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Ecological Aspects of Biomass Removal in the Localities Damaged by Air-Pollution

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1. Introduction

Removal of above-ground biomass is connected with nutrient exclusion from the forest ecosystem. This aspect is essential mainly in the localities with damage of soil conditions, e.g in the air-polluted areas. Therefore, quantification of possible biomass removal must be based on knowledge of current soil conditions (especially forest floor) under forest stands.

We illustrate this problem with the example of the forest stands of substitute tree species, which were established in the Czech Republic on the sites where the declining spruce monocultures could not be replaced by ecologically suitable tree species due to continual air pollution impact and damaged forest soils.

One of the most heavily air-polluted areas since the 1960s of the last century is the Krušné hory Mts. (figure 1). The Krušné hory Mountains (synonym: The Ore Mts. or Erzgebirge) are located in Central Europe on the border between the Czech Republic and Saxony, Germany. These mountains are known as an area where air pollution has had a very severe impact (Šrámek et al., 2008a). Sulphur dioxide, produced mainly by coal power plants and the chemical industry, caused extensive decline of forests in the upper part of the Krušné hory Mountains during the 1970s and 1980s. Therefore, some new tree species, considered to be more resistant to air pollution, substituted the declining spruce in these areas. The substitute tree species stands occupied in this place about 36% of forest land area, i.e. about 41 thousand hectares. The largest percentage of this area is covered with birch (*Betula* sp.) and blue spruce (*Picea pungens* Engelm.) or mixtures of these two species. The third species according to covered area is European larch (*Larix decidua* Mill.) with more than 6.5 thousand hectares of forest land in the Krušné hory Mts.

Nowadays, substitute stands are due to air pollution decrease in good health condition and grow well. Consequently, they are now at the beginning of tree species conversion. and the questions are: Is it possible to remove aboveground biomass for chipping (with respect to their effects of forest environment, especially in these heavily disturbed localities)?

Presented chapter focuses on the results from above-ground biomass investigation in the substitute stands of blue spruce, European larch and birch located in the Krušné hory Mts. Study was completed with the results of investigation of quantity and quality of forest-floor (humus) horizons and litter-fall under these stands. Possible nutrient loss after removal above-ground biomass for chipping is discussed.

Fig. 1. Location of the Krušné hory Mts. in the frame of Central Europe

2. Material and methods

Presented study is based on long-term observation managed by Forestry and Game Management Research Institute (Research Station at Opocno) in the Krušné hory Mts., Czech Republic. Compilation of our previous studies was completed with unpublished data. Results from three long-term experiments (table 1) were used for presented study. These experiments were established in substitute stands of common birch (location Fláje I), blue spruce (location Fláje II) and European larch (location Kalek) in 1989, 1996 and 1999, respectively. Experiments consist of partial plots with different thinning regimes but for our study, only control plots without thinning were used. In the frame of presented study we evaluate three parts of the biomass (and consequently nutrients) cycle – above-ground biomass, biomass of forest-floor and annual litter-fall. Detailed information on experiments, observation methods and periods are mentioned below.

2.1 History of experiments

2.1.1 Blue spruce – experiment Fláje II

Blue spruce is the first of the introduced tree species used for regeneration of clearcuts induced by air pollution since 1967–1968 in the Krušné hory Mts. (Šika, 1976). In contrast with the original habitat in the West of the USA where blue spruce creates unclosed mixed stands, young monocultures (thickets) of blue spruce in the Krušné hory Mts. create closed-canopy stands with unsatisfactory stability and repeated damage by climatic factors (mainly top breaks or windfalls, frost damage, etc.). Deformations and damage of the root system are frequent as well. Furthermore, an adverse effect of blue spruce stands on the forest soil was observed (Podrázský et al., 2003). On the other hand, the present blue spruce stands comply with the main objectives of cultivation of substitute tree species stands, i.e. they create more favourable microclimatic conditions for the gradual regeneration of forest stands by target tree species (Balcar & Kacálek, 2003).

Thinning experiment Fláje II was established in 1996 (Slodičák & Novák 2001, 2008). The blue spruce stand is situated on a south-facing gentle slope, 770 m above sea level in the spruce (8th) forest vegetation zone (*Piceetum acidophilum – Avenella flexuosa* according to Viewegh et al., 2003, table 1). The soil type was classified as cambisol modal oligotrophic. Mean annual temperature is 5.5-6.0°C; the mean sum of precipitation is ca 900 mm (for the period of 1961–2000). An experimental blue spruce stand was established by mound planting at initial spacing 2 × 2 m – 2,500 trees per ha (figure 2).

Species	Location	Elevation (m)	Forest site according to Viewegh et al. (2003)	Mensurational characteristics of the stands				
				Age and year of measurement	N (trees.ha-1)	G (m2.ha-1)	d (cm)	h (m)
Blue spruce	50°41´53´´ 13°37´52´´	770	*Piceetum acidophilum – Avenella flexuosa*	22 years (2006)	2 022	17.7	10.2	5.7
European larch	50°35´11´´ 13°21´11´´	780	*Piceeto-Fagetum oligo-mesotrophicum – Calamagrostis villosa*	20 years (2007)	2 140	27.8	12.0	10.8
Common birch	50°41´38´´ 13°35´20´´	800	*Fageto-Piceetum acidophilum – Calamagrostis villosa*	22 years (2003)	1 725	10.9	8.5	9.1

Table 1. Basic data about long-term experiments Fláje II (blue spruce), Kalek (European larch) and Fláje I (common birch) in the Krušné hory Mts.

The experimental series consists of three comparative plots 0.1 ha in size. Ecological aspects of biomass removal were studied on the control plot without thinning. The experimental stands have been measured (diameter at breast height, height, health condition) annually since 1996. The crown area covered 91% of the stand area at the age of 16 years in 2000. Full coverage of land by crowns (full canopy) was attained in the vegetation period 2001 (Novák & Slodičák 2006a). During the period of investigation, the number of trees on the control plot was practically unchanged (2,078–2,022 trees.ha^{-1}). Basal area on the control plot increased approximately six times during the period of observation from 2.8 to 17.7 m^2.ha^{-1} (at the age of 12–22 years).

Fig. 2. Control unmanaged plots in experimental forest stands in August 2003 – blue spruce 19-year-old (left), European larch 16-year-old (middle) and common birch 22-year-old (right).

Above-ground biomass was studied in August 2006 when the stand was 22-year-old (Slodičák & Novák 2008, table 2). Forest-floor investigation was done in October 2002 (Ulbrichová et al., 2005). Litter-fall was collected 5 years from October 2002 to October 2007 (age of 18-23 years) in this experiment.

Species	Observation (sampling)					
	Above-ground biomass		Forest-floor biomass		Litter-fall	
	Age (years)	Year	Age (years)	Year	Age (years)	Year
Blue spruce	22	Aug 2006	18	Oct 2002	18 - 23	Oct 2002 – Oct 2007
European larch	20	Aug 2007	19	Oct 2006	16 - 19	Aug 2003 – May 2007
Common birch	22	2003*	21	Oct 2002	22 - 25	Sept 2003 – May 2007

Table 2. Summary of observations included in presented study in substitute stands of blue spruce, larch and birch in the Krušné hory Mts. *Above-ground biomass was calculated for this year and age by published equations (see methods).

2.1.2 European larch – experiment Kalek

In the Krušné hory Mts., larch is referred to as a target tree species in the beech with spruce (6th) forest vegetation zone and as a transition from target to substitute tree species in the spruce with beech (7th) forest vegetation zone. As a rule, the larch stands are not envisaged to be subjected to stand conversion and, therefore, proper attention must be paid to their tending.

Thinning experiment Kalek was established in 1999 to investigate the tending of young larch stands in the Krušné hory Mts. (Novák & Slodičák 2006b). The stand is located in the beech with spruce (6th) forest vegetation zone at an elevation of 780 m a.s.l. in the fresh, medium-nutritive category (*Piceeto-Fagetum oligo-mesotrophicum – Calamagrostis villosa* according to Viewegh et al. 2003, table 1). The soil type was classified as Entic Podzol. Mean annual temperature is 5.5-6.0°C; the mean sum of precipitation is ca 800 mm (for the period of 1961–2000).

An experimental larch stand was established by line planting (at initial spacing 1 × 1.5 m – 6,667 trees per ha) after mechanical raking of slash to windrows (figure 2), i.e. planted area was practically without former forest-floor. The experimental series consists of four comparative plots 0.04–0.05 ha in size. Ecological aspects of biomass removal were studied on the control plot without thinning. The experimental stands have been measured (diameter at breast height, height, health condition) annually since 1999.

In the period of investigation (2000–2007, age of 13–20 years), the number of trees decreased from 3,400 to 2,280 trees.ha^{-1} (33%) by salvage cutting in control unthinned plot. Basal area in control plot increased approximately twice in the period of observation (from 14.3 to 28.6 m$^{2}\cdot$ha^{-1} at the age of 13–20 years).

Above-ground biomass was studied in August 2007 when the stand was 20-year-old (Novák et al., 2011, table 2). Forest-floor investigation was done in October 2006. Litter-fall was collected 4 years from August 2003 to May 2007 (age of 16-19 years) in this experiment.

2.1.3 Common birch – experiment Fláje I

Thinning experiment Fláje I was established in 1989 to investigate the tending of substitute birch stands in the Krušné hory Mts. (Slodičák & Novák 2001). The stand is located on the south-facing slope in the spruce with beech (7th) forest vegetation zone at an elevation of 800 m a.s.l. in the acid category (*Fageto-Piceetum acidophilum – Calamagrostis villosa* according to Viewegh et al. 2003, table 1). The soil type was classified as cambic leptosol. Mean annual temperature is 5.5-6.0°C; the mean sum of precipitation is ca 900 mm (for the period of 1961–2000).

An experimental birch stand was established by seeding (figure 2). The experimental series consists of four comparative plots 0.04–0.10 ha in size. Ecological aspects of biomass removal were studied in the control plot without thinning. The experimental stands have been measured (diameter at breast height, height, health condition) annually since 1990.

In the period of investigation (1990–2003, age of 9–22 years), the number of trees decreased from 8,825 to 1,725 trees.ha^{-1} (80%) by salvage cutting in control unthinned plot. Basal area in control plot increased approximately twice in the period of observation (from 5.8 to 10.9 $m^2 \cdot ha^{-1}$ at the age of 9–22 years).

Above-ground biomass was calculated (see below) for year 2003 when the stand was 22-year-old, table 2). Forest-floor investigation was done in October 2002 (Ulbrichová et al., 2005). Litter-fall was collected 4 years from September 2003 to May 2007 (age of 22-25 years) in this experiment.

2.2 Above-ground biomass investigation

As for blue spruce and European larch stands above-ground biomass was evaluated using previous studies (Slodičák & Novák, 2008, Novák et al., 2011), which were done by destructive analysis directly in mentioned experiments. Above-ground biomass was observed quantitatively (dry mass – total and by particular fractions) and qualitatively (amount of nutrients). Detailed methods are described in the mentioned studies.

Birch stand was not observed by detailed study of above-ground biomass. Therefore total above-ground biomass was calculated using known diameter structure at the age of 22 years (2003) and published equations (Varik et al., 2009) for 14-year-old birch stand with similar mensurational parametres:

$$Y = 121.59 \times d^{2.376} \qquad (1)$$

where Y is the amount of dry mass (in g) and d is diameter at breast height 1.3 m (in cm).

Quality of above-ground biomass (amount of nutrients) was not calculated for this tree species.

2.3 Forest-floor investigation

Forest-floor layers were observed directly in the experiments. Results from blue spruce and birch (sampling in October 2002) were published by Ulbrichová et al. (2005). Investigation in larch stand was done in October 2006 and the results are still unpublished. The uniform methods were used in all observed stands.

The samples were collected using steel frames (25x25 cm) to define sampling areas at four replications in all plots. Forest-floor humus horizons (L = fresh litter including herbal vegetation, F = fermented litter and H = humified litter) were investigated quantitatively and qualitatively.

All samples were dried, first under conditions of open air, later in a laboratory oven at 70°C, and dry samples were subsequently weighed. Nutrient content was assessed from composite samples from each layer (after mineralization by mineral acids). Total Nitrogen (N) concentration was analyzed by Kjehldahl procedure and Phosphorus (P) concentration was determined colorimetrically. An atomic absorption spectrophotometer was used to determine total Potassium (K) concentration by flame emission, and Calcium (Ca) and Magnesium (Mg) by atomic absorption after addition of La. Nitrogen content was assessed from composite samples (three per treatment) after mineralization by mineral acids and analysed using Kjeldahl procedure.

2.4 Litter-fall investigation

Litter-fall was collected using three steel litter collectors with an individual area of 0.25 m^2 (birch and larch) or 0,50 m^2 (blue spruce) installed within each of observed stands. The samples were taken twice to fourth times per year during the period of observation (table 2). All samples were dried, first under conditions of open air, later in a laboratory oven at 70°C, and dry samples were subsequently weighed. Nutrient content was assessed from composite samples from each sampling. As for forest-floor layers, the same laboratory methods for nutrient content investigation were used (see chapter 2.3). We calculate annual litter-fall (quantitatively and qualitatively) for individual stands and periods of observation.

3. Results and discussion

3.1 Quantity of biomass

3.1.1 Above-ground biomass

We found that 20-22-year-old substitute stands contain per hectare from 40.3 to 102.2 t of above-ground (dry) biomass (figure 3). The lowest amount of above-ground biomass was observed in birch stand (40,270 $kg.ha^{-1}$). Biomass accumulated in above-ground part of blue spruce stand was about 40% higher (56,237 $kg.ha^{-1}$). The highest amount (about 154% compared to birch stand) was found in the larch stand (102,215 $kg.ha^{-1}$). These results correspond with forest site classification in observed experiments. Lower vegetation zone (6^{th} – *Piceto-Fagetum*) in larch stand means better growth conditions compared to higher vegetation zone (8^{th} – *Piceetum*) in birch stand. For example, Li et al. (2003) found a relationship between aboveground biomass and elevation in larch stands, Tyrol (Austria). European larch stands (27-years-old) situated at the elevation of 1,680, 1,810 and 1,940 m showed aboveground biomass (without stumps) 135 t, 61 t and 20 t per hectare, respectively. In literature, total aboveground biomass of larch stands ranges from 80 $t.ha^{-1}$ in 50-60-years-old stand (Young et al., 1980, as cited in Burrows et al., 2003), 158 $t.ha^{-1}$ in 28-years-old stand (Komlenović, 1998) to 216 $t.ha^{-1}$ in 35-36-years-old stand (Eriksson & Rosen, 1994).

For common birch, above-ground biomass shows also a wide range of published results: 31 $t.ha^{-1}$ for 8-year-old stand (Uri et al., 2009), 20-66 $t.ha^{-1}$ (on fine sand) and 31-53 $t.ha^{-1}$ (on clay soil) for 12-year-old stand (Johansson, 2007) and 40 $t.ha^{-1}$ for 14-year-old stand (Varik et al., 2009).

For blue spruce similar data was not published in the Czech Republic. We can compare it only with similar studies in young Norway spruce (*Picea abies* [L.] Karst.) stands. Results of these studies showed higher values of aboveground biomass of Norway spruce stands – 14-year-old stand ca 65 $t.ha^{-1}$ (Chroust, 1993), 20-years-old stand ca 85 $t.ha^{-1}$ (Chroust & Tesařová 1985) or 24-years-old stand ca 79 $t.ha^{-1}$ (Vyskot, 1980). The difference is caused mainly by stand density and consequently by different characteristics of mean stem. Generally, the mean stem of blue spruce stand was shorter, but thicker than the mean stem of Norway spruce.

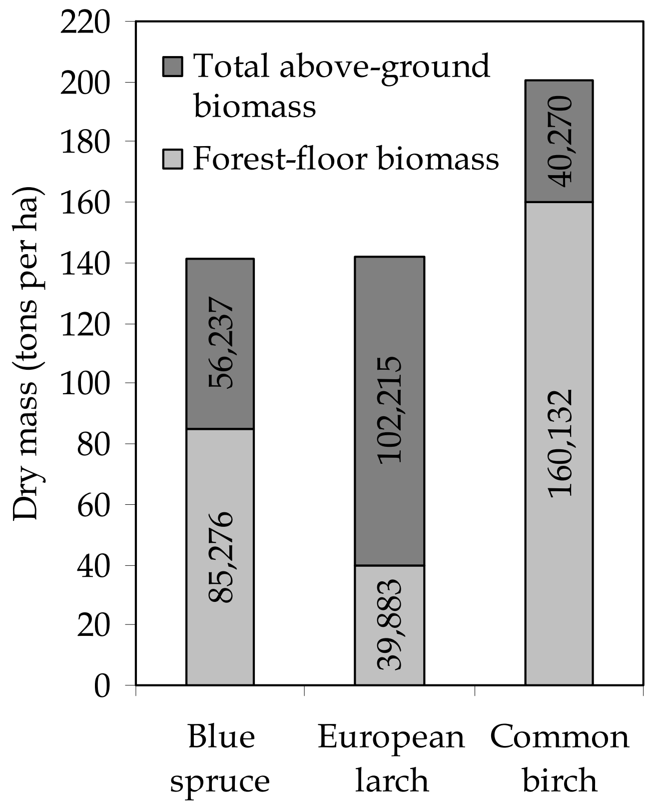

Fig. 3. Amount of above-ground and forest-floor biomass by species.

Despite the former and current air-pollution load (for all species) and raking of forest floor before planting (for larch), the amount of aboveground biomass produced by 20-22-year-old substitute stands of blue spruce, larch and birch is comparable with the results observed in corresponding stands on the other undisturbed sites.

3.1.2 Forest-floor

Dry-weight of forest-floor is undoubtedly influenced by history before planting (or seeding). Larch stand was planted on site without former humus layers (see methods) and consequently, amount of dry mass in humus horizons (L+F+H) under 19-year-old stand was small (39,883 kg.ha^{-1}) compared to other species (figure 3).

Humus horizons under 18-year-old blue spruce stand contained about 114% higher amount of dry mass (85,276 kg.ha^{-1}) compared to larch stand. The highest amount of dry mass was observed in humus horizons under 21-year-old birch stand (160,132 kg.ha^{-1}).

Under both blue spruce and birch stands, part of current humus layers is inherited from previous (probably Norway spruce) stands. Additionally, high stock of dry-mass in humus layers under birch may be caused by worse climatic conditions (lower temperatures) of 8th vegetation zone, i.e. slower process of decomposition.

We can compare these results with previous studies from Norway spruce monocultures, which were common in the Krušné hory Mts. before substitute stands. Humus horizons (L+F+H) under 30-35-year-old Norway spruce stands in similar growth conditions (6-7th

forest vegetation zone) contain per hectare from 195 t (Novák & Slodičák, 2004) to 202 t (Dušek et al., 2009) of dry mass. These stands were located on continually forest soil without site preparation before planting. Therefore, it mainly corresponds with results from birch stand, because of similar site and soil conditions.

3.1.3 Litter-fall

We found that annual litter-fall in young substitute stands reaches 2-5 t.ha^{-1} (figure 4). The lowest annual litter-fall was observed under 22-25-year-old birch stand (2,317 kg.ha^{-1}). Approximately two times higher amount of annual litter-fall was found under blue spruce (4,923 kg.ha^{-1}) and larch (4,216 kg.ha^{-1}) stand.

There is possibility to compare these results with studies from Norway spruce monocultures. Observed values of mean annual litter-fall (2-5 t.ha^{-1}) correspond to range of values 1.1 – 5.7 t.ha^{-1} reported by many authors (Bille-Hansen & Hansen, 2001, Berg & Meentemeyer, 2001, Novak & Slodicak, 2004, Hansen et al., 2009).

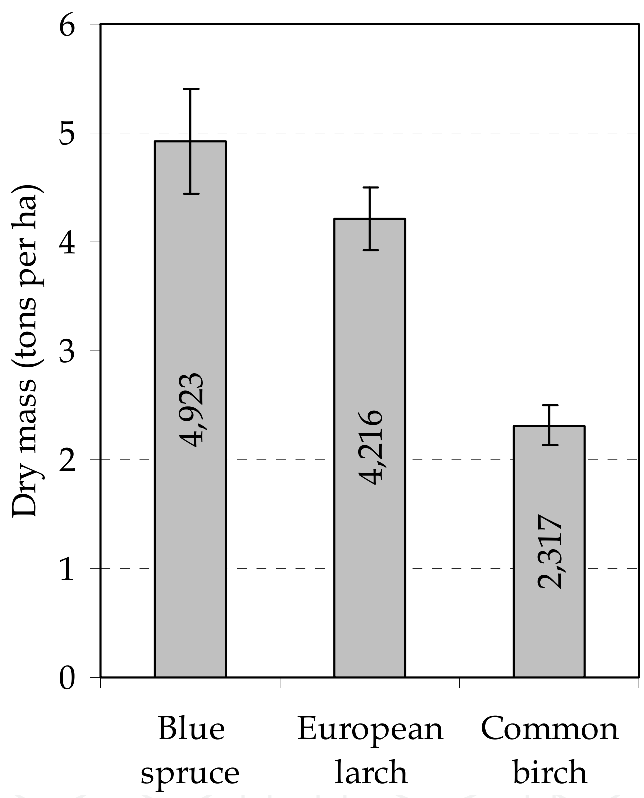

Fig. 4. Annual litter-fall in young substitute stands in the Krušné hory Mts. (means with standard deviations)

3.2 Quality of biomass

Amounts of main nutrients (N, P, K, Ca, Mg) in the individual parts of biomass cycle were compared for all three observed stands (table 3).

3.2.1 Blue spruce

Under blue spruce stand forest-floor contains per hectare about 1,082 kg of N, 86 kg of P, 176 kg of K, 22 kg of Ca and Mg. Total amount of Nitrogen (336 kg.ha^{-1}), Phosphorus (28 kg.ha^{-1}) and Pottassium (138 kg.ha^{-1}) was lower (about 69%, 67% and 22%, respectively) in above-ground biomass compared to forest-floor. On the other hand, above-ground biomass contains strongly higher amount of Ca (about 612%) and Mg (28%) compared to forest-floor.

Totally 48 kg of N, 3 kg of P, 4 kg of K, 42 kg of Ca and 2 kg of Mg was returned by annual litter-fall under observed blue spruce stand. For N, P, K and Mg it represents only about 2-7% of amount accumulated in forest floor. In the case of Ca we found higher amount of this nutrient (about 87%) in annual litter-fall compared to amount in forest-floor.

Thus, removal of above-ground biomass of observed blue spruce stand (totally or partly by thinning) may result in nutrient losses, especially Ca and Mg because of their low content in forest soil compared to content in above-ground biomass.

Species	Part of ecosystem	Nutrients (kg per hectare)				
		N	P	K	Ca	Mg
Blue spruce	Above-ground biomass	335.5	28.3	138.3	158.7	27.8
	Forest-floor	1082.3	85.9	176.4	22.3	21.7
	Annual litter-fall	48.0	2.9	4.4	41.8	1.5
European larch	Above-ground biomass	307.0	21.0	136.0	122.0	53.0
	Forest-floor	383.9	23.4	195.8	50.3	135.9
	Annual litter-fall	52.6	3.8	5.3	17.7	7.9
Common birch	Above-ground biomass	No data				
	Forest-floor	2026.2	123.5	373.6	72.8	51.6
	Annual litter-fall	39.4	2.2	2.7	5.5	1.8

Table 3. Nutrient content in above-ground biomass, forest-floor and annual litter-fall by species.

3.2.2 European larch

Forest-floor contains per hectare about 384 kg of N, 23 kg of P, 196 kg of K, 50 kg of Ca and 136 kg of Mg under larch stand (table 3). Similarly as in blue spruce stands total amount of Nitrogen (307 kg.ha^{-1}), Phosphorus (21 kg.ha^{-1}) and Pottassium (136 kg.ha^{-1}) was lower (about 20%, 10% and 31%, respectively) in above-ground biomass compared to forest-floor. Amount of Mg (53 kg.ha^{-1}) was obviously lower (about 61%) in above-ground biomass compared to forest floor. On the other hand, above-ground biomass contains higher amount of Calcium (about 143%) compared to forest-floor.

Totally 53 kg of N, 4 kg of P, 5 kg of K, 18 kg of Ca and 8 kg of Mg was returned by annual litter-fall under observed larch stand. For K and Mg it represents only about 3 and 6% of amount accumulated in forest-floor. Annual litter-fall contains about 14, 16 and 35% of N, P and Ca, respectively, compared to amount of these nutrients stored in forest-floor.

There are two general aspects in the case of nutrient status in observed larch stand. First, in contrast to blue spruce and birch stand, larch stand was established by planting on nearly mineral soil, when former forest-floor was almost completely removed after mechanical raking of slash to rows. It means that current forest-floor is a result only of litter-fall accumulation and decomposition during the age of current stand.
Second aspect is former liming management in the Krušné hory Mts., especially where experimental larch stand is located. The dolomite with increased amount of Mg (minimum amount of MgO is 17%) was used for liming (about 3 $t.ha^{-1}$) in the past. Last aerial application was done in mentioned locality in 2006 (Šrámek et al., 2008b).
Whilst the amount of Mg is high (mainly due to previous liming) in forest floor under observed larch stand, we cannot recommend removal of above-ground biomass mainly because of possible losses of Ca, which is highly represented in above-ground biomass and consequently in litter-fall. In the detailed study (Novák & Slodičák, 2011) we found, that more than 50% of Ca amount in above-ground biomass is stored in needles and branches. Therefore, we can recommend utilisation of larch stems only for chipping in the framework of thinning. Other aboveground biomass (mainly needles and branches) should be left in a forest ecosystem for decomposition.

3.2.3 Common birch

Under birch stand forest-floor contains per hectare about 2 026 kg of N, 124 kg of P, 374 kg of K, 73 kg of Ca and 52 kg of Mg. Above-ground biomass for birch stand was calculated by published equations (Varik et al., 2009) by real diameter distribution because we do not have data from exact study of above-ground biomass in observed birch stand. Mentioned equation was used for dry mass calculation only because we knew that each allometric equation did not compare favourably with other equations available in the literature and we agree with the recommendation of Gower et al. (1987), who suggested that discretion must be exercised when applying regression equations to other areas than where they were developed. Thus, amount of nutrients in above-ground biomass was not calculated for this species.
Totally 39 kg of N, 2 kg of P, 3 kg of K, 6 kg of Ca and 2 kg of Mg was returned by annual litter-fall under observed birch stand. For N, P, K and Mg it represents only about 1-3% of amount accumulated in forest floor. On the other hand, annual litter-fall contains about 8% of Ca compared to amount of these nutrients stored in forest-floor.
Summary of the results from birch stand is influenced by unknown amount of nutrients in above-ground biomass. However, on the basis of forest-floor and litter-fall observations we can conclude that removal of above-ground biomass may be possible because of relatively good amount of nutrients in forest-floor, which partly consists of humus accumulated under previous (Norway spruce) stand. On the other hand dry-mass of above-ground biomass is relatively low (about 40 $t.ha^{-1}$) and probably economically unfavourable. Furthermore, high mortality was found since 2003 in observed birch stand (Novák & Slodičák, 2006a).

4. Conclusion

Management of biomass removal in forests should be connected with knowledge about nutrient cycle in the forest ecosystem mainly in the localities with damaged soils.

This problem was illustrated by the example of the forest stands of substitute tree species (blue spruce, European larch and common birch), which were established in the Krušné hory Mts. (Czech Republic) on the sites where the declining Norway spruce monocultures could not be replaced by ecologically suitable tree species due to continual air pollution impact and damaged forest soils. On the basis of presented study we can conclude:

- Despite the former and current air-pollution load and (in the case of larch stand) raking of forest floor before planting, the amount of aboveground biomass produced by substitute 20-22-year-old blue spruce, larch and birch stands is comparable with the results observed in similar stands on the other undisturbed sites.
- Above-ground biomass represents important pool of nutrients in the frame of nutrient cycle of observed forest ecosystems.
- Forest-floor contains low amount of Ca and Mg under observed stands regardless of different history, i.e. both on sites with removal of former forest-floor before planting (larch stand) and on sites with continual forest-floor (blue-spruce and birch). Only exception was found under larch stand for content of Mg in forest-floor but it was probably caused by previous liming.
- Dry mass of annual litter-fall (2-5 $t.ha^{-1}$) is comparable with the results observed in similar stands in other undisturbed sites. Nutrients N, P, and K from annual litter-fall represent 1-3% compared to total nutrient stock in forest-floor. In the case of larch stand creating a new forest-floor these values were higher for N and K (14-16%). On the other hand amount of Mg in litter-fall represents 3-7% compared to amount in forest-floor. For Ca, results were different. Under birch stand about 8% of Ca was returned by annual litter-fall. For larch stand (removal of forest-floor before planting) this value reached 35%. Under blue spruce stand, amount of Ca from annual litter-fall was even about 87% higher compared to total nutrient stock in forest-floor.
- The removal of biomass for chipping in areas previously degraded by acid deposition may result in the deficiency of Ca and Mg because of their important content in above-ground biomass (and consequently in litter-fall) and low content in forest soil.
- Thinning and removal of some parts of trees (mainly stems) for chipping could be possible way in above-mentioned stands, because thinning supports the faster growth of trees left after thinning and consequently faster biomass and nutrient accumulation.

Our results about possible risk of removal of total above-ground biomass in some formerly damaged localities can be interesting and usable in the frame of common investigation of biomass. For further investigation of the effect of biomass removal on nutrient cycle in forest ecosystems mainly in the localities with damaged soils, more detailed (and replicated) analyses are needed (especially focused on below-ground biomass and nutrient content in lower soil horizons).

5. Acknowledgment

This study was supported by the long-term project of the Czech Ministry of Agriculture MZE-0002070203 "Stabilisation of forest functions in anthropically disturbed and changing environmental conditions" and NAZV QH91072 "Role of tree species and silviculture measures in forest soil formation".

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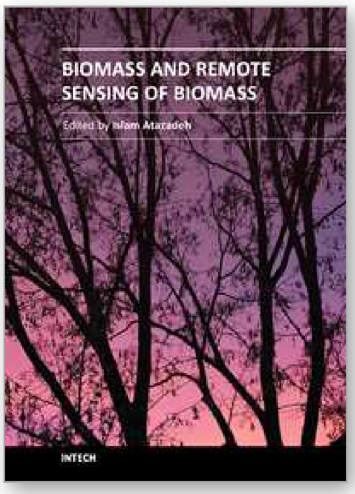

Biomass and Remote Sensing of Biomass
Edited by Dr. Islam Atazadeh

ISBN 978-953-307-490-0
Hard cover, 262 pages
Publisher InTech
Published online 06, September, 2011
Published in print edition September, 2011

Generally, the term biomass is used for all materials originating from photosynthesis. However, biomass can equally apply to animals. Conservation and management of biomass is very important. There are various ways and methods for biomass evaluation. One of these methods is remote sensing. Remote sensing provides information about biomass, but also about biodiversity and environmental factors estimation over a wide area. The great potential of remote sensing has received considerable attention over the last few decades in many different areas in biological sciences including nutrient status assessment, weed abundance, deforestation, glacial features in Arctic and Antarctic regions, depth sounding of coastal and ocean depths, and density mapping. The salient features of the book include:
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Jiří Novák, Marian Slodičák, David Dušek and Dušan Kacálek (2011). Ecological Aspects of Biomass Removal in the Localities Damaged by Air-Pollution, Biomass and Remote Sensing of Biomass, Dr. Islam Atazadeh (Ed.), ISBN: 978-953-307-490-0, InTech, Available from: http://www.intechopen.com/books/biomass-and-remote-sensing-of-biomass/ecological-aspects-of-biomass-removal-in-the-localities-damaged-by-air-pollution

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