Charles University, Faculty of Science
Institute for Environmental Studies

Doctoral study programme: Environmental Science

Summary of the Doctoral thesis

Importance of ecological stoichiometry in soil development

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Abstract

Ecological stoichiometry is a useful tool for understanding of ecological dynamics and related processes. There are only rare informations about nutrient cycling and nutrient dynamics in plant-soil system in restoration areas after coal mining. Different plant species have developed own strategies and treat differently with nutrients which can influence nutrient cycling and consequent nutrient return to the soil. In thesis, I investigated ecological stoichiometry as one of key factors which controls soil development in post mining sites. In general introduction are summarized known facts about e.g. plant traits, decomposition process, nutrient cycling and consequences for soil development and restoration practices. But still, relationship between leaves, plant litter, and soil is poorly understood in restoration areas.

The results of a doctoral thesis are presented in five papers, out of which three have been published, one has been already submitted and one manuscript is prepared for publication in an international journal with impact factor. In the first presented publication, the influence of soil fauna was studied (especially earthworms) on soil development. Soil development differed significantly between sites afforested with different tree species and it is strongly influenced by the presence and activity of soil fauna, especially by earthworm bioturbation. Second publication examines the life cycle of *Penthetria holoserica* and its correlation with C:N ratio of alder litter fall. The life cycle of *P. holosericea* is not dependent on seasonal changes in the quality and quantity of food. Third publication focused on nutrient competition strategy of *Calamagrostis epigejos*. *C. epigejos* reabsorbed most nutrients before the senescence of leaves at older sites while reabsorbing much less at the younger sites in spontaneous succession. *C. epigejos* reduced the availability of N for other plant species especially at the beginning of the growing season in spring especially at younger nutrient poor sites, when *C. epigejos* can use N stored during the previous season. In fourth publication was studied if the addition of nitrogen (N) into the system have negative effects on soil development which seems to be important especially in poor nutrient conditions. In the reclaimed sites, the higher amount of N released from plant litter caused a higher loss of nutrients (Ca, Mg, K, P) from the ecosystem which can lead to earlier depletion of nutrients in these sites. And last publication focused on seasonal changes in tree foliage and litter fall composition. Different foliage composition was found between individual tree species and between sites, especially in concentration of N, Ca, Mg, K and content of lignin.

This thesis provides broader insight into the ecological stoichiometry and its influence on plant-soil development and soil fauna development at restoration areas. The thesis also summarizes the consequences of the influence of plant for soil development and possible recommendation for restoration practices.

1. Introduction

Ecological stoichiometry provides new perspectives for studying ecosystems processes at different levels from leaf physiology to ecosystem productivity (Sterner and Elser 2002; Hessen et al. 2004). In literature, studies are mostly devoted to the relationships between living and dead organic matter, or plant-soil system at terrestrial ecosystem where stoichiometric ratio C:N:P is very variable (Sardans et al. 2016b; Zhang et al. 2017). The relationship between living and dead organic matter provides us knowledge about plant and soil dynamics, anticipating future soil and ecosystem development (Carnol and Bazgir 2013). Decomposition of plant biomass is influenced by many factors such as the chemical composition of plant litter, soil moisture and presence and composition of soil community (Aerts 1997). Studying of ecological stoichiometry of plant-soil system is important for the growth and dynamics of species, but stoichiometric relationship (especially other nutrients such as Ca, Mg, K) among leaf, plant litter, and soil is still poorly investigated in the literature (Carnol and Bazgir 2013; Zhang et al. 2017), especially in plant-soil system after coal mining in restoration areas. Publications included in the doctoral thesis (in bold) and also other papers with contributions of the author (underlined) are included in a broader context in general introduction „Importance of ecological stoichiometry in soil development“ of doctoral thesis.

In terrestrial ecosystems, local soil conditions, canopy development, and water supply interact to affect plant C:N:P stoichiometric ratios (Vitousek et al. 1993; Zechmeister-Boltenstern et al. 2015). According to the biogeochemical niche hypothesis, coexisting plant species tend to use the main nutrients N, P, K and other essential nutrients such as Ca, Mg and S in different proportions (Sardans et al. 2016b). **Publication 5** showed that even foliage quality and composition (especially N, Ca, Mg, K, lignin) differed between individual tree species and between nutrient poor and rich sites. The highest nutrient concentration (Ca, Mg, K) was found in foliage and litter at spontaneous regrowth vegetation. The amount of nutrients needed for producing a unit of aboveground is significantly different between plant species (Uri et al. 2002).

Plant functional traits are related to the specific leaf area (SLA), leaf N content and leaf dry matter content and affect primary productivity, litter decomposability, soil C storage, nutrient cycling and soil biota (Cornelissen et al. 2007; Cortez et al. 2007; Klimešová et al. 2008; Moradi et al. 2017). Generally, plant tree species treat differently with nutrients and can influence nutrient return to the forest floor and nutrient cycling through the amount and chemical composition of throughfall and plant litter (Warren and Adams 2001; Reich et al. 2004; Carnol and Bazgir 2013; **Publication 1**; Zhang et al. 2018). It is already well known that low nutrient input supports conservative plant species which grows slowly and have a very closed nutrient cycle, hold nutrients in biomass, produce plant litter with high C:N ratio and release only little nutrients to the soil (Chapin et al. 1986; Aerts and Chapin 1999; Reich et al. 2003). But also herbal species developed their own strategies which help them in competition about nutrients, especially in soils with low availability of nutrients. This has been shown in the **Publication 3** where rhizomatous highly competitive grass *Calamagrostis epigejos* with hardly decomposed litter showed that during decomposition litter, N is immobilized from soil which reduce availability of N for other plants particularly at the beginning of growing season in spring.

Nutrient foliar resorption is a primary mechanism of nutrient conservation in plants (Vitousek 1984; Shaver and Chapin 1991; Aerts 1996; Yuan et al. 2005) which allows to plants repeated use in metabolism within one ecosystem. The reallocation efficiency increases considerably with decreasing nutrient availability (Chapin et al. 1986). Foliar resorption efficiency is dependent mainly on ratios of foliar nutrients, plant growth type, ecosystem type and physiological limitations (Sohrt et al. 2018). Nutrient resorption from the foliage of temperate forest trees prevents nutrient losses for the individual trees and supports nutrient conservation in the ecosystem (Sohrt et al. 2018). Plant nutrient resorption efficiency is higher on soils with low nutrient availability (Zechmeister-Boltenstern et al. 2015; Sohrt et al. 2018; **Publication 5**) where the lower nutrient concentration in litter fall reduced decomposition rates, nutrient release and energy transfer to the other trophic levels.

The processes of litter decomposition represents an important role in C cycle and ecosystem cycling of the nutrients at both local and global scales (Melillo et al. 1982; Rahman et al. 2013) and can be characterized as a process during which fresh litter fall of different initial properties transforms into chemically very uniform soil organic matter (Aerts 1997). The main drivers of litter decomposition are generally water availability and litter chemical composition as indicated by its C:N ratio (Melillo et al. 1982; Aerts 1997) and the decomposition rate is controlled by soil organisms as well as by environmental conditions (Domenach et al. 1994; Sterner and Elser 2002; Zechmeister-Boltenstern et al. 2015). Plant litter is the basic energic source for detrit food web by which nutrients and energy stored in plant fresh tissue inputs back to the ecosystem cycling (Xia et al. 2015).

Plants and soil organisms play a crucial role in soil formation (Frouz et al. 2014). The development of soil biota plays an important role in litter decomposition and soil organic matter accumulation. Soil biota may affect plant fitness by several interactions with roots (mycorrhiza, N_2 fixation, root herbivory) and by other activities of various beneficial or pathogenous microorganisms in the rhizosphere. Soil biota have many important functions such as litter decomposition, nutrient release, formation of soil structure and mixing the soil profile (Frouz et al. 2014). Soil fauna also possitively correlated with an increase in plant cover, litter input and had higher abundance at older ecosystems (Moradi et al. 2017). But in **Publication 2** were found that life cycle of *Penthetria holoserica* is not depended on seasonal changes in the quality and quantity of food because the peak of larval numbers were occured in summer during production of litter with higher C:N (22.9).

The productivity of forest ecosystems is closely related to the availability and demand for nutrients, especially N and P (Sharma 1993; Vares et al. 2004). Using N_2 fixing plant is often recommended in restoration practice which helps in fast recovery of soil and namely N pool which is essential for ecosystem functioning (Manzoni et al. 2010; Mudrák et al. 2010; Macdonald et al. 2015; Świątek et al. 2019). But in recent studies (Frouz et al. 2015; **Publication 4**) has been shown that N_2 fixing plants have some disadvantages. Knowledge about nutrient dynamics of plant-soil system is important in decision about future restoration practice in disturbed areas after coal mining.

1. Aims of the study

- To evaluate the effect of tree species on soil faunal communities and on the contribution of such fauna to changes in soil properties during early pedogenesis (**Publication 1**).
- To describe the life cycle and population dynamics of *Penthetria holosericea* in an alder forest (**Publication 2**).
- To investigate the role of standing dead biomass of *Calamagrostis epigeios* on interactions within the plant community and on nutrient cycling (**Publication 3**).
- To explore how nitrogen availability affects cycling of N but also other nutrients and compare nutrient stock and nutrient cycling in reclaimed alder plantation (with high N input due to N_2 fixation) and unreclaimed sites covered by succession vegetation (with lower N input) of the same age (**Publication 4**).
- To explore seasonal dynamics of foliage and litter fall quality during the vegetation season in reclaimed and unreclaimed sites of Sokolov area (**Publication 5**).

2. Material and methods

Publication 1: The study was carried out at a large spoil heap near the town Sokolov, CZ. Average mean temperature is 6.8 °C and mean annual precipitation 650 mm. The heap was covered by a mosaic of patches that were overgrown with different types of vegetation of varying age. Sites that had been reclaimed (afforested) by the planting of one of six tree species (lime - *Tilia cordata*; alder - *Alnus glutinosa*, *Alnus incana*; oak - *Quercus robus*; larch - *Larix decidua*; pine - *Pinus concorta*, *Pinus nigra* and spruce - *Picea omorica*, *Picea pungens*) were chosen for the study. The aboveground biomass were estimated by circular sampling plots 200 m^2 at each sites and the individual tree species were identified with measured tree characteristics. Also data about litter fall from woody vegetation input, aboveground herb biomass, soil chemical properties and soil biota were collected at each site.

Publication 2: The study was conducted in alder (*Alnus glutinosa*) forest with sandy soils near Cesky Krumlov (CZ). Mean annual temperature is 7 °C and mean annual precipitation 644 mm. Soil samples were sampled in montly intervals for evaluate amount of soil organisms (larvae of *Penthetria holosericea)*. Extracted larvae were dried at 60 °C for 24 h and weighted. Pitfall treps were used for sampling adults becuase they exist in litter surface and ground vegetation. Also litter traps were deployed in the forest and litter fall were collected in same interval as soil samples. Laboratory feeding experiment was established as well in duration one week, after that remaining litter, the feces and larvae were dried 60 °C for 24 h and weighted. Total C, N content were determinated in the litter.

Publication 3: The study was conducted at unreclaimed post-mining sites (Sokolov, CZ). Sites were overgrowth by succession vegetation. The rhizomatous invazive grass *Calamagrostis epigejos* is commonly spread at all sites in all chronosequences 10, 20, 25, 30, 40 and 45 years after clay deposition but we studied two sites, 20 years old (young site) and the second 45 years old (old site). Grass biomass were sampled every other month during one year from five squares (0.5 x 0.5 m) at each site. Biomass was separeted in the three pools: living (standing) biomass, dead standing biomass, dead lying biomass. There were also established litterbag experiment with dead standing and dead lying biomass. Litterbags were placed on both of the study sites in three positions: buried in the soil (4 cm deep), lying on the soil surface, or hanging 90 cm above the soil surface. The litterbags were collected after one year of exposure. The remain content was dried, weighed, and analysed chemically. The litterbags with filtrate paper were used for evalutalition potential N immobilization. Litter bags were placed on soil surface for 6 months and then collected, filter paper were dried, weighted and analyzed for C, N content.

Publication 4: The study was carried out at post-mining sites (Sokolov, CZ). Four sites 25 years old were chosen each 10 ha. Two sites were planted by alder and other two were left for spontaneous succession. At each site were chosen two replicates at least 200 m apart. Data about vegetation (above-ground biomass trees, plant litter, belowground tree biomass) were sampled during vegetation season. For calculation were used allometric equations developed by Frouz et al. (2015). Also biomass samples were destructively harvested and divided into the compartments (trunk, branch, leaves, roots), weighed and nutrient content was analysed (C, N, Ca, K, Mg). Litter fall was collected with using five litter traps at each site. At sites were also collected data about throughfall precipitation, stemflow and lysimetric leachate. Chemical analysis (TN, NH_4^+, NO_3^-, Na^+, Mg^{2+}, K^+, Ca^{2+}) were done in water samples.

Publication 5: The study was conducted at unreclaimed post-mining sites (Sokolov, CZ). Two reclaimed sites were planted by alder and two unreclaimed sites were left for spontaneous succession. Fresh leaves sample were taken four times during the growing season (June, July, September, October). Samples were stored into the plastic vials, cooled and chlorophyll was analysed immediately. Another samples were collected into paper bags, dried at 60 °C for 24 h and analysed for soluble phenolics, lignin, cellulose, C, N, P, Ca, Mg and K. Also litter traps were used for collected litter fall four times (August to December) and chemical characteristics were analysed.

3. Results and discussion

Publication 1: Frouz J., Livečková M., Albrechtová J., Chroňáková A., Cajthaml T., Pižl V., Háněl L., Starý J., Baldrian P., Lhotáková Z., Šimáčková H., Cepáková Š. (2013). Is the effect of trees on soil properties mediated by soil fauna? A case study from post-mining sites. Forest Ecology and Management 309/1:87-95.

In publication 1, the effect of tree species of different foliage and litter chemistry was studied on the chemical, micro-morphological, and biological properties of soil. The study compared sites on post-mining sites afforested with one of six tree species (spruce, pine, larch, oak, lime, and alder) with sites left to natural succession (with willow as dominant tree species). It was found that a higher N content was greater in the litter produced by deciduous tree species which resulted in lower C:N ratio in deciduous than in evergreen litter. Faster soil development with thick organomineral A horizon was observed in sites with litter fall of lower C:N ratio. A higher accumulation of undecomposed litter fall at Oe horizon was evident in sites with evergreen trees producing litter fall of high C:N ratio. A high abundance of earthworms and bioturbation activity were the strongest predictor of faster soil development of A horizont and C accumulation in the mineral topsoil. Sites with high accumulation of C in mineral soil had higher microbial biomass and lower microbial respiration which is caused by the higher stock of C. Soil C stock significantly differed among the sites and was highest in lime and alder sites and lowest in successional sites. Results suggest that soil development differed significantly between sites afforested with different tree species and is strongly influenced by the presence and activity of soil fauna, especially by earthworm bioturbation.

Publication 2: Frouz J., Jedlička P., Šimáčková H., Lhotáková Z. (2015). The life cycle, population dynamics, and contribution to litter decomposition of *Penthetria holosericea* (Diptera: Bibionidae) in an alder forest. European Journal of Soil Biology 71:21-27.

Publication 2 examined the population dynamics of *Penthetria holosericea* and its influence on litter decomposition of alder (*Alnus glutinosa*) litter. The life cycle, population dynamics as well as the rate of litter consumption were described in the study. Samples were taken in monthly intervals (February to

November) in a alder forest near Český Krumlov. Results showed that larval abundance peaked in June (1078 ind m-2) and larval abundance peaked in August (1.3 g m-2), which was before maximum litter fall in September and October. This might be explained by higher litter quality during summer but this was not confirmed in our study because the lowest litter C:N ratio was found in November. Therefore, the results suggest that the life cycle of P. holosericea is not dependent on seasonal changes in the quality and quantity of food. Overall, the annual alder litter consumption by the population of *P. holosericea* was about 40 % of the annual alder litter fall.

Publication 3: Veselá H., Mudrák O., Frouz J. (2018). The role of dead standing biomass of *Calamagrostis epigejos* in nutrient turnover during spontaneous succession. Science of The Total Environment, 644, 717-724.

The role of dead standing biomass of rhizomatous expansive grass *Calamagrostis epigejos* in nutrient turnover during spontaneous succession was studied in publication 3. *C. epigejos* is well known for its high productivity of hardly decomposable standing litter which remains undecomposed long time without contact with the soil surface. This strategy gives a strong competitive advantage to *C. epigejos* over other plant species and can block the course of succession. *C. epigejos* also shows a high tolerance to very low soil N levels by reducing its growth which is also due to its higher N-use efficiency compared to other grasses. We found that *C. epigejos* reabsorbed most nutrients before the senescence of leaves at older sites while reabsorbing much less at the younger sites. Standing dead biomass was turned to lying dead biomass during winter and spring and its decomposition N then immobilized N from soil. Moreover, the greatest release of nutrients was observed from lying dead plant biomass immediately after death of living biomass and then losses of nutrients were slower. This competitive advantage of C. epigejos reduced the availability of N for other plant species especially at the beginning of the growing season in spring especially at younger nutrient poor sites, when *C. epigejos* can use N stored during the previous season.

Publication 4: Veselá H., Veselá M., Cejpek J., Frouz J. (manuscript). Reclaimed alder plantation in post mining sites have more open nutrient turnover causing loss of nutrients from the soil in comparison unreclaimed woody regrowth.

In publication 4, the nutrient budget and nutrient turnover were compared in post-mining sites with alder reclamation and with spontaneous succession in the Sokolov area. Use of N2-fixing trees is a favorite practice in restoration of disturbed areas after coal mining which supports faster soil development (due to the enhancing effect of litter with low C:N ratio) with higher availability of nutrients, especially N for plants and soil biota. In the study, measurements of nutrient concentration in biomass compartments, plant litter, throughfall, and in lysimetric leachates were collected during the whole year. The total content of P, Ca, Mg, K in plant biomass was found to be higher in spontaneous succession sites in comparison to the alder reclamation sites while the oppsite was true for N. In the reclaimed sites, the higher amount of N released from plant litter caused a higher loss of nutrients (basic cations and P) from the ecosystem which can lead to earlier depletion of nutrients in these sites, soil acidification due to high N input into the soil and consequent eutrophication with decrease in biodiversity of the ecosystem. On the contrary in succession site, there is more suitable nutrient efficiency because more nutrients are stored in the plant biomass, plant litter is decomposed slowly and leaching of nutrients is not high. Our study supports the idea that mixed stands should be used in further reclamation practice rather than alder monocultures.

Publication 5: Veselá H., Lhotáková Z., Albrechtová J., Frouz J. (prepared manuscript). Seasonal changes in foliage and litterfall bio-chemistry at reclaimed and unreclaimed sites.

Publication 5 examined relationship between seasonal changes in tree foliage and litter fall quality / composition in reclaimed and unreclaimed post-mining sites. Different tree species differ in their nutrient management which strongly influences nutrient return to the forest floor and nutrient cycling in the ecosystem. Leaves and litter fall chemical characteristics were measured during the vegetation season from April to December. The study showed different foliage composition between individual tree species and between sites, especially in concentration of N, Ca, Mg, K and content of lignin. As expected the highest amount of N was found in alder foliage and litter fall due to symbiosis with N2 fixing bacteria. However, concentration of other nutrients (Ca, Mg, K) was found to be higher in the foliage and litter fall of tree species at unreclaimed sites. The content of lignin slightly increased during the vegetation season in foliage and litter fall of all studied tree species. Litter fall at unreclaimed sites had the highest content of lignin which can be responsible for the slower decomposition of litter fall.

4. Conclusions

Ecological stoichiometry provides us the understanding of ecological dynamics and processes. The three most basic elements C, N, P in living organisms and plants play crucial roles in activities and functions of organisms, but stoichiometry relationship (especially other essential nutrients such as Ca, Mg, K) among leaf, plant litter, and soil is still poorly understood in the literature particularly in plant-soil systems at sites after coal mining in restoration areas.

Different plant tree species treat differently with nutrients and can influence nutrient cycling and return of nutrients to the soil. The higher nutrient concentration (except N) was found in biomass at spontaneous regrowth vegetation at nutrient-poor sites, which shows better treating with nutrients without wasting in comparison to sites with high availability of N at alder reclamation sites. Using N2 fixing plants is a favorite restoration practice used for fast soil development, but as it was shown N2 fixing plants have some disadvantages such as high leaching of nutrients from the system and low efficiency of nutrients by plants. Presented research supports the idea that for further reclamation practice will be useful plant mixed stands rather than alder monocultures.

Foliar resorption efficiency depends mainly on ratios of foliar nutrients, plant growth type, ecosystem type, and physiological limitations. Nutrient resorption from leaves is the prevention of nutrient losses and supports nutrient conservation in the ecosystem. Plant nutrient resorption efficiency is higher on soils with low nutrient availability where the lower nutrient concentration in litter fall reduce decomposition rates, nutrient release and energy transfer to the other trophic levels.

Herbal species developed their own strategies for nutrient competition. These strategies are important in soils with low availability of nutrients. A good example of studying competition strategy provides rhizomatous grass Calamagrostis epigejos which reabsorb most of nutrients just before senescence of leaves at older developed sites but much less at the young sites. This competitive advantage reduced the availability of nutrients for other plant species especially at the beginning of the growing season in spring because C. epigejos can use N and other nutrients stored during the previous season. This strategy is most important in undeveloped young soils.

Also, soil development varies between plant species and it is also strongly influenced by the presence and activity of soil fauna. Especially bioturbation of earthworms changes physical and chemical conditions in the soil and influence the composition of the soil microbial community. But for example, according to the presented study life cycle of Penthetria holoserica was not dependent on seasonal changes in the quality and quantity of food (litter fall of alder).

To conclude, this thesis provides insight into the importance of ecological stoichiometry as one of the key factors that influence the plant-soil system and soil fauna development at restoration areas after coal mining.

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Traineeships

September 2014	University of Antwerp, BE, Department of biology, soil sampling and chemical analysis, prof. Rudy Van Diggelen

August 2010	The Czech Environmental Inspectorate in Prague, department of Nature Protection, Prague, CZ
August 2007	Prague Zoo, Education centre, CZ

Curses/Workshops

May 2017 – Spring School on Stable Isotopes in Environmental Sciences (Freising, Germany)
August 2016 – Course of Rhetoric and presentation skills (Charles University)
January to June 2016 – Course of College education (Charles University)
June 2016 – Expert workshop of Good titration practice (Mettler Toledo)
January 2016 - Expert workshop of Pipetting technique (Eppendorf Czech and Slovakia s.r.o.)
June 2015 - Expert workshop of Current trends in gas chromatography (Agilent Technologies)
January 2015 – Workshop Presentation skills and scientific writing (Charles University)

Peer-review

2015-2016 – Ecological research (2 research papers)

Conference

Veselá H., Veselá M., Cejpek J., Dvorčšík P., Frouz J. (2019): Reclamation with alder plantation may caused more loss of nutrients from the soil in comparison unreclaimed succession sites after coal mining (Czech Republic). II. International Conference and Workshop, Kraków, Poland (presentation).

Šimáčková H., Veselá M., Cejpek J., Frouz J. (2017): Nutrient cycling in plant soil interaction in reclaimed alder plantations and succession sites after coal mining. Biogeomon 2017 – 9th International Symposium on Ecosystem Behaviour. Litomyšl, Czech Republic (poster).

Šimáčková H., Mudrák O., Frouz J. (2015): Changes in content of N and P in living and dead biomass of *Calamagrostis epigeios* during succession in two different old sites after coal mining. 5th International symposium on soil organic matter. Göttingen, Germany (poster).

Šimáčková H., Frouz J., Mudrák O. (2014): Seasonal changes in standing dead biomass and nitrogen content of *Calamagrostis epigeios*. Biogeomon 2014 – 8th International Symposium on Ecosystem Behaviour. Bayreuth, Germany, 328 (poster).

Pavlů V., **Šimáčková H**., Ludvíková V., Gaisler J., Pavlů L., Hejcman M. (2012): Effect of different grazing systems on sward structure during the first vegetation season after management introduction. In: Golinski P., Warda M., Stypinski P. (Eds.): Grassland – a European resource? – Grassland Science in Europe 17. Proceedings of the 24th general meeting of the European Grassland Federation. Lublin, Poland, 210–212 (presentation).

Selected publications

Veselá H, Lhotáková Z, Albrechtová J, Frouz J (prepared manuscript). Seasonal changes in Foliage and Litterfall bio-chemistry at reclaimed and unreclaimed sites.

Veselá H, Veselá M, Cejpek J, Frouz J (submitted manuscript). Reclaimed alder plantation in post mining sites have more open nutrient turnover causing loss of nutrients from the soil in comparison woody regrowth.

Angst Š, Harantová L, Baldrian P, Angst G, Cajthaml T, Straková P, Blahut J, **Veselá H**, Frouz J (2019). Tree species identity alters decomposition of understory litter and associated microbial communities: a case study. *Biology and Fertility of Soils*, 1-14.

Kukla J, Whitfeld T, Cajthaml T, Baldrian P, **Veselá-Šimáčková H**, Novotný V, Frouz J (2019) The effect of traditional slash-and-burn agriculture on soil organic matter, nutrient content, and microbiota in tropical ecosystems of Papua New Guinea. *Land Degradation & Development*, 30(2), 166-177.

Jílková V, Vohník M, Mudrák O, **Šimáčková H,** Frouz J (2019). No difference in ectomycorrhizal morphotype composition between abandoned and inhabited nests of wood ants (*Formica polyctena*) in a central European spruce forest. *Geoderma*, 334, 55-62.

Veselá H, Mudrák O, Frouz J (2018). The role of dead standing biomass of Calamagrostis epigejos in nutrient turnover during spontaneous succession. *Science of The Total Environment*, 644, 717-724.

Moradi J, Vicentini F, **Šimáčková H**, Pižl V, Tajovský K, Stary J, Frouz J (2018). An investigation into the long-term effect of soil transplant in bare spoil heaps on survival and migration of soil meso and macrofauna. *Ecological Engineering*, 110, 158-164.

Frouz J, Mudrák O, Reitschmiedová E, Walmsley A, Vachová P, **Šimáčková H**, Albrechtová J, Moradi J, Kučera J (2018). Rough wave-like heaped overburden promotes establishment of woody vegetation while leveling promotes grasses during unassisted post mining site development. *Journal of environmental management*, 50-58.

Moradi J, Mudrák O, Kukla J, Vincentini F, **Šimáčková H**, Frouz J (2017). Variations in soil chemical properties, microbial biomass, and faunal populations as related to plant functional traits, patch types, and successional stages at Sokolov post-mining site-A case study. *European Journal of Soil Biology*, 58-64.

Angst Š, Cajthaml T, Angst G, **Šimáčková H**, Brus J, Frouz J (2017). Retention of dead standing plant biomass (marcescence) increases subsequent litter decomposition in the soil organic layer. *Plant and Soil*, 1-9.

Jílková V, Vohník M, Dauber J, Marten A, **Šimáčková H** Frouz J (2017). Low root biomass and occurrence of ectomycorrhizal exploration types in inhabited wood ant (Formica polyctena) nests in a temperate spruce forest. *European Journal of Soil Biology*, 79, 57–62

Frouz J, Jedlička P, **Šimáčková H,** Lhotáková Z (2015). The life cycle, population dynamics, and contribution to litter decomposition of Penthetria holosericea (Diptera: Bibionidae) in an alder forest. *European Journal of Soil Biology*, 71:21-27.

Heděnec P, Novotný D, Ustak S, Cajthaml T, Slejška A, **Šimáčková H,** Honzík R, Kovářová M, Frouz J (2014). The effect of native and introduced biofuel crops on the composition of soil biota communities. *Biomass and Bioenergy*, 60:137-146.

Heděnec P, Novotný D, Ustak S, Honzík R, Kovářová M, **Šimáčková H**, Frouz J (2014). Allelopathic effect of new introduced biofuel crops on the soil biota: A comparative study. *European Journal of Soil Biology*, 63:14-20.

Frouz J, Livečková M, Albrechtová J, Chroňáková A, Cajthaml T, Pižl V, Háněl L, Starý J, Baldrian P, Lhotáková Z, **Šimáčková H**, Cepáková Š (2013). Is the effect of trees on soil properties mediated by soil fauna? A case study from post-mining sites. *Forest Ecology and Management*, 309/1:87-95.

Frouz J, Jílková V, Cajthaml T, Pižl V, Tajovský K, Háněl L, Burešová A, **Šimáčková H**, Kolaříková K, Franklin J, Nawrot J, Groninger JW, Stahl PD (2013). Soil biota in post-mining sites along a climatic gradient in the USA: Simple communities in shortgrass prairie recover faster than complex communities in tallgrass prairie and forest. *Soil Biology and Biochemistry*, 67:212-225.