BIOMASS PRODUCTION OF SELECTED GRASSLAND, WETLAND AND CROPLAND VEGETATION COMMUNITIES

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Abstract. Biomass production is a generally well-studied phenomenon but it often only focuses on simple habitats such as monodominant wetland communities. Information on aboveground biomass production of various managed and unmanaged communities was necessary for a research project called the “Minimization of Radioactive Contamination Impacts on the Landscape in the Emergency Planning Zone of the Temelín Nuclear Power Plant” to create growth models of selected plant communities to estimate the amount of biomass potentially contaminated by radiation in case of a nuclear power plant accident. In the present paper we introduce the results of biomass sampling carried out in the vegetation season of 2013 and compare it with the previously published data. Especially the curve shapes could be well compared where the relevant data was found in literature, namely in the case of monodominant wetland communities. In cases where the data on seasonal production was not available (e.g. Filipendula stands) the peak values were compared and found to correspond well, too. There was no relevant published data to be found for 9 stand types (some rich-in-species grasslands and crops); together with detailed description of the sampled stands the original data on the aboveground biomass production is published for the first time.
Keywords: *production curves; grassland stands; wetland stands; arable croplands*

Introduction

Primary production of plant biomass is a crucial basis for other ecosystem processes. It is strongly related to the flow of matter through an ecosystem (Mooney, 1991) and thus plays a key role in landscape functions (Wiegand et al., 2004). Besides the physiology of plants forming a plant community and their ecologic strategies biomass production is significantly influenced by environmental factors such as climate and microclimate and the resulting water supply (Palmer and Yunusa, 2011), soil properties, especially the nutrient regime (Čížková et al., 2001) and pressure from the herbivores (Moise and Henry, 2012) or – in case of agricultural ecosystems – an extra supply of nutrients, harvest and other farming practices (Heggenstaller et al., 2009).

The methods to determine biomass production can be generally divided into destructive and non-destructive types. Belowground (root) biomass is usually determined by destructive methods such as monoliths (dug samples) or sampling tubes where the soil is subsequently washed out (Dykyjová, 1989; Rychnovská, 1987). Destructive sampling of aboveground biomass is based on the removal of plants from a square plot of a precisely defined surface (for grass communities it is generally between

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0,25 x 0,25 and 1 x 1 m, cf. Dykyjová, 1989; Rychnovská, 1987). With helophytes, which often tend to form clusters, the sampling plots have to be larger than the average clusters (Ondok and Dykyjová, 1973; Ondok and Květ, 1978). Sampling plots can be distributed either randomly on the site, which requires more samples to capture the differences in plant size or density in various conditions (especially when it comes to nutrients and water availability). The second approach uses sample plots located at transects along the ecological gradients; this method is more advantageous as it requires less sampling plots.

Non-destructive methods – or rather a combination of both approaches – are based on the estimation of the aboveground biomass counting the number of stalks and/or plant leaves in a sampling plot, and multiplying it by the average weight of the relevant plant parts harvested from the neighbouring plants outside the plot (Ondok and Květ, 1978; Květ and Westlake, 1998). If the plots are held as permanent and the outside harvest is carried out in regular (usually monthly) intervals, the seasonal dynamics of biomass production can be observed (Ondok and Dykyjová, 1973).

There are also indirect methods to estimate the biomass production. One of the indices describing both the plant productivity and biogeochemical fluxes between vegetation and the atmosphere is the leaf area index (LAI) (Bréda, 2003). Together with the above described in-situ biomass sampling it is also often a subject of remote-sensing based estimations of biomass production in the landscape (Na et al., 2003; Cook et al., 2009) or the global scale.

The biomass production values can be obtained in various forms depending on the aim of the study, selected method and other circumstances influencing the experimental design. The biomass amount can be expressed as peak (i.e. the maximum) value or total (sum) value of the biomass produced by a plant community throughout the growing season (Scurlock et al., 2002). The seasonal variability of biomass production and its dynamics can be observed using growth models (e.g. Rosef and Bonesmo, 2005), which requires regular harvest of accumulated biomass during the growing season.

Biomass production and plant productivity were initially studied as a part of an overall ecological research of selected important biotopes. A broad research on productivity of terrestrial, freshwater and marine biotopes was launched as one of the chapters of the International biological program (IBP). A great amount of measurements of biomass production and productivity, vegetation density, LAI and other indicators (such as shoot length, inflorescence number, etc.) of both individual species and communities was gathered in the Czech Republic under this research project (cf. e.g. Hejný et al., 1970; Rychnovská, 1972; or Dykyjová and Květ, 1978). The campaign of such an extent and aim is rather unimaginable nowadays: biomass production is studied as a component of crop yield (Heggenstaller, 2009), an indicator of the plant potential as an energetic source (Bentsen et al., 2014) or a carbon sink (Aosaar et al., 2013).

The data on biomass production presented in this paper were collected in order to create the growth models of selected plant communities to estimate the amount of biomass potentially contaminated by radiation in case of a nuclear power plant accident (Brom et al., 2013); the actual amount of contaminated biomass which would be necessary to harvest, transport and decontaminate or safely store and its spatial distribution are some of the key parameters to design later phases of emergency planning aimed at landscape decontamination. As one of the objectives of the research project “Minimization of Radioactive Contamination Impacts on the Landscape in the Emergency Planning Zone of the Temelín Nuclear Power Plant” the grassland, wetland

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and crop vegetation communities at selected sites located in the Emergency Planning Zone of the Temelín Power Plant (south of the Czech Republic) were measured during the growing season 2013 in suitable intervals. There are a few studies covering this diversity of biotopes and presenting the primary values. The preliminary results of the aboveground biomass productivity of the studied biotopes are also compared with the relevant values obtained through a literature review.

Methods

Selection of permanent sample plots for aboveground biomass sampling

Preliminary plot selection was restricted to three model catchments of Žimutice, Knín and Krč (*Fig. 1*) located in the Temelín Nuclear Power Plant Emergency Planning Zone; it was based on the screening of the Natura 2000 maps and Land Parcel Identification System (LPIS) database. The final selection of the plots was done during the field survey in March 2013.

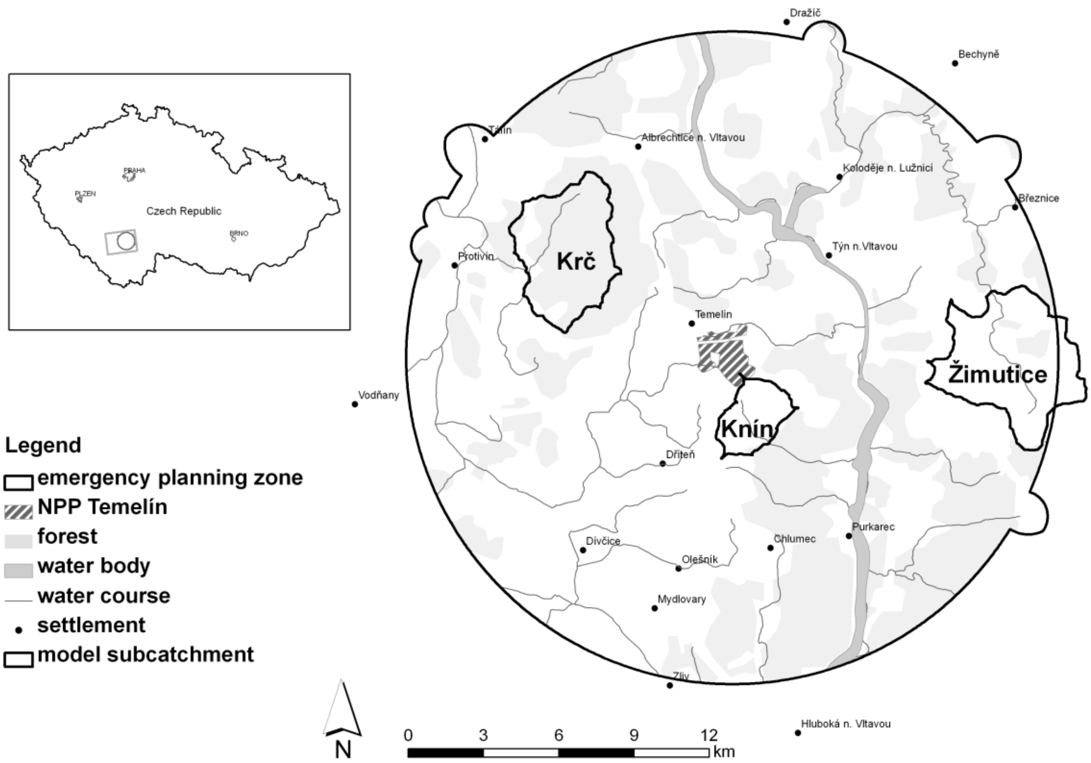

Figure 1. *Localization of the model catchments in Emergency planning zone of NPP Temelín and position of the zone in Czech Republic. The sampling sites of Filip-1, Cirs-2, Allop-3, ReedT-4, Oilseed-5, WheatW-6, WheatS-7, IntensM-8 and Maize-21 are situated in the Žimutice catchment, the ReedL-9, Glyc-10, Typha-11 and Carex-12 belong to the Knín catchment, and Filip-13, Typha-14, Carex-15, Cirs-16, Glyc-17, Allop-18, ReedT-19 and Arrhen-20 to the Krč catchment.*

The overall climatic parameters of the studied area during the 2013 vegetation season are given on *Fig. 2*.

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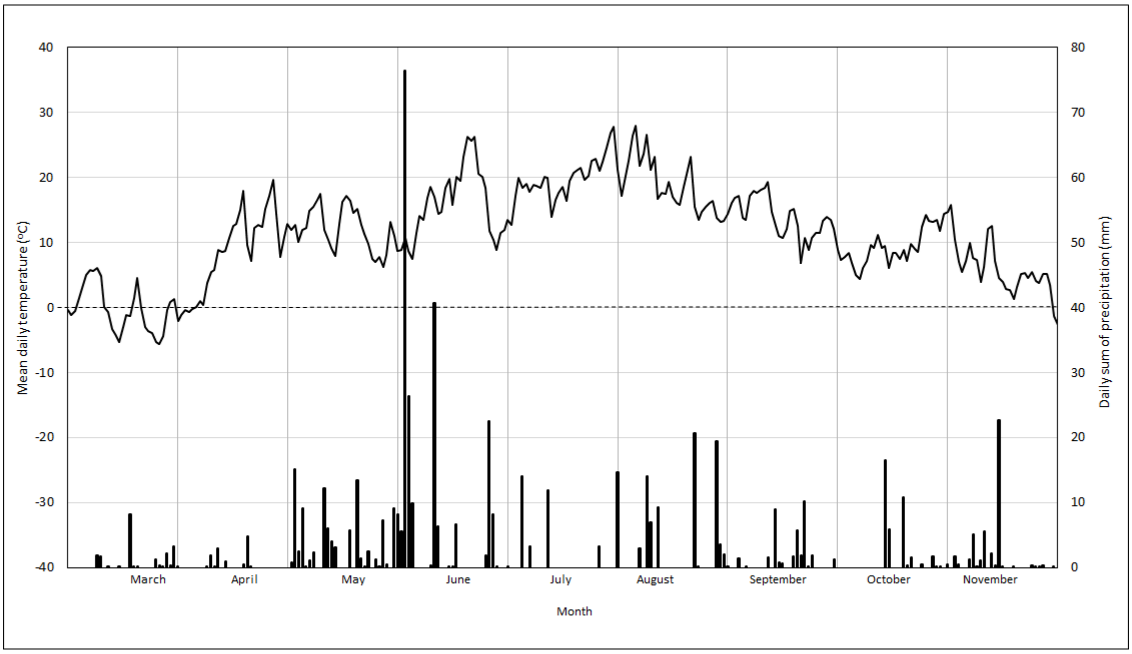

***Figure 2**. Daily sum of precipitation (columns) and mean daily temperatures (curve) in the Emergency planning zone area in the vegetation season of 2013 (source: Czech Hydrometeorological Institute)*

21 vegetation stands in total were selected covering a wide variety of natural conditions (from freshwater to terrestrial biotopes) and types of land use (agricultural arable and grassland stands and non-agricultural semi-natural and natural non-forest vegetation). Agricultural crops were sampled on a one-plot-per–crop basis given their low production variability. Four crop species were selected covering the largest area of the arable land in the Emergency Planning Zone, i.e. winter crop (the "WheatW-6" sampling site), spring crop ("WheatS-7"), oilseed rape ("Oilseed-5") and maize ("Maize-21").

The grassland stands were sampled along the gradient from a dry to wet grassland. The sample sites were selected to cover each wetness level by two stands (e.g. dry grasslands are represented by the "Intensively managed meadows"[1] ["IntensM-8"] and the "Mesic *Arhenatherum* meadows" ["Arhen-20"]). Pairs of the sites are also situated to cover the "agricultural" (Žimutice and Knín) and "natural" (Krč) model catchments.

In the present work we studied unmanaged stands such as the "Wet *Filipendula* grassland" ("Filip-1", "Filip-13") and "Wet *Cirsium* meadow" ("Cirs-16") which was not mowed. The managed stands were represented by a mowed "Wet *Cirsium* meadow" ("Cirs-2"), "Alluvial *Alopecurus* meadow" ("Alop-3", "Alop-18"), "Mesic *Arrhenatherum* meadow" ("Arrhen-20") and "Intensively managed meadow" ("IntensM-8"). All these meadows were mowed twice in the observed period, and the "IntensM-8" was even cropped in the autumn.

Natural and semi-natural grassland communities were represented by the "Wet *Cirsium* meadows", T1.5 ("Cirs-16"), "Wet *Filipendula* grasslands", T1.6 ("Filip-1", "Filip-13"), "Tall-sedge beds", M1.7 ("Carex-12", "Carex-15") and "Reed beds of

[1] The nomenclature and codes of the vegetation stands follow the Habitat catalogue of the Czech Republic (Chytrý et al., 2010), designed for the NATURA 2000 habitat mapping.

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eutrophic still waters”, M1.1 (“ReedT-4”, “ReedL-9”, “Glyc-10”, “Typha-11”, “Typha-14”, “Glyc-17”, “ReedT-19”). A short description of the communities both according to Chytrý et al. (2010) and our relevés performed on the studied habitats together with type of management of the sites is given in the following text and in *Tab. 1*.

Table 1*.Management type and phytocenologic characteristic of the sampled stands.M, J, S – cover (in percent) and number of species in May, July and September.Ratio (G:L:F) – proportion of grasses, legumes and herbaceous plants; the grasses group besides the Poaceae grasses involves also Cyperaceae, Juncaceae and Typhaceae. The percentage at the individual species represents the average cover calculated from all the three relevés. Diagnostic species are listed after Chytrý et al.(2010).*

	Management	Cover (M, J, S, %)	Number species (M, J, S)	Ratio G:L:F	Dominant species (%)	Species with cover higher than 5%	Diagnostic species (%)
ReedL-9	unmanaged	30, 97.5, 90	1, 2, 1	1:0:1	*Phragmites australis* (72.3)		*Phragmites australis* (72.3)
ReedT-4	unmanaged	10, 51, 95	1, 3, 1	1:0:2	*Phragmites australis* (51.7)		*Phragmites australis* (51.7), *Solanum dulcamara* (0.2)
ReedT-19	unmanaged	17.8, 97.2, 96.6	9, 7, 9	3:0:9	*Phragmites australis* (68.3)		*Phragmites australis* (68.3), *Equisetum fluviatile* (0.2)
Typha-11	unmanaged	12, 46.5, 41.5	3, 5, 4	3:0:2	*Typha angustifolia* (29.3)		*Typha angustifolia* (29.3), *Glyceria maxima* (2.5), *Typha latifolia* (1)
Typha-14	unmanaged	71.3, 65.9, 70.8	7, 6, 5	3:0:5	*Typha angustifolia* (48.3)	*Lemna minor* (20)	*Typha angustifolia* (48.3), *Typha latifolia* (0.5), *Equisetum fluviatile* (0.2)
Glyc-10	unmanaged	70.5, 80.5, 70.5	2, 3, 2	2:0:1	*Glyceria maxima* (72.7)		*Glyceria maxima* (72.7), *Phragmites australis* (1)
Glyc-17	unmanaged	65.9, 78.5, 90	9, 8, 7	3:0:9	*Glyceria maxima* (74)		*Glyceria maxima* (74)
Carex-12	unmanaged	31, 90.5, 76	2, 3, 4	3:0:2	*Carex acuta* (62.7)		*Carex acuta* (62.7), *Phalaris arundinacea* (0.2), *Lysimachia vulgaris* (0.2)
Carex-15	unmanaged	92, 83, 86.1	10, 12, 11	5:1:10	*Carex acuta* (68.3)	*Phalaris arundinacea* (15)	*Carex acuta* (68.3), *Phalaris arundinacea* (15), *Lysimachia vulgaris* (0.5), *Lythrum salicaria* (0.3), *Galium palustra* (0.3), *Peucedanum palustre* (0.1)
Filip-1	unmanaged	92, 95.5, 89	11, 9, 7	4:0:8	*Filipendula ulmaria* (83.3)		*Filipendula ulmaria* (83.3), *Caltha palustris* (0.8), *Scirpus sylvaticus* (0.8), *Lysimachia vulgaris* (0.5), *Alopecurus pratensis* (0.3)
Filip-13	unmanaged	76.2, 89, 95.5	7, 5, 4	1:0:7	*Filipendula ulmaria* (56.7)	*Phalaris arundinacea* (18.3), *Urtica dioica* (9.3)	*Filipendula ulmaria* (56.7), *Caltha palustris* (1.8)
Cirs-16	unmanaged	71, 92.2, 91.2	18, 18, 19	7:1:15	*Scirpus sylvaticus* (46.7)	*Phalaris arundinacea* (10), *Glyceria maxima* (8.3)	*Scirpus sylvaticus* (46.7), *Carex nigra* (2.3), *Deschampsia cespitosa* (2.2), *Cirsium palustre* (1), *Caltha palustris* (0.5), *Sanquisorba officinalis* (0.4), *Galium palustre* (0.3), *Lathyrus pratensis* (0.3), *Poa trivialis* (0.2), *Juncus conglomeratus* (0.2)
Cirs-2	mowing	92.5, 87, 52.5	17, 15, 8	7:3:14	*Scirpus sylvaticus* (36.7)	*Poa trivialis* (28.3)	*Scirpus sylvaticus* (36.7), *Poa trivialis* (28.3), *Carex nigra* (3), *Holcus lanatus* (2), *Alopecurus pratensis* (1.7), *Juncus effusus* (0.7), *Filipendula ulmaria* (0.5), *Ranunculus acris* (0.3), *Rumex acetosa* (0.3), Lychnis *flos-cuculi* (0.3), *Angelica sylvestris* (0.2), Lathyrus *pratensis* (0.2), *Sanquisorba officinalis* (0.2), *Cardamine pratensis* (0.2)
Allop-3	mowing	94, 65.5, 69.5	18, 17, 16	10:2:12	*Poa trivialis* (35)	*Ranunculus repens* (10), *Alopecurus pratensis* (6.7), *Festuca pratensis* (6)	*Poa trivialis* (35), *Ranunculus repens* (10), *Alopecurus pratensis* (6.7), *Festuca pratensis* (6), *Holcus lanatus* (4), *Ranunculus acris* (2.8), *Trifolium hybridum* (2), *Carex hirta* (1.2), *Sanquisorba officinalis* (0.5), *Lychnis flos-cuculi* (0.3), *Cardamine pratensis* (0.2), *Geranium pratense* (0.2)
Allop-18	mowing	74.1, 78.1, 88.3	25, 28, 31	15:3:17	*Festuca rubra* (13.3)	*Poa trivialis* (10), *Ranunculus repens* (8.3), *Lathyrus pratensis* (6.7), *Alopecurs pratensis* (5.8)	*Poa trivialis* (10), *Ranunculus repens* (8.3), *Lathyrus pratensis* (6.7), *Alopecurs pratensis* (5.8), *Holcus lanatus* (4.3), Poa pratensis (4), *Deschampsia cespitosa* (3.3), *Carex hirta* (3), *Ranunculus acris* (1.2), *Lysimachia nummularia* (0.5), *Sanquisorba officinalis* (0.5), *Lychnis flos-cuculi* (0.2), *Scirpus sylvaticus* (0.2), *Festuca pratensis* (0.2), *Glechoma hederacea* (0.1)
Arrhen-20	mowing	81.1, 94, 79.5	23, 21, 18	10:4:12	*Dactylis glomerata* (15)	*Holcus lanatus* (10), *Poa pratensis* (6.7), *Arrhenatherum elatior* (6), *Alopecurus pratensis* (6), *Trifolium pratense* (6), *Festuca rubra* (5),	*Dactylis glomerata* (15), *Holcus lanatus* (10), *Poa pratensis* (6.7), *Arrhenatherum elatior* (6), *Trifolium pratense* (6), *Festuca rubra* (5), *Trisetum flavescens* (5), *Festuca pratensis* (4.3), *Achillea millefolium* (4), *Plantago lanceolata* (3.3), *Rumex acetosa* (1.2), *Anthoxanthum odoratum* (1.2), *Ranunculus acris* (1), *Lotus corniculatus* (0.3), *Saxifraga granulata* (0.2), *Veronica chamaedrys* (0.2), *Lathyrus pratensis* (0.2)
IntensM-8	mowing, grazing	100, 96.5, 36	16, 14, 8	7:2:10	*Taraxacum* sect. *Ruderalia* (40)	*Trifolium repens* (12), *Trifolium pratense* (8.5), *Poa pratensis* (7.3)	
WheatW-6	arable land	80.6, 86, 0	3, 3, 0	2:0:2	*Triticum aestivum* (82.5)		
WheatS-7	arable land	50.3, 82.1, 0	4, 6, 0	2:0:6	*Triticum aestivum* (65)		
Oilseed-5	arable land	98.5, 99.1, 0	3, 4, 0	4:0:0	*Brassica napus* (97.5)		
Maize-21	arable land	5, 16.6, 61.5	1, 9, 3	4:0:6	*Zea mays* (26.7)		

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Reed beds of eutrophic still waters (ReedT-4, ReedL-9, Glyc-10, Typha-11, Typha-14, Glyc-17, ReedT-19)

The littoral vegetation of fishponds, dead river arms and banks of slow-moving river parts, poor in species. They are characteristically dominated by one species determining the physiognomy of the stand; the stands can reach 0,5–4 m in height and the adequate diverse amount of biomass (Chytrý et al., 2010). That is why the community was further classified according to the dominant species into three classes: Reed beds of eutrophic still waters with dominant Phragmites australis (ReedT-4, ReedL-9, ReedT-19), Reed beds of eutrophic still waters with dominnt *Typha angustifolia* and *T. latifolia* (Typha-11, Typha-14) and Reed beds of eutrophic still waters with dominant *Glyceria maxima* (Glyc-10, Glyc-17).

Both the littoral and terrestrial *Phragmites* stands of the ReedL-9, ReedT-4 and ReedT-19 classes belong to this group. The first two stands were relatively typical in terms of their species composition (see *Tab. 1*), with some untypical accompanying species only present in the ReedT-19 class, although their proportion was not high. These were species belonging to the Wet *Cirsium* meadow, e.g. *Scirpus sylvaticus*, *Cirsium palustre*, *Galium palustre*, and also ruderal species (*Urtica dioica*).

The Glyc-10 was a typical stand of its biotope type according to Chytrý et al. (2010) (see *Tab. 1*). The Glyc-17 species composition was more variable with *Glyceria maxima* as a dominating species but there was also a small proportion of the Tall sedge bed species such as *Carex rostrata*, *Peucedanum palustre* or ruderal species (*Urtica dioica, Cirsium arvense*).

Tall-sedge beds (Carex-12, Carex-15)

The stands dominated by tall sedges are typically situated on littoral shallows and banks of fishponds, river arms in late stages of succession, inundated river and stream alluvia or waterlogged depressions on meadows. Frequently they adjoin the eutrophic *Phragmites* stands (Chytrý et al., 2010).

Carex-12 and Carex-15 were both adjacent to the littoral reed stands. The water level had been under the soil surface for most of the year, which probably led to the absence of wetland species and the dominance of some ruderal species such as the *Urtica dioica* and *Galeopsis bifida*. In other aspects both of the stands with the dominant *Carex acuta* and other accompanying species corresponded with the biotope classification according to Chytrý et al. (2010).

Wet Filipendula grasslands (Filip-1, Filip-13)

The community usually arises from fallow Wet *Cirsium* meadows; it is often a monodominant stand of *Filipendula ulmaria* with an admixture of other tall plants.

Whereas the Filip-1 class corresponded well with this biotope type description according to Chytrý et al. (2010), the Filip-13 stand was partially ruderalised (with the presence of the *Urtica dioica*, *Galium aparine*).

Wet Cirsium meadows (Cirs-2, Cirs-16)

Wet meadows rich in species on waterlogged gleysols in stream and smaller river alluvia or springs ranging from lowlands to mountainous areas. The groundwater level

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is permanently high. The meadows are mown once or twice a year; they rapidly change in line with the change in management.

The Cirs-16 is situated in the estuarine part of a fishpond. It is a rich-in-species stand dominated by the *Scirpus sylvaticus* and including 22 more species representing up to 45% (cf. Tab. XY). The stand generally corresponded with the description according to Chytrý et al. but the proportion of the species from neighbouring biotopes (e.g. the *Glyceria maxima*, *Phalaris arundinacea* and also ruderal species such as the *Urtica dioica*, *Cirsium arvense*, *Galium aparine*, etc.) was higher.

Alluvial Alopecurus meadows (Alop-3, Alop-18)

Fresh wet meadows in inundated areas of stream alluvia, on deep soils rich in nutrients situated from lowlands to submontane areas. These meadows were mown at least once a year.

Mesic Arrhenatherum meadows (Arhen-20)

Meadows of lowlands and hilly areas rich in species on nutrient-rich soils dominated by the *Arrhenatherum elatius* or submontane meadows on oligotrophic Cambisols poorer in nutrients dominated by the *Agrostis capillaris* and *Festuca rubra*. The stands were usually mown twice a year and occasionally grazed.

Intensively managed meadows (IntensM-8)

The meadows or clover/grass mixtures poor in species, well manured and occasionally ploughed. The prevailing species are grasses (*Alopecurus pratensis, Dactylis glomerata*) and nitrophilous broadleaf herbaceous plants (*Taraxacum* sect. *Ruderalia*, *Rumex obtusifolius*, *Antriscus sylvestris*).

The mowed meadows with their structure and proportion of diagnostic species corresponded well with the biotope description according to Chytrý et al. (2010); the IntensM-8 was a standard trefoil-grass mixture with the dominant *Taraxacum* Sect. *Ruderalia* and presence of a small proportion of many field weed species. The stand was mown twice in the 2013 season and after the second mowing it was grazed until November.

Sampling of aboveground biomass

The amount of aboveground biomass was estimated by destructive sampling from sample plots situated along the moisture-based transect (to cover the variability of the stands as much as possible) at regular 5–50 m distances (according to the area of the stand). Five squares comprising the surface of 0,5 x 0,5 m were cut from each stand. The total of 105 plots (5 plots from each of 21 vegetation stands) was sampled during each sampling term. The biomass was cut just above the ground by garden scissors. In case of non-managed stands dead last year's shoots (i.e. at reed stands) were removed. The biomass was weighted, dried at 85 °C and weighted again (Dykyjová, 1989; Ondok and Květ, 1978; Rychnovská, 1987). The sampling was carried out from the beginning of March to mid-November 2013 (the exact values are stated in *Figs. 3 – 9* and *Tab. 2*)**.** The intervals between sampling dates were chosen according to the growth intensity of the stands (the highest intensity in spring; less frequent sampling in the autumn). 11 samplings were done altogether. Relevés of all stands (Moravec et al., 1994) were done

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during the sampling carried out on the 14th May, 16th July and 3rd September. One control sampling was done on the 15th July 2014 on the WheatW-6 and Oilseed-5 sampling sites.

Results

The production values are presented both in the form of production curves (*Fig. 3 – 9*) and the average values of the individual sampling dates of all the studied stands (*Tab. 2*).

The *Phragmites* production of biomass (*Fig. 3*) have similar curve shapes in all the locations; the minimum values were observed on the first sampling date in April and the maximum was reached in October, whereas the maximum value of the ReedL-9 littoral stand in Knín was higher (2,309 g DW*m^{-2}) than that of the ReedT-19 terrestrial stands in Krč (1,544 DW*m^{-2}) and the ReedT-4 stand in Žimutice (1,819 g DW*m^{-2}). The development of the ReedT-4 and especially the ReedT-19 terrestrial stand was notably slower in springtime than that of the ReedL-9 littoral stand; the differences between the values reached up to 1,300 g DW*m^{-2} in May and June. The decline of the curves is of a different intensity - the November values drop below the spring (ReedL-9), summer (ReedT-4) or only autumn (ReedT-19) values.

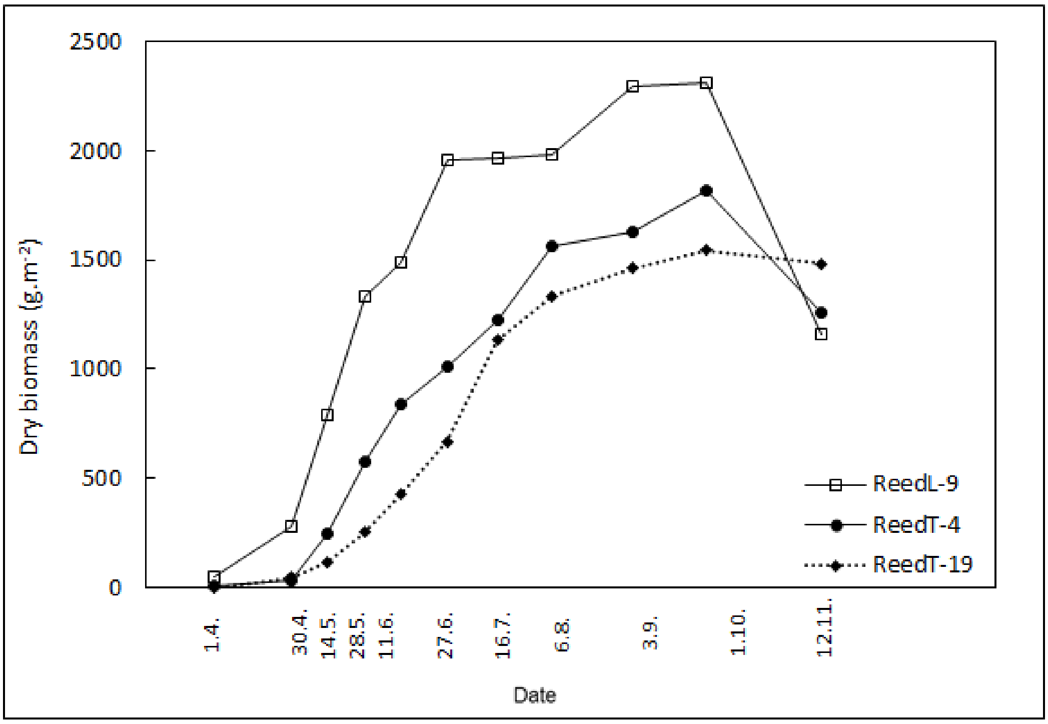

Figure 3. *Dry biomass production of the Phragmites reed bed community*

The *Glyceria* stands (*Fig. 4*) display a similar curve development in both locations. The Glyc-10 performed in general lower values than the Glyc-17. There is a greater difference between the maximum values at the Glyc-17 (1,291 g DW*m^{-2}) and Glyc-10 (940 g DW*m^{-2}), both reached in July. The Glyc-10 curve also declines faster and lower than the Glyc-17 one.

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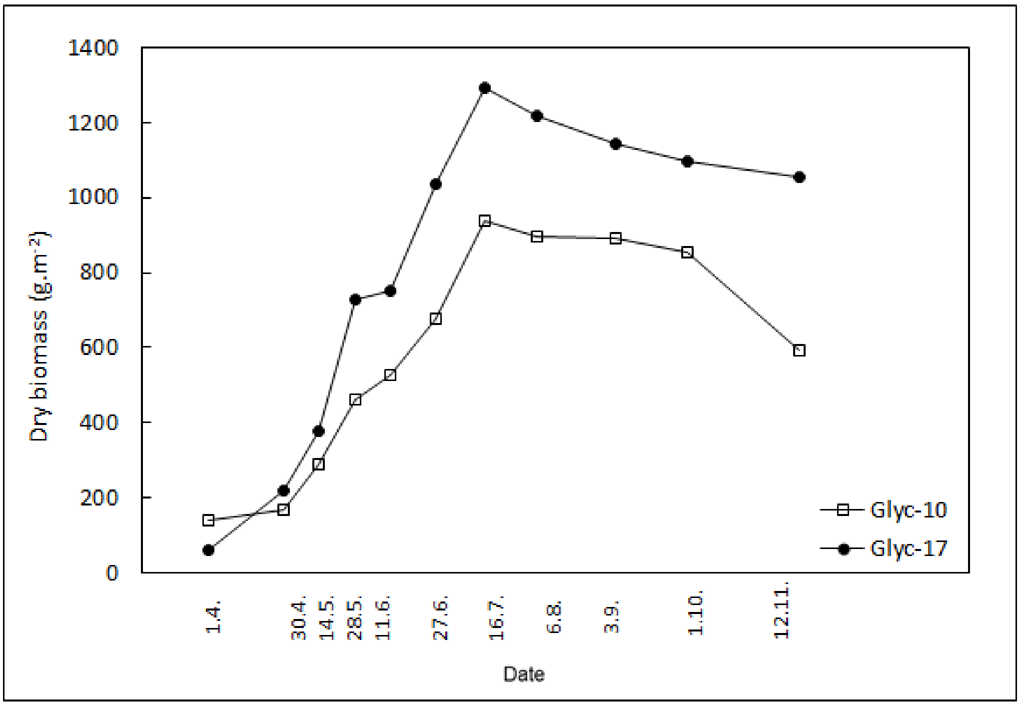

Figure 4. *Dry biomass production of the Glyceria reed bed community*

The curves of tall sedges stands (*Fig. 5*) follow a similar trend until the June sampling, when the Carex-12 stand reached its maximum (970 g DW*m^{-2}) and then slowly declines; the Carex-15 stand, on the other hand, increases until the beginning of August and then declines fast and low. The maximum value reached was almost identical (963 g DW*m^{-2}).

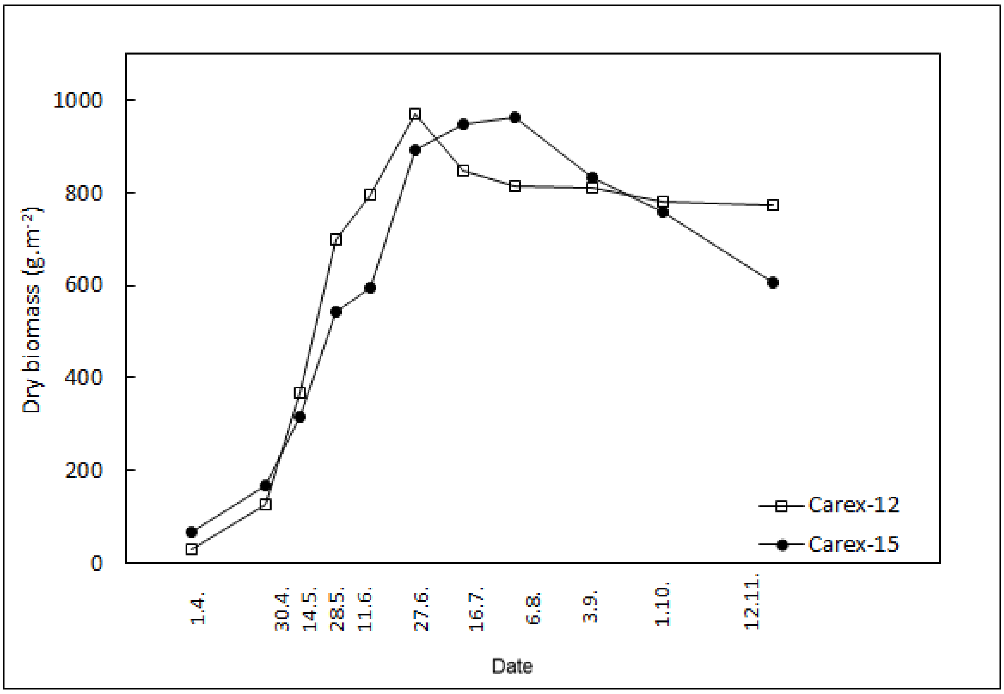

Figure 5. *Dry biomass production of the Carex reed bed community*

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The *Typha* curves (*Fig. 6*) have again a very similar development in both locations. Typical is a long, relatively slow increase and maximum values occurring in late September (1,461 g DW*m^{-2} at the Typha-11 stand, 1,129 g DW*m^{-2} at the Typha-14 stand). There is an insignificant peak at the Typha-14 stand, and the decline towards October sampling date is very slow.

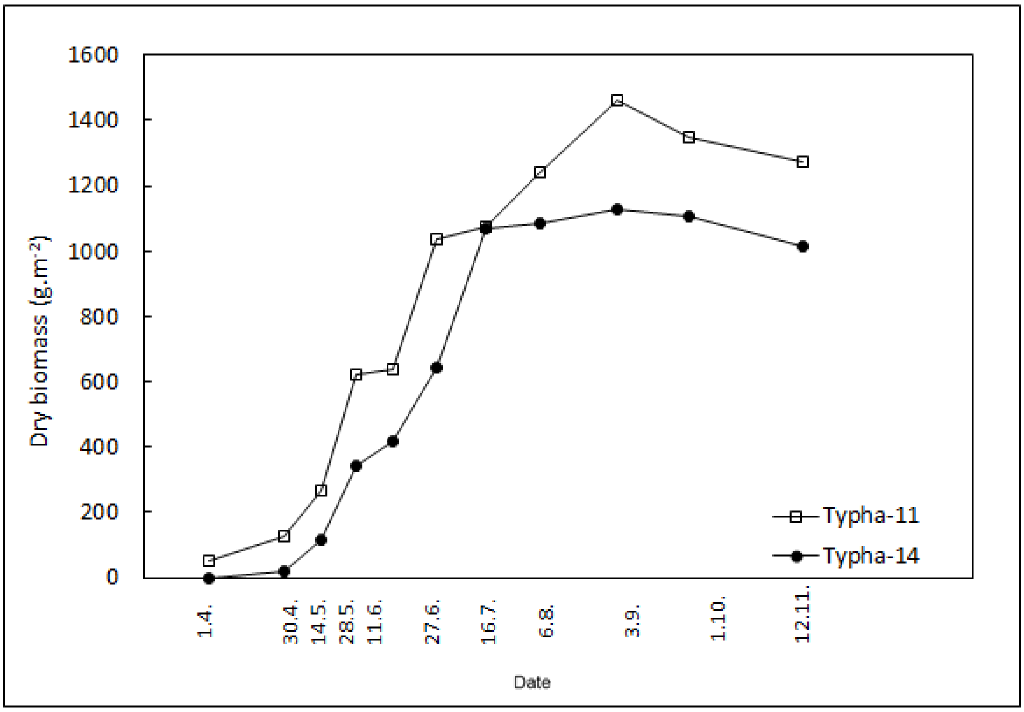

Figure 6. *Dry biomass production of the Typha reed bed community*

The biomass curves of unmanaged wet *Cirsium* and *Filipendula* meadows (*Fig. 7*) show an interesting similar trend between the Filip-13 and Cirs-16 stands which also reached the maximum values on the same date in August (1,248 g DW*m^{-2} at the Filip-13 stand, 922 g DW*m^{-2} at the Cirs-16 stand), then significantly declined. The Filip-1 stand had a different development – after a rapid increase between May and mid-June there were no dramatic changes in values. The maximum (1,172 g DW*m^{-2}) was reached in July.

The curves for managed (mowed) meadows of various types (*Fig. 8*) show many similarities in their development. In general, the first mowing (between 11 and 27 June) was obviously done after the first period of the post-peak decline; all the maximum values were reached at the end of May except for the Cirs-2 stand (11 June, 380 g DW*m^{-2}). Surprisingly, the highest biomass value was not observed in the intensively managed and nutrient-rich stand of the IntensM-8 class (540 g DW*m^{-2}) but in the Alop-3 stand (577 g DW*m^{-2}). The Alop-18 and Arrhen-20 stands had lower peak values (471 and 389 g DW*m^{-2} respectively).

The second peak was reached in August in all cases. All the locations except the Alop-18 were mown just before the sampling date of the 3rd September; the Alop-18 stand had not been mown until the 5th September. The highest values of the second peak occurred at the Cirs-2 stand (361 g DW*m^{-2}), which is comparable to the first peak

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value. The biggest difference was observed in the Alop-18 stand (by approx. 350 g DW*m^{-2}). Other locations show an even decline between the first and the second mowing by approx. 150–200 g DW*m^{-2}.

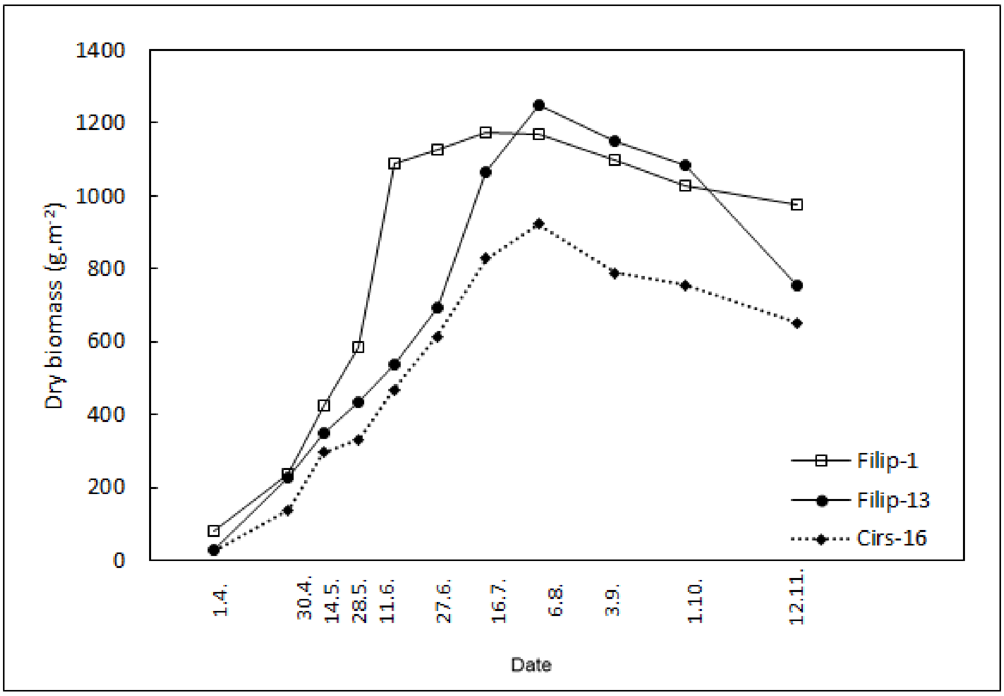

Figure 7. *Dry biomass production of unmanaged wet meadows*

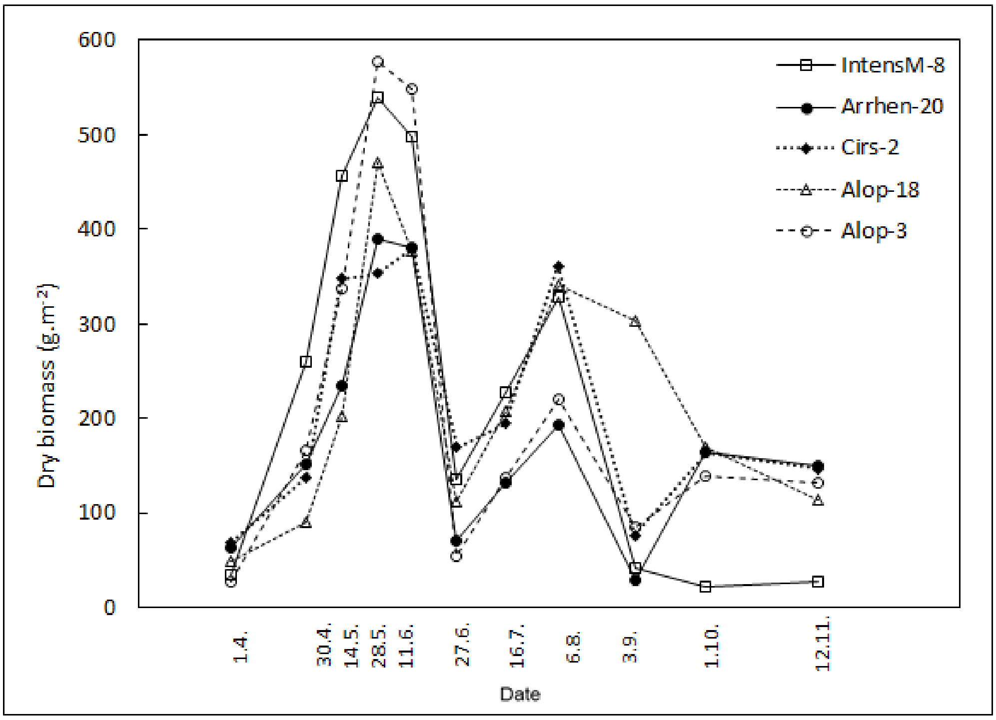

Figure 8. *Dry biomass production of mowed meadows*

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The Arrhen-20, Cirs-2 and Alop-3 stands also formed the third peak in October; the biomass amount was relatively even on these localities (165, 164, and 140 g DW*m^{-2} respectively). The continuing decline of the IntensM-8 curve is caused by autumn grazing.

Biomass curves of crops (*Fig. 9*) differ significantly both as to their trends and values.

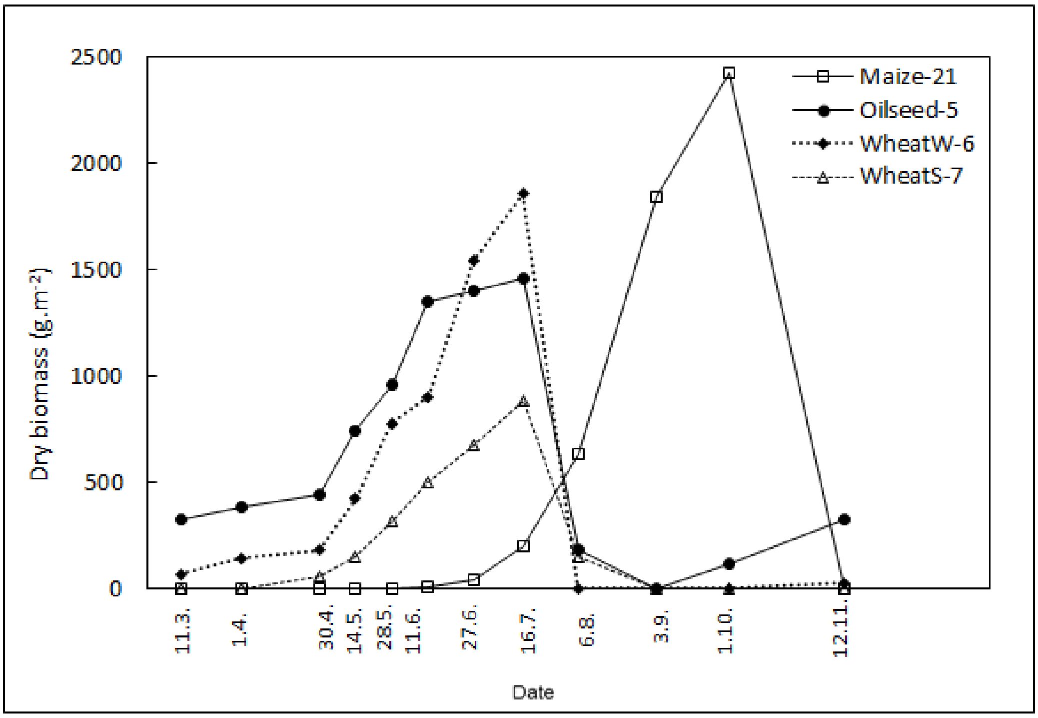

Figure 9. *Dry biomass production of agricultural crops*

Table 2*. Average values of average biomass values (g DW*m-2) of all stands in all sampling terms.*

	11.3.2013	1.4.2013	30.4.2013	14.5.2013	28.5.2013	11.6.2013	27.6.2013	16.7.2013	6.8.2013	3.9.2013	1.10.2013	12.11.2013
ReedL-9	0,0	47.7	282.8	793.6	1,334.4	1,487.0	1,953.8	1,964.9	1,980.0	2,291.8	2,308.7	1,162.5
ReedT-4	0.0	5.8	36.1	248.0	579.0	836.9	1,009.3	1,222.5	1,560.0	1,628.7	1,819.2	1,256.0
ReedT-19	0.0	0.0	48.4	116.4	252.3	427.8	669.5	1,133.8	1,334.5	1,460.8	1,543.6	1,480.4
Typha-11	0.0	52.7	108.0	269.4	621.4	636.6	1,038.2	1,076.7	1,242.6	1,460.8	1,346.2	1,275.5
Typha-14	0.0	0.0	21.4	116.1	341.9	420.1	641.1	1,068.6	1,085.8	1,128.6	1,107.7	1,016.0
Glyc-10	0.0	139.4	168.0	287.6	464.2	527.0	674.8	940.3	859.2	890.4	853.0	591.7
Glyc-17	0.0	58.6	218.5	376.3	726.2	753.3	1,036.7	1,291.1	1,216.2	1,141.2	1,094.8	1,053.1
Carex-12	0.0	30.7	126.8	367.2	699.3	795.5	970.2	847.3	815.2	811.3	781.2	772.7
Carex-15	0.0	66.3	166.3	314.5	540.8	596.3	893.3	947.5	963.3	831.4	759.7	606.2
Filip-1	0.0	78.6	237.6	423.3	584.0	1,087.2	1,125.8	1,172.4	1,167.8	1,096.6	1,025.3	972.9
Filip-13	0.0	29.1	226.4	349.3	431.3	538.1	691.5	1,066.8	1,247.6	1,151.5	1,081.7	754.9
Cirs-16	0.0	26.8	138.3	295.3	330.2	466.5	614.1	827.4	922.2	786.8	755.5	650.9
Cirs-2	0.0	69.1	138.0	347.4	353.7	379.8	169.0	194.3	361.1	76.2	163.9	147.0
Alop-3	0.0	27.2	166.3	338.1	576.9	548.2	53.9	137.1	219.8	85.4	139.7	131.1
Alop-18	0.0	49.7	91.2	202.1	470.6	376.7	112.8	207.6	340.6	303.8	169.7	114.0
Arrhen-20	0.0	63.6	152.3	234.4	389.4	380.7	70.5	131.7	192.5	29.7	164.9	150.4
IntensM-8	0.0	33.7	260.0	457.2	540.0	497.8	136.3	228.0	327.6	40.9	21.8	27.2
Maize-21	0.0	0.0	0.0	0.0	1.9	2.7	38.8	201.2	636.5	1,840.2	2,429.7	0.0
Oilseed-5	324.6	380.1	439.4	739.1	956.7	1,349.4	1,401.3	1,457.8	180.9	0.0	115.3	324.6
WheatW-6	65.3	140.5	181.0	423.5	778.4	902.4	1,538.8	1,856.3	0.0	0.0	0.0	25.2
WheatS-7	0.0	0.0	58.2	151.3	312.0	500.6	678.1	878.9	144.7	0.0	0.0	0.0

The Maize-21 curve shows a rapid increase between July and October and the maximum value was reached in this late period just before the harvest (2,430 g DW*m^{-}

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^{2}). The Oilseed-5 curve evenly increases until the harvest time in July (the maximum value is 1,458 g DW*m^{-2}); since it was grown as a winter crop, the curve declines after harvest (6th August), then falls to zero (3rd September – ploughing) and slowly increases again in the autumn. The wheat curves, interestingly, have a different development – the WheatW-6 curve shows more similarities with the oilseed biomass growth and reaches even a higher maximum value (1,505 g DW*m^{-2}) before the harvest, then it declines and only in November a slight increase could be observed. The WheatS-7 spring wheat curve increases slowly and evenly until the pre-harvest maximum also in July, which is only almost a half of the winter crop peak value (817 g DW*m^{-2}). It was possible to capture the biomass value of stubble in August (145 g DW*m^{-2}), then the field was ploughed.

Discussion

Discussion on methodology

The methodical approach of this study was defined to balance three factors – the needs of the above mentioned research project, representativeness of the samples and obtained data, and the possibility and requirements of the biomass sampling procedure and processing.

The studied biotope types present representative samples of non-forest landscape elements in the Emergency Planning Zone; they cover 51% of the non-forest area of the zone (34.1% of the total area of the zone) (Vinciková et al., 2010). The sampling locations were selected as typical stands of their type (Chytrý et al., 2010) in the studied catchments which were chosen as the sample areas of the project; nevertheless, it would be more accurate to sample at least five stands of each biotope to cover the nutrient, moisture and other variability of the environment and its impact on the biotope. This method would be of course much more demanding and time-consuming (sampling must be carried out on the same date) and it is generally applied for detailed studies of one or a few biotope types (e.g. Kaplová et al., 2011).

Similar limits defined the sampling method itself. Three sampling points is the minimum number to acquire representative data (Dykyjová, 1989), five samples present a good enhancement of the representativeness; situating the sampling points along (in most cases) the moisture transect helped cover the diversity of the stands even better. Also the sampling dates were chosen in sufficient intervals, covering more precisely the estimated peaks of the biomass amount than the end of the season. This approach is very important especially in case of wetland communities, with a rapid growth in the first half of the vegetation season such as the *Phragmites* stands (e.g. Čížková et al., 2001; Dykyjová and Květ, 1970).

The procedure of sampling the plots and further biomass processing was carried out according to the standard methodology (Dykyjová, 1989; Ondok and Květ, 1978; Květ and Westlake, 1998).

Discussion on results

The results of the biomass production sampling are generally difficult to compare with other authors regardless the fact the methods used are identical, because the conditions of the stands vary both in space and time. They are influenced especially by nutrient and water supply depending on the micro-, meso- and also macroclimate of the

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area. Comparing the biomass values of the same plot sampled during two different growing seasons can be a bit tricky as well because of the differences in the yearly distribution of precipitation, temperatures and sunny days; spring temperatures and water availability are especially important (Květ and Westlake, 1998). The season of sampling was significant for its very wet springtime and relative lack of precipitation in the second half of the year (cf. *Fig. 2*). In the following text the comparison of measured and reviewed biomass values was done mostly by comparing the trends of the production curves, where available, rather than focusing on the individual values. Especially in case of the rich-in-species stands the variability of values can be higher than in monocultures; that is why we provide a detailed description of the species composition of the stands both in *Tab. 1* and in the text to explain the occurring differences.

Reed beds of eutrophic still waters dominated by the Phragmites australis

The first shoots of the ReedL-9 littoral reed community appeared in March and an intensive growth was observed until the end of June; the maximum (2,309 g DW*m^{-2}) was reached at the beginning of October (*Fig. 3*). The shape of the growth curve is comparable to the results of Dykyjová and Hradecká (1976) from the Opatovice pond situated in the Třeboň region, South Bohemia, although the maximum was reached there in September and the value was lower (1,824 g DW*m^{-2}). Květ and Westlake (1998) published the *Phragmites* growth curves measured in South Moravia (Czech Republic), England and Denmark. These curves followed a similar trend, only the curve from South Moravia increased faster than the other curves, situated in colder areas. Our ReedL-9 littoral stand best corresponds with the curve from Moravia whereas the terrestrial reeds of the ReedT-4 and namely ReedT-19 stands, with their slower increase in spring, rather resemble the English production curve.

Significantly more information was found on the maximum reached values of the biomass of the *Phragmites* stands. Dykyjová and Květ (1970) stated maximum biomass values of eleven South-Bohemian and six South-Moravian fishponds (both locations to be found in the Czech Republic) sampled between 1965 and 1969. They ranged from 890 to 2,730 g DW*m^{-2} (littoral stands of South Bohemia) and from 865 to 1,930 g DW*m^{-2} at terrestrial stands in Moravia. This reflects the variability of biomass production; warmer Moravian locations also reached their maximum up to 1.5 month earlier than the South Bohemian fishponds. Květ and Husák (1978) mention the range of the aboveground biomass between 600 and 3,500 g DW*m^{-2}. In her study on the *Phragmites* biomass production in Estonia Ksenofontová (1988) measured the peak biomass values between 668 and 1,311 g DW*m^{-2}. Our measured maximum values correspond well with these data. The later maximum values (1st October 2013) could have been caused either by the site conditions or the sampling year climate course but are by no means unique – Dykyjová and Květ (1970) measured the peak value as late as 9th October 1966.

Reed beds of eutrophic still waters dominated by the Typha angustifolia

Květ and Westlake (1970) published the growth curves of the *Typha angustifolia* observed in various regions of the Czech Republic. Initially its increase was less steep than that of the *Phragmites* curves, which was confirmed in our locations as well. The Typha-11 curve trend, maximum value and date are in line with these data (Květ and

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Westlake, 1998). Dykyjová and Květ (1970) presented the maximum values measured in littoral stands of the Opatovice fishpond in South Bohemia in August and September, ranging from 1,570 to 3,880 g DW*m^{-2}. Květ and Husák (1978) provided similar results (1,000–3,000 g DW*m^{-2}). Our maximum values (1,461 and 1,129 g DW*m^{-2} respectively) correspond with the published results; nevertheless, the range of maximum values is again relatively wide.

Reed beds of eutrophic still waters dominated by the Glyceria maxima

The Glyc-10 and Glyc-17 growth curves, especially the increasing part until the June maximum, entirely correspond with the results published by Petřík (1972). The maximum values were identically measured in June and are fairly similar (1,090 measured by Petřík, our results are 940 and 1,291 g DW*m^{-2} respectively). The decrease of our curves is rather slower. The curves published by Květ and Westlake (1998) from the Czech Republic and England are similar except that the spring increase occured later and the maximum values were reached in September and October. Again, this can be caused by yearly weather development, general climatic conditions of the area and stand conditions. Květ and Westlake (1998) provided a low maximum stand crop (600–1,100 g DW*m^{-2}) in the mild climate and relatively poor soil conditions of the English location; also the peak is relatively broad, because while old shoots are dying new shoots are emerging from July to September. In the more extreme climate and fertile soils of the Czech Republic the maximum standing crop is higher (1,200–3,200 g DW*m^{-2}) and the peak is much more distinct. The growth strategy of the *Glyceria maxima* is different from the *Phragmites* and *Typha,* some of the green shoots overwinter and increases rapidly in the spring and new shoots grow later. This is also influenced by the maturity of the stand.

As to the maximum values, Květ and Husák (1978) state a range between 600 and 2,600 g DW*m^{-2}, Dykyjová and Květ (1970) measured 652 g DW*m^{-2} at the alluvial pond of the Dyje river (South Moravia) and 1,387 at a South Bohemian fishpond.

Tall-sedge beds

The growth curves of these stands (*Fig. 5*) are very similar until June. The Carex-15 curve continues increasing until August and falls down relatively quickly afterwards. A similar trend was published by Květ and Westlake (1978) for a *Carex rostrata* stand in Minnesota. The Carex-12 curve is more similar to the growth curve described by Novák (1977) who also noted an even growth until the June peak followed by a slow decline. Květ and Westlake state the maximum value for the *Carex rostrata* biomass reaching 700 g DW*m-2; Prach et al. (1996) measured 940 g DW*m-2 in the *C. acuta* stand in the river Lužnice alluvium, which is very similar to our results (*Tab. 2*). Lukavská (1988) stated the maximum biomass between 627 and 1,059 g DW*m-2 for a vegetation community dominated by the *C. acuta* and accompanied by the *Calamagrostis canescens* and other *Carex* species which was reached in August. Also Kuncová (2009) measured the total maximum biomass of this community of Wet Meadows in Třeboň (South Bohemia, Czech Republic) corresponding to 546 or 670 g DW*m-2 respectively where the proportion of the *C. acuta* was 423 and 618 g. Novák (1970) stated the maximum total biomass of a similar community of 644 g where the *C. acuta* biomass only reached 248 g.

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Meadow communities rich in species

A few studies were found focusing on the aboveground biomass production of the rich-in-species meadow vegetation communities. Their high variability poses difficulties when comparing the different stands: there were not many analogies to be found in literature especially for the unmanaged meadows of the Filip-1, Filip-13 and Cirs-16 classes. Prach et al. (1996) stated a maximum standing crop value for the stand dominated by the *Filipendula ulmaria* of 1,009 g in July, which is only slightly lower than our values.

The growth curves of the studied mown meadow stands are quite similar, characteristic by a steep increase until the first mowing (*Fig. 8*). The growth of grassland until the second mowing was less intensive and the maximum values reached approximately from one to two thirds of the first peaks. The maximum values especially before the first mowing were influenced by the stand type, especially its nutrient richness and water availability.

Petřík (1970) observed a biomass growth in the Continental inundated meadows and Intermittently wet *Molinia* meadows in South Moravia during three years. The seasons differed more in terms of the maximum values than the curve trends which were quite similar and are well comparable with our curves.

Crops on arable land

We sampled the crop species that are most common in the studied area nowadays. Only the production of the crop parts which are then used (i.e. grain, straw, tuber or seed) is important enough to measure so it is practically impossible to find relevant data on the total aboveground production of any crop stands. Bureš (1970) observed the growth of oats and the maximum biomass he provides is 890 g DW*m^{-2}; this value and the curve trend is analogous to our values for spring wheat. In case of silage corn, which is harvested as a whole, the yield values of various hybrids ranged from 1,400 to 2,050 g DW*m^{-2} (cf. http://www.zea.cz/). Our measured values are higher due to different cropping practices – whereas we harvested the biomass just above the ground, the harvest machines leave stubble of approx. 30 cm in height.

Surprising was the high production of biomass of winter wheat which far exceeded the seemingly richer production of oilseed. Facing the scarcity of relevant and comparable data in published papers we performed another sampling of both spring and winter wheat and oilseed crops in the estimated peak period of the 2014 vegetation season. Both the values were higher than the peak values of 2013 (2,612 g DW*m^{-2} for wheat and 1,921 g DW*m^{-2} for oilseed) which was probably caused by better growth conditions in 2014 but their ratio was almost identical (56 to 44% in 2013 and 58 to 42% in 2014). This can be understood as an example of a high year-to-year variability of the aboveground biomass production. On the other hand, it means the ratios could serve for comparing the production curves for different seasons and it is a certain proof that the methodological approach we used was correct and suitable.

Conclusion

The paper summarizes the results of the annual biomass production measurement for many different biotopes and vegetation stands. It is generally not common to study biomass production of such wide variety of biotopes, especially when it comes to the

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stands with high species diversity such as various meadow types; this paper can therefore be used as a reference material for similar vegetation stands. This was also the reason why we provided a detailed description of species composition and abundance of the stands.

The results are compared with literature in cases where the values of adequate stands were available and the measured and reviewed values and/or curve trends were in almost all cases similar. This also supports the credibility of our results for the stands where no comparable data was found during our review.

The outputs of this study will be used in the above mentioned project to model the total amount of biomass which could be potentially contaminated by a radiation leak. Such an event can occur anytime in the year so the estimation of a momentary biomass production of the vegetation stands prevailing in the Temelín NPP Emergency Planning Zone is necessary. Nevertheless, the data can be used in an even broader sense – for the purposes of an estimate of biomass production as a source of renewable energy, observation of carbon balance and nutrient supplement, etc. Another important aspect can be the contribution of these data to broad-scale biomass production models, which are usually based on satellite imaging and often lack the direct in-situ calibration of the computed values.

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APPENDIX

Electronic Appendix: Photographic documentation of the studied sites

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