information about the effect of litter arthropod community on litter C, nitrogen (N) or phosphorus (P) remaining after burn (Brennan et al., 2010; Throop et al., 2017), the relevant literature scarcely refers to the dynamics of biochemical metallic elements, such as potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), zinc (Zn), iron (Fe) and aluminum (Al). While initial Mn levels suppressed the decomposition (Wang et al., 2021), Mn is the essential element for enzyme production (Heim and Frey, 2004), and can stimulate lignin degradation through the enzyme manganese peroxidase (Archibald and Roy, 1992; Valášková et al., 2007). Mycorrhizal fungi can exude organic acids, which can form strong complexes with Fe and Al in podzol soils (Giesler et al., 2000; van Breemen et al., 2000). Such complexes may be transported by hyphae to litter and the metals are released from litter when hyphae die (Palviainen et al., 2004). The release of Ca is dependent on microbial decomposition of structural compounds (Ukonmaanaho and Starr, 2001). Mg is a co-factor for hundreds of enzymes supporting the growth and metabolic function of microbes and soil animals (Vivanco and Austin, 2019). The metallic element content of decomposing litter might indirectly be linked to litter arthropod through microbes and affect litter mass loss.

To better understand the effects of a prescribed burn on litter arthropod species diversity and element content of the decomposing grass litter, we performed a 469 days litter incubation experiment after a prescribed burn in a subtropical pastureland in Puerto Rico. We hypothesized the prescribed burn would (1) decrease the diversity of total litter arthropods, detritivores and microbivores, but have no significant effect on predator species diversity; (2) suppress the release of litter metallic element; and (3) reduce litter mass loss.

2. Materials and methods

2.1. Site description

We conducted this study in a pastureland managed by USDA Forest Service in the Guayama Research Area of Puerto Rico. Average annual temperature in the site was 23 °C, with an average annual precipitation of 1693 mm during the period of this study. The dry season lasts from December to March, followed by an early rainy season in April and May, a midsummer dry period in June and July, and a late rainy season through November. From 2014–2016, Puerto Rico experienced an extreme drought since the 1950s (Lugo, 2018). The study area had a gentle slope between 3 and 5 degrees. Soils belong to shallow Typic Haplustalfs (Muñoz et al., 2017), with a neutral pH 7 and bulk density of 1 g/cm^3. Soil texture was clay loam (Boccheciamp, 1977). Soil total C and total N contents were 3.91 %, 0.32 %, respectively. The original vegetation in this area was subtropical moist forest. But this site, with an approximate area of 100 m x 60 m, was deforested prior to 1937 and has been used with variable intensity as pastureland for horses from the nearby village. Surface fires were used by local villagers in 1–5 years interval to maintain the pasture over the last hundred years, with the last event occurring in 2006. In 2010, International Institute of Tropical Forestry, USDA-Forest Service, became the custodian of the Guayama Research Area from the USDA Farm Service Administration. Two non-native grasses, *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L. Jacobs and *Dichanthium annulatum* (Forssk.) Stapf, dominate the pastureland vegetation with a relative cover of 87 % and 13 % and standing biomass of 775±196 g/m^2 and 357±83 g/m^2, respectively. Concentrations of C, Ca, K, Mg, P and S of *M. maximus* litter were higher than *D. annulatum* litter (Table 1). However, concentrations of Al, Fe and Mn were significantly higher in *D. annulatum* litter than in *M. maximus* litter. The C/P of *M. maximus* litter was lower than *D. annulatum* litter. Some trees, shrubs and vines scatter in the pastureland.

2.2. Field manipulation

We located eight 20 m × 10 m rectangular plots in the pastureland. Four plots were randomly assigned as control without burning and four as burn treatment. Each plot was around 5 m apart from its neighboring plots. Burn breaks (2 m width) around each plot were set up to avoid burn spread into the vegetation outside plots. The prescribed burn was carried out in the morning of 31 March 2017 to simulate management practice of local villagers in this pastureland over last hundred years. Fire was ignited by burn gun by trained personnel of the Puerto Rico Fire Department and lasted around three hours. The plots were burned homogeneously, with a burn temperature of 537.5 °C at the litter layer. All aboveground parts of herbs, grasses, shrubs, and vines were burned to death, but stems of trees and grass roots remained alive. We observed a rapid regrowth of grasses in the post-burn raining season (April-August) with little regrowth of herbs, shrubs, and vines. Tree shading was avoided in the experimental plots.

2.3. Litterbags and arthropod collection

Litterbags of 20 cm × 20 cm were constructed with three different mesh sizes. The small mesh size bags were made of cloth with openings of 0.1 mm × 0.15 mm designed to allow micro-fauna (e.g. juvenile Oribatida mites) to enter and leave the bags but prevent excess for

Table 1
Test statistics for differences in initial concentrations of C, N, Al, Ca, Fe, K, Mg, Mn, Na, P, S and C/P between *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L. Jacobs and *Dichanthium annulatum* (Forssk.) Stapf litter in litterbags. Values are mean ± standard deviation, n = 24. Bold font represents significant differences in elemental concentration between litter species at $P < 0.05$.

Initial chemistry	Litter species		*P*
	M. maximus	*D. annulatum*	
Carbon (C, %)	**44.33±0.58**	42.52±0.95	<0.001
Nitrogen (N, %)	0.55±0.09	0.55±0.09	0.911
Aluminum (Al, mg/g)	0.14±0.03	**0.50±0.29**	<0.001
Calcium (Ca, mg/g)	**7.76±1.24**	5.71±0.67	<0.001
Iron (Fe, mg/g)	0.13±0.03	**0.45±0.33**	<0.001
Potassium (K, mg/g)	**7.99±2.14**	5.00±1.46	<0.001
Magnesium (Mg, mg/g)	**3.08±0.34**	1.71±0.27	<0.001
Manganese (Mn, mg/g)	0.02±0.00	**0.04±0.01**	<0.001
Sodium (Na, mg/g)	0.15±0.04	0.16±0.04	0.575
Phosphorus (P, mg/g)	**1.74±0.35**	0.72±0.15	<0.001
Sulfur (S, mg/g)	**1.06±0.11**	0.94±0.15	0.003
C/P	266.13±59.07	**614.47±130.44**	<0.001

Carbon-to-phosphorus ratio (C/P) is mass based.

medium- and large-sized fauna (> 0.2 mm). Medium mesh size bags were made of fiberglass and had openings of 1.5 mm × 1.5 mm in size that allowed micro- and meso-fauna (e.g. Collembola and Hymenoptera) to enter and leave the bags. Large mesh size bags were made of fiberglass and had openings of 6 mm × 6 mm in size that allowed micro-, meso- and macro-fauna (e.g. some Blattodea and Orthroptera) to enter.

All litterbags were filled with stem and leaves (both blades and sheaths) from the two dominant grass species. Grass litter consisted of aboveground parts of *M. maximus* and *D. annulatum*, collected from the study site in November 2016, cut into segments of approximately 20 cm in length, and air-dried. Litterbags were each manually filled with 10 g *M. maximus* or 10 g *D. annulatum* litter materials. There was a total of 48 litterbags (two litter species × three mesh sizes × eight collections) placed in each plot three days after the prescribed burn (3 April 2017). We secured each litterbag to the ground with two nails at opposite corners to ensure direct contact with soil surface. Six litterbags (two litter species × three meshes) were recovered after 0, 15, 31, 59, 133, 237, 344 and 469 days in each plot. The day 0 collection was used to correct for handling loss and initial dry mass relations (González and Seastedt, 2001).

After litterbags were returned to the laboratory, the litter sample was removed from each litterbag and placed in Tullgren funnels for arthropod extraction (González and Seastedt, 2001). We counted all collected arthropods, measured for body width, and identified to morphospecies. Morphospecies were assigned to broad trophic groups, based on the known biology of the taxa (Borror et al., 1989; Dindal, 1990; Hoy, 2009; McAlpine et al., 1981). Trophic groups were defined as detritivores (comminutors of litter), microbivores (feeding on fungi, bacteria, protozoa, and small detrital particles), herbivores (feeding on live plant leaves), predators (feeding on other meso- and macrofauna), scavengers (feed on dead animal bodies) and omnivores (feeding on multiple food sources). Shannon–Wiener index was used to indicate arthropod diversity. All litter samples were oven-dried 65 °C for five days to obtain mass remaining and performing chemical analysis after arthropod extractions. Soil on the surface of litter was cleaned by careful brushing before weighting mass remaining. Arthropod densities were standardized to abundance per gram of dry litter.

2.4. Microclimatic measurements

Soil temperature and volumetric water content were recorded using three Campbell 108 (Campbell Scientific) sensors per plot, connected to a Campbell data logger to give an hourly average. We used an UV radio meter (UV-X, UV Products, Upland, California, USA) to measure UV levels of the litter layer in each plot between 10:00 am and 11:00 am everyday of litterbag collection.

2.5. Chemical analysis

All litter samples were re-dried at 65 °C and ground to pass through an 18-mesh sieve (González et al., 2014). Total C and N for the litter samples were determined using the macro dry combustion method by means of the LECO TruSpec CN Analyzer (González et al., 2014). The ground litter samples were digested using a modification of the method recommended by Chao-Yong and Schulte (1985). This wet oxidation uses concentrated nitric acid (HNO_3), 30 % hydrogen peroxide (H_2O_2) and concentrated hydrochloric acid (HCl) and was achieved using a digestion block with automatic temperature control. The digests were analyzed in a Spectro SpectroBlue ICP Emission Spectrometer, for P, S, Na, K, Ca, Mg, Fe, Al, and Mn. The results are reported as mg/g on a dry basis at 105 °C. A blank and a certified reference material were analyzed in each batch to ensure the completeness of elemental recovery. A moisture factor correction at 105 °C was determined by the LECO Thermogravimetric Analyzer, model TGA 701 and applied to all reported values.

2.6. Statistical analysis

Mean differences in initial nutrient concentrations between *M. maximus* and *D. annulatum* were analyzed by T test. A repeated measure general linear model was used to assess the effects of prescribed burn (burn vs. control), litter species, litterbag mesh sizes and sampling time on percent mass reaming (PMR), arthropod diversity indices and density, the concentration of elements in the litter, percent of initial element remaining, and micro-climate. In this repeated measure general linear model, sample time were fixed factors and plot was a random-effect factor. At every collecting day, two-way ANOVAs were employed to test the effects of prescribed burn and litter species on (1) the Shannon-Wiener Index and density of all arthropods, microbivores, predators and Mesostigmata mites; (2) the percent of initial mass, and Fe, Mn Al, Ca Mg and P remaining; and (3) litter C, Ca, P and S concentration. One-way ANOVAs were employed to determine whether the effect of prescribed burn on UV level or soil temperature was significant at every collecting day. All data were tested for homogeneity of variance using the Levene's test of equality of error variances, and skewness. Log transformations were employed when the data did not meet the assumptions of normality. Pearson's Coefficient was performed among litter PMR, S concentration, percent of initial Fe (PMR-Fe) and Mn (PMR-Mn) remaining, arthropod diversity, UV level, soil temperature, and volumetric water content of soil. All ANOVA and Levene's test were conducted using SPSS 22 (IBM, USA).

3. Results

3.1. Microclimate changes

Burn significantly increased UV levels (Figure 1a, $F_{1, 22}$=25.8 P=0.002), corresponding to higher UV radiation in burn than in control plots during the initial 240 days post-burn, except for the 18th day post-burn (on day 3 post-burn $F_{1, 22}$ = 9.1 P=0.021, on day 34 post-burn $F_{1, 22}$=55.0 P<0.001, on day 62 post-burn $F_{1, 22}$=8.0 P=0.030, on day 136 post-burn $F_{1, 22}$=5.9 P=0.044, on day 240 post-burn $F_{1, 22}$=5.7 P=0.049). Burn also significantly increased soil temperature ($F_{1, 22}$=6.8, P=0.040). There was higher soil temperature in burn than in control treatment plots in the initial 136 days post-burn (Fig. 1b, on day 3 post-burn $F_{1, 22}$ = 5.6 P=0.048, on day 18 post-burn $F_{1, 22}$ = 30.6 P=0.001, on day 34 post-burn $F_{1, 22}$=5.6 P=0.045, on day 62 post-burn $F_{1, 22}$=8.0 P=0.030, on day 136 post-burn $F_{1, 22}$=15.0 P=0.008). Soil volumetric water content did not differ between burn and control treatments (Figure 1c, $F_{1, 6}$=1.9, P=0.224).

3.2. Arthropods

Burn significantly decreased the arthropod Shannon–Wiener index (Table S2; $F_{1, 34}$=7.2, P=0.011) during the initial 136 days post-burn (Fig. 2a, on day 34 post-burn $F_{1, 44}$=12.2 P=0.001, on day 136 post-burn $F_{1, 44}$=13.2 P=0.001). All arthropod density was not significantly affected by the burn (Table S2, $F_{1, 34}$=0.4, P=0.535), although it was significantly higher in burn than in control plots on day 136 post-burn (Figure 2b, $F_{1, 44}$=4.5, P=0.040). Microbivores and detritivores were the major groups of arthropods, accounting for around 40 % and 30 % of the total arthropod abundance, respectively (Table S1). There was no overall significant difference in Shannon–Wiener index ($F_{1, 34}$=1.0, P=0.316) and density ($F_{1, 34}$=0.3, P=0.567) of microbivores and detritivores between burn and control treatments (Table S2, Fig. 2 cd), although Shannon–Wiener index of microbivores were significantly higher in control than in the burn plots on day 34 post-burn (Figure 2c, $F_{1, 44}$=7.4, P=0.009). Shannon–Wiener index of microbivores was also significantly higher in *D. annulatum* than in *M. maximus* litter (Table S2, $F_{1, 34}$=4.9, P=0.035). The relative abundances of predators varied between 7 % and 17 % (Table S1). Predator Shannon-Wiener index was overall significantly decreased by the burn (Table S2, $F_{1, 34}$=5.8,

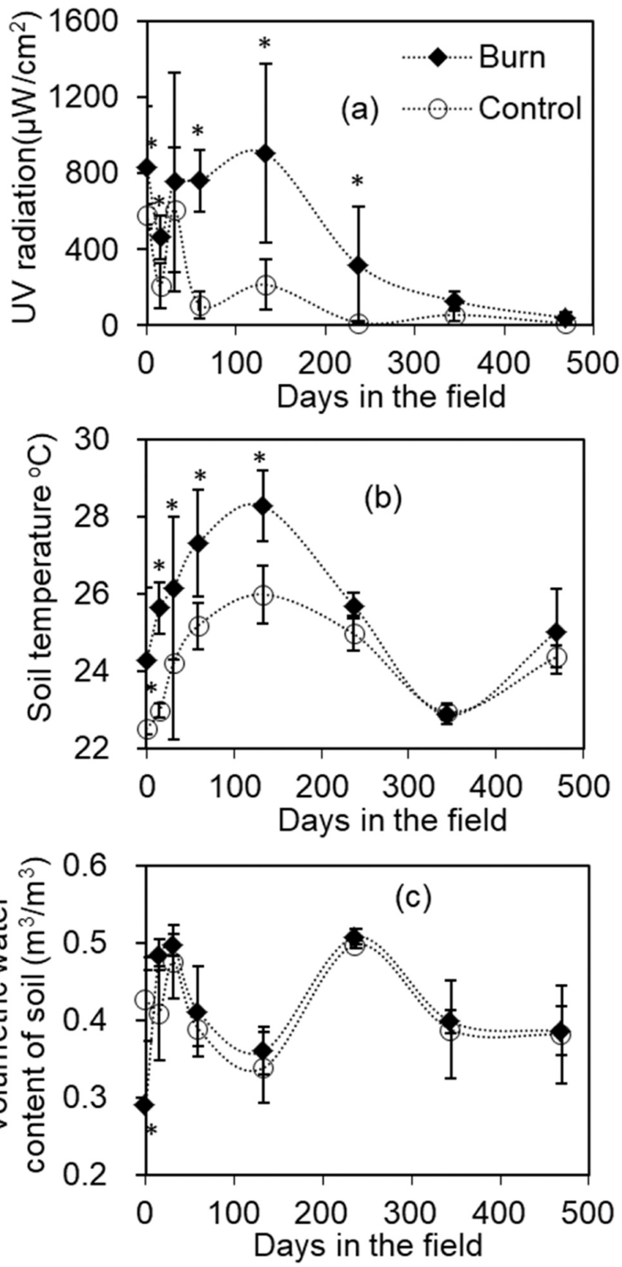

Fig. 1. Effect of prescribed burn on (a) ultraviolet radiation level, (b) soil temperature and (c) volumetric water content (mean ± standard deviation, n = 4). Asterisks indicate significant differences between treatments for a given sample date (P < 0.05).

P=0.022), with higher predator Shannon-Wiener index in control than in burn treatment in the initial 136 days post-burn (Fig. 2e, on day 18 post-burn $F_{1, 44}$=5.1 P=0.029, on day 34 post-burn $F_{1, 44}$=4.8 P=0.047, on day 62 post-burn $F_{3, 44}$=4.2 P=0.047, on day 136 post-burn $F_{1, 44}$=5.2 P=0.027). Predator density was significantly higher in *D. annulatum* than in *M. maximus* litter (Table S2, $F_{1, 34}$=4.6, P=0.040) at day 18 post-burn (Fig. 2 f, $F_{1, 34}$=4.9, P=0.032). Burn significantly decreased Mesostigmata Shannon-Wiener index (Table S2, $F_{1, 34}$=4.0 P=0.048) from day 18–136 and on day 472 post-burn (Fig. 2g, on day 18 post-burn $F_{1, 44}$=5.1 P=0.042, on day 34 post-burn $F_{1, 44}$=4.7 P=0.044, on day 62 post-burn $F_{1, 44}$=4.1 P=0.032, on day 136 post-burn $F_{1, 44}$=4.4 P=0.045, on day 472 post-burn $F_{1, 44}$=4.3 P=0.046). There was a significant interaction between burn and sampling date for all arthropod ($F_{7, 238}$=3.0, P=0.007) and Prostigmata ($F_{7, 238}$=3.3, P=0.004) Shannon-Wiener index, and for all arthropod ($F_{7, 238}$=2.7, P=0.016) and Oribatida ($F_{7, 238}$=2.3, P=0.040) density (Table S2). There was also a significant interaction among burn, litter species and sampling date for all arthropod ($F_{7, 238}$=3.6, P=0.002), microbivore ($F_{7, 238}$=2.8, P=0.014), and detritivore ($F_{7, 238}$=2.6, P=0.019) Shannon-Wiener index (Table S2). All arthropod density also revealed a burn × litter species × litterbags mesh sizes interaction (Table S2, $F_{14, 238}$=2.1, P=0.018). There was also a significant interaction among litter species, sampling date and litterbag mesh sizes for detritivores ($F_{14, 238}$=2.1, P=0.021) and Oribatida ($F_{14, 238}$=2.3, P=0.011) densities (Table S2). All arthropod and every trophic group arthropod Shannon-Wiener index changed significantly during the experiment, except for Mesostigmata Shannon-Wiener index (Table S2 and Fig. 2). Except for Prostigmata and Collembola densities, sampling date had a significant effect on densities of main trophic and taxonomic groups of arthropods. Litterbag mesh size had little effect on either arthropod Shannon–Wiener index or density (Table S2).

3.3. *Element concentration*

Burn significantly decreased litter S concentration ($F_{1, 34}$=15.9, P<0.001), with lower S concentration after 34 and 136–472 days post-burn (Table S3 and Fig. 3d, on day 34 post-burn $F_{1, 44}$=4.4 P=0.042, on day136 post-burn $F_{1, 44}$=13.1 P=0.001, on day 240 post-burn $F_{1, 44}$=4.0 P=0.049, on day 347 post-burn $F_{1, 44}$=5.3 P=0.035, on day 472 post-burn $F_{1, 44}$=4.6 P=0.038). Concentrations of C, Ca, P, S of *M. maximus* litter were significantly higher than those of *D. annulatum* litter (Table S3 and Fig. 3), corresponding to the higher C concentration in *M. maximus* than in *D. annulatum* litter during the initial 136 days ($F_{1, 44}$=23.5, P<0.001) and on day 472 post-burn ($F_{1, 44}$=8.6, P=0.005), the higher Ca concentration in *M. maximus* than in *D. annulatum* litter during the initial 136 days post-burn ($F_{1, 44}$=7.0, P=0.011), and the higher P concentration in *M. maximus* than in *D. annulatum* litter during the initial 240 days post-burn ($F_{1, 44}$=85.5, P<0.001). There was a significant effect of litterbag mesh sizes on litter concentrations of Al, Ca, Fe, K, P (Table S3). Concentrations of Ca ($F_{2, 34}$=3.8, P=0.039), K ($F_{2, 34}$=10.2, P<0.001), P ($F_{2, 34}$=6.0, P=0.007) were significantly higher in small than in medium and large mesh size litterbags. While concentrations of Al ($F_{2, 34}$=11.1, P=0.001) and Fe ($F_{2, 34}$=11.2, P=0.001) were significantly higher in medium than in small and large mesh size litterbags. Except for litter N concentration, all single element concentrations changed significantly overtime. There was a significant interaction of burn and days in the field on litter concentrations of Al ($F_{7, 238}$=5.0, P<0.001), Fe ($F_{7, 238}$=2.7, P=0.012), Mg ($F_{7, 238}$=3.8, P=0.001), Na ($F_{7, 238}$=2.4, P=0.021). But there was lack of interaction of burn × litter species on litter element concentrations.

3.4. *Percent of initial element remaining*

Burn significantly increased the percent of initial Fe ($F_{1, 34}$=7.5, P=0.017) and Mn ($F_{1, 34}$=7.0, P=0.014) remaining (Table S4), with the higher percent of initial Mn remaining in burn than in control plots at 240-days post-burn (Figure 4a and b, $F_{1, 44}$=5.6, P=0.022). The percent of initial Al and Fe remaining of *M. maximus* litter were greater than that of *D. annulatum* (Table S4 and Fig. 4a,c; Al $F_{1, 34}$=16.0, P=0.001; Fe $F_{1, 34}$=15.9, P=0.002), corresponding to the higher percent of initial Fe remaining in *M. maximus* than in *D. annulatum* litter after 240–472 days post-burn (on day 240 post-burn $F_{1, 44}$=12.5 P=0.001, on day 347 post-burn $F_{1, 44}$=4.8 P=0.038, on day 472 post-burn $F_{1, 44}$=6.5 P=0.016), and the higher percent of initial Al remaining in *M. maximus* than in *D. annulatum* litter 347–472 days post-burn (on day 347 post-burn $F_{1, 44}$= 7.9, P= 0.009, on day 472 post-burn $F_{1, 44}$= 10.0, P= 0.003). In contrast, the percent of initial Ca, Mg and P remaining of *D. annulatum* litter were greater than those of *M. maximus* (Fig. 4d, e, f; Ca $F_{1,34}$= 17.2, P= 0.001; Mg $F_{1,34}$= 8.2, P= 0.008, P $F_{1,34}$= 7.2, P= 0.012), corresponding to the greater values of initial Ca remaining in *D. annulatum* than in *M. maximus* litter after 240–472 days post-burn (Fig. 4d, on day

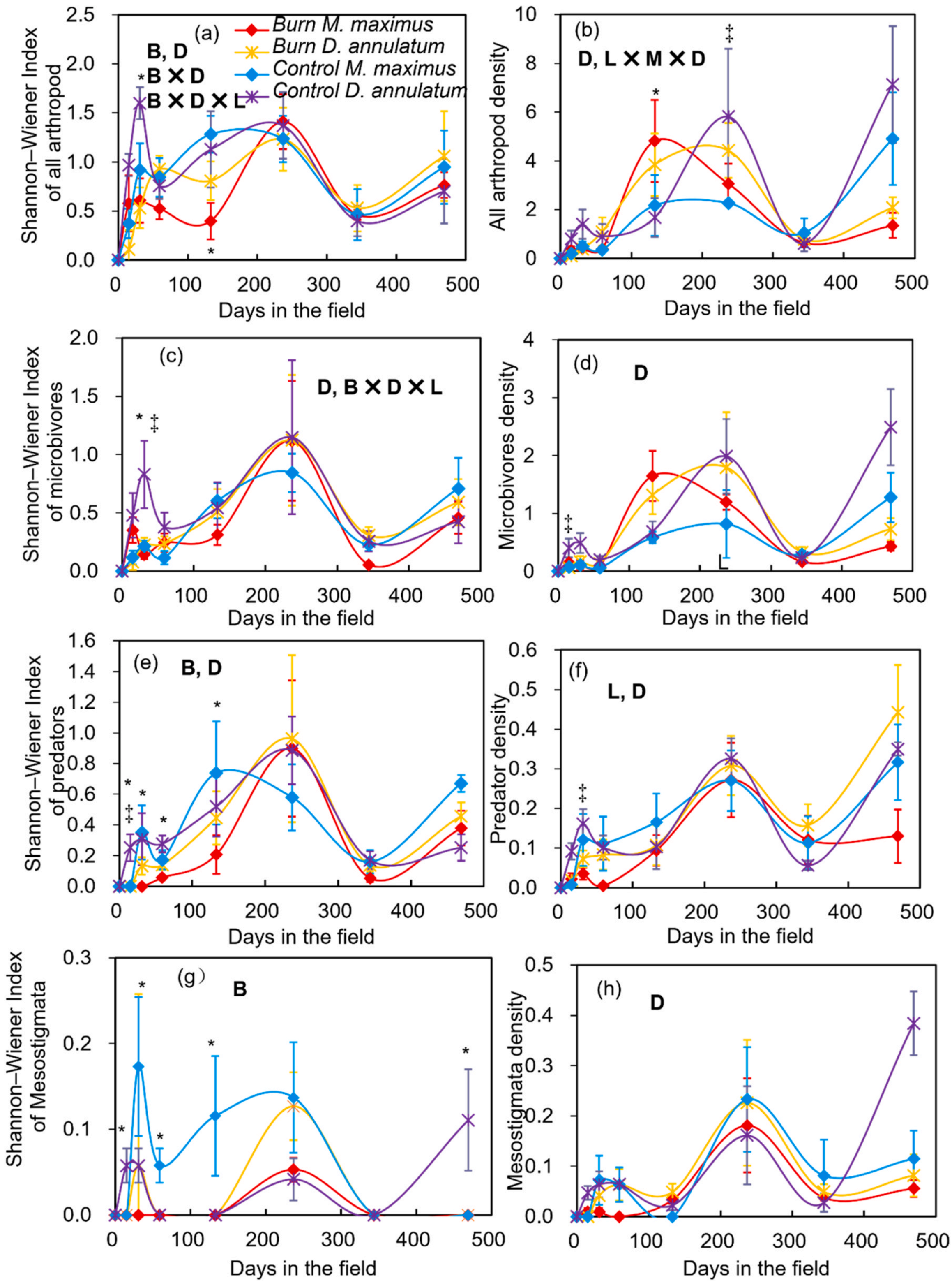

Fig. 2. Effect of prescribed burn on (a, b) all arthropods, (c, d) microbivores (e, f) predators and (g, h) Mesostigmata Shannon–Wiener Index and density (mean ± standard deviation, n = 12). Bold type highlights significant values for repeated-measures ANOVA (B-prescribed burn, L-litter species, M-litterbag mesh sizes, D-days in the field, $P < 0.05$), * indicates significant differences between burn and control treatments for a given sample date ($P < 0.05$), ‡ indicates significant differences between different litter species for a given sample date ($P < 0.05$).

240 post-burn $F_{1, 44}$=10.8 P=0.002, on day 347 post-burn $F_{1, 44}$=10.6 P=0.002, on day 472 post-burn $F_{1, 44}$=9.9, P=0.004), the higher value of initial Mg remaining in *D. annulatum* than in *M. maximus* litter after 34–472 days post-burn (Fig. 4e, on day 34 post-burn $F_{1, 44}$=7.5 P=0.009, on day 62 post-burn $F_{1, 44}$=6.2 P=0.017, on day 136 post-burn $F_{1, 44}$=13.4 P=0.001, on day 240 post-burn $F_{1, 44}$=7.0 P=0.011, on day 347 post-burn $F_{1, 44}$=6.8 P=0.013, on day 472 post-burn $F_{1, 44}$=5.9 P=0.020), and the greater value of initial P

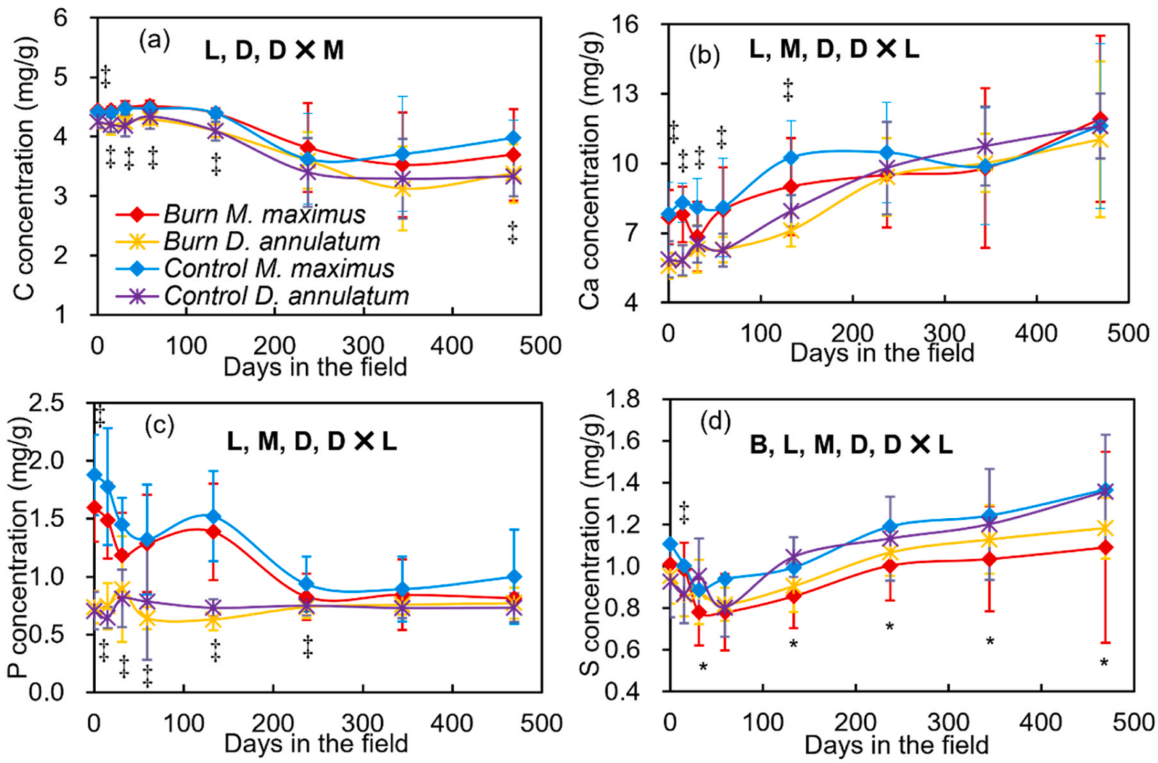

Fig. 3. Effect of prescribed burn on litter (a) C, (b) Ca, (c) P, and (d) S, concentrations (mean ± standard deviation, n = 12). Bold type highlights significant values for repeated-measures ANOVA (B-prescribed burn, L-litter species, M-litterbag mesh sizes, D-days in the field, *$P < 0.05$, **$P < 0.01$), * indicates significant differences between burn and control treatments for a given sample date ($P < 0.05$), ‡ indicates significant differences between different litter species for a given sample date ($P < 0.05$).

remaining in *D. annulatum* than in *M. maximus* litter after 34 and 136–472 days post-burn (Fig. 4f, on day 34 post-burn $F_{1, 44}$=5.8 P=0.020, on day 136 post-burn $F_{1, 44}$=4.1 P=0.028, on day 240 post-burn $F_{1, 44}$=21.8 P<0.001, on day 347 post-burn $F_{1, 44}$=24.8 P<0.001, on day 472 post-burn $F_{1, 44}$=14.1 P=0.001). Mesh size had a significant effect on the percent of initial remaining for C, Ca, K and P (Table S4). Litter in small mesh size litterbags had significantly greater percent of initial C, K and P remaining than medium and large mesh size litterbags (K $F_{2, 34}$=9.4 P=0.001, P $F_{2, 34}$=6.052 P=0.007). Litter in medium mesh size litterbags had significantly lower percent of initial Ca remaining than small and large mesh size litterbags ($F_{2, 34}$=3.8, P=0.041). Except for the percent of initial Mg remaining, days in the field had a significant effect on all percent of initial element remaining in the litterbags. There were significant effects of burn × days in the field on the percent of initial Al ($F_{7, 238}$=2.9, P=0.013), Mg ($F_{7, 238}$=2.6, P=0.021), Mn ($F_{7, 238}$=5.4, P<0.001), and Na ($F_{7, 238}$=2.2, P=0.048) remaining. But there was lack of interactions of burn × litter species on percent of initial litter element remaining, with the exception for the percent of initial Ca remaining ($F_{1, 34}$=6.7, P=0.019).

3.5. Percent mass remaining

There was no significant effect of burn and litter species on litter percent mass and carbon remaining (Fig. 4 g, $F_{1, 34}$=1.0, P=0.323; Table S4). The temporal patterns of percent mass remaining decreased over time ($F_{7, 238}$=568.2, P<0.001). Litter in large mesh litterbags decayed faster than in small and medium meshed litterbags (Table S4, $F_{2, 34}$=26.7, P<0.001). There existed interactions between days in the field and litterbag mesh size on the PMR ($F_{14, 238}$=24.1, P<0.001).

3.6. Biophysiochemical factors correlated to arthropod diversity

For *M. maximus* litter, all arthropod Shannon–Wiener index was significantly and positively correlated with S concentration (95 % confidence interval 0.025–0.348) and litter PMR-Fe (95 % confidence interval 0.092–0.364, Table 2). Microbivore Shannon–Wiener index was significantly and negatively correlated with litter PMR (95 % confidence interval −0.462 to −0.089), but significantly and positively associated with litter S concentration (95 % confidence interval 0.090–0.426), PMR-Fe (95 % confidence interval 0.123–0.463) and PMR-Mn (95 % confidence interval −0.054–0.333) in *M. maximus* litter. For *D. annulatum* litter, microbivore Shannon–Wiener index was also significantly and negatively correlated with litter PMR (95 % confidence interval −0.408 to −0.042), and significantly and positively related to litter PMR-Fe (95 % confidence interval −0.004–0.436) and PMR-Mn (95 % confidence interval 0.127–0.379). There was no clear pattern in Shannon–Wiener index of all arthropods, predators, Mesostigmata mires and microbivores with change in UV radiation, soil temperature and volumetric water content of soil.

4. Discussion

4.1. The difference between this and our previous study at the same site

An earlier publication in this study site focused on the effect of ultraviolet radiation on litter decomposition by using UV-blocking plastic panels (Huang et al., 2021). In this study, we did not use UV-blocking plastic panels. In the previous study, the UV panel sheltered experiment revealed a clear reduction in litter decomposition during the initial 240 days postburn, while there was an insignificant effect of prescribed burn on litter decay. This discrepancy is likely resulted from the decrease in the diversity and abundance of arthropods under the shelter treatments. The Shannon–Wiener Indexes of all arthropods were 0.78 under control treatments, and 0.45 under burn treatments in this study. While for the previous study, the Shannon–Wiener Indexes of all arthropods with UV blocking panels were 0.37 and 0.27 in burn and

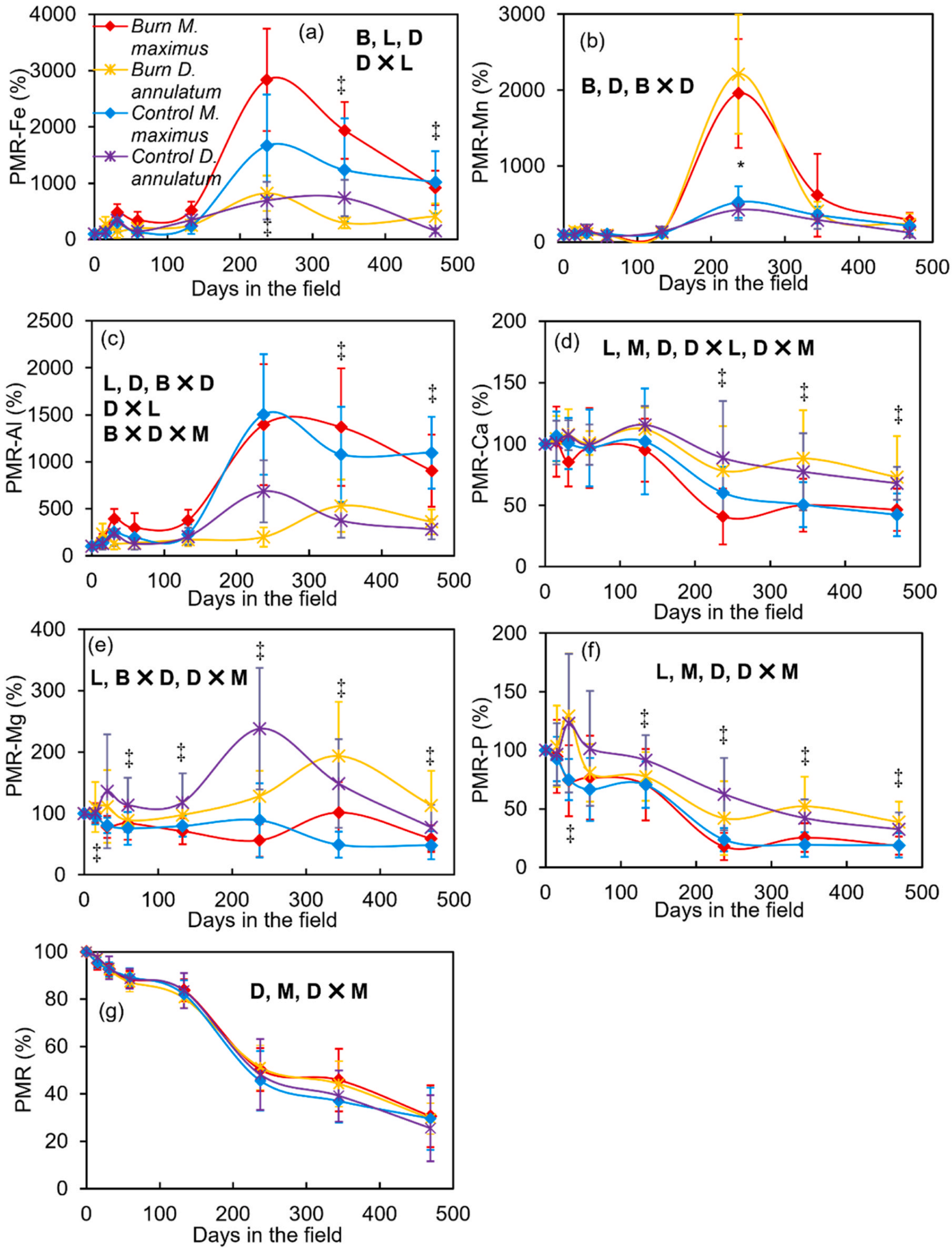

Fig. 4. Effect of prescribed burn on litter percent of initial remaining of (a) Fe, (b) Mn, (c) Al, (d) Ca, (e) Mg, (f) P, and (g) mass (PMR) (mean ± standard deviation, n = 12). Bold type highlights significant values for repeated-measures ANOVA (B-prescribed burn, L-litter species, M-litterbag mesh sizes, D-days in the field, $P < 0.05$), * indicates significant differences between burn and control treatments for a given sample date ($P < 0.05$), ‡ indicates significant differences between different litter species for a given sample date ($P < 0.05$).

control plots, respectively (Huang et al., 2021). Total arthropods densities were 11.90 under control treatments and 9.94 under burn treatments in this study. Total arthropods with UV blocking plastic panels were 7.88 and 5.97 in burn and control plots, respectively (Huang et al., 2021). The arthropod diversity and abundance in burn plots without panels were higher than that of control plots with plastic panels. It is likely the diversity and abundance of arthropods was not low enough to suppress litter decomposition in burn treatments without plastic panel cover. This suggest that some arthropods were functionally redundant for litter decomposition in our study, which could be supported by the lacking linkage between litter PMR and total arthropod diversity. Functional redundancy in the macroinvertebrates has also been reported

Table 2
Pearson correlation coefficients (r) (and two-tailed probability values) between arthropod diversity and UV radiation, soil temperature, volumetric water content of soil, litter percent mass remaining (PRM), S concentration, percent of initial Fe (PMR-Fe) or Mn (PMR-Mn) remaining for *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs and *Dichanthium annulatum* (Forssk.) Stapf litter (n = 118). Bold font represents significant correlations ($P < 0.05$, CIL-95 % lower bounds of confidence intervals, CIU, −95 % upper bounds of confidence intervals).

		M. maximus				*D. annulatum*			
		Arthropod Shannon–Wiener index	Predator Shannon–Wiener index	Mesostigmata Shannon–Wiener index	Microbivore Shannon–Wiener index	Arthropod Shannon–Wiener index	Predator Shannon–Wiener index	Mesostigmata Shannon–Wiener index	Microbivore Shannon–Wiener index
UV radiation	*P*	−0.121	−0.025	0.025	−0.155	−0.010	0.092	−0.007	−0.121
	CIL	−0.274 0.027	−0.194 0.149	−0.135 0.170	−0.286 −0.026	−0.179 0.153	−0.092 0.262	−0.101 0.096	−0.270 0.030
	CIU								
Soil temperature	*P*	−0.131	−0.036	−0.096	−0.052	−0.096	−0.045	−0.021	−0.123
	CIL	−0.276 0.021	−0.141 0.097	−0.117 −0.004	−0.160 0.072	−0.238 0.082	−0.168 0.111	−0.142 0.041	−0.240 0.024
	CIU								
Volumetric water content of soil	*P*	0.018	0.056	0.117	0.082	0.010	−0.014	0.141	0.076
	CIL	−0.162 0.198	−0.125 0.217	−0.082 0.249	−0.099 0.256	−0.155 0.180	−0.239 0.167	0.012	−0.086 0.257
	CIU							0.241	
PMR	*P*	−0.131	−0.117	−0.019	−0.263	−0.083	0.100	0.014	−0.215
	CIL	−0.305 0.047	−0.275 0.028	−0.130 0.122	−0.462 −0.089	−0.292 0.112	−0.088 0.252	−0.016 0.123	−0.408 −0.042
	CIU								
S concentration	*P*	**0.188**	0.055	0.012	**0.261**	0.014	−0.072	−0.081	0.090
	CIL	0.025	−0.090 0.203	−0.080 0.134	0.090	−0.157 0.184	−0.239 0.091	−0.212 −0.001	−0.064 0.256
	CIU	0.348			0.426				
PMR-Fe	*P*	**0.231**	0.143	0.067	**0.290**	0.039	0.076	0.017	**0.189**
	CIL	0.092	−0.023 0.310	−0.033 0.215	0.123	−0.142 0.259	−0.096 0.344	−0.019 0.081	−0.004 0.436
	CIU	0.364			0.463				
PMR-Mn	*P*	0.116	0.056	−0.018	**0.163**	0.140	0.063	−0.017	**0.250**
	CIL	−0.032 0.228	−0.076 0.203	−0.044 0.094	−0.054 0.333	0.037	−0.067 0.281	−0.035 0.035	0.127
	CIU					0.231			0.379

in stringybark of Australia (Buckingham et al., 2019).

4.2. The effect of prescribed burn on arthropods

We could only partially confirm our first hypothesis that prescribed burn significantly decreased litter arthropod species diversity. The mechanism for the reduction of total arthropod species diversity could be primarily originated from the death of arthropods via burn, and the lack of sufficient food resources for arthropods after burn (Certini et al., 2021). But contrary to our expectation, we found no evidence to support a reduction in the diversities of detritivores and microbivores following the burn. Although burning might eliminate some microbivores and detritivores on the ground surface, but they could be protected from fire stress by moving into soils a few centimeters from the surface and inoculate plant litter when litter bags were placed on the ground, resulting in invariant detritivore and microbivore diversity between the burn and control plots. However, we found that the diversity of predator species was significantly reduced by the prescribed burn. This observation corroborates an observation in a South African fynbos ecosystem (Pryke and Samways, 2012). This reduction in predator species diversity could be due to decreases in the availability of small arthropods on the surface soil layer after the burn (Certini et al., 2021), leading to a shortage of food for predator, suggesting a bottom-up control for the abundance and diversity of arthropod predators immediately following the burn. Mesostigmata mites were predators in our study site, and its species diversity was also significantly reduced by the prescribed burn. Thus, the decreased arthropod diversity following our prescribed burn originated largely from reduction in the predators, not the detritivores or microbivores.

4.3. The decrease in S concentration by prescribed burn

The higher temperature in the burn than in the control treatment might lead to higher loss of soil S (Jaggi et al., 1999), consequently enhancing soil microbial immobilization of S from plant litter and resulting in the lower S concentration in the burn treatments. The leaching rate of soluble C and inorganic sulphate increased with temperature (Das et al., 1982; Whitworth et al., 2014), thus the increased soil temperature on the burn site might also have contributed to the low litter S concentration.

4.4. The increase in Mn and Fe immobilization by prescribed burn

The prescribed-burn enhanced microbial immobilization of Fe and Mn in litter. The increase in Mn immobilization by burn paralleled to observations from Bryanin et al. (2020) that litter Mn concentration was greater in burn than in control treatment even one year after burn. It has been reported that mycorrhizal association significantly affected leaf litter Mn concentration (Peng et al., 2023). A relatively large body of research showed high resilience of the mycorrhizal community to prescribed seasonal burnings (Smith et al., 2004; Livne-Luzon et al., 2021). Our research showed that litter PMR-Mn positively related to microbivore species diversity. Thus, the recovery of microbes in burn plots probably caused the high immobilization of Mn in the burn treatment. Mn availability may determine the extent of lignin degradation (Berg et al., 2010). The positive correlation between mass loss and Mn concentration have been observed in fire-affected larch forests of the Russian Far East (Bryanin et al., 2020). The higher accumulation of litter Mn in burn treatment of our site might be benefit to lignin degradation, contributing to the no difference in litter percent mass remaining between burn and control treatment. Iron mobility can also be reduced by increases in Mn (Vieira et al., 2022). Numerous studies have shown accumulation of Fe in litter fungi (Laskowski et al., 1995). The higher immobility of Mn and resilience of the microbial community under burn treatments may also help explain the higher PMR-Fe in burn than in control treatments.

4.5. The invariant litter decomposition to prescribed burn

Contrary to our third hypothesis, the rate of litter decomposition was not reduced after the burn. This result is consistent with conclusions from the most arid savanna and damp sclerophyll forest of Australia (Buckingham et al., 2015; Davies et al., 2013), that litter PMR was not significantly affected by prescribed burn in a tropical pastureland. The lack of changes in detritivore and microbivore species diversity post-burn may explain lack of difference in litter decomposition between prescribed burn and control treatments. Detritivores contribute to litter decomposition through fragmenting fresh intact leaves or consuming microbially conditioned leaves and re-ingesting leaf material (Buckingham et al., 2019). Microbivores, who feed on algae, bacteria or fungi (Scheu, 2002), could influence litter decomposition by regulating microbe abundance and activity. The invariant litter decomposition to fire disturbance in our study may also be explained in part by the quick recover of microclimate after 240 days post-fire, by high functional redundancy in arthropod to fire.

4.6. The effect of litter quality on arthropod and element remaining

Litter quality can affect arthropod community structure. In our study, the lignin content was higher and C/P ratio was lower for *M. maximus* litter than those of *D. annulatum* litter (Huang et al., 2021). Several studies have recorded P availability important for consumer communities in tropical litter macro-invertebrates (Kaspari et al., 2009; Jochum et al., 2017). Yet a previous study indicated that leaf litter C/N and C/P ratios did not affect arthropod densities in island tropical wet and cloud forests (Yang et al., 2007). It has been reported that Collembolans, Oribatid, and Mesostigmatid mite densities were negatively correlated with the relative abundance of lignin (Wickings and Grandy, 2013). Most of Collembolans and Oribatida mites were microbivores, and all Mesostigmata mites were predators in this study. The lower microbivore diversity and predator density in *M. maximus* litter than in *D. annulatum* litter suggested that lignin concentration rather than C/P played a dominant substrate-quality role in shaping arthropod community structure. Nevertheless, P is a structural element for arthropods, and its changes during decay are highly dependent on the heterotrophic microorganisms (Isaac and Nair, 2005). Further, Ca and Mg release rates were reported to be positively associated with microbial diversity (Yue et al., 2021). The higher microbivore diversity in *D. annulatum* litter might lead to the lower microbial diversity, resulting lower P, Ca and Mg release rates and hence higher PMR-P, PMR-Ca and PMR-Mn in *D. annulatum* litter.

4.7. The effect of litterbag mesh size

Our results inferred that litterbag mesh size did not affect arthropod abundance and diversity. This view is also evidenced by Richardson et al. (2020), who found that mesh size was unimportant in determining invertebrate community composition of litterbags. Litterbags with larger mesh sizes are likely to loss larger fragments of litter than bags with finer mesh (Frouz et al., 2015). So litter in large mesh litterbags "decayed" faster than in small and medium meshed litterbags in our study. Thus, future studies shall consider the compounded effect of animals and mesh-size on litter decomposition using different mesh-sized litterbags to exclude fauna.

5. Conclusion

This study demonstrated that prescribed burn significantly decreased the diversity of total litter arthropods and predators in a subtropical moist pastureland in Puerto Rico. Prescribed burn decreased litter S concentration, but increased Mn and Fe immobilization in decomposing litter. Prescribed burn did not significantly affect litter decay, and the subsequent litter C, N, P, K, Ca, Mg, Al and Na release in this subtropical moist pastureland.

Our results suggested that prescribed burn is a good management practice to maintain the pastureland with little influence on the litter decomposition, and short effects on arthropod abundance, and C, N and P dynamics under subtropical moist conditions. Detritivores and microbivores of arthropod community are highly resistant to fire disturbance because of protection of subsurface soil as shelters, whereas predators are highly resilient following fire disturbance due to fast recovery of grass vegetation. Nevertheless, arthropod diversity, especially predator diversity, can be reduced by fire disturbance. Our analyses highlight the potential roles of litter Mn and Fe in litter decomposition and in the maintenance of soil diversity.

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CRediT authorship contribution statement

Grizelle González: Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition. **Wei Huang:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Weili Liu:** Methodology. **María Fernanda Barberena-Arias:** Investigation. **Xiaoming Zou:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.pedobi.2024.150990.

References

Archibald, F., Roy, B., 1992. Production of manganic chelates by laccase from the lignin-degrading fungus Trametes (Coriolus) versicolor. Appl. Environ. Microb. 58, 1496–1499. ⟨https://journals.asm.org/doi/pdf/10.1128/aem.58.5.1496-1499.1992⟩.

Alcañiz, M., Outeiro, L., Francos, M., Úbeda, X., 2018. Effects of prescribed fires on soil properties: a review. Sci. Total Environ. 613-614, 944–957. https://doi.org/10.1016/j.scitotenv.2017.09.144.

Berg, B., Davey, M.P., Marco, A.D., Emmett, B., Faituri, M., Hobbie, S.E., Johansson, M. B., Liu, C., Mcclaugherty, C., Norell, L., 2010. Factors influencing limit values for

pine needle litter decomposition: a synthesis for boreal and temperate pine forest systems. Biogeochemistry 100, 57–73. https://doi.org/10.1007/s10533-009-9404-y.
Boccheciamp, R.A., 1977. Soil survey of the Humacao Area of Eastern Puerto Rico. God Biblical Stories & Psychoanalytic Understanding..
Borror, D.J., Triplehorn, C.A., Johnson, N.F., 1989. Saunders college publishing. Introd. Study Insects.
Brennan, K.E.C., Christie, F.J., York, A., 2010. Global climate change and litter decomposition: more frequent fire slows decomposition and increases the functional importance of invertebrates. Glob. Change Biol. 15, 2958–2971. https://doi.org/10.1111/j.1365-2486.2009.02011.x.
Breemen, N., Lundström, U.S., Jongmans, A.G., 2000. Do plants drive podzolization via rock-eating mycorrhizal fungi? Geoderma 94, 163–171. https://doi.org/10.1016/S0016-7061(99)00050-6.
Bryanin, S., Kondratova, A., Abramova, E., 2020. Litter decomposition and nutrient dynamics in fire-affected larch forests in the Russian far east. Forests 11, 882. https://doi.org/10.3390/f11080882.
Buckingham, S., Murphy, N., Gibb, H., 2015. The effects of fire severity on macroinvertebrate detritivores and leaf litter decomposition. PLoS One 10. https://doi.org/10.1371/journal.pone.0124556.
Buckingham, S., Murphy, N., Gibb, H., 2019. Effects of fire severity on the composition and functional traits of litterdwelling macroinvertebrates in a temperate forest. For. Ecol. Manag. 434, 279–288. https://doi.org/10.1016/j.foreco.2018.12.030.
Butler, O.M., Lewis, T., Rashti, M.R., Maunsell, S.C., Elser, J.J., Chen, C., 2019. The stoichiometric legacy of fire regime regulates the roles of micro-organisms and invertebrates in decomposition. Ecology 100, e02732. https://doi.org/10.1002/ecy.2732.
Certini, G., Moya, D., Lucas-Borja, M.E., Mastrolonardo, G., 2021. The impact of fire on soil-dwelling biota: a review. . Ecol. Manag. 488, 118989 https://doi.org/10.1016/j.foreco.2021.118989.
Chao-Yong, L.H., Schulte, E.E., 1985. Digestion of plant tissue for analysis by ICP Emission Spectroscopy. Commun. Soil Sci. Plant Anal. 16, 943–958. https://doi.org/10.1080/00103628509367657.
Das, S.C., Sahoo, P.K., Rao, P.K., 1982. Extraction of manganese from low-grade manganese ores by FeSO4 leaching. Hydrometallurgy 8, 35–47. https://doi.org/10.1016/0304-386X(82)90029-9.
Davies, A.B., Rensburg, B., Eggleton, P., Parr, C.L., 2013. Interactive effects of fire, rainfall, and litter quality on decomposition in savannas: frequent fire leads to contrasting Effects. Ecosystems 16, 866–880. https://doi.org/10.1007/s10021-013-9657-0.
Dindal, D.L., 1990. Soil biology guide. New York.
Frouz, J., Roubíčková, A., Heděnec, P., Tajovský, K., 2015. Do soil fauna really hasten litter decomposition? A meta-analysis of enclosure studies. Eur. J. Soil Biol. 68, 18–24. https://doi.org/10.1016/j.ejsobi.2015.03.002.
Giesler, R., Ilvesniemi, H., Nyberg, L., van Hees, P., Starr, M., Bishop, K., Kareinen, T., Lundström, U.S., 2000. Distribution and mobilization of Al, Fe and Si in three podzolic soil profiles in relation to the humus layer. Geoderma 94, 249–263. https://doi.org/10.1016/S0016-7061(99)00057-9.
Girona-García, A., Galarza, R.Z., Mora, J.L., Armas-Herrera, C.M., Martí, C., Ortiz-Perpiñá, O., Badía-Villas, D., 2018. Effects of prescribed burning for pasture reclamation on soil chemical properties in subalpine shrublands of the Central Pyrenees (NE-Spain). Sci. Total Environ. 644, 583–593. https://doi.org/10.1016/j.scitotenv.2018.06.363.
González, G., Seastedt, T.R., 2001. Soil fauna and plant litter decomposition in tropical and subalpine forests. Ecology 82, 955–964. https://doi.org/10.1890/0012-9658(2001)082[0955:SFAPLD]2.0.CO;2.
González, G., Lodge, D.J., Richardson, B.A., Richardson, M.J., 2014. A canopy trimming experiment in Puerto Rico: The response of litter decomposition and nutrient release to canopy opening and debris deposition in a subtropical wet forest. For. Ecol. Manag. 332, 32–46. https://doi.org/10.1016/j.foreco.2014.06.024.
Heim, A., Frey, B., 2004. Early stage litter decomposition rates for Swiss forests. Biogeochemistry 70, 299–313. https://doi.org/10.1007/s10533-003-0844-5.
Hoy, M.A., 2009. A manual of acarology. Third edition. Fla. Èntomol. 92 (3), 526. https://doi.org/10.1653/024.092.0323.
Huang, Y., Zhang, J., Liu, Y., 2021. Litter chemical traits strongly drove the carbon fractions loss during decomposition across an alpine treeline ecotone. Sci. Total Environ. 753, 142287 https://doi.org/10.1016/j.scitotenv.2020.142287.
Isaac, S.R., Nair, M.A., 2005. Biodegradation of leaf litter in the warm humid tropics of Kerala, India. Soil Biol. Biochem. 37, 1656–1664.
Jaggi, A.C., Aulakh, M.S., Sharma, R., 1999. Temperature effects on soil organic sulphur mineralization and elemental sulphur oxidation in subtropical soils of varying pH. Nutr. Cycl. Agroecosyst. 54, 175–182. https://doi.org/10.1023/A:1009770919296.
Jochum, M., Barnes, A.D., Weigelt, P., Ott, D., Rembold, K., Farajallah, A., Brose, U., 2017. Resource stoichiometry and availability modulate species richness and biomass of tropical litter macro-invertebrates. J. Anim. Ecol. 86, 1114–1123. https://doi.org/10.1111/1365-2656.12695.
Kalinkat, G., Brose, U., Rall, B.R.C., 2013. Habitat structure alters top-down control in litter communities. Oecologia 172, 877–887. https://doi.org/10.1007/s00442-012-2530-6.
Kaspari, M., Yanoviak, S.P., 2009. Biogeochemistry and the structure of tropical brown food webs. Ecology 90, 3342–3351. https://doi.org/10.1890/08-1795.1.
Koster, K., Berninger, F., Heinonsalo, J., Linden, A., Koster, E., Ilvesniemi, H., Pumpanen, J., 2016. The long-term impact of low-intensity surface fires on litter decomposition and enzyme activities in boreal coniferous forests. Int. J. Wildland Fire 25 (2), 213–223. https://doi.org/10.1071/WF14217.
Laskowski, R., Niklinska, M., Maryanski, M., 1995. The Dynamics of Chemical Elements in Forest Litter. Ecology 76, 1393–1406. https://doi.org/10.2307/1938143.
Liechty, H.O., Reinke, M., 2020. The influence of repeated prescribed fire on decomposition and nutrient release in uneven-aged loblolly–shortleaf pine stands. Fire Ecol. 16, 6. https://doi.org/10.1186/s42408-019-0064-6.
Livne-Luzon, S., Shemesh, H., Osem, Y., Carmel, Y., Migael, H., Avidan, Y., Tsafrir, A., Glassman, S.I., Bruns, T.D., Ovadia, O., 2021. High resilience of the mycorrhizal community to prescribed seasonal burnings in eastern Mediterranean woodlands. Mycorrhiza 31, 203–216. https://doi.org/10.1007/s00572-020-01010-5.
Lugo, A.E., 2018. Characterization of ten extreme disturbance events in the context of social and ecological systems. Biogeochemistry 141, 385–400. https://doi.org/10.1007/s10533-018-0453-y.
Malmström, A., 2010. The importance of measuring fire severity—Evidence from microarthropod studies. For. Ecol. Manag. 260, 62–70. https://doi.org/10.1016/j.foreco.2010.04.001.
McAlpine, J.F., Peterson, B.V., Shewell, G., Teskey, H., Vockeroth, J., Wood, D., 1981. Manual of nearctic Diptera. Agriculture Canada, Ottawa, ON.
Muñoz, M.A., Lugo, W.I., Santiago, C., Matos, M., Ríos, S., Lugo. J., 2017. Taxonomic classification of the soils of Puerto Rico. 〈https://dire.uprm.edu/handle/20.500.11801/817〉 Accessed 23 Jan 2018.
Palviainen, M., Finér, L., Kurka, A.M., Mannerkoski, H., Piirainen, S., Starr, M., 2004. Release of potassium, calcium, iron and aluminium from Norway spruce, Scots pine and silver birch logging residues. Plant Soil 259, 123–136. https://doi.org/10.1023/B:PLSO.0000020938.78215.bd.
Podgaiski, L.R., Goldas, C.S., Ferrando, C., Silveira, F.S., Joner, F., Overbeck, G.E., Milton, D., Pillar, V.D., 2015. Burning effects on detritivory and litter decay in Campos grasslands. Austral Ecol. 39, 686–695. https://doi.org/10.1111/aec.12132.
Pryke, J.S., Samways, M.J., 2012. Differential resilience of invertebrates to fire. Austral Ecol. 37 https://doi.org/10.1111/j.1442-9993.2011.02307.x.
Peng, Y., Fornara, D.A., Wu, Q., Heděnec, P., Yuan, C., Yuan, C., Yue, Y., Wu, F., 2023. Global patterns and driving factors of plant litter iron, manganese, zinc, and copper concentrations. Sci. Total Environ. 857, 159686 https://doi.org/10.1016/j.scitotenv.2022.159686.
Scheu, S., 2002. The soil food web: structure and perspectives. Eur. J. Soil Biol. 38, 11–20. https://doi.org/10.1016/S1164-5563(01)01117-7.
Smith, J.E., McKay, D., Niwa, C.G., Thies, W.G., Brenner, G., Spatafora, J.W., 2004. Short-term effects of seasonal prescribed burning on the ectomycorrhizal fungal community and fine root biomass in ponderosa pine stands in the Blue Mountains of Oregon. Can. For. Res. 34, 2477–2491. https://doi.org/10.1139/x04-124.
Soong, J.L., Vandegehuchte, M.L., Horton, A.J., Nielsen, U.N., Denef, K., Shaw, E.A., Tomasel, C.M., Parton, W., Wall, D.H., Cotrufo, M.F., 2016. Soil microarthropods support ecosystem productivity and soil C accrual: evidence from a litter decomposition study in the tallgrass prairie. Soil Biol. Biochem. 92, 230–238. https://doi.org/10.1016/j.soilbio.2015.10.014.
Throop, H.L., Salem, M.A., Whitford, W.G., 2017. Fire enhances litter decomposition and reduces vegetation cover influences on decomposition in a dry woodland. Plant Ecol. 218, 1–13. https://doi.org/10.1007/s11258-017-0730-1.
Tan, Y., Wang, K., Xu, Z., Zhang, L., Li, H., You, C., Tan, B., 2022. The contributions of soil fauna to the accumulation of humic substances during litter humification in cold forests. Forests 13, 1235. https://doi.org/10.3390/f13081235.
Ukonmaanaho, L., Starr, M., 2001. The importance of leaching from litter collected in litterfall traps. Environ. Monit. Assess. 66, 129–146. https://doi.org/10.1023/A:1026432315707.
Valášková, V., Šnajdr, J., Bittner, B., Cajthaml, T., Merhautová, V., Hofrichter, M., Baldrian, P., 2007. Production of lignocellulose-degrading enzymes and degradation of leaf litter by saprotrophic basidiomycetes isolated from a Quercus petraea forest. Soil Biol. Biochem. 39, 2651–2660. https://doi.org/10.1016/j.soilbio.2007.05.023.
Vieira, M.S., Santos, A.R.D., Lopes, M.I.M.S., Gomes, E.P.C., 2022. Litter decomposition in a remnant of Atlantic Rain Forest and bamboo dominance. For. Syst. 31, e019 https://doi.org/10.5424/fs/2022313-18791.
Vivanco, L., Austin, A.T., 2019. The importance of macro- and micro-nutrients over climate for leaf litter decomposition and nutrient release in Patagonian temperate forests. . Ecol. Manag. 441, 144–154. https://doi.org/10.1016/j.foreco.2019.03.019.
Wang, L., Chen, Y., Zhou, Y., Zheng, H., Xu, Z., Tan, B., You, C., Zhang, L., Li, H., Guo, L., Wang, L., Wei, Q., Yin, R., Huang, J., h, Vogler, A.P., Lin, Y., Miao, X., Kardol, P., 2021. The diversity of soil mesofauna decline after bamboo invasion in subtropical China. Sci. Total Environ. 789, 147982 https://doi.org/10.1016/j.scitotenv.2021.147982.
Whitworth, K., Baldwin, D., Kerr, J., 2014. The effect of temperature on leaching and subsequent decomposition of dissolved carbon from inundated floodplain litter: implications for the generation of hypoxic blackwater in lowland floodplain rivers. Chem. Ecol. 30, 491–500. https://doi.org/10.1080/02757540.2014.885019.
Wickings, K., Grandy, A.S., 2013. Management intensity interacts with litter chemistry and climate to drive temporal patterns in arthropod communities during decomposition. Pedobiologia 56, 105–112. https://doi.org/10.1016/j.pedobi.2013.01.001.
Yang, X., Warren, M., Zou, X., 2007. Fertilization responses of soil litter fauna and litter quantity, quality, and turnover in low and high elevation forests of Puerto Rico. Appl. Soil Ecol. 37, 63–71. https://doi.org/10.1016/j.apsoil.2007.03.012.
Yue, K.,1, Ni, X., Fornara, D.A., Peng, Y., Liao, S., Tan, S., Wang, Di, Wu, F., Yang, Y., 2021. Dynamics of calcium, magnesium,and manganese during litter decomposition

in alpine forest aquatic and terrestrial ecosystems. Ecosystems 24, 516–529. https://doi.org/10.1007/s10021-020-00532-5.

Zaitsev, A.S., Gongalsky, K.B., Persson, T., Bengtsson, J., 2014. Connectivity of litter islands remaining after a fire and unburnt forest determines the recovery of soil fauna. Appl. Soil Ecol. 83, 101–108. https://doi.org/10.1016/j.apsoil.2014.01.007.

Zaitsev, A.S., Gongalsky, K.B., Malmström, A., Persson, T., Bengtsson, J., 2016. Why are forest fires generally neglected in soil fauna research? A mini-review. Appl. Soil Ecol. 98, 261–271.