ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LXI 13 Number 1, 2013

http://dx.doi.org/10.11118/actaun201361010107

CHANGES IN FORMS OF AVAILABLE NITROGEN AND RESPIRATION IN SOIL OF BEECH FOREST AS A REACTION TO A DEFORESTATION RESULTING FROM WIND STORM

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Received: June 4, 2012

Abstract

KUČERA ALEŠ, HOLÍK LADISLAV, MAROSZ KAREL, MARTINÍK ANTONÍN, VAVŘÍČEK DUŠAN: *Changes in forms of available nitrogen and respiration in soil of beech forest as a reaction to a deforestation resulting from wind storm.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 1, pp. 107–113

The article deals with the reaction of soil environment to a violent deforestation resulting from a wind storm. As a material, permanent inventory plot located in Training Forest Enterprise Masaryk Forest Křtiny was selected. The plot represents beech high forest, where soil was sampled from four types of sample plots: (1) maternal forest representing situation before the storm; (2) zone of transition from the maternal forest to the open area; (3) reafforested clearing; (4) natural evolution. From each sample plot type, 6 mixed samples of Ah horizon were analysed to assess N-ammonium (N-NH_4^+) and N-nitrates (NO_3^-) content and respiration activity. The results show a significant difference between the respiration activities of the particular sample plots, as well as a significant difference in the content of N-ammonium and N-nitrate forms, the maternal forest representing a site of the lowest biological (and respiration) activity on the one hand, and, on the other hand, site of high N-ammonium and low N-nitrate content, respectively. From the results, intensive nitrification caused by the deforestation is evident. The results are to be used as a starting level for a long-term observation of reaction of the forest beech ecosystem to deforestation and selected types of forest management.

European beech, N-ammonium, N-nitrates, nitrogen, wind storm, soil, clearing

In August 2010, wind storm Antonín damaged many forest stands in the Czech Republic, also affecting several in the Training Forest Enterprise, Masaryk Forest Křtiny (TFE). The areas are used to establish permanent inventory plots (PIP) with the aim (1) to observe a reaction of forest ecosystem to development of clearings; (2) to observe a reaction of forest ecosystem to different managements of forest restoration (Dobrovolný *et al.*, 2011). One of the PIPs was established in the beech stand in autumn 2011. In the case of this PIP, changes of nitrogen forms acceptable by plants (NH_4^+ and NO_3^-) and biological activity explained by respiration are observed, as a reaction to the development of a clearing.

Numerous works has been written, dealing with the reaction of soil environment to deforestation, and focusing on the amount of nitrogen in soil (Bormann, Likens, 1994; Hruška, Ciencala, 2005; Vitousek, Jerry, 1979; Weis *et al.*, 2006). Several articles focus on the influence of specific forest management or after-clearing melioration on soil (Akselsson *et al.*, 2004; Closa, Goicoechea, 2010; LeDuc, Rothstein, 2007; Prescott, 1997; Vitousek, Matson, 1985). Other works perceive the storm-clearing as a natural disturbation and, hence, they observe autonomic evolution of forest ecosystems (Attiwill, 1993; Legout *et al.*, 2009; Vitousek, Jerry, 1979).

In general, stand climate changes, changes of water regime, soil biochemistry and physical chemistry all represent an immediate effect of deforestation (Smerthurst, Nambiar, 1990; Striegl, Wickland, 1998). Plant nutrition and soil nutrient regime, as well as nitrogen dynamics, belong among soil properties with fast feedback as a reaction to a development of a clearing (Prescott, 1997). Disturbation can cause changes and flows of nitrogen in many forms: immobilization by decompositors, volatilization, denitrification, loss to streamwater or groundwater, clay fixation of ammonium, lags in nitrification, nitrate reduction to ammonia, nitrate adsorption on soil colloids, lack of water for nitrate transport, or (once the plant regrowth is established) plant nitrogen uptake. In general, the change of acceptable nitrogen forms causes a change of nitrogen dynamic as a consequence of nitrification (Weis *et al.*, 2006; White, 2006; Šimek, 2003), which, means a change of N-ammonium form ($N\text{-}NH_4^+$) to N-nitrates ($N\text{-}NO_3^-$). The principal result of the nitrification process is an increase of nitrogen mobility and a risk of nitrogen losses with a groundwater.

In the case of "non-extreme habitats", the process of deforestation results in changes in water and temperature regime and light conditions which causes, rising of biological activity, intensification of decomposition processes and nutrient cycles (Closa, Goicoechea, 2010; Marra, Edmonds, 1996; Marshall, 2000; Olsson *et al.*, 1996). The hereinabove named parameters can be explained using soil respiration tests (Fleming *et al.*, 2006). Except winter season, clear-cut areas represent sites with intensive respiration and CO_2 flux (Striegl, Wickland, 1998).

The present study deals with a content of two nitrogen forms (N-ammonium and N-nitrates) 1.5 year after inception of the clearing caused by the wind storm. To explain reaction of soil biota, respiration tests were performed within the investigated area. The character of the article is a "pilot study" starting a long-term observation of soil reaction to deforestation. Original data representing the starting point, which is to be used for the long-term research on PIP, are presented.

MATERIAL AND METHODS

The PIP is located in the TFE close to village Vranov. The maternal forest is composed of European beech (*Fagus sylvatica* L.). The bedrock is composed of mixed substrate of granodiorite and loess, with a Cambisol soil type (Michéli *et al.*, 2006). The research site is located on a medial slope with eastern exposition, with a potential risk of soil surface denudation resulting from the deforestation.

The investigated forest was cleared in August 2010. In March 2012, the clearing was reafforested with planting space of 10.000 pcs. per hectare using bare-rooted plants. The design of the study can be described as an area of four squares 25 × 25 m each, regularly deployed on the clearing. Between each two pairs of squares, a zone of natural evolution 20–25 ms wide, oriented concurrently with contours, is placed.

The soil was sampled in October 2011 and in April 2012 from four individual sampling plots. The sampling plots were marked as (M) adjacent maternal forest, which remained undamaged after the storm; (T) transitional zone between the maternal forest and clearing; (P) plantation and (N) natural evolution with no after-cleaning treatment. As the October sampling was performed before the reafforestation, two slightly different sample sets were provided: Sampling of October 2011 before plantation and sampling in April 2012 after plantation. The dataset of October 2011 is composed of M, T and N sampling plots, the dataset of April 2012 is composed of M, T, P and N sampling plots. From each type of sampling plot, six mixed samples were provided from organomineral horizon Ah. Each mixed sample was composed of three individual sample sites randomly selected from the sample plot.

Soil samples were analysed in a fresh condition, after sieving through a sieve with meshes of 2 mm diameter. The leachate of N-ammonium (NH_4^+) and N-nitrate (NO_3^-) was analysed spectrophotometrically, basal and potential respiration was analysed by titration (Zbíral *et al.*, 2004).

N-ammonium and N-nitrates were assessed in leach of 1M KCl, in three repetitions for each soil sample. After leaching, the sample was centrifuged. To assess N-ammonium, 4 ml of color reagent (130.0 g of sodium salicylate, 130.0 g of sodium citrate and 0.950 g of sodium nitroprusside, dihydrate dissolved in 1,000 ml of water), 4 ml of alkaline solution (32 g of sodium hydroxide and 2 g of sodium dichloroisocyanurate dihydrate dissolved in 1,000 ml of water) was added into 5 ml of soil eluate (ratio soil/1M KCl, 1/5, w/v). The total volume was supplied to 50 ml flasks by demineralised water. Concentration of NH_4^+ ($N\text{-}NH_4^+$) [mg NH_4^+ * 1 g dry mass^{-1}] was measured in wavelength of 655 nm (green coloured solution). The results were assessed according to a calibration curve. Nitrates were assessed in 20 ml of soil eluate (ratio soil/1M KCl, 1/5, w/v), into which 1 ml of 0.5% sodium salicylate was added. After evaporating, 1 ml of concentrated sulfuric acid, 3 ml of demineralized water and 10 ml of alkaline solution was added. Total volume was supplied to 50 ml flasks by demineralised water. Concentration of NO_3^- ($N\text{-}NO_3^-$) [mg NO_3^- * 1 g dry mass^{-1}] was measured in wavelength of 410 nm (yellow coloured solution). The results were assessed according to a calibration curve. Respiration was assessed as basal (BR) and potential (with 2 mg of glucose per 1 g of dry soil) (PR), in three repetitions for each soil sample. 40 g of sample was being incubated in hermetic boxes for 6 hours in 22°C with 1 M NaOH put on petri dish. After incubation, 2 ml of 12.5% $BaCl_2$ was added to NaOH and the solution was titrated with 0,05M HCl using phenolphtalein indicator. Results are given in mg $C\text{-}CO_2 * g^{-1} * h^{-1}$.

The data was processed using ANOVA, grouped according to the type of sampling plot (maternal – M, transitional – T, plantation – P, natural evolution – N). In the case of rejection of null-hypothesis (H_0), a post-hoc analysis was performed in the form of

I: *Average values of observed soil parameters on research plots (M – maternal, T – transitional, P – plantation, N – natural evolution)*

sample site	sampling in October 2011		sampling in April 2012	
	basal respiration	potential respiration	C-NH_4^+	C-NO_3^-
	[mg C-CO_2*g^{-1}*h^{-1}]	[mg C-CO_2*g^{-1}*h^{-1}]	[mg NH_4^+*1 g dry mass^{-1}]	[mg NO_3^- * 1 g dry mass^{-1}]
M1	1.83	3.27	28.64	10.71
M2	2.98	3.49	27.54	7.16
M3	2.10	5.15	36.44	10.95
M4	5.11	6.69	72.86	10.81
M5	3.54	8.60	25.89	10.27
M6	5.50	9.52	26.77	13.03
T1	4.62	12.97	3.41	16.78
T2	4.94	8.98	3.86	21.77
T3	5.38	14.83	5.59	12.83
T4	4.83	16.01	5.28	12.93
T5	3.86	8.81	4.64	18.90
T6	4.70	13.93	7.25	18.25
P1	-	-	4.91	13.92
P2	-	-	3.41	13.35
P3	-	-	3.40	13.98
P4	-	-	6.14	14.89
P5	-	-	5.57	33.45
P6	-	-	5.53	34.72
N1	3.42	9.58	4.16	23.43
N2	7.58	15.69	3.77	16.19
N3	5.56	19.38	4.03	13.13
N4	4.22	10.78	3.69	21.24
N5	4.76	12.09	3.71	22.48
N6	9.95	21.67	3.66	19.95

Turkey's test. The significance level $\alpha = 0.05$. The calculations were performed in Statistica Cz 9.0.

RESULTS AND DISCUSSION

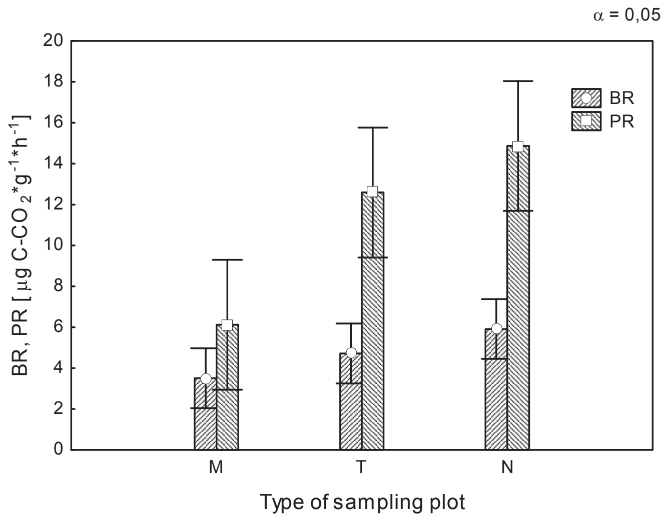
The average values of observed soil parameters are presented in Tab. I (each value represents the mean of three repetitions provided during analyses of soil samples).

Respiration tests were performed in October 2011. The data gathered from the three types of sampling plots are processed (M, T, N). The results from ANOVA show rejection of H_0 ($p < 0.05$) in the case of potential respiration ($p = 0.0766$ for basal respiration and $p = 0.0024$ for potential respiration). The results of Turkey's test for potential respiration are presented in Tab. II. Major difference between M and N is evident from the table, while T is moderately active (Fig. 1).

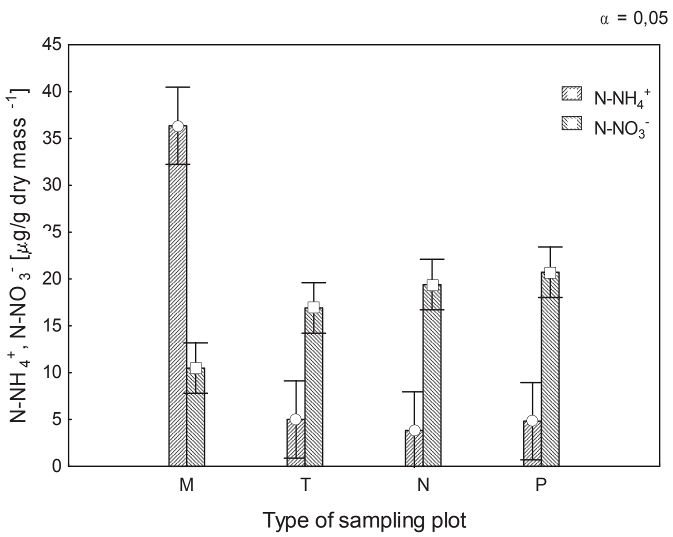
N-ammonium and N-nitrates amount were assessed in April 2012. The data gathered from the four types of sampling plots are processed (M, T, N, P). The results from ANOVA show rejection of H_0 in the case of N-ammonium, as well as of N-nitrates. Post-hoc analysis was performed for both forms of N (Tab. III, Fig. 2).

The results show significant differences between the soils of M (simulating the situation in the soil before the deforestation) and the other plots in the case of both nitrogen forms. The content of N-ammonium form is significantly higher in the M-plot, while in the rest of the plots the values are more or less similar. The amount of N-nitrates on M-plot are significantly lower, and their values rising over the over transitional zone (T).

Significant changes in the nitrogen forms content are typical for the cleaning sites (Akselsson *et al.*, 2004; Closa, Goicoechea, 2010; Legout *et al.*, 2009; Olsson *et al.*, 1996). The deforested area is typical for an increase of biological activity, at least for the first several years after clear-cutting (LeDuc, Rothstein, 2007). The raised mobility of nitrogen and other nutrients marked in soil solution is caused by mineralization of organic matter due to changes in the soil climate, and hence by disappearance of humus layer. The board of maternal forest represents a well-remarkable transitional zone in nitrification. On the other hand, according to several researches (Covington, 1981; Frazer *et al.*,



1: *Bazal respiration (BR) and potential respiration (PR) activities on sampling plots (M – maternal forest, T – transitional zone, N – natural evolution)*



2: *Concentration of N-ammonium (N-NH_4^+) and N-nitrates (N-NO_3^-) on sampling plots (M – maternal forest, T – transitional zone, N – natural evolution, P – plantation)*

II: *Results of Tukey's tests for potential respiration of three sampling plots types. Values in italic mark rejection of H_0.*

	M	T	N
M	-	*0.0201*	*0.0024*
T		-	0.5403
N			-

1988; Hazlett *et al.*, 2007), the development of a clearing has a longer-range effect on the surface soil properties, especially in the coniferous forests with lower dynamics of nutrient cycling. According to Smerthurst and Nambiar (1990), clearance lead to increased concentrations of mineral N in litter and mineral soil and despite leaching, concentration of

III: *Results of Tukey's test for N-ammonium and N-nitrates content on flow sampling plot types. Values in italic mark rejection of H_0.*

N-NH_4^+	**M**	**T**	**N**	**P**
M	-	*0.0002*	*0.0002*	*0.0002*
T		-	0.9781	0.9999
N			-	0.9865
P				-
N-NO_3^-	**M**	**T**	**N**	**P**
M	-	*0.0069*	*0.0002*	*0.0002*
T		-	0.5600	0.1991
N			-	0.9015
P				-

mineral N remained higher than those in the uncut areas for at least for 3 years.

The process of nitrification and nutrient losses can intensify an acidification risk, especially in soils of poor mineral fertility or with unsuitable physical properties (soil texture or drainage) (Groffman, Tiedje, 2002). The increased nitrate concentrations in soil solution resulting from a deforestation are obvious only at nitrogen-non-limited sites (Dahlgren, Driscoll, 1994; Huber *et al*., 2004; Katzensteiner, 2003; Weis *et al*., 2006). Leaching of N-nitrates explained by concentrations of $N\text{-}NO_3^-$ in soil solutions was the highest during the second year after deforestation; the leached N-nitrates can be partially retained within the B horizons or within the rooting zone by biological retention. Nitrogen and other nutrient mobility and loss by flux during the first two years after the storm can be limited by development of an herbaceous cover. Therefore we can presume the highest losses of nutrients during the first two years after clearing (Novák *et al*., 2009; Weis *et al*., 2006).

As far as the respiration or else CO_2 efflux, biological activity was highly affected by improving of soil surface (Fleming *et al*., 2006) and presence/absence of understorey cover which were not unfortunately taken into account in the presented study. Generally the disturbed areas are typical for intensification of metabolic processes of soil biota and the clearances represent a net source of CO_2 (Striegl, Wickland, 1998). Clearances are also typical for seasonal fluctuations of CO_2 emission rates (Marra, Edmonds, 1996) and for a spatial heterogeneity (Tang *et al*., 2005) compared with undamaged areas. However, for the short term the soil respiration can decrease in deforested areas, which is caused by decrease of root density, but only in unchanged temperature and moisture conditions.

CONCLUSION

The research confirms the presumption of changes in the forms of soil nitrogen as a reaction to clearing process. Within the deforested area, N-nitrate form of nitrogen formed during the first year after the deforestation. The nitrification refers to increased biological activity, explained by respiration tests. The tests show steeper gradient in the case of basal respiration which indicates more active and more stimulated soil biota at the deforested area. $N\text{-}NH_4^+$, as well as $N\text{-}NO_3^-$ were found in the highest content in the soil of maternal forest, which can indicate losses of nitrogen with percolating water. In this particular case, the results represent values for beech forest on mixed substrate of intermediate granitic rock and loess with the evolution of Cambisols. However, several questions remain to be answered: The seasonal dynamic of nitrogen content, the long-term changes of soil properties on the research plot, or long-term soil observing related to the forest management.

SUMMARY

The present article deals with the reaction of soil environment to a violent deforestation resulting from a wind storm. In August 2010, wind storm Antonín damaged many forest stands in Czech Republic, affecting also several stands in the Training Forest Enterprise Masaryk Forest Křtiny (TFE). As a material of the study, permanent inventory plot (PIP) located in TFE was selected. The PIP was established immediately after the wind-storm clearing with the aim to observe a long-term reaction of forest ecosystem on the deforestation. The plot, located close to village Vranov, represents beech high forest growing on substrate composed of granodiorite and loess, with Cambisol soil type. On the PIP, soil was sampled from four types of sample plot: (1) adjacent maternal forest representing the situation before the storm; (2) zone of transition from the maternal forest to the open area; (3) reafforested clearing; (4) natural evolution. The sampling was provided in two terms: firstly in October 2011 before reafforestation and, secondly, in April 2012 (two months after plantation). Therefore, in October 2011, soil was sampled only from three types of sample plot: (1) adjacent maternal forest representing the situation before the storm; (2) zone of transition from the maternal forest to the open area; (3) open area (clearing). From each sample plot type, 6 mixed samples of Ah horizon were analysed to assess the observed soil properties: In October 2011, respiration tests where provided while in April 2012, N-ammonium ($N\text{-}NH_4^+$) and N-nitrates ($N\text{-}NO_3^-$) content was assessed. The results show a significant difference between the respiration activities of the particular sample plots, as well as a significant difference in the content of N-ammonium and N-nitrate forms of nitrogen, the maternal forest representing a site of the lowest biological (and respiration) activity on the one hand, and, on the other hand, site of high N-ammonium and low N-nitrate content, respectively. In the organomineral horizon, nitrification is the remarkable biological process caused by a reaction to deforestation. The results are to be used as a starting level for a long-term observation of reaction of the forest beech ecosystem to deforestation and selected types of forest management.

Acknowledgement

This research was supported by Technology Agency of the Czech Republic (project No. TA02020867 – Use of the new organic mineral stimulators and natural organic materials for revitalization of the forest ecosystems influenced by biotic and abiotic impacts) and KUS (project No. QJ1230330 – Stabilization of forest ecosystems by balanced proportion of natural and artificial reforestation).

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